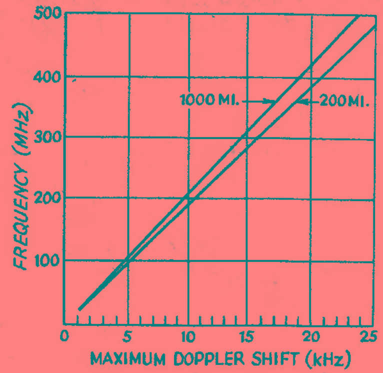


Fig. 15E-3 — Satellite transmitter frequency versus Doppler shift for satellite in 200- or 1000-statute-mile orbits. For a translator, use the difference between uplink and downlink frequencies as the "frequency."

within this circle, you will be able to use it for communication. Contact can be made with any other station having the satellite within its range at the same time. This is shown in Fig. 15E-2. Thus, the maximum map distance for communication would be about two times your map range.

The time duration for which a satellite will be within your range depends on two factors: the satellite's altitude and the distance between the subsatellite point (the point on the earth directly below the satellite) and your station. Higher altitude orbits increase the size of your range or acquisition circle, thus providing longer exposure to the satellite. Also, the longest duration for any given altitude will occur on orbits which pass directly over the station location. For example, a satellite in a 1000-mile orbit would be line-of-sight to a ground station for about 25 minutes on an overhead pass. At a map range of 1000 miles the duration would be 20 minutes, and at 2000 miles, availability would be about 10 minutes.

Conventional transceiver-type operation may offer some problems with satellites because of the Doppler phenomenon. Separate frequency control of the ground station's transmitter and receiver is desirable. (In some cases an "incremental tuning" feature on a transceiver will suffice.) Doppler is a frequency-shifting effect resulting from the motion of the satellite. It is a function of the transmitting frequency and the velocity of the satellite relative to the observing station. (Velocity is further a function of satellite's altitude.) Fig. 15E-3 compares Doppler shifts for frequencies up to 500 MHz for satellites in 200- and 1000-statute-mile orbits. The reason why Doppler shift requires a special consideration with transceiver operation is because two stations in contact would go through a series of frequency compensations, thus "walking" themselves across (and perhaps out of) the band! The frequency of a satellite moving toward a ground station appears higher than the actual satellite transmitter frequency. It drops as the satellite nears the ground station. At the exact point of closest approach, the observed frequency will be the same as the true frequency. Past this point, the satellite's signal will continue to drop lower in frequency as the satellite moves away.

There are two types of repeaters likely to be employed in future amateur satellites. A channelized repeater for fm would operate much like the ground-based fm repeaters used by amateurs; one station could use a channel at a time. Several contacts could be accommodated by a multichannel satellite. The other approach is called a frequency translator. It receives a segment of one band, say 100 kHz at 144 MHz, and retransmits the segment on another band, say 28 MHz. With a frequency translator, as many contacts as can be accommodated by the translator's bandwidth can take place simultaneously, and all modes can be used. Doppler shift from the fm repeater would be the same as expected for a transmitter on its downlink frequency. With a translator, however, the amount of Doppler shift is influenced by both the up- and downlinks. By employing a frequency inversion technique in the satellite's design, these amounts of Doppler will subtract; the resulting shift is then found from Fig. 15E-3 by using the frequency difference between up- and downlinks.

An aid to satellite communication is to monitor your own downlink signal coming from the satellite, while you are transmitting. This permits you to avoid interference from other stations, to compensate, where appropriate, for Doppler shift, and to adjust your transmitter power and antenna direction for maximum efficiency in sharing the satellite's output.

Best results in satellite communications are achieved when the ground-station antenna is pointed directly at the satellite. Movement of the antenna in elevation as well as azimuth is necessary. An easier alternative, providing adequate results, is also available. It is the use of a medium-gain antenna (about 10 dB) pointed at a fixed elevation of about 30 degrees and rotatable in azimuth. The beamwidth of such an antenna will

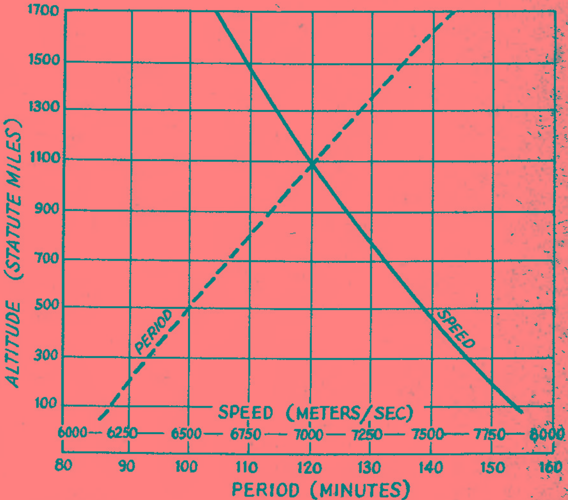


Fig. 15E-4 — Satellite altitude versus its period (time for one revolution) and speed.

allow satisfactory performance with most passes of the satellite. In the case of synchronous satellites, where the spacecraft maintains the same position relative to the observer, even the azimuth rotation can be eliminated – the antenna can be in a fixed position. However, greater antenna gain will most likely be needed in this case to compensate for the greater path loss from a satellite in such a high-altitude orbit.

Another antenna consideration for satellite communication is the use of circular polarization. Because the plane of a wave is rotated as it passes through the ionosphere, cross-polarization can occur between two linearly polarized (i.e., horizontal or vertical) antennas. This is called Faraday rotation. A circularly polarized antenna (such as a crossed-dipole, crossed-yagi, or a helix) at either the ground station or the satellite serves to minimize the effect.

Late Information

QST carries information about recent developments in Oscar. Since ground station requirements are dependent on the bands, modes, etc. used by the satellite, the amateur wishing to become equipped for space communication should consult ARRL headquarters to determine current amateur satellite plans.

PHONE PATCHING

A phone patch is an interconnection made between a radiotelephone system and a wire-line telephone. When the patch is made properly, the radio link and the wire line will effectively extend each other. Phone patches have provided vital communication when a natural disaster has caused disruption of normal communication facilities. More commonly, phone patches permit men in service or on scientific expeditions to talk with their families. Few activities can create a more favorable public image for amateurs than to bring people together in this way. Such public service is always appreciated. Amateurs are using phone patches for their own convenience, too. A phone patch might be used to talk with a friend in a distant city or to make a phone call from a car. In the latter case, a number of clubs are equipping their repeaters with unattended phone patch arrangements.

Occasionally, a phone patch will be used at both ends of a radio link. That is sometimes the case when the radio contact is made to overseas military bases. Some bases have a special phone booth or a small studio where the serviceman can have more privacy and be at ease while in conversation. The studio may be equipped with a regular telephone or it may have a microphone and earphones or a loudspeaker. It is common, too, for the participants to be asked to end each comment with the word "over" as a cue to radio operators (who may be using push-to-talk operation) to reverse the direction of transmission.

Fig. 15F-1 – The voice coupler, to the left of the touch-tone telephone, is supplied by the telephone company. The coupler is normally fixed to a wall or desk, and contains a jack for connection of the amateur's phone patch.

A few general considerations apply to phone patching. It constitutes the handling of third-party traffic. Agreements between governments specifically permitting such traffic must be in effect if the radio link is to a foreign country. Amateurs are responsible for conforming to regulations on station identification, prohibited language and the like while a phone patch is in progress. If a repeater is involved, the arrangement should meet all applicable rules regarding repeater-control facilities. Telephone companies, too, are concerned that the interconnection arrangements be made in the proper way and that the electrical signals meet certain standards.

THE TELEPHONE SYSTEM

Telephone company regulations are published in their tariffs, which in most states must be available in the company's business offices. In the tariffs, phone patches are included under "Interconnection Arrangements" or a similar designation. Telephone employees may not be familiar with the term, "phone patch" so it should be used with caution when talking with them. Patching is accomplished with the aid of devices called "couplers" or "voice connecting arrangements." These are provided by the telephone company and are important in several ways. They protect the amateur's telephone service from interruption that might result from a malfunction in his equipment; they protect other users, too. By isolating the amateur's equipment electrically from the telephone line, they give him a great deal of freedom in the design of his circuits. The protective device also permits proper adjustment of the circuit impedance, energy levels and other operating conditions to be met by the amateur's equipment.

Several different interconnection arrangements are listed in Table I.

A telephone line normally consists of a single-pair of wires which is used for both directions of transmission. At the amateur's station it will be terminated in a telephone set. A voice coupler will be connected in parallel with the telephone set when the phone patch is in progress. For design purposes, the telephone set and line are each assumed to have an impedance of about 900 ohms (in the case of residence service) and the best impedance for the phone-patch circuit is also 900 ohms. In operation, the patch will see a load of about 450 ohms. This small mismatch should not be cause for concern, however, as it is the best possible compromise. The phone patch's basic function is to connect the radio receiver's audio output circuit and the radio transmitter's audio input circuit to the telephone voice coupler. It should do this in a way that results in correct circuit impedances and voice levels. Provision should be made, too, for measuring and adjusting the voice level that is transmitted to the telephone line and for electrical filtering to the extent needed to comply with telephone company limitations.

Fig. 15F-1 shows a typical voice coupler and a related telephone set. A simplified schematic diagram of this setup is given in Fig. 15F-2. The telephone is equipped with an exclusion key and a turn button. The telephone operates in the usual way when the two switches are in their normal positions. Lifting the exclusion key causes the voice coupler to be connected to the telephone line. If it is requested when the voice coupler is ordered, the turn button will be supplied and can be wired by the telephone company to cut off the handset transmitter, the receiver, or both of them. The *transmitter* cutoff feature is preferred, as it will eliminate the pickup of room noise by the telephone while permitting the patched communication to be monitored on the handset receiver. The operator can restore the turn button as required for station identification or to break in for other purposes.

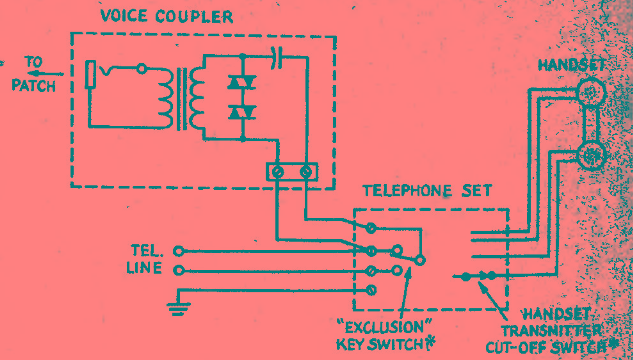


Fig. 15F-2 — Simplified diagram of voice coupler and telephone set. *Both the cutoff switch and the exclusion key switch are shown in their normal positions.

Supplemental information and pertinent telephone company technical specifications as they may apply to amateur radio are given in the appendix which appears at the end of this chapter.

PHONE PATCH CIRCUITS

Where push-to-talk operation is used, the phone patch can be as simple as a transfer switch (connecting the receiver and the transmitter, alternately, to the coupler) or it can be a resistive combining network of the kind shown in Fig. 15F-3. Included in the circuit is a 2600-Hz filter, the need for which is discussed later.

Hybrid Circuits

Where it is desirable to use voice-operated transmitter control (VOX), more elaborate arrangements are required. The VOX circuit must determine when the distant radio station is transmitting and inhibit the local transmitter. When the party

TABLE I

Voice Interconnection Arrangements of Interest to Amateurs

Applicable Bell System Publication	*Arrangement Service Code*	*Arrangement Description*
PUB42101	QKT	Provides manual connection of transmitting or receiving equipment to an exchange line by means of a telephone set; uses a 30A or L-7049A voice coupler. Telephone handset transmitter cutoff is optional. Connection to the coupler is made with a 1/4-inch tip-sleeve plug, provided by the user. Impedance, 900-ohms.
PUB 42208	STC (QX or VX)	Provides automatic (unattended) call origination and answering for one exchange line. Connection to the unit is made with a special plug to be supplied by the user. Required is a Cinch Co. No. 231-15-61-133 plug equipped with a hood, No. 239-13-99-069. Impedance, 600 ohms. Ac power is required.
PUB42402	CD8	Provides automatic (unattended) call origination for up to 14 trunks. Impedance, 600 ohms. Ac power is required.

NOTE: Publications are made available through the telephone company in local areas. Consult your telephone company about the use of these service arrangements.

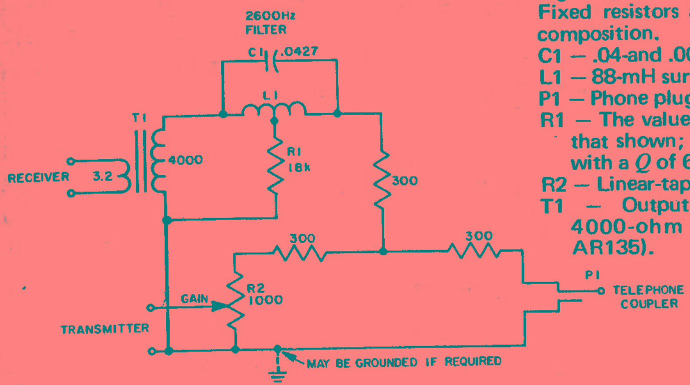


Fig. 15F-3 — Schematic of the simple phone patch. Fixed resistors are 1/2 watt, 5-percent tolerance, composition.

C1 — .04-and .0027-μF paper in parallel.
L1 — 88-mH surplus toroid.
P1 — Phone plug.
R1 — The value of this resistor may be varied from that shown; 18,000 ohms is correct for a toroid with a *Q* of 63.
R2 — Linear-taper composition control.
T1 — Output transformer, 3.2-ohm primary, 4000-ohm secondary (Lafayette Radio AR135).

on the land telephone is talking, the VOX circuit must activate the local transmitter. This function is made difficult by the difference in audio levels. The phone patch must transmit a voice level of approximately −5 VU toward the telephone line, whereas the level received from the distant land telephone may range from −45 VU to −10 VU.[1] The contrast in levels can be reduced considerably at the input to the local transmitter's VOX circuit by using a "hybrid" circuit. A hybrid circuit is an electrical network connecting together the transmitter, receiver and the voice coupler in such a way that the audio energy from the receiver is canceled at the input to the transmitter. Hybrids require a fourth circuit element, called a balancing network, in order to function.

Several kinds of hybrids can be constructed, the simplest of which is an adaptation of the Wheatstone bridge. Such a hybrid is shown in Fig. 15F-4.

1 Volume units (VU) are measured with an instrument which is basically an ac voltmeter of appropriate range and with dynamic characteristics which are carefully controlled to provide standardized measurement of complex wave forms. When sine-wave power is measured, a VU meter and one calibrated in dB relative to a milliwatt (dBm) should give the same numerical indication.

When the impedance of the balancing network is equal to the impedance at the input to the line filter, the bridge will be in a condition of balance. The amount of audio from the receiver that reaches the transmitter (or VOX circuit) will then be minimized.

The balancing network, shown schematically in Fig. 15F-5 is not complicated. In most cases it will consist only of a resistor and a capacitor in parallel. Typical values for a condition of balance when a voice coupler is used would be 470 ohms for R1 and .04 μF for C1. Other interface devices, such as might be used at repeaters for unattended operation, will require other values. The resistance might be between 500 and 1200 ohms and the shunt capacitance might range from .01 to 0.1 μF; in rare cases, a series capacitor in the order of 2 μF may be required. The values for a particular installation must be found by trial. The hybrid can be balanced by establishing a telephone call, and tuning in a clear voice signal on the receiver. With headphones connected to the transmitter audio circuit, adjust the hybrid balance network for minimum signal in the headset.

With the Wheatstone bridge hybrid circuit of Fig. 15F-4, losses between the receiver and the telephone line, and between the line and the transmitter, will be in the order of 6 to 10 dB. Transformer-type hybrid circuits exhibit lower losses, only 4.5 to 6 dB. A circuit for a single-transformer hybrid is shown in Fig. 15F-6. A two-transformer arrangement (giving better isola-

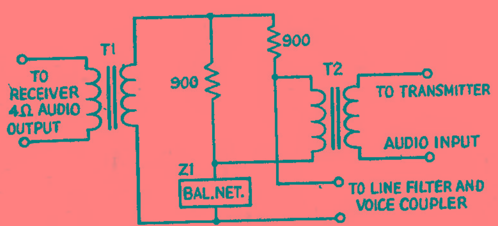


Fig. 15F-4 — Wheatstone-bridge hybrid phone-patch circuit. Resistances are in ohms. Half-watt resistors of 20-percent tolerance are adequate. Filters and level-measuring arrangements are not included in this simple circuit.

T1 — Line to voice coil; primary 1000 ohms, secondary 4 ohms, such as Allied 6W3HFL or equiv.
T2 — Audio; primary 1000 ohms, secondary as appropriate to match transmitter input impedance.
Z1 — Balancing network. See Fig. 15F-5 and text.

