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The Easy Way

It is a basic truism that you can't get something for nothing, but I am not using "easy way" in this context. Rather, I am using "easy way" as the opposite of "hard way"...and as I talk to hams, on the air or in person, I get the feeling that many of us are, indeed, doing it the hard way. A real challenge, though, is getting hams to believe what I am going to say.... and I am going set forth some principles that you must accept, without reservation, before we can develop what follows. Of course, I cannot expect you to accept this "gospel" from just one source, so I begin with qualifying words from several authorities who carry blue- ribbon credentials.

First, to set the tone of this talk, and to pay tribute to one of the great hams (who left us too soon in April, 1980), here is the essential part of an editorial by Jim Fisk, Editor (until his passing) of Ham Radio Magazine:

"In the evening when I'm working down in the shop, I flick on the receiver and tune around the 75 meter phone band. I can invariably find an interesting conversation about the sorry state of the economy, the high cost of fuel, the fine golfing in Florida, or a technical discussion on quads versus yagis. There's always something that starts the old adrenalin flowing. The other night, two characters with two-letter calls were holding forth on the low end of the phone band. The technical topic of the evening was transmission lines and, to hear these guys talk, they were the original experts....when all they really had to offer was a barge full of baloney."

"I don't know where all the feedline myths started, but I suspect it had something to do with the do-it-yourself swr bridges which first became popular back in the early 1950s. Until then, most amateurs didn't even know about standing waves and, if they did, they didn't seem to care. However, swr bridges soon caught on, and it wasn't too long before getting caught with your swr up was synonymous with getting caught with your pants down! Some hams dug into the books, but when they discovered that swr is caused by a mismatched antenna, it only served to reinforce the myth. If a mismatched antenna causes power to be reflected back down the line, they reasoned, this power obviously wasn't radiated by the antenna. Some even suggested that the reflected power got back into the transmitter tank and was dissipated in heat. Others apparently thought that reflected power was lost forever to some great swr heaven in the sky. A few well informed amateurs tried to nip these absurdities in the bud, but it was hopeless.....the disease spread faster than the cure. Transmission lines are too complex to be covered here, but let's bury the myths: First, reflected power is not lost nor does it heat up the tank circuit of your transmitter. Second, if the feedline has low loss, as is in the case on the HF bands, increased loss due to swr is so small that you can forget about it. Since a 10:1 swr on 100 feet of RG8U at 4 Mhz increases loss by less than 1 db, don't worry about the fact that the swr rises about 2:1 at the band edges....the station at the other end won't be able to tell the difference. If your transmitter doesn't like to load into a mismatch greater than 2:1, buy or build yourself an antenna tuner and save yourself a lot of grief by forgetting the swr on the line to the antenna if it's within reasonable limits, say 10:1."

Jim was a great admirer of M. Walter Maxwell, W2U, a ham since 1933, with credentials to the fields of antenna and feedline design. His background includes, for example, building antenna fields for the FCC, on this continent and in Hawaii. Then, in 1949, he joined RCA and, in 1958 became a charter member of RCA's Astro-Electronics Division. From 1960 until his retirement a couple of years ago, he was in charge of the antenna laboratory and test range at the RCA space center in Princeton, New Jersey. More than 50 orbiting spacecraft antenna systems were designed solely by Maxwell, including Echo I and all Tiros-Essa satellites. Walter is also a very "down-to-earth" ham. He is best known to amateurs for a series of articles entitles "Another Look At Reflections", which ran in QST from 1973 through 1976. The first of these was subtitled "Too Low A SWR Can Kill You." In this one, he said: "Judging by what we hear on the air, nearly everyone is looking for a vswr of l:1. Question why and the answer may be, I'm not getting out on this frequency because my swr is 2.5:1.... there's too much power coming back and not enough getting into the antenna ...or, If I feel a line having that much swr, the reflected power flowing back into the amplifier will burn it up......or still, I don't want my feedline to radiate. Any of these answers shows misunderstanding of reflection mechanics, symptomatic of the current state of education on this subject. Rational and creative thinking toward antenna and feedline design practice has been absent for a long time, having been replaced with an unscientific and thought-provoking attitude, as in the days before Copernicus persuaded the multitudes that the universe did not revolve around the earth. This situation originated with the introduction of coaxial transmission lines for amateur use, about the time we got back on the air after World War II, and has gained momentum since swr indicators appeared on the scene, and since the loading capacitor of the Pi-net tank replaced the swinging link as an output coupling control. We are in this state because so much misleading information has been and is still being published concerning behavior of antennas which are not self-resonant, feedline performance in the presence of reflections when mismatched to the antenna and, especially, the meaning and interpretation of swr data. Articles containing explicitly erroneous information and distorted concepts find their way into print, become gospel and continue to be perpetuated with chain letter effectiveness. These gems of intuitive logic include:

