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THE TRANSISTORIZED DIPOLE ANTENNAFIER

by

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THE OHIO STATE UNIVERSITY
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Investigation of	Research on Techniques for Integration of Active Elements Into Antennas and Antenna Structure
Subject of Report	The Transistorized Dipole Antennafier
Submitted by	W. J. Robertson and J. R. Copeland Antenna Laboratory Department of Electrical Engineering
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ABSTRACT

The transistorized dipole antennafier is a novel integrated design uniting a resonant half-wave dipole antenna with a VHF transistor amplifier, and providing a simple, stable, compact, high-gain, low-noise, and inexpensive element suitable for use alone or in arrays.

The design philosophy is to match the resonant dipole directly into the transistor amplifier, eliminating the usual transmission lines and auxiliary tuned circuits. The result is a maximum bandwidth device, with higher gain and better noise performance than is possible in conventional operation using the same components separately.

Measurements have been made at 146 Mc on a transistorized dipole antennafier, with results of 12.5 db gain, less than 400°K effective noise temperature, bandwidth approximately equal to that of the dipole antenna itself, and no effect whatever on the radiation pattern of the dipole.

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THE TRANSISTORIZED DIPOLE ANTENNAFIER

I. INTRODUCTION

The concept of integrating the design of an antenna and the circuitry with which it is intended to function is an evolutionary development which, when applied properly, is capable of providing improved system performance from fewer components in more compact form than the more conventional approach of separated design. A truly integrated design is one in which the antenna structure performs one or more circuit functions as well as its antenna function, and as a result of which no sharp division can be made which isolates antenna terminals from circuit terminals.

This duplication of functions in the antenna provides for the elimination of the usual matching and tuning elements between an antenna and its circuitry, and makes it convenient to incorporate some portions of the circuitry directly in the antenna structure, dispensing with transmission lines. As a result of the elimination of these circuit elements, RF losses are reduced, and in receiving applications, the operating noise temperature of the system is lowered.

The concept of integrated design has found application in transmitting, receiving, and echo-area control. Tunnel-diode oscillators and varactor harmonic-generators have been combined with dipoles to form two different kinds of integrated antenna-transmitters, or "antennamitters". Mixer-diode and tunnel-diode downconverters have been combined with broadband spiral antennas to form "antennaverters". Tunnel diodes, varactor parametric amplifiers, and transistor amplifers have been combined with slots, spirals, dipoles, and arrays of dipoles to form various kinds of "antennafiers". In echo-area applications, switching diodes and varactor parametric amplifiers have been used with slot antennas to modulate, increase, and decrease the echo area of simple structures with slot antennas in them.

The purpose of this report is to describe a basic type of antennafier suitable for use alone or as elements of a receiving array. It is comprised of a resonant half-wavelength dipole antenna matched directly into a transistor RF amplifier, whose collector tank circuit provides the output of the integrated device.

II. CONSTRUCTION

Figure 1 shows two schematic diagrams illustrating transistorized dipole antennafiers. In (a) the transistor amplifier operated with fixed bias for maximum gain or minimum noise temperature, while in (b) the technique of "Forward AGC" has been used to provide a variable-gain antennafier for use in array applications or elsewhere if gain control is required. Figure 2 is a photograph of one such antennafier constructed for 146 Mc.

The active portion of the circuit is provided by the 2N1742 VHF transistor, some of whose characteristics are reproduced in Figs. 3-5. Operating unneutralized in the test circuit of Fig. 6 at 146 Mc, selected units provided up to 12.5 db gain with 4.0 noise figure, when optimized for best noise performance.

The antenna as shown in Fig. 1 was a resonant half-wavelength dipole with a gamma-match feed connected directly to the base of the transistor. The length of the gamma rod and resonating capacitance were both made adjustable for proper matching between the antenna and the transistor.

The output circuit was a parallel resonant tank, using the parasitic output capacitance of the transistor alone in order to achieve maximum bandwidth. The 50-ohm coaxial output was tapped part-way up from the cold end of this tank circuit for an impedance match. Other tap points could be used depending on whether greater or less bandwidth were desired in the output circuit at the expense of power gain, but the condition of matched impedances was chosen here. This choice resulted in half-power bandwidth of about 20 Mc which corresponds to an operating Q of about 7.5.

It will be shown later that at these bandwidth limits the antenna VSWR is so low that the total bandwidth is determined primarily by the operating Q of the collector circuit.

