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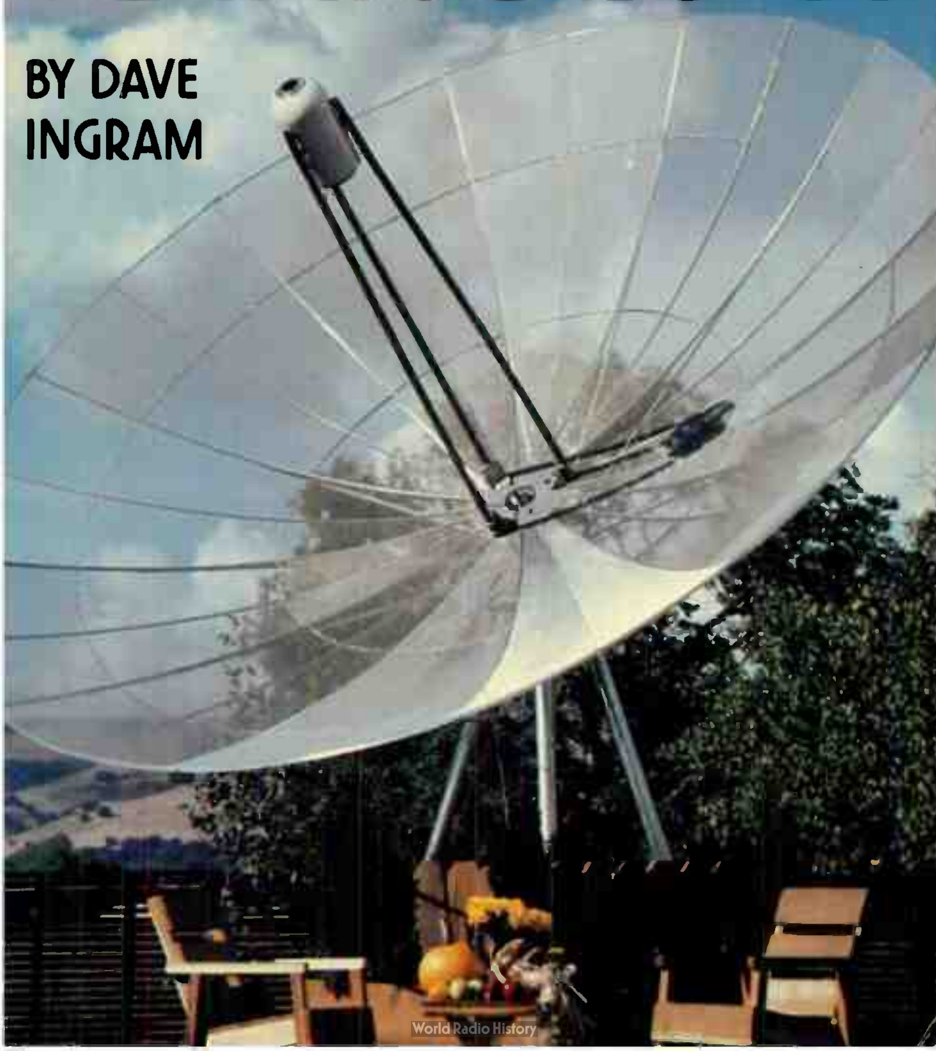
VIDEO ELECTRONICS TECHNOLOGY

BY DAVE INGRAM



Video Electronics Technology

by Dave Ingram

A practical, up-to-the-minute guide to modern video electronics technology with details on microwaves, satellites, recording/playback systems, and more. Here's complete coverage of the development of video electronics from it's beginnings to today's state-of-the-art . . . and a preview of possible future innovations like holographic video and personal video communications systems. Plus, this outstanding sourcebook includes an invaluable section on practical video troubleshooting techniques.

From the first faint video images transmitted back in 1875, the author follows the development of video science to black and white and color TV receivers (including how signals are generated, transmitted, and received). Various types of receiving antennas are covered. Multipoint Distribution Systems (MDS) for low power, microwave broadcasting are examined and there's data on a universal communications downconverter for use in the 2,000 to 2,500 MHz range. TVRO equipment and receiver systems, video cassette and video disc recorders, and amateur television (both fast and slow scan modes) are thoroughly discussed; and there's a look at the new frontier of medium scan amateur TV.

Of particular interest is a section called The Quick TV Troubleshooter. Here, you can find out the types of problems that occur in a TV receiver *and* how to locate the circuit causing the trouble. Detailed photographs illustrate how the video screen looks when the set is experiencing different problems—providing you with an additional aid in your troubleshooting practice.

Professional and amateur technicians, home video enthusiasts, amateur radio buffs, and do-it-yourself repairmen will all find this book an excellent source on every aspect of video electronics.

Dave Ingram is a professional electronics technician and broadcast engineer who holds a Commercial 1st Phone Radar Endorsed license and Amateur Extra Class license. He is the author of *Secrets of Ham Radio DXing*, published by TAB BOOKS.

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Other TAB books by the author:

No. 859 *The Complete Handbook of Slow-Scan TV*
No. 1120 *OSCAR: The Ham Radio Satellites*
No. 1189 *10-Meter FM for the Radio Amateur*

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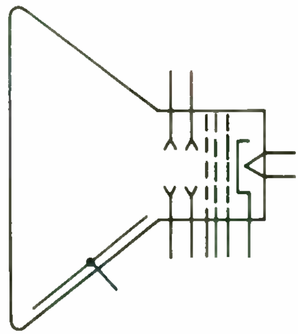
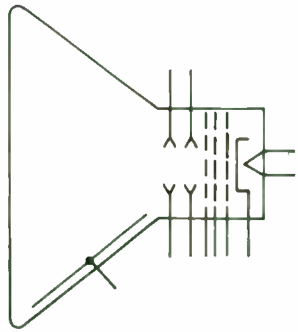
Contents



Introduction



Video technology is one of the hottest and most rapidly expanding areas in modern electronics. Embracing a number of unique concepts ranging from microwave and satellite TV to video cassette recorders and laser-scanned videodiscs, this specialized frontier holds substantial promise for the projected visual communications links destined to influence our lives.

The world of video has become recognized as significantly more than a mere entertainment medium. Through the joint use of television displays and home computer systems, one may soon handle the majority of daily, weekly, and monthly business transactions right from his living room, den, or study. This same system, when linked through interactive satellite-TV channels, can provide the ability to shop, order, and conclude transactions in distant cities or countries via the home-television system.

A new era of "home offices" is also projected to gain widespread popularity. Using television-equipped terminals in one's home, individuals are expected to sidestep increasing transportation costs while performing company duties during personally productive times. Microwave and satellite interlinked master-office systems will support such terminals, resulting in a truly effective and video-diversified social structure.

Although difficult to calculate accurately, additional systems using such techniques as holographic video may become competitive with "talk-back" television. Meanwhile, personal satellite-TV receive-only terminals and video record/playback units will continue in the technological limelight.

A true electronic revolution is on the horizon, with some almost unbelievable innovations due to be revealed in the near future. Single ICs capable of storing and processing four pictures simultaneously, flat screen displays which can be linked to a computer, and remote video displays which can provide personal communications via city and/or satellite links are only a tip of the forthcoming iceburg.

This book provides a straightforward guideline for understanding and using the equipment and concepts associated with both black-and-white and color television. Additionally, it presents in-depth, hands-on discussions and working explanations of home-satellite TV systems, microwave and MDS television, plus video recording/playback systems. If you're interested in keeping abreast of today's video techniques while getting involved with new frontiers on a face-to-face basis, this book should prove to be ideal.

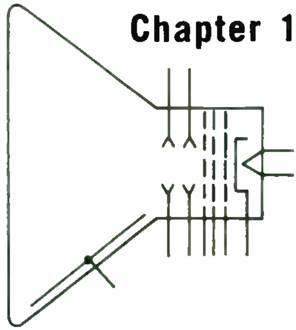
As with any progressive electronics frontier, technology continues to expand at a phenomenal rate. The key to successful existence and progression in this area calls for a logical starting point (such as this book) and expanding from that point. Accept older tried-and-proven concepts, and use new items to implement personal designs. A world of opportunity awaits today's innovators, and hopefully this work will provide the necessary inspiration.

Creating a book of this nature is not an easy matter and requires the help of many individuals and companies. Likewise, discussions of electronic frontiers and their associated expansions is a delicate and calculating situation. I would like to express sincere thanks to the following individuals and companies for their support and contributions to this book: Alf Wilson, W6NIF, past Editor of *ham radio magazine* and the Ham Radio Publishing group of Greenville, New Hampshire; Fred Staal, Advertising and Graphics Director for KLM Electronics of Morgan Hill, California; and Steve and Deborah Franklin, President and Vice-President of Universal Communications of Arlington, Texas.

A special word of thanks is also due Darlene Adkins and my wife Sandra Ingram, WB4OEE, for their assistance and extended indulgence in typing and assembling this manuscript, a project that encompassed over a ream of prepared papers.

Chapter 1

Overview



Television is one of today's most powerful and widespread means of mass communication. It directly influences our lives on both a short and long-term basis; it brings worldwide situations into our homes; it affords extensive opportunities for acquiring higher education; and it performs these tasks in a convenient yet effective manner. We are all aware of the popularly accepted applications of television, particularly those relative to entertainment and news broadcasting. Television, however, has also been a vital link in unmanned deep space exploration (such as the Voyager I and II missions), in providing visions from hazardous areas (such as proximity to radioactive materials or environments) in underwater research, in viewing storms moving across a metropolitan area (the camera being placed in a weather-protective enclosure near the top of a tower), etc. The earth's weather satellites also use TV cameras for viewing cloud cover and movements from 20,000 miles in space. Infrared filters are used for night views, and several systems include a spinning-mirror arrangement to permit wide-area views from the camera. Realizing the unlimited applications for today's television systems, one may thus logically ponder the true benefits of confining most of our video activities to the mass-entertainment field.

Conventional television broadcasting within the United States centers around free enterprise and public ownership. This requires funding by commercial sponsors, and thus functions in a revenue-producing business manner. Television in USSR-subjected areas, conversely, is a government-owned and maintained arrangement. While such arrangements eliminate the need for commercial sponsorship, it also has the possibility of limiting the type of programs available to viewers (a number of purely entertainment programs similar to the classic "Bewitched," however, have been seen on these government-controlled networks. All isn't as gray and dismal as the uninformed might unnecessarily visualize).

A highly modified form of television called Slow-Scan TV is presently being used by many Amateur Radio operators to provide direct visual communications with almost any area of the world. This unique visual mode recently allowed people on the tiny South Pacific country of Pitcairn Island to view, for the first time in their lives, distant areas and people of the world. The chief radio Amateur and communications officer of Pitcairn, incidentally, is the legendary Tom Christian—great, great grandson of Tom Christian of "Mutiny on the Bounty" fame. Radio Amateurs in many lands worked together for several months establishing visual capabilities for Pitcairners. The results have proven spectacular, yet the visual capabilities have only been used for health, education, or welfare purposes. Commercial TV is still unknown to natives of that tiny country.

Numerous other forms of television and visual communication have also been used on a semi-restricted basis. This indicates the many untapped areas of video and television which may soon be exploited on a more widespread basis. The old cliché of a picture being worth a thousand words truly has merit.

The majority of information presented in this book relates to popular video systems and their operation. Thus, a general overview of these areas is a logical point to begin our study. Since a full discussion of television's birth and growth is included in Chapter 2, we will begin this chapter's considerations with the first mass popular step after color TV—cable systems.

INTRODUCTION OF CABLE SYSTEMS

Following the widespread acceptance of television broadcasting, a desire for additional programming was indicated by the general public and by rural area viewers. Several large corporations, realizing the potential of that concept, instigated long range programs which resulted in the first television-relay satellites being placed in fixed positions (geostationary orbit) many miles above the earth. The satellites were originally used for relaying major network broadcasts, then a restricted-audience form of telecasting known as cable television began to use satellites in a revenue-producing manner. That concept has now expanded substantially, with almost a dozen satellites (each boasting 24 channels) providing a wide variety of both private and commercial network programming for earth-based satellite-receiving (cable) companies.

The general setups used by smaller cable-TV companies are relatively straightforward in design. An outline is shown in Fig. 1-1. A satellite-receiving earth station is used for obtaining the primary programming, with a varying amount of secondary programming being provided through video tapes and/or a small TV-studio setup at the cable company's main office. Occasionally, retransmissions from fringe-area stations are also included in these activities. The resultant TV signals are then distributed to subscriber's homes via coaxial cable. The extended bandwidth of the transmission requires extensive use of line amplifiers along each path and its branches to ensure that adequate signal strength is present at each termination point. The TV cable is often run between a city's utility poles, underneath telephone cables. Reviewing Fig. 1-1, one may thus surmise the only significant difference between a cable-TV setup

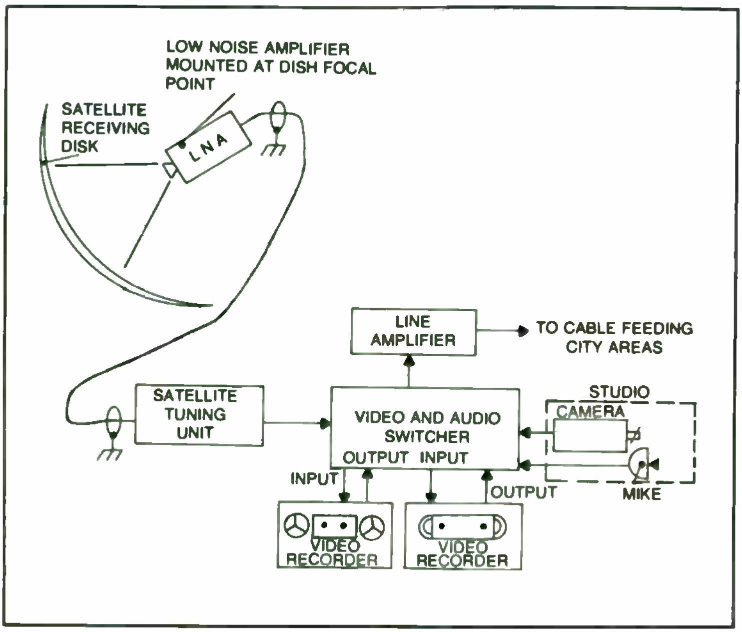


Fig. 1-1. Setup of a cable-TV company consisting of a satellite receiving terminal, video recorder/players, master video switcher, and several cable-line amplifiers. Studio and cameras are optional.

and a TV broadcast station is the substitution of cables and their associated amplifiers for the high-power transmitter for radiating signals to viewers. Studio systems and signal processors are required in either arrangement. One of the most vulnerable parts of a cable-TV setup is the low-noise amplifier (LNA) which is mounted at the parabolic antenna's focal point. These sensitive amplifiers necessarily use GaAsFET transistors: devices with finer-than-human-hair structures which can easily be destroyed by nearby static charges such as lightning. While protective measures for these expensive transistors afford a margin of safety, spare LNAs are vital for continued operation of satellite receivers. A large number of spare line amplifiers are also necessary for substained operations under various environmental and physical conditions. These units may thus be "field exchanged" with defective units as required, with defective units being repaired in a conventional "workbench" style.

A number of more advanced cable-TV systems have recently become popular, and that trend is expected to escalate. Among these advanced concepts are 30 (or more) channel programming, and talk-back-TV—a concept which allows viewers to participate in polls via their home cable units. The latter arrangement requires, in addition to an elaborate video arrangement, a substantial computer setup capable of tallying incoming data and directing the results back to the outgoing video system. These computer/video arrangements are expected to pioneer the use of home terminals for mail services, banking, etc. Ultimately, highly specialized cable-TV and computer networks will combine capabilities to provide various services to consumers with home computer terminals (which are likewise linked to their television sets). The systems will include capabilities of shopping and purchasing items on a local or international basis, with signatures being handled by means of light pens connected to the television system. The computer/television setup will respond to one's particular interest: news of specific areas, stock-market reports, aircraft weather for designated areas, etc. Awareness of these situations, and the fact that home-computer systems require visual displays, makes one keenly alert to the increasingly popular demand for full-service television systems.

TV SATELLITES

As the number of TV-cable systems increased, interest in TV satellites also began escalating. "Closed-Circuit" events relayed via satellite rose in popularity, with almost everyone wanting in on the action. This era marked the beginning of home satellite reception and TVROs, or Television Receive Only terminals. TVROs consist of low-cost satellite-receiving setups similar to those used by cable-TV companies. Smaller parabolic dishes, conventional-design LNAs and a simple type of feed to the TV-antenna terminals reduced the cost to affordable figures (see Figs. 1-2, 1-3, 1-4, and 1-5).

Satellite-transponder-time that is charged to uplink programmers/subscribers is usually quite expensive, consequently, maximum use of that time is vitally important. That consideration has resulted in many lasers leading unused satellite time to computer firms for data communications. Occasionally, a transponder may also be used for other experimental transmissions—or even conventional voice communications.

As this book is being written, plans are being finalized for placing another form of television satellite in fixed orbit. This spacecraft is projected to function as a low-power TV transmitter in the sky, broadcasting (relaying) directly to satellite receiving terminals placed at viewers homes throughout the United States. Commercial sponsorship will be included in the satellite's programming.

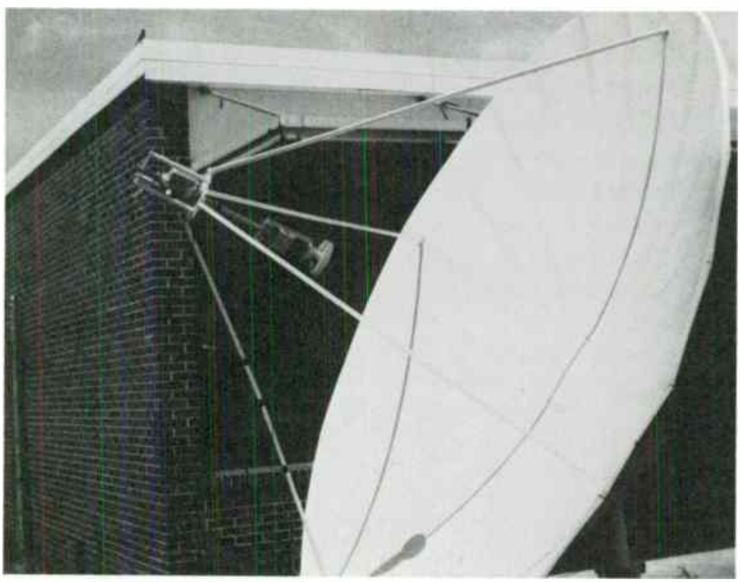


Fig. 1-2. Parabolic dish antennas used with home satellite television receive-only terminals (TVROs) range from 12 to 16 feet in diameter and provide reception of several TV satellites.

Fig. 1-3. A special unit, known as a low noise amplifier, is mounted at the focal point of the satellite TV dish and connected to the indoor unit via a coaxial cable. Note the circularly polarized waveguide on the front and the polarity rotor at the rear.

Fig. 1-4. One of a variety of indoor tuning units used with dish and LNA for satellite-TV reception.

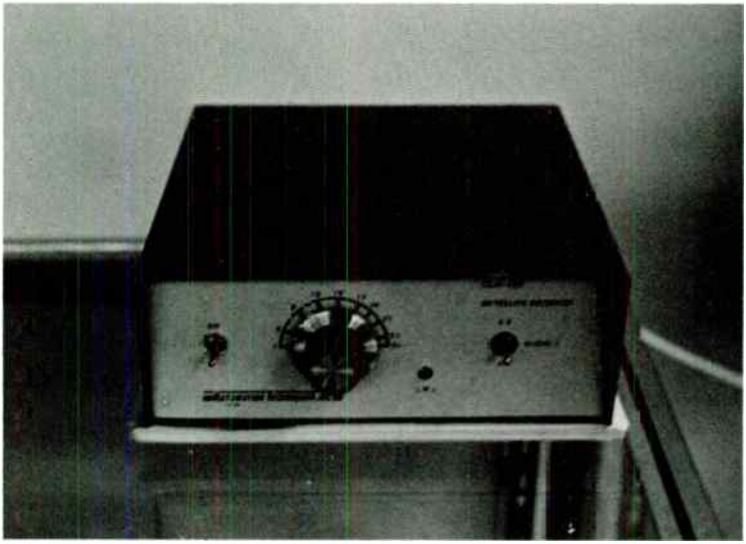


Fig. 1-5. Another TVRO indoor tuning unit, this one featuring single knob transponder tuning.

THE VIDEO-RECORDER BOOM

Although video tape players have been used since the early days of television broadcasting, they didn't acquire widespread public use until recent years. Unlike simple audio tape recorders, video recorders/players require complex, sometimes rotating heads to affect scanning of the tape. The tape motion then adds different frames, resulting in motion pictures. (A stopped tape which is being scanned by a rotating head will produce a "still" picture.) The first video-tape units were conventional reel-to-reel designs, using rather wide tape and high speeds to resolve the maximum amount of detail (high video frequencies). Large cartridges containing tape-feed and take-up reels were the next evolution, although these unwieldy units did not acquire mass popularity among home-video enthusiasts. The next evolution in video recordings resulted in a cassette-tape unit, approximately 4 times the size of an audio tape, which would "automatically load" into its player for use. The first of these video cassettes to acquire widespread popularity among home-video enthusiasts was the "Betamax." Commercially produced movies on numerous subjects flooded the market before Betamax tapes began sharing popularity with a similar video-cassette system called VHS (Video Home System). The longer playing time of VHS tapes is their prime

Fig. 1-6. This compact VHS video recorder requires very little room for setup and use, yet it provides many hours of taped movie viewing.

attraction, causing many tape users to switch to the VHS format. As this book is being written, video discs are rising in popularity. Their acceptance and widespread application is thus uncertain (see Figs. 1-6 and 1-7).

Fig. 1-7. This Betamax video recorder features internal vhf and uhf TV-tuner systems, permitting taping of movies independent of associated TV viewing.

PAY TV

Extensive requests for the capability of viewing current theater attractions and R-rated movies on private TV sets increased the popularity of pay-TV systems. This arrangement began with some hotels and motels providing closed-circuit broadcasts from video-tape recorders to paying customers. The concept then expanded to include pay-TV cable companies who supply these current box-office attractions to hotel and motel customers. The most recent development along pay-TV lines has been the instigation of Multipoint Distribution Systems (MDS) which transmit the movies and programs directly to subscribing hotels, motels, and some home customers. The MDS band used for this service is 2100 to 2200 MHz; a frequency range which requires a line-of-sight path between the transmitter and its receiving units. Since 2100 MHz receiving gear is relatively unavailable to the general public, and since a reasonable knowledge of electronics and microwave technology is required when working with these units, a form of signal "cloaking" is provided for the system. These pay-TV signals are transmitted over the airwaves, however, and enterprising and electronically competent individuals have begun producing kit receivers/converters for MDS TV reception. These units often perform *better* than the commercially supplied MDS receivers originally placed at subscriber locations. The legalities surrounding the use of such MDS receivers by non-subscribers is, as of this writing, an uncertain matter.

The designation of "pay TV" may seem confusing since cable-TV firms also charge for their service. While this is true, the "pay TV" term has gained its acceptance primarily through MDS systems (off-air, rather than via cable), and available "first-run" movies which are not placed on cable systems until a later date. There are always exceptions to such vague dividing lines. One such example is the pay-TV cable system available in Columbus, Ohio. This special system includes "talk-back" features, and may soon include capabilities for shopping, banking, etc., by television. The previously mentioned satellite transmitter which will relay programs directly to subscriber's homes is yet another example of a "pay-TV" system.

PROJECTION TV

One of the more recent trends in video electronics is an interest in extremes of television-screen size. While console TV sets with 25- and 27-inch screens previously held the esteemed position of "maximum screen size," recent projection systems have altered that situation. Today's three- to four-foot screens, as a result, truly turn one's den or viewing room into a home theater. Several commercially produced forms of projection TV are presently being marketed, their prices varying from approximately $1200 to $3000.

The general design concepts of color-TV projection systems is outlined in Fig. 1-8. Conventional television circuitry (with occasional "bells and whistles" such as automatic tuning, on-screen time display, etc.) is used for the front end, with video output stages modified for driving separate projection type cathode-ray tubes. The projection tubes are small (usually five or six inches in diameter), with extremely high voltages applied to create the necessary high light levels. The face of each projection CRT is then covered

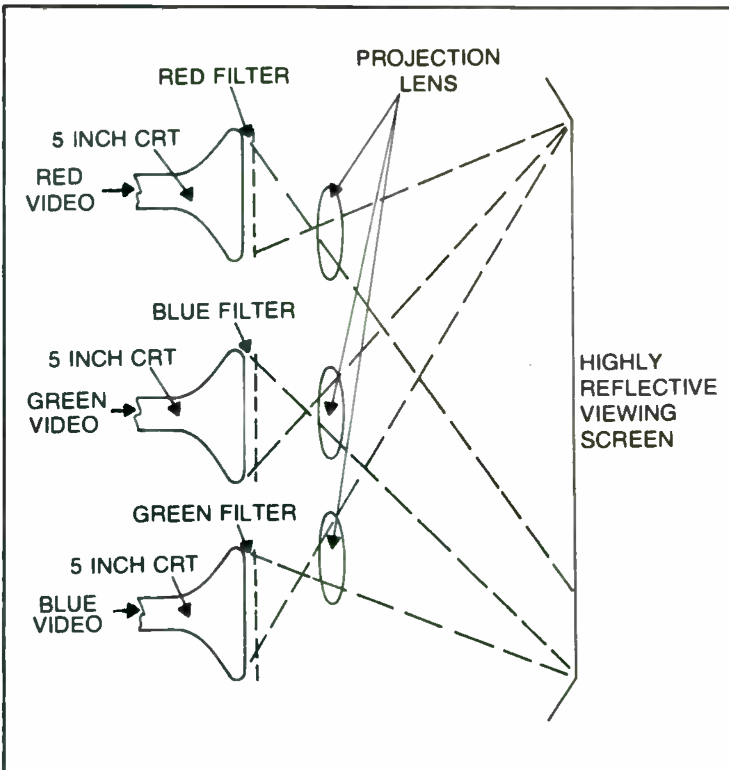


Fig. 1-8. Design of a projection-TV system includes small picture tubes with 75,000 to 100,000 volts, color filters, and projection lens. The reflectorized screen is slightly curved to provide accurate beam convergence at edges.

Fig. 1-9. This projection-TV system features a 48-inch screen for true home-movie buffs. Note channel-selector display panel below viewing screen.

with an appropriate color filter (red, green, or blue). This arrangement results in three primary-color rasters being projected onto the viewing screen and in consequent three- or four-foot pictures. See Fig. 1-9.

MINIATURE TV SETS

The mobility of our society has resulted in widespread interest in miniature and portable TV sets. Unlike so-called "portable" TV receivers of the 1960s and 1970s, these units boast very small size and light weight plus internal battery packs and associated chargers. The usual operation time from a fully charged battery pack ranges from four to seven hours.

The first "pocket TV" announced in the United States was a Sinclair unit imported from England. Its initial price was approximately $300, and featured a 2-½ inch screen. The television set could be carried in a coat pocket, and produce very good pictures. An external antenna jack, earphone jack, charge jack, and external-power jack were included with the unit.

The miniature receiver was an overnight success: demands exceeded supplies, indicating widespread interest in miniature televisions. The trend escalated, with numerous Japanese manufacturers joining the game. JVC, Sanyo, and Panasonic introduced pocket units only slightly larger than two packages of cigarettes, see Fig. 1-10. While one manufactured unit featured an internal clock (complete with programmable alarm) another unit included an AM/FM radio within its attractive cabinet.

Designs of miniature television receivers have recently expanded to include color units, and results have again been overwhelming. One of the more appealing color receivers is a Sony unit featuring automatic tuning and touch-controls, see Fig. 1-11. While miniature color-television receivers are not quite pocket size, they are comparatively small and reflect a significant breakthrough in technology.

The success of miniature television receivers requires specially designed integrated circuits which operate with analog parameters. A single IC, for example, performs multistage i-f amplification, video detection, agc derivation, and sync separation. Another IC performs all audio processing from 4.5-MHz i-f amplification and detection to audio amplification. Essentially, an input signal, operating voltage, a volume control, and a speaker are the only external items needed for that IC. Miniature tuners likewise consist of a mere two ICs and very few additional components. Sweep circuits require an IC each (one for vertical and one for horizontal), while complimentary-symmetry transistors used for

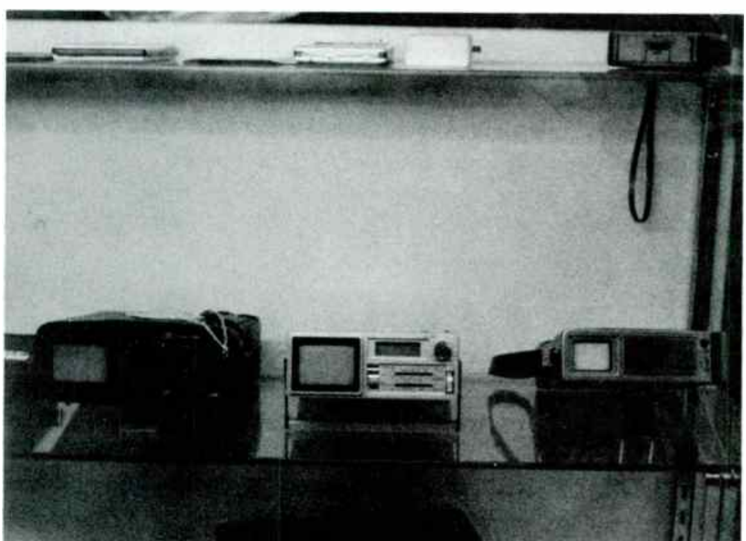


Fig. 1-10. Three miniature TV sets, each witn different features. Screen sizes range from 1.7 inches to 2.5 inches. All units feature rechargeable battery packs and ac chargers.

Fig. 1-11. This miniature color-television receiver features an on-screen tuning bar which moves left to right to indicate channels as they are tuned. The bar disappears five seconds after a channel is received.

driving the deflection yoke are mounted on heat-dissipating structures. Miniature color-TV receivers usually require two major ICs in their color section. One chip performs all color-bandpass amplification, phase shifts, color-burst oscillator, and automatic color-control/color-killer functions. Another chip performs color-signal demodulation, signal matrixing, and primary-color-signal baseband amplification.

Miniature television receivers appear to hold significant appeal for both present and future video-technology buffs. The extreme portability and flexibility of these units may not be fully realized until computer-based interactive concepts become popular. Regardless of those progressions, however, we are quite confident that miniature television has yet to realize its peak of success.

HOLOGRAPHIC VIDEO

As modern and glamorous as it presently appears, television as a whole may soon experience significant competition from a newly developed medium we will designate simply as holographic video. While presently a vision of future concepts, and strictly a laboratory project, holographic video was depicted in the science-fiction movie "Star Wars" when the drone R2D2 projected the holographic image of the princess's appeal for help to Obie One Ben Canabie. That example illustrates some advanced-phase holographic-video concepts. However, several development phases are expected before finished holographic movies will be available.

The final arrangements of holographic video would truly separate the television-set movie relation. Programs would be projected, or recreated holographic style, within a designated viewing area of adjustable size and background density. The holographic scenes would permit viewing any and all of a program's activity rather than merely those views and angles selected by the transmitting camera. The holographic system would use minimum cloud-chamber molecular-interference density, but reconstructed images would appear true to life—until a person within the viewing area walked through the holographic images! Holograms are presently displayed in many areas of our country (such as the space and science museum in Huntsville, Alabama). These arrangements employ two coherent laser beams, split by mirrors, firing into a rather dense cloud chamber. The reconstructed images can be viewed from almost any angle, permitting one to see around, behind, above, below, etc., the displayed objects. Essentially, the objects appear to actually be in the "reconstruction location," although the cloud chamber is merely creating a medium in which laser beams can produce patterns of coherent-light interference (the objects).

Since there's quite a difference between fixed display holograms and electronically scanned holographic images, the progression path of holographic video will follow a number of steps. One of the possible first phase systems is shown in Fig. 1-12. This arrangement is similar to present photographic-screen, or "window", holograms available from scientific suppliers . . . with some exceptions. A single, low-power laser beam (10mW, typical) is directed onto a screen containing interference patterns of the hologram. A simple diffusing lens (similar to those used in movie projectors) is used to spread the laser beam over the viewing-screen area. The viewer then looks through the holographic screen to see the recreated image. Moving about allows the viewers to see different areas in an "its actually there" manner. Continuing further, an examination of the photographic screen containing hologram interference patterns reveals a likeness to presently popular LCD (liquid-crystal display) readouts. The colors, densities, and such, are almost identical. However, LCDs have thus far appeared mainly in numerical readout devices such as watches. A change is again on the horizon: high-resolution LCDs for conventional television-picture display (primarily in microminiature TV sets) are presently being developed in Japan. Their commercial introduction will thus open many new doors of technological exploration. A high-

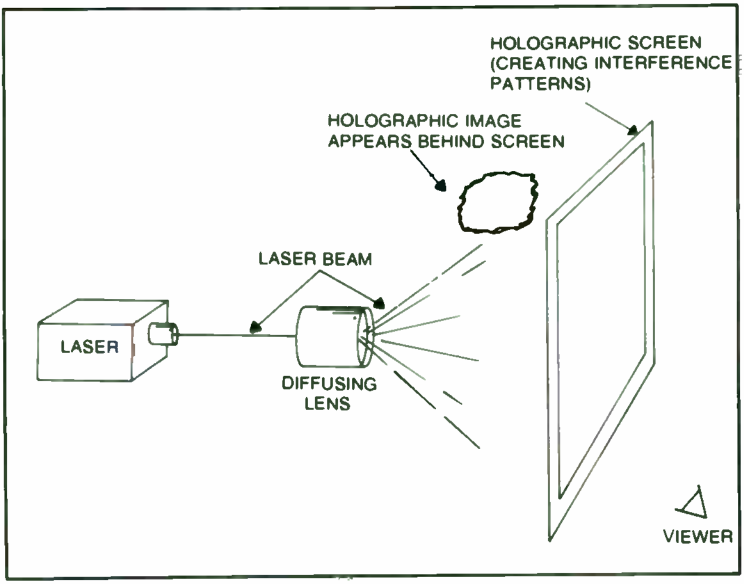
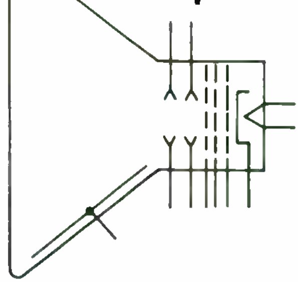


Fig. 1-12. Suggested method for displaying holographic video. Details are discussed in text.

resolution LCD requires a large number of external "activation wires" which are connected to a matrix for digital control of the display. (A television display would require 480 by 480 lines, or over 160,000 wires!) Scanning signals are converted and directed to the matrix for screen control of interference-pattern generation. This basic holographic video, while being several steps from the finished product is an area presently within easy grasp. Surely, additional evolutions could create wideband microwave holographic-video channels (required because of the vast information content) which would supplement (and eventually outmode) conventional television. Television of the interactive nature (two-way), however, should provide new benefits and again expand our horizons.

Chapter 2

Early TV Systems



Our exciting world of video electronics acquired its grand kickoff amidst an array of flashing neon lights and whirling metal discs during the early months of 1925. This was the time when Francis Jenkins transmitted a silhouette of a moving windmill from his workshop in Anacostia, Maryland, to the Navy Department in nearby Washington, DC. Later that year, Jenkins gave his first public demonstration of the radio transmission of live images (which he called "radiovision") and film ("radiomovies").

In a conference at the Department of Commerce on May 29th, 1925, the authorities decided to allow Amateurs to transmit pictures and facsimiles on any wavelengths for which they were licensed, but there is no record of any Amateur television transmissions until many years later.

THE EARLY YEARS

The transmission of visual images goes back over one hundred years to 1875, when George Carey in Boston used the system of Fig. 2-1 to simultaneously transmit each separate picture element by wire. This followed the discovery in 1873 by Lewis May, a British telegrapher, of the photoconductive properties of selenium. The principle of rapidly scanning each picture element in succession, line by line, was proposed in 1880 by Maurice Leblanc of France, and led to one of the first television patents which was issued to Paul Nipkow of Germany in 1884. The distinctive feature

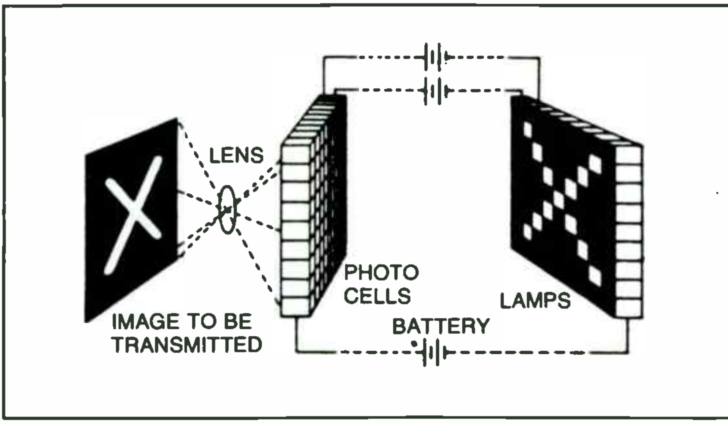


Fig. 2-1. Image-transmission system of the year 1875. At the transmitting end, light is converted into electrical energy which is used to energize a lamp at the receiving end. Since the output of each Selenium cell must be individually connected to a corresponding lamp, a large number of wires are required (courtesy *ham radio* magazine).

of the Nipkow system was the use of a spinning disc, with a spiral array of holes near its outer edge, to disassemble the image into a series of dots, and a similar disc at the receiving end to reassemble the picture (Fig. 2-2). Until the advent of all-electronic image scanning in the 1930s, all workable television systems depended on some form or variation (mirrored drums, lensed discs, etc.) of the sequential-scanning system of the Nipkow disc.

Although selenium was used by all the early television experimenters, it had one serious handicap—slow response to changes in light. The development of a potassium-hydride-coated cell in Germany in 1913 improved sensitivity and the ability to follow rapid changes of light, but experimenters were still limited by the slow response of incandescent lamps used to "rebuild" the image. This was solved by the invention of the neon-gas discharge tube by D. M. Moore in 1917.

