KURT SPEAKS OUT

By Kurt Sterba

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KURT SPEAKS OUT

Learn the truth about antenna theory, selection and use and avoid false and misleading information from antenna manufacturers!

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THE CRUEL WORLD OF ANTENNAS

It seems to be a never ending task to keep the fundamental principles of antennas straight in this cruel and unrelenting world. Misleading and sometimes completely wrong assertions are found in print. But in print at least there are editors who take out most of the trash. The editor-free Internet forums are another story. Anyone can say anything and many do.

In a recent posting a questioner had a dipole fed with 400 ohm ladder line. It had a SWR of about 4:1 at the transmitter. He wanted to trim the antenna length so get a better SWR at the transmitter and was afraid he'd have to measure the SWR at the antenna to do this properly.

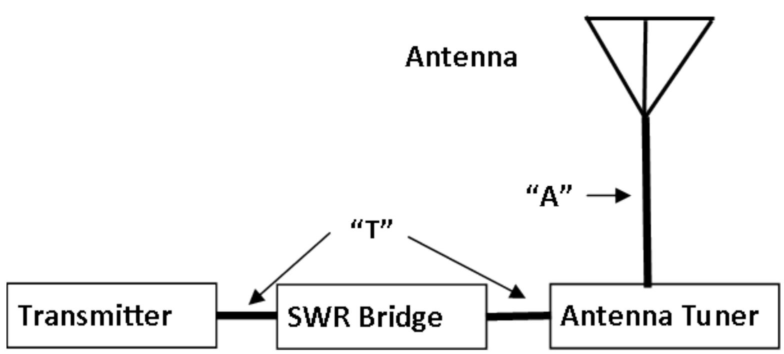
In the many responses not one of the "experts" told him that a dipole (about 75 ohms) at resonance will produce over 4:1 SWR on a 400 ohm line, maybe even over 5:1 (400/75 = 5.3). Since the lowest SWR you can get is at resonance his antenna most likely was resonant and any antenna pruning would almost certainly make things worse.

They also did not tell him that, since he had measured the SWR at the transmitter, there was no need to measure at the antenna. <u>SWR is the same anywhere on a transmission line</u>, unless there are significant losses, and you aren't going to find much loss on a 400 ohm open line.

To make matters worse the poor soul was led to an antenna where the SWR was made low by changing the length of a transmission line. At first reading I'm afraid the neophyte might misunderstand what was being done. Let Kurt repeat: <u>You can't change the SWR by changing the length of the transmission line.</u>

Many of these problems and misunderstandings arise because many of us use antenna tuners and forget what the whole system looks like. Kurt will straighten this out by getting down to basics.

In the typical installation the antenna is connected to the antenna tuner by a transmission line. We'll call this transmission line "A". The transmitter is connected to the tuner with a short coaxial line we'll call transmission line "T". The SWR meter is placed in line "T".



The load for line "A" is the antenna and the SWR on this line does not change as you tune your tuner. If you don't believe Kurt and if line A is coax, put your SWR meter in line with it and try to change the SWR with your tuner. Can't be done.

The load for line “T” is your tuner. You can adjust the tuner so as to get 1:1 SWR on this line by adjusting the tuner so its transmitter input is 50 ohms resistive. The tuner acts as a variable transformer to transform whatever impedance is at the end of line “A” into 50 ohms resistive for line “T”.

So when we “tune the antenna” with our tuner we are adjusting the tuner to give 1:1 SWR on line “T”. Line “A” keeps the same SWR it had before. Keep this in mind and many confusions will go away.

IMPEDANCE

SWR is Standing Wave Ratio. Ratio of what? Ratio of the maximum voltage along the line to the minimum voltage. The voltage changes along the line (standing waves, remember) and so does the current. Because of this the impedance along the line changes even though the SWR does not. (Ohms law: $Z = E/I$). So the impedance at the end of the line changes with line length. You can use this to get a more favorable impedance at your tuner just by changing line length.

COAX VS LADDER LINE

As I read on into the advice given the internet questioner tears came to my eyes again as a renowned antenna expert told him that ladder line to a balanced antenna does not give any better current balance than feeding with coax. So why do we have a cottage industry busily making baluns (<u>bal</u>anced-to-<u>un</u>balanced transformers) to connect coaxial cable to balanced antennas? And why don’t we have a similar industry selling bal-bals (or whatever you want to call a <u>bal</u>anced-to-<u>bal</u>anced transformer) to connect ladder line to balanced antennas? Kurt can tell you why.

A balanced antenna like a dipole fed with a balanced line like ladder line is a balanced symmetrical system. There are equal currents on each of the ladder line wires. Where they connect to the dipole current flows from one of the ladder line wires into one side of the antenna and an equal current flows from the other wire into the other side of the antenna. There is no problem of any kind.

But when a balanced antenna is fed from coaxial cable there is a problem. It is brought on by the fact that all of the current coming up the coax is confined to the inside of the cable. There is current on the center conductor and on the inside of the shield but none on the outside of the shield. Up where the coax meets the antenna current flows from the center conductor to one side of the antenna. An equal current flows out of the inside of the shield and should flow onto the other side of the antenna. But, look! There is another “wire” connected at this point; the outside of the shield. What prevents the current from flowing down it? Nothing. So the current divides and we have less in that side of the antenna than in the side connected to the center conductor. How to cure the problem? Put on a common mode choke configured as a balun (balanced output).

Yes, in the real world there can be unbalance with ladder line if the line doesn’t come straight down from the antenna, or if there are metal structures nearby. “Common mode” currents can flow on ladder line. But if the installation is neat and proper there is no problem. On the other hand a neat and proper coax installation without a common mode choke can have the problem and probably will.

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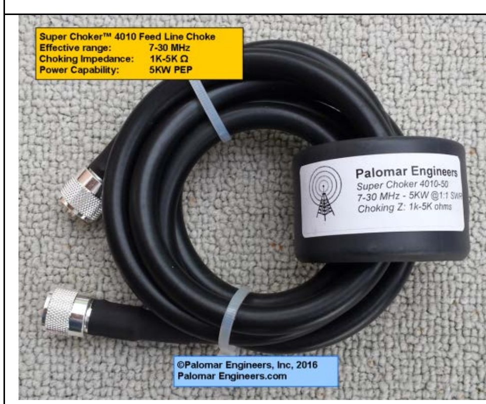
Palomar Engineers Common Mode Chokes for coax lines (click picture to link to website for more info).

Product Picture	Type
	**Slip On Beads**
	**Snap On Beads**
	**CUBE™ Choke with dipole connectors**
	**Assembled Feed line Chokes**
	**Tuned Coaxial Choke**
	**Super Choker™**

TIP SHEET: How to Choose a Feed Line Choke

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BROADBAND ANTENNAS

Once again the *Newington News* strikes out. In the Q&A section run by the Doctor an unsuspecting reader asks, “What is a small ‘broadband antenna’? “

I am pleased that this doctor is not my M.D. My health is good but if his prescriptions for health were similar to those for antennas I would not be writing this column for long.

To begin with the Doctor does not come out and tell the truth: small and broadband don’t go together. The smaller you make it the bigger the coils you have to add to resonate it and the smaller the bandwidth becomes.

Next the Doctor tells the poor reader that there is always a trade-off between broad-bandedness and efficiency. In other words if you want bandwidth you sacrifice efficiency.

Don’t you believe it! There are ways to get wider bandwidth and actually improve efficiency. These methods have been well known since the 1920’s and 30’s and are in use every day. You only have to look as far as your copy of the Antenna Book to find them.

The easiest is to use bigger wire or tubing. For example, look at a dipole for the 80-meter band. The band is 500 kHz wide. If you make your dipole out of heavy wire you’ll get a bandwidth (for 2:1 SWR) of about 150 kHz. But if you make it of 2-1/2” tubing it will cover the whole band.

Don’t want to use tubing? Use two or more wires spaced a foot or so apart. Use four wires to make a “Cage Antenna” and get full band bandwidth.

Should I mention the “Bow Tie”? How about the “Fan”? These are antennas used every day for broadband TV reception. They work fine for transmitting too!

How about efficiency? A “Cage” of four parallel wires or a “Bow Tie” of two in parallel will have less ohmic resistance than a single wire dipole and thus have *less* loss, not more. Actually the efficiency of a dipole is very high so the signal strength improvement of a “Cage” or “Bow Tie” is insignificant. But it is there and Kurt wants you to get it straight.

In all fairness to the Doctor I must say that the Antenna Book has a chapter on broadband antennas and that almost all of them have lower efficiencies than a dipole. That’s because of losses in the coaxial cable stubs used to increase the bandwidth.

Back in the early days of radio, before Kurt became a world expert in antenna matters, stubs were made of open-wire transmission line. Losses were almost nonexistent and stub-broad-banded antennas would have been efficient. You could do it today if you wanted to.

In closing, the Doc’s advice is to build a narrow-band antenna with loading coils to resonate.

Kurt says, forget the complicated antennas. Put up a piece of wire wherever you can and buy or build an antenna tuner. Now you can get on any part of any HF band. No problem. Easy.

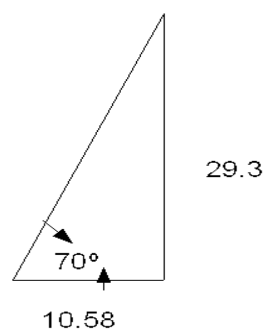
IMPEDANCE REVISITED

In a recent column Kurt ran a little contest whose purpose was to illustrate that antennas with widely different impedances can cause the same SWR on a transmission line. There were so many prize winners (of a Kurt White Hat) that the stockroom almost ran out

But one reader questioned Kurt's use of the term impedance. For example: One of the contest antennas had R = 10.58 ohms and X = 29.30 ohms. I said that its impedance was Z = 31.15 ohms. The reader says that Z is NOT 31.15 ohms. Well,

Kurt said it was 31.15 ohms and it IS 31.15 ohms.

How can Kurt be so sure? Easy. Using the equation for impedance found in the AC theory section of the Handbook: $Z = \sqrt{R^2 + X^2}$. You can check me with your little hand calculator. Square 10.58 and add it to the square of 29.30. Take the square root of the sum and you'll get 31.5 ohms.



Kurt's favorite way to look at this formula is as a right triangle. See the figure. R is the horizontal line drawn 10.58 units long. X is always a vertical line.

Up for positive reactance; down for negative reactance. In this case up 29.30. The hypotenuse (the long side) is the impedance. (I'm bringing this up for a reason; bear with me). The sum of the squares of the R and X sides equals the square of the hypotenuse. Take the square root of that and you have Z = 31.15.

Think you might forget that? Then remember this story: There were three Indian women. One slept on a buffalo hide. She had one son. Another slept on an antelope hide. She had two sons. The third slept on a hippopotamus hide. She had three sons. This illustrates that the squaw of the hippopotamus is equal to the sons of the squaws of the other two hides.

Getting back to business, there is one more important thing that the triangle shows. That is the phase angle of the impedance. The angle marked with the two arrows is the impedance's phase angle of 70 degrees. So the absolutely complete and correct way to describe the impedance of the antenna is: $31.15 \angle 70^{o}$ as the reader points out. If you leave out the angle you should write $|31.15|$ ohms. The vertical lines show that you left out the angle.

Kurt's way is the American way: Keep it simple as long as everyone knows what you're talking about. But, of course, the reader is correct.

I believe that, if I said that our flag is red, white and blue, this writer would say that I was wrong. He'd say, "The flag has a field of 13 horizontal stripes, 7 red alternating with 6 white and in the upper corner near the staff, a rectangular blue field, or canton, with 50 white five-pointed stars." He'd be right. But so is Kurt.

QUAD REVISITED

I have also been criticized for my disdain of a company advertising a 4-element quad with 12-dBd gain. I expressed my displeasure because the gain of an optimum 4-element quad design in free space when compared to a dipole in free space does not have 12-dB gain.

"Ah", my critic says, "but no one operates their beam in free space". If you add in the ground reflection gain you can get 12-dBd or more gain.

Piffle! Here we are again comparing apples and oranges. No one operates his dipole in free space either. So if we are to make a meaningful comparison lets have both the dipole and the quad in the same location. Now the dipole also gets ground reflection gain. This gives a realistic comparison and the gain of the quad over the dipole will be less than 12-dB.

Most quoted gain figures these days are from computer simulations, not real world measurements. Computer programs are great for designing antennas but, once the antenna is built, there is just one way to verify performance. That is with a field strength meter comparison of the antenna vs. a dipole.

When you write complaint letters to Kurt please include your field strength measurements.

THE CROSSED FIELD ANTENNA

A new antenna has come on the scene, an import from England. The descriptions of it state that 1) "Conventional" antennas are inefficient and 2) The Crossed Field type is much better. The promoters give an example of a 21 ft. tall crossed field antenna in Egypt that replaced a 211 foot broadcast tower and produced a radiated field 6 dB stronger. A 30,000 watt transmitter replaced the 100,000 watt transmitter and gave the same coverage. This seems to say that 70,000 watts formerly was wasted.

Olde Kurt believes in the principle of conservation of energy. Energy does not just disappear. So what happened to the missing 70,000 watts? If it didn't show up in any other way it must have been converted into heat. 70,000 watts makes a lot of heat. The transmitter site must have been a real sweatshop.

The next time you pass your local 50 Kw broadcast station's antenna site check the temperature and let Kurt know how much hotter it is there than in the surrounding countryside.

An article on the crossed field antenna explains that the wave from a dipole suffers a "transient" loss as the wave becomes "organized". And that only a relatively small part of the power applied to the antenna becomes part of the radiated wave. This is news to Kurt and to the authors of the ARRL Antenna Book who are convinced that a dipole of #14 copper wire placed high in the air is almost 100% efficient.

The U.S. patent disclosure for the crossed field antenna states that any antenna, to be efficient, must have perpendicular magnetic and electric fields with the proper phase relationships and "Presently known antennas are probably achieving the requirements in an uncontrolled or accidental manner." Kurt believes that those beams from Hy-Gain and Cushcraft are the products of careful engineering design, not just lucky accidents.

We are also told that, because these antennas are so big and erected so high above ground, a "comparatively weak" signal is developed.

Pity those Big Gun DX'ers who have gone to all the trouble and expense of erecting massive towers to get their antennas high in the air only to find them in a "large surrounding and lightly stressed volume". It must be their Alpha amplifiers that allow them to get out so well.

Is the crossed field antenna a major breakthrough that will revolutionize ham radio? Kurt recommends that you keep your Force 12 until further field tests are reported.

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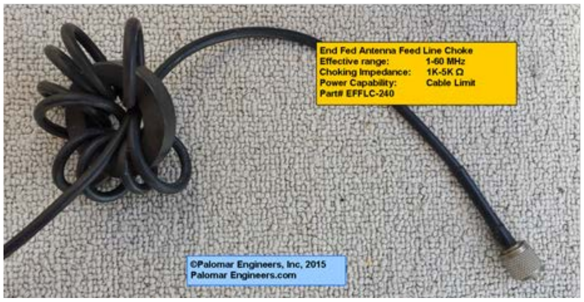
Need a portable antenna system? Here is a Grab & GO™ end fed antenna



Bullet™ Antenna System with:

71 Ft End Fed Antenna (160-6M) +

50 Feet RG-8X Coax feed line +

End Fed Feed Line Choke

Check Palomar-Engineers.com for updated product information

3

dB, dBi, dBd, ---- WHICH ONE IS RIGHT?

I had a pleasant experience with an antenna company last week. We'll call them the Granite State antenna works. I don't use their real name because the editor doesn't like to give free advertising to firms that don't have the good sense to advertise in this fine publication. I visited their nice web site (www.cushcraft.com) where you can view their antenna line and order one of their catalogs.

I asked for a catalog and it came in just a couple of days. I was pleased to see that the dB gain figures for all the antennas in the catalog stated what kind of dB's they were talking about. In this case they used dBi's or gain over isotropic. You may remember that I have complained in the past about firms that list antenna gain just in dB's. Since dB is a ratio the figures are meaningless without a reference. Score one for Granite State.

Now you may ask, " Why did they use dBi?" Kurt can tell you. It's because the numbers are higher when you do that. And they know from experience that there are a lot of amateurs out there who don't read Kurt's column and thus may not know a dBi from a dBd. A dipole in its favored directions (our dBd reference) has a gain of 2.14 dB over the isotropic radiator (our dBi reference). So if they gave the gain in dBd the numbers would be 2.14-dB less.

When you buy a beam you are interested in how much better it's going to be over the dipole you are now using. So you want to know the beam's gain in dBd. To find that from the catalogs' dBi you have to subtract 2.14-dB. So that 13-dBi gain turns into a real life 11.86-dBd (assuming that the 13-dBi is correct in the first place).

Is it? I note that the gain is stated with the antenna at one wavelength (one wavelength above the ground, I assume). There is an increase in gain due to ground reflection over the gain of the antenna in free space. But the reference dipole is still in free space. This means that we are comparing apples to oranges. If we put our dipole up at one wavelength it too will have an increase in gain, maybe as much as 6 dB. So, it is entirely possible that our new beam will only show a gain of 7 dB over our old dipole.

Hopefully you too will send for the catalog before you buy because the same company in their magazine advertisements drops the little "i" and just specifies the gain in dB which leaves you in doubt as to what the gain really is. You have to be careful in comparing antennas in the various ads because, for example, the "M" company honestly states their antenna's gains in dBd. Kurt says, "Be careful."

REFLECTED POWER REVISITED

Not long ago I, Old Kurt, explained how, if the SWR on the line going to the antenna is more than 1.0, some of the power is reflected and travels back down the line to the transmitter. At this point it is turns around and joins the forward power and travels back to the antenna. The amount of reflected power is termed "reflection loss" and some say that it is a real loss of power. I explained that it is not lost at all but returns to the antenna as part of the forward power after it is reflected.

I have been given a letter from a reader claiming that this is not always so. If

There is no antenna tuner and the 50 ohm line is directly connected to a 50 ohm transmitter then the transmitter will absorb all the reflected power, he says. His example is a 100 watt transmitter driving a 50 ohm line with 100 watts forward and 50 watts reflected. He states that the 50 watts reflected will be absorbed by the transmitter. This will overheat the finals and destroy them and that it why transistor transmitters need "reflected energy" protection circuitry.

So the transmitter is putting out 100 watts, which is the forward power. At the same time it is absorbing the 50 watts reflected from the antenna which is turned into heat in the transistors. 50 watts goes into the antenna.

Let Kurt assure you that this scenario is not correct. To see why it is not we need to look at some fundamental principles.

TRANSISTOR TRANSMITTERS

Transistors are well suited to driving low impedance loads like 50 ohms either directly or through a simple broadband matching transformer. A transmitter like this can be called a "50 ohm transmitter" but this does not mean that you will see 50 ohms if you look back into its output.

The load for a power transistor is determined by the collector voltage and the output power. The circuit is arranged so the transistor sees this load resistance. But when you look back into the circuit you see the transistor's output impedance. This may be a lot different than 50 ohms.

TRANSMISSION LINE IMPEDANCE

If a 50 ohm transmission line is connected to an antenna, what impedance do you see at the transmitter end of the line? If the SWR is not 1.0 you are not going to see 50 ohms. Why? Because the reflected power makes standing waves on the line. The voltage and current both vary with line length so you'll see different impedances depending on the length of the line.

CONCLUSION

The 50 ohm transmitter connected to the 50 ohm line is not matched. The 50 ohm line does not look like 50 ohms to the transmitter and the transmitter does not look like 50 ohms to the line. <u>50 watts does not disappear into the transmitter</u> to heat up the transistors.

What does happen? Instead of 50 watts going into the transmitter and at the same time 100 watts coming out, the two waves, transmitter power and reflected power, combine in a manner depending on the impedances involved. This may be complicated but the net result is that the transmitter power output is reduced to 50 watts and the combination provides 100 watts forward power to the line. There is no loss.

That is just an example. Your transmitter may drop to some other power level because transistor amplifiers' outputs are sensitive to load impedance. But the same ratio of forward to reflected power will remain (that's determined by the antenna, remember) and the transmitter will put out whatever power actually is taken by the antenna. There is no loss.

PROTECTION CIRCUITY

If there is no loss and the reflected power does not heat up the transistors then why do transistor transmitters have protective circuits that shut the rig down if the SWR is high?

Well, for one thing, transistors can be zapped by too high voltage. The peak voltage on the transmission line goes up as the square root of the SWR. If the transmitter is at a high voltage point on the line it may be “goodbye transistors”.

Also a low impedance load can cause excessive current to flow. The transistor current easily can double under certain load conditions. In addition to all that some reactive loads can cause the transistors to oscillate. So to protect against these problems the output is automatically reduced when the SWR goes up. This is voltage and current protection, not reflected power protection

Almost all of us use “Antenna Tuners”. When adjusted properly, they keep the SWR at the transmitter at 1.0.

Let us hope and pray that this discussion puts an end to the myth of lost reflected power for ever and ever. Sigh! Old Kurt should live that long!

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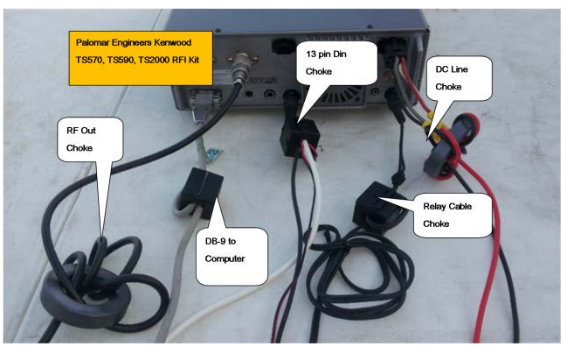
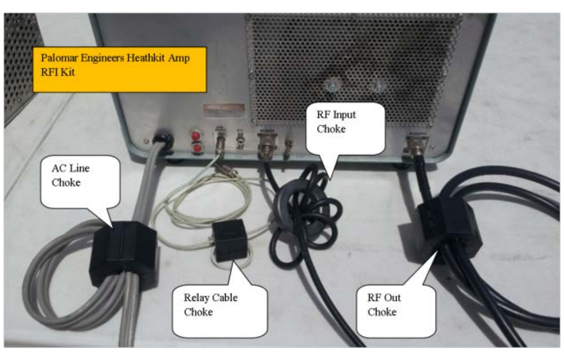
GOT RFI? Here are some simple solutions



Transceiver RFI & Noise Reduction Kit

The RFI kit is designed to be installed on your radio transceiver to reduce Radio Frequency Interference (RFI) caused by common mode current on the outside of the coax braid at the output of your radio and AC/DC power cable. Additional chokes are included to reduce common mode currents on 3 more transceiver cables including computer control, audio and one other.



Linear Amplifier RFI Kit

These kits are designed to choke common mode currents going into or exiting from your rig. Chokes are supplied for the RF In, RF Out, Relay Cable, and AC/DC power line. Use of the chokes often helps cure high SWR problems between exciter and power rig or between power rig and antenna tuner or direct to antenna.

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SMALL LOOPS REVISITED

Readers with long memories may recall that, some years ago, old Kurt questioned the efficiency claimed for a small commercial loop antenna. The claims were for on the order of 90% efficiency on the 10 meter band down to something like 60% on 20 meters. Kurt stated that these were unreasonably high because of losses caused by induction into nearby objects and other real world losses.

I received an irate response from the manufacturer including detailed analyses showing the radiation resistance, loss resistance and calculations showing the claimed efficiencies. The one thing I did not receive was field strength readings showing the actual output of the antenna. Theoretical calculations are important in antenna design but the proof of the pudding as far as Kurt is concerned is in field strength meter measurements that compare the antenna to a dipole.

Recently *RadCom*, the British equivalent of our QST, reported that such measurements have been made in the last couple of years. G4XVF has found that the overall radiation efficiency of a small loop is relatively low (usually under 10%) compared with a dipole at reasonable height. The difference between the calculated efficiency and the actual efficiency is attributed to eddy current losses in nearby structures.

The loops tested were built in England and may differ from those made in the U.S. but these are the only transmitting loop field strength measurements Kurt has heard of. Until we hear differently I advise that you keep them in mind when you plan your next antenna project.

RADIALS ONCE MORE

A while back old Kurt put on his Masked Avenger's cape and took QST's "Doctor" to task for misleading a poor fellow who wrote in about his homemade vertical with 5 radials. The answer was to add one more radial and see if a "substantial" increase in field strength resulted. Kurt pointed out that no such big increase was possible.

The good Doctor took the criticism in good humor like the true gentleman he must be. This is in contrast to those who become deeply offended when Kurt points out their idiocy and who then call Kurt bad names, as though that would somehow turn wrong information into good.

Kurt and the Doctor, each in his own way, are here to guide the newcomer on the path to technical correctness, good antennas and lots of DX. The Doctor does point out that even if you add 100 radials you only gain 3 dB. Of course there are DX'ers who might kill to get another 3 dB over the competition but the average operator has to weigh gain against cost. Installing 100 radials is a lot of work, but Kurt has done it on 160 meter antennas with good results.

How do we know that adding 100 radials gives 3 dB improvement? Well it does if you have a ¼ wave vertical. But if you have a shorter vertical it will give even more improvement than that. Why? It's all a matter of radiation resistance and loss resistance. Let's look at an example or two.

A quarter wave vertical has a radiation resistance of 36 ohms. When we measure the resistance between the antenna and its radial system we see both the radiation resistance and a “loss” resistance. In the case of a 5 radial system the total is 61 ohms. The 61 ohms is made up of the 36 ohms of radiation resistance and 25 ohms of loss resistance. This will vary a little depending on the kind of ground you have. It was 25 ohms in W2FMI’s yard. He made extensive tests and they are shown in the Antenna Book. If you’ve been following Kurt’s advice you have this on your bookshelf.

All of your transmitter power is dissipated in the total 61 ohms. But only the part used up in the 36 ohms of radiation resistance is radiated. The rest keeps your earthworms warm in the winter and hot in the summer. So what is the efficiency? It’s 36 (radiated) divided by 61 (total). That’s 59%.For every 100 watts you put in 59 watts is radiated.

If you put in 100 more radials the loss resistance drops to just about zero. Now the efficiency is 36 (radiated) divided by 36 (total) or 100% (theoretically at least). The improvement by adding the radials is 100/59 or less than 3 dB (actually only 2.2 dB). 100 radials probably is not worth the effort unless you are deeply into contesting.

SHORTER ANTENNA

But suppose the antenna is only 1/8 wave high. Now the story is a lot different. Short antennas have low radiation resistance. The 1/8 wave antenna has a radiation resistance of only 7 ohms. The total resistance you’ll see at the base between the antenna and the 5 radial ground system is 7 ohms plus the 25 ohms loss resistance or a total of 32 ohms. The efficiency is 7 ohms (radiated) divided by 32 ohms (total) or 22%.

But now let’s put in the 100 radials to get zero loss. Now the efficiency is 100%. The improvement? 100 watts / 22 watts, or 6-1/2 dB. That’s theoretical. Out in the real world you’re not going to do quite that well because there will be losses, especially in the loading coil you need to resonate the short antenna. This means that you’ll get less than 22 watts radiated with the 5 radials and less than 100 watts with 100+ radials. But you’ll still see a noticeable improvement after adding the radials.

CONCLUSION

First of all Kurt hopes that you noticed that, except for the loading coil problem, you get just as much power radiated from a shortened antenna as you do from a full ¼ wave tower *if you have a perfect ground.*

Second of all he hopes you remember that the shorter the antenna the more radials you need. You can get by OK with 5 radials if your antenna is ¼ wave but if it is only 1/8 wave or less you’ll be ahead to use more. Before you ask the question “how many radials should I use?” be prepared to tell how long your antenna is. An hour or so looking at those charts in the Antenna Book can save a lot of work in your backyard.

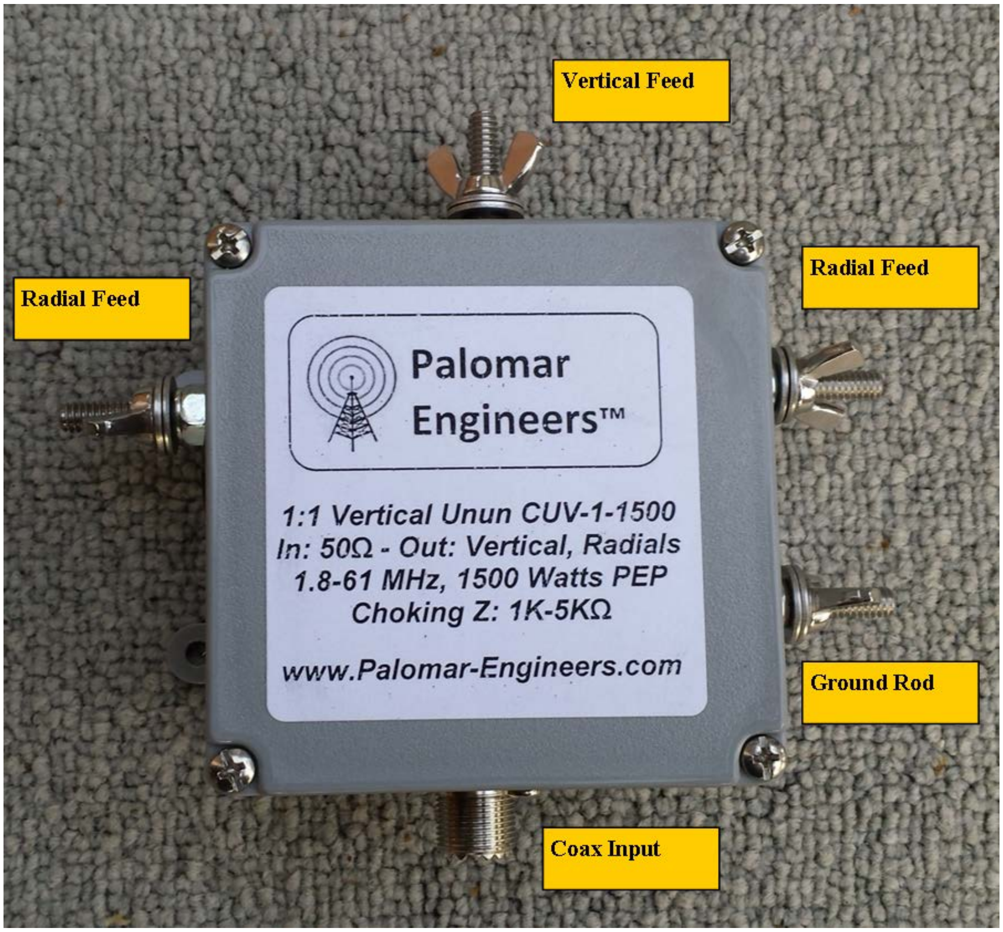
50 W GAIN

When Kurt, was a ham in the 1930’s, QST was the paragon of correctness. Always right. Never a mistake. And in those days “beam antenna” meant a Sterba Curtain or a W8JK end-fire array. The W8JK was by far the most popular since it was within the means of the average amateur and it worked well.

So when I picked up the new issue and spotted an article on the W8JK I was interested. Imagine my dismay to find, right in the first paragraph, the symbol “W” (for watts) instead of "Ω" (the standard symbol for ohms) not just once but repeatedly. Not only that but the English letter "l" replaced the Greek "λ" for wavelength. Pity the poor novice, who just learned the standard symbol usage from his license manual, and who now has to make sense out of this kind of thing.

One would think there would be enough experienced technical persons available to proof read articles before publication. But these days if the computer spell checker doesn't spot it we all suffer. Oh, well.

Palomar Engineers Feed Line Chokes for vertical antennas



1500 Watt Rated 1:1 Feed line Choke (Unun) for Verticals with radials

The CUV-1-1500ST unun is a common mode feed line choke for vertical antennas with radials that need to be isolated from the coaxial feed line to keep common mode current from using the coaxial braid as another radial. Very effective with high choking of 1K-5K from 1.8-61 MHz and also incorporates two side studs/wingnut terminals for radial or ground connection at the antenna while isolating the coax feed line braid from the radials via the internal common mode feed line choke. Top terminal with stud/wingnut for vertical connection enclosed in a 4″ x 4″ x 2″ box.

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5

THE TRUTH ABOUT VERTICALS

I always enjoy the Dayton convention. The crowds are enormous, it's hard to get a hotel room and, if you live far away, it costs a lot to get there. But – the vast flea-market allows you to view the whole history of amateur radio in the piles of "Junque" for sale. Have you seen a vacuum tube lately? Or a radio that uses them? You will in the Dayton flea-market. Need a part of some kind? It'll be there somewhere. You can even buy parts you *don't* need and probably you will. It's hard to resist a real bargain.

Kurt's eagle eye is mostly on the indoor exhibitor's booths. That's where you find all the newest and latest from manufacturers from all over the country and beyond. That's where you also find, in a few booths, exaggerated or sometimes wildly incorrect claims of performance of new antenna designs. The Masked Avenger found a few this year and is here to keep you from being hoodwinked.

RADICAL VERTICAL

There in booth #30 were some nice looking antennas from Florida. We'll call this firm Big Yellow from the color of their ads. The editor requests we not give the correct name as that is a freebie for a company that does not pay to advertise in Worldradio. You can see their products on the web at www.gapantenna.com.

The misinformation in the literature pained old Kurt when he realized that as many as 30,000 hams may have been subjected to it over the weekend. We'll set it right.

We're told that the conventional vertical (a ¼ wave vertical with ground radials) is "the most inefficient, noisy antenna available for amateur use…". Well, as Kurt has explained before, a ¼ wave vertical with 120 radials is almost 100% efficient. You can't do better than that.

Then we're told in their literature that a 26' vertical on 80 meters with three ground radials is woefully inefficient. Of course. This vertical is only a tenth wave long and, as Kurt has explained before, short verticals need lots of radials. But Big Yellow goes on to say that placing 60 radials with 4000 ft. of wire under the antenna still gives an efficiency of only 50% because there's 4 ohms of earth loss. Not exactly! The earth loss will be about 1 ohm and the efficiency probably will be better than 80%. The DX station you're working couldn't tell the difference between that and 100%. Follow Kurt's advice: If you use a short trap vertical and have the room, put in plenty of radials.

Next we are told "Radials are not the answer" Well, as Kurt just explained, they *are* the answer.

"Radials destroy multi-band operation. A multi-band vertical must have earth loss to work". The truth, of course, is just the opposite; the less the earth loss the better such antennas work.

"A multi-band vertical mounted on your roof won't work all the bands". I'm sure that this is news to all those who have done exactly that over the years with their Hy-Gain verticals. They know better. It's the newcomer to ham radio that Kurt is talking to keep him from falling for this malarkey before he learns the truth.

The further I read the worse it got. We were told that "Radiation resistance increases as the feed point is elevated". "Earth loss results from the capacitance of the antenna to ground *above the feed point*". Raising the feed point "virtually eliminates ground loss".

As explained in the Antenna Book, the *feed point* resistance increases as the feed point is elevated. This is because, the higher up you go on the antenna the less the current and the higher the voltage. Ohm's Law is R = E/I. But the radiation resistance at the base of the antenna does not change at all. The current flowing into the ground resistance does not change. The efficiency does not change.

A two color drawing in the brochure shows current flow through capacity to ground above the center feed point but none below the feed point. Presumably this is because the bottom half of the antenna is grounded at the top by being connected to the coax shield. This of course neglects the fact that, as Kurt has explained before, there is current on the inside of the shield equal to that on the center conductor. This current will flow down the antenna to ground giving the same current distribution we would get if we fed the antenna at the bottom. There is no change in operation of the antenna.

The only things that change are the outrageous claims made for this antenna design. "Exceeds conventional verticals by up to 600%". Kurt will welcome field strength measurements backing up this claim. Meanwhile he suggests you keep on working DX with your multi-band vertical whether mounted on your roof or not.

THE POYNTING VECTOR

How would you apartment dwellers like a 20 meter antenna (also covering 17, 15, 12, and 10 meters) that is only 3 feet high? And had almost 100% efficiency? And wide bandwidth?

Do you believe all this? Kurt sure doesn't.

But this antenna company wants us to believe. The three foot vertical has a six foot square ground plane at the bottom and a upside down wire basket on the top. Capacitance between the basket and the ground plane resonates the antenna. And, it is claimed, this capacitor causes a large electric field instead of the large magnetic field of a wire antenna. Maxwell and Poynting, pioneers in electromagnetic radiation, are brought in to support this nonsense.

The interpretation of Maxwell's equation is wrong, of course. The fact is that electromagnetic waves have equal energy in their electric and magnetic fields. This energy moves back and forth from one to the other as the wave moves along. The talk in this antenna brochure about "EDR: E field dominated radiators" and "MDR: magnetic field dominated radiators" is just so much hokum. I'd put this in the same category with copper bracelets and magnetic charms. Too bad newcomers are exposed to this balderdash; some of them may believe it.

SNOWFLAKES

Yes, a beam antenna in another Dayton booth claims that the hexagonal snowflake inspired its "controlled field" design. The result is a "super gain" beam that is half-normal size but with the bandwidth and efficiency of a full size beam. It works fine at low heights so high towers and rotors are not needed.

The world has been waiting for a beam that has gain in all directions so we can dispense with that expensive rotor. Too bad it's impossible.

What is a "controlled field"? How is it generated? We're not told. What gain measurements were made? Well, we're told that the beam's capabilities cannot be based on ground tests alone. They cannot be measured on a range, cannot be viewed on present computer modeling programs, and cannot be defined on paper. Only on-the-air tests will do and those show "noticeable signal intactness and less fading".

The tooth fairy lives out there in never-never land. Old Kurt thinks that this antenna came from the same fairyland. It should be sent back.

Palomar Engineers Feed Line Choke connection for vertical antennas

Feed line chokes for verticals require a special arrangement to isolate the coax feed line from the radials and ground system. Schematically, a good feed line choke for verticals with radials should be built as follows:

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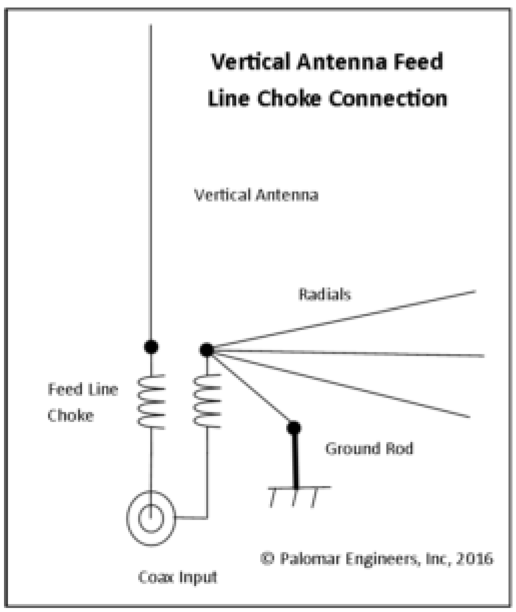

Check Palomar-Engineers.com for updated product information

6

GAIN AND FRONT-TO-BACK RATIO

An avid reader of this column noted an ad in QST for a new “Mini-32” antenna. Opposite “Gain” and “F/B Ratio” it read “Call”. He wants to know why they say that. “Call” usually is used for pricing that may change often.

