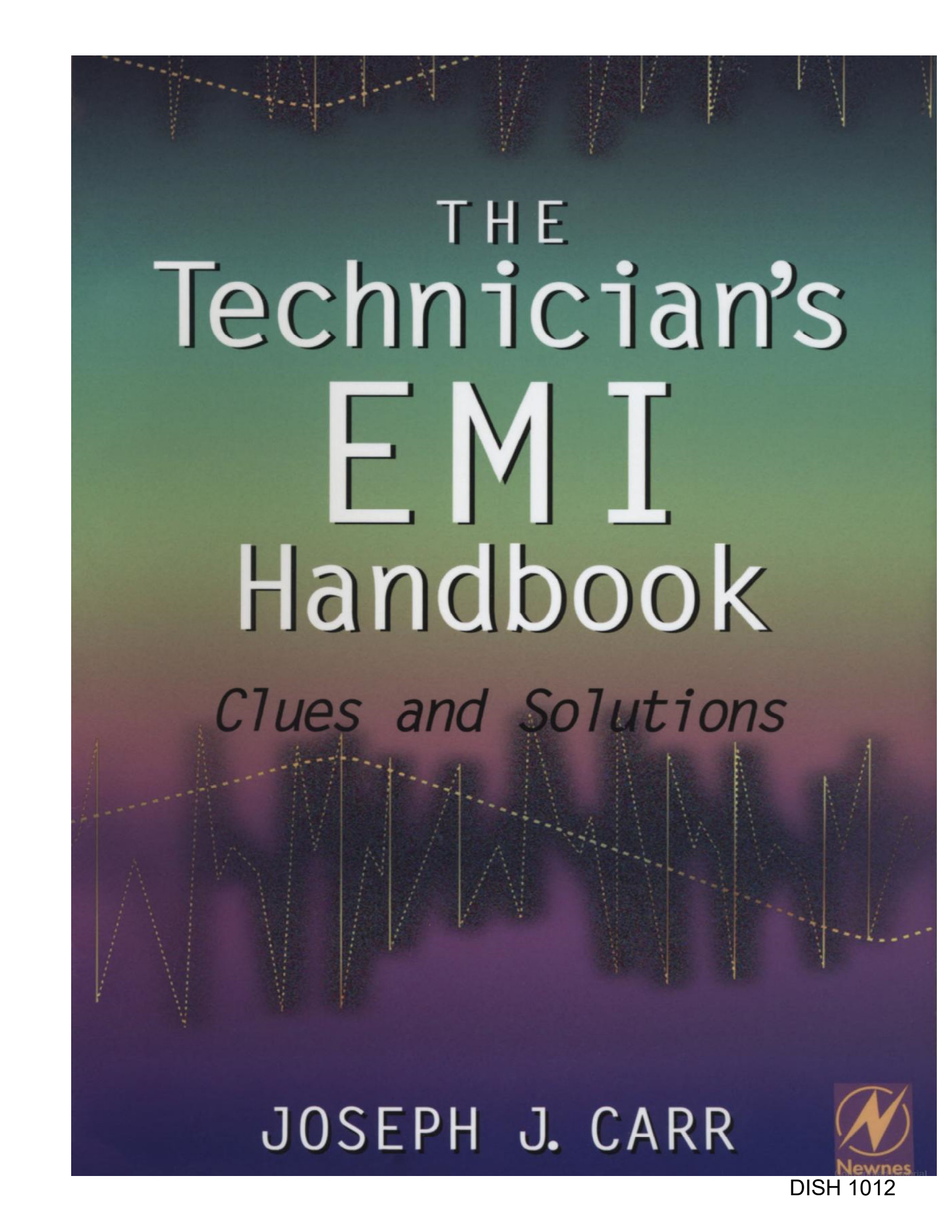




THE Technician's EMI Handbook

Clues and Solutions

JOSEPH J. CARR



DISH 1012

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Manager of Special Sales

Butterworth-Heinemann

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EMI to Television, Cable TV, and VCR Equipment

For many people, EMI to video and television equipment is all there is to the subject. Video and TVI is easily seen or heard and is terribly irritating to a large number of people. In this chapter we will take a look at video/TV interference and what can be done about it. Considered will be antenna connected television receivers, cable television receivers, and VCR equipment.

THE BASIC TELEVISION RECEIVER

Before we can deal with television interference, we must first deal with the standard television system. In the United States and Canada we use NTSC television, while foreign countries use SECAM or PAL systems. Some wags tell us the U.S./Canada standard means “never twice same color,” but in reality it means “National Television Steering Committee.” Figure 12.1 shows the basic NTSC color TV signal. The FCC has allocated space based on this model for transmission of TV.