The application of the cathode ray tube for television reception was first proposed by Boris Rosing in Petrograd, Russia, in 1907, but development of his patent was hampered by the lack of suitable photocells and electronic amplification. However, he did succeed in transmitting and reproducing some crude geometrical patterns. In 1908, Alan Campbell-Swinton, a Scotsman, outlined a method that is the basis of modern television when he proposed the use of a magnetically-deflected CRT at both the camera and receiver. Although his idea couldn't be translated into workable hardware be-

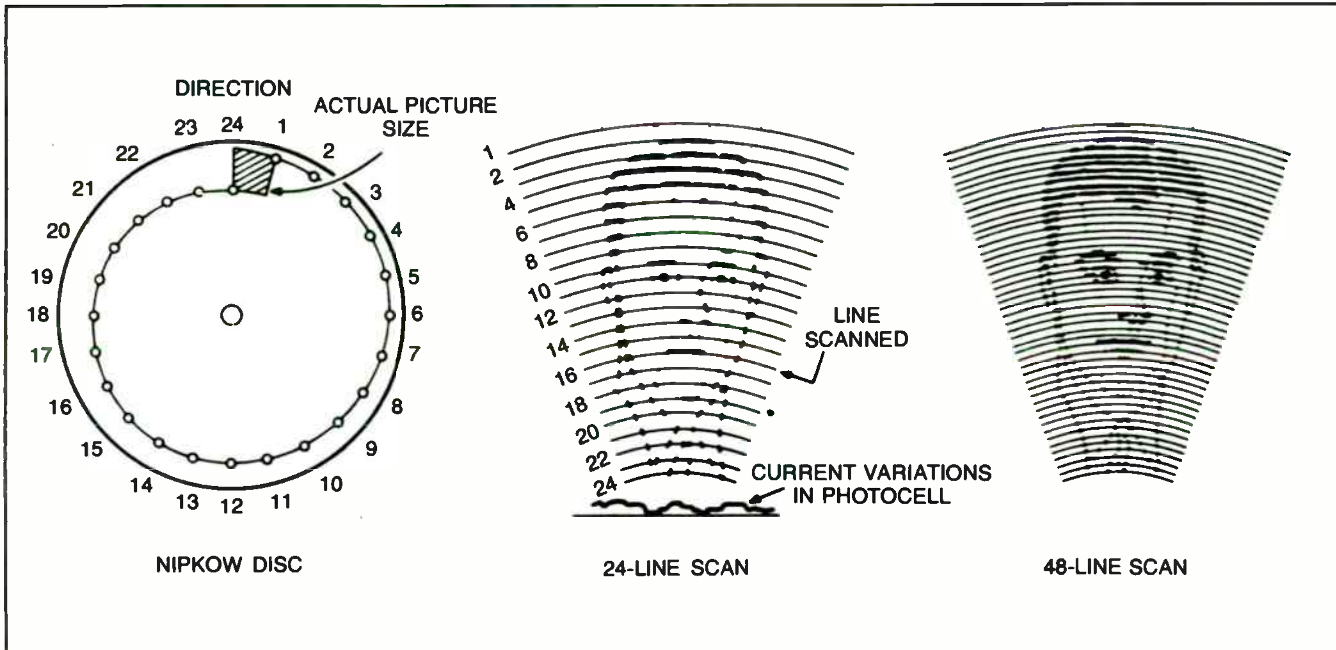


Fig. 2-2. Spiral hole layout in a 24-line Nipkow scanning disc is shown at left. The shaded area represents the size of the reproduced image. Enlarged view of an image produced by the 24-hole scanning disc in center shows poor resolution of 24-line scanning. At right is the same image produced by 48-line scanning disc. Resolution is improved but is still crude compared to modern standards (courtesy *ham radio* magazine).

cause he lacked suitable amplifiers, his proposed mosaic-screen image-pickup tube was remarkably like the iconoscope invented by Vladimir Zworykin some fifteen years later.

Because of the lack of suitable amplifiers, television experimenters continued to work with mechanical television systems and, in 1922, using his own version of the Nipkow disc, C. Francis Jenkins transmitted a still picture from one room to another. The next year, he received nationwide attention when he sent a recognizable picture of President Harding by wireless from Washington to Philadelphia.

In the Jenkins system, a disc with 24 (later 48) apertures was rotated at 2000 rpm by a motor whose speed was varied until it was synchronized with a similar setup at the transmitting end. A neon tube was positioned behind the receiving disc and connected in place of the receiver's earphones which, in the broadcast sets of the 1920s, were connected between the audio output tube's plate and B+ supply. A piece of ground glass or thin wax paper was placed in front of the neon tube to diffuse the light. Motor speed was difficult to regulate, and since exact synchronism was required for good image reproduction, copying a picture off the air was something of a challenge. The pictures were usually about two inches (51mm) square although many viewers used a magnifying glass to enlarge his area to five or six inches (13 to 15cm) square. See Fig. 2-3 and 2-4.

All of the mechanical systems, however, suffered from flickering and poor definition. Swinton and others had pointed out that at least 100,000 and preferably 200,000, elements were required for good quality and definition on a screen of reasonable size. John Baird of England gave the first true demonstration of television in 1926 by transmitting moving pictures in halftones, using 30 lines scanned 10 times per second. However, since the number of elements is approximately equal to the square of the number of lines, Baird's 30-line system was far from adequate—300 lines being more nearly the minimum.

Farsighted planners at American Telephone and Telegraph, Westinghouse, RCA, and General Electric saw the commercial possibilities of television in the mid-20s, and in April, 1927, AT&T set up the first long-distance telecast in the United States when Secretary of Commerce Herbert Hoover spoke from a makeshift studio in Washington, DC, and sight and sound were received over the telephone circuits in New York City, 200 miles away. In the considerable publicity given to the AT&T transmissions, the term "television" was used and soon came into widespread use as apply-

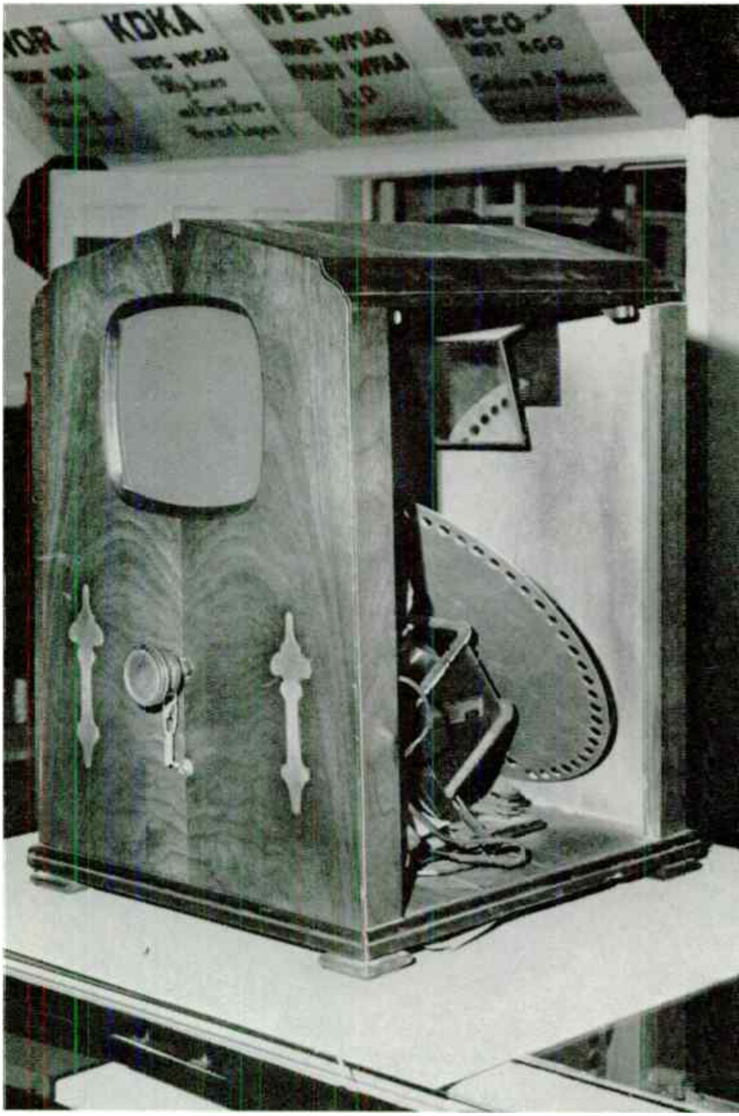


Fig. 2-3. Jenkins Radiovisor from the collection in the Antique Wireless Association Museum. In this set, the image was transmitted through a rotating disc (Nipkow) to a mirror and reflected onto the ground glass viewing screen (courtesy W2BWK and *ham radio* magazine).

ing to any form of visual broadcasting. "Television," of course, means transmission over wire, and, although you cannot argue with established usage, Jenkins stubbornly continued to call the new medium "radiovision" in his magazine articles and advertising.

In the summer of 1928, the Federal Radio Commission issued experimental television licenses to Jenkins Laboratories in Washington (W3XK) and to the General Electric Company in Schenec-

Fig. 2-4. Interior view of the Jenkins Radiovisor, showing Nipkow disc, mirror and amplifier section. This unit actually received pictures during the 1920s (courtesy W2BWK and *ham radio* magazine).

tady, New York (W2XCW). Jenkins began broadcasting radiomovies on a regular schedule on July 2nd, and a month later he reported that "one hundred or more had finished their receivers and were dependably getting our broadcast pictures . . ." Hugo Gernsback's magazine, *Television,* regularly reported new developments and published construction articles for Amateurs eager for information. The magazine was packed with advertising for the first five minutes of every hour, along with simultaneous sound which was broadcast by another local station.

In September, 1928, General Electric telecast the first live video drama from W2XCW in Schenectady; an old play called "The Queen's Messenger," selected primarily because it had only two characters. The accompanying sound was transmitted by WGY, GE's AM broadcast station. This created a lot of excitement in the press, but Dr. Ernst Alexanderson, who directed much of the television development at GE, cautioned that the program was experimental and didn't mean that television was yet ready for public consumption.

Indeed it wasn't. Although the Amateur Radio magazine, *QST,* devoted more space to television in 1928 than it did to radiotelephony, Amateur interest in the crude radiovision systems of the day waned quickly, and the topic received little coverage in *QST* in 1929. It wasn't until eight years later, and the development of cathode-ray television systems, that *QST* expressed renewed interest in the subject.

Aside from the very crude pictures of the disc television systems, the big problem was synchronization. The utility companies tried to maintain 60-Hz line frequencies, but there were no unified power grids as we know them, so synchronization was always slow and tedious, and often impossible. To quote ARRL's Percy Maxim, W1AW, ". . . for about half a second, I actually had a picture. It flickered and it was fuzzy and foggy, and about the time I was wondering why they picked on a cow to televise, it suddenly dawned on me that it was a man's face I was looking at. Then I lost synchronism and my man disappeared into a maze of badly intoxicated lines . . . "

By 1929, a total of twenty-six television stations were licensed by the Radio Commission, although few of them broadcast with any regularity. Jenkins, however, increased the power of W3XK and started work on a plant in New Jersey to build "radiovisors." In 1930, he petitioned the Radio Commission to commercialize television using his 60-hole disc system, but the request died without action when a Commission engineer said the mechanical system was "an absorbing field for the experimenter but not ready for entertainment." The major corporations—including GE, RCA, and Westinghouse—echoed the Commission's view.

The images, as seen in the receiver, were small and extremely crude. In addition, the pickup camera was fixed so the subject had to be brought to it, and the transmission of a person's head and shoulders strained all the resources of the scanner and transmitter. Obviously, a telecast with such technical limitations could have little entertainment value.

Nevertheless, continuing research resulted in increasing the number of scanning lines to about 180 lines per picture, and later, to 240-line images, all generated by mechanical methods. The increased image details forced higher and higher speeds in the mechanical parts, until engineers despaired of ever presenting an image of fine detail by mechanical-scanning methods.

By this time, news of all-electronic image-scanning systems were beginning to reach the hobby magazines, and the days of the whirling discs were numbered. In 1932, Jenkins terminated his broadcasts and merged with the Deforest Radio Company, which itself later drifted into bankruptcy. See Fig. 2-5.

In 1923, Dr. Vladimir K. Zworykin, a former student of Boris Rosing in Petrograd, was granted a patent on a system for the "cell storage of light" that was to become the basis of modern television. A year later, he demonstrated a crude tube, which he called the iconoscope, that electronically scanned a scene.

Although the iconoscope was used in nearly all the early electronic television systems, secondary-electron emission generated undesired outputs which had the effect of producing uneven shading. As a result, the reproduced image had large areas with varying brightness levels which were not contained in the original scene. This spurious shading signal is often called dark-spot shading because it can be generated when the mosaic plate is not illuminated. The spurious shading signal is inherent in the iconoscope camera tube but is minimized by using low values of beam current (at the expense of camera efficiency).

At about the same time Zworykin was working on his iconoscope, Philo T. Farnsworth was working independently toward an electronic scanning system somewhat along the same lines. However, while the iconoscope is based on electron storage, Farnsworth's image-dissector camera tube may be considered an instantaneous scanner.

Fig. 2-5. During 1975, the author, Dave Ingram (K4TWJ), reactivated 1925-style television and retransmitted copies of the original pictures to viewers. The 50th anniversary operation was quite successful.

In 1929, Dr. Zworykin demonstrated a television transmitter based on mechanical scanning, and a receiver in which an improved form of cathode-ray tube, called the kinescope, was used to reproduce the transmitted 120-line image. In 1931, RCA made experimental television transmissions over station W2XBS in New York City, and RCA's president, David L. Sarnoff, predicted that within five years television would become "as much of a part of our life" as radio. As with so many other, similar predictions, however, it proved to be premature. It was to be four more years before Dr. Zworykin had developed the iconoscope to the point where it could be used as the basis of a workable, all-electronic television system.

After several years of experimenting with mechanical scanning systems, RCA built an entirely new television transmitter at the Empire State Building and equipped NBC's nearby broadcasting studios for broad experimentation in all phases of television broadcasting. In the summer of 1936, RCA began extensive field tests from the Empire State Building with electronically scanned 343-line pictures, 30-frames per second. In January of the following year, however, definition was raised to 441 lines in accordance with the proposed standards of the Radio Manufacturer's Association, a figure which remained until 1941. See Fig. 2-6.

The television art was also advancing in other parts of the world. In England, Electrical and Musical Industries (EMI) set up a TV research group in 1931 under the direction of Isaac Schoenberg. He fostered the evolution of a practical system based on a camera tube known as the Emitron (which was an advanced version of Zworykin's iconoscope), and a CRT for the receiver. Schoenberg saw the need to establish standards that would endure for many years and proposed 405-line pictures, 50 frames per second.

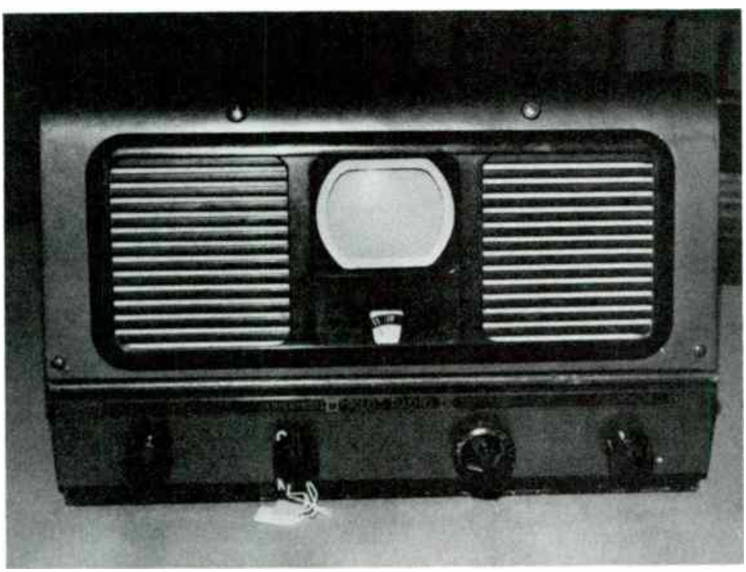


Fig. 2-6. This Pilot home-television set from the late 1930s was one of the first electronic-scanning sets offered to the public. Photo from Antique Wireless Association Museum (courtesy of W2BWK and *ham radio* magazine).

The British government authorized the BBC to adopt these standards as well as the complete EMI system, thus launching the world's first public, high-definition TV service in 1936. These same standards remained in effect until 1964, when they were gradually superseded by a 625-line standard.

Initially, and for only a short time, the EMI system was under comparison with alternate broadcasts from a 240-line, 25-frame system developed by John Baird. However, the Baird system used mechanical scanning and suffered from poor sensitivity.

Regular television broadcasts began in Germany in 1935, though with medium definition (180 lines). In France, engineers were working on a high-resolution, 1000-line system which eventually resulted in France's 819-line standard.

CAMERA-TUBE DEVELOPMENT

Later research in television camera tubes resulted in the development of pickup tubes, based on the iconoscope principle, which had greatly increased sensitivity. The first of these was the orthiconoscope or orthicon which was developed by Albert Rose and Harley Iams in 1939. Continuing research led to the development of the image orthicon by Albert Rose, Paul Weimer, and Harold Law of RCA in 1943.

In the image orthicon, Fig. 2-7, a glass plate coated on one side with a conducting layer of photoelectric material serves as the photocathode. The semitransparent plate receives the light image on one side while photoelectrons are emitted from the other side, which faces a wire mesh screen and target, to produce an electron image which corresponds to the scene focused on the front of the glass plate.

The electron gun produces a stream of electrons which is accelerated toward the target by the positively charged anode-wall coating. Beam deflection is accomplished with magnetic-deflection coils which are mounted externally on the tube. A decelerating ring with a very low positive potential is placed near the target to slow down the electrons so the scanning beam does not have sufficient velocity to produce secondary emission that generates spurious shading signals. High electron velocity is required in the neck of the tube, however, because of difficulties in magnetic deflection and focusing with a low-velocity electron beam.

Photoelectrons are emitted from the cathode surface in direct proportion to the light and shade in the scene, converting the optical image into an electron image. The electron image is accelerated

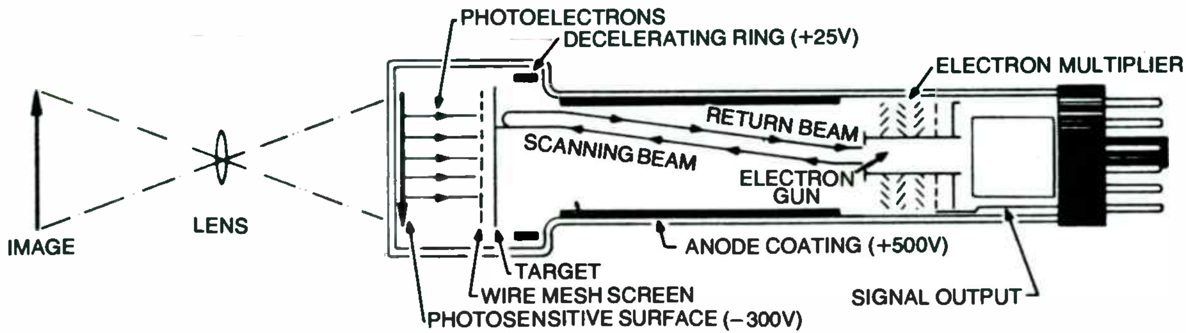


Fig. 2-7. Basic construction of the image orthicon. The external focusing and deflection coils are not shown (courtesy *ham radio* magazine).

toward the target (which is 300 volts positive in respect to the photocathode), and is focused through the screen onto the target plate by a uniform magnetic field in a manner very similar to that used in Farnsworth's image-dissector tube. As the electron beams scans the target, a charge distribution corresponding to the picture elements in the light image determines the number of scanning electrons returned to the electron gun.

The returning stream of electrons arrives at the gun close to the aperture from which the electron beam emerged. When the returning electrons strike the aperture disc, which covers the gun element and is at a potential of about +200 volts, they produce secondary emission. Therefore, the disc serves as the first stage of a five-stage electron multiplier—the output current from the final stage varies in magnitude with the light image.

While the image orthicon still plays a dominant role in television broad-casting, the more compact vidicon, introduced in the early 1950s, is used in most Amateur TV systems. The vidicon, Fig. 2-8, makes use of a semiconducting material which is characterized by a resistance that decreases upon exposure to light. The inside surface of the glass faceplate is coated with a very thin layer of photoconductive material; the optical image is focused on the other side of the plate and the photoconductive layer is scanned with an electron beam which deposits just enough electrons on each spot it touches to reduce the signal plate-to-cathode potential. During the short time between successive scans, a charge leaks through the photoconducting material at a rate which is determined by the intensity of light on that part of the photoconducting material. As the electron beam scans the surface of the photoconducting material, the charge remaining varies in accordance with the variations in the illumination. Therefore, the current through the load resistor, and

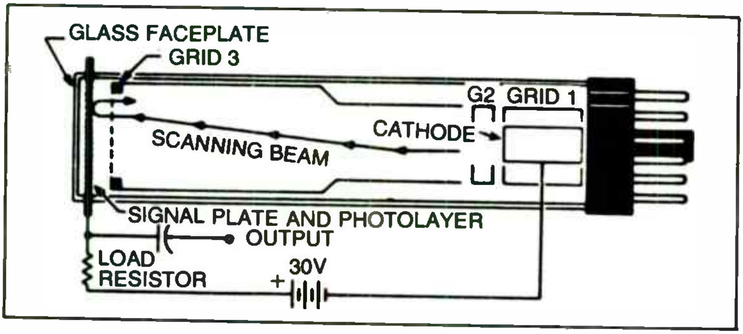


Fig. 2-8. Schematic diagram of the vidicon. External focusing and deflection coils are not shown (courtesy *ham radio* magazine).

hence the output voltage, electronically reproduces the light intensity of the scene.

FREQUENCY ALLOCATIONS

Late in the fall of 1937, the FCC announced new allocations for the spectrum between 30 and 300 MHz and, much to the delight of Radio Amateurs, reaffirmed the 56-60 MHz (5 meter) band as exclusively Amateur. The new rules also provided two new exclusive Amateur uhf bands: 112-118 MHz (2½ meters) and 224-230 MHz (1¼ meters). One of the big worries at the time was the huge spectrum space demanded by the impending arrival of television, still around several corners but getting closer. In fact, the Commission's press release on the new uhf allocations commented that, "The investigations and determinations of the Commission justify the statement that there does not appear to be an immediate outlook for the recognition of television service on a commercial basis. The Commission believes that the general public is entitled to this information for its own protection . . . "

Nevertheless, the FCC allocated seven main television channels, each 6-MHz wide, between 44 and 108 MHz, and twelve additional channels above 156 MHz. The 50-56 MHz TV channel was of special concern because of possible interference due to its proximity to the Amateur 5-meter band. In New York, this channel was assigned to CBS, and, in a brief survey, their engineers logged scores of Amateur stations operating between 54 and 56 MHz, well outside the band. When you consider that modulated oscillators and superregen receivers were the order of the day, this is understandable, but the new TV allocations spelled the end of broad signals from unstable 5-meter transmitters. Not unexpectedly, in December, 1938, the FCC required that all 5-meter Amateur transmitters meet the same stability requirements as those already imposed on the lower frequencies.

MODERN TELEVISION

The first regular television schedule in the United States was introduced by NBC's W2XBS in 1939 with a telecast of President Roosevelt opening the World's Fair in New York. RCA announced the new NBC programming in an advertisement for television receivers in *QST* which explained that NBC stations in New York, Schenectady, and Los Angeles would begin telecasting two 1-hour programs per week, plus special pickups of sports, visiting celebrities, etc. The public, however, didn't respond eagerly to the new medium, and after five months of broadcasting, RCA had sold only 400 television sets. The story was much the same in England where only 3000 receivers had been sold after two years of television broadcasting by the BBC.

The New York World's Fair also marked an important milestone for Amateur television. The Managing Director of W2USA at the World's Fair, Art Lynch, W2DKJ (now W4DKJ), after seeing a successful demonstration of Amateur television equipment at a radio show in Chicago in June, was convinced that television communications should be added to the station at W2USA, "the most visited Amateur Radio station in the world." Since the World's Fair was scheduled to close at the end of October, time was short, but Art lined up the necessary talent, and with some help from industry, the group built two complete television systems in an effort to establish the first two-way television contact. Their goal was accomplished on September 27, 1940, when Amateurs at W2USA and W2DKJ/2 at the New York Daily News Building in Manhattan began exchanging fair quality television pictures on the Amateur 112-MHz band. Accompanying sound was transmitted on 56 MHz. Distance between the two stations was about eight miles.

The television equipment at each end of the circuit consisted of a camera-modulator unit, and a receiver, and transmitter which were duplicates of equipment described earlier in *QST*. The system used 30-Hz vertical scanning, 3600-Hz horizontal scanning, and a 120-line raster. Considering that the pictures were viewed on a CRT with a P1 phosphor, the results were quite gratifying. Each station boasted the very latest in electronic equipment, including electro-magnetically-deflected cathode-ray tubes, free-running sweep circuits synchronized by external pulses, and iconoscope camera tubes. The equipment was donated by RCA, National, Hallicrafters, Hammarlund, Thordarson, and Kenyon. The station at W2USA used a single 1000-watt lamp for subject illumination, while W2DKJ/2 had a battery of smaller lights with reflectors.

A number of Amateurs in the vicinity of New York were working on their own television receivers, and on October 15th, W2AOE put on a demonstration for members of the Northern Nassau Radio Association by receiving TV signals from the 20-watt station at W2DKJ/2, 17 miles away. The range was increased to 29 miles on October 19th when good quality TV signals from W2DKJ/2 were received at W3FRE in Denville, New Jersey.

On July 1st, 1941, NBC's New York station, called WNBT, and CBS's station, WCBW, were licensed as the first commercial-television stations in the United States. The FCC authorization provided for an upgrading in picture definition by adopting a 525-line standard, and FM for the audio portion of the telecasts (replacing AM). However, the outbreak of the war in December brought television broadcasting to a standstill, and as critical materials and manpower were channeled into the war effort, television broadcasting ceased.

The FCC was carefully studying spectrum allocations during the last few years of the war, in anticipation of the armistice, and in March, 1945, they announced the new vhf allocations above 108 MHz and below 44 MHz. The spectrum between 44 and 108 MHz was to be allocated later, after running FM transmission tests during the summer. Since the release of raw materials was not imminent, this didn't appear to pose any problem. However, after VE day, cutbacks and labor layoffs commenced in industry and it appeared that needed raw materials would soon be available. On June 27th, the FCC announced the allocations between 44 and 108 MHz without running their planned tests. Under the new plan, Amateurs would get 50-54 and 144-148 MHz, FM broadcasting would move to 88-106 MHz (106-108 MHz was reserved for facsimile broadcasting), and television received Channels 1 through 13. Channel 1, originally slated for the 44-50 MHz slot, was later deleted.

By 1948, there were 36 television stations on the air, 70 more were under construction, an estimated one million television sets were in use by the public, and interference problems began to appear. In September, 1948, the FCC put a freeze on licensing any new TV stations in order to study the frequency allocations and to consider the problems posed by color television. This situation continued for three years, prolonged by the Korean War and a consequent shortage of critical materials. Finally, in April, 1952, the FCC lifted the freeze with a document that supplemented the twelve existing vhf channels with 70 new uhf channels. Within a few months, they had processed a backlog of 700 applications for new stations and had granted 175 new licenses. Within a year there were 377 stations on the air, and by 1955, about 95 percent of the country had television coverage. Today there are over 919 television stations (approximately 590 on vhf, 329 on uhf) throughout the United States and there are few places in the world that don't have television service.

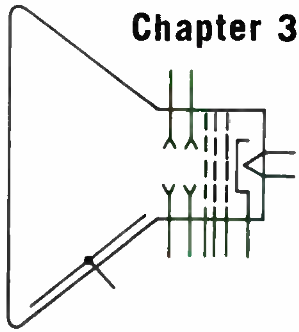
SLOW-SCAN TELEVISION

No history of television would be complete without some mention of slow-scan television and the important role that Amateurs played in its development. Copthorne MacDonald, W4ZII, introduced slow-scan television to Amateurs in a 1958 *QST* article which described a simple system, using a flying spot scanner, to transmit images of photo transparencies. Initial on-the-air tests were conducted on 11-meter AM between W4JP at the University of Kentucky, and K4KYY. MacDonald also tried to run tests with PJ2A0 in Curacao, but band conditions were too poor for satisfactory picture reception.

The slow-scan system, which requires no more bandwidth than an audio signal, was originally conceived as a facsimile system. It was a number of years before the medium was used to transmit live images. Since 11 meters was the only high-frequency band where facsimile transmission was permitted, most SSTV activity ceased when Amateurs lost 11 meters to the Citizens Radio Service. Eventually, however, the FCC granted special permission to conduct SSTV tests on 10 meters and, later, 20 meters. The SSTV standards which are used today were developed during these early tests. Since August, 1968, slow-scan television (designated narrow-band A5 and F5 emission) has been permitted on portions of all the high frequency bands plus most of vhf. A full discussion is presented in TAB Book No. 859 "The Complete Handbook of Slow-Scan TV," by Dave Ingram. Complete bibliographies of slow- and fast-scan television articles which have appeared in *QST* are available from ARRL, 225 Main Street, Newington, Connecticut 06111. Send a stamped, self-addressed, business-size envelope.

Chapter 3

Black-and-White TV Parameters



During the early years of electronic-scanning TV, several companies pursued their own set of video standards without due consideration to overall compatibility. Similar actions during the days of mechanical-disc scanning TV, however, had served as tangible proof of the need for fully compatible standards. Obviously, use of separate television sets for reception of NBC, CBS, ABC, etc., was impractical. The National Television System Committee was formed during 1940—its purpose centering around the establishment of standards for fully compatible television broadcasting. The rules established by that committee have remained essentially unchanged over the years, although slight modifications for color-TV broadcasting were included in 1953.

Unfortunately, the standards established four decades ago have television backed into a technological corner. The millions of sets presently in use simply cannot be discarded for better and more modern concepts. New sets, still using the standards established in 1940, continue to flood the market. The only solution to this delemma seems to consist of establishing a totally new video concept and broadcasting those signals in an unoccupied area of the microwave spectrum, an arrangement which could happen during the coming decade. As conventional television declines, plans can be formulated for reassigning that rf spectrum to another form of visual communications. Ultimately, an "updated" form of television can move into the public limelight.

The remainder of this chapter is devoted to the technical standards and considerations relative to transmission and reception of present television systems. Reference is made to additional textbooks and engineering papers for those who desire more technical information and engineering criteria.

CONSTRUCTION OF THE TV SIGNAL

A considerable amount of electrical information is necessary to transmit high-resolution television pictures. Since any transmitted signal's total bandwidth is directly related to information quantities, several megahertz are thus required for picture transmission. As mentioned, our present system was originally devised during the 1940s, when amplitude modulation (AM) was a state-of-the-art mode. The necessary 8 MHz bandwidth was reduced to a total of 5.25 MHz by using only a vestige, or trace, of the lower-sideband information. This vestige was required to allow AM detectors to function in a conventional manner. While vestigial-sideband transmission reduced video bandwidth to a more acceptable value, this broadband "channel" of information still required transmission in the vhf region. This was because low-frequency rf spectrum is at a premium, whereas vhf spectrum is considered less vital for mass communications.

Audio information in television broadcasting uses frequency modulation (FM) thus minimizing interaction between aural and visual signals. The FM signal is essentially wideband; frequency deviation is confined to ±25 Hz of center frequency. The resultant rf spectrum of a TV channel is shown in Fig. 3-1. The video carrier is situated 1.25 MHz above the channel's lower edge, and the audio carrier is situated 4.5 MHz above the video carrier. The video upper sideband contains frequencies up to 4 MHz, while the lower (vestige) sideband cuts off at 1.25 MHz. This loss of high-frequency video on the lower sideband can be compensated for as will be discussed later. A 250-kHz guard band is employed on both sides of the audio carrier's bandpass. The frequencies shown near the bottom of Fig. 3-1 represent a transmitted television signal for vhf channel 6.

The video carrier is transmitted on 83.25 MHz, and the audio carrier is transmitted on 87.75 MHz. Two separate transmitters are used for this operation, their outputs being directed to a common antenna via a diplexer or filterplexer. The audio transmitter's output is between 10 and 20 percent of the video transmitter's output. The information presented in Fig. 3-1 depicts only frequency rela-

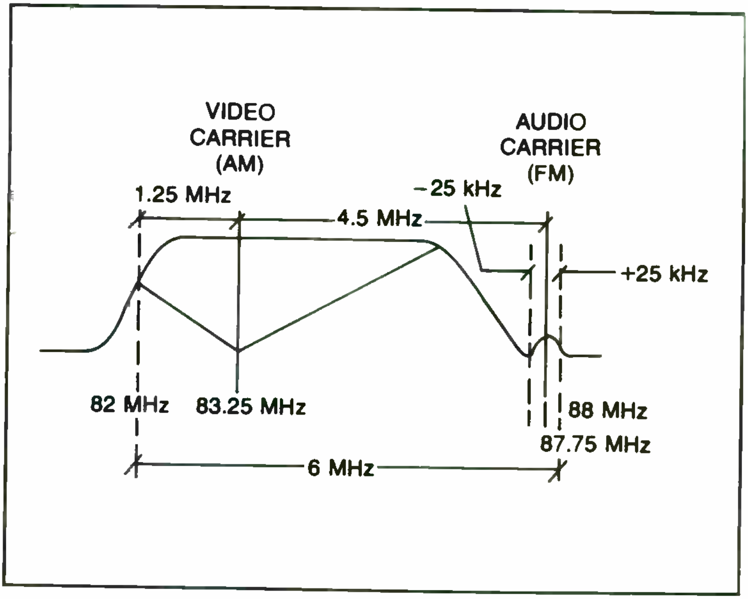


Fig. 3-1. Frequency-spectrum analysis of a black-and-white television signal. Frequencies shown are Channel 6 of vhf band.

tions in television signals. A television modulation-envelope must be analyzed for amplitude variations. This is shown in Fig. 3-2.

The waveform of Fig. 3-2A illustrates the modulation envelope during scanning of a white horizontal line. Peak carrier amplitude corresponds to sync-pulse tips, with blanking and black levels corresponding to lower amplitudes of the transmitted signal. White level corresponds to a minimum rf amplitude of approximately 15 percent, while 100 percent-amplitude sync pulses are present at the end of each line to maintain synchronization of the receiver. Figure 3-2B illustrates the modulation envelope during scanning of a black horizontal line. Notice, that carrier amplitude has been increased to 75 percent of maximum while, again, sync pulses maintain their level of 100 percent amplitude. Finally, Fig. 3-2C illustrates the modulation envelope produced during scanning of a stepped gray-scale line; black on the left and white on the right. Assuming all the horizontal lines comprising a television picture were identical to the single line shown in Fig. 3-2C, a display consisting of four vertical bars would be produced (black, grey, white). Since television pictures consist of substantially more information than mere gray bars, television-modulation displays become more compex in their content, see Fig. 3-3.

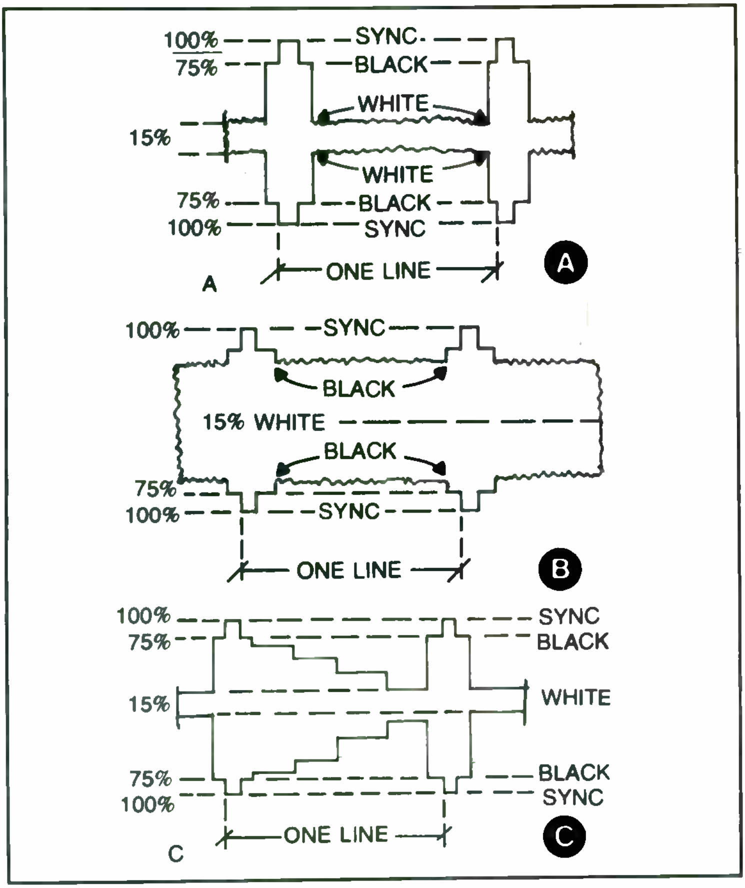


Fig. 3-2. Modulation envelopes for various forms of transmitted television signals. A represents scanning a white line; B represents scanning a black line; C represents scanning a gray-stepped line.

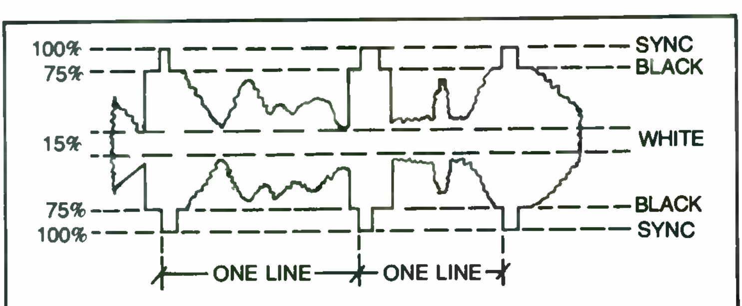


Fig. 3-3. Modulation envelope of a TV signal during modulation by video information.

SCANNING AND SYNCHRONIZATION

The transmission and reception of visual images in a television system is accomplished through the process of electronic scanning. Each line of the television picture is transmitted in sequence. This technique may be related to the operation of a typewriter, double-spaced, printing a page of information, see Fig. 3-4. The print head begins operation at the page's left top and progresses, letter by letter, across that first line until the right margin is reached. A bell then signals the need for "retrace" and "move down the page" movements. Following that mechanical action, the next line is created in a similar letter-by-letter manner. The bell again signals "retrace" and subsequent lines are, likewise, created until a complete page of information is produced. This full page may thus be related to a "non-interlaced" television picture. Since extremely fast scanning rates are used in television, we see complete pictures, or "pages" rather than a series of individual lines or scans of the viewing area. Returning to Fig. 3-4, we may now consider the technique of "interlaced" scanning. Notice that only 262.5 lines are shown. A complete picture in a United States TV system consists of

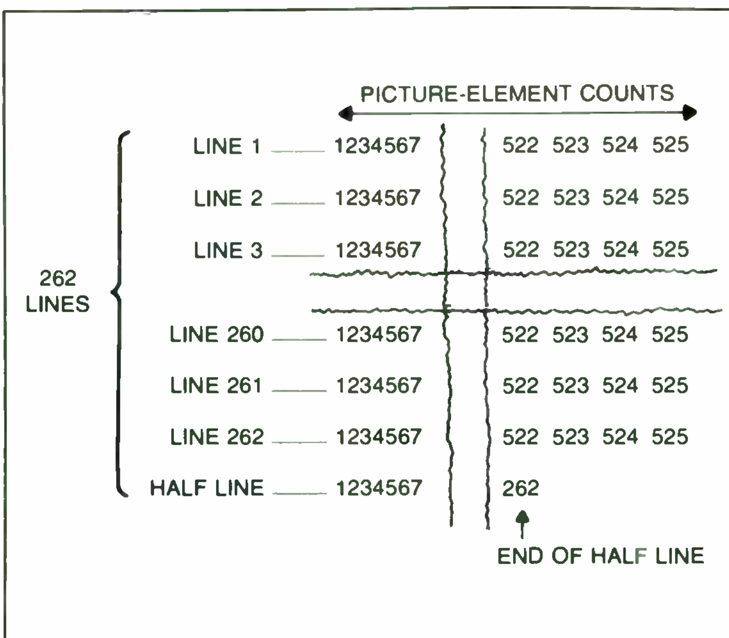


Fig. 3-4. Method of scanning a single field in interlaced scanning system. Note only 262.5 lines appear, and double line spacing is employed.

two scans, or "fields," each containing 262.5 horizontal scanning lines. The odd-numbered lines correspond to the previously described page (first field) of typed information; the even-numbered lines (second "field") can then be produced by running the typed page back through the typewriter. The paper is shifted up slightly during this second run, to permit placing another 262.5 lines of information in the blank area between the lines of the double-spaced typed copy. The final results of this effort are shown in Fig. 3-5. The first field contains 262.5 lines, with the half-line ending at the bottom. The second field contains the next set of 262.5 lines, with the half-line being produced at the top. In United States television systems, the combination of an odd and an even field produces one complete picture which is known as a "frame." A frame thus consists of 525 horizontal scanning lines.

The scanning rate used in television are relatively high in order to exceed persistence of viewing and persistence of the television screen's phosphors. This permits viewing complete pictures rather than merely viewing a single dot zipping its way from side to side and from top to bottom of a television screen. The single dot often briefly visible on inexpensive black-and-white sets when it is switched off is the same dot which zips around the screen, producing pictures when the set is operating.