Very simple. If you call them they’ll tell you the gain and the F/B ratio. They can’t put them in their QST ad.

The reason for this goes back to the early days of amateur radio when Kurt was just a tadpole. Antennas then were simple wire affairs that you built yourself. But then came the Yagi beam. This was more complex, required aluminum tubing and other materials not readily available.

Antenna manufacturers came on the scene. They could buy aluminum by the carload, spend time designing traps and experiment to optimize designs. Hams started buying instead of making. Antenna ads appeared in QST & CQ.

In the early 1960’s George Grammer, W1DF, QST’s technical editor, noticed that some of the manufacturers “stretched the truth” of their gain figures. He was a very diplomatic person. Old Kurt is not and can tell it like it was: they lied. Some still do.

Checking antennas for gain is not easy. To do it right you need tall towers, a big open space and some expensive equipment. QST didn’t have all that so they couldn’t check the gain figures. But they could tell that some of the quoted gains were not reasonable. Some were theoretically impossible.

So, to keep advertisers honest, at least in the pages of QST, the magazine forbid publishing of gain and front-to-back claims in any ad. This was in 1965.

Change comes slowly at ARRL headquarters. George Grammer retired. ARRL built a new headquarters building. Tubes went out and transistors came in. Satellites went up. Packet arrived. But QST’s ad policy remained exactly the same.

Then in 1998 it happened. Someone there woke up and realized that the world had changed. Personal computers had been invented and several QST advertisers were selling programs that allow one to design and to check antennas for gain and F/B. Now the accuracy of gain claims could be checked without an expensive test range.

So QST announced a new policy (you can see it at www.arrl.org). A manufacturer can advertise gain and F/B if he first tests his antenna on a certified antenna range according to Electronic Industries Association (EIA) standard RS-329. This is for antennas from 25 MHz to 1 GHz. It appears to leave out 20 meter beams, tribanders, and other commonly sold HF antennas.

Why the EIA’s RS-409 standard for amateur radio antennas was not used instead is not clear to Old Kurt. It would apply to all amateur radio antennas.

But there is a fairly easy out: Instead of running real world tests the manufacturer can model the antenna using YO or NEC programs. Kurt would expect manufacturers to jump at the chance to get gain figures back into QST. It wouldn’t cost a lot and would give real credibility to the ads. So far only one manufacturer, Telex Hy-Gain, has taken advantage of the new program and they have gone out of the amateur radio business. But watch the ads – the new policy may catch on. Let's hope so. A little truth in antenna advertising would be welcome.

TUNER PROBLEM

QST's "Doctor is In" had a reader whose antenna tuner knob became hot when he ran 100 watts. The good doc advised checking the shaft insulator to see if it was defective or installed incorrectly.

Kurt is pretty sure that when he looks under the hood he'll find that there *is* no shaft insulator. There is a very popular tuner that was built without conventional shaft insulators. Instead the "hot" shaft comes right through the front panel with a rubber grommet to insulate it from the panel. The plastic knob insulates the operator from the RF.

So Wise Old Kurt suggests a larger plastic knob to keep your hand further away from the shaft. But watch that set-screw! Or, if the problem is on just one band, change the length of the transmission line by an eighth or maybe a quarter of a wavelength. That should move the high RF voltage point away from the tuner so the knob won't get hot. That's Kurt's tip of the month.

COMMON MODE CURRENTS

Doc advised another reader whose SWR reading is higher at the end of the coaxial transmission line than it is at the antenna. Doc said that RF from the inverted-L was causing current to flow on the coax shield and this caused the SWR meter to give an incorrect reading. Kurt agrees.

But then Doc gave a technical explanation that is just plain wrong. The Masked Avenger is here to set things right. New hams especially should get correct information so they start out on the straight path. So let's look at some of Doc's statements.

1. The induced current flows only on the shield (since the coax's center conductor is shielded) and hence the fields inside the coax are not equal and opposite in phase as they should be.

   Not so says Kurt! Because of "skin effect" RF current flowing on the *outside* of the coax shield does not penetrate the shield and so does not affect the current flowing on the *inside* of the shield. It is as though they were separate wires. It is important to remember this when working with RF cables. Even if there is induced RF current on the outside of the cable the currents on the center conductor and the inside of the shield remain equal.

2. When the impedance varies (along the coax) your SWR meter will show different readings at different places along the coax.

   Not so. If there are any standing waves on the cable (*in* the cable in the case of coax) the impedance will vary with cable length. This is always the case with a mismatched cable and has nothing to do with current on the outside of the shield. SWR meters are made to work with any impedance they see along the cable.

THE RIGHT ANSWER

So what actually is going on? The RF voltage from the Inverted-L antenna causes a current to flow on the outside of the coax. Where does it flow? It flows into ground at one end of the cable and back up from ground at the other end. This makes a complete circuit. Almost always it takes a complete circuit for current to flow. It doesn't just start and end suddenly. Try connecting a wire to a battery and leave the other end of the wire open. How much current do you get?

The current flowing into the ground at the antenna end adds or subtracts from the antenna current. This changes the antenna impedance as seen by the cable. So the SWR changes. The longer the cable being radiated by the antenna field the more the current and the more the antenna impedance changes.

It is also possible for the current on the shield to get into the sensing element of the SWR meter. This shouldn't happen but it will if the meter's internal shielding is poor. This can cause completely wrong SWR readings. The reader should borrow a Bird wattmeter and see if he gets the same results.

He may find that the SWR still is higher at the antenna end than at the transmitter. This happens if the line is lossy. The forward voltage from the transmitter drops as it goes down the line. The reflected voltage also drops on its way back. At the transmitter the transmit voltage is highest and the reflected voltage lowest so the VSWR will be lower here than at the antenna.

It's amazing the amount of misinformation about antennas that gets into print. But, at least, you have Kurt here to tell it like it really is.

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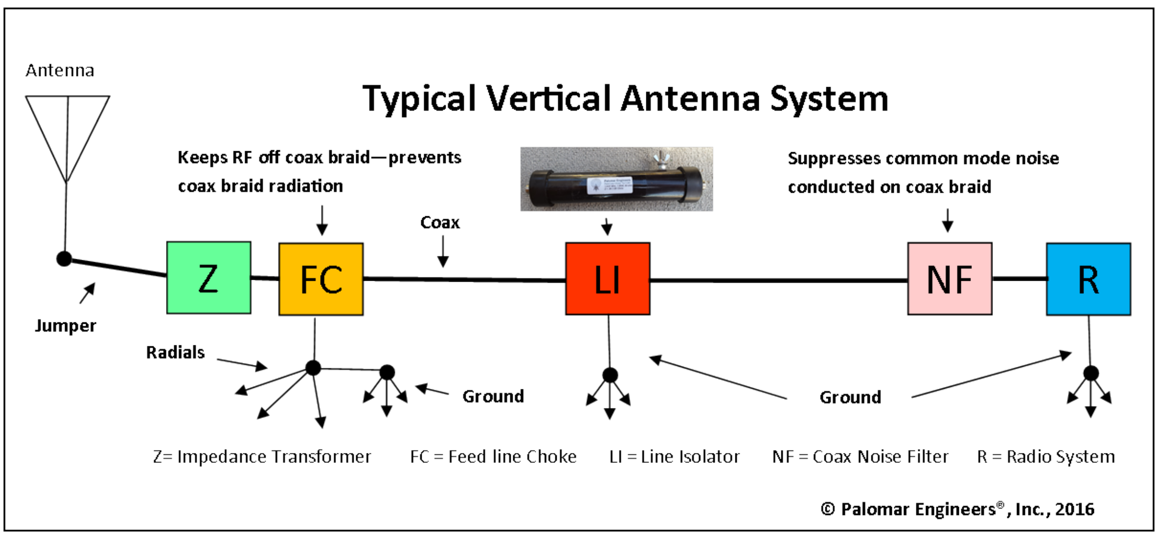
Setting up a vertical system the correct way



7

A GOOD, CHEAP. SMALL HF ANTENNA

An avid reader of this column writes to say that he wishes that the antenna manufacturers were all honest so Kurt could spend less time pointing out their unfounded claims and more time writing about antennas and how to build and adjust them. Don't hold your breath on the antenna claims but this month we will talk about building a wire antenna.

THE VER-TEE

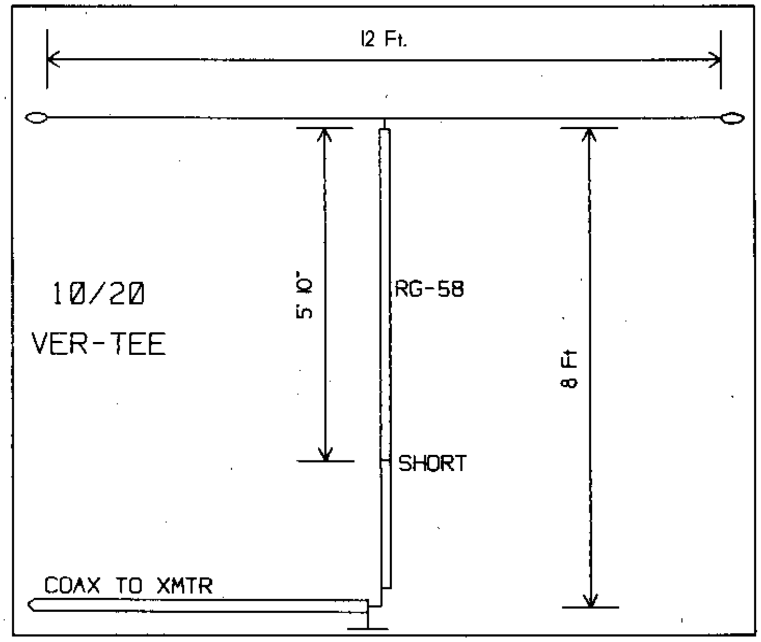
Here is a simple and inexpensive 10 and 20 meter antenna small enough to go on your patio or even on a small balcony. It was designed as a 40/80 dual band antenna by Pete Czerwinski W2JTJ (QST Dec 1961). He probably is better known as the designer of the beer-can vertical. Kurt has adapted the VER-TEE for 10/20 now that the sunspots are coming back. We'll have the 40/80 design too.

The 10/20 meter version is quite small. Its flat top is twelve feet long and, from its center, an eight foot length of ¼" coax drops to a ground screen. You must have an adequate ground for the antenna to work. I used a piece of hardware cloth 3' wide and 10' long. This is not cloth but a galvanized iron mesh that you find at your local handyman store. It is rugged and lies flat nicely but is a bit expensive. You could use inexpensive aluminum window screen. You can't solder to it but a good mechanical connection would work just fine. Another way is to use radials if you have room. There should be at least four, each 15 feet long. Twelve radials would be a lot better.

HOW IT WORKS

Kurt thinks that this design is masterful in its simplicity. To understand it you must remember that a coaxial cable can be considered a three-wire cable. There is the inner conductor, the inside of the shield (these two form the transmission line), and the outside of the shield. It's because of "skin effect" that RF currents don't penetrate the shield but just flow on its surface. That's why there can be completely separate currents flowing on the inside and the outside of the shield.

Take a look at the figure. The flat top is a 12' length of wire. At its center a length of RG-58 coax hangs down. Only the center conductor of the coax is connected at the top. Only the shield is connected at the bottom. Part way down from the top the center conductor is shorted to the shield.



What gives here? Well, the coax is a quarter wave long on 10 meters. At first we're interested only in the outside of the shield so the length is a quarter wave in "free space".

The top section of the coax above the short is a quarter wave long. Here we're interested in the cable as a transmission line. It's a quarter wave long where the velocity factor is about 0.66 making the length 2/3 of the "free space" wavelength.

On 10 meters the shorted quarter wave section of coax looks like an open circuit. It's in series between the coax shield and the flat top. So, on this band, the coax outer shield is disconnected from the flat top and serves as a quarter wave vertical antenna.

On 20 meters the shorted section is only an eighth wave long. At this length it looks like an inductor. So on this band the coax outer shield is a vertical antenna with an inductor in series between it and the flat top. The flat top acts as a "capacity hat". So we have a top loaded vertical resonant on 20 meters.

HOW TO BUILD IT

First put the flat top together. With an insulator at each end make it twelve feet long out of whatever antenna wire you have available.

Next cut an 8-foot length of RG-58 coaxial cable. At the top end where it connects to the flat top remove the outer jacket and braid for 3 inches. Trim the center conductor insulation back one-inch. Use this to wrap around the flat top wire at its center.

At the other end of the coax remove 2" of the outer jacket. Undo the braid mesh until you have just straight wires. Push this up the 2" and cut off the inner conductor and its jacket. Straighten the braid and twist it into a rope.

Next push a pin into the coax at a point 5' 10" from the top of the braid. (This is easier said than done. Kurt had a sore thumb when it was finally in place.) Use an ohmmeter to make sure you have shorted the braid to the center conductor.

TEST AND ADJUSTMENT

Now you can put the antenna together according to the drawing. Connect a length of coaxial transmission line to it long enough that you can stand away from it to measure its SWR. Connect your antenna analyzer or your SWR meter and transmitter and check the SWR across the ten meter band. I got a minimum of 1.2 at 28.5 MHz rising to 2.0 at 28.0 and 29.0 MHz. To get this minimum anywhere you want it in the band move the pin. Go up to move it higher, down to move it lower.

After you are satisfied remove the pin and make a permanent short. To do this remove some of the outer jacket. Then push the braid aside to make a “hole” in it. Pull the inner conductor slightly out of the hole so you can remove a bit of its insulation. Then make your short.

Now move down to 20 meters and check your SWR. I got a minimum of 1.5 at 14060 KHz rising to 1.6 at band edges. This was too broad indicating that my ground screen was inadequate (lossy) on 20 meters. In spite of what you may read in antenna catalogs flat SWR is not good. It indicates losses. A larger ground screen would fix this.

To adjust the minimum SWR frequency lengthen or shorten the flat top. That’s it! You are ready to go on the air with your low cost, small dual-bander.

THE 80/40 METER VERSION

Build this antenna in exactly the same way. Now the flat top should be 40’ long, the coax 33’ long and the short 22-1/2 feet from the top of the braid. And your ground screen or radials will have to be four times the size.

And the Beer Can Vertical? This will not be coming. For one thing Lil finally talked Old Kurt into giving up beer drinking so as to obtain a slimmer figure and better health. That takes a lot of the fun out of building this particular antenna.

More important is the fact that W2JTJ built his antenna back when beer cans were steel and of a shape that stacked well. Now they are aluminum, have rounded bottoms, and you can’t solder them together. That’s progress?

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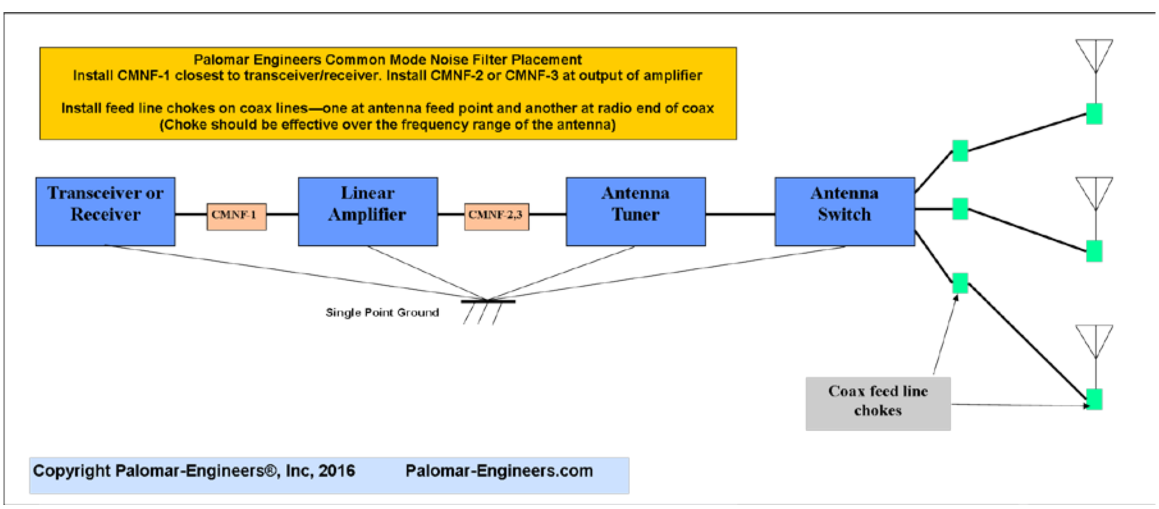
Use a Common Mode Noise Filter on your Coax Line to reduce background noise



8

ALL ABOUT COAX

Kurt frequently describes coaxial cable as acting like a three-wire cable. The inner conductor and the inside of the shield are the transmission line. The outside of the shield acts like a third wire at radio frequencies.

The reason for this is that, because of “skin effect”, the current flowing on the inside of the shield flows only on and near the surface. It does not penetrate the shield far enough to show up on the outside.

For the same reason currents induced on the outside of the shield do not affect the currents flowing inside.

A reader questions this explanation. He explains that there is capacitive and inductive coupling between the inside and the outside of the shield so that the currents are the same on both. Also high SWR can cause RF currents to be present on the outside of the coax.

KURT'S EXPLANATION

The reader is wrong on this one. There is no capacitive coupling between inside and outside of the shield because the shield is highly conductive. Currents are confined to the inside of the shield itself. Also, as the reader points out, the equal currents in the center conductor and the inside of the shield are in opposite directions and thus their fields cancel. So there is no inductive coupling.

High SWR causes higher currents in some parts of the cable and lower currents in other parts of the cable. Standing waves, remember? But in any portion of the cable the currents in the inner conductor and the shield remain equal. SWR does not cause currents on the outside of the shield and does not cause TVI regardless of what you may read in some advertisements.

THE PROOF

Theory is all well and good but actual tests are more convincing. Here is a simple test you can make.

Connect your 50 ohm dummy load to one end of a coaxial cable. At the other end apply 50 watts from your transmitter. From Ohm’s law you now know that 1-Ampere of RF is flowing along the inside of the cable shield. ($I^2 = P/R$). If P=50 watts and R=50 ohms then 50 watts / 50 ohms = 1 Ampere.

Now clamp your Palomar RF current meter on the outside of the cable. You will not read anything.

Don’t have a RF current meter? Use a flashlight bulb, or better yet one of those low-current pilot lamps. Remove the outer jacket from the cable at two places about a foot apart. Connect the lamp to the shield at these points. If there is appreciable current on the outside of the shield the lamp will light. This was the old time way to measure cable current when open wire line was in vogue. In this instance Kurt is sure the lamp won’t light at all.

Next, connect the cable to your antenna tuner and connect your dummy load to the tuner's output. Adjust for high SWR on coaxial cable. Check again for current on the outside of the shield. There won't be any.

THE CROSSED-FIELD ANTENNA REVISITED

This new antenna (the "CFA") has come on the American scene as an import from England. It sounds like a dream antenna: a 21-foot CFA outperforms a 211-foot broadcast antenna. It has wider bandwidth and is more efficient. Sound too good to be true? That's right. It is too good to be true.

The antenna has a large flat donut shaped plate. This lies flat to the ground but suspended a few feet above ground. Above this is a structure resembling a giant oil drum. Sitting on top of this is a wire mesh in the shape of a funnel making the antenna look like a giant tuba.

The explanation given for its operation is in three parts:

1) RF voltage applied to the donut shaped plate produces an "H" field.
2) RF voltage applied to the "oil drum" produces an "E" field.
3) A phasing unit adjusts the phase difference between the two so that an electromagnetic field is produced.

The inventors claim that Maxwell's equations show that the antenna actually works this way.

Old Kurt pulled out his dusty textbook and took a look at Maxwell's equations. The equations told *him* that these guys are full of hot air.

The claims made for the antenna are highly suspect and seem to change with the wind. For example: "High efficiency, with a 6-dB gain typical relative to a conventional one-quarter wavelength vertical radiator."

As Kurt will explain, this is impossible. A quarter-wave radiator with a good ground system is more than 95% efficient. 6 dB better than that would have us with an antenna putting out considerably more power than was put into it, the electronic version of a perpetual motion machine

When an interviewer from *Radio World* magazine asked about this the inventors stated that "a little confusion has arisen". The comparison actually was with " a fictitious or non-realistic antenna system." For a few minutes Old Kurt thought that his memory was going due to his advanced age. But, looking back at the broadcaster's convention report, it *did* say "conventional quarter-wavelength vertical radiator." Apparently it's the CFA inventors whose memories are weak.

On another occasion, in a brochure handed out at the National Association of Broadcasters convention the inventors claimed 90% efficiency for their antenna, as compared to a conventional half-wave antenna that "radiates with only 35% efficiency." All the "conventional half-wave antennas" that Kurt has used over the years have had about 99% efficiency. It makes him wonder what kind of engineers these guys are.

FIELD STRENGTH

Kurt's biggest problem with this antenna is the complete lack of field strength measurements. When asked about this following the broadcaster's convention the inventors promised field strength measurements in "about two years". This has old Kurt scratching his head in disbelief. Ten of these antennas are in use in Egypt at broadcast stations and there are no field strength measurements?

In the U.S. you have to supply the F.C.C. with complete measurements in eight different directions and at several distances before you can go on the air with programming. Try telling the F.C.C. that you'll give them that information in a couple of years! Good luck! What kind of engineered installations are these in Egypt that haven't been checked with field strength measurements?

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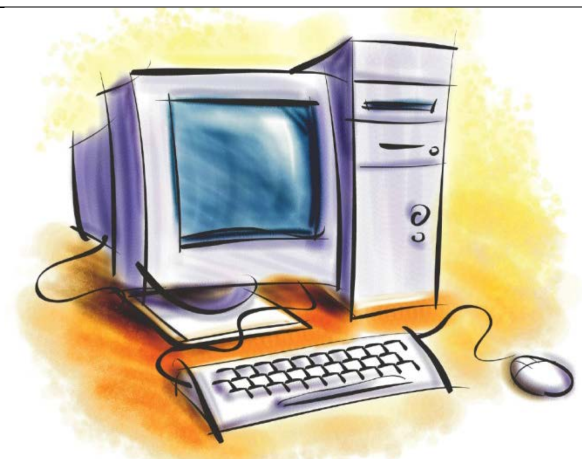
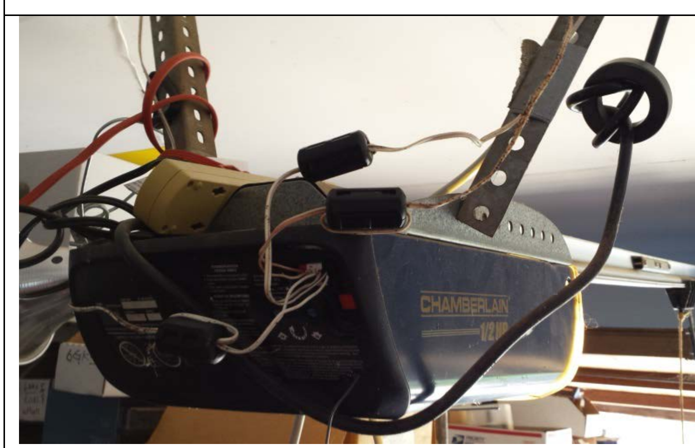
Got interference problem in your home or neighbor's house?

	**The Home Theater RFI Kits are specifically designed to cure most home theater systems triggered by Radio Frequency Interference problems from AM, FM, CB and Ham radio stations.**
	**These RFI kits are specifically selected to cure many computer device RFI problems. Kits available for desk top, lap top, DSL/cable routers, Ethernet hubs, network boxes, wall wart power supplies**
	**The Garage Door Opener RFI kit is specifically designed to cure most garage door opener systems triggered by RFI problems.**

9

THE TRUTH ABOUT LOOP ANTENNAS

Kurt keeps reading construction articles for small transmitting loop antennas. Many of them are woefully inefficient but you wouldn't know that from reading the articles. Kurt is going to show you how to tell how efficient a loop design is before you build it. This could save you a lot of disappointment.

By small loops we are talking about loops with a total conductor length of less than 1/10 wavelength. Examples are the commercial loops for 20/15/10 meters that are 3 feet in diameter.

The problems that are often overlooked are the very low radiation resistance of small loops, the large currents and high voltages that are present, and the very narrow bandwidths. If the bandwidth is not narrow and the voltages are not high the efficiency is low.

The loops are attractive because of their small size. If you live in an apartment with restrictions, as many do today, a three-foot loop is a lot easier to conceal than a 33 foot dipole for 20 meters.

THE EQUATION

The easy way to check the design of a small loop is to use the well-known equation for its radiation resistance. Normally Kurt hesitates to put an equation in an article; one good friend, when an equation is mentioned, gets glassy-eyed and usually stands up to leave. But, in this case, there is no other way and the equation is simple and can be solved with your $5 hand calculator. The equation is:

$$R_R = 31{,}200 \times N^2 \times A^2 / \lambda^4 \text{ ohms}$$

These are standard symbols: N is the number of turns, A is the area of the loop and λ is the wavelength.

To show how it works we'll look at an antenna by W6QIF in the Fall 1999 issue of *Communications Quarterly.* He describes a unique PVC mounting for a portable loop but the electrical design is just a bit modified from a design by W9BRD in July 1993 QST.

W9BRD's 40 meter loop has three turns. So N^2 is 3 x 3 = 9.

The loop is 3.5 ft. by 4.5 ft. so the area is 15.75 square feet. Both the area A and the wavelength λ have to be in the same units. The wavelength is 40 meters and so the area must be in square meters. All the rest of the world does everything in metric but here in the good old U.S.A. we're still stuck with English measurements. Even the English have given them up!

But Kurt to the rescue: multiply square feet by .093 and you get square meters. So our area is 15.75 x .093 = 1.46 square meters. And A^2 is 1.46 x 1.46 = 2.1 square meters. λ^4 is just 40 x 40 x 40 x40 = 2,560,000

I hope my equation-hating friend is still with us because we are close to the very interesting result. We put the numbers into the equation and see what the loop's radiation resistance is: R_R = 31200 x 9 x 2.1 / 2,560,000 . R_R = 0.23 ohms

This is bad news because the input resistance of the antenna is 50 ohms. The input impedance is the sum of the radiation resistance and the loss resistance. In this case it is mostly loss. The efficiency is the radiation resistance divided by the total input resistance or 0.23/50 = .0046 or 0.46%. This means that if you put 100 watts into the loop you will get less than ½ watt out! QRP lives!

WHAT NEXT?

Does this mean you should not build one of these loops? Not at all! Kurt thinks both W9BRD and W6QIF should be congratulated for coming up with these interesting designs and taking the time and trouble to write them up for publication. Our purpose here is to build on what they have done and improve the efficiency.

How is this done? To start with you have to change your thinking from the dipoles and beams we all use to thinking *loops*. Dipoles have R_R = 73 ohms or so. You could make an "invisible" dipole antenna for 40 meters with #30 wire and still have over 90% efficiency. No so with a small loop. They have R_R of less than one ohm, maybe as low as .02 ohm! You have to use big wire or tubing and keep all losses low if you expect any sort of reasonable efficiency.

W9BRD's loop used 48 feet of #18 "Zip" cord. This has an AC resistance of 3 ohms at 7-MHz. That's a lot larger than the radiation resistance of the antenna. So for starters you can see that you need larger wire. Actually you don't want wire at all. Kurt says: Use copper tubing. Not small tubing either. Start right off with 3/4 inch tubing. They call it "refrigerator tubing" at the handyman stores. It has lower RF resistance than the loop's radiation resistance so you have a good shot at high efficiency.

Next be sure to use split stator variable capacitors. Use the two stators as the two terminals. That way the resistance of the rotor connection is not in the circuit. But now that you have reduced the loss resistance the RF current will go way up and so will the capacitor voltage. Think 5000 volts or so even at 100 watts. And with the low loss comes high Q and narrow bandwidth. You'll have to retune for even small frequency changes. But you will get out.

Of course, when you get the losses down the input resistance of the loop will be something like one ohm. You can't connect directly to it or you'll have 50:1 SWR. Instead use a coupling link or gamma match.

CONTRAWOUND TOROIDAL HELICAL ANTENNA

QST's technical department looks at new products to ensure that the advertising claims are truthful. They especially have to worry about antennas since the historical record shows stretching of the truth in many instances. And it is difficult for the average amateur to evaluate an antenna's performance. Test equipment for the purpose is expensive and almost impossible to use on a city lot. On-the-air tests are subject to the rapid variations in propagation. So it is helpful to rely on the judgment of the folks at QST to keep fraudulent ads out of the magazine.

But Crusty Olde Kurt can see that they fell down on the job when they passed the ad for this antenna, the CTHA.

What is it? It has two pieces of wire wound on a PVC form that looks like, and is about the size of, a Hula Hoop. One wire is wound in one direction, the other in the opposite direction, *contra-wound*. When you wind a wire on a circular form it is *helical*. And a Hula Hoop is *toroidal*. So we have a "Contra-wound Toroidal Helical Antenna". Kurt doesn't believe the "Antenna" part but he does admire the Madison Avenue style name.

Toroidal coils, usually wound on ferrite or iron powder toroids, are used a lot in radio equipment. One of their favorable characteristics is that they have a very small external magnetic field so they can be placed next to other coils without interacting. This is the opposite of an antenna where you want the largest external field you can get.

Kurt would expect very small output from this antenna just from the way it is built. He hasn't tried one but W4KSY has. His report is in the November 1999 issue at www.antennex.com. The antenna is at its best on 10 meters where it is 4 or 5 "S" units down from a dipole. On 80 meters it is 7 to 8 "S" units down. Kurt's advice: You can buy a good dummy load for a lot less than $289.95.

You can read about this gem in November & December 1999 QST's ads for NOMOSNO.

TRUTH IN ADVERTISING

QST's new policy allows manufacturers to put antenna gain figures in their ads but only if they supply the magazine with proof that the numbers are correct. Old Kurt explained this recently but failed to give credit to the first manufacturer to take advantage of this opportunity and the only manufacturer to advertise antenna gain in QST for the last 35 years. That company is M^2 of Fresno, California. Its founder, Mike Staal, K6MYC, has been making amateur antennas for many, many years. You can see his honest figures at www.m2inc.com. Kurt is more than pleased to tell you this!

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Palomar Engineers 2:1 Loop Balun

2:1 (100:50) Baluns are useful between 50 ohm coax and 100 ohm balanced lines for loops, cubical quads, log periodics and other antennas where the impedance at the end of the feedline is 100 ohms (1/2 wavelength feedline).

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450 OHM LINE IS NOT 450 OHMS

A reader asks for help with his 80 meter dipole antenna. It's about 35' high and fed with 28' of 450 ohm line. This goes to a 9:1 Palomar balun (450 ohm to 50 ohm), then 50 ohm coax to the transmitter. No antenna tuner. He uses it on 80, 40, 20 and 10 meters.

The transmission line part *looks* all right. But is it? No, it's not. The problem is that the 450-ohm line does not look like 450 ohms to the balun.

Why is that?

If you look into one end of a 450 ohm line and the other end is connected to a 450 ohm antenna you *will* see 450 ohms. But if the antenna is some other impedance you will see something different. And you'll likely not see the antenna impedance either.

Let's look at this antenna on 80 meters. It's fairly low off the ground for this wavelength so, on its resonant frequency, it will look like about 30 ohms. But what will you see on the other end of the 450 ohm line?

To illustrate the problem in a simple manner let's make the line a half-wave long. A half-wave line repeats at its input whatever load is on its output. So with this antenna we'd see 30 ohms. Our SWR would be 450/30 = 15.

Another simple case is if the line were a quarter-wave long. A simple equation gives us the input impedance: Input Z = $(\text{Line Z})^2 \div$ Load Z

Our 450 ohm line transforms the 30 ohm load impedance up to 6750 ohms! The SWR would be 6750/450 = 15. So you can see that the input impedance we see depends strongly on the line length.

With this antenna setup we don't have a quarter-wave or a half-wave line. The actual length is about 1/10 wave on 80 meters.

Kurt just showed you the two line lengths that are easy to calculate. This one is not so easy! You could use the Transmission Line Equation shown in the Antenna Book. It's ghastly; don't even think of using it unless you enjoy mathematics.

There is the Smith chart that's a lot easier. Still, if you haven't used it before it takes some study before you understand it.

Better yet, use a computer program and let the computer do the math. One program comes with the latest edition of the Antenna Book. Kurt used it to find what this antenna looks like to the balun on 80 meters: R = 56 ohms and X =+j380 ohms. The SWR is 14.

So, even though the antenna is resonant and looks like a pure 30 ohms resistance, at the other end of the cable it looks non-resonant and of a different resistance. The balun sure doesn't see 450 ohms and at the other side of the balun we aren't going to see 50 ohms. No wonder the transmitter powers down on this band!

On 40 meters the antenna is a full wavelength long. The impedance will be something like 4000 ohms at resonance. The chances of our seeing 450 ohms at the end of the 28-ft 450-ohm line are so small that Old Kurt hated to compute it. But he did. It's R =55 ohms   X = -j102 ohms. The SWR is 9.

The conclusion: It's a hopeless case. This antenna system won't work with a modern transceiver that requires a 2:1 SWR. The advice: Buy an antenna tuner and start over. And always remember that you're not likely to see 450 ohms at the transmitter end of a 450 ohm line.

RADIATION RESISTANCE

A manufacturer of vertical antennas claims an improvement in efficiency by moving the feed point up above ground to get a higher radiation resistance. Kurt explained that this does not increase efficiency. The manufacturer disagrees and, in fact, is quite upset with Krusty Old Kurt. Who's right? Why Kurt of course. Here's why:

Let's start at the beginning: What is radiation resistance?

$$\text{Radiation Resistance} = \frac{\text{Radiated Power}}{I^2}$$

Where I = The RF current at the connection point

The current is different at different points along the antenna. So the radiation resistance depends on where the connection is made.

There is a special case that is important. That is when the connection is made at a point of maximum current. This is at the base of a grounded short vertical or at the center of a dipole. This is where the radiation resistance of a quarter-wave vertical is 36 ohms and where the radiation resistance of a half-wave dipole is 72 ohms. This is the connection point they always talk about in the Handbook and the Antenna Book. It is often called the "loop radiation resistance".

Why loop? Because in engineering texts a current maximum is called a "current loop".

RAISE THE RADIATION RESISTANCE

If you drive a short vertical antenna at its base the power you put in gets divided between the radiation resistance and the loss resistance. The radiation resistance part gets radiated and the loss resistance part keeps the earthworms warm. If you increase the radiation resistance by making the antenna longer or by top loading it you get more radiated signal. So increasing the radiation resistance increases the efficiency of the antenna.

But increasing the radiation resistance by moving the feed-point up

does not. Why not?

On a short vertical the current is highest at the base and tapers off to almost nothing at the top. The voltage is least at the base and gets higher as you go up.

Remember that R = E/I (Ohm's law). So as E (voltage) goes up and I (current) goes down R goes up. So the higher your feed-point the higher the radiation resistance. It's just as though you were driving the antenna through a transformer. The radiation resistance is transformed upwards *but so is the loss resistance*. The antenna losses do not change. The efficiency does not change.

PROOF

There are those will not believe Kurt's explanation. So he has devised a simple experiment that is easy to duplicate and that proves the point. You need an instrument that measures RF resistance. The neat little Autek antenna analyzer, for example.

Put up a 15 foot vertical wire. At its base put a ground screen. Kurt used a 3 ft. x 10 ft. wire screen. You'll recognize this as a 20 meter ¼ wave vertical antenna system.

Connect the meter between the ground screen and the vertical wire. Find the resonant frequency and measure the resistance. Kurt got 48 ohms. We know that the radiation resistance is 36 ohms. So the loss resistance is 12 ohms. (36 + 12 = 48). Your reading may be different but do the same calculation using your results.

Now connect the vertical direct to the ground screen. Go 4 ft. up the vertical. At this point cut the wire and insert the meter. Measure the resistance. Kurt got 74 ohms. Figure the ratio. In Kurt's case it was 74/48 = 1.54. The new radiation resistance is 36 x 1.54 = 55.5 ohms and the new loss resistance is 12 x 1.54 = 18.5 ohms. (55.5 + 18.5 = 74).

PROOF POSITIVE

Now for the test. Add a resistor between the vertical and the ground screen. Kurt used 22 ohms. What will the meter read now? At the base it will read 48 + 22 = 70 ohms.

But 4 ft. above the base what will it read? Will it read 74 + 22 = 96 ohms? Or is the added resistance value transformed up to give 74 + (22 x 1.54) = 107 ohms?

107 it is. The loss resistance goes up in the same ratio as the radiation resistance. There is no gain in efficiency by raising the feed-point, just an increase in feed-point resistance. The manufacturer's yellow catalog has it wrong.

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11

DIPOLES AND DOUGHNUTS

An engineering student wrote to Kurt recently. He misunderstood the professor and thought that a dipole had maximum radiation off the ends of the wire. Later he wrote that he was mistaken and that the maximum is off the sides. In a third letter he said that he was still a bit confused.

Kurt sympathizes because he too once suffered through an engineering professor or two who were not clear in their lectures and left their poor students bewildered.

Krusty Old Kurt is here to make the dipole radiation pattern easy to remember. All you need is a donut and a pencil. The donut should be a nice fat one. Put a mark right in the center of the pencil.

Put the pencil through the hole in the donut and center it. Keep it parallel to the ground. The pencil represents a half-wave or shorter dipole and the donut represents its radiation pattern in free space.

To find the radiation in any direction just draw an imaginary line from the center of the pencil out in that direction. The more donut the line has to go through the more the radiation in that direction.

For example, imagine a line going straight up from the center of the pencil. It has to go through the thickest part of the donut so *this is a direction of maximum radiation.* You can rotate this line downward around the wire clear around in a circle and you'll always have maximum radiation.

But now tilt the line away from the vertical in the direction of the wire. As you tilt it the radiation slowly drops off until the line is in the same direction as the wire. Now the line does not touch the donut and there is no radiation at all. And at small angles away from the wire there is very little radiation.

GROUND REFLECTION

If you move the dipole from outer space to a more convenient location such as your backyard you find that the lower half of the donut disappears. The downward radiation from the antenna hits the ground and most of it is reflected upward. This changes the pattern a little giving more gain in most directions.

Most importantly it affects the low-angle radiation near ground level. Our imaginary line going straight up still goes through the maximum amount of doughnut and thus indicates maximum radiation. But as you rotate this line around the wire and as it approaches the horizontal, the radiation drops of sharply until, when the line *is* horizontal, there is no radiation even though the imaginary line goes through the thick part of our half-donut. Keep this in mind.

This means you don't get low angle radiation from a horizontal dipole when it is above ground. But the higher up you put it the lower the radiation angle you get. So to work DX raise your dipole as high as you can.

