Build

A Double Bazooka

- - give your signal a blast

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An interesting fourteen page mathematical analysis of why the coaxial dipole antenna doesn't work for the average amateur appeared in the August 1976 issue of *Ham Radio.* I did a double take when I first read it. About a year ago, after having been off the air since 1935, I decided to get back on. My bright and new Yaesu FT-101-B worked fine, but a simple broadband antenna was needed for the 80 meter band. It seemed that a double bazooka, or coaxial dipole as it's also called, would be just the thing.

Before I built one, I did a bit of thinking as to just what made a double bazooka work. I realized that a very simple change would make it work a lot better than any of the ones previously described in the literature I had read. After reading the referenced article, I decided to repeat my previous experimental work and also delve a bit deeper into why my double bazooka worked so well when the theoretical analysis proved the coaxial dipole wouldn't work.

Being an old-time ham, ex-W3RN (1928), possessed of more low cunning than high math, I want to say that I won't write a long mathematical treatise as to why my antenna works as well as it does. The mathematics of the referenced article are absolutely correct, so anyone reading the referenced article can go to it and repeat any or all of the math he likes.

Instead of analyzing a theoretical thin wire dipole in free space, we'll analyze a dipole antenna that more closely represents the characteristics of one built by the average amateur. Then we'll add the coaxial stub sections and see what happens. At the same time we'll observe the improvement in lowering swr by using my new parallel connection technique as opposed to the series method previously used.

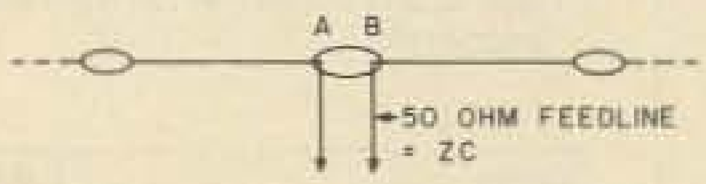


Fig. 1. Basic dipole antenna.

This analysis will be theoretically calculated and the resulting curves shown. The curves will show the antenna without any stubs connected, then with the series method, then with the parallel method just developed. And, finally, I'll show the same kind of curves as actually measured at my coax line feeding the antenna from the transmitter. This will allow each amateur to make his own decision as to whether a coaxial dipole has any reason for being.

But one of the most compelling reasons for not going through pages of math is quite practical. Most average hams like myself are more interested in seeing actual results. Besides, anyone can check the math for himself from the referenced article. And now, as an example, I'll pull some figures and values out of a hat in midair and show some results. Later I'll explain just why I chose the figures I did. This way we can show the results first and figure out the whys and whereofs later on. I guarantee it will be a lot easier that way. Lastly I'll add a few general comments when I compare a double bazooka to other antennas designed for broadband usage.

Some Basic Theory

First, to refresh our memories and see exactly what we are going to explain, let's think about a simple dipole antenna as shown in Fig. 1. It is a wire an electrical half wavelength long with an insulator in the center where our feedline will attach at points A and B. And we know that for practical purposes our antenna at resonance can be represented by the simple series circuit of Fig. 2. R_a is the antenna resistance. X_1 is the inductive reactance, and X_c is the capacititive reactance in Ohms. Also at resonance, X_1 is equal to X_c numerically, but of opposite sign. And so at resonance our impedance is simply R_a. The Q of the antenna is X_1/R_a. Z_c is the impedance of the feedline we will use, and for our purposes it will be 50 Ohms, as that's what is generally available and used by the average amateur. And also at resonance, the swr is Z_c/R_a when Z_c is larger than R_a, and the swr is R_a/Z_c when Z_c is smaller than R_a. And if we were really lucky and had an antenna with a resonant resistance of 50 Ohms, our swr would be simply R_a/R_c or 50/50 or 1:1, and you can't improve on that.

There is not only one fly in the ointment, but at least three big ones and a few smaller ones buzzing around, as I'm sure you have already guessed. First, our antenna resistance is not always 50 Ohms. It can be either higher or lower. Second, and more importantly, is what happens when we tune our transmitter

Fig. 2. Basic dipole antenna resonant at 3.75 MHz. Q = 10, swr = 1.25:1.

