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# DESIGN CONSIDERATIONS O[illegible]

# TELEVISION ANTENNA-MULTIPLE[illegible]

# SYSTEM[illegible]



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# LB-1060

## DESIGN CONSIDERATIONS OF

## TELEVISION ANTENNA–MULTIPLEX SYSTEMS



Approved

Stuart Wm. Seeley

The general requirements for a satisfactory television antenna-multiplex system are found to be (1) a minimum of 20-db isolation between outlets to eliminate undesired interactions, (2) a signal level of the order of 10 millivolts at the outlets, (3) a minimum passband of 4.5 mc with a voltage variation of less than 3.0 db across the passband, (4) an overall cross modulation of less than 1 percent, (5) low harmonic distortions in all channels, and (6) freedom from interference. All of these requirements have been fulfilled by careful selection and arrangement of components of the system. The requirement for isolation, however, led to the development of a new distribution network which, theoretically, is capable of exhibiting infinite isolation between outputs at the expense of a 12-db reduction in signal level at each output of a one-input, four-output network. The constructional details of the new distribution network and an illustrative working system for four television channels are described, together with complete performance characteristics.

## Introduction

A television antenna-multiplex system distributes the desired signals to a number of usable outlets so that many television receivers can be operated from a single antenna. The requirements for a satisfactory antenna-multiplex system are more stringent with the advent of color television transmission, thus necessitating special design considerations.

## General Requirements of Antenna-Multiplex Systems

### *Interaction Between Outlets*

The input circuit of most television receivers may be matched only to the channel at which the receivers are tuned, but it may vary from an open- to a short-circuit condition at the frequencies of the other television channels. Therefore, a high degree of isolation between outlets is stipulated to minimize the interaction from one receiver to another. Experimental results have shown that with a minimum isolation of 20 db, interaction between outlets is negligible.

A conventional method of obtaining the isolation is by means of resistive pads, but such isolation is achieved at the expense of signal level by exactly the same amount. Consequently, a new distribution network has been developed with theoretically infinite isolation between outlets, but practical limitations of components give an average value of 25 db of isolation for a one-input, four-output configuration. For this same configuration, however, the signal strength at each output is down only 12 db--6 db resulting from the theoretical insertion loss in addition to the expected distribution-reduction factor of 6 db.

### *Signal Level*

The signal level at the outlets must be of sufficient strength to override any interfering signal being picked up by the system. An interfering signal that is 40 db below the level of the desired signal is considered to be satisfactory in television receivers, according to most experienced observers.

In an antenna-multiplex system, stray pickups can take place in the long cables between the antenna and the outlets and the lead-in line between the television tuner and the receiver input terminals. Measurements have indicated a combined stray pickup in the order of 100 microvolts at locations about 10 miles from high-power stations. Because of the phase differences, such stray pickups of television signals usually degrade the picture quality received through the complete antenna-multiplex system. For this reason, such pickups are classified under interfering or undesired signals which must be kept 40 db below the desired signal. Therefore, the desired signal at the outlets must be in the order of 10 millivolts.

*Voltage Variation Across Passband*

Another important consideration for an antenna-multiplex system, especially so for a laboratory system, is the voltage variation or 'tilt' across the passband of any given channel. Excessive tilts may give rise to some serious consequences. For instance, a peak at the sound carrier increases the cross modulation percentage in the receiver which may result in visible sound bars in the picture. This tilt can cause peaking of the 'video highs' which results in pictures with 'white outlines.' Similarly, a peak at the picture carrier causes peaking of the 'video lows' which results in a 'smearing' picture.

Voltage maxima and minima within a passband usually aggravate conditions, especially in a color transmission if such abrupt variations occur in the vicinity of the 'color subcarrier.' Color distortion is thereby introduced because of the non-linear phase characteristic of a sharp amplitude change. Most experienced observers have agreed that the maximum allowable voltage variation across a passband is approximately ± 1.5 db.

*Cross Modulation*

Cross modulation in a typical antenna-multiplex system is primarily caused by the third order component of the amplifier characteristic. This third order component increases when the signal (desired or undesired) is driven further into the more non-linear region. Therefore, the signal, particularly the signal input to the last amplifier stage, must be maintained at such a level as to prevent excessive cross modulation. A cross modulation component of 1 percent represents an interference level down 40 db with respect to the desired signal level.