RADIATION OFF THE ENDS

There is no radiation directly off the ends of the wire. The Handbook horizontal pattern for a dipole shows a complete null of the ends. But you want to keep in mind that this is the pattern for zero degree elevation. *It does not apply at higher angles.*

Look again at your pencil and donut. Place your imaginary line right along the antenna wire. Then slowly raise the end of the line. As it goes up it soon hits donut. The higher the angle the more the radiation. This is in the direction of the wire but at higher angles. You can work in all directions with your dipole. As a matter of fact the ground reflection gives additional radiation strength at low angles in this compass direction.

As compared to the maximum radiation from the dipole the radiation off the ends is down about 8 dB at 30 degrees elevation. At 15 degrees it is down about 14 dB and at 9 degrees, 18 dB.

This sounds bad but 18 dB is just 3 “S” units. Instead of S9 you’d be S6. So what? If you can do it tune in the BBC or Radio Netherlands on shortwave AM broadcast. Watch your “S” meter. You’ll see fades of 7 to 9 “S” units frequently. The same thing happens in the ham bands of course but your “S” meter doesn’t show it because, with SSB or CW, there is no carrier. Three “S” units up or down is a minor difference in the world of F2 layer reflections.

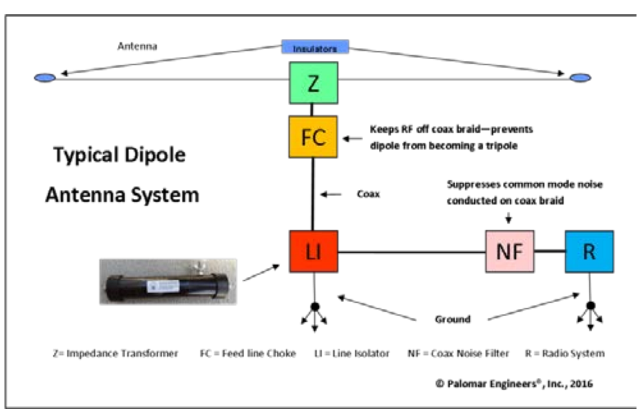
DIRECTIVITY

Kurt hopes that he has made the radiation pattern of the dipole clear and understandable. If you want maximum signal in a given direction orient the dipole so that direction is off the side. If you want low angle radiation to work DX put it up as high as you can get it.

But if you are restricted by your location to just one way to install your dipole, don’t worry. You’ll get out in all directions with it. And remember, a full size dipole is almost 100% efficient. Almost all the power you put into it gets radiated. It is very tolerant of nearby absorbing and reflecting objects. These are some of the reasons that the half-wave dipole is the most popular of all for amateur use.

One big mistake you can make, in a restricted location, is to replace your dipole with a gain antenna. If you have to mount it low to the ground and with trees and buildings surrounding it you won’t get the stated gain from it. And gain antennas have lower radiation resistance and bigger losses. Plus they cost more and don’t look as good.

You’ll be better off spending your money and efforts to improving your dipole by getting it higher up into the air and further away from trees and buildings.



12

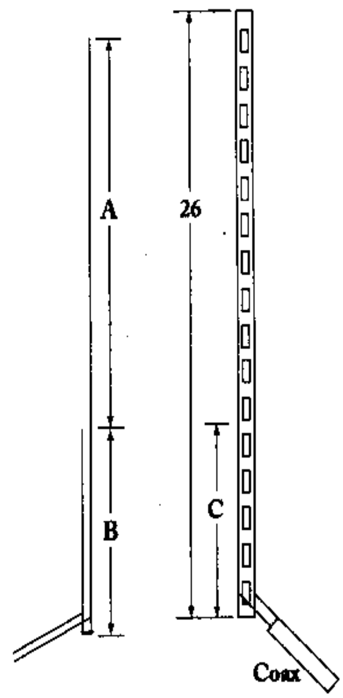
THE “J” POLE

Recent issues of a major amateur magazine carried an article on the J Pole antenna. Several of Kurt’s readers questioned some of the statements in the article. One reader even wonders if the J Pole is a good design. He says it is only seen in the amateur radio literature and not in engineering textbooks.

Let Kurt assure you that it is a good engineering design. It was originally designed for commercial use as an antenna for the early police radios. There was a description in the August 1935 issue of *Electronics* magazine.

At that time it was called the “Flagpole” antenna. This gives a clue to the way it was installed. Kurt thinks that this idea may be useful in this day of antenna restrictions and the search for disguised “stealth” antennas.

He will give the electrical details of two 10 meter versions. It will be up to you to mount it on your flagpole or make a flagpole out of it or devise some other mounting scheme.



HOW IT WORKS

The original Flagpole antenna used ladder line feed. But this was back when amateur transmitters and receivers were made for open wire line. Coaxial cable didn’t come in to widespread amateur use for another twenty years. So there soon appeared coaxial line versions of the Flagpole. And the name changed to “J Pole” from the appearance of the antenna and its matching section. Kurt will show both coax and ladder line versions.

The drawing above shows the 10 meter J Pole design by Stewart Becker W7AYB as described in *QST* fifty years ago.

Section A is a half wave vertical antenna fed at the bottom end. This is the high impedance point on the antenna. It looks like, maybe, 2000 ohms or even higher.

The U shaped section B is a quarter wave transmission line or “stub”. It is shorted at the bottom. A quarter-wave line shorted at one end looks like an open circuit, or at least a high impedance, at the other end. So this matches the antenna. If you tap down on the quarter-wave line the impedance gets lower the further down you go. W7AYB found a good match to 300 ohm line at a point eleven inches above the short. If you go higher up you can match 450 ohm line.

W7AYB made the antenna from “stranded antenna wire” with the antenna (A) 16 ft. 2-1/2 in. long. The matching section (B) was 8 ft. 2 in. long with 1 in. spacing between the two wires. He grounded the shorting bar. That's a big advantage of this antenna for use in areas suffering from static electrical charges and lightning.

SIMPLE J POLE

Krusty Old Kurt has designed a really inexpensive and simple version of the J Pole. Coaxial cable is now common in amateur radio so he has gone back to the coax feed used by Western Electric police installations 70 years ago. The wide-spaced open wire line used by amateurs in the olden days has given way to plastic insulated "ladder line". So that is used for the matching section and for the antenna itself.

As shown in Fig. 2 the antenna consists of one 26 ft. piece of 450 ohm ladder line. One of the wires is cut 7 ft. 9 in. from the bottom end. This forms the matching section (C) which is open at the top.

The antenna section has the wires connected together top and bottom. This improves the bandwidth over a single-wire antenna.

The coaxial line connects 10-1/2 in. from the bottom of the matching section, center conductor to one wire, and shield to the other.

Use a balun here. The easy way is to put two inches length of 43 mix ferrite beads over the cable. If you ground the antenna do so where the coax shield connects to the matching section.

ADJUSTMENT

Kurt's dimensions may have to be changed a bit in your installation depending on the characteristics of the ground, presence of nearby trees and buildings, and what part of the band you operate in.

He had 1.0 SWR at 28.5 MHz rising to 1.2 at 28.0 and 29.0 MHz. To raise the resonant frequency shorten the top (antenna) section; to lower it lengthen it. If the SWR at resonance is not 1.0 move the coaxial line connection up or down a little on the matching section.

You can do without a supporting structure and just hang the antenna from a "sky hook" of some kind. If you do, you should bridge the point where the ladder line was cut with something non-conducting so as to give more mechanical strength to the assembly.

RADIALS

As all those ads for "half-wave" verticals tell you, you don't have to have radials under this type of antenna. What they usually don't tell you is that you'll get improved signal strength, maybe even one whole "S" point, if you do have a ground screen or radial system under your half-wave vertical. So keep that in mind. Kurt told you so.

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13

18 dB IS A MINOR DIFFERENCE?

In a recent column about dipole antennas Kurt explained that signals off the ends of a dipole at low angles will be 18 dB down from those off the dipole's side. But, he said, "Don't worry. Considering the fading that takes place on shortwave signals 18 dB makes a minor difference.

One reader complained that Kurt was losing his mind. How could he say such a thing?

Easy. If your signal is S9 and it drops to S6 (18 dB) the fellow at the other end will hear no difference. Why? The audio output of a good receiver (the one Kurt uses) drops 3 dB if the signal drops 60 dB. A little drop of 18 dB is not noticeable <u>if signals are strong to start with</u>. And if there is no competition, he might add.

The reader has a good point though and we should look at the situation from his viewpoint. If your signal is weak to start with, then if it drops 18 dB it may well vanish completely.

Also, if your signal is a good clean S6 but the other station answering the CQ is S9 then he's the one who'll get the QSO. This is where the AGC works against you. When your signal is the only one the AGC adjusts you to a comfortable audio volume. But when the S9 signal comes on it adjusts <u>him</u> to a comfortable level by dropping the receiver gain 18 dB. This drops you down. Anyone who works contests knows that a big signal makes it easier to get contacts.

Let Kurt put it this way: QRP works but high power gets out better. You can work DX off the ends of your dipole but you'll do better off the sides.

FABULOUS NEW ANTENNA

Dave, KZ1O, brought Kurt's attention to a newly patented antenna that may revolutionize amateur radio. It is small in size, greatly reduces propagation losses and sends signals many times the speed of light,

The antenna is less than one foot in length and will work indoors without danger of RF exposure to those in the household because the power is transmitted into another dimension. The station at the other end must use the same type antenna. This will slow its penetration into the amateur scene but no more so than the startup of packet, for example. You can't work a station on packet unless he also has a packet setup.

HOW IT WORKS

This antenna sounds too good to be true and it would be if it followed conventional propagation methods. But it doesn't do that.

The antenna has two powerful electromagnets set so their fields are in opposition. This produces a plane of strong magnetic force. This plane is heated by a halogen lamp at 1000^{o} Fahrenheit. Wrapped around the lamp are two accelerator coils, one at +2000 volts, and the other at -2000 volts.

Right on the magnetic plane is the actual antenna, a quarter wave coil that pokes a small hole into another dimension (hyperspace). In this space the transmission can exceed the speed of light by many times.

The station at the other end also needs to produce an injection point to receive hyperspace signals.

The antenna is small enough to set on your operating table. It works fine indoors; no need to have any outside wires, cables, or towers. Also, if you have plants growing indoors they will flourish if you use the antenna regularly. The injection point "allows energy from another dimension to influence plant growth."

Does this antenna really work? That depends on whether or not the hyperspace it uses actually exists. Kurt knows all about hyperspace having been an avid reader of *Astounding Science Fiction* for many years. Hyperspace solves the problem of space travel. The stars are so far away that a spaceship traveling at the speed of light would take much longer to get to one than the lifespan of the crew. In hyperspace the ship can get there almost instantly.

Radio signals also will travel fast enough to eliminate the delay we now have in satellite transmission and other problems caused by signal delay such as selective fading, ghosting of TV images, digital signal dropouts, etc.

For full details on this antenna see U.S. patent 6,025,810. You can get a copy for $3. Go to www.uspto.gov.

UP A TREE

When testing a new antenna Kurt needs an anchor point or two in the sky to hold it up. There are a number of tall trees handy. The problem is getting a line up over a high branch. He has a favorite small transformer as a weight which is tied to a long piece of string stretched out on the ground. Kurt heaves the transformer skyward hoping it will go over the branch thus pulling the string up.

There are several problems with this approach. Sometimes the string gets caught briefly on a weed. This causes the transformer to miss its target. Also Kurt's throwing arm is not that accurate. This leads to string wrapped around branches and other unwanted results. If you've seen Charlie Brown try to fly a kite you get the flavor of the enterprise.

Lil objects to the language sometimes heard during these projects so when Kurt's birthday came around she bought him a commercial device made for the purpose. It is a plastic holder fitted with a slingshot and a fishing reel. A sinker as used by fishermen, painted bright yellow, is on the end of the fish line. The slingshot shoots it over the tree, it pulls the line over the tree and there you are all set to pull up the antenna.

If you haven't used a slingshot before it takes a little getting used to. But then the thing works just great. You can go as high as 100 feet if needed. You'll find the device advertised in all the better radio magazines, Worldradio for example. Or see it at www.ezhang.com.

CROSS POLARIZATION

A faithful reader of Old Kurt's column was wondering about using two dipoles for the same band, one horizontal and the other vertical. Will he see a difference in receive strength between the two? Would there be an advantage to setting up a rotatable dipole with horizontal/vertical ability?

Well, yes you will see a difference in receive strength, sometimes a big difference. It depends on the arrival angle, direction and polarization of the incoming signal so will be different for different signals.

Kurt prefers two separate antennas to a rotatable one. If you are listening in horizontal and you want to see if vertical would be better it is a lot nicer to be able to throw a switch and find out instantly instead of waiting for a motor to turn the rotatable dipole.

Of course there may be signals that come in best halfway between horizontal and vertical so there is at least that advantage to the rotatable. But there are other important considerations that favor the two antennas.

So far we've been talking about steady signals that are best heard either horizontal or vertical over a considerable length of time. A common problem on the HF bands is rapid fading and rapid change of polarization of signals. We're talking now of changes taking place in a few seconds or less.

These rapid changes can be taken care of with two antennas switched rapidly and automatically. This is *diversity reception*, something first introduced on the ham bands back in the 1930's.

DIVERSITY RECEPTION

The idea is to use two antennas, just as we have described, and to listen to just the one with the best signal. You use two receivers, one on each of the antennas, tuned to the same station.

In the simplest arrangement you have two loudspeakers for the two receivers and you listen to the one coming in best. This works, but not very well, because the receiver with the poor signal puts out a lot of noise. This makes an uncomfortable accompaniment for the signal coming in the other receiver.

DIVERSITY ON THE CHEAP

W2JCR, in a 1939 *QST* article, described a way around this problem.

He used stereo headphones with one receiver in each ear. He explained, "Noise is normally far less troublesome on headphones and, moreover, the two ears act as a sort of automatic selector in this system, the noise scarcely registering, and after a little practice it goes unnoticed."

He reported "a marked reduction in fading". Krusty Old Kurt, having used a similar system, can attest to the improvement that dual headphones can give.

IMPROVED DIVERSITY

There are two major drawbacks to the system just described. It is a real pain to have to tune two receivers exactly together as you tune across the band. Digital frequency readout on both receivers should make it easier but still it's awkward.

Although the brain removes the effect of the noise it would be a lot nicer if it could be eliminated. The X1G receiver, named after the Mexican amateur who paid for its development, solved both problems. It was described by Jim Lamb, QST's Technical Editor, and J. L. A. McLaughlin in May 1936 *QST*.

They built two receivers on one chassis but with just one high frequency oscillator. Tuning that oscillator tuned both receivers in unison.

Next they added the automatic gain control voltages together and applied the result to both receivers. The audio outputs were connected together.

The receiver with the strongest signal reduced the gain of the one with the weak signal so the noise from it was kept at a low level.

The X1G receiver had three "S" meters (called "R" meters in those days). There was one for each receiver channel and one for the combined output. The authors stated that, "Their action is fascinating to watch, giving a striking picture of the wide and ever-unlike variation of the signal input to the two receiver sections. The effectiveness of the diversity action is shown by the fact that, even though they may swing wildly, the combined output hardly ever shows more than a barely noticeable change." In Kurt's words: Diversity works.

LIMITATIONS

Now the bad news. The X1G receiver was designed when amplitude modulation was the norm on the ham bands. It works well on AM reception and so is well suited to shortwave broadcast listening. But it does not work on CW or SSB. Also not with synchronous AM detectors.

To see why that is we need to look at the incoming RF signals from the two antennas. At first glance you would think that you could just add the two antenna signals together. The strongest one would be heard.

Unfortunately, the changing phases of the two signals cause the combination to fade just as the individual signals do. These phase changes are also present in the i.f. following the receiver mixers. So you can't add the two here either. It is only after the diode detector, where we have the rectified envelope of the signal to work with, that the signals can be combined.

That's AM detection. To "detect" CW, or SSB, or to get synchronous AM detection, we don't use a detector diode. Instead we use an oscillator to mix the signal down to "baseband". It's just another mixer and the phase changes remain.

WHAT NEXT?

The basic setup of two receivers and a common oscillator (or one receiver controlling the other) is still valid. You have two AGC voltages and two audio outputs available.

Kurt thinks that any digital designer could connect a comparator to the AGC lines to determine which channel has the best signal. This would control a couple of gates that would feed the best signal to the speaker at all times.

Simple. Why didn't they do this back in 1936? Because a comparator alone would cost about as much as a receiver. You needed several vacuum tubes, plus and minus 150 volt regulated supplies, and a digital designer of which there weren't many around. Now you can buy a comparator for 50 cents and the other items as IC's for pocket change.

Six decades have produced big changes and made things that were impossible easy to do. It may be time to revitalize diversity reception. Have at!

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Palomar Engineers Combiner/Splitter for diversity reception. Two antennas combined or one antenna to two radios.

Use a noise filter to quiet reception on receive antennas

14

TWO TYPES OF HAMS

There are two kinds of ham radio operators: Those who have RFI problems and those who are going to have them. Really? You bet! The electronics industry is hiring engineers at a high rate to design new radio receivers and transceivers called "Personal Communications Devices". They're going to appear in your house, your neighbor's apartment, everywhere. And a lot of them are going to quit working when you start to transmit.

The FCC has made the manufacturers put warning labels on these devices stating "This device must accept any interference received. Including interference that may cause undesired operation."

So when your neighbor calls to tell you that the screen goes blank on his new digital TV at the same time that your voice comes out of his microprocessor-controlled expresso machine what do you do? Tell him to read the warning labels on the rear of the machines? Forget it! If your transmitter causes RFI you have a problem. It's partly a technical problem but mostly a people problem.

Now is the time, before you get that call, to get prepared with some technical knowledge about RFI, its causes and cures.

Let's begin by looking at a problem that is common these days, telephone RFI. Anytime you talk on 20 meters the lady next door hears you on her telephone. She uses her telephone a lot.

How do you stop it? Low pass filter on your rig? A filter on you transmitter's AC power line? Balun on your antenna? Better ground system for your station? All of these are considered "good engineering practice" and, if you are lucky, they may cure the problem but, more than likely, they won't help at all. Why not?

Let's look at the technical fundamentals of the problem. EMI engineers use what they call the "Source-Receptor-Path" model. To have an RFI problem there must be a SOURCE of RF, a RECEPTOR of interference and a PATH connecting them. In this case we think we know the SOURCE (our transmitter) and the RECEPTOR (the telephone), but we don't know the PATH just yet.

To find the PATH let's first look at the SOURCE. Our transmitter produces, let’s say, 100 watts. Because of our long history of TVI problems the manufacturer of the transmitter has provided a tight metal box to keep it from directly radiating. He also has put filters on the leads coming out of the box (power input, key and microphone leads, remote control wiring, etc.). Filters aren't perfect but the RF leakage from these leads will be in the low milliwatt or maybe the microwatt range.

There is one exit for the 100 watts and that's the antenna connector. If your station is typical, a length of good quality coaxial cable pipes the 100 watts to an antenna where it is radiated for all the world to hear. So, for purposes of examining our telephone RFI problem, we can consider our antenna as the SOURCE instead of our transmitter.

If the antenna is the SOURCE then putting a filter on the transmitter's power cord is not going to help at all. Improving the ground system won't help either because the antenna will still radiate the full 100 watts. Now that we've identified the SOURCE these facts are obvious. But remember, before we identified the SOURCE they weren't obvious. Thinking the problem through sure can help solve it!

Now we need to find the PATH. Since the RF is radiated from the antenna the path starts through the air. Is it then picked up directly by the telephone? Not likely - the 'phone is too small to be much of a receiving antenna. But it is connected to a large "antenna", the telephone wiring running through the building. If this cable runs through the attic it may not be far from your antenna.

Now that we identified the SOURCE, the RECEPTOR and the PATH we are ready to find the CURE. Clearly there is nothing to be done at the transmitter/antenna end (except possibly moving the antenna) because we want that radiation to continue so we can work DX with it. At the RECEPTOR end we almost certainly could get rid of the problem by shielding the telephone cable. That solution probably is not practical. Another, and easier, solution is to RF “decouple” the telephone from its cable. This can be done without affecting the voice and data going through it.

The first choice for this CURE is the use of ferrite toroids (rings) or snap on beads. One inexpensive toroid commonly available has a half inch hole (Palomar part No. FSB31-1/2) and snaps on the affected cable. The telephone line's modular plug will go through the hole. Run it through three or four times then plug it back into the telephone. The ferrite toroid acts partly as an RF choke but mostly like a resistor that absorbs RF. It will prevent the RF from entering the telephone (or at least reduces the amount going through) thus decoupling the telephone from the line at RF. It will not absorb the voice or DC going through the line. This is because the RF is "common-mode" and the voice signal is "differential-mode". We'll go into this phenomenon in detail in a future installment.

This CURE works most of the time but, unfortunately, not always. It depends somewhat on the RF characteristics of the telephone and on the RF signal strength. In simple telephones the RF is detected by diodes that are used to keep the audio signal level constant. As long as the RF voltage is large enough to cause the diode to conduct it will be detected. Even though the RF voltage is reduced the sound does not change if the diode still conducts but once the signal drops below the conduction level the sound suddenly disappears. So, even if one toroid appears to not help at all, a second toroid may CURE the interference completely. Experiment a bit for best results.

If ferrites don't do it the next step is to use a filter. These are available commercially for around $15 to $30. They are fitted with modular plugs and just plug into the line and the telephone. They contain inductor-capacitor filters that are quite effective.

One important feature of both of these CURES is that they do not modify the telephone in any way. You can't be held responsible for any later problems with the telephone. Keep in mind that the lady next door probably hasn’t the faintest idea of how the telephone works. She just wants to use it in peace. Try to leave her that way as a happy neighbor.

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ANTENNA TUNERS

A reader writes, "Ads talk about certain brands of antenna couplers as 'high efficiency'. It seems to me that the only way power can be dissipated in these circuits is in the resistance of the coil. Is there something else that affects efficiency?"

Usually most of the losses are in the coil. But they are not just due to the resistance of the wire. As a matter of fact, the best efficiency is down at the lower frequencies where most of the coil is in use. The "Q" of the coil here, in a quality tuner, will be about 200.

As you go higher in frequency more and more turns are shorted out to lower the inductance. This introduces losses and by the time you get up to ten meters the "Q" may drop to 20 or less. So significant power is lost in the coil at the high frequency end of the tuner's range.

There is no way to avoid this in a single coil tuner. It is possible to use a separate high frequency coil placed so it does not couple into the larger low frequency coil but this rarely done because of the added complexity and expense.

Another source of coil loss is in the cabinet itself. The metal cabinet should be distant from the coil by at least the coil radius. This is not always the case in modern equipment where "low profile" miniature cabinets are desired. If the cabinet is too close the coil "Q" and thus the efficiency will be further degraded.

There also is the contact resistance of the roller in the usual variable inductor. This gets worse with age when film and dust collect on the coil. The solution here is, of course, to clean the coil and roller once in a while.

YOU CAN HELP

There is another major source of circuit loss that the you can control. This is because there is more than one control setting that results in 1:1 SWR on the transmitter cable, but only one of these settings gives the best efficiency.

Here is how to get it: Start with both of the capacitors set at maximum capacitance. Next adjust the "antenna" or "load" capacitor and the coil to get minimum SWR. If this minimum is not 1:1 then reduce the capacitance of the "transmitter" or "input" capacitor and try again.

Keep doing this until you get 1:1 SWR with the "input" capacitor as large as possible. Following this procedure you may cut your losses in half!

THE BALUN

So far we've been talking about the standard "T" tuner with two capacitors and one inductor. This "single-ended" tuner drives coaxial cable to the antenna. Most of these tuners have provision to drive balanced "open-wire" lines and use a balun to do this. Baluns work pretty well for low impedance loads but can be very lossy when working into high impedances.

To check your tuner for losses and to see if and where they are a problem transmit "key down" for a minute or so. Then turn off the transmitter and check the tuner for warm or hot spots inside.

160 METER ANTENNA

A reader wants to get started on a 160 meter antenna. He plans to use a 30 ft. pole and top loading coil. How to calculate the coil inductance?

This is a good question to ask Kurt because he uses a 30 foot vertical on 160 meters and gets out very well. Not in the top rung of contesters of course because that is a very short antenna for this band. He'd like to have a quarter-wave vertical but can't go up the required 130 feet.

The trick in using a short vertical is to keep losses down by having a good ground system, using top loading to bring up the radiation resistance, and using a high Q coil or, better yet, no coil at all.

The radiation resistance of a 30 foot vertical is about 1.6 ohms. You will be lucky if you can build a ground radial system with a resistance of less than 15 ohms or so. These numbers give an efficiency of 10% - 10 watts out for 100 watts in.

With a top loading coil you can improve that to 25 watts out. And if you leave out the coil and use a big capacity hat instead you can get that up to 35 watts out.

Kurt uses a capacity hat of 12 radial wires, each 25 feet long, with a wire going around the outer ends tying them all together. At the end of each wire there is an insulator tied to a guy wire that goes to whatever tree or post can be found in that direction. Most guy wire ends are about 6 feet above ground. The resulting antenna looks like a big parasol.

RADIALS

You need radials at the base also. Very important. How many? Use at least twelve. More are better but those first twelve drop the resistance down the most. How long? Kurt's are mostly 50 feet; some longer. 35 feet will work fine if you are pressed for room.

LOADING COIL

Krusty Old Kurt's antenna resonates just a little above the 160 meter band. A small loading coil at the base brings it down to 1850 KHz. Why not a top loading coil? It's very inconvenient to tune exactly to the desired resonant frequency with a coil up there at the top of the mast. The big top umbrella eliminates the need for much of a loading coil and the small base coil is just for tuning.

You are going to want a small loading coil at the base with a tap or two if you want to move around the band. Kurt's vertical has a 2:1 SWR bandwidth of about 80 KHz; the band is 200 KHz wide. Remember, the better the efficiency of your antenna the less the bandwidth.

Don't be taken in by those commercial antenna ads that tout their wide SWR bandwidths as though they were something to be proud of. Loss resistance is what gives wide SWR bandwidth. Don't forget that.

FEEDING THE VERTICAL

If all goes well and you wind up with a base resistance of about 15 ohms, the easy way to connect your 50 ohm coax is through a 4:1 (50 to 12.5 ohm) unun (unbalanced to unbalanced transformer). Palomar Part #: CU5012-1500. Put one right at the base.

THE TOP LOADING COIL

If you can't put up a big umbrella then use a little one with a top loading coil. This better than a big base loading coil. You must have some capacity above the coil; a vertical whip, horizontal wires, or a capacity hat.

The amount of capacity above the coil affects the size of the coil you need. How to decide how big a coil you need? There are equations in the March 1990 *QST* article by W7XC. Great article. Your library may have it.

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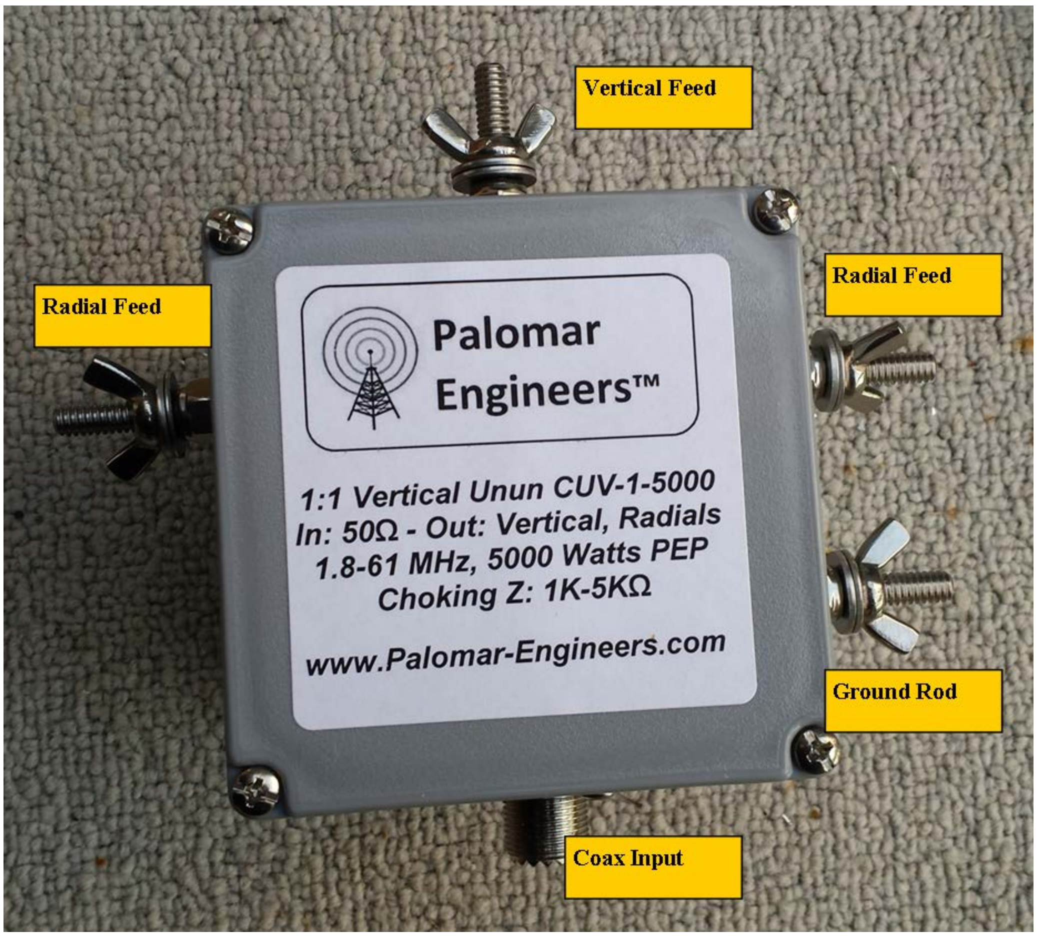
Vertical Antenna Feed Line Choke & Radial Connection



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WHICH SWR IS BETTER

Nothing makes Old Kurt's blood boil more than the antenna ads stressing low SWR across the band. As though that were a good thing, a desirable feature, and the important figure that separates the good from the bad antenna.

You've seen the beautiful full color ads from the big American manufacturer. The antenna glistening in the sunshine, the concave SWR curves - one for each band, the glowing text extolling the virtues of the new design. The gain figures either missing or in very small print.

The exasperating thing for Kurt is that, in spite of the thousands of words he has written to expose this fallacy, there are many who still believe SWR to be THE important figure to use to choose an antenna.

Tilting against windmills he may be but Krusty Old Kurt will charge on this time by looking at two antennas from Italy. One has the flattest SWR curve you are ever likely to see outside of a dummy load. The other has the unflattest SWR curve Kurt has ever seen. You have to re-tune if you move 2-KHz.

Which is the better antenna? Read on.

160 THRU 2 METERS, NO TUNING…the brochure's headline proclaims. There is a photo of what, at first glance, appears to be a two element beam. Closer examination though shows it to be a lot different than a beam. It is about the size of a 10-meter beam but the driven element is a folded dipole fed at the center with a matching transformer. The center of the second wire is open and connected to the center of the other element. The connecting wires are crossed to give a phase shift.

The second element, which would be either a reflector or director in a normal beam, is also a folded dipole. Its second wire is split and terminated with a resistor. So you have sort of a combined two-element beam and T2FD terminated dipole in one antenna.

Except that it is not a beam. The manufacturer does not use the word anywhere in his literature. He calls it a "1.5-200 MHz 1 Kw PEP Continuous Coverage Antenna". And continuous coverage it is; SWR a little above 2:1 maximum over the whole frequency range. You can operate without a tuner on all the HF bands and on 6 and 2 meters. If that is all you want in life, there it is!

The power rating is a different matter. Most antenna manufacturers put the PEP rating in big print at the top. Down below in little print (if at all) is the continuous power rating. In this case the manufacturer is up front about it and allows 100 watts on 160 meters, with gradually rising continuous power capability in the HF bands to 500 watts on 10 meters.

On HF the antenna gain is stated to be 3 dBd on 15 meters and 6 dBd on 10 meters. This is outstanding considering that the maximum possible gain for a two element 10 meter beam with this boom length is only 5 dBd! And this antenna dissipates some of the power into a resistor. Apparently miracles do happen.

There is no gain on 20 meters and the gain falls off rapidly below this frequency. The efficiency may be very low, particularly when you get down to 80 and 160 meters, but you will get out. Kurt proved this long ago with his garbage can and shopping cart loaded dipole.

If low SWR is your greatest wish, here it is in one 1.8 to 200 MHz antenna. Details at www.antenna.it.

BIG SMALL LOOP

A large loop (1/8λ diameter or larger) makes a good transmitting antenna. A small loop (1/10λ diameter or smaller) has a different directional pattern and usually is used for direction finding and low noise reception.

Small loops can be used for transmitting but you have to be careful. Their radiation resistance is very low so you have to use low loss construction. If their efficiency is even mediocre the capacitor voltage is very high. Kurt has seen many loops made of #18 or similar wire tuned by receiving type variable capacitors that just have to be woefully inefficient.

This Italian loop covering 160, 80, and 40 has none of these problems. First of all it is 13 feet in diameter which is about as big as you can go on 40 meters and still have a "small loop". That's why Kurt calls it a "big small loop".

Kurt calculates that a 13 foot loop has a radiation resistance of .006 ohms on 160 meters, still pretty small. So how do they keep the loss resistance low? By using a big conductor for the loop. No number 18 wire here! The loop is made of aluminum tubing five and a half inches in diameter.

No receiving type tuning capacitor either. The voltage across the capacitor? With 600 watts power into the loop the capacitor sees thousands of volts. It has the look of a giant heat sink. Really thick plates widely spaced.

There is no mention of how the loop is tuned across the bands. You'll have to tune it every time you change frequency. The bandwidth? On 160 meters 3-KHz.

The efficiency on 160 meters? 40%. On 40 meters its 93%. A lot better than the wide-band low-SWR antenna described above.

Why would anyone want such an antenna? Here's why: It's only 13 feet high and 13 feet wide so it can fit in a small yard. With a little advanced planning it could be concealed from the neighbor's view and thus used in a restricted area. Remember, a 160 meter dipole is 240 feet long and should be that high in the air to work really well. Loops work well when sitting right on the ground. 40% efficiency doesn't sound that great but short verticals or shortened dipoles are usually a lot worse on this band.

So is Kurt going to buy one? No. He'd love to have one but Lil is not likely to increase his allowance enough to spring for the $1,765 price tag. You get one and let Kurt know how well it works.

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THE DOCTOR IS IN

QST's "Doctor" recently described a linear loaded dipole for 30 meters. It looks to Kurt like a nice simple antenna that should work well if only it would stay up. It looks like a folded dipole but with both wires cut in the middle.

In the pictorial drawing it is nicely suspended in air as a "sloper". But if you build it like that it will fall to the ground. What to do? Old Kurt to the rescue!

Use two ordinary antenna insulators. When you cut the wires use the insulators to splice the wires back together mechanically, but not electrically. Then it will stay up just fine and also take the strain off the coax that attaches to center of the lower wire.

Actually, a purist like Krusty Old Kurt would put a few ferrite beads over the end of the coax to form a current balun. Any balanced antenna fed with "unbalanced" coaxial cable should have a balun to make sure no RF goes down the outside of the shield.

8 dB GAIN DIPOLE

This time Kurt is going to show you how to make a dipole with 8 dB gain. Sound impossible? No, it's easy. All you need is some antenna wire, insulators, and end supports.

First decide what band you want the antenna to be for. Then cut the antenna wire to length according to this formula:

$$\mathbf{Length_{feet} = 468/f_{MHz}}$$

Put an insulator on each end. Then cut the wire exactly in the center and put an insulator there. Connect your transmission line to the center. If you use coaxial cable put some #43 material ferrite beads on the cable just below where it attaches to the antenna. Without this current balun there may be radiation from the coax and you will not get the full gain.

Now raise the antenna. It should be at least ½ wavelength above ground. One wavelength is better.

And, Kurt forgot to warn you, the ground under the antenna must have conductivity of 10 mS/m or above. If it does not you will need to find a better location that does have really good ground. Most of the Central Plains is alright but, if you live west of the Great Plains or east of Dayton, you should find a nearby swamp, lake shore, or seacoast to erect the antenna.

GAIN CALCULATION

By now you probably want to see just how this fabulous dipole provides the stated gain. Here it is:

A dipole has a gain of 2.15 dB over an isotropic antenna. Of course isotropic antennas don't exist but it is helpful to compare your antenna to one because you immediately get some gain without really having to do anything.

Next, if you put your dipole up high as Kurt has suggested you get an additional gain from that part of the signal reflected from the ground. Over good ground this can be 5.9 dB at certain elevation angles.

Add these two gains together and you can see that this dipole has a gain of 8.05 dB over isotropic, that is, 8.05 dBi.

13 dB TRIBANDER

You thought Old Kurt was fooling you with that high gain dipole. It's a plain old dipole just about like thousands of hams have in their backyards. Nothing special. Yes, you can show that it has 8 dB gain by playing with figures and moving dB's around from one kind to another but what's the point?

Here's the point: Krusty old Kurt moved dB's around to up the dipole's gain in exactly the same way that the Big Antenna Company gets those marvelous gains for their antennas. Kurt wants you to remember this little exercise when you leaf through that nice full-color catalog.

Let's look at one of the Big Antenna Company's antennas. It's a tribander for 10, 15, and 20 with three active elements on each band. We know what the maximum gain over a dipole is for a three element beam (from reading the Antenna Book). It's 5.1 dBd.

But look closely at the specifications. They aren't talking dBd's, they are quoting dBi's. We already know that a dipole has a gain of 2.1 dB over an isotropic antenna. So already we have 5.1 + 2.1 = 7.2 dBi. See how easy that is without even going outside to work on the antenna!

You'll also note that the beam is up in the air at one wavelength. That means it's up about 30 feet on the ten meter band, 45 feet on the 15 meter band and 60 feet for 20 meter operation. Apparently the moveable tower is at extra cost. But by having the beam at one wavelength on each band you get an additional ground reflection gain of 5.9 dB.

Simple arithmetic now shows that the tribander indeed has 13 dBi gain. Kurt wants you to remember though that if you put it at the same height as your simple dipole the improvement will be just 5 dB. A real improvement but, nevertheless, 5 dB not 13 dB.

ADJUST YOUR TUNER

A short while ago Kurt told you how to adjust your antenna tuner for best efficiency: Start with both of the capacitors set at maximum capacitance. Next adjust the "antenna" or "load" capacitor and the coil to get minimum SWR. If this minimum is not 1:1 then reduce the capacitance of the "transmitter" or "input" capacitor somewhat and try again.

A reader says "My tuner manufacturer says to do it differently. It sounds like tuners need to be evolved further".

Wrong, wrong, wrong! There is no mystery to antenna tuners. Do it the way Kurt says and you'll get the highest efficiency possible. You'll get tuned up alright by following the manufacturer's instructions but you won't get the most efficient setting. Trust Old Kurt; he knows!

If you think there is any "mystery" to antenna tuners find a copy of the May 2000 RadCom (England's QST). In it G3LNP explains in great detail how tuners work and describes a simple modification you can do to make yours even more efficient.

