DESCRIPTION OF EXPERIMENTAL TELEVISION RECEIVERS

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Summary—*Several television and sound receivers were constructed for use in an experimental system. The major considerations involved in the design of these receivers are outlined. Curves are shown which illustrate the receiver performance characteristics. A brief discussion of some of the observations which were made during the field tests of the receivers is included.*

INTRODUCTION

THE necessity for a wide communication band to realize even limited picture detail has brought about a consideration of frequencies above 30 megacycles per second for the dissemination of television programs. One of the major factors in determining the desirability of these frequencies for television applications is the possibility of designing suitable receivers for such frequencies. Experimental television and sound receivers have been built for these ultra-high frequencies and have given satisfactory results in the reception of both sound and television programs. It is the purpose of this paper to describe the design of these receivers and report some of the observations which were obtained through their use. These receivers were used in the general television field tests and survey work referred to in the first paper of this series.

GENERAL

When the problem of providing experimental ultra-high frequency receiving equipment capable of receiving both picture and sound programs was first considered, it was decided to use separate receivers for the sound and picture communication bands. The use of two receivers would provide considerably greater flexibility in the choice of the picture and sound carrier frequencies than would have been possible if a combination picture and sound receiver had been used. The general performance requirements for the two receivers were as follows:

1. The sensitivity should be sufficient under normal receiving conditions to reach the level where noise and interference becomes objectionable.

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2. The selectivity of the receivers should be as great as consistent with the use of a reasonable number of tuned circuits designed to pass the necessary communication bands.
3. The fidelity of the sound receiver should be comparable with the fidelity of the modern broadcast radio receiver. The fidelity of the picture receiver should be such as to provide the faithful reproduction of the transmitted image. The maximum frequency required to reproduce the picture and synchronizing impulses with the television system in use was approximately 227,500 cycles per second.

After a brief consideration of these specifications, it was evident that the superheterodyne type of receiver was best suited to

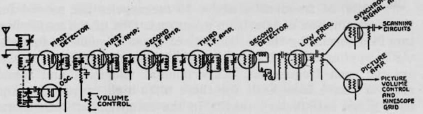

Fig. 1

provide the desired performance. Since both the sound and picture receivers were to operate in the same cabinet, the tuning range of the picture receiver was limited to 35 to 55 megacycles per second, and the sound receiver from 55 to 75 megacycles per second. These limitations on the tuning range of the two receivers

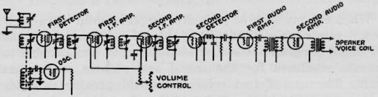

Fig. 2

were imposed in order to prevent the interference which might result from the oscillator frequency of the one receiver being adjusted to a frequency in the tuning range of the other receiver.

The schematic circuit diagrams of the picture and sound receivers are shown in Figs. 1 and 2. The same general design was employed in both the sound and picture receivers. The main differences between the two receivers were in the intermediate-frequency and low-frequency amplifiers. These differences will be discussed in detail in the sections of the paper devoted to these amplifiers.

ANTENNAS

Several types of ultra-high-frequency antennas were tested to determine the most suitable type for installation in the average home. Directional antennas were the most efficient of the types tested, but these would be unsatisfactory for receiving signals from television broadcast stations located in different directions unless some means for rotating the antenna structure were provided. A vertical half-wave antenna connected directly to the receiver was found to be the most satisfactory in the majority

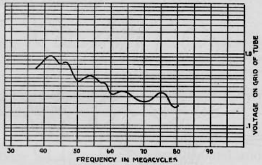

Fig. 3

of locations. An antenna of this type will function satisfactorily over a fairly wide frequency range, as indicated by the curve in Fig. 3. This curve shows the voltage developed across a tuned circuit directly connected to a half-wave vertical antenna 96 inches long.

A small number of homes were found where the indoor half-wave antenna did not intercept signals of sufficient strength to permit satisfactory reproduction of the television programs. At these locations it was necessary to erect the antenna in an unshielded location, such as above the roof of the building, and connect it to the receiver through a transmission line.

