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# Type S Series-Section Broad-banding of 75- to 80-meter Antennas

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## Introduction

A simple antenna modeling method is being presented, which is capable of increasing the bandwidth of most antennas, to about three times, without altering the basic design. It is not intrusive on the antenna itself, or its radiation characteristics. It does not add anything physically to the antenna. All of the broad banding is accomplished in the transmission line. It is called the Type “S” Series-section Broad-banding method.

This broad-banding method has taken all of the broad-banding components, of almost any antenna, and placed them as series-section parts of the transmission line. This means that no heavy and bulky items form a portion of the antenna radiator itself. This is a big improvement, reducing the load on the antenna radiator. Placing all of the broad-banding as part of the transmission line produces a broad-banding that is shielded from all weather effects.

To achieve the desired bandwidths, the series-sections may become longer than desired. For VHF and UHF antennas, these lengths are relatively short, but for the HF bands they may become unreasonably long and sometimes impractical when using the standard Type S method. To overcome this problem in the HF bands, a Transformer Enhanced Broad-banding version of the Type S broad-banding method has been developed. With this method, the broad-banding can generally be reduced to a single 0.5 wavelength line using the most common characteristic impedance lines such as 50 or 75 Ohms. At a frequency of 3.75 MHz, which is the center of the 75/80-meter band, this length is approximately 109 feet long when using a coaxial cable with a velocity factor of  $VF = 0.84$ .

Transformer Enhanced Broad-banding, has the potential to redefine how HF broad-banding is accomplished. Forget about discrete components such as inductors and capacitors, or coaxial stubs. To achieve the desired broad-banding all that must be considered is the transformer (Balun/Unun) impedance ratios, the characteristic impedance of the 0.5  $wL$  broad-banding line and its rated coaxial cable losses per 100 feet. Those are the necessary items required to achieve good broad-banding on many antennas.

In many cases, a Balun is used at the antenna feed point, in order to obtain a balanced feed, and prevent RF from flowing on the outside of the coaxial transmission line. Since this is common, it has become a typical part of the transmission line and by choosing a specialized design it can become part of the Transformer Enhanced broad-banding method.

## Why transformer enhanced broad banding lines are so important

From the very beginning of the development of the Type S series-section broad-banding method, all attempts to broad-band antennas was on the basis of using a single 0.5 wavelength of transmission line and not any multiples. It became evident, particularly in the VHF/UHF bands,

that many of the antennas which were broad-banded, required unusually low or very high line impedances to achieve a suitably low SWR bandwidth. Many required impedances as low as 10 Ohms or as high as 150 to 300 Ohms. Unfortunately, coaxial cable impedances are not available below 35 or above 125 Ohms.

It was quickly found that the use of the higher multiples of the 0.5 wavelength broad-banding lines could allow the use of more realistic coax impedances such as those normally available values of 35, 50, 75, 93 and 125 Ohms. Therefore, having series-sections which might require 1 to 3 wavelengths seemed acceptable for the VHF and UHF bands because the physical lengths were not very long and they were part of the overall transmission line going to the operating position.

There is a fairly constant relationship between the broad-banding line impedance, and the number of 0.5 wavelength sections required for adequate broad-banding. For instance, if you required 10 Ohms while using a 0.5wL line, you could likely use 20 Ohms with a 1.0wL line or 30 Ohms with a 1.5wL line and achieve the same broad-banding. This is also true where there's a need for line impedances above 125 Ohms.

That situation was fine for the VHF and UHF bands, but as soon as antennas in the 75/80-meter HF bands were being modeled, it was quickly realized the lengths were getting extremely long. Although it was possible to broad-band these antennas the coaxial lengths were becoming unrealistic to use.

The modeling program EZNEC Pro 2/v. 5, which has been used for all of the antennas described, has two important features. First, and very importantly, it can take transmission line losses into account when modeling antennas. In the HF bands the losses became a significant factor affecting the shape of the SWR bandwidth, so the cable must be chosen carefully. In the VHF and UHF bands these losses seem to have less effect on the SWR shape.

Secondarily, the program can simulate RF transformers, but unfortunately, it lacks the means to take the transformers insertion losses into account. Nevertheless, this program allows the simulation of transformers, which includes Baluns and Ununs. By using transformers in concert with the Type S series section broad-banding, it is possible to avoid the need for lengthy transmission lines. Instead, for many antennas, we can use a single 0.5 wL broad-banding line generally with 50- or 75-Ohm line impedances. All of the components, along with the modeling program, are now available to create what is called a Transformer Enhanced Broad-banding line.

Quarter-wavelength transformers or series-section matching transformers can be used to match the antenna impedances. The series-sections matching can additionally be modified to enhance the Type S Method so that the SWR at the bandwidth edges can be improved. In most cases, these matching methods are unnecessary when using the Transformer Enhanced method. Instead, a Balun that has the desirable transformer ratio can be used.