*Harmonics*

Harmonics, like the cross modulation, are caused by the operation of the amplifiers in the non-linear region of the amplifier characteristic. These harmonics are again classified as interfering signals which must be 40 db down with respect to the desired signal. The result is that any harmonic present in the output of any amplifier at any channel must be less than 1 percent of the desired signal to which that particular harmonic forms an interference signal.

*Other Interferences*

Cross modulation, harmonics, and stray pickup are all forms of interference already discussed. Obstructions or buildings near the antenna may cause reflected waves of the desired signals, thus resulting in possible 'ghosts' in the received picture. Ghosts may also be attributable to reflections in the system caused by improper terminations or source impedances. In addition, transmissions from other services such as amateur, aeronautical, medical, industrial, etc., are potential interfering signals to television reception. For these reasons, highly directive and selective antennas such as the Yagi are preferred in the antenna-multiplex installations.

## An Illustrative Working System

All necessary components of a working antenna-multiplex system are indicated in Fig. 1 which may be regarded as a hypothetical illustration. The system must fulfill all the foregoing requirements. It receives four channels (w, x, y, and z) and provides 256 outlets.

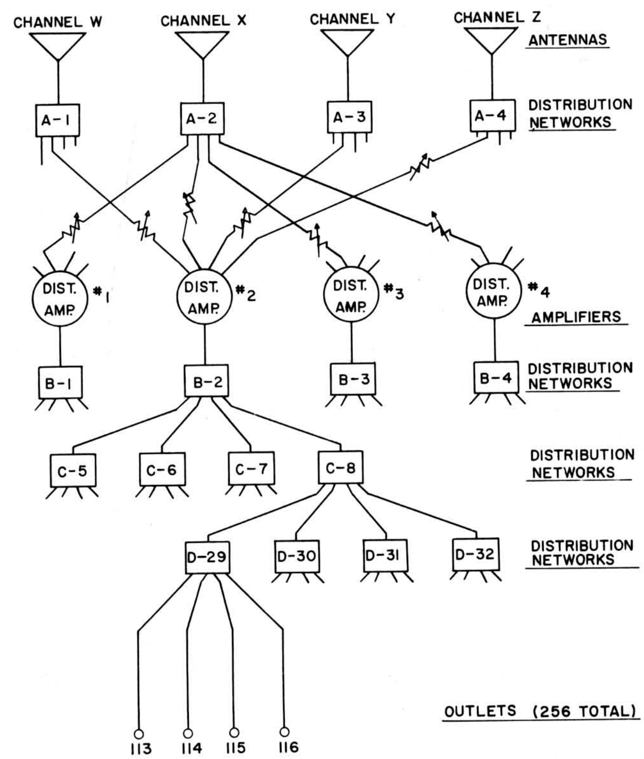


Fig. 1 – An illustrative antenna-multiplex system.

Four Yagi antennas are used, designed and orientated for channels w, x, y, and z respectively. A 300-ohm-balanced to 75-ohm-unbalanced device is incorporated in each antenna. The signal from each antenna is fed to four distribution amplifiers with RG-11U cables through a newly developed distribution network. The exact input signal to each amplifier from each antenna can be equalized by means of pads as shown in the diagram.

Four distribution amplifiers are needed to overcome the losses through the four branches of the system so that a signal of the order of 10 millivolts at any channel is available at the outlets. Each distribution amplifier consists of two separate entities, a 'high-gain, low-level' preamplifier, followed by a 'low-gain, high-level' power amplifier.

To provide a total of 256 outlets, each of the four amplifiers has to supply 64 outlets. Every outlet receives the signal from the amplifier through three distribution networks (networks B, C, and D) as shown in Fig. 1. Since the total signal reduction of each distribution network having one input and four outputs is 12 db, a signal level of approximately 1 volt is needed at the output of the distribution amplifiers to maintain a signal level of 10 millivolts at the outlets if a cable loss of 4 db is allowed.

