The Basic Antenna

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Part one

Two of hamdom's most sacred cows surely must be the 'Resonant Antenna Length' and the 'SWR' syndrome. This five part series of articles will examine these phenomena and, hopefully, stimulate and extend your thinking as they relate to the simple dipole, everybody's favorite basic antenna. Along the way, some fundamental antenna concepts commonly misunderstood by many amateurs will, again hopefully, be clarified as well.

Judging by the conversations I hear on the air there is almost universal agreement among the ham participants that if you use a simple dipole:

1. A resonant antenna length precisely a half-wave length long is the length of choice, in order to achieve optimum antenna operation.

2. In addition to the resonant length, there is almost universal agreement that the antenna impedance at the feedpoint must be 50-ohms.

It is claimed that the closer these two ideals are approached in practice, the closer the antenna approaches perfection.

The truth is that neither of these two conditions, either singly or in combination, is necessary for optimum antenna performance.

In spite of all that has been written to correct this thinking, why does it continue to persist throughout such a large segment of the ham population? How is it that so many hams are so enthusiastically committed to these two notions? Why do these two concepts so strongly dominate our thinking about antennas?

I do not mean to imply that a resonant antenna length and a low feedline SWR do not provide optimum performance. What I mean is that a non-resonant antenna length and a feedline operating with a finite SWR can provide just as good a performance.

Why then should we bother investigating these two phenomena, if a resonant length with low SWR is sufficient to attain optimum antenna performance? The answer to this question is because knowing a few simple facts about how a dipole works will enable us to achieve optimum performance when it is impractical to erect a resonant length. Moreover, this understanding can show us how to utilize our antenna systems in a much more productive and flexible way than we have done in the past.

Maybe a short review of history, and how it all came about will help us to better comprehend the problems. **Historically, the concept of the half-wave length appeared long before the idea of:**

1. **50-ohm, coaxial cable.**
2. **SWR**
3. **Reflections**
4. **Matched antenna loads.**

For several decades after the birth of Amateur Radio (Ham Radio), there were no such things as coaxial lines or SWR meters, and no one knew anything about them. There were reflections on our lines, but that didn't bother us in the least. Yet the simple dipole antennas of that era (pre World War Two) were radiating optimally. The simple wire dipole was used in a much different manner than it is today. **A single dipole antenna was usually used on all of the HF amateur bands and, moreover, used on all frequencies within those bands. The antennas were non-resonant on some bands, and the feedline SWR approached several hundred on some bands**. Yet the antennas were operating optimally. By "optimally", I mean on a par with the operation of the resonant coax-fed dipoles we use today. And, if the truth were known, those simple antenna systems operated at greater efficiency than our present ones, in most cases!

Antenna textbooks and technical articles treat the basic antenna as one, which is a half wavelength long. Why? The answer is not because it is the best or the ideal antenna, but because it is the simplest antenna configuration to characterize in technical terms for the beginner and the novice. By virtue of being resonant, the current and charge distribution along the wire can be drawn very nicely, and the antenna is relatively easy to describe mathematically. It is also conceptually simple, and easy to describe in general terms. Can you imagine an elementary antenna textbook describing the basic antenna element, and what happens on it, if it is 37/64-ths of a wavelength? Or 7/13-ths of a wavelength? What a mess that would be. But a half-wavelength antenna, well — how simple can you get? This exclusive treatment of the half wavelength antenna as the basic configuration has led many hams to believe that it must be the antenna of choice, to the exclusion of all others.

The problem of fixating on the half wavelength antenna was exacerbated by the appearance of coaxial line during World War Two, and shortly thereafter, by the appearance of the ubiquitous SWR meter. Nowadays these two concepts, the resonant antenna and a low feedline SWR seem to go hand-in-hand, each dependent on the other, and each contributing to optimum performance.

