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LABORATORY ANTENNA DISTRIBUTION SYSTEM

By Frank Mural

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Volume 25 No. 1

Introduction

The availability of high quality broadcast television signals is of considerable value in testing television receivers. The antenna distribution system described in this bulletin was designed for the Industry Service Laboratory where conditions of strong signals and severe multipath reception exist.

Individual antennas are used for each of the received channels. A central amplifier and signal-combining network make all of these signals available over each of a number of transmission lines for distribution to various points in the laboratory. This provides the best possible signals by specializing the structure and location of an antenna for each channel. Also, the confusion attending the construction of a multiplicity of antennas and transmission lines for each test position is avoided.

LABORATORY ANTENNA DISTRIBUTION SYSTEM

By

FRANK MURAL*

Presented before the Club on October 21, 1947

Antenna Distribution System

An antenna distribution system must perform the following functions:

1. Provide an antenna signal which is relatively free from multipath components. Where multipath receiving conditions exist a directive antenna must be used. If this requires a multielement antenna it becomes specialized for the reception of a single channel because of the critical adjustment of its elements, its orientation and its physical location. In this case an antenna for each of the channels to be received is necessary.

2. Provide selective circuits for each of these antennas so that only the desired signals may be obtained.

3. Provide amplification of the signal to overcome the attenuation inherent to the distribution system. This may be done most efficiently by means of tuned-circuit amplifiers at the signal frequency, combining the selective and amplification functions in a single unit.

4. Provide a means for combining the signals of the several channels in a common network so that all may be simultaneously available over each of the several distribution lines. This may be done by means of wide-band transformers, band-pass filter circuits or a combination of these.

5. Provide a means for isolating the distribution lines so that extraneous signals introduced at the termination of one line cannot cause interference on the other lines. This is conveniently done by means of a coupling tube.

The block diagram in Fig. 1 illustrates the principal components of the antenna distribution system to be described. Fig. 2A and 2B show respectively the top and bottom views of the distribution-system chassis corresponding to the central section of Fig. 1. The equipment is designed to provide for eight television channels and to distribute the signals to ten test positions in the laboratory. The eight channels include the seven assigned to the New York City area (Nos. 2, 4, 5, 7, 9, 11 and 13), and Channel 1 for distributing a laboratory-generated signal.

*Research Engineer
RCA Industry Service Laboratory

The purpose of this equipment is to provide the best possible signals, and to make these available at each of the test positions at about the same level of intensity unaltered either by distortion or by the introduction of extraneous disturbances. The several parts of this equipment will be described in turn beginning with the antennas.

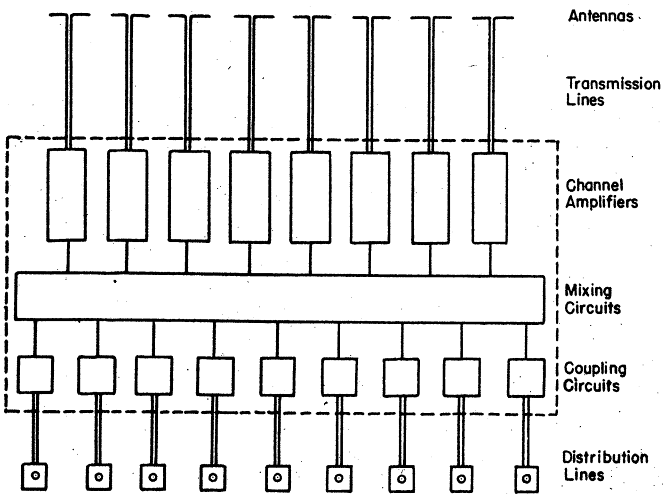


Fig. 1 - Block diagram of antenna system.

Antennas

From preliminary measurements it was found impossible to secure signals sufficiently free of multipath components with a simple dipole antenna at the laboratory location. After considering the use of several types of multi-element antennas it was decided, largely because of space limitations, to use an antenna with one driven element and three parasitic elements, commonly known as a four-element Yagi antenna.

The construction of this antenna is shown in Fig. 3, with all dimensions given in terms of wavelength corresponding to the center frequency of the channel for which the antenna is used. The antenna consists of a folded dipole with two parasitic directors, shorter than the dipole, and one parasitic reflector longer than the dipole. The elements are cut from aluminum alloy tubing five-sixteenths inch in outside diameter to give an inexpensive, light and sturdy structure.

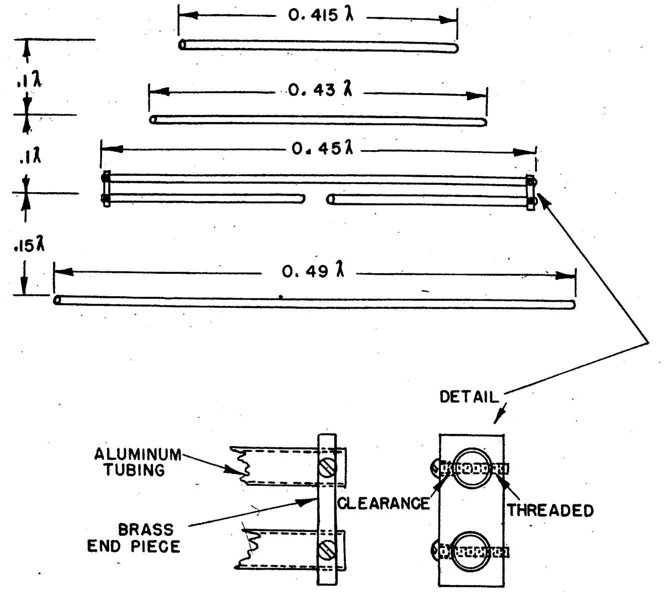


Fig. 3 - Four-element Yagi antenna.