The NTSC color TV standard requires a video carrier 1.25 MHz from the lower end of the channel. Spaced 3.579 MHz from the video carrier is a color burst carrier, which is not transmitted (it is suppressed in the transmitter). Spaced 4.5 MHz from the video carrier is an audio carrier. This latter is frequency modulated (FM) with a 25-kHz deviation. The video carrier is vestigial sideband (a species of AM in which one sideband is produced in full and one sideband is produced as a vestigial sideband). The chroma information is the color signal and is phase modulated onto the signal.

A typical television receiver is shown in block diagram form in Figure 12.2. This receiver is a superheterodyne, and so will have a front end inside the tuner, which is down-converted to an IF frequency. An AM envelope detector circuit called a video detector is used to demodulate the IF signal. It is the video detector that separates the video, color, and sound information.

The video amplifier section takes the composite black-and-white video and amplifies

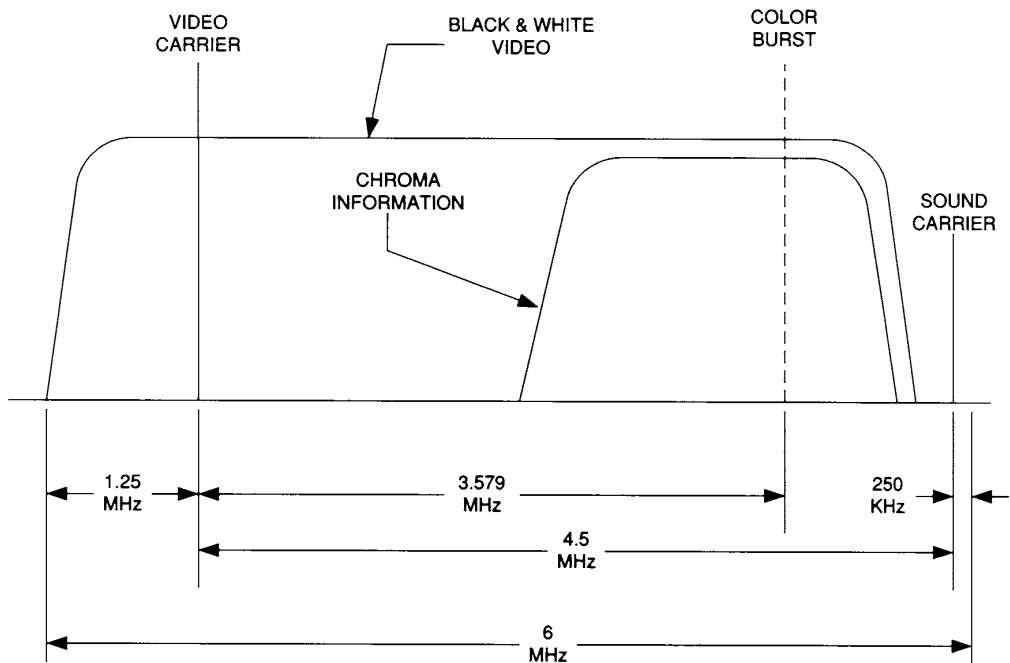


Fig. 12.1 Standard U.S. television channel.