I believe that it is a combination of inertia and failure to distinguish between the half wavelength antenna and every other length, which determines how we think about antennas today. Technically, the general or basic antenna is a wire of any length. Indeed, advanced and engineering antenna textbooks treat the basic dipole as a dipole of random length. The half wavelength antenna is treated as a special case of the more general random length. The resonant dipole does not possess any special attribute that makes it a superior radiator, just because it is a half wavelength long.

As I wrote before, there is nothing wrong with using a half wave antenna, over a narrow frequency span within a single amateur band. This is the way most dipoles are used today. What is disturbing is that a slavish adherence to this way of thinking and operating a station unnecessarily hampers and limits the enjoyment of our hobby. What needs to be more generally understood is that it is possible to use a simple single wire dipole antenna on all HF bands, as well as on all frequencies within those bands, without significant loss of radiating efficiency. Today, too many hams limit themselves to one band operation, which is the band their antenna is cut for. In addition, they limit their operation to a narrow portion of the band because elsewhere the SWR is too high.

A strict adherence to these two popular concepts causes us to seek antenna configurations that will provide a low SWR over as broad a frequency span as possible. Under these conditions, bandwidth is defined as the frequency band throughout which the feed line presents 50-ohm resistive impedance. This is not particularly easy to do with simple dipoles, and when carried too far, will impose restrictions on the radiating ability of the antenna. We can't pursue this impedance versus efficiency trade-off indefinitely. As a consequence, we restrict our operating frequency range.

In my opinion this is a poor way to come to terms with the problem. The ability to operate several or all bands with no frequency restrictions should be a high priority in our station planning. This was true in the past, but we have gotten away from that goal.

The remainder of this series will elaborate on these subjects, and propose an antenna system that closely approaches the ideal, and gives you maximum operating freedom and flexibility.

Part two

Amateurs (Hams) in general believe, correctly, that increased antenna current goes hand in hand with increased radiation. **Many hams believe, incorrectly, that the half-wavelength antenna provides maximum current compared to every other length.** What is true is that in a given antenna, resonant or not, increasing the current results in increased radiation, regardless of the length. But other lengths can have, for the same transmitter power, higher current flow than the resonant half-wave wire. Does that result in a "better" antenna? Not necessarily. I only propose to dispel one of the more popularly held notions about the half-wavelength antenna. Namely, that it is the length that has more current and, therefore, has better radiation than any other length.

The word "resonance" as applied to antennas has a different meaning than when the term is applied to lumped constants**. Half-wave resonance in an antenna means that length of wire that results in an electric charge traveling from the feedpoint to the end and back in the time of one half cycle of the exciting signal. The definition has nothing to do with current magnitude.** Nevertheless, there is a widely held perception that maximum current exists in the wire by virtue of being resonant. Consider the following example.

Imagine a half-wavelength dipole antenna strung high in the air, free of surrounding objects, and situated over a salty marsh ground. Cut it for the center of the 20 meter band, and it will be about 33 feet overall. The feed point impedance at the center of this ideal dipole will be not 50-ohms, but closer to 70-ohms. Connect your 100-watt transmitter to this antenna through a piece of 70-ohm coax. For the moment, disregard the fact that your transmitter was made to work into a 50-ohm load. However, if this bothers you, imagine that you have won the lottery and can order a specially made transceiver from your favorite manufacturer that is designed to work into 70-ohms.

From the basic power formula $P=I^2 R$, we can find the current $I=P/R$. In the example, the current will be the square root of 100 watts, divided by 70-ohms, and is approximately 1.2 Amperes. So far so good.

Now lower the antenna, lop off about 5 feet from each end so that the antenna is now too short. Haul it back up in the air. What happens to the feed point impedance? The resistance will be lower. Let us say it is decreased to 30-ohms. Now use more of your lottery money and order a piece of low-loss 30-ohm coax and a transmitter designed to work into 30-ohms. Feed the 100 watts to the antenna. What is the current? Using the same formula, as before, the current is the square root of 100 watts divided by 30-ohms, and is 1.8 Amperes. Notice anything? The current in the short, presumably inferior and unusable antenna is higher than the current in the half-wavelength dipole!