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Got Ferrites for fighting RFI Issues?

Ferrite Snap On Combo Pack

1/4"(6), 3/8"(6), 1/2"(6), 3/4"(4)

RFI Range 1-300 MHz

Ferrite Mix 31 Sampler Pack

Ring: F240-31(2) 1.4" ID

Snap On: 1/4"(4), 3/8"(4), 1/2"(4), 3/4"(2), 1"(1)

Slip On: 1/4"(4), 1/2"(4)

RFI Range 1-300 MHz

Ferrite Snap On/Ring Combo

Ring: F240-31(3) 1.4" ID

Snap On: 3/8"(6), 1/2"(6), 1"(1)

RFI Range 1-300 MHz

#31 (4), #61 (3), #77 (3)

Check Palomar-Engineers.com for updated product information

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THE G5RV ON TWENTY METERS

The G5RV is a multi-band center-fed antenna that will operate on all HF bands from 3.5 to 28 MHz. In spite of what you may have read elsewhere you have to use a tuner with the G5RV on all bands except 20 meters. That's what Louis Varney, G5RV says. If you don't agree, write to him, not to Kurt.

A reader of Kurt's column wants to put up a G5RV to use on 20 meters. His first question is: The formula gives a length (of the flattop) of 102.57 feet. But all the articles recommend 102 feet. Why?

Here's why: G5RV in his article uses the formula for long-wire antennas (the G5RV is 3/2 wavelength long on 20 meters) and gets a length of 102.57 feet. Then, for no reason at all that Kurt can figure, he says let's just make it 102 feet since we're going to use a tuner anyway.

But Kurt's reader is not planning to use a tuner because he's just going to use it on 20 meters where it is resonant. So he should use 102.57 feet. This puts resonance in the center of the band so it will work over the whole band with lowest possible SWR. That's where the 14.15 comes from in the formula.

The reader wants to work on the CW portion of the band centered on 14.05 MHz so he can replace the 14.15 in the formula with 14.05. He'll then find the proper length to be 103.3 feet.

If the U.S. were not a backward country still using Ye Olde English measurement system we wouldn't have to convert that 103.3 feet to 103 feet 3-5/8 inches to measure the wire. We would have had it in metric in the first place and school kids wouldn't have to study fractions anymore. Of course, that may never happen.

THE BALUN RATIO

Now that our reader has his 103-ft three and 5/8 inch flattop measured he next needs to measure the 34 ft. 450-ohm ladder line. This is a half-wave matching section going from the antenna center to the 50 ohm coaxial cable that goes to the transmitter.

The reader says an article he read says to use a 1:1 balun to connect the ladder line to the coax. Why, he wants to know, isn't it a 9:1 balun going from 450 ladder line to 50 ohm coax?

Krusty Old Kurt can't remember how many times he's had to answer that question. This probably is the most widespread technical misconception in amateur radio. Kurt wants you to repeat after him: "You don't necessarily see 450 ohms at the end of a 450 ohm line - You probably won't see 450 ohms at the end of a 450 ohm line - The impedance you see at the end of a 450 ohm line depends on what is connected to the other end and on the length of the line." If you can remember those sentences Kurt assures you that it will save you a lot of grief in years to come.

The 450 ohm line in the G5RV is a good example. On 20 meters it is a half-wave long electrically. A half-wave line always shows you exactly what is connected to the other end. In this case the other end goes to the antenna that G5RV says measures 90 ohms. So what you see at the bottom end of the line is 90 ohms, not 450 ohms. If you used 90 ohm coax to the transmitter a 1:1 balun would be perfect. This would give 1.0 SWR on the line but the transmitter would see the 90 ohms at the other end of the line, not the 50 ohms it was designed for. So you haven't gained anything.

Don't try to find 90 ohm coax. It is expensive and won't take much power. The most common type of 90 ohm coax has a center conductor of #30 wire. You can't put much power through that.

Stick with good old 50 ohm coax and a 1:1 balun. The SWR on the coax will be 1.8 instead of 1.0 but your rig will load up OK anyway so don't worry about it.

Palomar Engineers 1:1 balun for ladder line to coax such as G5RV, ZS6BKW antenna.

Kurt would like to make sure that you remember that a half-wave line always shows the impedance that is connected to the other end. If we connect 90 ohms resistive to the far end of our 450 ohm line we see 90 ohms at the other end, not 450 ohms. But what if we used a half-wave of 75 ohm twin lead and put 90 ohms on the far end? We would see 90 ohms, not 75 ohms, at the other end. The half-wave line repeats what is on the other end regardless of the impedance of the line we use.

This is THE interesting property of the half-wave line. In spite of what you may have read elsewhere there is no other magic characteristic of a half-wave line.

USE A TUNER

The G5RV used on bands other than 20 meters requires a tuner because the antenna plus matching section is not resonant on the other bands. The antenna length was selected to give good radiation patterns not for all-band resonance. Does this reduce its efficiency? Not at all. There is no magic about a resonant antenna. It is easy to match because it has no reactance but it is no more efficient than a non-resonant antenna.

Kurt heard a conversation on 20 meters wherein the ham explained that he couldn't work 80 meters because his antenna bandwidth was only about 80 KHz down there. Kurt wanted to tell him to get a tuner. Then he could work the whole 80 meter band. The antenna efficiency would be good across the band. The only penalty would be in losses in the coax feeder due to higher SWR. How much loss? A 100 ft. line of RG-8 with 1.0 SWR has a loss of less than .4 dB on 80 meters. With a 10:1 SWR the loss goes all the way up to 1.6 dB. You wouldn't even notice the difference on the air.

Get a tuner, work DX and be happy!

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KURT IS PREDJUDICED, NOT!

A longtime reader wants to know why Kurt praised a certain manufacturer's antenna a few years ago but recently complained that the same company put misinformation in their advertisements.

Very simple. The antenna Kurt praised was a good one. And Kurt found a lot of baloney in the firm's more recent advertisements. Krusty Old Kurt calls it as he sees it. If it looks good he says so. If it stinks he holds his nose. It doesn't matter who the manufacturer is or who wrote the advertisement.

The Masked Avenger is here to right wrongs and clear the path for the unwary. It keeps him busy; no other field has as much flimflam as the antenna business. It goes on and on.

HYDRONIC RADIATION

Thirty years ago the big flimflam was called Hydronic Radiation by its "inventor". This was a "new principle" that allowed long distance transmission of radio waves underwater.

Like most frauds it had a high-sounding technical principle, just complicated enough to intimidate the unwary.

It was "a new vector field related to the electromagnetic and magneto-hydrodynamic forces, characteristically propagated through a water medium and associated with electric oscillations". Kurt's translation: Radio transmission through water.

Navy radio engineers knew instantly that the claims were false; radio waves suffer horrible losses traveling through seawater. The higher the frequency the worse the losses. That's why they use very low frequencies, enormous antennas and really high power to send messages through the water.

The antenna for "Hydronic Radiation" looked like a small dipole wire antenna with big metal plates on each end. When the two plates of the transmitter antenna were in-line pointing at the receiver antenna and it was pointing at the transmitter antenna you got maximum signal. Turn one antenna to be at right angles and the signal disappeared. It appeared that the two plates acted like the elements of a Yagi beam.

Radio engineers said, "No. The wires connecting the plates <u>were</u> a dipole. The signal went to the surface of the water, then through the air, then down to the receiving dipole."

A simple experiment showed who was right: Position the plates for maximum signal. Keep them there and keep the same spacing between the two antennas. Then lower both antennas deeper into the water. If the signal traveled between the plates the received signal would not change because the distance between the antennas did not change. On the other hand, if the signal went up to the surface and then back down, the distance traveled would get longer as the antennas went deeper.

As the antennas were lowered the signal quickly dropped off. So much for "Hydronic Radiation".

THE "CROSSED FIELD" AND THE "E FIELD"

The latest "amazing new principle" is the generation of radio waves by separate E and H field generators. The two fields are then combined to form the ordinary radio wave. The stated advantage of the method is an antenna a tenth the size of a normal antenna but with the same efficiency and bandwidth. This is a result engineers have been unable to get in the past.

We first heard of this in the "Crossed Field" antenna originated in Great Britain and first installed in Egypt. Kurt has commented (unfavorably) on this antenna in past columns.

A new antenna has appeared on the scene using the same basic principle. It is called the Super "C" and you can see it at www.gapantenna.com. And you can read about it in detail in U.S. patent #5,796,369.

It is claimed that a 72-inch high "high efficiency compact antenna" will give performance equal to a 40-meter vertical dipole 72 feet high. Clearly this would solve the antenna problem for a lot of hams with outdoor antenna restrictions.

What does it look like? There is a flat plate set parallel to the ground. There is a hole in the center of it. A short vertical rod rises from the center hole. The coax feed is connected between the plate and the rod, sort of like feeding a vertical with radials.

There is a circular hat on top of the vertical. Sort of like a top loaded vertical.

How does it work? The theory is that a magnetic field (the "H field") is produced by RF current in the vertical rod. And an electric field (the "E field") is produced by current flowing in the capacitance between the top hat and the flat plate. If the correct length is selected for the vertical rod then the two fields are equal and combine to form a maximum strength radio wave.

How well does it work? It is claimed that you get full size radiation efficiency from a miniature antenna. The physical height is 1/20 to 1/40 of a wavelength. It gives optimal E x H operation by pattern shaping of the E field (this is the use of one of Maxwell's equations). Extensive ground radials are not required. The much smaller flat plate replaces them. It resonates without a loading coil and has a 2:1 SWR bandwidth of 15% (this would cover the entire 80 meter band 3.5-4.0 MHz).

WHAT DOES KURT THINK?

The theory of the crossed fields and the combining of the individual E and H fields to obtain improved performance over conventional antennas is an attractive sounding new discovery. We can sure use more compact and efficient antennas these days what with restrictive covenants in housing developments, local regulations against antennas and HOA snoops scouting the horizon for anything sticking up higher than a rooftop.

Unfortunately Kurt doesn't think that this antenna is going to do it. A simple fundamental physical law stands in the way. Current in the vertical mast cannot produce an isolated H field. And current through the capacitance between the top hat and the flat plate cannot produce an isolated E field.

Why is this? Because a RF current in a conductor produces a magnetic field. The magnetic field then produces an electrical field. One cannot exist without the other; the two fields are linked together. There is not a separate H field. Similarly a RF electric field produces a magnetic field. There is not a separate E field (Kurt is quoting Faraday's Law here). So the theory given to explain this breakthrough just does not hold water.

Does the antenna work anyway even though the theory is wrong? In the case of the crossed-field antenna no independent tests have been able to verify the claimed results and the designers have not revealed the key thing that Kurt wants to see: field strength measurements. This in spite of the fact that the antennas have been in commercial use for several years.

And the Super C "E field" antenna? No actual field strength measurements have yet been published. Until they are Kurt does not plan to install one in his backyard.

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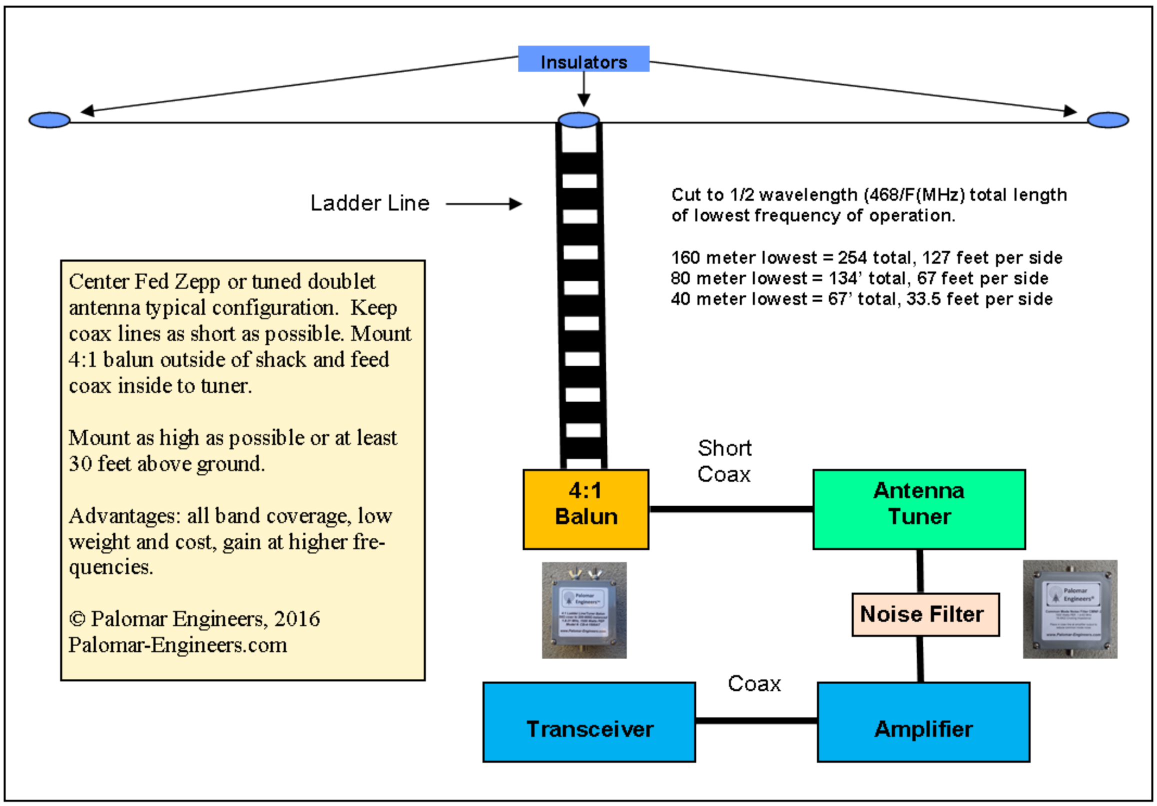
Ladder Line Fed Antenna Idea



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KURT REPEATS HIMSELF

Every once in a while Kurt receives a letter from a reader complaining that he (Lovable Old Kurt) keeps writing about the same old subjects over and over. Enough is enough!

Well, Kurt wants to point out that enough is not enough and he'll give a concrete example from a recent issue of *QST* to prove it.

How many times has Krusty Old Kurt explained that, if you put up a vertical antenna, you need to put radials under it? If it is a quarter-wave or shorter vertical you must use radials or it won't work right. If it is a half-wave vertical it may work without them but it sure will work better with them. How many times has Kurt explained this? Ten times? Twenty times? Thirty times? Who knows?

So, Weary Old Kurt read a recent letter to QST's *Doctor is In* wherein a reader described the antenna he has been using for a number of years. It was a trap vertical "mounted three inches above the ground and with no radials."

The good Doc set him straight saying, "The real problem is that your system doesn't have ground radials."

Why are these radials necessary? Simple! A short vertical is like half of a dipole. The dipole has maximum RF current at its center. And the short vertical has maximum current at its base.

The current in one side of the dipole flows into the other side. But the short vertical doesn't have another side. So where does the current go? Into the ground, that's where.

The problem is that ground has a fair amount of RF resistance. The current flowing through that resistance heats the ground and is lost to your signal. Radials, made up of low resistance wire, cut that loss. The RF flows through the wire instead of the ground and is not lost as heat. The more and longer the radials the less the loss.

How many do you need? AM broadcast stations use 120. For the average ham station 16 is plenty. Even 4 is a lot better than none. Always use some radials. Kurt told you so.

DIPOLES

There is another subject that Kurt has written about over the years. That is non-resonant antennas. An antenna does not have to be resonant to work well. All you have to do is use an antenna tuner to convert whatever appears at the transmitter end of your feedline to the 50 ohms resistive your transmitter was designed to work into.

So what does Weary Old Kurt read in a recent issue of the British QRP magazine? "Many beginners on H.F. begin by using a dipole. There is nothing wrong with this and a dipole can give good results, but it is by nature a single band antenna." Wrong, wrong, wrong!

For one thing, a dipole is resonant on its fundamental frequency and on odd harmonics of that frequency. How many have used a 7 MHz dipole as a resonant 21 MHz antenna? Works fine. The nitpickers will point out that the 21 MHz resonance is not exactly 3 times the 7-Mhz fundamental but the difference is small and the bandwidth wide enough that it can be used on both bands without a tuner.

But how about other bands? All you need is that trusty little tuner and you can operate on all the bands. So if you have a dipole already in place and want to work other bands just get a tuner and go with it.

Kurt has an old friend who has his PhD and has operated for years. He says that when he tuned his receiver to the antenna's resonant frequency the signals just jumped out of the noise. Don't you believe it. Kurt sure doesn't. There is nothing magic about a resonant antenna other than the fact that its impedance is purely resistive. This makes it a good match for coaxial cable and with a resistance suited for a modern transmitter. But that's it. There is no other magic to a resonant antenna. Just use your tuner with your antenna on any frequency you like. You'll get out just fine.

ANTENNA GAIN

Kurt has written much about antenna gain as expressed in dBi (compared to the theoretical isotropic antenna) and dBd (compared to a dipole).

A longtime reader wrote to Kurt complaining that an antenna manufacturer uses dBi to state the gain of his new antenna. And then they state gain with the antenna one wavelength over the ground. "Why", he asks, "can't they just give the gain over a dipole and let it go at that?"

Kurt agrees that the use of all these gain factors is confusing, especially to the newcomer and to the amateurs who are not that interested in the technical aspects of the hobby. As a matter of fact some manufacturers follow this route to confuse and to make their antennas sound better than they are.

But the world is changing and getting more complex. For example, Kurt still has his 8th edition of the Handbook published in 1931. The chapter on antennas does not contain the words "Gain" or "Decibel". Things were simple in those days.

By the 20th edition in 1942 both words appeared in a greatly expanded chapter on Antenna Systems. Gains were given in dB. with, almost always, an explanation in words that the gain was referred to a dipole. Sometimes it was just understood to be reference to a dipole.

The problem is that dB is just a ratio. When you say that an antenna has so many dB gain the statement is meaningless until you reveal your reference. "Five dB over a dipole" does have meaning as does "Seven dB over an isotropic antenna". But all these words take up valuable space so we've come to use dBd and dBi to keep the word count down but still be precise in what we say.

The difference is that a dipole has a gain of 2.15 dB over the isotropic antenna. So if the gain is given as dBi and you want to know how much better the antenna will be over your dipole you need to subtract 2.15 from the stated gain.

DBi and dBd both assume that the antenna is in free space, that is, ground is not present. If ground is nearby, as it is in the practical case, the gain of a dipole can increase. At the correct height and over seawater the additional gain may be 6 dB! Some manufacturers like to add this gain in, so look for footnotes like “at one wavelength” or “at 74 ft.”.

All this means that in today’s more complicated world it is important to understand dBi, dBd, ground reflection and other basic antenna parameters.

There is no question that computers have made the use of these precise terms more important. With programs like Kurt’s favorite, EZNEC, (which you can see at http://eznec.com) you can model your antenna, change it and see the effect, check it over different types of ground, and find out more than hams back in the “good old days” could ever hope to know about their antennas. It can be fun; try it.

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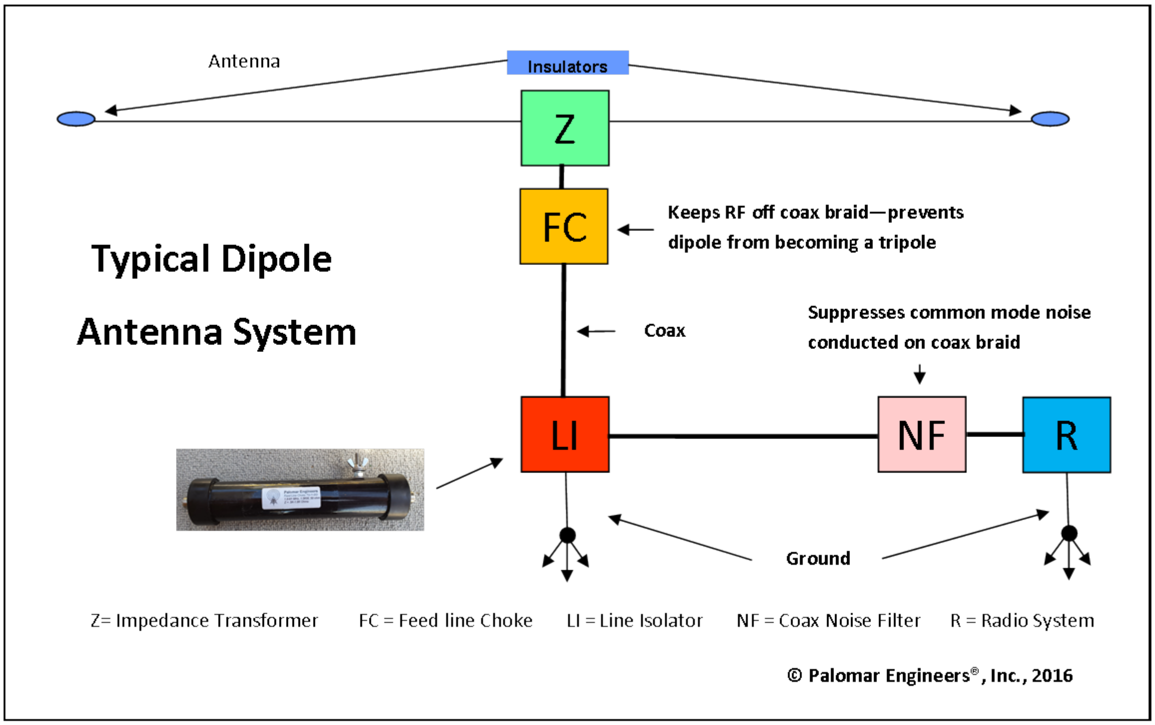

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IN WHICH THE MASKED AVENGER STRIKES

An interested and helpful reader brought to Kurt's attention an ad on the Internet. You can see it at http://looknbrowse.com/bcmatcher. This is a mobile antenna matcher used at the antenna to match its impedance to that of the feed-line. By placing the matching at the antenna instead of at the rig you can get 1:1 SWR on the feed-line. The exact way that the matcher does this is not described but as far as Kurt can see it does exactly what it is claimed to do.

But a problem arises in the claims made for the virtues of technique. Here we find one of the old chestnut incorrect ideas that Kurt sees over and over. The ad states that "The ability to obtain a near perfect match at the antenna means no pickup or radiation from the feed-line which in turn reduces vehicle noises that usually enter the system through the feed line."

This is wrong, wrong, wrong! The fact is that pickup or radiation from the feed-line has nothing to do with the SWR. There is no more pickup on receiving or radiation when transmitting when the line has 10:1 SWR than when SWR is 1:1. Why should there be? The transmitted power is contained within the coaxial cable as it goes from transmitter to the antenna. Reflected power caused by high SWR also it contained entirely within the cable as it goes back toward the transmitter. This all takes place within the cable. Nothing comes out through the shield.

If you don't believe Kurt just try this experiment: Connect your transmitter to your antenna and tune to a frequency off the antenna's resonant frequency such that the SWR is, say, 10:1. Apply full power. Now see how much RF is out the outside of the cable by using a RF probe of some kind or maybe just your hand. See if you get a RF burn. You won't!

High SWR does not cause radiation from the coaxial cable. And, by the principle of reciprocity, there will be no pickup of vehicle noises or any other signals due to the SWR. Remember, Kurt told you.

POWER LOSS IN THE CABLE

There is, of course, one thing that does happen with high SWR and that is increased loss in the cable. Is this bad? Not really. The increased loss is usually small and, in a HF mobile installation with a short length of cable, it is negligible.

The ad though tries to scare you: "The notion that SWR ratios of up to 2:1 or 3:1 are acceptable simply does NOT apply to mobile operation. In fact, degradation of performance begins at 1.2 and becomes dysfunctional at 1.5." Kurt can assure you that this is wrong, wrong, wrong!

Let's look at this with an example of a typical mobile installation. Our setup uses RG-8 coax ten feet long going from the rig to the rear mounted antenna. Using the nice chart in the Antenna Book we find that if we use the matcher and have 1:1 SWR the loss in the cable on the 40 meter band will be .055 dB. Not enough to even notice.

But what if we don't use the matcher and have that horrible 1.5 SWR where the system becomes "dysfunctional"? This awful mismatch is going to add almost .003 dB more loss. So now we have a total loss of .058 dB. If you remember that 1 dB is the smallest change in signal strength that a listener can even notice you can see that no one but you and your SWR meter will ever know that you let it go up to 1.5. Your system is not "dysfunctional"; far from it!

There is nothing wrong with even 10:1 SWR on your mobile's transmission line as long as you have a tuner at the rig end of the coax to convert to a low SWR for your transmitter. Kurt told you so.

COAXIAL CABLES

Kurt has given the impression that there is no signal leakage through the cable's shield. There can be a little because shields aren't always perfect. But don't worry about it if you have good cable. The signal loss and noise pickup is so far down from the radiation and pickup of the antenna itself that it is not a problem.

Of course there is some bad cable out there where the manufacturer has cut down on the braid coverage to get a lower priced product. Don't buy unknown brands. If you use MIL-Spec cables you will get 95% to 97% braid coverage. This is plenty to keep HF signals in. But there are cables out there with 75% or less coverage. The popular 9913 cable (50 ohms) has 100% braid coverage. Most cables have single braid shields. Double braid shields give another 30-40 dB attenuation. You don't really need that. Just don't buy junk and you'll be OK. Kurt told you so.

HYDRONIC RADIATION

In a recent column Krusty Old Kurt called the 1966 promotion of this underwater transmission scheme fraudulent. Kurt always calls it as he sees it.

A reader came to the defense of the promoter of Hydronic Radiation stating that he had done excellent experimental work in underwater sound. This is correct. He was a respected and well-known scientist with a number of patents and publications in chemistry and physics.

But in later work he made claims for underwater radio transmission that Kurt did not and does not believe. He claimed to have discovered "Hydronic Radiation" which was an electromagnetic radiation similar to radio.

He stated that it can be produced by the same equipment that generates radio signals. Depending on the size of the plates on the ends of the dipoles relative to the transmitter power the signal is a radio wave or a Hydronic wave.

When connected to a short dipole radio waves propagate at right angles to the wire. Hydronic signals propagate off the ends of the wires. They propagate through water more than 200 times as fast as radio waves and suffer much less attenuation with distance. Copper and aluminum do not make good hydronic antennas. Inert metals such as Monel, stainless steel, and gold do work well. Although Hydronic signals propagate rapidly through water they do not exist at all in air.

It would appear that Hydronic Radiation would be much more useful for underwater communication than radio. However, the nature of the specialized receiver required was not revealed so it was not possible for independent observers to verify the claims. Thirty five years have passed and Hydronic Radiation seems not to have replaced radio in underwater communication. Kurt doubts that it ever will.

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Need a Super Feed Line Choke for high power, high duty cycle?

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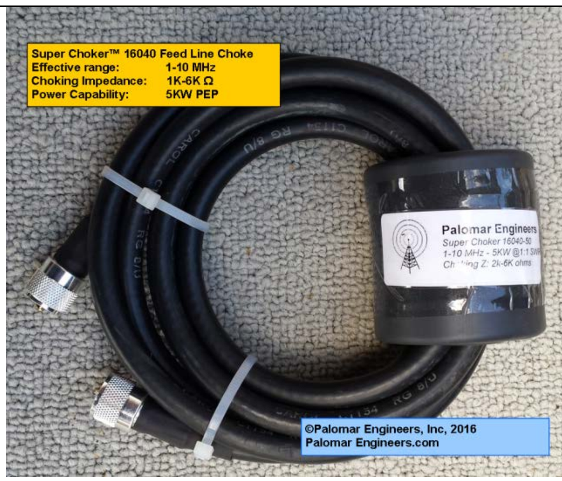
<tr><td>
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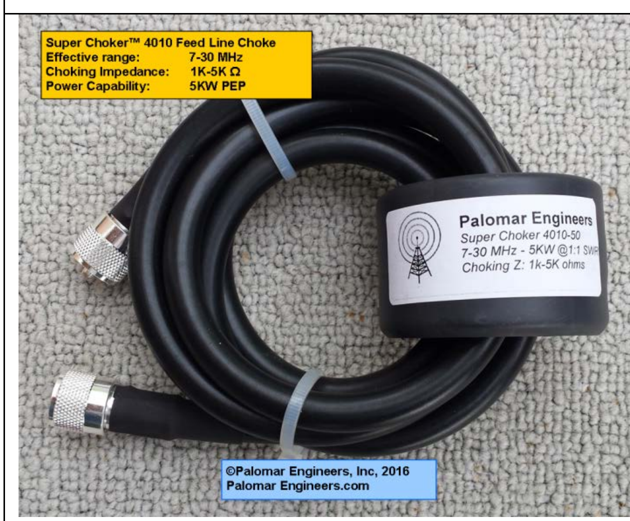
<tr><td>
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VERTICAL ANTENNAS AND SWR

A longtime reader of Kurt's column sent in an article from a recent QRP Quarterly. He thinks the author is wrong when, talking about a quarter wave vertical, he states that "lowest SWR does not equal most efficient or resonant in this case."

Well, the first part is absolutely correct. Lowest SWR does not equal most efficient in this case. Why is that? Very simple!

A quarter wave vertical has a radiation resistance of 36 ohms. If you put a perfect or near perfect ground plane under it so that there are no losses your transmission line will see the 36 ohms at the antenna's base. You can come close to this with 120 half-wave radials. Since SWR, for the purely resistive load that you see at resonance, is Z_o/R_a (where Z_o is the cable characteristic impedance and R_a is the antenna resistance) the SWR in this case is 50/36 = 1.39 for 50 ohm cable. Since there are no losses all the power is radiated.

But suppose you remove most of the radials. The ground losses go up and the antenna's base impedance goes up. Let's suppose the ground loss resistance becomes 14 ohms. The base impedance is now 50 ohms (36+14=50). It is a perfect match for the cable and SWR is 50/50=1.0. But the efficiency drops because only 36/50 or 72% of the power is radiated. 14/50 or 28% is used to heat the ground.

LOWEST SWR AT RESONANCE

QRP Quarterly's author goes on to say that lowest SWR in this case does not mean resonance. This is wrong. Lowest SWR does mean resonance. The author goes on to give an example where SWR is lower than expected. He suggests that the measurement could be a bit off resonance thus adding reactance to the 36 ohm antenna impedance and bringing it closer to 50 ohms thus lowering the SWR. Again, wrong, wrong, wrong. Adding reactance makes the SWR go up, not down.

You have to remember that the simple formula for SWR, Z_o/R_a (where Z_o is the cable impedance and R_a is the antenna resistance), holds only for resistive loads. If reactance is present another much more complicated formula holds. See the *Transmission Lines* chapter in your Antenna Book for the formula. If you don't own the Antenna Book and you are working with antennas you are working with one hand tied behind your back. Kurt told you so. Listen to him.

Using this formula (actually it is so complicated the Antenna Book breaks it down into three formulas) we find that the SWR with a 35 ohm antenna load is 1.39. But as soon as you add even one ohm of reactance the SWR goes up, not down. The lowest SWR is at resonance.

The only way to get a lower SWR is to add resistance which you can do by increasing the ground losses. Don't do it. It will make your signal weaker. As QRP's author says "BETTER SWR equals MORE LOSS" (in this case).

USING YOUR ANTENNA ANALYZER

Even major instrument manufacturers seem uncertain about the meaning of minimum SWR when measuring antennas. Advertising for a popular measuring device we'll call "259B" says: "Here's what you can do: Find your antenna's true resonant frequency". But the instruction manual that comes with the instrument doesn't tell you how to do this. Instead it states that "The resonant frequency is NOT always at the point of lowest indicated SWR". In other words, looking for the lowest SWR may not give you the resonant frequency of the antenna.

How do you usually find the resonant frequency of your antenna? By looking for the frequency of lowest SWR? Right! Keep on doing it that way and you will get along just fine. Kurt told you so.

Here is an easy way to help you remember that reactance in the load increases the SWR. Fact: If you have 50 ohm coaxial cable and the load is 50 ohms resistive you'll have an SWR of 1.0. Fact: If the load has no resistance but has 50 ohms reactance you'll have infinite SWR. Just keep that in mind and you won't forget that the formula SWR = Z_o/R_a applies only to a purely resistive load.

THE STERBA CURTAIN

The Curtain antenna is an array of dipoles stacked one over the other and also side-by-side. A Sterba Curtain with four dipoles one over the other and four in each line is called a 4 x 4 and has a gain of about 14 dBd. An 8 x 8, about 20 dBd. Nice gain figures but these arrays are big and mostly found in places like Radio Netherlands, Voice of America and the like. Too big for your backyard.

A reader wants to know if they would be useful for a field day installation. He plans to have a couple of 60 foot towers. Could he use a Sterba Curtain on 10 meters?

Yes he can, but not the Radio Netherlands kind. There is a minimum size Curtain, a 2 x 2 called the "Lazy H" that would work. Two half wave elements inline at the top of the towers and two more ¾ wavelength below them. Gain is 6.6 dBd and bidirectional. You can use it on 15 and 20 meters also with reduced gain.

Is it practical? Probably not. You'll have to use an antenna tuner with it. And it is not rotatable. Some of the Big Broadcasters mount the towers on railroad tracks and turn the whole curtain, but you aren't going to be doing that. In contrast, a triband beam will give about the same gain on all three bands, is easily rotatable, has good front-to-back ratio to eliminate interfering signals, and doesn't need a tuner.

On the other hand the Lazy H is inexpensive. You just need wire and insulators. If you have some handy trees and a dedicated 10 meter station it might be worthwhile. See the Antenna Book for details.

No, Kurt didn't invent the Sterba Curtain. It is named for the famous radio engineer E. J. Sterba who did pioneer work on shortwave antennas and transmission lines back in the 1930's.

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KURT STRIKES BACK

There is something wrong in radio-land. There is nothing wrong not knowing something; even Kurt doesn't know everything. The problem is when someone absolutely knows something that is wrong, wrong, wrong.

Not long ago Kurt wrote about a typical mobile installation with a ten foot length of coaxial cable between the rig and the antenna. And he said that there was nothing wrong with having as much as 10:1 SWR on that cable as long as you had a tuner at the transmitter end to give it the proper load. There is negligible loss in that short a cable especially down on the lower frequency bands

A reader brought up another (supposed) problem with 10:1 SWR; loss at the antenna due to the mismatch. After telling Kurt that he, Kurt, needs to repeat Radio 101 because he is ignorant of fundamental transmission theory he states: "Kurt should figure out, with a 10:1 SWR at the antenna, how much transmitter power is radiated by the antenna. In case he cannot figure it out it is approximately 33%. For a 100 watt transmitter, less than 33 watts will be radiated. I wonder where the rest of the power goes."

Kurt can tell him. It also is radiated by the antenna. With 10:1 SWR the power radiated from a 100 watt transmitter is 100 watts. Minus a tiny loss in the cable and whatever loss takes place in the mobile antenna itself.

KURT EXPLAINS

What the reader is talking about is "Reflected Power". When the antenna impedance does not match the coaxial cable impedance not all of the power coming down the cable is absorbed by the antenna. Some is reflected back toward the transmitter. How much? If the SWR is 10:1 and the transmitter power is 100 watts then 67 watts is reflected and 33 watts goes into the antenna.

This sounds terrible at first glance. But let's look a little further. What happens to the reflected 67 watts? It does not just disappear. Remember the First Law of Thermodynamics: *The amount of energy in a closed system remains constant*. In other words the 67 watts can't just disappear. It has to be somewhere. Kurt has already explained that there is negligible loss in the cable so the RF energy is not turned into heat energy there. Some will tell you that it goes back into the transmitter and heats it up. But it doesn't. So where does it go?

The 67 watts is totally reflected back at the transmitter end of the cable, adds to the transmitter power and goes back to the antenna. That's where it goes.

This means that, in this case, there is 167 watts going toward the antenna. Kurt will explain how you can check this out in a simple experiment you can do right in your shack.

The transmitter is putting out 100 watts. 167 watts is going down the cable toward the antenna. What happens at the antenna? 100 watts, the total transmitter power, goes into the antenna. 67 watts is reflected back toward the transmitter. Very simple. The 10:1 SWR has not caused us to lose any power at all.

EXPERIMENTAL PROOF

Here's how you can satisfy yourself that Wise Old Kurt is correct and that all those who try to convince you that reflected power is lost are full of baloney.

You need a transmitter, a watt-meter, a tuner, and an antenna connected to the tuner with coaxial cable.

Connect the watt-meter between the transmitter and the tuner. Then connect the antenna's coax cable to the tuner. Later we'll move the watt-meter to be between the tuner and this cable. Kurt used two identical watt-meters but you can use just one and move it.

Put the tuner on "Bypass" and find a frequency with high SWR. You probably won't be able to get 10:1. Kurt was able to get 3:1 by moving to the edge of the band. Whatever SWR you can get, the higher the better, just look up the expected amount of reflected power using the table in the Antenna Book. Use any convenient power. Kurt used 40 watts out from the transmitter.

Now, with the high SWR on the line to the antenna, cut in the tuner and adjust it for 1:1 SWR on the line between transmitter and tuner. Now adjust the transmitter and measure its output. If you have just one power meter make sure the power stays there when you turn the transmitter off and back on again.

Move the meter to between tuner and antenna cable. Measure the forward power there and also the reflected power. Write down the readings. But don't use them just yet. You know the transmitter power but you don't know how much of it is coming out of the tuner. There will be a power loss in it, Kurt guarantees it.

How to find the loss? Connect the tuner output to your 50 ohm dummy load. Or find a frequency where the antenna gives 1:1 SWR (tuner bypassed). Switch in the tuner and adjust it for 1:1 on the cable between tuner and transmitter. Adjust for the same power as before. Move the meter to the tuner output and measure the power. It will be less by the tuner's loss. Use this value in your calculations as the "transmitter power".

Now you know transmitter power, forward power on the antenna cable and reflected power on the antenna cable. The forward power should equal the transmitter power plus the reflected power just as Kurt explained.

KURT'S RESULTS

Kurt's setup was just as described above. Since his power meter was 50 watts full scale he adjusted the transmitter power so that he got exactly 50 watts forward on the antenna cable. (All the other readings will be smaller and so will be within the meter's limit). The reverse power there was 13 watts.

The measured power at the transmitter output was 42 watts. The loss in the tuner was 5 watts so the actual power out of the tuner was 37 watts.

You'll note that the forward power going down the antenna cable (50 watts) is 13 watts more than the transmitter power applied to it. That extra 13 watts is the reflected power that adds to the forward power to give you more forward power total than the transmitter puts out. That's what happens to the reflected power. Now, with 50 watts forward power, 13 watts can be reflected and the full transmitter power coming to the antenna cable (37 watts) goes into the antenna.

Try this experiment and convince yourself. Then you can straighten out those who talk about reflected power being lost.