### Basic Considerations

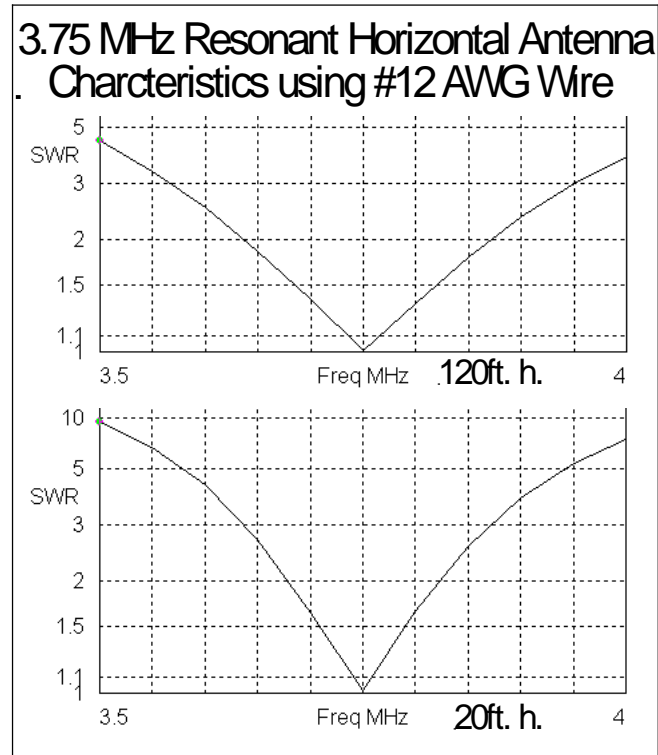
Before we consider the broad-banding aspects it seems appropriate to consider some of the basic horizontal antenna characteristics. It has been found, after broad-banding many antennas, that the basic antenna SWR bandwidth of horizontal antennas becomes narrower as the antenna is mounted closer to ground. Figure 1, shows distinct bandwidth differences between a horizontal antenna mounted at 120 feet and the narrower band with the antenna mounted at 20 feet. This means that the lower antenna starts out with a narrower bandwidth and it becomes more difficult to broad-band and also achieve the same bandwidth or SWR as the upper antenna.

Some of the 75/80-meter horizontal antennas using Type S Transformer hanced Broad-banding seems to have ter characteristic, and are able to achieve almost the same broad-banding over a range of mounting heights. Unfortunately, this entails using transformer ratio that over-broadband and reduces the radiation gain. As shown in Figure 2, the resonant impedance of a horizontal antenna at 3.75 meters varies from 46 to 91 Ohms as the mounting height is changed from 10 to 140 feet and adds more broad-banding difficulties.

The 75/80 meters is the widest of the HF amateur bands if considered on a percentage basis. So, whatever broad-banding can be achieved on this band, it can be achieved on the other bands. Antennas can readily be rescaled to other frequencies.

Most of the HF antennas discussed will have a 0.5 wavelength broad-banding line shortened by the velocity factor, which generally will be  $VF=0.84$ , unless stated otherwise. This length is approximately 109 feet for 3.75 MHz and will be used to make radiation gain comparisons between various antennas. All of the antennas cited have had their radiator lengths adjusted for the best SWR performance at each specific height above Average Soil.

Figure 1



Resonant Antenna height (ft)	Resonant Impedance in Ohms
140	63
120	75
100	88
80	91
60	81
50	71
40	66
30	51
25	48
20	46
15	47
.10	53