1. Always requiring a perfect antenna/feedline match.
2. Evaluating antenna performance or radiation efficiency only on the basis of feedline swr...and lower the better.
3. Pruning a dipole to exact resonance at the single operating frequency and feeding it with an exact multiple of a half wave coax.... no other length will do.
4. Adjust the height. Perhaps just lowering the ends into an inverted vee to make the resistive component equal to the line impedance, or...
5. Subtracting percent reflected power from 100 to determine usable percentage of transmitter output power (nomographs have even been published for this erroneous method)

"As a result of these misdirected concepts, we have been conditioned to avoid any mismatch and reflection like the plague.... one to one all the way! ...Sound exaggerated? Not if the readers' receivers are tuning the same amateur bands as the author's"

"In the current vernacular, one could say that we have a severe swr hang-up! In many instances, from the viewpoint of good engineering, this hang-up is inducing us to concentrate our impedance matching efforts at the wrong end of the transmission line. It is ironic that we should be in this situation, because the amateur is generally quite practical when it comes to following theoretical considerations. In this case, though, we have been following the perfect-match theory down the narrow path because many of the aforementioned articles have misled us to believe that all reflected power is lost, with never an inkling that, properly controlled, reflections can be turned to our advantage in obtaining increased bandwidth, which we are presently throwing away.".... So says Walter Maxwell.

Another accepted Ham antenna expert, Walter H. Anderson, VE3AAZ, writing in HAM RADIO MAGAZINE, says, in part: "A UA9 I worked recently said he was using a Zepp antenna. It occurred to me that at least one generation has passed since the Zepp was, by far, the most popular antenna. We didn't realize it then, but the Zepp's standing wave ratio probably ran as high as 30:1. However, history shows that the Zepp put out a good signal. Thus, it would seem that the Zepp didn't really have the side effects we hear attributed to high swr nowadays.... high plate dissipation, radiation loss and all the rest. I don't suggest we dismantle our beams and go back to Zepps. Rather, I propose to show that transmission line theory, properly understood, is free of the contradictions that arise when discussing swr, reflected power, line losses and other phenomena associated with antennas and feed systems."

Further along, Walter mentioned the transmatch: "It's easy to dispense advice on obtaining low swr, but it's much more difficult to specify cures for same. If you must live with kinky antenna impedances, then you might consider using an antenna tuner. If air-dielectric capacitors and silver-plated inductors are used, power loss from the tuner will be negligible. An antenna tuner will lower the impedance presented to the transmitter to be close to 50 ohms, and the transmitter will be satisfied. Such a tuner also pays dividends on receiving."

Jim Fisk, Walter Maxwell, Walter Anderson...note how the experts agree. And I hope the foregoing will encourage you to have faith in what follows. Here is what I will cover:

1. Antennas of non-resonant length.
2. Line attenuation.
3. The transmatch.
4. The Balun.

We'll combine these four ingredients to produce simple but effective antenna systems.........the EASY WAY.