What's that, you say? I forgot the reactance at the feedpoint? Indeed I did. A slight oversight. Where the half-wavelength antenna showed no, or very little reactance, the short antenna would show considerable capacitive reactance at the feed point. How can we get rid of it? Simply provide a reactance of opposite kind to tune it out. In our case, connect a coil of equal reactance at the feedpoint and VIOLA! We are left with a resistive 30-ohms. In spite of the difference in current in the two antennas, the resonant dipole and the shortened dipole will radiate equally well. Mathematical analysis and direct measurement show that the two antennas are practically identical, as far as radiation is concerned. Any difference is so minute that it is very difficult to detect in a laboratory, and absolutely undetectable impractical use. For all practical purposes, each antenna will radiate the full 100 watts!

There are difficulties implementing this information in a typical QTH. For one thing, you have not won the lottery, at least as far as I know, so you can't order special equipment. What then, was the purpose of this mental exercise? The purpose was to show that we could start to think about non-resonant antennas as viable alternatives to the resonant dipole, and not be enslaved by the half-wavelength syndrome. There is nothing magic about the half-wavelength long antenna. It is not a "better" radiator than some other length.

Not convinced? Okay. Let's try again. Take the basic 20-meter half-wavelength dipole and extend the ends. This time let's really detune the antenna. Let's cut the antenna for 5.5 megahertz. This is halfway between the 40 and the 75-meter bands, and so puts it as far as possible from resonance in any ham band. Accordingly, add 25 feet to each half of the twenty-meter dipole. This makes the overall length of your new dipole 83 feet, which is a half-wavelength at 5.5 megahertz. Haul it up and load it on 20 meters. Yes, you must again special order a transmitter/coax for this test but, hey, you've got to spend your lottery money on something, right? This time, just for variety, measure radiation directly using a remotely located receiver, which has an S-meter. Assume that the 20-meter dipole was measured in this way before you extended it so that we can compare the two. The antenna, now too long, not resonant, and therefore presumably inferior and unusable, will measure twice as good as the half-wave long dipole!

You have just put up a 20-meter extended double Zepp, which is 3 dB better than the resonant dipole. You may, if you wish, calculate the current, and you will find that it is now less than the 1.2 Amperes in the half-wavelength antenna. The feedpoint impedance is about 126 ohms, and so the current is approximately .9 Amperes. Think about it - less current but better radiation. In the first example, more current meant equal radiation.

The point of these comparisons is to show that the absolute magnitude of current has no meaning in comparing different antennas; but more importantly, that the half-wavelength antenna is not a better antenna because it has the most current. Shorter and shorter antennas will have higher and higher current, but not better radiation because of it.

In beginning to think about the feasibility of using a single antenna on all bands we are faced with two possibilities. The antenna may be cut to resonance on one band or it may not. If it is half-wave-resonant on one band, it will certainly not be on the other bands. There is no requirement that it be resonant on any band. In either case, resonant in one band or not, it can operate near optimum on all bands**. In other words nothing will be gained, as far as dipole-radiating efficiency is concerned, by pruning or trimming it to resonance.**

Despite what I have written above, there are valid reasons why the half-wavelength dipole may be the preferable length to put up.

1. Reason one, is when you want to work all bands but you can't find or build a tuner that will tune the feedline. More about this later.
2. Reason two, is when you want to restrict your band and frequency-span operation, and do not want to operate all bands and all frequencies.

I have never run into reason one. I am not yet ready to adopt reason two.

