ANTENNA FEEDPOINT INVESTIGATION

BY FRED JOHNSON,* ZL2AMJ

Using an r.f. bridge to make impedance measurements at the transmitter end of the antenna feeder can lead to improvements in antenna performance and a better understanding of its operation.

IN NOVEMBER and December 1963 *CQ* published articles on the use of the Smith chart as an aid to the solution of aerial matching problems.[1] This was followed in March 1964 with a further article on the use of the chart for designing a broadband matching unit.[2] These articles showed how the chart could provide answers that are otherwise difficult to determine without lots of calculation. These articles stimulated enthusiasm to analyze the performance of an eighty meter antenna using the Smith chart to see if its performance could be improved.

An idea of the construction of the antenna in question can be gained from fig. 1. The length of the flat-top was determined from the formula $468/f_{mc}$. A center feed-point is used for it is the more convenient and 75 ohm coaxial cable is used as the feeder. The transmitter uses a pi-coupler and feeds the coax direct; no antenna tuner or balun is used. This antenna has operated for many years and has given good performance across the entire ZL eighty meter band (3.5 to 3.9 mc). The antenna was restricted by siting problems and added height could not be managed. The theory books show that the

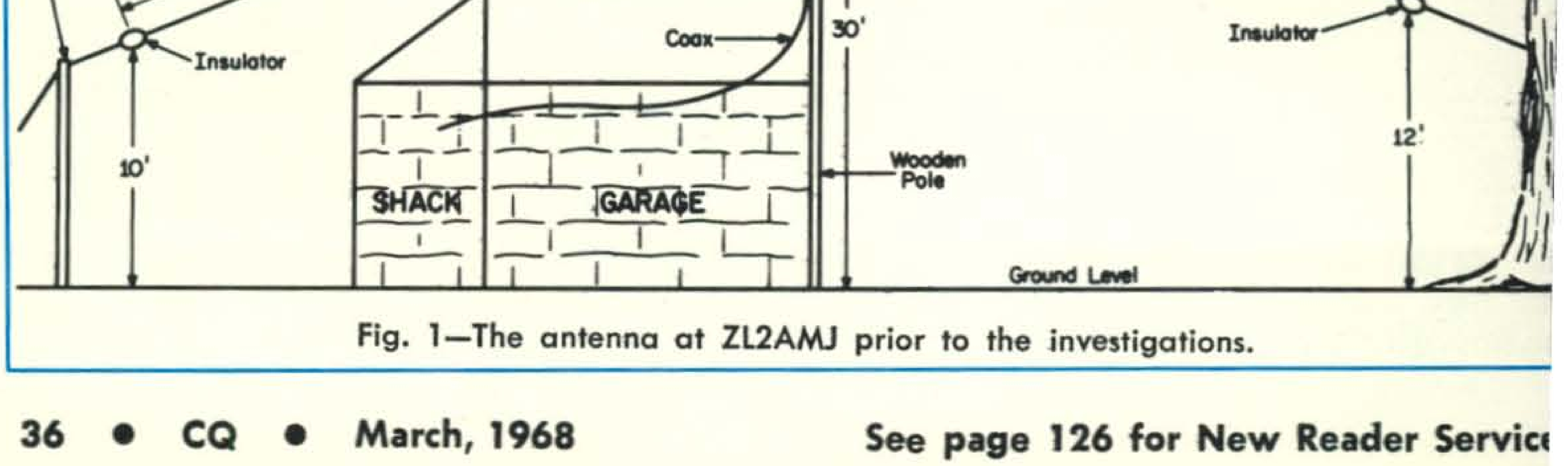

Fig. 1—The antenna at ZL2AMJ prior to the investigations.

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[1] Amis, P.C., "Antenna Impedance Matching," *CQ*, Nov., 1963, Part I, page 63; Dec., 1963, Part II, page 33.

[2] Lee, P.H., "Broadbanding the Mark III Antenna on Eighty Meters," *CQ*, March, 1964, page 43.