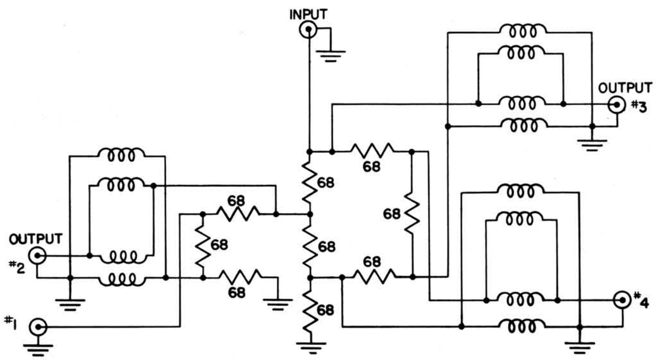


Fig. 2 – Experimental distribution-Network schematic. (1 input and 4 outputs)

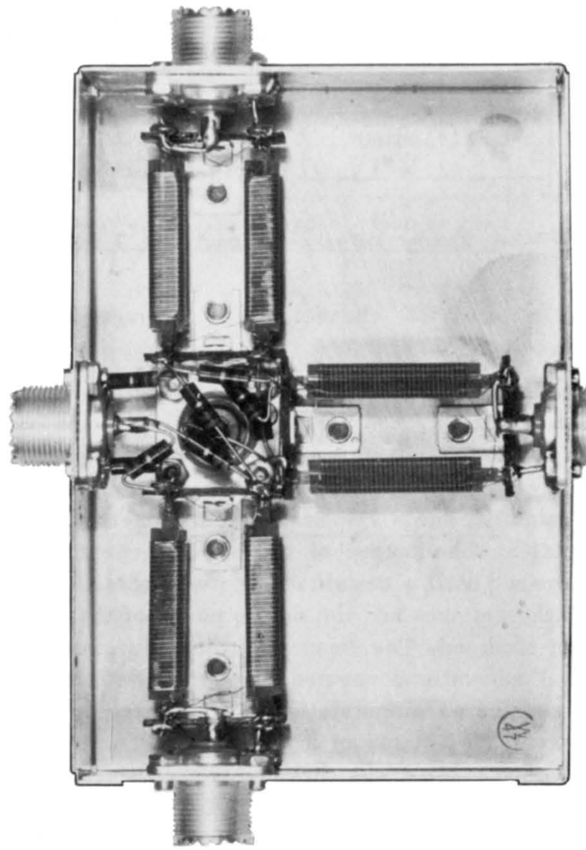

Fig. 3 – Experimental distribution network. (1 input and 4 outputs)

## Experimental Distribution Networks

Each distribution network of the hypothetical illustration used in position A, B, C, or D splits the signal from one input to four outputs. This typical application is shown schematically in Fig. 2. The components required are nine 68-ohm ½-watt resistors, six 150-ohm balun coils, (or if available, three 75-ohm balun coils) and five connectors. A preferred mechanical configuration for minimum magnetic coupling between outputs is illustrated in the photograph of Fig. 3.

*Operating Principle*

The principle of operation can be explained by a simpler network shown by Fig. 4 which has one input and two outputs. When output #2 is terminated with a 75-ohm load, the impedance $Z_{1t}$ (impedance of output #1 with output #2 terminated) looking across output #1 into the network is shown in Fig. 5.

The network looking back from output #1 is a bridge circuit with output #2 appearing in the galvanometer or bridge arm. Therefore, if the source impedance is also 75 ohms, the bridge is balanced and no current will flow through output #2 as a result of any changes at output #1. Vice-versa is also true. Since the bridge is balanced, output #2 can be left open, short-circuited, or terminated in any impedance and there will be no effect at output #1. Under these conditions, if all components are properly selected and arranged, the interaction between the outputs is theoretically zero.

Reflections due to mismatch at the distribution network or at the outlets, causing a time-delayed signal appearing as ghosts in a received picture, are virtually eliminated by the distribution network, provided the source impedance is matched to the line. This interesting property is illustrated in Fig. 6 where a 75-ohm source is connected to a simplified distribution network. Any reflected signal caused by a mismatch at outlet #1 going back along the line will be absorbed by the matched load at the distribution network; thus no time-delayed signal occurs at the outlet.

*Experimental Data*

Table I shows the losses through four typical production samples of the distribution network at 80 mc to simulate the lower VHF channels and 200 mc to simu-

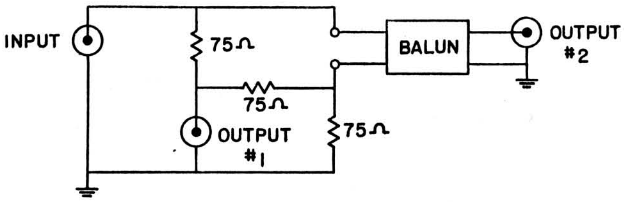


Fig. 4 – A simpler network (1 input and 2 outputs).

late the upper VHF channels. The average loss is approximately 12 db.