The field strength interference patterns encountered in the frequency range from 40 to 80 megacycles made it necessary to determine experimentally the antenna location which would provide the greatest signal strength. An indication of these variations in field strength is given by the contours in Fig. 4, which show the relation between received signal strength and antenna location on the ground floor of a house. A vertical half-wave antenna directly connected to a tuned circuit and vacuum tube voltmeter was used to determine the signal strength. From the contours in this figure it is evident that moving the receiving antenna a distance of but one or two feet may change the strength of the received signals by several hundred per cent. These interference patterns are functions of both the frequency on which the transmitter is operating and its geographical location. More than one antenna might, therefore, be necessary to obtain satis-

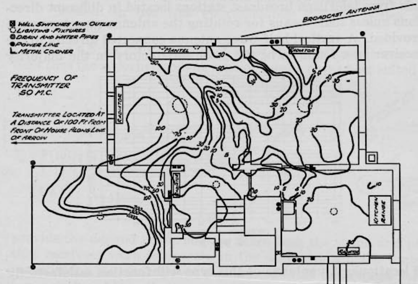

Fig. 4

factory results in receiving signals from a number of television transmitters. This requirement is not as serious as it would seem at first thought, since a half-wave antenna for frequencies above 30 megacycles is small and easily erected.

Radio-Frequency Circuits

Two coupled tuned circuits were used in both receivers to transfer the received signals from the antenna to the grid of the first detector. The first tuned circuit was provided with suitable terminals so that the antenna might be connected across either a part or all of the tuned circuit. This tuned circuit was also provided with a separate tuning control so that experiments with various antenna arrangements might be conducted. The coupling between the two tuned circuits was so adjusted as to provide a flat-topped selectivity characteristic. The self-supporting coils used in these tuned circuits were one inch in diameter, wound with No. 10 B. & S. copper wire. The radio-frequency resistance of the coils was as low as permissible on the basis of the communication band which the radio-frequency circuits must pass.

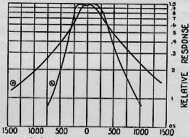

Fig. 5

The $\omega L/R$ ratio for the individual tuned circuits was approximately 125. Curve (a) in Fig. 5 shows the selectivity characteristic of a single tuned circuit at 50 megacycles. The selectivity characteristic of the two coupled tuned circuits is shown in curve (b) of the same figure.

Oscillator and First Detector

The oscillator circuit used in both the sound and picture receivers is shown in Fig. 6 A UY-227 tube functioned satisfactorily in this circuit up to 80 megacycles. Electromagnetic coupling between the oscillator and first detector tuned circuits was

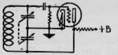

Fig. 6

used to apply the desired oscillator voltage to the grid of the first detector which was a negatively biased UY-224 tube. Fig. 7 shows the radio-frequency coil and tuning condenser arrangement.

In order to prevent the necessity of frequent retuning of a superheterodyne receiver, it is essential that the width of the frequency band which the intermediate-frequency amplifier is designed to pass be greater than the frequency deviations of the oscillator. The fulfillment of this requirement may make it necessary to design the intermediate-frequency amplifier to pass a frequency band which is several times the width of the communication band it is intended to amplify. This condition was encountered in the design of the sound receiver. The maximum frequency variation of the oscillator, due to temperature changes of the oscillator tuned circuit elements and variations in line voltage, was approximately 0.1 per cent. With the oscillator tuned to 60 megacycles, this degree of oscillator frequency instability might result in a frequency deviation as great as four times the width of the communication band which the sound re-

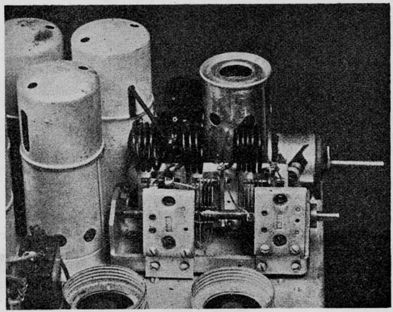

Fig. 7

ceiver was required to amplify. The communication band required for the reception of the picture signals, however, was several hundred kilocycles, making it unnecessary to consider the oscillator frequency variations in the design of the intermediate-frequency amplifier for the picture receiver.