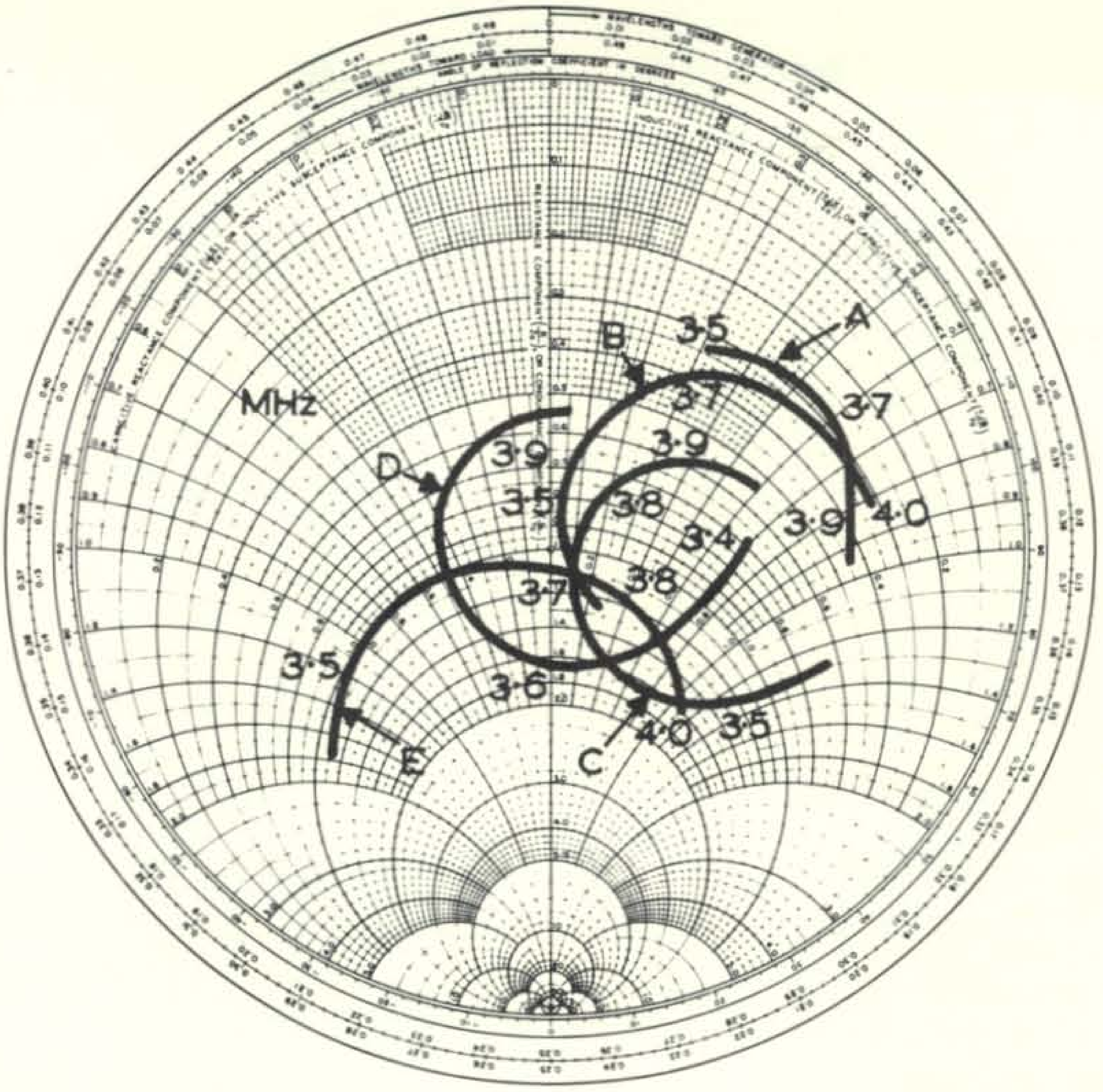

Fig. 2—The Smith chart showing the impedance plots for the various measurements. Curve "A" is for the original antenna. Curve "D" the transmitter end of the feeder and curve "E" the impedance at the dipole center after the improvements were made.

nput impedance of a half-wave dipole lo-ated less than a quarter of a wavelength bove ground will not be 75 ohms. On this asis alone a standing-wave could be ex-ected to exist on the feeder. The presence f the ground and obstacles would have the ffect of lowering the resonant frequency of he antenna. In spite of these points the de-ice worked, loaded up in the approved man-er, and gave acceptable results. It was only re-read of the *CQ* articles that prompted ny further work.