Part three

In the previous section we investigated the resonant length phenomenon. **Let us now take a look at the second sacred cow: the 50-Ohm syndrome.**

Back in the dark ages before transistors, hams used vacuum tube transmitters that had variable output tuning circuits with front panel adjustable controls. The variable tuning allowed transmitters to operate into many different feedline and/or load impedances. We were not limited by being required to provide a 50-Ohm load to the transmitter. That degree of freedom disappeared with the availability of solid-state transmitters. It didn't have to but it did. Perhaps it was because hams demanded more and more simplification and the elimination of the variable output tuning controls. Or maybe we were conned by the manufacturers who made us believe we didn't need them anymore. I think that it was because hams sought greater simplification. I think this because for many years' hams were almost universally very anti-antenna-tuner oriented.

However, since tuners have been automated they now seem to be in ever-increasing demand and are not looked upon as the evil monsters they were once thought to be. This is why I suspect that hams were not so much anti-tuner as they were anti-knob twirling. Anyway, we are now obligated to present a 50-Ohm resistive load to the transmitter. What better way to do this than to erect a half-wavelength long dipole? Isn't the impedance 50 Ohms? This is the trap many hams find themselves in today. It is what I call the 50-Ohm Syndrome.

Our present day transmitters are not happy with any load impedance other than 50-Ohms. In fact, they will automatically lower the power output or may shut down entirely when presented with some other value. This is the function of the output directional coupler, otherwise known as the SWR meter circuit. The main or prime function of the SWR meter is to protect the output stage power transistors and not to optimize the antenna. Surprise!

There is nothing magic about the number 50. It is an arbitrary number. Theoretically, any other number can do just as well. Transmitters can be designed to work into any other load impedance. But we have standardized on 50-Ohms and we are stuck with it.

Voltage Standing Wave Ratio (VSWR), most commonly referred to as SWR, is an indicator of power reflection on the feedline due to an impedance mismatch between the antennas feedpoint impedance and the feedlines characteristic impedance, and the ease with which the feedline SWR can be measured has lulled many hams to assume that a low reading optimizes antenna radiation. The fact of the matter is that the condition of the feedline has nothing to do with the "goodness" of the antenna radiator. The ideal half-wave dipole has a feed point impedance of 70-75 Ohms. When connected to a 50-Ohm coaxial cable the SWR will be almost 1.5:1, a value many hams are unhappy with. On the other hand, if they put up a dipole in less than ideal surroundings, over lossy ground, etc., the feed point impedance may be closer to 50-Ohms and so present a lower SWR reading. Many hams would prefer this antenna to the superior one. This is how pervasive the 50-Ohm syndrome has become. Worse becomes better!

How, if you will pardon the expression, pervasive is this pervasiveness? Many hams go so far as to trim the antenna, raise and lower it, droop the ends, slope it and who knows what else in order to get the impedance closer to 50 Ohms. Unknowingly, they may very well degrade or compromise the radiating ability of the dipole by

their efforts to attain the elusive 50-Ohms. In their minds 50-Ohms becomes the sole criterion by which an antenna is judged as to its radiating efficiency. The SWR meter was not put there so that you could adjust the way your feedline is operating. The meter was put there to insure that you could put a 50-Ohm resistive load to the transmitter. The two are not the same.

The SWR meter tells you how close you come to making the feedline impedance 50-Ohms, not because that optimizes the antenna or the feedline, but because that is what the transmitter was designed to see. Feedline SWR has no bearing whatsoever on what makes a good antenna. Manufacturers are first and foremost interested in protecting their transmitters. They have no control over what you attach to them. Of course, they are vitally interested that you use an efficient radiator but are not concerned if the antenna radiation resistance is 8-Ohms or the feedline impedance is 943-Ohms or anything else, as long as the transmitter load is 50-Ohms.

At the risk of repeating myself I will state again: it is a mistake to assert that feedline SWR is an indicator of antenna performance. A 50-Ohm load on the transmitter will protect the transmitter, not optimize the antenna.