The $\lambda/4$ sleeve balun shown in Figs. 1 and 2 was required only to prevent antenna currents from flowing on the supporting structure of the dipole. This is a common fault of the gamma-match type of unbalanced feed arrangement, and if uncorrected can lead to asymmetrical radiation patterns of the dipole.

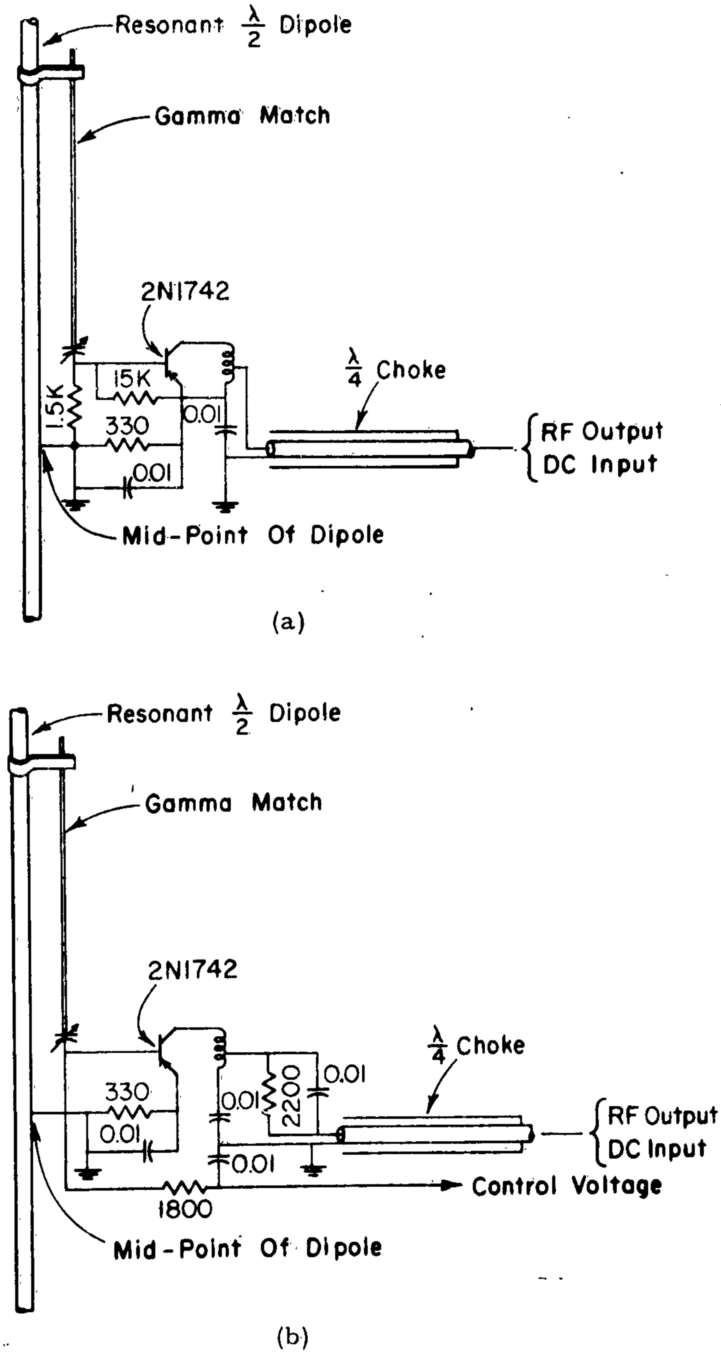

Fig. 1. The transistorized dipole antennafier.
(a) fixed gain, (b) controllable gain.