Smith Chart

A General Radio r.f. bridge type 1606-A as obtained on loan and used throughout e experiment. The shack receiver was used s a null detector and a signal generator as e signal source. The input impedance to e coaxial cable at the transmitter end was easured at different frequencies. These re-lts were normalized (*i.e.* divided by 75) d plotted on the Smith chart. This chart as then used to determine the nature of e improvements. The plot of the input impedance of the original antenna is shown as curve "A" on fig. 2. The standing-wave voltage ratio plotted as rectangular coordinates is shown in fig. 3 (curve "A"). These were obtained from direct measurement from the radial scales of the chart. Note that the s.w.r. varies from 3.5 to 4.9 across the band —not very good! The final curve, the s.w.r. as seen by the transmitter, is shown as curve "D" on fig. 3. This is the result of some very simple improvements. To improve the s.w.r., the impedance plot on the Smith chart should be "shifted" to be as close to the center of the chart as possible.

Antenna Adjustment

The first adjustment made to the antenna was to cut six feet off one leg of the flat-top by inserting an insulator at a point six feet from one end. A second plot was then made from a second set of impedance measurements. This is shown as curve "B" in fig. 2. At 3.5 mc the s.w.r. is now 1.2 rising to 4.7 at 3.9 mc. A distinct improvement! It appeared that the antenna should be shortened