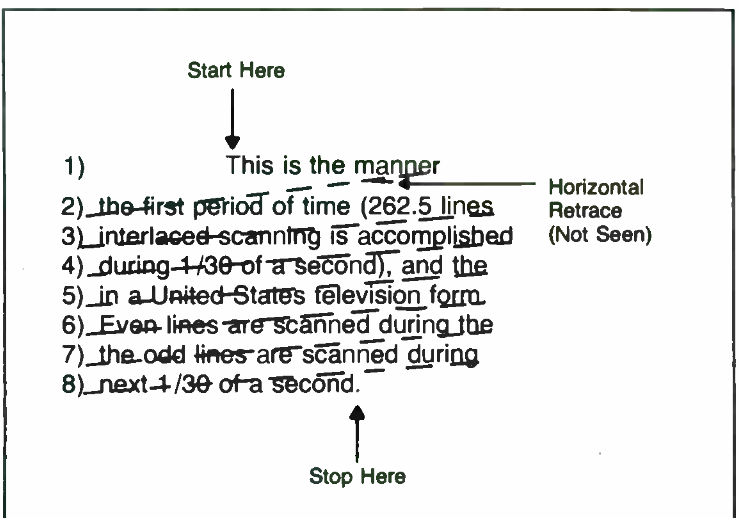


Fig. 3-5. Method of creating interlaced scanning involves "filling in" blank areas of Fig. 3-4 with additional information to create a full picture. Read all odd lines first, then read even lines.

The vertical scanning frequency is 60 Hz, thus 60 fields per second are displayed. Since two fields are required for producing each frame, 30 complete pictures are produced each second. We may now calculate the horizontal scanning rate in a definable manner: 252.5 (lines in each field) × 2 (fields per each frame) × 30 (frames per second) = 15,750 Hz (horizontal-sweep rate for scanning the horizontal lines). Likewise, 15,750 Hz divided by 30 frames = 525 lines, and 15,750 Hz divided by 60 fields = 262.5 lines. A number of additional mathematical calculations encompass the design criteria of television signals. However, they are specialized textbook material, and are not needed here.

Described in the most basic terms, television consists of variations of light and dark placed in the right place at the right time to reconstruct the originally-viewed image. The light and dark variations are produced through modulation of the TV transmitter's rf carrier, which ultimately controls instantaneous intensity of the picture tube's electron beam. The placement of these intensity variations in the right place is accomplished through horizontal and vertical scanning. The correct timing of the scanning sequence is controlled by sync which are transmitted along with the video information. These sync pulses signify the precise end of each horizontal line and each vertical scan. Lacking proper sync pulses, TV pictures become a mass confusion of variations of light in random locations.

Sync pulses are transmitted at maximum-amplitude levels during modulation of the TV signal. These pulses occur at regular intervals of 53.5 microseconds—the time period of each horizontal line. The time duration of each horizontal sync pulse is 5.1 microseconds, and the remaining 4.9 microseconds is distributed between leading and trailing portions of the blanking interval of 10 microseconds. This is illustrated in Fig. 3-6. As mentioned, the vertical scan rate of 60 Hz is approximately 262.5 times slower than the horizontal scan rate of 15,750 Hz. Likewise, the vertical sync pulse is approximately 262.5 times longer than the horizontal sync pulse. In order to be correct in this measurement, we must consider that 22.5 horizontal-scan lines are lost during retrace of each vertical field: 262.5 lines minus 22.5 lines = 240 *active* scanning lines. Also, 5.1 microseconds (horizontal sync) × 240 (horizontal lines for each field) = 1224 microseconds; time of the vertical-scan block. To sidestep additional technical discussions, we will simply say that the vertical sync block is broken into 18 segments; six preceding the vertical sync pulse, six during the vertical sync pulse, and six

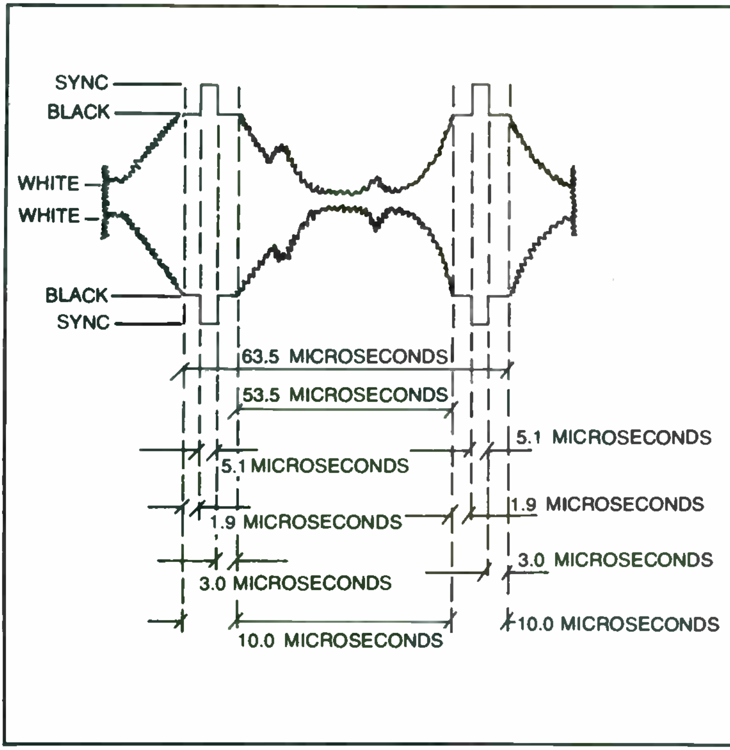


Fig. 3-6. Time periods associated with scanning in an NSTC television system. Note that the back porch of horizontal-blanking period is longer to permit beam retrace across screen.

following the vertical sync pulse. These interruptions serve two specific purposes: 1) maintaining horizontal sync during the vertical-retrace time, and 2) equalizing the vertical integrator's charge between fields to ensure interlacing of scans. The combination of these synchronization steps effectively "slaves" the TV receiver to the transmitted signal, causing video information to be placed in proper locations for accurate reconstruction of the image.

TV STANDARDS IN THE UNITED STATES

Many countries of the world use television standards particularly suited to their previously established design specifications, available power-line frequencies, etc. European television, for example, uses vertical-scan rates of 50 Hz and non-interlaced scanning (sequential scanning, with over 600 horizontal lines). Ac power systems within the United States, however, use 60-Hz, conse-

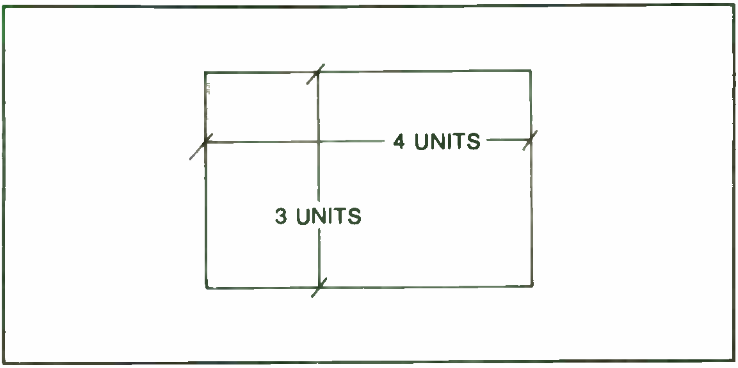


Fig. 3-7. Aspect ratio of a television picture in the United States is 4 wide by 3 high, creating rectangular view. A 1 wide by 1 high would create a square view.

quently, our television systems have 60-Hz vertical rates. The decision to use interlaced fields of horizontal lines centered around considerations to reduce picture flicker while providing maximum resolution for available bandwidth.

Another standard used in U.S. TV transmissions is negative modulation. In essence, this means minimum rf-signal levels in the transmitted modulation envelope correspond to white picture information, while maximum (70 to 75 percent) rf levels correspond to black picture information (sync pulse tips, it will be recalled, correspond to the absolute maximum rf level of 100 percent).

The next specification associated with U.S. TV standards is the aspect ratio of 4 to 3. Aspect ratio is the relation of picture width to picture height. This is illustrated in Fig. 3-7. The "4 wide by 3 high" is a fixed ratio, thus a small screen TV set would display a 2-inch by 1½-inch picture, a larger set would display a 12-inch by 9-inch picture, etc. Each display would contain the same number of horizontal scanning lines; 525 total, or 480 active. The smaller screen picture would merely be composed of smaller scanning lines.

CHANNEL ALLOCATIONS AND BANDWIDTHS

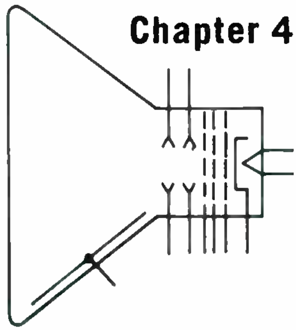
Each channel allocated for the transmission of a television signal encompasses 6 MHz of rf spectrum. A list of present vhf and uhf channel allocations is presented in Table 3-1. A "gap" in frequencies will be noticed between Channel 6 and Channel 7. That slot is used for commercial FM broadcasts, aircraft/control-tower communications, Amateur Radio activities, business and government communications, etc. Another gap will be noted between vhf Channel 13 and uhf Channel 14. This band is used by many services.

Table 3-1. Frequency Allocations for Vhf and Uhf Television Channels in the United States.

	Channel	Frequency in MHz	Channel	Frequency in MHz	Channel	Frequency in Mhz
	2	54-60	30	566-572	58	734-740
	3	60-66	31	572-578	59	740-746
	4	66-72	32	578-584	60	746-752
V	5	76-82	33	584-590	61	752-758
H	6	82-88	34	590-596	62	758-764
F	7	174-180	35	596-602	63	764-770
	8	180-186	36	602-608	64	770-776
	9	186-192	37	608-614	65	776-782
	10	192-198	38	614-620	66	782-788
	11	198-204	39	620-626	67	788-794
	12	204-210	40	626-632	68	794-800
	13	210-216	41	632-638	69	800-806
	14	470-476	42	638-644	70	806-812
	15	476-482	43	644-650	71	812-818
	16	482-488	44	650-656	72	818-824
	17	488-494	45	656-662	73	824-830
	18	494-500	46	662-668	74	830-836
	19	500-506	47	668-674	75	836-842
	20	506-512	48	674-680	76	842-848
U	21	512-518	49	680-686	77	848-854
H	22	518-524	50	686-692	78	854-860
F	23	524-530	51	692-698	79	860-866
	24	530-536	52	698-704	80	866-872
	25	536-542	53	704-710	81	872-878
	26	542-548	54	710-716	82	878-884
	27	548-554	55	716-722	83	884-890
	28	554-560	56	722-728		
	29	560-566	57	728-734		

Uhf signals exhibit defined line-of-sight propagation characteristics, much more so than vhf signals. Consequently, vhf spectrum is usually considered more valuable than uhf spectrum.

Chapter 4



The Black-and-White Television Receiver

While the modern black-and-white television receiver is an apparently complex and sophisticated unit, its basic design centers around many relatively simple and straightforward individual circuits. The combination of these circuits results in an overall receiver design; however, each circuit can be separated and analyzed for understanding or troubleshooting.

There are five basic sections in a black-and-white receiver: The tuner, the i-f amplifiers, the video amplifiers, the audio amplifier section, and the sweep section. Each section is further divided into additional subsections, which perform specific functions according to their design (see Fig. 4-1). The tuner section is responsible for selection of the desired channel and converting that channel of information to the i-f section's frequency range—usually 41 to 47 MHz. Both uhf and vhf tuners are included in the "general" category of tuners. The intermediate frequency, or i-f, section may consist of two, three or four specific stages, depending on design of the particular set considered. The purpose of this section is to amplify the weak incoming signal, eliminate adjacent-channel interference, and maintain a constant output level for the video detector. Following the i-f section is the video detector and the video-amplifier section. The video detector retrieves video information (30Hz to approximately 4MHz) from the i-f signal, and the video amplifier increases the amplitude of this information. The resultant video output then modulates the scanning electron beam to create

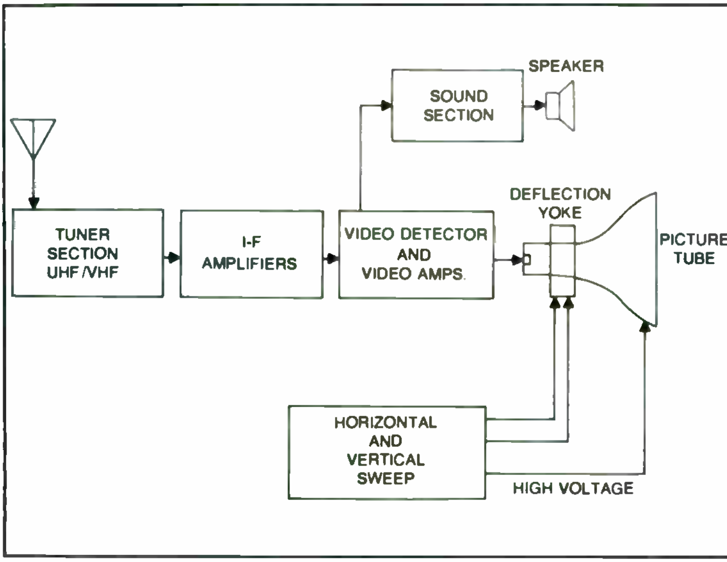


Fig. 4-1. Simplified block diagram of black-and-white television receiver illustrating five basic sections and their functions. Additional details are presented in text.

light and dark variations to create a visible picture. The video detector also performs a second function: mixing the video and audio carrier frequencies to produce the FM sound i-f signal of 4.5 MHz. The 4.5-MHz sound-i-f signal is usually permitted to "ride through" one or two video amplifier stages before being "picked off for its own circuitry. This permits the use of video amplifiers for minor amplification of the sound. The sound channel proper usually consists of one or two stages of 4.5-MHz i-f amplification, an FM detector of the ratio or quadrature type, and a conventional audio-amplifier section.

The final section which is considered in this general overview is the sweep section. This part of the television receiver is responsible for both horizontal and vertical scanning by the electron beam, synchronization of that beam with the camera's scanning beam, plus the development of high voltage for operation of the picture tube. A sixth section covering the receiver's power supply could be included if desired; however, the presence of this obviously necessary stage is assumed—and omitted from discussion for the sake of simplicity.

This overview depicts general arrangements common to all television receivers regardless of manufacturer or of design varia-

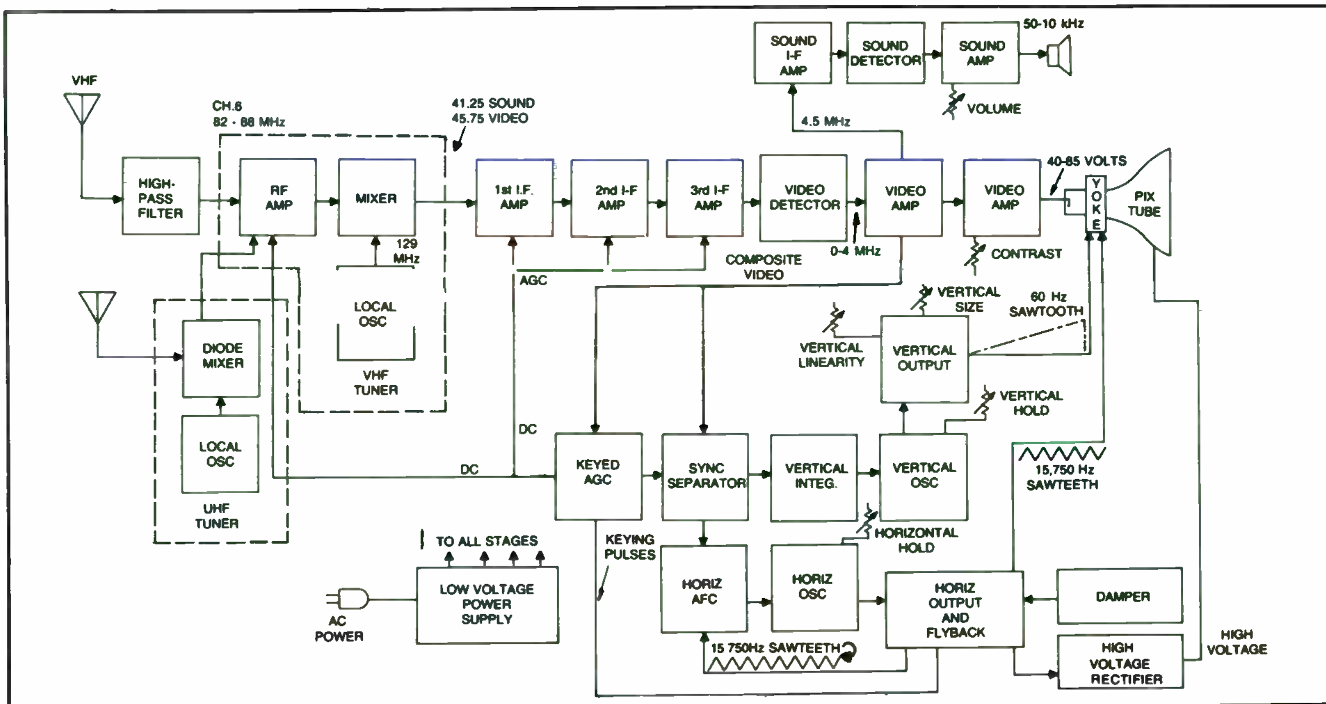


Fig. 4-2. Comprehensive block diagram of a typical black-and-white television receiver is expanded from simplified version of Fig. 4-1.

tions. This does not eliminate additional concepts such as Automatic Frequency Control (AFC), automatic brightness level, remote-control tuning units, exotic sync-tuning circuits, etc. Any and all "streamline" television sets, however, can be shaved of such frills and a straightforward television receiver will result.

A more detailed discussion of stages in a television receiver will now be presented, however the reader should be aware that no one single diagram can be representative of all. Some variations will be found between different units, the application of the principles of operation can provide a basis for understanding any television set.

A functional block diagram of a modern black-and-white television receiver is shown in Fig. 4-2.

THE VHF TUNER

Vhf television signals arriving at the antenna are directed to the television receiver's input terminals, and to the Vhf-tuner input. A high-pass filter and balun transformer are usually located between these two points inside the cabinet. The high-pass filter allows signals above 54 MHz (Channel 2) to proceed to the tuner, but signals below 54 MHz are attenuated to reduce interference. Such interference could be produced by nearby transceivers, shortwave transmitters, etc. Some manufacturers include only simple high-pass filters inside the television, and provide more elaborate filters as external add-on units, either free or at low cost, to customers requesting them. The balun is used to transform 300-ohm balanced input (twin lead) to low-impedance, unbalanced output for application to the tuner.

The vhf tuner consists of three specific stages: the rf amplifier, the local oscillator, and the mixer. The rf amplifier's purpose is to increase the incoming signal amplitude while maintaining the lowest possible noise level, and to preselect the correct band or channel of frequencies on the desired television channel. Since noise appearing in this stage can be amplified and processed by all subsequent stages, low-noise design is quite important. Tube-type sets usually have a single triode, or dual triodes in cascade, as low-noise, high-gain rf amplifiers. Transistor sets usually have low-noise bipolar transistors or (preferably) MOSFET transistors as rf amplifiers. The MOSFET's high signal-to-noise ratio and immunity to both crossmodulation and adjacent-channel interference makes it an ideal candidate as an rf amplifier in quality tuners. Additionally, the dual-gate MOSFET may be used with agc voltage applied to one gate and the incoming TV signal applied to the other gate. MOS-

FET's are usually quite susceptible to input-voltage spikes and/or transients, consequently, protective circuitry is usually included with these devices. The recent introduction of low priced GaAsFET promises yet higher gain and lower noise figures for television tuners. Industry, however, hasn't yet begun using these devices in significant numbers.

The tuner's local oscillator is usually conventional in design, with Hartley, Armstrong, Colpitts, or modified versions of them, used. A variable capacitor, or varicap diode, in the local-oscillator circuit provides fine tuning of the incoming TV signal. The oscillator, also, is operated on the tuner's "high side" of the selected channel. Assuming Channel 6 operation (82 to 88 MHz) and use of the popular 41.25 to 45.75-MHz i-f, the local oscillator frequency would thus be 129.00 MHz (± minor variations due to setting of the fine tuning). This conversion may be further stated as follows: Channel 6 video carrier is 1.25 MHz above the channel's low end (82 MHz), or 83.25 MHz, and the audio carrier is 4.5 MHz above this, or 87.75 MHz. Beating the local-oscillator frequency of 129.00 MHz with the video-carrier frequency of 83.25 MHz produces the i-f video-carrier frequency of 45.75 MHz. Beating this same local-oscillator frequency of 129.00 MHz with the audio-carrier frequency of 87.75 produces the audio-carrier i-f frequency of 41.25 MHz. 129.00 − 83.25 = 45.75, and 129.00 − 87.75 = 41.25). Notice that only one local oscillator is used to beat with both TV audio and TV video carriers, and the resultant i-f bandpass is inverted after this heterodyne action is performed in the mixer. The "low-end" video carrier is thus shifted to the "upper end," and the audio carrier is shifted from the "upper end" to the "low end."

The vhf mixer stage is straightforward in design and operation: it accepts inputs from the rf amplifier and mixer, and the output contains their sum and difference frequencies. The difference frequency, however, is the only frequency accepted and passed by the mixer-output circuits. These signals are then passed to the i-f stages via a shielded cable. Due to circuit complexity and construction techniques, television vhf and uhf tuners are usually considered as units rather than a combination of stages. Likewise, television-set manufacturers usually purchase tuners from sub-contractors rather than manufacturing their own. Television servicemen usually limit tuner repairs to basic cleaning and tube replacement, leaving more involved operations to a well-equipped "tuner specialist." The usual signal gain provided by a vhf tuner is between 15 and 25dB.

THE UHF TUNER

The uhf tuner is similar to vhf in design, with the noticeable absence of an rf-amplifier stage (exception: the more expensive and sophisticated color television receivers have recently included a solid-state, rf-amplifier stage in the uhf tuner. These sets are, obviously, higher quality and more desirable than their "bare bones" relatives). As illustrated in Fig. 4-2, the uhf tuner consists of a local oscillator, which operates at a frequency higher than the incoming signal, and a diode mixer. The local oscillator usually employs stripline tuning methods and/or varicap diodes, with a small "loop" of wire being used to couple the output signal into the mixer. The mixer diode accepts signals from both the local oscillator and the incoming rf signal. The two signals heterodyne to produce the resultant i-f signal. This output signal is directed to the vhf tuner, where it is amplified before being directed to the tuner output. The uhf tuner is quite critical in design and lead placement, primarily due to the frequencies involved.

I-F AMPLIFIER STAGES

The i-f amplifier's purpose is to increase the incoming TV signal to a level which can be handled by the video detector, and to provide rejection of adjacent-channel signals. The usual overall gain of the i-f "strip" is 50 to 60dB, and the usual bandwidth is 4 MHz. This i-f section may consist of one, two or three separate stages, depending on the design of a particular television receiver. Tube-type sets with high-gain capabilities may achieve satisfactory results with one i-f tube, for example, while transistor sets may require three transistors or stages to achieve comparable results.

The techniques for achieving broad bandwidth in i-f stages include stagger tuning, resistance-swamping, and overcoupling of tuned circuits on input and output sections. One circuit, for example, may be tuned to 41 MHz, a second circuit may be tuned to 45 MHz, and a third circuit is tuned to 43 MHz. A low value resistor may then be placed in parallel with each coil to lower its "Q" and broaden its bandwidth. The overall response curve would thus be the sum of these response curves. This is shown in Fig. 4-3. Some inexpensive black-and-white sets achieve maximum i-f gain at the expense of overall bandwidth. This technique is shown in Fig. 4-4. Assuming each tuned circuit is resonated on closely-related frequencies, and less swamping is employed, bandwidth is narrowed and gain is increased. The disadvantage of this situation is a loss of high frequencies, or fine picture details. Surprisingly, however,

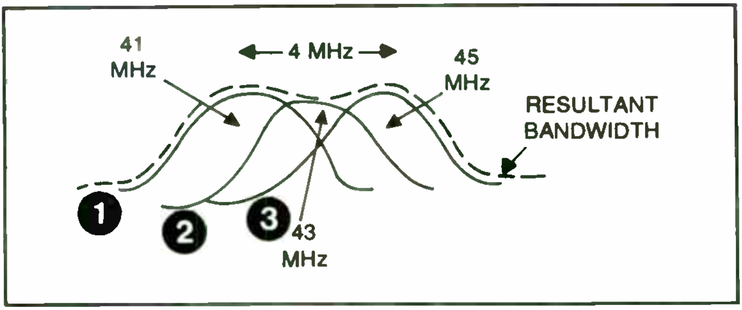


Fig. 4-3. Stagger-tuned i-f stages creates broad overall bandpass. Shown here, i-f 1, 2, and 3 are each separated by 2 MHz and overall response (dotted line) is thus 4 MHz.

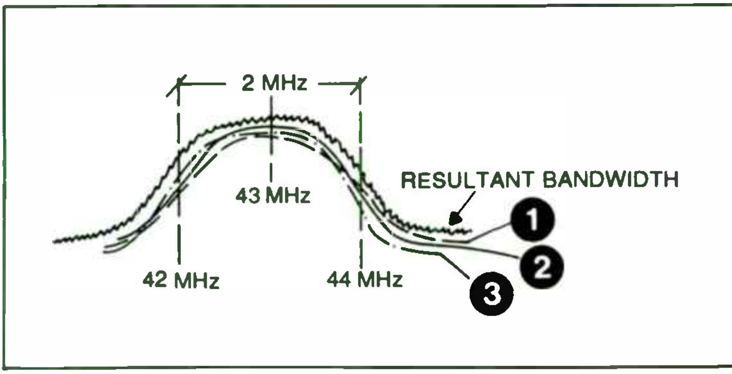


Fig. 4-4. Tuning all i-f stages to same frequency results in narrow bandpass and loss of fine picture detail. Gain, however, is increased.

small, portable TV sets with narrow i-f response display a reasonably acceptable picture.

AGC SYSTEMS

Every television receiver requires an Automatic Gain Control (AGC) system for the purpose of controlling signal amplification in the i-f and rf stages. Lacking this circuit, varying signal levels would ultimately produce varying contrast in the reproduced picture, and cause fluctuating audio levels. Video levels in a TV modulation envelope vary according to incoming picture level, but the sync-pulse amplitude remains constant. Therefore, television receivers can use time-keyed agc circuits which monitor incoming sync-pulse levels. The agc circuit is keyed into action 15,750 times per second by pulses from the horizontal-output transformer (flyback). This "on" period corresponds to the retrace time, when sync pulses are being received. The resultant voltage derived from sync level is then directed to the i-f and rf stages to vary their gain as necessary.

THE VIDEO DETECTOR

This relatively simple stage in a television receiver is responsible for detecting the video information (30 Hz to 4 MHz range) and producing the audio i-f signal of 4.5 MHz. This 4.5-MHz signal results when the video and audio carriers are mixed in the video detector. Video information leaving the detector is usually in the one- to four-volt range, with additional amplification being performed in subsequent video-amplifier stages. The video detector itself is usually enclosed in a shielded box to prevent pickup and reamplification of extraneous signals or noise. If shields attached to this box are moved (possibly during repairs, or when adding external video inputs to a TV set), care should be exercised to ensure their correct physical and electrical replacement.

VIDEO AMPLIFIERS

The video amplifier's purpose is to increase video-signal amplitude to approximately 85 volts (depending upon the setting of the contrast control). In order to obtain this amplification, one, two or three stages will be required (depending on design of the particular receiver being considered). Again, compared to tube sets which can achieve high gain in a single stage, solid-stage video amplifiers usually require two or three stages to achieve comparable gain figures.

Bandwidth of video amplifier stages usually extend from 30 Hz to near 4 MHz. High-frequency response is provided through the use of peaking coils and low-value plate (or collector) load resistances.

The 4.5-MHz sound i-f reproduced at the video detector is usually allowed to pass through one or two video-amplifier stages, as an economy measure, before application to 4.5-MHz i-f stages. One or two 4.5-MHz traps are inserted following the sound pick-off point to prevent interference to pictures. A contrast control is usually at the video-amplifier input; however, this control occasionally may be found between stages. Video information from the video amplifier may be applied to either the cathode or grid of the picture tube, depending on video signal polarity (and circuit composition). Positive-going video and negative-going sync (positive = white, negative = black) would be applied to the control grid. Negative-going video and positive-going sync (negative = white, positive =

black) would be applied to the cathode. Specific circuit designs, again, vary between manufacturers. A commonly employed concept is to apply video information to the picture-tube cathode, and to connect the brightness control to the control grid. This arrangement results in the high resistance (brightness control) being removed from the cathode's negative-feedback path (which would reduce gain), producing a brighter display.

THE AUDIO SECTION

The 4.5-MHz difference between video and audio carriers is the sound-i-f signal. Following amplification of this 4.5-MHz signal, a limiter is sometimes used to remove amplitude variations and noise pulses. The sound-i-f signal is then applied to a detector to recover audio information. Quadrature detectors or locked-oscillator detectors are often used in tube-type sets, while ratio detectors are usually found in solid-state sets. Ratio detectors are often included within multifunction ICs in modern TV receivers.

The volume control is usually located between the sound-detector output and the audio amplifier input. A shielded cable is often used when this control is mounted remote from associated circuitry.

The audio amplifier and speaker in a television set are almost identical to those found in AM or FM radios. There are no unusual requirements for audio sections in TV receivers.

SYNC SEPARATOR, VERTICAL INTEGRATOR, AND HORIZONTAL DIFFERENTIATOR

The sync separator's purpose is to extract synchronizing pulses from the received signal, and direct these pulses to the proper scan-producing oscillator. Composite video from the video detector or amplifier is applied to the sync-separator input. Since video and sync levels produce opposite-polarity voltages, sync pulses only cause this stage to conduct heavily and pass the amplified pulses. An R-C time constant on the sync-separator input establishes approximate operating times for the stage, reducing interference and "false triggering" from external sources.

The sync-separator output consists of both horizontal and vertical pulses which must be further separated and applied to their respective oscillators. This is the function performed by the vertical integrator and horizontal differentiator. These basic R-C circuits separate horizontal and vertical pulses according to their time period; a basically simple task, since vertical pulses are substan-

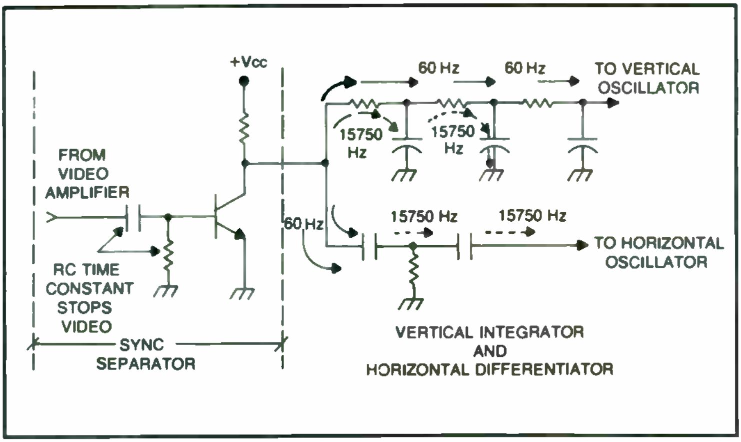


Fig. 4-5. A basic sync separator with vertical integrator and horizontal differentiator removes sweep-synchronization pulses from video and directs them to their respective circuits.

tially longer than horizontal pulses. A basic sync separator, with integrator and differentiator, is shown in Fig. 4-5. Notice that high frequencies (horizontal pulses) are shunted to ground through the integrator's capacitor, while low frequencies are blocked by the capacitor in the horizontal differentiator. The vertical integrator may also be considered as a passive filter for removing horizontal sync pulses from vertical pulses.

VERTICAL-SWEEP SECTION

The vertical-sweep section consists of the vertical oscillator and vertical-output stages. Their purpose is to sweep the scanning beam in a vertical direction, from the screen top to screen bottom, in sync with the transmitted signal.

The vertical oscillator is often a multivibrator circuit. However, simpler circuits such as Hartley oscillators are occasionally used in this stage. The oscillator "free runs" at approximately 55 Hz (as determined by the setting of the vertical-hold control), with sync pulses increasing the frequency to exactly that of the incoming signal (60 Hz). If the output level of this stage isn't sufficient for driving the picture-tube deflection yoke, an additional stage can be used. A sawtooth-generating capacitor is usually included between oscillator and amplifier stages for creating the vertical-sweep signal.

The vertical amplifier increases sweep-signal level to the amount required for the deflection yoke. The vertical-amplifier output may be directed to the deflection yoke via an impedance matching transformer, or a basic complimentary-symmetry stage may feed energy directly to the yoke. Damping resistors are often placed in parallel with each coil on the yoke for reducing oscillations which would otherwise occur during vertical-retrace time. Finally, electromagnetic deflection requires horizontally-oriented yoke coils for providing vertical beam movements, while vertically-oriented yoke coils provide horizontal beam movement.

THE HORIZONTAL-SWEEP AND HIGH-VOLTAGE SECTIONS

This portion of the television receiver consists of the horizontal AFC, horizontal oscillator and output, the output transformer (flyback), the damper and the high voltage rectifier(s), see Fig. 4-2. Since this area of the television set performs more work than any other area, it is more prone to failure. However, modern technology is reducing the overall failure rate of all TV circuitry. The horizontal section is usually characterized by its large and odd-shaped flyback transformer, x-ray shielding, and heat-dissipating components. Refer to Fig. 4-6.

Horizontal-sync pulses from the sync separator, and pulses from the flyback transformer, are directed to Automatic Frequency Control (AFC) circuit input. The afc compares those two signals, and generates a dc correction voltage proportional to their difference. This indirect synchronization according to the average rate of incoming pulses prevents noise pulses from disturbing the horizontal oscillator. The dc correction voltage from the afc circuit is used to maintain the horizontal oscillator in sync with the transmitted signal.

The horizontal oscillator operates at 15,750 kHz, and produces a sawtooth waveform which is amplified by the horizontal output stage. Typical oscillator circuits are Hartley or tuned-circuit-stabilized multivibrators. The high-frequency signal from this stage is occasionally audible to some people.

The horizonal-output stage provides amplification of the horizontal-sweep signal to cause movement of the picture tube scanning beam. This stage usually employs input-signal-developed bias for stability; however, this also means that a loss of horizontal-oscillator signal causes a loss of the horizontal amplifier's main components. As a precaution, many television sets have circuit breakers which remove horizontal-stage voltage when current demands increase significantly. The horizontal-output stage conducts only while the trace is in the middle to right-hand side of a TV

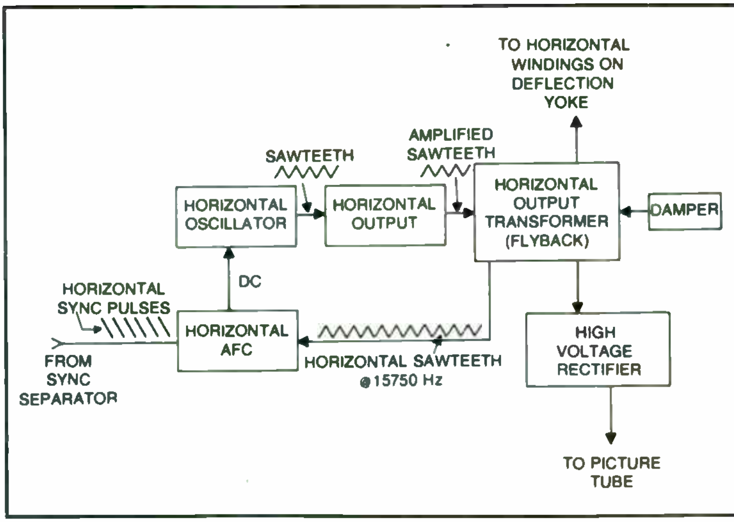


Fig. 4-6. Analysis of television-receiver horizontal section indicating signals and their associated stages.

screen. Self-bias then abruptly cuts off the stage. The deflection yoke's resultant kick or "ring" of oscillation at 70 to 80 kHz causes rapid retrace of the scanning beam. The damper tube then conducts, damping the rapid retrace into a smooth sawtooth wave which moves the scanning beam from the screen's left-hand side to the middle. The horizontal output stage then conducts again, and the cycle is repeated. A sketch of this operation is shown in Fig. 4-7.

The horizontal-output transformer, or "flyback," performs a number of functions: it matches horizontal output stage impedance to deflection yoke impedance, it develops a high-intensity pulse from the inductive kick for picture-tube high voltage, and a portion of its retrace voltage is used to the agc and horizontal afc. This transformer is thus the "heartbeat" of a television set's operation.

A large winding on the flyback transformer's outer area consists of many turns of fine wire. The purpose of this winding is to step up the inductive kick to a 10-20 kV level. This high voltage is then rectified and applied to the picture tube's accelerator, or ultor, connection for screen illumination. Some sets feature a simple half-wave rectifier in the high-voltage section, while others use voltage-doubler or tripler circuits. Since the input-ripple frequency is at the horizontal rate of 15,570 kHz, large-value filter capacitors are not required in the high-voltage supply. Typical capacitor values

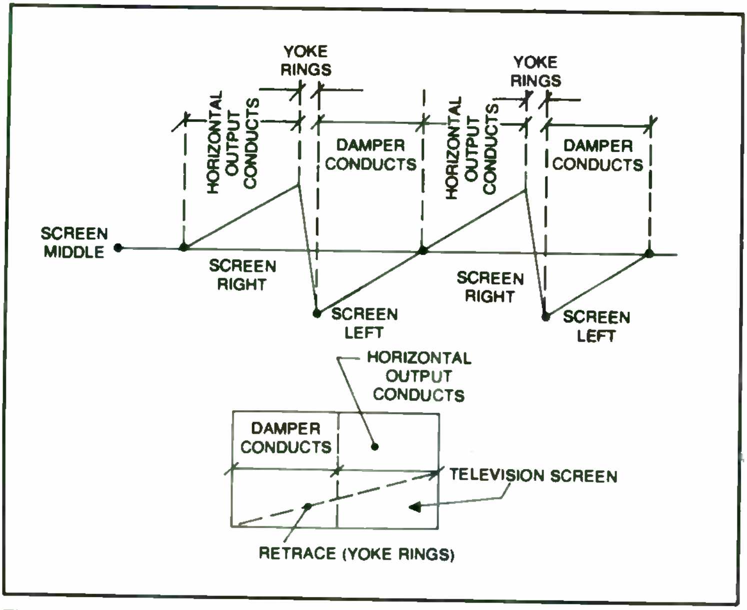


Fig. 4-7. Sequence of action in horizontal-sweep section of television receiver. Horizontal output device conducts from middle to right side of screen, then yoke "rings" for a half cycle to produce rapid retrace. Following that "flyback period," damper conducts and smooths trace to middle of screen. The horizontal output device again conducts and cycle is repeated.

are 500 pF—a value which may easily be obtained by using a picture tube's internal and external bell areas. (These metallic areas are separated by glass, thus forming a capacitor). Focus voltage for the picture tube is often obtained from a portion of the high voltage by means of a voltage-divider circuit.

PICTURE TUBES

The display device in presently popular television receivers is a cathode-ray tube which has a rectangular screen and employs electromagnetic deflection. This tube features an electron gun which scans a fluorescent screen to create images. The phosphorescent coating is a white substance designated P-4 in the electronics world.

While a complete discussion of cathode-ray picture tubes is beyond the scope of this book, some basic information is worthy of mention. The brightness is highly dependent upon the amount of high voltage applied to the tube. The higher the voltage, the brighter the screen. The higher-voltage electron beams are also more difficult to deflect from screen center, thus large deflection signals are required for deflecting high-intensity electron beams.

The method of modulating an electron beam as it moves around the screen area is relatively simple. The video signal is applied to either the cathode (negative-going signals for white picture elements) or the control grid (positive-going signals for white picture elements). This arrangement causes light and dark variations to be placed in the right place at the right time, recreating the transmitted picture.