Table II shows the isolation between the outputs for an average distribution network. The isolation was determined in the following manner. A signal generator was connected to the input of the network, three outputs were terminated, and a 75-ohm detector connected to the fourth output. The output of the signal generator was then increased until a certain reading was obtained on a meter at the detector and the output power of the signal generator recorded. The input was then terminated and the signal generator connected to one of the three previously terminated outputs, leaving the detector at the fourth output. The output of the generator was increased until the same reading was obtained at the detector meter as when the generator was connected to the input. The isolation is the ratio of the output power of the generator when connected to an output to that when connected to the input. The average isolation between outputs is about 25 db, and in no case is it less than 20 db.

Table III shows the input impedance data normalized to 75 ohms. The reactive component is small under all conditions and at all frequencies. With the outputs properly terminated, the input resistance is 75 ohms across the VHF television band. With the outputs open- and

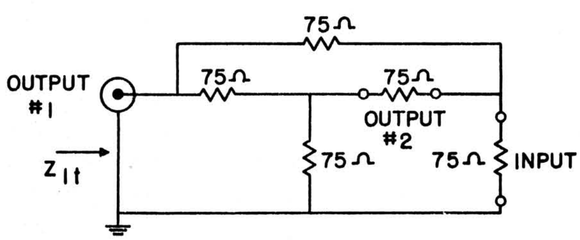


Fig. 5 – $Z_{1t}$ with output #2 terminated.

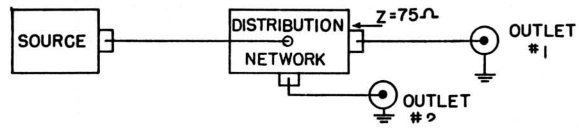


Fig. 6 – Matched load presented by new distribution networks.

short-circuited, the resistance is somewhat dependent on frequency, probably due to the inconsistent characteristics of the balun coils, although the maximum deviation from 75 ohms corresponds to a VSWR of 1.4 to 1.

Table IV shows the output impedance measurements with the input properly terminated and all remaining outputs open-circuited. These readings remained unchanged when the other outputs were short-circuited or terminated.

To further illustrate the isolation between outputs of the distribution network, the passband characteristics of any output of each 'D' distribution network are shown in Fig. 7 with extreme terminating conditions of the remaining outputs.

*Other Network Configurations*

The circuit of Fig. 4 shows the basic circuit which is used as a building block for other configurations to split a single input to any practical number of outputs. The experimental distribution network of Fig. 2 can be redrawn as Fig. 8, and it can be seen that this one-input, four-output network comprises three of the basic circuits. Other configurations are made possible by the addition or deletion of the basic circuit in the same manner as the experimental distribution network. For example, Fig. 9 illustrates a one-input, five-output network consisting of four basic circuits.

## Other Associated Components

*Cables and Connectors*

The transmission cable for an antenna-multiplex system must be carefully selected. The cable must be

**TABLE I**

| Loss Through Distribution Network in DB | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Distribution Network | Output #1 | | Output #2 | | Output #3 | | Output #4 | |
| | 80 mc | 200 mc | 80 mc | 200 mc | 80 mc | 200 mc | 80 mc | 200 mc |
| #1 | 12.0 | 12.0 | 13.2 | 11.8 | 13.2 | 12.0 | 13.0 | 12.2 |
| #2 | 11.7 | 11.8 | 13.1 | 11.8 | 13.2 | 11.8 | 13.0 | 12.0 |
| #3 | 11.9 | 11.8 | 13.4 | 12.1 | 13.4 | 11.8 | 13.3 | 12.1 |
| #4 | 11.8 | 11.8 | 13.5 | 12.1 | 13.5 | 11.8 | 13.1 | 12.3 |