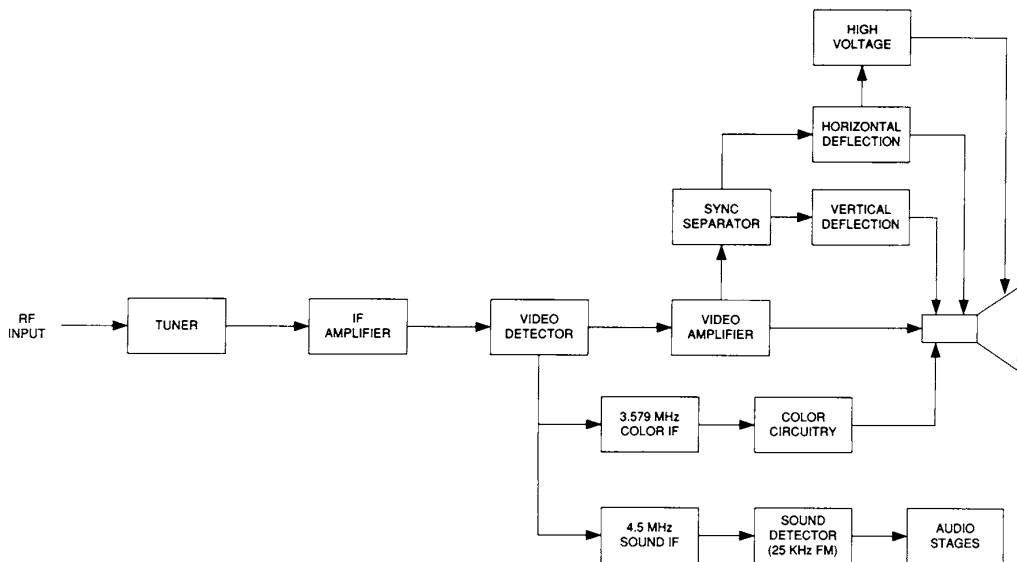


Fig. 12.2 Standard U.S. television set.

it to a point where it can drive the cathode ray tube (CRT). As part of the video amplifier or detector (shown as part of the amplifier here) is a circuit called a sync separator. This circuit will separate out the horizontal and vertical deflection pulses.

The deflection amplifiers control the vertical and horizontal aspects of the CRT. The vertical deflection is at 59.94 Hz, and the horizontal deflection is 15,734 Hz (these were changed from 60 Hz and 15,750 Hz to accommodate color). The high-voltage DC for the second anode of the CRT is derived from the horizontal amplifier circuit.

The color information is passed through a 3.579-MHz IF amplifier from the video detector. From there, it is processed and displayed on the CRT in the form of (usually cathode driven) red, blue, and green signals.

The sound information is passed through a 4.5-MHz IF amplifier and a 25-kHz FM detector to form the sound signal. From there, the audio signal is built up in a chain of amplifiers and output to a loudspeaker.

The front end of the television set is the tuner. It consists of a mixer circuit, a local oscillator, and (usually) an RF amplifier circuit. The front end is fed with the RF transmission line from the antenna. Either 300-ohm twin-lead or 75-ohm coaxial cable may be used. The latter case, 75-ohm coaxial cable, predominates today, but one can still find older television receivers and low-cost modern television receivers that use 300-ohm twin-lead.

FUNDAMENTAL OVERLOAD

Fundamental overload of a television receiver occurs when there is a strong signal present at the input of the receiver. The television receiver responds to the fundamental of the offending transmitter. It takes 25 to 30 dB of signal-to-noise ratio (SNR) to make a decent TV picture, and if there is less than that magic number, interference can result. The symptoms of fundamental overload include a herringbone pattern, or even a blanked-out picture.

HARMONIC OVERLOAD

Although fundamental overload is the most common form of EMI to TV receivers, harmonics from the transmitter may be second (especially with HF or low-band VHF transmitters). Harmonics are integer multiples of the fundamental frequency of the transmitter, and they can reach considerable heights in transmitters that are misadjusted. The FCC requires transmitter owners to keep the harmonic content of their emissions down -40 dBc (decibels below carrier) to -60 dBc, depending on service and frequency.

Harmonic overload may occur because of misadjustment of the transmitter. It may also be generated in the television receiver itself if there is a PN junction in the circuit that can be biased into nonlinearity by the transmitter signal. It may also be generated by dirty connections, corrosion, or even rusty bolts.

AUDIO RECTIFICATION

Audio rectification is heard rather than seen. It is audio from the offending transmitter's modulation being picked up, envelope detected, and amplified by the TV's audio amplifier chain. Interestingly enough, audio rectification occurs more often in cases where the antenna of the offending transmitter is vertically polarized. A good indication that interference is audio rectification is that it is audible regardless of the setting of the volume control.

IMD INTERFERENCE

A television receiver is an amplifier and demodulator of a radio signal, so it is susceptible to intermodulation distortion (IMD) interference. IMD interference occurs when two or more signals are present in the input of the receiver. They produce additional frequencies according to $mF_1 \pm nF_2$, where F_1 and F_2 are the frequencies and m and n are either integers or zero. That means a lot of frequencies! If two or more frequencies happen to follow this rule and produce a third

frequency that is on a television frequency, then IMD interference will result.

IF INTERFERENCE

IF interference exists because of the IF amplifier chain in the television set. It is easily identified because it affects all of the TV channels. Furthermore, it produces a fine herringbone pattern on the screen that rotates with the setting of the fine-tuning control. No other form of interference does this trick (although with other forms of interference the intensity of the interference does change with the fine-tuning).

