

# Television Interference

**ITS CAUSES AND CURES**

**FOR THE VIEWER, SERVICEMAN  
AND AMATEUR RADIO OPERATOR**



**PHIL RAND**



# TELEVISION INTERFERENCE HANDBOOK

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# TELEVISION INTERFERENCE

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# CITIZEN'S BAND

## TVI

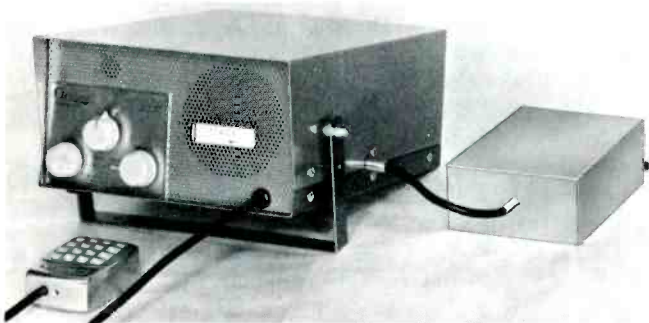
Since the original publication of this handbook, a new type of TVI has appeared, and so, with the printing of the Second Edition, this special chapter on "Citizen's TVI" is being added. This new radio service created by the FCC on 27 Mc. is already becoming very popular and it appears as though citizen stations will far outnumber amateur stations in the near future. In one nearby town where there have been three amateur stations for several years there are now 20 citizen's stations. This new class of station is licensed for only 5 watts of power and therefore the TVI from any one station will not be very widespread. Due to the large numbers of stations TVI will be a problem to nearby TV receivers, particularly TV receivers with a 27 Mc. i.f.

### ● HARMONICS

Television interference from citizen's band transceivers will generally be of two types. The first type is harmonic radiation from the transceiver while the second type is i.f. feed-through of the 27 Mc. signal. Harmonic type of TVI is caused by multiples of the 27 Mc. signal falling right into a TV channel. For example: the second harmonic of 27.125 Mc. is  $2 \times 27.125$ , or 54.250 Mc. This, of course, is right in the lower part of TV Channel 2. The same calculation may be carried out to determine other harmonic frequencies; simply multiply the citizen's band frequency by 2, 3, 4, etc. To find the TV channel that corresponds to these frequencies, refer to the list of TV channel frequencies given in Table 3 on page 54.

A quick approximation of the TV channels that might receive harmonic TVI from a citizen's band transceiver may be had by referring to Fig. 25, page 26. Read down the columns labeled 28 Mc., keeping in mind that 27 is slightly lower than 28, so that the harmonics will also be slightly lower. We see from this table that the 2nd, 3rd, 6th, and 7th harmonics may, if they are allowed to be radiated, cause TVI to TV Channel 2, channels 5 or 6, Channel 7, and channels 9 or 10. Fig. 24, page 25, shows graphically the relationship between the fundamental and the harmonics of a radio signal using the 21 Mc. amateur band as an example. Harmonic type of TVI should only be bothersome in weak TV signal areas and then only on nearby receivers, because of the low power used in citizen's transceivers.

One of the more popular citizen's band transceivers is shown in the photograph below. This is the "Citi-fone"



This shows use of harmonic filter on a typical citizen's band transceiver.

made by Multi-Products Co., Oak Park, Mich. It has five channels and is crystal controlled both on receive and transmit. This unit, like several others tested, caused no TVI when used in a strong TV signal strength area with modern TV receivers. Most citizen's band transceivers, when used in a weak or marginal TV signal strength area, do cause TVI to nearby TV receivers on channels 2, 6, or 9, as pointed out above.

### ● FILTERS

The simplest way to cure this type of TVI is through the use of a low-pass filter in the antenna feed line. Such a filter is shown in the photograph to the right of the transceiver. A suitable circuit for the filter is shown on page 42, Fig. 48. It is suggested that the values in column "A" be used. When building this filter, be sure to use the same type of shielded connectors that are used on the transceiver. In the case of the "Citi-fone", the connector is the same type as that used on Motorola auto radios. Heathkits and several others use a shielded phono type of connector, while still others use the type of coaxial fitting shown in photo 30, page 42, an Amphenol type 83-2R.

Users of citizen's band transceivers have a number of commercial low-pass filters to choose from if they do not wish to build their own. Very excellent filters are made by E. F. Johnson and Co., or Barker and Williamson Inc., however, these are designed for high power and are fairly expensive. A very good reasonably priced commercial filter is made by R. L. Drake Company and is called the TV-100-LP. This filter is so designed that it will attenuate all frequencies from the transmitter above 54 Mc. In this way, your 27 Mc. citizen's band signal is broadcast, while all of your harmonics are kept at home.

### ● WAVE TRAPS

At least one of the commercially available transceivers has built-in TVI precautions in the form of a wave trap. As shown in the diagram, this wave trap is in the antenna circuit between the antenna coil and the antenna connector. This coil and condenser does just what its name implies, it traps the interfering waves before they can get to the antenna. In practice, the wave trap is tuned to the frequency of the TV channel that is being interfered with, channel 2, 6, or 9. The best method is to adjust the con-

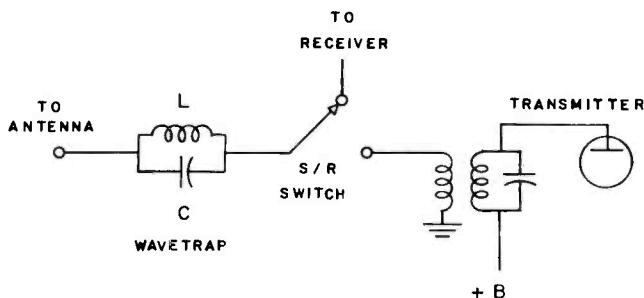


Diagram of a TVI wave trap installed in a citizen's band transceiver.



# CITIZEN'S BAND TVI

denser with an insulated screwdriver while watching the interference on the TV receiver. The correct setting is, of course, the one that gives the least crosshatching of the screen. The disadvantage of using a wave trap is that you can only eliminate the TVI from one TV channel. The low-pass filter described above, although slightly more complicated and more expensive, will protect all TV channels from TVI caused by harmonics from the transmitter. However, if you live in an area where you only have to worry about one channel, such as channel 2 or 6, then perhaps the easiest thing to do is to install a wave trap in your particular transceiver.

As shown in the diagram on page 3, a wave trap can be installed in most transceivers between the antenna jack and the send/receive switch or relay. The condenser, C, should be mounted on an insulated bracket so that its adjusting screw can be reached with an insulated screwdriver through a 1/4 inch hole drilled for the purpose through the chassis. This condenser can be any small variable such as a ceramic or mica trimmer with a range from 9 to 80 uuf. The coil, L, is wound with No. 16 tinned copper wire. It has 7 turns with a diameter of about 7/16 inch. The length of the coil should be about 3/8 inch. For best results, the tuning range of the completed wave trap should be checked with a grid-dip oscillator to be sure that it will cover the range of the TV channel in question. The tuning of the wave trap can be adjusted by squeezing or spreading the turns of the coil. The trap must tune to the frequency of the TV channel.

## ● 27 Mc. i.f. INTERFERENCE

The second type of TVI caused by citizen's band transceivers is called i.f. feed-through. Many TV receivers in use today have what is called 21 to 27 Mc. "intermediate frequency". This is explained in some detail in Chapter 3, pages 14 through 22. Most of the newer TV sets have an i.f. of 41 through 47 Mc., and therefore will not receive 27 Mc. This i.f. or intermediate frequency is a frequency within a TV receiver to which all incoming signals are changed so that they may be further amplified. Any radio signal on the air on either of these two i.f.'s is very apt

to be picked up and amplified along with the TV signal. If this happens, then you have TVI in either the picture of the sound, or both. The front end or tuner of a TV receiver does not have very much selectivity and therefore strong signals from a citizen's band transceiver on 27 Mc. often find their way into the i.f. amplifier of the TV set. Fortunately, some TV sets reject this interference better than others, and so not all sets in a given area will be interfered with. None of the 41 to 47 Mc. i.f. sets will receive this type of TVI, nor will older TV sets that have built-in high-pass filters. See Fig. 10, page 17.

## ● HIGH-PASS FILTERS

This i.f. feed-through type of TVI cannot be cured at the transmitter. The remedy must be applied at the TV receiver because the TVI is caused by a lack of selectivity in the TV receiver. The cure is the installation of a high-pass filter at the antenna terminals of the TV receiver. In stubborn cases it may be necessary to install the high-pass filter right up at the front end of the TV set as shown in the chapter on high-pass filters, Fig. 43, page 39. As shown in Fig. 46, on page 40, a good high-pass filter will pass all TV signals from the antenna through to the TV receiver but will attenuate all signals lower in frequency. Thus 27 Mc., which is lower in frequency than the TV frequencies, will be attenuated to the point that there will be no TVI.

There are several commercial high-pass filters available on the market, but probably one of the best is the R. L. Drake Type TV-300-HP. If you wish to build your own, a simple, yet very effective filter is shown in Fig. 42, page 39. This is constructed on 1/8 inch diameter plastic knitting needles as described on page 40.

In conclusion, remember that the need for a low-pass filter on the transmitter is indicated by TVI to only those TV channels which are harmonically related to the transmitter frequency, while the need for a high-pass filter on the TV receiver is indicated by TVI to all TV channels. Occasionally both types of TVI will be present at the same time, requiring the installation of both filters to cure the interference.

## ACKNOWLEDGEMENTS

The author wishes to express his appreciation and thanks to the editors and publishers of the following publications for their permission to use photographs, diagrams and charts which originally appeared in their publications.

*QST* and the *Radio Amateur's Handbook*, A.R.R.L., 38 LaSalle Road, West Hartford, Conn.: Photos 17, 18, 26, 27, 30, 34; Figures 1, 13, 18, 19, 21, 22, 24-29, 34-36, 38, 40, 41, 44-48, 52-54; Tables VI, VII, VIII; TVI References on page 51 and List of TVI Committees on page 52.

*CQ*, Cowan Publishing Corp., 300 West 43rd St., New York 36, N. Y.: Photo 25.

*Electronics*, McGraw-Hill Publishing Co. Inc., 330 West 42nd St., New York 36, N. Y.: Figure 33; Tables IV and V. *Electrical World*: Figure 55, Table I.

*G-E Ham News*, Electronic Components Division, General Electric, Schenectady 5, N. Y.; Figure 50.

Thanks are due RCA Service Co., Inc., of Camden, New Jersey for their fine co-operation over the years in the preparation of much of the material in this book. They have been especially helpful during the past two years during my investigation of color TVI. Their permission to use the following material from the RCA Institute's

*Lesson 17, Home Study Course*, is greatly appreciated:

Figures 4-11, 14, 17, and 20; Table II.

The author wishes to thank the following Companies for their co-operation in supplying photos for use in this book.

E. F. Johnson Company, Waseca, Minnesota: Photos 20, 21 and 22.

Grallen Electronics, Division of Clegg, Inc., Ridgedale Ave., Morristown, N. J.: Photo 28.

R. L. Drake Co., Miamisburg, Ohio: Photo 29.

Barker and Williamson, 237 Fairfield Ave., Upper Darby, Pa.: Photo 31.

Ace Engineering and Machine Co., Inc., 3644 North Lawrence St., Philadelphia 40, Pa.: Photo 35.

Metal Textile Corp., Roselle, N. J.: Figure 31, 56 and 57.

J.F.D. Electronics Corp., 6101 16th Ave., Brooklyn 4, N. Y.: TV Antenna on Cover.

The author is also grateful to the National Broadcasting Company for permission to use photographs of the NBC color peacock on the cover of this book showing a beautiful color picture first with, and then without, outside interference.

## CHAPTER 1

### SOURCES AND TYPES OF TELEVISION INTERFERENCE

Television Interference can be divided into two general classes or types, that caused by a steady or continuous wave radio frequency signal and that caused by spark or shot type of impulse noise or signal. All interference of the radio frequency type is generally characterized by a more or less steady cross hatch or basket weave pattern on the screen, while that of the impulse type is characterized by many small dashed or dotted lines or streaks that often look like snow in the picture.

#### ● RADIO FREQUENCY (R.F.) TYPE OF TVI

Any generator of radio frequency is a potential source of TVI. Equipment of this type includes:

1. Radio transmitters.
2. Radio receivers.
3. Industrial r.f. heat treating apparatus.
4. Medical diathermy machines.
5. Remote control devices.
6. Signal generators and certain other test equipment.

These six items all have one thing in common, a source of radio frequency power which can cause TVI providing the output or harmonics of the output land on a TV channel or the receiver's intermediate frequency. This output, or radiation of r.f. power, can be either intentional or unintentional. For example, a radio transmitter is designed to radiate as strong a signal as possible while a radio receiver is not supposed to radiate at all. The transmitter however, should be designed in such a way that only the desired fundamental signal is allowed to be radiated while all the harmonics are kept at home. The unintentional radiation of these harmonics and the reception of them by a TV receiver will cause TVI.

Practically all radio receivers to-day, and this includes FM and TV receivers, are of a so-called superhetrodyne type and therefore they must have at least one oscillator included in their circuit in order to function. This oscillator is a generator of r.f. and if it or its harmonics are on a TV channel frequency it will also cause TVI. How bad the TVI is will depend on how poorly shielded the receiver is and how far away it is. It is possible to build non-radiating receivers, but this makes them more expensive.

Industrial r.f. heat treating equipment and diathermy apparatus are both essentially high powered transmitters. They are connected to electrodes for either heating mechanical parts or the human body and any radiation of their signals into space is purely incidental. It is this incidental radiation, though, that causes TVI providing it is on a TV frequency.

Remote control devices usually consist of a short wave transmitter designed to send signals to a radio receiver to control an apparatus. An example might be a radio controlled garage door opener. The transmitter which is in the car is only turned on momentarily when it is desired to open the garage door and very seldom causes TVI. The receiver, on the other hand, must operate continuously and can cause a lot of TVI if its oscillator is on a TV frequency.

Signal generators are radio frequency generators for testing receivers and can, if left connected to an antenna, cause serious interference. There are also many other devices such as r.f. power supplies, germicidal lamps, and old style electric light bulbs that can cause this r.f. type of TVI.

#### ● SPARK TYPE OF TVI

This type of interference differs from the r.f. type in that it is not a continuous wave but rather a series of very short impulses of high amplitude that extend over a wide band of frequencies. Many types of electrical apparatus can cause this type of TVI. Some of the more common types are as follows:

1. Arcing brushes in motors.
2. Sparking contacts in thermostats.
3. Automobile ignition.
4. Oil burner ignition.
5. Defective light bulbs.
6. Static or lightning flashes.
7. Loose electrical connections.
8. Tube noise from the TV receiver itself.

These eight types of TVI may be divided into two general classes. 1) A synchronized pattern, and 2) a random pattern. Any device that is operated from a 60 cycle source such as arcing contacts, ignition spark or motors and generators that have brushes or commutators generally produces the dots and streaks in the picture in bands somewhat similar to diathermy. Devices operated from direct current or devices run at varying speeds will usually produce random patterns on the screen. Examples might be automobile ignition, chattering thermostats, loose connections, atmospheric static, tube noise, etc.

#### ● IDENTIFYING TVI

The easiest and best way to identify the source of TVI is to examine the interference pattern on the screen of the TV receiver. By comparing it with the photos in this handbook it will be possible in many cases to tell right away what it is. For example, the photos on pages 6 and 7 show a few of the types of TVI most frequently encountered.

In some cases only the general type of interference can be identified from the pictures. To make further identification it is necessary to note the time cycle of the TVI as well as the time of day that it occurs.

Recently several severe cases of "interference" were called to the author's attention. This "interference" was on all channels and was on almost continuously from 5 pm until 9 pm. It was reported as diagonal lines, streaks or smears. The solution was apparent when one of the complainants said the "interference" was so bad on the big set that they had to watch the evening programs on the small set in the bed room. A personal visit quickly confirmed my suspicions, there was no TVI, these receivers were losing horizontal sync due to aging tubes and low line voltage during the early evening hours. A slight adjustment to the horizontal speed control restored the picture.



# Chapter 1 — Sources and Types of Television Interference

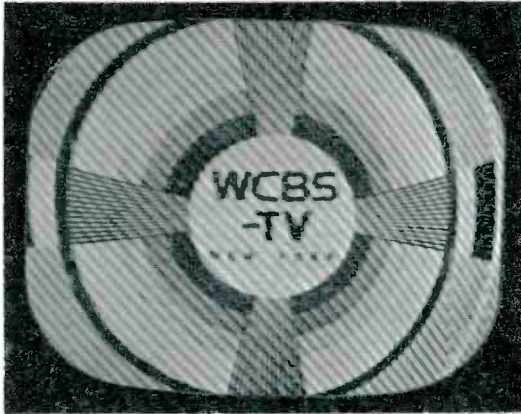


Photo 1 — Mild r.f. interference

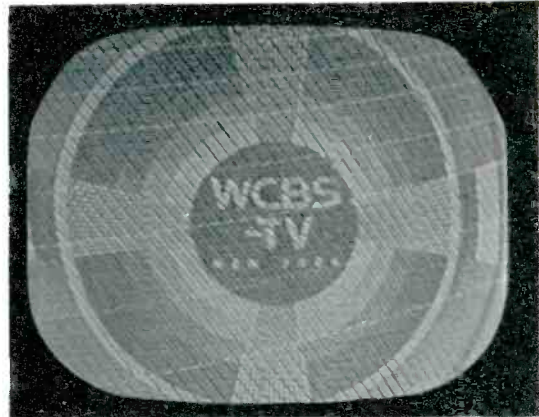


Photo 2 — Strong r.f. interference

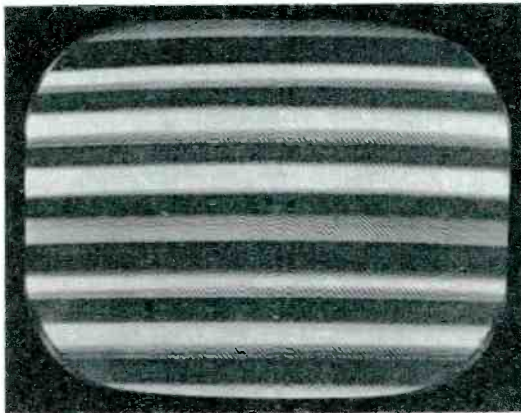


Photo 3 — AM modulation bars

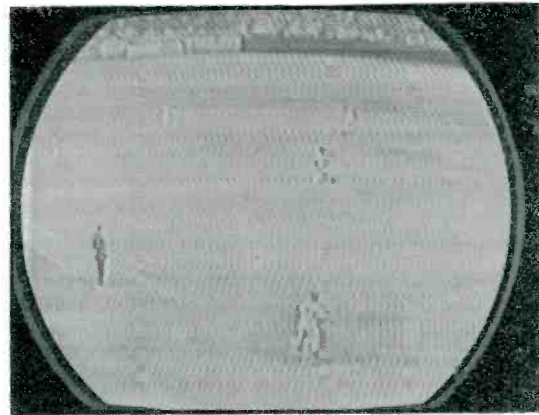


Photo 4 — FM modulation bars



Photo 5 — Old style electric light bulb

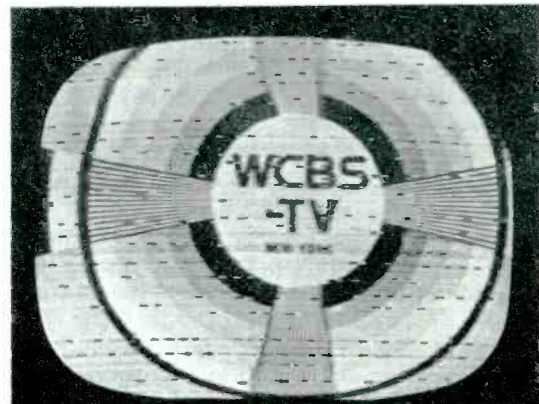


Photo 6 — Spark plug interference

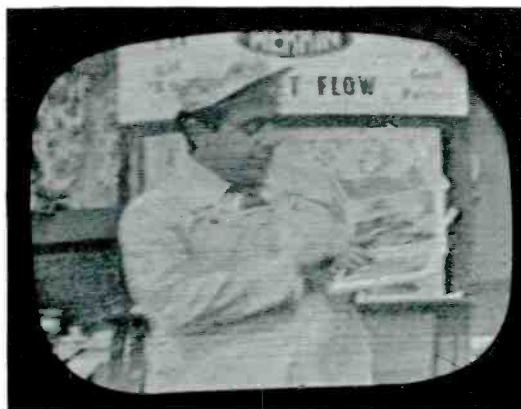


Photo 7 — Mild electrical appliance noise

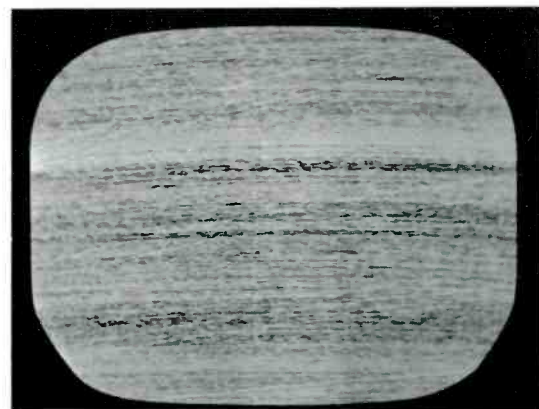


Photo 8 — Strong electrical appliance noise



# Chapter 1 — Sources and Types of Television Interference

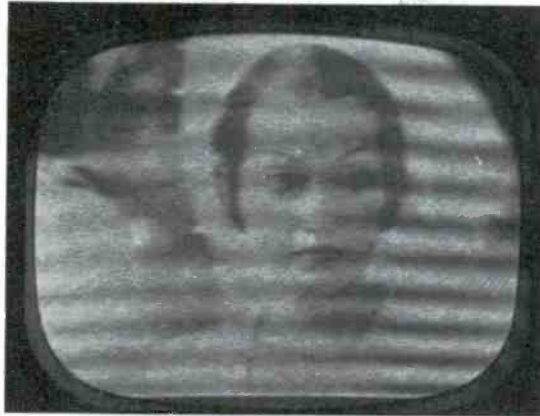


Photo 9 — Mild Venetian-blind effect

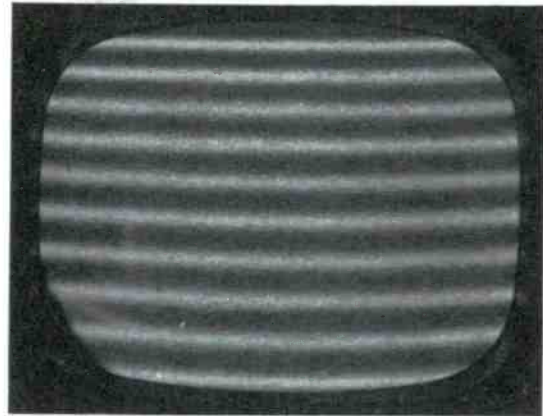


Photo 10 — Strong Venetian-blinds

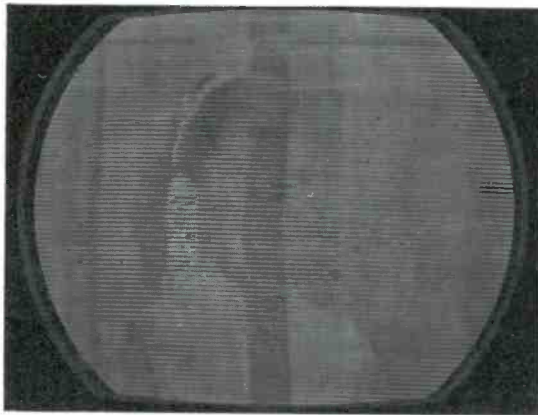


Photo 11 — Venetian-blinds plus windshield-wiper

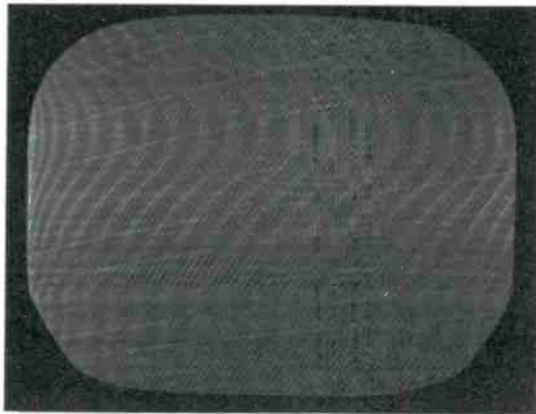


Photo 12 — Front-end overload



Photo 13 — Diathermy or industrial TVI

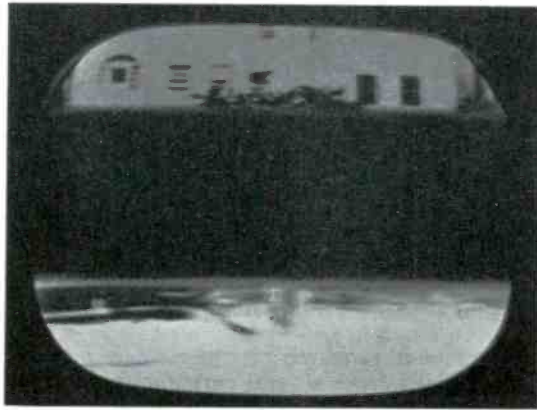


Photo 14 — Strong diathermy

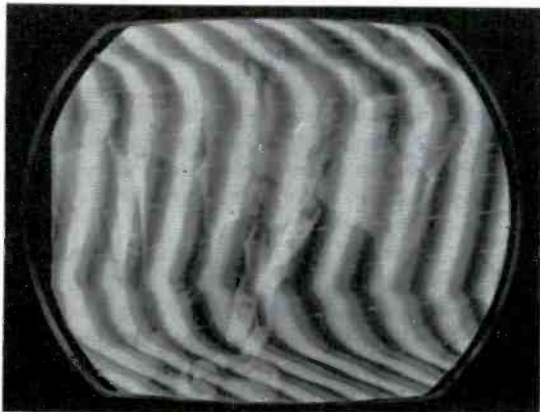


Photo 15 — Color TVI

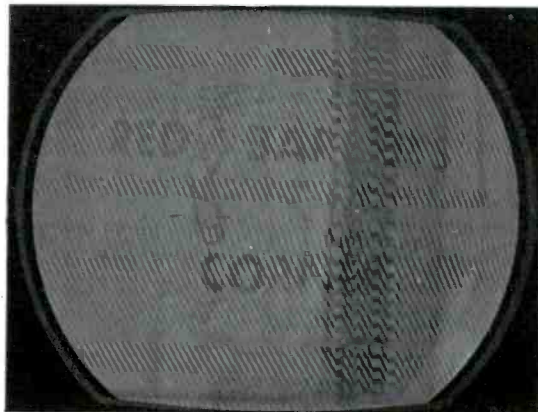


Photo 16 — Adjacent channel interference

## Chapter 1 — Sources and Types of Television Interference

### Photo 1 — Mild R.F. Interference

Here you see the familiar cross-hatched or basket weave pattern of r.f. interference. The lines may be horizontal, vertical, or diagonal depending on the frequency of the beat note that is causing them. You do not actually see the interfering signal in this type of TVI but rather you see the resulting heterodyne or beat note that is produced by the mixing of the TV signal and the interfering signal.

### Photo 2 — Strong R.F. Interference

This is the same type of interference as shown in Photo 1 except that it has overloaded the receiver and has turned the picture to a negative. Interference of the type shown in Photos 1 and 2 generally comes from a stable r.f. source such as a transmitter or another receiver.

### Photo 3 — Modulation Bars

This is what an AM (amplitude modulated) type of TVI looks like on the screen. The horizontal bars flash on and off with the changes of the voice or music. This could be one of several different types of radio transmitters.

### Photo 4 — FM Modulation

When an interfering signal is frequency modulated the beat note will also be frequency modulated and the resultant pattern will look like this. If the TV receiver fine tuning control is misadjusted this could be the sound of the channel you are watching.

### Photo 5 — Old Style Electric Light Bulb

This has most of the characteristics of diathermy except you will note that the bar or bars are very narrow as compared to Photos 11 and 12. The offending light bulb is one of the old fashioned tungsten clear glass bulbs with the sharp tip on the top. It has the zig-zag wire inside mounted on a glass rod. These bulbs can cause a lot of trouble when accidentally left burning for weeks at a time in an attic store room. Usually they affect only channel 4 or 5, but sometimes also 2, 3 or 6. Normally a given bulb will only bother one channel at a time.

### Photo 6 — Spark Plug Interference

Spark interference from cars is usually random because normally it is received from several cars simultaneously, however it can look like an a.c. type when received from a single motor whose RPM is related to 60 cycles. It is very difficult to photograph due to its very short duration and nonrepetitive nature.

### Photo 7 — Electrical Appliance Noise

This is the type of noise that is caused by household appliance motors. Note that the pattern has the appearance of being locked or synchronized and appears in bars or bands much like diathermy except that it is made up of hundreds of tiny dots or streaks instead of lines.

### Photo 8 — Strong Noise

This is the same type of noise that is shown in Photo 7, but is much stronger. It is so strong in fact, that it has completely washed out the picture.

### Photo 9 — Mild Venetian Blind Effect

Co-channel interference is another name for this type of interference. It is caused by two TV stations on the same channel being received at the same time due to unusual receiving conditions. A cold evening after a hot day in the spring or fall will often cause it.

### Photo 10 — Strong Venetian Blind Effect

This is the same as in Photo 9 except that the two TV stations are about the same signal strength.

### Photo 11 — Venetian Blinds plus Windshield Wiper Effect

The Venetian blinds are often very narrow and hardly noticeable or they may be wide like those shown above. When the signal strength of the distant TV station almost equals that of the nearby station, due to unusual receiving conditions, often times both pictures are visible at the same time. One will be locked horizontally and the other will slide back and forth from side to side. The vertical dark bar between pictures looks much like a windshield wiper as shown in the photo.

### Photo 12 — Front End Overload

This photo shows the pattern caused by a very strong r.f. signal close to the TV receiver. This signal is not on the TV channel but is so strong that reception has been ruined on most channels. This type of interference can only be cured at the TV receiver.

### Photo 13 — Diathermy Interference

Interference of this type is characterized by one or two horizontal bars in the picture. The interference is mild in this photo and you can see the bands of crosshatching. Equipment of the diathermy or industrial heat-treating type does not require a pure d.c. voltage on the tubes and therefore the r.f. signal will be modulated with either 60 or 120 cycle a.c. hum depending on whether the power supply has half-wave or full-wave rectification.

### Photo 14 — Strong Diathermy

Here the TVI is caused by a very strong diathermy or industrial heat-treating apparatus and the bars are solid black. The bars remain locked and the picture often rotates when the camera and receiver are on different 60 cycle power sources.

### Photo 15 — Color TVI

To obtain this interference pattern a grid-dip oscillator was carefully tuned to the amateur 6 meter band until a 3.58 Mc. beat note was produced with channel 2 video. The stripes are in bright red, green and blue.

### Photo 16 — Adjacent Channel TVI

The interference in this photo is caused by the beat between the video of one channel and the sound of the adjacent channel on the low frequency side. Note the FM sound bars. The video is also getting through and causing a windshield wiper effect.

**TVI CAUSES**

**AND CURES**

1 Amateur transmitter.	Reduce spurious emission by shielding, filtering and use of a low-pass filter. Install high-pass filter on TV receiver.
2 Arc welders using r.f. to strike arc.	Complete shielding, line filters.
3 Automobile ignition.	Move antenna as far from street as possible — use coax feeder.
4 Aviation transmitter.	Reduce spurious emission. Same as in No. 1.
5 Belt Static.	Bond machines together and to ground. Apply graphite to belt.
6 Blinker lights.	Install filter in controller.
7 Bushings.	Replace.
8 Commutating motors.	Install filter at motor (not at plug end of line cord).
9 Defective door bell transformer.	Replace.
10 Defective neon signs.	Check insulation, replace tubes.
11 Demand meter.	Install condenser filter as close to contact as possible.
12 Diathermy.	Old style sets using arc or self-rectifying oscillators require shielded room and line filter. New Style may require adjustment to eliminate harmonic or other radiation. See No. 1 above.
13 Electric fences.	Replace with newer type.
14 Electric shaver.	Filter should be built into the device (not at plug end of line cord).
15 Fluorescent lights and starters.	Replace.
16 Garage door opener (receiver).	Replace superregenerative receiver by non-radiating type.
17 Garage door opener (transmitter).	Reduce power, shift frequency.
18 Germicidal lamps.	Replace with 60-cycle type.
19 Industrial heaters.	Temporary cure by moving frequency so as not to interfere with local channels. Complete cure involves shielded room and line filters.
20 Insulators, dead-end.	Apply conducting grease to joints. Grease gun can be mounted on hot stick with bakelite shaft extension of screw.
21 Insulators, pin.	Replace.
22 Lightning arrestor.	Replace.
23 Loose antenna connections.	Tighten.
24 Mobile transmitter.	Reduce spurious emission. Same as in No. 1.
25 Oil burner.	Install spark plug suppressor and line filter, bond motor, burner and furnace.
26 Oscillating TV booster.	Separate input and output leads, install shielding, neutralize.
27 Pick-up from another TV receiver.	Provide shielding, improve front end isolation, and use booster to isolate antenna at offending receiver.
28 Pick-up of harmonic of same receiver's i.f.	Install additional shielding or filters to keep video i.f., harmonic radiation, and reentry to a minimum.
29 Power line equipment.	Sketches in Chapter 10 show pole-top equipment assembled in accordance with good engineering practice.
30 Spot welders.	Install filter usually available from manufacturer of machine.
31 Thermostatic devices.	Install condenser filter as close to contacts as possible.
32 Tie wires, insulated.	Clean conductor, use bare tie wire.
33 Traffic lights.	Install filter in controller.
34 Tree contact.	Use heavy insulating sleeve on line wire, trim trees.
35 Tungsten lamps.	Replace.

TABLE I



## CHAPTER 2

# LOCATING AND CURING TV INTERFERENCE

In order to cure TVI it is first necessary to locate the interference producing apparatus and then trace its path into the TV receiver. Many different types and sources of TVI have been discussed in Chapter 1 and at this point you should have a pretty good idea of the cause of the interference. In tracing the path of the TVI into the receiver it will be necessary to have a general understanding of how a TV receiver works. This will be covered in Chapter 3.

There are two methods of locating the source of the TVI once the general type has been established. The first is that of tuning-in the interference on portable direction finding equipment mounted in a car and actually running it down. The second method involves a little mental deduction or detective work. Often times both methods are used in combination.

### ● EQUIPMENT REQUIRED

A station wagon is to be preferred for carrying the miscellaneous receiving equipment as shown in Photo 17, however most any vehicle can be used. For general short wave listening, a tunable converter can be used in conjunction with the regular car broadcast radio. One of the newer all band battery operated short wave receivers that can be operated from the front seat would be even better. This will give a more or less continuous coverage from the broadcast band through the amateur 10 meter band (.55-30 Mc.). To complete the coverage it will be necessary to use a commercial TV signal strength meter, one of the very expensive laboratory type field strength meters or a tunable converter made from a TV receiver front end. The coverage should be continuous from 54 to 216 Mc. although it also would be desirable to be able to listen on 30-54 Mc. This converter should feed into your regular short wave receiver at 21 Mc. and of course, arrangements must be made for a power supply.



Photo 17 — Engineers measuring the signal strength of TVI from a battery of induction heaters just outside of a plastic molding plant.

Noise from the car's ignition system must be silenced by the usual procedures — resistor sparkplugs and bonding of motor to the other metal parts of the car. A spring mounted whip makes a good general purpose antenna for use while underway although at times a loop or a TV beam may be required to determine direction. The receiving equipment should have two meters, one to read the signal strength of radio frequency type interference, and one to read the audio output of the receiver for reading the strength of noise type interference.

One of the most important pieces of test equipment will be one of the newer personal or portable TV receivers. The car should be equipped with a power pack for converting 6 or 12 v. d.c. to 120 v. a.c. for operating this TV receiver.

