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EVOLUTION OF A TELEVISION ANTENNA

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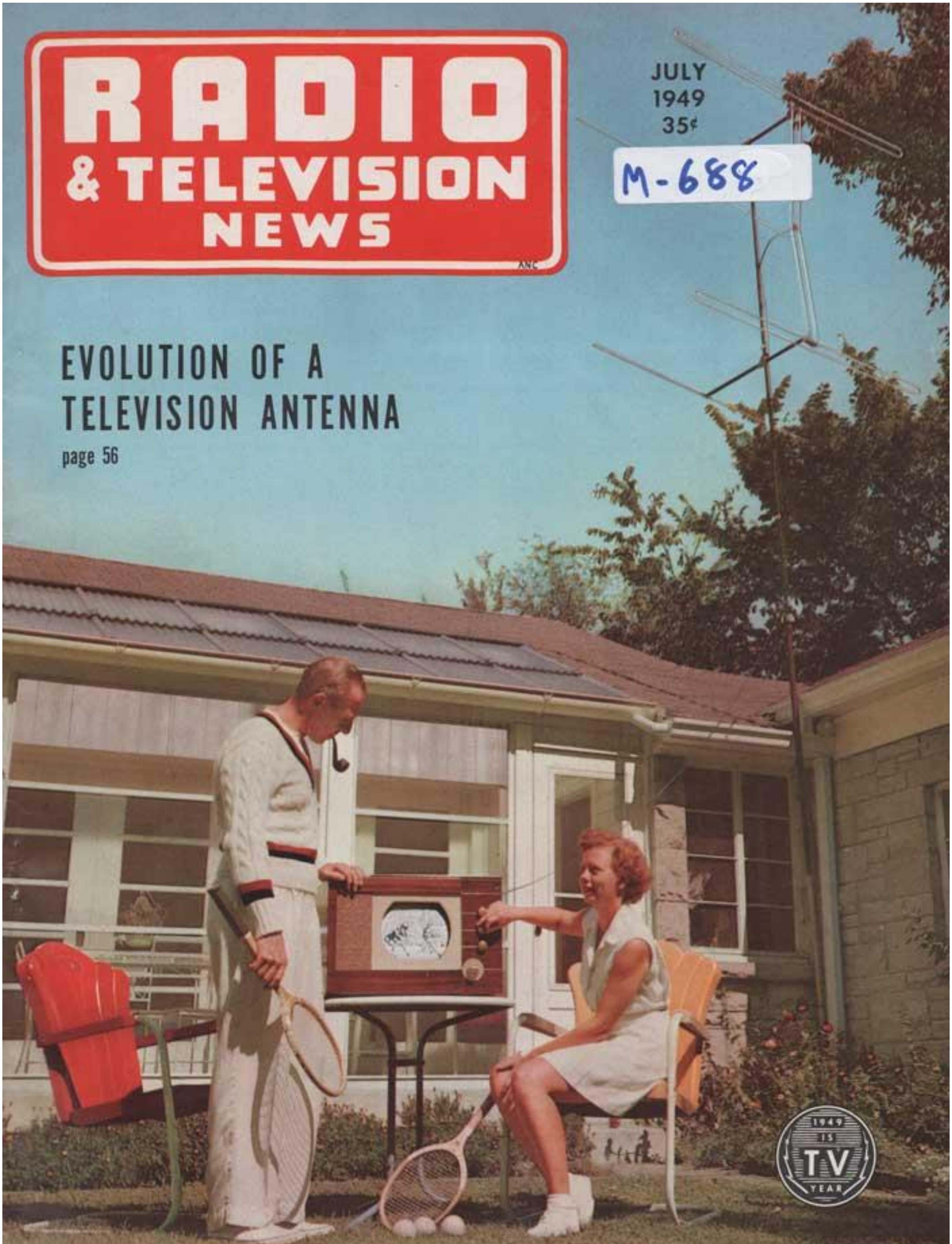


Evolution of a TV ANTENNA

Fig. 1. Test truck completely equipped to make field tests of any type TV antenna.