## TABLE II

Isolation in DB Between Outputs of An Average Distribution Network

| Frequency mc | Input to Output | Isolation of DB | | | |
|---|---|---|---|---|---|
| | | Output #1 | Output #2 | Output #3 | Output #4 |
| 80 | 1 | – | 27.0 | 26.0 | 23.0 |
| 80 | 2 | 26.1 | – | 24.7 | 26.5 |
| 80 | 3 | 25.6 | 24.1 | – | 28.6 |
| 80 | 4 | 21.8 | 26.2 | 27.8 | – |
| 200 | 1 | – | 23.1 | 30.7 | 22.2 |
| 200 | 2 | 23.1 | – | 30.0 | 25.4 |
| 200 | 3 | 30.7 | 30.3 | – | 32.6 |
| 200 | 4 | 22.0 | 25.2 | 31.8 | – |

## TABLE III

Input-Impedance Measurements (Normalized to 75 Ohms)

| Frequency mc | $Z_{in}$ | | |
|---|---|---|---|
| | All Outputs Shorted | All Outputs Open | All Outputs Terminated |
| 57 | 0.97 + j0.47 | 0.99 + j0.19 | 0.94 + j0.32 |
| 63 | 1.04 + j0.4 | 0.93 + j0.16 | 1.01 + j0.27 |
| 79 | 1.20 + j0.04 | 0.90 + j0.26 | 1.03 + j0.15 |
| 85 | 1.12 – j0.05 | 0.97 + j0.27 | 1.01 + j0.13 |
| 175 | 1.08 + j0.32 | 0.68 – j0.48 | 0.99 – j0.10 |
| 185 | 1.19 + j0.21 | 0.61 – j0.34 | 0.94 – j0.11 |
| 195 | 1.37 + j0.16 | 0.62 – j0.20 | 0.94 – j0.13 |
| 207 | 1.32 – j0.10 | 0.63 – j0.03 | 0.98 – j0.13 |

## TABLE IV

Output-Impedance Measurements (Normalized to 75 Ohms)

| Frequency mc | $Z_{output}$ (Input Terminated 75 Ohms) | | | |
|---|---|---|---|---|
| | Output #1 | Output #2 | Output #3 | Output #4 |
| 57 | 0.95 + j0.08 | 1.10 – j0.01 | 0.97 – j0.07 | 1.07 – j0.03 |
| 63 | 0.95 – j0.15 | 1.07 – j0.07 | 0.97 – j0.07 | 1.12 – j0.05 |
| 79 | 1.07 + j0.02 | 0.86 – j0.12 | 0.82 – j0.07 | 0.85 – j0.04 |
| 85 | 0.95 + j0.05 | 0.92 – j0.12 | 0.83 – j0.09 | 0.86 – j0.09 |
| 175 | 0.93 – j0.11 | 1.47 + j0.07 | 1.53 + j0.17 | 1.43 + j0.13 |
| 185 | 0.93 – j0.12 | 1.50 – j0.20 | 1.60 – j0.12 | 1.50 – j0.13 |
| 195 | 0.92 – j0.13 | 1.40 – j0.35 | 1.47 – j0.33 | 1.43 – j0.27 |
| 207 | 0.97 – j0.07 | 1.22 – j0.50 | 1.32 – j0.43 | 1.27 – j0.45 |