Figure 2

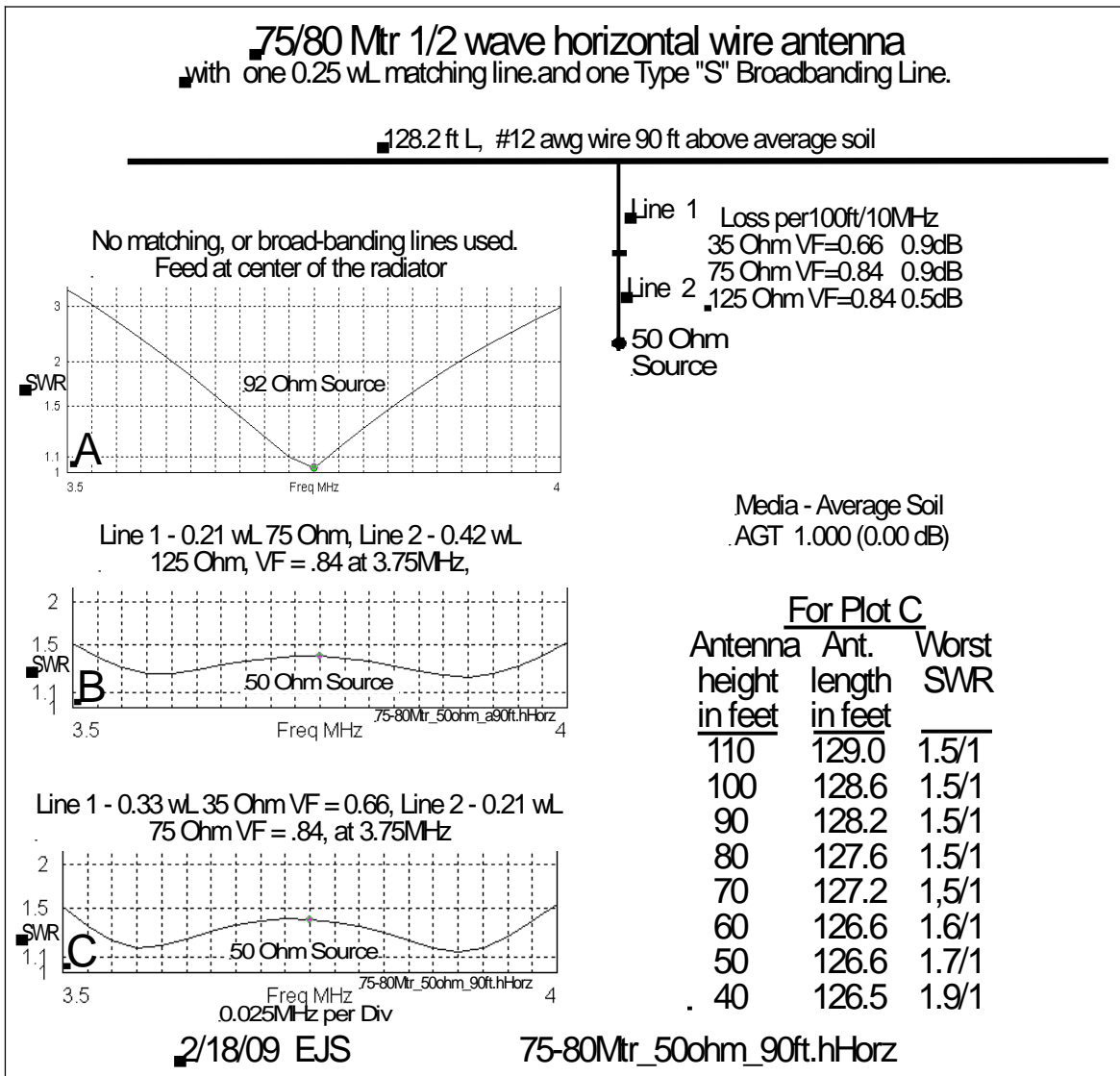


Figure 3

**75/80-meter 0.5 wL Horizontal Wire Antenna using one 0.25 wL matching section and one Type S Broad-banding Line**

Figure 3 shows a 75/80-meter antenna, which uses Type S series-section broad-banding and it has done it in a very simple fashion. A height of 90 feet was chosen arbitrarily but it happens to be a height where the SWR seems to be at its best. At antenna heights below 60 feet it becomes more difficult to obtain a good SWR. At a height of 90 feet the radiator center impedance was measured at 92 Ohms, as shown in plot A. If it had been 112.5 Ohms then a 75-Ohm quarter-wave line would perfectly match it to 50 Ohms. But, experience has shown that some mismatch at the band center can lead to better SWR across the band-pass. In this case, a 75-Ohm quarter-wave line will match 92 Ohms to 61 Ohms, which is adequate to obtain a SWR of less than 1.5:1 at the band center.

Often there are distinct advantages to interchanging the positions of the matching and the broad-banding lines. Doing this permits the use of totally different impedance for the broad-band line, which might produce a better overall SWR. Plots B and C have these lines reversed. Plot B

has the matching line next to the radiator while plot C has it after the broad-banding line. Both produced very good SWR responses so there is a choice in deciding which coax impedance is the best from a cost, availability and physical standpoint. Keep in mind that using series-section match at the antenna, and then adding Type S broad-banding, causes the bandpass to shift higher in frequency. This requires adjustments of the radiator length and/or rescaling the antenna back to the desired band center. This does not happen when using the broad-banding at the antenna and then adding the series-section matching line. A Quarter-wave matching line can be placed before or after the broad-banding lines and there will no shift in the frequency of the bandpass

Plot C seems somewhat better than plot B, so it was chosen to demonstrate how the SWR can change if the radiator height is changed gradually from 40 to 110 feet. A chart titled “For Plot C” is shown in Figure 3, located at the lower right side.

The chart shows the best SWR around 80 to 90 feet high and gradually getting worse toward 50 feet. As the radiator is raised to 110 feet the SWR is still good. Each time the radiator height was changed there was some shift in the band-pass center and deterioration of the SWR. To correct this, the radiator length was changed each time the height was changed and these radiator lengths are shown in the second column. The overall shape of the SWR plot was restored each time the height was changed and compared well with Plot C, except the overall SWR of the plot curve increased or decreased.

Obviously, this antenna needed to be matched from 92 Ohms to 50 Ohms, but beyond that, the only broad-banding added was of a single 0.5 wL line. This was a small effort to bring the 3:1 SWR at band edges down close to 1.5:1. The far-field gains for the antenna of plot B, mounted at 90 feet above average soil, are shown in Figure 4. The quarter-wave matching lines of both Plot B and C contribute some amount to the broad-banding although their basic function is to match.

Plot B gains in dBi at 90 ft. high		
3.5 MHz	3.75MHz	4.0 MHz
4.44	5.49	4.95
@45.4d.	@41.8d.	@38.9d.

Figure 4

### 75/80-Meter Horizontal Antennas using Transformer Enhanced Broad-Banding

The 75/80 meter Antenna shown in Figure 3 gave good SWR responses for plot B and C, but neither used 50-Ohm coaxial cable. Additionally, plot B required 166 feet of coaxial cable while plot C required 142.63 feet. Both the 125- and 35-Ohm cables are not the most available

such as the commonly used 50- and 75-Ohm lines. The Transformer Enhanced Broad-banding method, by comparison, will be used to show how a standard 50-Ohm coaxial cable of only 109.5 feet in length can be used. Figure 5 shows that we can obtain a SWR plot that is every bit as good as plot C in Figure 3 using a shorter line with commonly used 50-Ohm coaxial cable.

