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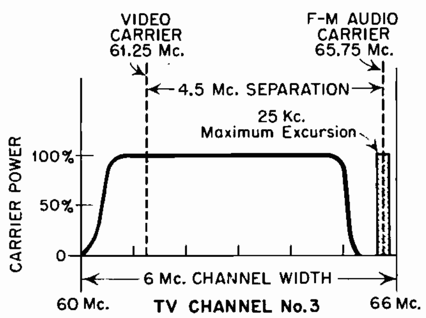
Television Inter-Carrier Sound Reception

By the Engineering Department, Aerovox Corporation

IN all present-day television systems, the sound, picture and synchronization information are transmitted simultaneously over a six-megacycle-wide television channel. Prior to 1942, this was accomplished solely by the use of an amplitude-modulation (AM) method, in which the audio intelligence and the video intelligence were each impressed on two completely separate carriers which differed in frequency by 4.5 megacycles. Subsequent developments in the art demonstrated the desirability of utilizing the much-enhanced fidelity and noise reduction properties inherent in frequency-modulation (FM) to improve the audio performance of the television system, and as a direct consequence to increase listener enjoyment and acceptance of the then new mode of entertainment. This combination of AM for the video carrier and FM for the sound carrier, with transmission standards as established by the F. C. C., is currently in use by all television broadcasting stations in this country. This changeover from AM sound to FM sound, while requiring rather extensive modification of the transmitter, did not involve obsolescence of existing TV receivers, since the FM sound could be received by the slope detection method. Fig. I graphically illustrates a typical spectrum analysis for one of the 12 U. S. channels in use at the present time.

In recent years, a number of schemes (References 1, 2, and 3) have been disclosed for the simultaneous transmission of both picture and sound on a single carrier. In general these systems were based on the use of a multiplex or time-division method of transmission in which it was proposed that the audio modulation be impressed on the video carrier during the intervals normally reserved for the synchronization pulses. Because of the fact that these sync pulses occur only during the blanked portion of the kinescope trace, audio signals transmitted during the retrace or fly back period should cause no interference with the picture. However, since the ratio of sync pulse duration to video pulse duration is quite small, roughly 10%, the average audio power which can be transmitted during the sync pulse interval, with a given carrier, is correspondingly reduced by a factor of 10. This could be overcome to some degree by increasing either the sensitivity of the receiver or the transmitter power. Another serious objection exists in the fact that adoption of such a system would not only require a major modification of the transmitters but would also make existing receivers obsolete.



TELEVISION CHANNEL SPECTRUM ANALYSIS
FIG.1

In 1947, exposition was made in papers by Parker (Ref. 4) and Dome (Ref. 5) of the development of a new method for recovery of the audio intelligence contained in a composite television signal. In this system, a 4.5 Mc. beat frequency, usually present as an undesired signal in the control grid circuit of the kinescope, is made to serve as what may be termed an audio sub-i.f. signal which can be amplified, clipped or limited and then demodulated in the usual manner. That such a 4.5 Mc. signal can exist may readily be seen from the following generalized consideration. It may be mentioned in passing that even though this ordinarily undesired signal is usually present in greater or lesser degree in all T V receivers, only one manufacturer, to the writers knowledge, has made particular provision for 4.5 Mc. trapping in the video amplifier circuit.

It will be remembered that in a conventional superheterodyne receiver, an incoming signal of frequency F and a locally generated oscillator signal of frequency f, are both passed through some non-linear device, variously termed the mixer, converter or first detector. In the conversion process the two signals are combined and form an i.f. signal of frequency equal to the difference between F and f. It must be stressed at this point however that this heterodyne or beat frequency will be generated only if the mixing