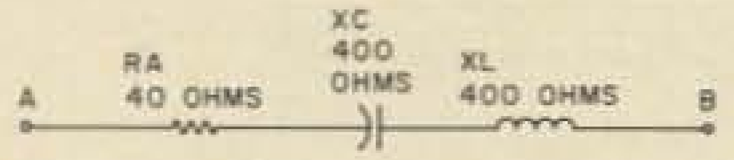
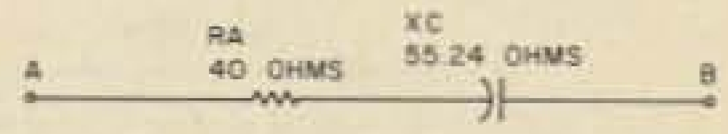


Fig. 3. Basic antenna dipole equivalent circuit at 3.5 MHz. Swr = 3.27:1.



to some frequency away from resonance. Then there is the third fly of basic antenna Q, which will have an important effect on how well our double bazooka antenna works.

But let's first stick with our basics a bit longer and see what happens, for example, when our antenna has a Q of 10 and a resonant resistance of 40 Ohms. We'll assume, and for practical purposes we won't be too far off, that our basic antenna dipole resistance will stay at 40 Ohms over the entire 80 meter band. Let's also assume our resonant frequency is in the middle of the band at 3.75 MHz. Our X_l will numerically be equal to X_c and will be equal to $X_l = (Q)(R_a) = (10)(40) = 400$ Ohms. And our swr at resonance will be $Z_c/R_a = 50/40 = 1.25:1$ at 3.75 MHz.

Now let's look and see what the antenna looks like at 3.5 MHz. Our inductive reactance will decrease to (400)(3.5 MHz)/(3.75 MHz) = 373.33 Ohms. Our capacitive reactance will increase to (400)(3.75 MHz)/3.5 MHz) = 428.57 Ohms. The difference will be 428.57 minus 373.33 which is equal to 55.24 Ohms. So at 3.5 MHz our antenna no longer looks like a pure resistance of 40 Ohms, but looks like a 40 Ohm resistance in series with a capacitive reactance of 55.24 Ohms, as shown in Fig. 3. And the calculations for the swr of our antenna at 3.5 MHz with the 50 Ohm coax feeder tied on turns out to be 3.27:1. As I mentioned earlier, the basic mathematics of the referenced article go into the details of how to calculate swr, and, as we didn't want to make this article too mathematical, we'll let it go at that. However, I'll do some more math calculations myself and just show the curves. It will save us all a lot of time and effort.

Well now that we've seen that our basic dipole has an swr of 3.27:1 at 3.5 MHz, we wonder if there is any way that we can reduce the swr to a lower value. Here is where the double bazooka comes in.

But before going directly to the antenna, let's see just what we are actually going to do. If we look at the characteristics of a parallel resonant circuit and compare it to the series circuit of our basic dipole, we will find some interesting things. Let us just arbitrarily take a condenser of 3600 pF and an inductance of .5 uH and connect them as a parallel circuit. It just happens that this circuit will resonate at 3.75 MHz. If we assume a perfect coil and condenser, the parallel impedance at resonance will be infinity. So if we were to place this parallel resonant circuit across the insulator of our basic dipole, nothing would happen at a frequency of 3.75 MHz.

But what happens to our parallel circuit by itself if we tune the transmitter to 3.5 MHz? With a bit of basic circuit theory, we find the parallel tuned circuit will be equivalent to an inductive reactance of 85.3 Ohms. And we already know that our antenna by itself at 3.5 MHz showed a capacitive reactance of 55.24 Ohms in addition to its resistance value of 40 Ohms. This tells us that when we look at Figs. 4 and 5, that the inductive reactance of the tuned parallel circuit at 3.5 MHz could be used in some manner to cancel all or part of the capacitive reactance of the antenna at this frequency.

Another interesting thing is that the equivalent antenna resistance will no longer look like 40 Ohms but will be at some higher value. Fig. 5 shows the total equivalent circuit impedance of the combined system. The equivalent resistance is now 116 Ohms and the capacitive reactance has dropped to the extremely low figure of 2 Ohms. So we have seen that by picking the right kind of parallel tuned circuit, we can practically eliminate the reactive component at the band edge of 3.5 MHz.

A similar action would take place if we left things as they were and tuned the transmitter to 4 MHz. And now if we were to calculate the swr of the combined circuit at 3.5 MHz, shown in Fig. 5, we would find that the swr has been reduced to a value of 2.33:1. And, as our original swr without compensation was 3.27:1, we see that there is a way to reduce swr in an antenna.

It might be reasonably asked at this point, if we can theoretically reduce the swr of an antenna system with a simple parallel resonant circuit, why go to the double bazooka system? There are two basic reasons. First, we notice that the value of capacity required is very high and that the inductance is only .5 uH. To properly tune and build such a network tuned exactly to 3.75 MHz and install it across your antenna insulator would be quite a job. Second, it would be hard to build such a system using practical components and still obtain a high Q. Since we want the Q of the parallel circuit to be as high as possible for best results, this means we want the losses to be as low as possible.