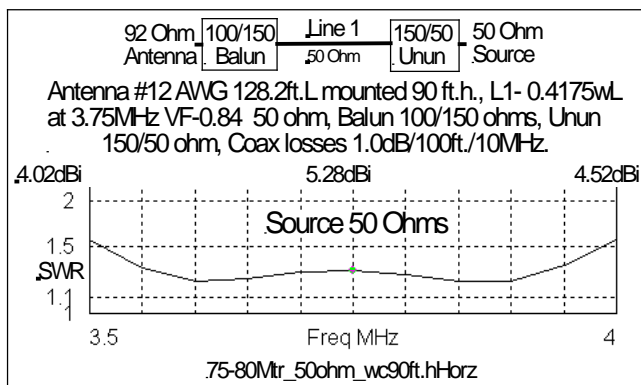


Figure 5

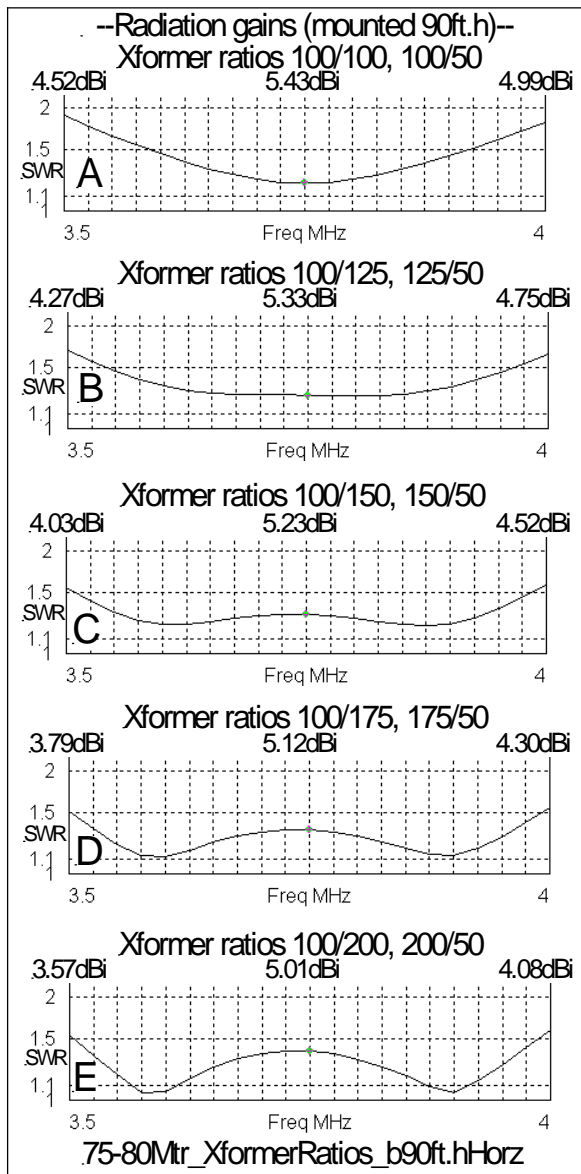


Figure 6

to maintain the highest dBi radiation gain. Therefore, it is desirable to choose the transformer ratios that produce adequate SWR across the band, and not the best SWR.

Plot B of Figure 6 has been enhanced with more details, as shown in Figure 7, and has been selected to demonstrate a possible choice. The transformer impedance has been transformed to only 125 Ohms, but it has achieved a SWR that is very good across the

Since the antenna impedance is 92 Ohms, which is not too far from 100, a balun with the transformer ratio of 100/150-Ohms is used. This new, higher impedance, which is three times as high as 50 Ohms, allows a 50-Ohm line to easily produce a very good SWR response. Then a 150/50-Ohm Unun is used to transform the impedance down to 50 Ohms. While using the 109.5-foot length of broad-banding coaxial cable, the radiation gains are as follows: 3.5 MHz – 4.02 dBi, 3.75 MHz – 5.28 dBi, and 4 MHz – 4.52 dBi.

The Transformer Enhanced broad-banding as shown in Figure 5 produced a very good SWR across the band, but the radiation is slightly lower compared to the standard Type S broad-banding method. Figure 6 shows several plots of the SWR using a variety of transformer ratios. Plot C is an exact plot of Figure 5, which will be used as a basis of comparison.