BILL ORR, W6SAI

Bill died in January (2001) at age 81. Over the years he was one of the most prolific writers in Amateur Radio. Kurt still has his *Radio Handbook* on his bookshelf. He wrote many articles for *QST* but Kurt remembers him for his “Ham Radio Techniques” column in *ham radio magazine* 1968-1990. He was an expert on big tube amplifiers and antennas. He wrote his column when Yagi’s were designed by cut-and -try. He promoted the first amateur computer antenna design program by K6STI. He described many useful antennas such as the “Australian broadband dipole”. He was one of those who really helped amateur radio.

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Wall Wart Power Supply Noise Filters

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THE RESONANT FEED-LINE DIPOLE

A reader sent Kurt a description of the “Resonant Feed-line Dipole” and asks if, in Wise Old Kurt’s opinion, it really works that way. Well, yes it does. It was described by W2OZH in August 1991 *QST*.

To make one you take a length of coaxial cable and at one end attach a quarter-wave length of wire to the cable’s center conductor. Don’t connect the cable’s shield to anything.

Now go a quarter-wave down the coaxial cable and make a RF choke by winding the cable into a coil. W2OZH used 13 turns on a 6-inch diameter form for the 80 meter band. Your antenna is the quarter-wave wire and the quarter-wave coaxial cable; they form a half-wave center-fed dipole. Suspend it in the air and run the rest of the coax down to your transceiver.

The nice thing about this arrangement is that there is no feed-line dropping down from the center of the dipole. The feed-line comes out the end. This can be very convenient. Quite often you can use the house to support one end of the antenna and a tree in the yard for the other end. If you put up a normal dipole this way you have to run the feed-line from the center of the antenna back to the house. This can be awkward and puts the feed-line parallel to the antenna so it can pick up RF as it goes along and bring it into the shack.

With the Resonant Feed-line Dipole the feed-line comes right out the end of the antenna there at your house. In this situation most hams put up a “random-wire” end fed. But the impedance at the end is high and you have to use a tuner. The Resonant Feed-line Dipole, on the other hand, gives low SWR on its design band so you don’t need a tuner at all.

HOW IT WORKS

The Resonant Feed-line Dipole takes advantage of the fact that coaxial cable acts like a three conductor cable for RF. There is the inner conductor, the inside of the shield, and the outside of the shield. RF signals travel down the inside of the cable with equal currents on the inner conductor and the shield. The current on the shield does not penetrate the shield. Think about it, why do we call it a shield? Because it shields the RF from the outside world, that’s why.

So we are left with the outside of the shield that has no RF on it that we can use as another conductor of RF. That’s what this antenna does.

On transmit we send RF down the cable. The current on the inner conductor goes right on down the quarter-wave wire we’ve attached to it. The current on the inside of the shield comes out and goes back down the outside of the shield. It has nowhere else to go. We want it to do this but we want it to stop after going a quarter-wave down the shield. To do that we put an impedance in its path by winding the coax into a coil. This does not affect the signal coming down the inside of the cable but it stops the flow on the outside of the shield. This gives us a half-wave center fed dipole.

Now, the impedance at the end of a dipole is high; several thousand ohms. W2OZH's 13 turn coil only has about 400 ohms impedance. Not enough. But he adjusts the spacing between turns, varying the capacitance, until the inductance of the coil and the capacitance resonate on the dipole's frequency. This increases the impedance until it is several thousand ohms. So no RF flows on the transceiver side of the shield.

KURT'S END-FED DIPOLE

W2OZH's coil requires some adjustment and it's large enough to call attention to an antenna installation that the neighbors otherwise might not notice. You know what Kurt is talking about.

So Kurt has devised an antenna using ferrite toroids to keep the coil small and to give it enough impedance so it doesn't need to be adjusted or resonated. It works very well at transceiver power levels.

The 20 meter version has a plain wire part 16 feet 4 inches long. Connect this to the center conductor of your RG-58 coax leaving the shield unconnected. Go 16 feet 4 inches down the coax and run the cable through two F240-61 toroid cores that you have either glued or taped together. Make 10 turns of the coax through the toroid. Be neat; place the turns side by side as you go and pull them tight so the coil is as small as you can make it.

Suspend this antenna up in the clear and feed the balance of the coax in to your transceiver. Kurt got SWR of 1.5 or less over the whole 20 meter band.

Don't use this antenna with your legal limit amplifier. 100 watts continuous or a couple hundred PEP is fine. The reason for this is that the coil is high impedance, about 3000 ohms, and ferrite cores don't like to work at high impedance. If you make them high impedance and apply lots of power they complain by absorbing some of the power and getting hot. You don't want that.

You can make this antenna for other bands by scaling the wire lengths as needed. On 10 meters one F240-61 is enough for the coax coil. On 40 meters you'll need four. You get the idea.

LOOP AROUND THE HOUSE

A reader would like to put a full-wave horizontal loop about 20 feet above the ground with his house located in the center of the loop. This will make a "sky warmer" for good local contacts. Will the house upset the pattern? How about RF in the house? He was told that there is no net field inside a loop.

Well, you are almost certain to lose some signal by absorption by metal structures in the house. But it may work perfectly well overall. A few dB loss is not likely to be noticeable in local contacts.

The RF field though may be a problem. Remember that when a wire has current in it a magnetic field forms around it. There will be places where the field from the wire on one side of the loop cancels that of the wire on the other side but that cancellation is at one location, not everywhere within the loop. Yes, there will be fields inside the loop.

Kurt wouldn't worry at all about the fields in the house but the FCC does. You have to meet their guidelines for human exposure to electromagnetic fields. This antenna location does not fit the usual simplified tables developed to make the calculation easy.

You can do it by figuring your power level and the distance from the loop wire to the nearest occupant of the home.

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4:1, 9:1 Multi Ratio End Fed Antenna Matcher

Check Palomar-Engineers.com for updated product information

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MORE ABOUT RADIALS

"Okay, so you explained why radials are needed under λ/4 verticals. But what I'd really like to know is why you think radials are needed under λ/2 verticals. How about a further explanation?"

Kurt is aware that several manufacturers of "half-wave" verticals claim "No radials or ground needed". Of course, there is no RF current at the bottom of a half-wave vertical. Usually it is not connected to ground at all, and you can tune it up just fine without any radials. So, why radials?

Krusty Old Kurt will tell you. Just like any other antenna radio waves come off of it. They travel along the ground and induce currents in the ground. If the ground is lossy, meaning it looks like a resistance, then some of your RF power gets turned into heat in this resistance. That power is lost.

Radials under the vertical lower the resistance and thus lower the loss. You have a bigger signal than without them.

VERTICALS ARE DIFFERENT

A λ/4 vertical has maximum RF ground current right at the base of the antenna. But a λ/2 vertical has maximum current about 1/3 wavelength out from the base. So you need longer radials for the λ/2 vertical than for the shorter verticals.

"But I get out just fine without any radials", you say. Sure. You can get out with a wet noodle. Have you measured your field strength with and without radials?

At WWVH on Kauai Island they did. The antenna is a half-wave on 2.5 MHz. That's a big antenna! And they found their field strength to be down until they installed an extensive radial system.

If you've been operating without radials under your "half-wave" vertical Kurt suggests you buy or borrow a copy of ON4UN's *Low-Band Dxing.* His chapter on verticals is a good antidote for the antenna manufacturers' literature.

EFFICIENCY REVISITED

In a recent column Kurt explained how lowest SWR on a vertical antenna does not necessarily mean most efficient. A reader got lost in the explanation because Kurt skipped over some of the logic involved. So here is a clarification.

The example was of a λ/4 vertical that has a radiation resistance of 36 ohms connected to the transmitter with a 50 ohm cable. The SWR will be 50/36 or 1.39:1. If the antenna has a perfect ground screen under it (no loss resistance) then all the transmitter power will be radiated. The efficiency of an antenna equals the radiation resistance divided by the total resistance (radiation resistance + loss resistance). In this case 36 / (36 + 0) = 100%.

But if the radial system is inadequate and has resistance, say 14 ohms, the SWR will be 50 / (36 + 14) or 1:1. But the efficiency suffers because it now is 36 / (36 + 14) = 72%.

So, lowest SWR does not mean most efficient in this case. Have you ever wondered about that mobile whip that is a perfect match to 50 ohm cable? Think about it!

One final word: Kurt wants you to notice that the *antenna* efficiency has nothing to do with the cable impedance or the SWR. If, for example, we used 75 ohm cable the antenna with no loss resistance would have SWR of 75/36 = 2.1 but the efficiency would still be 100%. The antenna with 14 ohms loss resistance would have SWR of 75/50 = 1.5 but the efficiency would still be 72%. There would be a difference in *cable* loss but that it another subject entirely.

WHICH ANTENNA IS BEST?

"In the course of my 40 meter QSO's I've heard 'Man, this double bazooka is the greatest antenna I've ever owned.' Others I hear brag about the performance of the Carolina Windom. Still others, many frankly, enthuse over the prolific G5RV." This reader of Kurt's column wants to know who is right; which antenna is the best.

Well, if best means biggest signal, there is not much to choose between them. They all, just like the simple dipole, are *single-element* antennas. That is, they don't have two or more elements that are phased to give gain. So they all are comparable to the dipole when it comes to gain.

Manufacturers and promoters of each antenna may tell you differently but Old Kurt advises you to take their claims with more than just one grain of salt.

As an example Kurt examines the "Carolina Windom". Promotional material for this antenna can be seen at www.radioworks.com where we see that it has as much as 10 dB gain over a dipole!

How does it get that? By adding some vertically polarized radiation to the normal horizontally polarized dipole radiation. This gives increased signal at low angles as compared to the dipole. So at some low angles it shows gain over a dipole.

Kurt can use the exact same reasoning to show you that a dipole has as much as 10 dB gain over a large rhombic. Maybe more!

Antenna books tell you that a sizable rhombic has more than 12 dB gain over a dipole. But antennas don't *make* power. They just *radiate* the power put into them. If the antenna puts out a bigger signal in one direction it must put out less in other directions. Rhombics are no exception. As a matter of fact, in some directions they have deep nulls with practically no radiation. And in the directions of the rhombic's nulls the dipole may show over 10 dB relative gain. See?

What's wrong with this analysis? It all goes back to the definition of gain. What exactly is dBd, gain relative to a dipole? It is an antenna's signal output *in its maximum signal direction* as compared to the signal output of a dipole *in its maximum signal direction*. It is *not* a comparison in any random direction.

Krusty Old Kurt wants you to look at the magnificent claims made by manufacturers and those of users of one antenna or another while always keeping in mind these simple fundamental principles. No antenna can violate them.

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KURT WRONG?

In a recent column Kurt explained that the lowest SWR is always at antenna resonance. This is why it is so easy to find resonance with a Noise Bridge or Antenna Analyzer.

The instruction manual for one of these instruments, the 259B, says that lowest SWR is not necessarily at resonance. A reader wants to know if Kurt is talking about a measurement right at the antenna and the manual is talking at the other end of the transmission line. No, Kurt is talking about at the transmitter end of the transmission line.

SWR is always thought of as a characteristic of the standing waves on the transmission line. When connected to the same antenna transmission lines of different impedance will have different SWR's. For example, if the antenna has 75 ohm impedance, a 75 ohm transmission line connected to it will have 1:1 SWR. Connect a 50 ohm transmission line to the same antenna and it will have 1.5 SWR.

In either case the lowest SWR measured at the antenna or at the transmitter end will occur at the antenna resonant frequency.

MORE ON KURT'S END-FED DIPOLE

Recently Krusty Old Kurt described a simplified version of W2OZH's "Resonant Feedline Dipole". It is a dipole with the coaxial cable feed coming out the end of the antenna instead of in the center like a normal dipole. This can be a more convenient physical arrangement.

At the antenna end of the cable a quarter-wave of wire connects to the center conductor. The shield is left unconnected. A quarter-wave back toward the transmitter a choke inductance stops any RF current flow on the outer shield. The quarter-wave of wire and the quarter-wave of outer shield form a half-wave dipole. The cable on the transmitter side of the choke is the feed-line to the transmitter.

A reader noted that, in W2OZH's original article, the cable to the transmitter was a quarter-wave or ¾-wave long. Should it be that long or can it be any convenient length?

The purpose of the quarter-wave line was to help stop any current that made its way through the choke. The choke is not perfect, of course. Since the transmitter end of the coaxial cable is grounded at the transmitter then, by the transforming action of a quarter-wave or ¾-wave line, the outer shield looks like a high impedance at the choke. This will inhibit any current leaking past the choke from going down the outer shield toward the transmitter.

Kurt looks on this part of the design as comparable to wearing both a belt and suspenders to keep your pants up. It doesn't hurt a thing but it's probably not necessary,

And there is a problem: A quarter-wave may not be a convenient length to reach to the transmitter. If is too long then what do you do with the excess length? If you coil it up you add inductance to the outer shield and it's not an electrical quarter-wave anymore. So now you have to change the length to bring it back to an electrical quarter-wave. This is a complication and Kurt likes to keep things simple. His antenna worked just fine with a random length of feeder. Yours will too!

QRP VERSION

Another reader would like a lightweight version of the end fed dipole using RG-174U cable and a toroid core choke just adequate for his 5 or 10 watt transmitter. (RG-174/U is a tenth of an inch outer diameter).

Kurt suggests making the RG-174/U antenna exactly the same as the RG-58 version with a choke having the same number of cores and the same number of turns but using F114A-61 cores instead of the big F240-61 cores.

THE MICROVERT

This is the decade of the tiny, wide-band, high-efficiency antenna. The latest in the lineup is called the MicroVert. Like its predecessors, the Crossed Field Antenna and the E-H Antenna, it operates on a principle not explained by standard antenna theory.

This vertical antenna, only .02 wavelength high, would have a radiation resistance of about 0.16 ohm, and, with a reasonable set of radials under it, an efficiency of about 1%. That's one watt radiated for every 100 watts applied. But, with the new principle applied, the radiation resistance is 30 ohms so the efficiency will be more like 80%. And this with an antenna for the 40 meter band that's less than three feet high!

The theory was developed by Prof. Friedrich Landsdorfer and Prof. Hans Heinrich Meinke of the University of Stuttgart (Germany) and published in the November 1973 issue of *Nachrichtentechnische Zeitschrift.* Kurt's local library does not have any issues of this publication and, even if they did, Kurt probably couldn't read it. If the truth were known he almost flunked German in college and that was many many years ago.

So all Krusty Old Kurt can go on is the explanation you can see at www.Antennex.com. It is unconvincing to say the least. Add a capacitor across the antenna and the radiation resistance increases almost 200 times. And to top it off you don't need any radials. Sure!

Theory is fine. Always interesting reading. Sometimes it's even correct. But the proof of the pudding is in field strength measurements, something that has been sorely lacking in all the descriptions of these wonder antennas. Kurt is not going to hold his breath while waiting for these measurements to be published.

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KURT’S 160 METER VERTICAL

A reader asks, “I’m looking for a way to build a 160m vertical - or is this even practical? I have a yard that is not all that conducive to stringing out a wire for this band and I thought maybe if I could put up a 30 ft. +/- pole with a top loaded coil it might put me on the air. How would I calculate the necessary coil size - say for 100 watts or less?

The reader couldn’t have found a better place to ask that question. Krusty Old Kurt has a 30 ft. pole top-loaded for 160 meters in his own yard. And it is living proof that such a short antenna actually works. It is considered short because a real quarter-wave vertical would about 130 ft. tall. A 30 foot pole is about 1/20 wavelength high and, if not top loaded, has a radiation resistance of a bit over one ohm. You want to raise this resistance as high a possible with top loading.

DESCRIPTION

Kurt’s vertical is a 30 ft. pole of 3 in. diameter aluminum tubing. At the top there are 12 radial wires each 25 ft. long equally spaced. At the end of each wire is an insulator. The other side of the insulator goes to a wire that runs to a tree, the garage, the house; whatever support can be found in that direction. A circle of wire connects the inside ends of the 25 ft. wires together. The whole thing looks like a big parasol.

At the bottom are 32 radials, some buried, and some on top of the ground. Lengths range from 30 to 60 ft. as space permitted. The resonance is at 2200 KHz. A base loading coil brings this down to the desired frequency in the 1800 KHz band. The measured resistance is about 12 ohms and a 4:1 wideband transformer matches the 50 ohm coax feedline.

THE POLE

Start your own antenna design by deciding on the pole. 30 ft. height gives you only about 1 ohm radiation resistance. If you can put up a taller pole do it because the radiation resistance goes up as the square of the height. If you can’t go any more than 30 ft. don’t be discouraged. Kurt easily works halfway across the U.S. with his and, with full power CW, Japan in one direction and Caribbean islands on the other.

Don’t use a thin wire instead of a pole. If you must use wire use two parallel wires spaced 3’ or so apart. This, or the 3” pole, gives more bandwidth. No matter what you do the antenna won’t cover the whole 160 meter band. If it does then something is wrong. Short antennas are always narrowband unless they are lossy and inefficient. You don’t want that.

THE TOP HAT

Kurt’s top hat takes a circular area 50 ft. across for installation. And the 12 wires also need end supports. Ideally the end supports would allow the wire to go out horizontally (the ends 30 ft. up). Kurt couldn’t do that so the wires tilt downward giving the parasol look. But keep them as high as you can.

That’s a pretty ambitious top hat project. If you don’t like that then just run out two top wires in opposite directions forming a “T” antenna. This will work just as well if you can make them long enough. If possible make them long enough to resonate just at the top end of the band. Then use the base-loading coil to bring the whole thing to frequency. If you can't make them long enough don't panic, just use a larger coil.

THE RADIALS

Radials are an essential part of any short vertical. Don't even think of trying to work without them.

If you have the space make your radials 50 ft. long or more. Longer is better. Try to put in at least 20 radials. More is better. And it is better to put in a lot of short radials than a few long ones. 50 ft. is short but if, for example, your house is in the way in one direction put radials in that direction no matter how short they have to be.

If you can get hold of a copy of *QST* for July 2000 read N6LF's article on ground systems. To go way back in time, W2FMI describes his 6 foot 40 meter vertical (which is shorter in wavelengths than Kurt's 30 foot 160 meter vertical) in March 1973 *QST*.

THE LOADING COIL

For best efficiency there should be enough top loading to resonate the antenna on your operating frequency. But, as a practical matter, it better to have it resonant somewhat higher in frequency. Then you can bring it to the exact frequency you want with a bottom coil. Remember, it's not going to be broadband enough to cover the whole 160 meter band with low SWR so you need to make the final frequency adjustment down at the bottom.

Use a really good coil here like quarter-inch refrigerator copper tubing.

STEER HORN ANTENNA

A loyal reader of Kurt's Klassy Kolumn described an antenna demonstration he had seen on a video tape. It looked like a dipole but, on each side of center about a quarter of the way out, it was bent at about a 45° angle for a short distance then bent back. So it looked like the horns on the Texas longhorn steers that were prevalent back in the days of the Frontier West. It was fed in the center just like a dipole.

In the video demonstration of a scale model in the gigahertz range a device of some kind with an audio output was moved around the antenna. The pitch of the tone varied with field strength and was used to show the radiation pattern. Radiation was strong off the ends; negligible off the sides.

This is the opposite of the radiation pattern of a dipole. The reader wants Kurt's opinion of the antenna. Well, Krusty Old Kurt has lots of opinions and is always happy to spread them around especially when he smells a rat.

Moving a measuring meter around close to an antenna is not the way to find its radiation pattern. You need to move out several wavelengths and be in an open field without reflecting objects. A few small bends in a dipole will change the pattern a bit but not enough to make any major difference in the pattern.

An old saying goes: It doesn't matter what fancy name you give to it. If it looks like a duck, walks like a duck and quacks like a duck it *is* a duck. The Steer Horn Antenna looks like a dipole and in Kurt's always Korrect opinion it *is* a dipole. Maximum radiation is off the sides, not the ends.

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CLARIFICATION

A reader took Olde Kurt to task for saying that a half-wave vertical has maximum current 1/3 wavelength out from the base. He says it is ¼ wavelength from the base and in the center of the antenna.

Of course the maximum current in a half wave antenna is in the center of the antenna and that is ¼ wavelength from the ends. But Kurt was talking about the currents in the ground. These are maximum about 1/3 wavelength from the base of the antenna but at right angles to the antenna in the ground. This is an important point and Kurt wants to be sure it is clear in your mind.

That's the big difference between your ordinary quarter-wave vertical and the half-wave vertical. The quarter-wave vertical has maximum current flowing right at the base of the antenna. So that's where the maximum ground current is found. The RF current drops off as you go out from the base. That's why it is more important to have lots of short radials than a few long ones with a quarter-wave or shorter vertical. That keeps most of the heavy current flowing in the radials instead of the lossy ground.

A half-wave vertical, on the other hand, has no current at the base. As a matter of fact it doesn't need to be grounded at all. The ground current comes through the antenna's capacitance to ground. And it turns out that the maximum is 1/3 wavelength from the base of the antenna. This means that <u>you need longer radials with the half-wave antenna than with a quarter-wave vertical</u>.

Kurt used the example of the Bureau of Standards WWVH giant half-wave vertical where the addition of ground radials greatly improved the radiated signal. Advertisements for "half-wave" verticals tell you that radials are not required. That's halfway right. They aren't required for the vertical to work but you'll sure get out a lot better with them.

The basic theory here is that if RF current flows in lossy ground its power gets turned into heat thus warming your earthworms. All the power lost here is lost to your radiated signal. If you reduce this loss you will have a bigger signal.

ROOF MOUNTING

Kurt's loyal reader goes on say that, yes, a ground mounted vertical will be helped by radials but what use are radials under a roof-mounted 16 foot vertical for ten meters?

Well. It is true that the higher the half-wave vertical is located the less the ground currents and the less you need radials. Probably in this case you can get along without them just fine. But are you sure that that roof is low-loss to RF? Think about it!

THE HY-GAIN HY-TOWER

It was over a third of a century ago that the Hy-Gain antenna company produced its "Hy-Tower". This was a 50 ft. tall 80-10 meter no-tune vertical. Their advertising said it needed only 4 square feet of real estate for installation. How did they do that? By making it self-supporting (mounted on a steel pipe driven into the ground) and by using four ground rods instead of radials.

A reader of Kurt's Klassy Kolumn is still using one of these things. He wants to experiment with putting some radials on it and wants to know how to measure any change in performance they make. Have a distant station listen and compare? Use a field strength meter? And also, do the radials have to be a quarter-wave long? His primary interest is improved performance for 40 meter Dxing.

Well, to start with, you don't need exact quarter-wave radials. Ground-plane antennas up in the air use quarter-wave radials. But when you lay those radials on the ground they aren't quarter-wave anymore. Their electrical length changes because of the capacitance to ground.

So, instead of trying to get resonant radials the idea is to put in enough of them and long enough to reduce your ground losses as much as possible. For good performance you should use at least 15 radials and, if possible, they should be 1/10 wave long minimum. More is better and if you have more they should be longer.

Will they work better than the four ground rods? You bet they will.

The easy way to tell if the radials help is to measure the base impedance. You can use an SWR meter although an impedance bridge is better. Check the resistance at resonance before and after adding the radials. The ground resistance will drop and thus the measured resistance will drop. For a quarter-wave vertical you can figure on 36 ohms radiation resistance. The rest is ground loss.

BOOKS

A reader writes: "Recently you reference the book *Antennas* by John Kraus. Sometime could you review or recommend antenna-theory books. At $80-$120 each I can't afford to make a mistake.

With an internet store listing 350 antenna books Krusty Old Kurt can't really cover the field. But here are some recommendations from his library.

First of all, all amateur radio operators should have a copy of ARRL's *Antenna Book*. It has a good deal of basic (and accurate) theory of antennas, transmission lines, and propagation. Also many practical antenna designs and useful tips. A steal at $30.

Along the same lines, but better organized because it was all written by one author, is RSGB's *HF Antennas for All Locations* by G6XN. It has good readable theory sections and description of a wealth of different antenna types. Kurt enjoys the way he calls a spade a spade in debunking some widely believed principles. Highly recommended. About $20 at www.rsgb.org.

Antennas by John Kraus, W8JK, goes much deeper into antenna theory and is a good reference for your bookshelf. But be warned that it is not an easy read. There is good material in the text but most explanations end up in mathematical equations. If you are not comfortable with calculus you will find it formidable. Get this later. $130.

Radio-Electronic Transmission Fundamentals by B. W, Griffith is a new reprint of a 1962 book. Exactly half of the book is about antennas, transmission lines, and electromagnetic fields. It is an easy read giving plenty of basic theory without complex mathematics. What math there is is explained to you in an early chapter in a readable manner.

Griffith was with Continental Electronics, the U.S.' major manufacturer of very high power transmitters. This book is for theory only, there are no antenna designs for amateur radio. If you really want to understand how transmission lines work and how antennas radiate this is for you. $60.

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Snap On Feed Line Chokes

Check Palomar-Engineers.com for updated product information

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COILED CHOKE

A local guru advised a reader of Kurt's Klassy Kolumn to wind a few loops of coax into a 3-foot diameter coil hung at the base of the tower just past his in-line lightning surge arrestor. The coil would act like an effective choke to any current surges which may not be protected by the arrestor. The reader has seen similar coils on telephone lines so he assumes the theory has validity.

But at the Dayton convention a manufacturer's rep from one of the makers of surge arrestors said that the coil acts like a transformer and increases the voltage going to the shack. So who is right?

The guru, of course. Think about it: You know that a coil is an inductor, not a transformer. And an inductor has reactance that is measured in ohms at radio frequencies. It offers resistance to RF current and will stop or reduce its flow. And a sharply-rising lightning surge has most of its energy at radio frequencies. So the coil will tend to prevent the lightning surge from going on down the coax.

The manufacturer's rep gave you bum advice. Commercial radio stations use the technique to protect their transmitters. Sometimes they put ferrites over the coax to accomplish the same thing.

The basic plan here is to put an inductance in-line with the coax shield to make it a difficult path for the lightning surge. Between this inductance and the tower you put the best possible path you can make from the coax shield to ground. The lightning surge probably will take the easy path.

The coils on telephone lines, though, may be for a different purpose. They may be "loading coils". These are inductance coils that are placed every 6000 feet on lines that are more than about 3 miles long. They compensate for the capacitance between the cable wires and improve the frequency response.

THE MIRACLE WHIP

A reader wants Kurt's opinion of The Miracle Whip. "Is it an expensive dummy load?", he asks.

Complete construction details on this interesting antenna appeared in July 2001 *QST*. And a commercial version is available at www.miracleantenna.com.

It uses a 48 inch collapsible whip mounted on a tiny metal box. In the box is a variable autotransformer that tunes the antenna from 3.5 to 30 MHz. The whip itself is the antenna for 6, 2 and 440-Mhz. On these bands you tune it by adjusting the length of the whip. So here is a miniature antenna for 3.5 to 440 MHz with just one tuning control. No other antenna tuner is required. Just connect it to your transceiver and you are ready to go.

VA2ERY designed it to go with his new FT-817 miniature QRP transmitter that covers all these bands. The whole setup of transmitter and antenna is small and light enough to go in your backpack or weekender traveling bag.

Sounds too good to be true, doesn't it? Well, there are serious limitations to it but, just like most projects, it is a compromise that fits a particular niche, in this case portable QRP operation.

The main limitation is that the efficiency is low. This is a short vertical antenna so it has low radiation resistance. Also it has a poor ground system so there will be appreciable ground resistance. Since the power divides between the radiation resistance (the part that gets radiated) and the ground resistance (the part that is lost to heat) not much of the power you put in on the HF bands will be radiated. This will change from band to band being worst at the low frequencies where the whip is a small fraction of a wavelength long.

The advertising says that you don't need a ground but what they mean is that you don't have to have anything more than the transceiver as a ground. No short vertical will work at all without some kind of ground. Why? Because the maximum RF current is at the base of the antenna and no current can flow there unless it has somewhere to go. The transceiver has enough capacity to ground to let some current flow. Not much though. The ground resistance is almost certain to be about 50 ohms. The radiation resistance of the antenna will be just a few ohms on 10 and about 50 milliohms on 80.

Kurt doesn't have a Miracle Antenna to measure but he can make an educated guess as to the radiated power. He won't be far off the mark. Here is the expected output radiated from the Miracle Antenna on each of the HF bands for 5 watts transmitter output:

Band	Output
10	½ watt
20	¼ watt
40	50 mw
80	5 mw

Obviously you are not going to work much DX on 80 meters. But up on 10, 15, and 20 you'll get out OK. Not in contest pileups, of course, but for friendly QSO's you can work around the world.

Look at it this way: What more efficient antenna are you going to put up in your motel room? Do you really want to lug around that antenna tuner, coil of coax, and your antenna wire coil with insulators and support wires? And then try to get away with putting it up without complaints from the management? Especially if you have a tiny rig like the FT-817 it makes sense to have a tiny antenna to go with it.

The autotransformer that tunes the antenna is a slick idea. Just one knob tunes the Miracle Antenna from 3.5 to 28 MHz. You should be aware that it doesn't work as nicely as your standard antenna tuner. On some bands the best SWR you can get is 2:1 and maybe a little more. Those who still believe that you lose a lot of signal with 2:1 SWR will be unhappy. But those who read Krusty Olde Kurt's Kolumn regularly know that you lose almost nothing. And in this case where your coaxial cable will be just a couple of inches long "almost nothing" is an overstatement. Not to worry. All you need is to get the SWR low enough that the rig won't power-down.

Kurt gives the Miracle Antenna a “thumbs-up” approval for convenience. Just don’t expect miracles from it.

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Palomar Engineers Tuned Coax Choke

This higher power BALUN or UNUN utilizes mil-spec coax cable for the windings Available wired as a BALUN (Palomar # TCC-40B) with +/- output terminals or as a UNUN (Palomar # TCC-40U) with PL-259 input and output connectors. Frequency range of 7-21 MHz, centered on 12 MHz.

Excellent for all vertical antennas and many others in harsh environments where a tough choke is required to withstand the elements.

Check Palomar-Engineers.com for updated product information

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SHUNT FED VERTICALS

Lovable Olde Kurt recently described his very short (1/16 wavelength) 160 meter vertical antenna. Its base is insulated from the ground and it is fed with coax between ground and the base using a loading coil to resonate.

A reader wants to know the merits of using shunt feed instead. With shunt feed you ground the tower. The coax end is some distance from the tower. A slant wire (at about a 45^o angle) connects to the tower some distance above the base. A very low impedance RF path must connect the coax shield to the base of the tower.

The triangle formed by the slant wire, the ground connection to the coax, and the portion of the tower below the feed point is a coupling loop that transfers the RF to the tower. The resistance seen by the coax is varied by changing the height of the connection to the tower. The inductance of the loop is tuned out by a capacitor in series with the slant wire.

The reader wants to know if this is not more efficient than using a base loading coil since capacitors have less losses than coils. This may be, but shunt feed is really only practical for towers about 0.2 wavelengths or more high. Shorter towers have high capacitive reactance requiring high induced voltage from the loop. At this height the loading coil is small and, in practice, you'd probably add a little top loading to make the tower a resonant quarter-wave.

The great merit of shunt feed is that the tower is grounded. If you live where lightning strikes this is a real safety factor for you and your equipment.

The main disadvantage is the amount of work required to adjust the slant wire height and the capacitor to get the proper match. Aged Olde Kurt is no longer interested in climbing up towers to make adjustments. He'd rather stay on the ground. Also, even at moderate power levels, the capacitor voltage will be high so a suitable one may be hard to find.

Still, shunt feed works well and you might want to use it.

MORE NONSENSE

W3EPR sent Krusty Olde Kurt some antenna advertising literature of the kind that makes his blood boil. The reasons given for the antenna's superiority ("Outperforms a conventional antenna many times its size") are so grossly incorrect that it would be laughable if it were not for the fact that many readers may believe and thus perpetuate the very myths that Kurt works so hard to dispel.

We are told: "Whereas the conventional antenna is inherently resonant to a given frequency and resists efforts to make it radiate on another channel, the JOYSTICK antenna is inherently non-resonant, has a substantially flat response curve over the entire HF spectrum, producing a high 'Q' resonance on any given frequency".

First we are told that an antenna will only radiate well on its resonant frequency. This is absolute nonsense! It will radiate equally well on any frequency. The only virtue of resonance is that it is an absence of reactance and thus is easy to feed. But with nothing but an ordinary antenna tuner it can be made to radiate just fine on any frequency.

Next the antenna is described as being non-resonant but also having high “Q” on any given frequency. You might as well say that black is white. That would be no more nonsensical. High “Q” means narrow bandwidth and resonant at one frequency.

So how does this wonder antenna achieve both resonance at one frequency and non-resonance over the whole range 1.5 to 30 MHz? By being connected to a circuit composed of a tapped inductance and two variable capacitors, that’s how. Some of us would call that an “antenna tuner”.

So what we see by looking closely is a 7-1/2 foot antenna connected to a tuner. And someone has gone to all the trouble of importing it from England!

MORE GARBAGE

Next we get to the performance of this magical device. The results are “Amazing”, of course. And the radiation pattern is “spherical, ‘up’ is the same as with a tennis ball.” At last Kurt has come across the true isotropic radiator. Engineers have been searching for this since the beginning of radio.

Even an esteemed engineer like John Kraus had given up on this. In his textbook for college students he says, “Although the isotropic source is convenient in theory, it is not a physically realizable type. Even the simplest antennas have directional properties, i.e., they radiate more energy in some directions than in others.”

The Joystick designers have done it? Baloney. Hooey. Poppycock.

And to prove the “Amazing” performance? Field strength readings comparing it to a “conventional” antenna? Of course not.

Antenna charlatans always resort to testimonials. It is always possible to get a few idiots to believe anything and tell how great it is. Works with hair restorers, vitamin mixtures and antennas. “Early results were astounding”. “Worked New Zealand on 160 meters”. “It really works like you said it would”. “Really surprised me”. Yes, when conditions are right you can work DX with a 7.5 ft. antenna. That’s not astounding; Kurt has done it with a shopping cart and a garbage can. But your signal is not going to be “astounding” by any means.

Kurt advises you to double your money: fold it in half and stick it back in your pocket.

FEEDLINE LENGTH

“In my mobile installation I could not get my antenna tuner to tune 10 or 6 meters. Then I moved the rig which meant I had to add about 15 feet of feed-line. Now I can tune the antenna just fine. It’s much improved since adding the additional 15 feet of coax. Can Kurt explain how this works for mobile installations?” Easy. This method has been used for years at home stations. Here’s how it works:

If the antenna does not match the feed-line then there will be standing waves on the line and the SWR will not be 1:1. That’s why you need a tuner in the first place. The standing waves of voltage and of current are like sine waves standing on the line. As you move down the line away from the antenna the voltage and the current change. Since from Ohm’s law Z = E/I the impedance, Z, at the end of the line changes as the line length changes.

If the impedance seen at the end of the line is such that your tuner won’t handle it, you just change the line length until you find an impedance that it will handle. That’s what happened in this mobile station. Simple, but effective!

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NEW ANTENNA BOOK

Several new antenna books have been added to Olde Kurt's library. They are interesting and he wants to call them to you attention. One or more of them may fit your needs.

First is *Everything You Forgot to Ask about HF Mobileering* by Don Johnson, W6AAQ.

This is almost all about antennas. Antennas for HF mobile have to be very short (in wavelengths) especially down on the 80 meter band. The radiation resistance of such a short antenna is very low and it becomes most important to keep all loss resistances low so as to get reasonable efficiency. Even then the efficiency is not that great. In an example of a "well-designed" 80 meter HF mobile antenna we find a 1 ohm radiation resistance and a total of 10 ohms of loss in the ground system and the loading coil. This gives 9% efficiency. That's 9 watts radiated for 100 watts into the antenna. And you can do a lot worse than that if you don't watch out.

That's why the book gives tips on many aspects of your installation. Locating the antenna on the vehicle, selecting a loading coil, placement of a "Top Hat", deciding what kind of coaxial cable to use, and so on.

There is so much good information in this book that Kurt advises you to get a copy if you plan to or are operating HF mobile. It could save you a lot of grief.

That said, there is one technical error Kurt wants to call to your attention. This has to do with the use of antenna tuner on a mobile antenna. You don't want to use one; on that the author and Kurt agree.

But the author says "Although a tuner may adjust for the mismatch (when you move off the resonant frequency) you better not forget that your antenna is still back there at the original frequency. The antenna must be resonated at the new frequency". This is wrong, wrong, wrong. The antenna will radiate just as well when it is off its resonant frequency as it would on the resonant frequency. There is no magic to resonance; it's just that at resonance its impedance is resistive and it is easy to apply power to it.

The problem here is that the mobile antenna is very short and short antennas are narrow-band. If you move 30-KHz off resonance using your full size 80 meter half-wave dipole the SWR will go up to maybe 1.1 or 1.2. If you move 30-KHz off resonance with your mobile antenna the SWR will go up to maybe 20 or 30. Your rig is not going to load into it and your automatic tuner is not about to bring it down from that height. That's why you need to bring the antenna back to resonance; if you don't you can't get the power into it. Even if you could, the tuner would add additional losses so your efficiency drops.

But if you have a tuner that will adjust for the mismatch then the antenna itself will radiate just fine. Don't forget that. A non-resonant antenna will radiate just fine <u>if</u> you can get the power into it.

W6AAQ's book is for the power user. Full of information to let you get out with a good signal. Because of this orientation he has little use for what he calls "A Dummy Load on a Stick". Presumably he is talking about the popular little Hamsticks and

Outbacker antennas. These antennas are going to give you about 6 dB or maybe 10 dB less signal than the center coil antennas he favors. But Kurt would like to have seen a little discussion of the small antennas in the book. Although their performance is low they have their place in the mobile scene.

Lil Paddle refuses to drive the family car to the grocery store when one of the efficient mobile antennas is in place. She says she feels like she's driving a Marine Corps Tactical Mobile Communications Center. And she'll have none of it.

A little Hamstick on the top of the car does not get this reaction. As a matter of fact the little "Antennas on a Stick" easily can be unscrewed and hidden in the trunk when not in use. This advantage can outweigh radiation efficiency considerations in many family situations.

But even users of the small antennas can benefit from this book. In fact, since these have even lower radiation resistance, getting loss resistance down is more important than ever.

ALL ABOUT DIPOLES

Krusty Old Kurt was very favorably impressed by Antennas from the Ground Up by L.B. Cebik, W4RNL.

W4RNL starts by explaining how a dipole radiates. Next he gives radiation patterns, input impedance, and effect of height, and instructions for computer modeling. Then he tells what happens when you bend it; bent ends to use less space, bent downward (Inverted Vee).

After giving all you need to know about dipoles he goes on to longer multi-band antennas both simple center-fed and off-center-fed (Windom) antennas and finally end-fed (Zepp) types. Plus good information on transmitting loops.

This book is full of practical information on all these simple wire antennas that you can put up at modest cost. It allows you to pick the one that fits your needs and your available space and to know what to expect in performance before you put it up.

Kurt can tell you that these simple, low cost antennas work very well and are nearly 100% efficient. You don't see many ads for them because they cost so little and you can roll your own just about as easily as buying one prebuilt. The ads you see all the time are mostly for more complicated and expensive beams or trapped verticals. With the beautiful pictures and impressive (often overblown) gain figures you soon believe that these are the only way to go.