DIRECT PICKUP

This form of interference, which requires transmitters of several kilowatts to accomplish, is picked up directly by the television receiver. It is generally due to internal wiring or printed circuit boards. To test for this type of interference, terminate the antenna in its characteristic impedance and note whether or not the signal level decreases. If it does, then the signal is arriving via the antenna terminals, and it is not a case of direct pickup.

COMMON-MODE VS DIFFERENTIAL-MODE SIGNALS

Very little has been written about the difference between common-mode and differential-mode interference. The difference is simple: differential-mode interference arrives entirely inside the feedline, while common-mode interference does not. The common-mode signal may arrive on the transmission line or on the AC line cord. The treatment of each form of interference depends on whether it is common or differential mode. It may be true that both forms of fix are required in a given case.

COMMON-MODE FILTERS

Common-mode filters come in two varieties: transmission line and AC line cord. Both are used to suppress EMI in TV systems. The transmission line variety is shown in Figure 12.3. It consists of a toroid core wrapped with the television antenna transmission line. This common-mode choke should be installed as close to the TV set as possible. To make an AC line cord type of common-mode choke, wrap the toroid with the AC line cord as close as possible to the TV set.

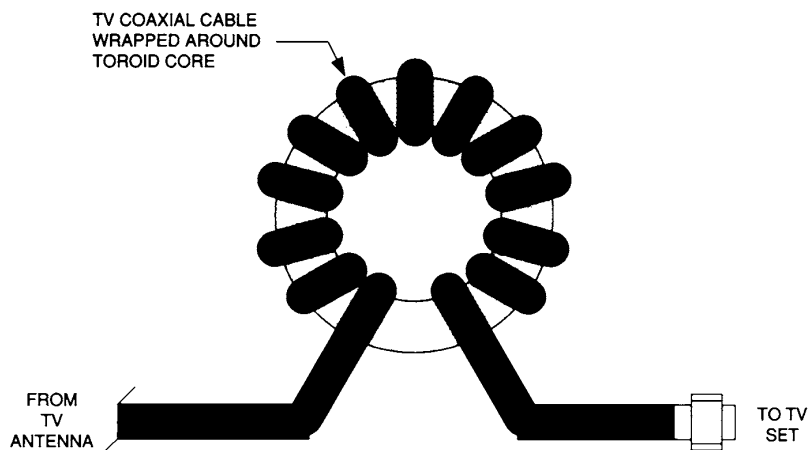


Fig. 12.3 Common-mode choke.

FILTERING

The television can be filtered at the antenna terminals or the AC line cord. For further information on the latter case, see Chapter 7. In this chapter we will discuss the type of filtering that one places on the transmission line.

Figure 12.4 shows the proper installation of the filter at the TV receiver. Figure 12.4A shows a 300-ohm system, while Figure 12.4B shows a 75-ohm system. The key in both cases is to make the transmission line between the television and filter *as short as possible*. In fact, it would be preferable to install the filter right at the antenna terminals of the tuner inside the TV set, but that is not usually possible unless you are a television repairman.

The type of filter to install depends on the nature of the transmitter causing interference to the particular TV set. In cases where the interference is being caused by an HF band transmitter (amateur, CB, or commercial), use a high-pass filter at the television set. It should have a cutoff frequency below TV channel 2. For VHF or UHF interference, use a high-pass, low-pass, bandpass, or bandstop (i.e., notch) filter, depending on the situation. If the offending transmitter affects more than one channel, it may be necessary to use a bandstop filter centered on the transmitter's frequency at the TV receiver.

Figure 12.5 shows a type of filter that works well for both common-mode and differential-mode signals in coaxial cable type systems. It consists of a 300-ohm twin-lead type of high-pass filter sandwiched between

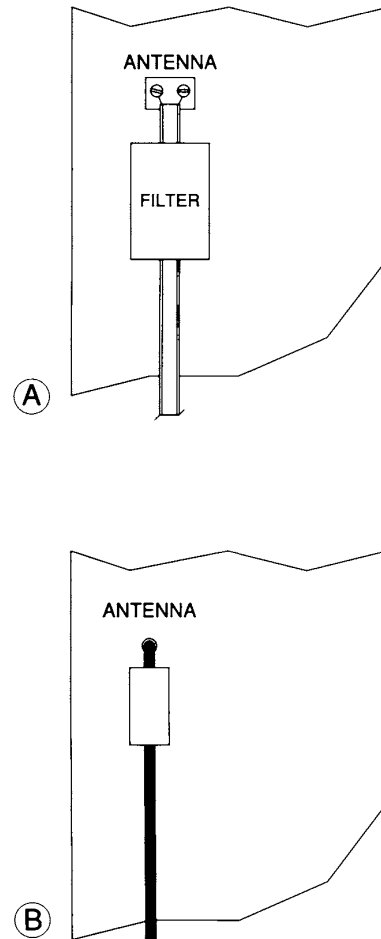


Fig. 12.4 Correct placement of filters: (A) 300-ohm twin-lead version; (B) coaxial version.

