Chapter 18

The Broadband Double-Bazooka Antenna — How Broad Is It?

(Adapted from Technical Correspondence, *QST*, September 1976)

Sec 18.1 Introduction

The increasing interest in using the coaxial dipole (sometimes called the Double-Bazooka antenna) for its questionable increased bandwidth is disturbing, especially in view of the results of an analysis and some experiments I performed and published several years ago. The antenna, with its inner section of coax and its end sections of open-wire transmission line (ladder line), was popularized for amateur use by Charles Whysall, W8TV, with an article in July 1968 *QST (Ref 29)*. It appears in several editions of *The ARRL Handbook,* although it has never appeared in *The ARRL Antenna Book*. The results of my analysis and experiments indicate that the coaxial stubs in the coaxial-dipole configuration in general use by amateurs cannot provide the degree of bandwidth that users of the coaxial dipole appear to be measuring. Thus, it appears that features other than the shunt-compensating reactance provided by the coaxial stubs within the dipole must be responsible for achieving the bandwidth credited to the coaxial feature.

Here's why the shunt-reactance compensating feature cannot make any significant contribution to bandwidth when the feed-line impedance is the usual Z_C = 50 ohms. Depending on the height above ground, the input impedance of the average 40-meter or 80-meter amateur dipole generally runs from 50 to 80 ohms of resistance at resonance. Thus, at resonance, the mismatch on a 50-ohm line is generally quite low, from less than 1.1 to around 1.6 at worst. On either side of resonance, the mismatch increases rapidly because of the reactance appearing in the dipole impedance. With the addition of the coaxial reactance-compensating shunt stubs, the dipole reactance should be either canceled at best, or at worst, reduced somewhat by the opposite shunt reactance provided by the stubs.

Sec 18.2 Reactance Cancellation

Although you'll see later why it can't be, let's first assume hypothetically that complete cancellation of the reactance can be achieved by the shunt reactance of the coaxial stubs. This means the cancellation is obtained by a *parallel*-connected reactance, which raises the series resistance of the dipole impedance to its equivalent parallel-circuit value, which is *much higher*. And here is the crucial point. When you use a feed line having an impedance which already matches the dipole terminal resistance rather well at resonance, the higher mismatch off resonance caused by the dipole reactance will not be significantly different, whether it is caused by the reactance of the uncompensated dipole or by the increased resis-