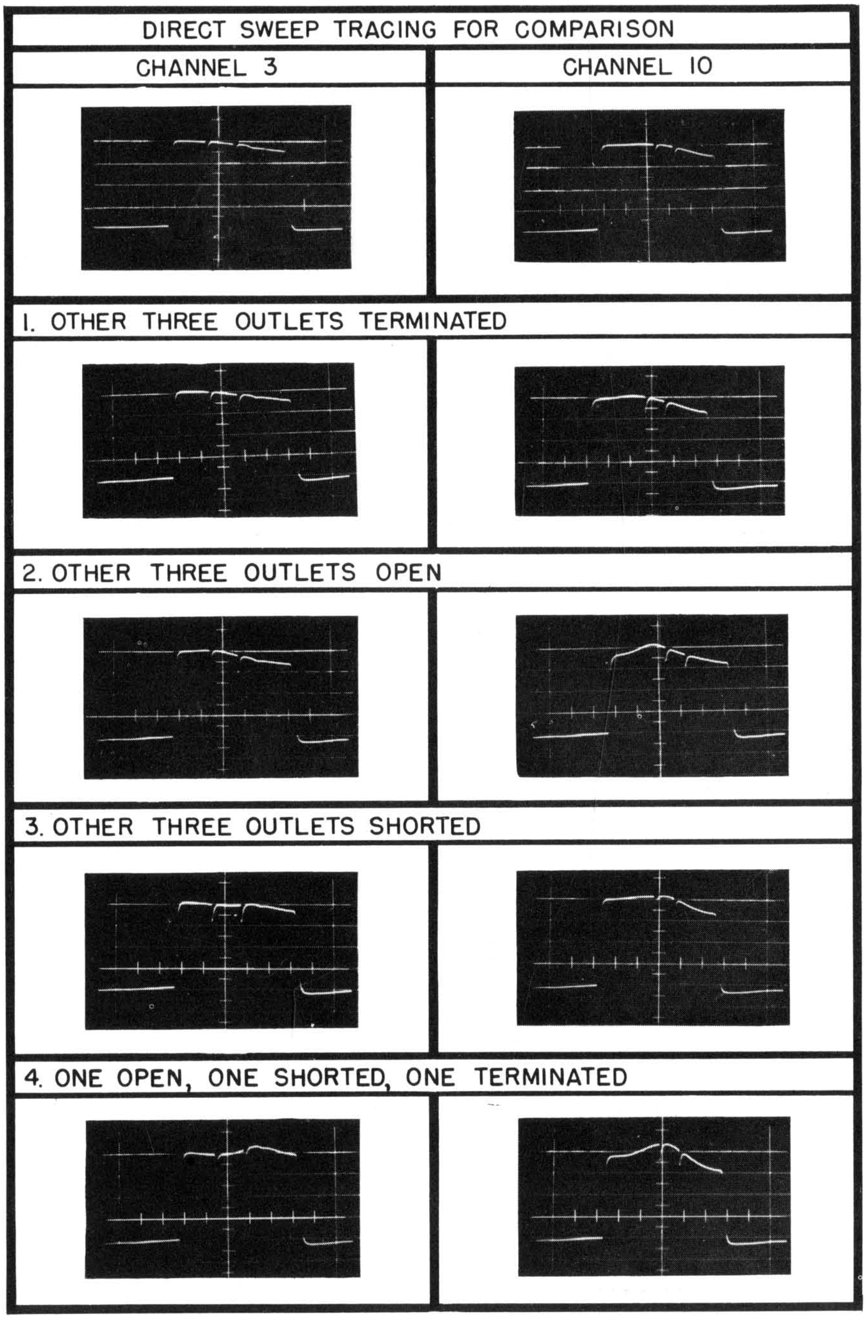


**Fig. 7 – Interaction between outlets.**

checked before installation for voltage standing wave ratio across the television band with a termination that is equal to the characteristic impedance of the cable and is not a function of frequency. It must not exhibit sharp changes in standing wave ratio which, if present, can cause maxima and minima responses within the passband of a single channel. Long runs of transmission cable having a VSWR greater than unity in the antenna-multiplex system can also cause maxima and minima responses. If the average run for the transmission cable exceeds approximately 50 feet, the maximum tolerable VSWR of the cable is 1.5 to 1, in order that the maximum voltage variation across the passband of any VHF channel does not exceed ± 1.5 db. If the average run is less than 50 feet, however, the requirement can be less stringent such that a VSWR of 2 to 1 can be tolerated

In addition, high quality connectors must be used. They must not introduce excessive discontinuities or loading effects when connected in the system.

*Amplifiers*

There are many commercially available amplifiers that, in most cases, will perform adequately for antenna-

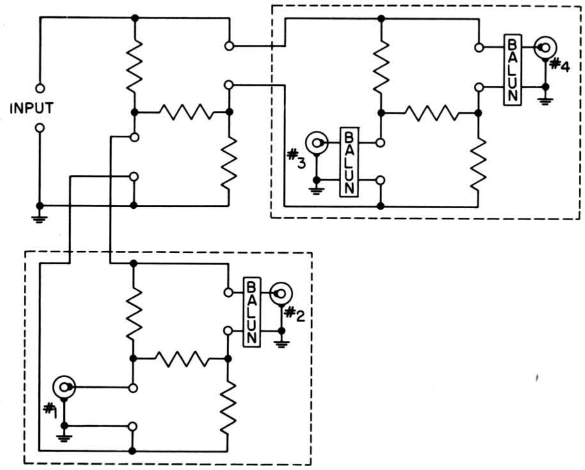


Fig. 8 – Experimental distribution network.
(1 input and 4 outputs)

multiplex applications. The gain required for a particular application automatically narrows the selection, with the final selection contingent on the amplifier satisfying the cross modulation and harmonic requirements.