Fortunately, a shorted quarter wavelength of coaxial cable will act like a high Q parallel tuned circuit. At the same time, the quarter wave sections will also act like a portion of the antenna radiating system. As a matter of passing interest, as it does have some bearing on our further discussion, we could in this example replace our parallel tuned circuit with a quarter wave piece of coaxial cable cut for 3.75 MHz. However, this piece of cable would have to have a characteristic impedance of nine Ohms. To my knowledge, there is no such kind of coaxial cable of this low impedance on the market available to the average amateur.

We know that our antenna will have two quarter wavelength stubs, one on each side of the center insulator. If we plan to use 50 Ohm coaxial cable, we can readily see that if we were to parallel the two stubs, we would get down to 25 Ohms. However, the double bazooka antennas used up to this time have all showed the two stubs connected a series, which gives a characteristic impedance of 100 Ohms. And we know that 25 Ohms is a lot closer to 9 Ohms than the

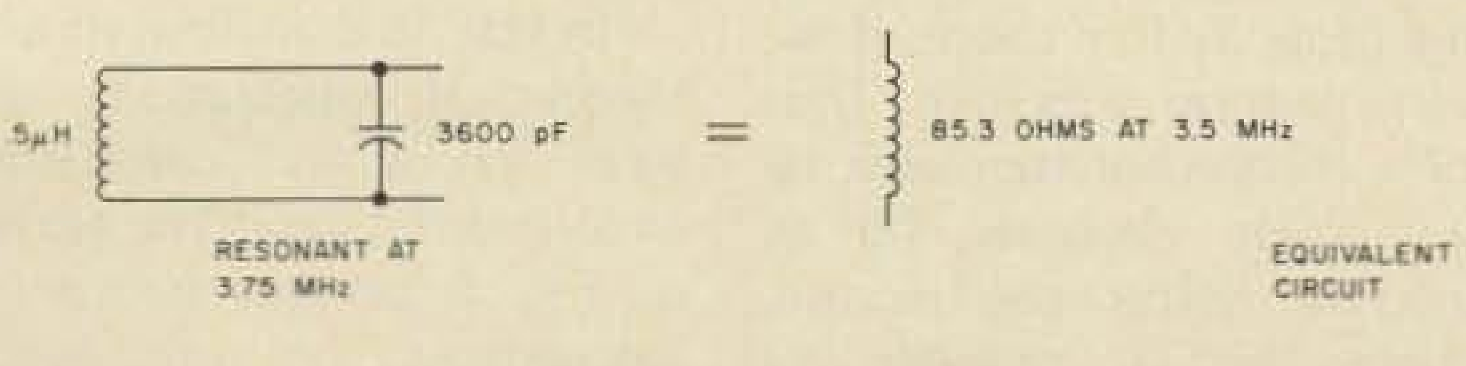


Fig. 4. Parallel tuned circuit.

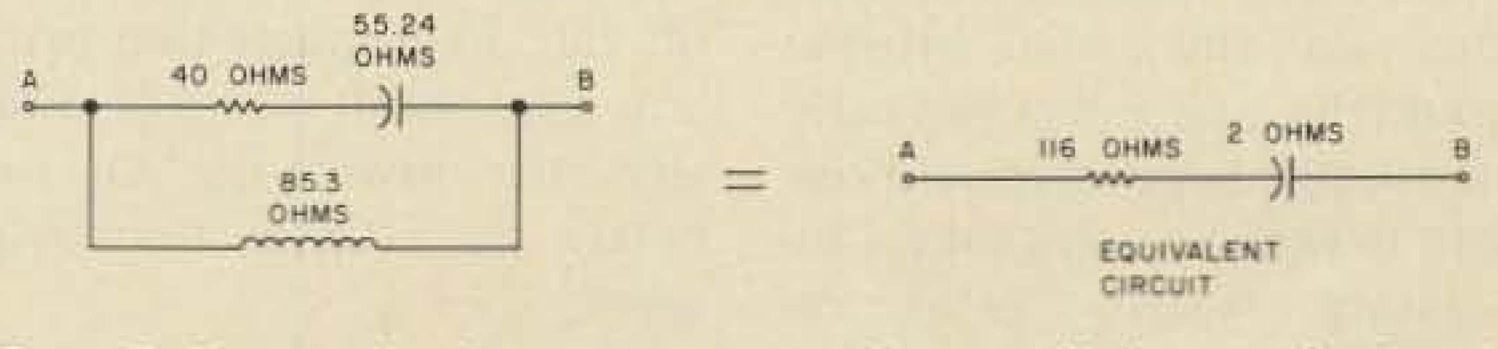


Fig. 5. Basic dipole antenna with parallel tuned circuit connected in at 3.5 MHz.