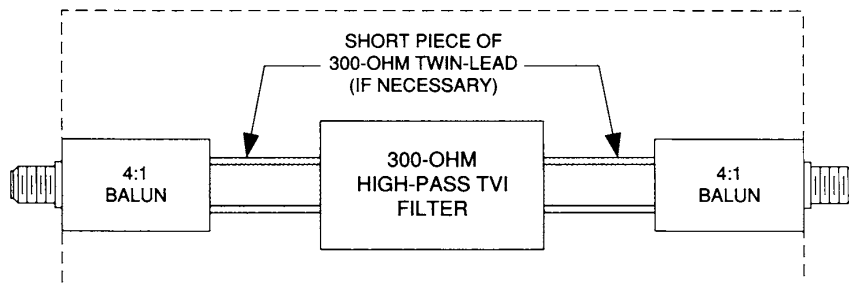


Fig. 12.5 Balanced filter circuit.

two 4:1 BALUN transformers. The 300-ohm twin-lead between the transformers and the filter should be as short as possible, or of zero length if possible.

STUBS FOR EMI ELIMINATION

Stubs can be used for EMI suppression on TV receivers. The usual quarter- and half-wavelength stubs are used, but Figure 12.6 shows a one-eighth wavelength stub. It is used to eliminate one particular frequency, and so it

functions as a notch filter. The frequency of the notch filter should be the frequency of the offending transmitter. The stub has a capacitor (C1) at the end, and this capacitor is used to tune the stub to the right frequency.

FARADAY SHIELDED COAXIAL CABLE

Figure 12.7 shows the use of a Faraday shielded coaxial cable for suppression of EMI. This forms a species of common-mode choke. To make the choke, take a short length of coaxial

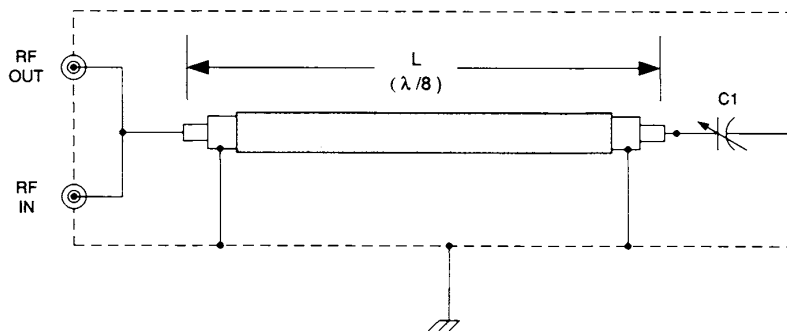


Fig. 12.6 One-eighth wavelength stub.

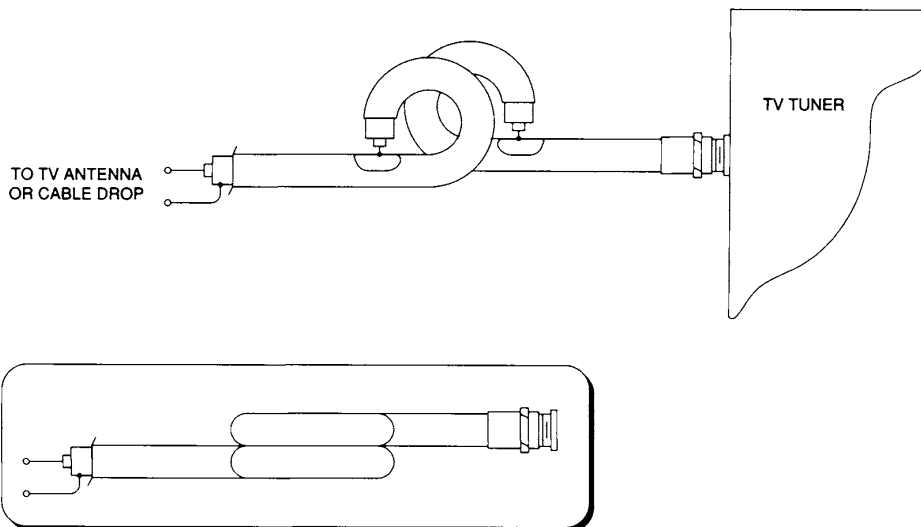


Fig. 12.7 Faraday shielded TV input.

cable with a connector on one end. Wrap the end into a loop of less than 6 inches in diameter. Scrap away a contact point on the outer insulator and connect the inner connector to it. Next, do the same thing to the cable from the antenna or cable TV customer drop. Lay the two cables over each other in the manner shown on the inset to Figure 12.7 and secure with tape or cable ties.