The picture tube is the most expensive component in a TV receiver, consequently it is constructed to provide long and dependable service. The filament, in particular, is made to withstand numerous on/off operations and to withstand substantial fluctuations in filament voltage.

As this book is being written, two new forms of television displays are being investigated: high-resolution LCD (liquid-crystal display) readouts and plasma panels. Both of these devices will require digital encoders and matrices for scanning and activating proper points within each display area. The LCD readout holds particular promise for use in miniature television sets. The picture, in many respects, will resemble a glorified form of a calculator readout. The LCD also shows promise for application with early forms of holographic video.

LOW-VOLTAGE POWER SUPPLIES

The low-voltage power supply provides operating potentials for all of the previously described stages. This section is noted for large filter capacitors and the presence of rectifier diodes. Circuitry of the low voltage section is not unlike conventional power supplies, with full-wave bridge rectifiers and voltage doublers being quite popular. The popularity of transformerless TV sets has created a need for polarized line cords and insulated cabinets, forewarning technicians to use isolation transformers when working on these sets. The low-voltage supply often includes voltage dividers for various stages as required, and surge resistors to prevent excessive turn-on current from destroying fragile components.

DYNAMIC TROUBLESHOOTING TECHNIQUES

As mentioned during the first part of this chapter, the complex television receiver can be broken into five basic sections. These sections, which are illustrated in Fig. 4-8, may be used in dynamic

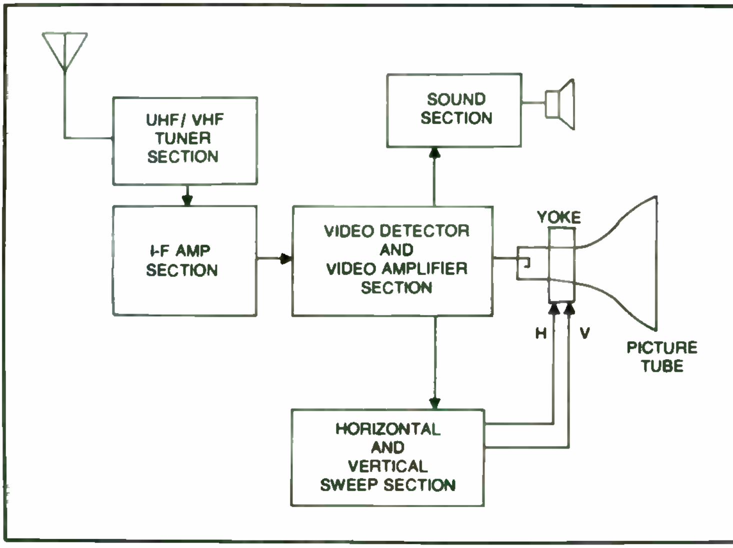


Fig. 4-8. The five basic sections of television receiver which are isolated for rapid troubleshooting.

troubleshooting merely by visualizing their operational functions and frequencies.

There are three strategic points in a black-and-white television set which can be used for dynamic troubleshooting: the contrast control (located in a video amplifier section), the i-f input connection (located at end of the cable running from the tuner to the main television circuitry) and the tuner input (the antenna connection). Signals of the proper frequency and amplitude can be injected at these three points, and the associated stages quickly checked for proper operation. Assume, for the following example, a television receiver exhibits an illuminated screen (indicating presence of high voltage and low voltage), but no picture (disregard the audio for this example). The problem could be in the video amplifier, the i-f, or the tuner section. A systematic process of rapid elimination is, obviously, desirable to locate the problem.

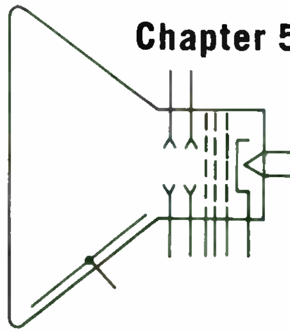
A signal of approximately 1000 Hz can be injected between the contrast control's wiper and ground. If the video amplifiers are operating properly, a noticeable response will appear on the CRT screen in the form of bars (usually diagonal). Varying the injected signal frequency will vary the width and number of displayed bars. The pattern will become faint and then disappear as the injected signal approaches the video amplifier's high-frequency limit (usually between 3.2 and 4.0 MHz). If there is no response to the injected signal, the signal can be increased in amplitude and applied to stages immediately preceding the picture tube, or a fixed bias can be applied to the picture tube to acquire this initial "starting point."

A signal tone-modulated of approximately 45 MHz can be applied to the i-f input, where the tuner output cable connects to the main chassis. Assuming all stages between this injection point and the picture tube are functioning properly, bars will again be displayed on the screen. The bar size and number will be determined by the modulation frequency. As with the video amplifier, the approximate frequency response of the i-f system can be estimated according to loss of displayed information and its correlation to the injected frequency. If a display isn't obtained on the screen when signals are injected to the i-f input, stages may be "jumped" with the injected signal until response is obtained. In that situation, the appearance of a display will indicate when the defective stage has been passed.

A signal may be injected at the antenna terminals for checking overall receiver performance and/or for isolating troubles in the tuner. The tuner should, obviously, be tuned to receive the injected signal (example: Channel 2 receives 54-60 MHz, Channel 6 receives 82-88 MHz, etc.). A display on the screen indicates proper tuner operation, and the absence of a display would indicate a defective tuner.

The methods of dynamic, or signal, troubleshooting are almost as old as television itself; however, they continue to be a highly beneficial tool. The same methods are equally adaptable to many electronic items, from broadcast transmitters to video recorders and tape players.

Chapter 5



Color-TV Standards and Operation

Although color television is generally accepted as a product of the past 25 years, it is nearly as old as television itself. One of the earliest proposals was patented in Germany in 1904, and the same Dr. Zworykin who invented the iconoscope filed a patent disclosure for an electronic color-TV system in 1925.

John Baird demonstrated the first practical color-television system in 1928. He used a Nipkow disc with three spirals of 30 apertures, one spiral for each primary color. The light source at the receiver used two gas-discharge tubes: one of mercury vapor and helium for the green and blue colors, and neon tube for red.

In 1928, Herbert Ives and his colleagues at Bell Laboratories transmitted 50-line color images between New York and Washington, DC. This was also a mechanical system, but one that simultaneously sent the three primary-color signals over three separate circuits.

In 1940, both NBC and CBS gave public demonstrations of color television which used 441-line scanning. Numerous demonstrations were also given after World War II, including one by RCA in 1946 in which a stereoscopic system was used to present a three-dimensional image. In all of these demonstrations, however, color-filter discs (or drums) rotated in synchronism in front of the camera tube and receiver.

At the receiver, the color images were presented sequentially (field-sequential system) so the red, green, and blue components of the scene were viewed one after the other. Because of the persistence of vision, the viewer perceived a full-color image; however, if he moved his head or scanned the picture rapidly, the image suffered from "color break-up." The rotating mechanical discs were also a drawback, and as black-and-white TV sets became widely distributed in the late 1940s, the inability of unmodified monochrome receivers to reproduce a color program made color-television broadcasting, on this basis, economically impractical.

These difficulties were solved by a simultaneous, three-channel color system introduced by RCA in 1946 in which the three component images (red, green, and blue) were separately transmitted and projected on a screen or presented on three separate CRTs which were viewed through a system of beam-splitting dichroic mirrors. RCA even developed a projection CRT for this purpose, which they call the trinoscope. Monochrome receivers were simply tuned to the green channel (Fig. 5-1).

However, both the field-sequential and simultaneous three-channel color systems required, for equal picture definition and freedom from flicker, much greater bandwidth than the 6-MHz channels. By reducing both the color frequency and the number of lines, the field-sequential color system could be transmitted within a 6-MHz bandwidth, but only with poor resolution and increased flicker.

Investigators at RCA (in 1949) found it was possible to retain full resolution, freedom from flicker, and monochrome compatibility with a simultaneous system that used a monochrome picture signal with a phase and amplitude-modulated subcarrier which carried the color, or chroma, information. The chromatic subcarrier, approxi-

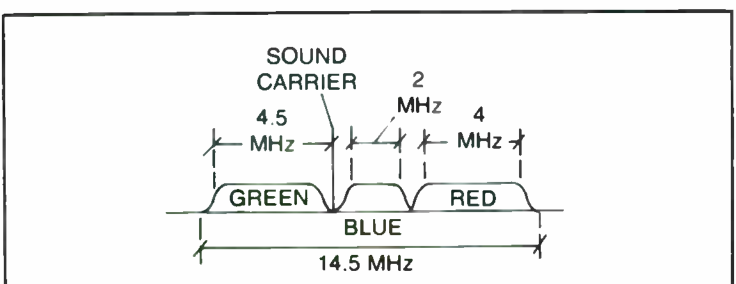


Fig. 5-1. Transmission channel for RCA's experimental simultaneous-color television picture signal required 14.5 MHz bandwidth. Monochrome receivers were tuned to the green carrier. Reduced bandwidth of blue signal didn't severely affect picture quality since a mere 11 percent blue information was required for full color reproduction.

mately 3.58 MHz above the picture carrier, was selected so that it had no visible effect on the picture reproduced by a monochrome receiver. In a color receiver, the subcarrier was used to distribute picture brightness between the three primary colors to produce a natural-color rendition of the original scene.

Nevertheless, in October, 1950, after a lengthy series of hearings, the FCC adopted the incompatible field-sequential color system as the standard for the United States. However, in December, 1953, the Commission rescinded its earlier ruling and issued a new set of specifications which had been submitted by RCA and the National Television System Committee (NTSC). These corresponded to the compatible color system developed earlier by RCA. This same basic color system is still used throughout North and South America, Japan, Korea, and parts of Europe.

MAKING THE STANDARDS COMPATIBLE

The beginning of our present color-TV system came at a time when black-and-white television enjoyed widespread popularity. The many thousands of black-and-white sets in homes throughout the country could not be directly outmoded, consequently, a fully compatible color/black-and-white arrangement was necessary. Since original TV design criteria had "backed industry into a technological corner" with black-and-white standards, few alternatives presented themselves. Channel allocations of 6 MHz, with the video carrier situated 1.25 MHz above the channel's low end and the audio carrier situated 250-kHz below the channels upper end, could not be altered. Likewise, the use of interlaced scanning, 525 lines, with 480 of these lines being actively for video information, FM audio situated 4.5 MHz above the video carrier, etc., could not be altered. Color information, quite simply, must be inserted within the existing bandpass without noticeably degrading the black-and-white picture. The solution is quite sophisticated and ingenious. More specific technical information may be found in the numerous readily available engineering manuals on color television.

Before delving into design specifics, some facts concerning color displays and vision should be reviewed. Research has shown that people see very fine details primarily as only black and white, and that the eye is forgiving of minor color variations if flesh tones are correct. As a result, today's color-TV system conveys large-picture detail in full color, medium-sized picture detail is only two colors (cyan and magenta — similar to the first "color" movies in theaters), and fine detail as only black-and-white variations. Quadrature, or orthagonal (90 degrees out of phase) sidebands are used to convey the color signals, while the "old standby" black-and-white carrier conveys all brightness variations. The brightness variations are interpreted by black-and-white TV sets as regular black-and-white telecasts, while the color information (in the video channel's upper area) is ignored. The color-television receiver retrieves color variations (color, and the intensity of that color) from the new sidebands, while also retrieving all brightness variations (amounts of white light) and fine-picture detail from the original black-and-white video signal.

Some of the modifications to black and white signals to include color information are shown in Fig. 5-2. The original video carrier situated 1.25 MHz above the channel's low end is retained intact,

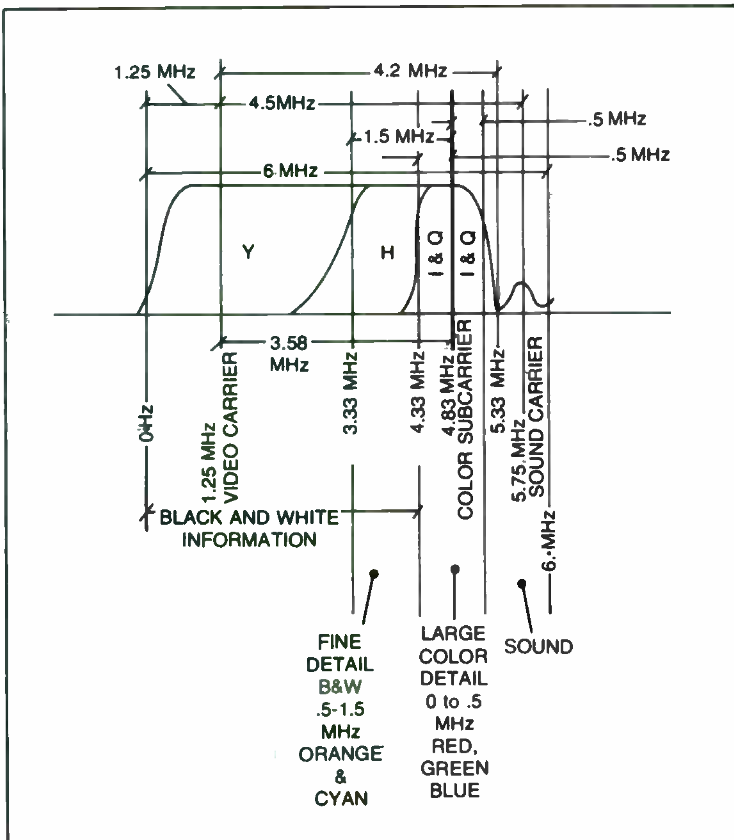


Fig. 5-2. Spectrum analysis of modified TV signal for inclusion of Y+I and Q color information. Details are presented in text.

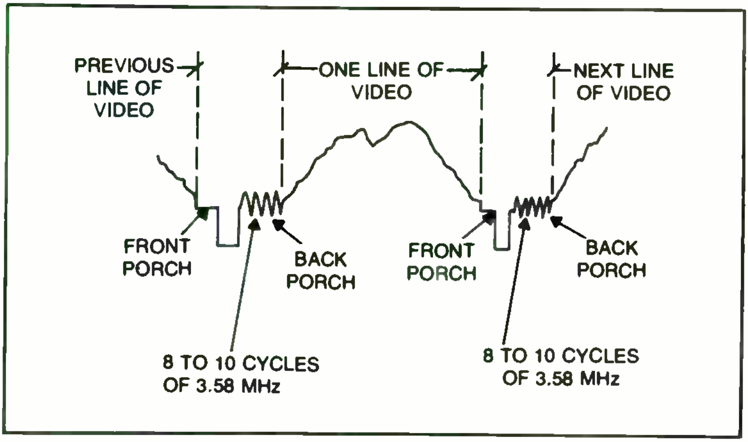


Fig. 5-3. Location of 3.58 MHz color-reference signal which is transmitted on "back porch" of horizontal-blanking pulse.

however, its modulating frequencies above 3.5 MHz are attenuated to accommodate color signals (this results in a minor loss of fine detail). The video bandpass is then extended to 4.2 MHz, resulting in a vacant area for color-signal insertion. These requirements for sharp-skirted selectivity (between color information and the audio signal) then fall solely upon the newly manufactured and more sophisticated color-television receivers. The vacant area for color information is frequency-restricted, thus picture detail beyond 1.5 MHz cannot be transmitted. Additionally, full-color information (which requires two color signals; I and Q) is restricted to 0.5 MHz.

Another modification to the black-and-white signal was the changing the horizontal and vertical scanning frequencies to permit frequency interlacing of black-and-white and color signals. The new rates of 15,734 Hz and 59.94 Hz were minor shifts, and within the lock-in range of all television receivers, consequently the change was permitted.

Since the color-difference signals must be transmitted as a separate signal modulating the main signal (a subcarrier), an interferring "beat," or hetrodyne is created on the desired 3.58-MHz frequency. That problem is alleviated by suppressing the 3.58 carrier and transmitting only its sidebands. The carrier is regenerated within the television receiver, (by a crystal-controlled oscillator) and kept in phase with the transmitting signal by means of a 3.58 MHz "burst." This 3.58-MHz color-burst signal is transmitted during the "back porch" interval of horizontal sync, as illustrated in Fig. 5-3.

CONSTANT-LUMINANCE AND COLOR-DIFFERENCE SIGNALS

Due to bandwidth and compatibility restrictions, a method to permit co-existence of both color and black-and-white video was devised. This technique combines color variations independent of their brightness, the results being transmitted on a subcarrier situated 3.58 MHz above the original video carrier. All brightness variations are transmitted on the original black-and-white video signal. Technically, this may be described as blue minus brightness (B–Y), green minus brightness (G–Y) and red minus brightness (R–Y). Brightness itself is thus designated Y.

Going a step further, we find white light is made up of 59 percent green light, 30 percent red light and 11 percent blue light. Since all colors may be created from these three primary colors, their transmission becomes a somewhat simpler matter. Realizing again, however, that three sets of sidebands are not available for separate color transmissions (and that the concept would not be compatible with existing black-and-white systems), a further development is required.

The (original) Y signal is brightness, or luminance, consequently, its information consists of 30 percent red, 59 percent green and 11 percent blue. Since the color-minus-brightness information is transmitted independently, and since the color signal contains only blue and red (less brightness), those contents may be subtracted from the Y signal to retrieve green information. A summary of these principles may be stated as follows:

$$Y = 59\%\ G,\ 30\%\ R,\ 11\%\ B \text{ (white)}$$
$$R = 0\%\ G,\ 100\%\ R,\ 0\%\ B \text{ (red)}$$
$$G = 100\%\ G,\ 0\%\ R,\ 0\%\ B \text{ (green)}$$
$$B = 0\%\ G,\ 0\%\ R,\ 100\%\ B \text{ (blue)}$$
$$R - Y = +100R - \underbrace{(59\%\ G,\ 30\%\ R,\ 11\%\ B)}_{Y}$$

$$R - Y = +70\%\ R - 59\%\ G - 11\%\ B$$

Likewise,

$$B - Y = +100\%\ B - \underbrace{(59\%\ G,\ 30\%\ R,\ 11\%\ B)}_{Y}$$

$$B - Y = +89\%\ B - 59\%\ G - 30\%\ R$$

Similarly,

$$G-Y = +100\%\ G - \underbrace{(59\%\ G,\ 30\%\ R,\ 11\%\ B)}_{Y}$$

$$G-Y = +41\%\ G - 30\%\ R - 11\%\ B$$

In each example, the respective color (one designated as +100 percent) was subtracted from its portion of the inverted Y signal. This is accomplished electronically by combining in-phase and 180-degree-out-of-phase signals, and using their resultant (non-cancelled) output. It should now be apparent that R–Y and B–Y may be subtracted from Y to retrieve red and blue, and red and blue may be subtracted from Y to retrieve green.

These concepts have resulted in a means of condensing color-signal bandwidths. This arrangement of constantly transmitting the luminance signal and separately transmitting the color-difference signals requires a subcarrier modulated with two sets of sidebands.

THE COLOR SUBCARRIER AND ITS SIDEBANDS

The color subcarrier is 3.58 MHz above the Y (main) carrier, and modulated "in phase," producing two sidebands, and also modulated "in quadrature" (90 degrees out of phase), producing two more sidebands. The two sets of sidebands are typically designated "I" (in phase) and "Q" (90 degrees out of phase). This arrangement was shown in Fig. 5-2. The lower-frequency I sideband, which extends 1.5 MHz below 3.58 MHz would appear to interfere with fine detail (high frequencies) in the Y signal, however this is not the case. Video information falls in energy clusters at multiples of the raster-scanning frequencies. The lower-frequency I information can be caused to interlace with Y information as shown in Fig. 5-4. This is accomplished through the previously mentioned change in scanning frequencies.

In order to understand the "invisible" Q sidebands which are 90 degrees out of phase with the regular television signal, a different point of view is desirable; we need to "look down" on Fig. 5-5.

Figure 5-5 shows that the Y signal conveys brightness variations while the I and Q signals convey the color information. The I signal is, in reality, 57 degrees behind the Y signal (which is considered as the phase reference, or zero degrees). The subcarrier itself is suppressed, with only its sidebands being transmitted. The

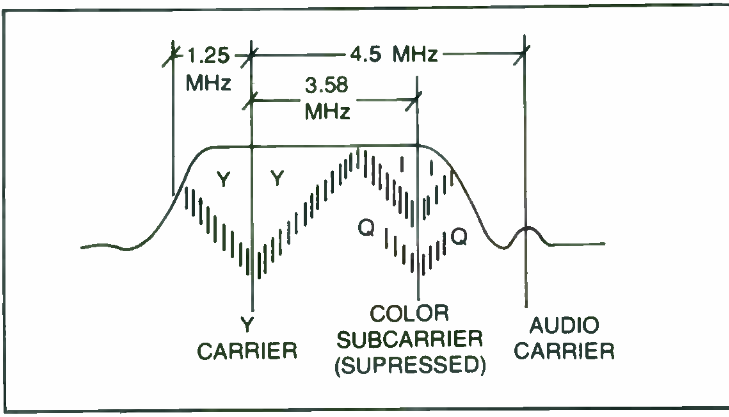


Fig. 5-4. Video information falls in clusters of rf energy which appear at multiples of scanning frequencies. Through careful selection of those frequencies, black-and-white signals interlace at "far end."

reference vector, which is in phase with Y information, is transmitted on the back porch of the horizontal-sync interval. That reference signal is extracted by the television receiver and used to properly phase-demodulate information contained in the color sidebands.

The "top view" of Fig. 5-5 also indicates vestigial sideband transmission of the I signal, while the Q signal is restricted to 0.5

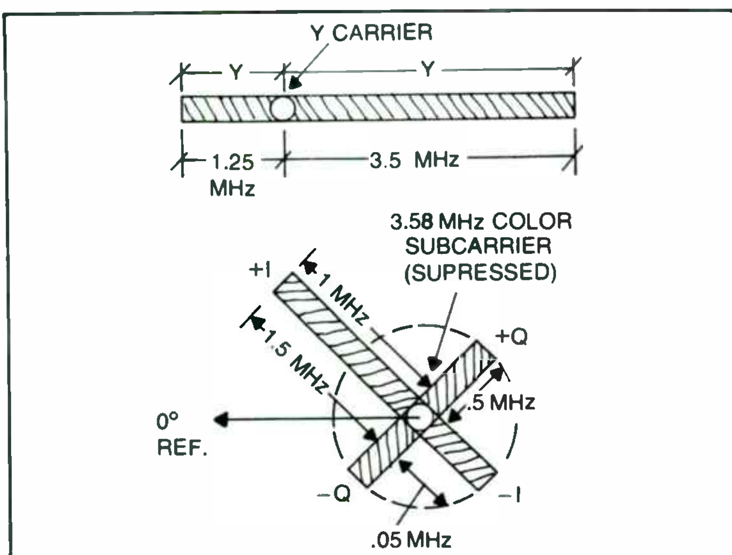


Fig. 5-5. Hypothetical "top view" of the TV signal shown in Figs. 5-2 and 5-4, showing phase relations of sidebands.

MHz. Realizing that 0.5 MHz corresponds to large picture details, we see that full color reproduction is thus quite limited in display. The I and Q signals are modulated with both R–Y and B–Y information, with the +I sideband (lower frequency sideband) containing only R–Y in the medium-fine-detail range of 0.5 to 1.5 MHz below the 3.58 (suppressed) subcarrier. The + and – designations on color sidebands are provided for identification purposes in color-burst understanding, and for designating phases of transmitted modulation.

The color burst, which is a vector display of each color's phase relation to I, Q and the transmitted reference, is shown in Fig. 5-6. Notice that +I (57 degrees) and –I (237 degrees) correspond to the I sidebands of Fig. 5-5, while +Q (147 degrees) and – Q correspond to the Q sidebands. Only one I and one Q signal are transmitted at any one instant. All colors in the burst may thus be represented through phase and amplitude modulation of I and Q. Red and magenta, for example are produced by the vectoral addition of +1 and +Q, while yellow and orange are produced by the vectoral addition of +1 and –Q, etc. Thus by varying vector lengths

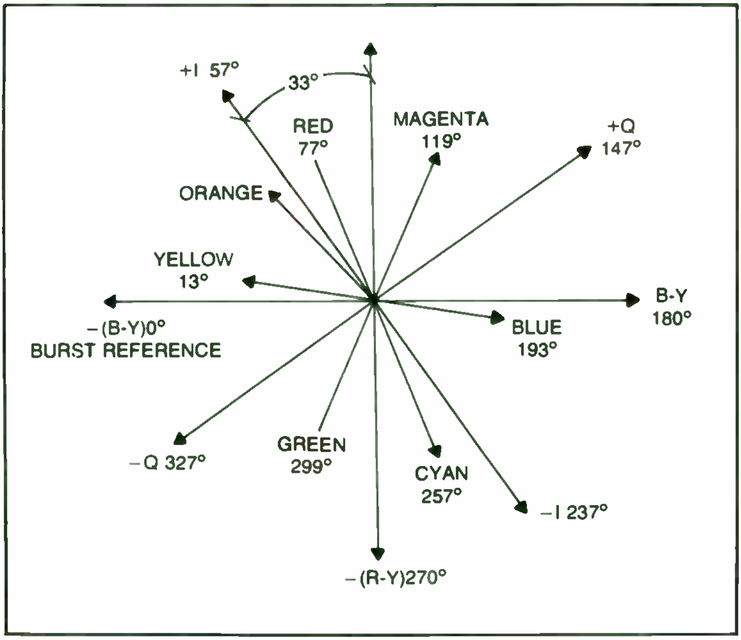


Fig. 5-6. Vector relations of all signals and colors used in commercial television. The zero-degree burst-reference signal is transmitted on back porch of horizontal blanking pulse.

(sideband energies) and shifting in/out of phase (+, − sidebands), all colors may be regenerated 3.58 million times per second. Attention is directed to the fact that the +I axis is located between orange and red: the prime colors necessary for reproduction of skin tones. The +I sideband (and only the +I sideband) extends 1.5 MHz from the subcarrier's frequency. All other sidebands extend only 0.5 MHz from the subcarrier's frequency.

WIDEBAND AND NARROWBAND SIGNALS

Since all colors are situated at specific phase angles with reference to the zero-degree burst reference, demodulation on any axis is possible. That is, I, Q, R−Y, B−Y, or even cyan-magenta may become a demodulation axis. The only criteria is establishing the time (in degrees) after the phase reference when demodulators conduct. As demodulation angles move from +I, however, bandwidths drop to near 0.5 MHz (for example, +I = 1.5 MHz, R−Y = 0.7 MHz, magenta and +Q = 0.5 MHz).

Many of today's popular color-television receivers use R−Y, B−Y demodulation, or (what is worse) X, Z demodulation of color signals. When compound to the more sophisticated (and expensive) I, Q-demodulation TV receivers, a noticeable difference is apparent. I, Q demodulation reproduces medium-fine detail in shades of orange and cyan while R−Y, B−Y reproduces medium-fine detail only in black and white.

THE COLOR PICTURE TUBE

Another of the radical innovations necessary for color-television reproduction was the creation of a color-picture tube. Early design was crippled by a number of obstacles, yet the resultant tubes perform quite well. Since all secondary colors may be created from proper mixtures of the three primary colors, three electron guns are required in a color-picture tube. Three light-emitting phosphors are deposited on the picture-tube screen, with their respective electron guns providing excitation according to incoming video signals. Since the three guns cannot be physically positioned in exactly the same place, an aperture mask is used to ensure that each beam strikes only its respective color phosphors. The three electron beams emanating from the electron guns thus converge on holes in the aperture mask (which is placed two or three inches from the screen, inside the picture tube), then diverge precisely the correct amount required to strike their respective color dots. An example of this action is illustrated in Fig. 5-7.

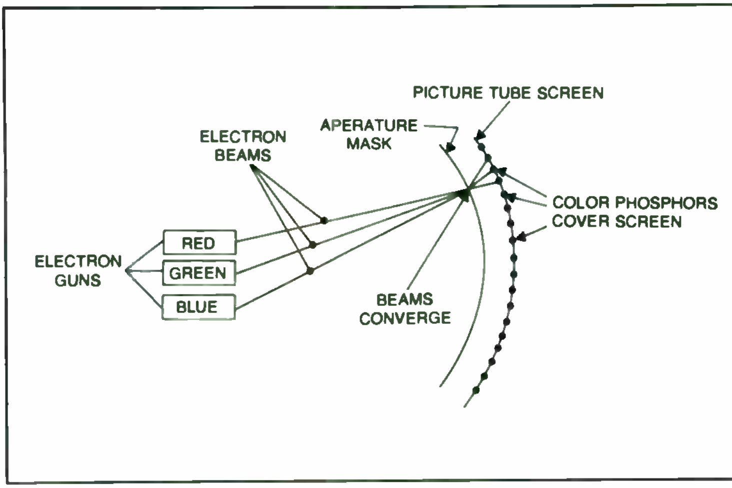


Fig. 5-7. Example of the aperture mask location and function, and of convergence of the three electron beams on their respective color phosphors. Note that at any one time all beams must pass through a single hole in the aperture mask.

The aperture mask provides a "shadow" on the phosphors, preventing accidental excitation of phosphors by incorrect electron beams. As a result of this measure, the beams are eclipsed approximately 80 percent of the time. This accounts for the approximate 20-percent efficiency of color picture tubes, for without the excitation of phosphors by electron beams, the screen remains dark. As a means of overcoming the aperture mask problem, higher voltages are used in color picture tubes.

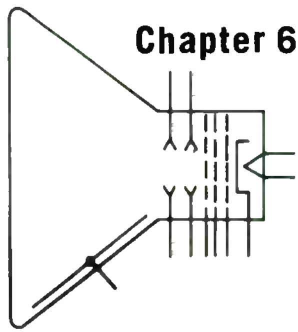
The phosphors necessary for producing red, green, and blue light were, at best, difficult to locate and refine for color-picture-tube application. Natural elements necessary for these phosphors soon become quite rare, necessitating laboratory development of synthetic phosphors. Today, rare-earth phosphor tubes are difficult to locate and are used in only the more expensive color television receivers. The difference in picture quality, however is noticeable: rare-earth phosphors create smooth pictures with natural semi-saturated colors, while synthetic phosphors create grainy pictures with vivid and more saturated colors.

All color phosphors are not equal in their light output. While green phosphors are relatively efficient, red phosphors are approximately 25-percent efficient. This requires that all phosphors be "hit" extremely hard during the limited time the electron beam clears the aperture-mask shadowing. Yet, all phosphors are limited by the output of the weakest phosphor, another aspect contributing to overall inefficiency of many color-picture tubes.

Three of the most popular styles of color-picture tubes are the delta gun, the in-line gun, and the single Triniton gun (used exclusively in Sony TV sets). The delta-gun tube has the guns and phosphor dots arranged in triangles, with round holes in the mask. Both static and dynamic convergence of the electron beams are necessary. The in-line-gun tube features all three guns mounted side-by-side, with phosphor strips coating the screen, and a slotted aperture mask. Factory alignment of yokes and stripes reduces convergence problems. The Triniton principle features a single electron gun, with proper excitation of color phosphors being performed without the assistance of an aperture mask. This process eliminates all convergence requirements (there's only one electron beam), while providing substantially increased picture-tube efficiency.

Chapter 6

The Color-Television Receiver



Due to the complex nature of a transmitted color-television signal, the modern TV receiver is a sophisticated unit. The implementation of new techniques these concepts resulted in a high-resolution color TV system which is fully compatible with existing black-and-white TV systems. This chapter will discuss receiver design for color operation, plus a look at the additional color circuitry required in color-television receivers.

The capabilities in the system used to convey television information had become somewhat neglected during the days of black-and-white-only telecasts. Manufacturers began sacrificing video high-frequency response and picture fine detail in return for fewer amplification stages and consequent lower price tags. The resultant frequency "gaps" in the circuitry were then used for color reception. Stringent tolerances thus returned and became vitally important for color-television reception.

The tuner in a color television receiver exhibits noticeable improvements in frequency response and overall bandwidth. The acceptable variations in bandpass saddle and tilt are limited to 15 percent, compared to the more lenient variation of 30 percent in black-and-white television sets. See Fig. 6-1. Most state-of-the-art color-TV receivers include MOSFET transistors in vhf tuners, and MOSFET rf amplifiers occasionally are included in uhf tuners. The low noise figures and superb insensitivity to crossmodulation exhibited by these devices make them particularly attractive for such

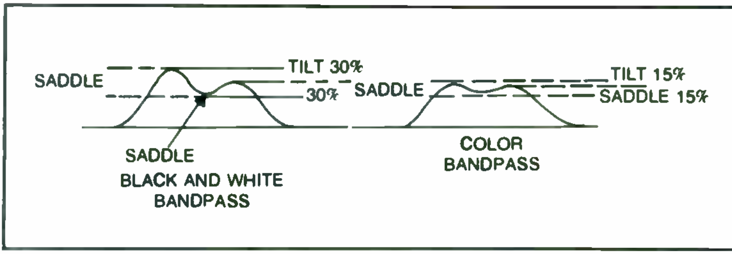


Fig. 6-1. Comparison of bandpass restrictions between tuners of color and black-and-white television receivers. Wide bandpass is accomplished by tuned circuits. Tilt variations are caused by different stage gains, and saddle is caused by offsets in stagger tuning.

critical applications. The popular intermediate frequencies of 41.25 MHz (sound) and 45.75 MHz (video) are retained.

The i-f section is also subject to the stringent bandpass specifications for tuners in color-TV receivers. The high video-frequency range of 41.6 to 42.6 MHz is particularly important, since this is the area occupied by the color signals. The broad bandwidth, combined with the need for high amplification of both luminance and chrominance information, often requires more stages of i-f amplification and more sophisticated agc circuits.

Because detector diodes mix all signals to which they are subjected, sound is extracted before the video detector in a color-television receiver. If this measure was not taken, color-sideband information would "beat" with the sound signal and produce interference in pictures.

The color and luminance signals proceed from the tuner, through i-f stages, to the video detector. Both color and luminance signals come from the video detector; however, each signal then follows different paths before recombination and application to the color-picture tube. The black-and-white, or luminance, amplifier channel takes on the new name of Y. However, its signals are the conventional black-and-white video signals. It should again be stressed that specific designs vary among manufacturers. Indeed, several forms of color detection and reproduction are common, and numerous circuit arrangements are used for each of the stages.

Two of the most popular types of color-television receivers are the narrowband arrangement, which demodulates on the R–Y, B–Y axis, and the wideband arrangement, which demodulates on the I, Q axis. The R–Y, B–Y type yields slightly limited color reproduction (0.5 MHz color), while I, Q yields the maximum obtainable color reproduction (1.5 MHz color). The differences are not stamped on the front (or rear) panel of a color television receiver, but the differences in picture quality are readily apparent.

A key to determining which system is used in a specific television receiver involves checking the pictorial layout inside the cabinet.

NARROWBAND RECEIVER CIRCUITS

Since the narrowband type of color-TV receiver is the more available unit, our discussion will begin with that system. The block diagram of a typical narrowband (R–Y, B–Y) color-television receiver is shown in Fig. 6-2. The video amplifier (top left) is connected to the video detector output, thus it amplifies both luminance and chrominance signals. Following along the top line, the Y amplifiers are tuned to accept lower video frequencies and thus amplify only the Y signal. A 1-microsecond delay line is then used, while color information passes through its respective circuits. The need for this delay will presently become apparent.

A second line will be noted running from the video amplifier to the first color-bandpass amplifier. This stage, and the color-bandpass amplifier stage, are tuned to accept higher video frequencies and thus amplify only the I and Q color signals, see Fig. 6-3. Before proceeding with circuit operation, the overall action of color section on/off keying must be considered. Recall that a color-burst reference signal of 8 to 10 cycles of 3.58 MHz are being received on the back porch of horizontal sync. This action happens during the end of each horizontal scanning line (every 53.5 microseconds). The color section must be keyed to accept these reference bursts and direct them to an internal 3.58-MHz circuit, plus keying off color amplifiers stages during this (retrace) period to prevent interference from reaching the picture tube. Following that (retrace) interval, the 3.58-MHz reference circuits are keyed off to prevent incoming video from creating false "lock." During that same time (during a line of incoming video), the color-amplifier stages are keyed on to allow incoming color-signal detection and amplification. This action is illustrated in Fig. 6-4. The "heartbeat" of activity centers around key pulses from the horizontal-output transformer. These pulses turn on color sync circuits while turning off color video circuits. Then, during transmission of color video information, color-sync circuits are switched off and color-video circuits are switched on.

Returning to the block diagram of a typical narrowband color-television receiver (Fig. 6-2), we continue from the input of the first

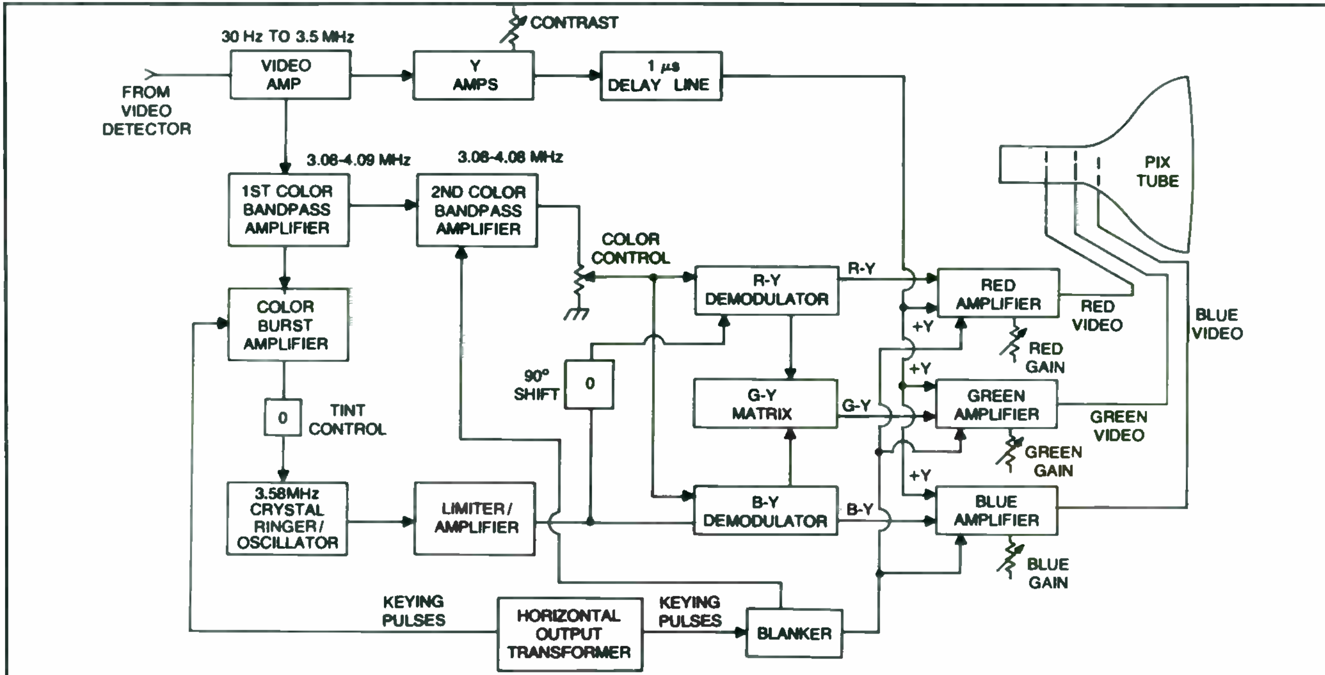


Fig. 6-2. Block diagram of typical color section in a narrowband (R-Y/B-Y) receiver. Unit shown uses crystal-ringer circuit. Overall bandwidth of color is 1 MHz.