Picture Receiver Intermediate-Frequency Amplifier

The wide communication band necessary to provide satisfactory reproduction of the television program required the use of a comparatively high intermediate frequency to obtain the desired amplification and selectivity characteristics. A high intermediate frequency was also desirable to minimize the interference due to a transmitter separated in frequency by twice the intermediate frequency from the transmitter whose signals it was desired to receive. A consideration of both these factors led to the choice of 6 megacycles as the intermediate frequency for the picture receiver. The complete intermediate-frequency amplifier used four transformers, each having two tuned circuits so coupled as to give a selectivity characteristic of the desired band width. A damping resistor was used across the primary of each transformer to flatten the top of the selectivity characteristic.

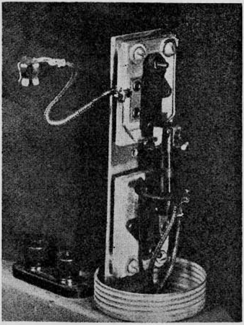

Fig. 8

The two resonant circuits in each transformer were tuned by means of small adjustable condensers. The arrangement of the coils and condensers in an individual transformer is shown in the photograph in Fig. 8. The long, narrow transformer construction permitted the location of a tuned circuit at the top and bottom of each transformer, thus making possible the use of very short leads to the grid and plate of the associated tubes. The same type of metal shield was used for both the transformer and amplifier tube.

The selectivity characteristic obtained from a single intermediate-frequency stage of the picture receiver is shown by curve (*a*) in Fig. 9. The over-all selectivity characteristic of the three-

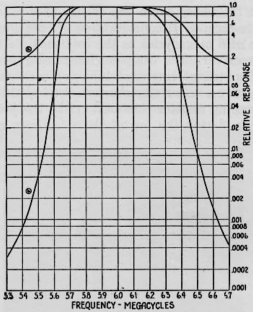
RELATIVE RESPONSE
FREQUENCY - MEGACYCLES
5.3 5.4 5.5 5.6 5.7 5.8 5.9 6.0 6.1 6.2 6.3 6.4 6.5 6.6 6.7
1.0 .8 .6 .4 .2 .1 .08 .06 .04 .02 .01 .008 .006 .004 .002 .001 .0008 .0006 .0004 .0002 .0001

Fig. 9

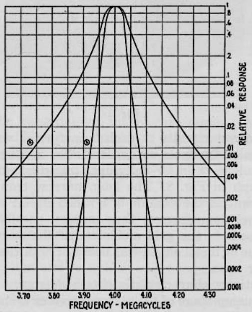
RELATIVE RESPONSE
FREQUENCY - MEGACYCLES
3.70 3.80 3.90 4.00 4.10 4.20 4.30
1 .8 .6 .4 .2 .1 .08 .06 .04 .02 .01 .008 .006 .004 .002 .001 .0008 .0006 .0004 .0002 .0001

Fig. 10

stage amplifier is shown in curve (*b*) of the same figure. The voltage gain of this amplifier as measured from the grid of the first detector to the grid of the second detector was approximately 7000.

SOUND RECEIVER INTERMEDIATE-FREQUENCY AMPLIFIER

Both the sound and picture receivers were to operate in the same cabinet, and it was therefore undesirable to use the same intermediate frequency in both receivers because of the possibility of coupling between the two amplifiers causing interference. Four megacycles was chosen as the intermediate frequency

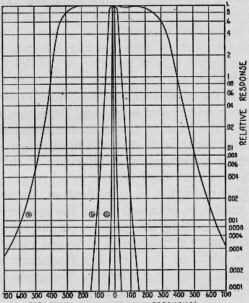

Fig. 11

for the sound receivers. The intermediate-frequency amplifier was designed to pass a band of 50 kilocycles in order to minimize the effects of the oscillator-frequency variations. The sound receiver intermediate-frequency transformers were similar in design to those used in the picture receiver. Three transformers were used in the complete amplifier. The selectivity characteristic of an individual transformer is shown in curve (*a*) in Fig. 10. Curve (*b*) in the same figure shows the over-all selectivity characteristic of the complete amplifier. The voltage gain, as measured from the grid of the first detector to the grid of the second detector, was 8000. Fig. 11 shows a comparison between the intermediate-frequency amplifier selectivity characteristics of the picture receiver, the sound receiver, and a typical broadcast receiver. These characteristics are shown in curves (*a*), (*b*), and (*c*), respectively.