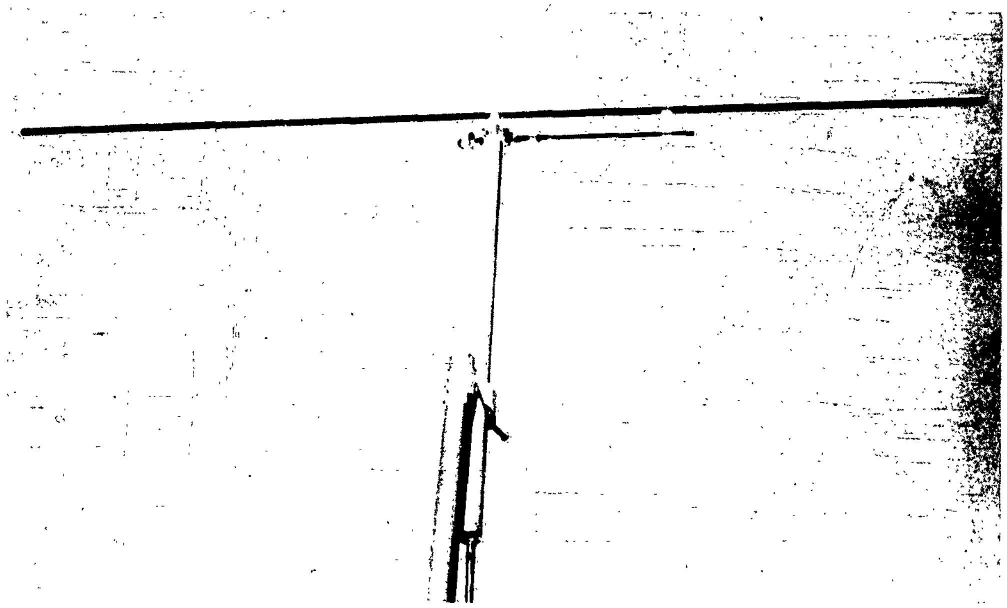

Fig. 2. A transistorized dipole antennafier for 146 mc.

The power supply used for the 2N1742 transistor amplifier was 12 V DC connected to the RF output line with an RF choke and DC block arrangement for isolation. A Microlab HW-02N monitor tee was more suited to this purpose.

III. PERFORMANCE

The parameters of interest in the specification of an antennafier are pattern, gain, and noise temperature. Patterns are easily measured and are interpreted in the same way as ordinary antenna patterns. Gain and noise temperature are not always easy to specify, however.

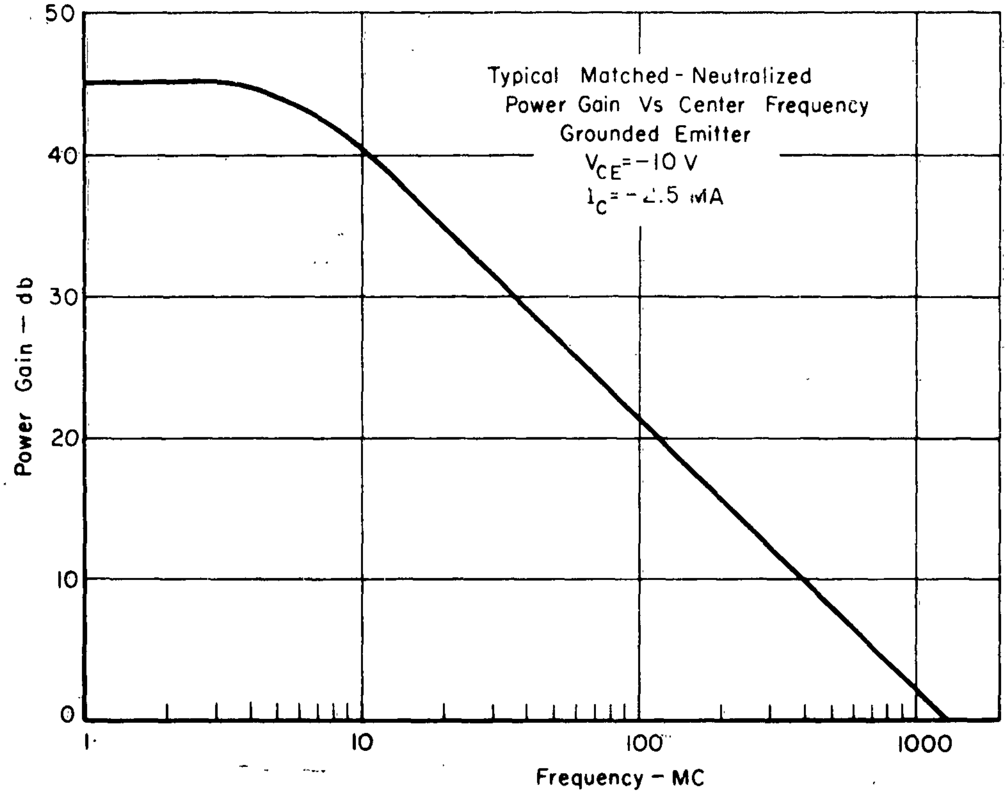

Fig. 3. Frequency capability of Philco 2N1742 transistor.