Let's recap what we know thus far:

1. We should not be compelled to use a half-wavelength dipole to the automatic exclusion of any other length.

2. We should not use the SWR meter as an indicator of antenna operation.

3. It should now be clear that we need some way of thinking about antenna performance that does not depend upon what the feedline is doing. I propose antenna efficiency as the criteria of antenna performance. The question we should ask is how well does our antenna radiate. We should not be primarily concerned with how the feedline is operating. In this context what's happening on the feedline is irrelevant and has no bearing on antenna radiation efficiency.

4. It is true that a high feedline SWR may or may not have serious ramifications as regards power transfer, but that is a different matter and does not impact antenna efficiency. What is under consideration here is the antenna dipole radiating efficiency and dipole-radiating efficiency is not influenced in any way by what the feedline is doing.

5. We shall return to feedline power transfer later in our next installment. We will continue examining antenna-radiating efficiency in greater detail.

Part four

How efficient is the half wave dipole? It is almost 100 percent efficient. How efficient is a half wave dipole when operated at all higher frequency bands? Almost 100 percent efficient. But what about that same dipole operated on lower frequency bands? How efficient is a short dipole? We have an intuitive feel that a very short antenna cannot operate well at very low frequencies. Nevertheless, a short dipole is almost 100 percent efficient if not too short. It becomes progressively less efficient as the length becomes shorter. We immediately see that we should now ask, "how much less than 100 percent efficient can an antenna be before we say it is unusable?" Or, what is essentially the same question, "how short can we make a dipole antenna and still realize acceptable radiating efficiency?"

To answer these questions, I find it easier to think in terms of dB and to do so in the following manner. Turn your receiver on and tune across a band and listen to several signals. Notice how the S-meter pointer flickers? It seems to follow the voice syllables. Also, notice that there is usually some QSB, or fading motion that causes the pointer to gradually or slowly roam up and down in addition to the more rapid voice fluctuations. The point is that it is difficult to tell if a signal is S7 or S7-1/2. But more importantly, if a signal changes from S7 to S7-1/2 or from S8 to S8-1/2 or from 10dB over S9 to 13dB over S9, would you hear any difference? I think not. If a signal is S8-1/2 or S8 do you really care? For the majority of ham QSOs how important is a one half S unit difference one way or the other?

In a correctly calibrated receiver S meter circuit, each S unit represents a power change of 6 dB. Therefore, a one half of an S-unit is a change of 3 dB. Let's be honest about it, for the vast majority of conversations / QSOs, a difference of 3 dB, or half an S-unit is of small, or no consequence.

Knowing that a half-wave long dipole is 100 percent efficient, would you use an inferior antenna that is only 50 percent efficient? That sounds like a huge amount, and many hams would consider a reduction of this magnitude to be an anathema. A short antenna that is "only" 50 percent efficient radiates half the power fed to it by the transmitter. This is a power reduction of 3 dB, or one half of an S-unit. We saw that in the vast majority of cases a one-half S-unit is of no consequence.

But wait. This antenna will be 100 percent efficient on all bands on which it is of reasonable length. And, in many cases, the antenna may not be as "bad" as 50 percent efficient on the lower bands. Once again, the lack of understanding of the way a dipole works is counter-productive to station planning. Hams that operate their resonant dipoles on the "next lower" band are almost non-existent. This self-deprivation is unwarranted. Let's look at this concept a little closer.

Most city lots can accommodate a forty-meter dipole without too much trouble. It is the 75/80 and especially the 160-meter bands that present installation problems. Most hams never think of operating their forty-meter antennas on 75/80 meters (or any of the higher frequency bands for that matter), and absolutely do not ever even dream of operating them on 160 meters. The idea of using a forty-meter dipole on 75/80 and 160 meters may surprise many hams, but it is practical. I do not wish to mislead you. A forty-meter dipole is not 100 percent efficient when operated on 160 meters. But it is not a totally useless exercise in futility, either.

