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A Simple, Lumped-Parameter Multicoupler for Transmitting Use

by
George Barry and Joseph Hawkins

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Prepared under
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STANFORD ELECTRONICS LABORATORIES
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Radioscience Laboratory
Stanford Electronics Laboratories
Stanford University Stanford, California

ABSTRACT

A number of hf transmitters may be simultaneously operated into a single, broadband antenna through the use of filter circuitry to prevent interaction. Several five-channel multicouplers have recently been constructed by the Stanford Radioscience Laboratory for use with 600-watt transmitters. It is possible, with these devices, to operate adjacent transmitters as close to one another in frequency as 1 Mc, while still obtaining isolation adequate to avoid transmitter-tuning interaction or the generation of undesirable intermodulation products. The multicouplers employ only a single tuned circuit for each transmitter and the tuning of any one of these circuits is independent of the rest. Over-all adjustment is thus very simple; individual transmitters can be retuned or disconnected from the common load without affecting operation of the others. Construction of higher-powered versions of the multicoupler appears perfectly practicable.

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ILLUSTRATIONS

I. INTRODUCTION

In order to take advantage of the broadband characteristics of three large rhombic antennas constructed in Okinawa for Project Minispot, multicouplers were constructed, permitting as many as five 600-watt transmitters to operate into each antenna. The requirements for such a device were: 1) that it be simply tunable, 2) that it provide good isolation between adjacent transmitters operating as close to one another as 1 Mc, 3) that it exhibit low insertion loss, and 4) that it present the common, output-line impedance to each transmitter.

An attractive and straightforward approach to multicoupler design, that of simply interposing a separate network between each transmitter and the common load, was suggested by Dr. Robert Tanner of TRG West. The network is designed to have no effect at the transmitter frequency, but at other frequencies it presents a high impedance to the common load. A series-resonant, L-C circuit between transmitter and load illustrates the principle. though practical limitation of available components usually dictates a more complex network.

II. DESIGN CONSIDERATIONS

In order to obtain simplicity of tuning it was decided that only one tuned circuit per channel should be used. The configuration chosen is shown in Fig. 1. A further simplification was achieved by making each of the five channels identical and each capable of operating over an octave frequency range (the nominal range of an antenna).

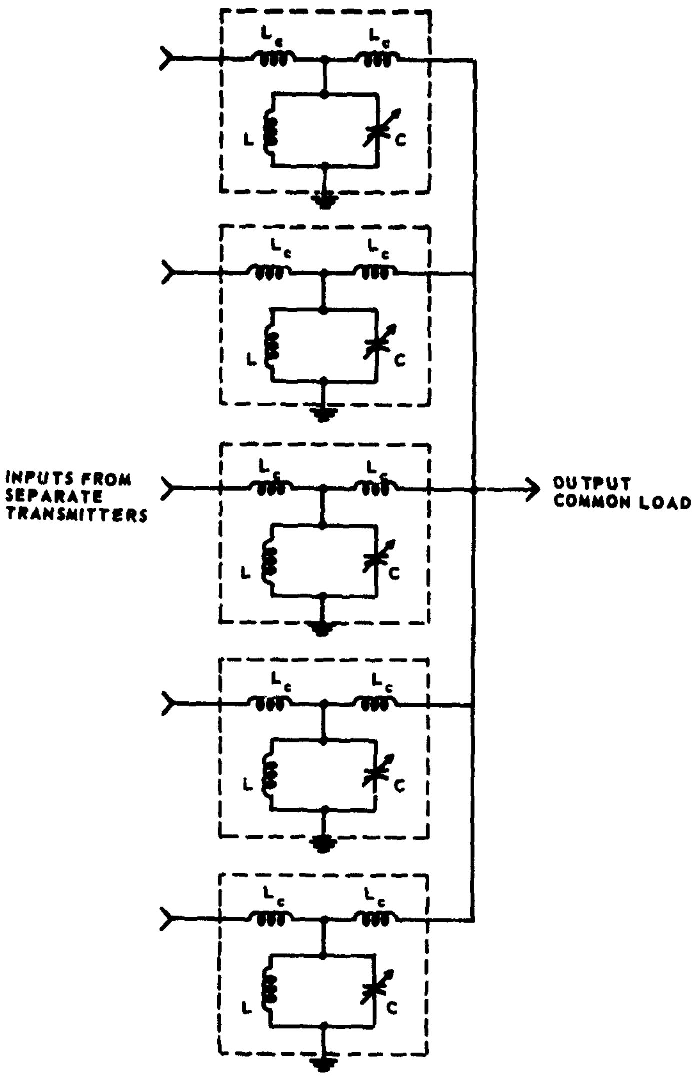
The insertion loss was specified to be less than 1 db because of cooling problems; with a power input of 600 watts, 125 watts would be dissipated in the tank circuit. If one assumes an unloaded-circuit Q of 500 (based on a preliminary experiment to determine a value practically attainable without unusual care in design or construction) the loaded-filter Q is defined by the usual relationship:

$$\text{Loss (db)} = 20 \log_{10} \frac{1}{1 - \frac{Q_\ell}{Q_u}} \qquad (1)$$

where Q_ℓ = loaded Q
Q_u = unloaded Q

Either inductive or capacitive coupling into the tank circuit might have been used; however, the variation of loaded Q with frequency is much greater with capacitive coupling than with inductive coupling. Even with inductive coupling the loaded Q varies linearly with frequency; however, this is just the behavior desired when the minimum transmitter spacing is specified as a fixed number of cycles (e.g. 1 Mc). The Q over each octave band was designed to vary from 30 to 60, satisfying Eq. (1) above, as well as providing adequate isolation between hf transmitters separated by 1 Mc.

To evaluate the effect of the multicouplers on the common load impedance, refer to Fig. 2, the equivalent circuit of the multicoupler as seen by one transmitter at its operating frequency. Each transmitter and filter operate into the common load impedance shunted by as many as four inductances, the output coupling coils of the other four multicoupler networks. These coils may be regarded as essentially shunt circuits to ground, because of the small impedance represented by each of the other tuned circuits tuned to different frequencies.



FREQUENCY	C	L	L_c
5.5 - 11 Mc	25-500 pf	2 μh	14 μh
8 - 16 Mc	25-500 pf	0.8 μh	6.8 μh
13 - 26 Mc	25-500 pf	0.3 μh	3.3 μh

FIG. 1. MULTICOUPLER CIRCUIT DIAGRAM.

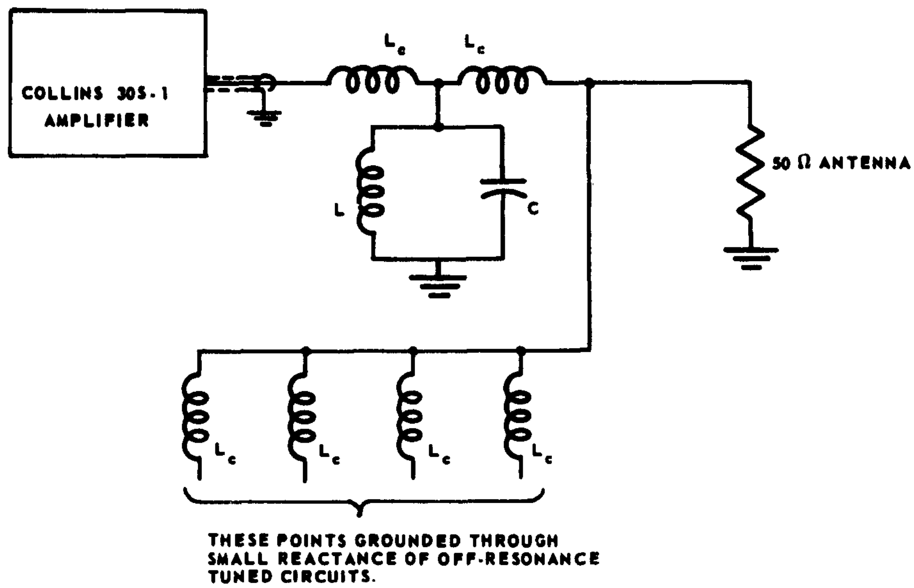


FIG. 2. EQUIVALENT CIRCUIT AS SEEN BY ONE TRANSMITTER.

The multicouplers were to be used with Collins type 30S-1 linear amplifiers, which require an output load of 50 ohms with less than a 2:1 standing wave ratio. Figure 3 shows a plot as a function of frequency of the corresponding minimum allowable total shunt inductance across the load.

