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CONTENTS

TELEVISION BROADCAST COVERAGE
By Allen B. DuMont *and* Thomas T. Goldsmith, Jr.

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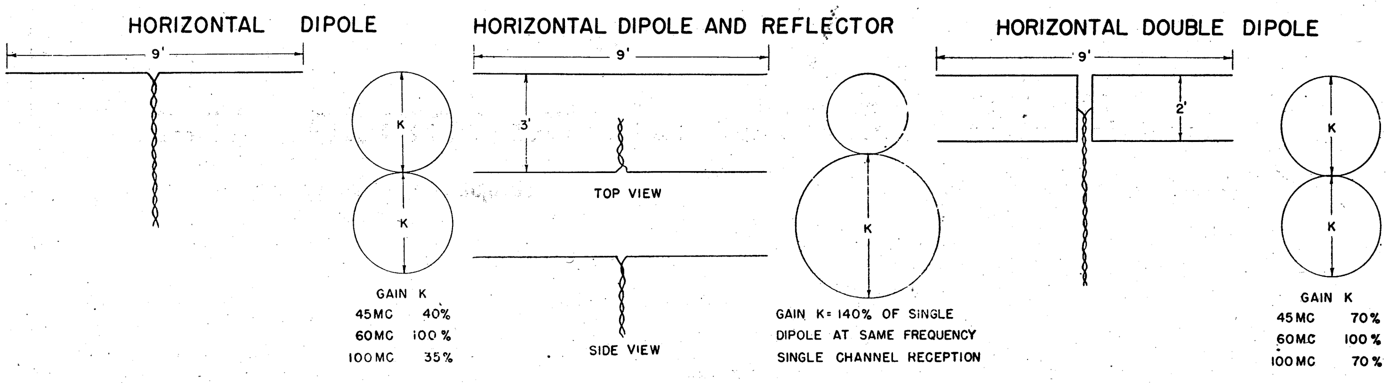

FIGS. 1, 2, 3, SHOWING THE ANTENNAS USED IN THE PRELIMINARY TESTS, AND THE DOUBLE DIPOLE WHICH GAVE IMPROVED RESULTS

TELEVISION BROADCAST COVERAGE

Presenting Multipath Distortion Data Obtained by an Exhaustive Survey in the New York City Area

BY ALLEN B. DU MONT AND THOMAS T. GOLDSMITH, JR.*

Summary ★ An extensive field survey has been made of the three television transmitters in the New York territory. The survey consisted of observations of many receivers permanently installed in the metropolitan area and of observations made with special receiving equipment mounted aboard the cruiser *Hurricane II*. Continuous recordings of field strength and still photographs have been made.

This paper deals extensively with the multipath problem in television broadcasting which causes multiple patterns in the received picture. Extensive use is made of photographs and diagrams illustrating the appearance of these patterns and explaining the causes of these various types of *ghosts*.

The findings of this survey definitely lead to the conclusion that the lower frequency channels provide the least multipath interference in metropolitan territory such as New York City. Reasonably good reception is found from all three New York stations at distances beyond five miles up to the distances where signal level becomes too low for satisfactory receiver operation.

Photographs are used to exhibit the quality of reception and types of programs now current in good locations around New York City.

Introduction ★ In the deliberations of the N.T.S.C. (National Television System Committee) before the adoption of standards in June, 1941, very little attention was given to the effect of secondary images or ghosts, upon the received signal. It was generally assumed that if a picture of 525 lines definition was faithfully transmitted and a receiver capable of reproducing that picture was employed, the resulting image would show no appreciable loss of detail. It is quite understandable how this happened. The only transmitter in operation was transmitting on a frequency between 44 and 50 mc., relatively few receivers were in operation and the picture was not viewed in the critical way it is today. With the elimination of this channel to make room for FM transmissions, and television broadcast stations going into operation on frequencies between 50 and 84 mc. it has become apparent since that time that secondary images are the No. 1 technical problem of the telecaster. Although this paper is concerned with television broadcast coverage generally, particular stress will be laid on the subject of secondary images because of their great importance.

To understand the problem of television transmission, it must be kept in mind that, unlike audio broadcasting, where multiple signals arriving several hundred micro-seconds apart cannot be detected by the ear, in television a difference of about 10 micro-seconds causes one picture to be superimposed on the other but displaced one inch from it.

The results and conclusions are based on television transmissions in the area covered by the New York stations which extends in a radius of approximately 75 miles from Manhattan. Although this area may not be typical of conditions throughout the United States, nevertheless similar problems in secondary images will be experienced in any locality with tall buildings, bridges or hilly terrain, and the other problems covered will be met with universally.

General Receiving Conditions ★ There are three television stations transmitting in this area —

Station WNBT of the National Broadcasting Company operates on Channel No. 1, 50 to 56 mc. Its antenna is 1,300 ft. high and its video transmitter output is 6.0 kw. peak power, while the sound transmitter operates at 3.5 kw. peak power.

Station WCBW of the Columbia Broadcasting System operates on Channel No. 2, 60 to 66 mc. Its antenna is 1,000 ft. high and its video transmitter output is 2.5 kw. peak power, while the sound transmitter operates at 1.0 kw. peak power.

Station W2XWV of the Allen B. Du Mont Laboratories, Inc., operates on Channel No. 4, 78 to 84 mc. Its antenna is 650 ft. high and its video transmitter output is 6.0 kw. peak power, while the sound transmitter operates at 1.0 kw. peak power.

Transmissions are staggered, WNBT operating Monday afternoon and evening with films, WCBW operating on Thursday and Friday evenings with films, and W2XWV on Sunday, Tuesday and Wednesday evenings with live talent and films. All three stations transmit test patterns Wednesday afternoons between 3:00 and 4:30 P.M. for service purposes. All transmitters are located near the center of Manhattan Island within a radius of one mile.

Some 6,000 television receivers are in

* President and Director of Research respectively, Allen B. Du Mont Laboratories, Inc., Passaic, N. J.
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operation and are being used to receive the transmitters. As a considerable number of these were of our own manufacture and were installed by the factory, the field problems encountered have undergone careful study leading to valuable solutions. To start with, only one station was in operation: W2XBS of the National Broadcasting Company operating on 44 to 50 mc. As we did not know what other stations might be on later or on what frequencies, simple dipole receiving antennas were installed with a twisted pair lead in, Fig. 1.

This particular antenna was generally used except in outlying areas where weak signals prevailed, in which cases a reflector was added, and a coaxial cable used to connect the antenna to the set to provide the maximum signal to the receiver, as in Fig. 2.

When W2XBS shifted frequency to the new No. 1 channel, 50 to 56 mc., and became WNBT, it was found advisable to cut the antennas so they would resonate at the new frequency to provide maximum signal strength and also to prevent deterioration of the picture quality due to the narrow band characteristics of the antenna. Considerably increased secondary images were noted on this higher frequency channel, and in a number of cases we found that it was advisable to install reflectors in high signal areas to sharpen the directional characteristics and reduce secondary images. With WCBW of the Columbia Broadcasting System on a frequency of 60 to 66 mc., and W2XWV of the Allen B. Du Mont Laboratories, Inc., on a frequency of 78 to 84 mc. going on the air, it was soon found that those receiving antennas and lead-ins were not suitable because of reduced signal pick-up on the still higher channels and the loss of picture detail. A broad band receiving antenna, consisting of a double dipole together with

TABLE 1. LISTENER REPORTS

Number of Reports	*Location*	*Approximate Distance From Transmitter*	*Estimated Distribution Percentage*
53	Manhattan	0– 5 miles	9.8
44	Bronx	4–12 "	8.1
53	Brooklyn	3–13 "	9.8
70	Queens	3–15 "	12.9
56	Nassau County, N. Y.	13–30 "	10.3
6	Richmond County, N. Y.	10–20 "	1.1
32	Westchester Co., N. Y.	12–30 "	5.9
1	Suffolk County, N. Y.	40 "	.2
1	Orange County, N. Y.	55 "	.2
21	Hudson County, N. J.	1–9 "	3.9
36	Bergen County, N. J.	4–20 "	6.6
36	Passaic County, N. J.	10–30 "	6.6
70	Essex County, N. J.	8–20 "	12.9
26	Union County, N. J.	11–25 "	4.7
6	Morris County, N. J.	20–35 "	1.1
9	Middlesex County, N. J.	20–40 "	1.6
5	Monmouth County, N. J.	25–40 "	.9
1	Mercer County, N. J.	45 "	.2
1	Sussex County, N. J.	45 "	.2
2	Philadelphia, Pa.	85–95 "	.4
14	Connecticut	25–50 "	2.6
543			100.0