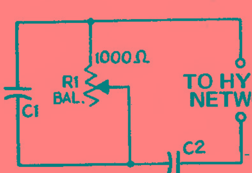


Fig. 15F-5 — Balancing network. R1 is a wire-wound control. C1 and R1 should balance a voice coupler; typicel values are 470 ohms and .04 μF. C2 is ordinarily not used, but values in the order of 1 to 4 μF may ba required with unattanded interconnection devices.

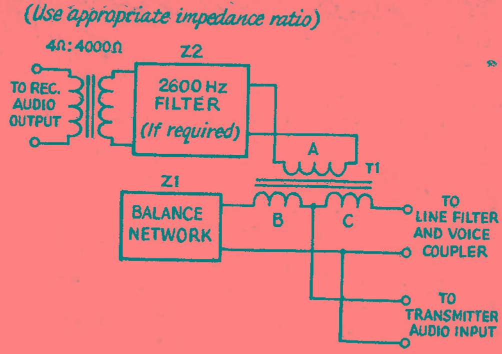


Fig. 15F-6 — Hybrid circuit made with a single audio transformer.
T1 — Windings designated "B" and "C" should be of about 900 ohms impedance each. Winding "A" may be of higher impedance if the 2600-Hz filter is used; a lower impedance may be used to match the receiver if a 2600-Hz filter is not needed.
Z1 — Balancing network. See Fig. 15F-5 and text.
Z2 — 2600-Hz filter (C1, L1, and R1 of Fig. 15F-3).

tion between elements) is shown later in this chapter.

Filters

Standards have been established for the maximum signal levels that can be connected to the input of a coupler or other interconnection device. They are listed in Table II. The limits of out-of-band energy are best met by using a low-pass line filter. Located between the coupler and the hybrid it will protect the line and also band-limit line signals to the transmitter. Filters of several types (image parameter, elliptic function, and so on) may be used. The filter should be of 600- or 900-ohm impedance (depending on the interface), passing frequencies below 3 kHz with losses rising rapidly above that point; a rejection notch should be provided at 4 kHz.

In the long distance network the telephone system uses 2600 Hz as a "disconnect" signal. If patched calls are made to telephone offices distant from your own, the need for filtering at that frequency can best be judged by experience. The filter can be made switchable, if desired. The best location for a 2600-Hz rejection filter is at the receiver output.

REPEATER PATCHES

Some interesting phone-patch possibilities exist at repeaters. Unattended interconnection devices are associated with the repeaters to provide a form of mobile telephone service for the clubs operating them. The connections to a typical unattended interface device are shown in Fig. 15F-7.

Suitable signals generated in mobile units work through a base station to activate the interconnection device, causing it to connect and pass dial

TABLE II

Maximum Permissible Energy Levels at the Input of a Voice Interconnection Arrangement

Freq. Band	*Maximum Level*
Direct current	0.5 milliampere
Voice range (nominally 300 to 3000 Hz)	Voice coupler: -3 dBm. Other arrangements: 9 dB below 1 mW (levels avaraged over 3 seconds, see note.)
2450 to 2750 Hz	Preferably no energy; in no case greater than the level present simultaneously in the 800- to 2450-Hz band.
3995 to 4005 Hz	18 dB below the voice-band level.
4.0 to 10.0 kHz	16 dB below one milliwatt (-16 dBm).
10.0 to 25.0 kHz	-24 dBm
25.0 to 40.0 kHz	-36 dBm
Above 40.0 kHz	-50 dBm

NOTE: The above limits should be met with amateur-provided equipment having an internal impedance of 900 ohms if it is to work into a voice coupler, or 600 ohms if other arrangements are to be used.

pulses to the telephone line. The system may be arranged so that the base transmitter carries both sides of the conversation or only the voice of the distant telephone user. Switching of the patch's voice path between the transmitter and the receiver could be done under the control of tones or a carrier-operated relay. A simple combining circuit may be used if both sides of the conversation are to be put out over the air. To equalize audio levels, a wide-range agc amplifier might have to be provided, or an attenuator in the transmitter audio line would have to be switched in and out. A

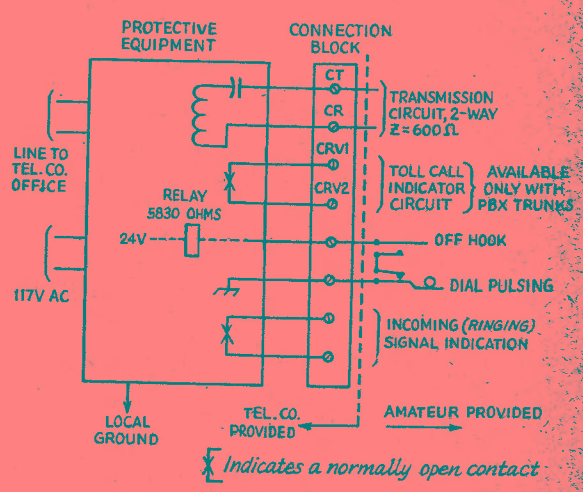


Fig. 15F-7 — Interconnection diagram for a Bell CD8 coupler, representative of connections to unattended interface devices.

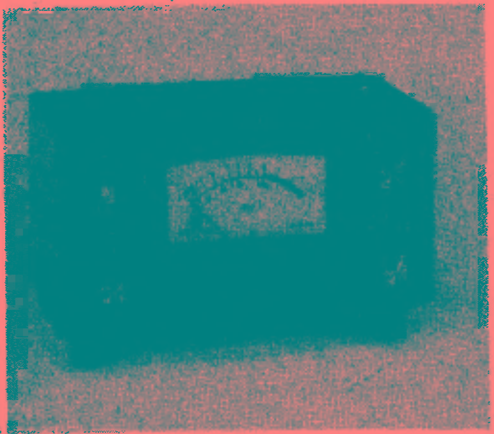
hybrid circuit could be used in this case but the retransmitted audio from the mobile unit would not be as free from distortion as with the combining arrangement.

Some telephone lines and interface devices can be arranged to signal the fact that a toll call has been dialed. Such a signal might be used to disconnect the phone patch if the repeater owners do not want long distance calls to be made. Clubs would probably want to control access to the patch in any case, as they would be responsible for all telephone service charges, even if the calls were not made by their members.

A HYBRID PHONE PATCH

The photographs and Fig. 1 show a deluxe 2-transformer hybrid phone patch for home construction. Some form of hybrid circuit is necessary if VOX control of the transmitter is to be used. A third transformer matches the 3.2-ohm output of the receiver. A 2600-Hz filter is provided in the line from the receiver to reduce the possibility of unwanted disconnections resulting from heterodyning signals during use over long-distance telephone lines. The filter may be switched out for local calls for a slight improvement in voice fidelity from the received signal to the telephone line. A modified VU meter indicates the levels received from and applied to the telephone line entering the amateur station. The use of surplus or "bargain" components, especially transformers, will greatly reduce the cost of construction.

The circuit of the phone-patch unit is shown in Fig. 1. C1, L1, and R2 form the 2600-Hz receiver-line filter. Its insertion loss at 1000 Hz is negligible, but is in excess of 15 dB at 2600 Hz. T2 and T3 are the hybrid transformers, with C3 and R5 provided to balance the network. Independent level adjustments are provided for the signal coupled from the receiver to the telephone line (R1) and from the telephone line to the transmitter speech amplifier (R3).



Tha phone patch unit is built into a homemade aluminum enclosure measuring 3 X 3 X 6 inches. A coating of spray-on enamel, rubber feet, and wet-transfer decal labels plus shiny knobs give the unit a professional appearance.

M1 is a Calectro model DI-930A "VU" meter with its time constant modified by adding external capacitance. The "A" model is identified with the letter A appearing in a circle near the bottom of the meter-scale card. Earlier models of the DI-930 meter, without the A, are unsuitable without internal modification. The correct value of damping capacitance is 400 μF, and may be obtained by connecting four 100-μF 6-V electrolytic capacitors in parallel. These are to be connected directly across the meter terminals, observing proper polarity. This capacitance value applies only to this particular make and model of VU meter. The modified meter responds to speech signals of 3 kHz or less in a way that compares very closely with the measuring sets mentioned in the Bell interface specifications. Error should be less than 1 dB and should be found to be on the safe side. The meter, as modified, has a 1-kHz impedance of approximately 6500 ohms. It should be mounted only on a nonferrous panel.

Construction

The component layout for the phone patch is not critical, and any of several construction techniques is quite acceptable. In the model photographed all components except the modified meter, controls, and phono jacks were mounted on a piece of circuit-board material. The balance control was mounted on the front panel, but this is a "set once and forget" control so some builders may wish to include it inside the enclosure. An etched pattern in the copper foil provides a few of the circuit interconnections, but most connections, including all those to the two hybrid transformers, are made with point-to-point wiring. The UTC transformers specified have mounting studs affixed to the top of the case, and these are used to mount the transformers in an inverted position on the circuit board. This same construction idea can be used with perforated phenolic board and point-to-point wiring for all components, instead of an etched circuit board.

The only precaution to observe during construction is to keep J3 insulated from chassis ground, to reduce rf coupling into the telephone line. In the model photographed this was done by drilling a 1/2-inch hole in the rear panel where J3 was to be mounted, and then, with machine screws, fastening a small piece of phenolic board to cover the hole. Next J3 was mounted on the phenolic board, centered in the hole. Some types of phono jacks come supplied with phenolic mounting material, and if the clearance hole is large enough these types may be mounted directly on a metal panel without grounding the outer contact.

Adjustment

If one has access to an accurately calibrated audio signal generator or to an electronic fre-

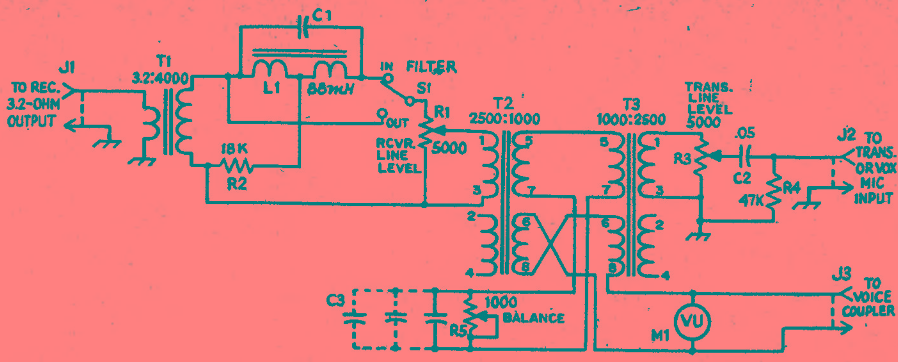


Fig. 1 — Schematic diagram of the phone-patch circuit. Resistances ere in ohms, k = 1000. Fixed resistors may be 1/2 watt, 10 percent tolerance. Capacitance is in microferads. Components not listed below are identified for text reference.

C1 — Capacitors in parallal to give required velue of .0427 μF; low-voltage metalized paper or Myler are suitable.
C3 — Typical value, .04 μF. See text and Fig. 15F-5 if hybrid network cannot be balanced.
J1, J2, J3 — Phono jack. J3 should be insulated from chassis.
L1 — Surplus 88-mH toroidal inductor, connected with half-windings in series eiding.
M1 — Calectro DI-930A VU meter, modified. See text.
R1, R3 — 5000-ohm audio-taper control (Mallory U12 or equiv.).
R5 — 1000-ohm linear-taper control (Mallory U4 or equiv.).
T1 — Audio transformer, 4 or 8 ohms to 4000 ohms (UTC SO-10 or equiv.).
T2, T3 — Audio transformer, 2500-ohm split primary, 1000-ohm split secondary (UTC O-19 or equiv.).

quency counter he may wish to check the notch frequency of the 2600-Hz filter, although this step is not essential. The frequency may be adjusted by using various combinations of fixed-value capacitors for C1 until the notch appears at exactly 2600 Hz. In the model photographed stock-value capacitors, selected at random to provide the specified total capacitance for C1, resulted in a notch frequency of 2621 Hz, which is quite acceptable.

Correct adjustment of the balance control, R5, will facilitate the operation of the transmitter VOX circuit by the distant party on the land telephone. Connect all station equipment to place the patch into operation. Connect a pair of headphones or an ac voltmeter to the transmitter audio circuit. If a sensitive ac VTVM is available, one which will measure in the millivolt range, it may be connected directly to the output from J2, in parallel with the line connected to the transmitter. Establish a phone call and connect the phone patch to the voice coupler. Tune in a clear voice signal on the receiver, and adjust R5 for the best null of the received signal as monitored in the transmitter audio section. If the null does not occur within the range of R5, experimentally try different capacitance values for C3 and a larger value for R5 (connect a fixed-value resistor in series with R5 to obtain a higher equivalent value). With R5 properly adjusted, the distant party should be able to trip the transmitter VOX circuit satisfactorily even though no anti-trip connection is used from the receiver. With such a connection made, VOX operation will be quite reliable.

Installation and Operation

The receiver input to the phone-patch unit may be taken in parallel with the speaker leads from the receiver. Most operators prefer to disconnect or disable the speaker, however, and to connect the patch directly to the speaker-output terminals of the receiver. The switching to and from phone-patch station operation is generally done in suitable control circuits which may be included in the phone-patch enclosure itself, if desired. Operating with the speaker disconnected will result in a 3-dB-greater audio signal being fed to the hybrid circuit, and monitoring of the receiver audio by the amateur operator may be done through the telephone handset.

The level of signal being fed from the receiver to the telephone line during reception may be adjusted either with R1 or with the receiver audio gain control. Similarly, the level of audio being fed to the transmitter from the telephone line during transmission may be adjusted with R3 and with the transmitter microphone gain control. If the distant party on the telephone line is not talking loudly enough for proper operation of the transmitter, remember that often he can be made to speak louder *simply by reducing the level of audio being sent to him.* The speech level should never be permitted to exceed −2 VU on the DI-930A scale. When the telephone connection is made to a nearby point (such as a line served out of the same telephone building as the patched line), the distant listener will receive a more comfortable listening

The layout of the phone-patch components is not critical. The two hybrid-network transformers are visible to the right of canter, and in the upper left corner of the circuit board the receiver matching trensformer mey be seen. Two damping capacitors added during modification of the Calectro DI-930A meter are visible atop the meter case; two more are hidden beneath the meter.

level if the maximum signal is held to about −9 on the meter scale.

Many times when phone-patch operation is heard over the air, the transmitted voice quality of the distant land-telephone party seems to be as good as if he were speaking directly into the station microphone. Occasionally, however, signals will be heard with an undue amount of power-line-frequency hum present on the signal. Of course the quality and level of the voice signal coming in on the telephone line plays an important part in how that voice signal sounds over the air, but sometimes a hum problem can be traced directly to the installation of the phone-patch equipment. In particular, the phone patch (and the voice coupler) should be located away from power supply transformers in station equipment. Complete magnetic shielding may not exist even with steel enclosures for power supplies. If other equipment is mounted nearby, the 60-Hz field can induce hum into the transformers of the phone patch. Hum problems of this sort can usually be solved simply by relocating the position of the phone-patch unit.

During operation of a phone patch in the hf amateur bands it is considered good practice to avoid the transmission of operator chatter, dial tones, dial pulses, ringing and busy signals, as they are not essential to communications.

Appendix

Signals and Circuit Conditions Used in the Telephone System

1) The status of a local telephone line (idle or busy) is indicated by on-hook or off-hook signals as follows:

On-Hook	Minimum dc resistance between tip and ring conductors of 30,000 ohms.
Off-Hook	Maximum dc resistance between tip and ring conductors of 200 ohms.

Telephone sets give an off-hook condition at all times from the answer or origination of a call to its completion. The only exception to this is during dial pulsing.

2) Dial pulses consist of momentary opens in the loop; dial pulses should meet the following standards:

Pulsing rate	10 pulses/second ± 10%
Pulse Shape	58% to 64% break (open)
Interdigital time	600 milliseconds minimum

Note: Two pulses indicate the digit "2," three pulses indicate the digit "3," and so on, up to ten, indicating the digit "0."

3) The standards for tone "dialing" are as follows:

a) Each digit is represented by a unique pair of tones as shown below.

Digit	*Low tone High tone*
1	697 and 1209 Hz
2	697 and 1336 Hz
3	697 and 1477 Hz
4	770 and 1209 Hz
5	770 and 1336 Hz
6	770 and 1477 Hz
7	852 and 1209 Hz
8	852 and 1336 Hz
9	852 and 1477 Hz
0	941 and 1336 Hz
*	941 and 1209 Hz
#	941 and 1477 Hz

b) In order for the central-office receiver to register the digit properly, the tone-address signals must meet the following requirements:

(1) Signal levels:
Nominal level per frequency: −6 to −4

dBm. Minimum level per frequency: Low Group, −10 dBm; High Group, −8 dBm. Max, level per frequency pair: +2 dBm. Max, difference in levels between frequencies: 4 dB.

(2) Frequency deviation: ± 1.5 percent of the values given above.