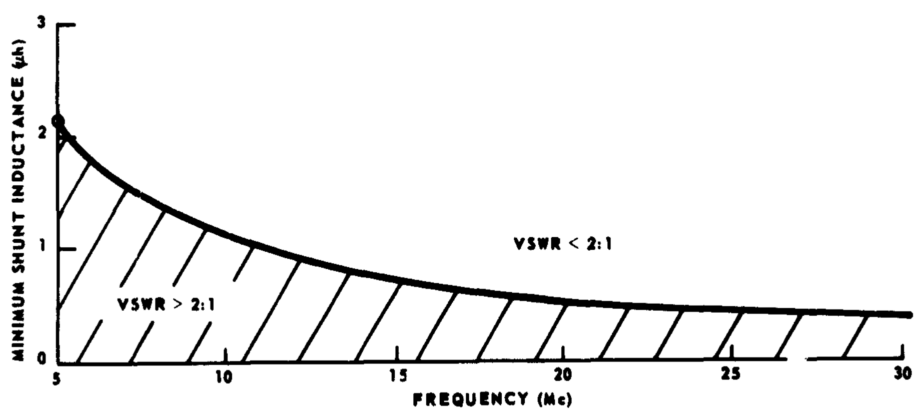


FIG. 3. SHUNT INDUCTANCE ACROSS 50 OHMS FOR 2:1 STANDING-WAVE RATIO.

For a low-frequency model. (tuning the range from 5.5 - 11 Mc) a coupling inductance L_c of 14 μh was chosen. Since the output coils of the other four filters are essentially in parallel (and are not coupled inductively to one another) the net reactance X across the load due to these four inductances is $X = X_{L_c}/4$. For the coupling inductance of the low-frequency model the total shunting impedance is equivalent to a single inductance of 3.5 μh. Examination of Fig. 3 shows that an adequate safety margin exists.

Higher-frequency models will, of course, require less coupling inductance, as well as revised tuned-circuit components. A table of component values for all models is included in Fig. 1.

As an aid in tuning the multicoupler, a pickup loop was installed near the bottom of each resonant circuit. Energy from this pickup was detected by a simple diode circuit whose output operates the 0 - 1 ma meter on the front panel. The circuit of the tuning indicator system is shown in Fig. 4.

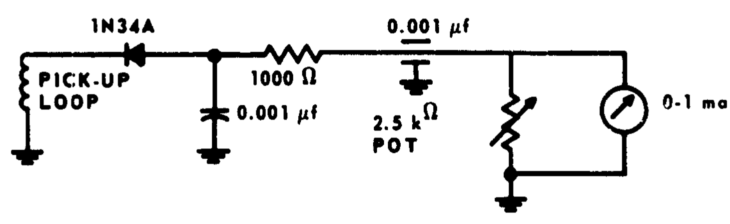


FIG. 4. TUNING-INDICATOR CIRCUIT DIAGRAM.

III. CONSTRUCTION DETAILS

Filters for each frequency were constructed within a separate sheet-metal box. Each of these was mounted on a standard $10\frac{1}{2}$-by-19-in. rack-mounting panel, and the separate units were installed on enclosed racks. Figure 5 shows a photograph of the entire assembly, and the interior view of one of the filter boxes is shown in Fig. 6.

In any high-Q device, attention must be paid to obtaining good rf connections between the various components. The connection between the capacitor and the box is excellent because of the flange construct of the capacitor mounting. However, in testing the units, it was found that the connections between the large coil and the capacitor flange and between the coil and box required special care. Appreciable differences in insertion loss were noticed between various units, and these could be attributed to poor connections at the ends of the large coil.

Referring to Fig. 6, the following materials were used in the filter construction. The tuning capacitor is a Jennings type UCS500 vacuum capacitor rated at 7500 volts. The coupling coils were Illumitronic No. 2006 AIRDUX, silver plated; this coil is available in 10-in. lengths and can be readily cut to size. The main coil was hand wound of 3/8-in. copper tubing and laterplated with 0.001 in. of silver. The hairpin pickup loop for the tuning indicator was made of 1/8 in. copper tubing, also silverplated. Standoffs were of 3/8-in. teflon rod. The boxes were fabricated in the Stanford Electronics Laboratories metal shop. Forced-air cooling is provided by a Rotron Corporation Muffin Fan on the right side of the box; the air exhausts through the screened holes on the opposite side. A panel located below the five multicoupler boxes provides 110-volt power distribution for the fans.

The inputs to each of the channels are type-N panel connectors. The output from each channel is connected to a common line that runs vertically down the stack of multicoupler boxes. A rectangular trough is used to protect personnel from the output line and to serve an an rf shield as well. Output is obtained from a type-Lc connector, installed on the trough.