The directional pattern and voltage response of this antenna in comparison with a half-wavelength dipole are shown in Fig. 4. These measurements were taken with the transmission line matched at the antenna and at the amplifier-input terminals. A shielded line of balanced construction was used to avoid pickup on the transmission line. The measurements indicate

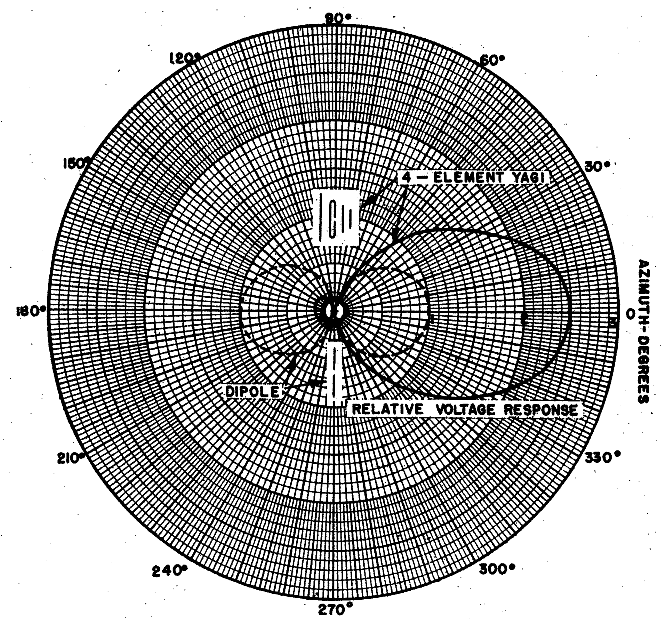
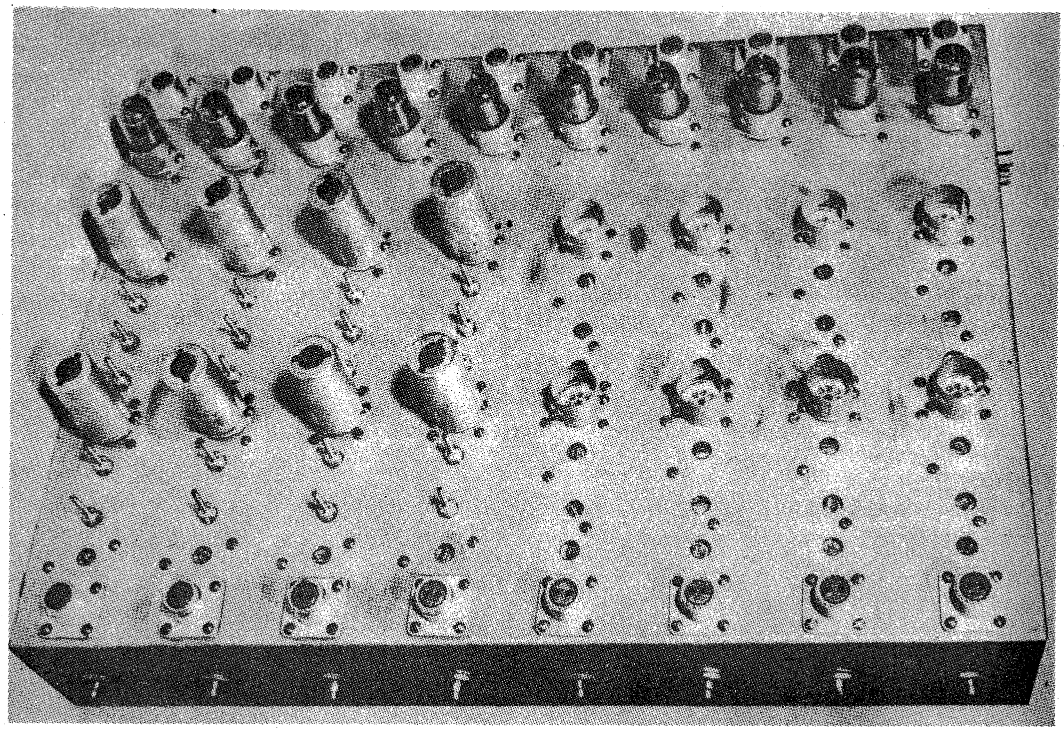
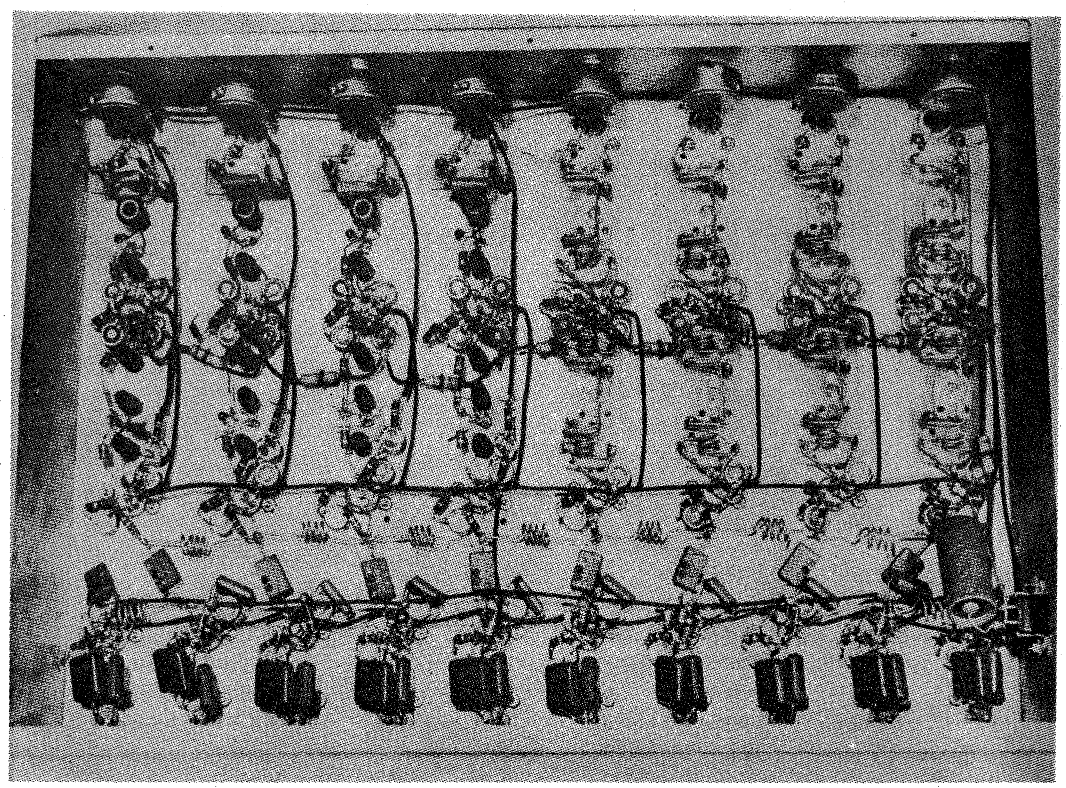


