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ELECTRONIC DEFENSE GROUP TECHNICAL MEMORANDUM NO. 26

SUBJECT: Modifications to the Antenna System of Technical Report No. 45 to Reduce VSWR

BY: B. F. Barton

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In EDG Technical Report No. 45, the results of a study of the feasibility of an efficient wide band antenna system were presented. Matching networks were obtained which were based on a somewhat idealized monopole antenna characteristic. These matching networks produced, theoretically, a match to within 1.44 db of the available generator power for a monopole of length to radius ratio $\ell/r = 60$ over a 3.1 to 1 frequency range. Experimental results indicate that, due to matching network imperfections and the existence of what has been referred to as base capacitance, a loss approaching 2 db which corresponds to a VSWR of approximately 4 may exist in limited regions in the band. This value corresponds to a reflection by the load of 36 percent of the transmitted power. Power distributed amplifiers which might be used to drive the antenna system in certain applications, however, are commonly designed to operate with an output VSWR not greater than 2. A VSWR of 2 corresponds to a loss of .5 db. In the following discussion, compromise designs are presented in which this restriction is met, or more nearly met.

The design of the antenna matching networks of Reference 1 was based on the results of Reference 2. A lowpass equivalent circuit was obtained for a monopole $\ell/r = 60$. This circuit was the lowpass equivalant of a bandpass antenna approximating circuit which was chosen in such a way that its input impedance approximated the input impedance of a mono-

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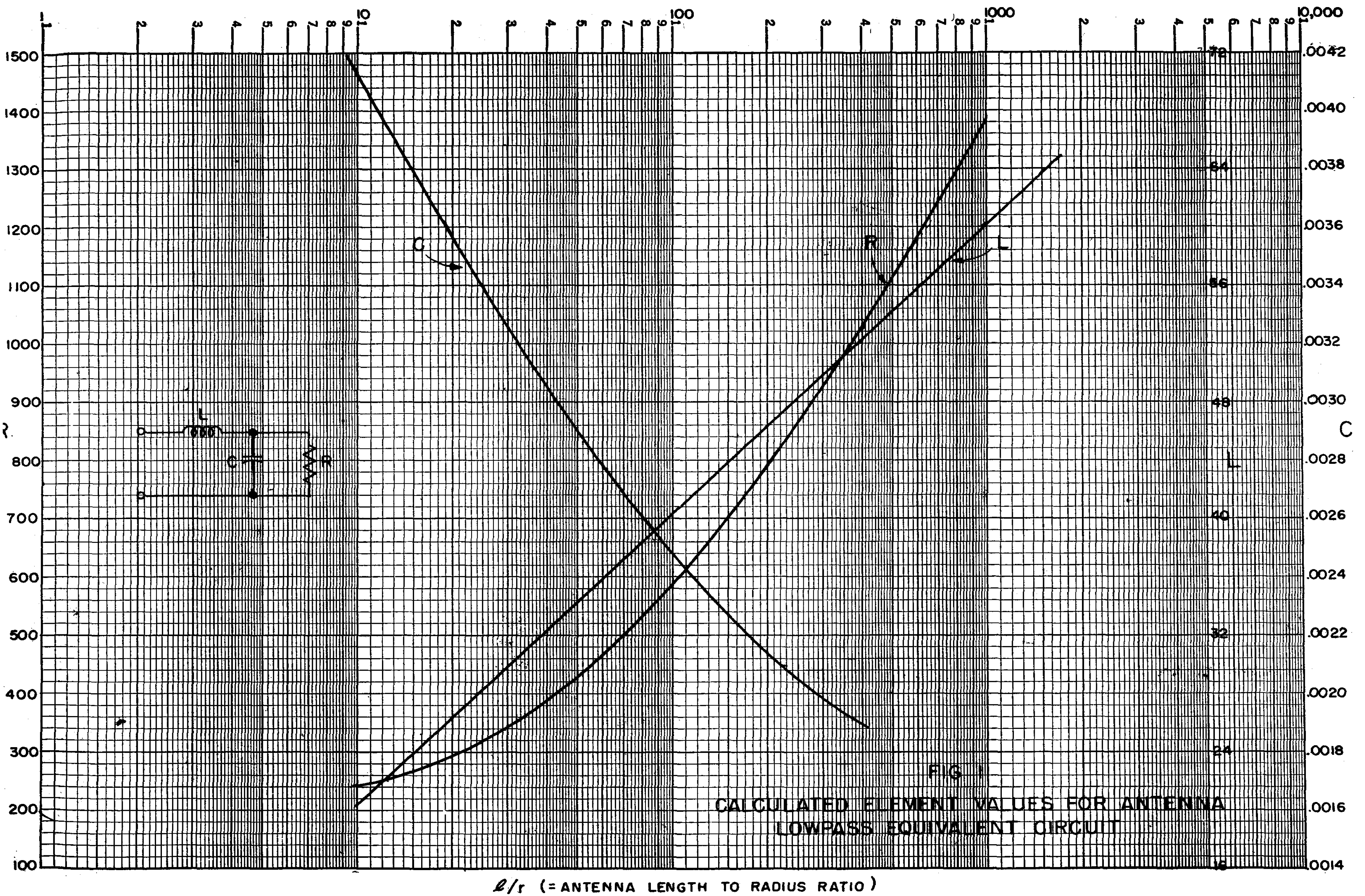