CABLE TELEVISION SYSTEMS

The cable television system in the United States is a closed system used to carry multiple channels to homes, businesses, and other subscribers. It should be very clean, but often isn't. The fact that they share certain

channels with other services (amateurs, navigation, and communications) makes the system ripe for interference.

The basic cable system is shown in Figure 12.8. It can be coaxial cable or fiber optic in nature, of which the fiber optic is by far most free of EMI problems. It is also the rarity. Although in some areas fiber has replaced coaxial cable, most cable systems are made of coaxial cable.

The head end of the cable system takes programming from various sources (off-the-air channels, satellite, local origin), and passes them to various trunk lines. Only one trunk is shown for clarity. The signal on the trunk is relatively low level, but is boosted by trunk amplifiers before being distributed further. From each trunk amplifier there is a bridger

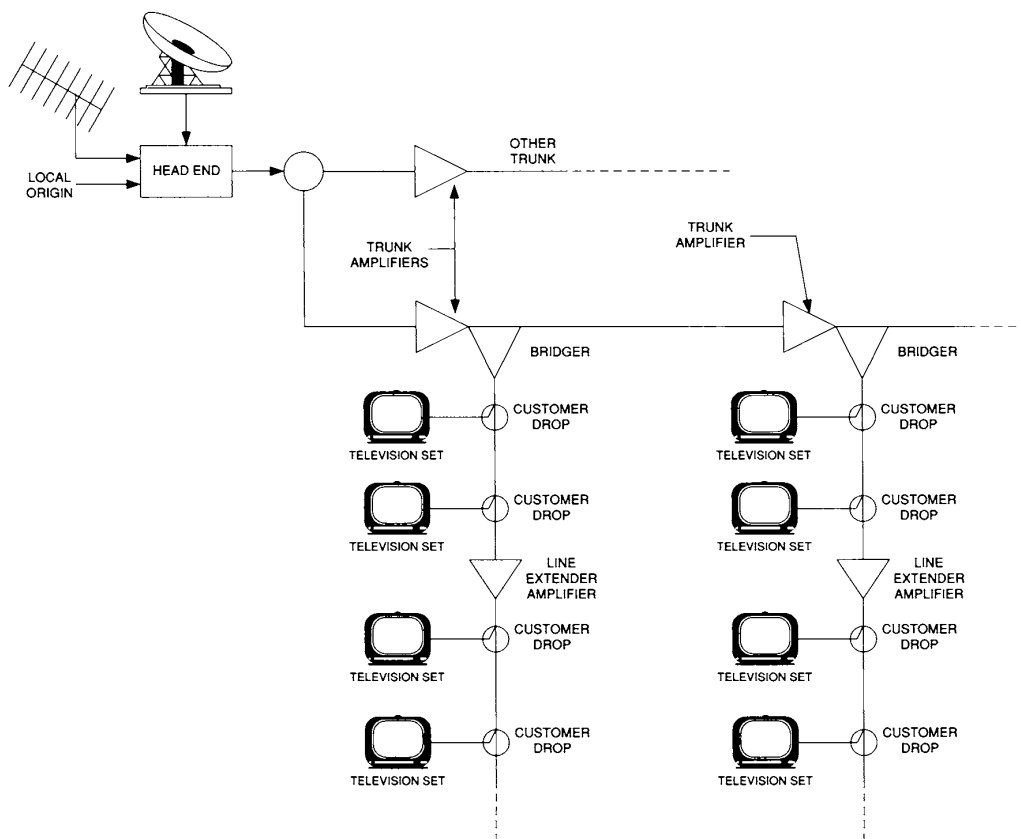


Fig. 12.8 Cable TV system.

network that distributes signal to the various subscribers. The subscriber tap into the system is called a drop. A line extender amplifier is used to boost the signal lost in the coaxial cable and various drops to a level that is useful in the system.

