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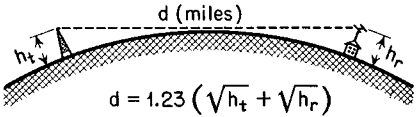
UHF Television

By the Engineering Department, Aerovox Corporation

THE impending activation of television broadcasting stations in the ultrahigh frequency band between 475-890 mc. makes a discussion of this subject very timely and of widespread interest. The inauguration of this service, with its many new technical and economical problems, is expected to have far-reaching effects on all phases of the video field. Occupying, as it does, a portion of the radio spectrum where the methods of transmission and reception depart considerably from those practiced in the present bands, this new frequency allocation will require the adoption of many new concepts and techniques in the development, manufacturing, and servicing fields. For although the Federal Communications Commission proposes to maintain the presently used television engineering standards for bandwidth, number of lines, and frame repetition rate in at least the lower forty-two channels of the UHF group, the differences in propagation, antennas, transmission lines, and r.f. circuitry make this band a radically new and interesting field of endeavor. In this issue of the AEROVOX RESEARCH WORKER we discuss some of these aspects of UHF television. Future issues will contain constructional details of UHF receiving antennas and converters.

Necessity for additional television channels arises from the fact that several metropolitan areas have exhausted the VHF channel allocations than can be safely made for that locality without causing interference with stations operating on the same channel in neighboring areas. Such co-channel interference restricts the minimum spacing between stations sharing the same television channel to about 150-200 miles. Even with this spacing, viewers located between such stations are frequently bothered with "venetian-blind" interference during periods of anomalous propagation. Therefore, the FCC, with many more applications for television station construction permits on file than it had channels available, decided upon the UHF frequencies between 475 and 890 mc. as the logical place to expand television broadcasting facilities.



$$d = 1.23\left(\sqrt{h_t} + \sqrt{h_r}\right)$$

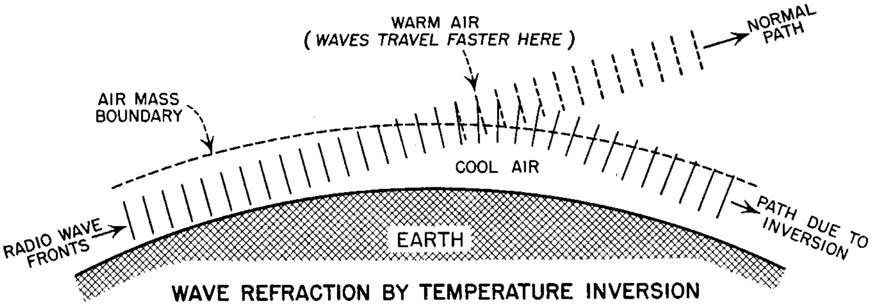
Where:
h_t = Transmitting ant. height (Ft.)
h_r = Receiving ant. height (Ft.)

OPTICAL LINE-OF-SIGHT DISTANCE
(Smooth Earth)
FIG.1

UHF Propagation

One of the chief difficulties in TV broadcasting has been the unpredictable nature of short wave propagation. The common characteristic of such propagation is that, although the range of transmission under normal, *undisturbed* conditions is comparatively short, abnormal conditions which occur quite frequently due to air mass movements in the *troposphere* may extend the range many times. Thus, although it is necessary to use appreciable transmitter power to cover a reasonable primary service area, this power may frequently cause co-channel interference on receivers hundreds of miles away under conditions of abnormal atmospheric bending. These effects bring about serious problems in station spacing and frequency allocations, and are considered important enough to warrant a brief discussion here.

Radio waves in both the VHF and the UHF portions of the spectrum normally follow line-of-sight laws. The relationship between transmitting and receiving antenna heights and station separation for a true optical path over a smooth earth's surface is shown in Fig. 1. Actually, because radio waves propagating in an "undisturbed" earth's atmosphere are bent or *refracted* slightly so that they follow a path which is theoretically four-thirds of radius of the earth, the radio line-of-sight is about 15% greater than optical line-of-sight distance. The constant 1.23 in Fig. 1 may be changed to 1.41 to include this effect. Of course, departures from a "smooth earth" and absorption or scattering caused by