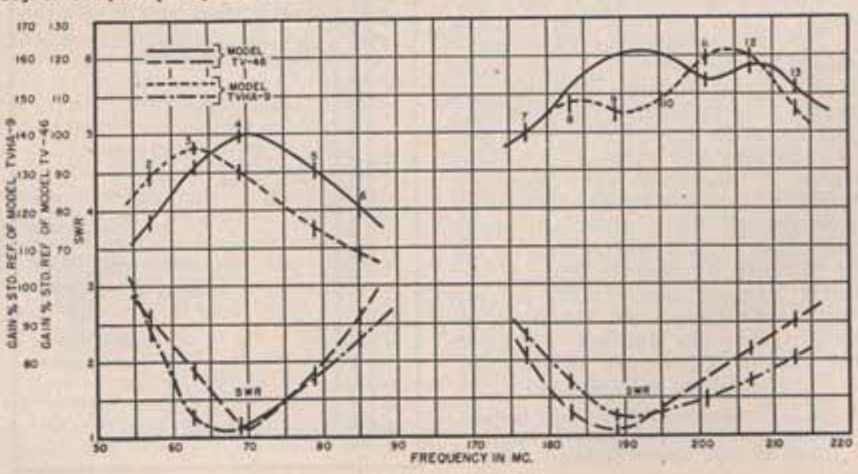
By
L. H. FINNEBURGH,
Chief Eng. Ward Products Corp.

The ultimate design of any good broadband high-low antenna can be derived only after various mechanical and electrical performance tests have been made.

THE television signal—from original image in the camera to the reproduced image on the receiving tube—requires the use of many types of circuits and components, taking in practically the entire field of electronics. The receiving television antenna occupies a unique position in that it is the first component handling the signal that comes under the control of the installer or service technician (and therefore the consumer!). In this position it obviously must have a tremendous effect upon the proper operation of the circuits and components which follow it—upon that part of the system which represents the major part of the consumer's investment. The antenna is therefore deserving of the best electrical and mechanical development and design.

The electrical design of a complete line of television antennas will, of necessity, have to be broken down into groups, each group being determined by the several types of antennas to be produced. Examples of the problems faced are involved in the design of a high-low antenna consisting of folded dipoles only and also the high-low antenna consisting of folded dipole and reflectors, as shown in Figs. 3A and 3B, respectively. For each type, the ideal characteristics should be set up as the goal for the design. These should include such factors as uniform response of a value commensurate with the particular type of antenna, uniform horizontal plane pattern on each of the television channels to be covered, uniformly low standing wave ratio, and elimination of interaction between the two antenna units making up the array.

Fig. 2. Frequency response and SWR curves for Ward models TV-46 and TVHA-9 antennas.



The response curve, of course, must have some reference so that intelligent comparison can be made. The basic reference requires the establishment of a definite field strength at frequency f_1 and measurement of the antenna response under test at this frequency; then establishing the same field strength at frequency f_2 and again measuring the response of the antenna at frequency f_2, etc. This test should be made for at least one frequency in each channel. A second method is to build a reference tuned and matched dipole for frequency f_1 and establish a field of satisfactory strength for this reference. The antenna to be tested is then subjected to the same field, and its response is compared to that of the test reference antenna number 1 to obtain its comparative response at frequency f_1. Another test reference antenna, number 2, is tuned and matched for frequency f_2 and is placed in a field of sufficient strength so that it has produced at its terminals a nominal voltage. Then the antenna being tested is subjected to this field of frequency f_2, and the terminal voltage developed in this antenna is again compared to that of test antenna number 2, thus giving the comparative response of the unit at frequency f_2. A series of test reference antennas is required, at least one being required for each channel.

Although antennas under test have been checked against both types of reference, the latter method has been found to be of more practical value in the service field because it requires less expensive equipment and fewer calculations to reproduce. The various curves shown herewith are based on this type of reference.

On a simple dipole antenna, either folded or straight, the uniformity of the response curve depends primarily upon the length of the unit and the ratio of D/L, where D is the diameter of the element and L is the length of the element. For a given unit of this type, the response falls off more rapidly when the frequency is reduced below its nominal resonant frequency than it does when the frequency is increased above the nominal value. Therefore, for usual values of D/L, the unit should be cut somewhat below the center frequency of that portion of the spectrum to be covered. The same statement holds for the design of the low-band unit and the high-band unit, independently, on an antenna of the type shown in Fig. 3A.

Controlling the response curve of an antenna of the type shown in Fig. 3B becomes somewhat more complicated since we have not only the same variables as described above, but also the added variables of spacing between reflector and dipole, as well as the length of the reflector element. With proper manipulation of this greater number of variables, greater control of the response curve is possible, and better "broad-banding" can be obtained. The shape and the actual magnitude of a response curve are both greatly affected by the mechanical configuration of the center insulator, due to the possible "bypass" of signal at this point.