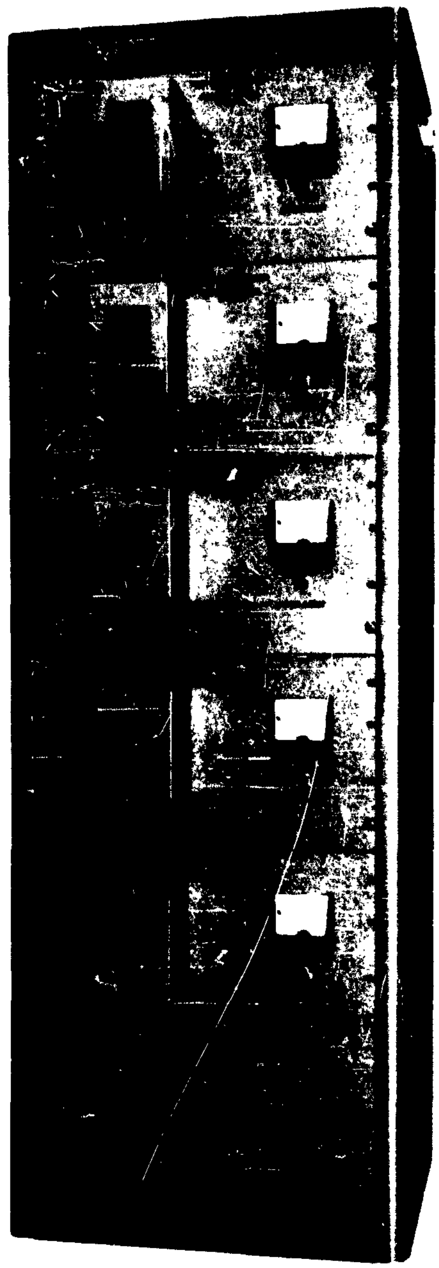


FIG. 5. PHOTOGRAPH OF FIVE-CHANNEL MULTICOUPLER FOR 8-16-Mc RANGE.