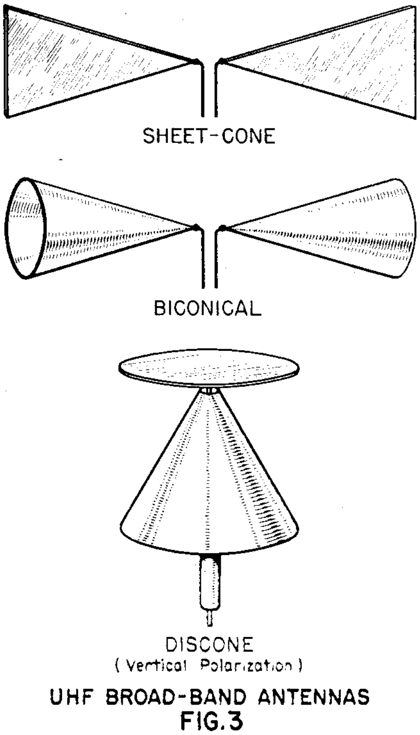
WAVE REFRACTION BY TEMPERATURE INVERSION
FIG. 2

large objects in the radio path modify the range considerably. It is usually the radio line-of-sight condition which determines the primary service area of a television station. Beyond this radio horizon the signal at ground level is attenuated rapidly with distance from the transmitter and a satisfactory picture signal can only be obtained by increasing the antenna height, the transmitter power or receiver sensitivity. This service zone is known as the "fringe area" and it is here that the effects of anomalous propagation are most pronounced.

Abnormal propagation of very short radio waves is caused by several sets of meteorological conditions which may exist in the lower several miles of the earth's atmosphere (the *troposphere*). The most widely recognized of these conditions is that known as "temperature inversion." Such an inversion exists when the temperature decrease of the earth's atmosphere with altitude departs markedly from the normal "lapse rate" of about 3 degrees F. per 1000 feet. When this condition occurs, bending of radio waves in the lower atmosphere increases. If the temperature of the air actually *increases* with altitude, downward bending becomes very pronounced, resulting in reception of the waves far beyond the normal range. This bending is caused by the fact that the waves travel faster in the light, warm, upper air than they do in the more dense, cooler lower air. Therefore, radio waves passing obliquely from one medium to the other are bent downward due to the optical phenomenon known as *refraction.* This process is illustrated in Fig. 2.

The basic differences between VHF and UHF propagation are that very much greater transmitter power is required in the UHF band to provide the same quality of television service that is presently offered in the VHF channels, although anomalous propagation effects will probably be worse. Actual field tests of UHF television transmission made by responsible commercial investigators and by the FCC indicate that up to 100 times as much power may be required to provide UHF coverage comparable to that presently experienced in the lower bands. Such power requirements are beyond the present status of the UHF transmitting tube art, although there is feverish activity in the industry to complete the development of suitable tubes. The great emphasis on microwave tube development for military radar applications and the lack of commercial services in the 500-1000 Mc. region has resulted in this frequency range being somewhat neglected in the past.

The need for extremely high transmitter power for UHF television arises from the poorer performance of receiving components at these frequencies, in addition to the propagation limitations mentioned above. The characteristics of receiving equipment for this band will now be discussed.



SHEET-CONE

BICONICAL

DISCONE
(Vertical Polarization)

UHF BROAD-BAND ANTENNAS
FIG. 3

Antennas

The problem of receiving antenna broad-banding is not as troublesome in the UHF television band as it has been at the lower frequencies. The frequency ratio involved is less than 2:1 in this case instead of the 4:1 frequency ratio which exists between the extremes of channels 2 and 13. In addition, half-wave antennas in this band are quite small, ranging from about one foot in length at the low end to approximately six inches at the high frequency end. The small physical size makes it possible to use special broadband designs which could not be employed at the lower television frequencies because of prohibitive wind resistance. Typical examples of such special UHF designs are the *sheet-cone* antenna, the *biconical* antenna, and the *discone* antenna depicted in Fig. 3. Antennas of these types can be effective over frequency ranges considerably greater than 2:1.

Balanced against the convenience of small physical size is the fact that a UHF antenna has a smaller "effective area," i. e., it extracts less energy from a passing wave. The effective area of an antenna is given by:

$$(1) \qquad \text{Area} = \frac{G\lambda^2}{4\pi}$$

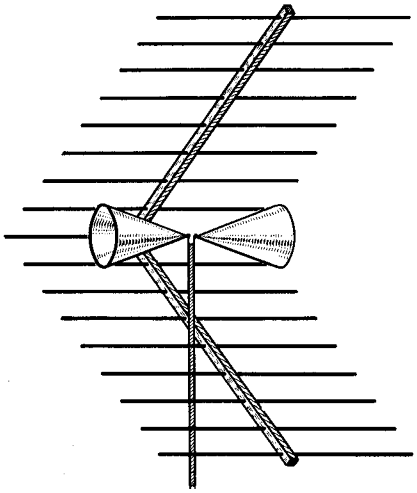
Where: G is the power gain of the antenna.
λ is the resonant wavelength.

Since the effective area is proportional to the wavelength *squared,* an antenna resonant at 60 mc. (5 meters) would intercept 100 times as much energy from a field of a given intensity as would an antenna of the same gain operating at 600 mc. (.5 meter). It will therefore be necessary to employ antennas having high values of gain, since the effective area increases directly with gain.