(3) Extraneous frequency components: The total power of all extraneous frequencies accompanying the signal should be at least 20 dB below the signal power, in the voice band above 500 Hz.

(4) Voice Suppression: Voice energy from any source should be suppressed at least 45 dB during tone signal transmission. In the case of automatic dialing the suppression should be maintained continuously until pulsing is completed.

(5) Rise Time: Each of the two frequencies of the signal should attain at least 90 percent of full amplitude within 5 ms, and preferably within 3 ms for automatic dialers, from the time that the first frequency begins.

(6) Pulsing Rate: Minimum duration of two-frequency tone signal: 50 ms normally; 90 ms if transmitted by radio. Minimum interdigital time: 45 ms.

(7) Tone leak during signal off time should be less than −55 dBm.

(8) Transient Voltages: Peak transient voltages generated during tone signaling should be no greater than 12 dB above the zero-to-peak voltage of the composite two-frequency tone signal.

4) Audible tones will be used in the telephone system to indicate the progress or disposition of a call. These include:

a) Dial tone: 350 and 440 Hz.
b) Line busy: 480 and 620 Hz, interrupted at 60 interruptions per minute (I/min).
c) Reorder (all trunks busy): 480 and 620 Hz, interrupted at 120 I/min.
d) Audible ringing: 440 and 480 Hz, 2 seconds on, 4 seconds off.
e) Reserved high tone: 1633 Hz.
f) Invalid dialing code: Voice announcement.

Bibliography

Source material and more extended discussions of topics covered in this chapter can be found in the references given below. This listing does not include every article published in *QST* on the subjects of this chapter, however. A detailed bibliography of references in *QST* on any of the subjects amateur television, slow-scan television, radioteletype, phone patching, Oscar and moonbounce, will be sent on request to ARRL, Newington, CT 06111. Please enclose a business-size stamped self-addressed envelope.

RADIOTELETYPE

Antanaitis, "A Simple Two-Transistor A.F.S.K. Generator," *QST*, September, 1969.

Craig, "Teleprinter Selector Magnets," Technical Correspondence, *QST*, September, 1971.

Drake, "An Audio Synthesizer – A Device to Generate RTTY Tones with Crystal-Controlled Accuracy," *QST* April, 1972.

Hall, "Frequency Shift Keying the Johnson Ranger, Valiant, Navigator," *RTTY Journal*, Jan. 1968; "What is RTTY?," *QST*, Dec. 1968.

Hoff, "Transmitting Radioteletype," *QST*, May, 1965; "Audio Frequency-Shift Keying for RTTY," *QST*, June, 1965; "The Mainline TT/L F.S.K. Demodulator," *QST*, August, 1965; "The Mainline ST-3 RTTY Demodulator," *QST*, April, 1970.

Petersen, "The Mainline TT/L-2 F.S.K. Demodulator," Part I, "Construction and Adjustment," *QST*, May, 1969, and Part II, "Circuit Description, and the Mainline F.S.K. Keyer," *QST*, June, 1969.

Schecter, "First Steps in RTTY," *QST*, June, 1971.

AMATEUR TELEVISION

Campbell, "Amateur TV – The Easy Way," *QST*, November, 1962.

Keller, "An Amateur Television Camera," *QST*, November, 1953.

Tilton, "Amateur Television – A Progress Report," *QST*, June, 1950.

SLOW-SCAN TELEVISION

Briles and Gervenack, "Slow-Scan TV Viewing Adapter for Oscilloscopes," *QST*, June, 1970.

Macdonald, "S.C.F.M. – An Improved System for Slow-Scan Image Transmission," Part I, "Slow-Scan Modulation Tests and Proposed Standards," *QST*, Jan. 1961, and Part II, "Circuit Details," *QST*, Feb. 1961; "A New Narrow-Band Image Transmission System," Part I, "Principles of Slow Scan Picture Reproduction," *QST*, August 1958, and Part II, "Circuit and Construction Details," *QST*, Sept. 1958; "A Slow-Scan Vidicon Camera," in three parts, *QST*, June, July and Aug. 1965.

Tschannen, "A Solid-State SSTV Monitor," *QST*, March, 1971.

PHONE PATCHING

Berry, "Legalize Your Phone Patch," *QST*, May 1969; "An Improved Phone Patch," Hints and Kinks, *QST*, Nov. 1970.

Hoff, "Stopping Telephone Interference," *QST*, March, 1968.

Schleicher, "Phone Patching – Legitimately," *QST*, March, 1969; "Phone Patching – One Year Later," *QST*, Nov., 1970; "Measuring Phone-Patch Levels Accurately," *QST*, February, 1972.

Interference with other Services

RADIO FREQUENCY INTERFERENCE (RFI) has probably been with us since the first amateur stations came on the air some 70 years ago. Fed by the technology that developed during and following WW II, the problem has become an increasing source of irritation between radio operators and their neighbors. Home-entertainment electronics devices now abound, with most families owning at least one television receiver, an a-m or fm radio, and any one of several audio devices (such as a phonograph, an intercom, an electronic guitar, or an electronic organ). Given the innate perversity of these objects to intercept radio signals, it should surprise no one to learn that RFI is one of the most difficult problems amateurs face in their day-to-day operations.

How Serious is the RFI Problem?

In 1974, the FCC received 42,000 RFI complaints, up 20% from the number of complaints received in 1970. Of these, 38,000 involved interference to home-entertainment equipment. Most important, 36,000 of these would never have come to the Commission's attention if the manufacturers had corrected design deficiencies in their home-entertainment products at the time of manufacture. It is of interest to note that over 60% of the interference cases reported in 1974 were related to television interference (TVI).

In the case of television interference, FCC experience shows that 90% of the problems experienced can only be cured at the television receiver. Further, when it comes to audio equipment, the *only* cure for RFI is by treatment of the audio device experiencing the interference. There is nothing an amateur can do to his transmitter which will stop a neighbor's phonograph from acting like a short-wave receiver. It should be emphasized that phonographs and Hi-Fi units are not designed to be receivers, but simply audio devices.

It is clear, therefore, that almost all RFI problems experienced with home-entertainment devices result from basic design deficiencies in this equipment. The few small components or filters which would prevent RFI are often left out of otherwise well-designed products as manufacturers attempt to reduce costs, and hence, to reduce the prices of their products.

The Solution – Consumer Protection

Given the present unacceptable situation, what can we as amateurs do to help the consumer resolve the RFI problem? One step which should certainly be taken is to advise our friends and neighbors to inquire, before they make a purchase of an electronic device, whether the product has been certified for operation in the presence of a radio transmitter. Manufacturers must be made to recognize the RFI protection of their home-entertainment equipment has become essential, and that this must be incorporated. Further, where interference is being experienced, the consumer should be encouraged to contact the manufacturer of his equipment and to request that the *manufacturer* furnish the components or services necessary to eliminate RFI.

What Are Manufacturers Doing Today?

Many responsible manufacturers have a policy of supplying filters for eliminating television interference when such cases are brought to their attention. A list of those manufacturers, and a more thorough treatment of the RFI problem, can be obtained by writing the ARRL. If a given manufacturer is not listed, it is still possible that he can be persuaded to supply a filter; this can be determined by writing either directly to him or to the Electronic Industries Association (EIA).[1]

With respect to audio devices, some manufacturers will supply modified schematic diagrams showing the recommended placement of bypass capacitors and other components to reduce rf susceptibility. One large American manufacturer of Hi-Fi equipment has in some cases supplied the necessary components free of charge, although no consistent policy has been evident and the consumer must still pay to have a serviceman install the components.

While these are encouraging developments, it appears likely that meaningful and widespread corrective action by equipment designers will require both pressure from consumers and establishment of suitable government standards.

Voluntary after-the-fact measures on the part of manufacturers simply are not enough. It is a foregone conclusion that as long as the inclusion of additional components for susceptibility reduction increases a manufacturer's cost, however slightly, there will be reluctance to take steps to improve equipment designs by the manufacturers themselves. What appears to be necessary, therefore, is federal legislation giving the FCC the authority to regulate the manufacture of home-entertainment devices and thus protect the consumer.

It's Up to Us

If requests to manufacturers of home-entertainment equipment for those components and installation services necessary to relieve RFI problems are to be successful, each of us, when faced with an RFI problem, must make known our position to

[1] Electronic Industries Association, 2001 Eye Street, N.W., Washington, DC 20006. Attention: Director of Consumer Affairs.

the manufacturers involved. While a respectful request for assistance will bring more cooperation than a blunt demand, do not hesitate to let the manufacturers know that they have a responsibility to the consumer for correcting the design deficiencies that are causing the problem. Before casting the first stone, however, make sure you're not sitting in a glass house. Certainly, if your own television receiver experiences no interference while you are on the air, it is most likely that interference to a more distant television receiver is not the fault of your transmitter.

All of the above is not to say, however, that we should not continue to assist in resolving RFI problems. Radio amateurs have typically sought to assist their neighbors in correcting RFI problems, even where those problems were in no way attributable to the performance of the transmitter. Ultimately, of course, it is the manufacturers' responsibility to correct those deficiencies which lead to the interception of radio signals. But in the interest of good neighborhood relations, we must continue to provide this assistance wherever older equipment designs are in use.

Clean House First

In approaching an RFI problem, the first step obviously is to make sure that the transmitter has no radiations outside the bands assigned for amateur use. The best check on this is your own a-m or TV receiver. It is always convincing if you can demonstrate that you do not interfere with reception in your own home.

Don't Hide Your Identity

Whenever you make equipment changes – or shift to a hitherto unused band or type of emission – that might be expected to change the interference situation, check with your neighbors. If no one is experiencing interference, so much the better; it does no harm to keep the neighborhood aware of the fact that you are operating without bothering anyone.

Should you change location, make your presence known and conduct occasional tests on the air, requesting anyone whose reception is being spoiled to let you know about it so steps may be taken to eliminate the trouble.

Act Promptly

The average person will tolerate a limited amount of interference, but the sooner you take steps to eliminate it, the more agreeable the listener will be; the longer he has to wait for you, the less willing he will be to cooperate.

Present Your Story Tactfully

Whenever a device intercepts your signals, it is natural for the complainant to assume that your transmitter is at fault. If you are certain that the trouble is not in your transmitter, explain to the listener that the reason lies in the receiver design, and that some modifications may have to be made in the receiver if he is to expect interference-free reception.

Arrange for Tests

Most listeners are not very competent observers of the various aspects of interference. If at all possible, enlist the help of another amateur and have him operate your transmitter while you see for yourself what happens at the affected receiver.

In General

In this "public relations" phase of the problem a great deal depends on your own attitude. Most people will be willing to meet you half way, particularly when the interference is not of long standing, if you as a person make a good impression. Your personal appearance is important. So is what you say about the receiver – no one takes kindly to hearing his possessions derided. If you discuss your interference problems on the air, do it in a constructive way – one calculated to increase listener cooperation, not destroy it.

VHF TELEVISION

For the amateur who does most of his transmitting on frequencies below 30 MHz, the TV band of principal interest is the low vhf band between 54 and 88 MHz. If harmonic radiation can be reduced to the point where no interference is caused to Channels 2 to 6, inclusive, it is almost certain that any harmonic troubles with channels above 174 MHz will disappear also.

The relationship between the vhf television channels and harmonics of amateur bands from 14 through 28 MHz is shown in Fig. 16-1. Harmonics of the 7- and 3.5-MHz bands are not shown because they fall in every television channel. However, the harmonics above 54 MHz from these bands are of such high order that they are usually rather low in amplitude, although they may be strong enough to interfere if the television receiver is quite close to the amateur transmitter. Low-order harmonics – up to about the sixth – are usually the most difficult to eliminate.

Of the amateur vhf bands, only 50 MHz will have harmonics falling in a vhf television channel (channels 11, 12 and 13). However, a transmitter for any amateur vhf band may cause interference if it has multiplier stages either operating in or having harmonics in one or more of the vhf TV channels. The rf energy on such frequencies can be radiated directly from the transmitting circuits or coupled by stray means to the transmitting antenna.

Frequency Effects

The degree to which transmitter harmonics or other undesired radiation actually in the TV channel must be suppressed depends principally on

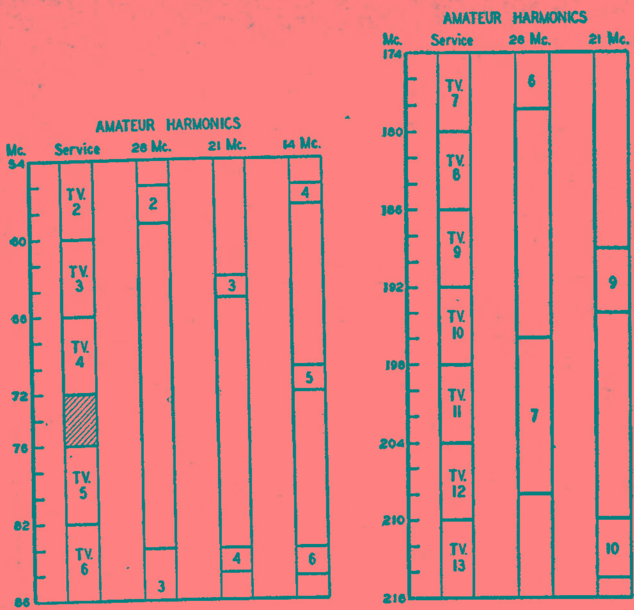


Fig. 16-1 — Relationship of amateur-band harmonics to vhf TV channels. Harmonic interference from transmitters operating below 30 MHz is likely to be serious in the low-channel group (54 to 88 MHz).

two factors, the strength of the TV signal on the channel or channels affected, and the relationship between the frequency of the spurious radiation and the frequencies of the TV picture and sound carriers within the channel. If the TV signal is very strong, interference can be eliminated by comparatively simple methods. However, if the TV signal is very weak, as in "fringe" areas where the received picture is visibly degraded by the appearance of set noise or "snow" on the screen, it may be necessary to go to extreme measures.

In either case the intensity of the interference depends very greatly on the exact frequency of the interfering signal. Fig. 16-2 shows the placement of the picture and sound carriers in the standard TV channel. In Channel 2, for example, the picture carrier frequency is 54 + 1.25 = 55.25 MHz and the sound carrier frequency is 60 – 0.25 = 59.75 MHz. The second harmonic of 28.010 kHz (56,020 kHz or 56.02 MHz) falls 56.02 – 54 = 2.02 MHz above the low edge of the channel and is in the region marked "Severe" in Fig. 16-2. On the other hand, the second harmonic of 29,500 kHz (59,000 kHz or 59 MHz) is 59 – 54 = 5 MHz from the low edge of the channel and falls in the region marked "Mild." Interference at this frequency has to be about 100 times as strong as at 56,020 kHz to cause effects of equal intensity. Thus an operating frequency that puts a harmonic near the picture carrier requires about 40 dB more harmonic suppression in order to avoid interference, as compared with an operating frequency that puts the harmonic near the upper edge of the channel.

For a region of 100 kHz or so either side of the sound carrier there is another "Severe" region where a spurious radiation will interfere with reception of the sound program and this region also should be avoided. In general, a signal of intensity equal to that of the picture carrier will not cause noticeable interference if its frequency is in the "Mild" region shown in Fig. 16-2, but the same intensity in the "Severe" region will utterly destroy the picture.

Interference Patterns

The visible effects of interference vary with the type and intensity of the interference. Complete "blackout," where the picture and sound disappear

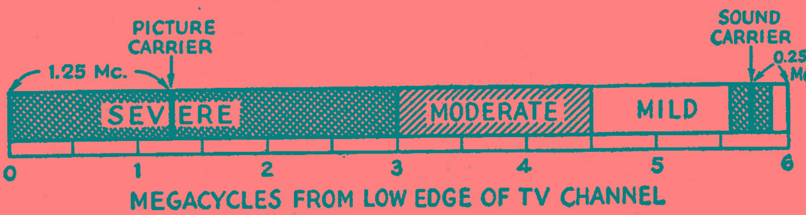


Fig. 16-2 — Location of picture and sound carriers in a monochrome television channel, and relative intensity of interference as the location of the interfering signal within the channels is varied without changing its strength. The three regions are not actually sharply defined as shown in this drawing, but merge into one another gradually.

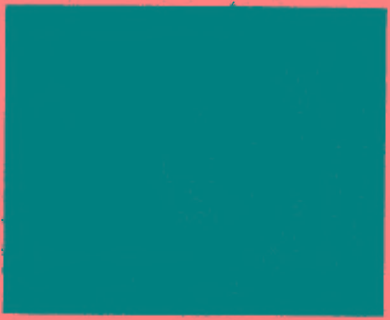


Fig. 16-3 — "Cross-hatching," caused by the beat between the picture cerrier and an interfering signal inside the TV channel.

completely, leaving the screen dark, occurs only when the transmitter and receiver are quite close together. Strong interference ordinarily causes the picture to be broken up, leaving a jumble of light and dark lines, or turns the picture "negative" – the normally white parts of the picture turn black and the normally black parts turn white. "Cross-hatching" – diagonal bars or lines in the picture – accompanies the latter, usually, and also represents the most common type of less severe interference. The bars are the result of the beat between the harmonic frequency and the picture carrier frequency. They are broad and relatively few in number if the beat frequency is comparatively low – near the picture carrier – and are numerous and very fine if the beat frequency is very high – toward the upper end of the channel. Typical cross-hatching is shown in Fig. 16-3. If the frequency falls in the "Mild" region in Fig. 16-2 the cross-hatching may be so fine as to be visible only on close inspection of the picture, in which case it may simply cause the apparent brightness of the screen to change when the transmitter carrier is thrown on and off.