The quality of the signal is determined by two factors: noise and distortion. The noise is mostly that of the amplifiers. It degrades picture quality. Distortion can be harmonic or IMD, but is mostly IMD. The length of each distribution leg is limited principally by the distortion characteristics of the amplifiers.

TWO-WAY CATV

It is possible for the cable TV provider to communicate two ways on their systems. The 5- to 40-MHz region is used to provide upstream communications between the subscriber and the cable TV provider, and the institutional net (or I-net) in the sub-split system (in the mid-split system 5 to 112 MHz is used, and in the high split 5 to 174 MHz is used).

CHANNELIZATION

There are three generally accepted channelization schemes used in cable TV systems: standard, harmonically related carrier (HRC), and incrementally related carrier (IRC). These are defined in standard EIA-542. Of these, the standard is by far the most common. It uses TV channels assigned from 54 MHz in $6n + 1.25$ MHz schemes, up to 1,002 MHz. The HRC method uses TV channels locked to a 6,000 MHz comb. The IRC uses the basic $6n + 1.25$ MHz carriers locked to an internal comb.

LEAKAGE

Cable TV is supposed to be a closed system. Cable TV leakage occurs, however. It is called ingress when an outside source interferes with the cable TV, and egress when the RF energy gets out. Frequencies from 5 to 750 MHz are used, including some assigned

Table 12.1 CATV Leakage Limits

<i>Frequency (MHz)</i>	<i>Distance (ft)</i>	<i>Field Strength (mV/m)</i>
5–54	100	15
54–216	10	20
216–750	100	15

to other services. Leakage limits are related to distance in Table 12.1.

A field strength of 15 mV/m at a distance of 100 feet from the cable TV is a strong signal. But the regulations also maintain that the cable TV system must not cause harmful interference to other services. The definition of “harmful” is not given, however.

RESPONSIBILITY

The responsibility for EMI to and from cable TV systems is split among the cable TV system, the transmitter owner, and the owner of the afflicted television receiver. The transmitter owner's responsibility is limited by the terms of his or her license. If the transmitter is operated according to the terms of that license, including the emission of spurious signals, then there is little one can do to the transmitter owner. That leaves the cable TV system and the subscriber. However, cooperation of the offending transmitter owner is needed to troubleshoot the interference problem.

FINDING LEAKS

The problems with cable TV ingress and egress start with the effects of weathering on the system, as well as intentional acts of the customer. To protect against the former the FCC requires cable TV operators to continuously patrol the system to find leaks. Finding the leaks is an exercise in radio direction finding. The technician will drive along the line while monitoring the leakage levels on a sensitive receiver. The mobile unit will locate the leak within about 80 to 100 feet, after

which hand-held receivers of lower sensitivity are required.

WHAT TO DO WHEN THE INTERFERENCE IS AT THE SUBSCRIBER END

What to do when the problem is at the subscriber end is a difficult problem. Some cable TV companies are willing to troubleshoot the situation to keep the subscriber happy, while others are not. Modifications to the television set should be done by competent personnel, but beyond that it is possible to troubleshoot the system.

First, diagnose the problem. Is the set or the converter really involved? The interference may be experienced by only one subscriber. In that case, assume that the subscriber's system is at fault (multiple faults along a line do not necessarily mean that the system is at fault, but do point to a system problem).

The basic fix for most problems is a common-mode choke. The common-mode choke can be made using the cable and a toroidal core per instructions given in Figure 12.3. It consists of a toroid core wrapped with coaxial cable. Figure 12.9 shows the placement of the common-mode choke in the system. This does not preclude placing a common-mode choke and a differential-mode high-pass filter at the television receiver's antenna input terminal.

There are two paths for interference to occur: power line conduction and direct radiation. The power line conduction scheme can be eliminated at the transmitter by placing either a common-mode choke or a differ-

ential filter in the power line. In other cases, however, the common-mode choke should be placed in the AC line cord of the converter or susceptible TV receiver. The common-mode choke is made by winding the AC line cord around the toroid core.

WHAT TO DO WHEN THE CUSTOMER IS AT FAULT

There are two cases where the customer might be at fault: (1) the existence of a susceptible TV and (2) the use of multiple sources. The case of the susceptible TV is usually found by disconnecting the converter from the antenna terminals and replacing it with a carbon resistor of either 300 ohms or 75 ohms (depending on the impedance of the set). If the interference persists, then the set is responsible. In that case, common-mode chokes on the antenna terminal and AC line cord, and differential-mode filtering at the antenna terminals, may help.