FIG. 1
CALCULATED ELEMENT VALUES FOR ANTENNA LOWPASS EQUIVALENT CIRCUIT

pole over a frequency band of interest. In Figure 1, the elements of the antenna lowpass equivalent for a monopole antenna as functions of ℓ/r are presented. These curves are based on the theoretical monopole impedance characteristics by Hallen.[1]

A reduction of the VSWR can be achieved in a number of ways, among which are:

(a) The use of antennas which are inherently more broadband types, such as monopoles with a smaller ℓ/r ratio.

(b) A reduction of the bandwidth covered by the individual antennas.

(c) The use of more complex matching structures.

The use of more complex matching structures will not be considered. It is doubtful whether increased network complexity would be beneficial in a practical structure.

Referring to Figure 14 of Reference 2, it is observed that for an optimum 4-pole structure and a loss of .5 db

$$\frac{2}{\omega_c C_1} = .86$$

where C_1 = RC of Fig. 1.[2] Using Figure 1, it is observed that this can be achieved, choosing a monopole of $\ell/r = 10$, with $\omega_c = 2.35$. Using a value of $\beta\ell = 2.7$ for the center frequency of the bandpass circuit (i.e., for $\beta\ell$ = length of antenna in radians at the midband frequency), it is found that this corresponds to coverage from $\beta\ell = 1.77$ to $\beta\ell = 4.12$. Thus, to achieve a VSWR of 2, a monopole of $\ell/r = 10$ can be chosen, and

1 See Jordan E. C., "Electromagnetic Waves and Radiating Systems," Prentice-Hall, New York, pp. 482-485, 1951.

2 The symbol C_1 used here is equivalent to L_1 on the design curves. The networks discussed here are duals of the circuits on the design curves. The dual realizations are discussed in Reference 2, pp. 11-12.

coverage of 2.33 to 1 frequency ratio results. (The antennas of Reference 1 covered a frequency ratio of 3.1 to 1.) Using the design curves of Reference 2, the corresponding 4 pole structure is

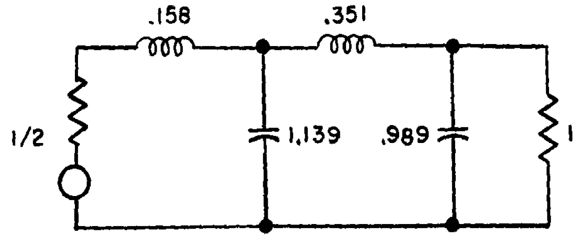

FIG 2

Raising the impedance level to 240 ohms, and converting to a bandpass circuit with normalized center frequency $\beta \ell = 2.7$

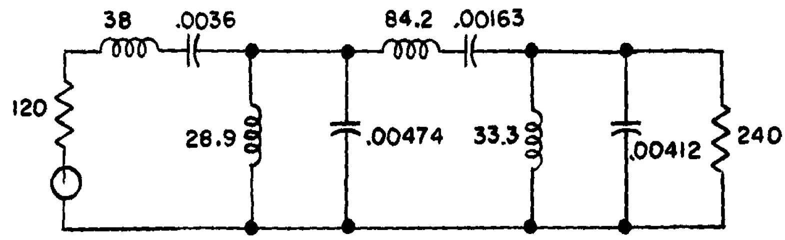

FIG 3

The generator impedance can then be adjusted through insertion of an ideal transformer as outlined in Reference 2, producing