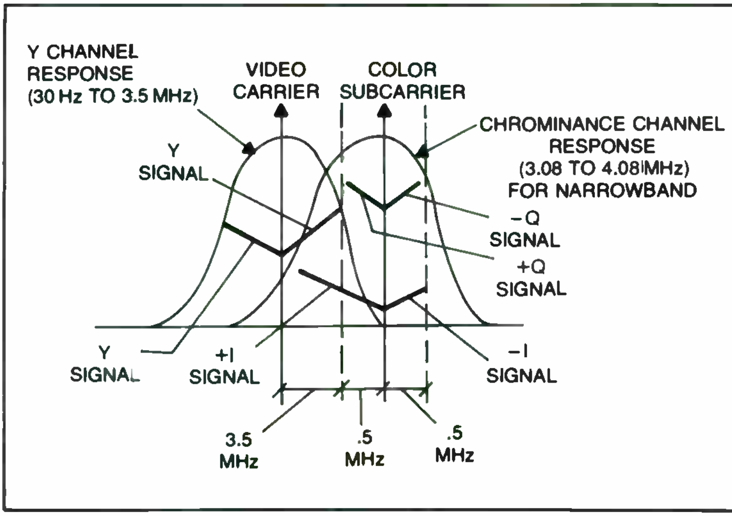


Fig. 6-3. Output of video detector as described in text.

color-bandpass amplifier. This stage accepts color information in the 3.08- to 4.08-MHz range, and lower frequency Y signals. Notice, also, this stage is *not* keyed by pulses from the horizontal output transformer. The reason for this is twofold: 1) it must continuously monitor for the presence of a color brust, and 2) the video path can be broken anywhere between the first bandpass amplifier and the color amplifiers to prevent on-screen interference. Color video signals leaving this stage are applied to the second bandpass amplifier, which operates during periods of video information and consequently amplifies the color signal. The output of this (second bandpass amplifier) stage is applied to the color control for determining the amount of color level in the reproduced picture. That signal is then applied to the input of the R – Y and the B – Y demodulators. Two input signals are required for inputs to each demodulator—incoming video, and the 3.58-MHz reference signal. Now, return to the first color-bandpass amplifier and follow the path leading to the color-burst amplifier. This stage is keyed on during retrace, thus passing the color burst to the 3.58 oscillator. There are three common types of 3.58 oscillator systems used in color-television receivers: the APFC system (best), the crystal oscillator (good), and the 3.58 crystal ringer (fair). For simplicity, the circuit chosen for this example is a 3.58 crystal ringer. Color-killer circuits and automatic-color-control are not required, since absence of a 3.58 MHz crystal-activating burst produces no signal for the de-

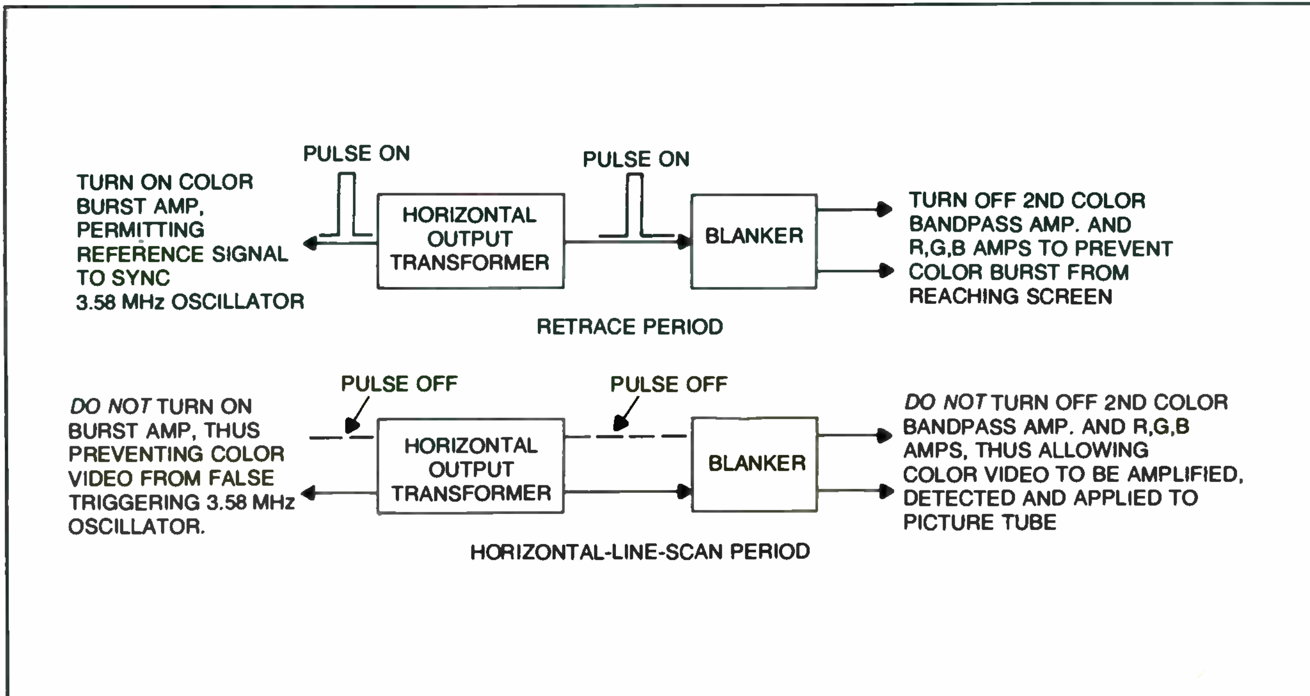


Fig. 6-4. Synopsis of key action in color circuits of television receiver.

modulator. Each 8 to 10 cycles of 3.58-MHz burst reaching the oscillator circuit synchronizes the phase of that stage with the phase of the transmitting station. This ensures that the reproduced colors will be accurate copies of the original colors. The 3.58-MHz signal is then amplified, limited, and applied to the R–Y and B–Y demodulators. A 90-degree phase shift is required for R–Y, because the +R–Y axis is 90 degrees lagging –B–Y. The two signals at the R–Y and B–Y demodulator inputs are then processed and converted to R–Y and B–Y video signals.

These modulators are conducting 90 degrees apart, with the 3.58-MHz signal determining precise conduction times. This technique of exact-time condition at specific degrees into each cycle of incoming color information that determines the exact demodulation axis. As an example, conduction at 57 degrees lagging the burst creates I information while conduction at 90 degrees lagging the burst creates R–Y information. The resultant R–Y and B–Y signals are then summed to regenerate the missing element, G–Y. This concept is relatively straightforward: R = 30, B = 11, combined = 41; 41 – 100 = 59; Green = 59. The R – Y, B – Y, B – Y, and G – Y signals are then applied to their respective amplifiers. Notice the (delayed) Y signal is also applied to these amplifier stages. The Y delay was necessary because of the inherent delay in narrowband R – Y, B – Y signals. Essentially, capacitors in narrowband circuits require additional time periods to charge and discharge and this delays color signals. The wideband Y signal must thus be delayed by a similar amount so all signals arrive simultaneously at the R, G, and B amplifier inputs.

There are two signals at the input of each color amplifier, and their purpose is signal summation. The R–Y signal and the (+)Y signal combine to produce red. Likewise, B–Y and (+)Y and G–Y and (+)Y combine to produce blue and green video. These modulating signals of 50 to 100 volts peak-to-peak (depending on the setting of red, green, and blue video-gain controls) are then applied to the color picture tube. A color television picture is the end result of this operation.

As mentioned, the R–Y, B–Y concept of demodulation is a narrowband and limited form of color-picture reproduction. This system is, however, less expensive than wideband-demodulation systems because fewer stages are required. Narrowband demodulation is often referred to as high-level demodulation because the narrowband stages provide higher signal gains and consequently produce a high signal level at demodulator outputs. Wideband demodulation, conversely, requires wideband stages which restrict output levels to accomplish their tasks. The result is a low-level signal at demodulator outputs. The selection of bandwidth and color-picture resolution are thus a "toss up" which must be left to the individual preferences. Wideband television receivers are more sophisticated and expensive; however, their color reproduction is noticeably better than that of simpler designed and less expensive narrowband television receivers.

WIDEBAND RECEIVER CIRCUITS

The wideband-type color-TV receiver is, in general, similar to the narrowband receiver. The demodulation axis shifts to I and Q, however, bringing into play wider bandwidths and additional amplifier stages. Since +I, −I, +Q, and −Q must be combined in proper proportions to recreate either R−Y, B−Y, red or blue, a matrix stage is required in a wideband television receiver. Finally, phase shift circuits are slightly different in wideband receivers, thus establishing the different demodulation axis. The block diagram of a typical wideband (I, Q) color-television receiver is shown in Fig. 6-5. The video amplifier's input (top left) is connected to the video detectors output, thus amplifying both luminance and chrominance signals. The Y signal continues "straight ahead," as it did in a narrowband receiver, while chrominance signals divert to the first color-bandpass amplifier. This stage is tuned to accept *wideband* color signals 2.08 to 4.08 MHz above the Y signal carrier, and pass that information to the second color-bandpass amplifier. Notice, as explained in narrowband receiver operation, the first color bandpass amplifier operates all the time. During a line of color video, incoming information proceeds through the second bandpass amplifier to the color-level control. That signal then continues to the (wideband) I and Q demodulators. Assuming a 3.58-MHz reference signal is also present at the demodulators, the output I and Q signals are directed to phase splitters for obtaining +I, −I, +Q, and −Q signals (merely in-and-out-of-phase signals: +I is signal "in phase" with itself, while −I is signal "out of phase" with itself). Since the narrowband Q signal (0.5 MHz) exhibits an inherent delay of 1 microsecond, the medium bandwidth "I" signal (1.5 MHz) must be delayed 0.5 microsecond and the wide bandwidth Y signal must be delayed 1 microsecond. These delays ensure that all three signals (Y, I and Q) arrive simultaneously at the matrix. There are five signals applied to the matrix: Y, +I, +Q, −I, and −Q. This stage combines specific proportions of the desired signals, and sends

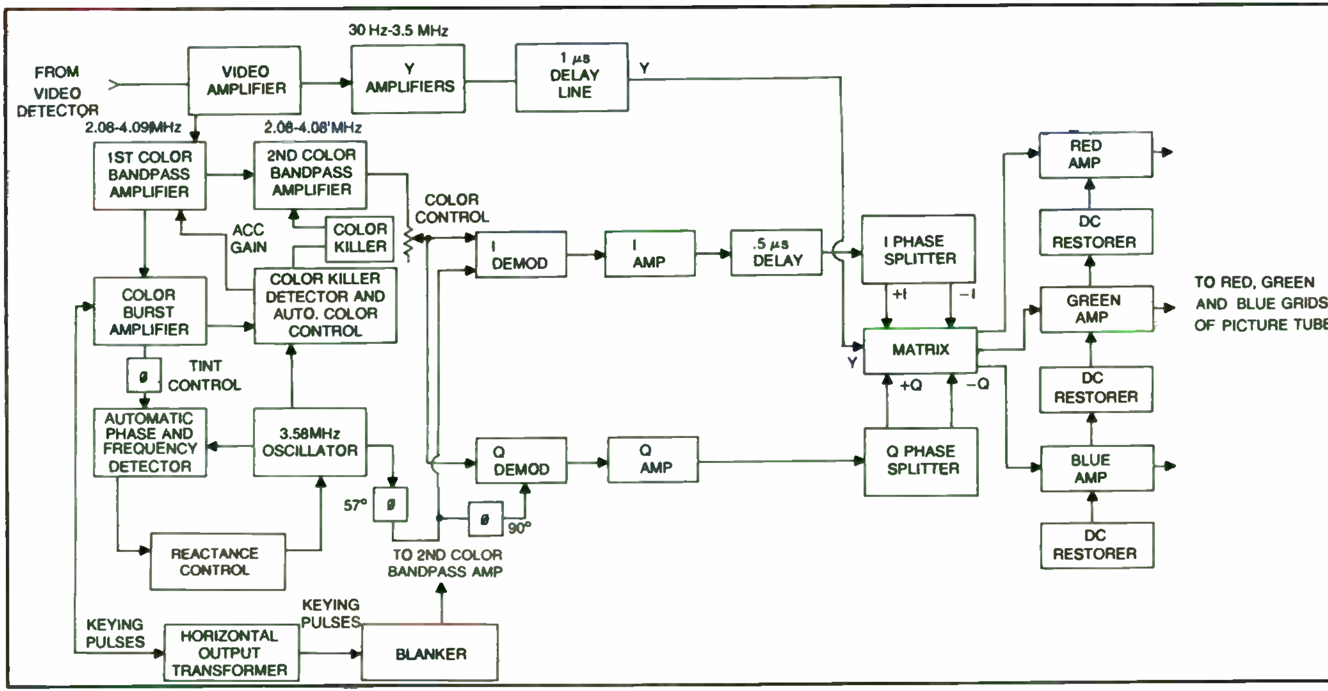


Fig. 6-5. Block diagram of typical color section in a wideband (I/Q) receiver. Unit shown uses APFC and reactance control. Overall bandwidth of color is 2 MHz.

those three signals to the red, green, and blue amplifiers. As an example, +I is composed of 74 percent (R–Y) and 27 percent of –(B–Y). Realizing that R–Y is composed of +70 red, –59 green and –11 blue, and B–Y is composed of –30 red, –59 green and +89 blue, +I thus contains color percentages as follows: +60 red, –28 green and –32 blue. The three retrieved colors eminating from the matrix are boosted in level by the red, green, and blue video amplifiers before application to the color-picture tube. Three dc restorers are used to ensure that all three amplifiers see the same "signal-black" level and cut off at the same point. Dc restorers might be omitted in inexpensive television sets. However, the logic of design in more elaborate (wideband) systems requires use of dc restoration. Additionally, dc restoration must be used in wideband systems which necessarily cannot use picture tube matrixing.

Returning to the first color-bandpass amplifier, note another line going from the first color-bandpass amplifier to the color-burst amplifier. Although both color video and 3.58-MHz color-burst reference signals pass along this path, the color-burst amplifier is keyed into operation only during the retrace period (the time when only a color burst is present). This action thus directs 3.58-MHz reference bursts through the phase-shifting tint control to the Automatic Phase and Frequency Control (APFC) detector circuit. Since the tint control "tricks" the television receiver concerning actual phase of the reference signal, the displayed pictures thus follow that reference and designate red, green, and blue as their true colors or as colors within approximately 30 degrees of those colors. The APFC circuit accepts two signals on its input: The TV receiver's 3.58-MHz oscillator signal and the transmitted 3.58 reference signal. The APFC circuit develops a dc correction voltage proportional to the phase difference between two signals. This dc voltage is applied to the reactance control, which in turn provides a reactance shift (either inductive or capacitive depending on receiver design) to synchronize the 3.58 MHz oscillator in the TV receiver with the transmitter. That phase-locked signal is shifted 57 degrees by an L/C circuit and applied to the I demodulator. Another 90-degree phase shift is used to further delay the 3.58-MHz reference signal, providing a Q-axis signal for application to the Q demodulator.

Returning to the diagram and the 3.58 MHz oscillator, note another line running to the color-killer detector and automatic-color-control. This circuit monitors the two 3.58-MHz signal amplitudes (TV receiver and transmitted signal) and develops a resultant dc voltage. The dc voltage directed to the first color bandpass amplifier controls that stage's gain, while the dc voltage directed to the color killer biases that stage on or off as determined by the presence of an incoming color burst and the television-receiver color burst. Conduction and non-conduction of the color killer, in turn, determines whether the second bandpass amplifier is on or off. This permits color section operation during, but only during, color-TV signal reception. Lacking that circuit, the color section would operate during black-and-white telecasts (when color information isn't available). The resultant display would include colored "snow" interspersed with the black-and-white picture.

The APFC system shown with the wideband color system of Fig. 6-5 is typically found in better quality receivers, primarily due to the additional cost of those units. The less sophisticated color-sync arrangement (crystal ringer) shown in Fig. 6-2 could be substituted in the wideband system, but the move wouldn't be financially logical.

PICTURE-TUBE MATRIXING

The previous descriptions of narrowband and wideband color-television receiver systems outlined two forms of summing R–Y, B–Y, G–Y, and (+)Y to produce red, green, and blue video signals. The narrowband system uses the common practice of video-amplifier combining, while the wideband system uses a resistor-network matrix. A third form of signal combining which may only be used in narrowband systems (high-level demodulation) is also quite popular: picture-tube matrixing. This arrangement is illustrated in Fig. 6-6. This concept applies demodulated R–Y, B–Y, and G–Y signals to picture-tube grids, while –Y is applied to the parallel-connected picture tube cathodes. (+Y and –Y is merely the same signal, inverted 180 degrees. A simple transistor or tube circuit exhibits such signal inversion between input and output.) The R–Y, B–Y, and G–Y signals are thus inverted and combined with the –Y signals, producing red, green, and blue video. Example: R–Y, B–Y, G–Y applied to grids become –(R–Y), –(B–Y), –(G–Y); –Y is applied to cathodes, and not inverted; –Y signals cancel; –(R–Y) and –Y = R; –(B–Y) and –Y = B, etc. A look at picture-tube action would show each grid increasing electron-gun output for its respective signal, while that particular gun's output would be reduced at that specific time according to only the Y signal.

Picture-tube matrixing is particularly beneficial from several standpoints: It reduces television-receiver circuitry to the min-

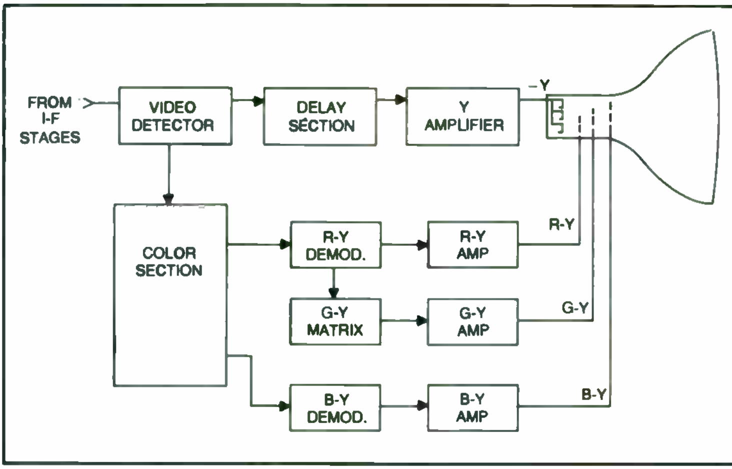


Fig. 6-6. Picture-tube matrixing provides R-Y, B-Y and G-Y applied to grids while −Y applies to cathodes. The −Y signals cancel, leaving red, green and blue video signals.

imum acceptable level; it's easier to construct and troubleshoot; and it can provide operation with only one dc restorer. This assumes that direct coupling is employed with stages between color demodulators and picture tube grids. Should that dc component be lost, three dc restorers will again become necessary.

COLOR-SYNC SYSTEMS

Three forms of color-sync system are used in color television receivers. The crystal ringer, burst-driven oscillator, and the APFC system each provide synchronization of the color receiver's demodulators by recreating a 3.58-MHz signal exactly like the 3.58-MHz signal at the transmitter.

The APFC system bears a striking resemblance to an AFC (automatic frequency control) system, with the end result of providing positive tracking of the 3.58-MHz signal which appears each 53.5 microseconds on the "back porch" of the horizontal sync pulse. A color-killer arrangement is used in receivers with APFC systems.

The burst-driven oscillator arrangement allows 3.58-MHz color burst signals to directly influence the color receiver's 3.58-MHz oscillator, synchronizing its oscillations to the transmitted signal. Color-killer stages are also required with the burst-driven oscillator.

The crystal-ringer system is a prime example of simplicity in accurate operation. The transmitted 3.58-MHz sync burst is applied directly to a 3.58-MHz crystal, which rings in a damped-wave fashion when hit by this signal from the bandpass amplifier. The actual waves from the crystal are varying amplitude, fixed frequency (3.58 MHz). An amplifier/limiter stage then amplifies the crystal output and maintains a constant output-signal level.

During black and white telecasts, the 3.58-MHz sync burst is obviously deleted from the horizontal "back-porch" period. Without this "shock-exitation signal," the color receiver's 3.58-MHz crystal stops ringing. The absence of that signal prevents color-demodulator operation, thus eliminating the requirement for color-killer stages.

HIGH-VOLTAGE SYSTEMS

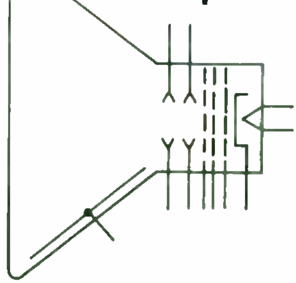
As mentioned in the previous chapter, the relative inefficiency of color picture tubes and their phosphors requires substantial high-voltage potentials. Additionally, three guns require three times the beam current required for single-gun tubes. This operational voltage is provided by the horizontal output transformer, or "flyback," in a color receiver.

The flyback in a color-television receiver is substantially larger than in a black-and-white television receiver. The high voltage produced is often multiplied two, three, or four times to provide potentials between 25 and 40 V for picture tube operation. Special forms of voltage doublers, triplers, etc., are commonly used. These power supplies subject rectifiers and filter capacitors to only portions of the total high voltage developed, while "dumping" all capacitor potentials on the picture tube proper. Power supplies of this nature have very poor regulation, however, their operation is ideally suited to color picture tubes.

Circuitry to generate the high voltages applied to color picture tubes can be a source of X-ray radiation, consequently, efficient metallic shielding of that area is required. As a matter of protection, such metal shields and cages should be kept intact during prolonged periods of receiver operation. An additional protective measure against X-ray radiation involves measuring, and adjusting as necessary, picture-tube high voltage to the manufacturer's specifications. The voltage may also be reduced slightly, provided focus and picture brightness are not sacrificed.

Chapter 7

Setting Up the Color-Television Receiver



During the early marketing period of modern color-television receivers, each unit was shipped to distributor/service centers in two boxes. One box contained cabinetry, color-picture tube, and all yoke assemblies while the second box contained the electronics. The distributor/service center's responsibilities thus included mounting the receiver electronics in its respective cabinet and performing a complete color checkout or setup of the unit. Since outside influences during shipment often effected sensitive components, service centers truly had their hands full preparing such units for sale. The operations involved included (in addition to unit assembly and all cable connections) degaussing, setting purity, static convergence, dynamic convergence, focusing, adjusting agc and high voltage, plus adjusting gray-scale tracking.

The next evolution involved, as a preliminary setup of the color-television receiver, simply degaussing the fully assembled unit and checking or fine-tuning convergence as necessary. The inclusion of automatic degaussing coils was a next step which resulted in "purchase, carry home, and view" color receivers. While this concept may be acquiring widespread acceptance, it is definitely a get-by compromise which limits a color receiver to less than its full capabilities—particularly when simple "rabbit ears" are connected to the receiver.

Reflecting on the previously outlined setup and adjustments of color-TV receivers, one can realize that superb picture-reproduction capabilities are available for a slight investment in alignment time. We should also point out that replacement of the picture tube in a color receiver requires the previously mentioned degaussing, purity, static, and dynamic convergence procedures. A description of color setup and alignment procedures is thus presented to this chapter. Many people have followed this information and consequently set up "from scratch" their own color television receiver. You, too, can obtain similar results by following the outlined procedures.

PRELIMINARY CONSIDERATIONS

The time devoted to setting up a color-television receiver to obtain maximum performance and quality has proven to be an effort which pays for itself tenfold. When considering the resulting long periods of excellent television performance, this fact should become vividly apparent. The techniques involved in proper setup of a color TV receiver are relatively straightforward and easily implemented, provided a systematic and logical procedure is followed. As an initial step, the specific unit's service manual should be reviewed thoroughly in order to gain acquaintance with the circuits of that particular receiver. Should the manual prove difficult to locate, a *Sam's Photofacts*® of the television set may be used *Sam's Photofacts* are sold at large electronic parts wholesale stores, especially those catering to television repairmen. In addition to containing a substantial amount of setup and service data, plus full schematic and pictorial diagrams, the sheets also feature a creditable amount of troubleshooting/repair data and signal-tracing waveforms. This information thus proves its worth to the serious video enthusiast.

The overall purpose of color-TV receiver adjustment is twofold. One is to assure the receiver isn't being influenced, and has not been influenced by external magnetic fields. As an example, either incorrect convergence or a magnetized picture tube could cause the condition of poor purity illustrated in Fig. 7-1. The term *purity* defines how pure a color is. Assuming only the red gun is activated, the blank raster should be pure, even, red and free of contamination from any other color. To eliminate the possibility of magnetization and to narrow the situation to a definite cause, the TV tube should be demagnetized and the purity checked again. The second purpose of color-TV receiver adjustment is to assure that each of the three electron beams hit their respective color phosphors (and only their respective color phosphors), producing a high

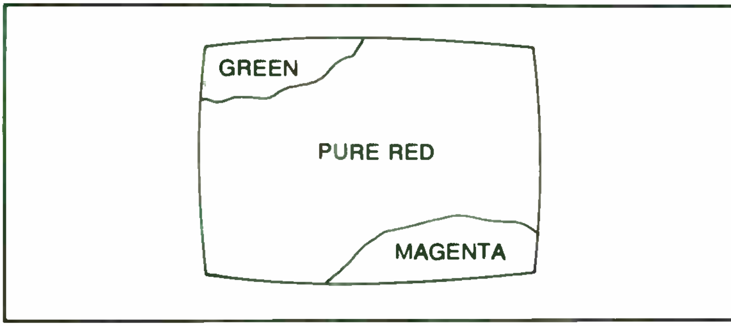


Fig. 7-1. Red raster with poor purity. This condition could be caused by either incorrect convergence or a magnetized picture tube. The unit should be degaussed before attempting internal adjustments.

quality color picture. This feat is accomplished through first converging the beams on phosphors located in the screen middle area (static convergence), and then on phosphors located at the screen outer areas (dynamic convergence). A stable display pattern, such as the dots or crosshatch provided by a color-bar/pattern generator is used for this operation. The fully converged television set is then refocused and rechecked for accuracy. Finally, gray-scale tracking is set to reproduce black and white scenes in original form. The technique of visualizing each step is emphasized. This will permit anticipating exactly what should happen with each adjustment, rather than "shooting blind" and watching to see what has happened to the reproduced display with each adjustment. It's also beneficial if only one person performs all adjustments while both that person and an assistant watch results on the reproduced scene. The "one set of hands" arrangement eliminates confusion and retracking various adjustments and/or steps. The assistant ensures that adjustments produce desired results in the specific screen areas and don't simultaneously produce undesired results in another screen area.

THE DEGAUSSING COIL

The item used for demagnetizing, or degaussing, the aperture mask and metal-bell portion of a color picture tube is simply an air-core electromagnet. It is similar to a very large tape-head demagnetizer. The degaussing coil may be purchased commercially, or home constructed, as desired. An outline for a degaussing coil is shown in Fig. 7-2. Approximately 450 turns of number 22 or 24 wire are wound (in the neatest possible manner) or a nonmetallic form (hoop) approximately 12 inches in diameter. Plastic electrical

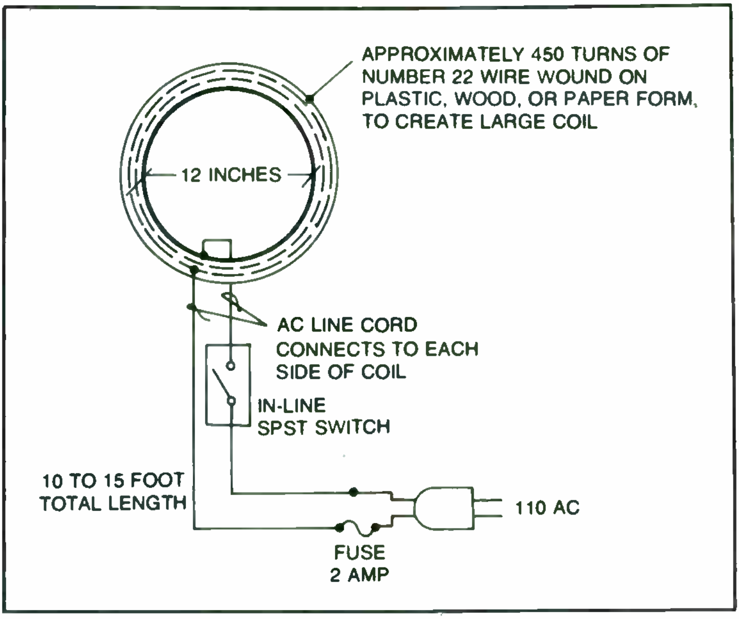


Fig. 7-2. Construction details for a degaussing coil. Wire may be obtained from electronic parts stores or salvaged from secondary winding of a discarded power transformer. Wind wire lengthwise around form to create a 12-inch coil.

tape may be used to secure each 50 or 100 turns, providing a neatly finished coil. The coil's ends are then secured and soldered to a 10- or 15-foot length of ac line cord which is open on one side to accept a single-pole, single-throw momentary switch and an in-line fuse. Care should be exercised to ensure both coil connections are *well insulated* and *secured against physical abuse or stress*. The finished product is then firmly wrapped with several layers of plastic electrical tape. Operation may be verified by watching the effect on a black-and-white television set. *Caution:* should power to the degaussing coil be interrupted when it is in proximity to a color-picture tube, the tube will actually become magnetized (loss of purity). Always check a degaussing coil for consistent operation before moving it close to a color-picture tube.

TECHNIQUE OF DEGAUSSING

In order to neutralize any stray magnetic fields which may have affected the color-picture tube, the degaussing coil's field is directed near that tube's sensitive areas. Ac power is applied and the coil is moved near the front, sides, and top of the picture tube (or receiver cabinet). If the bottom area is accessible, it should also be degaussed. Keep coil away from magnetic assemblies on the neck of the picture tube (rear area), as it could demagnetize the permanent magnets in the purity rings and convergence yoke.

Begin by holding the coil approximately six feet from the television and switching on the coil. Hold the coil parallel to, and at a distance of 6 to 12 inches from the area being degaussed. Remember to keep the coil in continuous motion all the time power is applied, and don't turn off power when the coil is near the television picture tube. Rotate the coil in a stirring motion as illustrated in Fig. 7-3, and cover all accessible areas in a smooth manner. Continue the smooth, circular motions as coil moves around the cabinet, then return to the front-screen area and conclude with widening circles while moving the coil away from the screen. When the coil is between six and eight feet from the screen, turn it at a right angle, and switch off the power. The entire degaussing procedure should last approximately one to two minutes.

Since the television receiver must be operational during the degaussing process, a display of unorganized colors following patterns similar to the degaussing-coil field will be noticed. This disarray of color is no cause for alarm, for the screen will clear into a smooth and correct display when the degaussing coil is finally moved away.

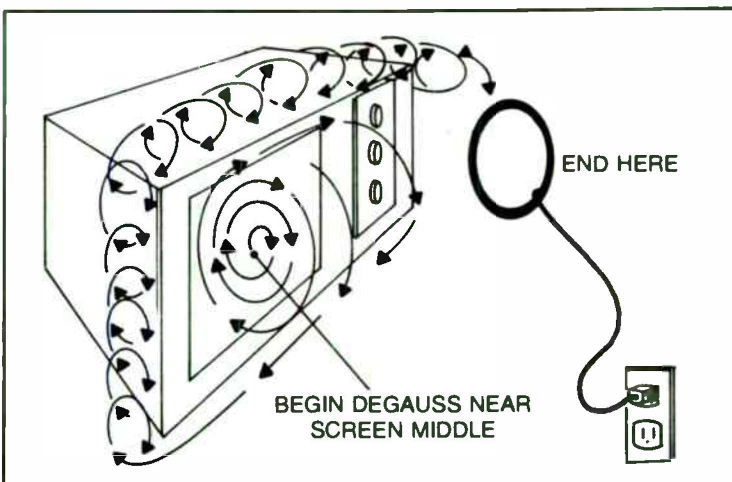


Fig. 7-3. Technique for degaussing color television. Spiral motion should begin at screen's center and progress outward. Spirals also circle sides, top and bottom of television receiver.

CHECKING AND SETTING HIGH VOLTAGE

In order to produce a bright, clear, and well-defined picture, a television receiver's high voltage should be set to the manufacturer's specifications. This value is listed in related data sheets. A high-voltage probe and a steady hand are required for this relatively simple procedure. While the high voltages in color receivers are low current and generally non-lethal, they can produce some experiences which are preferably sidestepped. This is best accomplished by *first* connecting the probe's ground strap to the TV receiver's chassis, and then using only one hand for handling measurements. The high-voltage probe's tip is then slipped under the picture tube's high-voltage, or ultor, connection. A solid connection is made when any arcing or "spitting" ceases, and the meter reading stabilizes. The high-voltage adjustment on almost all television receivers is located near the flyback and high-voltage cage. If the adjustment isn't readily apparent on the chassis rear apron, check on top of the inner chassis or refer to the data sheets.

CHECKING AND SETTING FOCUS

Focus should be adjusted next so that sharply defined, distinct, dots or lines will be available for color setup procedures and for a resultant superb color picture. This control is usually located on the chassis rear apron—often very close to the high-voltage adjustment. A mirror is advantageous when attempting this adjustment. Moving the focus control should produce a point at which individual, sharp, scanning lines are detectable. It may be necessary to readjust this focus control after all convergence adjustments, depending on individual preference of "sharp" or "soft" picture reproduction.

USING A TV PATTERN GENERATOR

The next steps in color TV setup will require the use of a stable test pattern, such as that produced by a pattern generator or color-bar generator. Several styles of pattern/bar generators are presently marketed, and most will perform in a very creditable manner. Become familiar with a particular unit by reviewing its instruction manual. One manufactured unit, for example, might generate its signal on Channel two or three while another unit might use Channel four or five. Likewise, some generators feature front-panel attenuators while others delete that function. While most pattern-bar generators are straightforward in design and ready for

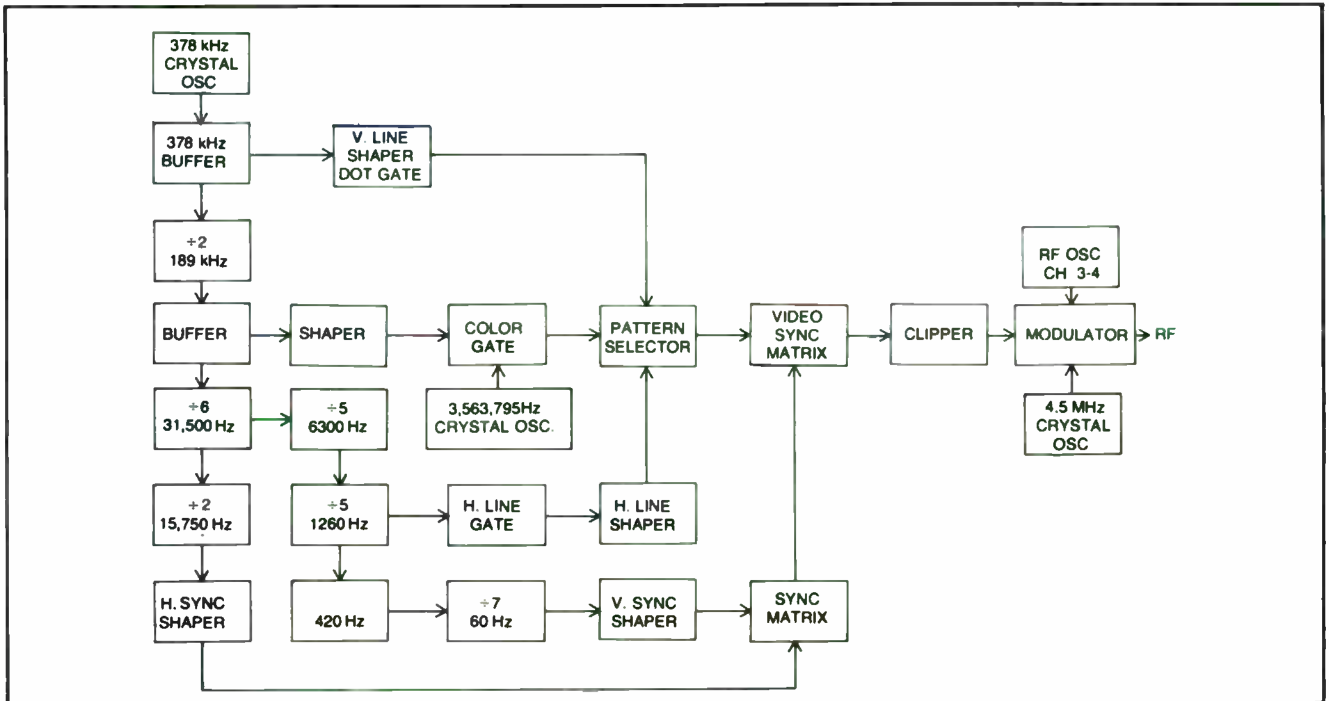


Fig. 7-4. Block diagram of a typical television pattern/bar generator. Specific design features often vary between units.

use by the technician, the benefits of reviewing an instruction manual shouldn't be simply ignored. A block diagram of a representative pattern/bar generator is shown in Fig. 7-4.

SETTING COLOR PURITY

In order to produce a high-quality color picture, a receiver must exhibit true and pure color rendition. Good purity exists when electrons from the picture tube's red gun strike only red phosphors, electrons from the blue gun strike only blue phosphors, and electrons from the green gun strike only green phosphors. Such being the case, color reproduction would be pure and free from extraneous contamination by undesired colors. One of the most popular means of checking color purity involves examining the blank raster produced by each electron gun one at a time. This is accomplished by disabling the two other guns and removing all video-signal information. The picture tube's guns can be disabled by the use of biasing voltages, if desired. However, a simpler method involves reducing rear apron color-drive controls for two of the three guns. Many bias systems use insulation-piercing clips which attach to the picture tube leads. As a result of using such clips, arcing may become troublesome at a later date. The disadvantage to using a receiver's screen, or drive, controls for varying electron gun output is a possible unbalance in red, green, and blue color mixture. This factor is of minor consequence, however, since color balance and gray-scale tracking will be reset (and possibly readjusted according to personal preference) later. Assuming the particular television receiver being adjusted includes both drive and screen controls, the drives (which affect picture highlights and thus have the most effect on beam outputs) are the preferred adjustments. It should be considered also that many color-pattern generators feature a "raster" position primarily intended for producing a blank raster on the television receiver under test. If using this arrangement, one only needs to then vary the screen controls to provide red, green, or blue rasters for purity examination and setup. If a suitable pattern generator isn't available, tune the receiver to an unused channel and short the antenna terminals. Alternately, the tuner's output cable can be unplugged from the i-f input connection (refer to Chapter 4 for this location).

Since the eye is highly sensitive to hues of red, the red raster should be examined first. Any evidence of color contamination (see Fig. 7-1), such as areas of green or magenta in the red raster, indicates that electrons from the red gun are exciting incorrect phosphors (magenta is produced by excitation of both red and blue phosphors). A display of improper purity could be caused by one of two situations: 1) a magnetized picture tube, or 2) incorrect purity-ring adjustment. The television receiver should be subjected to thorough degaussing at this time to narrow the search for color contamination.

Assuming improper purity still exists, the two purity rings located between the picture-tube's convergence yoke and the tube's rear connector will require adjustment (see Fig. 7-5). An outline of purity-ring action is illustrated in Fig. 7-6. When the rings tabs are together, their magnetic fields cancel and minimum effect is produced. As the ring tabs are separated, a beam-positioning magnetic field is released, its intensity being determined by the amount of ring tab separation. Rotation of the purity rings will determine both beam position and which of the three beams is most affected by that positioning. One of two techniques may now be used. While using a mirror to view the complete screen area (dim room suggested), vary the tab separation and ring rotation until a pure red raster is produced. This adjustment isn't highly critical, but it does take time—usually 15 to 20 minutes, depending on individual "perfection incentive." An alternate method involves loosening the deflection-yoke clamp and sliding the yoke forward or backward (depending on the particular picture tube) until a "red ball" is visible on

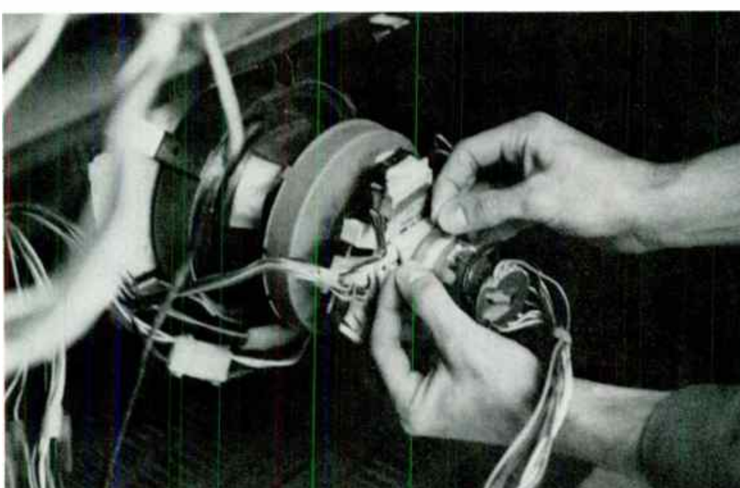


Fig. 7-5. Adjustment of purity rings on a color-picture tube. One ring is held stable by its tab while other ring is moved. Both rings may be moved by simultaneously moving tabs.