### ● LOCATING INTERFERENCE

In operating a radio equipped car of the type just described, the first thing to do is to study the interference pattern on the screen of the TV receiver at the complainant's home. Let's assume it looks like that in photos 13 and 14. It could be a doctor's diathermy, an induction heater at a plant, or an old style light bulb. We next determine from the complainant the hours and time cycle of the interference. We find it is on around 10 or 11 am for 20 minutes, it is on between 2 and 3 pm and again between 7 and 8. In the evening it may be on several times for 15 or 20 minutes with short intervals in between the "on" times. This points to a medical diathermy machine as it conforms to doctor's office hours. Heat treating equipment normally follows working hours with one, two or even three shifts, but has an "on" time of from 30 seconds or less to several minutes followed by a short "off" interval for reloading the machine. The interference normally shuts down at meal time and quitting time. The old style light bulb on the other hand would have a completely random "on" time. It might be on for a few minutes while someone looked in the attic or basement or it might be on during the dark evening hours. Sometimes it might be forgotten and left on continuously for a week at a time.

The next thing to do is to see if the interference is on only one channel (harmonic type) or all channels (i.f. type). If it is the latter type try a high-pass filter on the TV receiver. It may be a new FCC approved type diathermy operating on 27 Mc. These effect many of the old 21.9 Mc. TV receivers whose video i.f. has considerable response in the 27 Mc. region. If the high-pass filter does not cure the TVI go out to the car and try to pick up the interference on the mobile equipment. Proceed in all four directions (one at a time) while noting the signal strength of the diathermy. It will get stronger when you get closer. Keep a lookout for a doctor's office, hospital or clinic. If none are found but the interference is strongest in front of a private home, it may be that they have a portable unit for treating a bedridden patient.

When the source of the interference has been located it is necessary to contact the owner or operator of the offending equipment. In many cases the owner may be unaware that his equipment is causing TVI and will be glad to co-operate in making tests. At any rate, he may not know of the FCC Rules, Part 18, that apply to induction heating and diathermy type apparatus so it is well to have a copy of these Rules along with you. (Partially reproduced in Appendix.)



## Chapter 2 — Locating and Curing TV Interference

Other types of interference are run down in the same manner. R.f. types may be read on the signal strength meter but noise or shot type of interference is generally very broad-band and it will be necessary to use the a.f. output meter. Have the a.v.c. in the receiver turned off and keep the meter "on scale" with the r.f. gain control.

In tracking down TVI it is often advantageous to connect your TV field strength meter to rotatable TV antennas in various private homes in the area to take bearings on the interference. It is also a good idea to check several different TV receivers in the neighborhood to see if they all get the same interference on the same channels to be sure that the TVI is not being generated within the TV set itself.

### ● WHAT TVI SOUNDS LIKE

Although many different patterns are formed on the TV screen by various TVI producing devices, very few of these produce any sound in the loud speaker. There are basically three types of sound that are associated with TVI.

#### 1.) Noise

Household appliance motors, a.c./d.c. type, mixers, portable tools, sewing machines, etc., all produce a high speed scream or roar that varies with motor speed. Shavers, oilburners, and defective neon signs produce more of a steady roar while they are on. You can tell the difference by the on and off time cycle. Motor belts produce bursts of static while automobiles produce a steady clicking noise proportional to their speed. Thermostatic devices produce a random clicking or frying noise that may occur at more or less regular intervals. These include such things as household thermostats as well as the thermostatic elements in electric blankets, heating pads, water heaters for tropical fish aquariums, hot water tanks, etc.

Momentary contacts such as in defective fluorescent light starters, traffic and blinker lights, spot welders, electric fences, and even loose TV antenna connections often cause a loud clicking or thumping in the speaker. The exact culprit can often be identified by noting the regularity or repetition rate of the noise.

Noise from power line equipment is not as common on TV as on the longer wavelengths of the broadcast band. If it is encountered it has the same characteristic 60 cycle frying noise that is noticeable on the broadcast band. It may be steady or it may be interrupted as the wind shakes the wires or poles or blows tree branches into the wires. Also it may only occur during wet or windy weather.

The last type of noise that may be heard is atmospheric static or lightning flashes. The static makes the same scratchy noise as on the other radios while the lightning usually just makes a single loud click.

In general, the noise has to be very loud to be heard at all. The TV receiver has an FM detector for its sound channel which normally discriminates against all noise which is AM.

#### 2.) Diathermy

Although diathermy and induction heating apparatus are r.f. devices, they sound different than other r.f. generators in that they use a.c. or unfiltered d.c. on the tubes and therefore have a loud 60 cycle or 120 cycle buzz type of AM — FM modulation. Also their signals are generally

not too stable and may drift from one channel to another as the work load heats up. During this drifting cycle the interfering signal may drift through a sound channel where it will be heard and not seen and then as it disappears from the sound it may appear in the picture as TVI.

The old style tungsten light bulbs produce a somewhat similar sound to diathermy except that they sound a bit more raspy and usually do not drift around. Normally they are only in the picture. Old style germicidal lamps and arc welders that use r.f. to start the arc also fall into this class.

#### 3.) R.F.

Transmitters and receivers normally only bother the picture, but occasionally may be heard in the loud speaker under certain conditions. The receiver oscillator is fairly stable and unmodulated and therefore all you would hear even if this was in the sound channel would be a mushy sounding beat note as the oscillator beats with the FM audio signal of the TV program. The chances that it would be within the audible range and therefore be heard are remote.

A radio transmitter is modulated and will be detected if it is "on frequency" and is strong enough to override the audio part of the program. If you can hear the modulation you can usually identify the station.

There are several methods by which this modulation reaches the loud speaker, cross modulation, front-end overload, audio rectification, direct reception of i.f., etc. These will be taken up in more detail in the chapters on Transmitters and Receivers.

### ● CURING TVI

After having decided the type of device that is causing the TVI and having located the source of the interference, the next step is to cure the trouble. To do this, it is usually necessary to know the frequency of the interference, in this case, a diathermy machine, and to know the path that the interfering signal is taking in entering the TV receiver.

A handy meter to have, and one that is easy to construct is shown in Photo 18. The circuit diagram is given in Figure 1. It is simply an absorption type wave meter with a link coupled 1N34 crystal diode and a 0 to 100 ua. meter. With the plug-in coils in the coil table the frequency range is about .650 Mc. through 170 Mc. Although this meter does not cover TV channels 7 to 13 or the u.h.f. channels, it does cover the frequency range of most interfering devices.

By taking a few readings around a suspected diathermy machine with this meter, you can tell what the fundamental frequency is as well as that of several of the harmonics. You can also tell the relative strength of the harmonics. You may find, for example, that our diathermy machine is operating correctly right in one of the ISM bands. (These are listed in the Appendix in Part 18 of the FCC Rules.) On the other hand, you may be able to measure strong harmonics right on TV channels.

In curing TVI there are two facts that must always be kept in mind:

- 1.) Certain types of TVI can only be cured at the TV receiver because they are due to a fault of the receiver.
- 2.) Certain types of TVI can only be cured at the source of the interference because they are due to a fault in that equipment.

## Chapter 2 — Locating and Curing TV Interference



Photo 18 — This shows the construction of a simple wavemeter with its calibrated plug-in coils.

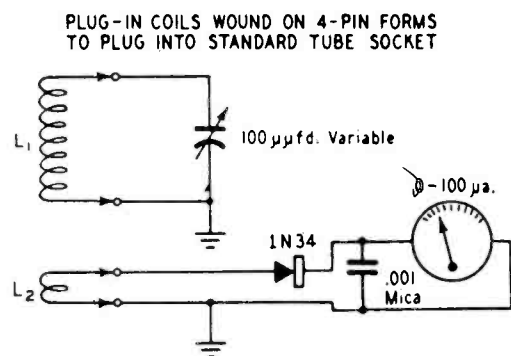


Figure 1 — Circuit diagram of the simple wavemeter. The 0-100  $\mu$ a. meter and crystal detector are link coupled to the tuned circuit. Winding data for the coils follows:

Frequency Range	No. of Turns $L_1$	Wire Size	Dia. of Coil	Length of Coil	No. of Turns $L_2$
60—170 Mc.	3/4	No. 18 En.	1/2"	—	1
40—110 Mc.	2	No. 18 En.	1/2"	1/16"	2
19—55 Mc.	4	No. 18 En.	1"	1/4"	2
7—19 Mc.	15	No. 18 En.	1"	5/8"	3
3.5—8 Mc.	30	No. 18 En.	1 3/8"	1 1/4"	4
1.7—4 Mc.	75	No. 24 En.	1 3/8"	1 5/8"	6
0.650—1.7 Mc.	170	No. 32 En.	1 3/8"	1 1/2"	10

You can work till doom's day in an attempt to cure TVI at the source when it is caused by a fault of the receiver, and visa-versa. The whole question boils down to this: Is the interfering signal actually on the TV channel or is it on some frequency other than the TV channel? If it is on the TV channel then it must be cured at the source. If it is on some frequency other than the TV channel then the TVI must be cured at the receiver.

It is often possible to block the path that the interference is taking on its way from the source to the TV receiver. For example, sometimes the interference follows the a.c. power lines from the radio transmitter or diathermy apparatus to the TV receiver and enters via the back door, so to speak. In this case an a.c. line filter such as shown in Figure 53 on page 47 should be installed on the apparatus generating the interference and a line filter such as shown in Figure 13 on page 19 should be installed in the TV receiver. Thus we have not only blocked the escape route for the interference but also have closed the back door on the TV receiver.

If the interfering signal is being radiated from the source and is being picked up by the TV antenna then it is necessary to first find what metal object is acting as a transmitting antenna for the interference and then to filter the interference out of this metal object. Oftentimes in an industrial installation this metal object that is acting as a transmitting antenna for the interference turns out to be an overhead steam pipe, water pipe or electrical conduit. A pipe 100 feet long makes an antenna just as good, if not better than a 100 foot piece of wire. Long ground wires are to be avoided. Radio transmitters can radiate spurious signals from their antennas as well as from their cabinets. In each of these cases the cure is to prevent the undesired r.f. or spurious signals from reaching a metal object where they can be radiated. This calls for better shielding, bonding, good low inductance grounds and low-pass filters in the transmitting antenna feed lines. A high-pass filter should be installed in the TV receiver antenna feed line to block the entrance of any interference that the TV antenna might pick up.

If we could look at the radio spectrum and actually see each radio signal and the frequency that it was on, it would look something like Figure 2-A. Note that the 82 TV channels occupy 492 of the 1000 Mc., almost half of all the frequencies available up to that point. Figure 2-B shows an expanded view of the first 100 Mc. of Figure 2-A. Starting at the left is the regular broadcast band .55 Mc. to 1.6 Mc. The bands labeled "A" are amateur bands whose frequencies are assigned by international conferences and treaties. Those portions labeled ISM are the places where industrial, scientific and medical apparatus is supposed to be operated.

Note that the amateur six meter band, 50-54 Mc. adjoins channel 2 while marker beacons are between channels 4 and 5, and FM broadcast stations are along side channel 6. In fact, there just is no empty space left in the spectrum.

If we find that our diathermy machine is on its correct frequency then the trouble is probably that the TV receiver uses that frequency for its intermediate frequency amplifiers. If this is so, a high-pass filter will cure the trouble. If we find that the diathermy machine is an old model and is operating right on the TV channel (as some used to do) then the cure is to put the machine in a shielded room or to purchase a newer type. On the other hand the machine may be on the right frequency and the TVI is from harmonics. In this case, shielding, filtering, etc. must be done to the machine.

The actual methods of curing TVI have only been dealt with in a general way because each is covered in detail in other chapters.

### ● TAKING MEASUREMENTS.

In photos 17 and 19 engineers are shown measuring the interfering signals both outside and inside a plastics moulding plant. This is necessary to see if the signal strengths and frequencies are in accordance with FCC part 18 of the Rules. In both of these photos a standard laboratory type of field strength meter is being used. In the left background of photo 19 can be seen the large plastics moulding presses while to the right rear is the culprit, a 2 KW induction heater that is not shielded well enough to prevent TVI. This unit is used to preheat the plastic pellets just prior to placing them in the press. It is only one of a battery of 10 similar units. Needless to say it was necessary to shut them all off and then check them one at a time for interference.

## Chapter 2 — Locating and Curing TV Interference

The general procedure is to first make a rough check on say machine No. 1 using the wavemeter shown in Photo 18 and Figure 1. This will reveal the frequency of the fundamental as well as that of all harmonics that can be found. Next, using this information, measure the frequency and signal strength under fixed conditions using the commercial field strength meter. Keep a written record of all measurements and the conditions under which they were made so that after modifications have been made to the induction heater the reduction of TVI can be measured under the same conditions.

Checks should be made with the TVI complainant to see if this No. 1 machine causes the trouble and if so on which channels. Inspect the machine as to a.c. line filter, shielding, bonding, grounding, etc. and explore around the cracks and joints for r.f. leaks. Always be sure that the regular plastic pellet load is in the machine when making these measurements as the load effects the tuning, frequency, harmonics etc. You should now be in a position to make recommendations for curing the TVI from this No. 1 and can proceed to checking machine No. 2. You may find that only one or two of the battery of 10 are giving trouble.

Operators of radio frequency generating equipment should be reminded that their equipment needs periodic inspection if it is to remain TVI-proof. All joints in the shielding should be checked for tightness. Be sure that

the r.f. weatherstripping or contact fingers on the doors and lids are making a good electrical contact. The a.c. line filter and ground connection should also be inspected.



Photo 19 — Measurements being made at close range. The TVI producing plastic pellet preheater, behind the engineer's left elbow, operated in the 30 to 35 Mc. range and caused TVI with its harmonics.

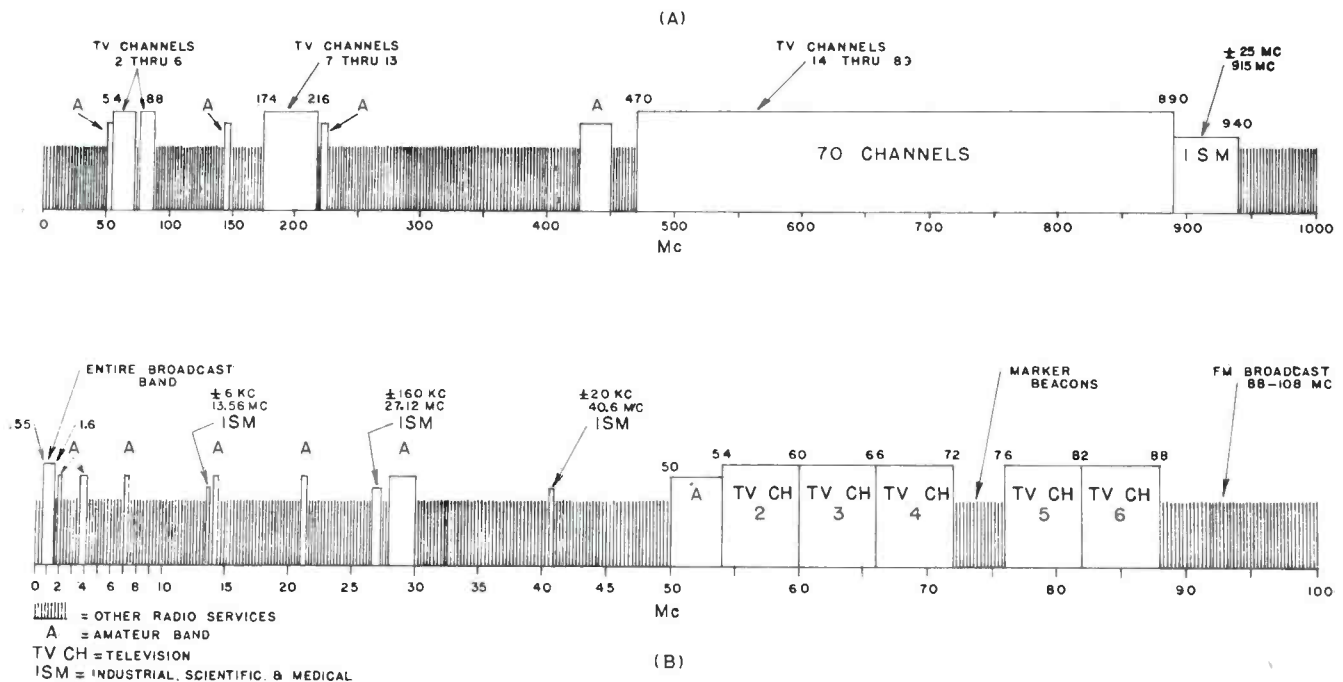


Figure 2 — (A) at the top, shows the entire radio spectrum from 0 - 1000 megacycles while (B) at the bottom shows the first 100 megacycles expanded to give more detail. TV channels are labeled

with their channel numbers. I S M stands for Industrial, Scientific and Medical Services. The segments labeled "A" are amateur bands. All the other radio services are indicated by the fine vertical lines.



## CHAPTER 3

### THE TV RECEIVER

In order to understand television interference it is necessary to understand a few things about the TV receiver and the way in which it receives a signal. For example, a single TV channel is 6 megacycles (6,000,000 cycles) wide, see Figure 3. (For foreign TV standards, see Tables 5, 6 and 7 in the appendix.) This is six times as wide as the entire broadcast band which can hold 100 regular broadcast stations on separate channels. To get all this room, it was necessary to put the television channels in the very short wave region which is called the v.h.f. (very high frequencies). Five 6 Mc. channels were squeezed in between 54 Mc. and 88 Mc., and seven more between 174 Mc. and 216 Mc. The remaining 70 channels, 14 through 83 had to be put in the u.h.f. (ultra high frequencies) from 470 Mc. through 890 Mc. See Figure 2-A and B.

#### ● HOW A TV RECEIVER WORKS

To receive a clear TV picture one must first pick up as much signal and as little noise and interference as

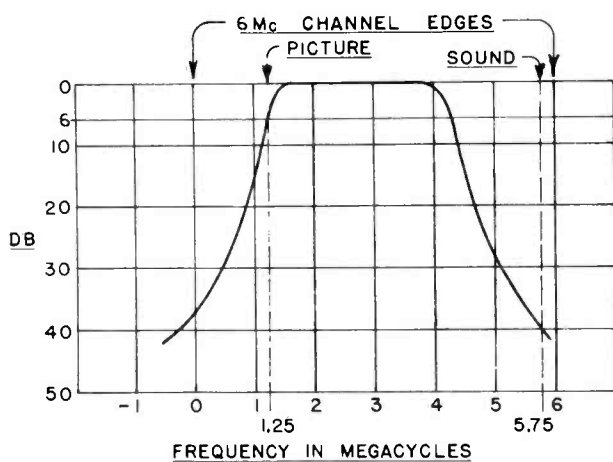


Figure 3 — A typical TV channel. The picture carrier frequency is 1.25 Mc. inside the low end while the sound is 0.25 Mc. inside the high end. The spacing between them therefore is 4.5 Mc.

possible. This means that a good outdoor TV antenna is usually required. After getting as much amplification in the front end of the TV set as possible, it is necessary to change the frequency of the incoming signal to a new lower frequency called the "intermediate frequency" or "i.f.". This is done in order to amplify the signal further and in order to get the necessary selectivity or band-pass. The signals (actually two, both the picture and sound signals are amplified together) are next detected in the detector tube and are separated, the sound going to the loud speaker and the picture or video signal going to the picture tube. The horizontal and vertical synchronizing signals are separated from the video signal and are used to lock-in the picture.

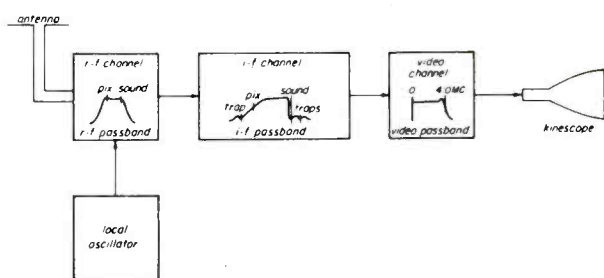


Figure 4 — A simplified "block diagram" of a typical TV receiver showing the passband of the r.f., i.f. and video amplifiers.

When the frequency of the incoming signal is changed to an intermediate frequency, the receiver is called a superheterodyne. It employs a "mixer" tube or circuit to mix two signals together to obtain a third. To do this the TV signal is fed into the mixer tube along with a signal from a local oscillator in the set. When these two signals mix together, they actually produce two new signals, their sum and their difference. In a TV receiver the difference signal is used as the new intermediate frequency. For example, when receiving channel 2 picture signal on 55.25 Mc. the signal is mixed or heterodyned with a local oscillator signal of 81 Mc. This produces two new signals, 81 Mc. plus 55.25 Mc. or 136.25 Mc. and 81 Mc. minus 55.25 Mc. or 25.75 Mc. (the i.f.). The mixer circuit thus contains four different signals not considering the sound signal, harmonics and images. They are 25.75, 55.25, 81, and 136.25 Mc. All oscillators like musical instruments have harmonics, that is, they have other frequencies which are multiples of the main signal. Two times, three times, four times 81 Mc. etc. in our case 162, 243 and 324 Mc. These of course, are not as strong as the 81 Mc but the 2nd harmonic, 162 Mc. will probably mix with the incoming signal to produce plus and minus signals of 217.25 Mc. and 106.75 Mc. We have therefore, three more somewhat weaker signals in the mixer in addition to the original four.

In a superheterodyne type receiver, operating normally and without interference, we have a whole family of signals from which the tuned circuits of the intermediate frequency amplifier must select only one for further amplification. In a TV receiver we have twice as many signals in the mixer stage because we are receiving two signals at once, the picture carrier and the sound carrier. With the wide bandpass characteristics (6 Mc.) that are necessary in a TV receiver it is no small wonder that interference becomes such a problem. With plenty of local oscillator voltage leaking into the r.f. stage, this stage becomes a "first" mixer and beats signals far removed from the r.f. passband either into the r.f. passband or into the i.f. passband. Only a few of the possible combinations have been touched on, more will be discussed a little farther on the book.



## Chapter 3 — The TV Receiver

In order for our intermediate frequency amplifier stages to separate the desired frequencies from all the others present in the mixer stage, the i.f. amplifier must have certain selectivity characteristics. It must have the ability to pass and amplify the desired signals and reject all others. Figure 3 shows a typical overall response curve for a TV receiver. Note how it occupies most all of the 6 Mc. channel.

The various sections of the TV receiver that we have been discussing are shown in the "block" diagram of Figure 4. The bandpass characteristics of each section are shown in the center of each block.

Figure 5 shows approximately how a 21 Mc. i.f. TV receiver tuned to channel 2 responds to various frequencies. Of all the frequencies shown from 0 to 120 Mc., you will note that the receiver has the highest response to channel 2, to which it is tuned. The next best response is to signals within the "Image Band". Remember we said earlier that in a superhetrodyne we converted the incoming signal to the i.f. by addition or subtraction of the local oscillator frequency and the incoming signal. You will see in Figure 5 that the difference in frequency between the local oscillator 81 Mc., and the image band is also 21 Mc. and therefore any signals in the image band will be received simultaneously with the picture on channel 2 and therefore cause TVI. The next strongest response

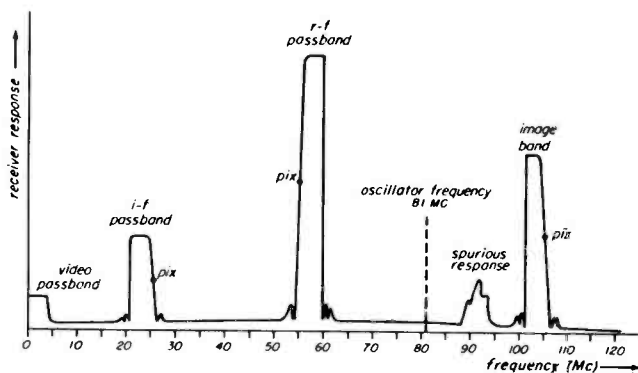


Figure 5 — TV receiver responses from 0 - 120 Mc. as exhibited by most sets with a 21 Mc. i.f.

is that at the i.f. passband. Here you will see that a television receiver is susceptible to receiving interfering signals that are on the intermediate frequency. The weakest response to outside signals are those that are in the video passband 0-4 Mc. as shown at the left of the diagram. The chart does not show the relative responses accurately. It is intended only to provide an indication of the relative ease with which signals in the four passbands can cause interference. In between these main passbands the receiver usually has little response, however, there is often an accidental rise in response at some frequency. This is indicated in the chart as a "spurious response". The frequency of this spurious response would depend on the resonant frequency of some component or circuit wiring or combination of same in the receiver. For example, the wiring in the grid circuit of the first audio stage often has a high impedance to 144 Mc. and therefore any strong 144 Mc. signals in the locality will be detected and fed to the loud speaker if this is the case in your particular receiver.

### ● TVI — CAN BE THE FAULT OF THE RECEIVER

As mentioned previously, some kinds of interference are the fault of the receiver and as such must be cured at the receiver. There are a number of measures that can be taken to cure this type of interference and each will be discussed along with each particular type of TVI.

### ● IMAGE TVI

As shown in Figure 5, the second greatest response of a TV receiver is the image band. Any radio signal falling into this band with sufficient strength will be received by the TV receiver as interference. This is not the fault of the signal but of the method of reception used in a superhetrodyne. It should be remembered that the whole radio spectrum is jam-packed with radio signals of one kind or another and that there are no clear spots where you can place an image band or an i.f. band. The receiver designer must design his receivers so that they will not respond to signals outside of the r.f. passband.

The image band is always twice the intermediate frequency higher than the r.f. passband. The frequency of the image band is different for each TV channel and of course, is different for receivers of different i.f.'s. Figure

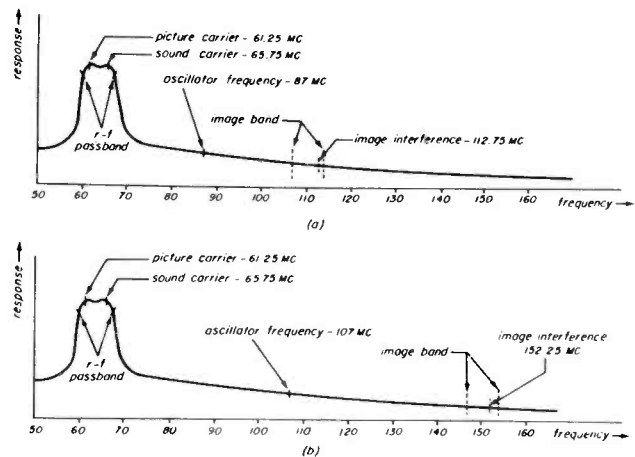


Figure 6 — The r.f. passband and image band for TV receivers with (a) 21 Mc. i.f. and (b) 41 Mc. i.f. Both receivers are tuned to channel 3, 60-66 Mc.

6 shows the r.f. passband and image band for channel 3, 60 to 66 Mc., for two receivers with different i.f.'s. In (a) the receiver's i.f. is 21 Mc., and an interfering signal falling in the image band, 107 to 113 Mc., would be received. In (b) the receiver's i.f. is 41 Mc. so that the oscillator frequency must now be 107 Mc. for channel 3 and the image band is now 147 Mc. to 153 Mc. Note that the receiver's response to the higher image band is less. This is due to the selectivity characteristics of the r.f. tuned circuits. This type of interference does not appear on all channels simultaneously, and in this respect is somewhat like interference that is on the channel.

To identify image interference, adjust the fine tuning control while observing the pattern. If the number of lines in the beat pattern changes as the fine tuning control is adjusted, and if the interference appears on only one channel, then the interfering signal is in the image band.

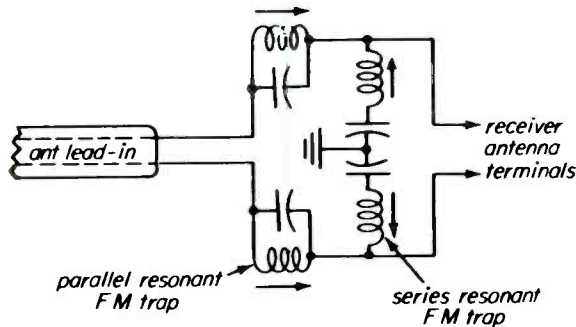
## Chapter 3 — The TV Receiver

To cure this type of interference it is necessary to either re-align the receiver to a new i.f. or to trap out the interfering signal. The latter method is usually used and suitable wave traps are shown in Figure 7. Either the parallel or series tuned type may be used or they may be used in combination as shown to trap out two frequencies. Stubs cut to the proper frequency may also be used. A tuned stub suitable for trapping out an FM broadcast station is shown in Figure 8. In this case the interference would be to channel 2 in a receiver with an i.f. of 21 Mc.

For additional information on image TVI from the two meter band (144-148 Mc.) see Chapter 6.

### ● SIGNAL IMAGE TVI OR DOUBLE CONVERSION

In a superhetrodyne the desired signal is converted to the intermediate frequency by beating it against a local oscillator. The difference in frequency of these two signals is the intermediate frequency and would be received in a normal fashion. An undesirable signal that is separated from the local oscillator by the desired channel frequency would be converted to the channel frequency where it would be again converted, this time to the intermediate frequency, thus giving us TVI.



traps for FM interference from two sources

Figure 7 — Parallel or series tuned wave traps may be used to trap out TVI from a fixed source such as an FM or an amateur station. The coil-condenser combination must be tuned to the frequency which is to be attenuated.

Suppose there is a strong undesired TV signal on channel 8, 181.25 Mc., and suppose the TV receiver has a 45 Mc. i.f. and is tuned to channel 4, 66 to 72 Mc. We note that there is strong interference in the picture on channel 4. The way channel 8 gets into channel 4 is as follows:

The video of channel 8 is ..... 181.25 Mc.  
 The local oscillator when  
 tuned to channel 4 is ..... 113.00 Mc.  
 The difference is ..... 68.25 Mc.  
 This makes a 1 Mc. beat with channel 4 video on 67.25 Mc. and causes TVI to channel 4.

If channel 7 is strong in the area the interference would be as follows:

The sound of channel 7 is ..... 179.75 Mc.  
 Channel 4 local oscillator is ..... 113.00 Mc.  
 The difference is ..... 66.75 Mc.  
 This makes a beat of .5 Mc. with channel 4 video and so channel 7's sound would appear as FM bars in the picture of channel 4.

This phenomenon only happens when the undesired signal is very strong. The mixing action usually takes place in the r.f. stage. The cure is to attenuate the strong signal on the higher channel by means of an equalizer.

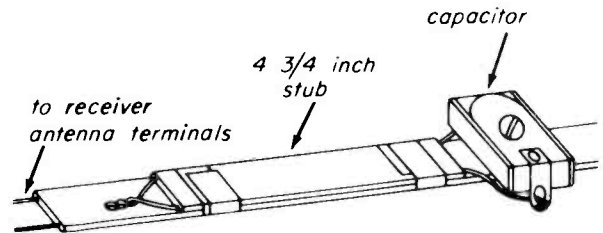


Figure 8 — A stub, made from 300 ohm ribbon  $4\frac{3}{4}$  inches long and tuned by a 3-30 uuf condenser can be attached with Scotch tape to the TV receiver feed line for attenuating FM broadcast stations in the 88 to 108 Mc. range.

### ● EQUALIZERS

These are devices for reducing the signal strength of an unusually strong signal to make it more or less equal to the rest of the channels. In Figure 9 (a) is shown a series resonant trap connected across the feeder with a resistor in series with it. The trap must tune to the frequency of the offending channel and the value of the resistor is varied until the right amount of attenuation is obtained. The parallel traps in (b) are adjusted in a similar fashion. In (c) the  $\frac{1}{4}$  wave stub is cut to resonance at the undesired channel's frequency and then the value of the resistor across the end is varied until the attenuation is correct.

### ● INTERMEDIATE FREQUENCY INTERFERENCE

Radio stations that are operating on frequencies in the i.f. passbands of TV receivers, approximately 21-27 Mc. and 41-47 Mc. are doing so with the full permission of the FCC. Usually they are police, fire, amateur, industrial, medical, etc. It is unfortunate but true that usually a TV receiver located near one of these services will pick up interference from this service. In the FCC rules in the Appendix you will not find that the FCC gives no protection to the TV viewer for this type of receiver deficiency.

In several places in the Rules you will find paragraphs such as this: "... the provisions of paragraph (a) of this section shall not apply in the case of interference to a receiver arising from direct, intermediate frequency pick-up ...".

This type of interference can be identified as i.f. if, when the fine tuning control is adjusted, the beat pattern changes and the interference is on more than one channel — usually on all channels but stronger on the low channels.

The only possible cure for this type of interference is to modify the TV receiver either by shifting the i.f. to avoid the interference or by adding a high-pass filter to the antenna feed line. In severe cases it may be necessary to do both, and also to do some shielding. Figure 10 (a) shows the antenna matching used on some RCA models to attenuate i.f. and FM image interference. Figure 10 (b) shows the cut-off response of the filter. Figure 11

## Chapter 3 — The TV Receiver

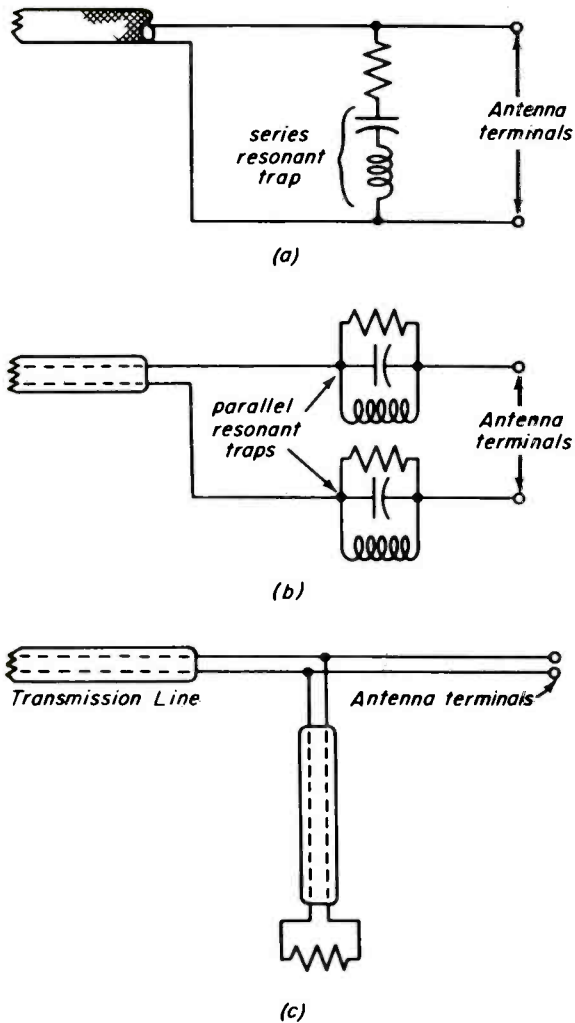


Figure 9 — Equalizers for reducing the signal strength of strong local TV signals to prevent double conversion, cross modulation, etc. are shown in (a) series tuned type, (b) parallel tuned type and (c) stub type.

shows a TV receiver all fitted up with a shielded coax antenna lead-in, an image trap, a high-pass filter, an a.c. line filter, a shielded power cord and a bottom pan under the chassis. Precautions such as these are only needed in extreme cases. Details for changing the i.f. are given in Figure 14 and in Table II.

### ● CROSS-MODULATION

Internal cross-modulation, or front-end overload occurs when an extremely strong radio signal is present in the front-end of the TV set. This may be another TV or FM signal or a signal from another radio service. Cross-modulation may transfer the picture or modulation from the interfering signal onto the desired TV carrier so that both the interfering picture signal and the desired picture appear on the TV screen simultaneously. This type of interference can be identified by the fact that the interference usually appears on all channels and the number of lines in the pattern does not change with fine tuning adjustment.

The cure for internal cross-modulation must be effected at the TV receiver. If the interfering signal is lower in frequency than channel 2, then a high-pass filter is in order. If the offending signal is higher, then a trap, stub or equalizer should be tried.

External cross-modulation occurs when a strong local signal gets rectified by a non-linear detector in the neighborhood such as a rusty connection or corroded joint between two metal objects. This is covered in Chapter 9.