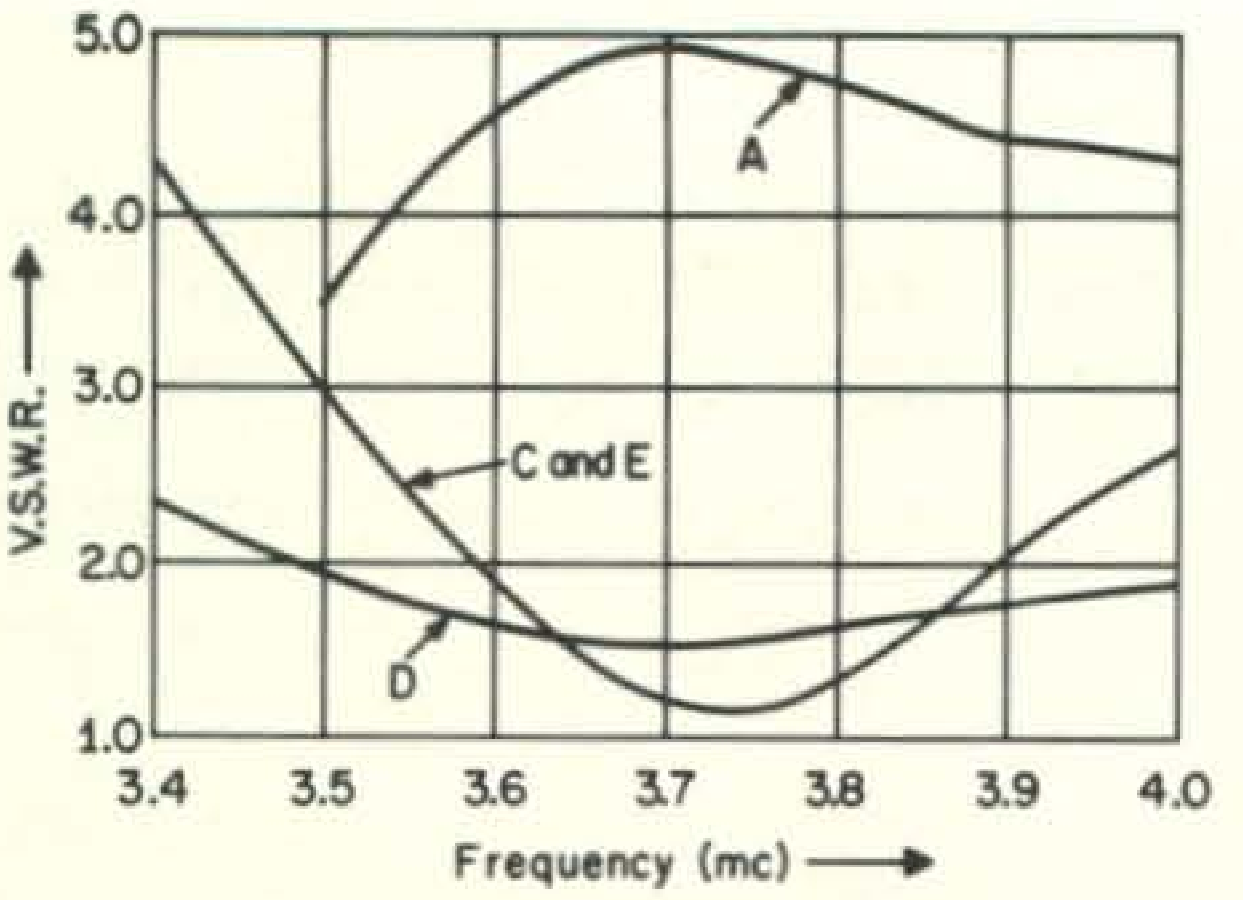

Fig. 3—The voltage standing-wave ratio for the various curves of fig. 2. These have been read off the Smith chart using the radial "voltage standing-wave ratio" scale and transferred to these rectangular coordinates for easier interpretation.

further to bring the point of lowest s.w.r. towards the band center (3.7 mc). So the next adjustment was to shorten the other leg of the flat-top by six feet and make a third set of measurements. These are plotted as curve "C" in fig. 2. The s.w.r. is now 3.0 at 3.5 mc and 2.0 at 3.9 mc with lowest value 1.1 at about 3.75 mc. This would be ideal provided operation was contemplated around 3.75 mc with a higher s.w.r. accepted at each end of the band. The transmitter loaded into this quite happily but further improvements were considered possible.

If the plot could be shifted to enclose the center of the chart then a lower s.w.r. could be expected at each end of the band but with a higher s.w.r. at the center, possibly a constant value of s.w.r. across the band.