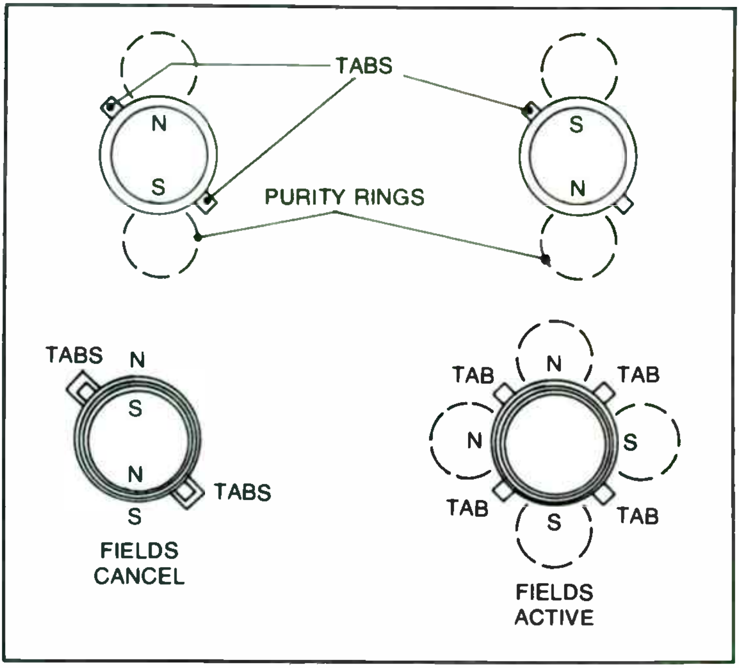


Fig. 7-6. Outline of magnetic-field action of purity rings as discussed in text.

the screen. The purity rings are then adjusted until the ball is in screen center. The yoke is then returned to its original position, causing the ball to expand and precisely fill all the screen with only the individual color (red in our example). Should the latter technique result in a ball which doesn't maintain center when the deflection yoke is repositioned, the first technique (not moving the yoke) may be preferred. Note: The convergence yoke is not to be moved. When purity of the red raster has been obtained, the blue and green rasters may be checked by activation of each gun according to the previously described technique.

After purity of the red, green, and blue rasters has been confirmed, all three guns are readjusted to produce a pure white raster. This is easily accomplished in the following manner. Lower all screen controls to minimum (screen goes dark). Increase the red screen control until the raster is a definite red. Next increase the blue screen control until the raster becomes a definite magenta (under-adjustment creates red; over-adjustment creates blue). Finally, increase the green-screen control until the raster becomes true white, or grayish (under-adjustment creates pale magenta;

over-adjustment creates green). The entire white raster should now be free of any excessively bright areas or color contamination.

SETTING STATIC CONVERGENCE

The term *static*, when used in color-television setup refers to the no-signal, or middle-of-picture-tube screen area. Static convergence thus deals with producing true color rendition in this area. Technically speaking, good convergence exists in a color-picture tube when all three beams converge on the same hole in the aperture mask and then diverge to excite their respective color phosphors. The necessary corrections for such misalignments are provided by permanent magnets mounted inside the convergence yoke (see Fig. 7-7).

The convergence yoke for a delta-gun tube is assembled in a "Y" form. Inside the assembly, three permanent magnets wound with coils are situated on "tracks," or provided with shunts to permit varying their flux and its effect on respective electron guns within the color picture tube. The coils on each magnet are provided with waveforms for setting dynamic convergence while the magnet position sets static convergence. Some interaction between these fields is inevitable, consequently, static convergence is adjusted

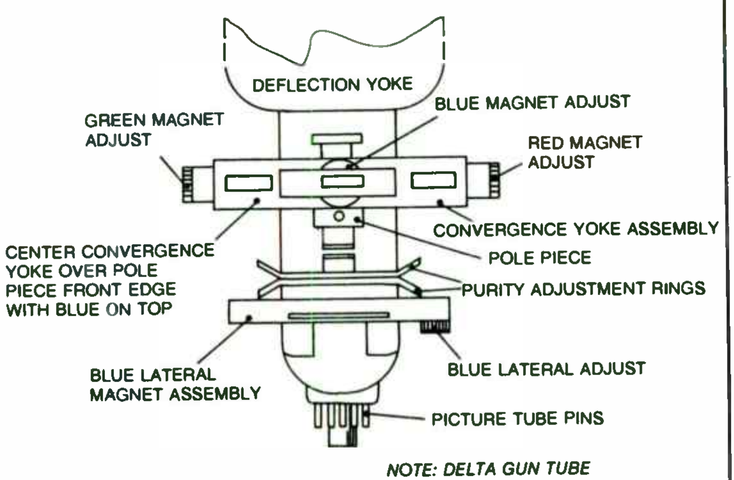


Fig. 7-7. General outline of convergence yoke plus blue-lateral assembly and purity rings on rear of color picture-tube neck. Note deflection yoke, convergence yoke, blue-lateral and purity rings are separate items. Some receivers place blue lateral ring against convergence yoke, with purity rings behind both.

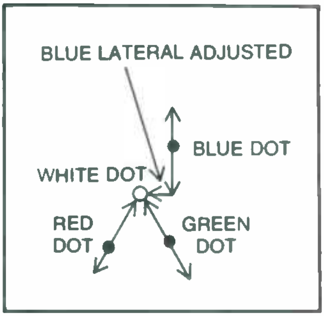


Fig. 7-8. Movement of electron beams on color picture-tube screen as produced by convergence yoke.

first. Three static-convergence thumbwheels will be noted on the ends of the convergence yoke; one wheel for red, one for green, and one for blue. Each beam's position on the screen can be adjusted by its thumbwheel. Movements of those beams is illustrated in Fig. 7-8. Notice that a fourth adjustment, lateral movement of the blue beam, is required for complete "stacking" of the three beams. This function is performed by the blue lateral magnet and it's thumbwheel adjustment, see Figs. 7-9, 7-10, and 7-11.

A test-pattern generator is then connected to the television receiver's antenna terminals and a crosshatch pattern (black-and-white lines) is selected. If the receiver is properly converged, no color lines or "fringes" will be visible. If the receiver needs converging, separated color lines will be visible. Should a question on

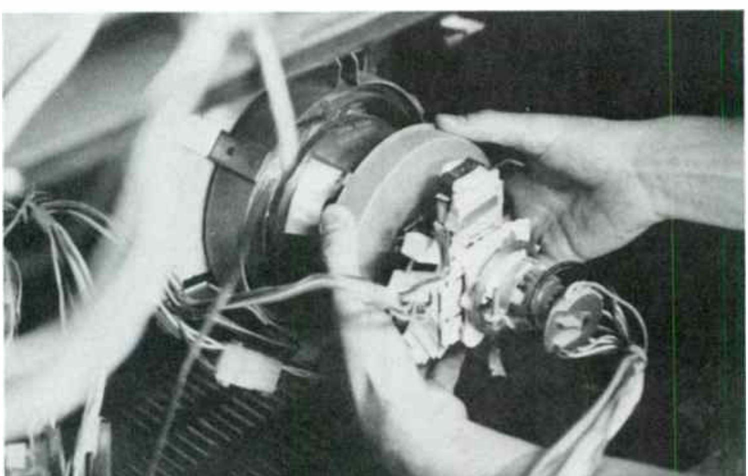


Fig. 7-9. Moving deflection yoke and delta-gun tube to produce "red ball" on screen as described in text. This is first step in static convergence procedure. It is followed by adjustment of purity rings as previously described.

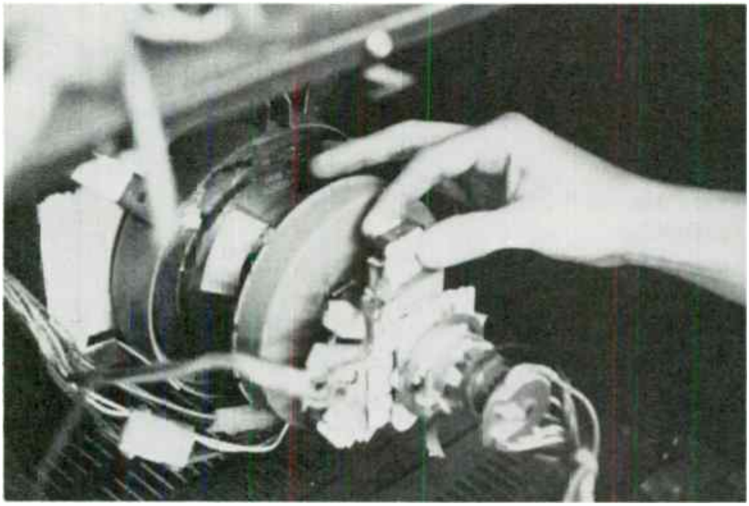


Fig. 7-10. Adjusting blue magnet on convergence yoke to move beam vertically as shown in Fig. 7-8.

line convergence arise, the test pattern generator may be switched to "dots" for a more detailed examination. Assuming lines/dots within the screen's middle area are not in register, the beam positioners located on the convergence yoke, and the blue-lateral magnet can be adjusted. These adjustments are semi-critical, but

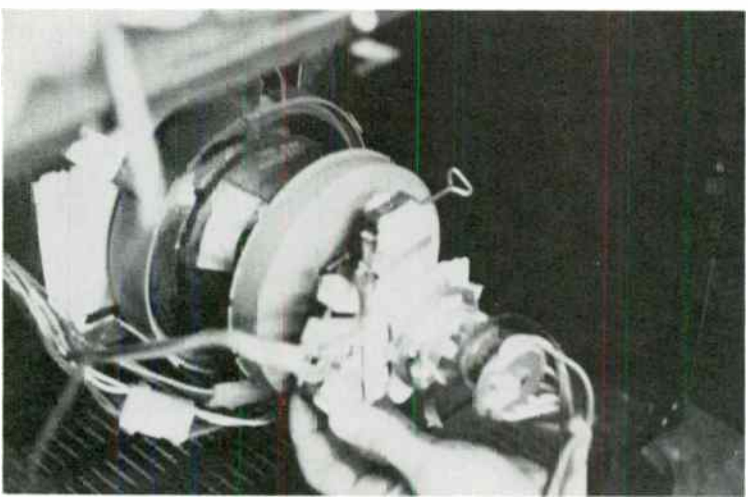


Fig. 7-11. Adjusting green magnet on convergence yoke to move beam diagonally as shown in Fig. 7-8.

the visible display of dots/bars on the screen allows one to carefully guide each beam into its proper location (the technique is often referred to as being similar to playing a space-invader game on a screen—from behind the set!). Patience and confidence will guide you through this 15- to 30-minute step. Notice that adjustment of red and green static-convergence magnets move the red and green beam diagonally at two different angles with respect to the blue beam which can move vertically or laterally. The usual procedure for adjusting static convergence is to adjust the red and green beams to produce yellow dots/lines in the screen's mid areas, then use the blue-beam positioners to include that beam and produce white dots/lines. Whenever possible, try to converge as much total screen area as possible with static convergence adjustments. This step will simplify the task of dynamic convergence. Remember, however, static convergence should be primarily directed at screen center areas: this consideration is primary while outer screen edges (dynamic convergence) are secondary. In other words, static convergence may affect all areas but dynamic convergence basically affects outer areas. An assistant "viewer" and a floor-stand mirror will prove invaluable during all convergence adjustments. Remember to watch for both desired *and* undesired effects during all convergence adjustments. Now, review the complete procedure, and proceed to dynamic convergence.

SETTING DYNAMIC CONVERGENCE

The screen's outer areas come under close scrutiny during this operation; it is necessary to "stack" all three beams, thus producing only white dots/lines throughout the screen's viewing area. At this point, it should be pointed out that some color television receivers are not capable of *total* perfect dynamic convergence. This especially holds true for short-neck-picture-tube portables with high deflection angles. Top and bottom areas may, therefore, require "compromise" adjustments in order that other screen areas exhibit proper dynamic convergence. The secret of successful dynamic convergence involves knowing what is optimum—and when to stop. The virtues of patience and persistence essential, realizing all the while that dynamic convergence adjustments are not critical and do not create the serious disorders readily apparent in poor static convergence. Indeed, many brand-new color receivers on display in dealer showrooms often exhibit misconvergence at screen extremes.

The usual color-TV receiver features an arrangement of six to

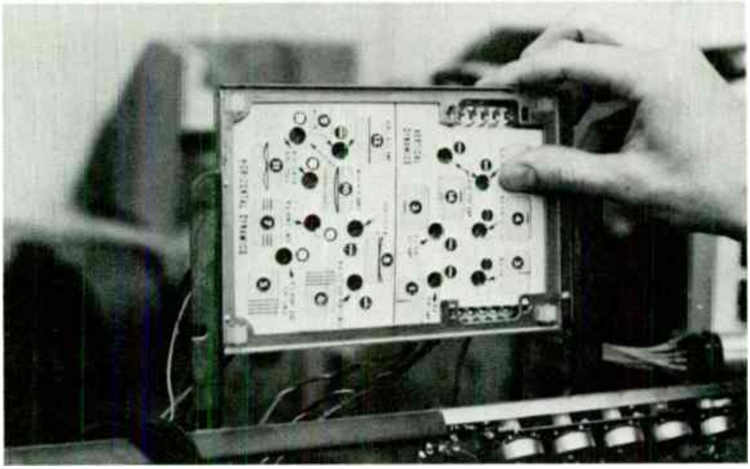


Fig. 7-12. A typical dynamic-convergence panel features 6 to 9 potentiometers and three variable inductors. A heavy paper overlay describes numerical sequence of adjustments while screen sketches illustrate effects.

nine potentiometers and three variable inductors on the dynamic-convergence panel. See Fig. 7-12. This panel is usually mounted to allow moving and repositioning in rear-cover screw holes, which should result in your being able to reach the controls from the receiver's front. The adjustments are usually grouped so the red and green beam movements are interconnected and blue adjustments are separate. Figure 7-13A shows the location of the controls on the convergence circuit board, while B shows the area of the screen and the beams affected by each control. Similar information for individual color-TV receivers usually appear on, or near, the unit's dynamic-convergence panel. Since the sequence of dynamic control adjustments may be different for various receivers, that unit's service sheets should be consulted and followed. Many receivers include an overlay on their dynamic convergence panel, indicating numerical order of adjustments, complete with arrows indicating control location and sketches showing those control's effects on screen displays. The chances of going wrong while using such guidance are thus minimized.

Bear in mind that dynamic-convergence adjustments affect outer areas of the screen, and that while one adjustment produces desired results in one area, it may produce undesired results in another area. Again, the extra eyes of an assistant are suggested. During the initial dynamic convergence, the test-pattern generator will probably be set to create a crosshatch of lines. As lines con-

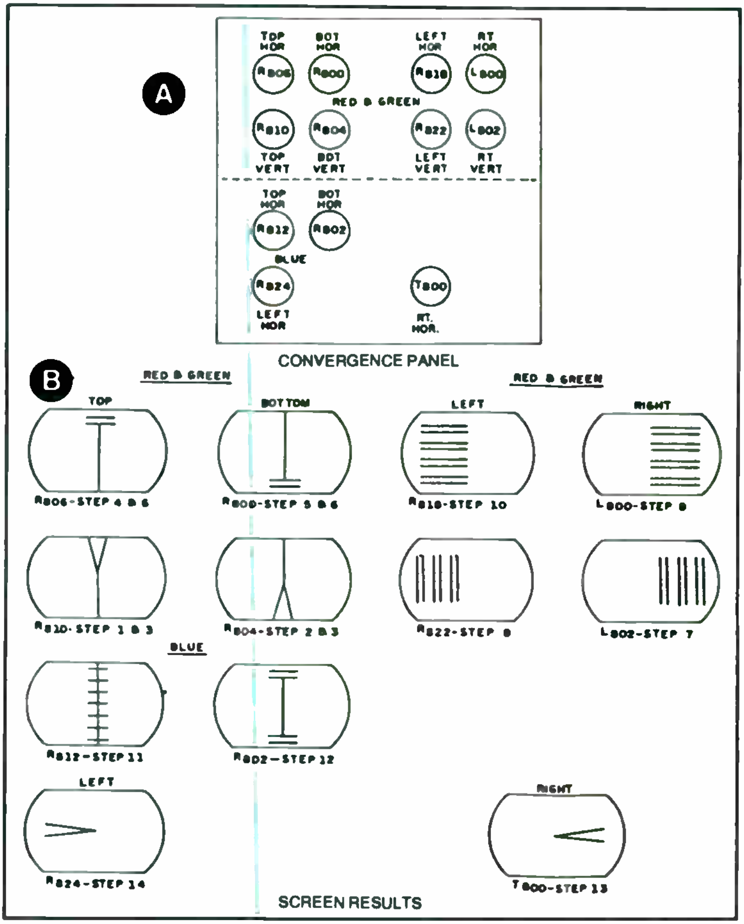


Fig. 7-13. Adjustment of controls on dynamic-convergence panel (A), and results produced on screen by each control (B).

verge, the generator's dot pattern will prove beneficial in providing a more accurate display for final adjustments. Before concluding, recheck and, if necessary, adjust static convergence. This, in turn, may require a touch-up of dynamic convergence. Finally, recheck/readjust picture focus as desired.

GRAY-SCALE ADJUSTMENTS

The purpose of these adjustments is to provide proper black-and-white or color reproduction of displayed pictures during both low-light and high-light periods. These adjustments are also known as proper painting of color lighting in reproduced pictures. The results will provide optimum color reproduction of both dim and bright scenes and their combinations during normal telecasts. While a receiver's service-normal switch is often used for initial set-up of color guns, it is not used in this procedure in order to obtain a more accurate overall picture display.

A cluster of color controls is usually located near or on the chassis apron of a color receiver. Close inspection will reveal three of these controls are marked red, green, and blue screens, while the second group of controls are marked red, green, and blue drives. Some receivers may designate drive controls by other names, such as background. If, however, the controls are not labeled screens, their functions are similar to drives. Furthermore, a small number of color receivers have been manufactured lacking drive controls. These receivers allow only limited adjustment of gray scale/color tracking.

As a starting point, we will assume all three color guns are operating normally and relatively accurate color reproduction is being obtained. If this is not the case, increase red, green, and blue screens as previously described in this chapter to obtain a full-color picture (or a blank white raster if a color pattern generator is available). Reduce room lighting to a low value to permit easy recognition of displayed effects, and prepare to switch between a blank raster and an incoming full-color picture as required.

The three screen controls affect primarily lowlights, or dim picture contents while the three drive controls affect primarily highlights, or bright-picture contents. Some interaction between screens and drives will be noticed. The following adjustments can be repeated until satisfactory results are obtained, see Fig. 7-14.

Reduce the three screen controls to a minimum, or to the point where a black raster (dark screen) is produced. If the viewing screen doesn't go dark, but instead exhibits one color, that color's drive control can be adjusted to provide a black raster. At this time, the color-burst vectors illustrated in Fig. 7-15 should be reviewed to understand upcoming action. Note, for example, an equal combination of red and blue light produce a resultant vector pointing to magenta light. An additional amount of blue would "swing" the vector in its direction, changing magenta to blue. Assuming the vector is at magenta, the inclusion of green (magenta's compliment) would cancel vectors and create white light. Likewise, green and red would properly mix to create orange. Blue would then increase to cancel orange, leaving only white light.

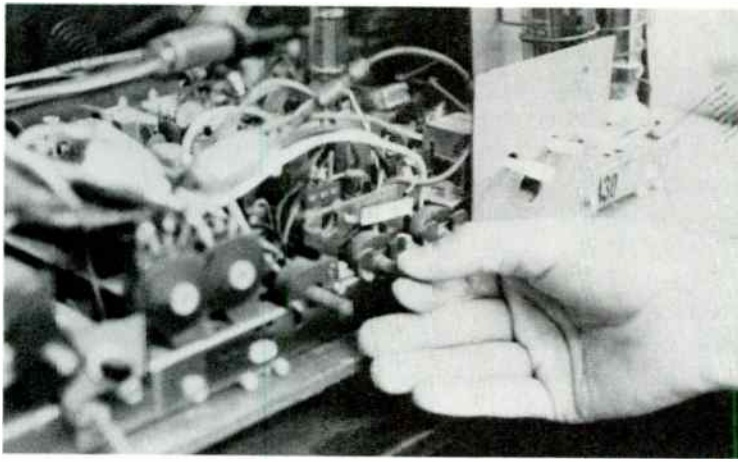


Fig. 7-14. Adjustment of screen controls on rear of television receiver for proper tinting of low lights as described in text.

Increase the red-screen control until a dim but pure red raster is visible. Next, increase the blue screen control until the raster becomes a pure magenta color (excessive blue will produce a predominately blue raster). Finally, increase the green screen control until the (dim) raster becomes purely white. Now readjust the receiver's brightness and contrast controls to produce a bright raster. Stand back and study the raster for predominance or lack of any particular color, then adjust that color's drive control accordingly until a pure white raster is achieved. Readjust the brightness control for a dim raster and recheck/readjust screen controls as required, then return to a bright screen and readjust drive controls if

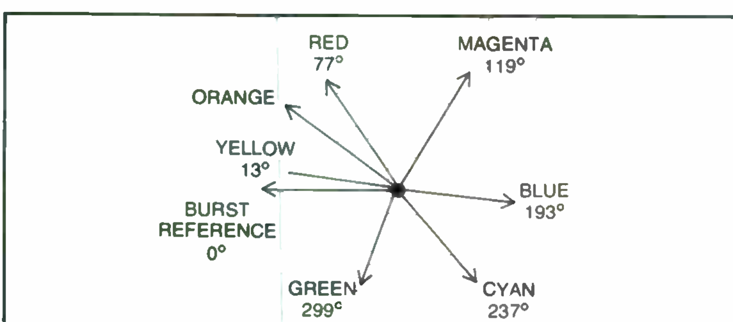


Fig. 7-15. Review of color vectors or clarification of color-gun mixtures. Red and blue, for example, produce magenta. Magenta's complement, green, would then produce white.

necessary. Finally switch to a color telecast and study the picture for personal appeal (some people desire an extra amount of blue, while others desire an extra amount of red). Adjust screens or drives (again according to individual preference, as previously noted) accordingly, but *only slightly* in order to maintain true gray scale/color tracking. Now sit back and view the superb results of your efforts. Your color picture probably looks better than many new sets!

SUMMARY

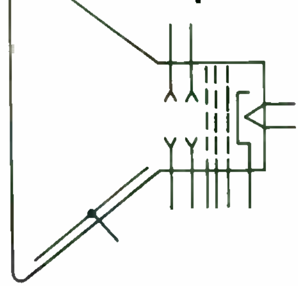
This chapter has presented, in a straightforward manner, a "hands on" technique for setting up a color receiver or monitor. The technique may be used in its entirety or piecemeal as desired. If you've never performed these adjustments, we suggest rereading this chapter and visualizing each step and its action before attempting color TV setup. The sequence of purity, static and dynamic adjustments are numerically linked; that is, purity affects both static and dynamic. Static affects static and dynamic, and overlooking the miniscule interaction between dynamic and static, dynamic is essentially self-standing.

Don't become misled or over-enthusiastic. Check the situation before beginning action. If color fringing is noted on faces, objects, etc., lower the color amplitude (kill the color) and check the black and white picture. If the receiver is misconverged, color fringing will still be apparent. If color fringing disappears, the TV antenna system is probably producing ghosts and the receiver is merely coloring them. Finally, the most-often used technique in receiver evaluation is reducing color level and viewing the resultant black and white picture. This simple technique readily displays errors in color setup—and you now have the information for correcting those errors.

The static and dynamic convergence adjustments outlined applied to delta-gun picture tubes. Some color receivers (such as those manufactured by K-Mart, etc., employ in-line-gun picture tubes. The convergence yoke on such in-line-gun sets is permanently affixed to the yoke during construction, resulting in few available adjustments. Dynamic convergence is fully eliminated, with a slotted aperture mask providing the only compensation for beam misplacements. Static and dynamic convergence adjustments of in-line tubes are thus referred to that manufacturer's instructions. The adjustments of gray-scale tracking, focus, high voltage, etc., are applicable to all color receivers.

Chapter 8

The TV Antenna



The overall performance and picture quality obtained from any television receiver can be directly related to its antenna system. Lacking that prerequisite, even the most sophisticated receiver is limited in its capabilities. (The arrangement of using "rabbit ears" with a new color-television receiver might be compared to placing four bald tires on a new Cadillac.) Realizing this, this chapter will present information concerning efficient and popularly priced antennas which may be used.

Horizontal polarization, as applied to television receiving antennas, is beneficial in reducing man-made noise such as that eminating from power lines, motors, etc. While this electrostatic interference is generally vertically polarized, television signals contain both electrostatic (vertical) and electromagnetic (horizontal) energy. The horizontal receiving antenna thus accepts primarily electromagnetic energy. The antenna lead-in wire is usually vulnerable to electrostatic interference; however, recent developments in shielded cables and twin lead have reduced this problem.

Television signals are broadcast on vhf and uhf bands, consequently, their propagation is line of sight. This requires that transmitting antennas (and receiving antennas) be as high as possible to obtain maximum range. Occasional storm fronts and unusual weather changes create reflective conditions known as signal-ducting paths, but this form of propagation is the exception rather than the rule. Additional information concerning long-distance reception of television signals will be presented later in this chapter.

GHOSTS

One of the oldest and most common phenomena associated with television receiving systems is displaced images, or "ghosts." The ghosts appear to the right of primary video information, their intensity being directly related to strength of this "second signal" video. Through general understanding of television signals and their propagation, ghost interference may be eliminated in a very effective manner.

One form of ghost interference is created through multipath propagation. The high frequency waves used for TV transmissions reflect from numerous structures such as billboards, water towers, buildings, etc, in a manner comparable to the action of a single light bulb in a room full of mirrors. Visualize the transmitting station illuminating its primary coverage area with energy, and then consider the many reflective items in that area. The difficulties of receiving a single "direct" signal without any reflections should be readily apparent. The results of multipath propagation are shown in Figs. 8-1 and 8-2. While the basic signal travels 15 miles in a straight line to the receiving antenna, the reflected signal travels 17 miles before also arriving at the same receiving antenna. Radio waves

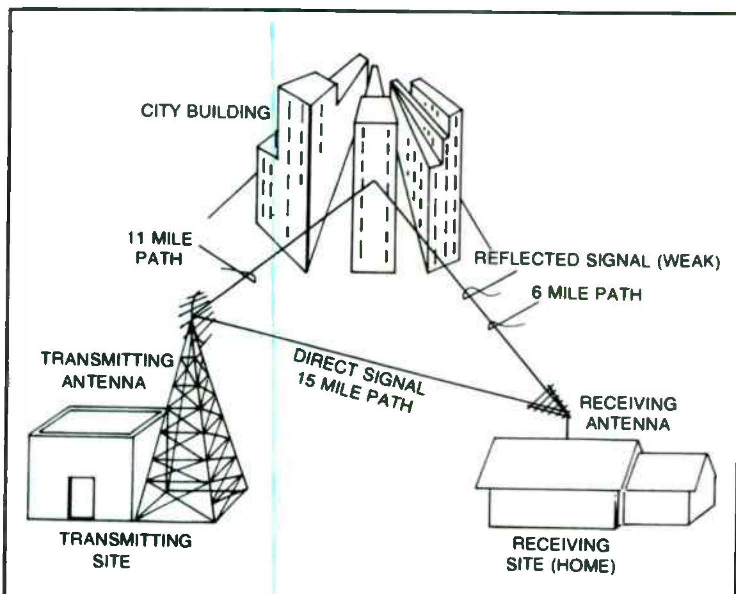


Fig. 8-1. Multipath propagation may be caused by television signal being conveyed over two or more paths of different lengths. The delayed signal arrives at the receiver later than the original signal.

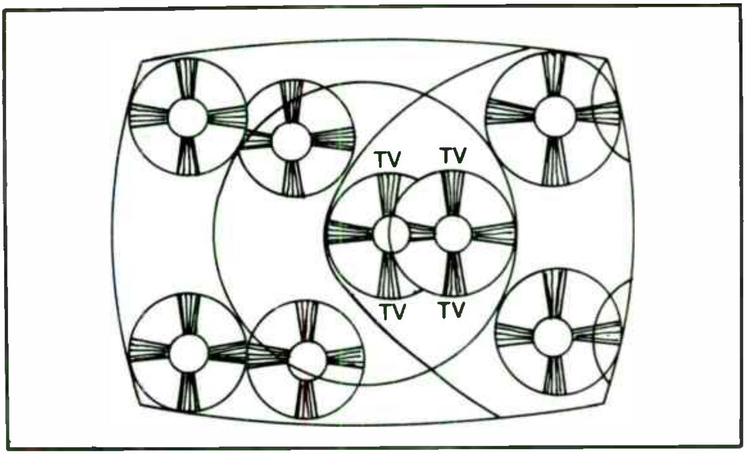


Fig. 8-2. Results of multipath propagation as produced on television receiver screen. Note dim image displaced slightly to right.

travel at 186,000 miles per second (speed of light), thus the reflected signal is 2/186,000 of a second "late." This 2/186,000 reduces to 1/93,000 of a second, or 10.7 microseconds. The time period of each horizontal scanning line in a TV picture is approximately 55 microseconds, thus the 10.7 microsecond delayed image appears displaced approximately 1/5 the screen area (10.6 microseconds) to the right of the original image. The solution here involves using highly directional receiving antennas which accept signals from only their "front" and reject signals off their sides and back. Such antennas are multi-element Yagis and corner reflectors.

Another form of ghost interference is created through improper impedance matching between the lead-in and the receiver. Assume, for example, a 300-ohm antenna is connected through 300-ohm twin lead to the 75-ohm input of a receiver. While some signal energy is coupled into the receiver and produces a display on the screen, other signal energy is reflected (by the impedance mismatch) back *up* the twin lead to the antenna, where it is reflected down again. The reflected energy then returns to the television set (late by a number of microseconds) and the delayed image is displaced as a ghost. While few people would make the obvious mistake of connecting 300-ohm twin lead to a receiver's coaxial 75-ohm input, a less obvious mismatch can occur when the twin lead impedance changes to lower values due to outside influences. These reflections can be the result of moisture or grime between conductors or twin-lead edges, proximity to metal rain gutters, metal window frames, etc. or it may be the result of poor splicing techniques. It is important to use twin lead or cable best suited for the particular installation. Dirty, humid environments usually require tubular or shielded twin lead, while runs near metal or inside wiring require 75-ohm coaxial cables and impedance-matching transformers. Antenna, lead in, and proper installation are vitally important to proper television-receiver operation.

THE FOLDED-DIPOLE ANTENNA

The most basic form of television receiving antenna is a simple half-wave folded dipole similar to that illustrated in Fig. 8-3. The feedpoint impedance of this antenna is 300 ohms—ideal for TV-receiver operation, however, its non-directivity and unity gain leave something to be desired. The usual television receiver needs between 250 and 500 microvolts of signal input to produce a quality picture; the folded dipole is thus restricted to locations near the transmitter. This simple antenna, however, is used as a basic reference for gain comparisons of larger antennas.

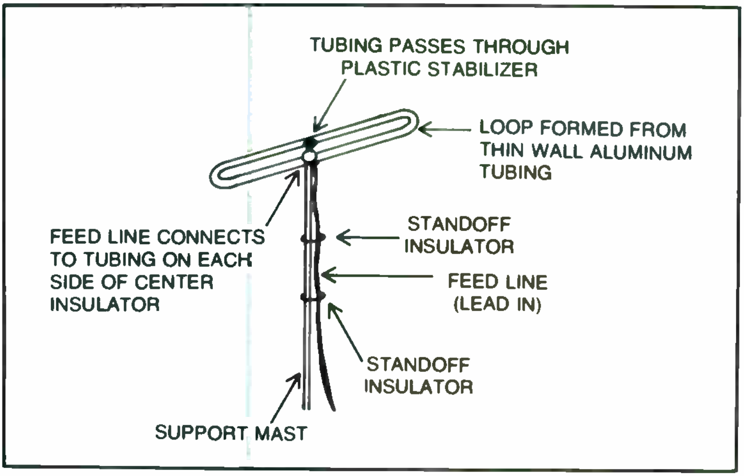


Fig. 8-3. The basic folded-dipole antenna is a half-wavelength of tubing broken at its feed point and connected to 300-ohm TV "twin lead."

THE YAGI ANTENNA

This antenna, named in honor of its Japanese inventor, uses a number of parasitic elements to provide gain and directivity. Longer elements placed behind the driven element act as reflectors, while shorter elements in front act as directors. The overall action concentrates antenna effectiveness in only one direction at the expense of losing action off the array's sides and rear. Note that only the folded dipole-driven element is connected to the lead-in wire. See Fig. 8-4.

The Yagi's action may be thought of as an electrical reflector and magnifier, with resultant increased energy focused onto the folded dipole proper. Yagi-type antennas have proven their worth for many years in both vhf and uhf television-antenna systems.

The Yagi antenna is, essentially, a narrowband array of elements of proper length for operation across a specific channel range. That is, one area might need Yagi's with elements of the proper

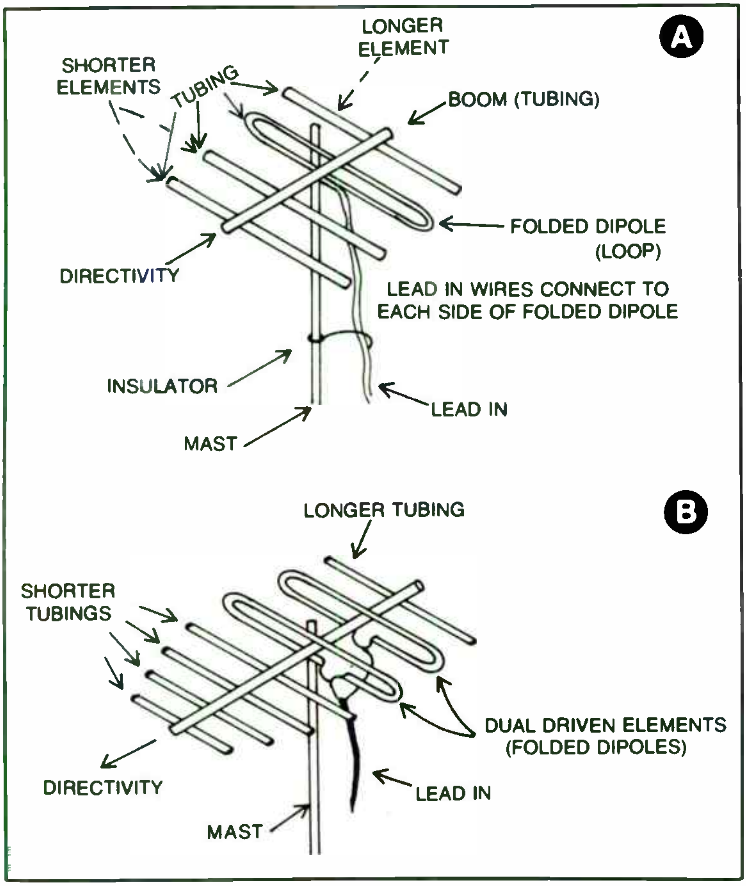


Fig. 8-4. Two versions of the popular Yagi antenna: (A) is conventional 4-element array, and (B) uses dual driven elements for broadband coverage of vhf Channels 2 through 13.

length for reception of vhf channels two through six, and another area might need a Yagi for seven through thirteen.

Recently another form of Yagi known as an all-channel, or broadband, Yagi has become popular. The design of this antenna is essentially the same as a conventional Yagi, except two folded-dipole driven elements are used and connected to the lead-in cable. One driven element is cut for Channels two through six, while the other driven element is for Channels seven through thirteen. The parasitic elements (reflector and directors) then function for both driven elements to provide full-channel reception, see Fig. 8-4.

The Yagi antenna is particularly useful for medium-fringe-area reception, and for use in locations with signal reflections and multipath propagation. The superb front-to-back and front-to-side ratio of Yagi antennas allows them to "see" only one signal while ignoring signals which could create "ghosts." The Yagi has also been helpful in reducing man-made noises (such as power-line noise), provided the Yagi can be mounted facing the TV-station antenna and its "back" in the direction of the noise source. The Yagi is primarily used as a vhf rather than a uhf antenna because of size limitations. Parabolic-reflector antennas would be huge if used at vhf (although their performance would be superb), while Yagi (antennas would be small at uhf. Since size isn't a critical factor at uhf, larger antennas (such as parabolic dishes) are logical choices. Referring back to previous chapters on television-receiver designs, recall that uhf tuners seldom feature an rf-amplifier stage. High-gain antennas are thus more important to uhf rather than vhf reception. The Yagi sometimes appears at uhf, however—it can be found at the focal point of parabolic dishes, collecting rf energy in an effective manner and passing it down the lead-in cable to the television receiver.

An individual can select a Yagi vhf antenna that is almost "tailored to fit." Careful study of a location will reveal the signal reflection possibilities and the areas of possible power-line-noise generation. Next, the location of TV transmitters and their distance from the receiver can be considered for determining antenna size. Assuming, for example, three stations within a few miles of each other are located 25 to 30 miles from the receiver, a high-gain (many elements) Yagi can be used quite successfully. On the other hand, three stations spread over 40 to 50 degrees of horizon, and located 10 to 20 miles from the receiver calls for using a Yagi with fewer elements, which would present a broader beamwidth. The question of long distance *and* broad beamwidth can be answered in only one way: get a high-gain antenna and use a rotor.

THE LOG-PERIODIC ANTENNA

The log-periodic vhf antenna is quite popular for use in metropolitan areas with extensive vhf broadcast activity and minimal multipath possibilities. The array is quite broadbanded, and thus capable of covering the full vhf spectrum of Channels 2 through 13. Front-to-side rejection is roughly equivalent to the Yagi antenna; however, front-to-back rejection is noticeably less than the Yagi. The log-periodic antenna (Fig. 8-5) consists of a series of driven elements (dipoles) connected to the lead-in cable by means of a phasing section which passes down the middle of the array. Gain is obtained through the large "capture area" provided by these phased dipoles, while its wide bandwidth is accomplished through the use of dipoles individually cut for operation on specific channels. A number of dipoles (although not *all* of the array's dipoles) are active during reception of any specific channel. Reception of Channel 6, for example, might resonate one dipole as a half-wavelength wire, and another dipole as a three-eighth wavelength wire. The dipole elements providing resonance effects are automatically brought into play by energy from the transmitter. There's also a possibility of "parasitic-element effect" from many of the dipoles: Longer elements may act as reflectors while shorter elements can act as

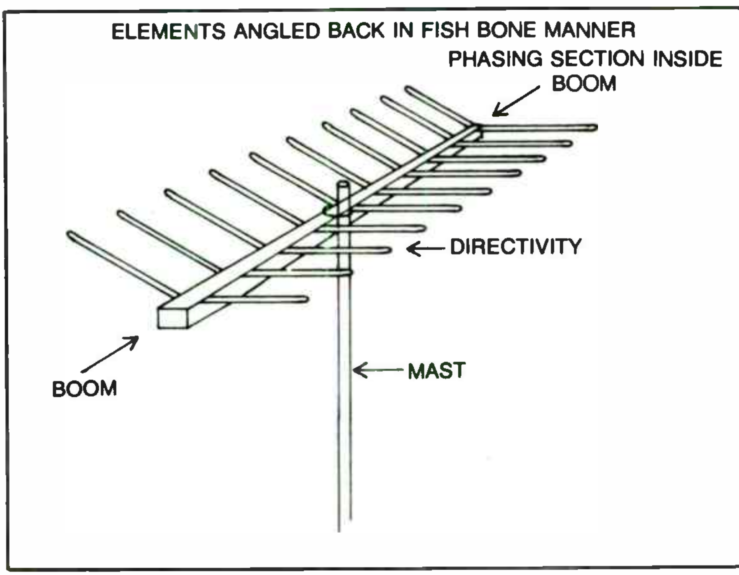


Fig. 8-5. The log-periodic antenna features "fish bone" elements which are driven through a phasing network. All elements are connected to the lead-in, whereas a Yagi uses only one driven-element connected to the lead-in.

directors. A certain amount of additional directivity is also achieved by angling the elements in a fish-bone pattern. This concentrates antenna effectiveness in the "short-element" direction while reducing rear signal pickup.