Fig. 4 - Antenna directional pattern and voltage response.



(A) Top view



(B) Bottom view

Fig. 2 - Antenna distribution system chassis.

that this antenna has a beam width of about 85 degrees for half voltage response, a front-to-back voltage response ratio of about 10, and a voltage gain over the half-wavelength dipole of about 2.5. The antenna has an impedance of about 90 ohms.

Transmission Lines

The choice of transmission line was determined by two principal requirements, namely, shielding and balance to ground. The use of a shielded line avoids stray pick-up of the received signal, which would cause the same disturbances observed in multipath reception. It also reduces noise and other types of interference, and prevents irregularities in transmission where the line is installed on or near metal surfaces. A balanced line is desirable both for connection to a balanced antenna structure and for connection to receivers with balanced input circuits.

A suitable line, which is commercially available, is the cable RG-22/U. This cable has two flexible inner conductors, low-loss polyethylene dielectric, braided shield and a tough weather-resistant vinyl outer jacket. It has a surge impedance of 95 ohms, a velocity of propagation of 65.9 per cent and a loss of 3.4 db per 100 feet at 100 Mc. It is conveniently connected by means of commercially available plugs and sockets.

Since the impedance of the antennas is 90 ohms the transmission line is connected directly to the antenna terminals.

The Amplifier Circuit

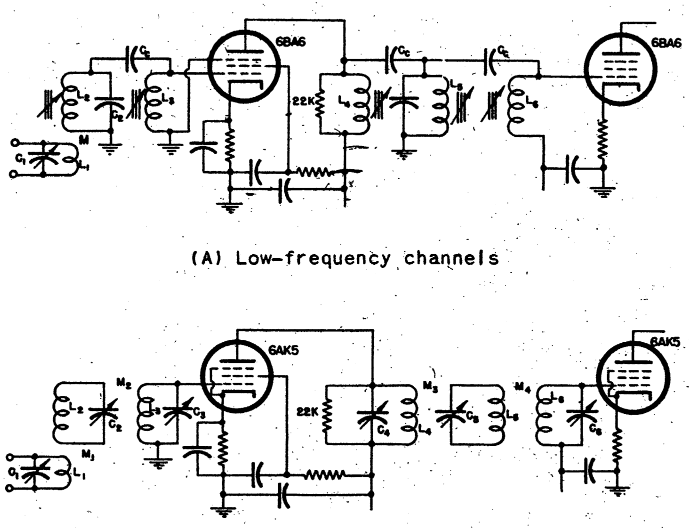
Each antenna is intended to pick up the signal for a single channel. The antenna is made directionally selective for the optimum signal on this channel by means of its construction and orientation. However, since the antenna will also pick up some signal at other frequencies it is necessary to add selective circuits so that only the desired signals are obtained. This function is provided for in the r-f amplifier circuit.

Since attenuation results from the combining of the signals from the several antennas and from their distribution, it is necessary to provide amplification to restore the signal levels. The required amplification is placed in the circuits preceding combining and distribution, where it fits in efficiently with the other requirements of the r-f amplifier. This arrangement, however, limits the signal available at the end of each distribution line to a level determined by the overload characteristics of the amplifier output tube. The significance of this limitation will be discussed in the section on performance.

In addition to the selectivity and gain requirements, the r-f amplifier should keep the signal-to-noise ratio from masking this characteristic in the receiver under test. This is done by the use of tuned input circuits which make possible a voltage gain between the antenna transmission line and the grid of the first tube.