FIRST, ANTENNAS OF NON-RESONANT LENGTH:

Quit worrying about them. Some 4000 commercial radio broadcast stations (and a few hams) use antennas with non-resonant dimensions. The broadcast station must operate with specified radiation pattern and efficiency; reach the greatest possible number of patrons without causing interference to other broadcast stations. The antenna height required to do such a specific job is seldom a resonant height. Which means that the antenna is invariably non-resonant, but it is generally fed with 50 ohm coax... how do they do that...

That's right, they use a "transmatch". That's what you'll find in that little house at the tower base. Just like any other transmatch, its input looks like 50 ohms to the coax, and its output is adjusted to the complex antenna impedance. The circuit used is generally a "T" or "PI" network, just as in currently available ham tuners.... except that, since the broadcast station uses only a single frequency, the network is "fixed-tuned".

Closer to home, most of us who are mobile on 2 meters use a 5/8 wave whip and find it more effective than a 1/4 wave ship...but the quarter-wave is a resonant length and the 5/8 is not! However, our 50 ohm coax sees a proper load, thanks to matching at the base, so our transmitter happily dumps optimum power into an antenna SYSTEM, which includes a non-resonant antenna that efficiently radiates all the power, delivered to it...Just a couple examples demonstrating why you don't have to worry about antennas of non-resonant length. You just need a resonant antenna SYSTEM, consisting of antenna, feedline and a matching device.

SECOND, LINE ATTENUATION:

If we are going to use a non-resonant antenna, a feedline and a matching device, obviously there will be some standing waves and reflected power to manage. The point here, though, is that on the HF bands it is usually much less of a problem than we think it is. To evaluate this statement, we need four ingredients:

1. The frequency.
2. The type of feedline.
3. The length of the feedline.
4. The feedline attenuation.

To demonstrate how these ingredients are used, let's go back to Jim Fisk. Remember, he said that 100 feet of RG8U, at 4MHZ, feeding an antenna with an swr of 10:1 resulted in less than 1 db more loss, compared to a perfectly matched line. He got this information from two readily available sources:

1. The coax manufacturer's specs showed him that RG8U, at 4 Mhz, feeding a perfectly matched load, will suffer a loss of .3 DB per 100 feet.
2. Using this information, he consulted a graph on page 82 of the ARRL Antenna Book (page 3-12 in the newest edition). This graph shows increased loss with swr, compared with loss into a perfect match.

Jim took the .3 DB, which appears at the bottom of the graph, along the horizontal axis, and projected vertically to intersect the 10:1 swr curve. From this point, he projected left to the vertical axis, where he read "additional loss" of just under 1 DB.

A much more informative chart will give you the above in more comprehensive fashion if you have available the December, 1974 QST, containing Chapter VI of Walter Maxwell's seven-part series, "Another Look At Reflections".... plus, it will properly explain the manner in which "re-reflection" takes place. This phenomenon seems to be one of the difficult things to understand, and believe...but, until you do master it, you will remain puzzled as to why all of that reflected power isn't lost. If you can't find that issue, let me know of your problem and I will be glad to help...it is of the utmost importance.

So far, we have considered only coax...and it is quite important to this discussion that we also cover balanced open-wire line. This category includes 600 ohm bare line, plastic-coated ladder line and 300 ohm twin-lead, all featuring three advantages:

1. Much less loss...as little as 10% of that with coax.
2. Handles much higher voltages without breaking down.
3. Tunes the antenna system over a much broader frequency range.