Picture-Frequency Amplifier and Detector

The picture-frequency system of the television receiver consisted of a negatively-biased detector and a two-stage resistance-coupled amplifier. The television system for which the receivers were designed made use of a carrier wave which was modulated with both picture and synchronizing impulses. The synchronizing impulses were slightly larger in amplitude than the picture impulses. In order that this difference in amplitude between the picture and synchronizing impulses might be accentuated in the receiver, two separate output tubes were provided. One of these tubes was used to supply the picture impulses to the grid of the kinescope, while the other was used to impress the synchronizing impulses on the vertical and horizontal deflection circuits in the kinescope unit. The bias on the synchronizing output tube was made sufficiently negative to distort the impulses supplied to its grid, and thereby accentuate the difference in their amplitudes. The high negative bias used on the synchronizing output tube caused a decided reduction in amplification. In order that sufficient output might be obtained from the synchronizing output tube without overloading the picture output tube, the grids of these two tubes were connected to a tapped resistor which was coupled to the plate of the first low-frequency amplifier tube through the usual coupling condenser. The grids of the two output tubes were connected to the tapped resistor so that the impulses applied to the grid of the synchronizing output tube had twice the amplitude of those applied to the picture output tube. A potentiometer connected in the plate circuit of the picture output tube was used to control the amplitude of the signals applied to the grid of the kinescope. A potential variation of only ten volts on the grid of the kinescope was sufficient to provide full modulation of this type of light source. This voltage could readily be obtained from a UY-224 tube, even though a comparatively low value of load resistance was used to obtain the desired frequency response characteristic. UY-224 tubes were likewise used for the synchronizing output tube, the first low-frequency amplifier and the negatively-biased detector. The over-all frequency response characteristic of the complete amplifier is shown in curve (*a*) Fig. 12.

Audio-Frequency Amplifier and Detector

The audio-frequency system of the sound receiver was similar to that employed in conventional broadcast receivers. The negatively-biased UY-224 detector was followed by a resistance-coupled audio-frequency stage using a UY-227 tube. This tube, in turn, was coupled through a transformer to the UX-210 output tube. The UX-210 tube was used because it minimized the power required from the combined socket power unit since the high plate potential used with this tube was also required for the synchronizing circuits. The frequency-response characteristic of the complete audio-frequency amplifier is shown in curve (*b*) of Fig. 12. A comparison between curves (*a*) and (*b*) in this figure shows the relative frequency characteristics of both the picture and sound low-frequency amplifiers.

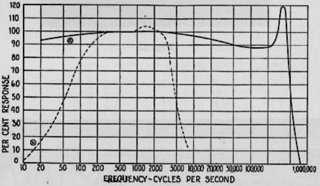

Fig. 12

Complete Receivers

The general chassis arrangement of the picture receiver is shown in Fig. 13. The four metal shields in the middle of the chassis contain the intermediate-frequency transformers. The tubes are enclosed in the other shields. Fig. 14 is a photograph showing the bottom view of the chassis. The arrangement of the by-pass condensers and coupling resistors is illustrated in this figure. Fig. 15 shows the general arrangement of the sound receiver chassis. Three of the shields on this chassis contain intermediate-frequency transformers; the remainder are tube shields. Both receivers were mounted in the cabinet on blocks of sponge