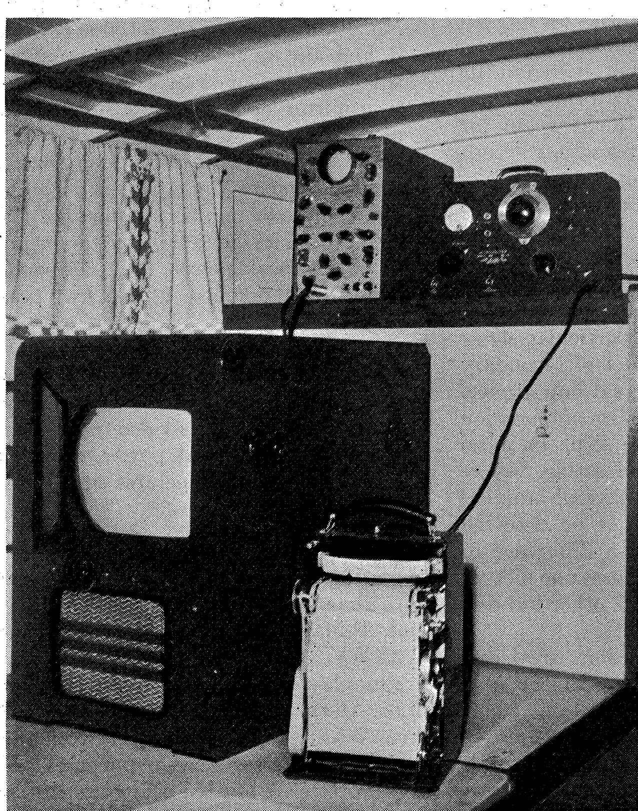


FIG. 4. RECEIVER AND RECORDER SET UP ABOARD THE BOAT USED TO EXPLORE RECEPTION CONDITIONS IN THE N. Y. AREA

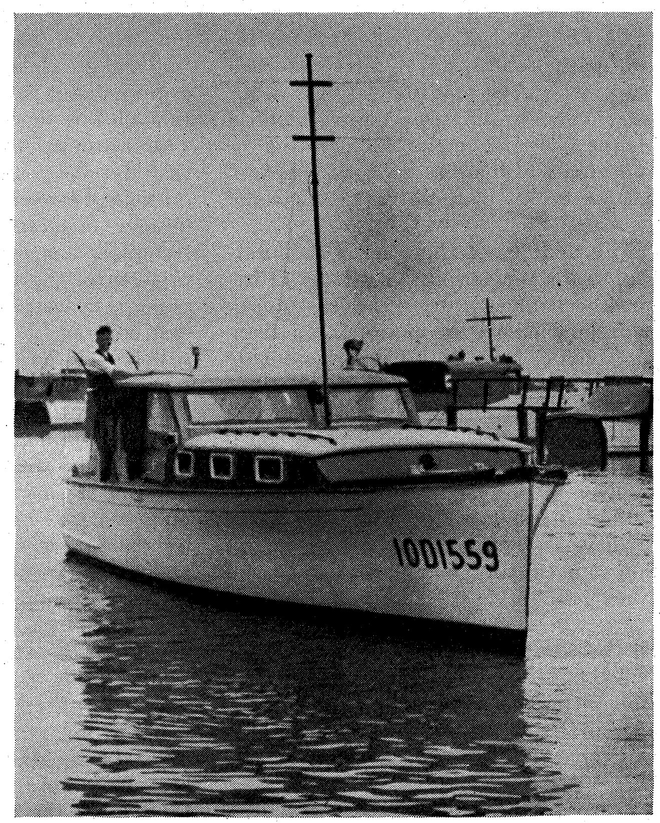


FIG. 5. THE HURRICANE II WITH THE DOUBLE DIPOLE EMPLOYED BY AUTHORS TO OBTAIN RECEPTION DATA PRESENTED HERE

FIG. 6. MAP SHOWING THE DISTRIBUTION OF TELEVISION RECEIVERS IN THE NEW YORK AREA, AND POINTS WHERE RECORDINGS, SHOWN IN FIGS. 22, 25, 26, 27 WERE TAKEN

a low loss lead in, Fig. 3, has been utilized for the past year with good results as far as signal strength and picture detail are concerned, although greatly increased secondary images in certain areas became very objectionable.

Generally speaking, the greatest difficulty has been experienced with secondary images within a radius of about eight miles from the transmitters. This should be more or less expected, for within that area the tall buildings and bridges of New York City are located. Difficulty is also experienced outside of this area where the receiving antenna is blocked by hills or buildings, or is located between the transmitter and a prominent hill.

Signal strengths of above 500 microvolts at the receiver have generally been obtained at distance up to 35 miles from WNBT and W2XWV, and up to 20 miles from WCBW. It has been found that signal strengths of 100 microvolts at the receiver are adequate in quiet locations.

Table 1 gives a summary of listener reports received by W2XWV in connection with its transmissions during the past nine months. This gives an idea of the distribution of receivers.

It is interesting to note in this connection that a number of listeners at distances up to one hundred miles are receiving programs. These listeners have usually erected 40- to 50-ft. poles for their antennas and, in some cases, have added additional RF amplification to their sets. At these locations the signal is influenced by atmospheric conditions.

While diathermy interference has not been particularly objectionable except in isolated cases, it may become a serious problem after the War if the use of such equipment is greatly increased. Hence, it is important that action be taken to see that either operating channels are assigned to this service or, preferably, that the apparatus be shielded adequately.

Interference from automobile ignition has not been serious within a 40-mile radius from the transmitter. In a few cases it has been necessary to relocate the antenna to minimize its effect.

Practically no difficulty has been experienced from natural atmospherics (static and thunder storms) within 40 miles from the transmitter. Over the past several years, a receiver located about 20 miles from the transmitter has been operated during thunder storms with lightning flashes close by, with no effect on the picture or sound.

The synchronism of pictures has been very satisfactory from all three stations on the majority of receivers and up to dis-

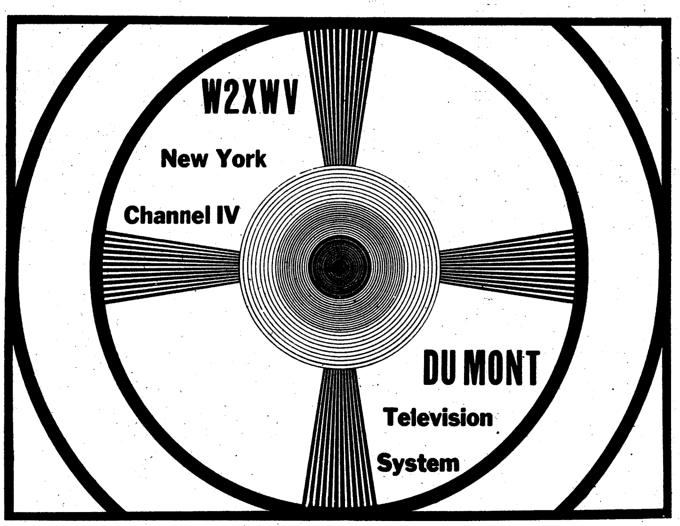


FIG. 7. STANDARD TEST PATTERN EMPLOYED AT STATION W2XWV

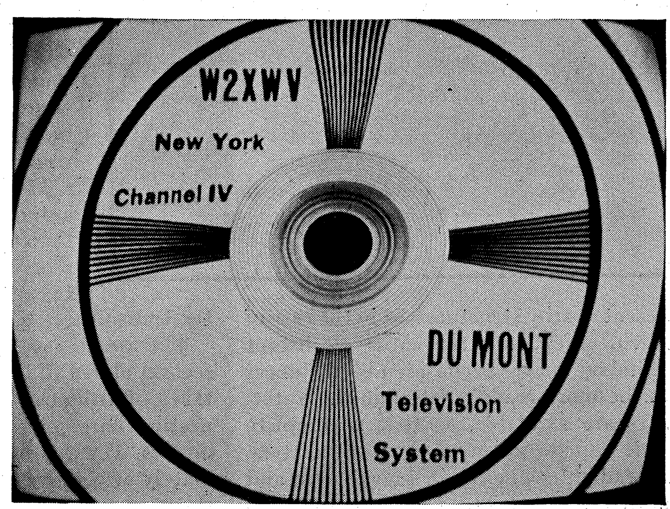


FIG. 8. RECEPTION OF PATTERN ON W2XWV'S STATION MONITOR

tances of 75 miles, provided multipath conditions are not too severe. It has been found necessary to use a ratio of not more than 2 to 1 between peak video transmitter power and peak sound transmitter power if reasonably good sound quality is to be maintained.

Field Tests ★ In order to obtain a comprehensive overall picture, field tests of the signals radiated from the three television stations in New York City have been made, using calibrated television receiving equipment installed aboard the cruiser *Hurricane II*, Fig. 4.