The selectivity required to provide effective elimination of signals on other channels is estimated to be about 100 to 1. The gain required to overcome the attenuation in the combining and distribution circuits is estimated to be about 40. The required gain is approximately provided by means of the antenna step-up transformer and a single stage of r-f amplification, which is coupled to the combining circuits by means of an additional tube. If four tuned circuits are used it is theoretically possible to secure a bandwidth of 6 Mc with a rejection of 100 to 1 at a frequency 4 Mc removed from the pass-band edge, which is the worst condition in the low-frequency television band. However, a number of practical considerations make this selectivity difficult to obtain. Therefore two triple-tuned circuits are used as shown in Fig. 5.

In the low-frequency channels the unbalanced circuits are capacitance-coupled, thus making it possible to use slug-tuned inductors. For the high-frequency channels this was found to be impractical and magnetic coupling is used throughout. Also, 6BA6 and 6AK5 tubes were used in the low- and high-frequency channels respectively to provide more comparable tube input loading and a differential in g_m favoring the high-frequency channels to make up, in part, for lower antenna step-up. It should be noted that a loading resistor is provided in the plate circuit to reduce regenerative tendencies, which may be particularly troublesome during alignment. The average gain from antenna to grid is about 5 in the low-frequency channels and a little over 2 in the high-frequency channels. This deficiency at high frequencies may be partly attributed to the residual inductance in the primary tuning condenser and to the limitation on usable L-C ratios imposed by physical considerations. More antenna gain could have been obtained at high frequencies by using a push-pull neutralized 6J6. This circuit was not used, however, because the neutralizing adjustment when both plate and grid circuits are tuned is rather critical and stable neutralizing condensers suitable for attachment to a miniature socket were not available.



(A) Low-frequency channels

(B) High-frequency channels

Fig. 5 - Amplifier Circuits.

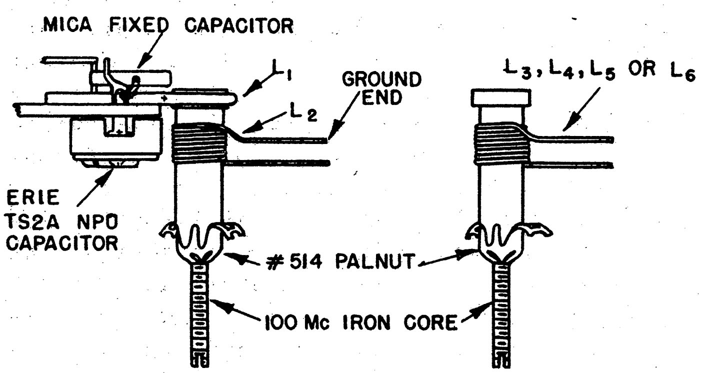
In designing the tuned coupled circuit preceding the grid of the first tube it is desirable that the input to this circuit present an impedance to the transmission line equal to the latter's surge impedance. Assuming that the secondary (coupling) circuit is a lossless tuned link, this condition requires that the Q of the primary (antenna) circuit, when loaded with a resistance equal the transmission line surge impedance, be made equal to the Q of the tertiary (grid) circuit. This Q is determined by the band-pass requirements of the amplifier. This condition is for the case of transitional coupling but also holds very closely for the case of slightly overcoupled circuits, which are used in this amplifier. Since the L-C constants of the tertiary circuit are determined by the residual capacitance of the grid circuit, the corresponding L-C constants of the primary circuit may be calculated through the relationship of equivalent Q's. Thus the primary and tertiary circuit constants are uniquely determined. The secondary circuit constants may have any convenient practical values which permit this circuit to act as a lossless tuned link. The couplings are adjusted for the slightly overcoupled case, characterized by a triple-peak response, to secure more selectivity and more uniform response in the passband. The degree of overcoupling is limited by the allowable peak-to-trough variation of response in the passband, which should not exceed 1.15 for the complete amplifier.

In the circuit following the first amplifier tube, the primary and tertiary circuit constants are determined by the residual capacitances in the plate and grid circuits respectively, with the secondary circuit constants again being arbitrary. The unbypassed cathode resistor of the second tube in the amplifier circuit serves to compensate for input capacitance variation with change of bias voltage. The reason for controlling the gain of this tube is to adjust the intensity levels of the signals and will be discussed later. The couplings of this triple-tuned circuit are also adjusted for the condition of slight overcoupling, giving a response similar to that obtained in the preceding triple-tuned circuit.

The structural details of the coils used, together with winding data, are given in Fig. 6. In application it should be kept in mind that variation in other structural factors of the circuit may have an appreciable effect at the frequencies involved so that this information should be considered only as approximate.