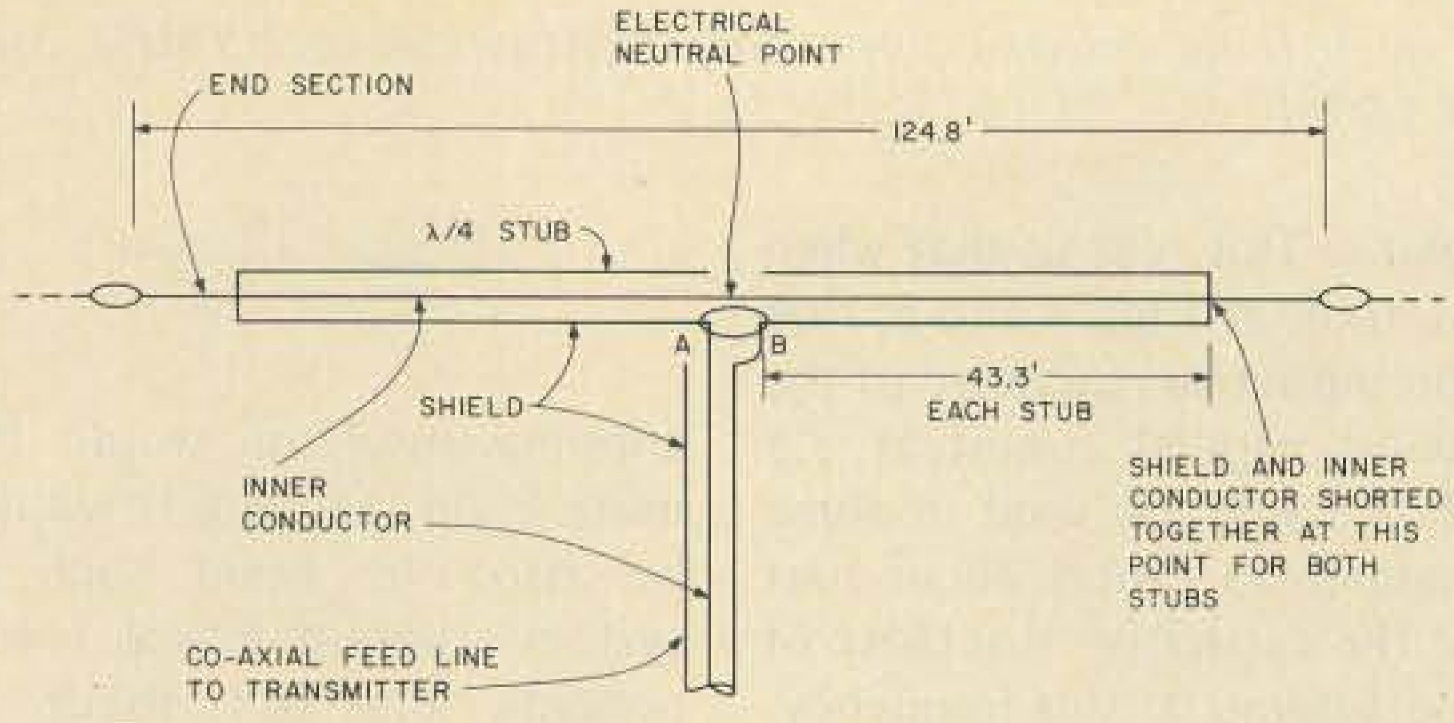


Fig. 6. Coaxial dipole series connected.