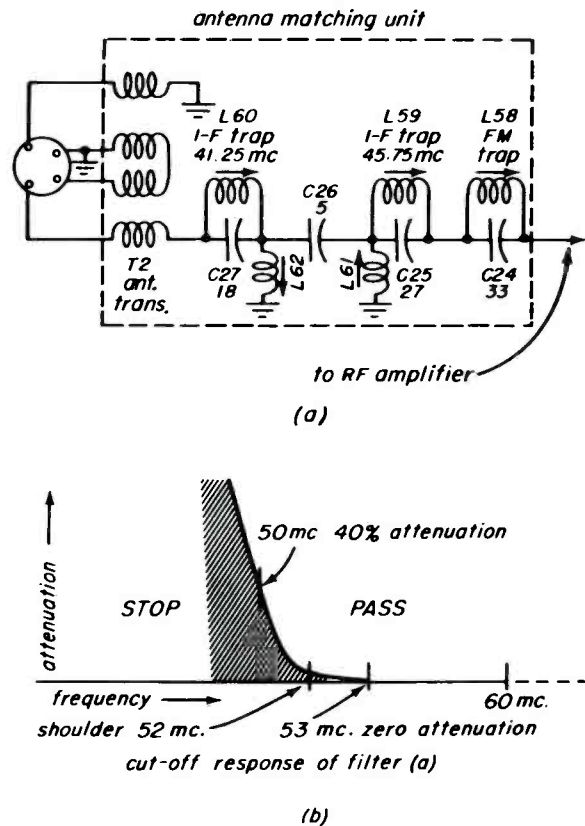


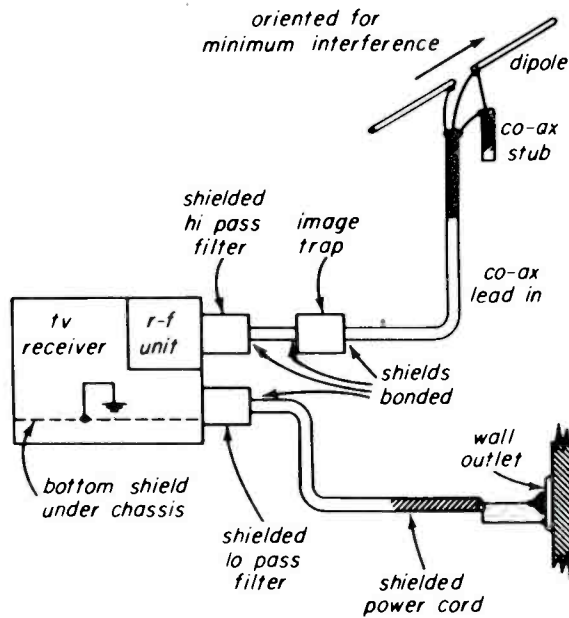
Figure 10 — (a) Antenna matching unit and filter used on some RCA TV receivers with a 41 Mc. i.f. (b) Cut-off response of the circuit shown in (a).

### ● ADJACENT CHANNEL TVI

Generally it is not possible for two TV stations to occupy adjacent channels. Except for channels 4 and 5, 6 and 7, 13 and 14, all other TV channels are adjacent. See Figure 2. In the case of channels 4 and 5 there is a guard channel 4 Mc. wide between them. Channels 6 and 7 are separated by 86 Mc. and 13 and 14 are separated by 254 Mc. Except for the above, adjacent channels are never assigned for use in the same city. This type of interference in primary reception areas therefore, occurs usually between the amateur 6 meter band (50Mc.) and channel 2 or between channels 4 and 5 and airport marker beacon stations in band of 72 to 76 Mc. or between channel 7 and FM broadcast in the 88 to 95 Mc. range. In fringe areas, half way between cities, adjacent channel interference between TV stations will be common.



## Chapter 3 — The TV Receiver



precautions at receiver to minimize interference from nearby transmitter

Figure 11 — The use of all of these TVI reducing measures is only necessary in extreme cases.

The tuned circuits in the r.f. and mixer stages of the TV receiver front-end do not have the necessary selectivity to separate the stations. The picture carrier of one channel beats with the sound carrier of the other channel or visa versa and produces a heterodyne or beat note of the difference in frequency. This would be 1.5 Mc. and would appear in the picture as a 1.5 Mc. pattern with FM modulation when the interference is caused by a TV signal on the next lower channel.

A windshield wiper effect is often caused as illustrated in Photo 16, on page 7, when a higher frequency channel interferes with an adjacent lower channel.

The fine tuning will not effect the number of lines in the pattern but may effect the intensity of the pattern especially when caused by a station one channel higher in frequency.

The cure for this trouble is a stub or wave traps tuned to the offending station to reduce its signal strength to a low enough level to eliminate the pattern. See Fig. 9. Two sets of traps are built into most sets, one for the upper channel and the other for the lower channel. The service man should check the adjustment of these traps before trying other measures.

If the two TV stations are in different directions from the receiver, an antenna of greater directivity equipped with a rotator may solve the problem. The antenna is simply turned to favor the desired station and to reject the interfering station.

### ● AUDIO RECTIFICATION

Often times a considerable amount of r.f. can be fed into the TV receiver from its antenna and although the r.f. circuits are able to reject the off frequency signal so that there is no interference to the picture, enough of the

interfering signal finds its way to the grid of the first audio amplifier tube. Here, if it is strong enough, it will be detected, amplified and fed to the loud speaker. If the volume control has no effect on the volume of the interference this indicates the detection is taking place after the volume control.

The cure for this audio interference is a high-pass filter and/or a slight circuit change in the a.f. stage as shown in Figure 12, a, b or c. If the r.f. pick-up is due to a long unshielded lead to the volume control, shielding this lead may cure the trouble. It is necessary, at any rate, to get rid of the r.f. at the audio tube's grid.

### ● TVI FROM THE SAME RECEIVER

There are four types of interference caused by a receiver to itself.

#### 1.) Harmonics of the Sound I.F. Amplifier

Many radio circuits are capable of generating harmonics. A circuit that detects or rectifies is a good generator of harmonics. The last sound i.f. stage or the FM detector may generate a whole set of harmonics from the 21 or 41 Mc. i.f. signal. In a 21 Mc. TV receiver the third harmonic of its own sound i.f., 3 times 21.25 or 63.75 Mc., lands right in channel 3. The interference looks like the FM pattern shown in Photo 4 on page 6. The fifth harmonic of this same 21 Mc. i.f. lands in the image band of channel 2.

To identify this type of interference it is only necessary to remove the sound i.f. amplifier tube from its socket. If the interference disappears, then it is this type. If not, then it may be adjacent channel or FM image. You can calculate what TV channels are harmonically related to the particular i.f. of the receiver in question and the TVI should only appear on that channel.

To cure this type of TVI it is usually necessary to reduce the radiation of the harmonics at the source by better lead dress in the sound i.f. and better bypassing. Grounds for condensers may have to be found by experiment. Shifting the intermediate frequency a little may often move the harmonic out of the desired channel. The main thing is to prevent signals in the sound detector from reaching the front-end of the set.

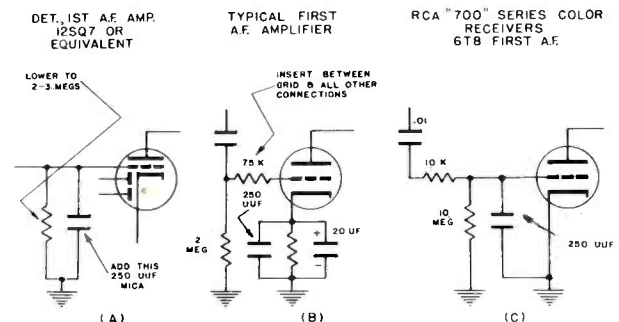


Figure 12 — Three methods of preventing audio rectification in the first a.f. stage of a receiver.



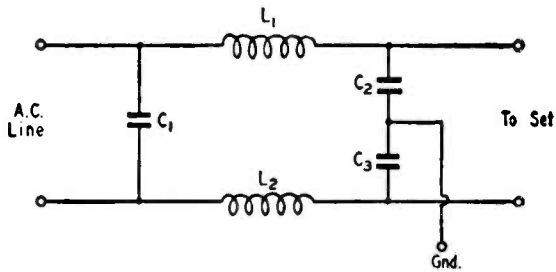


Figure 13 — A.c. line filter for receivers. The values of  $C_1$ ,  $C_2$ , and  $C_3$  are generally not critical; capacitances from .001 to .01  $\mu\text{f}$ . can be used, preferably of the disc ceramic type.  $L_1$  and  $L_2$  can be a winding of No. 18 enamelled wire wound on a half-inch diameter form, the winding being about 2 inches long.

### 2.) Harmonics From the Pix I.F.

This interference is much the same as that just described except it comes from harmonics of the picture i.f. The third harmonic of the pix, 25.75 Mc., is 77.25 Mc., which falls right in the r.f. passband of channel 5. This interference may make the picture appear grainy or may make a crosshatch pattern.

Here again this interference is only on channels which are harmonically related to the picture i.f. and the cure is to try to prevent r.f. from the video detector and amplifiers from reaching the front-end or r.f. input of the receiver. Better lead dress, bypassing, shielding, etc. are called for at the video detector.

### 3.) Barkhausen Oscillation

This type of interference is generated in the horizontal output tube of the TV receiver and shows up as vertical black lines on the left side of the picture. The signal is actually bursts of r.f. energy which are in the passband of the receiver, most often in the higher channels.

To cure this type of TVI it is usually necessary to adjust the horizontal drive control and/or replace the horizontal output tube.

TABLE II

#### CHANGING INTERMEDIATE FREQUENCIES —

It is possible to change the intermediate frequency of a receiver by retuning the sound and picture i.f. amplifier circuits, and retuning the local oscillator so that the i.f. signal produced in the converter corresponds to the new frequency to which the i.f. amplifiers are tuned. The stations are still received at the same settings of the channel selector. Three changes are involved.

1. The local oscillator frequency is changed.
2. The frequency of the i.f. signal is changed.
3. The frequency passband of the i.f. amplifier is changed.

It follows that three types of interference can be eliminated:

1. Radiation of local-oscillator signal.
2. Radiation of harmonics of the i.f. signal.
3. Reception of interfering signals within the i.f. passband.

Table II — Directions for changing the intermediate frequency of a TV receiver to dodge TVI.

### 4.) Spook Interference

Spook interference is generated in the damper stage. It appears as a vertical line at the extreme left of the picture and is strongest on the lower channels. It may be cured by placing r.f. chokes in the leads to the plate and cathode of the damper tube. The shielding on the high voltage supply should be checked for good contact as this shielding helps prevent this radiation.

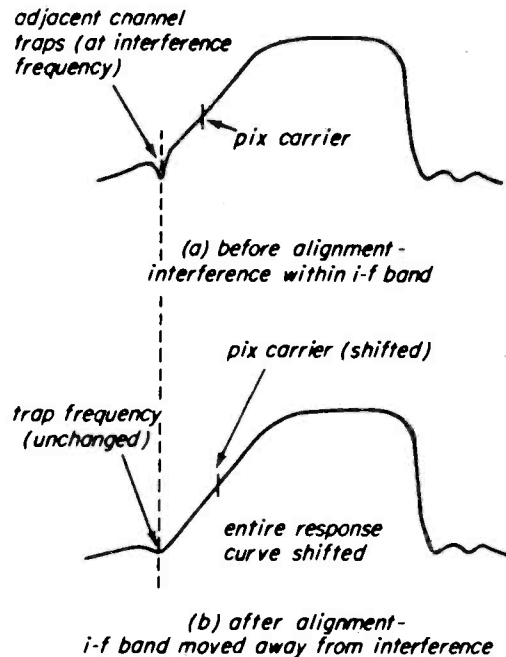


Figure 14 — (a) shows interference in i.f. passband before realignment and (b) interference outside i.f. passband after realignment.

### ● TVI — NOT THE FAULT OF THE TV RECEIVER

Interference to a television receiver which is not the fault of the receiver obviously cannot be cured at the receiver. TVI in this category is an interfering signal that is actually right on the same frequency as the television station.

The commonest form of this type of interference is called:

### ● CO-CHANNEL INTERFERENCE

When two TV stations occupy the same TV channel and are located relatively close together (150 to 200 miles), they offset their picture carriers by 10.5 kc. This increases the beat note between them so that the horizontal interference lines in the picture tend to blend into the scanning lines like in Photo 11 instead of forming a heavy Venetian blind pattern like that shown in Photo 10 on page 7. This helps the viewers that live half way between the two stations.

## Chapter 3 — The TV Receiver

With the sun spot cycle nearing a maximum as it is doing this year, distant TV stations will frequently come in very strong and one is apt to get a combination of two or three sets of various width Venetian blinds all at the same time on the same channel. At times the viewer will find all the v.h.f. channels, 2 through 13, almost completely useless. The only cure is to turn off your set and occupy your time the way you did before TV. You cannot filter out an interfering signal on a TV channel without also filtering out the TV signal.

### ● HARMONIC TYPE TVI

Other signals that may get right into a TV channel are harmonics of radio transmitters belonging to other services such as police, fire, public utilities, amateur and taxis, as well as equipment in the Industrial, Scientific and Medical Service such as diathermy.

The problems of shielding and filtering this type of equipment will be taken up in the following chapters. Generally speaking this type of interference must be cured at the offending equipment except in the case of harmonics generated in the front-end of the TV set itself. In this latter case, a high-pass filter generally works.

### ● NOISE TVI

Noise or impulse type of interference is another type that must be cured at the source. Sometimes this source is your own TV set such as a noisy tube in the front-end or a spark jumping in the high voltage section. More often, though, the trouble originates in some household appliance. A number of causes and cures have been given in Table I on page 9. About the only thing that can be done at the TV receiver is to put up a better, more directional antenna with coax cable feed line, and in general fix up the receiver with a high-pass filter, a.c. line filter and bottom pan in an effort to keep any strong local noise fields out of the set. See Figure 11.

### ● INTERFERENCE FROM YOUR TV RECEIVER TO OTHER RADIO SERVICES

Most TV receivers are good sources of interference to other radio services, including the regular broadcast band, 550 to 1600 Kc., short wave receivers, FM broadcasting, 88 to 108 Mc. and even to other TV receivers. The source of the interference to the lower frequency services is the radiation of harmonics from the horizontal sweep frequency circuits of the TV receiver. The fundamental frequency is 15.750 kc. and therefore harmonics appear every 15.750 kc. up through the spectrum. This causes a series of disagreeable whistles in the BC band that vary in tone and which are somewhat stronger at the 550 end. It is possible, when driving down a street with your automobile radio turned on, to tell who is watching TV. The whistles and squawks from some TV sets can be heard all the way up to 30 Mc.

Another type of interference from TV receivers is the radiation of the local oscillator signal and its harmonics. It is this signal that often causes TVI to other TV sets. This interference looks like the typical r.f. type of diagonal lines shown in Photo 1 on page 6. It can be strong enough to turn a picture negative like Photo 2. This TVI is caused only by TV receivers using 21 Mc. i.f. The newer 41 Mc. i.f. places the local oscillator frequency out of the TV range but probably right in the range of some other ser-

vice. The FCC requires that radiations of this type be suppressed in all new receivers and even in old receivers if they cause interference. See paragraph #15.69 from Part 15 of the FCC Rules in the Appendix.

A TV receiver with a 21 Mc. i.f. tuned to:	Will cause interference to another TV receiver tuned to:
Channel 2	Channel 5
" 3	" 6
" 7	" 11
" 8	" 12
" 9	" 13

This is because the local oscillator frequency falls into the other channel. The local oscillator frequency of channel 2 is in channel 5, etc.

Image interference can also be caused as follows:

A TV receiver with a 21 Mc. i.f. tuned to:	Will cause interference to another TV receiver tuned to:
Channel 5	Channel 2
" 6	" 3
" 11	" 7
" 12	" 8
" 13	" 9

The local oscillator frequency of channel 5 is in the image band of channel 2, etc.

To identify this type of TVI watch to see if it comes and goes when programs are changing and the owner of the interfering set might be switching channels. There is no modulation on the pattern and it shows only on the channels listed above. Neighbor's sets may be checked by turning them off momentarily to see if the pattern disappears.

To cure the trouble the offending receiver must be located and worked over. The best solution is to shift the i.f. enough to put the local oscillator frequency out of the channel in question. Better bypassing, shielding, filtering, etc., may also be tried on the offending receiver.

To cure the 15.750 kc. harmonic radiation that interferes with broadcast reception, it is sometimes necessary to install an a.c. filter in the power cord of the TV receiver just inside the TV set. See Fig. 13. Often it is also helpful to dress the leads going to the deflection yoke tight against a bracket or other metal support so that they get some shielding as shown in Figure 15. A metal bottom pan attached to the chassis or a piece of copper screening placed under the chassis often helps considerably. See Figure 16. Check the shielding on the high voltage supply to be sure it is tight. Have the TV service man check the horizontal oscillator control for correct adjustment. Try a ground on the TV chassis and last but not least, install a high-pass filter to prevent this radiation from reaching the TV antenna.

### ● COLOR TVI

If you do not yet have a color TV set you really are not living. The author's receiver, a 21 inch RCA Victor table Model #21-CS-7816 cost no more than the early black and white sets and has required no more service. Color TV is really beautiful, just as good and sometimes better than Technicolor movies. Color seems to add so much more information to the picture — just like another dimension.

When color TV was first introduced it was thought that it would be extremely susceptible to interference. It was also thought that a color set would radiate tre-

## Chapter 3 — The TV Receiver

mendous amounts of interference to other radio services. The author had the privilege of serving on an industry-wide committee set up to investigate this possibility, and while the early tests showed that there was reason for concern, subsequent tests proved that with reasonably good design, shielding and filtering, the problem would not be any worse than with black and white receivers.

A color TV receiver is essentially a black and white receiver with slightly wider bandpass as far as the r.f. and i.f. portions are concerned. After this point however, it is considerably more complicated. Fortunately, its TVI rejection characteristics have to do with the receiver's r.f. and i.f. sections except for one type of interference. This type of TVI is peculiar to color sets. It is when a heterodyne or beat note upsets the color subcarrier. If

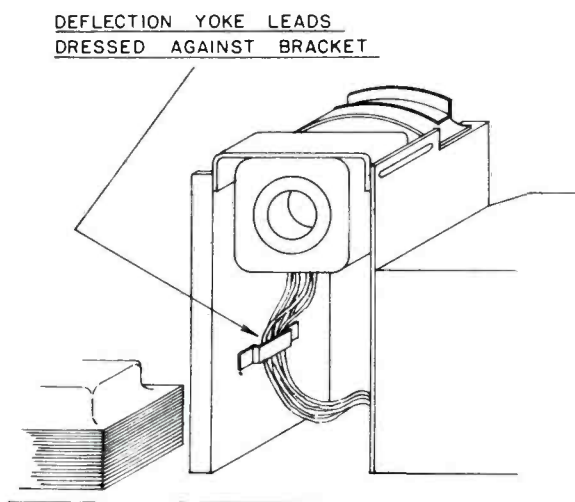


Figure 15 — Example of method of dressing deflection yoke leads against bracket to reduce radiation.

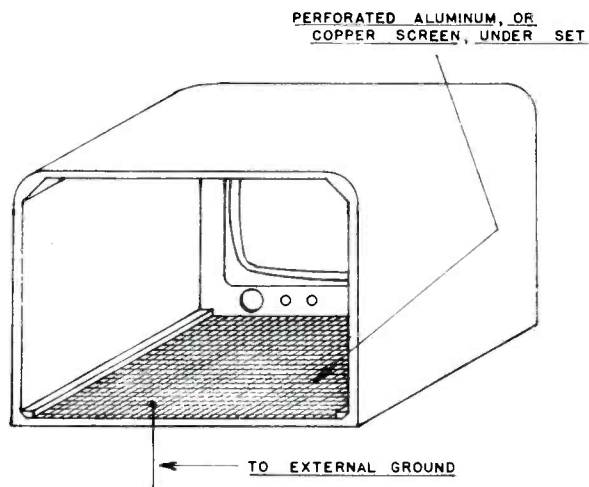


Figure 16 — Use of perforated aluminum or copper screening as a bottom shield set to reduce radiation.

this happens while the set is receiving a color picture, the picture turns to a black and white picture with colored diagonal lines. If this happens while the set is receiving a black and white picture with the color control turned on, you still get the colored diagonal lines or crosshatching superimposed on the black and white picture. In either case the interference disappears completely when the color control is turned off. The color picture can now be viewed as a black and white picture but without a trace of interference.

The color subcarrier referred to above is the signal sent to the receiver to tell it what color to turn on at a given instant. Its frequency is 3.58 Mc. and it is included as part of the video modulation. It is sent in bursts of 8 cycles each during the horizontal blanking intervals. The color TV receiver has a 3.58 Mc. crystal oscillator whose frequency and/or phase is controlled by a reactance tube from the subcarrier bursts.

Any signal near 3.58 Mc. that can get through the r.f. and i.f. circuits and reach the video is sure to have some effect on the color. As was pointed out in Figure 5, on page 15, the video has the least response to outside signals. It has been found experimentally that 1000 watt transmitters on 3.58 Mc. have very little effect on color sets. On the other hand, a low powered transmitter on the 6 meter band operating at 51.67 Mc. will very likely completely upset the color on channel 2. This is because 51.67 Mc. is the color image for channel 2, that is, 55.25 minus 51.67 equals 3.58 Mc., the color subcarrier frequency. The heterodyne produced by this beating action goes through the TV set as part of the video modulation on the TV signal.

Table III is a comparison of the response of the two types of receivers to various types of TVI. Most r.f. types of interference produce crosshatching in tones of gray, while static and noise produce colored spots or streaks like confetti being thrown in the picture.

The two photos of NBC's Color Peacock on the cover were taken in color from the screen of an RCA table model color receiver with Ansco's new high-speed color film. The interference in one was caused by the 5th harmonic from an amateur 14 Mc. transmitter. The picture itself is still in color while the diagonal lines are in tones of gray. If the interfering signal had been on the color sub-carrier frequency or image frequency, then the picture itself would have changed to black and white with the crosshatching in red, green and blue stripes like in Photo 15 on page 7.

The interference was cured, as shown in the second photo on the cover by installing a low-pass filter in the antenna feed line of the 14 Mc. transmitter.

The colored stripes or crosshatching are caused by the interfering signal coming into the receiver exactly on the color subcarrier frequency and taking color control away from the color camera. When this happens the picture turns to a black and white and the crosshatching becomes colored. This same thing will happen to a color receiver tuned to a black and white program. When the interference is on the color subcarrier frequency, colored stripes appear across the black and white picture. To eliminate this trouble it is necessary to turn the color switch on the TV receiver off.

On black and white programs TVI can often be cured by adjusting the fine tuning control so that the interfering signal just falls out of the i.f. passband. This cannot be done when watching a color program because you must have the fine tuning set for correct color. Any mistuning and you lose the color.



## Chapter 3 — The TV Receiver

### ● TV ANTENNAS FOR COLOR

A great many TV viewers get along with makeshift TV antennas. These vary from "rabbit ears" to folded dipoles made of 300 ohm ribbon and neatly tucked underneath the living room rug. If you live near a TV transmitting station this antenna arrangement may be perfectly satisfactory for the average black and white program. The majority of TV viewers however live far enough away to require something a little better. There is a difference between just getting a satisfactory picture and getting a picture that is strong enough to override interference. It is an established fact that the severity of the interference depends on the ratio of the signal strength of the interfering signal to the signal strength of the TV picture. In other words, the stronger the picture, the less the TVI. One of the easiest ways to get a stronger picture is to put up a better TV antenna.

In choosing a new TV antenna a number of factors should be considered particularly if you have, or are planning to have, a color TV receiver. The bandwidth requirements for a color signal are more stringent due to the color sub-carrier at 3.58 Mc. The band-pass characteristics of the color TV receiver are of necessity generally better than that of a black and white receiver. To complement this you therefore need a good antenna system that will pick up with equal strength the entire video signal including the color subcarrier. In other words, the antenna should have a bandwidth that matches the TV channel width and should be properly matched to the feeders so that there are no standing waves or reflections to give double images.

A good all-channel (2 to 13) antenna designed for color reception is illustrated on the cover of this book. It is manufactured by the JFD Manufacturing Co., Inc., 6101

Sixteenth Ave., Brooklyn 4, N. Y., and is available at most dealers. It is called the Power Helix, Model PX-911 Color-tenna.

If your problem is co-channel or adjacent channel TVI this JFD antenna is especially good as it has a good front-to-back ratio, a good front-to-side ratio and a good power gain off the front. This means that it will not only amplify the desired TV station at which it is pointed but it will also reduce the strength of interfering signals coming from other directions. At the author's home this antenna is mounted on a TV antenna rotator so that the antenna can be turned and pointed in any desired direction. In this way it can be aimed to the southwest toward Philadelphia to receive a good picture on channel 6 or it can be pointed to the northwest at Schenectady, N. Y. to receive a different program from a different station right on the same channel 6.

Prior to the installation of this type of antenna mounted on a rotator, reception of channels 7 and 9 from New York had been very poor due to adjacent channel interference from a local Connecticut station on channel 8 in New Haven. Some difficulty was also encountered with channel 3 in Hartford, Conn., due to adjacent channel TVI from channels 2 and 4 in New York City. Since the installation of the rotatable TV Colortenna there is no longer any trouble with these channels. For this system of eliminating co-channel and adjacent channel TVI to be successful, the interfering signals and the desired signals must be coming from different directions.

### ● PREVENTING RADIATION FROM A COLOR TV RECEIVER

A color TV receiver can cause serious interference to other radio services when receiving a compatible color TV picture. This interference takes the form of a series of birdies or signals being radiated by the color TV receiver at the color subcarrier frequency and its side-bands and harmonics thereof. Fortunately, this interference can easily be reduced by adhering to good design practices in the application of circuit, layout, shields, and filters in the various circuits when the receiver is originally designed.

The color oscillator circuit, the color demodulator circuit and the high potential monochrome circuits are all possible sources of interference. In general, interference from these sources is by direct radiation from any suitable antenna such as the color receiver's antenna, the power line or by other metallic objects acting as radiators.

The most feasible method of preventing this radiation of interference is to shield the offending circuits. The 3.58 Mc. cw circuits should be examined to see if they are operating in as linear a fashion as possible and at the proper levels. The cw currents should be contained to their own respective circuits by placing shield cans over all tuned circuits and tubes. The power circuits should be filtered in such a fashion that the paths to ground for r.f. currents are as short and direct as possible.

Both the I and the Q demodulator circuits should be checked to determine that the amplitude response to the subcarrier frequency is a minimum. This requirement can be met with proper design of low-pass filters. The filtering should be checked as well as the arrangement of ground return paths in the color demodulator circuit to keep circulating currents to a minimum.

The use of an ac line filter should not be overlooked, as well as a bottom pan or shield for the chassis. The bottom shield alone in some TV receivers may reduce the radiation up to 20 db.

TABLE III

COMPARISON OF COLOR AND BLACK AND WHITE FOR TVI	
Type of TVI	Resulting TVI
R.F.	Color is more susceptible to r.f. interference at frequencies near the color subcarrier.
Co-channel	Color and black and white are equally susceptible.
Lower Adjacent Channel	Color and black and white are equally susceptible. Lower adjacent sound signal is cause of interference. Receiver attenuation in lower channel is determining factor.
Upper Adjacent Channel	Color is somewhat more susceptible than black and white. Attenuation of upper channel's lower sideband one of determining factors along with receiver attenuation of upper channel.
Multipath	Color is slightly more susceptible.
Random Noise	Color is slightly more susceptible.
Impulse	Color and black and white about equal.

## CHAPTER 4

### THE RADIO TRANSMITTER

In chapter 3 we went into some detail in discussing TV receiver deficiencies. In this chapter a few shortcomings of transmitters will be discussed. Superhetrodyne receivers may have their spurious responses but transmitters have plenty of spurious radiations, that is, they do unless special precautions have been taken to prevent this radiation.

#### ● SPURIOUS RADIATION

A good definition for spurious radiation is contained in Part 12 of the FCC Rules, paragraph 12.133. "... For the purposes of this section a spurious radiation is any radiation from a transmitter which is outside the frequency band of emission normal for the type of transmission employed, including any component whose frequency is an integral multiple or submultiple of the carrier frequency (harmonics and subharmonics), spurious modulation products, key clicks, and other transient effects, and parasitic oscillations...." In other words, a spurious radiation is any radiation other than the fundamental signal.

It should be obvious to the reader that if all spurious radiations from the transmitter are suppressed and all spurious responses of the TV receiver are prevented, there can be no interference except in cases where the transmitter fundamental frequency coincides with the TV channel frequency. This type of TVI of course, is co-channel — that caused by two TV transmitters assigned to the same channel in different cities. The object of this chapter is to detail several methods of preventing spurious radiations or reducing them to the level specified by FCC.

Again quoting from paragraph 12.133 of Part 12 of the Rules, "... This spurious radiation shall not be of sufficient intensity to cause interference in receiving equipment of good engineering design including adequate selectivity characteristics which is tuned to a frequency or frequencies outside the frequency band of emission normally required for the type of emission being employed by the amateur station...."

#### ● GENERAL

The reduction of spurious emissions from a transmitter can be divided into three categories.

1. Preventing the radiation of these spurious signals by the antenna.
2. Preventing the radiation of the spurious signals by the transmitter cabinet and wiring.
3. Reducing the generation of the spurious signals in the transmitter.

A fourth measure can sometimes be taken and that is to move the transmitter's fundamental signal to another part of the band so that the offending harmonic falls into a vacant channel or into the region near the sound carrier. See Figure 37 on page 34. This dodge cannot be used so successfully on color receivers because of the color sub-carrier frequency as shown.

#### ● PREVENTING THE RADIATION OF SPURIOUS SIGNALS BY THE ANTENNA

If the television signals are very strong as they would be in a primary signal strength area, the job of preventing TVI is relatively easy in most cases. Probably nothing

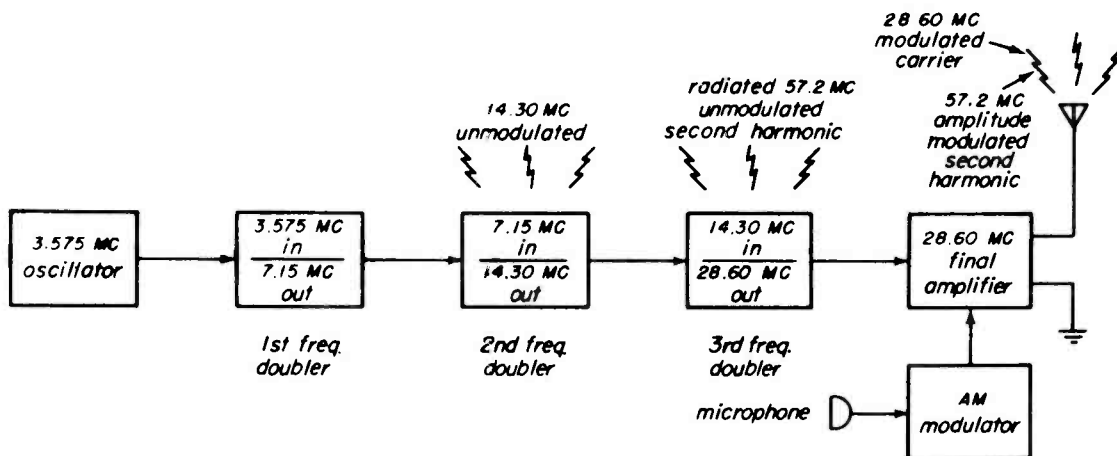


Figure 17 — A block diagram of a typical transmitter showing harmonics leaking out of the various stages.

## Chapter 4 — The Radio Transmitter

will have to be done to most low frequency transmitters, and relatively simple measures will cure all but the most stubborn cases of TVI even from high frequency transmitters.

Figure 17 shows the block diagram of a typical amateur or commercial transmitter for use in the 25 to 50 Mc. range. Note how spurious signals are leaking out of the frequency multiplier stages as well as from the antenna. In a primary area all that may need to be done to this transmitter is to add a link coupled antenna tuning unit and possibly a shorted quarter wave stub to the feed line. Other measures may also prove helpful such as grounding the center tap on the antenna coil in the case of balanced feeders or the use of a shielded antenna coil in the case of coax feed. Figures 18 and 19 give the details. In Figure 19 the coax cable of course, is grounded in the transmitter where it leaves the shielded amplifier stage through a coax fitting. Otherwise the harmonics would follow the outside braid of the cable up to the antenna.

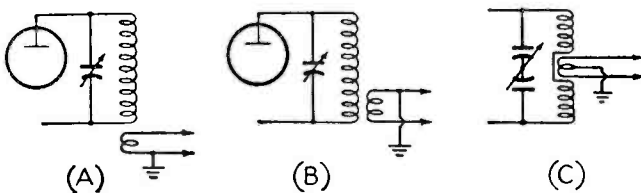


Figure 18 — Methods of coupling and grounding link circuits to reduce capacitive coupling between the tank and link coils. Where the link is wound over one end of the tank coil, the side toward the hot end of the tank should be grounded as shown at (B).

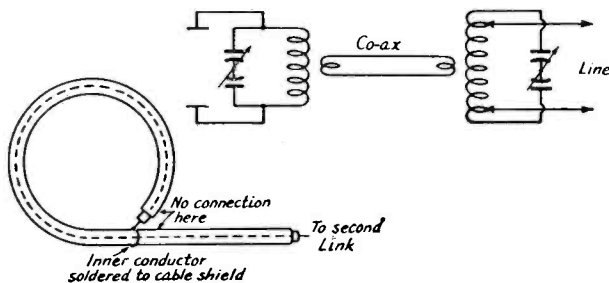


Figure 19 — Shielded coupling coil constructed from coax cable. Type RG-59/U may be used for low power and RG-8/U for higher power.

Where a definite harmonic from a fixed frequency transmitter is to be attenuated, often times a simple wave trap or traps in the feed line will suffice. These may be either series or parallel resonant as shown in Figure 20.

In areas where the TV signal strength begins to be marginal or where the TV receiver is very close to the transmitter, the problem becomes more difficult and the remedies described above are no longer adequate. It now becomes necessary to start plugging up the holes in the shielding through which the spurious r.f. radiations are leaking. Under these conditions we need much more attenuation than simple wave traps and stubs will give, so we must turn to the use of low-pass filters.

The design and use of low-pass filters will be covered

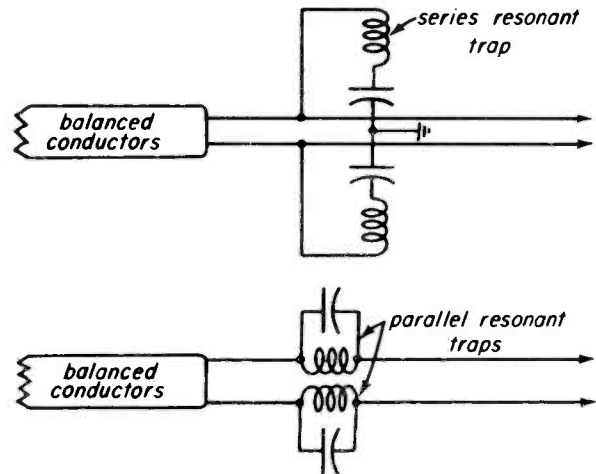


Figure 20 — Series or parallel tuned wave traps for use in 300 or 600 ohm transmitter feed lines. These should be tuned to the frequency of the offending harmonic while watching the effect on a TV receiver. For coax cable a single trap would be used in a metal box connected in the feed line.

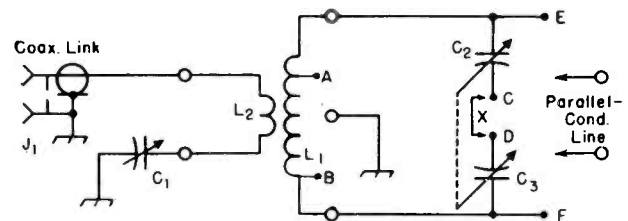


Figure 21 — Circuit diagram of the "universal" coax-coupled matching network. For use as a tapped matching circuit, connect the line to taps on  $L_1$ , as at A-B, and connect the jumper, X to C-D; the jumper is also used for parallel tuning but with the line connected to E-F. For series tuning, remove the jumper and connect the line to C-D. The ground connection to the middle prong of the coil socket is provided for cases where it is desirable to ground the center of  $L_1$ .

$C_1$  — 300-uuf. variable, approximately 0.024" spacing.

$C_2, C_3$  — 300-uuf. variable, 1000 volts (National TMS-300).

$J_1$  — Chassis-type coax connector.

### Coil Data

Band	$L_1$ , turns	$L_2$ , turns
3.5-7 Mc.	20 (14 uh.)	10 (5 uh.)
7-14 Mc.	10 (5 uh.)	6 (2.5 uh.)
14-28 Mc.	4 (1.5 uh.)	2

$L_1$  — No. 12 tinned wire, 2½ inches dia., 6 turns per inch (B & W 3905-1).

$L_2$  — No. 16 wire, 2 inches dia., 10 turns per inch (B & W 3907 or 3907-1).



## Chapter 4 — The Radio Transmitter

in more detail in Chapter 8, however, it cannot be stressed too much, that, to be effective, the low-pass filter must be backed up by a good r.f. tight job of shielding, coupled with a thorough job of lead filtering. It is almost more important how you use the low-pass filter than the kind of a filter you use.