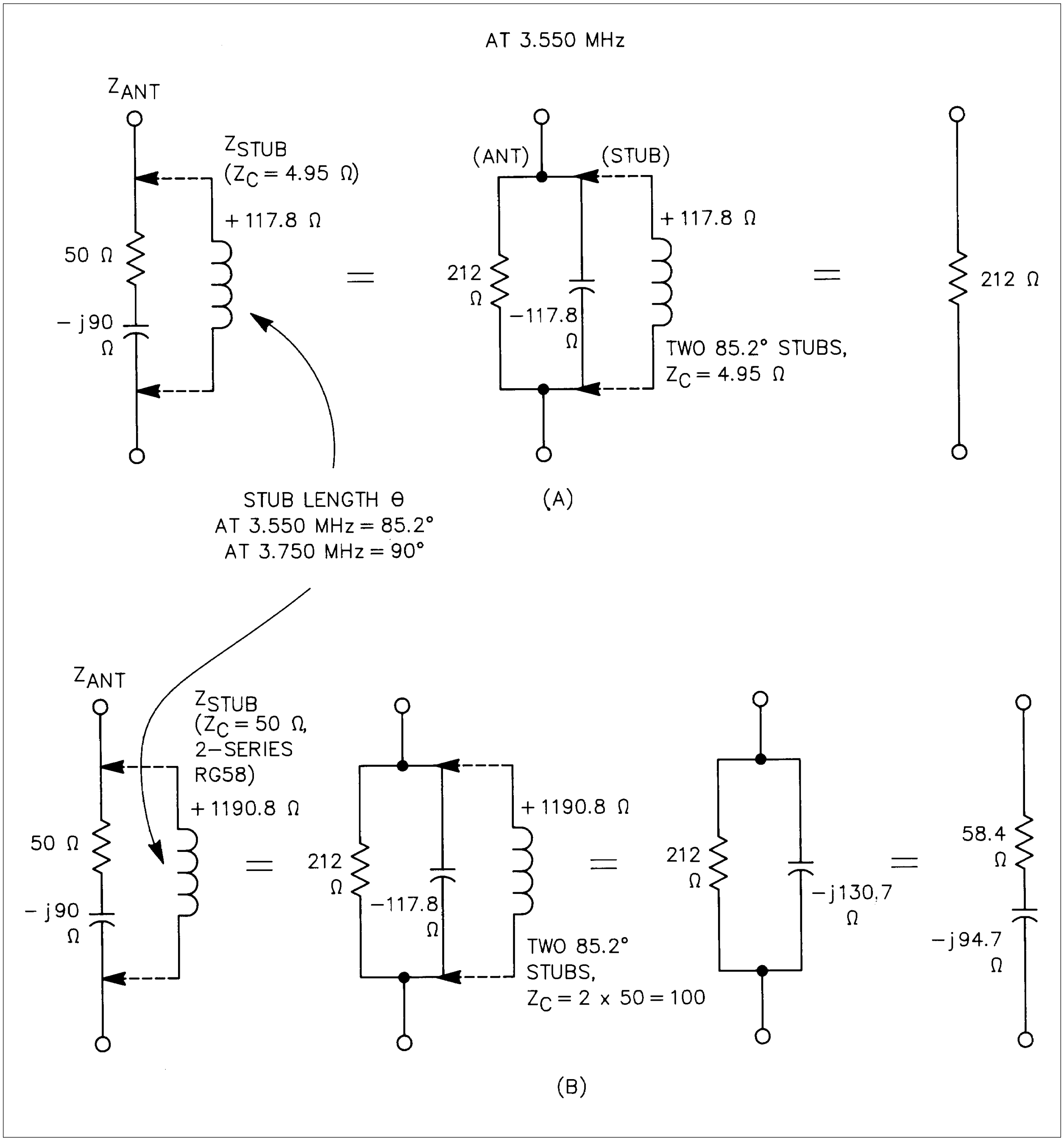

Fig 18-1—Showing the impedance transformation for (A) 4.95-ohm center coaxial section, and (B) 50-ohm center section. At both A and B, the SWR without coaxial stubs is 5.04:1; with stubs at A it becomes 4.24:1, and in the practical case at B, 4.9:1.

tance received in exchange for the canceled reactance.

To illustrate with an example, consider an 80-meter dipole at a height which yields a resonant terminal impedance of 55 + j0 ohms at 3.75 MHz. The mismatch is 1.1 referred to 50 ohms. At 3.55 MHz, 200 kHz below resonance, the series impedance of the dipole is approximately 50 – j90 ohms, which yields a 5.04:1 mismatch. Now a 90-ohm inductive reactance placed in *series* with the dipole terminals would *cancel* the 90-ohm capacitive dipole reactance, and would leave the terminal resistance at 50 ohms. And we would indeed have a perfect match.

Unfortunately, the reactance provided by the stubs in the coaxial dipole is in *parallel* with the dipole terminal impedance, *not in series*. And what a difference this makes! The values of the equivalent parallel-circuit components of the dipole impedance at 3.55 MHz ($50 - j90$ ohms) are $R_P = 212$, and $X_P = -117.8$ ohms, as shown in Fig 18-1A. When the –117.8 ohms of capacitive dipole reactance is completely canceled by an equal inductive reactance in *parallel* with the dipole impedance, the resulting impedance is $212 + j0$ ohms. Bad news! The terminal resistance of the dipole made resonant at 3.55 MHz by the shunt inductive reactance is now 212 ohms, raised from 50 ohms by the parallel connection! Canceling the dipole reactance with *parallel* circuitry has raised the resistive component by a factor of 4.24 from 50 ohms up to 212 ohms, and coincidentally, the mismatch is now 212/50 = 4.24:1. This is the lowest mismatch obtainable with any type of parallel compensation, because even though the dipole reactance has been completely canceled, we're still stuck with the 212-ohm dipole terminal resistance.