Either of the antenna elements of Fig. 3A would be expected to produce a figure eight horizontal plane pattern, and either bay of the antenna shown in Fig. 3B would be expected to produce a modified figure eight pattern, having a front to rear ratio and forward gain. However, when the two bays of either antenna are combined to feed into one transmission line, extremely "off-shaped" patterns are possible. The interconnecting system between the two antenna bays and the transmission line must properly isolate the two antennas on their respective bands of operation. The low-band antenna, when operating on the high-band frequencies, is approximately 3/2 wave length for those frequencies, and its pattern will break up into multiple lobes.

If this signal were fed directly into the transmission line along with that coming from the high-band antenna itself, the over-all high-band pattern obviously would be greatly distorted and on some channels would show the multiple lobe formation as established by the large antenna. This makes the elimination of ghosts or reflected images more difficult, impossible in many instances, and dictates, then, the requirement of effectively eliminating the low-band antenna from the system when operation on the high band is desired. This can be accomplished by attaching to the terminals of the low-band antenna an open stub which is quarter-wave length long for the high-band frequencies and will effectively short-circuit the low-band antenna at the high-band frequencies. This short-circuit at high-band frequencies must then be connected to the transmission line with another quarter-wave length stub (or an odd number of quarter-wave lengths) or else it will obviously short-circuit the entire system on the high-band frequencies. However, when it is connected to the transmission line with such a stub, it represents a high impedance and will have a negligible effect on the system.

The interconnecting system also has a very marked effect on the standing wave ratio since it deals with the combining of two impedances to one transmission line, both impedances varying with frequency in each of the two bands involved. The system described above enables the over-all array to have a remarkably low standing wave ratio on the high band because the impedance of the low-band unit is reflected into the transmission line as a very high impedance, and its disturbing effect on the standing wave ratio is negligible. In fact, it can be made

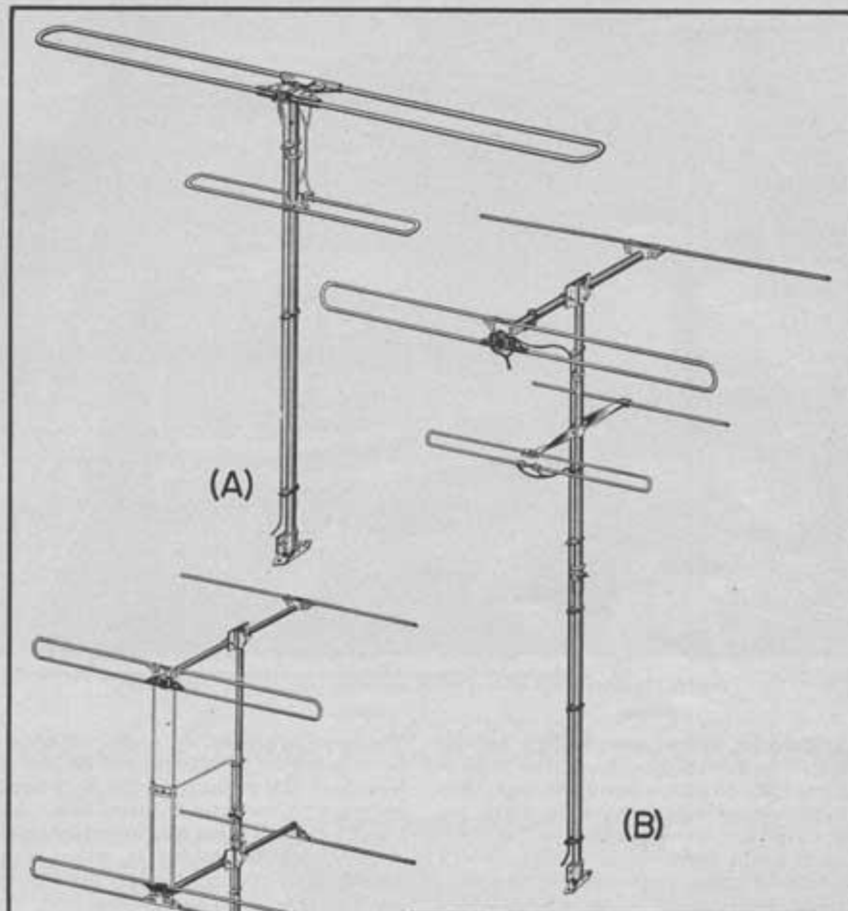
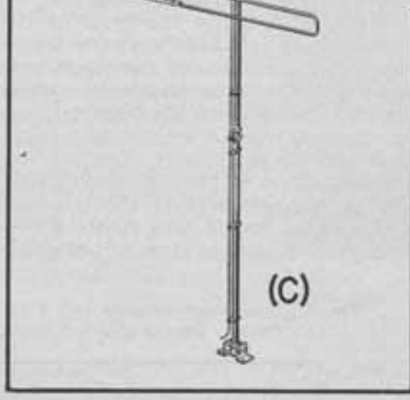