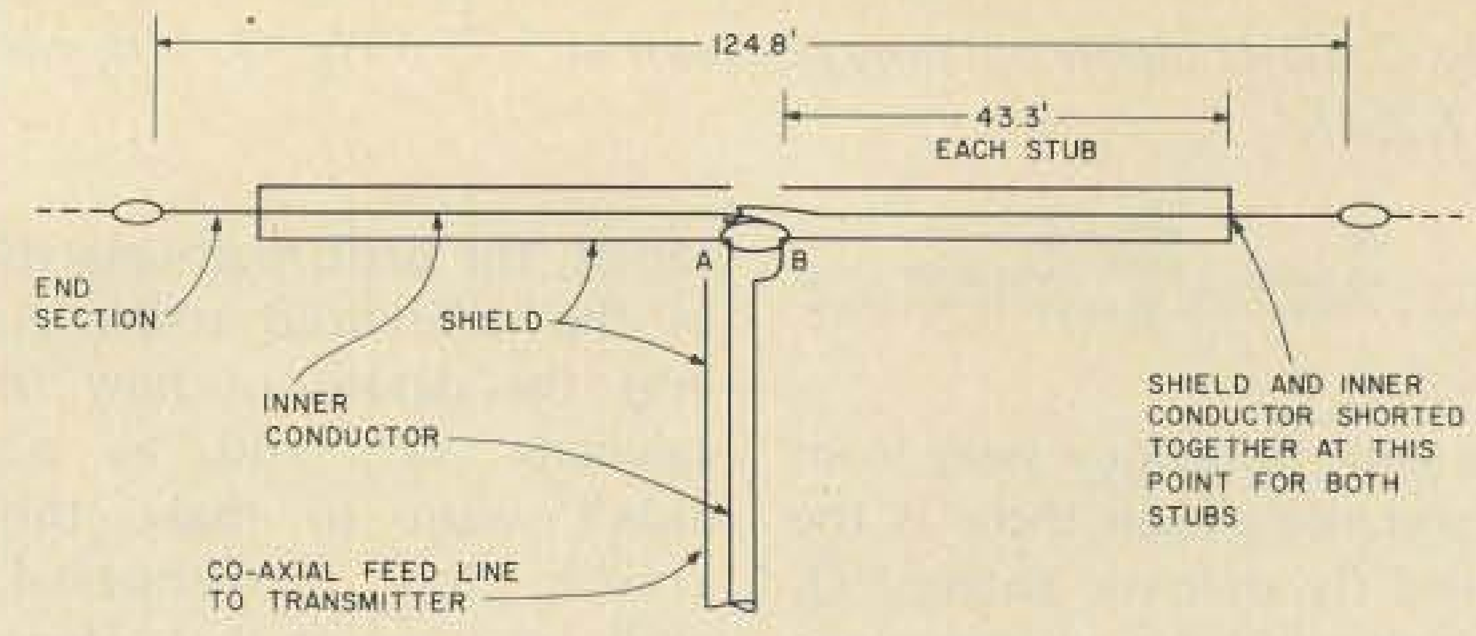


Fig. 7. Coaxial dipole parallel connected.

previously used series connection of 100 Ohms. The stub improvement ratio is a factor of four to one, which is nothing to be sneezed at in any antenna system. So if anyone already has a series double bazooka antenna up, all he has to do is to change over to the new parallel configuration and notice the marked reduction in swr. The series and parallel stub configurations are shown in Figs. 6 and 7.

The original coaxial stub antenna was designed by the staff of MIT for radar use. Their design shows a series stub system. Actually when you start from an original design and are not limited like we are to the use of 50 Ohm coaxial cable for feedline and stubs, the antenna system could be optimized using either a series or a parallel stub system. Naturally the feedline and stub impedances would be different for the two different types of antennas.

The series stub system was apparently used for a very good and simple practical reason. In the series stub system, there is an electrical neutral point where the center conductors of the coaxial stubs join, while the parallel stub system does not have such an electrical neutral. And the electrically neutral point of the series system was used as a mechanical support point. In this way the radar antenna could be easily mechanically physically supported without an expensive electrical insulating system being required. One would have been needed if the parallel stub method had been used.

Apparently, whoever first adopted the concept of a double stub antenna for amateur use just went ahead using the series stub connection without realizing that a parallel stub system is quite superior when using 50 Ohm coaxial line. But that's why I can't help but feel that basic concepts are sometimes better than high mathematics where you can easily lose sight of the basic objective which, to me, is to build an antenna with the lowest possible swr. And that's what this article is really all about.

Antenna Characteristics

Although we mentioned that the referenced theoretical mathematical analysis of a thin wire in free space was correct, there are a few things that should be further considered. There is no disagreement that the free space thin wire coaxial dipole will not work well in the series configuration using a 50 Ohm feedline and 50 Ohm stubs. But, and this is a very big but, the average antenna put up by the average amateur differs markedly from an antenna in free space. An analysis of a coaxial dipole using thin wire implies that there is such a thing as thin wire coaxial cable to be used for the stubs. There is no such thing. The very fact that coaxial cable has a finite thickness would lower the Q of the free space thin wire antenna. And we will find that the lower the Q, the better the stub sections will work.