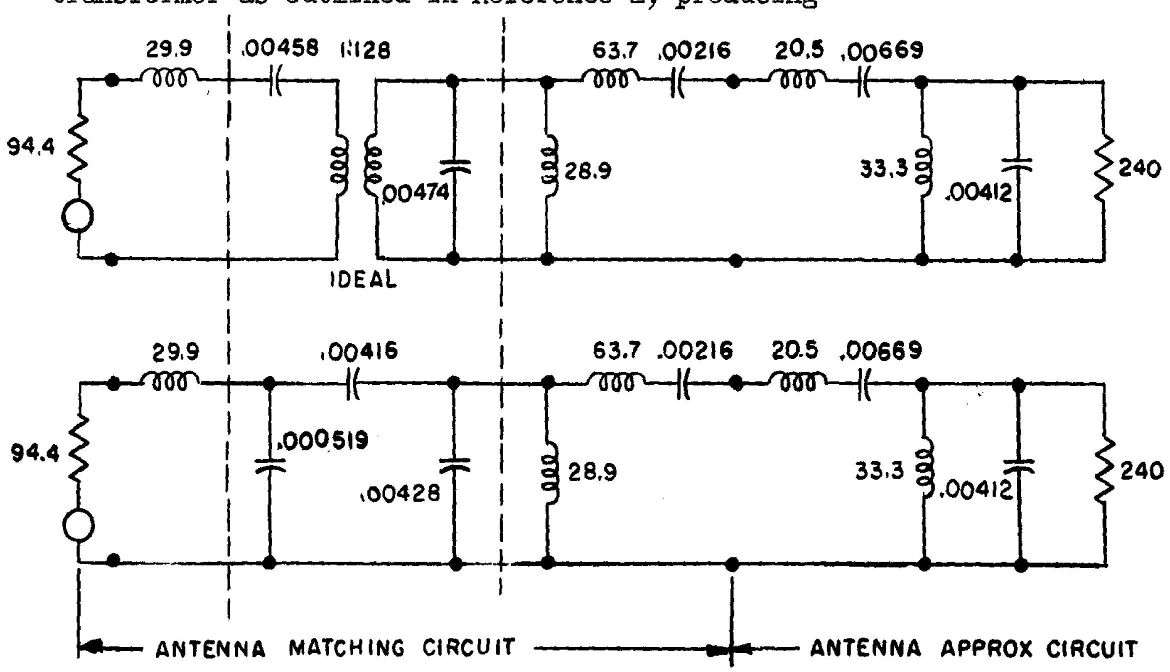

FIG 4

For operation over a 3.1 to 1 frequency band, and using a monopole with $\ell/r = 10$, it is found that a loss of .93 db results, corresponding to a VSWR of 2.5. The lowpass 4-pole network is then

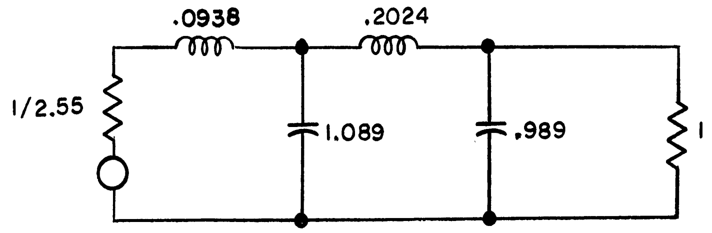

FIG 5

Transforming to a 240 ohm impedance level, and converting to a bandpass network with $\beta\ell = 2.7$,

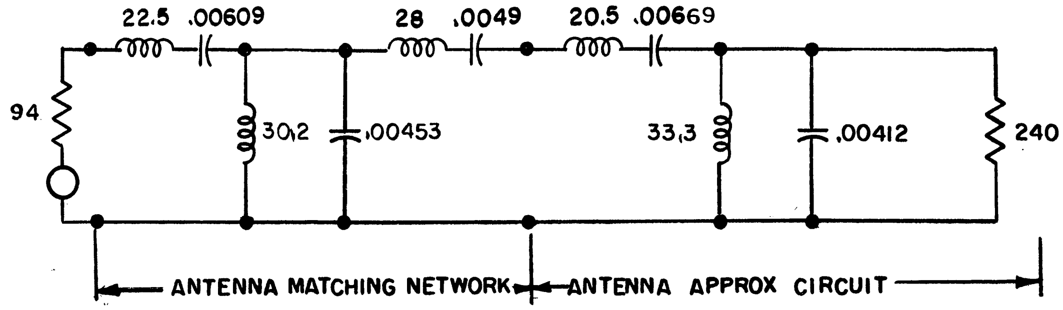

FIG 6

In this case, the insertion of an ideal transformer is unnecessary.

To design a matching network utilizing either Figure 4b or Figure 6, it is only necessary to choose the mean radian frequency ω_o of the band to be covered. In the case of Figure 4, the derived matching networks match over a 2.33 to 1 frequency ratio, as previously stated. For Figure 6, similarly, a match is obtained over a 3.1 to 1 frequency ratio. The individual L's or C's in Figures 4 or 6 determine the elements L' and C', respectively, in the matching networks, according to

$$L' = \frac{2.7}{\omega_0} L$$

$$C' = \frac{2.7}{\omega_0} C$$

The resulting element values are in henries and farads.

It is observed that the elements of Figures 4 and 6 are not greatly different from the corresponding elements in the networks of Reference 1. However, the effective "base capacitance" may well be greatly increased with larger diameter antennas. It is probable that a larger optimum value of base spacing will be observed with larger diameter antennas than were observed previously.

When used over a lossy ground plane, the Q of an antenna is reduced. For this reason, it is suggested that the above matching networks be used with an antenna of $\ell/r = 12$ (approximately). In addition, due to the reduction in antenna resonant frequency by the "base capacitance", it is suggested that the actual monopole be made approximately 12 percent shorter than the theoretical length.

REFERENCES

1. B. F. Barton, "The Design of an Efficient Wideband Antenna System," Technical Report No. 45, Electronic Defense Group, University of Michigan, 1955.

2. B. F. Barton, "The Design of Efficient Coupling Networks," Technical Report No. 44, Electronic Defense Group, University of Michigan, 1955.

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