In nature, there are no sharp stops and starts, no sudden on and offs. Instead, every transition occurs gradually. So when we say that an antenna is less efficient on the low bands we do not mean that it is a go no-go situation. It all depends on how much less efficiency you are willing to settle for. Remember our discussion of the S meter? Would you not use an antenna on the next lower band where it may be only 75 percent efficient? This sounds like a lot, but it is only 1-1/2 dB worse. This is one fourth of an S-unit. If your S meter face is as skimpy as mine, the S-unit calibration marks are about 3/16ths of an inch apart. See how small a one-quarter S-unit is? Big deal, right? You see how thinking in terms of S units helps our appreciation of what is and what is not relevant, when it comes to antenna signal strength?

A measure of antenna radiating efficiency is obtained by the ratio of the radiation resistance to the loss resistance. The factor that determines antenna efficiency is not the absolute magnitude of the radiation resistance, but the magnitude of the radiation resistance compared to the loss resistance. Shortened antennas exhibit progressively lower radiation resistance. A short antenna, using 14 or 12 gauge copper wire with good insulators and erected an adequate height above a good ground, has a very low loss resistance. That is why it is practically 100 percent efficient. This means that we can make the antenna short and still realize good efficiency, if we can keep the loss resistance low in comparison to the lowered radiation resistance. This holds true provided we do not go to extremes and make the antenna ridiculously short. Implicit in this statement is that the antenna will exhibit 100 percent or near 100 percent efficiency on all higher frequency bands where it cannot be considered short. It is only on the lower bands that the radiation resistance begins to approach really low values. This is why it is of the utmost importance to keep all losses low in what are necessarily really short antennas - those for 40 and 80-meter mobile use.

As an antenna becomes shorter, its radiation resistance decreases, and the loss resistance takes on a proportionately greater role in dissipating power, thus leaving less to be radiated into space. It is interesting to note that if we could find ways to lower the loss resistance we could reduce our antennas indefinitely, but here we come up against the natural restrictions of the practical world.

Let us calculate how efficient a forty-meter dipole is on 75/80 meters and on 160 meters and translate that into S meter units. This will give us a much better idea of what we are talking about.

The half-wavelength dipole is 100 percent efficient. A 3/8ths wavelength antenna is 98 percent efficient. A ¼ wavelength antenna is 95 percent efficient. And a 1/8-wavelength antenna, such as a 40-meter dipole on 160 meters, is about 67 percent efficient. In the calculation, a forty-meter dipole on 160 meters will be 1.7 dB worse than on forty meters.

These quoted efficiencies are calculated values, using realistic values of copper loss and skin effect resistance. It does not include an additional loss due to the proximity of surrounding objects and the effect of the ground. These additional losses can be considerable, but can only be guessed at. It is important to keep in mind that these additional losses affect all antennas - not just the shortened dipole.

This may be an appropriate place to comment on the popular antenna design and optimization computer programs, which are available for ham use. These are the MININEC derivations, of which there are several versions. While these programs are extremely helpful and accurate for certain classes of antennas, they have serious limitations when used to analyze short dipoles near real earth. Read carefully the comments in this regard in the article "Comparing Mininecs" in the spring, 1994 issue of Communications Quarterly magazine.

A sad point is that antenna system efficiencies of the magnitudes quoted previously may not be realized in practice because of losses in the remaining parts of the antenna system. The remaining parts are the feedline and, if used, an antenna tuner. This additional loss may or may not be significant. Read that sentence carefully. The radiator part of the antenna system will maintain its calculated efficiency in any case. The antenna system viewed as a whole may not be as efficient as the radiating portion. But the deterioration in system efficiency is the result of limitations in the feedline and tuner—not the radiator portion.

It is important to keep this distinction in mind when we continue the next segment of "The Basic Antenna."