Whether or not cross-hatching is visible, an amplitude-modulated transmitter may cause "sound bars" in the picture. These look about as shown in Fig. 16-4. They result from the variations in the intensity of the interfering signal when modulated. Under most circumstances modulation bars will not occur if the amateur transmitter is frequency- or phase-modulated. With these types of modulation the cross-hatching will "wiggle" from side to side with the modulation.

Except in the more severe cases, there is seldom any effect on the sound reception when interference shows in the picture, unless the frequency is quite close to the sound carrier. In the latter event the sound may be interfered with even though the picture is clean.

Reference to Fig. 16-1 will show whether or not harmonics of the frequency in use will fall in any television channels that can be received in the locality. It should be kept in mind that not only harmonics of the final frequency may interfere, but also harmonics of any frequencies that may be present in buffer or frequency-multiplier stages. In the case of 144-MHz transmitters, frequency-multiplying combinations that require a doubler or tripler stage to operate on a frequency actually in a low-band vhf channel in use in the locality should be avoided.

Harmonic Suppression

Effective harmonic suppression has three separate phases:

1) Reducing the amplitude of harmonics generated in the transmitter. This is a matter of circuit design and operating conditions.

2) Preventing stray radiation from the transmitter and from associated wiring. This requires adequate shielding and filtering of all circuits and leads from which radiation can take place.

3) Preventing harmonics from being fed into the antenna.

It is impossible to build a transmitter that will not generate *some* harmonics, but it is obviously advantageous to reduce their strength, by circuit design and choice of operating conditions, by as large a factor as possible before attempting to prevent them from being radiated. Harmonic radiation from the transmitter itself or from its associated wiring obviously will cause interference just as readily as radiation from the antenna, so measures taken to prevent harmonics from reaching the antenna will not reduce TVI if the transmitter itself is radiating harmonics. But once it has been found that the transmitter itself is free from harmonic radiation, devices for preventing harmonics from reaching the antenna can be expected to produce results.

REDUCING HARMONIC GENERATION

Since reasonably efficient operation of rf power amplifiers always is accompanied by harmonic generation, good judgment calls for operating all frequency-multiplier stages at a very low power level. When the final output frequency is reached, it is desirable to use as few stages as possible in building up to the final output power level, and to use tubes that require a minimum of driving power.

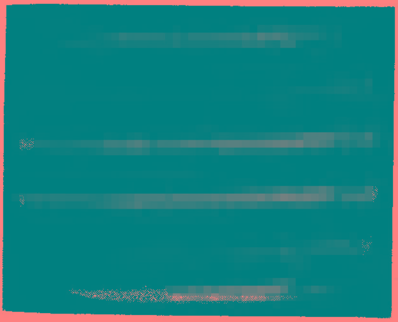


Fig. 16-4 — "Sound bars" or "modulation bars" accompanying amplitude modulation of an interfering signal. In this case the interfering carrier is strong enough to destroy the picture, but in mild cases the picture is visible through the horizontal bars. Sound bars may accompany modulation even though the unmodulated carrier gives no visible cross-hatching.

Circuit Design and Layout

Harmonic currents of considerable amplitude flow in both the grid and plate circuits of rf power amplifiers, but they will do relatively little harm if they can be effectively bypassed to the cathode of the tube. Fig. 16-5 shows the paths followed by harmonic currents in an amplifier circuit; because of the high reactance of the tank coil there is little harmonic current in it, so the harmonic currents

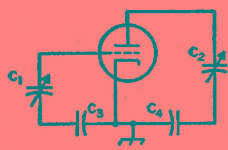


Fig. 16-5 — A vhf rasonant circuit is formed by the tube capacitance and the leads through the tank and blocking capacitors. Regular tank coils are not shown, since they have little affect on such resonances. C1 is the grid tuning capacitor and C2 is the plate tuning capacitor. C3 and C4 are tha grid and plata blocking or bypass capacitors, respectively.

simply flow through the tank capacitor, the plate (or grid) blocking capacitor, and the tube capacitances. The lengths of the leads forming these paths is of great importance, since the inductance in this circuit will resonate with the tube capacitance at some frequency in the vhf range (the tank and blocking capacitances usually are so large compared with the tube capacitance that they have little effect on the resonant frequency). If such a resonance happens to occur at or near the same frequency as one of the transmitter harmonics, the effect is just the same as though a harmonic tank circuit had been deliberately introduced; the harmonic at that frequency will be tremendously increased in amplitude.

Such resonances are unavoidable, but by keeping the path from plate to cathode and from grid to cathode as short as is physically possible, the resonant frequency usually can be raised above 100 MHz in amplifiers of medium power. This puts it between the two groups of television channels.

It is easier to place grid-circuit vhf resonances where they will do no harm when the amplifier is link-coupled to the driver stage, since this generally permits shorter leads and more favorable conditions for bypassing the harmonics than is the case with capacitive coupling. Link coupling also reduces the coupling between the driver and amplifier at harmonic frequencies, thus preventing driver harmonics from being amplified.

The inductance of leads from the tube to the tank capacitor can be reduced not only by shortening but by using flat strip instead of wire conductors. It is also better to use the chassis as the return from the blocking capacitor or tuned circuit to cathode, since a chassis path will have less inductance than almost any other form of connection.

The vhf resonance points in amplifier tank circuits can be found by coupling a grid-dip meter covering the 50-250 MHz range to the grid and plate leads. If a resonance is found in or near a TV channel, methods such as those described above should be used to move it well out of the TV range. The grid-dip meter also should be used to check for vhf resonances in the tank coils, because coils made for 14 MHz and below usually will show such resonances. In making the check, disconnect the coil entirely from the transmitter and move the grid-dip meter coil along it while exploring for a dip in the 54-88-MHz band. If a resonance falls in a TV channel that is in use in the locality, changing the number of turns will move it to a less-troublesome frequency.

Operating Conditions

Grid bias and grid current have an important effect on the harmonic content of the rf currents in both the grid and plate circuits. In general, harmonic output increases as the grid bias and grid current are increased, but this is not necessarily true of a *particular* harmonic. The third and higher harmonics, especially, will go through fluctuations in amplitude as the grid current is increased, and sometimes a rather high value of grid current will minimize one harmonic as compared with a low value. This characteristic can be used to advantage where a particular harmonic is causing interference, remembering that the operating conditions that minimize one harmonic may greatly increase another.

For equal operating conditions, there is little or no difference between single-ended and push-pull amplifiers in respect to harmonic generation. Push-pull amplifiers are frequently troublemakers on even-order harmonics because with such amplifiers the even-harmonic voltages are in phase at the ends of the tank circuit and hence appear with equal amplitude across the whole tank coil, if the center of the coil is not grounded. Under such circumstances the even harmonics can be coupled to the output circuit through stray capacitance between the tank and coupling coils. This does not occur in a single-ended amplifier having an inductively coupled tank, if the coupling coil is placed at the cold end, or with a pi-network tank.

Harmonic Traps

If a harmonic in only one TV channel is particularly bothersome — frequently the case when the transmitter operates on 28 MHz — a trap tuned to the harmonic frequency may be installed in the plate lead as shown in Fig. 16-6. At the harmonic frequency the trap represents a very high impedance and hence reduces the amplitude of the harmonic current flowing through the tank circuit. In the push-pull circuit both traps have the same constants. The L/C ratio is not critical but a high-C circuit usually will have least effect on the performance of the plate circuit at the normal operating frequency.

Since there is a considerable harmonic voltage across the trap, radiation may occur from the trap unless the transmitter is well shielded. Traps should be placed so that there is no coupling between

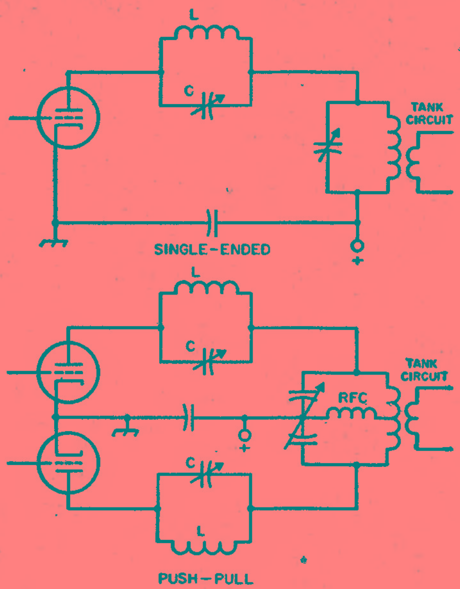


Fig. 16-6 — Harmonic traps in an amplifier plate circuit. L and C should resonate at the frequency of the harmonic to be suppressed. C may be a 25- to 50-pF midget, and L usually consists of 3 to 6 turns about 1/2 inch in diameter for Channels 2 through 6. The inductance should be adjusted so that the trap resonates at about half capacitance of C before being installed in the transmitter. The frequency may be checked with a grid-dip meter. When in place, the trap should be adjusted for minimum interference to the TV picture.

them and the amplifier tank circuit.

A trap is a highly selective device and so is useful only over a small range of frequencies. A second- or third-harmonic trap on a 28-MHz tank circuit usually will not be effective over more than 50 kHz or so at the fundamental frequency, depending on how serious the interference is without the trap. Because they are critical of adjustment, it is better to prevent TVI by other means, if possible, and use traps only as a last resort.

PREVENTING RADIATION FROM THE TRANSMITTER

The extent to which interference will be caused by direct radiation of spurious signals depends on the operating frequency, the transmitter power level, the strength of the television signal, and the distance between the transmitter and TV receiver. Transmitter radiation can be a very serious problem if the TV signal is weak, if the TV receiver and amateur transmitter are close together, and if the transmitter is operated with high power.

Shielding

Direct radiation from the transmitter circuits and components can be prevented by proper shielding. To be effective, a shield must completely enclose the circuits and parts and must have no openings that will permit rf energy to escape. Unfortunately, ordinary metal boxes and cabinets do not provide good shielding, since such openings as louvers, lids, and holes for running in connections allow far too much leakage.

A primary requisite for good shielding is that all joints must make a good electrical connection along their entire length. A small slit or crack will let out a surprising amount of rf energy; so will ventilating louvers and large holes such as those used for mounting meters. On the other hand, small holes do not impair the shielding very greatly, and a limited number of ventilating holes may be used if they are small – not over 1/4 inch in diameter. Also, wire screen makes quite effective shielding if the wires make good electrical connection at each crossover. Perforated aluminum such as the "do-it-yourself" sold at hardware stores also is good, although not very strong mechanically. If perforated material is used, choose the variety with the smallest openings. The leakage through large openings can be very much reduced by covering such openings with screening or perforated aluminum, well bonded to all edges of the opening.

The intensity of rf fields about coils, capacitors, tubes and wiring decreases very rapidly with distance, so shielding is more effective, from a practical standpoint, if the components and wiring are not too close to it. It is advisable to have a separation of several inches, if possible, between "hot" points in the circuit and the nearest shielding.

For a given thickness of metal, the greater the conductivity the better the shielding. Copper is best, with aluminum, brass and steel following in that order. However, if the thickness is adequate for structural purposes (over .02 inch) and the shield and a "hot" point in the circuit are not in close proximity, any of these metals will be satisfactory. Greater separation should be used with steel shielding than with the other materials not only because it is considerably poorer as a shield but also because it will cause greater losses in near-by circuits than would copper or aluminum at the same distance. Wire screen or perforated metal used as a shield should also be kept at some distance from high-voltage or high-current rf points, since there is considerably more leakage through the mesh than through solid metal.

Where two pieces of metal join, as in forming a corner, they should overlap at least a half inch and be fastened together firmly with screws or bolts spaced at close-enough intervals to maintain firm contact all along the joint. The contact surfaces should be clean before joining, and should be checked occasionally – especially steel, which is almost certain to rust after a period of time.

The leakage through a given size of aperture in shielding increases with frequency, so such points as good continuous contact, screening of large holes, and so on, become even more important when the radiation to be suppressed is in the high band – 174-216 MHz. Hence 50- and 144-MHz transmitters, which in general will have frequency-multiplier harmonics of relatively high intensity in this region, require special attention in this respect if the possibility of interfering with a channel received locally exists.

Lead Treatment

Even very good shielding can be made completely useless when connections are run to external power supplies and other equipment from the circuits inside the shield. Every such conductor leaving the shielding forms a path for the escape of rf, which is then radiated by the connecting wires. Hence a step that is essential in every case is to prevent harmonic currents from flowing on the leads leaving the shielded enclosure.

Fig. 16-7 — Proper method of bypassing the end of a shielded lead using disk ceremic capacitor. The .001-μF size should be used for 1600 volts or less; 500 pF at higher voltages. The leads are wrapped around the inner and outer conductors and soldered, so that the lead length is negligible. This photograph is about four times actual size.

Harmonic currents always flow on the dc or ac leads connecting to the tube circuits. A very effective means of preventing such currents from being coupled into other wiring, and one that provides desirable bypassing as well, is to use shielded wire for all such leads, maintaining the shielding from the point where the lead connects to the tube or rf circuit right through to the point where it leaves the chassis. The shield braid should be grounded to the chassis at both ends and at frequent intervals along the path.

Good bypassing of shielded leads also is essential. Bearing in mind that the shield braid about the conductor confines the harmonic currents to the *inside* of the shielded wire, the object of bypassing is to prevent their escape. Fig. 16-7 shows the proper way to bypass. The small .001-pF ceramic disk capacitor, when mounted on the end of the shielded wire as shown in Fig. 16-7, actually forms a series-resonant circuit in the 54-88-MHz range and thus represents practically a short circuit for low-band TV harmonics. The exposed wire to the connection terminal should be kept as short as is physically possible, to prevent any possible harmonic pickup exterior to the shielded wiring. Disk capacitors in the useful capacitance range of 500 to 1000 pF are available in several voltage ratings up to 6000 volts.

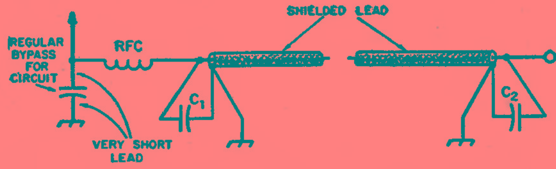


Fig. 16-8 — Additional rf filtering of supply leads may be required in regions where the TV signal is very weak. The rf choke should be physically small, and may consist of a 1-inch winding of No. 26 enameled wire on a 1/4-inch form, close-wound. Manufactured single-layer chokes having an inductance of a few microhenries also may be used.

These bypasses are essential at the connection-block terminals, and desirable at the tube ends of the leads also. Installed as shown with shielded wiring, they have been found to be so effective that there is usually no need for further harmonic filtering. However, if a test shows that additional filtering is required, the arrangement shown in Fig. 16-8 may be used. Such an rf filter should be installed at the tube end of the shielded lead, and if more than one circuit is filtered care should be taken to keep the rf chokes separated from each other and so oriented as to minimize coupling between them. This is necessary for preventing harmonics present in one circuit from being coupled into another.

In difficult cases involving Channels 7 to 13 — i.e., close proximity between the transmitter and receiver, and a weak TV signal — additional lead-filtering measures may be needed to prevent radiation of interfering signals by 50- and 144-MHz transmitters. A recommended method is shown in Fig. 16-9. It uses a shielded lead bypassed with a ceramic disk as described above, with the addition of a low-inductance feed-through type capacitor

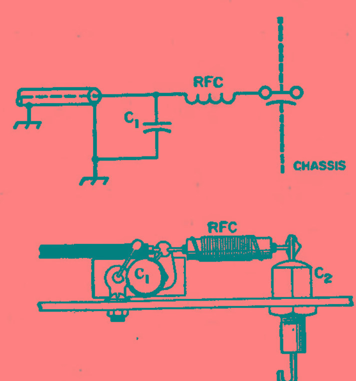


Fig. 16-9 — Additional lead filtering for harmonics or other spurious frequencies in the high vhf TV bend (174-216 MHz).
C1 — .001-μF disk ceramic.
C2 — 500- or 1000-pF fed-through bypass (Centrelab FT-1000. Above 500 volts, substitute Centralab 858S-500.).
RFC — 14 inches No. 26 enamal close-wound on 3/16-inch dia. form or composition resistor body.

and a small rf choke, the capacitor being used as a terminal for the external connection. For voltages above 400, a capacitor of compact construction (as indicated in the caption) should be used, mounted so that there is a very minimum of exposed lead inside the chassis, from the capacitor to the connection terminal.