In order to obtain the full attenuation of a filter it should be used in a coax line between the final amplifier and an antenna tuner. In this way the low-pass filter catches the higher frequency harmonics while the antenna tuner blocks the lower frequency subharmonics and at the same time it provides a low standing wave ratio on the coax feed line.

Figure 21 gives the circuit of a suitable antenna coupler although any type that will bring the standing wave ratio down to 1 to 1 will work out satisfactorily.

The reason why good tight shielding is necessary is shown in Figure 22. In (a) it is easy to see how the r.f. can flow up the outside of the coax and thus by-pass the low-pass filter. The filter can only attenuate the harmonics that actually try to go through it. If half the r.f. is on the

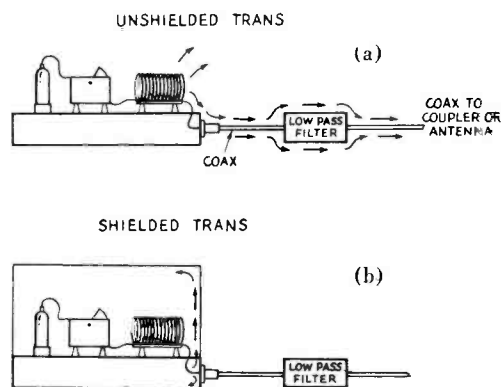


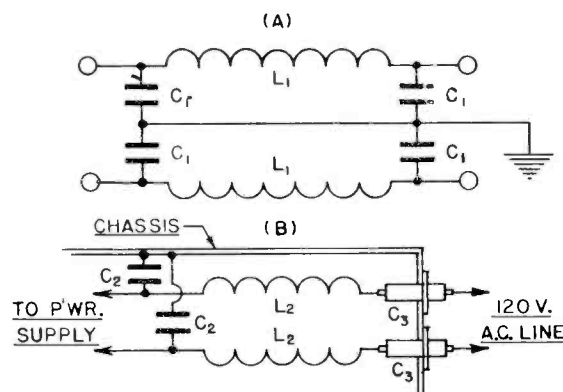
Figure 22 — (a) Without proper shielding the harmonics flow along the outside of the coax and effectively bypass the low-pass filter. (b) Proper r.f. tight shielding now forces all harmonics to stay on the inside of the coax where the low-pass filter can stop them.

outside of the filter then the attenuation would only be 3 db. instead of the 60 to 80 db. that you expected. In Figure 22 (b) you can see how the r.f. now is all forced to go through the filter where the harmonics will be attenuated. It is necessary to prevent the r.f. from escaping on the a.c. power leads and suitable filters for doing this are shown in Figure 23. In (a) the filter is wound with number 12 wire and will handle a high power transmitter, while in (b) the coils are of only number 18 wire and so are suitable for lower powered rigs. In this line filter the use of Sprague "bulkhead" type of .1 to .25 ufd High-pass condensers is illustrated. This type of feed-through condenser mounted in the chassis will give about the best filtering. See Photo 24 on page 31.

### ● PREVENTING HARMONIC RADIATION BY THE TRANSMITTER CABINET AND WIRING

In order to prevent the cabinet and wiring from radiating any spurious signals that a transmitter might generate, it is necessary to do a thorough job of shielding and lead filtering. Methods that have been employed successfully

### AC LINE FILTERS



$C_1 = .005$  UF TO  $.01$  UF DISC CERAMIC CAPACITOR.  
 $C_2 = .005$  UF DISC CERAMIC CAPACITOR.  
 $C_3 = 0.1$  UF 250 V. A.C. BULKHEAD TYPE SPRAGUE "HIGH-PASS" CAPACITOR.  
 $L_1 = 1/2$ " DIA., 3" LONG, NO. 12 ENAM. WIRE.  
 $L_2 = 1/2$ " DIA., 2" LONG, NO. 18 ENAM. WIRE.

Figure 23 — A. C. Line Filters (A) for high power and (B) for low power.

on all sorts of transmitters will be given in detail in Chapter 5 on page 29, and so will not be repeated here. Suffice it to say that this phase of TVI-proofing is important enough to be treated in a separate chapter.

### ● REDUCING THE GENERATION OF SPURIOUS SIGNALS

There are of course, a number of different types of spurious emissions in addition to harmonics. For example:

1. Self-oscillation in the final amplifier or one of the buffer stages due to lack of neutralization.
2. Parasitics in one of the r.f. stages.
3. Key clicks in the case of a c.w. (code) transmitter.
4. Side-band splatter in the case of a phone transmitter.
5. Parasitics in the modulator.

To cure self-oscillation the stage should be neutralized. To eliminate parasitics one may employ parasitic chokes in the plate or grid leads or a resistor in the screen grid lead. All of these types of spurious emissions are well covered in the ARRL Radio Amateur's Handbook to which the reader is referred for additional information.

The difference between harmonics and the other types

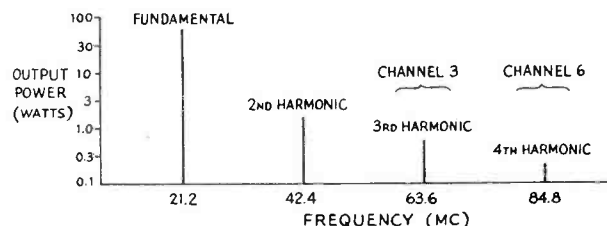


Figure 24 — Chart showing the relationships of a 21 Mc. signal and its harmonics. In actual practice, the harmonics might not have the amplitudes shown. The important point to remember is that there are harmonics.

## Chapter 4 — The Radio Transmitter

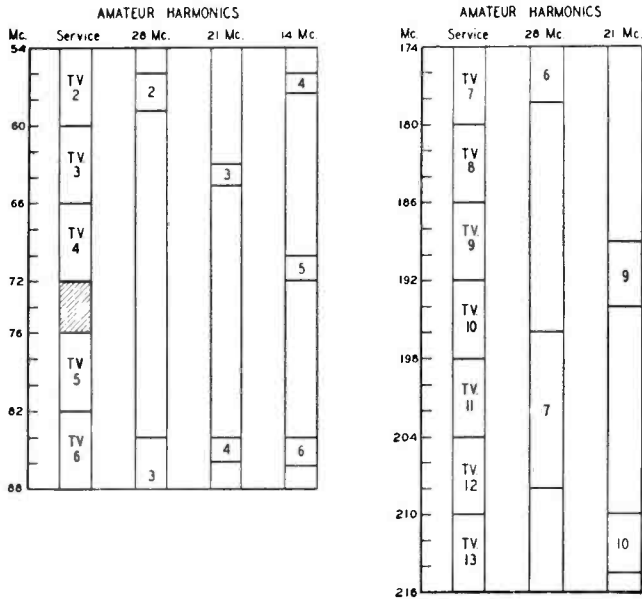


Figure 25 — The relationship of amateur band harmonics to v.h.f. TV channels is shown above. Harmonic type of TVI from transmitters operating below 30 Mc. is apt to be most serious in TV channels 2 to 6 shown to the left.

of spurious radiations is that every r.f. amplifier and frequency multiplier has some harmonic output while they may or may not have any of the other types of spurious radiations. The amount of harmonic output from a given r.f. stage in a transmitter depends on a number of factors. Harmonics occur on specific frequencies as compared to other spurious emissions which may occur at various unrelated frequencies. In Figure 24, a 75 watt fundamental signal is shown on 21.2 Mc. Note that the second harmonic is exactly twice that frequency while the third and fourth harmonics are exactly three times and four times respectively. Thus you see, if you know the fundamental frequency, you can predict the exact frequency of the harmonics and by consulting a table of TV channel frequencies, such as Table 3 in the Appendix, you can tell whether or not a given harmonic will land in or near a TV channel.

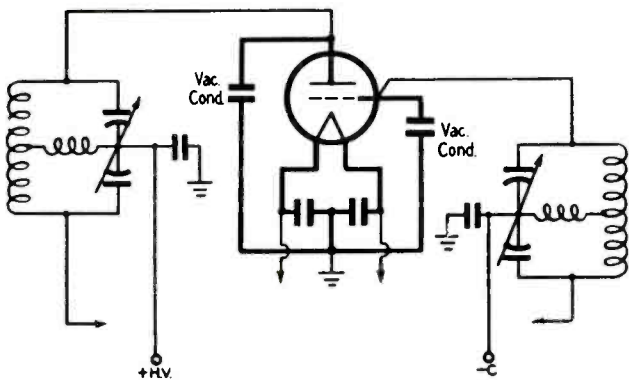


Figure 26 — This illustrates the use of vacuum condensers to provide a short direct path to the cathode for harmonic currents. Better yet, use vacuum variables as the main tuning condensers.

In Tables 1 and 2 in the Appendix the frequencies of typical VFO/crystal oscillators are listed in the first two columns together with their harmonics. The five columns on the right list typical frequencies that might be used in the following stages of the transmitter, both in frequency multipliers (doublers and triplers) as well as final amplifiers. For example, if you want to know what the harmonics are from a 21 Mc. final, look under the 6X column in Table 1 and you will see that they are: 2nd harmonic 42 Mc., 3rd 63 Mc., 4th 84 Mc., etc. The 7 Mc. frequency multiplier would have the following harmonics: 2nd — 14 Mc., 3rd — 21 Mc., 4th — 28 Mc., 5th — 35 Mc., 6th — 42 Mc., etc. One thing you will note is that a lot of these harmonics are not on TV frequencies and if they leak out they may cause interference with police, aircraft, fire and other such services. Table 2 is similar to Table 1 except the frequencies are for the amateur 2 and 6 meter bands. For 50 Mc. use the column marked X6 and for 144 Mc. use the column marked X18.

The relationship of amateur band harmonics from 14, 21 and 28 Mc. transmitters to TV channels, are shown in Figure 25. It should be remembered that a strong harmonic in an unused channel next to a used channel still can cause TVI by what was previously described as adjacent channel TVI. In this case it is the transmitter's fault rather than the lack of selectivity in the receiver because you are not supposed to be radiating harmonics in the first place.

The procedure for determining whether or not the TVI is caused by harmonic radiation is as follows:

- 1.) Does the TVI occur only on channels that are

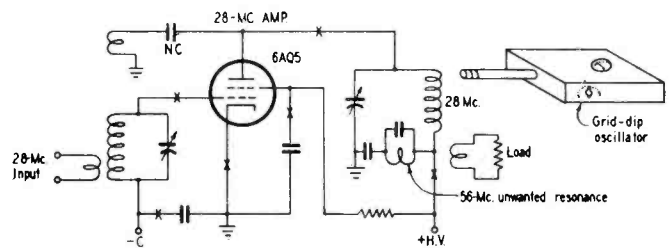


Figure 27 — Using a grid-dip oscillator to locate an unwanted 56 Mc. spurious resonance in a 28 Mc. amplifier tank circuit.

harmonically related to transmitter frequency? If so it is probably caused by harmonic radiation.

- 2.) Does the number of lines in the TVI pattern remain the same when the fine tuning control on the TV receiver is adjusted? If it does it is another good indication that harmonics are causing the trouble.

If all channels are bothered or if the number of lines in the pattern changes it is probably front-end overload, i.f. or image TVI.

A good way to analyze your trouble is to start by turning on only your oscillator. Observe the TVI or lack of it and then progress, adding one stage at a time, each time noting the change in the TVI and the channels on which it appears. The final amplifier should be connected to a shielded dummy load for the test. Any TVI under these conditions is most likely to be harmonic and you can tell from which stage it is coming.

● PI-NETWORK CIRCUITS

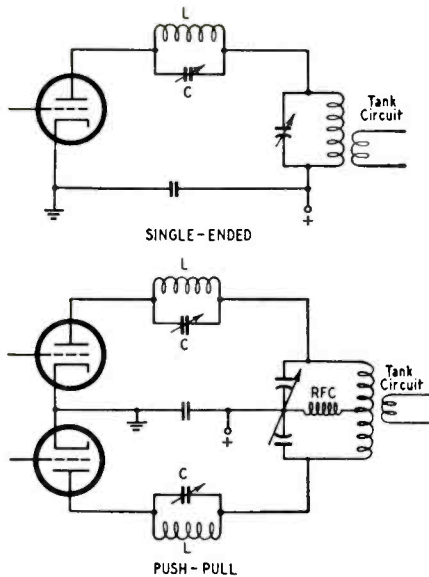


Fig. 28 — Harmonic traps in an amplifier plate circuit.  $L$  and  $C$  should resonate at the frequency of the harmonic to be suppressed.  $C$  may be a 25- to 50-uufd. midget, and  $L$  usually consists of 3 to 6 turns about  $\frac{1}{2}$  inch in diameter for Channels 2 through 6. The inductance should be adjusted so that the trap resonates at about half capacity of  $C$  before being installed in the transmitter. It may be checked with a grid-dip meter. When in place, it is adjusted for minimum interference to the TV picture.

● REDUCING HARMONIC GENERATION

Class "C" amplifiers are good harmonic generators and normally have harmonic currents flowing in both the plate and grid circuits. It is very important therefore, that no tuned circuit appear in either the plate or grid that is accidentally at harmonic frequency. If this should happen then that particular harmonic will be very strong. On the other hand, if these harmonic currents can be effectively bypassed to the cathode they will do relatively little harm. Vacuum condensers are excellent for this job. See Figure 26. In high power final amplifiers vacuum variable condensers are recommended as the main tuning condenser. The lead lengths in the grid, plate and cathode circuits must be watched because they may resonate in series with the tuning capacity and inter-electrode capacity to some TV channel.

A method of checking for these spurious resonances is shown in Figure 27. A grid-dip oscillator is used to probe around the r.f. amplifier looking for any resonances near the frequency of the harmonic that is giving trouble. If any are found they must be eliminated or moved in frequency by rearranging the parts layout, using different components, shortening leads, better bypassing, etc.

A given harmonic in a one band transmitter can be reduced satisfactorily by using plate traps. These require careful adjustment while watching a TV screen and should be set for minimum crosshatching. Traps of this type, if out of adjustment, can make the harmonic worse than without them, so they must be tuned up carefully. Figure 28 gives the circuit for both single-ended as well as push-pull amplifiers. Traps are recommended only as a last resort on a band switching rig.

The pi-network is probably the most popular circuit in use today, especially for band switching transmitters. As far as harmonic type of TVI is concerned it is very good if properly designed and properly tuned up. Its big advantage is the ease with which it can be switched from one band to another plus its ability to match a wide range of antenna impedances. It is efficient and works particularly well into a 52 ohm coax cable.

The partial schematic of a typical high-power final amplifier using a pair of 4-125A's in parallel in a pi-network is shown in Figure 29. Constructional data on this amplifier is given in the ARRL's Radio Amateur's Handbook for 1956. It is reproduced here to illustrate the proper use of a pi-network. Note the parasitic suppression chokes  $L_1$  and  $L_2$  in the grid circuit and  $L_3$  in the plate circuit. The chokes are paralleled with resistors. The grid tank circuit, not shown, uses a National MB-40-L all band tank. Also note the series tuned wave trap  $L_5$  and  $C_{27}$  across the output. This should be adjusted to trap out the harmonic which gives the most trouble in your neighborhood.

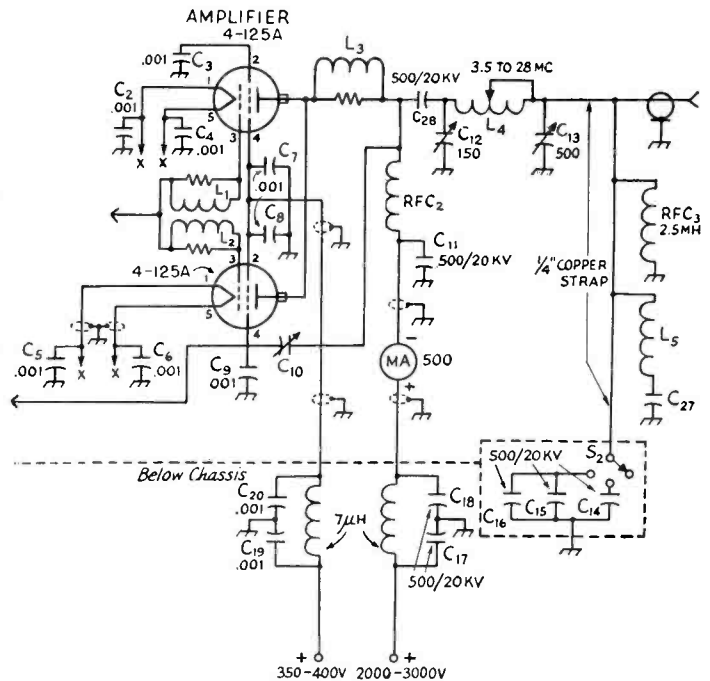


Figure 29 — This illustrates an excellent design for a high power final amplifier using a pi-network in the tank circuit. An improvement would be to use a variable vacuum condenser for  $C_{12}$ . For further details see the ARRL Amateur Handbook.



## Chapter 4 — The Radio Transmitter

### ● PUSH-PULL VS. SINGLE-ENDED

Theoretically a push-pull amplifier should be somewhat better than a single-ended one, however, it is almost impossible to get a push-pull amplifier well enough balanced so that the even harmonics will cancel and therefore I do not see any particular advantage to them as far as TVI is concerned.

### ● TRIODES VS. TETRODES

In general, tetrodes are to be preferred to triodes mainly because they require less drive and therefore the exciter portion of the transmitter can be lower powered. This means that you will have less trouble with harmonic radiation from this part of the rig. It is best to do your frequency multiplying in low powered stages and then build up the power in Class B stages on the output frequency.

Triodes can be used in the final amplifier if desired, however it means that a better job of shielding and filtering may be needed and the excitor section will be larger due to its higher power.

### ● SINGLE-SIDE-BAND

One of the reasons for the popularity of s.s.b. is the relatively less severe TVI experienced with this mode of transmission. There are several reasons why a given transmitter produces less TVI on s.s.b. than on a.m. In the first place there are no Class C amplifiers or frequency multipliers in a s.s.b. transmitter. All the stages must be operated either as Class A or Class B linear amplifiers. Frequency changing is done by the heterodyne method. There are therefore fewer harmonics to worry about.

In the second place there is no steady carrier present to cause cross hatching. At worst, all you see on the TV receiver are sort of "flashes" of interference with modulation peaks, a sort of combination of herringbone and sound bar pattern which are somewhat similar to a.m. sound bars but less intense. Without a steady carrier fundamental overload and audio rectification are less troublesome, however, a high pass filter is usually still necessary on some of the nearby TV receivers.

### ● CLASS B LINEAR AMPLIFIERS

The linear amplifier is a radio-frequency power amplifier adjusted so that the voltage developed across the load is proportional to the exciting voltage applied to the grid of the tube. Linear amplifiers are used extensively in broadcasting to amplify modulated waves, since such amplifiers will not distort the modulation envelope. In the past they have also been used by amateurs, although they were never too popular because of their low efficiency. More recently they have been receiving considerable favor as amplifiers for Gonset Communicators for 2 and 6 meter C/D equipment. The most popular amateur use for linear amplifiers is, of course, in single-side-band suppressed carrier transmitters where they are a necessity.

The main TVI-proofing feature of a Class-B linear amplifier is the greatly reduced generation of harmonics. The same general precautions, however, must be taken to prevent spurious resonances, parasitics and self-oscillation as with a Class-C amplifier. A given amplifier will have lower harmonic output when operated in Class-B than in Class-C.

The author has seen a 28 Mc. transmitter with a Class C final completely cleared of TVI simply by adding a higher powered Class B linear amplifier.

### ● NARROW-BAND FREQUENCY MODULATION

Audio rectification in a TV or broadcast receiver, audio amplifier, record player, etc. usually has to be cured by installing a small r.f. filter in the piece of equipment receiving the interference. Suitable methods were described in Figure 12 in the chapter on receivers. This type of interference is sometimes tied in with "non-linear detectors" in the neighborhood as described in Chapter 9. Often times the interference becomes so wide spread that it is difficult to cure by the above methods. Under these circumstances considerable relief can be obtained by using narrow-band f.m.

The use of n.f.m. instead of a.m. on 28 and 50 Mc. during evening hours will for example, cure your audio rectification type of interference in all types of equipment and will remove the a.m. sound modulation bars in the TV picture. It's use, however, will not reduce the cross hatching in the picture, the effect of fundamental overloading or the generation of harmonics.

### ● MOBILE TVI

Mobile transmitters can and do cause TVI unless a few simple precautions are taken to guard against it. TVI-proofing a mobile is generally rather easy. With a trunk mounted transmitter the most important step is the installation of a simple low pass filter. In most cases the car's trunk lid and body are a sufficient shield. The whip antenna should have a coax fitting and should be mounted in the car body. The shielded low pass filter is connected in the coax cable between the transmitter and the antenna and left there for all band use. Better shielding and filtering may be necessary on mobile rigs when a bumper mounted antenna is used because here the coax cable leaves the trunk and can conduct harmonics out to the outside of the car's body. If the mobile transmitter is well shielded, filtered, and equipped with a low pass filter the installation in the car is not critical as far as TVI is concerned.

When operating for long periods in one location it should be remembered that mobiles also cause fundamental overload, therefore a location should be chosen at least 1000 feet from a thickly populated area.

### ● ANTENNAS

With today's improved techniques for the use of low-pass filters coupled with shielding and lead filtering, no trouble should be experienced with harmonic type TVI from the use of any particular type antenna. There should be no measurable harmonics reaching the antenna. The one thing you must guard against, however, is dirty, loose or cold soldered connections in your antenna and feeder systems. These can cause TVI from externally generated harmonics.

For the higher frequencies, 14 Mc. and up, rotary beams are to be desired simply because you can beam your fundamental only in the desired direction and often times away from a sensitive TV receiver.

## CHAPTER 5

# SHIELDING AND FILTERING

The basic techniques for preventing radio or television interference apply equally well to all types of interference regardless of whether the source is an electronic business machine, radio transmitter, diathermy equipment, radiating FM or TV receiver, or any other electrical or electronic device. To prevent radio or TV interference, we need only prevent r.f. from the interfering device from reaching the nearest receiver.

How do you accomplish this? First, completely shield the source of the interference to prevent direct radiation by coils or other circuit components.

Second, effectively filter the interference out of any wires that must enter or leave the shielded compartment. Use the approximate filter types: high, low or bandpass.

Third, prevent shock excitation of nearby metal objects that might act unintentionally as antennas and radiate the interference.

ALL HOLES DRILLED & TAPPED FOR 6-32 MACHINE SCREWS.

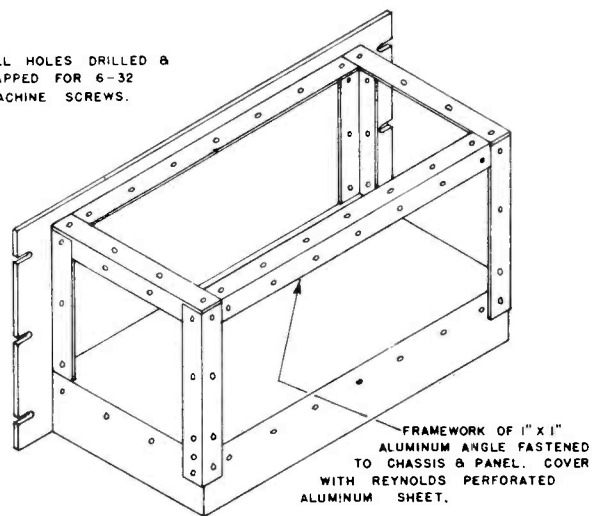


Figure 30 — A simple method of constructing a framework on existing transmitters to give a good job of shielding. When covered with Reynold's perforated aluminum it will look like that shown in Photo 19.

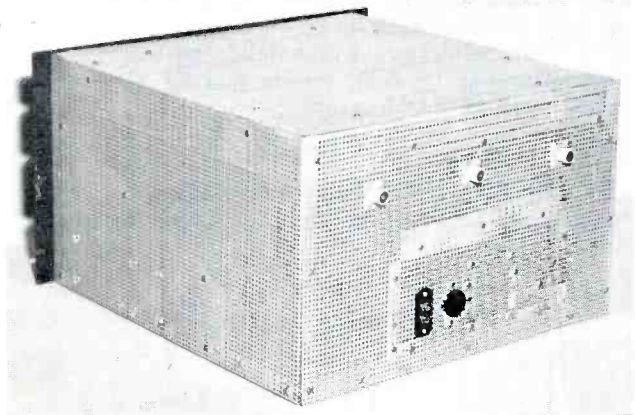


Photo 19 — This illustrates not only an easy and neat method of shielding, but also a very effective one. See Figure 30 for frame work.

### ● SHIELDING

Experiments prove that an interfering signal can be bottled up in a shielded enclosure, even with several wires leaving this shielded enclosure. To do this, the source of the interference must be completely shielded; any wires leaving the shielded enclosure must be filtered; no r.f. can be allowed on the outside of the shielding where it can be radiated.

An example of good shielding using Reynold's perforated aluminum is shown in Photo 19. This material is easy to work with and is usually available at the corner hardware store. Ordinary metal cabinets of the type normally employed for receivers and 100 watt transmitters are of no use as shielded enclosures. Even enclosed relay

racks are very poor shields without special treatment.

Figure 30 shows how aluminum angle framework can be built on the rear of an existing transmitter which, when covered with perforated aluminum and replaced in its regular dust cover, will provide an excellent job of shielding. In fact, you will now have a double shielded enclosure if you do a little work on the old cabinet such as weatherstripping cracks and joints in the cover, covering large openings, removing paint from joints, etc.

Examples of using this electronic weatherstrip or r.f. gasket are shown in Figure 31. This material is made from a knitted wire mesh in several shapes suitable for attaching to hinged doors or removable front panels. It is made by the Metal Textile Corp. of Roselle, New Jersey. Photo-

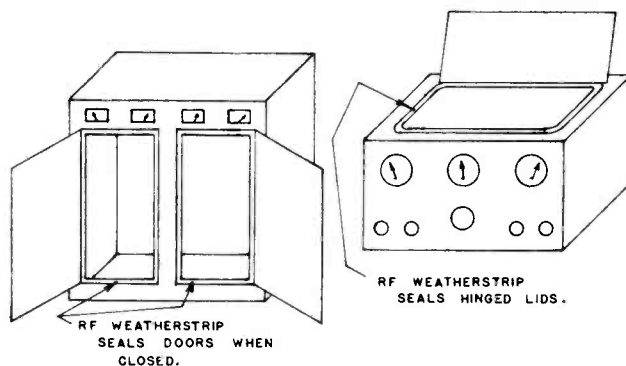


Figure 31 — This shows two methods of using Metex R. F. Electronic Weatherstrip. Provisions must be made so that bare metal on the doors and lid make contact with the weatherstrip under pressure.

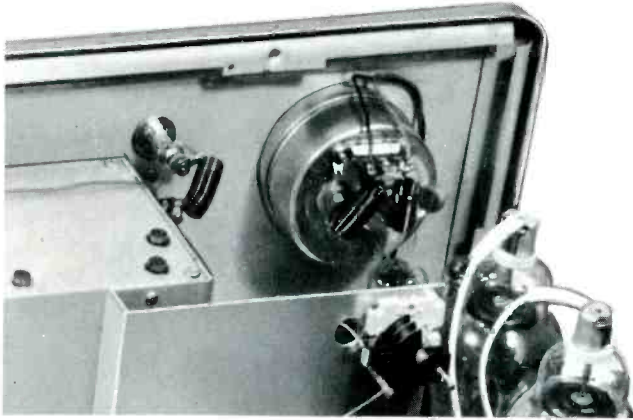


Photo 20 — A closeup of the recommended method of shielding and filtering meters in a transmitter. Note that even the lead to the dial light is filtered (top center). Also note the flanges along the edge of the panel for r.f. weatherstrip. This is a Johnson Valiant transmitter.

graphs of the material appear in Chapter 10.

To insure a good job of shielding no large holes or cracks should be left in the cabinet. This includes meter holes. Photo 20 illustrates the use of a shield or box around the rear of the meter. This box should be attached to, and make good contact with, the panel. Note that the leads to

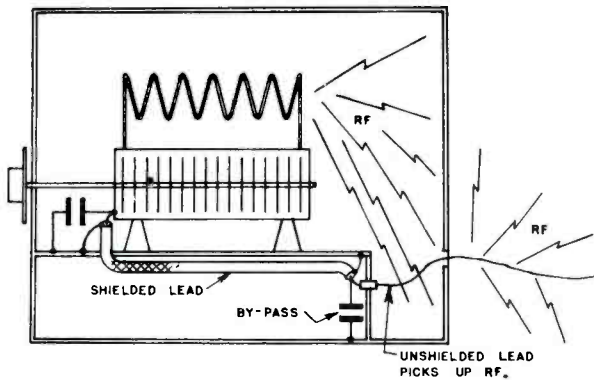


Figure 32 — A metal cabinet can be an adequate shield but there will still be radiation if the leads inside can pick up r.f. from the transmitting circuits and conduct it outside of the shield as shown.

the meter are shielded and the meter bypassed with .001 disk ceramic condensers.

All the filtering and by-passing shown in Figure 32 is for naught, because, due to improper shielding, the spurious signals are picked up by the unshielded power leads inside the cabinet and then conducted outside. The proper way would have been to shield the top of the r.f. chassis to confine the r.f. field and then to have continued the use of shielded leads to the point where the power leads leave the main cabinet. At this point another r.f. choke-

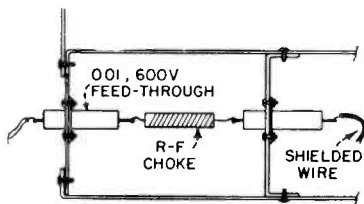


Figure 33 — Circuit details and mechanical construction of a shielded filter for cleaning the interference out of power leads just before they leave the shielded enclosure. This is often necessary in TV fringe areas. This is Test 12 in Table V.

Experiment	Field Strength
(1) Oscillator shielded, batteries external, no filtering.	7,000 $\mu$ v
(2) Oscillator unshielded, batteries shielded	2,000 $\mu$ v
(3) Oscillator partly shielded, batteries shielded	1,800 $\mu$ v
(4) Oscillator and batteries shielded, but poor contact	1,400 $\mu$ v
(5) Oscillator and batteries shielded, but better contact	730 $\mu$ v
(6) Oscillator and batteries shielded, fair contact, no screws	114 $\mu$ v
(7) Oscillator and batteries shielded, good contact, no screws	40 $\mu$ v
(8) Oscillator and batteries shielded, good contact with all screws in place	1 $\mu$ v
(9) Oscillator shielded as in (8), but with external batteries	7,000 $\mu$ v
(10) Oscillator shielded with one-section lead filters.	45 $\mu$ v
(11) Oscillator shielded with two-section lead filters, plus extra iron shield over coil	>1 $\mu$ v

Table IV — Showing effectiveness of various degrees of shielding.

condenser filter is required.

An example of good shielding is shown in Photo 21. This is a Johnson Viking Pacemaker Single-side-band exciter/transmitter. In addition to a shielded cabinet which was removed for the picture, note the shielded meter and the shielding on the main chassis. Of particular interest are the flanges all the way around the front panel. The metal weatherstripping is contained in the groove between this flange and the lip on the front panel. The front edges of the cabinet are drawn tightly against this radio weatherstripping by long screws making an r.f. tight joint for perfect shielding.

### Shielding Test

To determine the relative effectiveness of various arrangements of shielding and its relation to filtering,

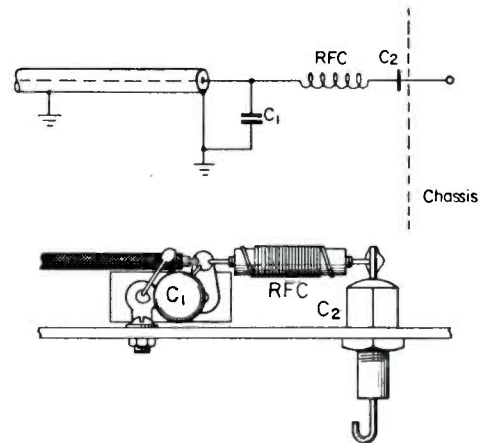


Figure 34 — Method of lead filtering, not quite as effective as that of Figure 33, but often adequate. This is Test 5 in Table V.

C<sub>1</sub> — 0.001-ufd. miniature disk ceramic.

C<sub>2</sub> — 0.001-ufd. feed-through by-pass (Erie Style 326). (For 500–2000-volt lead, substitute Plasticon Glass mike, LSG — 251, for C<sub>1</sub> and C<sub>2</sub>.)

RFC — 14 inches No. 26 enamel close-wound on 3/16-inch diam. form or resistor.



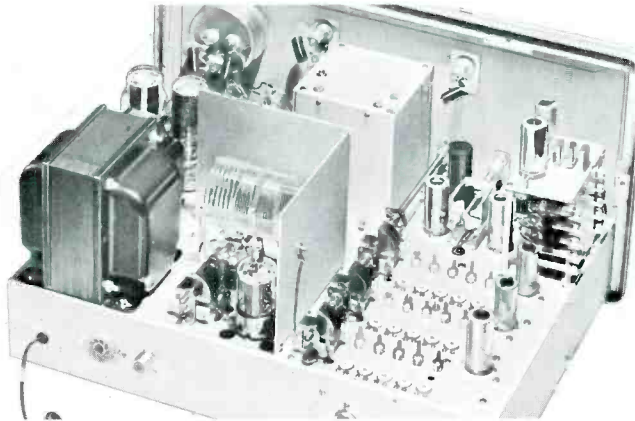


Photo 21 — Close up of a Johnson Pacemaker S.S.B. transmitter showing the shielding and filtering for the meter and dial lights. Also shown is the method of using r.f. weatherstripping to insure an r.f. tight cabinet. The weatherstrip is placed in the slot around the edge of the panel and the cabinet is drawn against it tightly by long screws. The top, right side and rear of the shielding on final amplifier was removed for the picture.

a set of 11 experiments were conducted as outlined in Table IV. The oscillator, a 6J6, was operating on about 30 Mc. at 1 watt. Note that in the first eight experiments the field strength goes down as the shielding is improved until it reaches a barely readable 1 uv. when all the screws are in place. In 9, 10 and 11, the batteries are external to the box with three degrees of filtering in the 18 inch battery leads. Note that with no filtering it is of no use to shield and visa-versa. To be effective both shielding and filtering are necessary.

● LEAD FILTERING

The type of lead filtering and the location of the filters is important. Figure 33 shows an excellent way to filter a lead. Here the lead carrying a.c. or d.c. voltage is fed to the filter in shielded wire. It penetrates into the shielded filter box through a Sprague high-pass bulkhead type condenser. This filter compartment contains the r.f. choke. The lead leaves the filter compartment through another high-pass condenser. This method is recommended in TV fringe areas where TVI is difficult. In primary reception areas the method shown in Photo 23 may suffice. This is equivalent to Test 3 in Table V. Here, a condenser, .005 to .01 uf. disk ceramic, replaces the shielded filter. It must be mounted right at the point that the lead leaves the shielded cabinet. These condensers that are used to by-pass



Photo 23 — Proper method of by-passing the end of a shielded lead using a disk ceramic condenser. A 0.001 ufd. to 0.005 ufd should be used for 1600 volts or less; 500 uuf. at higher voltages. The leads are wrapped around the inner and outer conductors and soldered so that the lead length is negligible.

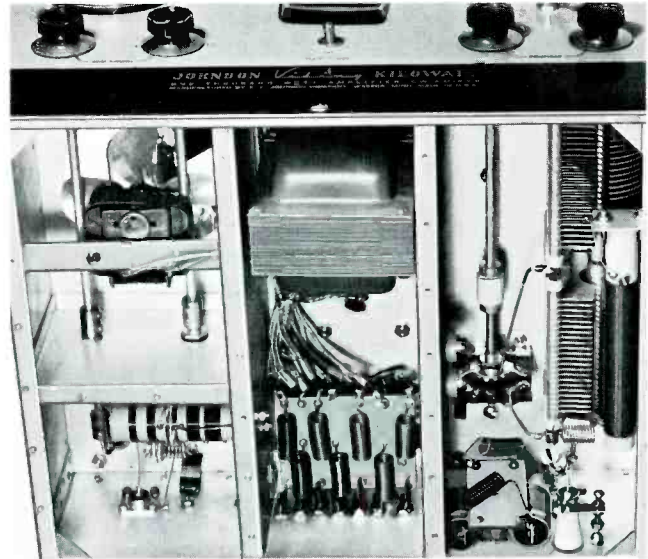


Photo 22 — This is a view of the underside of a Johnson Viking kilowatt chassis showing how it is divided into sub-compartments to contain r.f. in its proper places. At the bottom center you will note the double section r.f. filters in the leads just before they leave the cabinet. Note that the wiring to these filters is shielded wire.

the ends of the shielded wire should be soldered between the inner conductor and the braid with practically no leads. A properly soldered disk ceramic is shown in Photo 23.