Not so. The dipole probably is more efficient and it gets out well in almost all directions. It doesn't need ground radials, an expensive tower, a rotator, or approval from the town council.

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LOW BAND – HORIZONTAL LOOP OR VERTICAL

One of Krusty Olde Kurt's longtime readers is fortunate indeed - he lives on a five-acre parcel of land. Also he has a 55-foot tower. He has put up a 160-meter horizontal loop at a height varying from 45 to 30 feet. He wants to know "what is the best antenna for this band?" He's been told that an inverted L with many ground radials is the best way to go.

Well, to start with, the horizontal loop probably is not it. Since it is so low to the ground it will radiate mostly upward. This is fine for local QSO's out to a few hundred miles but will not be that good for DX. The reader is in Southwestern Colorado, an area with a low density ham population, so he'll most likely want to work out past 500 miles most of the time. For those who might consider a 40 foot high antenna as not "low to the ground", remember that we are talking about 160 meters. The wavelength is about 480 feet, so 40 feet is less than $1/10^{th}$ wavelength on this band. The antenna is low to the ground.

At low frequencies verticals usually are the best. The inverted L is a good choice and usually easy to implement because the feed point is under one end of the horizontal part. This can be near the radio shack. Kurt calls this a vertical because the low-angle DX radiation is from the vertical part of the L.

Kurt favors the T style where the top of the vertical section has equal length wires going in two directions. This does get the feed point out in the middle of the horizontal part which usually means a longer feed-line than with the inverted L. But long coaxial lines at 160 meters don't have much loss so that's not a big problem. By having two wires going in opposite directions the radiation from the horizontal part tends to cancel so most of the signal is from the vertical section most favorable to DX.

Better yet, add more top "radials" thus making a true capacity hat. With a vertical section 40 feet long it shouldn't take too many of these radials to resonate the antenna on 160 meters. Actually you should try to get it to resonate just higher in frequency than the band. Then a small base loading coil can be used to bring it to frequency and, with taps, move it around the band. These short antennas have narrow bandwidth and won't cover the whole band with one setting.

One caution: Keep away from the trees. The top radials have high RF voltage and it has been shown that, if these wires are close to trees, especially if close to the trunk or large branches, there can be significant losses.

You can improve the bandwidth a lot by making the vertical section large diameter. Use large tubing or use two or more wires spaced about three feet apart for the vertical portion. You need this because efficient short verticals have narrow bandwidth. If your short antenna is wide-band you have heavy losses somewhere!

The reader could use his 55 foot tower by utilizing shunt feed. Shunt feed is not easily adjusted but works well with grounded towers.

GROUND RADIALS

And never forget the ground radials. Use lots of them. How many? Well broadcast stations use 120 of them each a wavelength long. That's 525 feet each on 160 meters and it is overkill for amateur stations.

N7CL suggests these alternatives: 100 quarter-wave (130 foot) radials. Or 50 eighth-wave (66 foot) radials. With either of these you will get out almost as well as though you had the full broadcast ground system.

KURT'S DIPOLE - AGAIN

A reader is going to take some of Kurt's Resonant Feed-line Dipoles on a Dxpedition. He wants to use them as verticals along the island's shoreline. His question is: "Could we make these directional through the use of a reflector? And would it be possible to make the reflector so it could also be a director by installing some type of stub that could be put in or out of the circuit to change its effective length?"

Kurt sees no problem with that. Start by attaching your Resonant Feedline Dipole to your "skyhook" so it is vertical. For those who missed Kurt's description of this antenna, here is a quick description: To make one you take a length of coaxial cable and at one end attach a quarter-wave length of wire to the cable's center conductor. Don't connect the cable's shield to anything.

Now go down the cable a quarter-wave and make a RF choke by winding the cable 10 times through two F240-61 toroids (20 meter band). This makes a half-wave dipole with the cable coming out the end instead of in the center. In this case it comes out the bottom of the vertical, handy to connect to the transceiver.

Put the vertical parasitic elements on each side of the dipole and spaced a quarter-wave away. Each element should be about 8% shorter than the dipole to act as a director. Raise this element so it is above ground far enough to add another part. With a knife switch at the bottom add another section so when the switch is closed the element is about 8% longer than the dipole. Then it will be a reflector.

You can change from director to reflector with the switch. If you'd rather not go out in the rain to change direction connect a piece of coaxial cable in place of the switch and make it long enough to reach the operating position and a quarter-wave or some multiple of a quarter-wave in electrical length.

Remember that a quarter-wave section reverses everything. If it's a quarter-wave or odd multiple of a quarter-wave leaving it open at the end will make the other end look like a short thus closing the switch. Shorting it will open the switch.

Half-wave or multiple sections repeat at the far end what you do at your end. Shorting the end will close the switch and leaving it open will open the switch.

You'll have to wind the cable around two toroids right where it connects to the reflector/director element so it won't affect the operation of the element. Use the same toroids and winding as you did when you made the dipole.

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WHAT HAPPENED TO THE ZEPP?

In the early days of radio a half-wave antenna fed by a quarter-wave ladder-line was designed as a trailing antenna for Zeppelin airships. The two-wire line had one wire connected to one end of the antenna. The other wire was not connected to anything. Both wires were connected at the transmitter end to send RF up the line.

There has always been a question about how this works: How does the transmission line work when one wire is left unconnected?

Terman in his *Radio Engineers Handbook* explains that the unconnected side of the line is terminated through the capacity from it to the antenna.

The *Radio Handbook* explains that the quarter-wave feedline is an additional half-wave length of the antenna folded back on itself so that the radiation from the two halves cancels.

The *ARRL Antenna Book* (16^{th} edition 1991) says that the difficulty lies in thinking of current flow in ordinary circuits where it is necessary to have a complete loop between both terminals of a battery before any current can flow at all. But when circuit dimensions are comparable with the wavelength no such complete loop is necessary. *The antenna itself is an example of an "open" circuit in which large currents can flow.* The current in the feedline is caused by electromagnetic fields traveling along the wire. The transmission-line conductors serve as "guides" for the fields so the electromagnetic energy will go where we want it to go. When the energy reaches the end of the transmission line it meets another guide, the antenna, and continues along it. The transmission line has two wires with currents in opposite directions so the radiation from them cancels. But the antenna is a single wire so it radiates.

The explanations may vary but the antenna found a place in many commercial and amateur stations over the years. End feed is so convenient. You can run the flat top from the building to a single support pole or tree. From the building end a short transmission line to the transmitter completes the installation. The SWR on the line may be high so open wire or, nowadays, window line is used. Most tuners will accept this kind of line.

George Sterling's *The Radio Manual*, popular back in the 1940's, gave commercial radiomen three ways of connecting their transmitters to the Zepp. QST , the *Radio Amateur Handbook*, and the *ARRL Antenna Book* gave full details of its use in amateur stations. That is, until recently. The 1991 *Antenna Book* described the Zepp in detail. The 1995 *Antenna Book* has just three paragraphs about the Zepp and advises that the ¼ wavelength feeder should be avoided because it "gives trouble with parallel currents and radiation from the feeder portion of the system." So much for the old ¼ wave fed Zepp!

To make things worse for the Zepp, ARRL's new book *Stealth Amateur Radio* tells us that "End fed wires NEED counterpoises or other suitable RF grounds to be effective." It recommends that any end fed antenna have at least a quarter-wave of wire inside the house as a ground or counterpoise for the antenna. This pretty well rules out the Zepp.

More disheartening than that to Krusty Olde Kurt is the Zepp description in Les Moxon's *HF Antennas for All Locations*. He says that "It is a pity that in its recognized form it does not work." And he goes on, using equivalent circuits, to explain why it does not work.

Analysis with equivalent circuits and, in particular, computer modeling of antennas has brought a new and better understanding of antennas of all kinds and Kurt is all for it. There is one problem you have to watch out for: the model or equivalent circuit must exactly match the real antenna. It's always worthwhile, when the analysis is done, to build one and check it out. If its performance matches the model then your model was OK. But if it doesn't perform as your model predicted then you need to rethink your model. It's difficult to do this with most antennas unless you have an antenna range available. But the Zepp is so simple it can be tested in your own back yard. After reading all these slaps at the Zepp, that's what Kurt decided to do.

OLDE KURT'S ZEPP

Kurt built the basic 40-meter Zepp. The half-wave flat top was 67 feet long. The feeder was made of The Wireman's 450 ohm "window line" (see www.thewireman.com) and was an electrical quarter-wave, 32 feet long. The antenna end of the line has one wire open and the other connected to the flat top. At the transmitter end there is a series tuned circuit connected across the line. This resonates on 40 meters with the variable capacitor used to tune it exactly. Kurt planned for C = 100-pf and L = 4.75 uH. Six turns 3" diameter did the job for the coil. A three-turn link coil connects across the coaxial cable going to the transmitter.

With an SWR meter in the coax line Kurt adjusted the capacitor to resonance (lowest SWR) and the coupling between the coil and the link for lower SWR. SWR of 1.0 could be obtained anywhere in the band. The 2:1 bandwidth was 150 KHz.

Did the antenna work? Yes. Was Kurt surprised? No. Did Kurt get RF in the shack? No. Was there radiation from the line? Probably some. The currents in the two legs differed by 10% so there would not be perfect cancellation. This was good enough for Olde Kurt but, for perfectionists, methods to equalize the currents are described in older issues of QST. Kurt figures he's better off with a slight bit of feedline radiation than he would be with half the antenna inside the house as recommended in *Stealth Amateur Radio*.

And what can you learn from all this? Well, for one thing, don't believe everything you read. And stick with Krusty Olde Kurt to keep your station simple and efficient.

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THE T2FD ANTENNA

The "Terminated, Tilted Folded Dipole" (T2FD) originated many years ago. It is manufactured for commercial, military, and amateur use by B&W (see www.bwantennas.com). One of Kurt's loyal readers wants to know how it works.

Imagine an ordinary folded dipole. Instead of feeding the center of one wire with balanced line, drive it with 50 ohm coax through a 12:1 balun. Cut the second wire in the center and insert a 600 ohm resistor. That's a T2FD. It matches the coax over a wide band.

One of B&W's antennas is 90 feet long and gives continuous coverage from 1.8 to 30 MHz. A shorter version, 65 feet long, covers 5-30 MHz.

What exactly is meant by "continuous coverage?" That means that the SWR on the coaxial line to the transmitter is a reasonable value (less than 2:1) at any frequency in the range. Let's look at that in a little more detail.

The ordinary folded dipole has an impedance four times that of a dipole. If the dipole is 75 ohms then the folded dipole is 300 ohms at resonance. On either side of resonance the SWR goes up. On most bands the SWR will stay below 2:1 over the band. Outside the band the SWR can become very high.

So what happens to the folded dipole when we put the terminating resistor in one leg? The feed point impedance goes up and the variations (around this new higher impedance) become less. Why are the variations less? Because we have resistive loading. Imagine an ordinary dipole with a 600 ohm resistor across its feed point. If the dipole is 75 ohms then the combination of dipole and resistor will look like 67 ohms. SWR on your 75 ohm coax will be 1.1, not much change at all.

But let's move the antenna off resonance to where it looks like 600 ohms. Normally you would have SWR = 600/75 or 8:1. But with the resistor in place the feed point resistance is only 300 ohms and SWR = 4:1. So you can see that resistive loading reduces the SWR variation. Of course you don't get something for nothing; In the example of SWR = 4:1 half the RF power is dissipated in the resistor! Note: Off-resonant antennas are mostly reactive, not resistive, in impedance so Kurt's calculations above are not quite accurate, but you get the idea.

NOW TO THE ADVERTISING

Krusty Olde Kurt looked carefully at B&W's website advertising for the "Broadband Folded Dipole" and was not pleased at what he saw. It is not exactly untruthful but, worse, it is deliberately misleading and wrong. You saw, in Kurt's example above that, with resistive loading, a lot of power can be lost in the resistor.

So what does B&W say about that? Well, to start with, they don't call the resistor a resistor. It's a "Terminator" or "Balancing Network". And does the Terminator create losses? "No, it does not create losses", they say. "It dissipates losses from the ever present lack of antenna efficiency. No antenna is a perfect radiator. In transmit mode, the terminator absorbs energy that did not get radiated out of the antenna. In most antenna systems this gets carried back to the rig where it can do serious damage. For a terminator to create losses, it would have to have a low impedance. Ours has a high impedance."

Krusty Olde Kurt tends to turn purple when he reads such misleading and completely wrong statements as this. It is so bad Kurt hardly knows where to start.

But let's start with the losses. B&W intimates that the "Terminator" just burns up the RF that the antenna failed to radiate. Kurt would rather say that the antenna can't radiate what the "Terminator" absorbs. Of course all the power goes either into radiation or into the "Terminator". The question is: How much is lost in the "Terminator"?

We get a clue from the answer to the question "What does the folded dipole look like? Can I paint it?" In the answer we find that "The 'Balancing Network' may get very hot with linear operation, so a thermal paint must be used here."

And why does it get very hot? Kurt can tell you: It gets very hot because it burns up a lot of your RF power, that's why. And how much power does it burn? To answer this question we turn to W4RNL's web page (www.cebic.com). He modeled a very similar antenna and found that the average losses over most of the band were about 5 dB. But below 5 MHz the losses increased rapidly to 8 dB at 4 MHz, 12 dB at 3 MHz and on up at lower frequencies. To put this another way, over 2/3 of your RF power goes into the resistor. The T2FB has 33% efficiency. Worse below 5 MHz. Your ordinary dipole is 99% efficient. But it isn't broadband. You have to decide whether you want broad-bandedness or efficiency from your antenna.

W4RNL shows that the T2FD has the same pattern as a dipole. And he shows that the T2FD has losses of about 5 dB on 10 meters. Kurt would sure like to know how B&W arrived at their figure of 3 dB gain over a dipole on 10 meters. And their loss of 2 dB on 160 meters. W4RNL shows a loss of 18 dB on 160 meters.

Now to the part about the power not radiated by ordinary antennas that goes back to the rig where it causes serious damage. Anyone who believes that has not followed Kurt's explanations of reflected power and what happens to it.

Kurt can't repeat that right now. He just has room to tell you that the statement is full of baloney. Not true at all. A full and complete explanation along with a lot of other good information is to be found in *Reflections II* by W4DU. You should have one in your library, especially since it's so inexpensive. The original *Reflections* book was published in 1990 at a price of $20. The new revised and expanded edition, even after a decade of inflation, is $19.95.

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USING A TUNER WITH A MOBILE INSTALLATION

One of the wrong ideas that seem to pop up every so often is that, in a mobile installation, if you have high SWR on the cable from the rig to the antenna or from the antenna tuner to the antenna you will have horrendous losses. In a recent column on mobile antennas Krusty Olde Kurt explained that this is just not so. If you have a long run of coax such as you might have in your home station you may have significant losses. But the cable in a mobile setup usually is short. So short that you'll have no losses to worry about no matter how high the SWR.

Not everyone believes Kurt so let's look at some figures. Suppose the cable is 10 feet long and we are operating on 80 meters. If the SWR is really really high, let's say 100:1, what are the losses? They are .64-dB. Is this horrible? For every 100 watts coming out of the transmitter we lose almost 8 watts. Could you tell the difference on the air? Not on your grandpa's eyebrows!

How about if the SWR was more reasonable, say 20:1? Now the loss is .24 dB. Your hundred watts is going to be reduced to a little under 96 watts at the antenna. Kurt's advice: Don't worry about it.

At higher frequencies than 80 meters the loss for a given SWR is higher, of course. But at the same time you aren't going to see as high SWR as you do on eighty. There are two reasons for this: the antenna is longer in wavelengths the higher in frequency you go so it has higher bandwidth. So the SWR off the resonant frequency doesn't go up so fast. Secondly, higher frequency bands are narrower, in percentage of frequency, so you don't move so far percentage-wise going across the band.

RESONANCE NECESSARY?

Kurt also shot down another common misconception that an antenna radiates more efficiently at resonance than it does when not resonant. Wrong! It radiates just as well off resonance as it does on its resonant frequency. The main reason for using a resonant antenna is that gives your transmitter a resistive load usually of a reasonable value. A dipole at 75 ohms for example.

Off resonance it has reactance, often a large value. This is more difficult to match. But if you have a tuner that will match it properly then the antenna will radiate just fine.

That means that you can use a tuner with your mobile antenna instead of tuning the antenna itself as you go across the band. You may have read elsewhere that you can't do this but the fact is that you can.

In a recent column Kurt said you could use a tuner with your mobile antenna. Then, in the next paragraph, he advised against it. An eagle-eyed reader wrote in to tell Kurt that he seemed to be contradicting himself? Should you or should you not use a tuner with your mobile antenna?

Well you can use one but whether you should use one depends on the antenna you are using and whether or not you are trying to get the last watt from your transmitter radiated.

If you are using one of the small inconspicuous antennas that Lil Paddle favors your tuner likely will work just fine. The power users call these antennas “dummy loads on a stick”. That is not doing them justice because they are very useful antennas. But they do have relatively high resistance and thus both low efficiency and wide bandwidth. So the tuner doesn't have to contend with very high SWR.

On the other hand, if you use one of the giant antennas with the great big coil in the middle and a top hat above it you may have a problem. Kurt’s problem is that Lil won’t drive the family car with one of those on it. She says it looks like she’s driving a Marine Corps mobile command post and she’ll have none of it. Your problem is that the antennas have lower losses and thus tune sharply. Off resonance the reactance goes up quickly and your tuner may not handle it.

The other problem is that you can lose a lot of power in the tuner. Normally you don’t think of the tuner when you think of losses but they are there. This can be a problem if the SWR gets really high. The tuner losses go up when this happens. How bad? Depends on the tuner. Even when operating into a reasonable load you may lose 5% of your power. At high SWR it may double, triple, or even more.

The losses are mostly in the tuner’s coil. You can tell if there is a problem by running full power for a minute or so then, after turning the transmitter off, feel the coil. Losses show up as heat. If the coil is warm you are losing some. If it is hot you are losing a lot.

Kurt doesn’t like the looks of some of the “transceiver power” tuners being sold today. Transceivers are getting smaller because they have eliminated big tuning dials, multi-gang band-switches and the like. This is possible because of advances in design.

Some manufacturers have made tuners smaller to match the smaller rigs. But there have not been advances in design here. Tuners still have capacitors big enough to handle the RF voltages and coils hopefully big enough to handle the RF currents. To make the tuners smaller the metal cabinet has shrunk bringing the metal closer to the coil. This is not good. As the *Antenna Book* explains, a good coil may have a Q of 200. But move the metal cabinet close to it and its Q may drop to 25 or 50. This means higher losses.

So Kurt suggests that, particularly in a mobile installation where you may see high SWR, you make the heat test. Estimate the power you are losing as best you can and decide if the convenience is worth it. It depends on what you are trying to do, work friends across town or work maximum DX.

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RESONANCE

Krusty Olde Kurt has explained that an antenna does not have to be resonant to radiate well. There is no magic to a resonant antenna. We use them this way because they are easy to match since they present a purely resistive load and, usually, a reasonable value of resistance.

A reader asks: “If that is true then why is it that, when a receive antenna is tuned through resonance, the signal jumps up in S-units a great deal?

That depends on what you do to tune through resonance. For an example let’s look at Kurt’s shortwave receiver, a 1940 Hallicrafters SX-28. The antenna is connected to a small link coil. This is wound on a parallel-tuned circuit that is connected to the grid of the first RF amplifier. It is tuned by the main tuning control and has a fine tuning knob that turns a trimmer capacitor called “Antenna Tuning”.

The link coil and the tuned circuit form a transformer with a high step-up ratio to match the low impedance antenna (300 ohms) to the tube grid (100,000 ohms or more). The coupling is loose so you don’t get an exact match. The reason is that the antenna is not expected to be resonant. You don’t want the reactance to detune the tuned circuit too much. But it will detune it some.

When you tune the trimmer to resonance the signal jumps up in S-units. The reason you get the increase in signal at resonance is because the impedance of the circuit peaks there thus giving the highest step-up in voltage. In this case you haven’t really tuned the antenna to resonance, just the receiver input circuit.

ENTER THE TUNER

In your amateur station you have to match the antenna circuit to your transmitter. So here, if your antenna is not resonant, you use an antenna tuner or transmatch as it is sometimes called. This goes between the transceiver and the antenna and it does bring the antenna into resonance although there are many who will tell you that it just “fools” the transceiver into thinking the antenna is in tune. Not so. It does tune the antenna.

The way this works is very simple. Your non-resonant antenna presents an impedance to your coaxial cable that is partly reactance and partly resistance. If the cable is a half-wave long that same impedance will be present at the transceiver end. But if the cable is some other length then you see some other impedance. It doesn’t really matter to us because our tuner will match whatever it is. The way it matches is to provide the proper resistance and reactance at this point to provide resonance.

The resistance and reactance of the antenna will be different than the resistance and reactance at the tuner (except in the half-wave case) but the impedance provided by the tuner will be different when looked at from the antenna end. As a matter of fact, since the distance from antenna to tuner is the same as from tuner to antenna (has to be since it is the same piece of cable) the change is such as to provide just the right impedance to resonate the antenna. So the antenna and the whole system are now resonant. And the receive signal peaks nicely.

What does all this mean? It tells us that a non-resonant antenna receives just fine. In the first example we used it non-resonant. We peaked the receiver response by resonating the coupling transformer. In the tuner example we left the coupling transformer alone and brought the antenna to resonance with an external circuit. You get an increased signal when you do this just as you do with any resonant circuit. The voltage across it goes up by the Q when you hit resonance.

This doesn't necessarily mean that you will receive better. The signal comes up but so does the external noise. This external noise usually is the limiting factor in reception on the high frequency bands.

PROXIMITY LOSS

Three related questions have come into Kurt's mailbox. One operator wants to hang his antenna between two metal towers. The dipole is nearly as long as the space between the towers. He wants to know if 1-1/2 feet will be sufficient space from the metal tower to the ends of the dipole.

Another operator lives in a restricted neighborhood so he threw a wire over the top of his house. It rests on clay tile common in the southwest. It doesn't seem to work very well. Is this due to proximity to the tile?

The third operator also is in a restricted area. He wants to festoon his Yagi with plastic ivy leaves and vines to conceal it. Will this detune it?

Well, the antenna books always tell you to keep your antenna high and in the clear so as to prevent proximity losses. Garden catalogs always tell you to plant in sandy loam. Kurt has soil similar to concrete but that doesn't stop Lil from gardening. You have to make do with what you have. Your antenna will work if it is not high and in the clear and it can work really well if you are careful.

At the ends of your dipole there is a strong electric field and if near a conducting surface you will have losses. The minimum distance depends on the frequency and on how much loss you'll tolerate. 1-1/2 feet from the towers looks awfully close to Kurt. If it was his antenna he'd move his end insulator back a few more feet and at that point run the rest of the wire straight down making an inverted "U" dipole. The antenna will still be resonant and will work just fine but it will be further from the tower.

Clay tile probably is lossy. With the wire right on the tile the capacity from wire to tile is large. RF current from the antenna flows through this capacitance into the tile. Capacitance varies with the spacing between the two. If you are using bare or enameled wire the spacing is less than .05 inches. If you raise the wire by just one inch by using spacers you cut the capacitance by a factor of 20. This should improve operation. Your antenna may still not be a world beater but it will be better.

To festoon the Yagi Kurt advises lowering it enough to do the festooning. Transmit at low power with a field strength meter of some kind in the main beam. Start putting on the plastic and vines watching the meter closely. If you lose too much try a different material or a different plastic that will do the same job. This way you can find out for sure and do the job right.

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TOO COMPLICATED

Olde Kurt supposes that it had to happen sometime. Still it was a shock. A reader actually returned one of Kurt's books because he didn't like it. "Too complicated. Over my head."

Kurt is sure that Worldradio cheerfully sent a refund but, nevertheless, he is mystified. The book returned was *Aerials II*, a compilation of Kurt's articles from several years ago. The articles include Kurt's use of common household items as antennas. He actually got on the air and proved that one could get out using them. In the sweepstakes he used two shopping carts from the market. In the CQ WW contest he used his car's body (by hooking to the rear bumper), an ordinary metal umbrella, and verticals 1/5 normal size with a pizza plate for top loading. All these were connected through an antenna tuner to resonate them. The results: 43 countries in 21 zones.

The purpose of these exercises was to shame those who don't operate from their restricted condos because they can't put up towers and beams and thus can't get out. You can get out. Use your head. Use your aluminum downspout. Use whatever is available and connect it to your tuner to resonate.

In deference to the reader Kurt must say that this *Aerials* column is a technical one. Easy to read, he hopes, but still technical. On the other hand amateur operators come in many different interests. Some are interested in the technical aspects of the hobby. Others in contests, rag chewing, or you name it.

Even though your prime interest may be in a different aspect of radio it is still worthwhile to learn about others. After all, if you only read about what you already know, how can you progress? The most fun and gratification from the hobby come when you gradually learn more and become better at it. Don't be a stick-in-the-mud and never change! And don't send books back to Worldradio. They probably need the money worse than you do!

160 METER LOOP

A reader from Florida is using a horizontal loop about one wavelength in circumference with sides supported from 36 feet at the lowest to about 50 feet at the highest. It is fed with 450 ohm ladder line. The signals are good on all bands except 160 meters where it definitely is a cloud burner.

His question is, "Would it be worth putting up more wire and getting the loop size up to two wavelengths? Or could I improve the signal with another type of wire antenna?"

Krusty Olde Kurt's advice is to stick with the one wavelength antenna you have. Use it as is on the higher frequency bands where it works well. But on 160 meters use it as a top loaded vertical. Here's how: Tie the two wires of the ladder line together down at your antenna tuner. Use the feeders as a vertical antenna. The loop will act as top loading to make the feeders look longer thus bringing the resonance down lower than it would be with just the 36 foot vertical section.

Work this antenna against a ground system of at least 20 radials. Make them about 70 feet long. Kurt guarantees that you will work better DX with this arrangement than with the loop itself. The radials take more wire than you would use increasing the loop size but wire is inexpensive and the results will be worth it.

NO RADIALS

A sharp eyed reader brought Kurt's attention to an ad that appeared in March 2002 *Worldradio*. This is for the Anttron 8010-B eighteen foot vertical that needs no radials. He wants to know what they have done to prevent the need for radials. "If they are saying that it only works 80-10 meters with an antenna tuner doesn't it still need radials? Doesn't it need radials to keep it from being a 'long wire' and to keep RF out of the shack?"

Krusty Olde Kurt knows that you can get out with a couple of shopping carts for an antenna. Also you will get out with this eighteen footer. The question is, "How well?" Kurt will now explain his easy method for analyzing short vertical antennas. His method will answer the question, "How well?"

Eighteen feet is pretty short on 80 meters to consider the antenna a long wire. Kurt prefers to consider it a short vertical with one radial. Where does the one radial come from? From the outside of the shield on your coaxial cable that runs from the antenna to your transceiver. That's a radial.

The antenna is 18 feet long which is approximately 6 meters. So the length on the 80 meter band is 6/80 wavelength or .075 wavelength. There are graphs showing the radiation resistance of short verticals in most handbooks. Kurt was surprised to find that the table is not in the *Antenna Book* for some strange reason. But there is one in ON4UN's great book *Low-Band Dxing.* You should have a copy of this in your library if you have any interest in antennas for the lower frequency amateur bands.

To make things difficult ON4UN expresses antenna length in degrees. A quarter wave antenna is 90 degrees and our .075 wavelength antenna is just 27 degrees in length. The table shows us that the radiation resistance will be about 2 ohms. Next we look at the table showing the resistances of radial systems. It doesn't go down to just one radial so we can use the figures for a two radial system and be close enough for our purposes. The ground resistance for two radials of any length is about 28 ohms.

Now we have all the information we need to calculate the efficiency of the antenna. It is the radiation resistance divided by the total resistance. In this case 2/30 or a bit less than 7%. So for every 100 watts you put into this antenna on 80 meters you can expect to get 7 watts or less out.

Will you get out? Sure you will but not very well on this band. As you go to the higher bands the antenna length in wavelengths is greater and the efficiency will be a lot better. If you take a look at Anttron's website http://anttron.tripod.com you will note that customer's pleased comments are about their results on 10, 20, and 15. No mention of 80 meters for reasons that are obvious from our quick analysis.

Kurt's suggestion: If you buy this antenna put a few radials under it. It will get out a lot better.

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RAI vs M^2

Kurt's mail brought this letter: "I wonder what Krusty Olde Kurt has to say about the RAI beams that were featured recently. The gain figures are pretty high for the boom length quoted. It is hard to see how these beams can beat the M^2 antennas."

Well, the only way to make a positive comparison is to put both antennas on a test range and, with a field strength meter, measure the relative gain. Kurt doesn't own a test range so that approach is out.

What Kurt can do is look at the claims and, with his vast experience, make a realistic evaluation. Let's first look at the claims. The first thing Kurt sees is that M^2 gives their antenna gain in dBd, gain over a dipole. Kurt likes this since it gives the prospective purchaser the gain he's likely to get over his present dipole antenna. RAI gives gain in dBi, gain over isotropic. This gives a gain figure 2.1 dB higher and so makes the antenna look more attractive than it really is.

Kurt has converted M^2's gain to dBi so both antennas are stated in the same manner. The comparison for three element 6-meter beams is:

M^2 Boom length = 6' 9"

Gain = 8.5 dBi

RAI Boom length = 6'

Gain = 10 dBi or greater.

Both gain figures indicate excellent performance. For example, the FCC in their RF exposure regulations, considers a typical three-element beam to have 7.2 dBi gain. How does M^2 get that extra gain? Probably by making better than average antennas. Bear in mind that this is the only firm that has submitted proof of gain to *QST* so that they can advertise gain figures in that magazine. This means that gains have been tested on an approved antenna range or that modeling data from YO or NEC programs have been submitted to *QST.* Kurt is willing to accept this as proof that M^2 gain figures are correct.

But how does RAI get 1.5 dB more gain with a shorter boom? The theory is to be found on their web site: www.raibeam.com. Here, to Kurt's astonishment, we find that Maxwell's electromagnetic field theory does not apply to RAI beams. Neither do the modeling programs YO or NEC because they can't "see" the complex currents flowing in RAI beam elements.

We also find that the concept of electromagnetic waves, on which radio theory is based, is an obsolete concept. It is supplanted by Quantum Electrodynamics vision of particle action at a distance. This theory apparently shows how "critical coupling" of antenna elements allows greater gain than the older methods. Thus we have "super-gain" antennas.

Does Kurt buy this explanation? Not for one minute! Krusty Olde Kurt has lived through so many “breakthrough” schemes that he doesn't get excited in the least at glowing terms like “Critically couples bi-periodic method”, “infinite self-energy” or a new and different theory of operation,

Could anything change Kurt's mind? Of course! Certified antenna range field strength measurements showing the claimed gain. For some reason this seems to be the one thing that the proponents of these breakthrough antennas can't come up with. Kurt is waiting for this one.

LOOP IN A LOOP

Another loyal reader asks Krusty Olde Kurmudgon Kurt, “Can you tell me if it is detrimental to put a 20-meter loop inside a 40-meter loop? Or would I be better off to hang them separately?”

Just mount them with the little one inside the big one. It will work fine. And how can Kurt be so sure of this? Take a look at tri-band quads. They are a 20-meter loop with a 15-meter loop inside it and a 10-meter loop inside of that one. They work well and have been used by hundreds of Hams over the years. Yours will just be a bigger version of the quad's driven element.

RADIALS AGAIN

A reader asks, “Most antenna books say any vertical antenna should have as many radials as possible. My question is, how does the manufacturer of antennas that are advertised in *CQ* and *QST* get by without using any ground radials?”

Simple. By showing beautiful pictures of complicated antennas, describing their advantages (small footprint, small size), neglecting their drawbacks, and throwing in some wrong technical explanations. Most of these ads are flim-flammery at its worst.

The technical basics are these: A quarter-wave vertical has high current at its base. So it must have ground radials or a substantial counterpoise. A half-wave vertical has no current at its base and so can work without any radials. That's *can work.* It will work better with radials under it as Kurt has explained in earlier columns.

A half-wave antenna on 80-meters is 66 feet high. On 40-meters it's 33 feet. But it is possible to shorten this by adding loading of some kind. One Southern manufacturer has a “half-wave” vertical on 40-meters that is only 12 feet high.

“Is this something for nothing?”, you may ask. “Not so”, Krusty Olde Kurt replies. When you shorten an antenna this way the radiation resistance drops and the bandwidth is less. With a 12-foot antenna the radiation resistance drops from 72 ohms to 8 ohms. This means that any losses in the antenna become more significant and the efficiency drops. The drop in bandwidth probably is more painful because you aren't going to be able to work across the whole band without retuning the antenna. The 12-foot antenna, for example, has 40-KHz bandwidth, not enough to cover the whole 'phone band.

Take a careful look at the SWR curves for other such antennas if they are given. The big 80 through 2-meter 34 foot high “no radials” from the big Northeaster company has about 75-KHz bandwidth on 80-meters, 100-KHz on 40 meters. Your simple dipole will do a lot better than that.

Then there is the feed-point hype. Raise the feed-point and get higher radiation resistance, more efficiency, and better DX radiation angle. Get the current up where it is most useful. This is all baloney. Raising the feed-point changes nothing but the input impedance seen by your coax.

These "no radial" antennas may have their place but Krusty Olde Kurt cautions you: don't take the ads at face value. Read the fine print at the bottom. Check to see if anything important has been left out.

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ANOTHER FANTASTIC ANTENNA

A reader suggested that Krusty Olde Kurt take a look at the website www.eh-antenna.com. *Kurt d*id so and found another too-good-to-be-true antenna.

The EH antenna is a Ham's dream. It's a very small size,2% of a wavelength long (a dipole is 50% of a wavelength long) high efficiency (near 100% - just like a dipole) and has wide bandwidth. All very small antennas have narrow bandwidth. But since this antenna works on a "new principle" conventional concepts do not apply. And what is this new principle? It is a special application of the Poynting vector.

And what is the Poynting vector? It is a measure of the power passing through an area far away from the antenna. The vector (think of an arrow) points in the direction the wave is moving. The power is the wave's current multiplied by its voltage. This is not hard to understand. After all, we remember from simple DC circuit theory that power equals current times voltage. The only difference here is that the power is flowing in a certain direction. This makes it a "vector".

But in the web site's description of the Poynting vector it becomes much more complicated. The vector "specifies the relationship of the E and H fields required to produce radiation." Kurt can assure you that it does nothing of the kind.

We are told that the Poynting vector requires an antenna to develop E and H fields in proper physical relationship (the H field must encircle the E field), have a ratio of 377 ohms, and both the E and H fields must be developed in phase.

The Poynting vector does *not* do this at all. It is a measurement of power that has already been put into a wave. The impedance of free space is 377 ohms so any wave propagating in it will have a ratio of E and H of 377 ohms. Ohm's law works in outer space the same as it does inside a radio transmitter. And the E and H fields are at right angles. They are generated at the same time by the same accelerating charges on the antenna and so are in phase. This has nothing to do with the Poynting vector but it makes a great sounding pseudo-scientific explanation that will impress anyone not familiar with the Poynting vector. Are you familiar with it? Do you know anyone who is?

THE EH ANTENNA

The EH antenna is impressive. Imagine a big round horizontal metal plate part way up a short tower. A few feet above it is a large metal cone. They form the plates of a capacitor. The displacement current through this capacitor develops a magnetic field. Displacement current? What is that?

If you connect a resistor across a battery current will flow through the resistor. This is called conduction current (it flows through a conductor). It really is a flow of electrons through the resistor and back to the battery.

If you put a capacitor in series with the resistor the electrons can't flow through it because the capacitor is two plates separated by an insulator. Electrons don't go through insulators. But when you first connect the battery current does flow and keeps on flowing until the capacitor is charged up. Then it stops. How can this be? Because when a capacitor is charging, there is a changing electric field between its plates. This changing field acts just like it was electron flow. This is called “displacement current” and it produces a magnetic field just like conduction current does. It's the same principle “if it looks like a duck and acts like a duck, then it is a duck.” It is not electron flow but it is a current.

If you replace the battery with an RF generator then current flows through in one direction, but not long enough to charge the capacitor very much. Then the polarity changes and current flows in the other direction. The capacitor never gets fully charged and the circuit acts as though the capacitor wasn't even there. But it does block any DC. That's your ordinary coupling capacitor.

So now you know what displacement current is. This is valuable knowledge. The next time your young son asks “Dad” (or “Mom”, as the case may be), “What is displacement current?,” you'll be able to explain it to him and the whole family will think that you are really in the know about radio.

ANOTHER FLAW

The theory given for the EH antenna says that current through a capacitor leads the voltage in phase (true). Since the current and voltage are not in phase the antenna will not radiate. But by using a special network the voltage and current can be brought into exact phase and thus the antenna will radiate.

Kurt can assure you that this is not correct. Yes, the current and voltage are not in phase. But the voltage that causes the current to flow has nothing to do with radiation. It is the current that causes a magnetic field to develop. This magnetic field itself develops an electric field and radiation begins. By this time you may have deduced that Krusty Olde Kurt doesn't think much of the theory behind the EH antenna. And you are right. It is a bunch of baloney, to put it politely.

Still, there are inventions that work even though the theory explaining them is wrong. The question is, does the antenna really work as claimed? The only public tests Kurt has heard about are the ones run last October at radio station

WKVQ(AM) in Eatonton, Georgia. The EH was tested against a standard broadcast antenna. The result: The EH antenna suffers from poor efficiency.

The theory is wrong and the antenna appears not to work as claimed. Until Kurt sees some independent field strength measurements that show otherwise he's going to stick with his conventional antennas. They do work.

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RAI vs M^2 CONTINUED

In response to a reader's request Krusty Olde Kurt looked over the gain claims of these two manufacturers and gave his opinion of them. Kurt liked what he saw of M^2 but was critical of RAI's supporting theory.

The proprietor of RAI, W7RAI, has written criticizing Kurt's column and defending has antenna's performance. He points out that he is a 22 year member of the Society of Broadcast Engineers, and has been chief engineer of several radio and TV stations. He considers it amusing that Kurt "holds his opinion higher than the works of Dr. John Wheeler, and the late Nobel laureate, Dr. R. P. Feynman regarding quantum electrodynamics and action-at-a-distance."

Well, it is not widely known but Olde Kurt put in more than 22 years as a broadcast engineer and supplier of equipment to radio and TV stations. As to Drs Wheeler and Feynman, Krusty Kurt is aware that each has made great contributions to quantum dynamics theory. But he has not seen where either has done any antenna work. Further, Kurt fails to find any theoretical explanation of the application of quantum dynamics to RAI antennas anywhere in RAI's literature.

All we have is the statement that "critical coupling" is a major advancement in antenna technology such as we have not seen in the last 75 years. So, what is "critical coupling"? It is a term used for two tuned circuits that are coupled together. If the coupling is "critical" the maximum transfer of power takes place. If the coupling is either too small or too large the transfer is less. Elements in the RAI beams are said to be critically coupled. Just why critically coupling improves the gain is not proven or even explained.