For frequencies within the UHF TV band, relatively high gains are obtainable with special dipoles of the types shown in Fig. 3 when used in conjunction with cylinderical parabolic or square-corner reflectors. An arrangement of this type is illustrated in Fig. 4. Reflectors of this kind are preferably constructed of metal spines or wire mesh to reduce wind loading. Power gains of over 16 db. are available in the UHF band with antennas of practical size.

Transmission Lines at UHF

Another serious problem in the reception of UHF television signals is the high attenuation in common transmission lines at ultrahigh frequencies. The r.f. losses in the standard 300-ohm ribbon-type lines make the use of them prohibitive at UHF frequen-



UHF ANTENNA WITH SQUARE CORNER REFLECTOR
FIG.4

cies. These losses are mainly due to radiation from the line which becomes much greater if an appreciable standing wave exists. Even high quality solid-dielectric coaxial lines such as RG-8/U exhibit attenuations which range from almost 6 db. per hundred feet at 500 mc. to nearly 10 db. at 1000 mc. This means that only one-fourth to one-tenth of the energy intercepted by the antenna would reach the input of the receiver, if the transmission line is 100 feet long. Thus, the advantage of a high antenna to improve the signal strength is partially offset by the increased losses incurred by the long line needed to feed the receiver. This suggests that in some cases it will be necessary to place the UHF receiver front-end at the antenna so that the lead-in works at the lower frequency of the i. f. where the losses are much smaller. Lines with low losses at UHF are available, but are quite expensive.

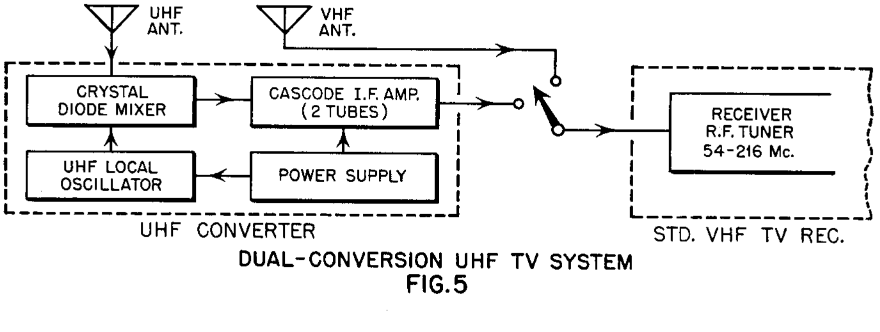
Receiver Considerations

One of the primary reasons for maintaining the present black-and-white standards in the lower part of the UHF band (Channels 14 through 55) is to make it possible to adapt any of the several million existing low-band viewers to UHF by the addition of a simple frequency converter. Future television sets will undoubtedly have built-in UHF coverage, but it is anticipated that the dual-conversion system will be used. This is because the UHF band lies in the "awkward" transition frequency range where lumped-constant circuits are unsuitable, and yet true distributed-constant circuits such as cavities and lecher lines are quite bulky. For this reason, combination VHF-UHF tuners appear impractical. In addition, dual conversion has advantages in image rejection, local oscillator range, gain, and flexibility.

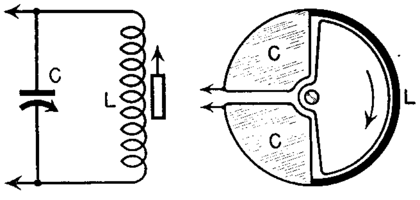
Fig. 5 shows, in block diagram form, the rudiments of the dual-conversion scheme. The incoming UHF television signal is heterodyned with the UHF local oscillator signal in a mixer of the vacuum tube or crystal type. The frequency of one of the VHF television channels is chosen as the difference frequency, so that the output of the converter may be fed into the input terminals of the standard receiver. The receiver r.f. stage acts as the first i. f. amplifier and the signal is again converted by the VHF mixer to the i. f. of the receiver. The signal has thus undergone two frequency conversions before final detection.

Vacuum tubes of special design are required for r. f. applications at UHF because of the limitations of conventional designs discussed in the AEROVOX RESEARCH WORKER for October. As mentioned there, silicon crystals are favored for mixers at these frequencies because of better noise performance and greater simplicity. The noise figures of inexpensive r. f. amplifiers for UHF are so poor that most converter designs do not use r. f. stages ahead of the mixer, but may have a tuned preselector or r. f. filter circuit to improve image rejection.