Photo 24 shows the bulkhead type of high-pass feed-through condenser referred to as C<sub>3</sub> in Table V and also shown in Figure 33.

A practical method of incorporating these filters is demonstrated in the Johnson Viking Kilowatt shown in Photo 22. At the lower center can be seen the filter chokes for all leads leaving the shielded enclosure. The condensers are on the other side of the mounting board. The shielded bottom pan was removed for the picture. The filter for the 2500 volt plate lead is at the bottom right of the photo.

Filter Tests

Table V gives a comparison in filtering effectiveness of various combinations of capacitors, resistors and chokes as measured in the external B-plus supply lead of an 80 Mc. test oscillator.

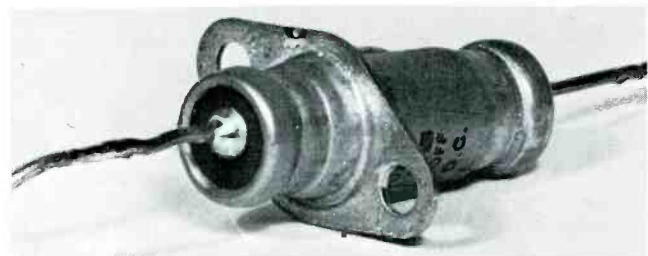


Photo 24 — This is a bulkhead type of high-pass condenser. In use, a hole large enough for the body of the condenser is drilled in the shield and then the condenser is inserted and bolted in place. The connections or terminals of this type of condenser are the "through wire" and the case.

## Chapter 5 — Shielding and Filtering

### Filter Circuit Arrangements

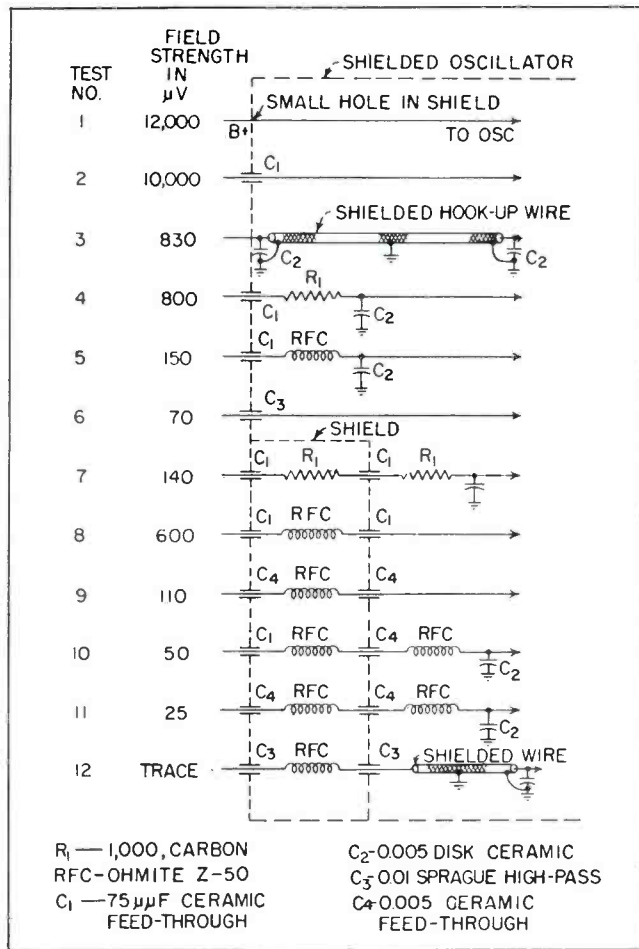


Table V — Showing effectiveness of various types of lead filtering.

The 12 tests listed in Table V were conducted to get actual figures on the effectiveness of lead filtering. The three important factors in designing a lead filter are the frequency to be attenuated, the current in the lead and the voltage.

Radio-frequency chokes must be used in filament or heater circuits, as well as in a.c. line circuits. If the current is high, a large wire size should be used, but the inductance should be maintained in the vicinity of 6 to 10  $\mu$ h. Resistors are satisfactory in a.v.c. circuits or low current B-plus lines. Small disk ceramic capacitors are good (500 to 5,000 uuf.) if the voltage is 300 volts or less. Bulkhead or feed-through capacitor types are preferable when passing a lead through a shield. The high-pass type is good, especially for the higher voltages. The best attenuation is attained when each section of the filter is shielded. For high power transmitters with plate voltages of 1000 v and up the TV type of ceramic stand-off condensers may be used. Several can be strapped in parallel to get a higher capacity if needed. These are 500 uuf. at 10,000 v. The filament or cathode circuit is always a "hot" place for harmonics and therefore it is often better to shield the filament transformer along with the rest of the final amplifier. It is then easy to filter the low current 120 a.v.c. primary line. Note the filament transformer in Photo 22, top center.

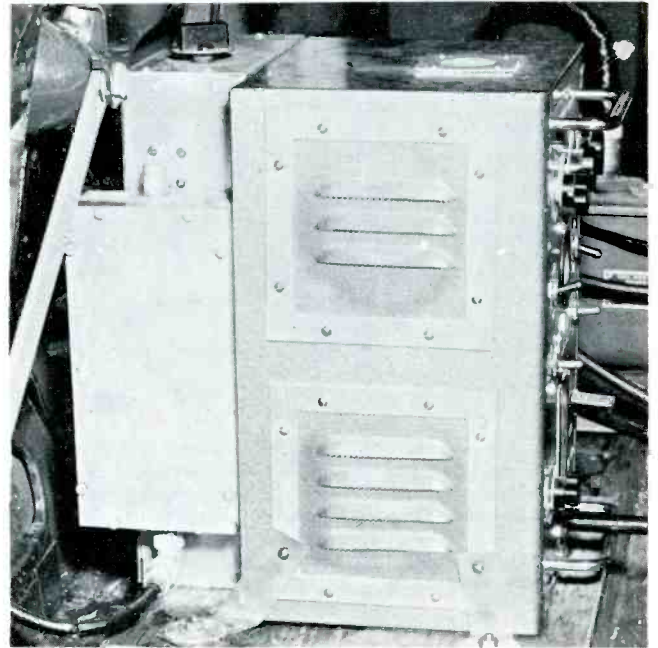


Photo 25 — A method of TVI-proofing a mobile transmitter (Harvey-Wells TBS-50). A lead filter box and a low-pass filter have been bolted on the rear and the louvres on the cabinet have been covered with screening. The front panel has been bonded to the cabinet and the entire works strapped across the shock-mounts to the body of the car.

### EXISTING EQUIPMENT

One is often faced with the problem of TVI-proofing an existing piece of transmitting gear. The amount of work you will have to do depends on several things, for example, the frequencies involved, the TV signal strength, the extent of the TVI, the distance between your equipment and the TV receiver, etc. The first thing to try would be a low-pass filter connected to the transmitter on the chance that the TVI was being caused by harmonic radiation. The next thing to try would be a high-pass filter on the TV receiver. If you are in a weak to medium signal strength area and the transmitter is operating on 14 Mc. or higher, you may have to give the transmitter the "treatment". That is, shield it like that shown in Figure 30 and Photo 19 and filter the leads like that shown in Figure 34. A low-pass filter and an antenna tuner should be used.

Some commercially built transmitters just do not have enough room for the installation of the necessary filters in each of the wires or leads that leave the shielded cabinet and so it is often more convenient to mount these filters in an external box built for the purpose and tightly attached to the rear of the transmitter. Such a filter box is shown in Photo 25 attached to the rear of the Harvey-Wells TBS-50. The smaller box in the lower left is the low-pass filter.

Generally speaking, on an existing transmitter, it is not necessary to rewire the whole thing with shielded wire. It is usually easier to do an extra good job of shielding and filtering. If the present transmitter does not have a coax fitting for the antenna connection one must be added. It is very important that coax feed-line from the transmitter to the low-pass filter and on to the antenna or antenna coupler be properly equipped with coax fittings so that no r.f. can manage to get on the outside of the shielding.

## CHAPTER 6

### SPECIAL V.H.F. PROBLEMS

When operating a radio transmitter in the v.h.f. range of 50 to 150 Mc. in close proximity to TV receivers certain special problems arise in addition to those already discussed in Chapters 3, 4 and 5. For example, an amateur radio operator who chooses to work in the amateur six meter band (50 to 54 Mc.) may cause TVI directly or indirectly in any one or combination of the following ways:

#### ● 50 Mc. TVI

- 1.) Radiation of transmitter harmonics on the TV channels.
- 2.) Overload of the TV receiver's front end by the 50 Mc. signal.
- 3.) Adjacent channel interference to channel 2.
- 4.) 4.5 Mc. sound beat with Channel 2 video carrier.
- 5.) 3.58 Mc. color beat with Channel 2 video carrier.
- 6.) External generation of harmonics by a non-linear detector in the vicinity (corroded joint).
- 7.) Hetrodyne type of TVI due to the 50 Mc. signal beating with some other radio or TV signal.
- 8.) Audio rectification.

Of the eight above types of TVI only one, the first, is the fault of the transmitter. The other seven are due to the lack of rejection by the TV receiver of the 50 Mc. signal. Also most of the TVI will be caused to channel 2 which is adjacent to the 6 meter band. If channel 2 is not used in your locality most of the troubles will be missing.

Let's discuss each of the eight types of 50 Mc. TVI separately in turn.

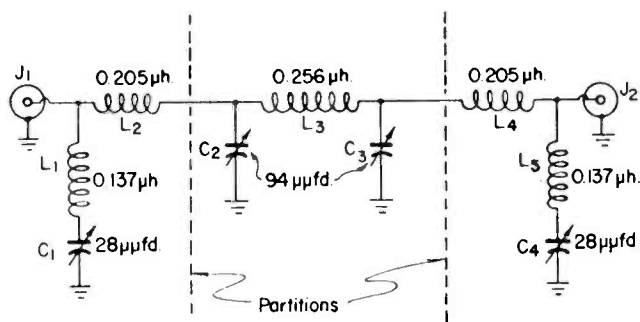
#### 1.) Radiation of Harmonics

All the usual steps in reducing harmonic type of TVI that were discussed in the chapter on transmitters apply here equally well. A lot of trouble due to the radiation of harmonics from frequency multipliers can be avoided quite easily by dispensing with the frequency multipliers. In other words, start off directly on 50 Mc. with a 50 Mc. crystal oscillator. The only harmonics to worry about in this case will be the 2nd on 100 Mc., the 3rd on 150 Mc., the 4th on 200 Mc. and the 5th on 250 Mc. Of these, only the 4th hits a TV channel, channel 11, 198 to 204 Mc. when an operating frequency of 50 Mc. is used, Channel 12, 204 to 210 Mc. for 52 Mc. and channel 13, 210 to 216 Mc. when using 54 Mc. If you do have trouble with this type of TVI it is sometimes possible to shift your frequency so that your harmonic lands in an unused channel. The best way of course, is to improve your shielding and filtering and use a special 50 Mc. low-pass filter.

A filter of this type is shown in Figure 35. A regular low-pass that would be used on a 3 to 30 Mc. transmitter would have a cut-off frequency of around 35 to 40 Mc. and so would block the 50 Mc. signal. This special low-pass is designed to cut-off around 75 Mc. and so blocks the second harmonic at 100 Mc. and all higher harmonics including those that might cause TVI to channels 11, 12, 13 and the UHF channels. No frequencies lower than 100 Mc. need be worried about if a 50 Mc. crystal is used.

#### 2.) Front-End Overload

This is a problem that is similar to that described in the chapter on TV receivers. It is more difficult in this case because 50 Mc. is within the passband of the RF stage of the receiver when tuned to the low TV channels. It will only happen to nearby receivers (within a few hundred feet) and then not to all of them. It is marked by picture interference to several low channels. If channel 2 is not being used in the area, wave traps, stubs (see



C<sub>1</sub>, C<sub>4</sub> — 50 Mc.: 50-*uufd.* variable, shaft-mounted, set to middle of tuning range (Johnson 50L15).  
144 Mc.: 11-*uufd.* fixed ceramic (10-*uufd.* useable).

C<sub>2</sub>, C<sub>3</sub> — 50 Mc.: 100-*uufd.* variable, shaft mounted, set with rotor  $\frac{1}{4}$  inch out of stator (Bud MC-905).  
144 Mc.: 38-*uufd.* stand-off by-pass (Erie Style 721A).

50-Mc. coil data:

L<sub>1</sub>, L<sub>5</sub> —  $3\frac{1}{2}$  turns  $\frac{5}{8}$  inch long. Top leads  $\frac{3}{4}$  inch, bottom leads  $\frac{1}{4}$  inch long.

L<sub>2</sub>, L<sub>4</sub> —  $4\frac{1}{2}$  turns  $\frac{3}{8}$  inch long. Leads  $\frac{1}{2}$  inch long each end.

L<sub>3</sub> —  $5\frac{1}{2}$  turns  $\frac{7}{8}$  inch long. Leads 1 inch long each.

All 50-Mc. coils No. 12 tinned,  $\frac{1}{2}$ -inch diam., coil length measured between right-angle bends where leads begin.

144-Mc. coil data:

L<sub>1</sub>, L<sub>5</sub> — 3 turns  $\frac{1}{4}$  inch long. Leads  $\frac{1}{4}$  inch long each end.

L<sub>2</sub>, L<sub>4</sub> — 2 turns  $\frac{1}{8}$  inch long. Leads 1 inch long each end.

L<sub>3</sub> — 5 turns  $\frac{3}{4}$  inch long. Leads  $\frac{5}{8}$  inch long each end.

All 144-Mc. coils No. 18 tinned,  $\frac{1}{4}$ -inch diam., lengths measured as for 50-Mc. coils.

J<sub>1</sub>, J<sub>2</sub> — Coaxial fitting.

Figure 35 — Schematic diagram of the 50- and 144-Mc. filters. No partitions are built into the 144-Mc. unit. Values on the drawing are for the 50-Mc. filter.



Figure 39) or special high-pass filters attached to the TV receiver will usually cure the trouble. If channel 2 is being used you must be careful to use a device that will not attenuate 54 to 60 Mc. while attenuating 50 to 54 Mc. A double parallel stub taped to the TV feeder and tuned with a small split-stator condenser, as shown in Figure 36, has been used quite successfully by a number of 50 Mc. operators. One of the new 50 Mc. Drake or Grallen high-pass filters will be better of course, because they protect the TV receiver for all transmitting frequencies from 52 Mc. down to 1.8 Mc. A home made filter of this type is discussed in the chapter on filters.

### 3.) Adjacent Channel Interference

This results from hetrodynes or beats between the video or sound carriers on one TV channel and an r.f. signal in the adjacent channel. This appears as horizontal or

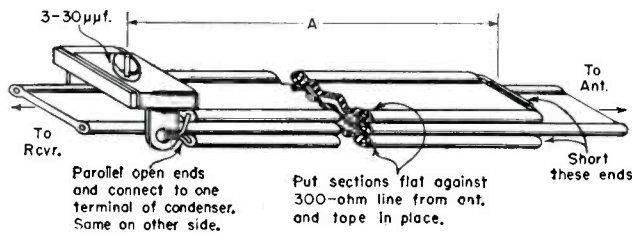


Figure 36 — Absorption-type wavetraps using sections of 300 ohm line tuned to have an electrical length of  $\frac{1}{4}$  wavelength at the transmitter frequency. Approximate physical lengths are as follows: Dimension "A", 40 inches for 50 Mc. and 11 inches for 144 Mc., allowing for the loading effect of the capacitance at the open end. Note that two traps are used in parallel, one on each side of the TV receiver feed line.

diagonal lines in the TV picture. Of course if the adjacent channel signal is strong enough it will completely destroy the picture on the desired channel.

An example of this involves TV signals on channels 7, 8 and 9. In this case channel 8 was measured at 28,000 uv at the receiver antenna terminals while channels 7 and 9 were only about 4,000 uv. With this 7 to 1 ratio in signal strength one TV receiver was able to discriminate against channel 8 and receive clear pictures on channels 7 and 9 while a second could not. The solution to the problem was to attach a frequency conscious attenuator such as a wave trap to attenuate channel 8 to a point where the receiver could handle the situation. The same solution applies to 50 Mc. adjacent channel interference to channel 2. As pointed out in the preceding Section 2, the most satisfactory devices are probably the new Drake or Grallen high-pass filters, although the tuned stub works very well and is cheaper. One characteristic of this type of interference is that it occurs only on selected receivers scattered over a wide area. TVI may be reported from receivers up to several miles away while many receivers close by may get no TVI.

### 4.) Sound Beat

This type of TVI is caused when an r.f. signal is 4.5 Mc. away from the video carrier. (See Figure 37.) On an inter-carrier type of TV receiver as explained in the receiver chapter, a TV receiver receives the sound part of the TV program by amplifying and detecting the 4.5 Mc. beat note that occurs between the video transmitter and sound transmitter. These are always separated (in the U.S. and

Canada) by exactly 4.5 Mc. with the sound transmitter always on the high frequency side of the video transmitter. (See Tables 5 and 6 in the appendix for other countries.) In the case of channel 2 the video is on 55.25 Mc. and the sound is on 59.75 Mc. Now if an amateur transmitter operates on 50.75 Mc. a beat note or hetrodyne will be generated at the sum and differences of the two frequencies, or on 4.5 Mc. and 106 Mc. The 106 Mc. signal would fall in the video image range for channel 2, see Figure 5 on page 15, and cause cross hatching with a 0.75 Mc. beat, while the 4.5 Mc. would feed straight through the loud speaker just like the sound channel. The cross hatching may not be too bad if the TV receiver has reasonable selectivity because 106 Mc. is quite a bit above channel 2 in frequency. By far the worst damage will be to the TV sound.

The solution again is a special high-pass filter or stub and if the trouble still persists avoid operation on or near 50.75 Mc.

### 5.) 3.58 Mc. Color Beat from 50 Mc.

This type of TVI only happens to channel 2 on color receivers. When a radio station operates 3.58 Mc. above or below a video or sound carrier, a beat note of that frequency will be generated and it will be passed and amplified by the TV receiver in the regular manner along with the video and sound. In the case of the six meter amateur band the frequency to avoid is 51.670 when there are nearby color receivers, otherwise flashing rainbows may appear on the screen. (They are really quite pretty - at first). The cure is the above mentioned high pass filter

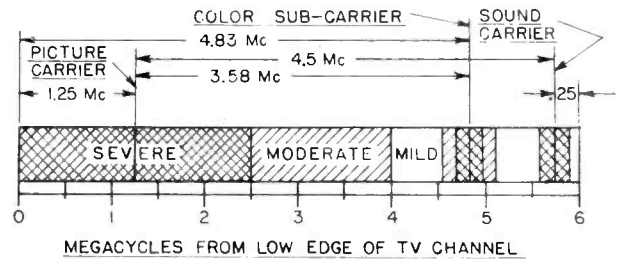


Figure 37 — Location of picture, sound and color sub-carrier in a television channel. The cross hatching indicates the relative severity of the TVI caused by interfering signals in various parts of the channel. For minimum interference, the transmitter frequency should be adjusted so that harmonics fall in either of the clear areas.

or stub and the avoidance of 51.670 Mc. This beat note, of course, is the frequency of the color sub-carrier that is transmitted by the TV station in bursts of a few cycles each to control the color in the color picture. Any interference with this signal will change the color of the picture when the receiver is receiving a color program. When receiving a black and white picture this beat note supplies a color sub-carrier that triggers off the color in a random fashion and it is very disturbing to the viewer. Fortunately it is difficult to "get" a 3.58 Mc. signal into a TV receiver except by the beat method.

### 6.) External Generation of Harmonics

This problem has been discussed at some detail in another chapter and if trouble is suspected it is worth while to look into this angle. A check can be made by using two

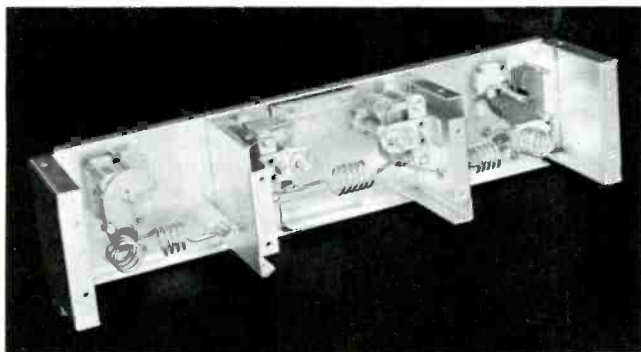


Photo 26 — Inside view of the 50 Mc. low-pass filter shown in Figure 35. It uses variable air condensers adjusted to the proper capacitance values and is suited to powers up to a kilowatt.

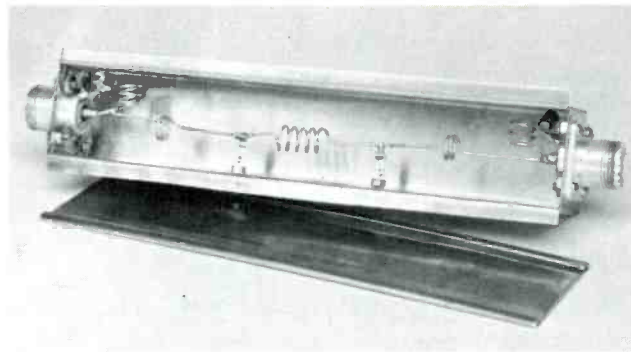


Photo 27 — Inside view of the 144 Mc. low-pass filter shown in Figure 35. It uses fixed ceramic condensers and is designed for low powered transmitters.

six meter transmitters tuned up 1.5 Mc. apart and listening for the beat note on a broadcast portable receiver at 1500 kc. For example, put your rig on 51 Mc. and a borrowed rig or your mobile on 52.5 Mc. Run feed lines to portable transmitting antennas near the suspected non-linear detector. Then look for the strongest beat on 1500 kc.

7.) Hetrodyne Type of TVI

This type of TVI is generated in exactly the manner described above for checking non-linear detectors. Two signals beat together and generate two new signals equal to their sum or difference. For example, a signal on 51 Mc. could beat with an FM broadcast signal on 108 Mc. and produce two new signals of 159 and 57 Mc. The 159 Mc. signal would cause interference to some mobile service, while the 57 Mc. signal would jam channel 2 if strong enough. A signal on 52 could beat with another on 123 Mc. and produce two new signals on 71 Mc. and 175 Mc. The 71 Mc. signal would cause TVI to channel 4 while the 175 Mc. beat would simultaneously jam channel 7.

To generate a strong enough beat or hetrodyne to cause this kind of TVI it is usually necessary to have a good mixer or non-linear detector in the vicinity. One of the best such devices of course, is built right into the front end of the TV set. The cure therefore, is to prevent the 50 Mc. signal and/or the other beating signal from reaching the r.f. stage or mixer of the TV set. The 50 Mc. high-pass or stub will handle the 50 Mc. signal, however traps are necessary for the other signal. See Fig. 7 page 16.

8.) Audio Rectification

This has been covered in the receiver chapter and the usual steps of installing a resistor in the 1st audio grid lead generally suffice. It is of course, perfectly possible to have audio rectification only from one band such as six meters. In such cases there is usually a resonance tuned to 50 Mc. in the audio grid circuit. The resistor breaks this up and removes the trouble by forming an RC filter circuit with the stray capacity of the grid wiring and tube input capacity. See Figure 12 on page 18. This type of TVI may also be cured by shifting to NBFM.

● 144 MC. TVI

Interference problems from 144 Mc. are less numerous and less severe than from 50 Mc. The most troublesome type is probably image interference to Channel 2 on the newer TV receivers that use an i.f. of around 44 Mc. The image, as you know, is twice the i.f. plus the signal fre-

quency or 54 to 60 plus 88 Mc. This means that any signal in the range of 142 to 148 Mc. will be received as an image. See Figure 38. (Also refer to Fig. 6 Chapter 3 page 15.) The higher in the band the worse the crosshatching will be because of the lower frequency beat between the 148 Mc. signal and the channel 2 video carrier.

The cure for this type of interference is to trap out the 144 to 148 Mc. signal with a stub, Figure 39, a tuned stub, Figure 8, page 16, or wave traps similar to FM traps, Figure 7.

● HARMONICS from 144 MC.

Harmonics from a 2 meter final amplifier do not cause trouble to channels 2 - 13. Their frequencies are: 2nd - 288 to 296 Mc.; 3rd - 432 to 544 Mc.; 4th - 576 to 592 Mc.; 5th - 720 to 740 Mc.; 6th - 864 to 888 Mc. It is

Harmonic Relationship—Amateur V.H.F. Bands and U.H.F. TV Channels

Amateur Band	Harmonic	Fundamental Freq. Range	U.H.F. TV Channel Affected
144 Mc.	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	58
	6th	144-144.33	79
		144.33-145.33	80
		145.33-147.33	81
		147.33-148	82
220 Mc.	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 Mc.	2nd	420-421	75
		421-424	76
		424-427	77
		427-430	78
		430-433	79
		433-436	80
		436-439	81
		439-442	82
442-448	83		

Table VI — This table shows the harmonic relationship of amateur v.h.f. bands to u.h.f. Television channels.

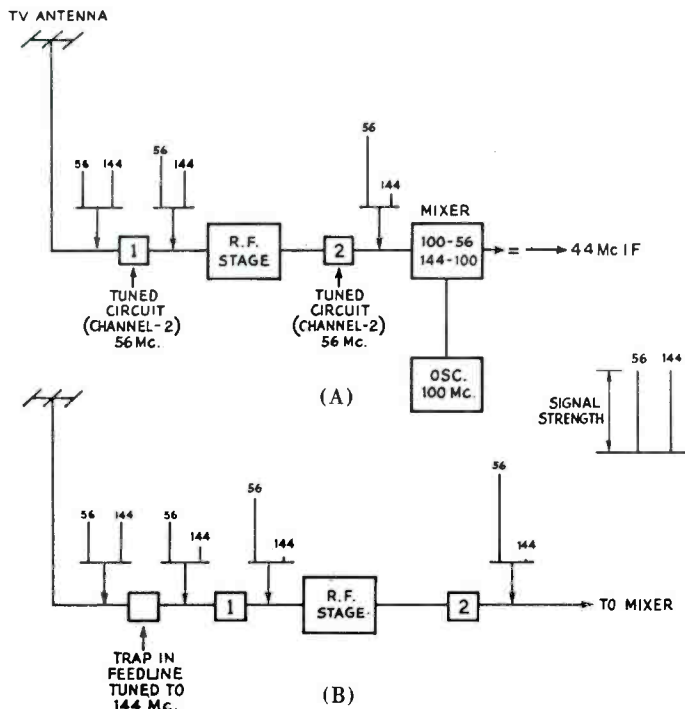


Figure 38 — Block diagram of the input stages of a TV receiver with 41-45.5 Mc. i.f. (A) receiver tuned to channel 2 but with inadequate selectivity in the input stages will pass enough strong 144 Mc. signal to cause image interference with reception. (B) Adding a 144 Mc. "trap" in the antenna feed line improves the selectivity of the TV receiver and prevents image interference from 144 Mc.

usually difficult to generate r.f. on these frequencies even when you want to and so in most cases the higher harmonics from a two meter rig cause no trouble. If you do have TVI on a specific UHF channel that is harmonically related to the above frequencies a simple low-pass filter will generally correct it. See Table VI. The filter has to be specially designed to pass 148 and yet block 288 and higher. A suitable filter for use in a 52 ohm coax line from a two meter transmitter to an antenna or antenna coupler is shown in Figure 35 and Photo 27.

**HARMONIC LEAKAGE**

Another thing to watch out for when operating on the 144 Mc. band is harmonic leakage from your frequency multiplying stages. Since the advent of the now famous 522 war surplus 2 meter transmitter it has been customary to use 8 Mc. crystals followed by frequency multipliers in most 144 Mc. transmitters. This means multiplying the crystal 18 times to reach 144 Mc. Depending on the circuit and layout used, this would make it possible to have a harmonic every 8 Mc. or nearly one per TV channel. The strongest ones will be those associated with the last doubler or tripler. The low-pass filter of Figure 35 and Photo 27 will not block these sub-harmonics because they are lower in frequency than the fundamental. A good solution is to use a higher frequency crystal. It is not always practical to start out with a 144 Mc. crystal therefore the best you can do is to use either a 48 or 72 Mc. crystal.

In the first case you must triple and in the latter case you double the frequency to get 144 Mc. The 48 Mc. crystal is preferable because its second harmonic, 96 Mc. lands out of the TV range and even avoids an image relationship by landing in the image of the guard channel half way between channels 4 and 5. The 72 Mc. crystal on the other hand is right on the edge of channel 4 and will require good shielding. This same thing should be born in mind when multiplying up from an 8 Mc. crystal or VFO. Triple in the last multiplying stage to avoid TVI to channel 4. In any case, good shielding and lead filtering are in order to prevent sub-harmonics on TV channels from escaping from frequency multipliers.

**U.H.F. TV STRIPS**

A type of i.f. interference which is unique for the 2 meter band occurs in areas where certain u.h.f. TV channels are in use. It is caused only to certain type TV tuners that use plug-in, double conversion type of u.h.f. tuning strip. These strips are designed to use a first i.f. that varies with the channel received. In some cases this 1st i.f. is either in or close to the 2 meter band (144-148 Mc.). Since u.h.f. front-ends have practically no selectivity an amateur 144 Mc. signal has no difficulty in getting into this first i.f. and thereafter, of course, it passes through the rest of the TV receiver in a normal fashion — all through no fault of the amateur.

The cure, if the TV receiver is not too close to the transmitter, is the usual stub or wave-trap. If the interference is heavy, the cure may require that a TV serviceman retune the 1st. i.f. to a new frequency away from the 2 meter band.

**U.H.F. Channels Likely to be Affected.**

Receivers with 21 Mc. i.f.	Receivers with 41 Mc. i.f.
Channels 14 - 18 inc.	Channels 20 - 25 inc.
" 41 - 48 "	" 51 - 58 "
" 69 - 77 "	" 82 - 83 "

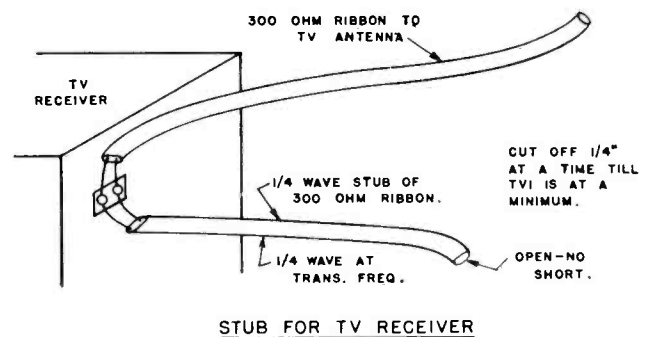


Figure 39 — Method of connecting a 1/4 wave open stub on rear of TV receiver for preventing TVI from v.h.f. transmitters. Stub should be 49 inches long for 50 Mc. and 17 inches long for 144 Mc. Trim length a little at a time for minimum TVI.



● V. H. F. STUBS

Figure 39 shows a simple  $\frac{1}{4}$  wave stub that in many cases will cure 50 or 144 Mc. TVI providing it is caused by the fundamental and not by spurious signals. To start with, it is cut a few inches too long from 300 ohm TV ribbon and after attaching to the antenna terminals of the TV set, it is cut off  $\frac{1}{4}$  inch at a time while watching the TV picture until the TVI is at a minimum. The final length should be close to .84 of an electrical quarter wave at the transmitter's output frequency. This would be around 17 inches for 144 Mc. and about 49 inches for 50 Mc. If you make this latter stub too short it will cut out channel 2 so you may end up with a compromise of 50 inches in channel 2 areas. The bottom end is open — not shorted.

● ANTENNA COUPLER

When using 300 ohm feeders with a low-pass filter, it is necessary to use an antenna tuner so that the low-pass filter can be used in coax cable and the coax in turn may be matched to the 300 ohm feeder. A suitable tuning or matching unit is shown in Figure 40 together with coil specifications for both 50 and 144 Mc.

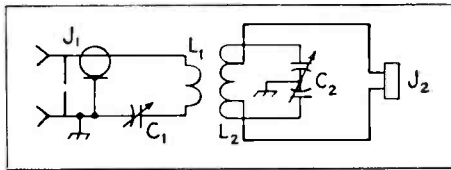


Figure 40 — Antenna Coupler for 50 and 144 Mc. Matches 52 ohm coax to 300 ohm ribbon.

- C<sub>1</sub> — 100 uuf. variable for 50 Mc., 50 uuf. for 114 Mc. (Hammarlund MC-100 and MC-50).
- C<sub>2</sub> — 35 uuf. per-section split-stator variable, 0.07-inch spacing (Hammarlund MCD-35SX). Reduce to 4 stator and 4 rotor plates in 144-Mc. coupler for easier tuning.
- J<sub>1</sub> — Coaxial fitting, female.
- J<sub>2</sub> — Crystal socket.
- L<sub>1</sub> — 50 Mc.: 4 turns No. 18 tinned, 1 inch diameter,  $\frac{1}{8}$ -inch spacing (Air-Dux No. 808T).  
144 Mc.: 2 turns No. 14 enam., 1 inch diameter,  $\frac{1}{8}$ -inch spacing. Slip over L<sub>2</sub> before mounting.
- L<sub>2</sub> — 50 Mc.: 7 turns No. 14 tinned,  $1\frac{1}{2}$  inch diameter,  $\frac{1}{4}$  inch spacing (Air-Dux No. 1204). Tap  $1\frac{1}{2}$  turns from each end.  
144 Mc.: 5 turns No. 12 tinned,  $1\frac{1}{2}$  inch diameter, 1 inch long. Tap  $1\frac{1}{2}$  turns from each end.

There is only one way to quickly tune an antenna coupler and that is to use some form of standing-wave bridge connected between the transmitter and the antenna coupler. Set the bridge to read forward power and adjust the taps on the coil and the tuning condensers roughly for maximum power output. Next switch the bridge to read reflected power and carefully adjust tuning and taps for minimum reflected power. Usually it is possible to bring the reflected power reading to zero. The antenna coupler is now correctly adjusted for that particular antenna. All adjustments for power output and transmitter loading are done at the transmitter not at the coupler.

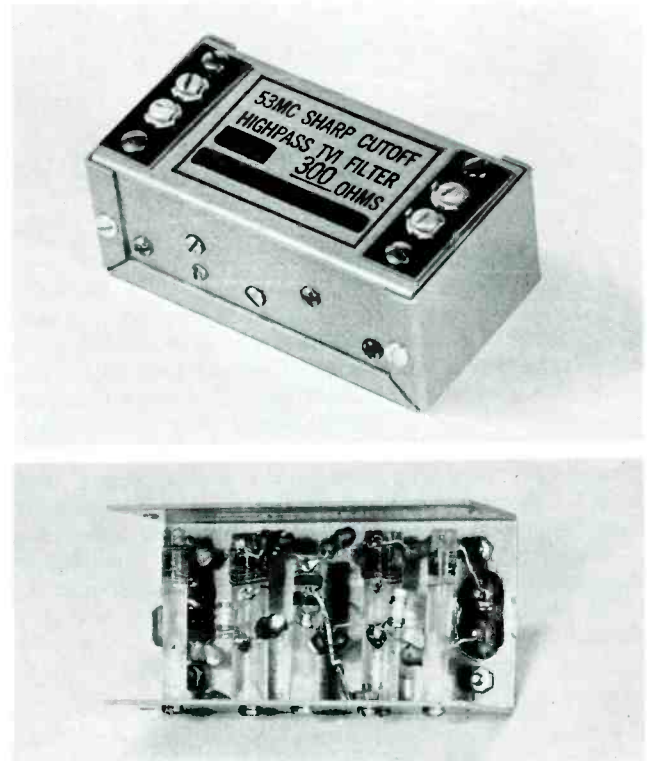


Photo 28 — Construction of a high-pass filter with a sharp cut-off at 53 Mc. This will protect a TV receiver against TVI from all amateur bands up to and including 6 meters (50-52 Mc.) Circuit diagram similar to the Ladd filter in Chapter 7.

● V. H. F. ANTENNAS

In general, if you do not feed harmonics on TV frequencies to the antenna, then it does not matter what kind of an antenna is used. There are cases, particularly on 6 meters, where TVI to channel 2 will be considerably less if a vertically polarized transmitting antenna is used. By doing this, the amount of 6 meter signal picked up by the horizontally polarized TV antenna is a good deal less and therefore the adjacent channel TVI is less.