But more important than the previous technical point is that the resonant resistance of an average amateur antenna is considerably lower than that of an antenna in free space. For a horizontal antenna to have a resistance of 73 Ohms, which is the same as free space resistance, the antenna height has to be at least a quarter wavelength high. And this, for our resonant frequency of 3.75 MHz, turns out to be 65.5 feet high. And in all honesty, how many average amateurs can boast of a pair of poles that high supporting a horizontal antenna 125 feet long? There are none in my acquaintance. Usually our average amateur is lucky if he can get up an inverted V with the center pole about 35 to 40 feet above the ground, with the ends sloping downward. Antenna resistance drops rapidly as the antenna height is decreased. Also, when an antenna is formed into a V, the resonant resistance decreases. Combining these factors and actual antenna resistance measurements, I have found that a good conservative value of antenna resistance will work out to be about 40 Ohms. And that, oddly enough, is the value we have used in our basic dipole calculations. This value is opposed to the theoretical free space value of 73 Ohms. And that is a big difference.

The other important factor is actual antenna Q. An antenna in free space does not have any losses except its radiation to free space, if we want to term it as such. Thus for a theoretical thin wire, its Q is high. However, for an antenna nearer the ground, there are a number of additional but unavoidable losses. These losses are ground losses, losses due to local buildings and bushes, and actual losses in the antenna system itself. My own measurements on amateur antenna systems have confirmed that such combined losses will have a marked effect on reducing the basic antenna Q. And after much thought, a Q value of 10 was chosen. And, as we mentioned earlier, a low Q of our basic antenna system will make the stubs relatively more effective. This fact has been known for some time in the construction of coaxial dipole antennas. Some amateurs even make the end sections of their coaxial dipoles out of open wire transmission line to reduce the Q. A very good example of this is shown in the 1975 ARRL *Amateur Handbook* in the description of a broadband dipole popularized by W8TV. He used open wire line for his end sections, and reported measured values of swr of 1.7:1 at 3.5 MHz and 1.9:1 at 4.0 MHz. But every amateur will have to make his own trade-offs in determining just how he wants to build his own antenna. In my case, I didn't use any open wire line for the end sections, but just extended the coaxial cable. And my own measured swr was a bit higher than obtained by W8TV.

Theoretical and Actual Measured Swr Curves

In the final analysis of any theoretical calculation, the best proof is correlating experimental data. The curves of Fig. 8 are the theoretical calculations of swr based upon an antenna that we had assumed approached the characteristics of that put up by the average amateur. Curve A is the antenna without any stubs connected. Curve B is the same antenna with the quarter wave 50 Ohm stubs connected in series. And lastly, curve C shows what happens when the stubs are connected in parallel. It is very obvious that the parallel stub system is quite superior to that of the series connected system. And, as we had previously indicated, these calculations did not take into account feedline losses.

Fig. 9 is the proof of the pudding. The curve nomenclature is the same as Fig. 8. These measurements were made directly at the transmitter using two four inch Swan WM-1500 wattmeters capable of reading forward and reverse power. The meter accuracy is 10 percent at full scale. Swr calculations were made from the forward and reverse power measured. It was interesting to note that the actual measured data showed a better swr improvement than what the theoretical calculations had predicted. But the measured data clearly shows that a broadband coaxial dipole is an actual reality and not a mathematical impossibility. My own advice is, "Try one, you'll like it."

Final Observations

The final question that should be thought of is, are there any better simple broadband antennas for 80 meters than the coaxial dipole? In my personal knowledge, I don't know of any. The writer of the referenced article mentions such things as a multiwire fan shaped bow tie dipole invented by P.S. Carter of RCA and used since 1937 to obtain the bandwidth necessary for television. This is correct, but when we magnify such an antenna to the proportions needed for an 80 meter antenna, I would suspect that just the mechanical construction would be a bit formidable. He also mentions the work done by Dwight Borton W9VMQ titled, "80 Meter Bow Tie Antenna," *Ham Radio*, May, 1975. This is an extremely interesting article to read. However, from the curves shown by W9VMQ, the double bazooka antenna shows a lower swr than a bow tie antenna made of regular copper wire. It is only when the bow tie antenna was constructed out of galvanized wire, rather than regular copper wire, that the swr of the bow tie was lower than that of the coaxial dipole. Unfortunately, this fact was not brought out by the writer of the first referenced article. It should be quite apparent that the swr of any antenna system can be lowered by using wire with a higher electrical resistance than regular copper wire. But why intentionally introduce losses that are not necessary? That's a trade-off that every amateur will have to decide for himself. My final advice is to "keep your bazookas up and your swr down!"