The transformer ratios were gradually changed from transforming from 200 Ohms impedance down to 100 Ohms as shown in plots A thru D. As can be seen from these plots, transforming to 100 Ohms produces much less SWR broad-banding, but it has the advantage that the radiation gains are higher and those gains at the band edges do not drop off as much. What this means, is that it is desirable to use the least amount of broad banding as necessary in order

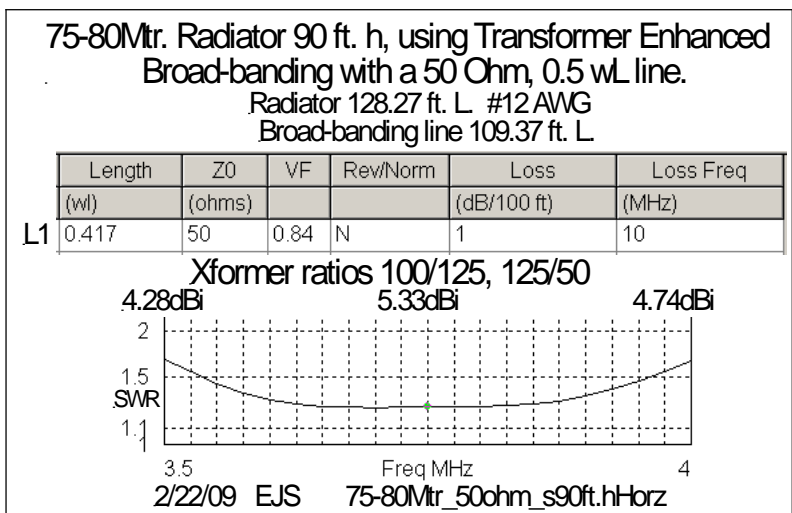


Figure 7

band. The radiation gains are very good, considering that it is using 109 feet of coaxial cable, but additionally, the gains at the band edges has only dropped moderately. This shows the flexibility of using the Transformer Enhanced broad-banding method.

### 75/80-Meter Horizontal Antennas using Transformer Enhanced Broad-Banding and mounted at 120 feet height down to 30 feet

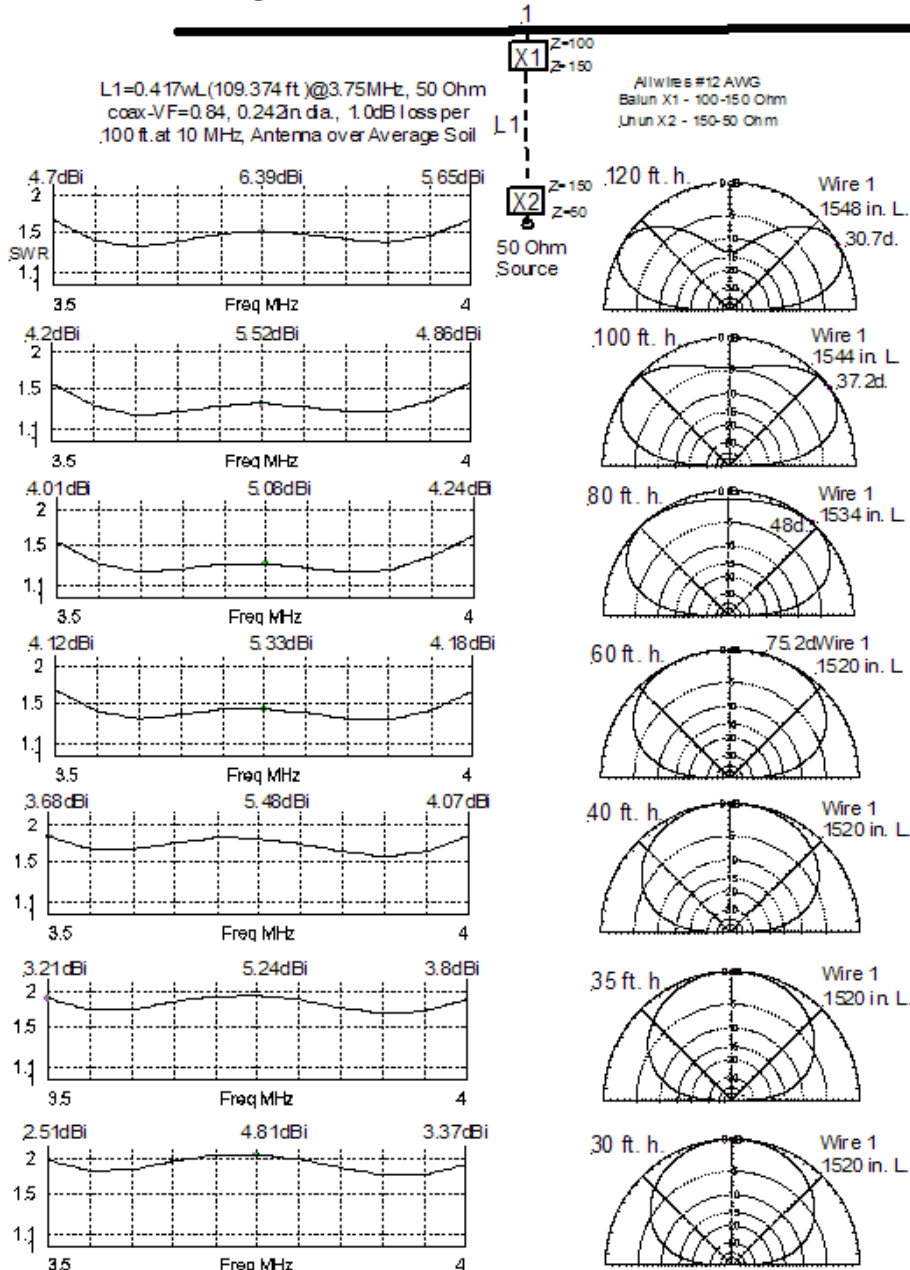


Figure 8

Figure 8, is an antenna with transformer ratios that have been restricted to 100-150 Ohms and 150-50 Ohms in order to keep the band edges from dropping off as much as using greater transforming ratios. It has produced good SWRs down to an antenna height of about 60 feet. The radiation gains seem relatively good within this range. As stated earlier, it is hard to get good SWR

when the antenna is mounted closer to ground. In this antenna the SWR becomes 2:1 across the bandwidth with the antenna mounted 30 feet high.