When large multi-element horizontal beams are used TVI from both 6 and 2 meter fundamental overload can be severe when the transmitting beam is pointed directly at nearby antennas. It is advantageous under these circumstances to aim the beam in between TV antennas and if possible to turn it "ends on" to the nearest TV antenna.

● GENERAL

To reduce or eliminate TVI from v.h.f. transmitters, the same general procedures should be followed that were outlined in chapters 4 and 5 with particular emphasis placed on the techniques outlined in this chapter. Care must be exercised to prevent sub-harmonics (signals from the frequency multipliers) from reaching the antenna because these will not be blocked by either 50 Mc. or 144 Mc. low-pass filters. If anything, shielding and filtering must be done more carefully due to the higher frequencies involved. Narrow band frequency modulation can often be used to advantage on v.h.f. to cure bothersome audio recifications so common on these frequencies.

## CHAPTER 7

# THE DESIGN AND USE OF HIGH-PASS FILTERS

High-pass and low-pass filters are networks designed to pass a given range of frequencies while attenuating all others either lower or higher in frequency. A band-pass filter is a network that passes a given band of frequencies while attenuating all others both higher and lower. Such selective networks are called wave filters and are used in electronic circuits where their characteristics are needed. These filters are composed of low loss inductors and capacitors. In order for the filter to receive power from the generator and to deliver it to a load it is necessary that the input and the output or terminating impedances of the filter equal those of the generator and load. It must offer a resistance load to the generator at all frequencies to be passed and must look like a pure reactance at all frequencies that are not to be passed.

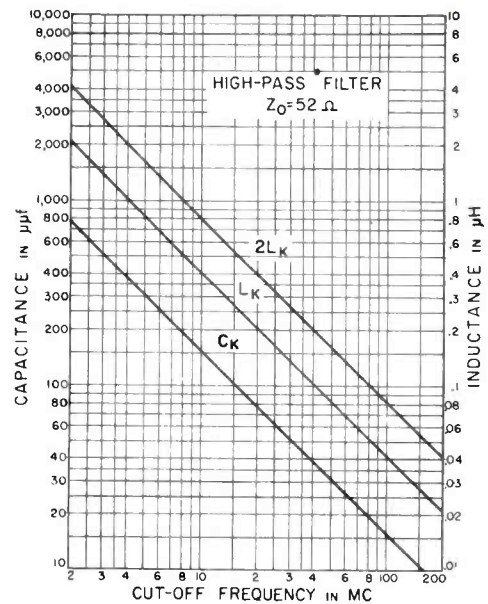
For a more detailed study of the theory of wave filters, the reader is referred to *Terman's Radio Engineers' Handbook*, published by the McGraw-Hill Book Company.

### ● HIGH-PASS FILTERS

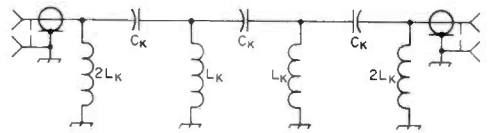
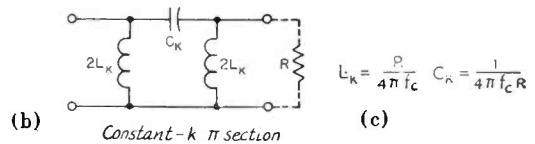
As pointed out in an earlier chapter, although wave traps and stubs may be used to attenuate undesired interfering signals, in most cases it is preferable to use a high-pass filter. Wave traps and stubs only attenuate a specific frequency while a high-pass filter will reject all signals regardless of frequency below its cut-off. The cut-off frequency is that frequency that separates the transmission band from the attenuation band. This cut-off frequency generally is selected to be about half way between the lowest frequency that is desired to be passed without attenuation and the highest frequency that is desired to be attenuated. In the case of TVI, most high-pass filters, except the special 50 Mc. type, must pass 54 Mc. and higher and must block 30 Mc. and lower. The cut-off frequency,  $f_c$ , therefore is chosen at around 40 Mc. This allows for some variation in component values and line impedances.

The basic formula for a Constant- $K\pi$  section type of high-pass is given in Figure 41 (c). You will note that the value for inductance,  $L_k$ , equals  $R$ , the terminating impedance, divided by  $4\pi$  times  $f_c$ , the cut-off frequency. The value of the capacitance,  $C_k$ , equals one divided by  $4\pi$  times  $f_c$  times  $R$ . Therefore you will see that any errors in component values, line termination, high SWR on line or use of wrong type of feeder, will result in a shift in the cut-off frequency and a general degrading of the filter's ability to pass and reject desired signals. This applies also to low-pass filters.

The high-pass filter in Figure 41 (d) is a single ended type designed for use in a 52 ohm coax cable. The values



(a) 52-ohm high-pass filter design chart.



(d) High-pass filter.

Figure 41 — (a) Design chart for 52 ohm high-pass filters. This may be used for 300 ohm filters by dividing the capacities by 3 and multiplying the inductances by 3 as explained in the Text. (b) Circuit of a simple Constant- $k$  section filter. Note that when several sections are used together as in (d) the coils are paralleled therefore the inductance of the "inside" coils is  $\frac{1}{2}$  the end coils. If you want to calculate your own the formula is given in (c).

for the various inductances and capacitances may be read directly from the chart in Figure 41 (a) simply by selecting an appropriate cut-off frequency at the bottom and then drawing a vertical line from this point intersecting the  $C_k$  and  $L_k$  curves. Next draw horizontal lines to the left for capacity in uuf, and to the right for inductance in uh.

## Chapter 7 — The Design and Use of High-pass Filters.

Although the chart shown is calculated for 52 ohms it may be also used for other values of  $R$  by simply multiplying the inductances and dividing the capacitances obtained from the chart by the ratio of the new  $R$  to 52 ohms. For example, if you wish to design a high-pass filter for 104 ohms, the ratio is 2 and you multiply your  $L_k$  and  $2L_k$  by 2 to get the proper values of inductance. Similarly, you divide  $C_k$  by 2 to get the proper capacitance.

To design a 300 ohm balanced high-pass filter for use in 300 ohm twin-lead type of feeder you must design two 150 ohm single ended filters back to back so to speak. In this case the ratio would be 3 when using the chart. A filter of this type is shown in Figure 42. The grounded center taps on the coils represent where the two single ended 150 ohm filters are connected together to form the balanced 300 filter. From the chart we find that the condensers should be 13 uuf, 39 divided by our ratio of 3, for a cut-off of 40 Mc., standard values of 10 or 12 uuf may be used without sacrificing any performance. Also from the chart we find that the end coils,  $2L_k$ , should be

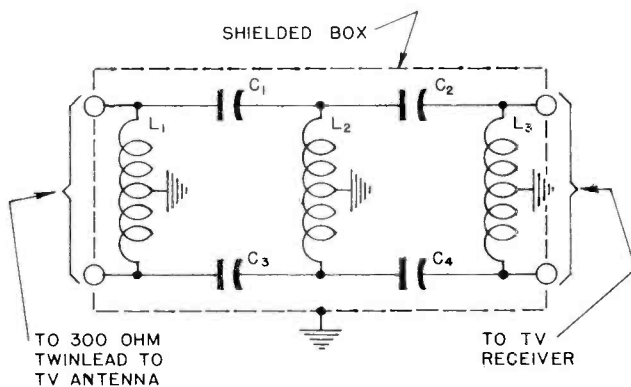


Figure 42 — A high-pass filter for 300 ohm feed line or TV ribbon. The two end coils should have an inductance of 1.2 uh. The center is .6 uh. All coils have their center-taps grounded to the metal shield box in which the filter is mounted. The condensers are small ceramic units of 10 to 12 uuf. Construction of the coils is given on page 40. This filter is good only up to about 40 Mc.

1.2 uh, .2 times our ratio of 3 times 2 for each filter, (.2x3x2=1.2). The center coil is  $\frac{1}{2}$  this, or .6 uh. All coils are center tapped and grounded to the small copper or aluminum box in which the filter is mounted.

High-pass filters of considerably more complicated design can, of course, be built but generally their use is reserved for special jobs. For example, a filter with  $m$ -derived sections will provide a much sharper cut-off than a constant- $K$  type. Two forms of  $m$ -derived filters exist, the series derived and the shunt derived. The series  $m$ -derived type is more commonly used in TVI filters where a very sharp cut-off is desired and where there is a certain frequency near cut-off that must be highly attenuated. Filters of this type are used for attenuating a six meter (50 Mc.) signal while passing channel 2, 54 to 60 Mc. The Drake TV-300-HP High Pass Filter is of this type and is shown in Photo No. 29.

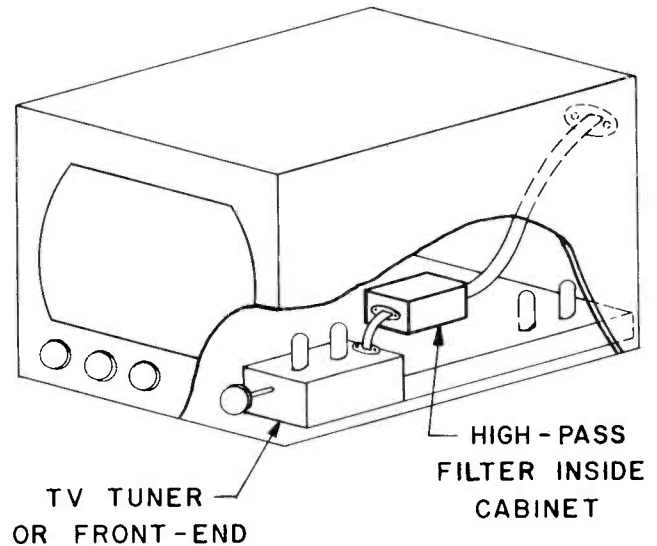


Figure 43 — A filter is only as good as the way it is used. Proper installation of a high-pass filter is inside the TV cabinet right up at the input terminals of the tuner as shown. The filter case should be grounded to the TV chassis except on transformerless a.c.-d.c. type of sets.

### ● USE OF HIGH-PASS FILTERS

In general, a wave filter of any type is no better than the way in which it is used. It must be born in mind that a filter can only filter out signals that go through it. If the interfering signals are getting into the TV receiver by means other than the antenna feed line then the high-pass filter cannot attenuate them. The methods and routes taken by interfering signals to reach the sensitive TV circuits have been covered in an earlier chapter. A high-pass filter is of use only when the interfering signal is coming down the TV feeder and when its frequency is such that it falls into the attenuate band of the high-pass. For example, a high-pass filter is of no help in curing image type of TVI. To really be effective the filter must be mounted inside the cabinet right up at the front end of the set with very short leads. See Figure 43. In many cases of mild interference the filter will do a good job mounted on the rear of the TV set, but in stubborn cases always mount it as close to the tuner as possible. Be sure it is a 300 ohm filter if your TV set uses 300 ohm ribbon for a feeder. In real troublesome cases it may also be necessary to take other precautions such as a bottom pan on the chassis or an a.c. line filter. See Figure 11 on page 18.



Photo 29 — Inside and outside views of new Drake Type TV-300-HP filter. This filter is the new type that cuts off at 52 Mc. and therefore gives protection to TV receivers from adjacent channel TVI from 50 to 51 Mc. amateur stations. It also, of course, works on all other lower frequency amateur bands as well as commercial stations.



## Chapter 7 — The Design and Use of High-pass Filters.

### Ladd 50 Mc. High-Pass

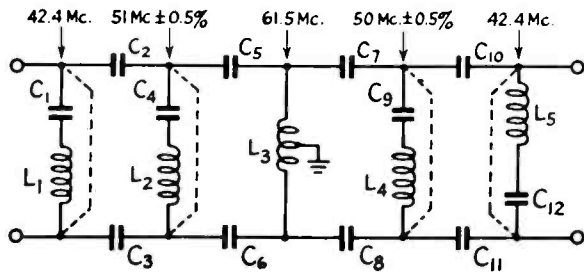


Figure 44 — Schematic diagram and parts information for the 300 ohm balanced-line filter designed by Ladd. The circuit of the filter in Photo 28 is similar. The frequencies listed at the top are for the tune-up procedure given in the text. The dotted lines are shorts which must be removed before using the filter. This filter cuts off at 52 Mc. therefore is good for 6 meters.

C<sub>1</sub>, C<sub>12</sub> - 10-uuf. ceramic, 10 per cent tolerance (Erie Ceramicon).  
C<sub>2</sub>, C<sub>3</sub>, C<sub>10</sub>, C<sub>11</sub> - 20-uuf. silver mica, 5 per cent tolerance (El-Menco CM-15).

C<sub>4</sub> - 5-uuf., similar to C<sub>1</sub>.

C<sub>5</sub>, C<sub>6</sub>, C<sub>7</sub>, C<sub>8</sub> - 15-uuf., similar to C<sub>2</sub>.

C<sub>9</sub> - 6.8-uuf., similar to C<sub>1</sub>.

L<sub>1</sub>, L<sub>5</sub> - 1.4 uh., 18 turns No. 28 enam. on ¼-inch form.

L<sub>2</sub> - 1.85 uh., 17 turns No. 24 enam. on ⅜-inch diam.

L<sub>3</sub> - 0.4 uh., 10 turns No. 24 enam., center tapped on ¼-inch form.

L<sub>4</sub> - 1.45 uh., 14 turns No. 24 enam. on ⅜-inch form.

### ● CONSTRUCTION OF HIGH-PASS FILTERS

The coils for the simple filter shown in Figure 42 may be constructed as follows:

L<sub>1</sub> and L<sub>3</sub> — measure off a 24 inch length of No. 30 enameled wire and, after twisting a small loop at the center and scraping the ends, close wind it on an eighth inch diameter plastic knitting needle. Cement the turns in place with plastic cement or coil dope.

L<sub>2</sub> — measure off a 12 inch length of No. 30 enameled wire and proceed as for L<sub>1</sub> and L<sub>3</sub>. The coils should have approximately 40 and 20 turns respectively.

The coils and condensers should be mounted on a small bakelite terminal board and the entire works enclosed in a small metal box equipped with terminals. The center-taps on the coils are grounded to the box.

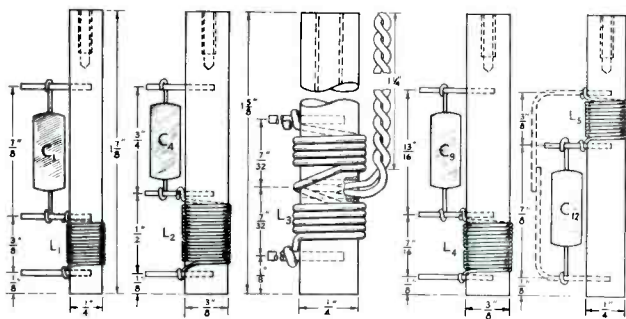


Figure 45 — Details of the coils used in the Ladd filter of Figure 44. Note that the scale of the center coil is enlarged to show details more clearly. The form is drilled to permit bringing the center-tap leads through the form as shown. They are cleaned, twisted together, and soldered.

For amateur TVI, it is always best to use a filter that will give protection for 6 meter (50 Mc.) signals even though that band is not being used at the moment. These filters work equally well for other lower frequency bands and have the advantage of 6 meter protection against the day that band is used in your locality.

Such a filter was designed by F. E. Ladd and the circuit diagram is shown in Figure 44. The construction of the coils is shown pictorially in Figure 45. Note that the center coil is enlarged to show the details of the center-tapped coil more clearly. The sharp cut-off at 52 Mc. is shown in Figure 46. The attenuation reaches 100 db. at 4 Mc.

This filter should be shielded and may be mounted in any suitable metal utility box. For size and physical layout, see the filter in Photo 28.

### Adjustment Procedure

It will be noted that at the top of the circuit diagram, Figure 44, there are tune-up frequencies given for each section of the filter. The dotted lines across the coil-con-

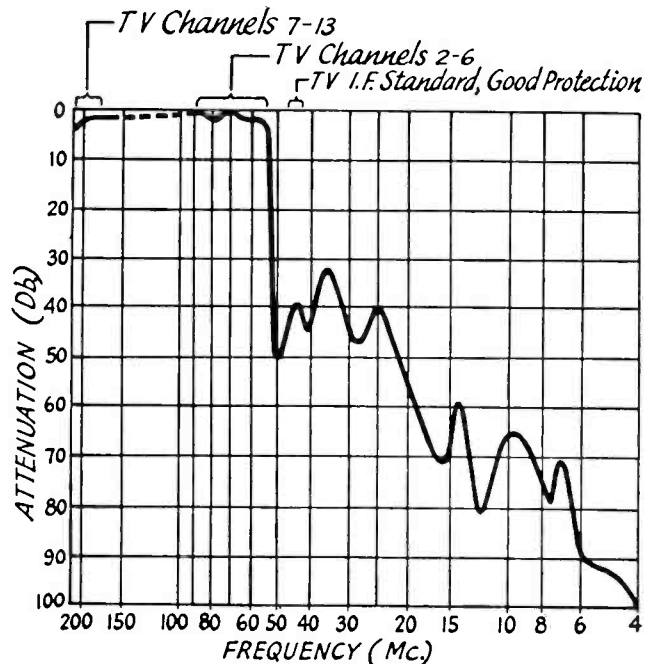


Figure 46 — Transmission characteristics of the Ladd high-pass filter. Front-end overload protection to TV receivers is very good on all frequencies below 52 Mc. Attenuation below 4 Mc. is in excess of 100 db.

denser assemblies represent short, heavy wire busses. These busses are installed after the filter has been assembled and wired. The tune-up procedure consists in adjusting the turns on each coil so that it resonates at the prescribed frequencies with a grid-dip oscillator. All four busses should be in place during this tune-up. The coil turns are now cemented in place and the busses removed. The filter is now ready for use after placing the cover on the box.

The frequencies indicated for the two coils either side of the center coil must be held within very close limits if the desired characteristics are to be attained. Check your grid-dip meter against a well calibrated 50 Mc. receiver before making these adjustments.

## CHAPTER 8

### THE DESIGN AND USE OF LOW-PASS FILTERS

Many of the things said about high-pass filters also apply to low-pass filters. It is desirable for the operator of a transmitter to have his low-pass filter complement the TV viewer's high-pass filter. In other words, there would be no interference if the low-pass filter in the transmitter feed line passed all frequencies below 40 Mc. and blocked the radiation of all frequencies above 40 Mc. provided the high-pass filters on all the nearby TV receivers blocked all signals lower than 40 Mc. and passed all TV signals above 40 Mc. In such a case the transmitter could not broadcast any spurious signals on TV channels and the TV receiver could not pick up any signals being sent on non-TV frequencies. With this in mind most low-pass filters are designed to have a cut-off frequency of around 35 Mc. This gives a little overlap between the two filters. A transmitter with such a filter can be used on all frequencies up to about 30 Mc. Transmitters operating on 50 Mc. or 144 Mc. require special low-pass filters. These have been discussed in Chapter 6.

#### ● LOW-PASS FILTER DESIGN

Low-pass filters are relatively easy to design and build and can be built quite inexpensively as compared to the fairly high cost of purchased units. Figure 47 gives the circuit of an effective filter together with the formula and a design chart. The circuit shown in (b) has series  $m$ -derived end sections and two constant- $K$  type  $T$  center sections. A filter of this type will give no measurable attenuation on 10 meters and yet will have very high attenuation for channel 2 and other TV channels. An  $m$  of .6 was used in laying out the chart and this means that if the cut-off frequency,  $f_c$ , was 45 Mc. the frequency of infinite attenuation,  $f_\infty$ , would be 57 Mc. or coinciding with the 2nd harmonic for ten meters. A low-pass filter for 50 Mc. with a cut-off at 65 Mc. and one for 144 Mc. with a cut-off about 175 Mc. are shown in Figure 35 on page 33.

A filter could be made with more sections than the one just described, however, we actually would not gain much in usable attenuation. After a certain point we find that the radiation that is leaking out through cracks in the shielding and escaping on insufficiently filtered power leads is masking any further attenuation by the low-pass filter. Most filters are capable of more attenuation than is actually obtained.

To demonstrate the use of the chart in Figure 47 (a) let us determine the values of the parts in Column A in Figure 48:

$$Z_0 = 52 \text{ ohms}$$

$$f_c = 36 \text{ Mc. (cut-off frequency)}$$

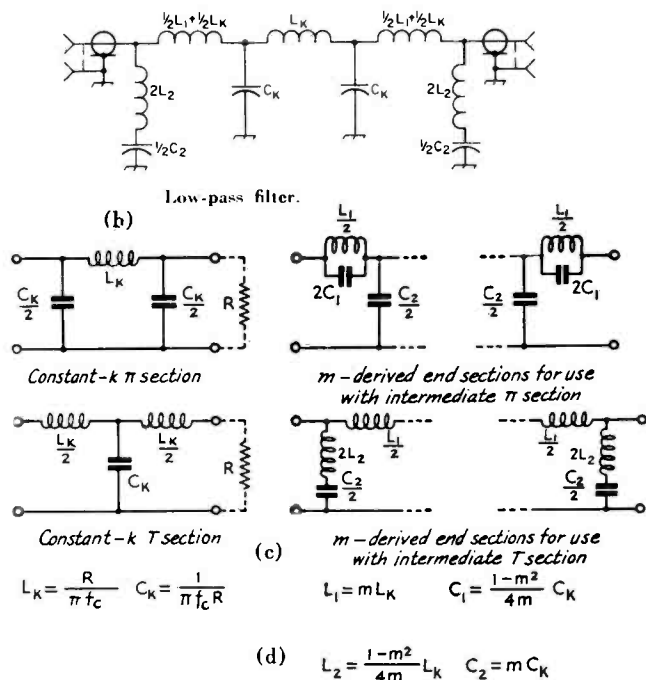
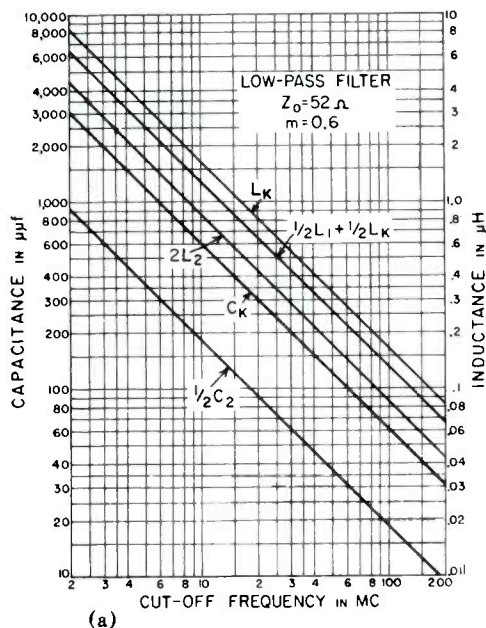


Figure 47 — (a) Design chart for 52 ohm low-pass filters. To use this chart, draw a vertical line at the cut-off frequency chosen and then read the capacitances on the left and the inductances on the right opposite the intersections of the vertical line and the diagonal lines. (b) Circuit of the low-pass filter for use with the chart. (c) Basic filter circuits and (d) design formulas for designing your own filters.

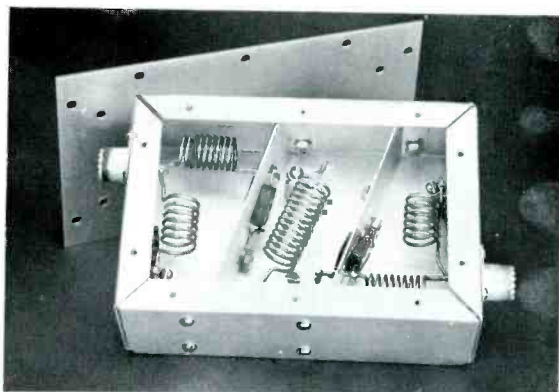


Photo 30 — An inexpensive low-pass filter using silver-mica postage-stamp condensers. The box is a 2 by 4 by 6 aluminum chassis. Aluminum shields, bent and folded at the sides and bottom for fastening to the chassis, form shields between the filter sections. The diagonal arrangement of the shields provides extra room for the coils and makes it easier to fit the shields in the box, since bending to exact dimensions is not essential. The bottom plate, made from sheet aluminum, extends a half inch beyond the ends of the chassis and is provided with mounting holes in the extensions. It is held on the chassis with sheet-metal screws.

Note that  $C_1$  and  $C_4$  in Figure 48 are  $\frac{1}{2}C_2$  in Figure 47-(b), therefore to find their value draw a vertical line from 36 Mc. at the bottom of the chart up to the  $\frac{1}{2}C_2$  diagonal line, and from this point draw a horizontal line to the left hand edge. Now read the value of  $C_1$  and  $C_4$  as about 52 uuf. The 50 uuf shown in Figure 48 is the closest standard value and will be satisfactory. To find the value of  $C_2$  and  $C_3$ , note that they are  $C_k$  in Figure 47 (b) so continue the vertical line from 36 Mc. until it intersects the  $C_k$  diagonal and then go horizontally to the left and read about 175 uuf. The 170 uuf specified in Figure 48 will be satisfactory.

Proceed in the same manner for the coils, each time first finding the counterpart of the coil in Figure 47 (b).  $L_3$ , for example, is really  $L_k$  and its value is about 0.47 uh, found by going up from 36 Mc. to the  $L_k$  diagonal and then to the right to the inductance scale.  $L_1$  and  $L_5$  are really  $2 L_2$  in Figure 47 (b). The 36 Mc. vertical intersects the  $2L_2$  line at about 0.29 uh. Similarly  $L_2$  and  $L_4$  equal  $\frac{1}{2}L_1$  plus  $\frac{1}{2}L_k$  which is found to be 0.35 uh. The coil winding data given in Figure 48 will produce coils of approximately these inductances.

Other filters of the low-pass type may be similarly designed using other values of cut-off frequencies. The special 50 Mc. and 144 Mc. low-pass filters were designed in this manner.

Special purpose filters using a different value of "m" may be designed by using the formula in Figure 47 (d). There are of course other filter configurations and the reader is referred to any good radio engineer's handbook for further details.

### ● PROPER USE OF LOW-PASS FILTERS

It is more important to use the filter correctly than to add more sections. The right and wrong ways of using a low-pass filter were pictorially shown on page 25 in Figure 22 (a) and (b). In Figure 22 (a) up to half of the harmonic power can reach the antenna via the outside shield of the coax cable while the filter is blocking all but one millionth of the other half that is flowing

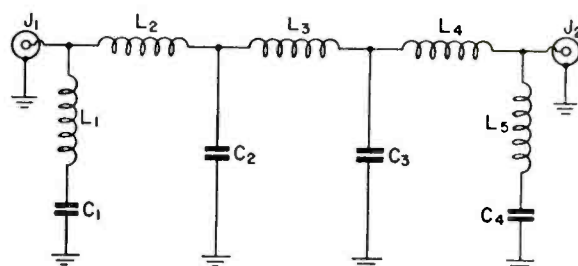


Figure 48 — Low-pass filter circuit for attenuating harmonics in the TV bands.  $J_1$  and  $J_2$  are chassis-type coaxial connectors. In the table below, the letters refer to the following:

- A — Using 100- and 70-uufd. 500-volt silver mica condensers in parallel for  $C_2$  and  $C_3$ .
- B — Same as A but with 70- and 50-uufd. silver mica condensers in parallel for  $C_2$  and  $C_3$ .
- C — Using 100- and 50-uufd. mica condensers, 1200- volt (case-style CM-45) in parallel for  $C_2$  and  $C_3$ .

	A	B	C	
$Z_0$	52	75	52	ohms
$f_0$	36	35.5	41	Mc.
$f_\infty$	44.4	47	54	Mc.
$f_1$	25.5	25.2	29	Mc.
$f_2$	32.5	31.8	37.5	Mc.
$C_1, C_4$	50	40	50	$\mu\mu\text{fd.}$
$C_2, C_3$	170	120	150	$\mu\mu\text{fd.}$
$L_1, L_5$	$5\frac{1}{2}$	6	4	turns*
$L_2, L_4$	8	11 <sup>1</sup>	7	turns*
$L_3$	9	13	8	turns*

\* No. 12 or No. 14 wire,  $\frac{1}{2}$ -inch inside diameter, 8 turns per inch.

through the inside of the cable. Despite the fact that the filter attenuation is 60 db. the total harmonic reduction is only 50 percent. Probably no difference in TVI will be noticeable upon installation of the filter in this case. In Figure 22 (b) the total overall harmonic reduction with the same filter is now 60 db. simply because the shielding now forces 100 percent of the harmonic power to attempt to go through the low-pass where it is blocked. A tremendous reduction in harmonic TVI is now evident when the filter is installed.

A low-pass filter, to be effective, must be well shielded and must be used with coax cable with coax fittings. There must be no break in the continuity of the shielding of the transmitter, the low-pass filter or the feed line through which the harmonics can escape to find their way around the filter.



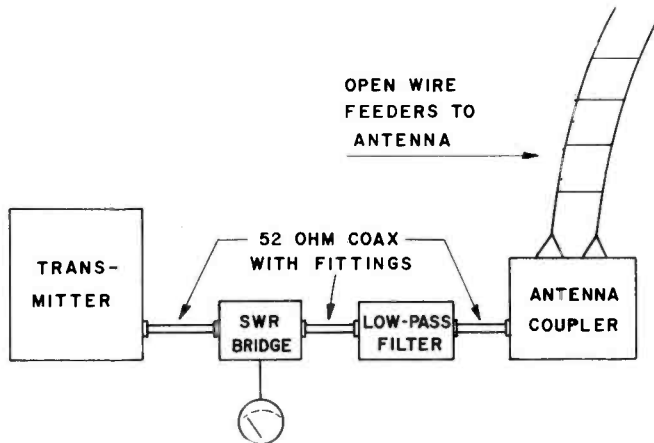


Figure 49 — This illustrates the correct use of an SWR monitor, a low-pass filter and an antenna coupler between a transmitter and an antenna.

If the antenna is fed with open wire line or anything other than 52 ohm coax, an antenna coupler should be used as shown in Figure 49. Note the placement of the SWR bridge.

Since SWR bridges contain crystal diodes and hence can generate harmonics which could be fed to the antenna via the coax, it is always wise to place the low-pass filter in the line after the SWR bridge. This same thing is true concerning T-R switches which are often used with single-band transmitters.

Low-pass filters can be designed to work in 300 or 600 ohm open wire lines, however, they are generally not as effective because it is difficult to keep the harmonics from bypassing the filter. It is also more difficult to tell when a 300 or 600 ohm line is properly matched and is really 300 or 600 ohms.

● HALF-WAVE FILTER

A filter that is well suited for use in open wire lines is the half-wave filter described in G. E. Ham News for November - December, 1949, and called the "Harmoniker". The main disadvantages of this filter are that the attenuation attainable is generally under 30 db. and that it is a one band filter. (You need a separate filter designed for each band). The circuit diagram is given in Figure 50 for both balanced and unbalanced lines. The values of C and L must be calculated for each band according to the following formula:

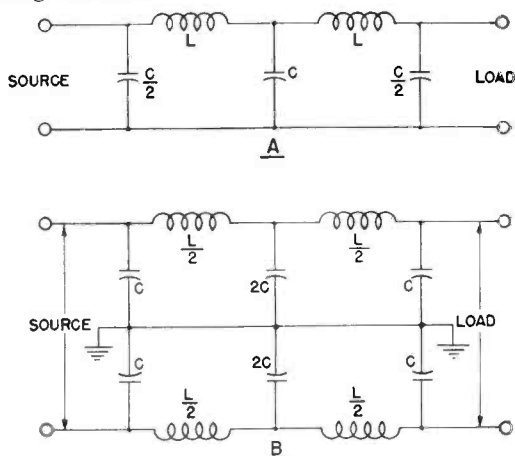


Figure 50 — Circuit diagram of a half-wave filter, See text for details.

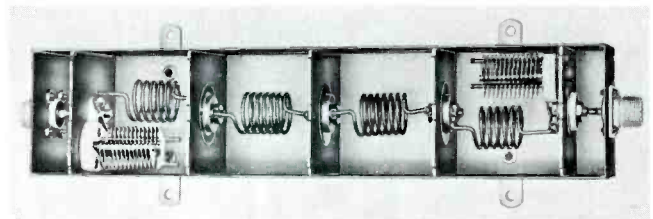


Photo 31 — An interior view of a Barker and Williamson Inc. low-pass filter. It has one more section than the filters in Figure 48 and therefore somewhat higher attenuation. The three center condensers are of a feed-through type mounted on the partitions while the end condensers are a preset air variable.

$$L = \frac{Z_0}{2\pi f_0} \quad \text{and} \quad C = \frac{1}{\pi Z_0 f_0}$$

where  $Z_0$  is the impedance of the feed line and  $f_0$  is the frequency at which the filter will be used.

- $Z_0$  is in ohms
- $f_0$  is in cycles per second
- L is in henrys
- C is in farads

In a 300 ohm filter for 28 Mc., L would have a value of 1.68 uh and C would be 37 uuf.  $L/2$  would be .84 uh and  $2C$  would be 74 uuf.  $C/2$  would be 19 uuf.

This filter should not only be shielded but the individual coils should be shielded from each other. Its main advantage is that it is easy to build and that it protects from both harmonics and sub-harmonics. It is in effect a band-pass filter, passing only the band for which it is designed.

● SWR ON LINE

When using a low-pass filter on a high power transmitter it is necessary to maintain a low standing wave ratio (SWR) on the 52 ohm coax line in order to prevent the soldered connections from melting in the filter or to prevent the condensers from blowing out. It may even be impossible to make a 10 meter transmitter load an antenna when using a low-pass filter if the SWR is too high. You will notice from the formula in Fig. 47 (d) that with fixed values of L and C in the filter the cut-off frequency changes with changes in line impedance. At a given point the coax line will not be 52 ohms if the SWR is high, therefore the cut-off frequency of the filter might go below 30 Mc. and block the fundamental.

To be sure of the proper operation of a low-pass filter it is well to monitor the reflected power in the line with

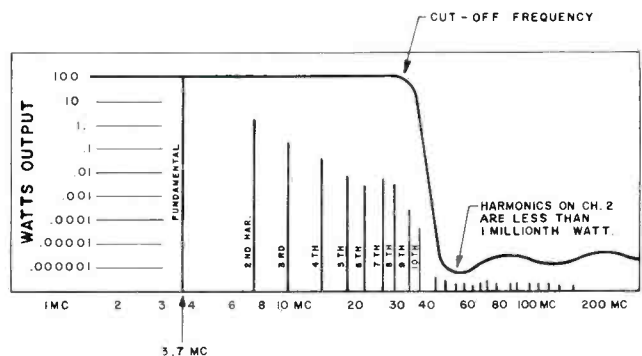


Figure 51 — The relationship of the various harmonics from a 3.7 Mc. signal to the attenuation characteristics of a low-pass filter with a 35 Mc. cut-off. Note that the lower order harmonics are unaffected by the filter, while those in the TV range are suppressed. To reduce the lower harmonics an antenna coupler is called for.

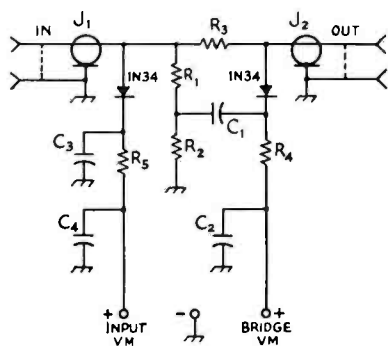


Figure 52 — Bridge circuit for s.w.r. measurements. This circuit is intended for use with a d.c. voltmeter, range 5 to 10 volts, having a resistance of 10,000 ohms per volt or greater.

$C_1, C_2, C_3, C_4$  — 0.005- $\mu$ fd. disk ceramic.

$R_1, R_2$  — 47-ohm composition,  $\frac{1}{2}$  or 1 watt.

$R_3$  — 50- or 75-ohm (depending on line impedance) composition,  $\frac{1}{2}$  or 1 watt.

$R_4, R_5$  — 10,000 ohms,  $\frac{1}{2}$  watt.

$J_1, J_2$  — Coaxial connectors.

Meter connects to either "input" or "bridge" position as required.

a bridge similar to the Jones Micro-Match. It is also a good idea to use an antenna coupler like the Johnson Matchbox so that the SWR on the coax line where the low-pass is installed can be kept at a low value. The low-pass filter should be placed in the line after the Micro-Match so that it can attenuate the harmonics that are generated by the crystal diodes in the bridge. This is shown in Figure 49. A simple SWR bridge that you can build yourself is shown in Figure 52. This is not a power device and cannot be left in the line as a monitor like the Micro-Match. Power to the final must be reduced to a few watts before connecting this unit in the line to avoid burning out the components. Complete details for using this and other bridges are contained in the ARRL Radio Amateur's Handbook.