The r.f. circuitry used for UHF tuners represents a considerable departure from conventional low frequency types although evolved directly from them. Tuning circuits in particular present a new appearance at first glance. This is because a tuning range of nearly 2:1 is required to cover the entire band, so that it is necessary to use combination inductive and capacitive tuning. Special tuners which use this general principle are the butter-fly, the semi-butterfly, and the split-cylinder types. The development of a UHF resonant circuit of the semi-butterfly type from the conventional coil-condensor parallel resonant circuit is illustrated in Fig. 6. The frequency of the L-C combination (6a) can be varied either by changing the meshing of the condensor plates or by introducing a body into the coil which effects the permeability. If a brass "slug" is used, the frequency *increases* as it is inserted into the center of the coil.



DUAL-CONVERSION UHF TV SYSTEM
FIG.5



L-F TUNED CIRCUIT
(a)

UHF SEMI-BUTTERFLY TUNED CIRCUIT
(b)

FIG.6

In the UHF version (6b), the coil has become a single half-turn loop and the many condensor plates of the low frequency circuit have been reduced to two quarter-plates which form the stator plates of a split-stator condensor. The rotor performs a double tuning action in this arrangement because it acts as a tuning "slug" in the position shown and increases the resonant frequency; then as it is rotated to mesh with the stator plates, it decreases the frequency. The tuning range of this double-action type of tuning is greater than with either inductive or capacitive tuning used alone.

The conversion loss in a crystal mixer may be as much as 10 db. For this reason, it is usually necessary to add a stage of i. f. amplification to the UHF converter output to compensate for this loss. The very popular *cascode* amplifier is widely preferred in this application because of it's excellent noise properties. The noise figurue of the i. f. amplifier used here is very important in establishing the overall noise performance of the receiver, since the preceeding stages have little or no gain. Noise figures of about 10 db. appear to be about the best that can be expected from commercially feasible UHF television converters.

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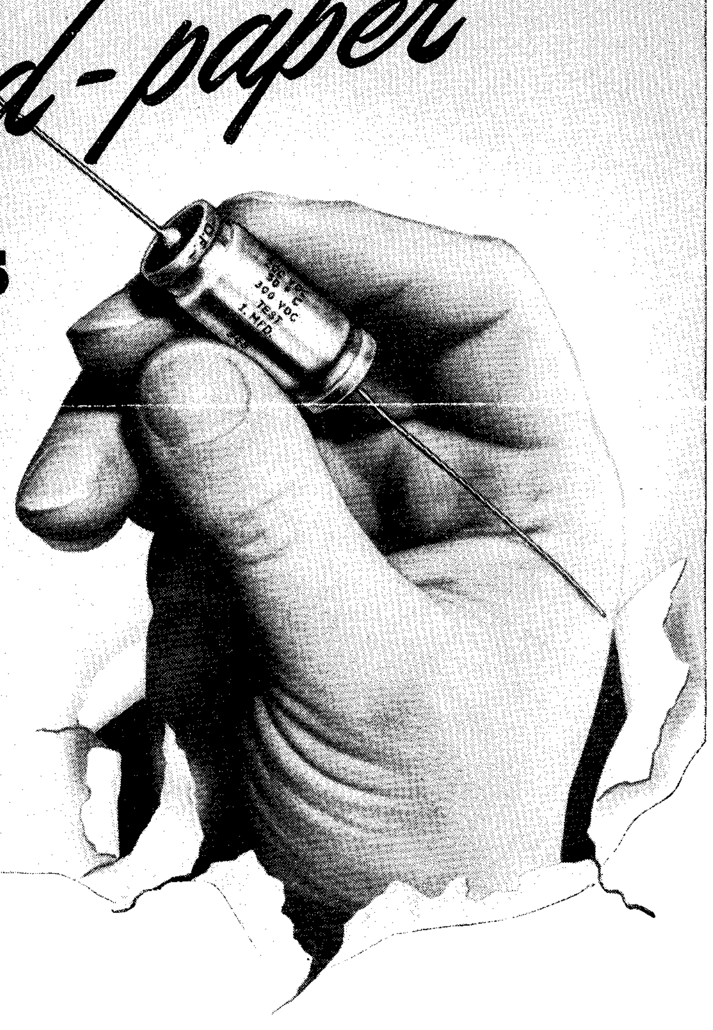

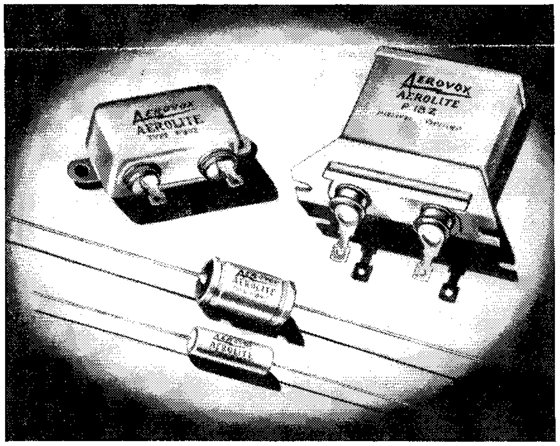

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