### Obtaining the best SWR with an antenna mounted 30 feet above ground

Looking back at Figure 2, we find the antenna impedance is approximately 50 Ohms when a horizontal wire antenna is mounted 30 feet above ground. In Figure 8, all of a better SWRs obtained have been seen with the antenna mounted from 60 to 120 feet above ground, where the antenna impedances are in the area of 63 to 91 Ohms. So an attempt was made to improve the SWR at 30 feet by changing the transformer ratios.

In Figure 9, the 30-foot high antenna of Figure 8 was modified to use transformer ratios of 75/175 and 175/50 Ohms. This change did not improve the SWR on the band edges but it made significant improvements across the greater portion of the bandwidths with SWRs in the vicinity of 1.5:1. When the impedances were transformed up to 200 Ohms there was no overall improvement.

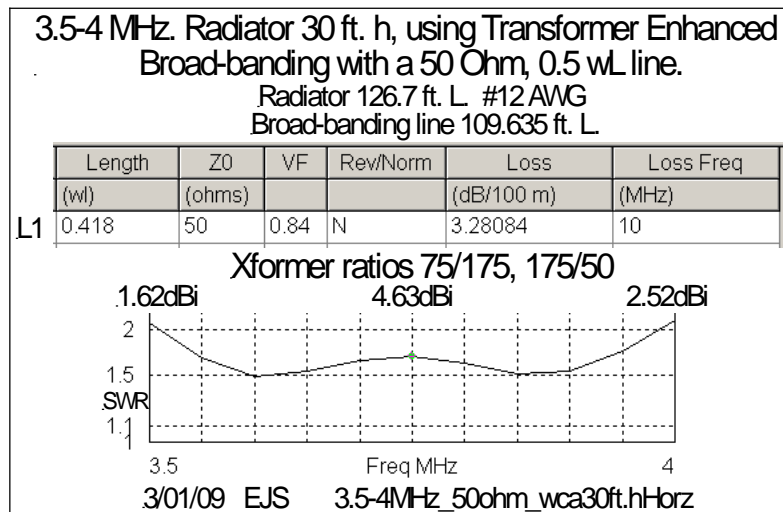


Figure 9

### The effects of coaxial cable losses

There is a question as to the effects that changes in the broad-banding coaxial cable losses have on the SWR bandwidth and radiation gains. In order to show this clearly, Figure 10 is presented. The various figures displayed show the 50-Ohm coaxial cable losses ranging from 0.5 to 1.5 dB. From these plots, it can be seen that the greater the coaxial losses the lower the SWR is across the bandwidth. As might be expected, the radiation gains at the center of the bandwidth are reduced in about the same inverse proportion as the coaxial cable losses. But, the most significant changes occur on the band edges where the gains change much more. In plot A, the band edge gains drop off at 0.67 dB and 0.24 dB in respect to the gain at the bandwidth center. In contrast, the plot E drop off is 13.6 dB and 0.84 dB. It would seem that plots C, which uses coaxial cable with losses of 1dB/100feet/10MHz, is the best compromise and happens to be the cable losses that have been specified in most of illustrations. Many of the RG-8X (0.242 inch od) coaxial cables have losses at 0.9 dB/100feet/10MHz.

**75/80-meter 0.5 wL Horizontal Wire Antenna using Transformer Enhanced Broad-banding with 35-Ohm coaxial cable**

The antenna shown in Figure 11 is transformer enhanced using a stepped-up impedance of 100 Ohms. Since the impedance of the antenna is 92 Ohms, there is no need for any step-up. This allows the use of a 1:1 ratio Balun, which is readily available. Instead of using a 50-Ohm 0.5wL broad-banding line, a characteristic impedance of 35 Ohms was used. Then a 100- to 50-Ohm Unun is used to match it to 50 Ohms. This produced a SWR bandwidth that is generally below 1.5:1 and has good radiation gains across the band. This antenna is capable of performing well but the 35-Ohm cable is not very common. This is a good example of the versatility of this broad-banding method. Since the 35-Ohm coax has a velocity factor of VF=0.66, the broad-banding line length has been used at 86 feet. So, this antenna has everything going for it except obtaining the coaxial cable.