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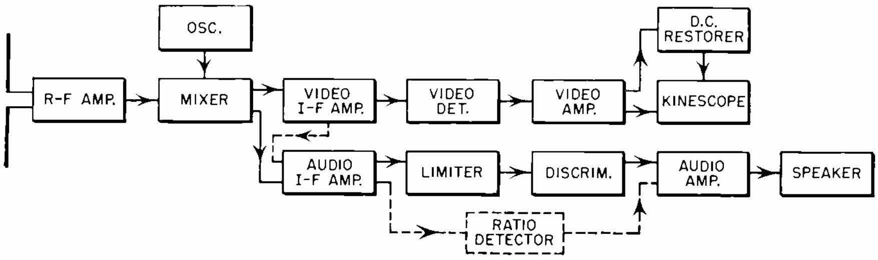


CONVENTIONAL DUAL-I-F TV RECEIVER
FIG. 2

device (vacuum tube, crystal diode, thermistor, etc.) possesses some nonlinearity in its impedance characteristic.

In the conventional dual-i. f. television receiver, both the picture and sound carriers, comprising the composite television signal, are amplified by a common broad-band r. f. stage, heterodyned with a single local oscillator signal and converted to a complex signal containing video and audio i.f. components. Although the conversion process lowers the frequency of the two carriers, the 4.5 Mc. frequency difference between them remains unaltered. If, as is usually the case, the oscillator is operated on the high frequency side of the signal, a sideband reversal takes place, i. e., the relative positions of the video and audio carriers are interchanged.

The use of a common r. f. amplifier, mixer and oscillator for both picture and sound adds to ease of operation and at the same time affords a material saving in cost. A natural extension of this dual function technique to the i. f. portion of the receiver has resulted in the recent appearance on the market of several commercially designed TV receivers in which one, or even two of the i.f. stages are made to function as combined picture and sound amplifiers. From this point on, two signals are separated by appropriate filters or traps, amplified further as required and then demodulated, as shown in Fig. 2.

In the intercarrier sound system, Fig. 3, both the picture and sound i. f. signals are handled simultaneously by a common wide band multistage i. f. amplifier. In the video detector, usually a vacuum tube or germanium crystal diode, the frequency modulated sound i. f. signal is heterodyned with the amplitude modulated video i. f. signal. The resulting 4.5 Mc. beat, produced by the non-linearity of the detector characteristic, is both frequency modulated by the sound and amplitude modulated by the video. It has been shown, however, that if a low level FM signal is heterodyned with a high level AM signal, the resultant signal is largely frequency modulated and is relatively free of AM. This 4.5 Mc. sub-i. f. is further amplified by the video amplifier, passed through one or more amplifier limiter stages where the residual AM is removed, and is finally demodulated by any of the well-known methods of FM detection. Use of the ratio detector for this function provides adequate AM clipping without resort to a separate limiter.

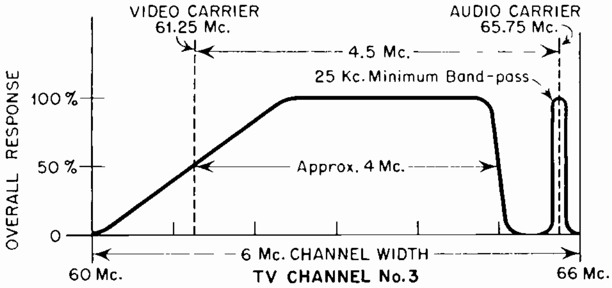
Although not adequately demonstrated by the simple block-diagrams of Figs. 2 and 3, the intercarrier system represents a considerable simplification in circuitry when compared with the actual schematic of the dual-i. f. system of television reception. In addition to this advantage, with its attendant economy, the Parker system possesses several other desirable characteristics among which may be mentioned simplicity of tuning, freedom from oscillator drift and microphonism, and reduction of inter-channel crosstalk.