An SWR monitor that is easy to construct and that can be left permanently in the transmitter feed line even at high power is described in an article in QST for February 1957, entitled "Monimatch, Mark II" by Lewis G. McCoy.

### ● FILTER ATTENUATION

The attenuation curve shown in Figure 51 is typical of several low-pass filters that were measured. Novice amateur operators should pay particular attention to the amplitude of the harmonics that could be radiated from a 3.7 Mc. transmitter using a low-pass filter. Note in particular the strength of 2nd through the 10th. These, except for the 9th and 10th, are not attenuated at all by the low-pass filter. The filter though is doing its job well with a sharp cut-off near 35 Mc. and with about 80 db. of attenuation at TV frequencies. To correct this situation, an antenna coupler or Matchbox is needed as shown in Figure 49. With a set up as shown in Figure 49 all harmonics both low and high would be attenuated. This is particularly necessary with today's trend toward all band antennas. With the popularity of Zepps, long wires, Vee beams, Rhombics, and tri-band beams, we must take steps to keep our spurious emissions at home, and there is no better way to do this than to use an antenna coupler.

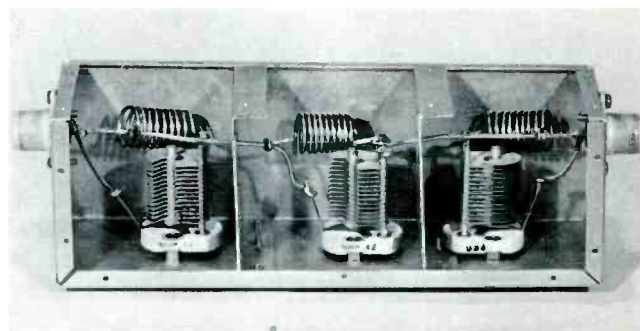


Photo 32 — Interior view of a simple home-made low-pass filter using air variable condensers. Note the partitions between the coils.

### ● FILTER CONSTRUCTION

When constructing the shielded box for the low-pass filter provisions should be made for dividing partitions so that the coils may be shielded from each other as shown in Photos 30, 31 and 32. If two coils must be put in the same compartment they should be oriented at right angles to each other. Install chassis type coax fittings at each end as shown.

If laboratory measuring instruments are not available for checking the values of the coils and condensers, the coils should be made according to the table in Figure 43 and then adjusted with a grid-dip meter after installation as follows:

Short the coax connector  $J_1$  and adjust the turns of  $L_1$  by squeezing or spreading until the  $L_1$ - $C_1$  combination tunes to  $f_\infty$  in the table. Next, adjust  $L_3$  and  $C_4$  by the same method.

To adjust  $L_3$ , disconnect temporarily  $L_2$  and  $L_4$  and spread or squeeze the turns of  $L_3$  so that the combination  $C_2, L_3$  and  $C_3$  resonates with the grid-dipper to the frequency  $f_1$  in the table. This is 0.71 times the cut-off frequency,  $f_c$ .

Next with  $L_3$  disconnected, adjust  $L_2$  until the combination of  $C_1, L_1, L_2$  and  $C_2$  resonates at  $f_2$  with no short at the coax fitting.  $L_4$  is similarly adjusted by tuning the combination of  $C_3, L_4, L_5$  and  $C_4$  to the frequency of  $f_2$  in the table. During this step do not touch  $L_1$  or  $L_5$  as they were previously adjusted.

$L_3$  should now be carefully soldered back into the circuit and the filter is ready to use. With no connections to either terminal of the filter the grid-dipper should now show resonance at the cut-off frequency  $f_c$ . Be sure to attach the cover securely before using. The coax cable is usually the only ground necessary for the filter. The transmitter cabinet of course should be connected to a good low resistance ground such as a waterpipe.

Filters using the silver mica condensers in columns A and B are good for about 50 watts on 28 Mc. while those using the 1200 volt micas in column C are good for about 250 watts. By substituting air variables like those in Photo 32, set at the listed capacities, a power of 1000 watts may be used.

## CHAPTER 9

### EXTERNAL HARMONIC GENERATION

There are two kinds of harmonics, those that are generated in a transmitter and those that are generated externally to the transmitter. The latter type are the most confusing to the TVI investigator and are probably the hardest to cure due to the difficulty in locating their source. Fortunately they are not too common on the lower frequencies but are encountered frequently in the frequency range of 25 to 50 Mc.

#### ● NONLINEAR DEVICES

Any rectifier is basically a nonlinear device and can therefore produce a whole set of harmonics from any r.f. signal fed into it. The low-order harmonics, the second, third and fourth, generally will be the strongest while the higher-order harmonics will become progressively weaker. As pointed out in Chapter 4, if any resonant circuit is connected to this rectifier and the resonant frequency happens to be at or near the frequency of a given harmonic, then that harmonic will be much stronger than any of the others. If this resonant circuit also happens to be a good radiator, then this harmonic will be radiated for considerable distances.

Nonlinear devices are not confined to diodes and rectifiers. All vacuum tubes and transistors are nonlinear. To obtain linear operation it is necessary to confine the operating range to the small straight or linear portion of their characteristics curve. Whenever a larger signal than normal is applied, the straight portion of the curve is exceeded and distortion in the form of harmonics is generated. To be linear the output wave form must faithfully represent the input wave form. When the input tube of a receiver is overloaded by a strong r.f. signal to the point where it draws grid current, it means that the grid-cathode circuit has become a diode rectifier. This rectifying action clips the incoming r.f. sine wave and produces a square wave which by definition is rich in harmonics.

#### ● CORRODED JOINTS

Everyone is familiar with rust on iron, the tarnishing of silverware and the fact that nice bright shiny copper turns green when exposed to the elements. Very few connect this phenomenon with TVI, or for that matter, BCI (broadcast radio interference). Practically all metals corrode, the difference being that some corrode faster than others. Nature is a prolific producer of natural rectifiers. Moisture, salt air, oxygen, and the sulphuric acid fumes from oil burners all help to produce oxides and other corrosion products from various metals. These products frequently will pass currents better in one direction than the other and hence become a natural rectifier. The efficiency is generally low but many of nature's products do make excellent rectifiers. Remember the old

galena crystal detector? Silicon and germanium diodes are used in many modern applications. Copper oxide and selenium are extensively used for power rectification.

#### ● GENERATION OF HARMONICS

The ability of natural rectifiers to produce harmonics varies immensely because the corrosion of metals such as iron, aluminum and copper depends on so many environmental conditions. If the material (film of corrosion) can pass current slightly better in one direction than the

<b>Nonlinear Systems</b>		
<i>Manufactured:</i>		
Amplifiers	Fluorescent lamps	Phonographs
Battery chargers	Hearing aids	Power supplies, regulators
Diode probes	Intercoms	Radios
Electronic control devices	Modulation indicators	TV receivers
Field-strength meters	Neon bulbs	Toy trains (d.c.)
<i>Corroded joints in conjunction with:</i>		
Air ducts		
Bathroom, kitchen, and laundry fixtures and equipment		
BX cable		
BX boxes, switches		
Ceiling and wall fixtures, chandeliers		
Chains		
Conduits		
Furnace and hot-water installation		
Ground clamps: power line, telephone, radio, TV		
Gutters and roof drains		
Guy wires and lanyards		
Lightning arrestors and lightning rods		
Metal fences		
Metal-mesh lath for plaster and stucco		
Metal towers and masts		
Outside power and telephone lines and equipment		
Pipes: gas, steam, water, sewer, and vents		
Radiators and registers		
Receiving antennas — radio and TV		
Re-enforcement rods in concrete		
Telephone installation		
Thermostat system		
Transmitting antennas		
Sheet metal roofs and structures		
Stove pipes		
Structural steel beams and framework		
Wiring: bell, intercom, power and light		

Table VII — In addition to the nonlinear devices listed above the amateur radio operator should suspect diodes in SWR bridges, c.w. and phone monitors as well as T-R switches.



other, and if it is part of a circuit arrangement in which r.f. signals can be admitted and released, harmonics will be produced. In other words, if there is a joint or splice in an antenna wire, feed-line, guy wire, etc. that had not been soldered and that had become corroded and covered with copper oxide, we would have a good generator of harmonics provided this rectifying joint and the metal conductors attached to it are subjected to a strong r.f. field.

Table VII gives a list of possible nonlinear systems, both manufactured and natural, that have been encountered. In each case there must be either a diode or vacuum tube whose circuit is subjected to r.f. or there must be two pieces of metal such as BX cable, air ducts, stove pipes, etc., touching each other through a film of corrosion. If the lengths of the pieces of metal resonate at a harmonic frequency then this harmonic will be much stronger than the others.

All of the necessary elements required to produce a harmonic-generating system are present in, and around, the average home. If it were possible to see the maze of water pipes, wires, conduit, furnace pipes and other metal objects listed in Table VII you could more easily visualize the possibility of two pieces of corroded metal touching each other. You could also see how this whole system would pick up any strong radio signal just like a receiving antenna and feed it to the various corroded connections for detection. The harmonics produced are reradiated by this same complicated mass of metal pipes and wires.

The author, like many others, had always been troubled to a certain extent by TVI from nonlinear detectors, some of which had been difficult to find. On the occasion of building a new home in 1952 he decided to eliminate this problem once and for all by writing into the specifications that all metal objects such as BX cable, conduit, water pipes, sewer pipes, furnace, washing machine, sinks, roof vents, gutters, flashing, etc., must be bonded together with a copper strap and connected to a common ground. It was also specified that no two pieces of metal were to be allowed to touch each other in the partitions, floors or ceiling. The result has been a complete freedom from TVI, BCI and telephone interference even when running a full kilowatt. It is therefore strongly recommended that anyone building a new house instruct their contractor to allow no metal-to-metal contacts without bonding at the point of contact.

### ● LOCATING NONLINEAR DEVICES

Locating nonlinear devices can often be difficult and curing the trouble can be even more difficult especially when the corroded joint appears to be embedded in the walls or ceilings of a home. The first step in the search for a suspected nonlinear device is to investigate any of the manufactured rectifiers listed in Table VII that may be located in the immediate neighborhood. The most obvious place is, of course, the TV receiver's front-end. Any of the steps outlined in Figure 11, Chapter 3, may be tried. Generally a high-pass filter will cure the TVI if it is caused by harmonics generated in the TV r.f. stage.

If the interference pattern is intermittent, if the strength of the TVI varies from day to day with changes in weather,

or if the pattern is affected by vibrations in the building, you can be fairly sure that it is caused by some natural nonlinear device. The next step then is to investigate the possible sources listed in the bottom half of Table VII. Bear in mind that a BX cable or air duct as such cannot cause TVI — it must be making a poor contact with another piece of metal through a film of corrosion. If any such joints are found they should either be insulated from each other with plastic tape or should be bonded together with a copper strap well soldered.

A brute force method of locating natural nonlinear devices is to have an assistant watch the TVI pattern while you go around banging on pipes, stamping on the floor, pulling on cables, etc. When this procedure makes the interference start and stop you are getting close to the trouble. Outdoors the procedure is much the same — shake feed lines and guy wires, pound on TV masts, etc. Look especially for any guy wires that are rubbing on the metal gutter of the house. Inspect all wires or antennas for unsoldered or cold soldered joints and if any are found resolder them.

If the above methods fail it becomes necessary to take readings on the strength of the interference and to probe around suspected locations. A TV field-strength meter such as those used by TV servicemen should be equipped with a small six inch diameter pick-up loop on the end of a shielded cable. This can be carried around looking for the maximum signal coming from walls, ceilings or floors. It is not always possible to pinpoint the source because it is often being radiated by a considerable length of pipe or conduit.

Lacking a TV field-strength meter, one may use the two-signal or heterodyne method. A nonlinear device will not only rectify but it will also act as a mixer. For example, if two r.f. signals are fed into our corroded joint, two signals equal to their sum and difference will be generated in addition to the harmonics. If for example, two transmitters are operated simultaneously with their antennas close to the nonlinear detector on frequencies of 50.0 Mc. and 51.5 Mc. we will get a beat frequency of 1.5 Mc. This is of course 1500 kc. and can be received with a battery portable broadcast receiver that can be carried around the house while searching for the strongest signal. Two 6 meter Gonset Communicators could be used for the transmitters. For ten meter equipment the frequencies might be 27 Mc. and 28.6 Mc. Here you would tune to 1600 kc. Reception of this beat note generated by the mixing action of a nonlinear device confirms the presence of such a device and it is therefore a good test to make if there is any question as to the source of the harmonic interference.

### ● CURING THE TVI

The cure for this type of TVI is simple once the nonlinear device is found. If it is the front-end of a TV receiver, install a high-pass filter. If it is two pieces of metal touching each other, insulate them or solder them together. Often times it is impossible to reach the actual rectifying point, however, a jumper connecting the two together will often help even though several feet away.

## CHAPTER 10

### INDUSTRIAL, MEDICAL AND PUBLIC UTILITY TVI

Television interference caused by ISM equipment (industrial, scientific and medical) or public utility apparatus is generally located and treated in much the same way as TVI from other sources that have already been covered in earlier chapters.

#### ● FCC RULES GOVERNING ISM DEVICES

A complete set of the rules and regulations governing industrial, scientific and medical apparatus may be obtained for 10 cents from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Ask for: Title 47 — Telecommunication, Chapter 1 — Federal Communications Commission, Part 18 — Rules Governing Industrial, Scientific and Medical Service. Pertinent excerpts from these rules are reprinted in the Appendix on page 56. The important thing to remember is that all radio frequency generators come under the regulation of the FCC and so if you own and operate such a device it is well to know the requirements and/or restrictions for its operation. If the device that you are operating falls into a miscellaneous category you should also send for FCC's Part 15 — Incidental and Restricted Radiation Devices, Price 5 cents.

You will generally find a paragraph in the FCC Rules such as Paragraph 18.8, which states that even though your equipment is type-approved and meets all other FCC

requirements, if it causes interference to any authorized radio services, steps must be taken immediately to correct said interference. An exception is where the interference is caused by intermediate frequency pick-up by the receiver of type-approved equipment operating within an ISM band. In other words FCC does not protect TV receivers from interference originating from i.f. reception of diathermy equipment operating in the 27 Mc. band. This type of interference as pointed out before is easily cured at the receiver with a high-pass filter.

#### ● INDUSTRIAL TVI

Industrial TVI is often caused by r.f. heating units used for heat treating metal parts, pre-heating plastic pellets prior to a molding process or for joining plastic sheets together like an r.f. sewing machine.

To prevent this type of TVI it is only necessary to bottle up all the r.f. regardless of frequency in a shielded enclosure.

This shielded enclosure can often times be the cabinet of the apparatus providing it is made r.f. tight and providing a good a.c. line filter is installed. A suitable filter for industrial use is shown in Figure 53 and Photo 33. The method of shielding it and installing it on the equipment is shown in Figure 54. This filter is actually a low-pass filter designed for a balanced line and you will note the similarity of its circuit to that of the filters shown in Chapter 8.

#### ● SHIELDING

As in the case of transmitters, it is necessary to do a thorough job of shielding in order to keep the r.f. on the inside of the cabinet instead of the outside. In Photo 34, notice the "horse-blinders" attached to the cover of the

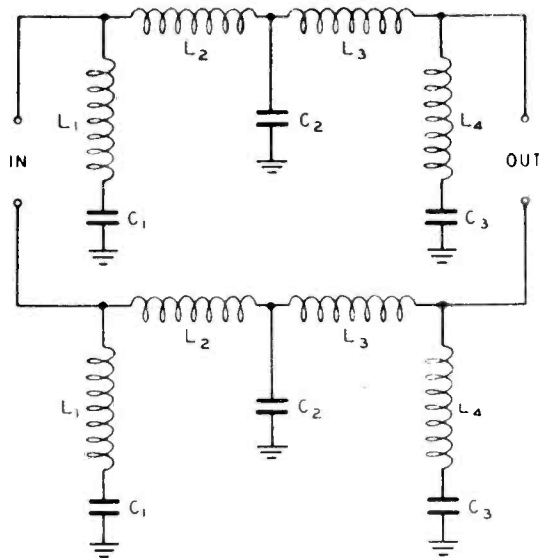


Figure 53 — Line-filter designed for installation in a 3-wire 220 v a.c. power line feeding an industrial or medical r.f. heating unit. The two "hot" wires go through the coils while the ground wire connects to the inside of the case.

$C_1, C_3 = 72 \text{ uuf mica (75 uuf satisfactory).}$

$C_2 = 300 \text{ uuf mica.}$

$L_1, L_4 = 0.72 \text{ uh.}$

$L_2, L_3 = 1.25 \text{ uh.}$

Coil dimensions will depend on conductor size necessary to carry the current required for the particular machine. No. 12 enameled wire will be satisfactory for currents of 15 amps. and less.

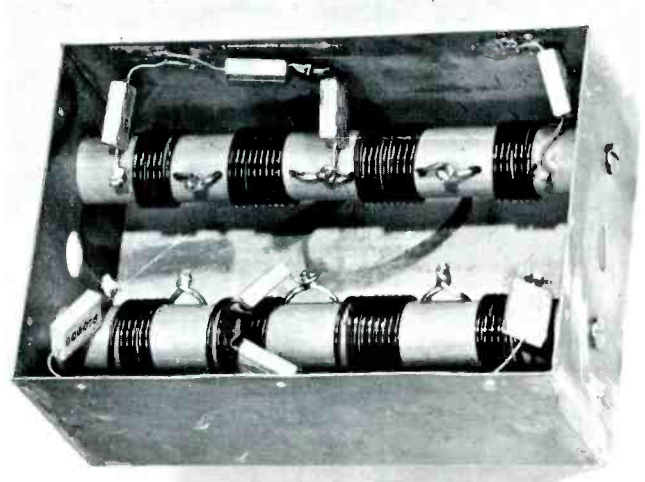


Photo 33 — Inside view of filter of Figure 53 with cover removed. Box is made of copper with corners soldered. Cover will be soldered on.

plastic pre-heater as well as the additional screening installed inside of the cover. These "horse-blinders" were necessary to stop r.f. leaks that were occurring around the cover when closed. Note also that the paint has been removed from all the cabinet joints and additional screws have been installed to make an r.f. tight joint.

Table VIII lists the before-treatment and after-treatment field strengths measured in microvolts per meter of a typical pre-heater. This particular machine was operating on a frequency of about 25 Mc. utilizing a self-excited 2 kilowatt oscillator. The frequency changed several megacycles during the heating cycle as the load heated up. This caused the fundamental signal to sweep across the TV receiver's i.f. blanketing all channels. Shifting the frequency of the pre-heater away from the TV i.f. would have cured this trouble, however, the oscillator's harmonics would still have blanketed certain channels. Shielding and filtering as shown cured the harmonic TVI and at the same time cured the fundamental i.f. feed-through.

● PUBLIC UTILITIES

Tests made indicate little or no interference from power lines under normal operating conditions even with the TV antenna in close proximity. Television receivers are not necessarily influenced by conditions which might interfere with the standard broadcast band. Cracked insulators, defective lighting arrestors and static discharges from some types of line hardware will cause TVI which looks like ignition type of interference on the screen.

TV interference within the power system may be traced to the specific piece of equipment by the same methods which have been described in Chapter 2. Most all sources produce a random type of noise and cover a wide band of frequencies usually including the BC, SW, FM and TV

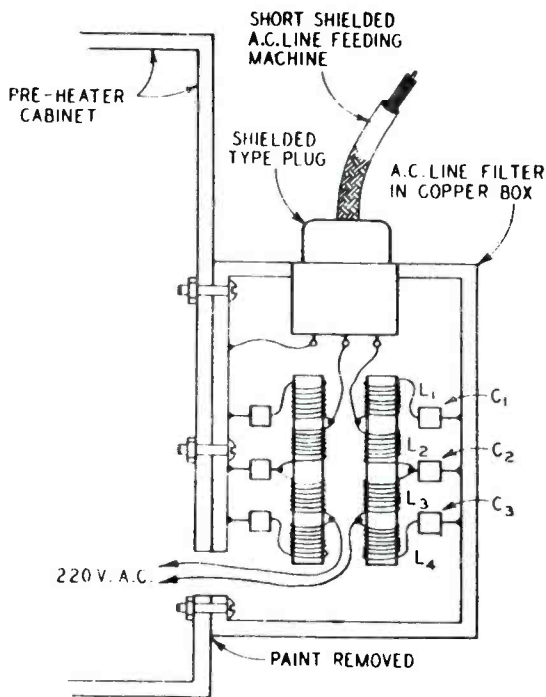


Figure 54 — Pictorial diagram of the installation of the a.c. line filter on a piece of ISM apparatus. This could equally well be an amateur or commercial radio transmitter.

Preheater #5 Before and After Treatment

Distance	uv/m—frequency 25 mc.		Harmonics	
	before	after	before	after
10 ft.	38,500	920	462	35
80 ft.	970	8	118	0
150 ft.	835	0	68	0

Table VIII — The before and after-treatment field strengths of fundamental and harmonics measured at three distances from an ISM r.f. heater.

bands. Striking poles with a sledge hammer while listening for a change in the interference is a good way to pinpoint the pole where the defective equipment is located. Figure 55 gives details on good and bad practices in line construction as well as some mobile interference detection arrangements. See also Table I on page 9.

● MEDICAL TVI

Diathermy equipment probably causes more TVI than any of the other electrical apparatus used by doctors or hospitals. TVI from some of the older type equipment was very difficult to get rid of without placing the unit in a screened room. Doctors who are building new offices would do well to have the contractor install a screened room for their diathermy treatments. The newer FCC type-approved models usually operate in the 27 Mc. ISM band. Unfortunately this does not mean that they will not cause TVI to all channels on all of the older type of TV receivers using an i.f. of 21.25 to 25.75 Mc., particularly if they are located nearby. Under these circumstances a high-pass filter installed on the TV receiver usually cures the trouble. For best results be sure to get a high-pass filter with a 52 Mc. cut-off similar to the Drake

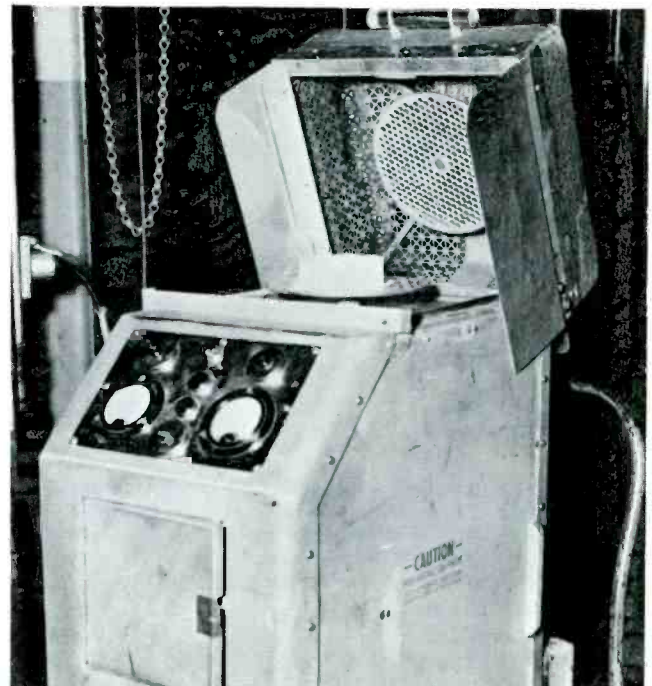
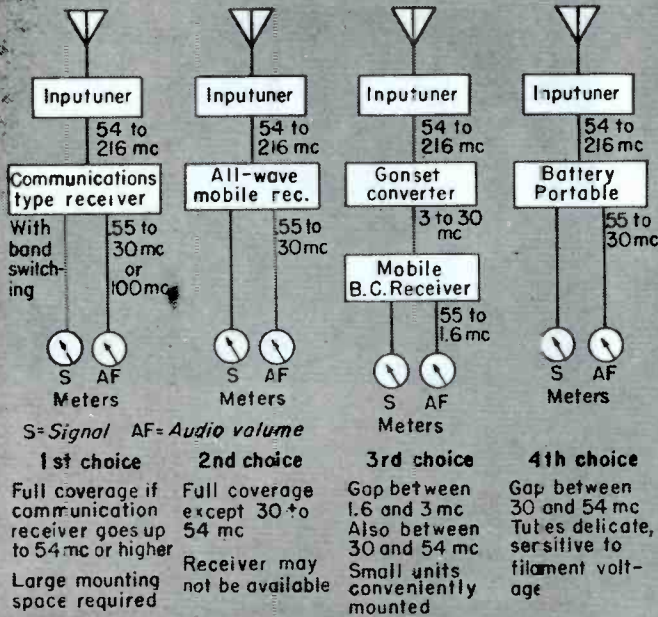


Photo 34 — "Horse-blinders" and extra shielding and bonding necessary to bottle-up r.f. in cabinet.



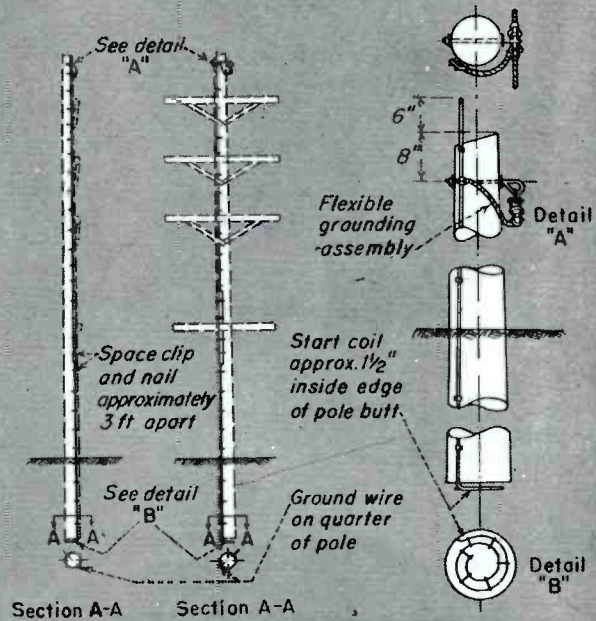
# Elimination of interference requires accurate detection and proper construction

## Mobile detection arrangements



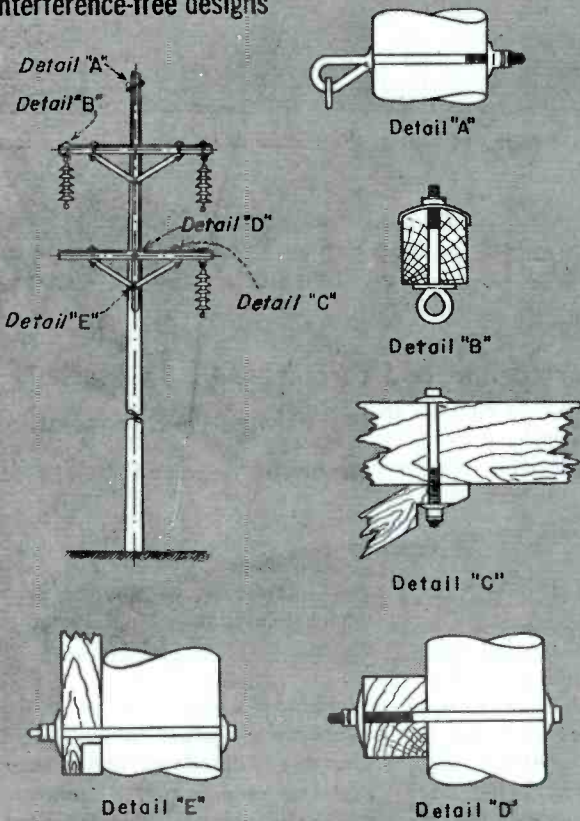
Receiver circuits for use in interference investigations are shown with primary advantages and disadvantages

## Good grounding scheme



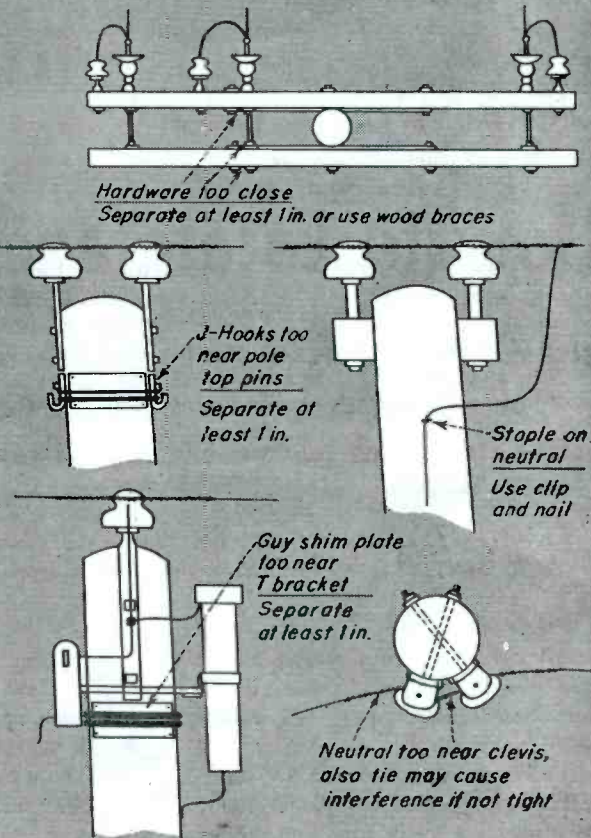
Proper grounding methods used in line construction will serve to eliminate sources of interference

## Interference-free designs



Good line design plus attention to details during construction eliminates interference caused by power lines

## Practices to avoid



These designs of line equipment on 6.9-kv. or higher circuits are potential causes of interference

Figure 55 — Upper left gives 4 choices for mobile detection arrangements discussed in Chapter 2. Interference-free designs and practices to avoid for utility company systems are shown to the right and lower left.

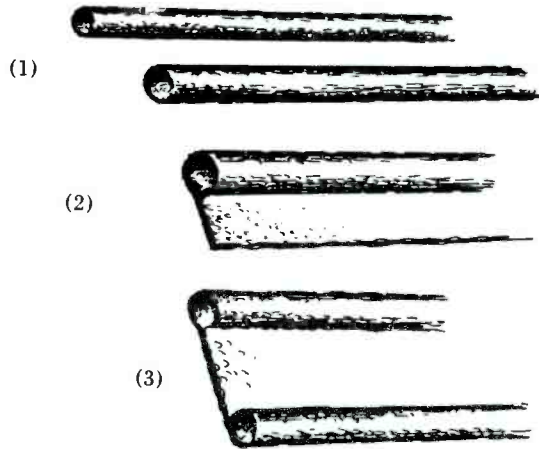


Figure 56 — Standard knitted wire mesh weather-strip types; Top to bottom: (1) round, (2) single round strip with attachment fin, (3) two round strips with one connecting fin.

or Grallen. This type will protect the newer 41 - 45 Mc. i.f. TV receivers as well as the older ones.

### ● R. F. WEATHERSTRIPPING

The only difference between weatherstripping the doors and windows of a house and the doors and windows of an r.f. cabinet or shielded enclosure is the type of material from which the weatherstrip is made. To stop r.f. drafts it is necessary to have a metal material that can be squashed into good electrical contact between the cabinet door and the cabinet. This contact should be continuous. A suitable material has been developed by the Metal Textile Corporation of Roselle, N. J. In Figure 56 are shown three different types of this knitted metal mesh that can be used in the construction of shielded cabinets.

Figure 57 (a) shows one method of attaching the weatherstrip by rivets through the attached fin. This type is the 2nd. from the top in Figure 56. Figure 57 (b) shows the use of the round cross-section type (top in Figure 56) wedged between the outer lip of the panel and a small angle spot-welded to the panel. This is the type of construction described in Chapter 5 which is used by E. F. Johnson & Company. Figure 57 (c) and (d) show how to weatherstrip the top lid of a cabinet. Note that in (d)

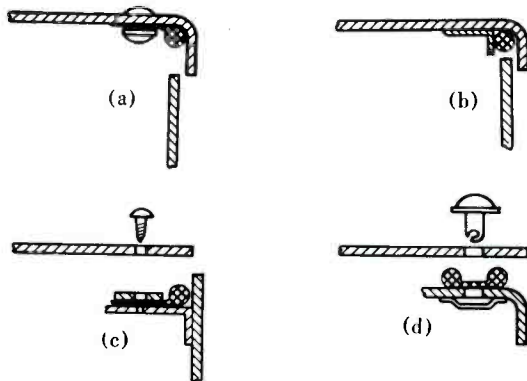


Figure 57 (a) and (b) — Two methods of joining front panel to cabinet using r.f. weatherstrip and (c) and (d) two methods of making top cover r.f. tight with weatherstrip.



Photo 35 — A commercial screened room is often the easiest solution to ISM interference problems. The one shown is manufactured by Ace Engineering and Machine Co., Inc.

a double web of material is used for better contact when using quick fasteners. In all of these examples bare metal should be touching bare metal — no paint at the joint — and a sufficient pressure should be exerted to maintain a good electrical contact.

### ● SHIELDED ROOMS

Often times it is necessary to have leads of considerable length connecting the work load to the r.f. generator. These leads carry and radiate r.f. and so shielding the r.f. generator alone is not enough. The entire work area should be shielded under these conditions. Other installations requiring the complete shielding of the work area are induction heaters fed by conveyer belts. Here the belt should enter and leave the shielded enclosure via a shielded tunnel.

Usually the most economical solution to the ISM interference problem is the installation of a shielded or screen room. Such rooms are commercially available in various sizes, the one shown in Photo 35 is manufactured by the Ace Engineering and Machine Co. Inc., of Philadelphia.

Screened rooms are used for either of two purposes, first, to contain an interference producing apparatus and thereby prevent the interference from reaching radio and television receivers and second, to contain instruments and measuring equipment and to protect them from the general interference level existing on the outside of the room. In either case no power lines or other wires may enter or leave the shielded enclosure without proper filtering. No water or steam pipes may pass through the room. If it is necessary for any pipes to enter the room they must enter at the one common ground point and be well bonded to the room and to ground.

Screened rooms are generally manufactured in modular sections that can be fastened together to provide rooms of various sizes. They are also made of various types of screening or sheet stock depending on the frequency range and use to which they are to be put. For a screened room to meet a given set of specifications it is best to consult one of the manufacturers. A screened enclosure of the "cell" type usually has a guaranteed attenuation of 100 db. from 14 kc to 1000 Mc. The solid shield enclosure type may be somewhat better at the low frequency end.



## Appendix

### QST REFERENCES TO TVI REDUCTION

In addition to the comprehensive technical data contained in the ARRL Handbook, the following selected QST references will prove valuable in interference-elimination procedures.

### COMMITTEES — PUBLIC RELATIONS

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- On the TVI Front, Revised Roster of TVI Committees, 54, Sept. 1955.
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- TV Receiver Radiation, Najork, 57, Nov. 1954.
- Progress and Activities Report — Washington TVI Committee, Richman 52, July 1954.
- TVI "Diplomatics", Rowe and Lake, 30, June 1954.
- On the TVI Front, Raytheon Advises Consumers on TVI, 31, June 1954.
- TVI Checking at Headquarters, 34, April 1954.
- On the TVI Front, ARRL TVI Script Availability, 28, March 1954.
- On the TVI Front, Licking UHF Strip TVI — A Success Story, 28, March 1954.
- Spurious Radiation Problems, 31, Jan. 1954.
- UHF Strips, A Problem for the VHF Man, Tilton, 62, Dec. 1954.
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- Channel Strip TVI, ARRL Letter to FCC regarding 2-meter TVI, 45, Nov. 1953.
- Handling TVI Complaints Due to Poor TV Sets, Shook, 51, June 1953.
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- On the TVI Front, TVI Committee Plan of Attack, 52, Dec. 1952.
- On the TVI Front, TVI Causes, 53, Sept. 1952.
- TVI Report to Manufacturers, *Rand*, 47, Aug. 1952.
- 21-Mc. Letter to TV Manufacturers, 30, June 1952.
- On the TVI Front, VHF Heterodyne TVI, 44, June 1952.
- On the TVI Front, Club Reports, 26, Mar. 1952.
- Letter from TV Receiver Manufacturers, 27, Mar. 1952.
- Letter to TV Receiver Manufacturers, 35, Feb. 1952.
- TVI Committees, Editorial, 9, Feb. 1952.
- FCC's Plan for Handling TVI, Turner, 22, Jan. 1952.
- Dayton Plan for TVI, 34, Sept. 1951.
- Dallas Plan for TVI, Skelton and Shook, 26, June 1951.
- TV Interference Problems, Kiser, 45, Feb. 1950.
- TVI Patterns, *Rand*, 43, May 1949.