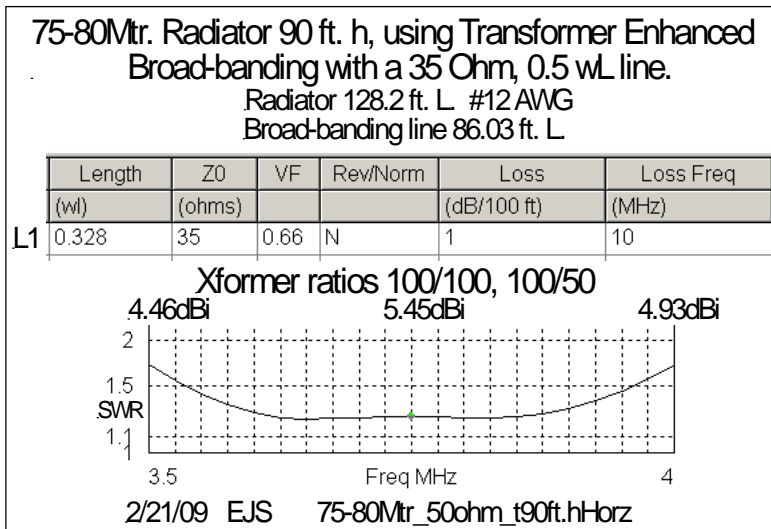


Figure 11

**75/80-meter Horizontal Reference Antennas, showing the maximum gains possible at 90 feet high over Average Soil**

75-80Mtr. Reference Antenna at 90ft.h			
Freq.	Gain	Wire length	Impedance
3.50MHz	6.15dBi	1642in.#12	92.0 Ohms
3.75MHz	6.23dBi	1530in.#12	91.3 Ohms
4.00MHz	6.36dBi	1443in.#12	89.3 Ohms

Figure 12

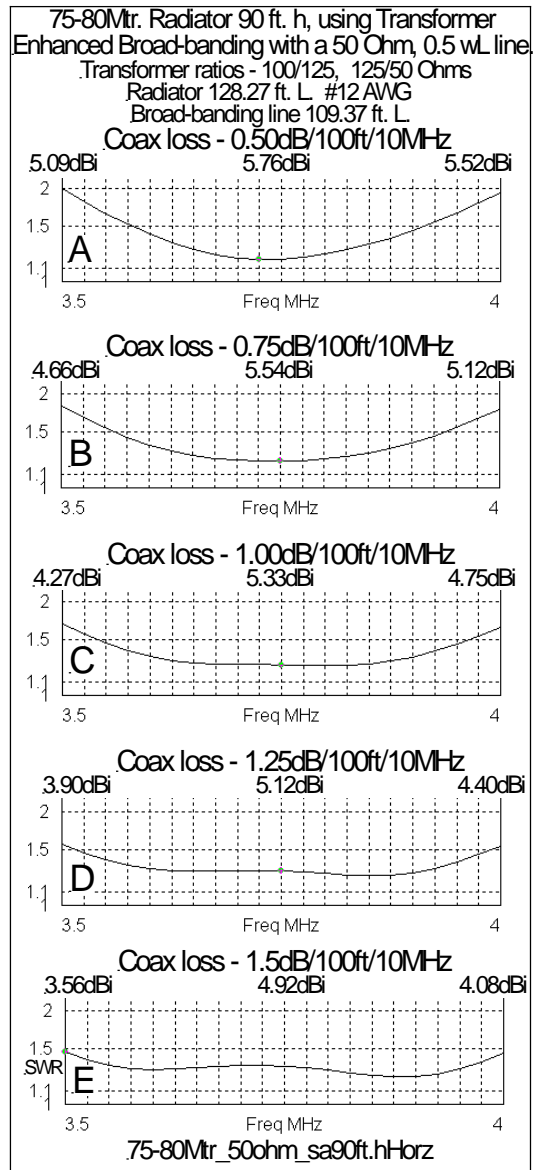


Figure 10

The chart in Figure 12 was created to show the maximum possible radiation gains in dBi possible from a wire radiator mounted 90 feet above Average Soil. The radiator lengths were adjusted for resonance at each of the three frequencies and center-fed. It is very hard to achieve these gains from a single antenna, but it is a reference to be strived for and compared to.

A Couple-Radiator broad-banded wire antenna, which should have the lowest losses of most antennas, was mounted at the same height and its SWR and radiation gains were measured. It had a SWR of 1.5:1 across the band and its radiation gains were 6.12, 6.23 and 6.09 dBi at 3.5, 3.75 and 4.0 MHz. As you can see, these gains were very comparable with the reference chart.

If a 100-foot length of coaxial cable is used, with losses of 1.0 dB/100feet/10MHz, you could expect the radiation gains at 3.75 MHz to drop to about 5.3dBi with the reference antenna and many of the type S broad-banded antennas described.

### **A challenge for specially designed Baluns and Ununs**

In order to achieve Transformer Enhanced Broad-Banding, there exists a great need for Baluns and Ununs to be designed with a variety of impedance ratios and with balance at the antenna end. Without these special designs, many of these antennas cannot be built. They only have to cover 75/80 meters but they have to have the typical Power handling capabilities.

Are there any of the *antenneX* readers, up to the challenge of designing such Transformers and building some of the Transformer Enhanced antennas? Once you have the proper transformers, building the antenna is pretty simple. I'm sure the *antenneX* readers would be very interested to see the results.