The gain of an antennafier is a function of both antenna gain and circuit gain, and is usually measured in terms of gain over a half-wave-length reference dipole. In simple examples such as the present case, the circuit gain can be more or less separated from the antenna gain, but in more complicated cases such as antennafier arrays, this separation becomes difficult and it is necessary to specify pattern and gain independently.

The noise temperature of an antennafier is even more difficult to measure. In conventional receiving systems, a direct measurement of noise temperature with respect to input terminals can be made on a receiver, and the effective noise contribution due to losses in the antenna and matching circuits can be measured and added. However, this approach is inapplicable to antennafiers generally, because no such set of input terminals to the receiver exists.

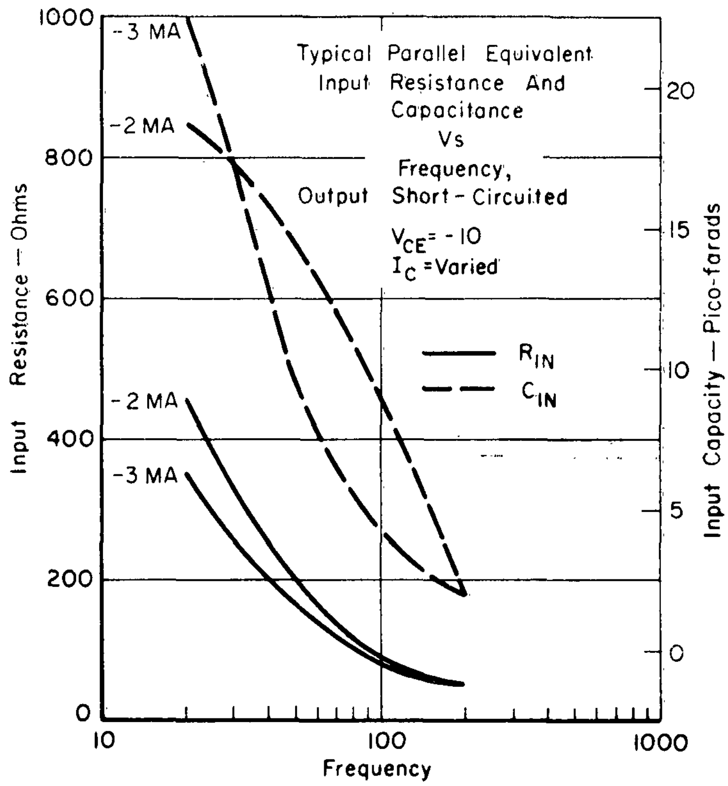

Fig. 4. Input characteristics of Philco 2N1742 transistor.

The only related parameter which can be measured easily is the field-strength sensitivity, defined as the power density of the electromagnetic wave in which the antennafier must be immersed in order to provide signal output equal to noise output:

$$FSS = \left| \overline{P}_{inc} \right| \Big]_{S_{out} = N_{out}}$$

where $\overline{P}_{inc}$ is the incident Poynting vector, S_{out} is signal power output, N_{out} is noise power output.

This measurement is then repeated using the reference dipole and a receiver of known noise temperature. The resulting ratio of field-strength sensitivities, along with the measured power gain of the antennafier and the effective antenna temperatures, is sufficient to determine the effective noise temperature of the antennafier:

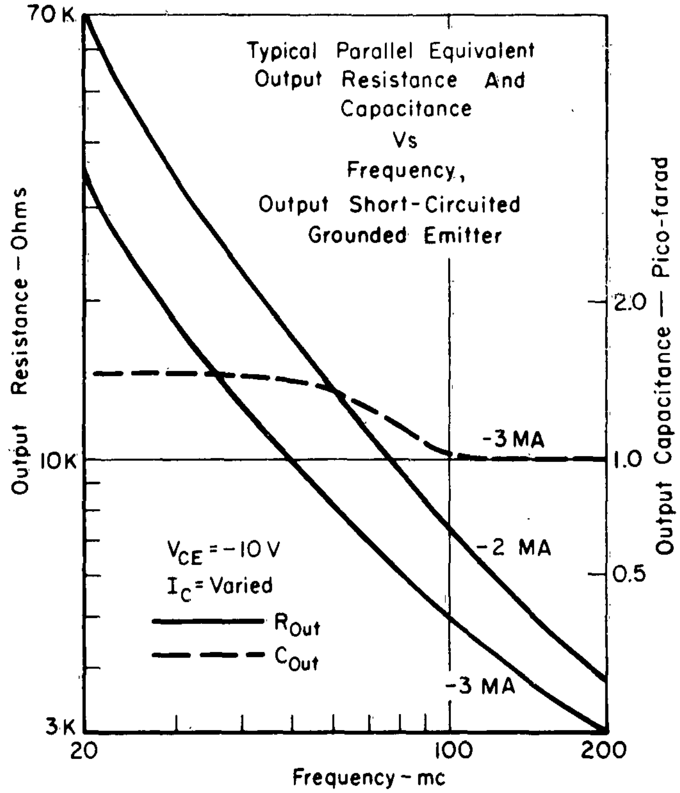

Fig. 5. Output characteristics of Philco 2N1742 transistor.

$$T_a = T_e(\text{FSSR} - 1) + T_r(\text{FSSR} - 1/G)$$

where

T_a = antennafier noise temperature

T_e = antenna noise temperature

T_r = noise temperature of the receiving system following the antennafier

G = gain of the antennafier

FSSR = field-strength sensitivity ratio.

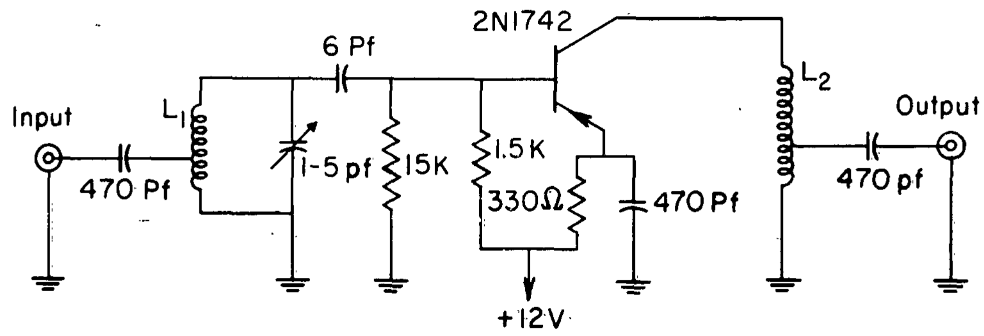

Fig. 6. 146-mc test circuit for 2N1742 transistor.

This type of measurement has been discussed in greater detail in Report 903-29.*

The gain of the transistorized dipole antennafier was measured as 12.5 db relative to the reference dipole. The pattern was identical to the reference dipole pattern as shown in Fig. 7. The 12.5-db gain difference was removed for better comparison of the two patterns. It was found that the controllable-gain antennafier of Fig. 1b could be adjusted over the range from 20 db loss to 12.5 db gain by variation of the control voltage.

* Final Engineering Report, Report 903-29, 31 December 1962, Antenna Laboratory, The Ohio State University Research Foundation; prepared under Contract AF 33(616)-6211, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio.