Antenna Length Calculations

The following information is used in calculating the lengths of the stubs and also the overall length of the antenna. Calculations are shown for an antenna that is resonant at 3.75 MHz. All dimensions are in feet.

$$\text{Stub length} = \frac{(246)(\text{Velocity factor of coaxial cable})}{\text{Frequency in MHz}}$$

And, assuming we use RG-58/A, we look up in the antenna handbook and find it has a velocity factor of .66.

$$\text{Length of each stub} = \frac{(246)(.66)}{3.75} = 43.3 \text{ feet}$$

The antenna overall length is calculated using the equation:

$$\text{Length} = \frac{468}{\text{Frequency in MHz}}$$

$$= \frac{468}{3.75} = 124.8 \text{ feet.}$$

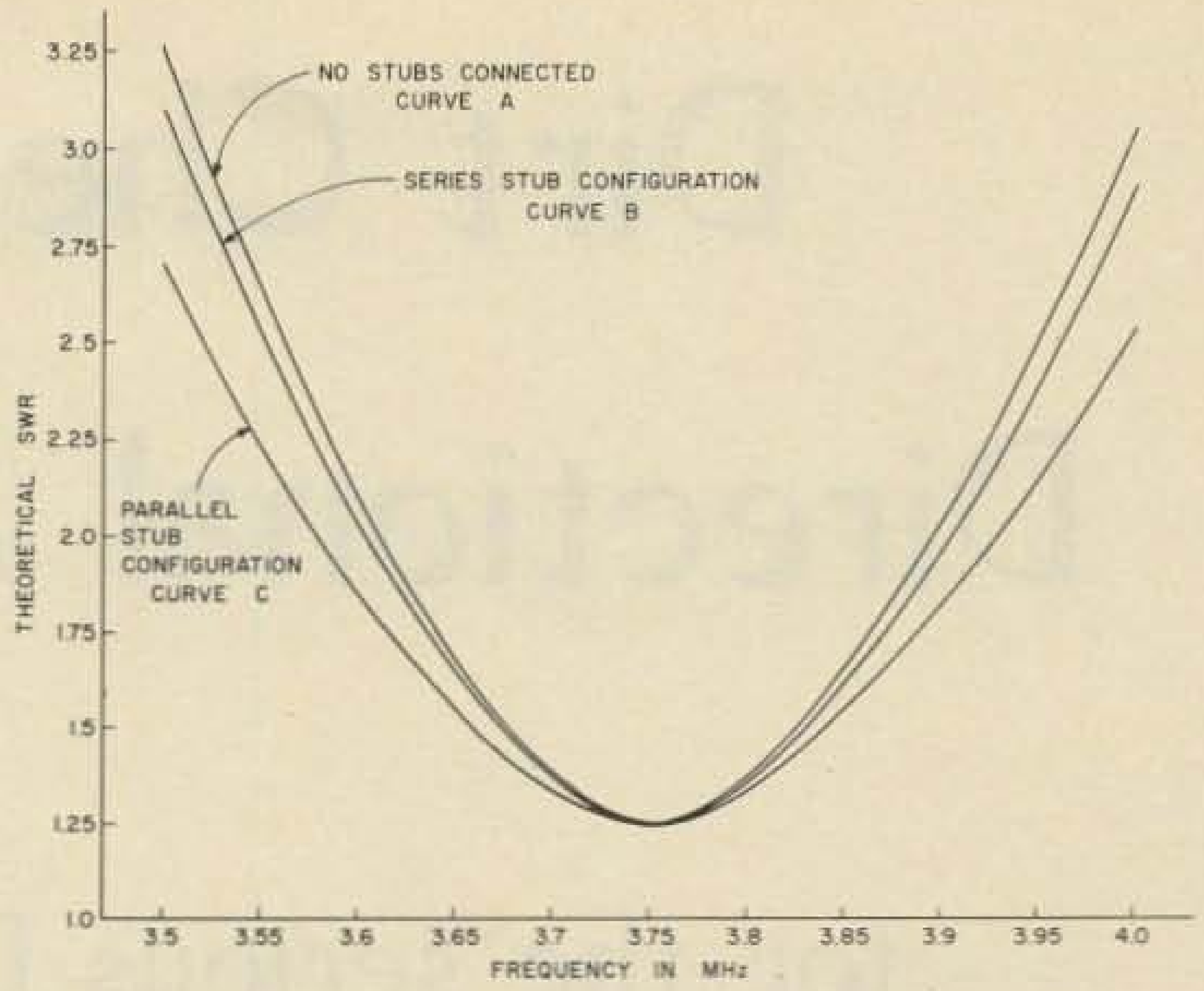


Fig. 8. Theoretical calculations for dipole antenna. $R_A = 40$ Ohms, $Q = 10$, resonant frequency at 3.75 MHz.

If it is desired to make experimental measurements to see what the swr of your antenna is without the stubs connected, it can easily be done as follows. Just connect the center conductor of each coaxial stub to its own shield. Leave the feeder connections as they were.