Obviously, a reduction in mismatch from 5.04:1 to 4.24:1 is hardly worthwhile, even if it could be accomplished. But it can't. Why? Because a canceling reactance of 117.8 ohms would require a coax having a characteristic impedance Z_C of only 4.95 ohms for the stubs — impractical to build. Here's more bad news: Stubs made from 50-ohm coax yield a reactance ten times too high — useless. What about 75-ohm coax? — 1.5 times worse. Incredible, you say? Example continues: A short-circuited stub, λ/4 resonant at 3.75 MHz made from 50-ohm coax, yields an inductive reactance of 595.4 ohms at 3.55 MHz, again 200 kHz below resonance. These values are calculated from the following equations below at 3.55 MHz.

$$\text{Stub length } \theta = \frac{3.55 \times 90^\circ}{3.75 \text{ MHz}} = 85.2^\circ \qquad \text{(Eq 18-1)}$$

Shunting reactance per stub

$$X = Z_C \tan\theta = 595.4 \text{ ohms} \qquad \text{(Eq 18-2)}$$

when stub $Z_C = 50$ ohms, and $\theta = 85.2^\circ$

Stub impedance required, each stub

$$Z_C = \frac{X \cot\theta}{2} = 4.95 \text{ ohms} \qquad \text{(Eq 18-3)}$$

when $X = 117.8$ ohms, and $\theta = 85.2^\circ$

The stubs in each dipole half (595.4 ohms each) are connected in series with each other through their center conductors, so the total inductive reactance of the series combination is twice the value of the single stub, or 1190.8 ohms. This is the value appearing in parallel with the dipole impedance when using 50-ohm stubs. (Stubs of 75 ohms would yield 1786.3 ohms.) The combined parallel components of the dipole impedance and shunt-stub reactance ($R_P = 212$ ohms and $X_P = -117.8$ ohms in parallel with stubs of +1190.8 ohms) yield total parallel-circuit component values of $R_P = 212$ ohms and $X_P = -130.7$ ohms. The series-equivalent dipole input-terminal impedance is now $58.4 - j94.7$ ohms, also shown in Fig 18-1 at B. The result? A whopping big reduction in mismatch from 5.04 without stubs, all the way down to 4.9:1 with stubs! Going still further, using the impractical 4.95-ohm stubs that would cancel all the dipole reactance, the resulting non-reactive dipole terminal impedance of $212 + j0$ ohms would still yield a 4.24:1 SWR on the 50-ohm feed line. Conclusion? Isn't it obvious that the stubs are ineffective? And shouldn't it be disturbing?

So you ask what other features can be responsible for the lower mismatch values that appear to be measured by many coaxial-dipole users. I'll give you a number of possibilities.

First, the mismatch values shown here are those which appear at the junction of the feed line and the antenna, while values measured at the input of the feed line will be somewhat lower because of line attenuation.

Second, increased radiator thickness, especially when the stubs are constructed from RG-8, reduces the dipole characteristic impedance, resulting in less reactance than with the thinner wire dipole for the same frequency excursion away from resonance. (But who wants to hang 125 feet of RG-8?)

Third, the extensions for building out from the shortened, short-circuited ends of the coax stubs to obtain an *external* half wave are usually of multiwire construction such as ladder line, which further increases the effective radiator thickness. Such is especially helpful at the outer ends of the dipole, where the voltage and the electric field are high. This reduces the off-resonance reactance still further.

Fourth, the external dielectric material covering the stub coax increases both dipole capacitance (increasing the electrical length) and effective diameter of the radiator. However, indications under investigation suggest this increase in effective diameter is also accompanied by increased ohmic loss in the external dielectric, which decreases the Q, and thus increases the bandwidth at the expense of efficiency.