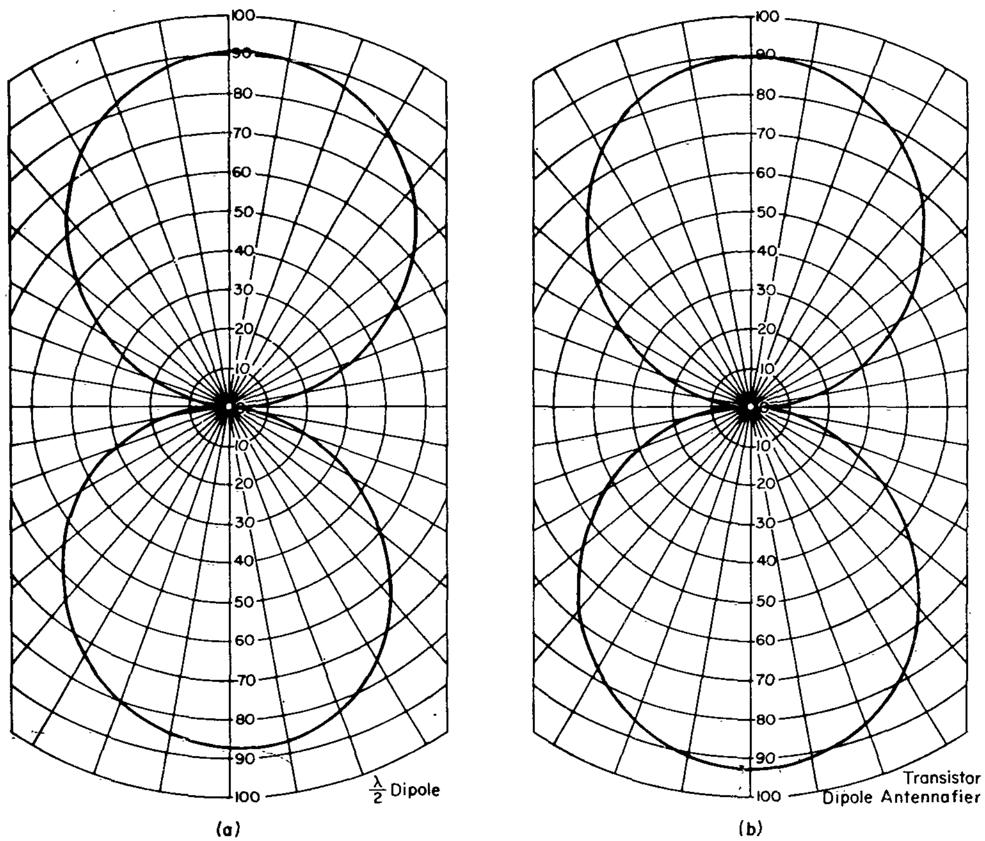

Fig. 7. Field patterns of transistorized dipole antennafier and reference dipole antenna.

Figure 8 shows the frequency response of the antennafier. This curve was obtained from comparison with the response of a reference dipole constructed to the same dimension as the antennafier, with an identical reference dipole used as the transmitting antenna. Figure 9 shows a VSWR curve of the two identical reference dipoles. In this way the frequency behavior of the transmitting antenna was known and accounted for in the frequency-response measurements.

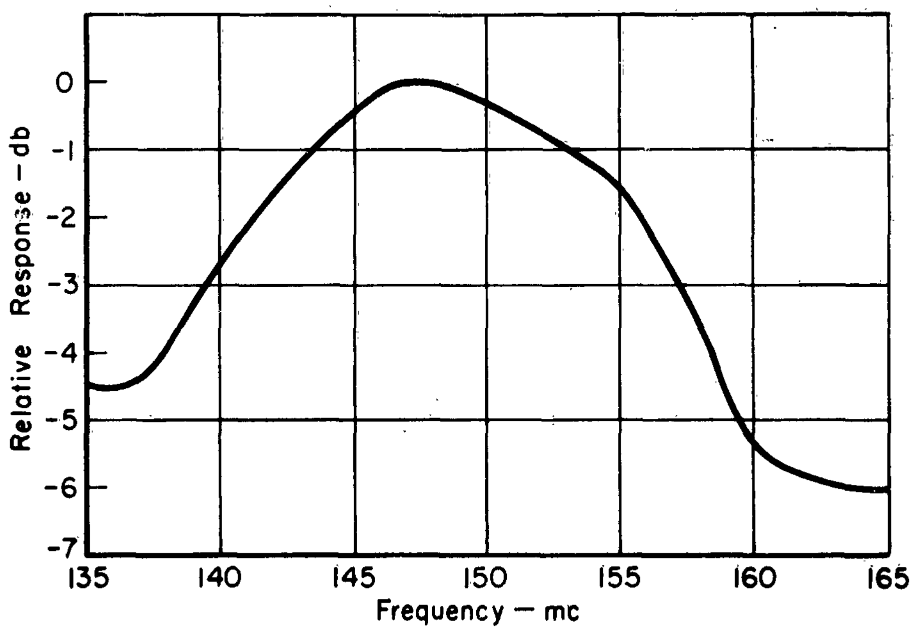

Fig. 8. Frequency response of the transistorized dipole antennafier.

As mentioned earlier, since the half-power bandwidth of the antennafier corresponds to VSWR limits of less than 2 on the antenna (a VSWR of 5.8 would correspond to a half-power mismatch), the bandwidth of the antennafier is determined principally by the choice of loaded Q in the collector circuit.