### **Some History**

The 20th edition of the ARRL antenna handbook pages 9-7 through 9-9 presents a background, showing that in 1950, R. M. Fano presented a theory of "Broadband Matching of Arbitrary Impedances," but it was limited to lossless matching networks. In 1990, Frank Witt wrote an article titled "Optimum Lossy Broadband Matching Networks for Resonant Antennas," which was published in RF Design on April 1990. In September 1993, Frank Witt AI1H presented an article titled "A Simple Broadband Dipole for 80 meters," published in QST September 1993. Frank Witt brought the use of 0.5 wavelength transmission lines for broad-banding to a practical reality in this article.

On November 1997, L.B. Cebik W4RNL (SK) became aware of this broad-banding method, and placed a very complete article titled, "Notes on a wideband 50/75-Ohm coaxial feed system for low HF band dipoles and Vees" found at the site [www.cebik.com](http://www.cebik.com) (just create a login for access). L.B. Cebik enhanced our understanding of Frank Witt's broad-banding methods, and gave him due credit.

I also, give Frank Witt recognition for his lengthy efforts and his many articles regarding the use of 0.5 wL (or multiples) transmission line sections, as a means of broad-banding antennas.

Frank Witt started with discrete components (L and C) to achieve broad-banding of an antenna, and then converted them to a transmission line equivalents. This is where he began to use 0.5 wL (or multiple) line sections on HF antennas. My broad-banding started with a 146 MHz, 0.25

wL transmission line transformer's broad-banding characteristics and added 0.5 wL sections to improve the SWR bandwidth. We both began from totally different starting points, but have been accomplishing the same effect. Certainly, Frank's efforts predate mine by many years and I give him credit for his accomplishments.

L.B. Cebik is to be thanked for his valuable assistance in reviewing an earlier version of my book on Type S Broad-banding and his many suggestions, particularly including coaxial cable losses in each of the modeled antennas shown. L.B. Cebik is now deceased, but his greatness, knowledge, expertise and willingness to help others will not be forgotten.

My "Type S series-section Broad-banded Antennas" book is soon to be published by *antenneX*. It covers a large variety of antennas with many broad-banding and matching methods, and is full of illustrations. **-30-**

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## Brief Biography of Author



Edward J. Shortridge, W4JOQ has been a licensed amateur for 70+ years. Ed began his interest in radio and electronics at the early age of 14, when the VHF/UHF state-of-the-art was super-regenerative tube detectors, Long-Line oscillator transmitters, using #45 or #10 tubes. The only choice of frequency measuring devices at that time was Lecher Wires. He became a licensed Amateur radio operator at 18 years of age.

He joined the Naval reserves as a radioman in order to save money for college. After radio school, he was assigned to the Key West naval base. He had duty in the radio laboratory, radio receiving room, and was in charge of the main transmitter room.

Ed met his wife Marilyn while stationed at the Key West Naval base (NAR) and they were happily married together for only a short period of time before a national emergency was declared and he was soon shipped overseas during World War II. He had to remain in the U.S. Navy for a total of five years. He was chief radioman for two years as part of Admiral Hall's staff of the "5th Amphibious Force" and participated in invasions of Algeria, Italy (Salerno), Normandy (Omaha Beach), Philippine Islands and Okinawa. After returning to civilian life he fathered two children and worked at the following companies in Miami, Florida:

- Communications Company- Chief engineer-22 years
- Microtenna-Chief engineer-2 years
- Wackenhut Electronics-Chief engineer-3 years
- Shakespeare Marine Electronics-Chief Engineer - 7 years
- Hallicrafters-Director of radio engineering-3 years
- Aerocom-Chief engineer-7 years

Profession was directly involved in the design and development of:

- First VHF/UHF land mobile radio, and repeaters

- Balloon mounted VHF/UHF repeaters for Vietnam war
- Moon Landing VHF radio communication simulation
- Ground base to satellite communications
- HF and VHF Marine radio
- Marine depth finding equipment
- US military radio equipment
- Antenna design and manufacturing

Constant study, correspondence and seminar courses, along with professional engineering study groups, provided him with a background for continued electronic knowledge enhancement. His antenna design experience at several of these companies propelled his interest and experience in antenna design.

He retired in 1990, built a very nice retirement home. But in 1992, one third of it was destroyed by Hurricane Andrew, with all the ham radio, very good test equipment and all of his engineering library. In 1999, Ed bought a 116 acre mountain cove in western North Carolina and built another home.

Being in a mountain cove, there were concerns about what type of antenna could be used to get signals out of the cove, so the purchase of an EZNEC antenna modeling program helped. Over his engineering career, he designed many types of antennas, but had to do it the hard way without the new technological tools that emerged. There were many ideas over the years, but they had been too difficult, and time-consuming to pursue.

With the new modeling program, it became much easier to come up with designs. Several basic ideas that seemed a standout were worked on. They worked out quite well and were expanded into a large variety of antennas. First it was wideband antennas, but another basic idea was adaptable to widening most narrowband antennas.

So far, Ed has spent 9 years of constant full-time effort on antenna designs, and is very excited about many ideas and concepts. There is not enough time in the day to satisfy his curiosity.

In July 2009, Ed turns 89 years of age, still in relatively good health. His Grandfather lived to be 98 and was quite active throughout. Possibly, Ed can equal or even outlive him and have many more years of productive life ahead with the hope of contributing to the understanding of antennas.

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