As an alternative to the series-resonant bypassing described above, feed-through type capacitors such as the Sprague "Hypass" type may be used as terminals for external connections. The ideal method of installation is to mount them so they protrude through the chassis, with thorough bonding to the chassis all around the hole in which the capacitor is mounted. The principle is illustrated in Fig. 16-10.

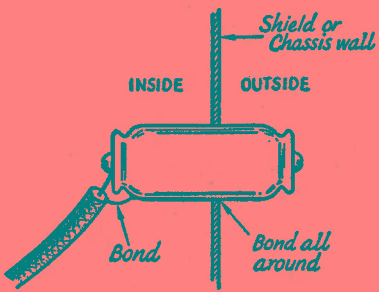


Fig. 16-10 — The best method of using the "Hypass" type feed-through capacitor. Capacitances of .01 to 0.1 μF are satisfactory. Capacitors of this type are useful for high-current circuits, such as filament and 117-volt leads, as a substitute for the rf choke shown in Fig. 16-8, in cases where additional lead filtering is needed.

Meters that are mounted in an rf unit should be enclosed in shielding covers, the connections being made with shielded wire with each lead bypassed as described above. The shield braid should be grounded to the panel or chassis immediately outside the meter shield, as indicated in Fig. 16-11. A bypass may also be connected across the meter terminals, principally to prevent any fundamental current that may be present from flowing through the meter itself. As an alternative to individual meter shielding the meters may be mounted entirely behind the panel, and the panel holes needed for observation may be covered with wire screen that is carefully bonded to the panel all around the hole.

Care should be used in the selection of shielded wire for transmitter use. Not only should the insulation be conservatively rated for the dc voltage in use, but the insulation should be of material that will not easily deteriorate in soldering. The rf characteristics of the wire are not especially important, except that the attenuation of harmonics in the wire itself will be greater if the insulating material has high losses at radio frequencies; in other words, wire intended for use at dc and low frequencies is preferable to cables designed expressly for carrying rf. The attenuation also will increase with the length of the wire; in general, it is better to make the leads as long as

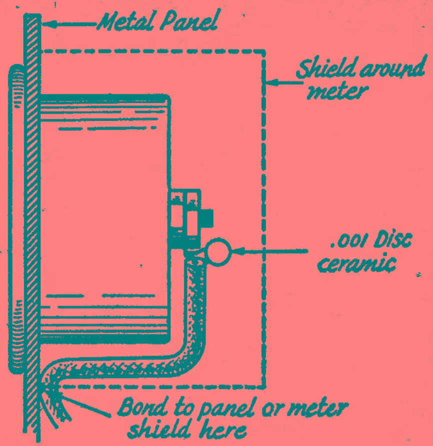


Fig. 16-11 — Meter shielding and bypassing. It is essential to shield the meter mounting hole since the meter will carry rf through it to be radiated. Suitable shields can be made from 2 1/2- or 3-inch diameter metal cans or small metal chassis boxes.

circumstances permit rather than to follow the more usual practice of using no more lead than is actually necessary. Where wires cross or run parallel, the shields should be spot-soldered together and connected to the chassis. For high voltages, automobile ignition cable covered with shielding braid is recommended.

Proper shielding of the transmitter requires that the rf circuits be shielded entirely from the external connecting leads. A situation such as is shown in Fig. 16-12, where the leads in the rf chassis have been shielded and properly filtered but the chassis is mounted in a large shield, simply invites the harmonic currents to travel over the chassis and on out over the leads *outside* the chassis. The shielding about the rf circuits should make complete contact with the chassis on which the parts are mounted.

Checking Transmitter Radiation

A check for transmitter radiation always should be made before attempting to use low-pass filters or other devices for preventing harmonics from

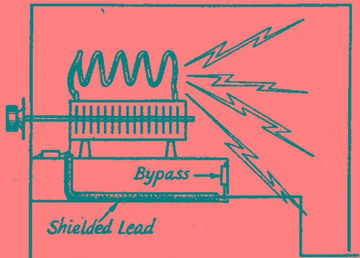


Fig. 16-12 — A metal cabinet can be an adequate shield, but there will still be radiation if the leads inside can pick up rf from the transmitting circuits.

reaching the antenna system. The only really satisfactory indicating instrument is a television receiver. In regions where the TV signal is strong an indicating wavemeter such as one having a crystal or tube detector may be useful; if it is possible to get any indication at all from harmonics either on supply leads or around the transmitter itself, the harmonics are probably strong enough to cause interference. However, the absence of any such indication does not mean that harmonic interference will not be caused. If the techniques of shielding and lead filtering described in the preceding section are followed, the harmonic intensity on any external leads should be far below what any such instruments can detect.

Radiation checks should be made with the transmitter delivering full power into a dummy antenna, such as an incandescent lamp of suitable power rating, preferably installed inside the shielded enclosure. If the dummy must be external, it is desirable to connect it through a coax-matching circuit such as is shown in Fig. 16-13. Shielding

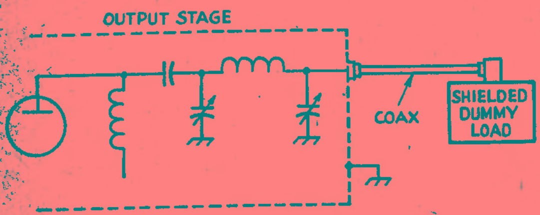


Fig. 16-13 — Dummy-antenna system for checking harmonic radiation from the transmitter and leads.

the dummy antenna circuit is also desirable, although it is not always necessary.

Make the radiation test on all frequencies that are to be used in transmitting, and note whether or not interference patterns show in the received picture. (These tests must be made while a TV signal is being received, since the beat patterns will not be formed if the TV picture carrier is not present.) If interference exists, its source can be detected by grasping the various external leads (by the insulation, not the live wire!) or bringing the hand near meter faces, louvers, and other possible points where harmonic energy might escape from the transmitter. If any of these tests cause a *change* – not necessarily an *increase* – in the intensity of the interference, the presence of harmonics at that point is indicated. The location of such "hot" spots usually will point the way to the remedy. If the TV receiver and the transmitter can be operated side-by-side, a length of wire connected to one antenna terminal on the receiver can be used as a probe to go over the transmitter enclosure and external leads. This device will very quickly expose the spots from which serious leakage is taking place.

As a final test, connect the transmitting antenna or its transmission line terminals to the outside of the transmitter shielding. Interference created when this test is applied indicates that weak currents are on the outside of the shield and can be conducted to the antenna when the normal antenna connections are used. Currents of this nature represent interference that is conducted *over* low-pass filters, and hence cannot be eliminated by such filters.

TRANSMITTING-ANTENNA CONSIDERATIONS

When a well-shielded transmitter is used in conjunction with an effective low-pass filter, and there is no incidental rectification in the area, it is impossible to have "harmonic-type" TVI, regardless of the type of transmitting antenna. However, the type of transmitting antenna in use can be responsible for "fundamental-overload" TVI.

To minimize the chances of TVI, the transmitting antenna should be located as far as possible from the receiving antenna. The chances of fundamental overload at the television receiver are reduced when a horizontal transmitting antenna or beam is mounted higher than the TV antenna. Other things being equal, fundamental overload is more likely to occur with a vertical transmitting antenna than with a horizontal one, because the vertical antenna has a stronger field at a low angle. If a ground-plane antenna can be located well above the height of the TV receiving antenna, there is less likelihood of fundamental overload than when it is at the same height or below the television antenna.

The SWR on the line to the transmitting antenna has no effect on TVI. However, when the line to the antenna passes near the TV antenna, radiation from the line can be a source of TVI. Methods for minimizing radiation from the line are discussed in the chapter on transmission lines.

FILTER FOR TVI HARMONICS

Most low-pass filters are designed to be driven from a *purely* resistive source impedance and loaded into a resistive termination. The typical transmitter output impedance is resistive *only* at the frequency to which the transmitter is tuned and is highly reactive at harmonic frequencies. It is quite possible that the transmitter reactance will partially or (in especially unfortunate instances) wholly cancel the filter input reactance at one or more harmonics of the transmission frequency.

The solution to this dilemma is to use a low-pass filter which achieves filtering by absorp-

TABLE I

Filter Design Formulas

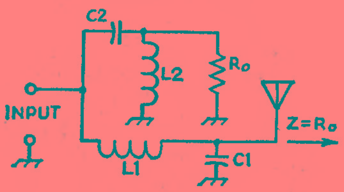
(a) Basic Absorptive Filters

$\omega_C = 2\pi f_C$ $\quad$ f_C = cut-off freq.

R_O = effective load resistance due to antenna

All reactances are positive and are computed at f_C, i.e. $X_L = \omega_C L$, $X_C = \dfrac{1}{\omega_C C}$

2-POLE FILTER



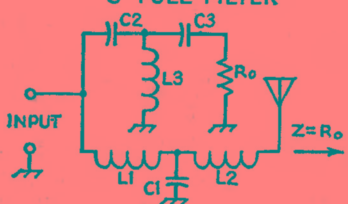
$X_{L2} = 1.414\ R_O$

$X_{C2} = X_{L2}$

$X_{C1} = 1.414\ R_O$

$X_{L1} = X_{C1}$

3-POLE FILTER

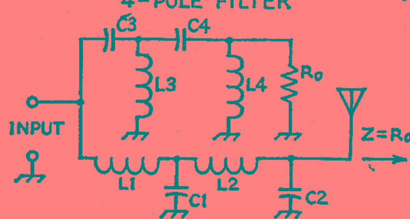


$X_{C3} = X_{L2} = 0.5\ R_O$

$X_{L3} = X_{C1} = 1.489\ X_{C3}$

$X_{C2} = X_{L1} = 2X_{L3}$

4-POLE FILTER



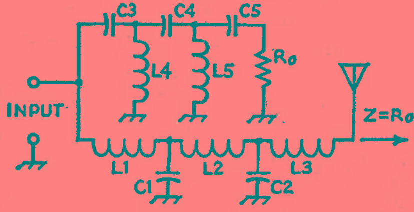
$X_{L4} = \dfrac{R_O}{.383} = X_{C2}$

$X_{C4} = X_{L2} = \dfrac{X_{L4}}{2.435}$

$X_{L3} = X_{C1} = 0.585\ X_{C4}$

$X_{C3} = X_{L1} = \dfrac{X_{L3}}{0.415}$

5-POLE FILTER



$X_{C5} = X_{L3} = 0.309\ R_O$

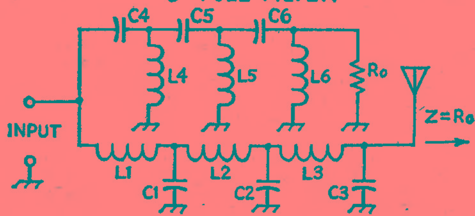
$X_{L5} = X_{C2} = 3.61\ X_{C5}$

$X_{C4} = X_{L2} = \dfrac{X_{L5}}{0.81}$

$X_{L4} = X_{C1} = 0.428\ X_{C4}$

$X_{C3} = X_{L1} = \dfrac{X_{L4}}{0.383}$

6-POLE FILTER



$X_{L6} = X_{C3} = \dfrac{R_O}{0.259}$ $\qquad$ $X_{C5} = X_{L2} = \dfrac{X_{L5}}{0.536}$

$X_{C6} = X_{L3} = \dfrac{X_{L6}}{5.11}$ $\qquad$ $X_{L4} = X_{C1} = 0.367\ X_{C5}$

$X_{L5} = X_{C2} = 1.102\ X_{C6}$ $\qquad$ $X_{C4} = X_{L1} = \dfrac{X_{L4}}{0.367}$

(b) Formulas for Resonant Traps

$X(\omega_C)$ = Design value of reactance at the cutoff frequency (f_C). See (a) above.

f_{trap} = Trap frequency

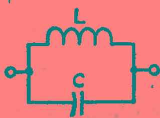
All reactances computed at f_C.

Series Trap (Shunt capacitor of filter series-tuned)

$$X_L = \frac{X(\omega_C)}{\left(\frac{f_{trap}}{f_C}\right)^2 - 1},\ X_C = X(\omega_C) + X_L$$

Parallel Trap (Series coil of filter parallel-tuned)

$$X_C = X(\omega_C)\left[\left(\frac{f_{trap}}{f_C}\right)^2 - 1\right]$$



$$X_L = \frac{X_C X(\omega_C)}{X_C + X(\omega_C)}$$

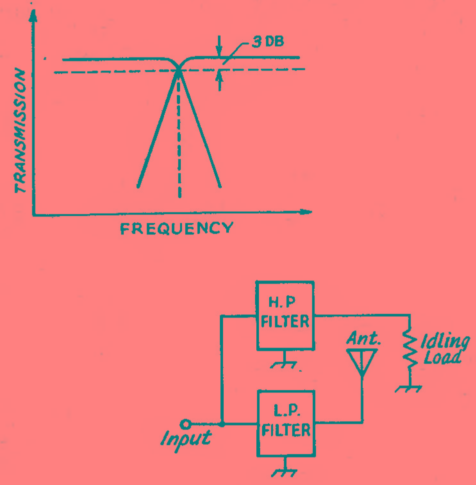


Fig. 1 — General configuration and theoretical response of absorptive TVI filter.

tion rather than reflection. This approach requires the use of two contiguous filters, one low-pass and one high-pass (see Fig. 1).

The need for very high rejection relatively close to the filter cut-off frequency often arises. The basic absorptive filter provides an attenuation of approximately 6*n* dB/octave above its cutoff frequency, where *n* is the number of reactive elements in the low-pass section of the filter. Filters of practical complexity may not provide sufficient rejection at frequencies close to the edge of the hf band.

Experiment has shown that one or more of the shunt capacitors in the low-pass section can be series-tuned at the unwanted harmonic frequencies to provide very deep "holes" in the rejection characteristic. If this is done properly, the pass-band attenuation and the out-of-band *SWR* are affected very little. It is also possible to achieve substantially the same result by parallel-tuning one of the series coils.

The design formulas for the basic absorptive filter and the resonant traps are given in Table I. The formulas for the basic filter are exact. Typically, little or no "tweaking" is required to obtain satisfactory operation. The formulas which apply to filters having resonant traps, however, are approximate in the sense that some pass-band degradation may occur if the exact computed values are used. Usually, some small readjustment of the filter element values is required. The four-pole filter shown in Fig. 2 is shown in the photograph.

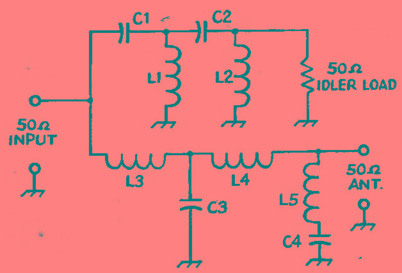


Fig. 2 — Circuit of the pc-board filter shown in the photographs. The board used is MIL-P-13949D, FL-GT-.062*ii*, C-2/2-11017, Class 1, Grade A, Polychem Bud Division. Capacitance between copper surfaces is 10 pF per square inch. Values are as follows for a design cutoff frequency of 40 MHz and rejection peak in Channel 2:

C1 — 52 pF	L2 — 0.52 μH
C2 — 73 pF	L3 — 0.3 μH
C3 — 126 pF	L4 — 0.212 μH
C4 — 21.6 pF	L5 — 0.24 μH
L1 — 0.125 μH	

In cases where the antenna reactance at a harmonic frequency is such as to produce an effective low-impedance series resonance at the input of the low-pass portion of the filter, the filter will not function properly. (It does, however, provide protection against a high-impedance resonance at the low-pass input.) In the event that a low-impedance antenna-filter resonance does occur it can be changed into a high-impedance resonace by changing the length of the feed line by a quarter wavelength at the harmonic frequency. Cases where the "wrong" kind of resonance occurs are probably quite rare, however.

Inside view of a sample filter constructed in the ARRL Lab.

Construction and Test Techniques

If good performance above 100 MHz is not a necessity, this filter can be built using conventional fixed capacitors. Copper-clad Teflon board may not be readily available in small quantities from many supply houses. Regular fiberglass-insulated board is satisfactory for low power. One such filter has been used with an SB-100 transceiver running 100 watts. Although the *Q* of the fiberglass capacitors will be lower than that of Teflon-dielectric capacitors, this should not greatly affect the type of filter described here.

Test equipment needed to build this filter at home includes a reasonably accurate grid-dip oscillator, a *SWR* bridge, a reactance chart or the ARRL Lighting Calculator (for *L*, *C*, and *f*), a 50-ohm dummy load, and a transmitter.