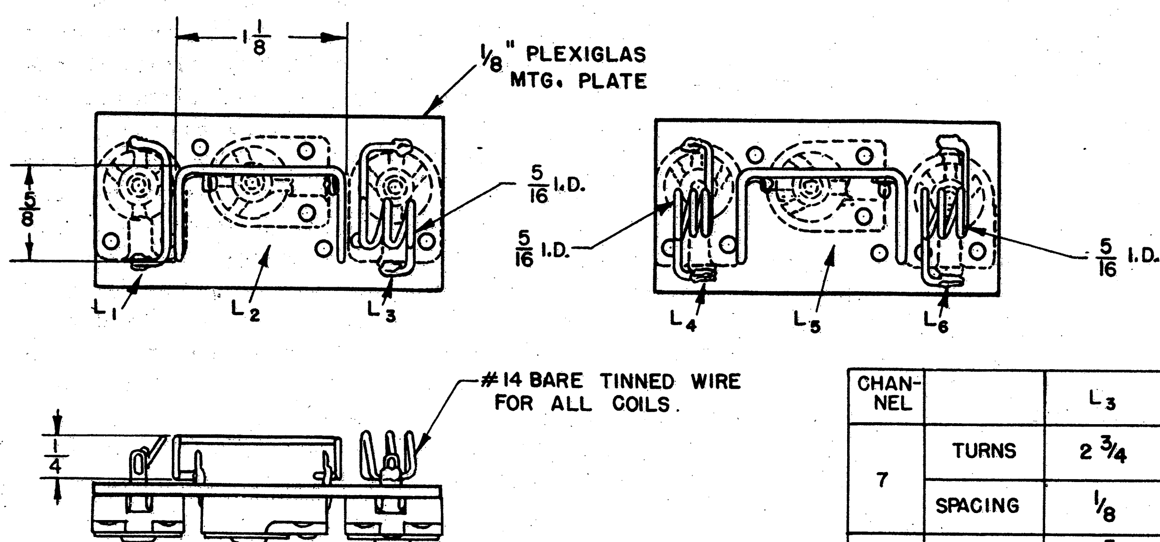
The Signal-Combining Circuit

This circuit is required to combine the signals at the output of the channel ampli-



(A) Low-frequency channels

	CHANNEL	L_1	L_2	L_3	L_4	L_5	L_6
NO. TURNS	1	1.6	12.5	12.5	14.5	9.0	12.5
	2	1.2	9.5	9.5	11.0	8.0	10.0
	3	1.0	7.5	7.5	9.0	7.0	8.0
	4	0.8	6.5	6.5	7.3	6.0	6.5
WIRE SIZE		#14 E	#22 E	#22 E	#24 E	#24E	#24 E

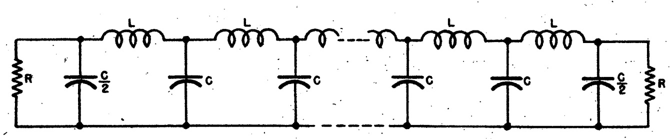


(B) High-frequency channels

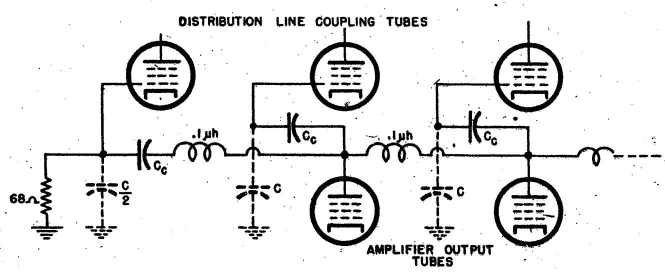
CHANNEL		L_3	L_4	L_6
7	TURNS	2 3/4	3 3/4	3 3/4
	SPACING	1/8	1/8	5/32
9	TURNS	2 3/4	3 1/4	3 1/4
	SPACING	5/32	3/32	1/8
11	TURNS	2 1/4	2 3/4	2 3/4
	SPACING	3/32	3/32	1/8
13	TURNS	2 1/4	2 1/4	2 1/4
	SPACING	5/32	1/8	1/8

Fig. 6 – R-F coil construction data.

fiers. This may be physically realized through a number of circuit configurations. Probably the highest efficiency of signal transfer could be obtained by the use of wide-band transformers which would not only restrict the passbands to within the required range but also provide separation of input and output capacitances. Since two bands must be passed, i.e. 44-88 Mc and 174-216 Mc, a double band-pass network might also be used. This would be less complex but also less efficient than wide-band transformers. The circuit actually used is a low-pass circuit, passing up to 216 Mc, which although still less efficient is considered adequate for the requirements of this particular antenna distribution system, and is very simple.



(A) Basic circuit



(B) Application

Fig. 7 - Signal combining circuit.

The circuit is shown in Fig. 7. C is the residual capacitance of the circuit, and since end-to-end attenuation in the network is negligible, the plate and grid connections to the circuit may be uniformly distributed. This residual capacitance amounts to about 20 μμf. Using standard formulas such as found in Shea, T. E., *Transmission Networks and Wave Filters*, L is calculated to be 0.1 microhenry and R 69 ohms.

Distribution Line Coupling Circuits

These circuits couple the output of the signal-combining circuit to each of the balanced distribution lines, at the same time providing for a minimum of reaction between the individual lines. The circuit used is given in Fig. 8. The tube in the circuit acts as an unbalanced-to-balanced transformer and provides isolation between distribution lines.

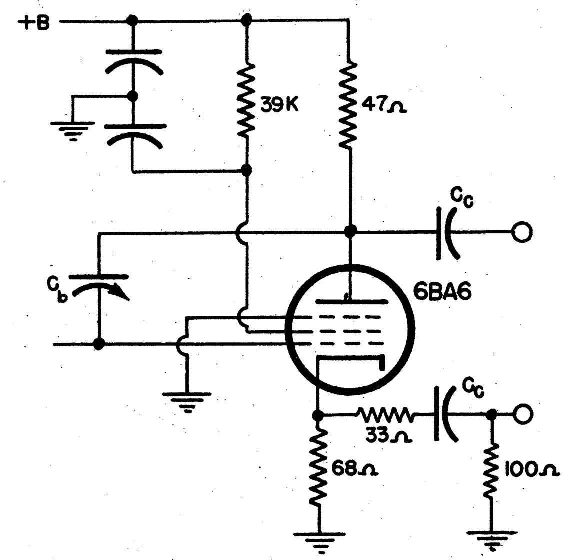


Fig. 8 - Distribution line coupling circuit.