Fig. 3. Three distinct variations of the television antenna: Ward models (A) TV-46 folded high-low band. (B) TVHA9 high-low band folded dipole with reflectors, and (C) high-gain stacked array.

Fig. 4. Rear view of mobile test unit. Cables connect receiving and transmitting antennas to test equipment.

Fig. 5. Interior view of test truck showing part of test equipment.

to have a cancellation effect on the out-of-phase component of the impedance (jX) of a high-band antenna, thus maintaining a low standing wave ratio over a greater portion of the high-band frequencies.

The interaction between the two antennas of such an array is determined primarily by the separation between the two, which is quite simply determined. However, the "loading" of one antenna by the other is likewise affected by this interconnection system. This loading can be either way so that both parts of the interconnection system are of importance. On the low-band frequencies, one of the most important considerations of the small high-band unit is its loading effect on the large low-band antenna. This can be eliminated by the proper choice of length of link connecting the high-band antenna to the transmission line. Although this problem was attacked originally from the point of view of a simple stub connecting the high-band antenna to the transmission line, results were found in the experimental work which indicated that the length and configuration of the high-band folded dipole had considerable effect on the stub action. Through such experimental work, it was found possible not only to practically eliminate the loading effect of the high-band antenna on the low-band at the low-band frequencies, but to also create a cancellation effect of the out-of-phase components (jX) of the low-band antenna impedance. This enables the complete system to display a low standing wave ratio over an increased proportion of the low-band frequency.

It can readily be understood from the above that you cannot deal with only a single characteristic of the antenna at a time, since practically all of the characteristics are involved to some extent when any of the variables are altered. The simple change of length of an element will usually call for some comparable change in one or more other parts of the system.

Therefore, to obtain true broad-band response, retain the gain expected from the type of array, have uniformly desirable patterns on all channels, produce low standing wave ratios over wide portions of the spectrum, and have minimum interaction and loading between the antennas, a game of chess results in which the moves cannot be isolated but must be planned in advance due to their effects upon one another.

The problem of the mechanical design of the antenna likewise has several facets. The unit should require minimum assembly time in the field, should handle easily to facilitate erection, and should withstand the battle of the elements.

These factors are again interlocking in their effect upon one another and cannot be considered independently. The requirement of minimum assembly time in the field obviously reduces itself to as complete a preassembly at the factory as possible. However, preassembly by itself does not mean that the antenna will be easy to handle while it is being readied for erection. The antenna should be designed so that the elements and other components will stay in their preassembled position or in their final position and not dangle loosely while the few re-

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Fig. 6. Test pattern of Ward model TVSA-6.