The tests aboard ship have been found to be particularly useful as compared to a previous survey made with the equipment installed in a field survey truck, as all readings are taken at a fixed elevation. The readings are not influenced by always-present nearby structures, as in the case of a field truck, and the cause of distant secondary images at considerable distances can be more readily determined. Waterways are available, so that a complete circle can be made of the transmitters, and radials can be run in a north, east and south direction. The field intensity was recorded on a continuous-paper Esterline-Angus 1-milliampere recorder, running at a recording speed of 0.71 ins. per minute. The sensitivity of the receiver was changed as necessary to prevent overloading of the recorder, and the microvolts input to the antenna terminals of the set were measured for calibration using a Ferris Type 18B Microvolter. During the calibration, the dial settings of the contrast control were recorded and the microvolts output from the Ferris 18B Microvolter were recorded. The calibration signals were applied to the antenna terminals through a 100-ohm resistor.

Although the recorder used gives valuable data, and is generally sufficient for field measurements on audio transmitters, a film record of the received pictures at various intervals is necessary to interpret video results. In the case of dynamic rather than static secondary images, a motion picture record is vital. Films have been taken illustrating the results at various locations.

During the field runs, the antenna was connected to the receiver through a simplex cable and could be rotated to keep it in line with the transmitter, Fig. 5.

The antenna was a double dipole, one section above the other, the signal being taken off from the centers of the two connecting bars joining the centers of the dipoles. The antenna center was approximately fifteen feet above the water line of the boat.

Power for the receiver, the monitoring oscillograph, and calibrating microvolter, was taken from a 60-cycle, 115-volt generator, driven by one of the Chrysler marine engines.

Numerous test runs were made between the following points during the past three years, also shown in Fig. 6.

1. From Englewood, New Jersey, to Red Bank, New Jersey (South).
2. From Englewood, New Jersey, through the Harlem River, and out the Long Island Sound to Huntington, Long Island (East).
3. From Englewood, New Jersey, up the Hudson River to Croton-on-Hudson, New York (North).
4. From Englewood, New Jersey, to Hackensack, New Jersey, through the Hudson River, Lower Bay, Newark Bay, and Hackensack River.
5. Circuit of Manhattan Island.

The recorder records show interesting phenomena of interference patterns and rapid variations of signal intensity where buildings and terrain offer interfering and reflecting surfaces.

Ghost Patterns ★ Several types of ghost patterns have been observed, some of

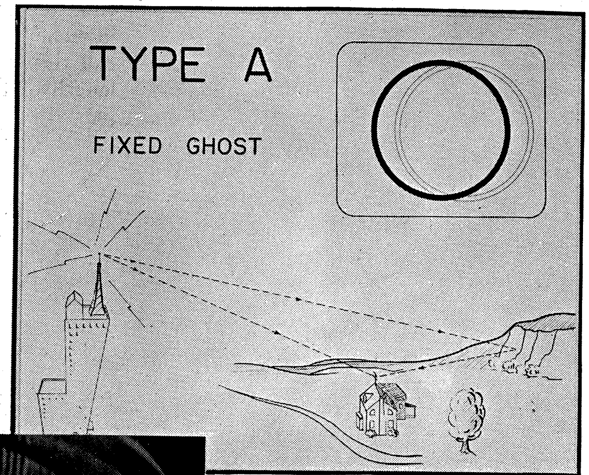


FIG. 9, ABOVE. TYPICAL CONDITION NEAR A TELEVISION RECEIVER WHICH CAN CAUSE A FIXED GHOST, DUE TO MULTIPATH DISTORTION. IN MOST CASES, THE GHOST PATTERN APPEARS AT THE RIGHT OF THE MAIN PATTERN

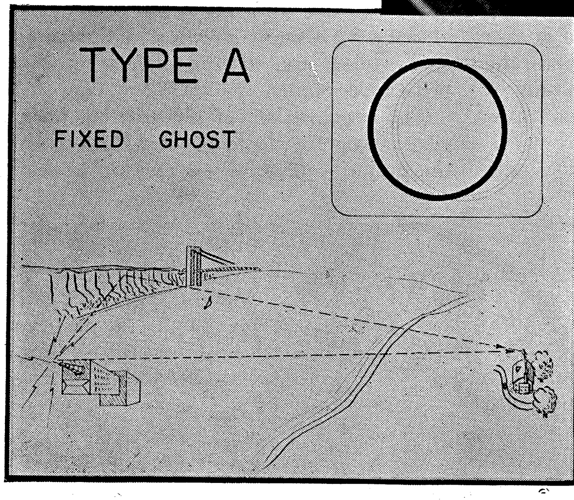


FIG. 10, BELOW. IN THIS CASE THE REFLECTION IS FROM AN OBJECT NEAR THE TRANSMITTER. THIS ALSO CAUSES A FIXED GHOST AT THE RECEIVER. FIG. 12A, RIGHT. ACTUAL PHOTO OF A FIXED GHOST, DISPLACED TO RIGHT OF MAIN PATTERN which may be briefly classified as follows:

Type A — Fixed ghost
B — Smear ghost
C — Racing ghost
D — Pulsating ghost
E — Negative ghost
F — Bouncing pattern
G — Sync. ghost

These ghost patterns are most readily observed when the receiver is in motion, but these characteristic interference patterns can be interpreted for many fixed location receiving sets.

The Type A (fixed ghost) and Type B (smear ghost) are the most common.

As a number of examples of distorted test patterns are shown later, Fig. 7 illustrates the test pattern used at the transmitter, and Fig. 8, this test pattern as observed on the station monitor.

Type A — Fixed Ghost ★ A fixed ghost appears as another and generally weaker pattern displaced usually to the right of the main pattern. It may be caused either by a reflecting object near the receiver, Fig. 9, or near the transmitter, Fig. 10, or at some intermediate point. In certain cases this reflection only occurs within a narrow arc, Fig. 11. The three figures illustrate only a few of the many position conditions which can produce a rather crisp displaced pattern in addition to the main picture. For such a fixed ghost, a reflecting object near the transmitter can give appreciable energy to the receiver over a path of greater distance than the straight line from the transmitter to the receiver. If the receiver is at rest, or is moving in a direction such that the difference in these two paths is not changing rapidly, then the ghost pattern may remain essentially fixed and be of an unchanged relative intensity with respect to the main pattern.

An ellipse diagram is useful in determining the relative position of transmitter secondary target and receiver for these fixed ghosts. The displacement of the ghost pattern from the main pattern can be measured on the face of the cathode-ray tube. From this displacement, measured in inches, converted to micro-seconds, one can then compute the difference in path length of the ghost path over the direct path from the transmitter. The ellipse pattern can then be drawn.

Place a dot representing the transmitter on paper and another dot representing the receiver at a distance proportional to the distance from transmitter to receiver. These dots will be foci of an ellipse. To determine the amplitude of the ellipse next plot a point on the line extended from the transmitter through the receiver and at a distance beyond the receiver proportional to half the path difference computed from the cathode-ray tube screen. This would locate one possible target which could cause the spurious ghost pattern. Now using this point, describe through it an ellipse about the two foci. A reflecting object located anywhere on the ellipse could produce a type A fixed ghost pattern of the measured displacement observed on the cathode-ray tube screen.

Many times the use of such an ellipse plotted directly on a map will help in identifying the sources of ghost images.

Ghost patterns displaced a lesser or a greater amount will require respectively thinner or fatter ellipses about the same foci for a given transmitting and receiving location.

Some examples of type A ghosts might be mentioned. In Fig. 9 is a condition quite prevalent in Montclair, New Jersey, where the antenna is located between the Watchung Mountains and the New York transmitters. It can be considerably reduced by directive antennas using reflectors. Fig. 12 is a typical pattern where the receiving antenna is approximately one-eighth of a mile from the mountain, and Fig. 12A where it is located about one-half mile away. It also occurs in Maywood, New Jersey, and other points in a small sector as shown in Fig. 11. This condition is very difficult to correct, as the angle between the direct and secondary image is extremely small, so a directive antenna does not help. Some improvement has been accomplished by using two antennas and feeding the output into a phasing arrangement to cancel out the secondary image.

Type B — Smear Ghost ★ In the smear ghost, the receiver screen has no separate and distinct test patterns displaced, but particularly the wedged lines which run vertically appear blurred and have no crisp definition. Such loss of high-frequency resolution may be expected when the receiver is located at a point such that practically no direct energy is received, but nearly all of the energy at the receiving antenna comes over paths reflected from nearby objects, Fig. 13. If these reflected energy paths are numerous and have only small differences in path, then the several patterns received will not be appreciably displaced, but will tend to smear one another, causing poor resolution. In some cases, the wedge running vertically in the test pattern can exhibit periodical regions of good and poor resolution running down the wedge. This smear ghost is quite common at fixed receiver locations in New York City, where the receiver is located in a canyon between several tall buildings. If a receiver is in motion, such that a number of local reflecting surfaces give the main energy to the receiver, then these smear ghosts can come and go with the relative motion of the receiver antenna.