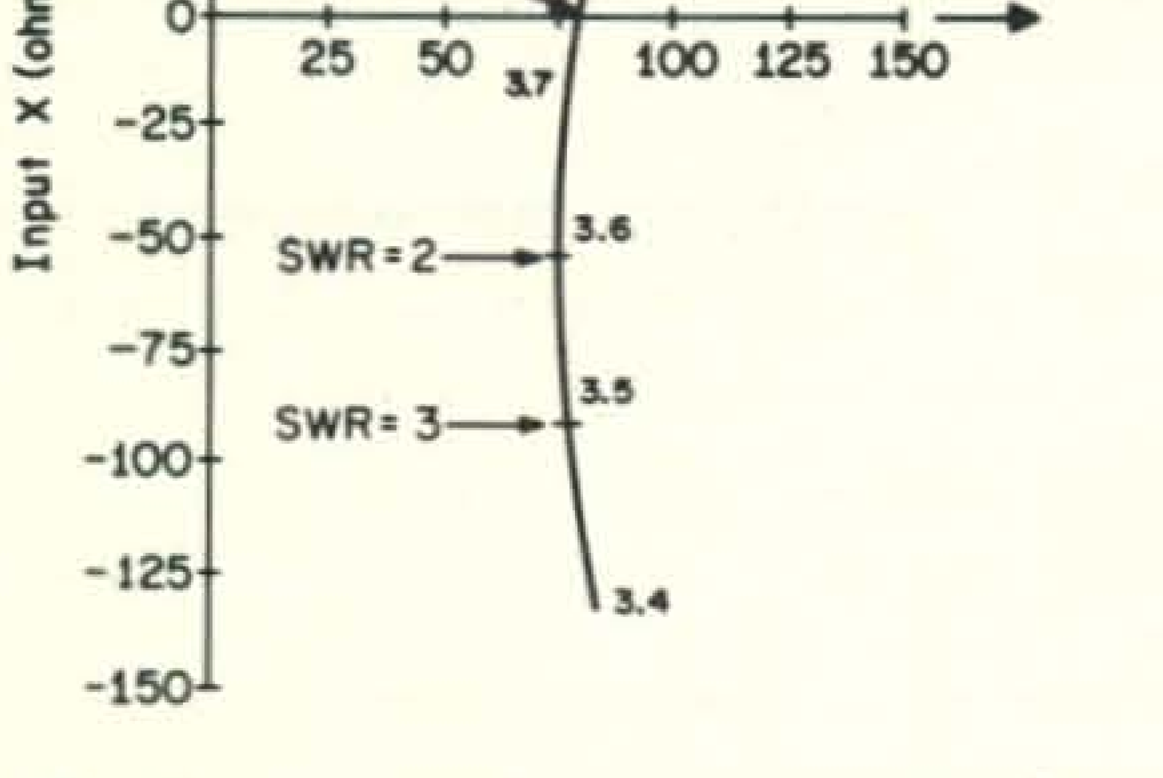

Fig. 4—The input impedance at the dipole center expressed in rectangular coordinates. This diagram is obtained from curve "E" of fig. 2.

Inspection showed that if 0.55 ohms capaci tive reactance at 3.9 mc were added in serie at the transmitter end of the cable, then th loop would encircle the center. This 0.5 value is a normalized value and is 0.55 × 75 = 41 ohms in practice which works ou to be a capacitor of 1000 mmf. With thi capacitor in series at the feed point, th input impedance as measured is shown a curve "D." The s.w.r. is now 1.6 across mos of the band and rises to 1.8 at the ends. Thi is a vast improvement over the original inpu characteristic. It must be remembered tha the transmitter "sees" curve "D" but th actual s.w.r. on the feeder coaxial is sti curve "C". This is important whe feeder-line losses are to be considered. A the frequencies in question, these losses ar negligible and can be readily neglected.

Feeder Length

The physical length of the feeder used i 67 feet. By putting a temporary short acros the distant end (at the dipole center) an measuring the input impedance of the coaxi cable, it was found that the input impedanc was zero ohms at 4.86 mc. This represen the frequency for which the cable length an electrical half-wavelength or multiple c a half-wavelength. The free-space wav length for this frequency is 101 feet, so th velocity factor of the cable is 67 ÷ 101 c 0.66.

Now that the velocity factor and physic length is known it is possible to produ a table showing the electrical length of th cable as multiples of a wavelength, for eac of the frequencies under consideration. Th is shown as Table I.

Curve "E" is produced from Table I an curve "C." This represents the input in pedance at the center of the dipole. It is co structed by travelling round the chart on constant s.w.r. circle for the distance state in Table I towards the load. Each frequenc point is plotted independently using the out wave-length scales on the chart. For exampl travelling counter-clockwise (*i.e.,* towar the load) for 0.393 of a wavelength fro the 3.9 mc plot (curve "C") and at a co stant distance from the center of the cha produces the 3.9 mc plot on curve "E."

Curve "E" is the plot that would obtained if the r.f. bridge and all its trir mings could be elevated to the dipole cent to measure its input impedance. This of course, rather impractical.

TABLE I

f_{mc}	*length*
3.4	0.343λ
3.5	0.353λ
3.6	0.363λ
3.7	0.373λ
3.8	0.383λ
3.9	0.393λ
4.0	0.403λ

Table I—Relationship between frequency and the electrical length of the feeder.

From curve "E" a graph with rectangular coordinates can be produced to show how the input reactance and resistance varies with frequency. This is shown as fig. 4. The normalizing has been removed to give practical figures.

The bandwidth of an antenna can be expressed in several ways, between frequencies of certain s.w.r. (say 2 or 3) or between frequencies where the input impedance phase-angle is 45 degrees. It's necessary to express the method of measurement whenever quoting the antenna bandwidth. The size of wire used for the flat-top could be altered to effect some change in the bandwidth. However the pi-coupler in the transmitter can handle the present feeder input impedance characteristic quite successfully —so things are going to be left as they are.

Fig. 4 shows that the input impedance of the dipole is 82 ohms resistive at 3.73 mc. Figure 3 (curve "D") shows that the s.w.r. is 1.9 maximum across the band of frequencies in question. These are features that I was not aware of before this experiment started.

The radiation pattern from this antenna has not been considered for with limited space there is little that can be done to improve it.

From a transmitter point of view the antenna now loads better and on-the-air tests indicate an improvement *at negligible cost*. Even if there had been no improvement, I now *know* a lot more about my antenna, which, after all, is one of the things ham radio is for! ■

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