In Figs. 6 and 7 I've shown the feeder line of coax cable connected directly to the antenna without the use of a balun. My own antenna seems to work fine without a bulun, although a balun may make your antenna more electrically balanced.

It may be necessary to trim and adjust the overall length of the antenna to compensate for end effects and the presence of nearby objects. In my own case, I notice measurable changes in both antenna resonant frequency and swr when I even trim the hedge near the ends of my inverted V coaxial dipole. The ends are about twelve feet above the ground.

And, as previously mentioned, if you use something like an open wire line for your end sections, you will probably further reduce your overall Q and your band edge swr values. The swr you get is a function of several variables, and you'll find that experimentation is both fun and truly instructive, as it has been in my own case. ■

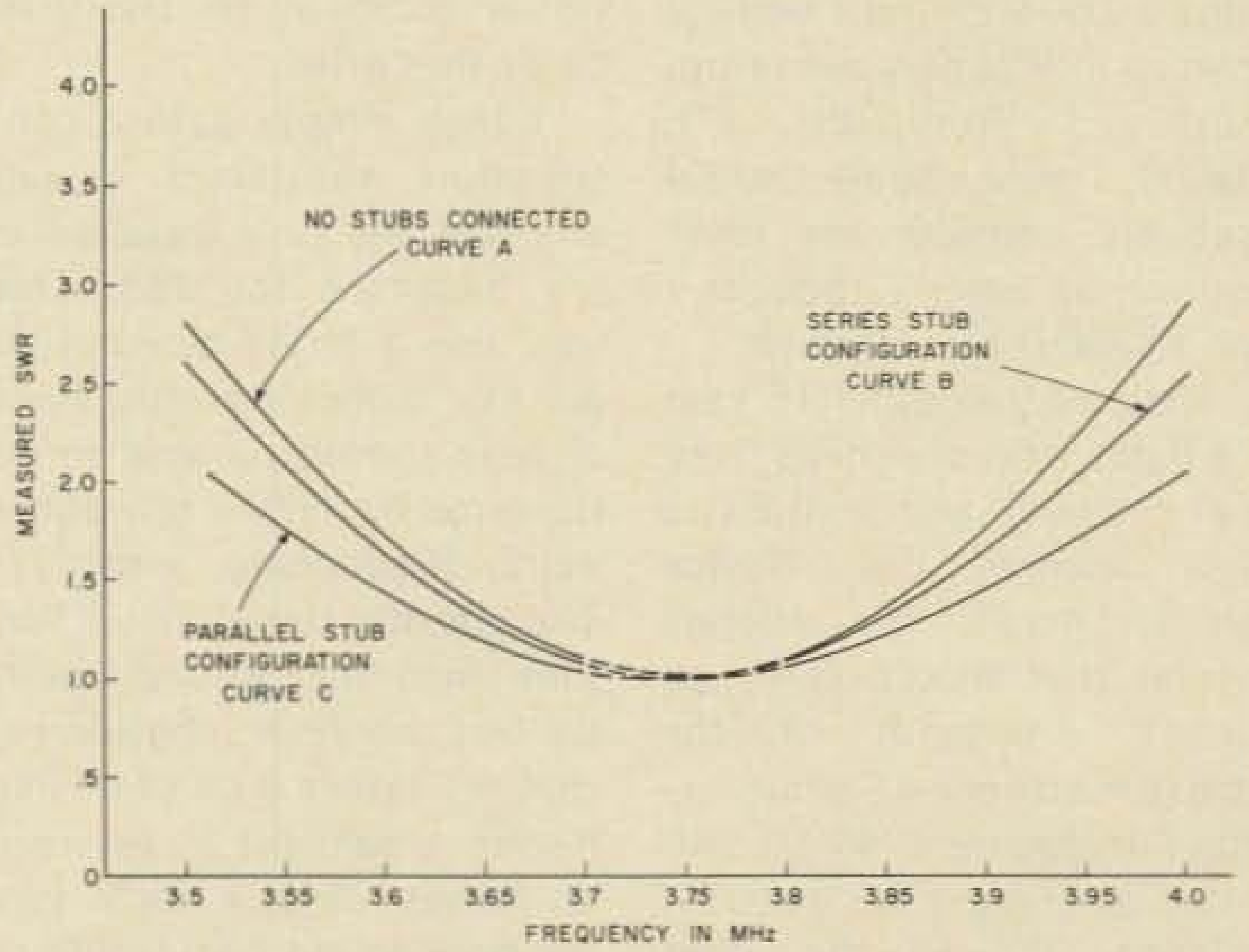


Fig. 9. Actual measured values of swr for inverted V coaxial dipole.