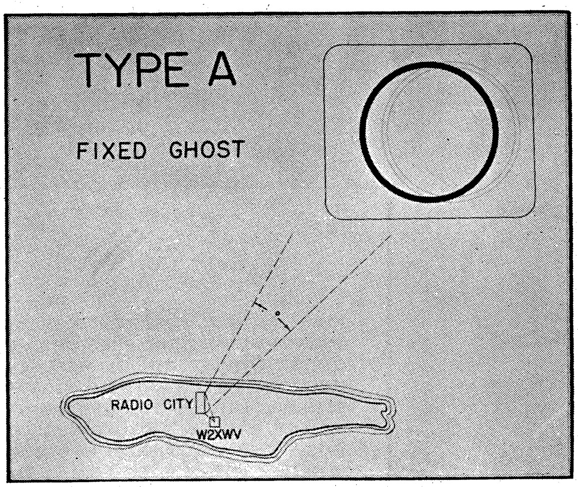


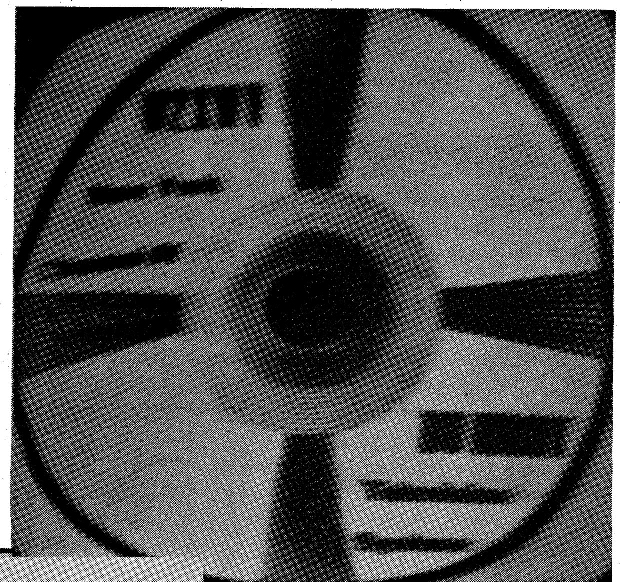
FIG. 11. THE NARROW-ANGLE REFLECTION IS DIFFICULT TO OVERCOME. ORIENTING ANTENNA DOES NOT HELP

FIG. 12. GHOST DUE TO MULTIPATH DISTORTION FROM A REFLECTING OBJECT ONE-EIGHTH MILE FROM THE RECEIVER

Figures 14 and 15 show typical patterns. They were taken in Warwick, New York, a town situated 45 miles from the transmitter and located in a valley with no direct signal path from the transmitter. A 1,600-ft. hill screens the receiving location from the transmitter.

Another typical location is in the Valley of the Hudson River between the George Washington Bridge and almost to Tarrytown, New York. At some spots in this section it occurs even though the transmitting tower can be seen from the receiving location.

Likewise, a receiving antenna located on the top of the 42-story building at 515 Madison Avenue, which houses the Du Mont transmitter, about one mile from the NBC transmitter on the Empire State Building and in direct line of sight, cannot resolve more than a 200 line definition picture from NBC. This because of the many secondary images from numerous buildings in the skyscraper section between the two television stations.



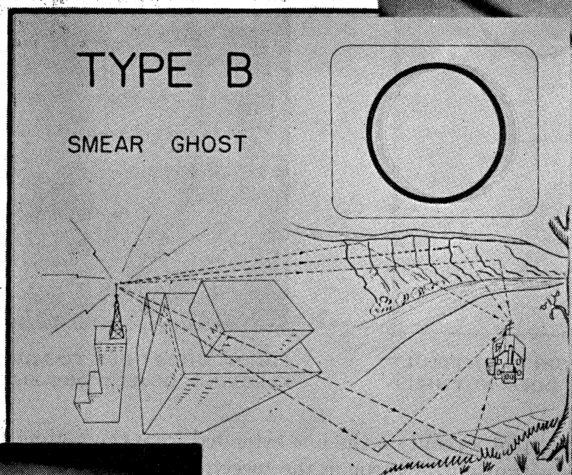


FIG. 13, RIGHT. UNDER CONDITIONS ILLUSTRATED, NO DIRECT SIGNALS CAN BE PICKED UP AT THE RECEIVING ANTENNA. RECEPTION DUE TO REFLECTIONS FROM A NUMBER OF OBJECTS RESULTS IN THE SMEAR GHOST

FIGS. 14, ABOVE AND 15, BELOW. TWO TYPICAL EXAMPLES OF SMEAR GHOST IMAGES DUE TO REFLECTED ENERGY PATHS ARRIVING FROM SEVERAL DIRECTIONS OF COMPARATIVELY SMALL ANGULAR DIFFERENCE. THIS CONDITION IS COMMON WHERE THERE ARE MANY HIGH BUILDINGS

Type C — Racing Ghost ★ The appearance on the screen for the racing ghost is a main image of good intensity with ghost patterns of relatively weak intensity which appear to travel rapidly across the main image when the receiver is in motion. However, the direction of travel of this racing ghost may be either left to right or right to left, depending upon the relative motion of the receiver with respect to surrounding objects. A probable explanation of such racing ghosts is reception of signals from an extended headland scattering reflections from any portion of the headland, Fig. 16.

The receiver will accept a direct signal from the transmitter not reflected by such a headland. Other signals are received over several different paths but reflected from the extended headland. At a given position of the receiver, some one of these reflected path signals will arrive in phase with the direct carrier and consequently will register a ghost pattern, say, 3 ins. to the right of the main pattern. However, upon a small motion of the receiver, perhaps parallel to the headland, this 3 in. displaced ghost signal will no longer arrive in phase, but may arrive out of phase and thus be practically neutralized, whereas energy over one of the other reflected paths now may be in phase with the main signal and its ghost image will be strong enough to be predominantly visible occurring, for example, at a displacement of 2½ ins. In the same way, as the receiver moves along for a wave length or so further, other reflected path signals may cause the predominating ghost to appear at 2 ins., 1½ ins., and 1 in., for example, causing an appearance of a travelling ghost, racing from right to left across the main pattern. If the receiver moves in the opposite direction, then one should expect the racing ghost to appear to move from left to right.

Among the places where this condition has been noted are along the Palisades below the George Washington Bridge, and at the confluence of the Harlem and East Rivers.

Type D — Pulsating Ghost ★ A pulsating ghost has been observed wherein the ghost image is displaced to the right of the main image and in which the ghost image will vary up and down in intensity while the main image stays nearly fixed in intensity, Fig. 17.

Such a pulsating ghost image was observed when approaching the Whitestone Bridge, sailing east from the transmitter. The displacement of the ghost image from the main image could be correlated with the distance to the Whitestone Bridge, and as the boat approached the Whitestone Bridge the ghost pattern came closer and closer to the main image. As the signal of the reflected pattern beat successively in phase and out of phase with the signal over the direct path, the ghost image was intensified and annulled. As soon as the boat passed the bridge a steady signal with no secondary images was obtained.

It was observed that the reflected signal in the case of WNBT's transmission on 50 to 56 mc. was weaker than the direct signal, while the reverse was true in the case of W2XWV, operating on 78 to 84 mc. when the boat was near the bridge. In this case, the reflected signal was more than three times the signal strength of the direct signal, and at some points this delayed signal actually took over synchronizing of the receiver, causing the direct path signal to appear with weaker intensity to the left of its normal position on the face of the cathode-ray tube. This is an unusual occurrence.