Long mathematical proofs are not usually put in product literature. But a complete explanation of the greatest advance in antennas in 75 years should be available somewhere. Our national amateur radio society, ARRL, has a highly technical publication *QEX*. Kurt is certain they would welcome an explanatory article and urges RAI to send one to them.

MODELING vs TESTING

Kurt was cut to the quick by RAI's accusation that he "propagates the myth that computer modeling is infallible - being an indisputable substitute for empirical measurement." If there is any one thing that Kurt wants and asks for it is field strength measurement of gain. As a matter of fact, following Kurt's criticism of the RAI beam in his article, he then said, "Could anything change Kurt's mind? Of course! Certified antenna range field strength measurements showing the claimed gain." Kurt looked carefully at RAI's letter and fails to find any mention of certified field strength measurements.

W7RAI does suggest that Kurt borrow one of his beams owned by Worldradio's publisher and compare it with any same size beam to see if the claims are valid. Well, Kurt doesn't have access to a test range. Anyhow it is not up to the user to prove claims. It is the manufacturer who makes the claims and who sells the antennas to hams on the strength of these claims who should at the very least test the antennas to ensure that the claims are valid. This should be done before the first antenna is sold.

As Kurt pointed out in his original article, our society's magazine QST allows gain figures in the magazine only if proof is given to them first. This proof can consist of certified test range measurements. M^2 has done this and Kurt accepts their gain figures because of that. Kurt suggests that, if RAI has run valid tests, they should be submitted to QST also. When they accept his claims Kurt will become a believer.

Meanwhile, the fancy terminology and explanations do not convince him in the least. It's just smoke and mirrors, something that the amateur radio antenna field is full of.

RADIATION RESISTANCE

A reader wants to know how to measure radiation resistance and how to change it.

It is easy to measure the radiation resistance of a horizontal center-fed dipole. Just connect your antenna bridge to it and measure the resistance. The resistance number you see in the antenna books for a dipole is 72 ohms. That is for a dipole located somewhere in outer space. When the dipole is near the earth the resistance usually will be different. When the antenna is down low it might be 25 ohms or less. Higher up it may go to 100 ohms or so.

What exactly is radiation resistance? Well, you put power into an antenna and it disappears as radiation. It is just as though you put the power into a resistor except instead of heat you get radiation. So we consider it as being a resistance, radiation resistance.

The reason it changes with antenna height over ground is that some of the radiated energy is reflected back to the antenna and changes the antenna current. The amount and phase of the reflection changes with height.

Another way to measure the radiation resistance is to use Ohm's law. Measure the RF voltage and current at the feed point. Then R = E/I. Simple.

We've been talking about resistance at the center of the dipole where the current is highest. If you move the feed point away from the center the radiation resistance goes up. The current drops down and the voltage goes up as you move away from the center so, from Ohm's law, the resistance has to go up. So a dipole can have a number of different radiation resistances depending on the feed point. But when we talk about the radiation resistance of a dipole we mean when it is fed at the center, the high current point.

The high current point on a quarter-wave vertical is at the bottom. The radiation resistance is 36 ohms. But when you measure you'll get a higher reading. That's because you see both the radiation resistance and the loss resistance. The dipole has practically no loss resistance but a vertical has loss in its ground connection. You are lucky if you read only 45 ohms (9 ohms loss resistance).

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MATH PROBLEM

Krusty Olde Kurt is a whiz at calculus, differential equations and other such supposedly difficult subjects. But he fails at arithmetic. This has been pointed out by a number of readers including N∅NB and W8DL. It seems that a half wavelength vertical antenna on 40 meters is not 33 feet high but a lot closer to 66 feet. And a half-wavelength antenna of 80 meters is not 66 feet long but about 132 feet long.

Kurt is happy to have his readers correct him on these mistakes. He doesn't want any incorrect information to go out in this column. There is plenty of that to go around in some antenna manufacturers' literature.

RADIATING FEEDLINE

One of those astute persons wrote Kurt as follows: "It is often pointed out that an antenna does not need to be resonant in order to radiate. This argument is often followed by presenting the design of an antenna tuner that brings the system into resonance. Apparently a resonant system is needed to radiate RF. It would seem then that the total, which is now at resonance, should all be considered part of the antenna. My question is: Now that the antenna tuner and feedline are part of the aerial they too should radiate. Or how does one limit the radiation to the antenna alone?"

Well, Kurt can affirm that an antenna does not have to be resonant to radiate. As a matter of fact, the system does not have to be resonant to radiate. You can connect your transmitter to a feedline and the feedline to an antenna that is not resonant and you will get out. You won't be able to put full power from the transmitter into the feedline because of the mismatch. And the antenna won't take all the power from the feedline because of the mismatch there.

When you use a tuner you give the transmitter a good match and it puts out full power. At the other end of the feedline the antenna takes all that power. The system is resonant but only the antenna radiates. Why is that? For one thing the tuner is in a metal box that, if properly designed, does not allow any significant amount of RF to get out except through the connector to the feedline. If the feedline is coaxial cable it cannot radiate because the RF current is totally inside its shield. There is current on the inside of the shield but it penetrates only a little way into the shield (skin effect) and does not appear on the outside of the shield where it could radiate.

If the transmission line is "ladder line" it does not radiate either. There are equal but opposite polarity currents in the two wires so the fields around them cancel and there is no radiation.

The coaxial cable has one problem you have to watch out for. At the antenna end of the cable the center conductor goes to one side of the antenna. The shield goes to the other. But right there, as the current from the inside of the shield comes out, it also is connected to the outside of the shield. Some of the current may flow down the outside of the shield instead of going to the antenna. To prevent this you can put some ferrite beads over the cable. These present a higher impedance to the current than the antenna does so naturally the current takes the path of least resistance and flows into the antenna. A balun transformer can be used instead and does the same thing.

Now we come to the antenna. It is high and in the clear with nothing to prevent it from radiating. So all the power from the transmitter is radiated from it. That's what we want.

E-H AGAIN

Not long ago Krusty Olde Kurt read the information on the www.e-hantenna.com website. Then he wrote a column highly critical of it. In particular he stated that the theory given for the operation of this antenna was completely wrong.

Kurt received two long letters in response; one applauding him and the other highly critical. Both were printed in Worldradio's "Letters to the Editor". There is no point Kurt's commenting on the favorable letter since the reader is obviously a person of discernment and wisdom. After all, he agrees with Kurt.

The other reader decided that Kurt must not be a licensed amateur operator and has probably never built any antennas in the last 70 years. Well Kurt must admit that he has been building antennas only for the past 65 years. That is how long he has been a licensed amateur. He has designed and built antennas that are in use in amateur and commercial radio stations all over the world.

The reader complained that the example Kurt gave of the E-H broadcast band test at WKQV-AM did not tell the reference antenna. Well, the reference antenna was WKQV's standard broadcast antenna. The tests showed that "the E-H antenna is not an efficient radiator."

Krusty Olde Kurt believes that there are certain fixed laws of nature that cannot be broken. One is Ohm's law. It always works and when a junior tech brings results that do not conform to Ohm's law, Kurt sends him back to rerun the test. Another law is the law of Conservation of Energy. Bring Kurt your perpetual motion machine and he will insist on a demonstration. Then we have Ampere's Law that says both conduction current (current through a wire) and displacement current (current "through" a capacitor) produce magnetic fields. The theory of the E-H antenna violates this law. So Kurt says the E-H theory is baloney.

Do the E-H antennas work? Certainly they do. So does Kurt's shopping cart antenna. A lot has been written about the E-H antenna, many have been built, but Kurt has yet to see a verified field strength measurement proving the claims. What's holding that up?

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DANGER!

The scaremongers are here again. This time in the flowing robes of a pair of English college professors. They have learned that ferrite beads placed over a cable will absorb RF and prevent it from flowing down the cable. Kurt has talked about this many times and recommends that beads be used to keep RF from flowing down your antenna's coaxial cable feedline. Works fine all the time.

The professors have many people all worked up about the RF flowing down the microphone cable of "hands-free" cellphone cables. They say that the ferrites stop the radio waves travelling up the wire and into the head. Of course radio waves don't travel up the wire and into the head. If there are any radio waves on the cable they will act just like part of the antenna and radiate into space. They don't travel down the wire and into the head. Pure bunk.

And how dangerous are these waves anyhow? The strongest field comes directly from the antenna. How many people have you seen with their cellphone practically glued to their head as they walk down the street talking? How many cell phone users are there? Millions. How many have become ill from using cell phones? Zero.

If the antenna radiation is not harmful then how harmful is the tiny bit that might be on the microphone cable? The whole thing is ridiculous. The professors admit that "There is no evidence yet that mobile phones are harmful to health." Then they add. "But people have not been using them long enough to be sure."

Krusty Olde Kurt is sure. There is no known mechanism whereby radio waves can harm the body with just one exception: A strong enough RF field can heat the fluids in the body, even boil them, and thus be dangerous. This effect is known and has been measured. The required field strength is orders of magnitude greater than that of cell phones. Kurt has spent years working all day in the shadow of the transmitter towers of high power broadcast stations. The field intensities were far greater than that of cell phones; actually a lot higher than now permitted by F.C.C. exposure limits. And here sits Olde Olde Kurt in perfect health except for some wear and tear that needs patching from time to time.

Don't waste your money putting ferrite beads on your cellphone.

TRAP CAPACITORS

A reader writes: "A fellow ham and I are into building traps for a dipole. We find no information in the Handbook or the Antenna Book that tells us how to figure what the voltage rating of the capacitors should be. What voltage rating should they be if the transceiver is a 100-watt rig? If one runs 1500 watts? The ARRL gave me no answer except that this was a complicated electrical engineering problem."

Well, the ARRL is correct. An exact figure is hard to come by and requires information that is not generally available. To start with, don't forget that the voltage rating you see in the capacitor catalog is for DC. RF is different. As for the silver mica capacitors you plan to use here is some wisdom about mica capacitors in the Handbook:

“High working voltages are possible but they must be severely derated as the operating frequency increases”.

In other words, the actual voltage rating of the capacitors will vary from band to band. They are a lot less for your RF than for DC. And you will not find information in most catalogs that allows you to calculate the derating to use.

Also knowing the voltage rating is not enough. At RF there will be current flowing through the capacitor so you must know the current rating. This is usually not given except for “transmitting” capacitors. Vacuum capacitors and tubular ceramic “doorknob capacitors” are typical of these. They are rated for current. Micas usually are not. Kurt has had micas explode at high currents and does not recommend them for traps.

To give you an idea of the currents involved you can calculate from Ohm’s law where the current is equal to the square root of power/resistance. At the center of a 75-ohm dipole this gives 1.15 amperes at 100 watts and 4.5 amperes at 1500 watts. Some of this will be flowing through your trap capacitors depending on the band in use.

The Antenna Book describes traps made of doorknob capacitors and commercial coil stock. This is from the article by W2CYK/W2LH in October 1956 QST. These are efficient high Q traps. When the article was written you could get these components at your local amateur radio store. Nowadays they are difficult to find.

A simple way to make inexpensive traps uses coaxial cable wound on a PVC tube. The cable serves as both capacitor and inductor. It was described by W3JIP in May 1981 QST. N4UU gave complete design curves for these in his December 1984 QST article.

A different and improved coaxial cable trap design by W8NX appeared in July 1996 QST. Using RG-59 coax, the traps can be used at full 1500-watt power levels.

Some of these articles and others on trap construction are available on the web at www.arrl.org/tis/info/Trapped.html. One design uses silver mica capacitors and iron powder toroid inductors. It is for QRP 5-watt use but has been tested at 100 watts. Kurt advises you not to try to run silver micas at 100 watts. For QRP they are OK.

Kurt has an old triband beam. The inductors are wound on a plastic form with a hole in the center to accept the ¾” aluminum element tubing. The tubing is in two pieces that do not quite meet inside the coil forms. So the coils can be put in series with the element portions. There is a 2” diameter aluminum sleeve covering the coils that is connected to the midpoint of the two coils. This is part of the capacitor. It is about 12 inches long. This requires a special coil form with the center hole and raised ends to hold the 2-inch tubing. So it is not practical for the average home constructor.

But it does have one feature worth remembering: The coil is wound of heavy (#10) aluminum wire. Why aluminum? So when it is connected to the aluminum element tubing there is no galvanic corrosion. Keep that in mind.

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SWR CHANGE

A reader asks: “I understand the antenna impedance repeats every electrical half-wave along a transmission line. Can you explain why the SWR seems to change along a transmission line?”

To start with, have you ever wondered why the antenna impedance repeats every electrical half wave? Here’s why: The power coming from the transmitter is an electromagnetic wave that travels down the transmission line from the transmitter to the antenna. It is one electrical wavelength long. That is, its voltage goes from zero to a positive peak, to zero, to a negative peak and back to zero again in one electrical wavelength of the transmission line. Just like any AC waveform.

When it arrives at the antenna some of the power goes into the antenna but, if the antenna impedance is different from that of the transmission line, some of the power is reflected. This starts another electromagnetic wave but this one goes in the opposite direction from the first one, back toward the transmitter.

At every point along the line the voltages from the two waves combine. When their polarities are the same the voltages add. When they are opposite, they subtract. This causes a “standing wave” on the line. The voltage (and the current) both change with distance down the line. At some places along the line the voltage is maximum and at others it is minimum. The VSWR (voltage standing wave ratio) is the ratio of the maximum to the minimum.

We know from Ohm’s law that the impedance is equal to the voltage divided by the current. Since both change along the line as the voltage and current of the standing wave change, the impedance is different at each point along the line. That’s why, if your tuner won’t tune up on a certain band, you can change the line length at get it to work. You have found a new impedance that your tuner will handle.

You might expect this standing wave to be one wavelength long so any given impedance would repeat every wavelength. But the standing wave isn’t one wavelength long. It is a half-wavelength long. Why is that? Well, one of the waves that causes it is going forward and the other backward. So they pass one another in just a half wavelength. It’s just like two cars, each going 50 mph that are going in opposite directions. They come together at 100 mph. Or twice as fast as if one were standing still.

So now you see that the antenna impedance repeats every half wave down the line. Also you can see that the voltage peaks and the voltage minimums also repeat every half-wave down the line. Since the SWR equals the peak divided by the minimum it does NOT change along the line.

There is an exception to this rule: If there are losses in the line then the voltage peaks of the transmitter wave will get smaller as they go toward the antenna. And the voltage peaks of the reflected wave will get smaller as they travel toward the transmitter. This means that the SWR WILL change along the line. It will be the same as before at the antenna but lower near the transmitter. (Right at the transmitter the transmit voltage will be the same as before but the reflected wave will be smaller because of the losses in the line). Thus the ratio, or VSWR will be smaller.

So a really poor lossy old coax line will give you a better SWR reading at the transmitter than what actually exists at the antenna. If the line is lossy enough you'll read 1:1 at the transmitter no matter what the antenna SWR might be

There is one other cause of SWR change as line length changes. That is, connecting coaxial cable (an unbalanced line) to a balanced antenna. The current on the center conductor goes to one side of the antenna. The current on the inside of the shield goes to the other side of the antenna. But it also can go down the outside of the shield. The amount going down the outside of the shield depends on the antenna impedance and the shield impedance. The shield impedance depends on the length of the cable. As the length changes the impedance changes very much like we described above. The cable sees the parallel impedance of the antenna and the shield. If this changes the SWR changes. The cure here is to use a balun.

So if you've followed Krusty Olde Kurt's explanation you see that if you have low loss cable and a balun on the antenna you should never see a change in SWR with line length. If you see a change you know what to do about it.

LOOP

A reader wants to build a full wave horizontal loop. Such a loop usually is built in a square shape with ¼ wavelength sides. He would like to reduce the size by making the sides 1/8 wavelength but having two turns so as to keep the wire length the same.

Yes, you can do that but the antenna will not act the same. You've probably seen small loops with multiple turns of wire. A "small loop" has a diameter of a tenth of a wavelength or less. Changing the size and adding turns to make it resonant does not change the pattern, although it does change the radiation resistance. Maximum radiation is in the plane of the loop and there are sharp nulls at right angles to the loop plane.

But a full wave loop has minimum radiation in the loop plane and maximum signal at right angles to it. So if you mount it horizontally it is a "cloud burner" that is very useful for short-range contacts, giving really good local coverage.

If you cut this down to half size you have a "half-wave" loop with a different pattern. It has radiation in all directions, strongest opposite the feed point but still pretty much omni-directional. This may or may not be an advantage depending on what you want from the antenna. You can use two turns on the loop to get a better feed-point impedance.

MORE BALONEY

Here's a letter to Krusty Olde Kurt: "I recently became interested in a Log Periodic Antenna by Tennadyne, however in their antenna comparisons article they state that any 20m antenna having a gain of 5.0 dBd and a radiation resistance of 15 ohms will have an efficiency of about 83.3%, thus lowering the real world gain to 4.2 dB. The Log Periodic has a radiation resistance of about 200 ohms, thus it is more efficient (99.2%) than the above mentioned 20m antenna."

"I think that I read somewhere that the radiation resistance of an antenna has no bearing on the efficiency, and that two different antennas with different radiation resistances could have the same efficiency. I guess that the antenna matching system might have some loss, but I have never considered a Gamma or Omega to have much loss. When I mentioned this to Tennadyne, their guru said I was nuts. Let's have some clarification on the efficiency of beam antennas as a function of radiation resistance."

The only nut in this story is the Tennadyne guru. He is wrong, wrong, wrong. The relationship between radiation resistance and efficiency is very simple. The efficiency is the radiation resistance divided by the sum of the radiation resistance and the loss resistance. If two different antennas have the same loss resistance but different radiation resistances then the antenna with the higher radiation resistance will have higher efficiency. This difference may be very small if the losses are small. On the other hand, if you have an antenna with high radiation resistance and high losses it may be less efficient than one with lower radiation resistance and low losses. You are absolutely right in saying that two antennas with different radiation resistances may have the same efficiencies. It all depends on the antenna's loss resistance.

Let's take a look at some of their figures. They claim 99.2% efficiency for their Log Periodic. If it has 200 ohms radiation resistance then, using the simple formula above, its loss resistance is 1.6 ohms. They say that the 20m antenna with 15 ohms radiation resistance has an efficiency of 83.3%. If that were so its loss resistance would be 3.0 ohms. And where did they find the 3.0 ohms loss resistance? They don't say. And why does the 3 element beam have greater loss than a 10 element Log Periodic? Doesn't make sense to Kurt.

It's a lot more likely that the beam has less loss than the Log Periodic. Suppose for the moment that it was the same (1.6 ohms). The efficiency would be 90.4%. Olde Kurt suspects that the loss is less than that. He is just now putting together one of Worldradio's 20 meter 3-element beams. The high current center portion of the driven element is 1" tubing. Les Moxon in his great book *HF Antennas for All Locations* tells us that the loss resistance of a half-wave of ½" aluminum tubing is about 3/10 ohm. Kurt's beam has larger tubing with less loss but let us say that there are additional losses in the parasitic elements and we'll settle for overall 3/10 ohm loss. Now what is the efficiency? 98%. This is much more likely to be correct than the figure given by Tennadyne. Of course they are trying to sell their antenna and don't want you to buy the 3 element beam. Unfortunately they are less than honest in their sales message, first by telling you that high radiation resistance antennas are always more efficient than low radiation resistance ones and, secondly, by quoting fanciful loss resistance figures for the comparison beam.

Let's look a little further at the Worldradio 20 meter 3-element beam. Kurt has shown that its efficiency is 98%. Now let's look at an ordinary wire dipole. A half wave of #12 copper wire has about 1.5 ohms loss at 20 meters. With 73 ohms radiation resistance the wire dipole efficiency is 98%, the same as the 20 meter beam with its aluminum pipe elements. Kurt wants you to notice that right here we have a high (73 ohm) radiation resistance antenna and a low (15 ohm) radiation resistance antenna. And their efficiencies are exactly the same. So much for Tennadyne's expert's opinion.

WHAT IS IT?

The Tennadyne antennas are Log Periodic Dipole Arrays (LPDA). And what is that? According to the textbooks the Log Periodic part tells you that the structure repeats periodically with the logarithm of the frequency. In Kurt's plain English: Each element is longer than the one before it and also the spacing gets larger as the elements get longer. Each element is a dipole and there are a number of them so it is an "array".

On any one frequency there is one element that is close to being a half wave dipole. This takes the place of the usual Yagi beam's driven element. Next to it is a shorter element that acts as a director and on the other side is a longer element that acts as a reflector. This is the active antenna for this frequency. The other elements mostly just sit there. But as the frequency changes the radiation moves to other elements that are of the proper length for the new frequency.

The beauty of this arrangement is that the LPDA works on any frequency within its range. Tennadyne's T10 model, for example, covers 13-33 MHz and so will work on the 10, 12, 15, 17 and 20 meter bands (and anywhere in between the bands). And if your rig will work up to 2:1 SWR you don't need a tuner at all.

Kurt likes the idea of a wide-band antenna for long term stability. The competitor to the LPDA is the well-known tribander. This is a narrow-band antenna with sharp resonances in each of the three bands. The traps have to hold to close tolerances. For example, on 20 meters the resonant frequency has to be within 100 KHz or so. At 14 MHz this means accuracy to 7/10 percent. This is tough to hold long term out in the weather. On the other hand, the aluminum tubing of the LPDA is not likely to change in length over time.

Palomar Engineers TUBE™ Feed Line Chokes with grounding stud

TUBE feed line chokes are used to suppress common mode current carried on the outside of the coax braid which is often responsible for receiver noise and RFI in the receiver/transmitter. These chokes are very useful for suppressing RFI common mode current at the antenna feed point, at 1/4 wavelength intervals along the coax feed line and also at the entrance to the radio station. They are available with various input and output connectors so as to conveniently connect to standard output connectors already installed on your feed line.

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Check Palomar-Engineers.com for updated product information

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BALUNS – WHAT DO THEY DO?

The most popular, simple, and effective antenna is the horizontal dipole. It is a balanced antenna, that is, the wires on both sides of the center insulator are of equal length. In the early days of radio it was fed with "ladder-line", two wires in parallel spaced by insulators. It too is balanced. Feeding a balanced antenna with a balanced feeder works well. Many amateurs still use this method because of the very low loss of ladder-line.

But back around the time of World War II coaxial cable was introduced. It has certain advantages over ladder-line: It is self-shielded and so does not radiate, it can be routed next to metal objects or even buried in the ground with to affect on is operation. But it has a major defect in that it is unbalanced. Refer to Fig.1.

Here we see the coaxial cable with a center conductor and a surrounding metal shield. The center conductor connects to one side of the dipole and the shield to the other. There are equal currents in the center conductor and in the shield so we expect equal currents in the two sides of the dipole. This looks simple and straightforward but there is a problem.

The problem is caused by something called "skin effect". This tells us that, at radio frequencies, the current in a conductor flows just in the "skin" of the conductor and does not penetrate further into the conductor. This means that the current in the shield of the coaxial cable is confined to the inside of the shield. No current reaches the outside of the shield. Therefore the outside of the shield is just like a third conductor. But this third conductor is connected to one side of the antenna, the same side the inner surface of the shield is connected to.

Now it is possible that not all of the current from the inside of the shield goes into one side of the dipole. Some may go down the outside of the shield. This can cause problems. With less current in the antenna its radiated signal will be less. The radiation from the outside of the shield brings radiation closer to the house and may cause TVI. When the antenna is used for reception there will be pickup from the dipole and from the coax shield. Most man-made noise is vertically polarized so the horizontal dipole discriminates against it. The vertical shield, on the other hand, readily picks up the noise so your antenna becomes noisier and reception is poorer.

BALUN TO THE RESCUE

The current flow down the outside of the shield can be eliminated by use of a balun, a balanced to unbalanced device. There are several ways to make a balun but all of them place high impedance between the antenna and the outer shield. This prevents any current flow down the shield.

Fig. 2(a) shows a very simple balun. The top portion of the coaxial cable is wound into a coil. This does not affect the currents flowing inside the cable but now the outside of the shield is a coil and just like any coil it has inductive reactance that presents an impedance to any flow of RF. At low frequencies it is difficult to get enough inductance to be effective and the coil tends to whip in the wind and is physically unwieldy. But it works.

In Fig. 2(b) we see a transmission-line balun. This a short section of two-conductor transmission line connected between the coax and the antenna. The currents from the center conductor and the inner shield flow through this transmission line. The transmission line is wound into a double coil around a ferrite toroid. The ferrite increases the inductance of the coil so it is high impedance to RF. And since the two windings are tightly coupled the currents in them are equal. So now equal currents flow into the two sides of the antenna and no current reaches the outer surface of the shield.

In Fig. 2(c) we see a ferrite bead balun. Enough ferrite beads are placed over the coax to provide a high impedance to RF. This prevents any current flowing down the shield. This is a simple and effective balun and is in widespread use today following its initial introduction to radio amateurs in an article by Walt Maxwell, W2DU, published in 1982.

MATCHING TRANSFORMERS

The baluns described above are 1:1 baluns, that is, their input and output impedances are the same. They are useful for connecting 50-ohm coaxial cable to dipoles or other antennas that have impedances close to 50 ohms. But some antennas have higher or lower impedance's where an impedance change in the balun can provide a better match.

The transmission line balun adapts itself easily to 4:1, 9:1, 16:1 ratio step-up and step-down transformers. Other ratios are also available. Thus the impedance matching function can be built right into the balun.

AT THE TRANSMITTER

We have been talking about the use of baluns at the antenna feedpoint. Another common use of baluns is at or near the transmitter. Quite often ladder-line is used to feed the antenna. But it is difficult to run the ladder-line into the radio shack. So a short length of coaxial cable is run from the transmitter or antenna tuner out to the ladder-line. At this connection we have the same problem as before - connecting unbalanced coax to a balanced feedline. Again a balun is required.

The ladder-line usually has 450-ohm impedance. And since we are connecting a 50-ohm coax to 450-ohm line it would seem that we need a balun with a 9:1 step-up to get a good match. No, no, no! Remember that the 450-ohm line is connected to a 75-ohm antenna. If the line is a half-wave long we'll see 75 ohms at the bottom, not 450. At other cable lengths we'll see impedances from less than 75 ohms up to much higher than 450 ohms. So we are not at all likely to get a match. It is helpful, however, to have a step-up transformer and a 4:1 step-up is a good compromise value to use.

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CURRENT METER

A reader asks, "Some time ago Kurt referred to the Palomar PCM-1 RF Current Meter. My question is, What does it measure? The magnitude of the current? Palomar says it measures RMS current. The RMS current of what? Since the current that is being measured is transmission line or antenna leg or ground wire currents, the current is going to be complex with a real and imaginary component, or stated otherwise, a vector quantity."

Well, Krusty Olde Kurt can tell you exactly how it works. Unfortunately the Palomar meter is no longer in production. But there are a lot of them out there. And they measure RMS current magnitude. And nothing else, just current. Current, all by itself, is not a vector quantity. There is no such thing as imaginary current. Current is just a flow of electrons. The moving electrons create a magnetic field. The Palomar meter has a magnetic "current sensor" that converts this field to a voltage that is displayed on a panel meter.

The vector business comes in when the current is compared to something else, usually the voltage that produces the current. By looking at them both you can see if they are "in phase", that is they rise and fall together, "out of phase", that is one falls while the other rises, or somewhere in between. Vectors are used to describe the relative phases and the vectors have "real" and "imaginary" components. Meters are made that measure all these things but they are much more complicated and expensive than the Palomar meter.

As the reader guessed, the meter actually measures the peak of the voltage and converts it to a RMS value by assuming that the wave is a sine wave. It will be in error measuring something like a pulsed waveform. But its normal use is with a sine wave RF carrier and it measures that accurately regardless of the wire or cable impedance.

OFF-CENTER FEED

A long time reader of Kurt's column says "Thank you for your fearless debunking of phony gain claims by antenna manufacturers. I have always doubted these claims and had reason to suspect the publishers of being too self-interested to question them." Well, advertising is essential to help pay for the operation and publication of a magazine and this does cause most publishers to overlook many unfounded claims. This self-interest does not apply in any way to Krusty Olde Kurt's *Aerials* or to *Worldradio* itself. The object of the publication is to inform the readers and enhance their amateur experience.

The reader requests comments on off-center fed dipoles, their advantages and disadvantages. He has just built the Compact Off-Center Fed Antenna from Bill Orr's *W6SAI HF Antenna Handbook.* His results on 40, 20 and 15 meter bands were very good.

The original purpose of off-center feed was to get improved matching on several bands. If you feed a dipole at its center it gives about 70 ohms input impedance. On the second harmonic (twice the fundamental frequency) it is up in the thousands of ohms. But if you move the feed point off about .14 wavelength the impedance is near 300 ohms on the fundamental frequency, just about right for 300 ohm open wire line. On the second harmonic the high current low-impedance point is a quarter wave from the center and again the feed point is far enough away from it to give a match to 300 ohm transmission line. If you don’t want to use 300 ohm line then put in a 4:1 balun to drop the impedance down to match coaxial cable. You’ll still want an antenna tuner but the multi-band match is a lot better than with center feed.

Some commercial versions of off-center feed (OCF, Windom, Carolina Windom, etc.) carry claims of vastly improved performance over a normal center-fed dipole. Such claims are not to be believed. It is important to remember that an antenna cannot manufacture power. It can only radiate the power you put into it. It does not matter whether you feed a dipole in the center, off-center, or at the end (Zepp feed) it is still a dipole. The pattern and the gain remain the same. There is no difference in performance among them.

The patterns change on the various harmonics of the fundamental dipole frequency and there is increased gain in some directions. But there also is decreased gain in other directions. Remember, an antenna cannot manufacture power. If more power goes out in one direction then there must be less power going out in some other direction. If someone tells you that their antenna has gain in all directions they are absolutely wrong. There is no such thing.

But sometimes it seems that way. If your new dipole is a lot higher up than the old one it may have better low angle radiation and thus work DX a lot better than your old antenna. It seems to have gain in all directions over the old one. What is actually happening is that it has a lot less gain at high angles and the antenna puts that power down at low angles where it needs it to work DX. You don’t notice that your signal in the next town (the high angle reflected signal) has dropped from S9 to S7. Who cares? But that’s where that gain came from. An antenna cannot manufacture power.

Bill Orr did a lot of work on off-center fed antennas and came up with a design that allows operation on 40, 20, 15 and 10 meters with less than 2:1 SWR. At 3:1 SWR it works on the 18 and 24 MHz bands. The antenna uses a 4:1 balun transformer and coaxial cable to the transmitter. For details and a good discussion of off-center feed and its history see the *W6SAI HF Antenna Handbook*, available from CQ Communications. Bill mentions another good source of information on off-center feed, Frank Witt AI1H’s article in ARRL’s *Antenna Compendium Vol. 3*.

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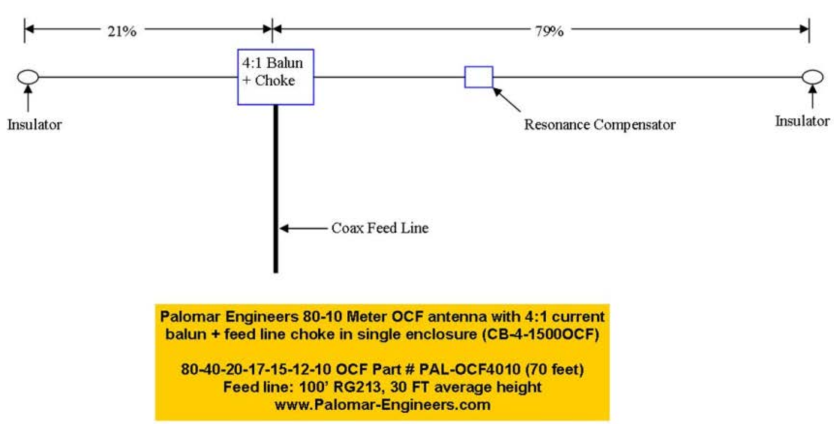

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ANTENNA GARBAGE

In Krusty Olde Kurt's opinion the 75 meter band is a black hole of antenna misinformation. Just listening around this band one finds absolutely outrageous advice being given. Fortunately most of the operators on this band seem to be old foggeys. In a way this is good because it means that the bum dope is not being passed on to new hams. But in case some of them were listening to this tripe Kurt is going to set it straight.

Ham #1 wondered if it would help his signal if he raised his beam 20 feet higher. Ham #2, the wise old guru, told him no. There would be enough loss in the extra cable that it would negate any advantage that the greater height might give.

This, of course, is pure balderdash. A quick look in the ARRL Antenna Book (which should be on your bookshelf - If not, get one right away) shows that 100 feet of RG-8 cable has a loss on 75 meters of .4 dB. That means that an extra 20 feet of cable would have .08 dB loss. Horrible! Put 100 watts in and you would lose almost two whole watts. Do you think the operator listening to you could tell the difference? Not on your Aunt Fanny's rear end.

Do you think he could tell the difference in signal caused by putting the antenna up another 20 ft.? If it is already up at 120 feet, maybe not. But if it is now up at 30 feet, yes at 50 feet you could tell the difference. It is a general rule that the higher your antenna the better. And don't believe everything you hear on 75 meters.

SWR GARBAGE

N9ZGE brought Kurt's attention to an article in POP'COM where he read with disbelief the following: "The day I visited the Loran site the crew was pumping 5000 gallons of salt water in the ground under the operations building and the four towers. They explained that the desert soil is so hot and dry and the water table so far underground that this 'salting' is needed to maintain a good RF 'earth' ground. As the soil dries and the ground becomes less effective, the SWR goes up on the antennas and the reflected power gets back into the building and equipment. The window frames and even the metal garage doors begin to vibrate when this happens. Anything metal becomes a shock hazard. This is much like ham operators who sometimes get "RF in the shack" from poor ground or other antenna/drive line problems

Krusty Olde Kurt finds it hard to know where to start on this balderdash. It is true that saltwater improves ground conductivity. It is used sometimes to lower the resistance of ground-rod grounds. In the Loran case, to get good conductivity out about a half wave you'd need to water a mile out in all directions. 5000 gallons wouldn't cut it in the desert. Much better to put in ground radials as Kurt recommends for ham radio verticals. If you put in enough radials that are long enough the current flows through them and not through the ground. Kurt suspects that that is exactly what the installation engineers did. And, being an old-time ship radio operator, he can smell a sea story when he hears it. Those desert bound Coast Guard technicians, just like ship bound sailors, have plenty of time on their hands to think up good ones.

And without the saltwater the SWR goes up. That makes the reflected power go back into the equipment and the building. Baloney. All it would do is change the loading on the transmitter amplifier and probably reduce the power output. It is not going to cause the building to shake or the windows to rattle.

Kurt has lived in the desert and he can tell you what dries out the ground and causes the buildings to shake and the windows to rattle. It's the desert wind. It blows a lot out there and generates dust storms. The dust that gets between your teeth is lovingly called vitamin K in those parts.

So if you read that story in December PopCom consider it a joke. The engineers that put up Loran did a lot better job than that.

DIPOLE CURRENT

A reader of Krusty Olde Kurt's Kolumn writes: "With a resonant center-fed dipole the RF current is maximum at the feed point, and the voltage is minimum. As you go towards the ends of the dipole the current declines and the voltage increases. At the ends the current is minimum and the voltage maximum. Is there a formula that will give the percentage of RF current that appears at various points along each side of the antenna? If the current is 1 ampere at the feed point what will it be ¼ of the way to the end, ½, etc.?"

Yes, there is a formula. The current follows a sine curve, zero at the ends (zero degrees and 180 degrees) and maximum at the center (90 degrees). It's easier to consider the center as zero degrees and the ends 90 degrees. For this you use a cosine table. The cosine of zero degrees is 1 showing maximum current at the center. The cosine of 90 degrees is zero showing no current at the ends. Halfway in between at 45 degrees the cosine is .707. At ¼ of the way from the center, 22-1/2 degrees, it is .92 and at 67-1/2 degrees, ¾ of the way to the end, it is .38.

So, to answer the question: If you have 1 ampere at the feed point then ¼ the way to the end you'll have .92 ampere. Halfway to the end you have .707 ampere and ¾ of the way to the end you have .38 ampere. At the end, zero or very close to it. Use a cosine table to find the current at any other point.

GROTE REBER

In 1931 Karl Jansky of Bell Labs discovered radio signals coming from outer space. Only one man paid much attention to it - Grote Reber, W9GFZ. He built a radio telescope, a parabolic dish, in his backyard. With it he pioneered radio astronomy. He died in December 2002 at age 90.

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160 METER VERTICAL

A new antenna system for AM broadcast has just been announced by Kintronic Labs (www.Kintronic.com). When Kurt read about it his first reaction was that here was another pie-in-the sky scheme promising full-size results with a miniature antenna. There are enough of those around already.

But after reading and rereading the basic concept it appears that this one is for real even though it seems to get something out of nothing. One minute a vertical has 10 ohms radiation resistance and then, without changing it at all, it suddenly has 40 ohms resistance. How can that be?

Kurt will illustrate the basic principle with a quarter-wave vertical over perfect ground. The vertical consists of a single wire and we are going to put 100 watts into it. We know that the radiation resistance of a quarter-wave vertical is 36 ohms. So, from Ohm's law we calculate the impressed RF voltage as 60 volts and the base current as 1.666 amperes.

Now let us make a cage antenna. We'll have four wires spaced apart but connected together at the bottom. The cage is used to get better bandwidth and, now that we have a "fat" antenna we'll need to shorten it a little to maintain resonance. But it is still has 36 ohms radiation resistance and needs 60 volts of RF to accept 100 watts power.

But take a look at one of the four wires. Since the RF current splits equally among the wires each one has only .42 amperes in it. But it has 60 volts RF impressed on it. So, if Ohm's law is to be believed, the radiation resistance of each individual wire is 60/.42 or 144 ohms. That's the basic principle behind the Kintronics antenna.

The purpose of the design is to make an antenna much shorter than a quarter-wave and they give an example that Kurt has scaled to work on 160 meters. Imagine four vertical wires .044 wavelength long. That's 23 feet, not a very high antenna at all. To make each wire resonant use a top loading wire 105 ft. long. This makes each antenna an "Inverted L" just as described in all the handbooks. Space the vertical wires about 6 feet apart. Now comes the interesting part: A .044 wavelength vertical has a radiation resistance of 3.125 ohms. But, as explained above, each of the four wires has a radiation resistance four times that or 12.5 ohms. Now we connect a quarter-wave of 50 ohm coaxial cable to each wire. This transforms the 12.5 ohms impedance up to 200 ohms. If we connect the 200 ohm ends of all four cables together (parallel) we get 50 ohms, just right to connect our 50 ohm transmitter cable. No tuner needed.

This sounds like some slight-of-hand but it appears to be fundamentally sound. Computer modeling shows 93% efficiency. Tests on a full size antenna at 1680 KHz are being made under an FCC experimental license and results that are being evaluated by an independent engineering firm will soon be available.