The log-periodic antenna is quite appealing to viewers who desire reception of the full vhf range of channels. Its capability for receiving distant signals are not as great as that of the Yagi, but it isn't far behind either.

UHF ANTENNAS: BOW-TIES AND LOOPS

The basic uhf receiving antenna, comparable to the vhf folded dipole, is the uhf bow-tie or loop. The loop resembles a folded dipole which has been opened into a circle, while the bow-tie resembles its namesake. Since neither antenna provides gain or directivity, they are seldom used alone but are incorporated into arrays. The bow tie, which is usually cut from aluminum, exhibits surprisingly wide bandwidth—an important consideration for the broad uhf television-broadcast spectrum. Screen reflectors are often placed behind the bow tie to act as a parasitic element and increase forward receiving capabilities. Stacked arrays of bow ties, backed by large reflector screens, are also popular in some metropolitan areas. Fringe reception of uhf signals is, because of their extremely high frequency range, quite difficult. The loop antenna may only be compared to conventional "rabbit ears." It can only be used effectively when very near the uhf transmitting station. Some experiments with multiloop parasitic arrays have been tried, but they have not been introduced commercially on a wide basis.

THE CORNER REFLECTOR

A very popular modification of the bow-tie-and-screen-reflector antenna for uhf reception is the corner reflector. This antenna realizes increased gain because the signal from in the corner reflector is concentrated on the active element. While solid metal sheets may be used for the reflector, the increased wind resistance severely degrades lifespan and rigidity. Therefore, most corner reflectors are a metal framework (screen) of welded construction. The slots, or holes, in a corner reflector should not be larger than one-tenth wavelength at the highest uhf channel received, otherwise signals can pass through the screen rather than being reflected by it.

The bow-tie driven element placed within the corner reflector is often bent in a manner matching the screen as a means of optimizing performance and increasing overall antenna efficiency. The bow-tie-and-screen-antenna is probably the most popular metropolitan uhf antenna in use, not because of gain (a parabolic dish is best) but because it provides fair gain and reasonable size combined with generally acceptable appearance. The uhf antenna should be mounted high for best results, thus "stacked" vhf and uhf antennas should have the uhf antenna at the top.

PARABOLIC DISHES

The uhf parabolic dish is usually considered as a top-of-the-line performer for reception of weak signals or signals severely affected by multipath propagation. The forward gain of a parabolic dish antenna is quite high. The most common sizes are three foot and five foot diameters, and rugged installations are required. Although basic bow ties or folded dipoles are usually placed at the dish focal point, a small Yagi can be used as well. Isolated areas realize maximum benefit from parabolic dishes, the larger the better. While a smaller parabolic dish might suffice in some areas, its limited performance as compared to larger dishes suggest that one should purchase the largest dish affordable and "do it right the first time." Cost fades quicker than performance!

The parabolic-dish uhf antenna is a highly desirable antenna, particularly for remote areas or areas susceptible to reflections. Additional details on *large* parabolic dishes are presented in the chapter on satellite-TV receivers.

COMBINATION ANTENNAS

Probably the most popular metropolitan and suburban television antennas are the combination vhf/uhf arrays. These antennas are available in a number of sizes, ranging from two feet to eighteen feet long, and capable of rather impressive performance. The "combo" antenna usually features a vhf Yagi or log-periodic of between four and ten elements, and a uhf Yagi or corner reflector. See Fig. 8-6. The uhf Yagi usually consists of between six and eighteen elements, while recent designs in corner reflectors have seen a move from bow ties to multi-element Yagis. Such Yagi-corner reflectors provide quite acceptable performance.

The combination antenna works best when both vhf and uhf transmitting stations are in the same direction; otherwise, an antenna rotor is required to aim the antenna when changing received channels. A lead-in coupler or signal splitter is used to connect both vhf and uhf antennas to a single lead-in cable, and an indoor splitter

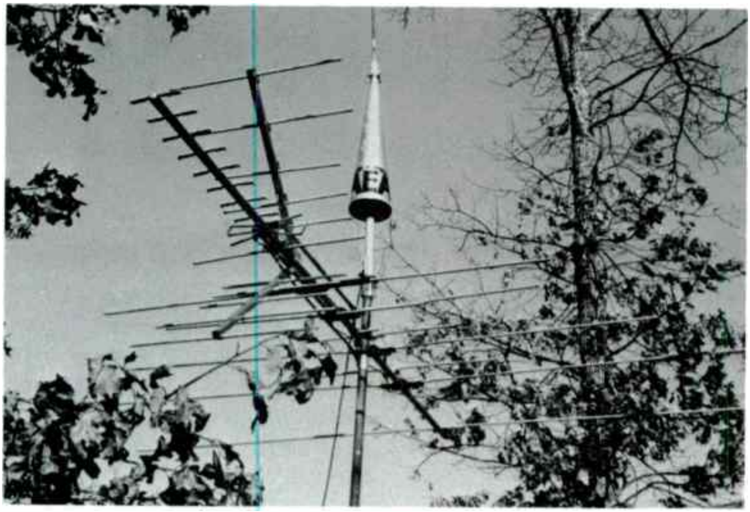


Fig. 8-6. A combination vhf/uhf TV antenna consisting of a log periodic array for vhf and a corner reflector with center Yagi for uhf reception. Performance is quite acceptable up to 50 miles from transmitters.

is then used for separating the signals for separate vhf/uhf tuner connections. A slight amount of signal loss will be experienced in each coupler/splitter used, thus one should originally select a "combo" antenna capable of slightly more gain (presently designated distance in miles) than actually required. This extra margin may prove quite useful as the antenna system ages or as additional television receivers and couplers are added.

Regardless of the antenna selected, "overbuying" is definitely preferred to "underbuying." Few distributors allow you to "trade up" a smaller antenna; you simply become stuck with the poor selection. Alternatively, "too much" antenna usually brings positive returns (look at those distant stations, and their clarity) which persists long after financial outlays are forgotten. Don't skimp on this vital link in a television-receiving setup.

ANTENNA LEAD-IN AND CABLES

An often overlooked or underrated link in a quality television-antenna system is the lead-in, or cable, connecting the antenna to the receiver. All signals received by the antenna must pass through this lead-in cable to arrive at the television receiver, and any "shortcuts" or cut-rate cables will reduce the quality of the system. Lead-in cable should always be kept as short as possible to minimize losses.

The most popular type of TV lead-in is 300-ohm twin lead. However, all twin lead is not the same. The common 300-ohm "ribbon" consists of two conductors separated by a plastic dielectric, which also covers the cable, acting as weather protection. This least expensive twin lead is suitable for indoor use (a TV antenna in the attic), but outdoor collections of dirt and grime, mixed with rain on the line, causes changes in impedance and attenuation of signals along the line. Soon, the inexpensive twin lead becomes an outdoor attenuator for an otherwise creditable antenna system. An early replacement for lossy ribbon cable was nitrogen-foam-filled tubular twin lead. This cable had a round cross section, and was filled with a moisture inhibitor. It provided quite acceptable results in a variety of environments. The disadvantage to this cable was its susceptibility to nearby metallic objects. Assuming, for example, the twin lead was placed near metal rain gutters, antenna masts, etc., a noticeable attenuation of conveyed signals would be apparent. Plastic standoff insulators rectify this situation, resulting in good performance at a fair price. Remember to use standoffs and keep the lead-in at least three inches from metallic objects, and foam tubular twin lead should serve quite well for most antenna-system installations.

The top 300-ohm lead-in is shielded twin lead. This cable consists of conventional twin lead, usually with a nitrogen-foam filler, and an outer shield which is grounded to prevent noise intrusion from outside sources. The cable is fully covered with a heavy plastic jacket for weather protection. Shielded twin lead is sometimes stiff and difficult to handle, however, its superb performance will offset installation hassles once it is in use. Its long life is a hedge against future problems and additional expenditures. The shield permits placing this twin lead directly against metal fixtures (or running through conduit, if desired). The outer shield should be connected to permanent ground, such as an outdoor cold-water pipe, in order to realize its noise-reduction/shielding benefits.

Coaxial cable of 75-ohm impedance may also be used effectively for television lead-in. In this case, two impedance-matching transformer/baluns are required: one mounted at the antenna and one mounted at the television receiver. These baluns match the antenna's 300-ohm balanced output to the coaxial cable's 75-ohm unbalanced input, and the coax 75-ohm unbalanced output to the television receiver's 300-ohm balanced input. Coaxial cable is quite useful for vhf applications; it may be placed directly against metallic structures and it is fully protected against the weather. Its disadvantage is excessive attenuation, particularly at frequencies above 200 MHz. Short lengths are suggested.

A final form of coaxial cable is 75-ohm "hardline," a low-loss cable often used by cable-TV corporations to carry signals into residential areas. The advantage of this cable is long life and extremely low attenuation; however, its disadvantages are very high cost per foot and rigidity. It is extremely difficult to handle.

INSTALLING TV ANTENNAS

Almost every TV-antenna installation reflects its own unique situation and restrictions which must be surmounted through a knowledge of mounting systems and techniques. Antenna type and location carry almost identical weight in proper installations, so pick the two for optimum performance according to location, safety, and available funds. Reducing initial costs with cut-rate antennas or mounts can prove disastrous during severe weather.

Safety should be a prime consideration during antenna installation: antennas and their supports coming into contact with outdoor power lines is the number one killer in this respect. Each year, numerous individuals installing large antennas either lose control of the array or accidentally move the array near power lines, often with fatal results. Don't take chances! Even "covered" power lines are dangerous. Don't install large arrays during windy weather and don't install an antenna at dusk or during early evening hours. Never install an antenna where it can fall on any power lines, and don't install antennas during periods of nearby thunderstorms.

A relatively popular TV-antenna installation technique for metropolitan areas involves using five- or ten-foot sections of TV mast strapped to the side or chimney of a house. These masts are available at electronic houses which also sell antennas and mounting hardware. The use of slip rings, guy wire, and turnbuckles can't be over emphasized. Secure the installation in place, then tighten guy wires with turnbuckles. Don't over-tighten, too much downward force could fracture the mast.

One of the most logical ways to learn which antenna and what mounting hardware should be considered for a particular area involves asking advice at local electronic parts suppliers. These "parts houses" cater to TV repairmen and technicians—professional antenna installers capable of setting up a quality system in minimum time. Their advice can provide the needed leadership.

A convenient antenna mount for most houses is a chimney mount. Two stainless-steel straps are wrapped around the chimney and bolted to a clamp assembly which holds the antenna mast. The use of guy wires and turnbuckles will be determined by each particular situation. Remember to ground the mast through a separate heavy wire to earth ground, and dress lead-in neatly in a weather-secure manner. See Fig. 8-7.

Another popular antenna mount is an eave, or wall, mount. These brackets hold a TV mast, and their other end bolts into the house frame. Again, the mast should be grounded via a separate line

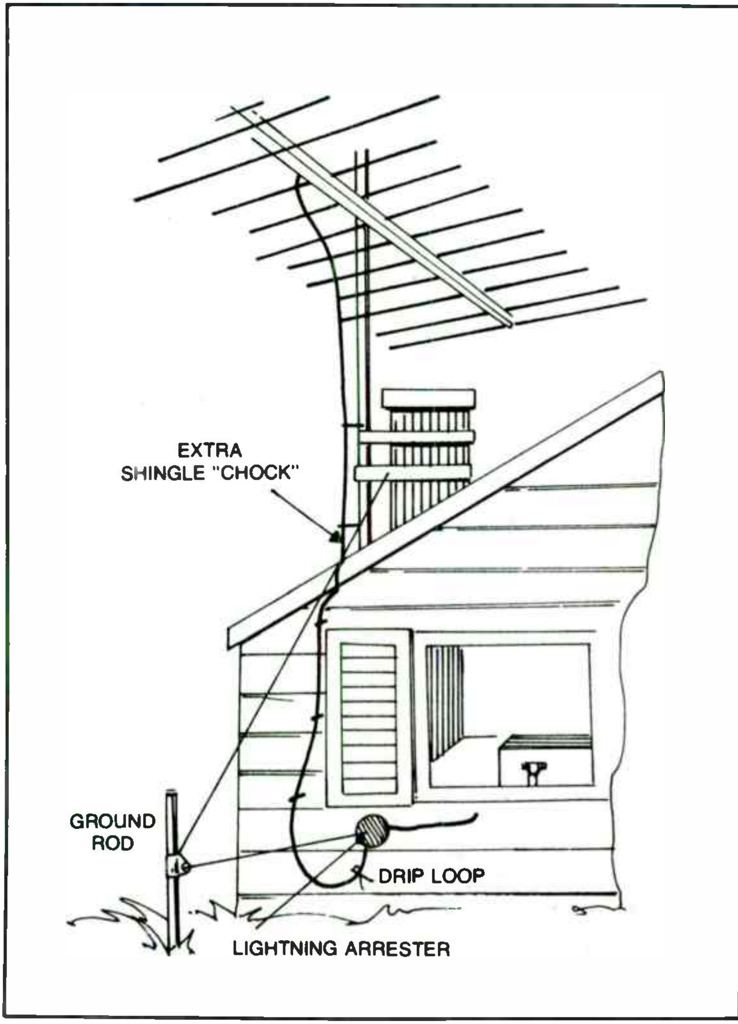


Fig. 8-7. Chimney-mount arrangement for mounting a television antenna.

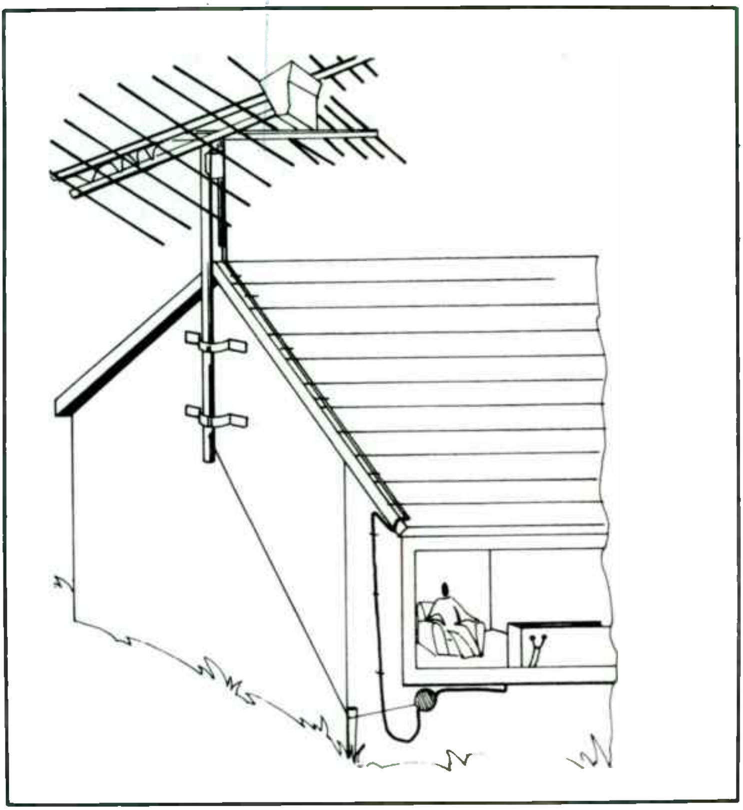
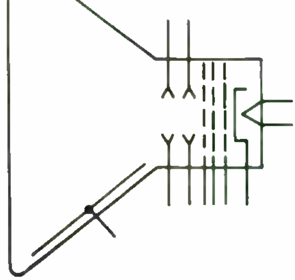


Fig. 8-8. Wall-mount bracket secures television antenna on end of house under eave.

and the antenna lead-in should be secured. See Fig. 8-8. Lightning arrestors, mounted *outside* the house, are definitely suggested: they "bleed off" static-charge buildup, reducing the chance of direct hits by lightning.

Chapter 9

MDS Concepts and Systems



One of the most recent forms of restricted television broadcasting involves the rapidly growing medium of Multipoint Distribution System (MDS), to carry pay-TV type programming to subscribers within a particular metropolitan area. This service may be considered as a cross between conventional television broadcasting and cable-TV operations with some notable exceptions. Only one channel of television programming is available, and that programming usually involves subjects not covered by normal TV broadcast coverage. This chapter will present an overview of MDS concepts as an aid to understanding their techniques.

MDS is a low-cost, common-carrier service designated for point-to-point communications by various independent services. The system, which is allocated for use in the 2150 to 2180 MHz (2.15 to 2.18 GHz) microwave range, was originally established by the Federal Communications Commission as a form of commercial transmitting service for relatively narrowband signals. When the demand for this service fell short of its predicted goal, the FCC reapportioned MDS channel bandwidths to 6 MHz for inclusion of NTSC-acceptable television signals. Thus began the saga of low-power microwave broadcasting of pay-TV programs. Microwave pay TV took several years during the latter 1970s to become popular. MDS began by relaying special satellite programming and video-tape-recorder "runs" of restricted movies to hotels, motels, etc. The service grew to include numerous metropolitan broadcasts of similar programs for subscribing home viewers. Additional MDS broadcasting services, many instigated by individuals rather than corporations, joined the action and began broadcasting to specific sections in each metropolitan area. Activity soon flourished in an almost out-of-hand manner as the microwave-TV broadcasting (MDS) craze gained an almost immediate foothold in densely populated areas. Suddenly, the vision of one establishing his own revenue-producing TV station was strikingly close to reality. The bare-bones setup for many of these "neighborhood TV stations" consisted of a satellite-TV receiving-only terminal (TVRO), a video tape recorder/player, and possibly a basic TV camera for brief live announcements. The MDS transmitter was remotely located and maintained by its licensed owner (an early FCC ruling required that MDS transmitter ownership be different from its user; a true leased-transmitter arrangement). As this book is being written, MDS arrangements continue their phenomenal rise in popularity with little indication of slowing down.

OPERATIONAL CONCEPTS OF MDS

The arrangement for MDS transmissions of pay-TV signals consists of a satellite-TV terminal and/or a studio containing one or more video tape players which feed video and audio information to the MDS transmitter. The antenna radiation pattern is tailored to cover a specific area. Microwave signals are strictly line-of-sight in nature, thus restricting coverage to a usual 20- to 25-mile range. Exact distance depends on terrain and the MDS transmitter elevation. See Fig. 9-1. This is a cost-effective game: receive terminals must be dependable, but they must also be inexpensive if a revenue-producing system is to be realized.

While the MDS concept is cloaked from mass public reception only by its difficult-to-receive microwave range and its area-coverage restrictions, additional "scrambling" techniques are being

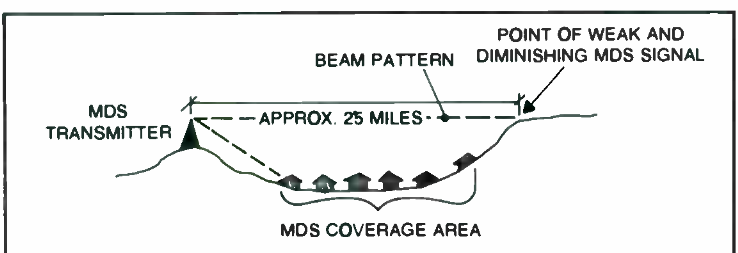


Fig. 9-1. MDS coverage area is strictly line of sight and limited by local terrain.

considered for some locations. These techniques cut into microwave pay-TV profits, however, so inexpensive but effective measures similar to conventional cable-TV scrambling are desirable. Essentially, this arrangement consists of transmitting a precisely located interfering carrier within the video bandwidth, and removing that interfering carrier with an active or passive high-Q filter at the subscriber's location (for a monthly charge).

Each MDS subscriber is then provided with a receiving unit which downconverts 2.1 GHz to TV Channel 2, 3, or 4 as required in his area. Descrambling filters, if needed, are connected between the downconverter and the television receiver. In addition to the monthly MDS charge, an installation fee, and possibly a downconverter deposit, are often required.

The question of whether an individual with a "get-rich-quick" gleam in his eye should consider joining the MDS game is debatable. The first thoughts give such a project appeal: invest in a TVRO ($6,000), a video-tape player and monthly tape exchange service ($1,000), a 10-watt output MDS transmitter and 2.1 GHz antenna ($2,000), and 50 or 60 receiving downconverters ($2,000). That $11,000 figure could be reduced to nearly $6,000 during the start-up period, and letting the system grow with its income and acceptance.

In addition to financial considerations for MDS-station equipment, another vitally important hurdle must be overcome before one can actually take to the airwaves: The MDS station must be licensed by the Federal Communications Commission, and permission to transmit television programming must be secured. The FCC doesn't grant a license to use the airwaves without justification. A meaningful purpose must be served in a constructive and positive manner, and the new service must not infringe on rights or franchises of others also using the airwaves. The prospective microwave-TV enthusiast must do his homework in a number of areas before applying for a license. In addition to surveying the projected coverage area to identify the audience and their requirements, a frequency/signal-strength study of the area must be conducted. This will ensure that the new signal will peacefully co-exist with other services while serving the intended area in a reliable manner. Additionally a market analysis considering growth and funding according to projected revenues should also be considered, along with plans for continued growth in the wake of possible future cable systems or public-broadcast satellite-TV networks. After fulfilling these requirements, the individual can then file with the FCC and feel confident of results—providing a "counterfile" isn't registered by another individual or corporation. In the past, some groups or individuals have made a habit of practically "camping" on the FCC's doorsteps merely for the purpose of filing "on top" of others and thus throwing applications into court battles. The initial applicant, possibly drained of funds by previously mentioned activities, is then faced with either additional cash outlay or watching his efforts go down the drain. Fortunately, most of this "blocking" "counterfiling" is usually confined to commercial television rather than microwave TV, but since that possibility exists, forewarned is forearmed. Educational and religious roups are often exempt from the "counterfile syndrome;" indeed, commercial groups often assist these applicants in an effort to protect their own domain from competition by new outside sources. Assuming, however, the individual acquires a license and permission for microwave-TV (MDS) operations, the basic hurdles are behind him and the future is quite promising.

CONSTRUCTING A LOW-COST MDS SETUP

The first steps will involve setting up a TVRO and licensed MDS transmitter (which must legally operate as a common carrier and be owned and operated by a separate person). Since satellite-acquired programs will be resold to area viewers, license must be obtained from satellite programmers for the use of their service. Conventional NTSC television information (AM video, FM audio 4.5 MHz above the video carrier, etc.,) may then be applied to the MDS transmitter. Video switching arrangements at the TV studio, plus additional video/audio equipment, may also be included as desired. See Fig. 9-2. The MDS transmitter, which transmits a conventional TV signal containing the modulation information, must include vestigial sideband filtering and preemphasis for audio. These prerequisites are not hardships, since MDS transmitters must be FCC approved and thus usually incorporate such features. The MDS transmitting antenna design will depend on coverage area, terrain, transmitter location, etc. The specific criteria is left to the MDS transmitter engineer. A number of MDS-equipment suppliers are usually listed in monthly Broadcasting and Amateur Radio magazines.

The use of inexpensive MDS downconverters is of paramount concern, since each unit must provide a good return on the investment. Essentially, what's needed is a $5 unit with high rf gain, low noise figure, and which can provide reception up to 50 miles from the transmitter. Unfortunately, such a design simply doesn't exist.

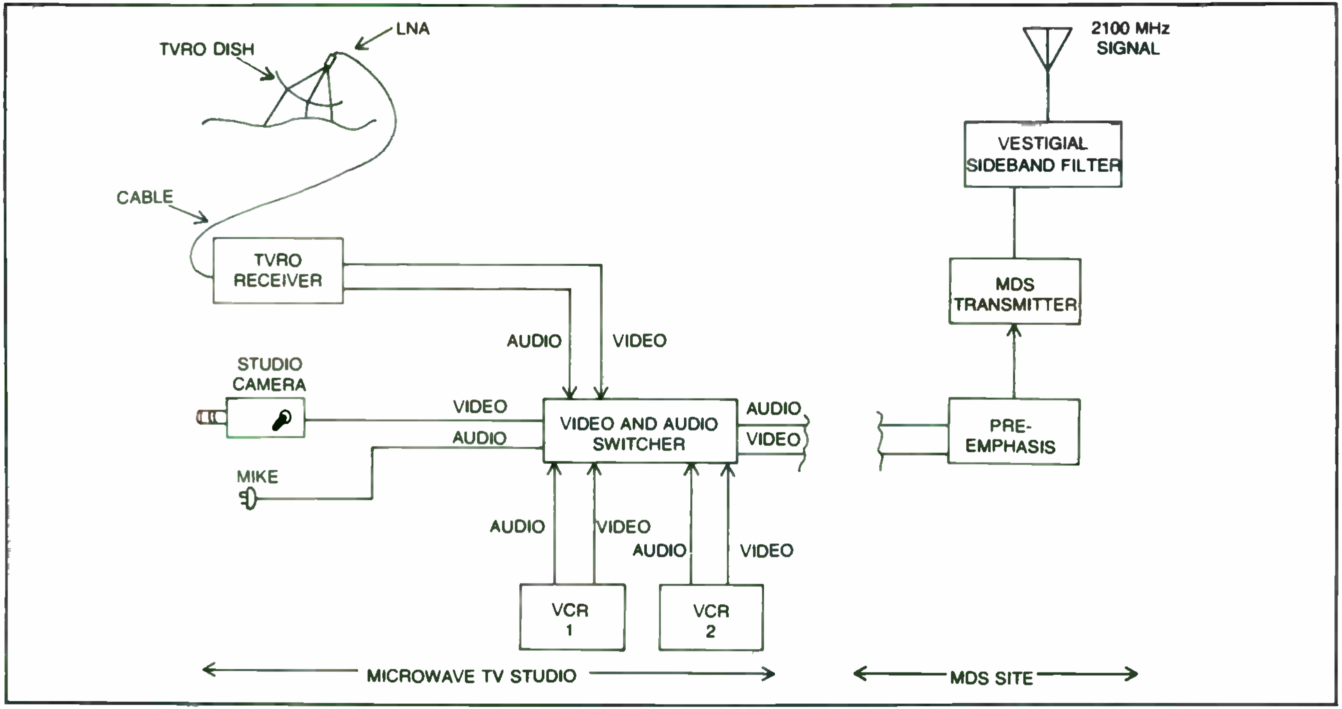


Fig. 9-2. Basic layout of an MDS TV broadcasting system. Studio is linked to transmitter via telephone or microwave link.

However, two approaches to the MDS downconverter setup are possible: 1) use a simple diode-mixer/local-oscillator arrangement similar to older uhf converters in commercial television receivers, or 2) use a reasonably priced rf-amplifier stage, low-noise diode mixer, bipolar-transistor local oscillator, and an i-f amplifier in a sophisticated but relatively low-cost downconverter. The first approach holds merit if low-noise microwave diodes and 2-foot parabolic-dish antennas are used—and provided the desired coverage or transmitter-to-receiver distance is less than 4 miles. Beyond that point, diode noise "masks" the incoming signal and produces only noise. Enterprising technicians interested in trying this approach are referred to Fig. 9-3. The unit should be constructed on double-sided G-10 printed-circuit board; the "back" plane being used to provide a common ground plane for the converter. Connections for rf input, local oscillator, and i-f output should be through the miniature hard-line coaxial cable as shown in Fig. 9-4. Although BNC connectors could be used, they are somewhat difficult to assemble. The local oscillator stripline will require tuning for optimum operation. This may be accomplished by trimming 1/16-inch increments with a sharp knife. If too much foil is cut from the strip, it can be bridged with solder, or a short piece of stiff wire may be added. Finally, the through-board ground connections are made by

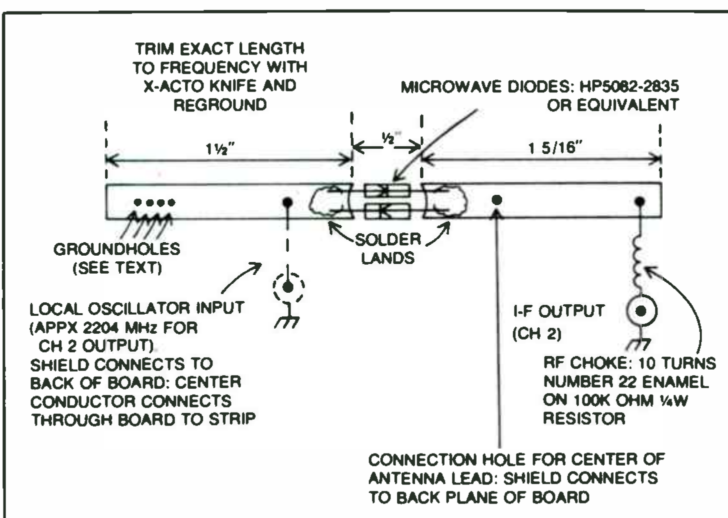


Fig. 9-3. Strictly "bare bones" MDS converter. Unit is constructed on double sided G10 board. Microwave diodes are available at most Radio Shack stores. Local oscillator design is similar to that included in downconverter of Fig. 9-5.

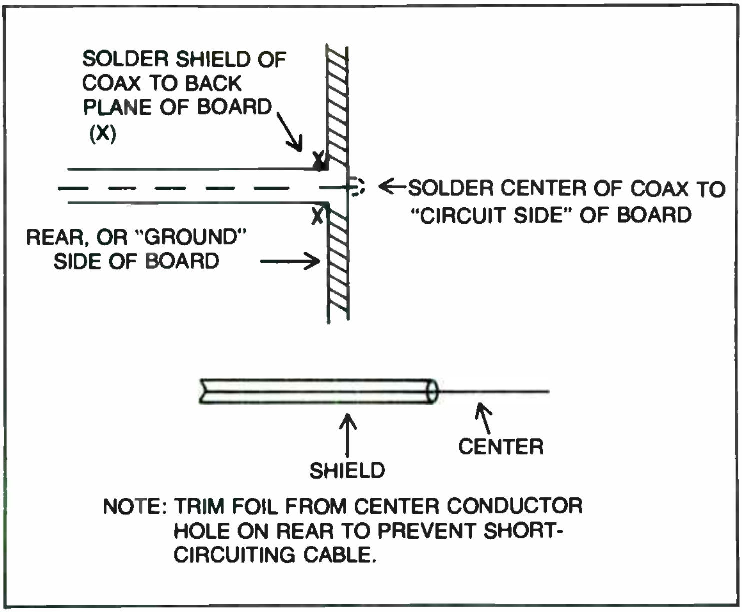


Fig. 9-4. Detailed outline of soldier connectors of unit in Fig. 9-3. Similar microwave techniques are used in all MDS converters.

drilling holes through the board and soldering a wire to connect both board sides. A local oscillator suitable for use with this converter will be included in the next unit considered: A first class, yet relatively inexpensive 2-GHz downconverter designed, produced and marketed by Universal Communications (P.O. Box 339, Arlington, Texas 76010).

THE UNIVERSAL COMMUNICATIONS DOWNCONVERTER

The following unit is state-of-the-art downconverter designed for reception in the 2000 to 2500-MHz range. The unit is thus capable of receiving Amateur TV, education TV, or MDS signals according to frequency-trimming of the unit's striplines. It should be emphasized that MDS TV reception by unauthorized sources may be in violation of some local ordinances.

The Universal Communications 2300-MHz downconverter was designed with the microwave experimenter/hobbyist in mind. The converter can be constructed in one of two ways. The Standard-Feed method integrates the converter into a "coffee-can" antenna and requires no additional microwave connectors or coaxial cable. Alternatively, the converter can be built into a box as an individual unit, permitting connection to different antennas. See Figs. 9-5 and 9-6.

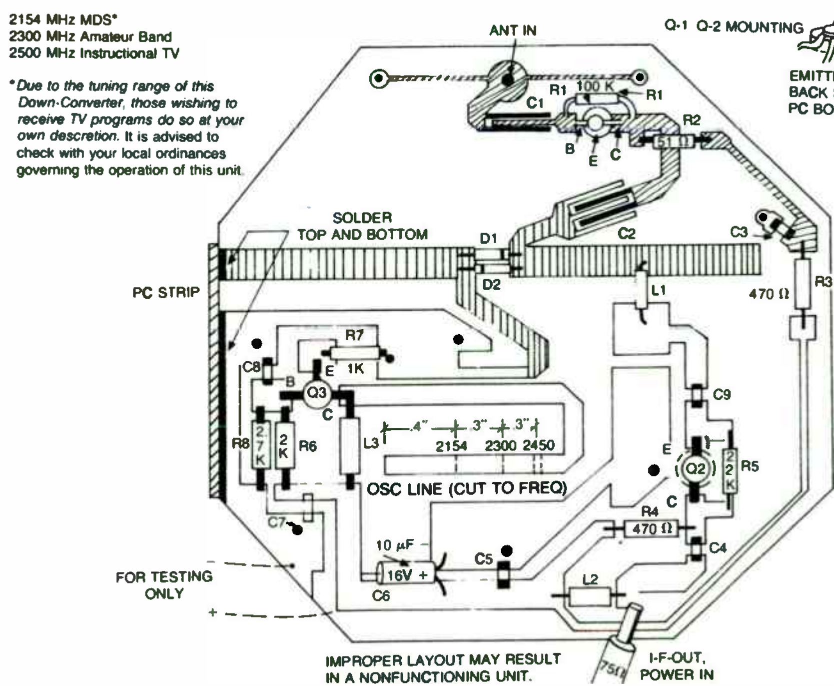
The receiving unit can be a TV set or a radio receiver tuned to an i-f of 54-88 MHz (TV Channels 2-6). Specifications are given in Table 9-1.

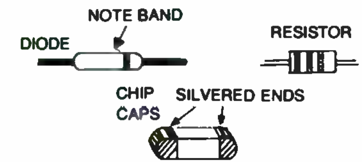
Construction

1. Using excess wire clipped from resistor leads, connect all holes marked with a black dot to top and bottom of pc board. (Solder)
2. Install transistors on board using assembly drawing as a guide. Emitters of Q-1 and Q-2 must be soldered to back side of pc board. Transistor layout is shown in Fig. 9-7.
3. To install chip capacitors, first solder-tin the area where chip is to be placed. Hold the capacitor in place with a toothpick. While heating the board, apply solder near and on ends of capacitors. (DO NOT PLACE SOLDERING IRON DIRECTLY ON CHIP.) Install C-8, C-7, and C-3 first. These areas are critical. Ceramic capacitors (0.001 μF) may be substituted for C-5, C-4, and C-9.
4. Install L-1, the 0.1 μH coil (color code-silver, gold, brown, black, silver).
5. Install L-2 and L-3 as shown (color code-silver, gold, green, blue, silver).
6. Install remaining parts using assembly drawing as a guide. Parts must be placed on pc board in position shown. Resistor leads must be kept to a minimum length, and soldered in position as shown on assembly drawing.
7. Install the semi-rigid cable on the board as shown under "Standard Feed Assembly." This should complete the board assembly.
8. Before mounting board to the coffee can do a complete check.

   Check List:

   — Make sure all ground-hole connections are soldered top and bottom.
   — The pc edge strip is soldered onto the board edge as shown. (Top and bottom as in assembly drawing.)
   — Parts placement should be as drawn. No long resistor leads, etc.





QTY	PARTS	
1	PC Board	
2	Diodes	
3	Transistors	
6	Chip caps	
1	10 μF	
1	51 ohm Resistor	- (green-brown-black)
2	470 ohm Resistor	- (yellow-purple-brown)
1	1k ohm Resistor	- (brown-black-red)
1	2k ohm Resistor	- (red-black-red)
1	2.7k ohm Resistor	- (red-purple-red)
1	22k ohm Resistor	- (red-red-orange)
1	100k ohm Resistor	- (brown-black-yellow)
2	0.56 μH choke Resistor	- (silver-gold-green-blue-silver)
1	0.1 μH choke Resistor	- (silver-gold-brown-black-silver)

Fig. 9-5. Circuit-board layout for Universal Communications MDS downconverter described in text.

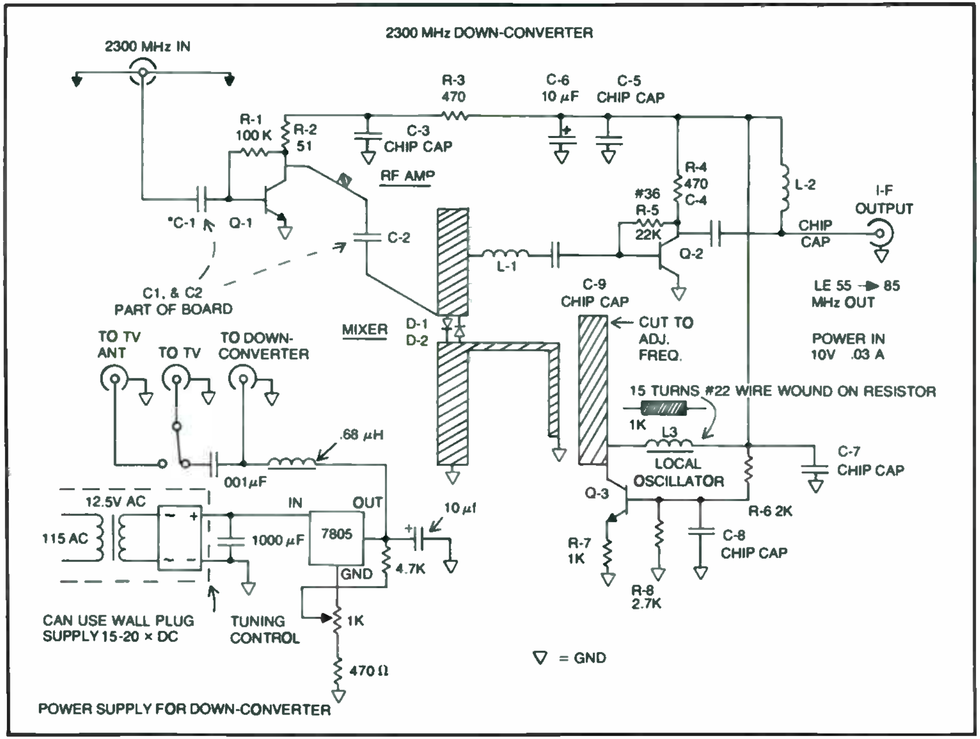


Fig. 9-6. Schematic diagram of Universal Communications downconverter described in text.

Table 9-1. Specifications of the Universal Communications Downconverter.

Frequency Coverage	2000 - 2500 MHz
Gain	20 - 24 DB
Noise figure	6 dB max.
Vco tuning voltage	8 - 12 VDC
Vco tuning rate	8 MHz per volt
Current requirement	30 mA
Output impedance	75 ohms
I-F frequency	54 - 88 MHz
Oscillator injection	High side of carrier

— Check voltage. Apply 10 V to the converter board, + to C6+ side, – to ground plane, and measure voltage at these points.

	Base	Collector
Q-1	0.7 V	6-7 V
Q-2	0.7 V	3.5-5 V
Q-3	5.5 V	10 V

If all checks are complete, then continue.

9. Refer to the can-assembly view. To mount the pc-board to the coffee can, make a small hole in the back of the can approximately 0.4″ from the rim. Slide the antenna probe through the hole and place the pc board on the back of the can.
10. Solder the antenna probe to the can as shown in the drawing (This grounds the probe end).