The dual-i. f. television receiver suffers from the serious disadvantage that even comparatively slight mistuning or drift of the local oscillator seriously affects both audio quality and discriminator impulse-noise susceptability. In common with other types of FM receptor, background noise and hiss are also increased by such oscillator maladjustment. Automatic frequency control of the oscillator has been applied in certain television models as a means of reducing these shortcomings, but this if course adds to the complexity and consequently to the cost. A commentary on the efficacy of AFC circuits as applied to TV receivers may be made by noting that one manufacturer, after marketing a receiver using AFC, subsequently issued a modification kit for adding a fine-tuning control to sets in the field.

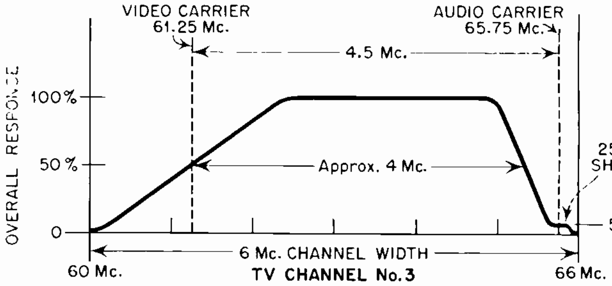
These conditions are further aggravated by the fact that the TV sound deviation is only 12.5 kc. as compared with 37.5 kc. for standard FM broadcast transmissions. The discriminator coil Q can therefore usually be made higher, requiring almost pinpoint accuracy in TV set tuning.

Sixty-cycle frequency modulation of the local oscillator in the standard dual-i. f. system, due to insufficient filtering or cathode-heater leakage, is often manifested as objectional hum in the speaker. In one commercially built set, it was found necessary to include a small dry-disc rectifier and filter to supply pure d. c. to the heater of the local oscillator to reduce such hum. Acoustic feedback from the speaker diaphragm to any microphonic portion of the oscillator circuit, such as trimmer condenser plates, switch contacts, coil slugs, tube elements, and the like, can cause annoying ringing or even audio howl at high volume.

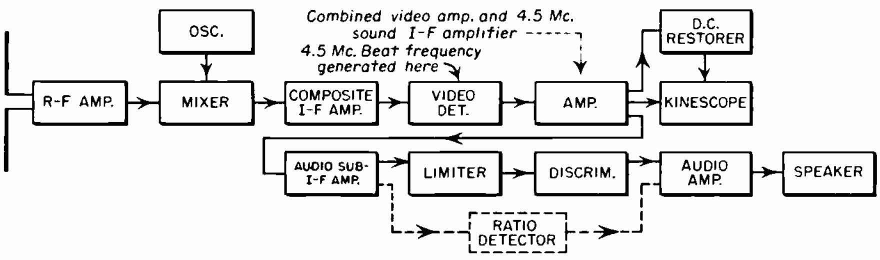
The Parker system, in which constancy of the 4.5 Mc. frequency difference between carriers, which is used as the sound i. f., is maintained by accurate control at the transmitter



IDEALIZED OVERALL RESPONSE CURVE
FOR DUAL-I-F TV RECEIVER
FIG. 4



IDEALIZED OVERALL RESPONSE CURVE
FOR INTER-CARRIER TV RECEIVER
FIG. 5



INTER-CARRIER SOUND TV RECEIVER
FIG. 3

rather than by the relationship existing between received and locally generated signals, is immune to these troubles. Since the video i. f. is normally of the wide band type (See RESEARCH WORKER for January, 1949), misadjustment or drift of the local oscillator sufficient to cause severe distortion of the sound in dual-i. f. receivers, causes no appreciable degradation of either picture or sound quality in sets equipped for inter-carrier sound reception.

The discussion thus far of the comparison between the two systems has been confined to the credit side of the inter-carrier ledger. There are, of course, the ever present debits. Chief among these is the susceptability of the inter-carrier system to audio interference caused by; (a) frequency or phase modulation of the video carrier, (b) momentary disappearance of the video carrier during modulation peaks, (c) failure at the transmitter to accurately maintain the prescribed 4.5 Mc. difference between video and audio carriers, and (d) drift of the receiver discriminator tuned circuits.