The use of multiple sources for their TV signals may be the problem. Look for connections that should not be present. If the connections are made through an A/B switch, then disconnect the A/B switch and connect the converter directly. If the interference disappears, then you have solved the problem. If not, keep trying!

VCRS

The VCR is a special device that is placed in the TV system to record signals off the air or play back tapes. The two systems in the

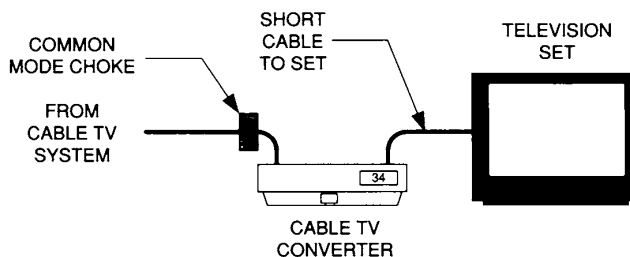


Fig. 12.9
Common-mode choke in cable TV system.

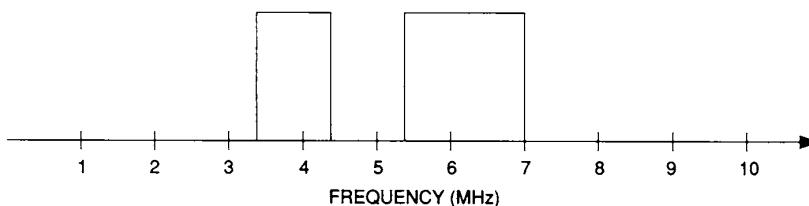


Fig. 12.10 Luminance signal in straight and Super VHS VCRs.

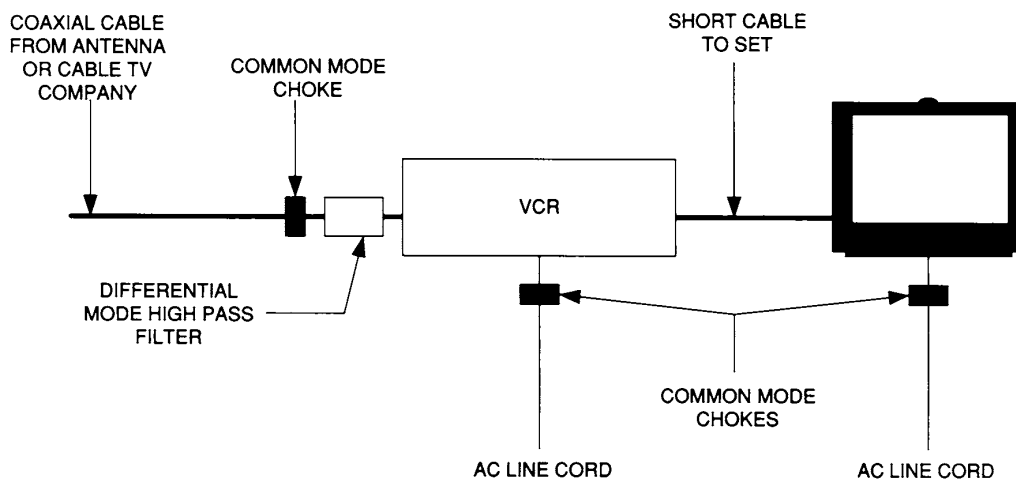


Fig. 12.11 Placement of chokes in VCR system.

United States and most of the world are VHS and Super VHS. They present certain problems to the troubleshooter.

The easiest way to record the 6-MHz bandwidth onto tape is to use frequency modulation with the baseband video signal. Of course, one can tape-record it directly, but that would be prohibitively expensive on consumer-grade equipment. The luminance (brightness) signal is recorded from 3.4 to 4.4 MHz in VHF, and 5.4 to 7.0 MHz in Super VHS (see Figure 12.10). Some VCRs will record the audio portion separately from the video portion.

Figure 12.11 shows the approach for attacking the EMI problem to VCRs. Common-mode chokes should be placed in the AC

line cords of the television and the VCR, as appropriate. A common-mode choke should also be placed at the antenna input connector of the VCR. If differential-mode signals exist, then use a differential-mode high-pass filter (or band-reject filter in the case of VHF transmitters).

It is uncommon to find this, but be aware that a VCR is a transmitter, and if the output of the VCR is connected to the antenna, it will radiate on the channel being viewed. This is usually channel 3 or 4. This means that the neighborhood will view the same pictures as the original viewer! The antenna should go through the VCR even if the user does not intend to record off the air.