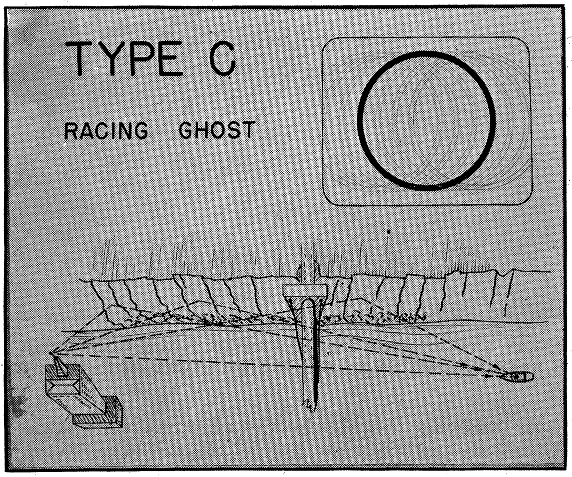


FIG. 16. RACING GHOST, PROBABLY CAUSED BY OUT-OF-PHASE RECEPTION OF SEVERAL REFLECTED SIGNALS

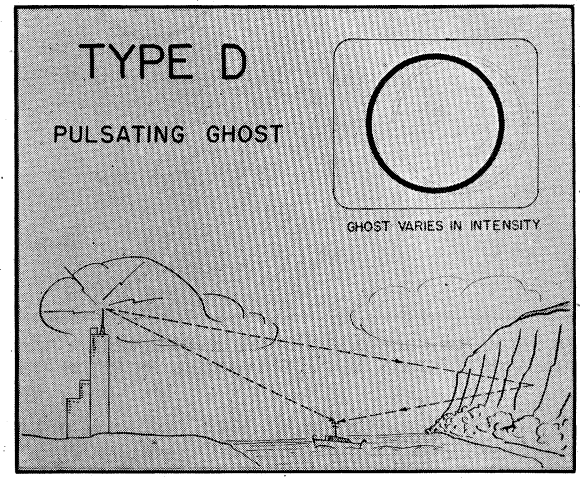


FIG. 17. PULSATING GHOST DUE TO REFLECTION BEATING IN AND OUT OF PHASE WITH DIRECT PATH SIGNAL

FIG. 18. OUT OF PHASE SIGNALS CAUSE A WHITE GHOST OF A BLACK IMAGE UNDER SOME SPECIAL CONDITIONS

FIG. 19. PHOTO OF AN IMAGE IN WHICH A WHITE GHOST APPEARS OFFSET TO THE RIGHT OF THE BLACK LETTERS

This same condition prevails near the many bridges around New York City. Its effect extends for about $\frac{1}{2}$ mile from the larger bridges, such as the Whitestone and George Washington bridges.

Type E — Negative Ghost ★ Under some conditions, a main image, say of a black signal, can be observed while a ghost image appears displaced some distance to the right, the ghost image being white instead of black, thus being reversed in polarity. Out-of-phase signals combined with a gray field produce reversed intensity which is frequently observed, as in Fig. 18. Another simple way of observing such a ghost pattern is the appearance of the horizontal blanking signal displaced slightly from the left side of the picture. Since this signal is no longer blacker than black, this blanking signal appears upon the normal test pattern and indicates a negative ghost appearing as a white vertical bar.

The photograph of Fig. 19 illustrate this negative ghost wherein the lettering appears displaced well to the right of the picture and seems to be white instead of the original black.

One of the locations where this has been observed is in the Hudson River above the George Washington Bridge, for a distance of about 5 miles.

Type F — Bouncing Pattern ★ 1. Sometimes a test pattern will be present which has good resolution and which has practically no displaced ghost pattern at all, but nevertheless this rather clean pattern will rise and fall in intensity. Such a pattern could be produced where the receiver gets no direct signal from the transmitter but gets two approximately equal intensity signals over approximately equal paths from rather widely separated reflecting objects, Fig. 20.

If the receiver is moving with respect to

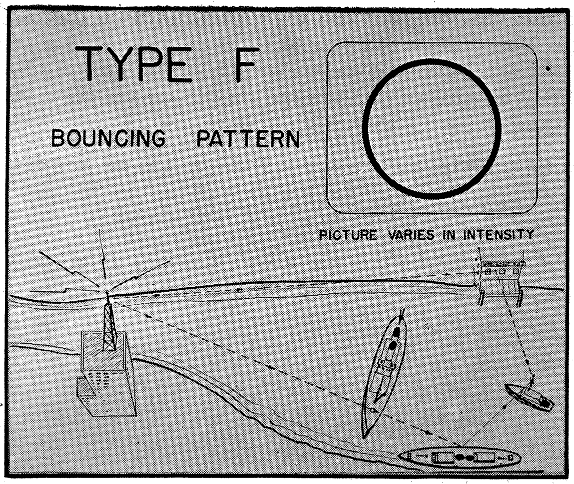


FIG. 20. WHEN A BOUNCING GHOST IS PRESENT, THE RESOLUTION IS GOOD, BUT IT CHANGES IN INTENSITY

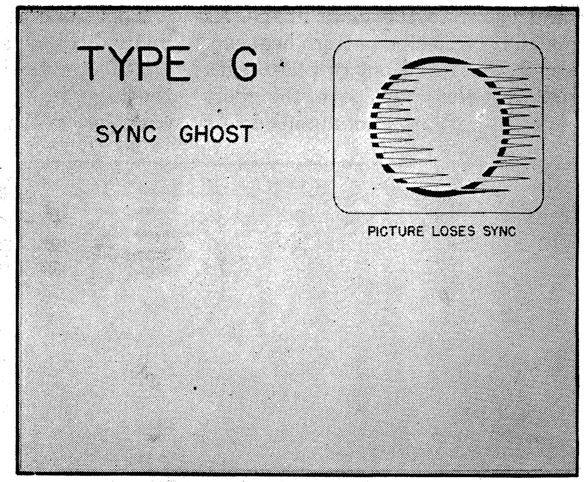


FIG. 21. SYNC GHOST OCCURS WHEN VIDEO COMPONENT IS STEADY, BUT SYNC SIGNAL CHANGES IN INTENSITY

these two objects, then the energy over these two nearly equal length paths will combine so as to give resultant energy varying over a possible value from nearly zero to approximately twice the energy of each path separately.

2. If the path difference is only slight, but insufficient to produce a predominantly visible displaced ghost, then a receiver at rest could exhibit this bouncing pattern where the pattern varies up and down in intensity if the transmitter frequency should vary slightly and periodically.

3. A bouncing pattern can be produced where energy is received directly from the transmitter over the main path and energy is also received over a path reflected by a bridge between the receiver and the transmitter and at some distance from the receiver so that the angle between these two received signals is very small. In this case the energy reflected down from the bridge may be of approximately the same magnitude as the energy over the direct path, due to the fact that the bridge received its energy with less attenuation than the