Part five

Using no-loss open wire feedline**.** If the feedline is lossy even a perfect radiator will not make up the loss. Obviously, we should try to operate our stations with the least amount of power loss everywhere in the system in order for as much power as possible to be radiated. Inherent feedline loss can be obtained from tables such as are found in the ARRL Handbook and the Antenna Book. Unfortunately, this is not the only loss that occurs in a feedline that is operating with a finite SWR.

There is an additional loss incurred over and above the values shown in textbook tables, and it is a function of the SWR on the line working in conjunction with the specified inherent line loss obtained from the tables. With progressively shorter antennas, the radiation resistance of the antenna decreases, causing an increasingly higher SWR on the feedline. The higher standing wave ratios produce higher loss on the feedline, over and above the inherent loss. This feedline transfer loss, or to use the correct technical term, "reflection loss," can be alleviated by either of two ways:

1. Operate with a low SWR.
2. Use of a low-loss line.

Low line SWR is not compatible with the intent of this article, and so we must try to decrease the line loss.

By now you may have suspected that our all-band, all-frequency antenna will use an open wire feedline with, at most times, a high SWR and use an antenna tuner. It is the inter-relationship between the radiator portion and the feedline/tuner that has caused many hams to condemn a non-resonant antenna length as having an objectionable loss. "Aha!" you say, "but that is why I want a low feedline SWR on my feedline!" Well yes, you have a point. But that is important only if you are using a high-loss line to begin with. That is something; I think we will agree you should not be doing.

While a non-resonant length has contributed to a loss mechanism, the loss does not occur in the radiator. Moreover, a zero-loss line will exhibit no reflection loss, even with astronomically high SWR's. So it is essential to use the lowest-loss line possible. The lowest-loss line you can use is the open wire feedline. Not coax, not "window" line, or what is called "ladder line" with the Polyethylene insulation, but open wire line. A reasonably well constructed open wire feedline will have an inherent loss of no more than about 0.01 dB per 100 feet on any of the HF amateur bands. The use of such a line with a non-resonant antenna operating with moderately high feedline SWR will not incur unreasonable power transfer loss due to this cause.

The following short explanation may help you acquire an elementary understanding of how high line SWR contributes to line loss when the line is lossy to begin with. High SWR results in high values of reflected power in a feedline. Power reflected by the load is re-reflected by the transmitter tuner termination. This re-reflected power flows back to the antenna, where a portion of it is reflected again. This process continues with time, each reflection resulting in a re-reflection at both ends of the line. This multi-reflection process results in a certain amount of power lost in the line each time the power traverses the line from one end to the other. The effect is accumulative, so that the high SWR coupled with high line loss, results in lower net radiated power. In other words, high SWR results in greater reflected power, which is subjected to the line loss, and thus becomes unrecoverable. It is dissipated as heat in the line. In a zero-loss line, all of the reflected power will be radiated, because it adds to the incident power -- it has no place to dissipate, other than into space! Since the line is lossless, no power well be spent heating the line, no matter how much reflected power keeps bouncing back and forth.

It is obvious that the specified loss of a lossy line will cause a greater proportional amount of reflected power to be lost the larger the reflected power. This means that less net power will be available for radiation into space. But because we cannot lower the SWR due to our non-resonant and/or shortened dipole, the only alternative is to lower the line loss. Walter Maxwell W2DU provides a thoroughly readable and clear description of these phenomena in the ARRL book "Reflections." Much clearer, I am afraid, than I attempted here.

What we must realize is that in a line with no loss, even extremely high SWR’s would result in no loss due to this cause. It is not necessary to have a clear mental picture of the reflection loss mechanism in order to appreciate this fact. And it should be obvious that a lossy line with an SWR of one-to-one, will also result in less radiated power than will a no-loss line, but we knew this all the time and is nothing new.

If it is permissible to use a feedline with high SWR, how do we connect it to the transmitter, which wants to see a 50 ohms resistive load? Simple, use a tuner. But aren't tuners lossy? They can be, and many surely are lossy. But they need not be so lossy as to preclude their use in lieu of the benefits to be gained.