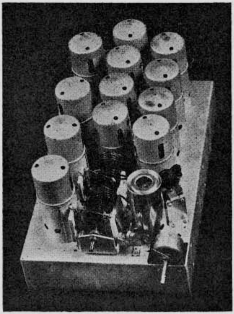

Fig. 13

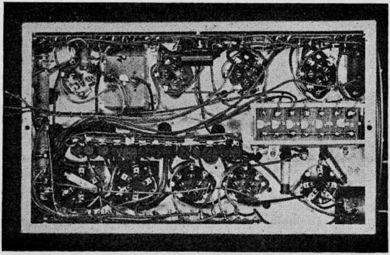

Fig. 14

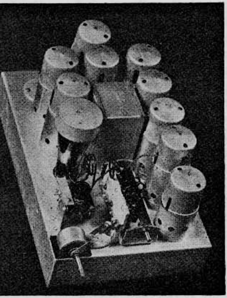

Fig. 15

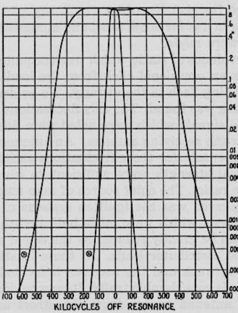
RELATIVE RESPONSE
KILOCYCLES OFF RESONANCE
700 600 500 400 300 200 100 0 100 200 300 400 500 600 700

Fig. 16

rubber to prevent the vibrations from the loud speaker being transmitted to the receiver chassis. The plate, grid, and filament potentials for both receivers were supplied from the common socket power unit.

At the time the receivers were designed and built, a reliable attenuator for ultra-high frequencies was not available for use in measuring the absolute sensitivity of the receivers. Field tests of the receivers at various locations, however, indicated that the sensitivity of both the sound and picture receivers was sufficient to reach the normal noise or interference level. The over-all selectivity curves of the sound and picture receivers are shown in Fig. 16. Curve (*a*) is the selectivity characteristic of the picture receiver, and curve (*b*) the corresponding characteristic of the sound receiver. The over-all fidelity characteristics of the two receivers are substantially the same as the characteristics of their low-frequency amplifiers, as shown in Fig. 12. The fidelity of the picture receiver was such that the reproduced pictures were practically identical in detail with those obtained on the monitor unit at the transmitter.

Observations on the Reception of Television and Sound Programs

These experimental ultra-high-frequency picture and sound receivers were in use for some time, and a number of interesting observations were made.

The only evidence of static which was encountered during the field tests was an occasional click from the loud speaker at the time of a lightning flash in the vicinity. No evidence of multiple images or fading was found. The only fluctuations in the strength of the received signals which were noted were due to the motion of objects near the receiving antenna. An automatic volume control could compensate for these fluctuations satisfactorily if the minimum signal strength were sufficient to give the required signal-to-noise ratio. The chief source of man-made interference which was observed was the ignition systems of airplanes and automobiles. Tests which were made indicated that this type of interference can be greatly reduced by the use of resistors in the spark plug and distributor loads. At those locations where the field strength is weak and the receiver is located near a street on which there is considerable traffic, it may be desirable to erect the receiving antenna as far from the street as possible and connect it to the receiver through a shielded transmission line.

The psychological effect of interference in the picture and sound programs is very interesting. Prior to the tests it was felt that for a given interference the field strength necessary to give a satisfactory signal-to-noise ratio would be much greater for the picture signals than for the sound signals, because of the wider communication band required for the picture signals. The conclusion reached by a number of observers, however, indicate that the effect of interference, such as that due to the ignition systems of automobiles, on the picture programs was not as serious as expected on the basis of the above assumption. In several instances such interference produced a more objectionable effect on the sound program than it did on the picture program. Whenever the interference was of sufficient amplitude to destroy the picture synchronization, it likewise prevented the satisfactory reception of the sound program. The effect of interference of a temporary nature on the picture program could easily be avoided by glancing away from the picture. With the sound program, however, the only means of obtaining relief from such interference was either to turn off the set or turn down the volume control.

In the case of the usual sound broadcast program, the listener can obtain some measure of enjoyment while reading or engaged in some other diversion. To derive any degree of pleasure from a television program requires the entire attention of the observer.