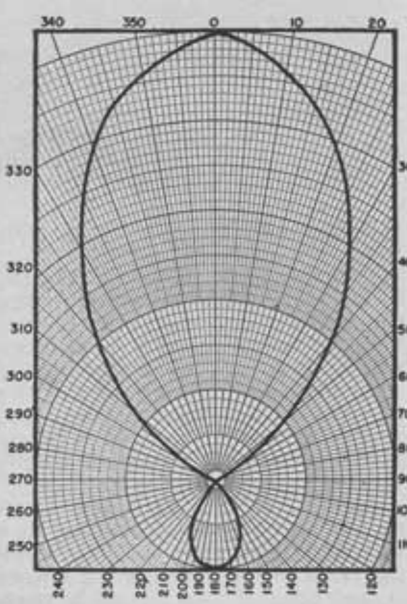
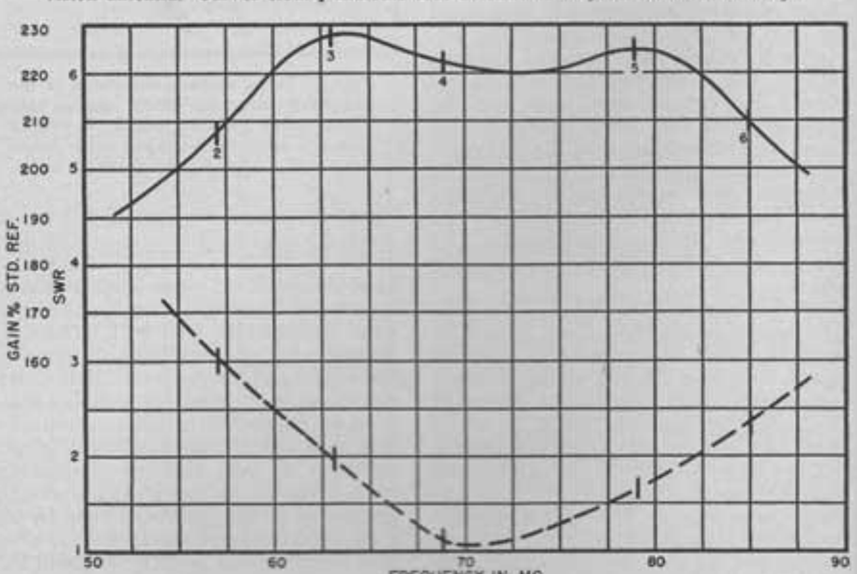


Fig. 7. Frequency response and SWR characteristics of Ward Model TVSA-6 television antenna. Curves clearly indicate that antenna is of good broadband design.



TV Antenna

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quired screws are being tightened.

All of the components are required to withstand the ice loads and wind loads which, of course, vary considerably in the several areas of the country. Various surveys made in connection with electric power distribution indicate that at least a one-half-inch ice load should be considered minimum. The calculations involving this ice load are comparatively simple, as some parts can be considered as uniformly loaded cantilever beams and other parts as cantilever beams having a uniform load, also a concentrated load, at certain locations. The physical test can be very closely approximated by adding the correct amount of weight every 1" or 2" along the various elements.

In the above, it will be noted that the ice load was named prior to the wind load. This is a logical sequence since the wind load should be calculated on the antenna with the ice load in place. This is necessary because of the increased projected area subjected to the wind by the ice loaded members. These calculations have proven that the turning moment or torque of an antenna bay relative to the mast is surprisingly high.

Therefore, the hardware and brackets mounting the crossarm to the vertical mast must be capable of exerting very high locking pressures. In working with the various non-ferrous materials in the mast, it was found that the required locking pressures could not be obtained because such mast material would swage down or reduce in diameter as the brackets were tightened. Vibration tests also proved that the material continued to "flow," and in a comparatively short length of time the right angle connection of the crossarm and mast was found to be loose and unable to withstand the turning moment of the above referred wind loads. Due to this, the requirements of this joint dictated the use of a steel tube and a plug inside of the tube to make a completely solid joint. In addition, the bolts are passed directly through both tubular members to eliminate any possibility of the bay's slipping around the mast and losing its orientation. The mechanical attachment of the straight dipole, folded dipole, and reflectors on the low-band units to crossarm or mast are accomplished in a similar manner.

This type of joint was found unnecessary on the high-band units where the projected area subjected to the wind is not as great and the lever arms involved in the turning moment are comparably smaller.

The above referred plugs in the ends of the low-band crossarm and in the upper end of the mast also eliminate the "pipe organ" effect which these tubular members may otherwise have in certain wind velocities and directions. This howling sound is very readily transmitted into and through the house structure and can prove very annoying. Closures, for similar reasons, are also placed in the ends of the antenna elements themselves.

The 1¼" O.D. steel tubing used in the mast and low-band crossarm was likewise found to satisfy other important considerations. The torsional twist of the cross-arm must be held to a minimum since a torsional vibration set up in this member will cause the antenna element on one end and the reflector on the other end to mechanically vibrate out-of-phase. If this torsional vibration of the crossarm, amplified through the length of the reflector and the dipole, swings the tips of these two elements excessively relative to one another, the picture on the CR tube will definitely be modulated. The results of a series of tests indicated that with the use of steel tubing in the crossarm, 1¼" O.D. was required to eliminate this picture modulation. The use of various non-ferrous materials, which have a lower Young's modulus and less torsional rigidity, would require considerably larger diameters if this picture modulation is to be controlled.