Once the value of a given capacitor has been calculated, the next step is to determine the capacitance per square inch of the double-clad circuit board you have. This is done by connecting one end of a coil of known inductance to one side of the circuit board, and the other coil lead to the other side of the circuit board. Use the grid-dip oscillator, coupled lightly to the coil, to determine the resonant frequency of the coil and the circuit-board capacitor. When the frequency is known, the total capacitance can be determined by working the Lightning Calculator or by looking the capacitance up on a reactance chart. The total capacitance divided by the number of square inches on one side of the circuit board gives the capacitance per square inch. Once this figure is determined, capacitors of almost any value can be laid out with a ruler!

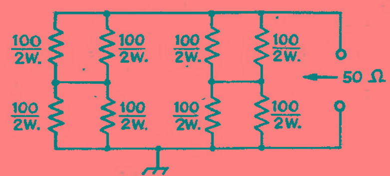


Fig. 3 – Dummy load for tha high-pass section of the filter.

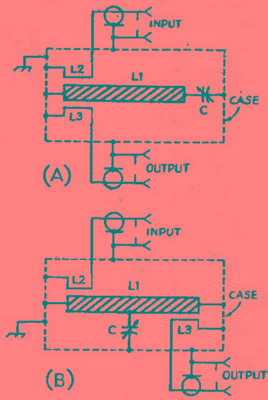
High voltages can be developed across capacitors in a series-tuned circuit, so the copper material should be trimmed back at least 1/8 inch from all edges of a board, except those that will be soldered to ground, to prevent arcing. This should not be accomplished by filing, since the copper filings would become imbedded in the board material and just compound the problem. The capacitor surfaces should be kept smooth and sharp corners should be avoided.

If the filter box is made of double-clad fiber glass board, both sides should be bonded together with copper stripped from another piece of board. Stripped copper foil may be cleaned with a razor blade before soldering. To remove copper foil from a board, use a straight edge and a sharp scribe to score the thin copper foil. When the copper foil has been cut, use a razor blade to lift a corner. Careful heating with a soldering iron will reduce the effort required to separate the copper from the board. This technique of bonding two pieces of board or two sides of a piece of board can also be used to interconnect two capacitors when construction in one plane would require too much area. Stray inductance must be minimized and sufficient clearance must be maintained for arc-over protection.

Capacitors with Teflon dielectric have been used in filters passing up to 2 kW PEP. One further word of caution: No low-pass filter will be fully effective until the transmitter with which it is used is properly shielded and all leads filtered.

Fig. 16-14 – Equivalent circuits for the strip-line filters. At A, the circuit for the 6- and 2-meter filters are shown. L2 and L3 ere the input and output links. These filters ere bilaterial, permitting interchanging of the input and output terminals.

At B, the representative circuit for the 220- and 432-MHz filters. These filters are also bilatarial.



The terminating loads for the high-pass section of the filter can be made from 2-watt, 10-percent tolerance composition resistors. Almost any dissipation rating can be obtained by suitable series-parallel combinations. For example, a 16-watt, 50-ohm load could be built as shown in Fig. 3. This load should handle the harmonic energy of a signal with peak fundamental power of 2 kilowatts. With this load, the harmonic energy will see a *SWR* under 2:1 up to 400 MHz. For low power (under 300 watts PEP), a pair of 2-watt 100-ohm resistors is adequate.

In the model shown the high-pass filter series capacitors are bonded and mounted on Teflon standoff insulators.

FILTERS FOR VHF TRANSMITTERS

High rejection of unwanted frequencies is possible with the tuned-line filters of Fig. 16-14. Examples are shown for each band from 50 through 450 MHz. Construction is relatively simple, and the cost is low. Standard boxes are used, for ease of duplication.

The filter of Fig. 16-15 is selective enough to pass 50-MHz energy and attenuate the 7th harmonic of an 8-MHz oscillator that falls in TV Channel 2. With an insertion loss at 50 MHz of about 1 dB, it can provide up to 40 dB of attenuation to energy at 57 MHz in the same line. This should be more than enough attenuation to take care of the worst situations, provided that the radiation is by way of the transmitter output coax only. The filter will not eliminate interfering energy that gets out from power cables, the ac line, or from the transmitter circuits themselves. It also will do nothing for TVI that results from deficiencies in the TV receiver.

Fig. 16-15 – Interior of the 50-MHz strip line filter. Inner conductor of aluminum strip is bent into U shape, to fit inside a standard 17-inch chassis.

Fig. 16-16 – The 144-MHz filter has an inner conductor of 1/2-inch copper tubing 10 inches long, grounded to the left end of the case and supported at the right end by the tuning capacitor.

Fig. 16-17 – A half-wave strip line is used in the 220-MHz filter. It is grounded at both ends and tuned at the canter.

The 50-MHz filter, Fig. 16-15, uses a folded line in order to keep it within the confines of a standard chassis. The case is a 6 X 17 X 3-inch chassis (Bud AC-433) with a cover plate that fastens in place with self-tapping screws. An aluminum partition down the middle of the assembly is 14 inches long, and the full height of the chassis, 3 inches.

The inner conductor of the line is 32 inches long and 13/16 inch wide, of 1/16-inch brass, copper or aluminum. This was made from two pieces of aluminum spliced together to provide the 32-inch length. Splicing seemed to have no ill effect on the circuit *Q*. The side of the "U" are 2 7/8 inches apart, with the partition at the center. The line is supported on ceramic standoffs. These were shimmed up with sections of hard wood or bakelite rod, to give the required 1 1/2-inch height.

The tuning capacitor is a double-spaced variable (Hammarlund HF-30-X) mounted 1 1/2 inches from the right end of the chassis. Input and output coupling loops are of No. 10 or 12 wire, 10 inches long. Spacing away from the line is adjusted to about 1/4 inch.

The 144-MHz model is housed in a 2 1/4 X 2 1/2 X 12-inch Minibox (Bud CU-2114-A).

One end of the tubing is slotted 1/4 inch deep with a hacksaw. This slot takes a brass angle bracket 1 1/2 inches wide, 1/4 inch high, with a 1/2-inch mounting lip. This 1/4-inch lip is soldered into the tubing slot, and the bracket is then bolted to the end of the box, so as to be centered on the end plate.

The tuning capacitor (Hammarlund HF-15-X) is mounted 1 1/4 inches from the other end of the box, in such a position that the inner conductor can be soldered to the two stator bars.

The two coaxial fittings (SO-239) are 11/16 inch in from each side of the box, 3 1/2 inches from the left end. The coupling loops are No. 12 wire, bent so that each is parallel to the center line of the inner conductor, and about 1/8 inch from its surface. Their cold ends are soldered to the brass mounting bracket.

The 220-MHz filter uses the same size box as the 144-MHz model. The inner conductor is 1/16-inch brass or copper, 5/8 inch wide, just long enough to fold over at each end for bolting to the box. It is positioned so that there will be 1/8 inch clearance between it and the rotor plates of the tuning capacitor. The latter is a Hammarlund HF-15-X, mounted slightly off-center in the box, so that its stator plates connect to the exact mid-point of the line. The 5/16-inch mounting hole in the case is 5 1/2 inches from one end. The SO-239 coaxial fittings are 1 inch in from opposite sides of the box, 2 inches from the ends. Their coupling links are No. 14 wire, 1/8 inch from the inner conductor of the line.

The 420-MHz filter is similar in design, using a 1 5/8 X 2 X 10-inch Minibox (Bud CU-2113-A). A half-wave line is used, with disk tuning at the center. The disks are 1/16-inch brass, 1 1/4-inch diameter. The fixed one is centered on the inner conductor, the other mounted on a No. 6 brass lead-screw. This passes through a threaded bushing, which can be taken from the end of a discarded slug-tuned form. An advantage of these is that usually a tension device is included. If there is none, use a lock nut.

Type N coaxial connectors were used on the 420-MHz model. They are 5/8 inch in from each side of the box, and 1 3/8 inches in from the ends. Their coupling links of No. 14 wire are 1/16 inch from the inner conductor.

Adjustment and Use

If you want the filter to work on both transmitting and receiving, connect the filter between antenna line and SWR indicator. With this arrangement you need merely adjust the filter for minimum reflected power reading on the SWR bridge. This should be zero, or close to it, if the antenna is well-matched. The bridge should be used, as there is no way to adjust the filter properly without it. If you insist on trying, adjust for best reception of signals on frequencies close to the ones you expect to transmit on. This works only if the antenna is well matched.

When the filter is properly adjusted (with the SWR bridge) you may find that reception can be improved by retuning the filter. Don't do it, if you want the filter to work best on the job it was intended to do: the rejection of unwanted energy, transmitting or receiving. If you want to improve reception with the filter in the circuit, work on the receiver input circuit. To get maximum power out of the transmitter and into the line, adjust the transmitter output coupling, not the filter. If the effect of the filter on reception bothers you, connect it in the line from the antenna relay to the transmitter only.

SUMMARY

The methods of harmonic elimination outlined here have been proved beyond doubt to be effective even under highly unfavorable conditions. It must be emphasized once more, however, that the problem must be solved one step at a time, and the procedure must be in logical order. It cannot be done properly without two items of simple equipment: a grid-dip meter and wavemeter covering the TV bands, and a dummy antenna.

To summarize:

1) Take a critical look at the transmitter on the basis of the design considerations outlined under "Reducing Harmonic Generation."

2) Check all circuits, particularly those connected with the final amplifier, with the grid-dip meter to determine whether there are any resonances in the TV bands. If so, rearrange the circuits so the resonances are moved out of the critical frequency region.

3) Connect the transmitter to the dummy antenna and check with the wavemeter for the presence of harmonics on leads and around the transmitter enclosure. Seal off the weak spots in the shielding and filter the leads until the wavemeter shows no indication at any harmonic frequency.

4) At this stage, check for interference with a TV receiver. If there is interference, determine the cause by the methods described previously and apply the recommended remedies until the interference disappears.

5) When the transmitter is completely clean on the dummy antenna, connect it to the regular antenna and check for interference on the TV receiver. If the interference is not bad, a Transmatch or matching circuit installed as previously described should clear it up. Alternatively, a low-pass filter may be used. If neither the Transmatch nor filter makes any difference in the interference, the evidence is strong that the interference, at least in part, is being caused by receiver overloading because of the strong fundamental-frequency field about the TV antenna and receiver. A Transmatch and/or filter, installed as described above, will invariably make a difference in the intensity of the interference if the interference is caused by transmitter harmonics alone.

6) If there is still interference after installing the Transmatch and/or filter, and the evidence shows that it is probably caused by a harmonic, more attenuation is needed. A more elaborate filter may be necessary. However, it is well at this stage to assume that part of the interference may be caused by receiver overloading, and take steps to alleviate such a condition before trying highly-elaborate filters and traps on the transmitter.

HARMONICS BY RECTIFICATION

Even though the transmitter is completely free from harmonic output it is still possible for interference to occur because of harmonics

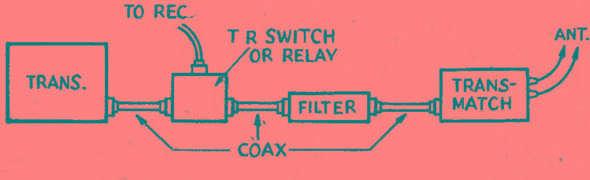


Fig. 16-18 — The proper method of installing a low-pass filter between the transmitter and a Transmatch. If the antenna is fed through coax, the Transmatch can be eliminated, but the transmitter end filter must be completely shielded. If a TR switch is used, it should be installed between the transmitter end low-pass filter. TR switches can generate harmonics themselves, so the low-pass filter should follow the TR switch.

generated outside the transmitter. These result from rectification of fundamental-frequency currents induced in conductors in the vicinity of the transmitting antenna. Rectification can take place at any point where two conductors are in poor electrical contact, a condition that frequently exists in plumbing, downspouting, BX cables crossing each other, and numerous other places in the ordinary residence. It also can occur at any exposed vacuum tubes in the station, in power supplies, speech equipment, etc., that may not be enclosed in the shielding about the rf circuits. Poor joints anywhere in the antenna system are especially bad, and rectification also may take place in the contacts of antenna changeover relays. Another common cause is overloading the front end of the communications receiver when it is used with a separate antenna (which will radiate the harmonics generated in the first tube) for break-in.

Rectification of this sort will not only cause harmonic interference but also is frequently responsible for cross-modulation effects. It can be detected in greater or less degree in most locations, but fortunately the harmonics thus generated are not usually of high amplitude. However, they can cause considerable interference in the immediate vicinity in fringe areas, especially when operation is in the 28-MHz band. The amplitude decreases rapidly with the order of the harmonic, the second and third being the worst. It is ordinarily found that even in cases where destructive interference results from 28-MHz operation the interference is comparatively mild from 14 MHz, and is negligible at still lower frequencies.

Nothing can be done at either the transmitter or receiver when rectification occurs. The remedy is to find the source and eliminate the poor contact either by separating the conductors or bonding them together. A crystal wavemeter (tuned to the fundamental frequency) is useful for hunting the source, by showing which conductors are carrying rf and, comparatively, how much.

Interference of this kind is frequently intermittent since the rectification efficiency will vary with vibration, the weather, and so on. The possibility of corroded contacts in the TV receiving antenna should not be overlooked, especially if it has been up a year or more.

TV RECEIVER DEFICIENCIES

When a television receiver is quite close to the transmitter, the intense rf signal from the transmitter's fundamental may overload one or more of the receiver circuits to produce spurious responses that cause interference.

If the overload is moderate, the interference is of the same nature as harmonic interference; it is caused by harmonics generated in the early stages of the receiver and, since it occurs only on channels harmonically related to the transmitting frequency, it is difficult to distinguish from harmonics actually radiated by the transmitter. In such cases additional harmonic suppression at the transmitter will do no good, but any means taken at the receiver to reduce the strength of the amateur signal reaching the first tube will effect an improvement. With very severe overloading, interference also will occur on channels *not* harmonically related to the transmitting frequency, so such cases are easily identified.

Cross-Modulation

Upon some circumstances overloading will result in cross-modulation or mixing of the amateur signal with that from a local fm or TV station. For example, a 14-MHz signal can mix with a 92-MHz fm station to produce a beat at 78 MHz and cause interference in Channel 5, or with a TV station on Channel 5 to cause interference in Channel 3. Neither of the channels interfered with is in harmonic relationship to 14 MHz. Both signals have to be on the air for the interference to occur, and eliminating either at the TV receiver will eliminate the interference.

There are many combinations of this type, depending on the band in use and the local frequency assignments to fm and TV stations. The interfering frequency is equal to the amateur fundamental frequency either added to or subtracted from the frequency of some local station, and when interference occurs in a TV channel that is not harmonically related to the amateur transmitting frequency the possibilities in such frequency combinations should be investigated.

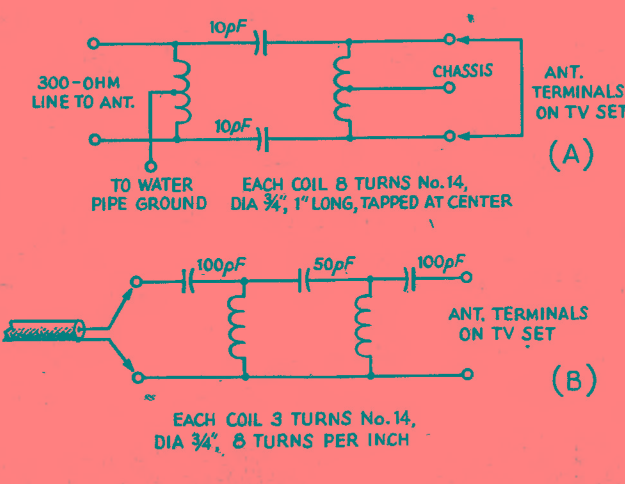


Fig. 16-19 — High-pass filters for installation at the TV receiver antenna terminals. A — balanced filter for 300-ohm line. B — for 75-ohm coaxial line. *Important:* Do not use a direct ground on the chassis of a transformerless receiver. Ground through a .001-μF mica capacitor.

I-f Interference

Some TV receivers do not have sufficient selectivity to prevent strong signals in the intermediate-frequency range from forcing their way through the front end and getting into the i-f amplifier. The once-standard intermediate frequency of, roughly, 21 to 27 MHz, is subject to interference from the fundamental-frequency output of transmitters operating in the 21-MHz band. Transmitters on 28 MHz sometimes will cause this type of interference as well.

A form of i-f interference peculiar to 50-MHz operation near the low edge of the band occurs with some receivers having the standard "41-MHz" i-f, which has the sound carrier at 41.25 MHz and the picture carrier at 45.75 MHz. A 50-MHz signal that forces its way into the i-f system of the receiver will beat with the i-f picture carrier to give a spurious signal on or near the i-f sound carrier, even though the interfering signal is not actually in the nominal passband of the i-f amplifier.