Let's look at that third advantage. I will use, as an example, an 80 meter dipole, resonant at 3750 kHz (the middle of the band):

If I use coax, a transmatch will allow me to cover all of the 80 meter band, presenting 50 ohms to the transmitter on any frequency from 3500 to 4000 kHz.... but for coax, that's about the limit. If I tried to use this same antenna on 40 meters, it would not be unusual for the 80 meter antenna to present an impedance of 4000 ohms. Using coax, I would find the swr by dividing 50 into 4000, indicating an swr of 80:1! The trans- match could not handle this, nor could the coax, which would be subjected to abnormally high voltages and high attenuation losses...maybe you have found that your transmatch, when using coax, would not tune a particular antenna or frequency...now you can see why...but don't give your transmatch away...that's not the problem. Let's take that same antenna with the 4000 ohm impedance and see what happens with balanced twinlead (say, 450 ohm ladderline): Now, the swr is 4000/450, or less than 9 to 1, which any good transmatch can handle very easily...and, what is even more important attenuation losses are negligible and voltage breakdown is no longer a problem. The result is that you can use your 80 meter dipole, not just for 80 and 40 meters, but on all the frequencies everywhere. Of course, as you go higher in frequency, an 80 meter dipole will become more directional, forming a cloverleaf pattern as you get up to 20 meters and, finally, becoming more directional off the ends of the dipole as you get up to 10 meters but these patterns are not all that clearly defined, and you will be surprised at the DX you can work up there.

Thus far we've talked about (1) not worrying about antennas of non- resonant length and (2) putting line attenuation in perspective, bringing us now to:

THIRD, THE TRANSMATCH:

Before we get into the transmatch proper, let's review that part of basic AC theory, which says that when the internal impedance of the generator is equal to that of the load, maximum power will be transferred from the generator to the load.

You can regard your final amplifier as an AC generator (tube or transistor) which, in order to transfer maximum available power into a load, must see an impedance we call the optimum load impedance (not the same as internal impedance). The network in the output circuit of your transmitter is actually a limited range transmatch, built within the transmitter for the purpose of matching the amplifier to the load.

Actually the PI net will tune the amplifier to other impedances, When working into a feedline that presents something other than 50 ohms, just tune for a plate dip (using low power) and when that dip is as deep as usual, you are matching the rig to the antenna and transferring power to the antenna.... so the PI net serves as a transmatch and, if it cannot match some widely-differing feedline impedance, then the transmatch you use externally is simply extending the range of the transmatch in your rig. Many of the older rigs had all of this included inside, because back there in "BC" (before coax) there were many more antennas with widely-varying impedances for the transmitter to look at (the Zepp, for example). In either case, though all we're trying to do is match the generator to the load...and how does that fit with MYTH #1..."a transmatch just fools the transmitter.

If you were using only the PI net inside the transmitter, to do the matching, would you then say, "the transmitter is just fooling itself?" your rig's high-impedance make input, would you say, "the transformer is just fooling the mike?" In each case we are talking about the same thing: impedance matching.

Generally, the load presented to the transmitter by the feedline is not 50 ohms...nor is it purely resistive. Either, it is a combination of resistance and either inductive or capacitive reactance. Inductive reactive reactance is a "minus J factor". Therefore, when the input impedance of the feedline is not purely 50 ohms of inductive reactance. In the vernacular of feedline mechanics, we would call this "100 plus J50". It is the interface between it and what the transmitter sees when looking at the other end of the transmatch. When each end of the transmatch is matched to what it's connected to, the antenna load is properly matched to the source and maximum power is transferred to the antenna SYSTEM. Of course, when maximum power is transferred out of the amplifier, minimum power remains to be dissipated internally bringing us to MYTH. #2, which is: "Reflected power gets back into the amplifier, overheating the tubes etc.".... NOT SO!...heating is the result of an impedance mismatch, with less than optimum power getting out of the amplifier, and too much power REMAINING IN THE AMPLIFIER to be dissipated as excessive heat...all the amplifier wants is a proper impedance mach. It wouldn't recognize swr or reflected power if you introduced them!