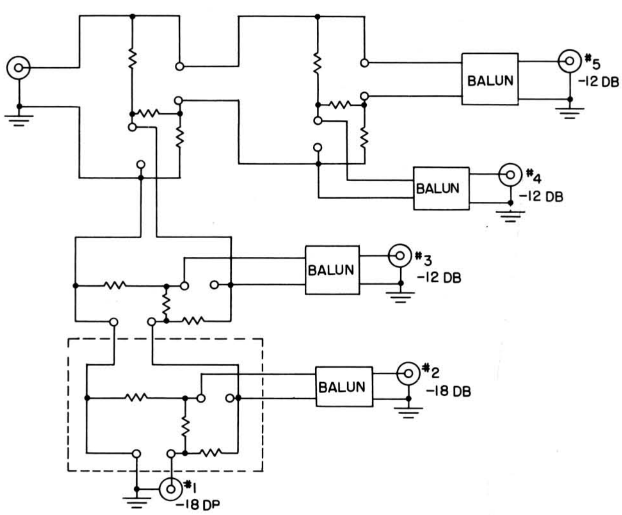


Fig. 9 – Experimental distribution network.
(1 input and 5 outputs)

## Flexibility of Antenna-Multiplex Systems

Often a locally-generated television signal such as a test pattern or slide picture of known quality and controllable signal levels is also desired for laboratory experiments. Provision was made in the illustrative

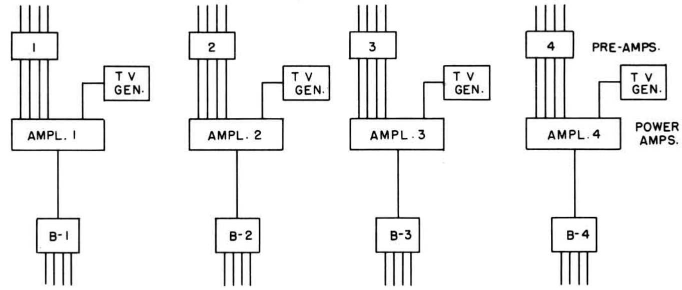


Fig. 10 – Locally-generated signal using separate generators for each amplifier branch.

working system that such a signal could be included in the distribution system.

To illustrate this flexibility, Fig. 1 is modified and is shown in Fig. 10. In every amplifier branch a television

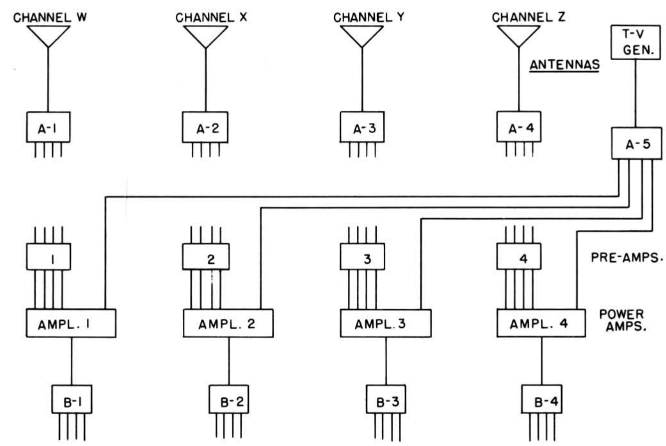


Fig. 11 – Locally-generated signal using one generator.

generator (marked TV GEN) has been added to supply the locally generated signal. Each of the four generator outputs is fed to the fifth power amplifier strip and is added to the other four television channels (w, x, y, and z) at the outputs.

Fig. 11 shows another arrangement for the insertion of the locally generated signal to the working system. There is only one generator needed in this case, with a distribution network used to split the signal four ways to provide an input for each amplifier branch. Other combinations are also possible, since a distribution network can be designed for any number of outputs from a single input. For example, two generators can be used in such a manner that (1) each supplies two amplifier branches, or (2) one generator feeds three branches and the other only one branch of the system.

Ole K. Nitssen　　Wen Yuan Pan　　Harry K. Schlegelmilch