There is a type of i-f interference unique to the 144-MHz band in localities where certain uhf TV channels are in operation, affecting only those TV receivers in which double-conversion type plug-in uhf tuning strips are used. The design of these strips involves a first intermediate frequency that varies with the TV channel to be received and, depending on the particular strip design, this first i-f may be in or close to the 144-MHz amateur band. Since there is comparatively little selectivity in the TV signal-frequency circuits ahead of the first i-f, a signal from a 144-MHz transmitter will "ride into" the i-f, even when the receiver is at a considerable distance from the transmitter. The channels that can be affected by this type of i-f interference are:

Receivers with 21-MHz second i-f	*Receivers with 41-MHz second i-f*
Channels 14-18, incl.	Channels 20-25, incl.
Channels 41-48, incl.	Channels 51-58, incl.
Channels 69-77, incl.	Channels 82 and 83.

If the receiver is not close to the transmitter, a trap of the type shown in Fig. 16-21 will be effective. However, if the separation is small the 144-MHz signal will be picked up directly on the receiver circuits and the best solution is to readjust the strip oscillator so that the first i-f is moved to a frequency not in the vicinity of the 144-MHz band. This has to be done by a competent technician.

I-f interference is easily identified since it occurs on all channels – although sometimes the intensity varies from channel to channel – and the cross-hatch pattern it causes will rotate when the receiver's fine-tuning control is varied. When the interference is caused by a harmonic, overloading, or cross modulation, the structure of the interference pattern does not change (its intensity may change) as the fine-tuning control is varied.

High-Pass Filters

In all of the above cases the interference can be eliminated if the fundamental signal strength can be reduced to a level that the receiver can handle. To accomplish this with signals on bands below 30 MHz, the most satisfactory device is a high-pass filter having a cutoff frequency between 30 and 54 MHz, installed at the tuner input terminals of the receiver. Circuits that have proved effective are shown in Figs. 16-18 and 16-19. Fig. 16-18 has one more section than the filters of Fig. 16-19 and as a consequence has somewhat better cutoff characteristics. All the circuits given are designed to have little or no effect on the TV signals but will attenuate all signals lower in frequency than about 40 MHz. These filters preferably should be constructed in some sort of shielding container, although shielding is not always necessary. The dashed lines in Fig. 16-20 show how individual filter coils can be shielded from each other. The capacitors can be tubular ceramic units centered in holes in the partitions that separate the coils.

Simple high-pass filters cannot always be applied successfully in the case of 50-MHz transmissions, because they do not have sufficiently-sharp cutoff characteristics to give both good attenuation at 50-54 MHz and no attenuation above 54 MHz. A more elaborate design capable of giving the required sharp cutoff has been described (Ladd, "50-MHz TVI – Its Causes and Cures," *QST*, June and July, 1954). This article also contains other information useful in coping with the TVI problems peculiar to 50-MHz operation. As an alternative to such a filter, a high-Q wave trap tuned to the transmitting frequency may be used, suffering only the disadvantage that it is quite selective and therefore will protect a receiver from overloading over only a small range of transmitting frequencies in the 50-MHz band. A trap of this type is shown in Fig. 16-21. These "suck-out" traps, while absorbing energy at the frequency to which they are tuned, do not affect the receiver operation otherwise. The assembly should be mounted near the input terminals of the TV tuner and its case should be grounded to the TV set chassis. The traps should be tuned for minimum TVI at the transmitter operating frequency. An insulated tuning tool should be used for adjustment of the trimmer capacitors, since

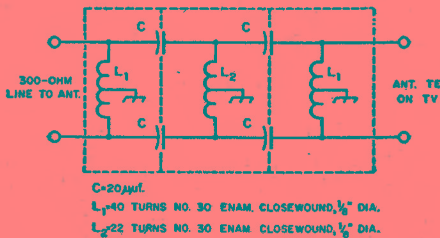


Fig. 16-20 – Another type of high-pass filter for 300-ohm line. The coils may be wound on 1/8-inch diameter plastic knitting needles. *Important:* Do not use a direct ground on the chassis of a transformerless receiver. Ground through a .001-µF mica capacitor.

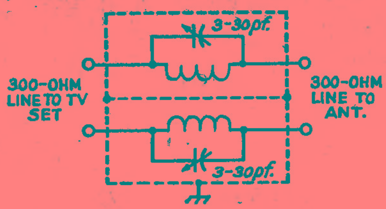


Fig. 16-21 – Parallel-tuned traps for installation in the 300-ohm line to the TV set. The traps should be mounted in an aluminum Minibox with a shield partition between them, as shown. For 50 MHz, the coils should have 9 turns of No. 16 enamel wire, close wound to a diameter of 1/2 inch. The 144-MHz traps should contain coils with a total of 6 turns of the same typa wire, close-wound to a diameter of 1/4 inch. Traps of this type can be used to combat fundamental-overload TVI on the lower-frequency bands as well.

they are at a "hot" point and will show considerable body-capacitance effect.

High-pass filters are available commercially at moderate prices. In this connection, it should be understood by all parties concerned that while an amateur is responsible for *harmonic* radiation from his transmitter, it is no part of his responsibility to pay for or install filters, wave traps, etc. that may be required at the receiver to prevent interference caused by his *fundamental* frequency. Proper installation usually requires that the filter be installed right at the input terminals of the rf tuner of the TV set and not merely at the external antenna terminals, which may be at a considerable distance from the tuner. The question of cost is one to be settled between the set owner and the organization with which he deals. Don't overlook the possibility that the manufacturer of the TV receiver will supply a high-pass filter free of charge.

If the fundamental signal is getting into the receiver by way of the line cord a line filter such as those shown in Fig. 16-22 may help. To be most effective it should be installed inside the receiver chassis at the point where the cord enters, making the ground connections directly to the chassis at this point. It may not be so helpful if placed between the line plug and the wall socket unless the rf is actually picked up on the house wiring rather than on the line cord itself.

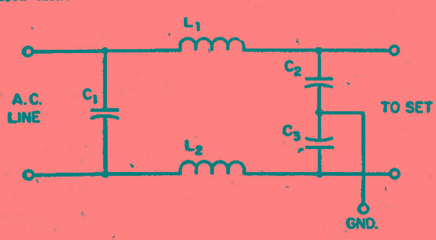


Fig. 16-22 – "Brute-force" ac line filtar for receivers. The values of C1, C2 and C3 ere not generally critical; capacitances from .001 to .01 μF can be used. L1 and L2 can be e 2-inch winding of No. 18 enameled wire on a half-inch diameter form. In making up such e unit for use external to the receiver, make sure that there ere no exposed conductors to offer e shock hazard.

Antenna Installation

Usually, the transmission line between the TV receiver and the actual TV antenna will pick up a great deal more energy from a nearby transmitter than the television receiving antenna itself. The currents induced on the TV transmission line in this case are of the "parallel" type, where the phase of the current is the same in both conductors. The line simply acts like two wires connected together to operate as one. If the receiver's antenna input circuit were perfectly balanced it would reject these "parallel" or "unbalance" signals and respond only to the true transmission-line ("push-pull") currents; that is, only signals picked up on the actual antenna would cause a receiver response. However, no receiver is perfect in this respect, and many TV receivers will respond strongly to such parallel currents. The result is that the signals from a nearby amateur transmitter are much more intense at the first stage in the TV receiver than they would be if the receiver response were confined entirely to energy picked up on the TV antenna alone. This situation can be improved by using shielded transmission line – coax or, in the balanced form, "twinax" – for the receiving installation. For best results the line should terminate in a coax fitting on the receiver chassis, but if this is not possible the shield should be grounded to the chassis right at the antenna terminals.

The use of shielded transmission line for the receiver also will be helpful in reducing response to harmonics actually being radiated from the transmitter or transmitting antenna. In most receiving installations the transmission line is very much longer than the antenna itself, and is consequently far more exposed to the harmonic fields from the transmitter. Much of the harmonic pickup, therefore, is on the receiving transmission line when the transmitter and receiver are quite close together. Shielded line, plus relocation of either the transmitting or receiving antenna to take advantage of directive effects, often will result in reducing overloading, as well as harmonic pickup, to a level that does not interfere with reception.

UHF TELEVISION

Harmonic TVI in the uhf TV band is far less troublesome than in the vhf band. Harmonics from transmitters operating below 30 MHz are of such high order that they would normally be expected to be quite weak; in addition, the components, circuit conditions and construction of low-frequency transmitters are such as to tend to prevent very strong harmonics from being generated in this region. However, this is not true of amateur vhf transmitters, particularly those working in the 144-MHz and higher bands. Here the problem is quite similar to that of the low vhf TV band with respect to transmitters operating below 30 MHz.

There is one highly favorable factor in uhf TV that does not exist in the most of the vhf TV band: If harmonics are radiated, it is possible to move the transmitter frequency sufficiently (within the amateur band being used) to avoid interfering with a channel that may be in use in the locality. By restricting operation to a portion of the amateur band that will not result in harmonic interference, it is possible to avoid the necessity for taking extraordinary precautions to prevent harmonic radiation.

The frequency assignment for uhf television consists of seventy 6-Megahertz channels (Nos. 14 to 83, inclusive) beginning at 470 MHz and ending at 890 MHz. The harmonics from amateur bands above 50-MHz span the uhf channels as shown in Table 16-1. Since the assignment plan calls for a minimum separation of six channels between any two stations in one locality, there is ample opportunity to choose a fundamental frequency that will move a harmonic out of range of a local TV frequency.

TABLE 16-I

Harmonic Relationship – Amateur VHF Bands and UHF TV Channels

Amateur Band	*Harmonic*	*Fundamental Freq. Range*	*Channel Affected*
144 MHz	4th	144.0–144.5	31
		144.5–146.0	32
		146.0–147.5	33
		147.5–148.0	34
	5th	144.0–144.4	55
		144.4–145.6	56
		145.6–146.8	57
		146.8–148.0	58
	6th	144.0–144.33	79
		144.33–145.33	80
		145.33–147.33	81
		147.33–148.0	82
220 MHz	3rd	220–220.67	45
		220.67–222.67	46
		222.67–224.67	47
		224.67–225	48
	4th	220–221	82
		221–222.5	83
420 MHz	2nd	420–421	75
		421–424	76
		424–427	77
		427–430	78
		430–433	79
		433–436	80

COLOR TELEVISION

The color TV signal includes a subcarrier spaced 3.58 MHz from the regular picture carrier (or 4.83 MHz from the low edge of the channel) for transmitting the color information. Harmonics which fall in the color subcarrier region can be epected to cause break-up of color in the received picture. This modifies the chart of Fig. 16-2 to introduce another "severe" region centering around 4.8 MHz measured from the low-frequency edge of the channel. Hence with color television reception there is less opportunity to avoid harmonic interference by choice of operating frequency. In other respects the problem of eliminating interference is the same as with black-and-white television.

INTERFERENCE FROM TV RECEIVERS

The TV picture tube is swept horizontally by the electron beam 15,750 times per second, using a wave shape that has very high harmonic content. The harmonics are of appreciable amplitude even at frequencies as high as 30 MHz, and when radiated from the receiver can cause considerable interference to reception in the amateur bands. While measures to suppress radiation of this nature are required by FCC in current receivers, many older sets have had no such treatment. The interference takes the form of rather unstable, ac-modulated signals spaced at intervals of 15.75 kHz.

Studies have shown that the radiation takes place principally in three ways, in order of their importance: (1) from the ac line, through stray coupling to sweep circuits; (2) from the antenna system, through similar coupling; (3) directly from the picture tube and sweep-circuit wiring. Line radiation often can be reduced by bypassing the ac line cord to the chassis at the point of entry, although this is not completely effective in all cases since the coupling may take place outside the chassis beyond the point where the bypassing is done. Radiation from the antenna is usually suppressed by installing a high-pass filter on the receiver. The direct radiation requires shielding of high-potential leads and, in some receivers, additional bypassing in the sweep circuit; in severe cases, it may be necessary to line the cabinet with screening or similar shielding material.

Incidental radiation of this type from TV and broadcast receivers, when of sufficient intensity to cause serious interference to other radio services (such as amateur), is covered by Part 15 of the FCC rules. When such interference is caused, the user of the receiver is obligated to take steps to eliminate it. The owner of an offending receiver should be advised to contact the source from which the receiver was purchased for appropriate modification of the receiving installation. TV receiver dealers can obtain the necessary information from the set manufacturer.

It is usually possible to reduce interference very considerably, without modifying the TV receiver, simply by having a good amateur-band receiving installation. The principles are the same as those used in reducing "hash" and other noise – use a good antenna, such as the transmitting antenna, for reception; install it as far as possible from ac circuits; use a good feeder system such as a properly balanced two-wire line or coax with the outer conductor grounded; use coax input to the receiver, with a matching circuit if necessary; and check the receiver to make sure that it does not pick up signals or noise with the antenna disconnected.

HI-FI INTERFERENCE

Since the introduction of stereo and high-fidelity receivers, interference to this type of home-entertainment device has become a severe problem for amateurs. Aside from placing the amateur antenna as far as possible from any hi-fi installation, there is little else that can be done at the amateur's ham shack. Most of the hi-fi gear now being sold has little or no filtering to prevent rf interference. In other words, corrective measures must be done at hi-fi installation.

Hi-Fi Gear

Hi-fi gear can consist of a simple amplifier, with record or tape inputs, and speakers. The more elaborate installations may have a tape deck, record player, fm and a-m tuners, an amplifier, and two or more speakers. These units are usually connected together by means of shielded leads, and in most cases the speakers are positioned some distance from the amplifier, via long leads. When such a setup is operated near an amateur station, say within a few hundred feet, there are two important paths through which rf energy can reach the hi-fi installation to cause interference.

Step number one is to try to determine how the interference is getting into the hi-fi unit. If the volume control has no effect on the level of interference or very slight effect, the audio rectification of the amateur signal is taking place past the volume control, or on the output end of the amplifier. This is by far the most common type. It usually means that the amateur signal is being picked up on the speaker leads, or possibly on the ac line, and is then being fed back into the amplifier.

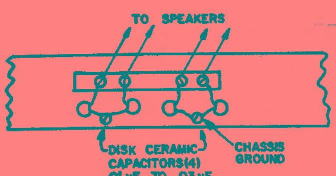


Fig. 16-23 — The disk capacitors should be mountad directly between the speaker terminals and chassis ground, keeping the leads as short as possible.

Experience has shown that most of the rf gets into the audio system via the speaker leads or the ac line, mostly the speaker leads. The amateur may find that on testing, the interference will only show up on one or two bands, or all of them. In hi-fi installations speakers are sometimes set up quite some distance from the amplifier. If the speaker leads happen to be resonant near an amateur band in use, there is likely to be an interference problem. The speaker lead will act as a resonant antenna and pick up the rf. One easy cure is to bypass the speaker terminals at the amplifier chassis. Use .01- to .03-μF disk capacitors from the speaker terminals directly to chassis ground; see Fig 16-23. Try .01 μF and see if that does the job. In some amplifiers .03 μF are required to eliminate the rf. Be sure to install bypasses on *all* the speaker terminals. In some instances, it may appear that one of each of the individual speaker terminals is grounded to the chassis. However, some amplifiers have the speaker leads above ground on the low side, for feedback purposes. If you have a circuit diagram of the amplifier you can check, but in the absence of a diagram, bypass all the terminals. If you can get into the amplifier, you can use the system shown in Fig. 16-24A.

In this system, two rf chokes are installed in series with the speaker leads from the output

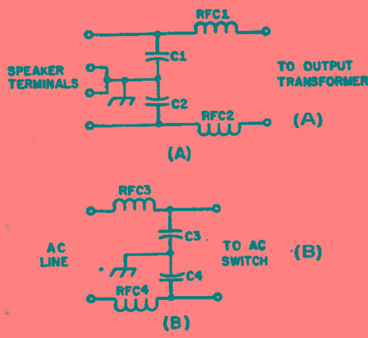


Fig. 16-24 — At A, the method for additional speaker filter, and at B, filtering the ac-line input. In both cases, these installations should be made directly inside the amplifier chassis, keeping the leads as short as possible.
C1,C2 — .01-to .03-μF disk ceramic.
C3, C4 — .01 disk ceramic, ac type.
RFC1 through RFC4 — 24 turns No. 18 enamel-covered wire, close-spaced and wound on a 1/4-inch diametar form (such es a pencil).

transformers, or amplifier output, to the speakers. These chokes are simple to make and help keep rf out of the amplifier. In particularly stubborn cases, shielded wire can be used for the speaker leads, grounding the shields at the amplifier chassis, and still using the bypasses on the terminals. When grounding, all chassis used in the hi-fi installation should be bonded together and connected to a good earth ground (such as a water pipe) if at all possible. It has been found that grounding sometimes eliminates the interference. On the other hand, don't be discouraged if grounding doesn't appear to help. Even with the bypassing and filtering grounding may make the difference.

Fig. 16-24B shows the method for filtering the ac line at the input of the amplifier chassis. The choke dimensions are the same as those given in Fig. 16-24A. Be sure that the bypasses are rated for ac because the dc types have been known to short out.

Antenna Pickup

If the hi-fi setup includes an fm installation, and many of them do, there is the possibility of rf getting into the audio equipment by way of the fm antenna. Chances for this method of entry are very good and precautions should be taken here to prevent the rf from getting to the equipment. A TV-type high-pass filter can prove effective in some cases.