MYTH #3 goes something like this: "but look at all the power I'll lose in that transmatch".... and the fellow who said that probably has a low-pass filter at the output of his rig...a small box packed full of small coils and fixed capacitors which, the manufacturer says, introduces loss of less than 1/4 DB. Well, a transmatch is a larger box, containing one large silver plated coil and two large wide-spaced air-dielectric capacitors no resistors to consume power. Since the actual ohmic resistance in the transmatch is negligible, you lose very little power in that box.

Here's how the transmatch works: Let's continue with that example of "100 plus J50"...and let's use the popular "T" circuit for our transmatch. This circuit consists of two air-variable capacitors in series, with a variable coil connected between the junction of the two capacitors and ground. The antenna feedline is connected to the free end of one of the capacitors and the transmitter is connected to the free end of the other capacitor. Manipulation of the transmatch is simple: First, set both capacitors halfway open. Then, with the receiver operating, adjust the variable inductor for the strongest received signal...this puts you in the ball park. Then, applying low power, alternately juggle the two capacitors back and forth, exactly as you juggle the "plate" and "load" controls on your rig, until you see maximum power output and minimum swr at the same time, both being measured between the rig and input to the transmatch. It is important that you use the minimum amount of inductance necessary, thus assuring maximum efficiency. After getting tuned up like this, what have we done? Remember, the tuner output is looking into "100 plus J50". Therefore, if we were to disconnect the feedline and put a bridge on the output terminals of the transmatch we would measure "100 minus J50", the conjugate of the feedline impedance. Now reconnect the feedline to the transmatch. With conjugate impedance looking at each other, the plus and minus J factors cancel, leaving only 100 ohms, resistive...but the transmitter wants 50 ohms, resistive, so that the input capacitor combines with the shunt inductor to perform an impedance match, bringing the 100 ohms down to 50.

Of course, since the shunt coil is shared by both input and output capacitors, there will be some interaction and both capacitors must be juggled alternately for optimum tuning. This is all much simpler than it sounds and takes less time to accomplish than I have taken to tell about it. When you have become accustomed to your transmatch this all happens in a few seconds. Also, you should log the transmatch settings for favourite frequencies. Tuning is fast thereafter.

FOURTH, THE BALUN:

If you have transmatch that includes a good husky balun, and if you plan to use balanced open line, you have no problem; if you are using coax, no transmatch, a balun at the antenna, and are staying well under 2:1 swr, with modest power, still no problem...but let's take the fellow who has an 80 meter dipole, cut for the middle of the band (3750). He tried it first without a balun...swr is low at resonance, but around 7:1 at the extreme band edges. Next, he puts a 1:1 ferrite- core transformer-type balun up at the feedpoint of the antenna. What happens? His swr comes down to 1.5:1 at the band edges. Boy, that balun really solved the problem. Right?.....WRONG! In this case, if his rig would load up (or if he used a transmatch) he would be much better off without a balun. You see, the antenna hasn't changed at all. The swr is still just as high as ever...but he hasn't changed at all. The swr is still just as high as ever.... but he thinks his swr came down.... Didn't his meter say so? Yes, it did, and that's just the point. The meter is reading less reflected power, all right, because the high reactive currents on both sides of resonance are being absorbed in the balun's ferrite core. That means that both radiated and reflected power are down, making the meter read lower in the reflected power mode. This fellow could carry this a step farther...He could replace the ferrite balun with a 50 ohm resistor.... as Walter Maxwell says, "low swr can kill you!"

This is not a blanket condemnation of transformer-type baluns. Used correctly, they are often helpful and necessary, but you need to know, from experience, how basic types of antennas should work, so that when you run into one such as I have described here, you don't rejoice and assume that you got something for nothing.... instead, worry about what's wrong! There are two considerations when using transformer-type baluns:

1. Operate them well within their power ratings (there are some transformer-type ferrite baluns rated at 3KW, 5KW and even higher). To operate all way across several bands, handling widely-varying impedances and swrs, you need either the husky balun provided in a good transmatch or, even better, a well-designed coaxial balun.
2. Don't operate them in the presence of high swr.