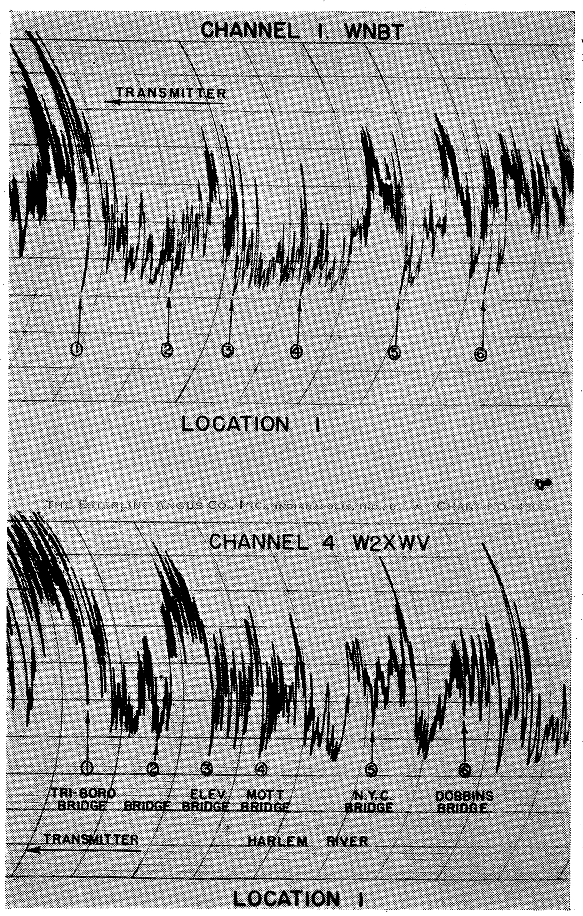


FIG. 22. FIELD STRENGTH INTENSITY RECORDED IN THE HARLEM RIVER, WHERE SHARP VARIATIONS WERE FOUND

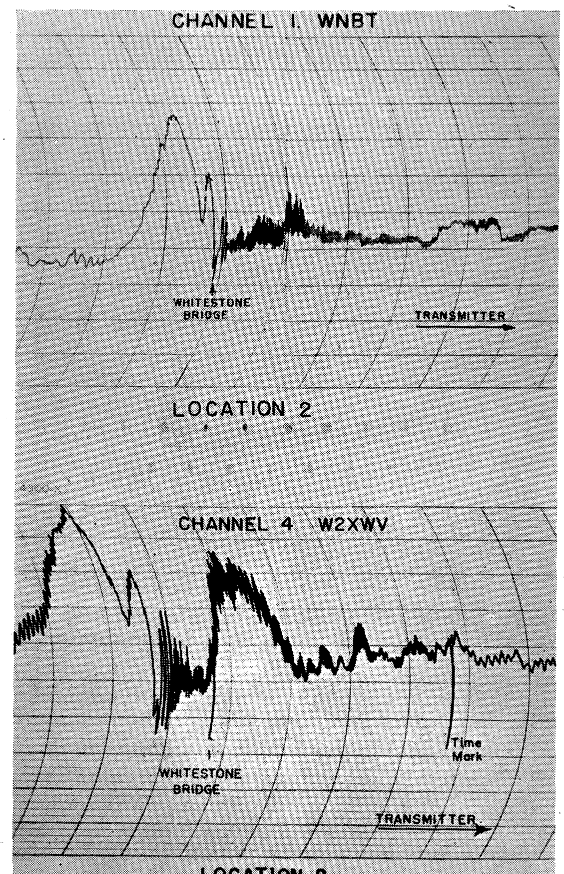


FIG. 25. CHANGE IN FIELD STRENGTH RECORDED WHEN THE BOAT PASSED UNDER WHITESTONE BRIDGE

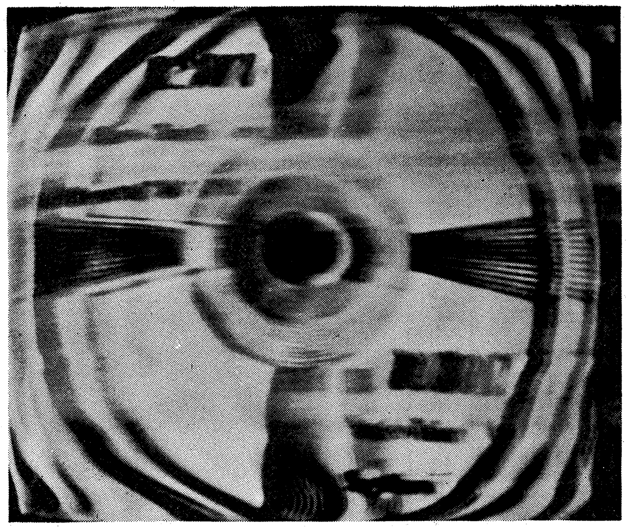


FIG. 23. PATTERN RECEIVED ON THE HARLEM RIVER

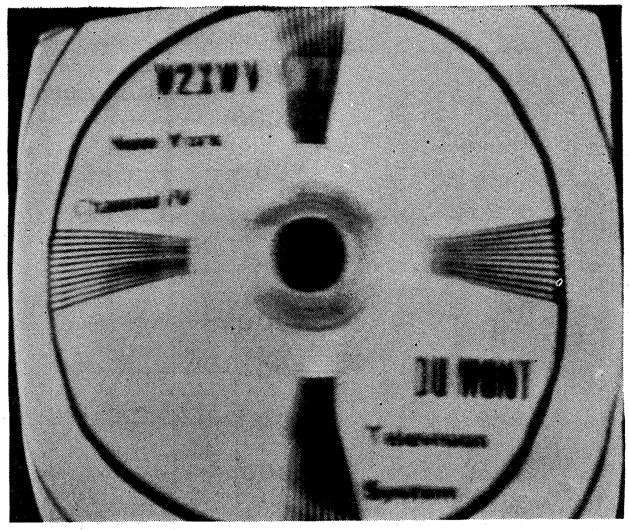


FIG. 24. PATTERN AT ANOTHER POINT ON HARLEM RIVER

energy over the direct path beneath the bridge, since a direct path would be, let us say, much closer to the salt water. The receiving antenna would accept the signals over the two paths with very little time delay between the two. Still, as the receiver antenna moves there would be a beat in and out of phase of the two carrier signals.

4. A bouncing pattern can be observed both on the direct path pattern and on ghost patterns when a receiver is at rest and a surface of reflection of secondary energy is in motion. A typical example of this type of interference has been observed where an airplane flying overhead makes a direct energy pattern go up and down in intensity. With careful observation of the interference, it sometimes can be seen that the airplane causes a displaced ghost to appear and disappear periodically, but this ghost is frequently of very low intensity compared with the main pattern.

Type G — Sync. Ghost ★ Under some conditions, it has been noticed that a pattern may have certain ghosts present, but is

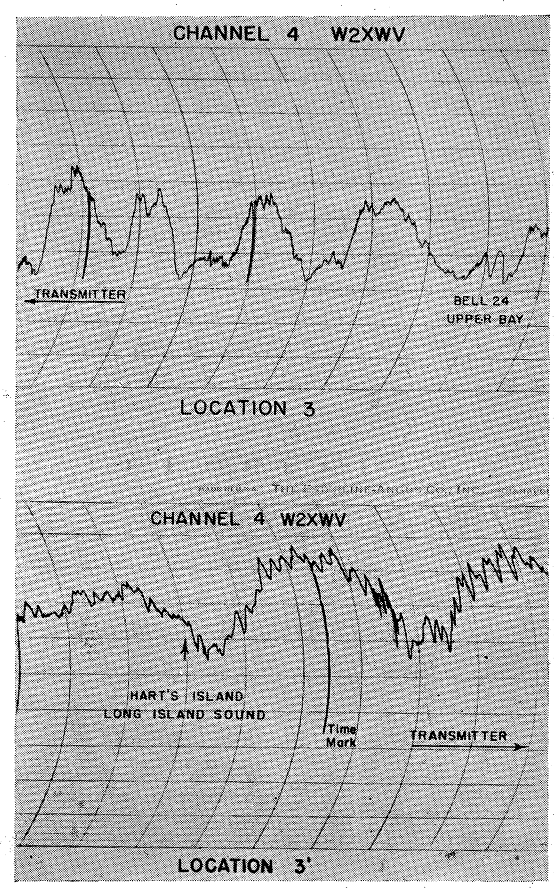


FIG. 26. RECORDINGS TAKEN AT A POINT WHERE ONLY REFLECTED SIGNALS COULD BE RECEIVED

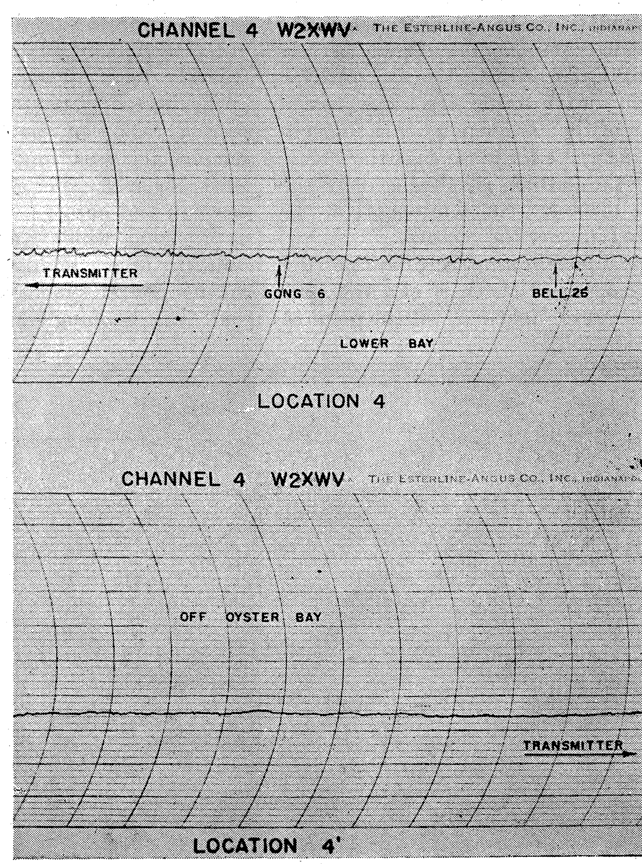


FIG. 27. RECORDINGS OF STABLE SIGNALS WHEN THE BOAT WAS IN THE CLEAR FROM THE TRANSMITTER, ABOUT 8 MILES AWAY

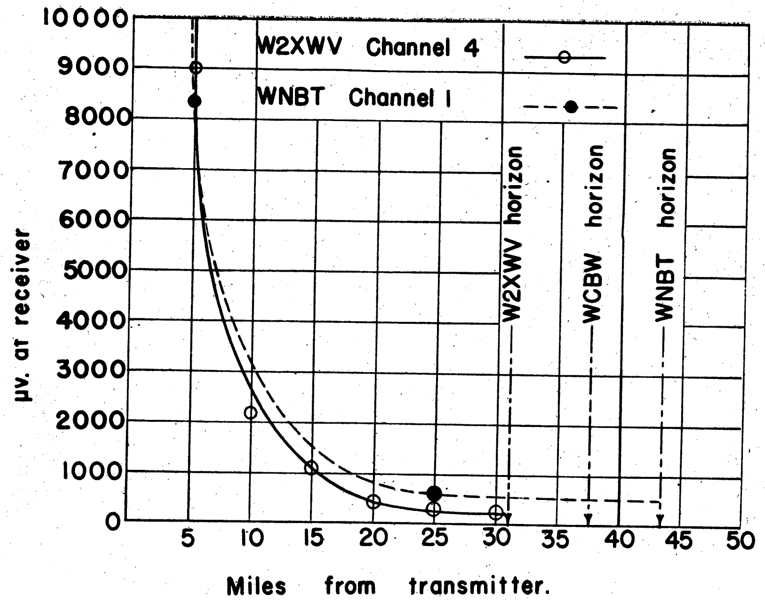


FIG. 28. MEASURED MICROVOLTS AT THE RECEIVER, FROM W2XWV, WCBW, AND WNBT

reasonably constant in intensity while the synchronizing signals come and go, Fig. 21.