Turntables and Tape Decks

In the more elaborate hi-fi setups, there may be several assemblies connected together by means of patch cords. It is a good idea when checking for RFI to disconnect the units, one at a time, observing any changes in the interference. Not only disconnect the patch cords connecting the pieces together, but also unplug the ac line cord for each item as you make the test. This will help you determine which section is the culprit.

Patch cords are usually, *but not always,* made of shielded cable. The lines *should* be shielded, which brings up another point. Many commercially available patch cords have poor shields. Some have wire spirally wrapped around the insulation, covering the main lead, rather than braid. This method provides poor shielding and could be the reason for RFI problems.

Record-player tone-arm connections to the cartridge are usually made with small clips. The existence of a loose clip, particularly if oxidation is present, offers an excellent invitation to RFI. Also, the leads from the cartridge and those to the amplifier are sometimes resonant at vhf, providing an excellent receiving antenna for rf. One cure for unwanted rf pickup is to install ferrite beads, one on each cartridge lead. Check all patch-cord connections for looseness or poor solder joints. Inferior connections can cause rectification and subsequent RFI.

Tape decks should be treated the same as turntables. Loose connections and bad solder joints all can cause trouble. Ferrite beads can be slipped over the leads to the recording and play-back pickup heads. Bypassing of the tone-arm or pickup-head leads is also effective, but sometimes it is difficult to install capacitors in the small area available. Disk capacitors (.001μF) should be used as close to the cartridge or pickup head as possible. Keep the capacitor leads as short as possible.

Preamplifiers

There are usually one or more preamplifiers used in a hi-fi amplifier. The inputs to these stages can be very susceptible to RFI. Fig. 16-24 illustrates a typical preamplifier circuit. In this case the leads to the bases of the transistors are treated for RFI with ferrite beads by the addition of RFC2 and RFC4. This is a very effective method for stopping RFI when vhf energy is the source of the trouble.

Within the circuit of a solid-state audio system, a common offender can be the emitter-base junction of a transistor. This junction operates as a forward-biased diode, with the bias set so that a change of base current with signal will produce a linear but amplified change in collector current. Should rf energy reach the junction, the bias could increase, causing nonlinear amplification and distortion as the result. If the rf level is high it can

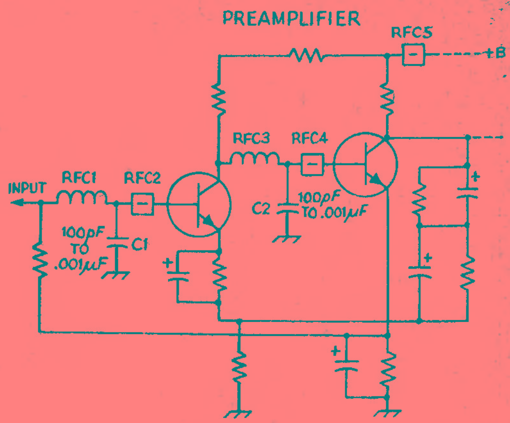


Fig. 16-25 — Typical circuit of a solid-state preamplifier.

completely block (saturate) a transistor, causing a complete loss of gain. Therefore, it may be necessary to reduce the transmitter power output in order to pinpoint the particular transistor stage that is affected.

In addition to adding ferrite beads it may be necessary to bypass the base of the transistor to chassis ground, C1 and C2, Fig. 16-25. A suitable value is 100 pF, and keep the leads short! As a general rule, the capacitor value should be as large as possible without degrading the high-frequency response of the amplifier. Values up to .001μF can be used. In severe cases, a series inductor (RFC1 and RFC3) may be required, Ohmite Z-50 or Z-144, or their equivalents (7 and 1.8 μH respectively). Fig. 16-25 shows the correct placement for an inductor, bypass capacitor, and ferrite bead. Also, it might help to use a ferrite bead in the plus-B lead to the preamplifier stages (RFC5 in Fig. 16-25). Keep in mind that Fig. 16-25 represents only one preamplifier of a stereo set. *Both* channels may require treatment.

FM Tuners

There is often an fm tuner used in a hi-fi installation. Much of the interference to tuners is caused by fundamental overloading of the first stage (or stages) of the tuner, effected by the amateur's signal. The cure is the installation of a high-pass filter, the same type used for TVI. The filter should be installed as close as possible to the antenna input of the tuner. The high-pass filter will attenuate the amateur *fundamental* signal, thus preventing overloading of the front end.

Shielding

Lack of shielding on the various components in a hi-fi installation can permit rf to get into the equipment. Many units have no bottom plates, or are installed in plastic cases. One easy method of providing shielding is to use aluminum foil. Make sure the foil doesn't short circuit the components, and connect it to chassis ground.

INTERFERENCE WITH STANDARD BROADCASTING

Interference with a-m broadcasting usually falls into one or more rather well-defined categories. An understanding of the general types of interference will avoid much cut-and-try in finding a cure.

Transmitter Defects

Out-of-band radiation is something that must be cured at the transmitter. Parasitic oscillations are a frequently unsuspected source of such radiations, and no transmitter can be considered satisfactory until it has been thoroughly checked for both low- and high-frequency parasitics. Very often parasitics show up only as transients, causing key clicks in cw transmitters and "splashes" or "burps" on modulation peaks in a-m transmitters. Methods for detecting and eliminating parasitics are discussed in the transmitter chapter.

In cw transmitters the sharp make and break that occurs with unfiltered keying causes transients that, in theory, contain frequency components through the entire radio spectrum. Practically, they are often strong enough in the immediate vicinity of the transmitter to cause serious interference to broadcast reception. Key clicks can be eliminated by the methods detailed in the chapter on keying.

BCI is frequently made worse by radiation from the power wiring or the rf transmission line. This is because the signal causing the interference, in such cases, is radiated from wiring that is nearer the broadcast receiver than the antenna itself. Much depends on the method used to couple the transmitter to the antenna, a subject that is discussed in the chapters on transmission lines and antennas. If it is at all possible the antenna itself should be placed so that it is not in close proximity to house wiring, telephone and power lines, and similar conductors.

The BC Set

Most present day receivers use solid-state active components, rather than tubes. A large number of the receivers in use are battery powered. This is to the amateur's advantage because much of the bc interference an amateur encounters is because of ac line pickup. In the case where the bc receiver is powered from the ac line, whether using tube or solid-stage components, the amount of rf pickup must be reduced or eliminated. A line filter such as is shown in Fig. 16-22 often will help accomplish this. The values used for the coils and capacitors are in general not critical. The effectiveness of the filter may depend considerably on the ground connection used, and it is advisable to use a short ground lead to a cold-water pipe if at all possible. The line cord from the set should be bunched up, to minimize the possibility of pick-up on the cord. It may be necessary to install the filter inside the receiver, so that the filter is connected between the line cord and the set wiring, in order to get satisfactory operation.

Cross-Modulation

With phone transmitters, there are occasionally cases where the voice is heard whenever the broadcast receiver is tuned to a bc station, but there is no interference when tuning between stations. This is cross-modulation, a result of rectification in one of the early stages of the receiver. Receivers that are susceptible to this trouble usually also get a similar type of interference from regular broadcasting if there is a strong local bc station and the receiver is tuned to some *other* station.

The remedy for cross modulation in the receiver is the same as for images and oscillator-harmonic response – reduce the strength of the amateur signal at the receiver by means of a line filter.

The trouble is not always in the receiver, since cross modulation can occur in any nearby rectifying circuit – such as a poor contact in water or steam piping, gutter pipes, and other conductors in the strong field of the transmitting antenna – external to both receiver and transmitter. Locating the cause may be difficult, and is best attempted with a battery-operated portable broadcast receiver used as a "probe" to find the spot where the interference is most intense. When such a spot is located, inspection of the metal structures in the vicinity should indicate the cause. The remedy is to make a good electrical bond between the two conductors having the poor contact.

Handling BCI Cases

Assuming that your transmitter has been checked and found to be free from spurious radiations, get another amateur to operate your station, if possible, while you make the actual check on the interference yourself. The following procedure should be used.

Tune the receiver through the broadcast band, to see whether the interference tunes like a regular bc station. If so, image or oscillator-harmonic response is the cause. If there is interference only when a bc station is tuned in, but not between stations, the cause is cross modulation. If the interference is heard at all settings of the tuning dial, the trouble is pickup in the audio circuits. In the latter case, the receiver's volume control may or may not affect the strength of the interference, depending on the means by which your signal is being rectified.

Having identified the cause, explain it to the set owner. It is a good idea to have a line filter with you, equipped with enough cord to replace the set's line cord, so it can be tried then and there. If it does not eliminate the interference, explain to the set owner that there is nothing further that can be done without modifying the receiver. Recommend that the work be done by a competent service technician, and offer to advise the service man on the cause and remedy. Don't offer to work on the set yourself, but if you are asked to do so use your own judgment about complying; set owners sometimes complain about the overall performance of the receiver afterward, often without justification. If you work on it, take it to your station so the effect of changes you make can be seen. Return the receiver promptly when you have finished.

MISCELLANEOUS TYPE OF INTERFERENCE

The operation of amateur phone transmitters occasionally results in interference on telephone lines and in audio amplifiers used in public-address work, plus other audio devices. The cause is rectification of the signal in an audio circuit.

Organs

An RFI problem area is the electronic organ. All of the techniques outlined for hi-fi gear hold true in getting rid of RFI in an organ. Two points should be checked – the speaker leads and the ac line. Many organ manufacturers have special servicemen's guides for taking care of RFI. However, to get this information you or the organ owner must contact the manufacturer, not the dealer or distributor. Don't accept the statement from a dealer or serviceman that there is nothing that can be done about the interference.

P-A Systems

The cure for RFI in p-a systems is almost the same as that for hi-fi gear. The one thing to watch for is rf on the leads that connect the various stations in a p-a system together. These leads should be treated the same as speaker *leads* and bypassing and filtering should be done at *both* ends of the lines. Also, watch for ac-line pickup of rf.

Telephone Interference

Telephone interference may be cured by connecting a bypass capacitor (about .001 μF) across the microphone unit in the telephone handset. The telephone companies have capacitors for this purpose. When such a case occurs, get in touch with the repair department of the phone company, giving the particulars. Section 500-150-100 of the Bell System Practices *Plant Series* gives detailed instructions. This section discusses causes and cures of telephone interference from radio signals. It points out that interference can come from corroded connections, unterminated loops, and other sources. It correctly points out that that rf can be picked up on the drop wire coming into the house, and also on the wiring within the house, but (usually) the detection of the rf occurs inside the phone. The detection usually takes place at the varistors in the compensation networks, and/or at the receiver noise suppressor and the carbon microphone. But interference suppression should be handled two ways: prevent the rf from getting to the phone, and prevent it from being rectified.

The telephone companies (Bell System) have two devices for this purpose. The first is a 40BA capacitor, which is installed at the service entrance protector, and the second is the 1542A inductor, which is installed at the connector block. According to the practices manual, the 40BA bypasses rf picked up on the drop wire coming into the house from the phone, and the 1542A suppresses rf picked up on the inside wiring. These are mentioned because in very stubborn cases they may be necessary. But first, it is suggested that the telephones be modified.

Since there are several different series of phones, they will be discussed separately:

500 series – These are the desk and wall phones most commonly in use. They come in several different configurations, but all use a 425-series compensation network. The letter designation can be A, B, C, D, E, F, G, or K, and all these networks contain varistors. The network should be replaced with a 425J, in which the varistors are replaced by resistors. Also, .01-μF disk-ceramic capacitors should be placed across the receiver suppressor. The suppressor is a diode across the receiver terminals. The carbon microphone in the handset should be bypassed with a .01-μF ceramic capacitor.

Series 1500, 1600, 1700 – These are the "Touch-Tone" phones, and the cure is similar to that for the 500 series, except that the network is a 4010B or D, and should be replaced with a 4010E.

Trimline series – These are the "Princess" series phones. The practice manual says that these should be modified by installing bypass capacitors across *all* components in the set that may act as demodulators. This statement is rather vague, but evidently a solution is known to the telephone company for these sets.

At the end of section 500-150-100 is an ordering guide for special components and sets, as follows:

Ordering Guide:
Capacitor, 40BA
Inductor, 1542A
-49 Gray, -50 Ivory
Set, Telephone, -rf Modified
Set, Telephone Hand, 220A, -rf Modified
Set, Telephone Hand, 2220B, -rf Modified
Set, Hand G, -rf Modified
Dial, – (Touch-Tone dial only) -rf Modified.

The type "G" Handset is the one used with the 500 and Touch-Tone series phones. Also, Mountain Bell has put out an "Addendum 500-150-100MS, Issue A, January 1971" to the practices manual, which states that items for rf modified phones should be ordered on nonstock Form 3218, as follows:

(Telephone Set type)
Modified for BSP 500-150-100
for Radio Signal Suppression

The FCC

The Field Engineering Bureau of the FCC has a bulletin that will be of help to the amateur in cases involving RFI to audio devices. These bulletins are available from any of the field offices. The bulletin is addressed to the users of hi-fi, record players, public-address systems, and telephones. It clearly spells out the problem and the obligation of the owner of such gear.

It is suggested that the amateur obtain copies of this bulletin, which is listed as *Attachment III, Bulletin, Interference to Audio Devices.* When the amateur receives a complaint he can provide the complainer with a copy of the bulletin. This approach will help put the problem in correct perspective.

Chapter 17

Test Equipment and Measurements

Measurement and testing seemingly go hand in hand, but it is useful to make a distinction between "measuring" and "test" equipment. The former is commonly considered to be capable of giving a meaningful quantitative result. For the latter a simple indication of "satisfactory" or "unsatisfactory" may suffice; in any event, the accurate calibration associated with real measuring equipment is seldom necessary, for simple test apparatus.

Certain items of measuring equipment that are useful to amateurs are readily available in kit form, at prices that represent a genuine saving over the cost of identical parts. Included are volt-ohm-milliammeter combinations, vacuum-tube and transistor voltmeters, oscilloscopes, and the like. The coordination of electrical and mechanical design, components, and appearance make it far preferable to purchase such equipment than to attempt to build one's own.

However, some test gear is either not available or can easily be built. This chapter considers the principles of the more useful types of measuring equipment and concludes with the descriptions of several pieces that not only can be built satisfactorily at home but which will facilitate the operation of the amateur station.

THE DIRECT-CURRENT INSTRUMENT

In measuring instruments and test equipment suitable for amateur purposes the ultimate "readout" is generally based on a measurement of direct current. A meter for measuring dc uses electromagnetic means to deflect a pointer over a calibrated scale in proportion to the current flowing through the instrument.

In the D'Arsonval type a coil of wire, to which the pointer is attached, is pivoted between the poles of a permanent magnet, and when current flows through the coil it sets up a magnetic field that interacts with the field of the magnet to cause the coil to turn. The design of the instrument is usually such as to make the pointer deflection directly proportional to the current.

A less expensive type of instrument is the moving-vane type, in which a pivoted soft-iron vane is pulled into a coil of wire by the magnetic field set up when current flows through the coil. The farther the vane extends into the coil the greater the magnetic pull on it, for a given change in current, so this type of instrument does not have "linear" deflection – the intervals of equal current are crowded together at the low-current end and spread out at the high-current end of the scale.

Current Ranges

The sensitivity of an instrument is usually expressed in terms of the current required for full-scale deflection of the pointer. Although a very wide variety of ranges is available, the meters of interest in amateur work have basic "movements" that will give maximum deflection with currents measured in microamperes or milliamperes. They are called **microammeters** and **milliammeters**, respectively.

Thanks to the relationships between current, voltage, and resistance expressed by Ohm's Law, it becomes possible to use a single low-range instrument – e.g., 1 milliampere or less full-scale pointer deflection – for a variety of direct-current measurements. Through its ability to measure current, the instrument can also be used indirectly to measure voltage. Likewise, a measurement of *both* current and voltage will obviously yield a value of resistance. These measurement functions are often combined in a single instrument – the **volt-ohm-milliammeter** or "VOM", a multirange meter that is one of the most useful pieces of measuring and test equipment an amateur can possess.

Accuracy

The accuracy of a dc meter of the D'Arsonval type is specified by the manufacturer. A common specification is "2 percent of full scale," meaning that a 0-100 microammeter, for example, will be correct to within 2 microamperes at any part of the scale. There are very few cases in amateur work where accuracy greater than this is needed. However, when the instrument is part of a more complex measuring circuit, the design and components of which *all* can cause error, the *overall* accuracy of the complete device is always less.

EXTENDING THE CURRENT RANGE

Because of the way current divides between two resistances in parallel, it is possible to increase the range (more specifically, to decrease the sensitivity) of a dc micro- or milliammeter to any desired extent. The meter itself has an inherent resistance – its **internal resistance** – which determines the full-scale current through it when its rated voltage is applied. (This rated voltage is of the order of a few millivolts.) By connecting an