Since it is not possible to secure both balanced impedance and voltage conditions simultaneously with a single cathode resistor the resistive π-section is used. This takes into consideration both the effects of cathode degeneration and the higher effective g_m of the cathode circuit due to the presence of screen current, but does not include the effects of capacitance currents.

The signal fed through the grid-to-cathode capacitance is balanced out by the capacitor C_b connected between grid and plate. This provides isolation so that externally applied signals at the termination of any distribution line are to a high degree prevented from being fed into any of the other distribution lines. The attenuation of such signals was measured to be of the order of 1000 to 1. In this circuit arrangement the neutralizing capacitor had a value of 4.2 μμf. The capacitor is adjusted by feeding a signal in at the termination of one distribution line and connecting a sensitive receiver tuned to receive this signal at the termination of a second distribution line. Capacitor C_b in the coupling circuit of the first distribution

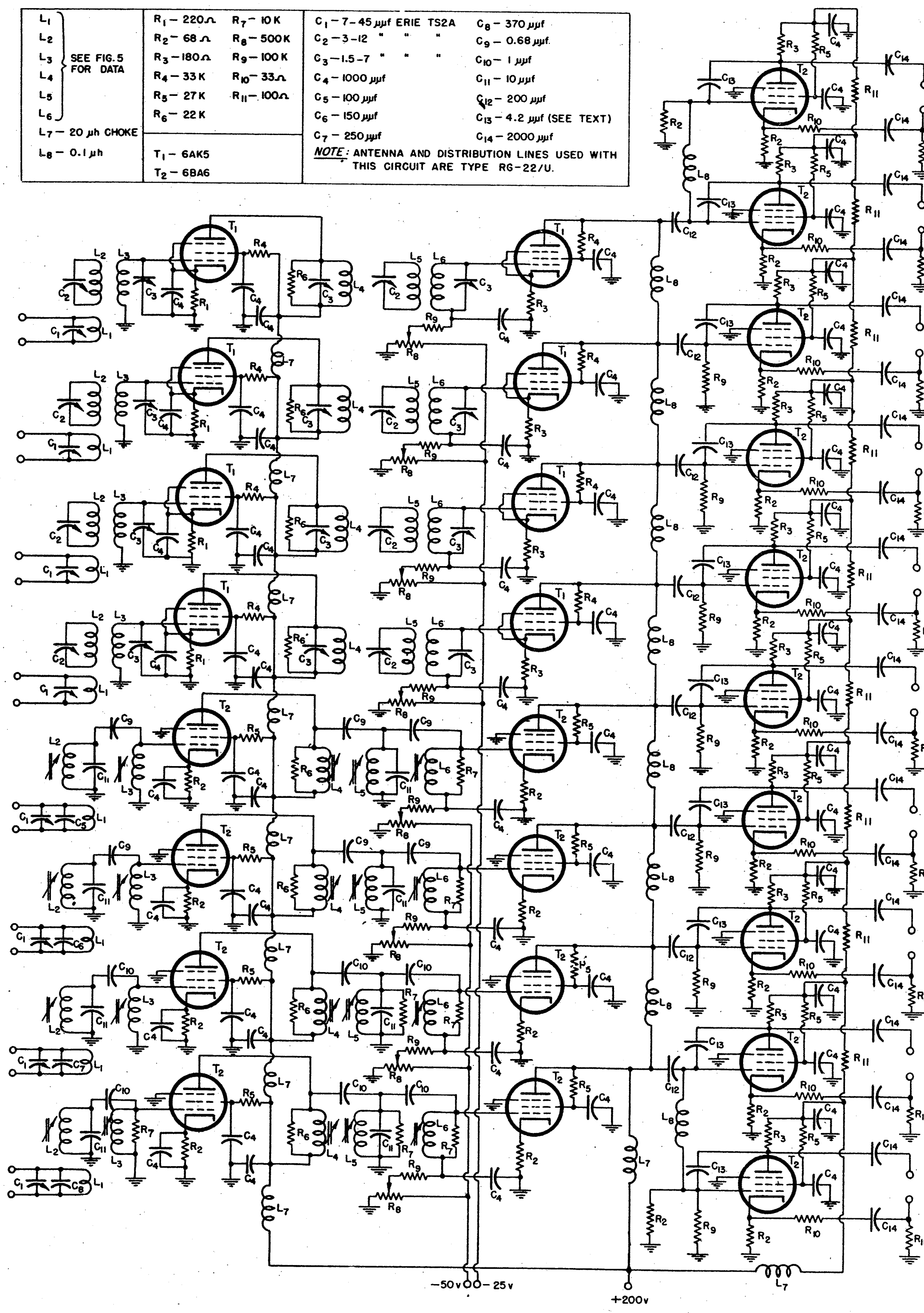


Fig. 9 - Circuit diagram.

line is then adjusted for minimum signal at the receiver.

Performance

The circuit diagram for the antenna distribution system is shown in Fig. 9. The transmission characteristics for each of the channels, from the antenna input at the amplifier to the distribution line coupling tube output, are given in Figs. 10 and 11. Since these measurements do not include the loss in the distribution lines, which is a variable element, the results should be modified by consideration of the latter in any application.