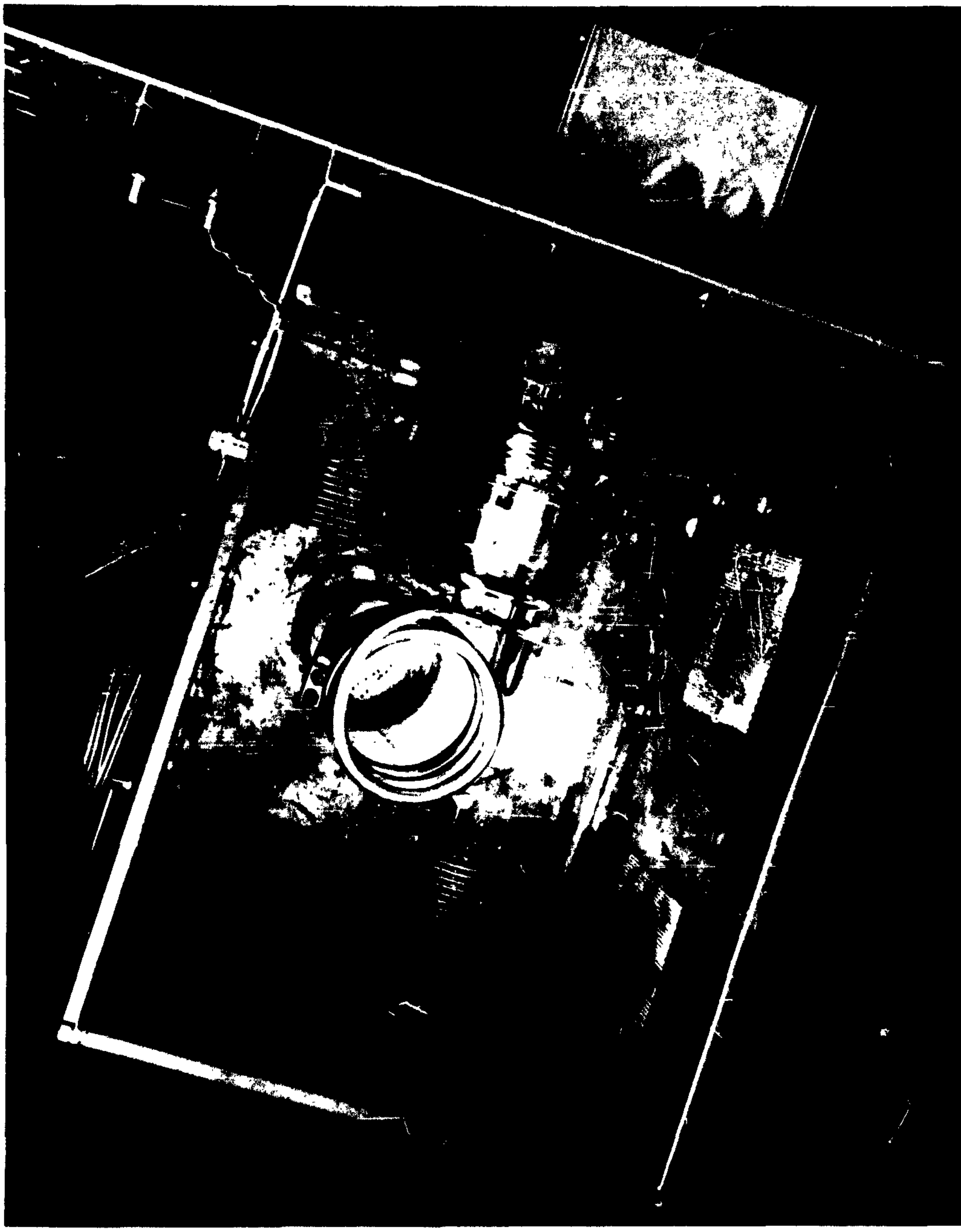


FIG. 6. PHOTOGRAPH OF MULTICOUPLER UNIT WITH TOP REMOVED.

IV. PERFORMANCE

The complete multicouplers operate very much as predicted. The measured filter Q increases linearly with frequency across the octave range as expected; Fig. 7 shows the measured Q of a unit for the low-frequency band, (5.5 - 11 Mc). The measured insertion loss of the same unit is shown in Fig. 8. (The unloaded Q of the tuned circuit would be about 700 at 8 Mc.) The area within the circle on the Smith Chart of Fig. 9 shows the permissible region of transmitter operation (a VSWR of less than 2:1), and points are shown corresponding to measured standing-wave ratios at several frequencies throughout its range.

The multicouplers have performed well in several months' service to date. The only problem encountered has been a relatively minor one of frequency drift with heating—the units must sometimes be retuned after warmup from a cold start. The lack of mechanical regidity in the tuned circuit (apparent from Fig. 6) makes this behavior readily understandable, and modifications are in progress to improve the situation. As a practical matter, even the present drift represents only a minor nuisance, since the transmitters are normally run continuously, and retuning after breakdowns involves turning a single knob to peak the meter.

The units were designed for a power level of about 600 watts, and thus far they have not been tested to establish a maximum rating. They would be expected to operate conservatively up to perhaps 1500 watts/channel.

Above this the voltage rating of the input (Type N) connector would be exceeded at a VSWR of 2:1. Higher power units could, of course, be easily constructed with appropriate connector (and eventually capacitor) changes.

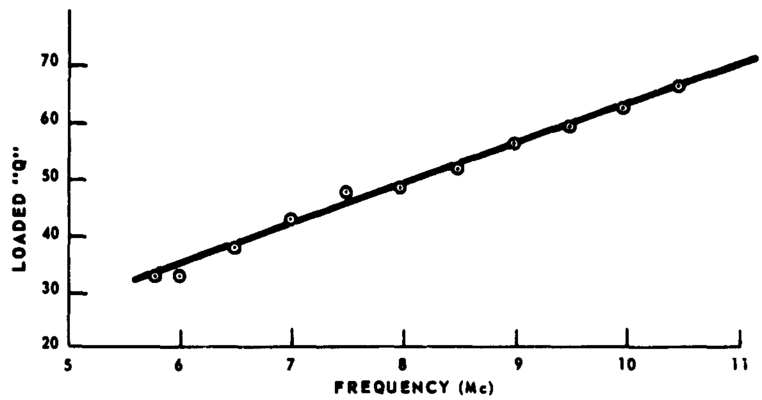


FIG. 7. LOADED Q VS FREQUENCY FOR LOW-FREQUENCY MULTICOUPLER.