And fifth, in the range above 3:1, many SWR indicators show readings considerably lower than the true value. If you are interested in pursuing the subject further, I invite you to read my paper entitled, "A Revealing Analysis of the Coaxial Dipole Antenna," appearing on page 46 of *Ham Radio* for August, 1976 *(Ref 62).*

Sec 18.3 Resistive Losses

Since I wrote the Technical Correspondence item on which the above information is based, the true reason for the increased dipole bandwidth obtained with the Double-Bazooka has been discovered. But the reason is not a happy one. Frank Witt, AI1H (ex-W1DTY), with the aid of a computer, has discovered that the increased bandwidth of the Double-Bazooka obtained by many amateurs actually arises from the previously undetermined resistive loss due to the shunt conduction of the internal dielectric material in the coaxial cable used to form the stubs, and not by reactance cancellation from parallel-connected coaxial stubs *(Ref 122)*. In other words, the reduction in SWR obtained by those who use the Double-Bazooka is from lossy resistive loading, and not from reactance cancellation. Unfortunately, the resistive loading results in a reduction in radiated power, power lost in heating the stubs. Thus the users of this antenna are trading radiated power for a lower SWR on the feed line.

This turn of events is ironic for two reasons. First, as I showed earlier, the reactance available in the coaxial stubs in the Double-Bazooka is insufficient to obtain any practical amount of reduction in the SWR-producing antenna-terminal reactance, much less total cancellation. And second, even if the stubs could provide sufficient reactance to obtain complete cancellation, the improvement in bandwidth would still have been inconsequential as a result of the cancellation, as I proved mathematically.

Earlier in this chapter, and in my coaxial dipole analysis *(Ref 62)*, I pointed out the reason *no bandwidth improvement is possible from parallel-circuit reactance cancellation when the feed line impedance is 50 ohms.* You'll remember, this is because the parallel-circuit form of the stub connection used in the cancellation raises the effective terminal resistance as the reactance is lowered, resulting in a negligible reduction of mismatch. I also pointed out in the analysis that an improvement in bandwidth could be achieved with parallel-circuit reactance cancellation by using a feed line having an impedance higher than the resonant terminal resistance of the dipole, and then accepting a corresponding increase in mismatch at the resonant frequency of the dipole. I showed that by using a 144-ohm feed line to feed a dipole having a resonant terminal resistance of 72 ohms (yielding a 2:1 SWR at resonance), the 2:1 SWR bandwidth could be improved from 165 kHz (on 50-ohm line with no stubs) to 565 kHz by canceling the off-frequency dipole reactance with 19.7-ohm stubs. This results in a bandwidth improvement factor of 3.4. This arrangement is particularly appealing for the 80-meter band, because it achieves an SWR of less than 2:1 across the entire band, except at the center frequency where it is exactly 2:1.

In my analysis I offered no concrete suggestion for practicing this arrangement, except to suggest the use of two 75-ohm coaxial lines side by side resulting in a 150-ohm balanced feedline. However, I considered using a lumped-constant capacitor and inductor at the feed point for an impedance transformer to obtain the required increase in feed-point impedance, and for reactance cancellation. But I decided it was impractical to use, so I discarded the idea. On the other hand, Frank Witt came up with the same idea and made it work! *(See Ref 122.)* In addition, he also came up with a very clever method of using a shorted λ/4-stub impedance transformer to obtain both the required step-up of impedance and the reactance cancellation *(Refs 123 and 124)*. His method uses the larger RG-8, or RG-213 coaxial cable for the λ/4 stub, ensuring optimum bandwidth improvement by reactance cancellation but with minimal loss in the cable stub. The Snyder dipole *(Ref 130)* uses a somewhat similar method of broad-banding, but with higher loss than with Witt's method, because the Snyder dipole uses the higher-loss RG-141 coax for the reactance cancellation.

For anyone wishing to build a true broad-banded 80-meter dipole, the Witt articles referenced above provide all of the necessary details, plus the explanation of how it works.

One-of-a-kind Double Bazooka, RCA Model POW! POW!, with double end-fire, narrow-beam, high gain, heavy particle thruster, presented to the author at the dinner celebrating his retirement from the RCA Astro-Electronics Division's Space Center in November 1980 after 31 years with the Company.