This type of interference is best observed by noting the "tear-out" of the pattern horizontally which recurs cyclically and also by noting the video signals on the oscillograph. On the oscillograph, the synchronizing signals seem to go up and down in intensity while the major video components remain relatively unchanged. These distortions of the synchronizing wave forms upset the normal function of the "front porch" of the synchronizing wave forms so that the "tear-out" of the pattern is influenced by the relative blackness or whiteness of the associated lines of the picture.

For example, the relatively dark portion of the wedges in the center of a test pattern may cause "tear-out" at the point in the presence of sync. ghosts, while the relatively brighter portions of the remainder of the test pattern stay reasonably stable. The low-frequency response characteristics of the television receiver synchronizing circuit will cause certain receivers to be more susceptible than others to sync. ghost interference.

The best way to diagnose the presence of sync. ghosts is the observation of the video wave form on an oscillograph, wherein the blacker-than-black level cyclically is depleted of all signal while the picture region of the video wave forms remains relatively unchanged. A possible cause for such sync. ghosts might be the beats in and out of phase of a secondary path signal which arrives displaced in time by approximately the duration of the horizontal synchronizing signals period. The bobbing up and down of the synchronizing components may also be related to those causes of negative ghost patterns.

While the preceding analysis might lead one to believe that only one of these various types of ghosts is present at one location, actually one or more may be present.

Recordings ★ While it is impractical to reproduce the Esterline-Angus recordings in full, as some of them are in excess of 30 ft. in length, sections have been picked out for comment. The recordings and observations made on various trips show a number of interesting effects which had been suspected from the results of the installation of receivers. These may be summarized as follows:

1. From the George Washington Bridge to the Narrows, in the Hudson River,

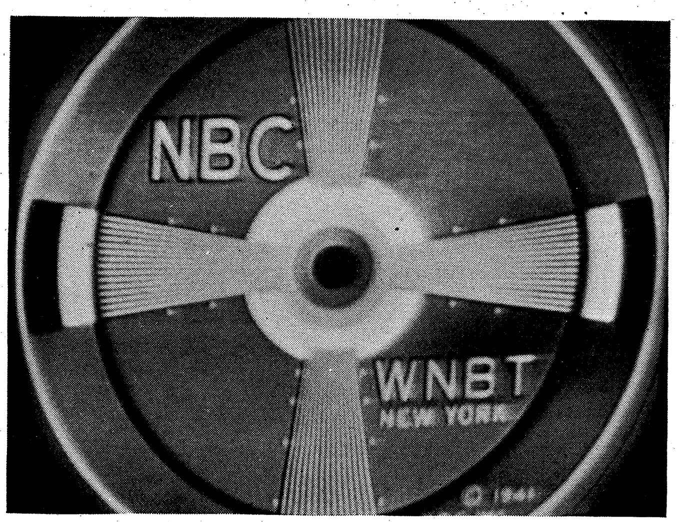


FIG. 29. CHANNEL NO. 1 TEST PATTERN AS RECEIVED ON PREWAR TELEVISION SET OPERATED AT AVERAGE LOCATION

FIG. 30. CHANNEL NO. 2 TEST PATTERN AS RECEIVED ON PREWAR TELEVISION RECEIVER OPERATED AT AVERAGE LOCATION

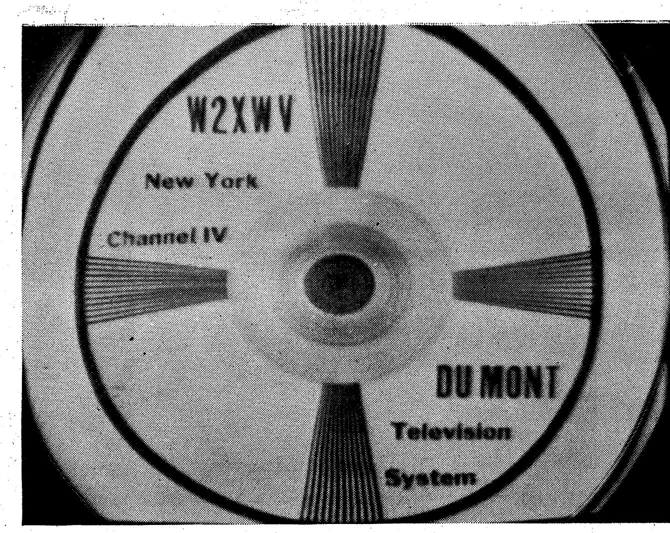


FIG. 31. CHANNEL NO. 4 TEST PATTERN AS RECEIVED ON PREWAR TELEVISION RECEIVER OPERATED AT AVERAGE LOCATION

large variations in signal strength may be expected. These variations in many cases occur within relatively short distances — not over 50 ft. In this section, secondary images of various types are prevalent for most of the distance. The same condition holds true for the entire length of the Harlem River and for the East River from the battery to the Hell Gate Bridge.

2. From the George Washington Bridge to Dobbs Ferry, in the Hudson River, the picture is smeared considerably.

3. From Dobbs Ferry northward, a ghost-free pattern is obtained, and from Hell Gate Bridge eastward out the Long Island Sound the same is true except while passing under the Whitestone Bridge, and a ghost-free pattern is also obtained from the Narrows southward.

4. In runs made to determine the maximum range of the transmitters it was found that with a ratio of 2 to 1 between the video and audio transmitter the best balance between them was obtained.

5. No difficulty was experienced with synchronization at extreme distances even when the video signal could be just observed.

6. Secondary images became progressively worse on the stations operating on the higher frequencies.

In Fig. 22 is shown a typical recording made in the Harlem River on Channel No. 1 and Channel No. 4. It will be observed that variations in signal strength of up to 500% may be experienced in distances not over 100 ft. apart.

Figs. 23 and 24 illustrate the wide variation in quality of received signal in the Harlem River within a relatively short distance. It is apparent from Fig. 22 that, although the variations in signal strength are somewhat worse on the higher frequency Channel No. 4, the effect is quite similar on Channels No. 1 and No. 4. However, when the test patterns are observed, secondary images are considerably worse on Channel No. 4 than Channel No. 1. This is shown best by studies with motion picture film records.

In Fig. 25, a recording is shown of the signal strength variation on Channel No. 1 and Channel No. 4 when passing under the Whitestone Bridge. It will be noticed that the increase in signal strength of the reflected signal is considerably greater for Channel No. 4 than for Channel No. 1. This is also confirmed by noting the test patterns in which the density of the direct and reflected patterns can be observed.

Fig. 26 shows a typical recording obtained where the transmitter is shielded from the receiver, thus providing no direct signal.

In Fig. 27 are recordings taken in Long Island Sound, off Oyster Bay, and in lower New York Bay. The variations are typical of the signal at distances greater than approximately 8 miles from the transmitters in Manhattan.

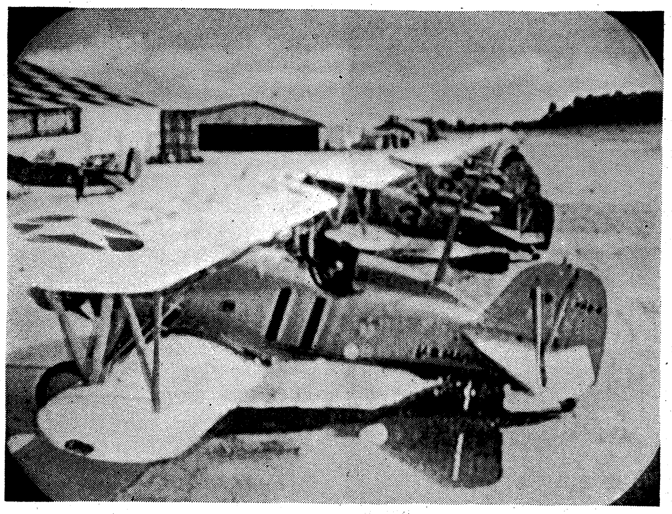
The field patterns produced by the transmitters on Channels No. 1 and No. 4 have been averaged from the recorded signal strengths. The actual recordings show extreme variations in regions where buildings cause multi-path reception. An average signal drawn through these curves indicates a satisfactory field strength to distances of 35 miles in most directions. Wherever there is a receiving location free of large obstacles and relatively free of local interference, good pictures can be expected. A study of the unobstructed field strength can be obtained best from the recordings taken on the second trip, illustrated in Fig. 6, going from Hell Gate Bridge out in Long Island Sound to Huntington. Measurements were made of the equivalent signal generator microvolts required to give the same recorder deflection as that produced by the antenna shown in Fig. 5, connected to the television receiver.