To operate all the way across several bands, handling widely-varying impedances and swrs, you need either the husky balun provided in a good transmatch or, even better, a well-designed coaxial balun.

It is beyond the scope of this talk to cover coaxial baluns properly, but I have a wealth of good information on the subject and will be happy to send it, following your request. Whatever kind of balun you use for balanced open line should be 4:1 or higher. It is quite practical to put the balun just outside the shack, terminate the balanced line there, and come into the unbalanced transmatch input with 10 feet or less of coax. This is convenient and simplifies switching antennas.

Now we have discussed the four ingredients:

1. Antennas of non-resonant length.
2. Line attenuation.
3. The transmatch.
4. The balun.

This brings us to the "bottom line"...THE EASY WAY. What I have been leading up to is the suggestion we tune our antenna systems at the other end of the feedline.... IN THE SHACK. To nail this point down, let us listen again to Walter Maxwell, who starts first with a few philosophical comments, then follows with some hard, practical applications. Here is Mr. Maxwell:

"Before going further, the reader might ask, 'why match at the input?' The answer is that without matching at the feedline input we have very little operating flexibility. In the absence of a line-matching network we are restricted to operating in a narrow part of the band (especially on 80 meters) unless effective measures for broadbanding the antenna have been taken. We are restricted because, as we deviate from the antenna-resonant frequency, a resulting increase in feedline-to-antenna impedance mismatch is transferred to the line input as an increased transmitter-to-feedline impedance mismatch. As a result, the transmitter load impedance varies beyond acceptable limits, the transmitter fails to load properly, and it can be damaged by arc-overs caused by under loading. These phenomena (plus unawareness of the remarkable performance capability of line matching.) are largely responsible for the traditional low swr mania. On the other hand, simple impedance matching at the feedline input provides stupendous improvement in operating flexibility because the line matching network compensates for the impedance changes at the feedline input, and provides the correct load impedance for the transmitter at whatever frequency we select adjusting the network, at the operating position.

"So, the next question is: 'Why not broadband the antenna and avoid retuning a matching device when changing frequency?' The answer is that we can, but only to a limited degree...because, for example, the typical techniques which would permit coupling the average amateur transmitter directly into the feedline over the entire 80 meter band (with no adjustments other than retuning the transmitter) are not practical in the average amateur setup. This includes the coaxial dipole (sometimes called the double bazooka) which, contrary to prevalent opinion, fails to deliver any significant bandwidth improvement over a simple dipole when it is fed with the usual 50 ohm feedline." NOTE: Documentation of this startling statement is available from the writer.

And now Mr. Maxwell practices what he preaches:

"First, in the Tiros-Essa weather satellites, of which the entire multifrequency antenna-system design was the work of the author, the dipole terminal impedance at the beacon-telemetry frequency of 108 Mhz was 150-J100 ohms, for a vswr of 4.4, reflected power 40% Matching was performed at the LINE INPUT, where it was fed by a 30 milliwatt telemetry transmitter (we can't afford much power loss here!) The feedline and matching network attenuation was .24 db (5.4%), for a total loss of .44 db (9.6%).

"On the prevalent but erroneous assumption that all reflected power (40%) is lost, only 18.1 milliwatts would reach the antenna, and efficiency, determined on the same erroneous basis, would be only 60%...But 27.1 milliwatts were measured! Of the 2.9 milliwatts lost in total attenuation, only 1.6 milliwatts of it was from the 4.4:1 swr! So the real efficiency would have been 95.5% if perfectly matched at the load, but it reduces to 90.4% by letting the 4.4 vswr remain on the feedline. The second example was the Navy Navigational Satellite (NAVSAT), used for precise position indications for ships at sea. The antenna terminal impedance at 150 Mhz was also matched at the line input, where flat line attenuation was .25db, and the additional loss from swr was .9 db, for a total system loss of 1.15 db. Approximately 1/6 of an "S" unit. This was an insignificant amount loss for this situation, even in a space environment where power is at a premium. Why did we match at the line input?.... Because critical electrical, mechanical and thermal design problems made it impractical to match at the antenna. "Line matching provided a simple solution by permitting the matching elements to be moved to a non-critical location. This design freedom afforded tremendous saving in engineering effort with negligible compromise in RF efficiency, in spite of swr levels many hams would consider unthinkable."