The remedial measures necessary to reduce the above effects present no insurmountable problems, as may be seen from the following considerations:

(a) Frequency or phase modulation of the video carrier appears, in the Parker system, as undesired modulation and distortion products in the reproduced sound. This can be prevented, or at least minimized, by proper transmitter design and adjustment.

(b) Since the inter-carrier system depends upon both carriers for its sound reproduction, it is evident that momentary disappearance of the video carrier, such as might be caused by over-modulation of the transmitter, also causes interruption of the sound. By imposing the limitation at the transmitter that the picture carrier shall never fall below 10 or 15% of maximum amplitude, the possibility of such sound "break-up" is prevented. Another effect which has symptoms very similar to sound break-up by video carrier disappearance is that occasioned when one of the video i. f. amplifier stages is driven to cutoff, as it is sometimes possible to do by improper adjustment of the contrast control. Since the peak signals are the "sync" pulses, which are in the infra-black region, this type of operation is not necessarily deleterious to the performance of the dual-i. f. sets. In the Parker system, however, operation at cutoff results in sound break-up.

(c) Failure at the transmitter to accurately maintain the 4.5 Mc. spacing between the video and audio carriers results in the same kind of audio performance degradation as that caused by misadjustment of the tuning control or discriminator circuit in the conventional dual-i. f. system. Whereas this condition can easily be corrected by the user of the older system by adjustment of the fine-tuning control, the inter-carrier arrangement must depend upon the broadcaster for the correction of this condition.

(d) The effects of drift in the discriminator circuit of the inter-carrier sound system are usually slight since the sound sub-i. f. is at a relatively low frequency and can be virtually eliminated by careful design and the judicious use of small fixed capacitors having the proper capacitance versus temperature characteristic.

Figs. 4 and 5 show the overall response curves for the two TV systems discussed above. The only difference lies in the shape of the curves in the vicinity of the sound portion of the spectrum. In the dual-i. f. system, full response over at least a 25 kc. band-width, centered on the sound "resting" frequency is desired, while in the inter-carrier method the sound acceptance notch is in the form of a small shelf of similar width and center frequency. The reason for a plateau rather than a gradual roll-off for the intercarrier sound response is that in this way partial demodulation of the FM sound by slope detection, and possible picture interference is prevented. As shown by Fig. 5, the response at the sound shelf should not exceed 5% of full amplitude. This, as mentioned earlier, reduces the video amplitude modulation of the sound sub-i. f. to a negligible value and also prevents possible distortion of the picture by the sound modulation.

The sound trapping requirements in the Parker system are not nearly so stringent as in conventional sets. A single trap, providing about 26 db. of attenuation is required immediately preceeding the video detector to reduce the sound response to the 5% level. This rather large attenuation is subsequently compensated for by the additional gain of the one or two video amplifier stages.

In closing, it may be remarked that the results of rather extensive field tests, and the likelihood of industry-F. C. C. cooperation in setting up the transmission standards necessary for insuring satisfactory performance, may well lead to the eventual complete adoption of the inter-carrier system for television sound reception.

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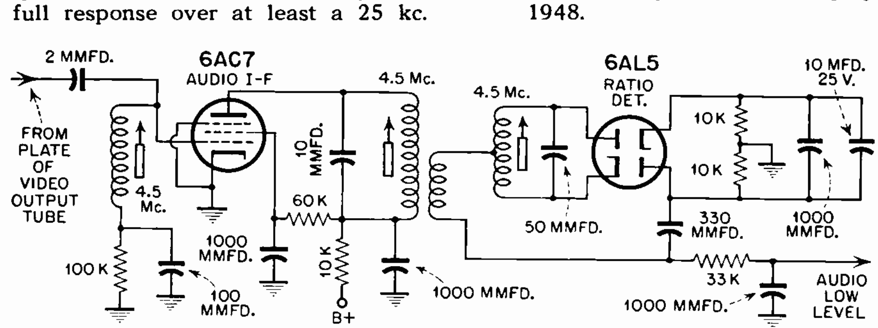

4.5 Mc. CIRCUITS FOR INTER-CARRIER SOUND
FIG. 6

BOOST KVA RATING BY FIVE OR MORE . . .