### ANTENNA COUPLING — Matching

- Standing Waves and TVI, 44, Jan. 1954.
- Home-Built Shielded Link (H&K), 63, Aug. 1952.
- Stub for TVI Reduction (H&K), 62, Aug. 1952.
- Harmonic Reduction with Stubs (H&K), 58, Dec. 1948.

### LEAD FILTERING

- More on Signal Shifter TVI Suppression, Grainger, 32, Mar. 1955.
- Suppressing TVI in the Meissner Signal Shifter, Filtering and Shielding tips, McCoy, 33, Oct. 1953.
- Curing Industrial TVI, *Rand*, 29, Sept. 1951.
- By-Passing for Harmonic Reduction, Grammer, 14, Apr. 1951.
- TVI Tips, Shielded Hook-up Wiring, 45, Aug. 1949.

### LOW-PASS FILTERS

- Adjusting Low-Pass Filters, Montgomery, 32, Mar. 1955.
- Tin Can Low-Pass, McCoy, 29, Sept. 1954.

- Low-Cost Low-Pass Filters from Standard Mica Condensers, 39, Dec. 1952.
- Low-Pass Filters for High Power, Fosberg, 28, Oct. 1951.
- Low-Cost TVI Filter, Dene, 16, May 1950.
- Eliminating TVI with Low-Pass Filters, Part I, Grammer, 19, Feb. 1950.
- Eliminating TVI with Low-Pass Filters, Part II, Grammer, 20, Mar. 1950.
- Eliminating TVI with Low-Pass Filters, Part III, Grammer, 23, Apr. 1950.
- Re: Half-Wave Filters, 34, Feb. 1950.
- High-Attenuation Filter for Harmonic Suppression, Pichitino, 11, Jan. 1950.
- Design of Low-Pass Filters, Seybold, 18, Dec. 1949.
- Design of Low-Pass Filter, Feedback, 21, Jan. 1950.
- Half-Wave Filters, 36, Dec. 1949.

### HIGH-PASS FILTERS

- TVI Tips, High-Pass Filter, 47, Aug. 1950.
- TVI Tips, High-Pass Filter, Feedback, 10, Oct. 1950.
- High-Pass Filters for TVI Reduction, 46, May 1949.

### SHIELDING

- Homemade Perforated Aluminum (H & K), 96, Dec. 1955.
- Preventing R.F. Leaks with Aluminum Foil (H & K), 122, Feb. 1954.
- Suppressing TVI in the Meissner Signal Shifter, Filtering and Shielding Tips, McCoy, 33, Oct. 1953.
- Another Inexpensive Source of Shields (H & K), 50, Sept. 1953.
- Electronic Weatherstripping as an Aid to Shielding, Schreiber, 29, Aug. 1953.
- Improved Shielding with Copper Screen (H & K), 68, Dec. 1952.
- Fishbox Shielding (H & K), 69, Dec. 1952.
- Source of Shield Cans, 66, Sept. 1952.
- Curing Industrial TVI, *Rand*, 29, Sept. 1951.
- Simple Experimental Shielding (H & K), 66, Dec. 1950.
- Shielding for TVI Reduction (H & K), 118, Oct. 1950.

### TEST DEVICES

- Baking Pan Wavemeter, McCoy, 32, Feb. 1955.
- A Handy Handful (miniature GDO using a magic eye indicator). Chambers, 29, Mar. 1953.
- Increasing the Sensitivity of Grid-Dip Meter Frequency Measurements (H & K), 40, June 1953.
- Effective TVI Probe (H & K), 69, May 1952.
- Phase Angle Detector for RF Transmission Lines, Mezger, 17, July 1952.
- Bandswitching UHF Converter and Harmonic Checker, Tilton, 33, July 1951.
- TVI Tips, Harmonic Separators, 31, Dec. 1950.
- Regenerative Wavemeter, Grammer, 29, Nov. 1949.
- Useful Tool for TVI Reduction, 69, July 1949.
- More on TVI Elimination (Crystal Wavemeter), *Rand*, 29, Dec. 1948.

### TVI-PROOFED TRANSMITTERS

- Operating the BC-696 in TV Fringe Areas, Ticen, 22, Dec. 1953.
- Suppressing TVI in the Meissner Signal Shifter, McCoy, 33, Oct. 1953.
- TVI Treatment for "Command" Transmitters (H & K), 66, Apr. 1952.
- Chasing TVI Out of the BC-610 Transmitter, Harlow, 65, May 1951.
- TVI-proofing the ARC-5 VHF Transmitter, Johnson, 50, Nov. 1950.



## Appendix

# List of TVI Committees

**T**HE FCC ROSTER of TVI committees continues to grow. In the past year 85 committees have been added in 79 cities, to bring the grand total registered with the Commission to 522 committees serving in 491 cities, as of August 1, 1956. Hearty congratulations to all who are participating in this cooperative endeavor. The list of cities served follows:

*Alaska:* Anchorage, Fairbanks.

*Alabama:* Anniston, Birmingham, Gadsden, Huntsville, Mobile, Montgomery.

*Arizona:* Phoenix, Tucson.

*Arkansas:* Fayetteville, Little Rock.

*California:* Alhambra, Arcadia (2), Artesia, Azusa, Bakersfield, Baldwin Park, Burbank (2), Camarillo, Canoga Park, China Lake, Colton, Compton, Coronado, Covina, Downey, Dunsmuir, Eagle Rock, East Bay, Edwards Air Force Base, El Monte, Encino, Etiwanda, Fairfield, Fresno, Fullerton, Glendale, Granada Hills, Hawthorne, Hayward Area, Hemet, Hollywood, Inglewood, La Canada, Lake-wood, Lancaster, Long Beach, Los Angeles, Lynwood, Manhattan Beach, Marin County, Marysville/Yuba City, Merced, Modesto, Monrovia, Monterey Bay, Monterey Park, Monte Vista, Mt. Diablo, Mountain View, North Bay, North Hollywood, North Peninsula, Norwalk, Orange, Orange County, Oxnard, Pacoima, Pacific Palisades, Palo Alto, Palmdale, Palos Verdes, Pasadena, Pomona/Ontario, Pt. Magu, Redlands, Redondo, Reseda, Rialto, Riverside, Richmond, Sacramento, San Bernardino, San Diego, San Fernando, San Francisco (5), San Gabriel, San Mateo, San Pedro, Santa Ana, Santa Barbara, Santa Clara County, Santa Monica, Sherman Oaks, Sonoma County, Southgate, South Pasadena, Stockton, Studio City, Sylmar, Tarzana, Temple City, Topanga, Torrance, Turlock, Upland, Van Nuys, Ventura, Walnut, West Covina, Westchester (in City of Los Angeles), Whittier, Woodland.

*Connecticut:* Darien, Norwalk, Norwich, Shelton, Torrington, Waterbury.

*Colorado:* Alamosa, Boulder, Colorado Springs, Denver, Grand Junction, Greeley, Pueblo.

*Delaware:* Wilmington (3).

*District of Columbia:* Washington.

*Florida:* Bradenton, Clearwater, Daytona Beach, Ft. Lauderdale, Ft. Walton Beach, Gainesville, Jacksonville, Key West, Lakeland, Miami, Orlando, Pensacola, Sarasota, St. Petersburg, Tampa, West Palm Beach.

*Georgia:* Albany, Atlanta, Augusta, Cartersville, Hapeville, Macon, Marietta, Savannah, Valdosta, Warner Robins.

*Hawaii:* Hilo, Honolulu, Lihue, Kauai, Wailuku, Maui.

*Idaho:* Boise, Kellogg, Nampa, Twin Falls.

*Illinois:* Alton, Belleville, Chicago, Creve Coeur, Decatur, Des Plaines, East Moline, East Peoria, East St. Louis, Freeport, Galesburg, Granite City, Joliet, LaSalle, Moline, Morton, Mt. Prospect, Mt. Vernon, Pekin, Peoria, Rock Falls, Rock Island, Silvis, Wheaton.

*Indiana:* East Chicago, Elkhart, Evansville, Ft. Wayne, Gary, Hammond, Portland, South Bend.

*Iowa:* Conway, Davenport, Newton, Sioux City, Spencer, Waterloo.

*Kansas:* Kansas City, Lawrence, Leavenworth, Salina.

*Kentucky:* Lexington.

*Louisiana:* Algiers, Bogalusa, Monroe, New Orleans, Baton Rouge.

*Maine:* None.

*Maryland:* Annapolis, Baltimore (3), Cumberland, Hagerstown.

*Massachusetts:* Adams, Boston, Dennisport, Fitchburg, Framingham, Marshfield, New Bedford, Pittsfield, Scituate, Worcester.

*Michigan:* Allegan, Berkley, Birmingham, Bloomfield Hills, Clawson, Ferndale, Flint, Grand Rapids, Grosse Point, Grosse Point Park, Hazel Park, Ishpeming, Lansing, Marquette, Menominee, Mt. Clemens, Mt. Pleasant, Muskegon, Oak Park, Pontiac, Royal Oak, Traverse City, Troy.

*Minnesota:* Fairmont, Minneapolis, Red Wood Falls, St. Paul (2).

*Mississippi:* Cleveland, Hattiesburg, Jackson, Keesler Air Force Base, Pascagoula.

*Missouri:* Sedalia, St. Louis.

*Montana:* Great Falls, Livingston.

*Nebraska:* North Platte, Omaha, Scotts Bluff, Sydney.

*Nevada:* Las Vegas.

*New Hampshire:* None.

*New Jersey:* Denville, Kearny, Millburn, Millville, Morris Plains, Mt. Ephraim, Paterson, Red Bank, Scotch Plains, Summit, Ventnor, Washington.

*New Mexico:* Albuquerque, Hobbs, Las Cruces, Roswell.

*New York:* Albany, Amsterdam, Batavia, Bellerose, Bethpage, Binghamton, Bronx, Brooklyn, Buffalo, Clayton, Elmira, Franklin, Harrison, Hornell, Hudson Falls, Huntington, Jamestown, Lockport, Niagara Falls, North Tonawanda, Penn Yan, Poughkeepsie, Rochester, Rome, Salamanca, Schenectady, Silver Creek, Syracuse, Trumansburg, Watertown, White Plains.

*North Carolina:* Asheville, Charlotte, Dunn, Greensboro, Lumberton, Spindale, Winston-Salem.

*North Dakota:* None.

*Ohio:* Bellaire, Canton, Cleveland (6), Columbus, Conneaut, Dayton, Greenville, Middletown, Newcomers-town, Springfield, Wadsworth, Zanesville.

*Oklahoma:* Bartlesville, Clinton, Enid, Lawton-Fort Sill, McAlester, Oklahoma City, Ponca City, Shawnee, Tulsa, Wagoner.

*Oregon:* Astoria, Bend, Coos Bay, Eugene, Klamath Falls, Medford, Newberg, Pendleton, Portland (2), Roseburg, Salem, St. Helens.

*Pennsylvania:* Altoona, Ardmore, Ardsley, Beaver Falls, Belle Vernon, Belleview, Bethlehem, Boyertown, Bradford, Chalfont, Connellsville, DuBois, Easton, Erie, Fairview Village, Lahaska, Lancaster (3), Larchmont, Lebanon (2), Lehigh, Lititz, Levittown, Lock Haven, McKeesport, Morton, Myerstown, Morristown, Northampton, Philadelphia (8), Pittsburgh, Reading, Red Lion, St. Mary's, Scranton, Selinsgrove, Sharon, Springfield, State College, Tamaqua, Washington, West Lawn, Wilkes Barre, York (3).

*Puerto Rico:* San Juan.

*Rhode Island:* None.

*South Carolina:* Charleston, Columbia, Florence.

*South Dakota:* Rapid City, Sioux Falls.

*Tennessee:* Bristol, Chattanooga, Humboldt, Jackson, Knoxville, Memphis, Nashville, Oak Ridge.

*Texas:* Alice, Arlington, Baytown, Corpus Christi, Dallas, El Paso, Ft. Worth, Galveston County, Garland, Houston, Kermit, Lubbock, Midland, Odessa, Orange, Refugio, San Antonio, Snyder, Texas City, Tyler, Waco, Woodsboro.

*Utah:* Ogden, Provo, Salt Lake City.

*Vermont:* Burlington, Middlebury.

*Virginia:* Christiansburg, Fredericksburg, Hopewell, Newport News, Norfolk, Petersburg, Radford, Richmond, Roanoke, Staunton, Winchester.

*Washington:* Bellingham, Bremerton, Centralia, Chehalis, Ellensburg, Ephrata, Everett, Kennewick, Longview, Pasco, Richland, Seattle, Spokane, Sunnyside, Tacoma (2), Vancouver, Walla Walla (2), Yakima.

*West Virginia:* Dunbar, Fairmont, Huntington, Morgantown, Nitro, Parkersburg, St. Albans, Weston.

*Wisconsin:* Eau Claire, Fond du Lac, La Crosse, Marinette, Milwaukee, Neenah, Oshkosh, Port Edwards, Racine, Wausau.

*Wyoming:* Casper, Cheyenne, Gillette, Powell, Sheridan.

## Appendix

HARMONICS OF FREQUENCY MULTIPLIERS	VFO OR CRYSTAL OSCILLATOR FREQUENCY	FREQUENCY MULTIPLICATION				
		X2	X3	X4	X6	X8
Fundamental	3.5-3.7 MC	7.0-7.4 MC	10.5-11.1MC	14.0-14.8MC	21.0-22.2MC	28.0-29.6MC
2ND	7.0-7.4 MC	14.0-14.8MC	21.0-22.2MC	28.0-29.6MC	42.0-44.4MC	56.0-59.2MC
3RD	10.5-11.1MC	21.0-22.2MC	31.5-33.3MC	42.0-44.4MC	63.0-66.6MC	84.0-88.8MC
4TH	14.0-14.8MC	28.0-29.6MC	42.0-44.4MC	56.0-59.2MC	84.0-88.8MC	112-118 MC
5TH	17.5-18.5MC	35.0-37.0MC	52.5-55.5MC	70.0-74.0MC	105-111 MC	140-148 MC
6TH	21.0-22.2MC	42.0-44.4MC	63.0-66.6MC	84.0-88.8MC	126-133 MC	168-178 MC
7TH	24.5-25.9MC	49.0-51.8MC	73.5-77.7MC	98.0-104 MC	147-155 MC	196-207 MC
8TH	28.0-29.6MC	56.0-59.2MC	84.0-88.8MC	112-118 MC	168-178 MC	224-237 MC
9TH	31.5-33.3MC	63.0-66.6MC	94.5-99.9MC	126-133 MC	189-200 MC	252-267 MC
10TH	35.0-37.0MC	70.0-74.0MC	105-111 MC	140-148 MC	210-222 MC	280-296 MC
11TH	38.5-40.7MC	77.0-81.4MC	115-122 MC	154-163 MC	231-244 MC	308-326 MC
12TH	42.0-44.4MC	84.0-88.8MC	126-133 MC	168-178 MC	252-267 MC	336-356 MC
13TH	45.5-48.1MC	91.0-96.1MC	136-144 MC	182-193 MC	273-288 MC	364-385 MC
14TH	49.0-51.7MC	98.0-104 MC	147-155 MC	196-207 MC	294-310 MC	392-415 MC
15TH	52.5-55.5MC	105-111 MC	158-167 MC	210-212 MC	315-333 MC	420-444 MC
16TH	56.0-59.2MC	114-118 MC	168-178 MC	224-237 MC	336-355 MC	448-474 MC

**TABLE 1.** — This is a list of harmonically related frequencies tabulated for your convenience in determining which harmonic of which stage in your transmitter might be causing TVI. The first column lists the order of the harmonics while the second column lists common VFO or crystal frequencies used by amateur radio operators. The X2 to X8 columns list frequencies that are two times, three times, up to eight times the frequencies of the VFO column. Assume your transmitter has a VFO in the 3.5 Mc. range and is designed for output on 28 Mc. The first frequency multiplier doubles to 7 Mc., the second to 14 Mc., and the third to 28 Mc. To find the harmonics that could come from the first doubler look under the X2 column. They are 14, 21, 28, 35, 42, 49, 56 Mc., etc. Similarly look under X4 for the harmonics from the 14 Mc. doubler and under X8 for the harmonics from the final amplifier. The latter will be 56, 84, 112, 140 Mc., etc. Now turn to Table 3 and determine to which channels the harmonics will cause TVI.

HARMONICS OF FREQUENCY MULTIPLIERS	VFO OR CRYSTAL OSCILLATOR FREQUENCY	FREQUENCY MULTIPLICATION				
		X2	X3	X6	X9	X18
Fundamental	8.0-8.2MC	16-16.4MC	24-24.6MC	48-49.3MC	72- 74 MC	144-148 MC
2ND	16-16.4MC	32-32.8MC	48-49.3MC	96-98.6MC	144-148 MC	288-296 MC
3RD	24-24.6MC	48-49.3MC	72-74 MC	144-148 MC	216-222 MC	432-444 MC
4TH	32-32.8MC	64-65.7MC	96-98.6MC	192-197 MC	288-296 MC	576-592 MC
5TH	40-41.1MC	80-82.2MC	120-123 MC	240-246 MC	360-370 MC	720-740 MC
6TH	48-49.3MC	96-98.6MC	144-148 MC	288-296 MC	432-444 MC	864-888 MC
7TH	56-57.5MC	112-115 MC	168-172 MC	336-345 MC	504-518 MC	1008-1036
8TH	64-65.7MC	128-130 MC	192-197 MC	384-394 MC	576-592 MC	1152-1184
9TH	72-74 MC	144-148 MC	216-222 MC	432-444 MC	648-666 MC	1296-1332
10TH	80-82 MC	160-164 MC	240-246 MC	480-493 MC	720-740 MC	1440-1480
11TH	88-90 MC	176-180 MC	264-271 MC	528-542 MC	792-814 MC	1584-1628
12TH	96-98 MC	192-197 MC	288-295 MC	576-592 MC	864-888 MC	1728-1776
13TH	104-107 MC	208-213 MC	312-320 MC	624-641 MC	936-962 MC	1870-1925
14TH	112-115 MC	224-230 MC	336-344 MC	672-690 MC	1008-1036	
15TH	120-123 MC	240-246 MC	360-370 MC	720-740 MC	1080-1110	
16TH	128-130 MC	256-263 MC	384-394 MC	768-789 MC	1150-1185	
17TH	136-139 MC	272-279 MC	408-418 MC	815-836 MC	1225-1258	
18TH	144-148 MC	288-295 MC	432-444 MC	864-888 MC	1296-1332	

**TABLE 2.** — This table is used in the same fashion as Table 1 except the frequencies are those normally used in 50 Mc. and 144 Mc. transmitters. (Six and two meters) Suppose you decide to use a 48 Mc. crystal in your 144 Mc. transmitter. Go down to the 48-49.3 Mc. line in the VFO column and then to the right to the X3 column. We see that the frequency must be tripled to reach 144 Mc. In the X6 column we see that the 2nd harmonic of the crystal oscillator will be 96 Mc. and may give interference to the FM band. (88 to 108 Mc.) We also see that the 4th harmonic lands in the bottom of channel 10. In the X18 column we see that no harmonics of 144 Mc. will hit the v.h.f. TV channels, however, the 4th, 5th, and 6th will land in some of u.h.f. TV channels depending upon which part of the 144 Mc. band is used. Check Table 3 for the u.h.f. TV frequencies.

The same procedure is used for 50 Mc. using the appropriate columns and frequencies.

## Appendix

Channel Number	Picture Carrier Freq. Mc.	Sound Carrier Freq. Mc.	Receiver R F Osc. Freq. Mc.	Channel Number	Picture Carrier Freq. Mc.	Sound Carrier Freq. Mc.	Receiver R F Osc. Freq. Mc.	Channel Number	Picture Carrier Freq. Mc.	Sound Carrier Freq. Mc.	Receiver R F Osc. Freq. Mc.
2	55.25	59.75	101	29	561.25	565.75	607	57	729.25	733.75	775
3	61.25	65.75	107	30	567.25	571.75	613	58	735.25	739.75	781
4	67.25	71.75	113	31	573.25	577.75	619	59	741.25	745.75	787
5	77.25	81.75	123	32	579.25	583.75	625	60	747.25	751.75	793
6	83.25	87.75	129	33	585.25	589.75	631	61	753.25	757.75	799
7	175.25	179.75	221	34	591.25	595.75	637	62	759.25	763.75	805
8	181.25	185.75	227	35	597.25	601.75	643	63	765.25	769.75	811
9	187.25	191.75	233	36	603.25	607.75	649	64	771.25	775.75	817
10	193.25	197.75	239	37	609.25	613.75	655	65	777.25	781.75	823
11	199.25	203.75	245	38	615.25	619.75	661	66	783.25	787.75	829
12	205.25	209.75	251	39	621.25	625.75	667	67	789.25	793.75	835
13	211.25	215.75	257	40	627.25	631.75	673	68	795.25	799.75	841
14	471.25	475.75	517	41	633.25	637.75	679	69	801.25	805.75	847
15	477.25	481.75	523	42	639.25	643.75	685	70	807.25	811.75	853
16	483.25	487.75	529	43	645.25	649.75	691	71	813.25	817.75	859
17	489.25	493.75	535	44	651.25	655.75	697	72	819.25	823.75	865
18	495.25	499.75	541	45	657.25	661.75	703	73	825.25	829.75	871
19	501.25	505.75	547	46	663.25	667.75	709	74	831.25	835.75	877
20	507.25	511.75	553	47	669.25	673.75	715	75	837.25	841.75	883
21	513.25	517.75	559	48	675.25	679.75	721	76	843.25	847.75	889
22	519.25	523.75	565	49	681.25	695.75	727	77	849.25	853.75	895
23	525.25	529.75	571	50	687.25	691.75	733	78	855.25	859.75	901
24	531.25	535.75	577	51	693.25	697.75	739	79	861.25	865.75	907
25	537.25	541.75	583	52	699.25	703.75	745	80	867.25	871.75	913
26	543.25	547.75	589	53	705.25	709.75	751	81	873.25	877.75	919
27	549.25	553.75	595	54	711.25	715.75	757	82	879.25	883.75	925
28	555.25	559.75	601	55	717.25	721.75	763	83	885.25	889.75	931
				56	723.25	727.75	769				

**TABLE 3.** — This is a tabulation of picture carrier, sound carrier and TV receiver oscillator frequencies for all of the presently assigned U. S. TV channels. The oscillator frequencies are for TV receivers using 41.25 Mc. for sound and 45.75 Mc. for video i.f. amplifiers. One use of this table is to determine with which channel a TV receiver will interfere when tuned to another channel. Note that when TV receivers are tuned to channels 2 and 3 their local oscillators are in the FM band. Also note that when a TV receiver is tuned to a channel such as channel 20 its local oscillator falls into a higher channel, in this case channel 27. Normally these two channels would not be assigned in the same area.

Channel	Frequency		L.O. Freq. 21.25-25.75 I.F.	Image	L.O. Freq. 41.25-45.75 I.F.	Image
	Picture	Sound				
2	55.25	59.75	81.00	102.25-106.75	101.00	142.25-146.75
3	61.25	65.75	87.00	108.25-112.75	107.00	148.25-152.75
4	67.25	71.75	93.00	114.25-118.75	113.00	154.25-158.75
5	77.25	81.75	103.00	124.25-128.75	123.00	164.25-168.75
6	83.25	87.75	109.00	130.25-134.75	129.00	170.25-174.75
7	175.25	179.75	201.00	222.25-226.75	221.00	262.25-266.75
8	181.25	185.75	207.00	228.25-232.75	227.00	268.25-272.75
9	187.25	191.75	213.00	234.25-238.75	233.00	274.25-278.75
10	193.25	197.75	219.00	240.25-244.75	239.00	280.25-284.75
11	199.25	203.75	225.00	246.25-250.75	245.00	286.25-290.75
12	205.25	209.75	231.00	252.25-256.75	251.00	292.25-296.75
13	211.25	215.75	237.00	258.25-262.75	257.00	298.25-302.75

**TABLE 4.** — This is a tabulation of local oscillator frequencies and image band frequencies for each TV channel, 2 through 13, for receivers with both 21 and 41 Mc. i.f.'s. It was from this table that the information for Figures 5 and 6 on page 15 was obtained. It is easy to see that with a local oscillator frequency of 81 Mc. the top part of the FM band is in image relation to channel 2. If you can find out the v.h.f. frequency of your local police, fire or taxi, you can determine from this table just which channels may receive image type of TVI from them and can therefore tell for what frequency to make traps or stubs.



## Appendix

**TABLE 5** Characteristics of Television Systems

System	I	II	III	IV	V	VI	VII	VIII
Name of System	British	United States		Gerber	U.S.S.R.	French	Belgian 625	Belgian 819
Number of Lines	405	525	625	625	625	819	625	819
Video Bandwidth Mc	3	4	4	5	6	10.4	5	5
Channel Width Mc	5	6	6	7	8	14	7	7
Sound Carrier Relative to Picture Carrier Mc	-3.5	+4.5	+4.5	+5.5	+6.5	11.15	+5.5	+5.5
Line Frequency cps	10,125	15,750	15,625	15,625	15,625	20,475	15,625	20,475
Field Frequency cps	50	60	50	50	50	50	50	50
Picture Frequency cps	25	30	25	25	25	25	25	25
Picture Modulation	AM	AM	AM	AM	AM	AM	AM	AM
Sense of Picture Modulation	+	-	-	-	-	+	+	+
Sound Modulation	AM	FM 25 kc	FM 25 kc	FM 50 kc	FM 50 kc	AM	AM	AM

**TABLE 6** Countries Using or Planning to Use the Television Systems of Table 5

I	II	III	IV	V	VI	VII	VIII
Great Britain <sup>1</sup> Ireland New Zealand	U.S.A. Canada Mexico Cuba Dominican Republic Guatemala Uruguay Columbia Brazil Philippines Japan Thailand El Salvador	Argentina Brazil Venezuela	Norway Sweden Denmark Netherlands Australia Austria  W. Germany Italy Luxembourg Spain Switzerland Turkey	U.S.S.R. Poland Czechoslovakia E. Germany Hungary	France N. Africa Saar Monaco	Belgium	Belgium

<sup>1</sup>The London and Northern Ireland transmitters use a 7 Mc channel for double sideband transmission.

Region 1	Band I	Band III	Bands IV & V
Europe, U.S.S.R. inside and outside Europe, Mongolia, Asia Minor, Africa, and additional out-of-hand frequencies for:	41-68 Mc	174-216 Mc	470-585 Mc
France		162-174 Mc	
Italy	81-88 Mc		
Belgian, Germany, Switzerland		216-223 Mc	
Region 2			
Western Hemisphere including Hawaii	54-72 Mc 76-88 Mc	174-216 Mc	470-890 Mc
Region 3			
Oceania, Asia (less parts in Region 1)	54-68 Mc 76-88 Mc	174-216 Mc	470-585 Mc 610-940 Mc
Australia	49-56 Mc 63-70 Mc 85-92 Mc 132-146 Mc	174-202 Mc 209-216 Mc	500-855 Mc

**TABLE 7** Frequency Allocations for Television Broadcasting

# Appendix

## FEDERAL COMMUNICATIONS COMMISSION

### TITLE 47—TELECOMMUNICATION

#### Chapter I—Federal Communications Commission

##### PART 12—AMATEUR RADIO SERVICE

§ 12.133 *Purity and stability of emissions.* Spurious radiation from an amateur station being operated with a carrier frequency below 144 megacycles shall be reduced or eliminated in accordance with good engineering practice. This spurious radiation shall not be of sufficient intensity to cause interference in receiving equipment of good engineering design including adequate selectivity characteristics, which is tuned to a frequency or frequencies outside the frequency band of emission normally required for the type of emission being employed by the amateur station. In the case of A3 emission, the amateur transmitter shall not be modulated to the extent that interfering spurious radiation occurs, and in no case shall the emitted carrier wave be amplitude-modulated in excess of 100 percent. Means shall be employed to insure that the transmitter is not modulated in excess of its modulation capability for proper technical operation. For the purposes of this section a spurious radiation is any radiation from a transmitter which is outside the frequency band of emission normal for the type of transmission employed, including any component whose frequency is an integral multiple or submultiple of the carrier frequency (harmonics and subharmonics), spurious modulation products, key clicks, and other transient effects, and parasitic oscillations. When using amplitude modulation on frequencies below 144 megacycles, simultaneous frequency modulation is not permitted and when using frequency modulation on frequencies below 144 megacycles simultaneous amplitude modulation is not permitted. The frequency of the emitted carrier wave shall be as constant as the state of the art permits.

§ 12.152 *Restricted operation.* (a) If the operation of an amateur station causes general interference to the reception of transmissions from stations operating in the domestic broadcast service when receivers of good engineering design including adequate selectivity characteristics are used to receive such transmissions and this fact is made known to the amateur station licensee, the amateur station shall not be operated during the hours from 8 p. m. to 10:30 p. m. local time, and on Sunday for the additional period from 10:30 a. m. until 1 p. m. local time, upon the frequency or frequencies used when the interference is created.

(b) In general, such steps as may be necessary to minimize interference to stations operating in other services may be required after investigation by the Commission.

##### SUBPART B—RADIO AMATEUR CIVIL EMERGENCY SERVICE

§ 12.235 *Alleviation of harmful interference.* (a) When emissions of stations in the Radio Amateur Civil Emergency Service, other than those necessary to carry on the desired communications, cause harmful interference to stations in this or any other service, the Commission may, in its discretion, require appropriate technical changes in the equipment to alleviate the interference.

(b) When the emissions of stations in the Radio Amateur Civil Emergency Service that are necessary to carry on the desired communications cause harmful interference to stations in other radio services, appropriate action shall be taken to alleviate such interference including, if necessary, the suspension (except during times of an actual state of civil emergency) of such emissions as cause the interference.

### TITLE 47—TELECOMMUNICATION

#### Chapter I—Federal Communications Commission

##### PART 15—INCIDENTAL AND RESTRICTED RADIATION DEVICES

15.207 *Interference from low power communication devices.* Notwithstanding the other requirements of this part, the operator of a low power communication device regardless of date of manufacture which causes harmful interference to an authorized radio service, shall promptly stop operating the device until the harmful interference has been eliminated.

1. Add the following definition to Section 15.4

§ 15.4 *General definitions.*—(a) *Radio frequency energy.* Electromagnetic energy at any frequency in the radio spectrum between 10 kc and 3,000,000 Mc.

(b) *Harmful interference.* Any radiation or induction which endangers the functioning of a radio navigation service or of a safety service or obstructs or repeatedly interrupts a radio service operating in accordance with the regulations in Part 2 of this chapter.

(c) *Incidental radiation device.* A device that radiates radio frequency energy during the course of its operation although the device is not intentionally designed to generate radio frequency energy.

(d) *Restricted radiation device.* A device in which the generation of radio frequency energy is intentionally incorporated into the design and in which the radio frequency energy is conducted along wires or is radiated, exclusive of transmitters which require licensing under other parts of this chapter and exclusive of devices in which the radio frequency energy is used to produce physical, chemical or biological effects in materials and which are regulated under the provisions of Part 18 of this chapter.

(e) *Community antenna television system.* A restricted radiation device designed and used for the purpose of distributing television signals by means of conducted or guided radio frequency currents to a multiplicity of receivers outside the confines of a single building.

*NOTE:* The television signals that are distributed are modulated radio frequency signals and may be:

(a) Broadcast signals that have been received and amplified.

(b) Broadcast signals that have been received and converted to another frequency.

(c) Any other modulated radio frequency signals fed into the system.

(f) *Low Power Communication Device.* A low power communication device is a restricted radiation device, exclusive of those employing conducted or guided radio frequency techniques, used for the transmission of signs, signals (including control signals), writing, images and sounds or intelligence of any nature by radiation of electromagnetic energy.

Examples: Wireless microphone, phonograph, oscillator, radio controlled garage door opener and various types of radio controlled toys.

##### § 15.62 *Radiation interference limits.*

The radiation from all radio receivers that operate (tune) in the range 30 to 890 Mc, including frequency modulation broadcast receivers and television broadcast receivers, manufactured after the effective date of this subpart shall not exceed the following field strength limits at a distance of 100 feet or more from the receiver:

Frequency of radiation (Mc)	Field strength (uv/m)
0.45 up to and including 25	See note.
Over 25 up to and including 70	32
Over 70 up to and including 130	50
130-174	50-150 (linear interpolation).
174-260	150
260-470	150-500 (linear interpolation).
470-1000	500

*NOTE:* This requirement applies only to radio receivers intended to be connected to power lines of public utility systems.

Pending the development of suitable measurement techniques for measuring the actual radiation in this band, the interference capabilities of a receiver in this band will be determined by the measurement of radio frequency voltage between each power line and ground at the power terminals of the receiver. The voltage so measured shall not exceed 100 uv at any frequency between 450 kc and 25 Mc inclusive.

§ 15.69 *Interference from a radio receiver.* The operator of a radio receiver, regardless of tuning range, date of manufacture, or of certification, which causes harmful interference shall promptly take steps to eliminate the harmful interference.

### Part 18—Rules Governing Industrial, Scientific, and Medical Service

§ 18.2 *Definitions.* For purposes of the provisions of this part the following definitions in the industrial, scientific, and medical service shall be applicable:

(a) "Radio frequency energy" shall include electromagnetic energy generated at any frequency in the radio spectrum between 10 kilocycles and 30,000 megacycles.

(b) "Medical diathermy equipment" shall include any apparatus (other than surgical diathermy apparatus designed for intermittent operation with low power) which utilizes a radio frequency oscillator or any other type of radio frequency generator and transmits radio frequency energy used for therapeutic purposes.

(c) "Industrial heating equipment" shall include any apparatus which utilizes a radio frequency oscillator or any other type of radio frequency generator and transmits radio frequency energy used for or in connection with industrial heating operations utilized in a manufacturing or production process.

(d) "Miscellaneous equipment" shall include apparatus other than that defined in or excepted in paragraphs (b) and (c) of this section which uses radio-frequency energy for heating, ionization of gases, or other purposes in which the action of the energy emitted is directly upon the work load and does not involve the use of associated radio receiving equipment.

§ 18.6 *ISM frequencies and frequency tolerances.* The following frequencies are allocated for use by ISM equipment with the tolerance limits specified:

ISM frequency	Frequency tolerance
13.560 kc	± 6.78 kc
27.120 kc	± 160.00 kc
40.680 kc	± 20.00 kc
916 Mc <sup>1</sup>	± 25 Mc
2460 Mc <sup>1</sup>	± 50 Mc
5850 Mc <sup>1</sup>	± 75 Mc
18,000 Mc <sup>1</sup>	± 150 Mc

<sup>1</sup> By public notice and order dated December 26, 1946, the Commission announced the availability of this frequency for industrial, scientific and medical purposes. It was expressly stated in the said public notice and order that such use of this frequency would be governed by the conditions set forth in that order and set out as Appendix A hereto rather than Part 18 of the Commission's rules.

<sup>2</sup> By public notice and order dated May 15, 1947, the Commission announced the availability of this frequency for industrial, scientific and medical purposes. It was expressly stated in the said public notice and order that such use of this frequency would be governed by the conditions set forth in the Commission's order of December 26, 1946 and set out as Appendix A hereto rather than Part 18 of the Commission's rules.

§ 18.8 *Interference from ISM equipment.* (a) Subject to the exceptions in paragraphs (b) and (c) of this section and irrespective of whether the equipment otherwise complies with the rules in this part, the operator of ISM equipment that causes harmful interference to any authorized radio service shall promptly take steps as may be necessary to remedy the interference.

(b) The provisions of paragraph (a) of this section shall not apply in the case of interference to an authorized radio station operating on an ISM frequency (including tolerance).

(c) The provisions of paragraph (a) of this section shall not apply in the case of interference to a receiver arising from direct intermediate frequency pick-up by the receiver of the fundamental frequency emissions of ISM equipment operating on an ISM frequency (including tolerance) and otherwise complying with the requirements of this part.





the 1990s, the number of people in the UK who are aged 65 and over has increased from 10.5 million to 13.5 million, and the number of people aged 75 and over has increased from 4.5 million to 6.5 million (Office for National Statistics 2000).

There is a growing awareness of the need to address the needs of older people, and the need to ensure that the health care system is able to meet the needs of older people. The Department of Health (2000) has identified the need to address the needs of older people as one of the key priorities for the health care system in the UK.

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