Walter Maxwell's experiences give you the real thing, not just opinions, and I hope you are beginning to believe that what I am talking about REALLY WORKS. I have been doing it "the easy way" for some 10 years. It's been a long time since I walked through rain or snow to adjust a tuning capacitor at the base of my tower, change a clip lead or change out a remote-tuning motor that gave up the ghost during a critical QSO! I use an 80 meter dipole at 65 feet, 450 ohm balanced line and a transmatch, performing with high efficiency from 3.5 to 29.9 Mhz.

My "folded umbrella" is a seven-band folded unipole using 450 ohm line and a transmatch, showing 50 ohms (R) to the rig on all HF frequencies. The antenna proper is resonant at 1.9 Mhz, but it works DX on all bands. It's also a bonus for general coverage receivers and the new WARC bands.

At my desk in the shack I have a 3KW transmatch. Under the glass desktop I have all pertinent transmatch settings, across all appropriate bands and for each antenna. Most hams today enjoy all the conveniences afforded by broadband "no-tune" rigs, memories, scanners, computer controls etc. so it seems quite strange that we should be content to remain in the dark ages when it comes to tuning our antennas. Believe me it is a real pleasure to be able to do it all at your desk.

What kinds of antennas can we tune this way? Actually, just about any kind. A ham friend called me, saying that he had a 60 foot tower with beams on top and had put a gamma rod down the side. I asked him to try feeding it with 450 ohm line and a transmatch. I worked him later that evening...he was S9 on 160 meters and a bit stronger on 80 meters...and he was barefoot from Indiana (I was near Dallas).

I have tuned delta loops, quads, zepps, ground-plane verticals and others. However, don't expect instant success every time. For instance, if you want to employ a multiband antenna, there will be an optimum length of feedline, which gives the best compromise in swrs across all the bands. An 80 meter dipole will tune up most easily on all frequencies. If your feedline is approximately a quarter-wavelength at the lowest frequency used (any odd multiple of this length works the same). Depending on the environment, this length will vary slightly, but it is not critical, and some "cut-and- try will get it just right. Now let's review what we've been talking about:

First, realizing that I needed "third party credibility" to support me in presenting a controversial subject, I quoted Jim Fisk Walter Maxwell, and Walter Anderson...with their "endorsement", I developed four "axioms":

1. Don't fear antennas of non-resonant length.
2. Put line attenuation in proper perspective.
3. Understand and trust the transmatch.
4. Know what you can and cannot do with baluns.

I promised that all of this would add up to "THE EASY WAY".

I hope this has brought you something of value...I realize how difficult it is to change a concept that has been maturing for years...I have only to tune in the 75 meter phone band late at night to remind myself that, as Dale Carnegie says, "A man convinced against his will is of the same opinion still!"

"Although reader response to this series of articles has been excellent, some have told the author, 'your story is interesting but you'll never convince me that I won't get out better with a perfect 1.0:1 swr.' Now any reader who still entertains any scepticism of these entire proceedings concerning swr is reminded that the information presented herein is not simply a recitation of the ideas or opinions held by the writer, but has been taken from the professional and scientific literature and has been paraphrased specifically for the radio amateur with great care not to change the meaning; moreover, in striking contrast to the many differing opinions heard on the subject during amateur discussions there are NO SUCH DIFFERING OPINIONS AMONG THE PROFESSIONALS (including textbook authors), because the principles involved are completely understood and based on true scientific facts, which are not subject to divergent opinions as found in politics or religion."