Kurt wants you to note that the antenna has the standard 120 radials. This contributes to the good efficiency. If you put one in your backyard you are not likely to do quite as well or get the same impedances. The antenna has great advantages for AM broadcasters: The short towers don't need lighting and it will be easier to get building permission in urban areas and it has adequate bandwidth for high fidelity transmission even though short. The advantages for amateur use may not be worth all the complexity but that's up to the individual.

CCD ANTENNA

A reader asks: "I wonder if you would be so kind as to hold forth a bit about these Controlled-Current-Distribution antennas. Do they really radiate better with more gain than a dipole? If they are so 'hot' why don't we see more of them around?

The basic idea of CCD is this: A dipole can be shortened but still be made resonant by adding inductors in series with the wire. It is also possible to make the dipole longer but still be resonant by adding capacitors in series with the wire. The shortened antenna with inductors will have lower radiation resistance and lower bandwidth. The lengthened antenna will have higher radiation resistance and higher bandwidth.

One version of the CCD is a full wavelength long and has capacitors in series strung along each side of the feed point. The capacitor sizes are such that the antenna is resonant. The wire is split into 48 equal sections with a capacitor between each one. This is not easy to build.

Does it work better than a dipole? Not really. Is it more efficient than a dipole? Not really. You have to remember than an antenna cannot make power. All it can do is radiate the power you put into it. A dipole is about 98% efficient, more or less, depending on the size wire or tubing you use to make it. No antenna can be more than 100% efficient so, no matter how good the CCD might be, it's not going to be enough more efficient than a dipole to make any discernible difference.

The CCD does have gain over a dipole. KJ6GR using MININEC found the gain to be 0.9 dBd. A full wave wire, the same length as the CCD, shows a gain of 1.3 dBd. There is no advantage to the CCD here.

The impedance at the CCD's feed point is about 300 ohms. That's a lot easier to match than the several thousand ohms at the center of a full wave antenna. Of course, a half wave dipole at 70 ohms matches coaxial cable better than either of them.

The big advantage of the CCD, its proponents argue, is that the current through the antenna is nearly constant all the way out to the ends. This is reputed to have some radiation advantage that is not apparent to Kurt. The fact is that KJ6GR's analysis shows that the current distribution is not constant but follows the same curve as for a dipole. See ARRL's *Antenna Compendium Vol. 3* for his article.

Would Kurt build a CCD? No way, Jose! Far too difficult to construct for no apparent improvement.

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OVER AND OVER

Wrong concepts appear in print and on the airwaves. Kurt and other writers explain that they are wrong and publicize the correct explanation. All seems well with the world but then up pops the wrong concept again. This happens over and over.

The most recent of these appeared in the February 2003 edition of the *Newington Times* (also known as *QST).* Here Kurt read to his dismay that "The name 'antenna tuner' is something of a misnomer. It does not tune the antenna at all, but acts as an impedance transformer that provides your transmitting equipment the proper load, usually 50 ohms." This is wrong, wrong, wrong!

Of course the tuner provides your transmitter with the proper load but it also tunes your antenna to resonance. If you look at the tuner from the coax side toward the transmitter it does convert the impedance at the end of the cable down or up to 50 ohms, whichever transformation is required to give you 1:1 SWR on the line from the tuner to your transmitter.

But looking in the other direction it transforms the 50 ohms of the transmitter cable to a different value as seen by the coaxial line going to the antenna. When you change the impedance at the tuner end of the cable from 50 ohms to some other value, what happens at the antenna end of the cable? The impedance seen by the antenna changes from 50 ohms to some other value. And as Walt Maxwell explained in his 1970's *QST* articles and again in his book *Reflections*, the change in impedance is exactly that needed to bring the antenna to resonance. So your antenna tuner actually does tune your antenna. Remember, Kurt told you so.

For those diehards who still do not believe, Krusty Olde Kurt has made up a simple example. We have this 80 meter dipole resonant at 3750 KHz. On this frequency it looks like 75 ohms resistive. But we are going to operate on 3600 KHz. The antenna is not resonant here and looks like 72 ohms with 150 ohms of capacitive reactance. To make things easy we'll use one wavelength of 50 ohm coaxial cable to go in to the antenna tuner.

Since a full wave cable repeats what it sees at its input end, we'll see 72 ohms resistance and 150 ohms capacitive reactance at the tuner end of the cable. The tuner has to do two things: First it supplies 150 ohms of inductive reactance to the cable. This cancels the capacitive reactance and leaves 72 ohm resistive. By transformer action it converts this to 50 ohms resistive for the transmitter.

The result of this is that on the transmitter side of the tuner we see 50 ohms resistive. On the antenna side of the tuner the coaxial cable sees 72 ohms resistive and 150 ohms inductive. Remember that a full wave cable repeats what it sees at its input end. So the antenna now sees 72 0hms resistive and 150 ohms inductive. The 72 ohms exactly matches the antenna's resistive component and the 150 ohms inductive cancels the antenna's 150 ohm capacitive reactance. *Thus the tuner has tuned the antenna to resonance*.

If the coaxial cable is not a convenient length, like the full wave in the example, the explanation gets more complicated. The explanation in Maxwell's new book *Reflections II* makes it easy to see for any length of cable. You should have this book in your library if it is not already there. You can get it from *Worldradio*. Kurt hopes that they will send one to *QST.* Their editor could use it.

E-H ANTENNA

Awhile back Krusty Olde Kurt reviewed the E-H antenna. This is a very small antenna reputed to be efficient and with good bandwidth. Kurt said that the theory behind it is a bunch of baloney.

Kurt received a letter from W5QJR, the inventor of the concept. He states that "The United States patent office as well as foreign patent offices have awarded a patent on the EH Antenna concept and Hams all over the world are singing its praises. Noted Physicists agree this is the most important antenna enhancement in the last 120 years. Kurt should hide in shame for trying to debunk a new concept that can be a major benefit to every Ham.

Kurt is unmoved. The concept is baloney. Why is Kurt so unwilling to believe?

1) Patents are granted if the concept is new. But, unless you are trying to patent a perpetual motion machine, you don't have to prove that it works. Remember, not long ago Kurt reported on a patented antenna only one foot long that achieved the small size by transmitting through hyperspace. The fact that hyperspace exists only in science fiction stories did not stop the issuance of a patent.
2) None of the physicists that Olde Kurt knows agree that it works.
3) Broadcast band tests at WKQV showed that the E-H antenna was not an efficient radiator.
4) The theory of the E-H antenna violates Ampere's law (current through a capacitor produces a magnetic field just like current through a wire).
5) No verified field strength measurements have been revealed.

Kurt believes that field strength measurements are the proof of the pudding. What's holding them up?

BALUN BANDWIDTH

A reader asks if his high power current balun will block frequencies above 29.5 MHz. He uses the HF antenna to listen on 6 meters and to FM broadcast. The answer is that if it is a balun made of ferrite beads placed over the cable then it will not affect reception on any frequency. This type of balun does not affect the signals going through the coax. It gets its balun action just by preventing RF from going down the outside of the shield.

Other baluns are ordinary transformers or, better, transmission line transformers (a transmission line wound on a ferrite core). These will attenuate signals outside their design bandwidths.

So if you want to use the antenna to listen outside the HF bands it is best to use the ferrite bead type balun.

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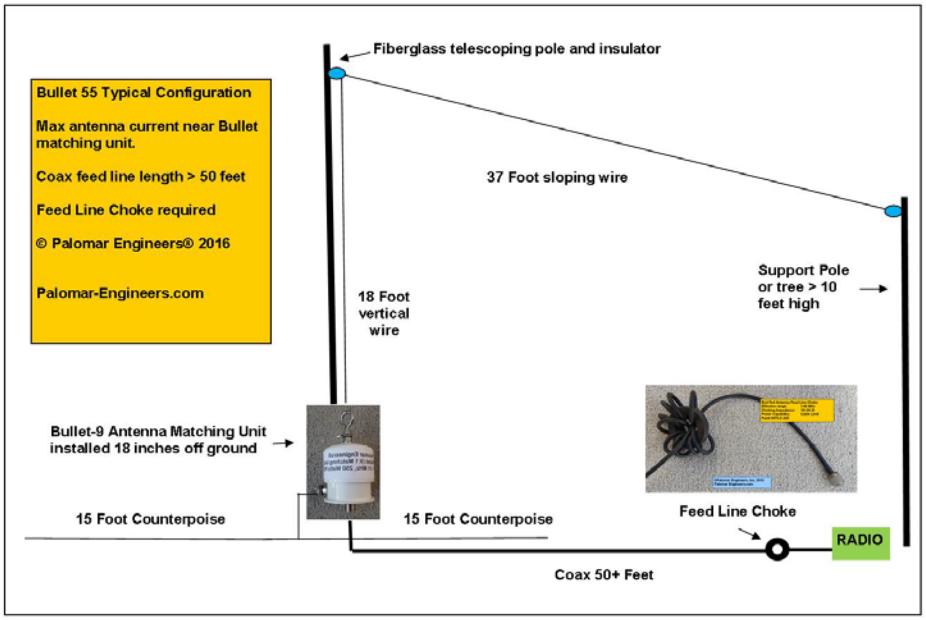
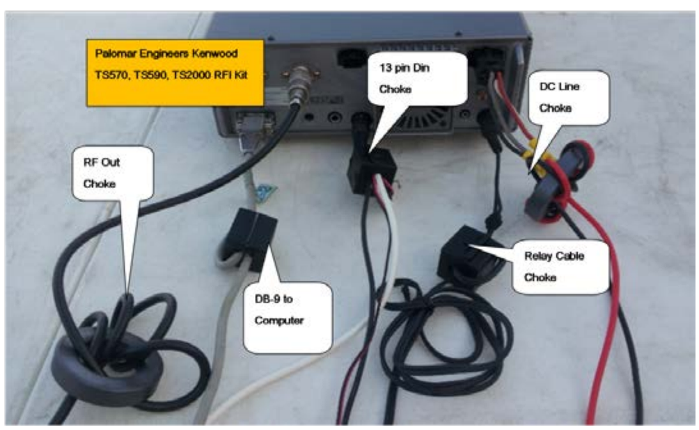
Palomar Engineers BULLET™ End Fed Antenna System



For best results raise the Bullet matching unit as high as possible (use a tree or vertical support) and then extend the antenna wire horizontally or as an "L" (horizontal with vertical end drop).The antenna may also be deployed as a sloper with the Bullet matching unit at the top (best) with the wire sloping toward the ground (with the end high enough to avoid contact by humans or animals), or at the bottom of the sloper with the antenna wire rising to a higher point

Palomar Engineers HF Base RFI Kit for Transceivers (# RFI-HF-BASE)



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THE RAT TAIL ANTENNA

K6ZWB wrote to Krusty Olde Kurt: “I’ve just read an antenna booster review in The February 2003 *CQ* magazine that just seems too good to believe.”

You’ll find this in Karl Thurber’s (W8FX) *CQ* column. It’s called the Rat Tail Antenna Booster and it is made up there in beautiful Victoria, British Columbia. There is a little piece of Velcro that attaches to your handheld radio. It has a drawing of a rat on it with a red “eye” that lights up when properly adjusted. Hanging from it is the “tail”, an insulated wire about 20” long. You just affix the Velcro to the radio, move it around a bit until the rat’s eye lights up the brightest and it is set to go. The manufacturer says it increases your signal 9 to 12 dB.

Does it really work? Kurt thinks so although he hasn’t actually had one to try. How does it work? Well, look at your little handheld. It probably has that stubby little antenna about six inches long. It functions as a quarter wave vertical. Of course a quarter-wave antenna on 2 meters would be 20” long, so the stubby obviously has inductive loading to make it resonant.

Short antennas like this are inefficient unless they have a good ground system. What is the ground system for your handheld? Just the case and inner works of the rig. Plus your body which is capacitively coupled through the rig’s outer finish. Kind of a so-so ground system. The antenna efficiency probably is not too great.

The Rat Tail adds a quarter wave element to the rig’s ground. This gives you a half-wave vertical that doesn’t need a ground to work. Thus the efficiency should be a lot better and the signal will be concentrated lower to the horizontal putting the power where you need it. The manufacturer may be a bit optimistic as to the gain but Kurt is willing to believe that it provides a worthwhile amount.

You could get the same effect by adding the proper length of wire to your rig and then making sure it had current through it. But the Rat Tail has the indicator light built-in, and the handy Velcro so you easily can hook it up and take it off. Not bad for $24.95. You can see more at www.RatTailAntenna.com.

STEALTH ANTENNAS

One way to make a “Stealth Antenna” to get around deed restrictions or just to keep your neighbors from knowing that you are a ham operator is to make the antenna invisible by using tiny wire.

W0NQ writes along these lines: “Because I trust you to disclose the truth as you see it, I seek your help in answering the following practical question, which has often troubled me. Through calculation or experience, can you cite the range of theoretical efficiencies of half-wave antennas made with AWG 22 copper wire, for example, as compared with those made with AWG 12 copper wire, for each of the several HF bands?”

A computer program could give exact answers to the questions. Kurt doesn’t have one like that. Not to worry! Nothing more than a look at the wire tables in the Handbook and a few simple calculations give answers good enough for amateur radio purposes.

Let's look at a 40 meter dipole. The RF resistance of #12 wire of that length (66 feet) is about 2 ohms. The loss due to that resistance is about .1 dB. If you make the dipole from #22 wire the resistance goes up to about 7.5 ohms and the loss to about .5 dB. These losses are not worth worrying about and either size wire will take full legal power.

Unfortunately, neither wire is invisible. You have to go smaller. To see just what size to use Kurt is going to go by the practical experience of W6RVQ almost a half century ago (*QST* February 1965). He first tried #36 enameled wire. "It simply cannot be seen at distances greater than 15 feet under normal conditions, even by someone with 20/20 vision. It also breaks very easily. The elements didn't last very long."

Next he tried #28. "Perfect results. The elements stay up. It seems to be invisible at distances greater than 25 feet." Kurt's calculations show the wire RF resistance to be about 13 ohms and the loss about .7 dB. It should handle transceiver power without difficulty. If you plan to run the full gallon and a half Kurt suggests you run a power test.

It appears to Krusty Olde Kurt that you could operate on any of the HF bands with #28 wire dipoles. His calculations were for 40 meters and they are just rough calculations. The RF resistance rises with frequency but the dipole length gets shorter. So the efficiency won't be a lot different on the other bands.

W6RVQ had some good tips: "The wire comes with either of two colors of insulation: clear so that the wire is actually a bright copper, and dark mahogany. The lighter colored wire is good for use against a sky background and the darker wire against a roof background. I've tried dipoles, inverted Vs, and phased arrays. All of those antennas were supported at the feed point, since the elements will not carry the weight of the feed line." Kurt also has seen magnet wire with green insulation. This should be good against a foliage background.

MORE TIPS

W6ZMZ (February 1949 *QST*) used #40 wire which Kurt does not recommend. But he had some useful advice: "Handle the wire on a reel and avoid kinks. Forget masts, towers, rope and cable; think of slender sticks, small string and coarse thread. Glass headed push pins will serve for knob insulators. Light rubber bands are excellent strain insulators. Short Plexiglas rod insulators are nearly invisible but rubber bands should be used also, as jerk insurance."

Of course the recommended #28 is a lot stronger than W6ZMZ's #40 but these same principles still apply.

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SWR

A reader asked Krusty Olde Kurt for the exact definition of SWR. SWR is the Standing Wave Ratio which is the ratio of the maximum voltage to the minimum voltage on the transmission line. To be academically precise this is VSWR, the Voltage Standing Wave Ratio. There is also such a thing as the Current Standing Wave Ratio which is exactly equal to the VSWR. So, in true American simplification, we just call them SWR. The purists now can't complain that Kurt didn't explain it fully.

What is the Standing Wave and what causes it? Imagine the voltage wave sent out from your transmitter into the transmission line. It is a string of sine waves at the transmitter frequency that moves down the line from transmitter to the antenna. Since it is always moving down the line it is called a Traveling Wave. If the antenna is a perfect match to the line then the wave goes out the far end of the line into the antenna and is radiated. There is no Standing Wave.

But if the antenna does not match the line some of the wave is reflected to form a new backward moving wave. So now we have two traveling waves, the big one from the transmitter moving toward the antenna and a smaller one moving toward the transmitter. Unless the antenna is a dead short or completely open in which case the whole wave is reflected and the two traveling waves are equal.

As these waves pass one another there is some place along the line where their peaks pass at the same time. At this place on the line we have the maximum voltage because their voltages add. A half wavelength away the minimum voltages of the two pass at the same time. At this place on the line we have the minimum line voltage.

The maximum voltage point is always at the same place along the line unless the antenna impedance changes. This is because the distance traveled by the waves from this point to the antenna and back is always the same. So what we get is a waveform that does not move, in other words, a Standing Wave of voltage. It's not a pure sine wave but looks about like one if the reflected wave is small. Also its wavelength is half that of the two traveling waves. This is because things go by twice as fast when one wave is going forward and the other backward. It is the same as two cars going opposite directions on the highway. If they are both going 50 mph then they pass each other at a relative speed of 100 mph.

MEASURING

How do we measure SWR? With an SWR meter, of course. But how does the SWR meter work? It works using a little known property of the reflected wave.

The forward wave from the transmitter has voltage and current in phase. That is, at its voltage maximum the current also is at maximum. But the reflected wave voltage and current are exactly out of phase. That is, when the voltage is maximum, the current is minimum. This happens when the reflected wave just starts at the antenna. Suppose that, instead of an antenna, the load is an open circuit.

The forward wave is completely reflected, so right there we have two waves a forward one and a reflected one of equal size. Their voltages add so the voltage is twice that of the forward wave. This is the beginning of the standing wave. But no current can flow into an open circuit so what happens to the current of the forward wave? To make zero current there the current in the reflected wave must be exactly out of phase with it so that they cancel. This makes it out of phase with its voltage. It continues going back up the line just like that: voltage and current out of phase.

If you have a dead short at the load the forward wave is also totally reflected but it is the voltage that has to change phase because you can't have any voltage at a short circuit. The reflected wave still has voltage and current out of phase.

This out of phase for the reflected wave is true for any load except a perfect 50 ohm resistive. If the antenna has an impedance more than 50 ohms the current changes phase. If it is less than 50 ohms the voltage changes. So the reflected wave always has voltage and current out of phase.

So how does the SWR meter use this information? The usual "directional coupler" type of SWR meter has a toroidal current transformer that measures the line current. It also has a capacitive voltage divider that measures the line voltage.

The voltage and current anywhere along the line is composed of the forward voltage and current and the reflected voltage and current. If you add a sample voltage of the reflected wave and a sample voltage from the reflected current you get zero because they are out of phase. When the meter is built it is adjusted this way. Then any meter reading is of the forward wave only. So now the meter knows the forward power.

If you reverse the meter in the line it changes the current reading 180^{o}. Now the DC voltage representing current in the meter is reversed. The forward voltage and current readings cancel. The reflected readings add and the meter reads reflected power. It's a pain in the rear to reverse the meter each time you want to read reflected power so SWR meters have two opposite sensors and you just switch between them.

Now that you know both forward and reflected power you can find SWR. You start by dividing the forward power reading by the reflected power reading. This is done by setting your forward power reading to full scale on the meter. Then you switch to reflected power. It will read some fraction for the forward power. The actual formula for SWR is more complicated than just dividing but the face of the meter is calibrated to account for the actual formula so you just read the SWR directly. SWR=3 is at half scale and SWR=infinity is full scale (open circuit or dead short).

That was a long and complicated explanation, but Kurt wants to be sure you know how these things work.

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EFFECT OF GROUND

Armond, N6WR, considers 80-meters a sinkhole of wrong information about antennas. He cites a recent conversation he overheard on this band. This poor soul cut a 160 meter dipole to length according to the formula he found in the Handbook. But, when he measured it, the SWR was not 1:1. Instead he got 1.8:1. And when he raised it up to the height he could get with the supports he had, the SWR went up to 2.2:1. Why didn't he get 1:1 he asked. The answers varied but all were wrong. "You measured the length wrong." "You need to change the length of your coax." Etc.

Krusty Olde Kurt can tell you why he got those readings. The antenna impedance changes a lot with its height above ground. You measure the height in wavelengths. On 160-meters the wavelength is 530-feet. Let us suppose that the antenna was about 6-feet above ground when the first measurements were made. This is about 1/100 of wavelength. Over perfect ground the impedance of the antenna would be about zero ohms as shown in the Antenna Book's drawing Radiation resistance of half-wave antennas above ground.

But above real ground the radiation resistance will be more like 90-ohms. This means the SWR on 50 ohm coax would be 1.8:1, exactly what the constructor measured. Why the big difference in resistance between perfect and real ground? The antenna has a strong "inductive field" that remains close to the antenna. This is different from the "radiating field" that sends our signals to distant listeners. As the inductive field gets closer and closer to the ground more and more of its energy is absorbed in the lossy ground. This loss of energy shows up as added resistance in the antenna.

When we raise the antenna higher above ground these losses decrease and the antenna resistance becomes closer the the values expected over perfect ground. At 2/10 of a wavelength above ground, 100-feet on 160 meters we get the 73-ohms we always talk about as the feed-point impedance of a center-fed dipole. SWR would be about 1.5:1. At 100-feet, 0.35-wavelength above ground we would see 100-ohms and 2:1 SWR. Maybe the constructor put his dipole up this high. More likely much lower where we would expect to see close to 1:1 SWR. If so, why did he see 2.2:1 SWR? Without knowing the surroundings Kurt can only guess. Proximity to trees, building and power lines can influence and lower the resistance. Those obstructions can look to be far away but, remembering that the wavelength is 530-feet, the distance in wavelengths may be rather small.

Why does the antenna resistance vary so with height above ground? We've seen that ground losses make a big difference when over real ground. But even over perfect ground the resistance varies from zero to 100 ohms as the height changes. This is due to ground reflected RF power changing the current in the antenna from what it would be in free space and thus changing its resistance. We know from Ohm's law that Power = current squared times resistance. So for a given transmitter power if he current goes up the the resistance goes down. Depending on distance above ground the added current may be in phase and thus increase the antenna current and lower the resistance or be out-of-phase, decrease the antenna current and raise the resistance. . The result of all this is shown graphically in the Antenna Book and is well worth looking at and remembering.

TUNER TUNES YOUR ANTENNA?

John, K8JS, asks: “A multi-band center-fed balanced dipole fed with 50/52 ohm coax has an antenna tuner located at the rig PLUS either

1) A 4:1 balun located st the dipole antenna center feed point

OR

2) A 4:1 balun located near the rig. A short piece of coax between the rig and balun then balanced ladder line from the balun to the cnet of the antenna.”

“Obviously there will be a reactance present at some frequencies in the various bands covered. Will the antenna tuner match the antenna reactances THROUGH the balun? Or will the tuner only “tune out” whatever reactance is present between itself and the coax feedline because the balun does not entirely pass through the antenna reactance back to the tuner? If it does not then the antenna will not accept full power, causing the balun to heat up causing additional RF loss and, depending on power level might possibly destroy the balun?”

To start with Kurt wants to make one thing clear: An antenna does not have to be resonant to accept the full transmitter power. Even if the balun does not “pass through” the antenna reactance to the tuner it will still radiate all the power fed to it. This will be the full transmitter power less power lost in the balun and the transmission line.

The real question here is, if you apply 50 ohms resistance and 100 ohms reactance to one side of a 4:1 balun do you get 200 ohms resistance and 400 ohms reactance on the other side? If you don't is there loss of power in the balun?

A lot depends on the balun and the power level. If you use a 100-watt balun at 500 watts the core may saturate, little power will pass through and there will be big losses. If you use a 500 watt balun at 100 watts it should work fine. That doesn't mean that the exact resistance and reactance expected will be seen on the output side. But it will be close enough to work well and the losses will be minimal.

Any loss in the balun will subtract from the power delivered to the antenna but all the rest of the power, minus feedline loss, will be radiated. To get an idea of balun loss just put full power through it for a few minutes and then see if it is hot. If it gets really hot get yourself a bigger, better balun. ·–·–·

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1:1 or 4:1 BALUN?

Harry, W5PNY writes about the book The Easy Way HF Antenna Systems by WB5IRR (deceased) and published by WorldRadio Books. He states in several places in that book that a really good way to feed multi-band antennas is with a tuner in the shack, a short piece of coax to a 4:1 balun and 450 ohm line to the antenna."

"While I really support the information in that book and an glad to see another attempt to dispel all the misinformation about antennas one gets when talking to most hams, that is one statement that isn't quite on. I think."

"I've found references to this occasionally among the antenna savvy types, but not often. I'm guessing a 1:1 50 ohm balun is a better choice. So except for the 4:1 balun, I agree with what he is saying."

"Why? - I've found if one does full spectrum scans with something like an AIM 4170 at the end of a typical 450 ohm line to a multi-band antenna he will see wide excursions in the impedance – but what is interesting is that they usually have very narrow peaks and wide valleys. This means most of the time the impedance one sees at the end of a 450 ohm line to such antennas is much closer to 50 ohms than to 450 ohms. So, for most frequencies, it seems to me you'd be better off with a 1:1 balun."

"What do you think????"

Kurt has always advised using a 4:1 balun in this setup so he agrees with the book's author. To see why let's look at a 40 meter dipole and it's impedance on other amateur bands. The dipole is high enough above ground so its feed point impedance on 40 meters is 75 ohms. And, to keep things simple, the 450 ohm feeder is a half-wave on 40.

The Antenna Book has a plot of the impedance of a 5-MHz dipole over a large frequency range. Kurt has changed the dipole frequency to 7-MHz and converted the R + jX figures to the actual impedance for the major amateur bands. Then, using the TLW program, he found the impedance at the transmitter end of the 450-ohm transmission line. See the figure. Note: The SWR figures are based on 50 ohm coax.

Frequency (MHz)	Antenna Impedance (Ω)	XMTR End Impedance (Ω)	1:1 Balun (SWR)	4:1 Balun (SWR)
3.5	1000	1000	20	5
7	75	75	1.5	2.6
14	3700	2400	48	12
21	100	100	2	2
28	1900	1500	25	7.5

It is apparent that on the harmonic frequencies the antenna impedance is much higher than on the fundamental (except for 21-Mhz). The transmission line changes the impedance some but it is still high. The SWR on the coaxial cable going to your tuner is mostly a lot higher using a 1:1 balun than for a 4:1 balun. This is why a 4:1 balun is preferred.

The numbers change for other lengths of transmission line but, generally speaking, you will have lower SWR with the 4:1 balun and Kurt recommends it.

RADIATION RESISTANCE

Donald, K4KYV comments on Kurt's recent kolumn Non-Resonant vs. Resonant Antennas. “I wish to point out a slight error in the statement regarding increasing the the length of the antenna, but otherwise the explanation is perfectly correct.” Now, suppose the dipole is too long for the frequency. Now it looks like Fig 1(b), the same radiating resistor as before but with an inductor in series. This inductor's reactance increases rapidly as the antenna is lengthened and can be much more that 70 0hms.

“Actually, the radiating resistor will be different from before. It will not stay exactly the same when the length of the radiator is changed. If only a few feet are added to or subtracted from the antenna length, the difference will be small, but there will still be a difference. If we lengthen or shorten the antenna to a large degree, the effective change in value of the 'resistor' will be large. For example, if the total length of the dipole is shortened from a half-wave to a quarter-wave the radiation resistance will drop from 72 ohms in free space down to about 12 ohms The reactance can still be tuned out as described and the antenna will take a load, but the efficiency will take a drop because resistive losses in the system become a much larger percentage of the total”

K4KYV is absolutely right and has explained it very well. Of course, when we are looking at just one amateur band the change is small. Possibly 2 or 3 ohms change from one end of the band to the other. Meanwhile the reactance may change 200 or 300 ohms. But when you move to another band here is a big difference. Look at the table for the 40-meter dipole. On 80 meters the impedance is shown as 1000 ohms. Kurt simplified this – the actual figures are 1000 ohms reactance and 15 ohms resistance. This is quite a drop from the 75 ohms resistance on 40-meters

This rarely is a problem with dipoles because we usually can make them fairly long in wavelengths and with heavy enough wire to have low loss resistance. But vertical antennas on the low frequency bands are another matter. A thirty foot vertical is nearly a quarter-wave on 40 meters and will have a radiation resistance of about 36 ohms. But that same vertical on 160 meters will have a radiation resistance of about 6 ohms. When you consider that a modest backyard radial system is likely to have more than 15 ohms resistance you can see right away that your antenna's efficiency suffers because of that low radiation resistance. In this case for 100 watts into the antenna you get only 29 watts radiated. And that's for a good installation.

On these bands always try to keep that radiation resistance up by making the vertical as high as you can and then use top loading to make it look even higher. “T” and inverted “L” arrangements are easy ways to do this.

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NON-RESONANT VS. RESONANT ANTENNAS

Let's look at a resonant dipole, Figure 1(a), a too-long non-resonant dipole, Figure 1(b) and a too-short non-resonant dipole, Figure 1(c).

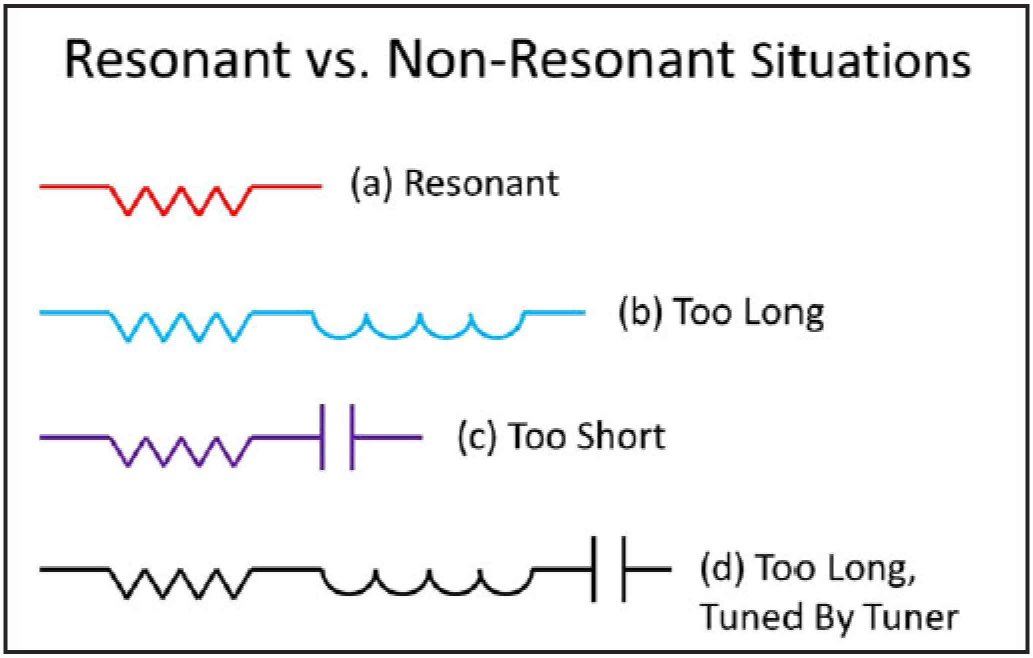

Figure 1.

The resonant antenna looks just like a resistor. If the dipole is a half-wave above ground the resistor is 70 ohms. But it is not an ordinary resistor that turns the current passing through it into heat. This resistor turns the current into electromagnetic waves that radiate outward to distant places and allow us to communicate with one another.

There is a little bit of ordinary resistor in it - the resistance of the wire from which the dipole is made. But we almost always use large enough wire, or even aluminum tubing, to make this resistance very small compared to the radiation resistance. So we can neglect it in our present discussion. The usual dipole is 99 percent efficient or better.

Suppose the dipole is too long for the frequency. Now it looks like Figure 1(b), the same radiating resistor as before but with an inductor in series. This inductor's reactance increases rapidly as the antenna is lengthened and can be much more than 70 ohms. The total series impedance is now higher than 70 ohms. To get the same radiated power – the same current through the resistor as before – we have to apply a higher RF voltage. Our 50 ohm transmitter may not be able to do this but let's suppose we have an RF generator that can do it.

The resistor radiates exactly as before because it carries the same current as before. The inductor produces a magnetic field during one-half of the RF cycle. On the other half-cycle, the field collapses and returns the energy to the circuit. There is no loss, so the efficiency of the too-long antenna is just as good as that of the resonant antenna.

If the antenna is too short for the frequency, then there is a capacitive reactance in series with resistor, Figure 1(c). If we apply enough RF voltage to get the same current through the resistor, the result is the same. Only this time the capacitor charges during a half-cycle of the RF and discharges during the other half-cycle. No power is used and, again, the non-resonant antenna radiates just as well, and with the same efficiency, as a resonant antenna does.

If the inductive or capacitive reactance is too high for our transmitter to drive the antenna, we use a tuner to reduce the reactance to zero. In the case of the too-long antenna of Figure 1(b), the tuner adds an equal capacitive reactance as shown in Figure 1(d). The current in the inductor lags the current in the resistor by 90-degrees. The current in the capacitor leads the resistor current by 90-degrees. So these two currents are 180-degrees apart.

If we make the two reactance equal then the two currents cancel and our transmitter sees just the resistor, it can drive it just as though it was a resonant antenna. The inductor is still there and so is the capacitor that the tuner added. Current flows through both of them but there is no loss in either.

The non-resonant antenna radiates just as well as a resonant antenna!

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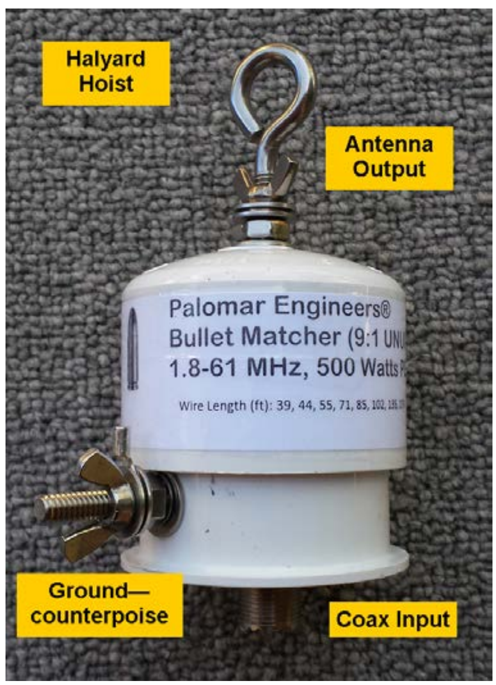
BULLET Antenna Matcher for Non-Resonant End Fed Antennas



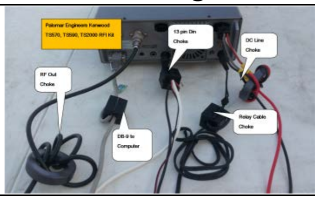
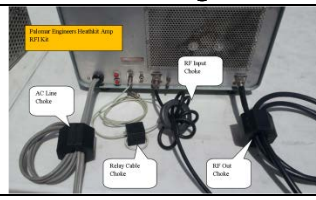
Check Palomar-Engineers.com for updated product information

MY STATION CAUSES RFI – WHAT DO I DO?

All RFI problems have a SOURCE, a PATH, and a VICTIM. You have to identify the source, choke off the path, and protect the victim. In most cases of mobile/home/portable ham radio operation or commercial broadcast, the transmitter is the source, the path is the "receiving" antenna disguised as the AC/DC wiring, phone lines, cable/satellite feeds of the VICTIM, and the VICTIM(s) are electronic devices that amplify the received signal and create the disturbance in the form of sounds, buzzes, non-operation or scrambled video.

RFI Solution Kits

#1: Clean up the SOURCE OF RFI and Choke the PATH

Transceiver RFI KITS Choke RFI into AC/DC lines, Coax, interconnecting lines	Amplifier RFI Kits Choke RFI into AC/DC lines, coax, interconnecting lines	Mobile/Portable RFI Kit Choke RFI into AC/DC lines, coax, interconnecting lines
		

Antenna RFI Kits – feed line chokes configured as baluns (balanced output) or ununs (unbalanced output)

Slip On	Snap On	CUBE™	Super Choker	Tube
				

#2: Protect the VICTIM OF RFI (shack, home, neighbor)

Home Theater System RFI Kit – audio, video, speaker, sub-woofer RFI protection
Computer RFI Kits – laptops, desktops, DSL/Routers, network boxes, CAT5 cables, wireless devices
Alarm System RFI Kit – multi sensor, multi alarms, home automation, dimmer light RFI Kits
Garage Door Opener Kit – AC power and sensor protection
Generic RFI Kit for electronic projects and small RFI problems including LED and garden lighting
AC/DC Power Line Chokes – kitchen, household appliances, Heating/air conditioning, sprinkler systems
Ferrite Snap On's – Mix 31 (1-300 MHz), Mix 61 (200-2000MHz, Mix 77 (100 KHz-50 MHz)

Got a tough RFI problem and need a quick solution? Call RFI Hotline at 760-747-3343 or check out the website at http://Palomar-Engineers.com

MY STATION IS A VICTIM OF RFI – WHAT DO I DO?

CAUSE: RFI, or a high noise level, to ham radio receivers can be caused by broadband signal hash or "birdies" from consumer electronic devices including computers, routers, DSL/cable modems, plasma flat screen TV's, HVAC control circuits, switching power supplies (wall warts), battery chargers, and other low power "transmitters" coupling their RFI into your AC power line, speaker cables and RF cables. Common mode noise can also be picked up on coax feed lines, rotor/antenna control lines and equipment interconnect cables.

#1: Clean up the SOURCE, choke the PATH, protect the VICTIM

Determine the primary interfering frequency of the source and **select a ferrite mix** that is effective at the fundamental interfering frequency. Select a ferrite form (Snap On, Slip On, or toroid ring) with a diameter that will allow one or more turns thru the center. Remember that the choking impedance increases with the SQUARE of the number of turns. If 1 turn = x, 2 turns = 4X, 3 turns = 9X, etc.

Wall Wart Noise Filters	Computer/DSL/Router Noise Suppressors	Appliance Noise filters – AC/DC line chokes
		

Common Mode Coax Noise Filters – neighborhood noise suppression picked up on coax braid

	Suppress Common mode RFI in coax line of transmitter Install at transceiver or amplifier output	CMNF-1 – 500 Watts PEP 1-61 MHz CMNF-2 – 1500 Watts PEP 1-61 MHz CMNF-3 – 5000 Watts PEP 1-61 MHz
	Suppress common mode RFI in coax line to receiver Install at receiver antenna input	CMNF-4 – Receive only, 3-60 MHz CMNF-5 – Receive only, 15-180 MHz CMNF-6 – Receive only, .2-30 MHz

Individual Ferrites – **Toroids**, **Slip On**, **and Snap On** – for 1/8″ wire to 3″ cables available in convenient 10, 25 and 100 packs and combination packs of various mixes and sizes for general RFI troubleshooting.

Check out other Kurt Books including: ***Kurt Strikes Again, Kurt Spills the Beans, Kurt Tells All***