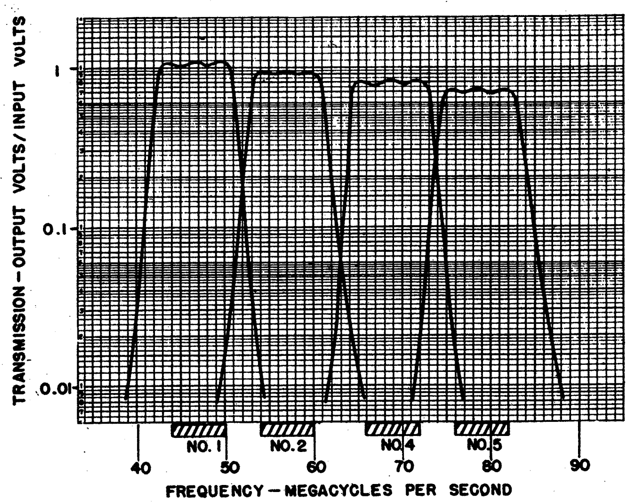


Fig. 10 – Overall transmission from antenna input to distribution lines for low-frequency channels.

An important consideration in the performance of this circuit is the signal level handling capacity. Because of the gain in the r-f amplifier the highest signal level will occur at the grid of the second tube. Fig. 12 shows an overload characteristic taken on Channel 4 with normal bias voltage on this tube. The points of interest are the change in slope occurring near 15,000 and 100,000 microvolt input. These correspond roughly to the points at which the second and first tube, respectively, overload. The occurrence of overload may be observed in its effects on the performance of a receiver. These effects are due to three principal causes, i.e. cross-modulation of the sound and picture carriers, production of harmonics of the r-f signal, and distortion of the picture and synchronizing signal modulation. Cross-modulation of the sound and picture carriers may result in an interference pattern in the picture and rumble in the sound. There is also

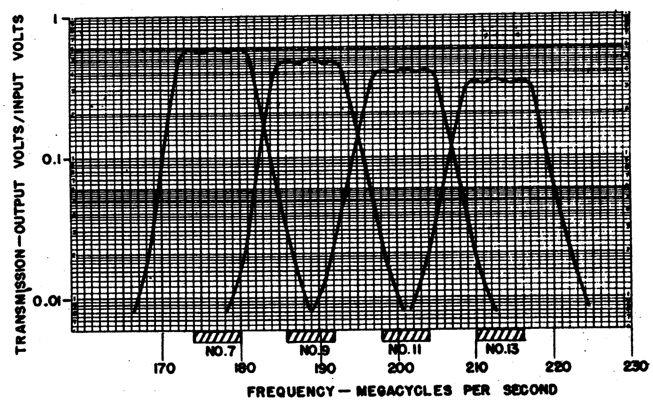


Fig. 11 – Overall transmission from antenna to distribution lines for high-frequency channels.

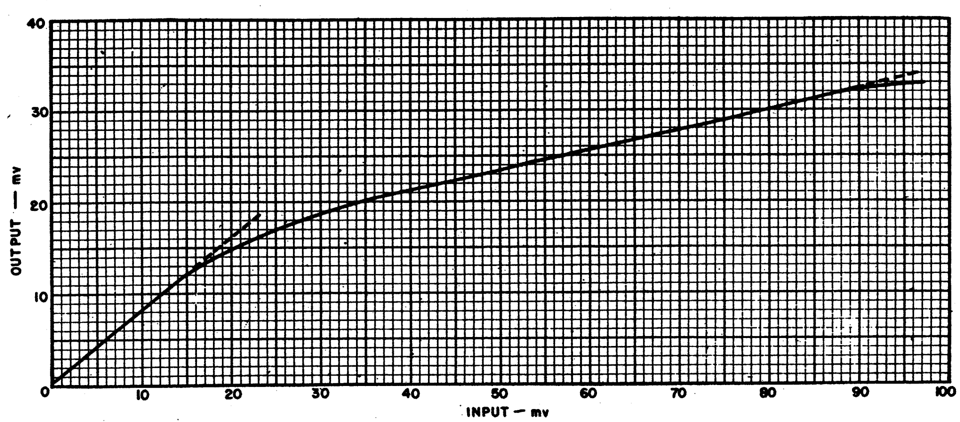


Fig. 12 – Overload characteristic measured on Channel 4.