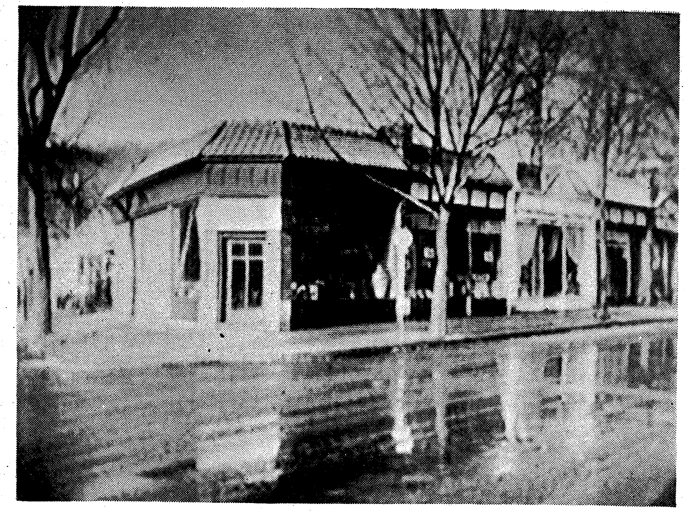
Fig. 28 shows this average field strength measured out Long Island Sound from Station W2XWV, Channel No. 4, and Station WNBT, Channel No. 1. It is difficult to arrive at a figure of absolute microvolts-per-meter, since the characteristics of the antenna and transmission line are not completely accounted for in this method of field strength measurement. However, the curves indicate very accurately the signal strength available for operation of the average television receiver.

Multipath Effects on FM Sound Channel ★ The quality of the FM sound accompanying the picture transmissions has been studied along with the picture signal strength recordings and photographic picture records. It was found that the sound quality varies tremendously in territories where picture multipath conditions exist. As would be expected, the sound intensity varies over a rather wide range in a relatively short distance of motion of the receiving antenna.

However, a much more serious condition was observed wherein the FM sound quality was found to be permanently degraded for certain fixed locations of a receiving antenna. This degradation of the sound quality is to be expected with frequency modulation transmission when multipath conditions exist. The sound becomes quite distorted as though an over-load condition existed, even at a low sound level.

Let us consider, for example, the condition where a main signal arrives at the antenna over path $P1$ which has a total path length d1. When a second path $P2$, having a path distance $d2$, provides con-





FIGS. 32 AND 33. EXAMPLES OF PICTURE QUALITY AVAILABLE ON RECENT TELEVISION PROGRAM TRANSMISSIONS

siderable energy to the receiving antenna, the FM receiver will respond to the summation voltage from these two signals. If $d2 - d1 = \Delta d$, and Δd is of the order of 1,000 meters, then this will be 200 wavelengths of the rest frequency of an FM transmitter whose wavelength is 5 meters or 60 mc.

In this case, both signals will arrive in phase with one another and will reinforce each other to provide a strong receiver signal. However, a slight displacement of the receiving antenna to a new location will cause a change in Δd say of half a wavelength, and the two signals then arrive out of phase and if each is of approximately the same magnitude they can practically cancel each other. Unfortunately where frequency modulation transmission is present the swing in frequency of the transmitter can cause this same effect of successive reinforcement or cancellation as is experienced with a small displacement of the receiving antenna.

This condition becomes most critical when Δd is a number of wavelengths plus a fraction of a wavelength, such that the resulting receiver signal is just above the limiter level. Now when the audio modulation is applied at the transmitter the frequency swing will cause the receiver signal to be reinforced on one phase of its swing and cause the signal to be annulled on the other phase of the swing to such an extent that the limiter momentarily goes out of operation. When this happens a very serious distortion occurs.

In effect, the multipath conditions literally transform the constant-amplitude, variable-frequency radiated signal into a signal which is variable in amplitude and variable in frequency, thus making it impossible for the receiver to take this signal and utilize it for high quality reproduction through its limiters and sloping discriminator. The presence of several multipath signals unfortunately does not offer a smooth discriminator slope in its generation of amplitude modulation upon the carrier.

Multipath conditions are common in which two signals of approximately equal strength arrive at a receiving antenna and therefore this type of distortion with FM sound transmission can be expected to occur frequently.

In a region where multipath conditions exist, it is difficult to find any one location for the receiving antenna where good sound quality is available from several different FM stations.

Since this distortion of FM sound is related to the phase shift between two signals arriving over different paths, then the distortion will prove more serious on shorter wavelength stations such as the higher television channels than on the television Channel No. 1 or the present FM broadcast channels.

The time delay of 5 to 50 microseconds between signal over one path and signal over another path gives very little noticeable distortion to the audio signals as such, since this time interval is quite short in comparison with the period of the highest audio frequencies in use.

In the past several years, transmissions were first made on amplitude modulation and then with modification of standards frequency modulation has been employed on the sound channel. Field tests generally have shown satisfactory sound reception in most cases, but in a number of cases reports from the field indicate that the sound quality is worse with FM transmission than it was previously with the AM transmission. It is therefore worth while to seriously consider the fundamental advantage of amplitude modulation transmission of the sound to regions where multipath conditions abound.

Fortunately amplitude modulation sound transmission is free of some of these distortions. If the receiving antenna receives appreciable energy, then the antenna is not subject to this pseudo-displacement by a fraction of the wavelength in position which is experienced with the FM reception.

Multipath Effects on Color ★ Just before the war started considerable field experimentation was carried on with color television. Only a few complete color receivers were operated in the field though many receivers were provided which could receive these transmissions in black and white. Although a complete study of color reception in multipath receiving locations has not been made, the multiple images in color become even more serious than multiple images in black and white due to the improper blending of colors at the receiver. For example, a green portion of a main pattern may have superposed upon it a red portion of a displaced ghost pattern causing both patterns to be rendered in false colors.

Since multipath problems become more serious at the higher frequencies it is expected that the best color transmissions will be possible on the lower frequency channels.

FM Video Transmissions ★ A few test transmissions have been made using frequency modulation on the video transmitter. Reasonably good reception was experienced where only a crisp direct path signal was received. However in the presence of multi-path received signals the frequency modulation transmission of pictures proved very unsatisfactory. This is to be expected since the much wider frequency shift with pictures augments the difficulties already outlined for sound transmission. Under certain multi-path conditions, a change in level from black to white would cause the receiver detected signal to go through several null voltages while the transmitter is making a uniform frequency swing over its 4-mc. range.

Obviously, these distorted wave forms cannot reproduce a crisp undistorted picture. The appearance of the ghost patterns produced when frequency modulation of the video is employed shows displaced images of about the same displacement as with amplitude modulation but much more prominent in contrast. For multi-path pictures received by AM that could be considered reasonably satisfactory, the corresponding FM pictures were hopelessly degraded.

Frequency modulation, with its higher transmitter efficiency does prove promising for relay transmission purposes, where both the transmitting and receiving locations can be suitably chosen to have very little multi-path difficulty.

Television Conclusions ★ By way of summary the following points are presented:

1. The primary obstacle to be overcome is the secondary images (ghosts) which become worse with higher frequencies.

2. Diathermy interference is worse on Channel No. 1 than on Channel No. 4. Although generally not serious, a plan should be worked out to gradually eliminate it.

3. Auto ignition is not particularly serious and can usually be corrected by antenna design or location.

4. Natural atmospherics are only noticeable at extreme ranges.

5. Particular attention must be paid to antenna design to cover a wide frequency-band and reduce secondary images.

6. Particular attention must be paid to the type of lead in used, so as not to discriminate against the higher frequency stations.

7. In practice, a power ratio of 2 to 1 of the video transmitted power to the audio power works out satisfactorily.

8. Synchronism difficulties with either type pulse are minor, even at extreme ranges.

9. No interference between stations has been detected.

10. Increased transmitter power will reduce present troubles very materially.

The major portion of this paper may have given certain readers the impression that television is not very practical due to the multipath conditions. However this is far from true since a great many locations in and around New York are excellently suited for the reception of good programs from the three existing New York transmitters. The enthusiastic listener response to the rather extensive programs which were possible before the war and the somewhat curtailed programs of the present time indicate that television is very satisfactory as a medium of entertainment and education. Figs. 29, 30 and 31 illustrate the test pattern reception available from the three New York transmitters as photographed recently from a pre-war receiver in an average location. While still further improvement in quality of reception can be obtained the pictures are quite satisfactory.

Figs. 32 and 33 illustrate the picture quality available via television in recent transmissions.

Television in New York is technically ready to render an excellent service within the present standards, and is awaiting an opportunity to resume its expansion with improved transmitting and receiving equipments and extended programs when war conditions permit it.