Since mechanical design can be finally proven only by actual mechanical tests, a number of the units were made in the laboratory prior to final tool release. However, to simulate the final design as closely as possible, temporary single cavity molds and temporary dies were actually made in the lab, and parts were produced, using the same materials and processes that would be involved in the production quantities. Only in this manner could the entire over-all design be completely checked in every respect before the production tools were made.

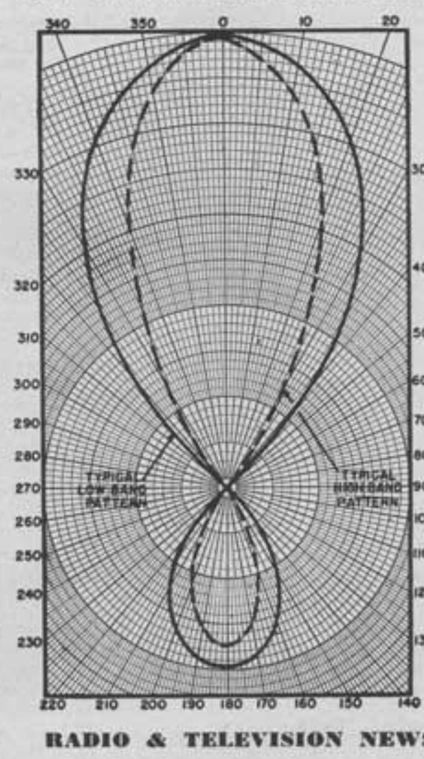
As explained above, the element mounting insulator and some of the associated hardware can have a "bypass" effect on the antenna and can affect its apparent impedance. It was necessary then to recheck the electrical design and make a few small changes in order to finally approve the mechanical design. In this recheck of the electrical characteristics, the entire procedure of test sequence was repeated.

In the original electrical design and test as well as the final electrical design check, it was necessary to use several different types of laboratory test equipment, some of which had to be mobile for the field testing. Fig. 1 shows the test truck with the racks on top for carrying the several antennas as well as the reference standards. Likewise, the two-way telephone antenna can be seen mounted forward over the driver's position. Fig. 4 shows a general interior view with the rear of the truck opened. The compartment on the left houses a gasoline-driven generator for the 117 volt a.c. supply. The housing for this generator is completely shielded electrically, is lined with soundproofing material, and has its own ventilation system. Fig. 5 is a close-up view of a portion of the interior, showing the signal generator and field strength meter on the workbench, the two-way telephone under the left end of the workbench, and a voltage regulator on the floor. In between the signal generator and the field strength meter is mounted a remote indicating meter and a selsyn indicator for antenna position. Other equipment, such as sweep oscillators, cathode-ray oscilloscopes, etc., are mounted to the rear of the generator housing when required.

A typical field setup uses the cable from one reel to connect the signal generator to a transmitting antenna. The other reel handles the cable to connect the receiving antenna under test back to the field strength meter, and it also carries conductors for the selsyn indication, as well as phone circuits for two-way conversation between the operator handling the receiving antenna, remote from the truck, and the test engineer handling the equipment in the truck. With this setup, a complete response curve and field pattern for both high and low bands can be obtained on the average antenna very rapidly and with excellent accuracy.

By the use of the sweep oscillators, detector, and cathode-ray oscilloscope, which can be mounted behind the shielded generator, a very rapid determination of antenna impedances and standing wave ratios is made possible. These values are checked in the laboratory by the slotted line method and also by heavily exciting the antenna and probing the line with a sensitive pickup feeding into the field strength meter. This pickup has negligible loading on the transmission line during the operation. The two last methods are much more laborious and time-consuming but are used to check

Fig. 8. Field pattern of Ward Model TVHA-9.



the results of the first tests using the sweep oscillators. The sweep oscillator method has a big advantage in that it is capable of showing impedance matching characteristics over a broad portion of the spectrum at one time when displayed on the oscilloscope.

The above discussion has centered around only two of the several models which are required for a complete line of television antennas. Fig. 3C shows a stacked array which incorporates all of the various problems outlined with several additional variables. Fig. 7 shows response curves, and Fig. 6 shows typical field patterns for such a unit. These three types of antennas are typical examples and show the procedures necessary to be carried out if a full knowledge of the capabilities of the antenna, electrically and mechanically, are to be known with accuracy. —30—