a tendency for the horizontal synchronization to fail. The production of harmonics makes it possible for a signal on the lower channels to interfere with one in the higher channels. For example, using a receiver with a 22-26 Mc picture i-f amplifier, signals on Channel 2 produce a pattern in the background of a picture being received on Channel 4. In this case the second harmonic of the signal on Channel 2 was higher than the local oscillator frequency of the receiver by approximately the i-f frequency. Other effects of overload such as loss of contrast and strengthening of "ghosts" are not as readily discernible. The significance of this consideration is that the full gain of the amplifier should be used only with signals below a value of about 10 millivolts at the input of the amplifier. For signals which are greater than this but less than 100 millivolts the gain should be adjusted for about 10 millivolts output. For signals stronger than this an attenuating pad should be inserted in the antenna input circuit or gain control should be applied to the first tube also.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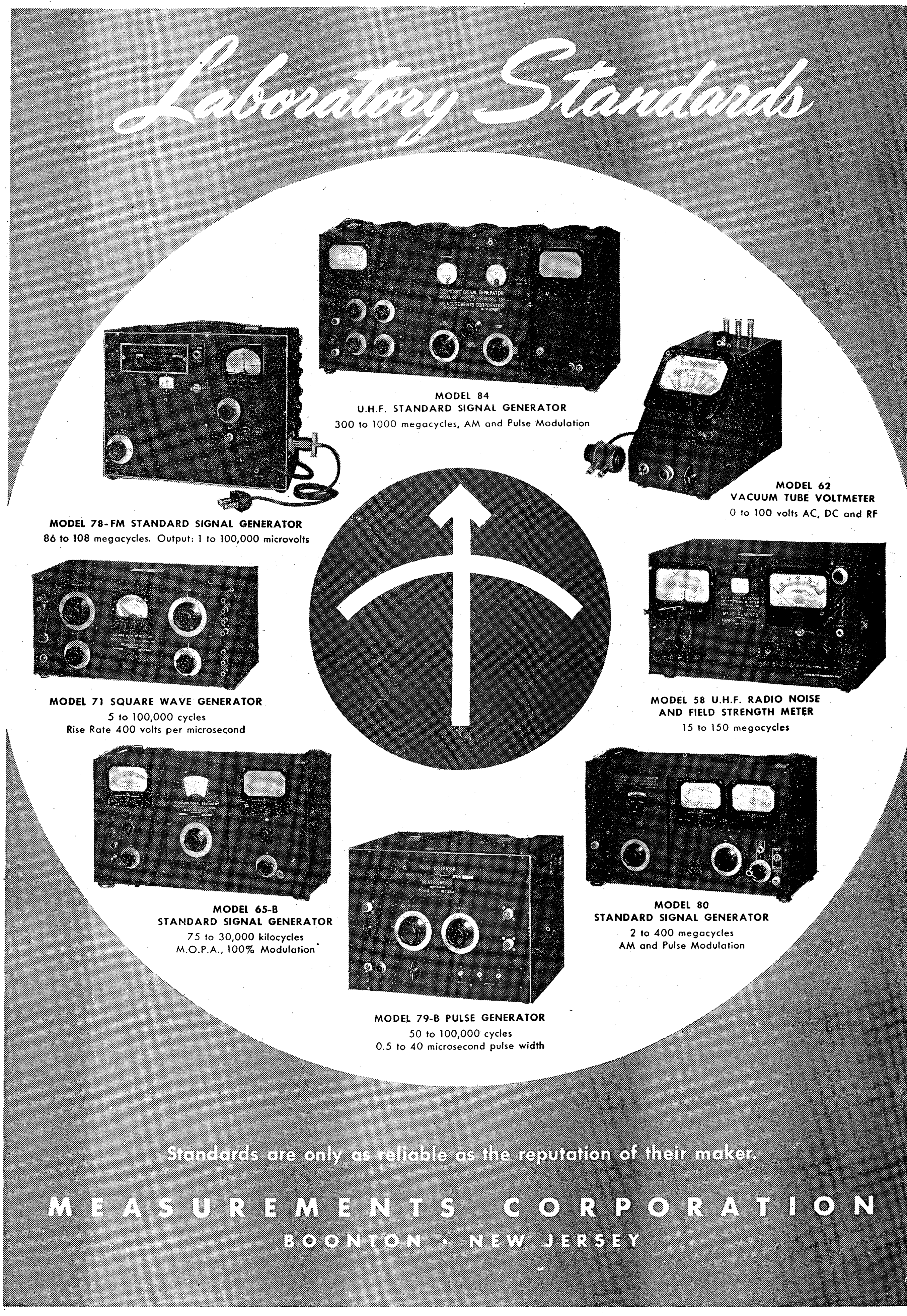
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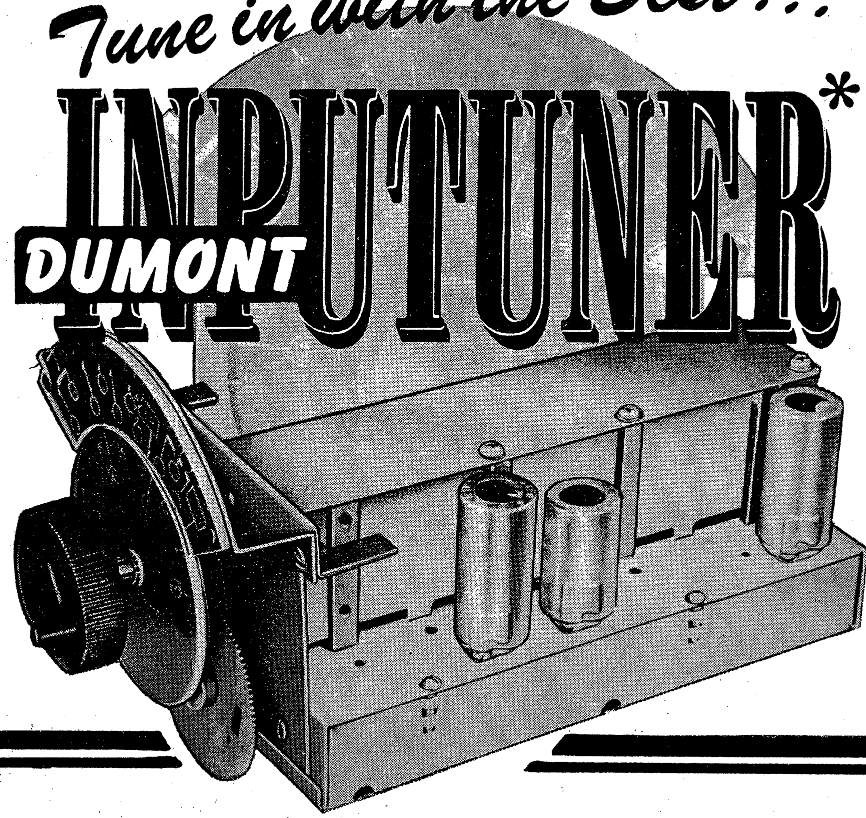

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