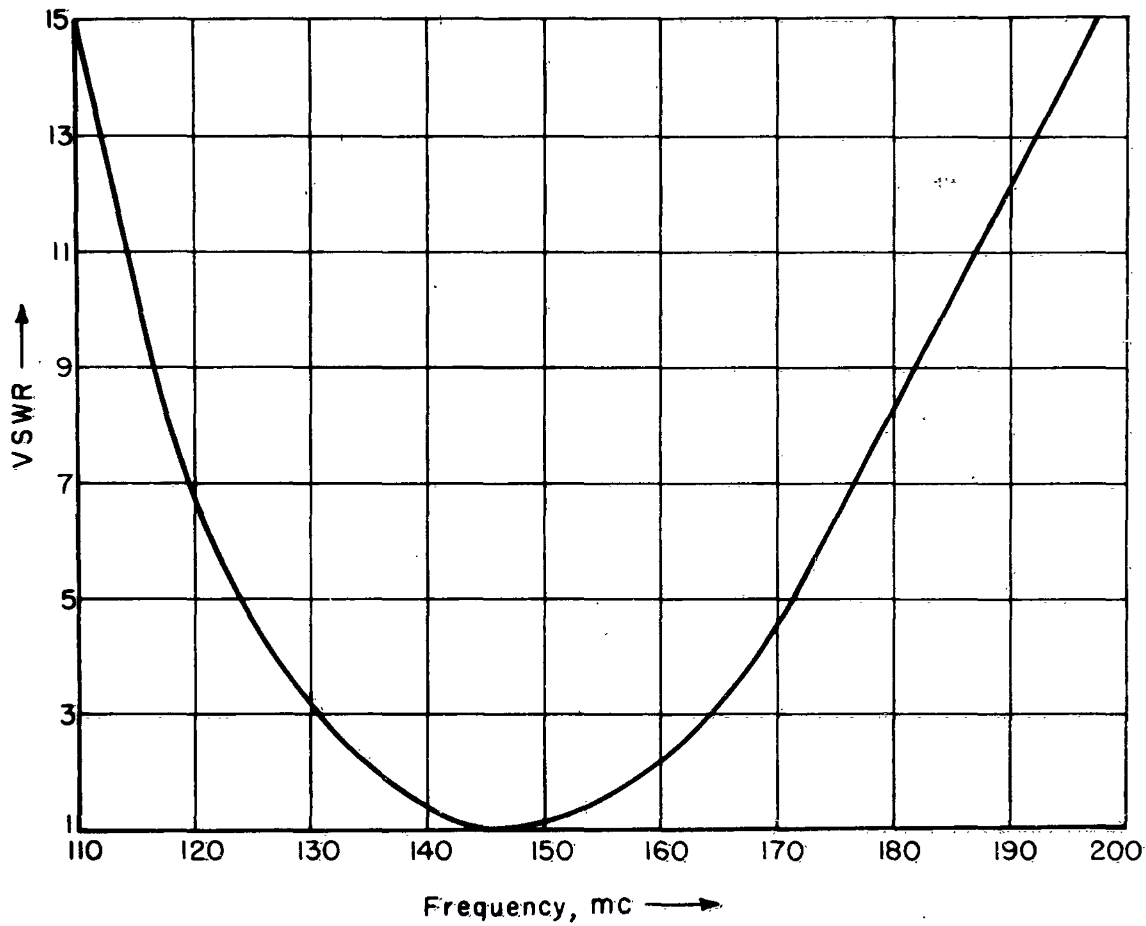

Fig. 9. VSWR of reference dipole antenna.

The spot noise temperature measured at 146 Mc by the method described above indicated about 350°K for the complete antennafier. This turns out to be slightly better than the approximately 425°K measured for the same transistor in the amplifier test circuit. This difference is believed to arise from the losses which inevitably occur in the input circuit of the amplifier, and which have been eliminated in the integrated design.

It is interesting to note that even at this frequency of 146 Mc, the noise temperature of the antennafier approximates the lowest level of cosmic noise temperature to be found in the coldest regions of the sky, and this element is therefore well-suited to VHF communications applications.

IV. CONCLUSIONS

The transistorized dipole antennafier is a practical and useful integrated design of a resonant half-wavelength dipole with a simple and completely stable VHF transistor amplifier. The device is compact, inexpensive, features high gain with low noise, and is suitable for use singly or in arrays with similar elements, all of whose gains may be controlled independently.

Measurements at 146 Mc indicate that the element has 12.5 db of power gain with respect to a reference dipole, 350°K effective noise temperature, bandwidth comparable to that of the dipole itself, and achieves this with no effect whatever on the radiation pattern of the dipole.

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