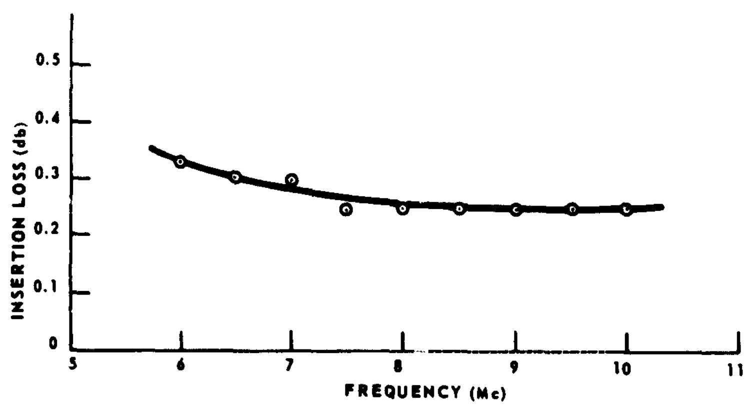


FIG. 8. INSERTION LOSS VS FREQUENCY PLOT FOR LOW-FREQUENCY MULTICOUPLER.

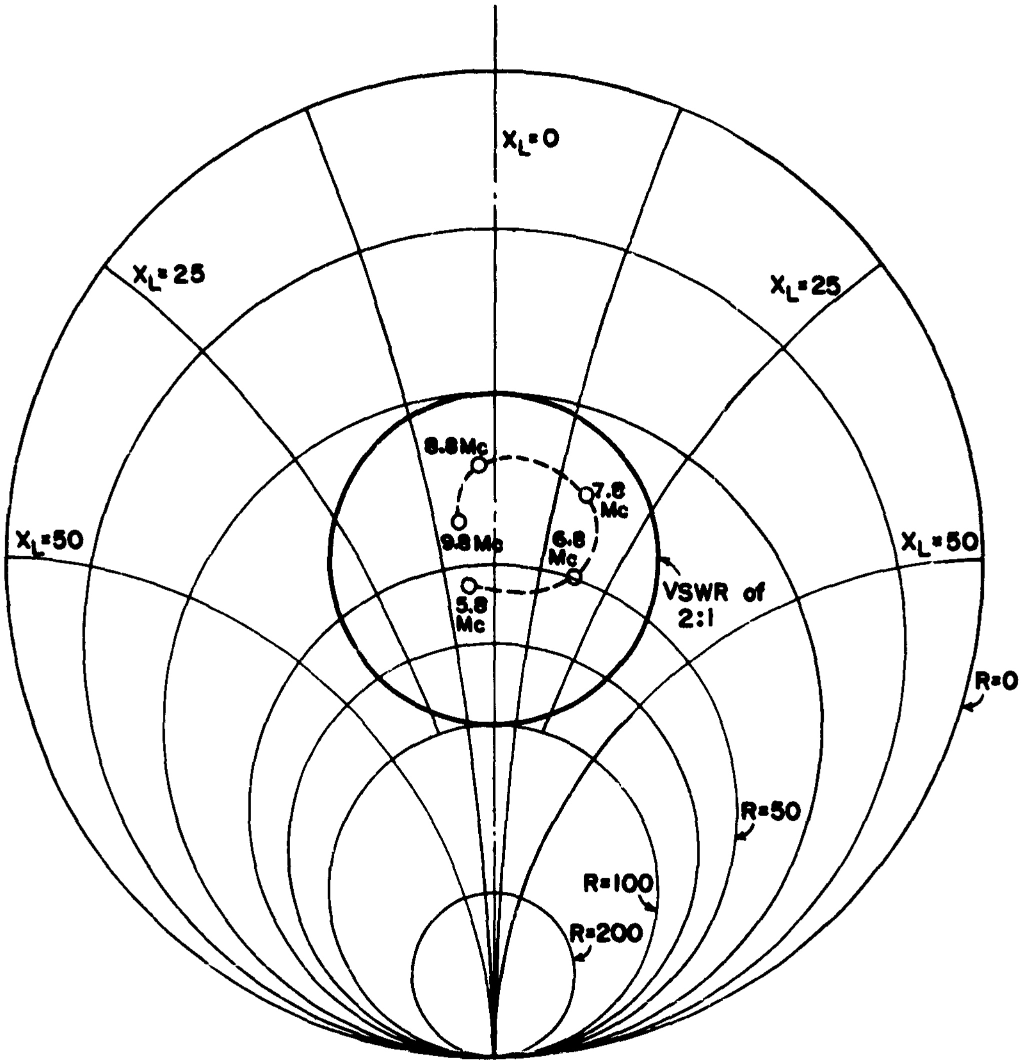


FIG. 9. SMITH CHART IMPEDANCE PLOT FOR LOW-FREQUENCY MULTICOUPLER.

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