CUT PRESENT SIZES OF POWER CAPACITORS . . .

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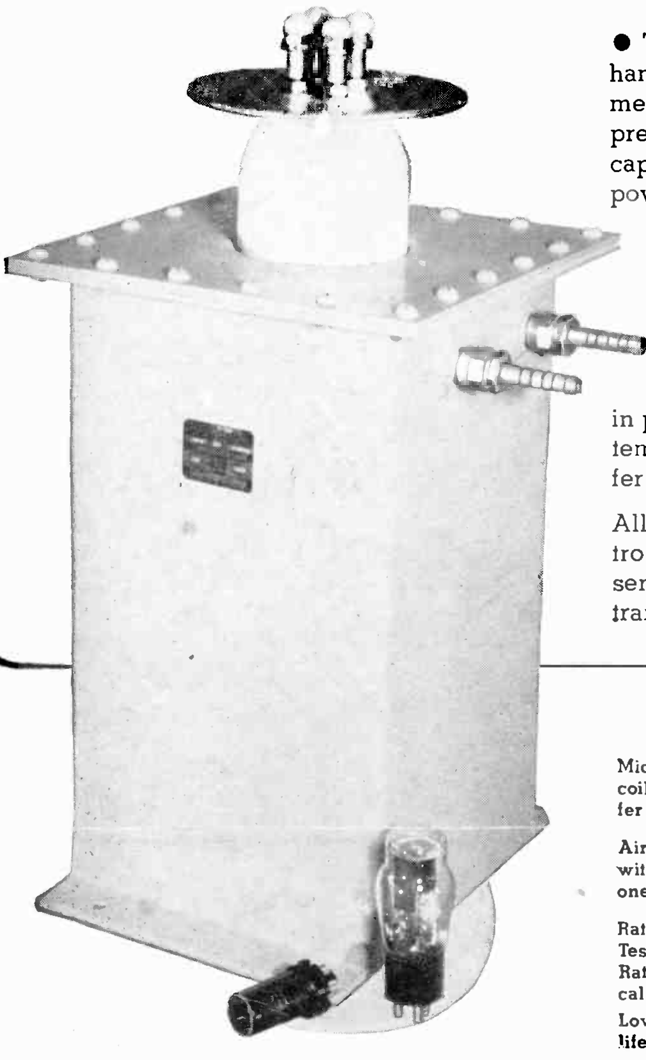
Water-cooled

MICA CAPACITORS



● This new water-cooled oil-filled mica capacitor handles exceptional KVA loads for its size. This means that more power can be handled than with previous capacitors of similar size or, conversely, capacitor size can be greatly reduced for given power ratings.

Series 1780 capacitors attain their higher KVA ratings in two ways: (1) By exceptional design such as critical arrangement and location of sections; choice of materials; specially-plated parts; large cross-section of conductors; careful attention to details and true craftsmanship in production. (2) By the use of a water-cooling system so designed as to provide maximum heat transfer from capacitor section to cooling coils.

All in all, here is a sturdy, compact, hard-working, trouble-free mica capacitor for extra-heavy-duty service, such as induction furnaces and high-power transmitters.

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Air-cooled operation, 200 KVA; with water-cooling, 1000 KVA—a one-to-five ratio.

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Lower power factor (.01%). Long life and large factor of safety.

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Heavy welded metal case, hermetically sealed. Exceptionally sturdy construction.

Series-parallel mica stack designed for uniform current distribution throughout.

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