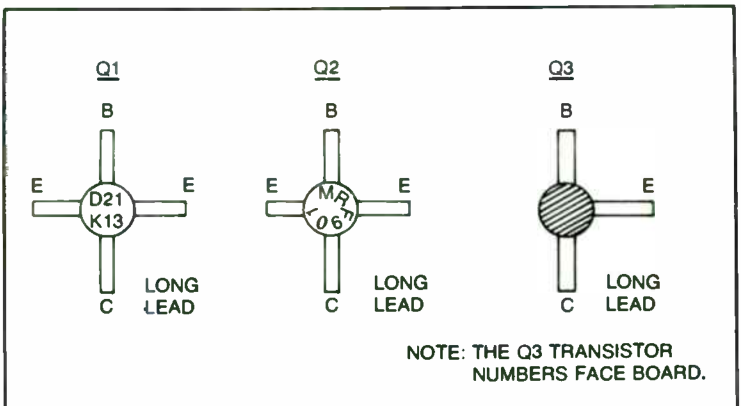


Fig. 9-7. Transistor configurations used in Universal Communications downconverter.

Oscillator Adjustment

In some areas, a small amount of signal will bounce around to make tune-up impossible on ground level. Ideally, a line-of-sight path or a signal generator is preferable. 2300 MHz signals are severely attenuated by hills, buildings, trees, etc.)

The oscillator in this unit is voltage sensitive. When the voltage is increased, the frequency increases, and vice versa. To properly tune in a signal, pick out the frequency to be received and cut the oscillator stripline at the point indicated. Remove the remaining copper line not used. The oscillator frequency is determined by the applied voltage and the oscillator line length.

With the converter hooked up to a variable power supply and a TV set on Channel 2, vary the voltage from 6-14 V. (The antenna should be pointed at the transmitter site or signal generator at this time.) When the signal is located, measure the applied voltage. (If no signal appears, either no signal is present or construction is faulty. If the voltage is below 10, this indicates the oscillator frequency would be too high at the 10 V operation level. If so, solder a small length of cut-off resistor lead (0.25" or less) to the cut end of the oscillator line and trim its length so the oscillator frequency is correct at 10 V.

If the voltage is higher than 11 for reception, it indicates that the frequency is too low at 10 V. Trim the oscillator line another 1/16-inch. This will increase the oscillator frequency at the 10-V level. Test again. If too much has been cut off, use a small wire as described before.

This oscillator runs at ½ the frequency required which makes it more stable than some other designs. Oscillator frequency is:

Receiving Frequency + i-f

Ch-2 = 55 MHz
Ch-3 = 61 MHz

Spraying a *light* coat of clear acrylic spray on the board will help moisture-proof it. Too much spray can detune the oscillator somewhat. If this should happen, cut off 1/32 inch from the oscillator line to make up the frequency loss.

Final Test:

With the TV receiver on Channel 2, and receiving a picture, change the TV set to Channel 3. Increase the voltage, (1 V) and the picture should come back in. If it requires a lower voltage than for

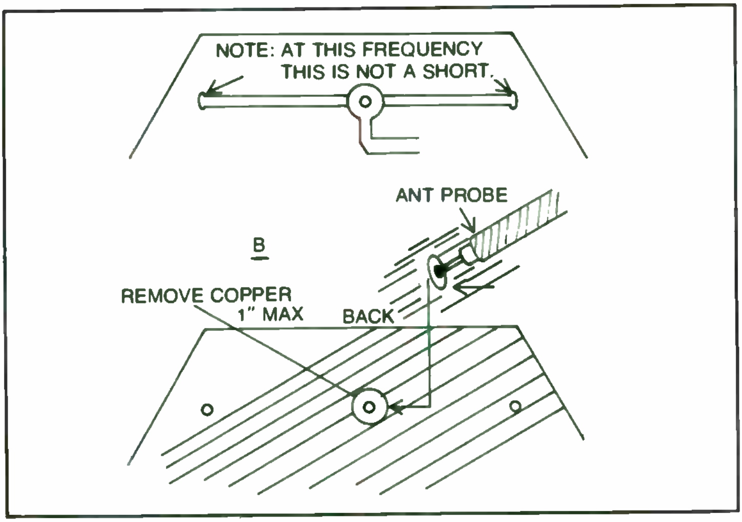


Fig. 9-8. Method of trimming board and antenna-hardline cable for use with downconverter. Shield connects to back plane while center conductor connects to circuit-side of board.

Channel 2, the unit has wrong-side injection, which means the oscillator line is too long (frequency too low).

Standard Feed Assembly

A 4-inch length of miniature hardline (semi-rigid coax) is supplied with the kit. This may be used for the standard-feed

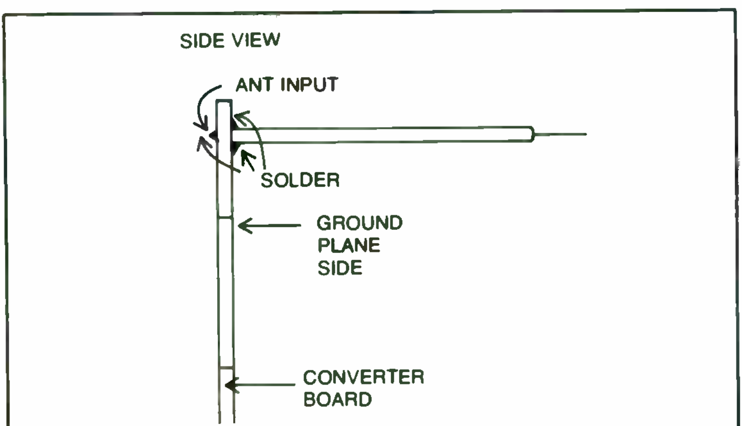
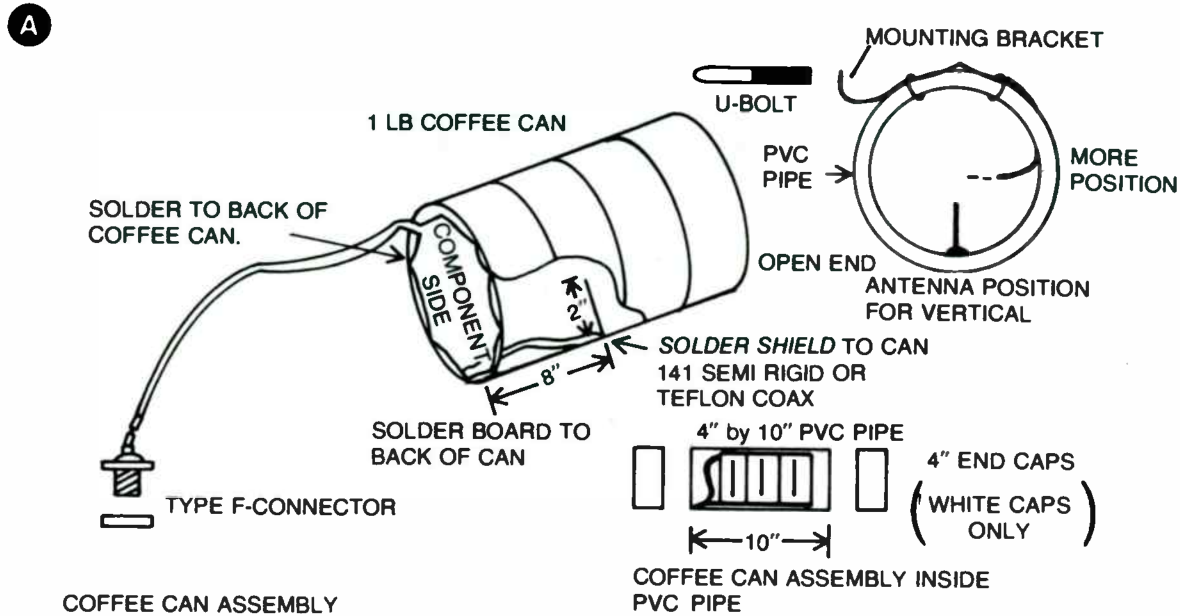


Fig. 9-9. Method of orienting hardline and antenna probe for insertion in coffee-can cavity.


A
MOUNTING BRACKET
U-BOLT
1 LB COFFEE CAN
PVC PIPE
MORE POSITION
SOLDER TO BACK OF COFFEE CAN.
COMPONENT SIDE
2"
OPEN END
ANTENNA POSITION FOR VERTICAL
SOLDER SHIELD TO CAN
141 SEMI RIGID OR TEFLON COAX
8"
SOLDER BOARD TO BACK OF CAN
4" by 10" PVC PIPE
4" END CAPS
(WHITE CAPS ONLY)
TYPE F-CONNECTOR
10"
COFFEE CAN ASSEMBLY
COFFEE CAN ASSEMBLY INSIDE PVC PIPE

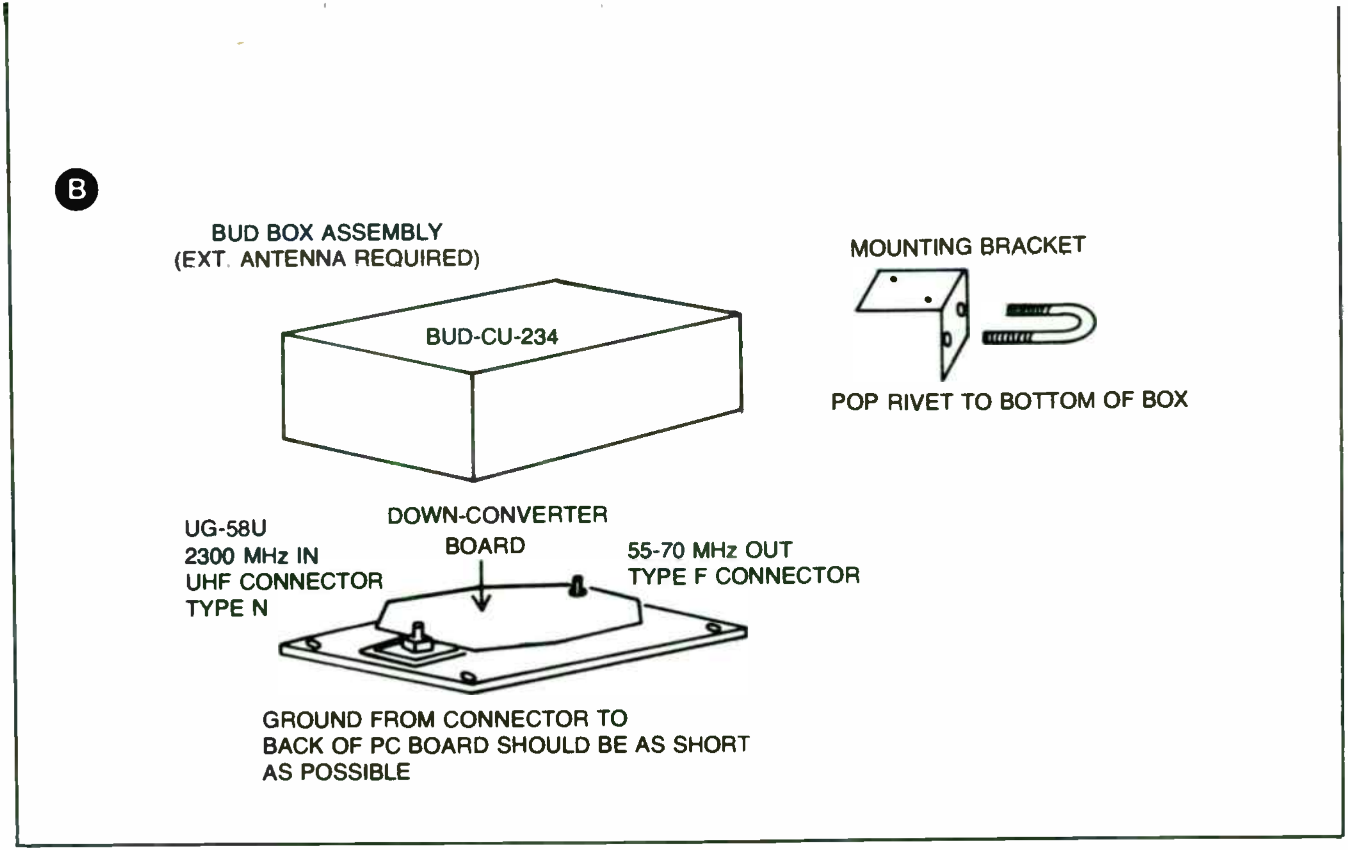


Fig. 9-10. Methods of mounting downconverters to coffee-can (A), or metal-box (B), enclosures.

coffee-can version. Optionally, a type N-connector may be attached to the converter to permit the use of different feed horns and or antennas.

Trim the copper foil from around the antenna-feed hole on the ground-plane (non-etched) side of the board. This will prevent the signal line from shorting to ground. See Fig. 9-8. Form the coax hardline as shown. Small-diameter, 50-ohm Teflon coax, with the outer insulation removed may be substituted for the hardline. To trim the coax, cut through copper and Teflon. To remove the unwanted piece, heat with soldering iron and remove with pliers.

Insert the inner conductor of the hardline coax through the input-terminal hole on the board, from the ground plane side. The inner conductor should extend out of the top of the board a small amount. Position the hardline in respect to the board as shown in Fig. 9-9, and solder the shield of the coax to the ground side of the board. Some suggested receiving antenna designs are included in Figs. 9-10 through 9-13.

THE UNIVERSAL COMMUNICATIONS 2-GHz PREAMPLIFIER

This preamp differs from most existing 2300 MHz preamps available in that the filter on the output stage removes the image and noise that can degrade the picture quality and preamp noise figure. On any wideband preamp, noise is present at the frequency to be received and at the image frequency. Any receiver or converter that has a wideband front end and no filtering can receive on two frequencies at the same time.

Preamp Specifications:

2 stage,
20 - 22 dB gain,
Filter: ±50 MHz - 10 dB, ±100 MHz - 18 dB (4 dB insertion loss)
Power: 10 - 15 Vdc
Max. input: −20 dBM

Preamp Assembly

1. Install all resistors on the circuit board (R1, R2, R3, R4, R5, and R6).
2. Install the three chip caps (6.8pF) for C1, C2, C3.
3. Install the two 470pF chip caps for C4, C5.
4. Install Q1 and Q2. Be sure of polarity. The base is the sliced lead. Excess lead length should be cut off.

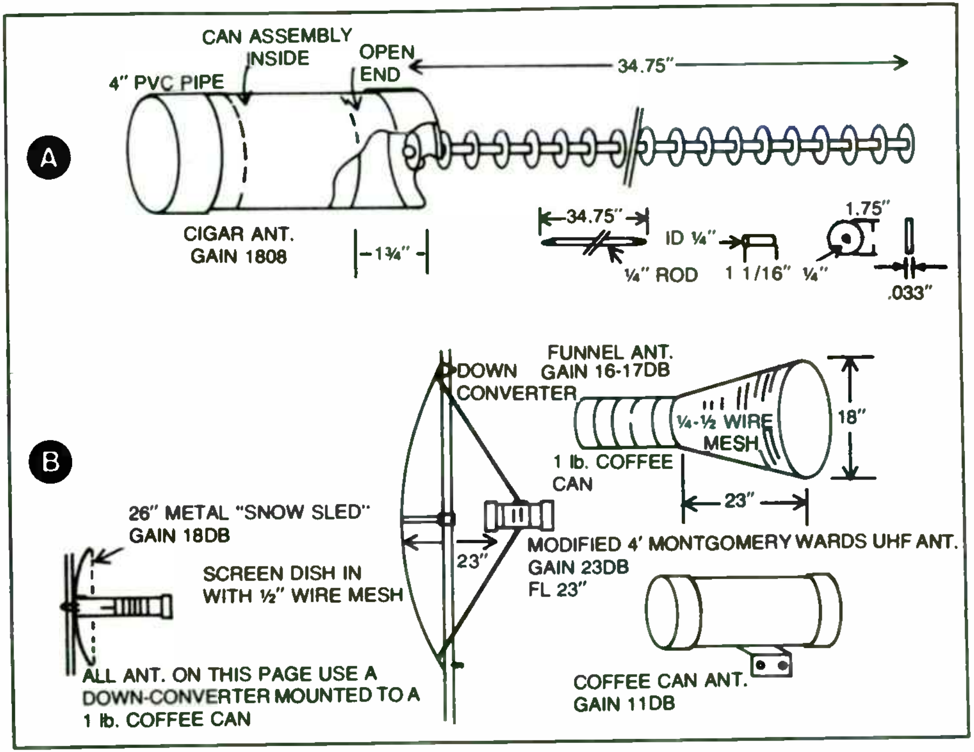


Fig. 9-11. Two "gain" antenna setups. A is "cigar" antenna of 18 dB gain; B shows parabolic dishes of 18 to 23 dB gain. Reference figure is 11-dB gain, 1-lb coffee can.

Fig. 9-12. Deborah Franklin, General Manager of Universal Communications, holding MDS downconverter and power supply/remote control which she personally constructed. The system worked on the first try.

5. Assemble the filter board as shown in Figs. 9-14 and 9-15. The filter capacitor is soldered on both sides. Try to avoid a solder short through the hole from excess solder.
6. Position filter board onto main board as shown in Fig. 9-16. Hold upright and solder it in all places (in-out line, and along ground strap on both sides).

Fig. 9-13. Deborah with Universal Communications 4-foot parabolic dish and plastic enclosure for coffee-can cavity.

This completes the preamp assembly.

If the preamp is used with the Universal Communications Downconverter the preamp and converter will stack together as in Fig. 9-17. Before adding this preamp make sure the converter works.

1. Remove the antenna probe from the converter board and place on the preamp board in the same fashion.

2. Align the two boards so the preamp *output* line is under the converter antenna *input* line. (On both boards the component side faces up and away from the can.)

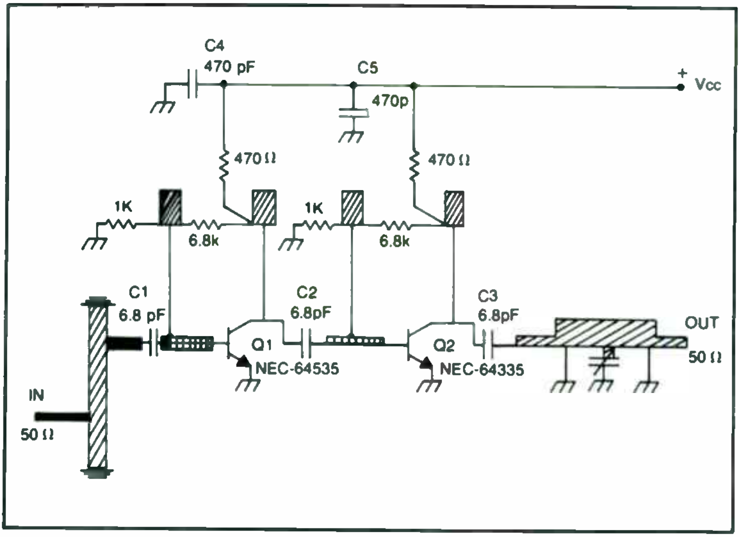


Fig. 9-14. Schematic diagram of the Universal Communications 2-GHz preamplifier.

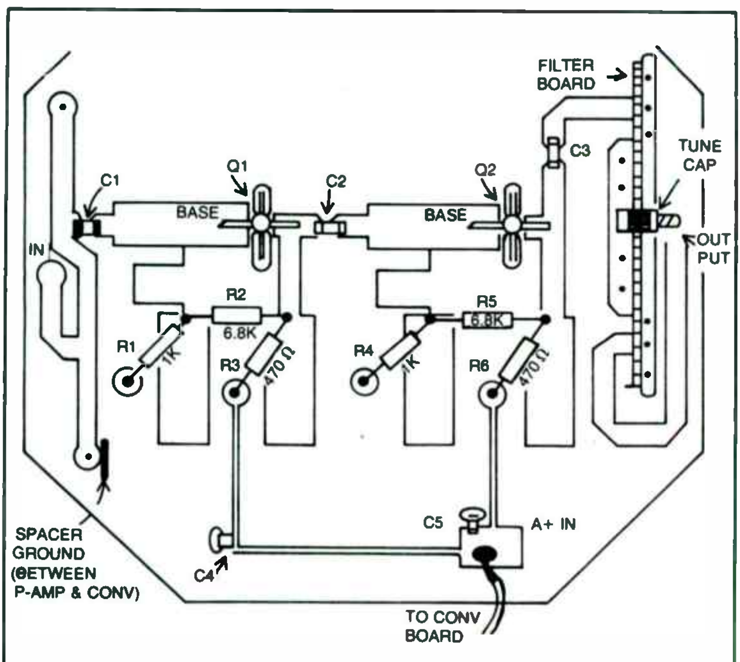


Fig. 9-15. Parts-placement diagram of the Universal Communications preamplifier.

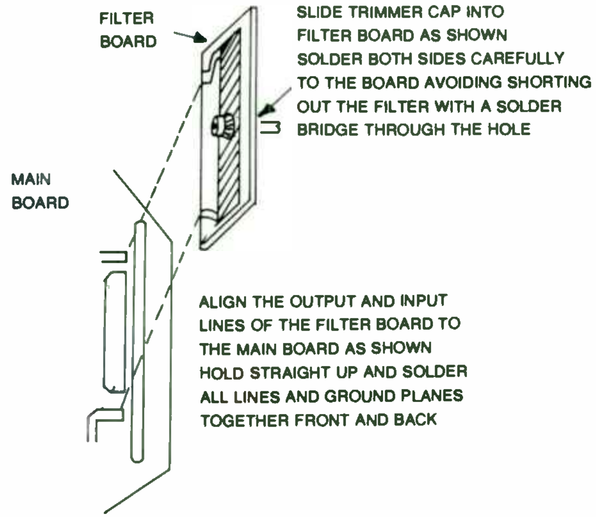


Fig. 9-16. The filter board used with preamplifier.

3. Solder the ground-plane side of the filter (solid metal) to the converter board ground plane.
4. Insert the small spacer between the two boards and solder it in place. (On the assembly drawing, the lower left section shows the spacer location. This is ground and a good place to

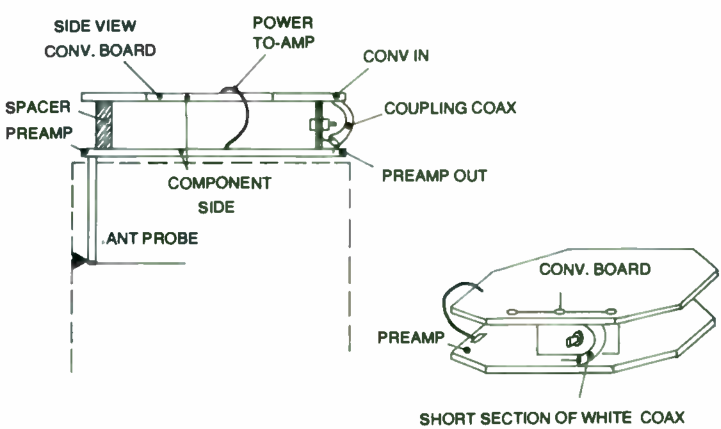


Fig. 9-17. Method of stacking preamplifier and downconverter on rear of coffee can.

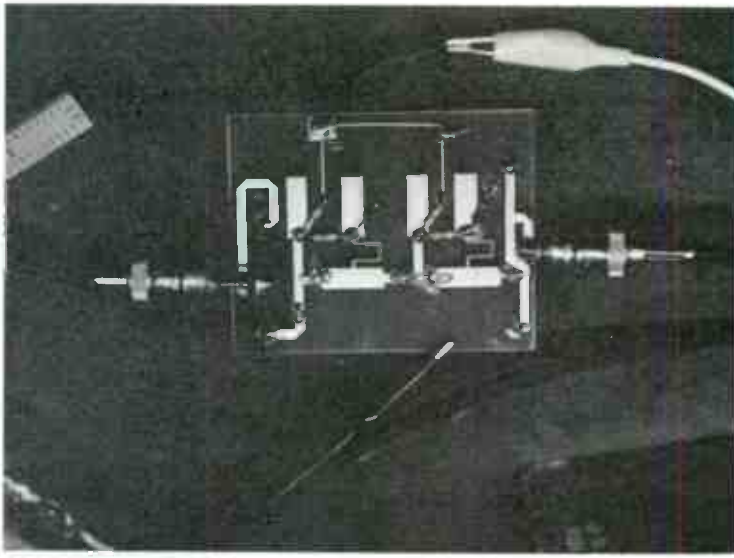


Fig. 9-18. Prototype 2-GHz preamplifier of Universal Communications design. Once optimum performance was achieved, design was transferred to that of Fig. 9-19.

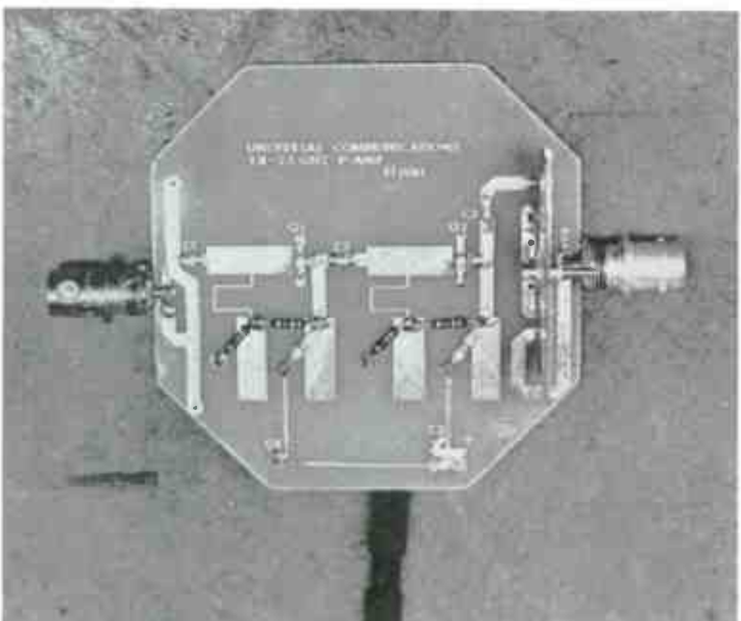


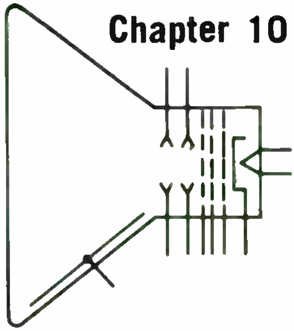
Fig. 9-19. The finished product, a 2-GHz preamplifier by Universal Communications. Unit is stacked with coffee-can-mounted downconverter for added gain.

solder the spacer.) Solder spacer to converter board ground plane and to spacer location on the preamp.

5. Trim both ends of a small section of coax. One end of the coax shield connects to the converter ground plane, and the center conductor goes through the antenna input hole of the converter and solders to it on the top side. On the other end, connect the shield to the filter ground plane and the center conductor to the preamp output line. Be sure to remove the ground-plane foil from around the input hole on the preamp.
6. Run a small insulated wire (1.5″) to the A+ input line on the preamp then over to the top side of the converter board. It connects right at the A+ line on it (10 V side of R-3).

With the converter and pre-amp assembly facing the transmitter (or hooked to a signal generator), adjust the output filter capacitor for the best picture. See Figs. 9-18 and 9-19.

Chapter 10



Satellite-TV Receiver Systems

The reception of satellite-relayed television programming through relatively inexpensive home receiving terminals marks the dawn of a new era in video activities. This era shows promise of new capabilities and opportunities for individuals, small-business, and large corporations in an undefinable manner. The future of conventional television broadcasting will, indeed, be directly related to the satellite field and its operations. Cable-TV companies will continue their use of satellites while also embracing "talk-back" features (known as interactive cable) allowing viewers to participate in opinion polls and the like. Another feature, known as videodata, or viewdata, will link subscribers with a master computer for home shopping, purchasing, banking, etc., while sitting in the comfort of one's home. Through the use of TV satellites, these functions will expand nationwide and then worldwide in a truly fantastic manner.

Independent satellite-TV-receive-only terminals (TVROs), which are already gaining extreme popularity, will become more commonplace. These "backyard receiving terminals" are presently providing their owners with up to 100 channels of specialized viewing. Additional satellites will complement the numerous units presently in operation around the globe, and new satellites specifically designed for direct home broadcast will become popular and escalate "national telecasting" from their vantage point in the skies. Additional innovations and expansions are likewise unlimited, with resultant applications which truly stagger the imagination.

The concepts of modern satellite-TV relays trace back approximately three decades, while their roots, and the beginnings of cable systems, can be traced into similar radio systems used during the 1930s. Various areas of Europe, unable to receive distant radio broadcast during the early period, were served through the use of cable which carried programs to individual homes on a monthly basis. In some cases, audio signals were relayed via cable rather than rf signals. The receiving setups were "audio monitors" rather than complete radios, thus providing true noise-free reception. During the infancy of modern television, residents in remote and rural areas were "cut off" from the range of broadcasting systems. A type of cable system was implemented to serve these areas with video—the Community Antenna TV system (CATV). This arrangement consisted of a elaborate TV-receiving setup atop a mountain near the served area. Received signals were then distributed to subscribers via cable. The broad bandwidth of television signals required line amplifiers and distribution amplifiers every few miles of cable. As systems grew in channel capacity, techniques also expanded to provide the required bandwidths. Soon, CATV systems began carrying numerous TV-channels and providing to subscribers "converter boxes" which converted cable signals to an unused channel. The compacting of vhf channels, quite interestingly, was accomplished by using the frequency spectrum between television Channels 6 and 7. Although this range could not be used for radiated TV signals, cable systems were nonradiating mediums which could quite feasibly utilize this range.

During this same period, larger television networks began using commercial communication satellites to relay programs across the country or ocean during special events. This alternative to expensive broadband telephone-line links quickly proved its merit, and additional communication satellites were launched. Earth-based uplinks (transmitting facilities for TV signals) and downlinks (receiving facilities for those TV signals) began to spring up in numerous metropolitan areas, and the era of satellite TV began to come of age. As satellite relays gained widespread popularity, numerous cable-TV companies joined the action by installing downlink terminals for receiving TV relayed by these "birds" (nickname for satellite). The rest of the story is history. Numerous networks, both independent cable programmers and established broadcasters, began relaying signals via satellite to cable companies across the country—and cable-TV activity flourished. The number of television networks presently transmitting via satellite is difficult to estimate, however a conservative figure is approximately 70. The number of commercial-television satellites is also surprising; over 20 popular "birds," and approximately 20 more secondary-services satellites. The popular satellites include 24 transponders, or channel relays, thus providing capabilities of between 200 and 400 TV channels.

The modern cable system consists first of the original programming studio or network, and second of its numerous cable-TV receiving agreements. See Figs. 10-1 through 10-4. The downlink, or satellite receiver, consists of three basic items as illustrated in Fig. 10-5. The large parabolic-dish antenna provides high gain. The necessary gain is approximately 40 dB at this 4-GHz frequency. In order to achieve this gain figure, parabola accuracy must be maintained to within ⅛-inch tolerances. In order to receive different satellites, the dish must be movable in azimuth and elevation. Reception of some transponders requires rotation of the LNA (Low-Noise Amplifier) feedhorn which is placed at the dish's focal point. The LNA is required to provide an additional 30 to 50 dB of gain with a 1 to 2 dB noise figure (typical requirements for mid-U.S. operation). There are no logical "sidesteps" for reducing gain/noise figures—satellite signals are hidden from mass public reception by their microwave frequencies and their apparently weaker-than-

Fig. 10-1. Studios at Eternal Word Network, Our Lady of the Angels Monastery, Birmingham, Alabama, are as complete as any in the country. Above is a view of the broadcast-quality video-tape recorders.

Fig. 10-2. The switching and monitor positions for the Eternal Word studios.

noise-level signals. Receiving terminals must be capable of "digging" these signals out of the noise by a margin of at least 10 dB. The dish-and-LNA combination provides this ability. The LNA uses

Fig. 10-3. Another view of the switching console and the video-tape recorders.

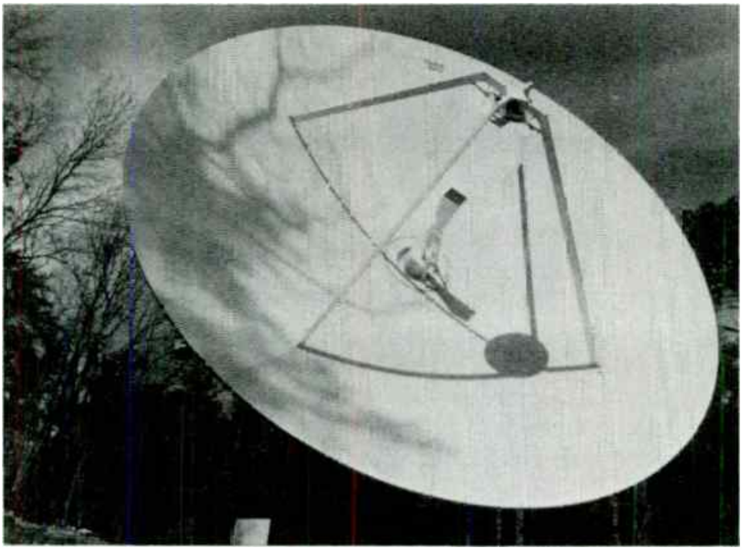


Fig. 10-4. Uplink transmitter and 10-meter dish at Eternal Word facilities.

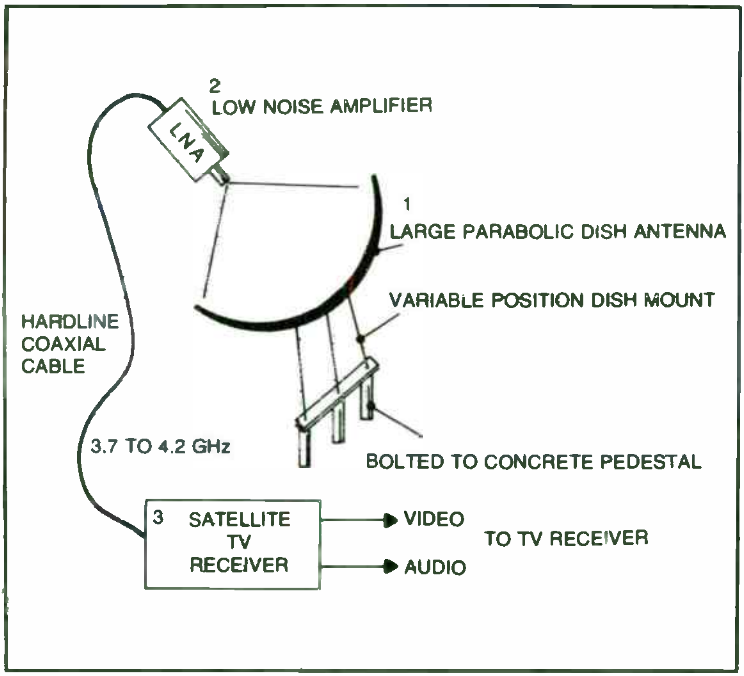


Fig. 10-5. Outline of basic satellite-TV receiving system (TVRO), consisting of parabolic dish, low-noise amplifier, and indoor tunable receiver.

GaAsFET transistors to achieve low noise figures. These devices are quite expensive and fragile. Additionally, the GaAsFET LNA must be mounted at the dish's focal point, a location which subjects it to extremes of weather conditions, lightning spikes, etc. Reliable cable-TV operations thus maintain several LNAs for rapid replacement during unforseen outages. The cable connecting the LNA to the indoor satellite receiver is low-loss hardline coax (½-inch Heliax, typical). The indoor satellite receiver is a single- or dual-conversion unit, usually exhibiting 50 or 60 dB gain with a 10 to 15 dB noise figure. I-f bandwidth is typically to 20 to 30 MHz, and audio detectors operate on 6.8 or 6.2 MHz. The output of this (24 transponder, 500-MHz range) satellite receiver is baseband audio and video. Signals from the satellite receiving setup at a cable installation are then processed and selected for feeding to subscribers as required. A basic block diagram of this cable setup is shown in Fig. 10-6.

Extensive use of commercial satellites for relaying TV programs to earth-based ports and cable-TV corporations soon led the way for another innovation—the home satellite receive-only terminal (TVRO). Paralleling their substantially more elaborate commercial counterparts, these units consist of a parabolic dish, LNA, and satellite receiver which provide baseband TV signals. The

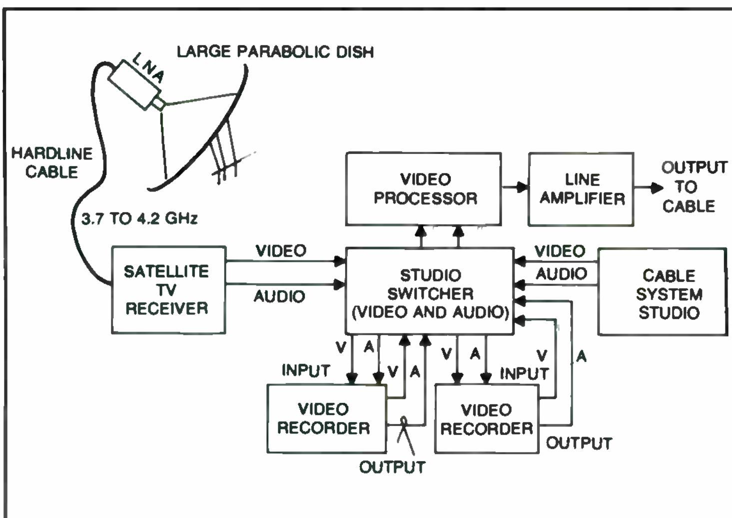


Fig. 10-6. Basic arrangement of a cable-TV system. Studio switcher selects signal source feeding cable, and directs record/playback of tapes to/from recorders, studio, or satellite receiver.

individual possessing such a TVRO then enjoys unlimited viewing of satellite-relayed signals. Original prices of home TVROs were placed in the $20,000 and up category, but technical innovations recently dropped those prices to the $15,000 range. As this book is being written, additional developments and innovations in the home TVRO field are resulting in full units in the $4,000 category, and hints of yet lower (although not substantially lower) prices are being heard. The legality of home TVRO operation is presently somewhat a vague situation: satellite operators and users do not want outside intruders eavesdropping on their revenue-producing operations, while the FCC hasn't provided a hard-and-fast rule for all situations. The individual using his TVRO strictly for personal enjoyment argues his point (the signal is on my property, I can justifiably view it—otherwise, they can remove the signal), officials occasionally intervene and reflect other opinions. The concensus is, as of this book's writing, that using home TVROs strictly for personal use—and not relaying that information to neighbors is acceptable. Indeed, the concept of TVRO-relayed programs falls into the MDS or microwave-TV broadcast category and encompasses franchise-style operation. At this point, reception of satellite-TV programs is a relatively difficult and expensive endeavor which can best be attained through a clear understanding of the satellites and earth-based TVROs.

THE SATELLITES AND THEIR PROGRAMS

All of the popularly used TV satellites are in a "parked," or geostationary, orbit located approximately 22,000 miles above the equator. This group of satellites comprise what is known as the Clarke belt, so named in honor of its imaginative science-fiction author and envisioner of the 1940s. Since the satellites directly follow earth's rotation, they appear absolutely stationary in the sky (movement, or roll, is less than 1 percent!). Satellite frequency bands are 5.9- to 6.4-GHz uplink, and 3.7- to 4.2-GHz downlink. Most of the satellites employ 24 transponders, or separate channel relays, and each channel is 40-MHz wide. A quick calculation indicates that only 12 channels would fit into a 500-MHz spectrum, however a combination of horizontal and vertical signal polarization is used to overcome this obstacle. See Fig. 10-7. Cross-modulation is not created because bandwidths are typically 30 MHz, and an extra 10 MHz is used for guardbands. The video is wideband FM, with an overall frequency deviation of 30-MHz, which provides a very good signal-to-noise ratio. Audio is conveyed as a channel

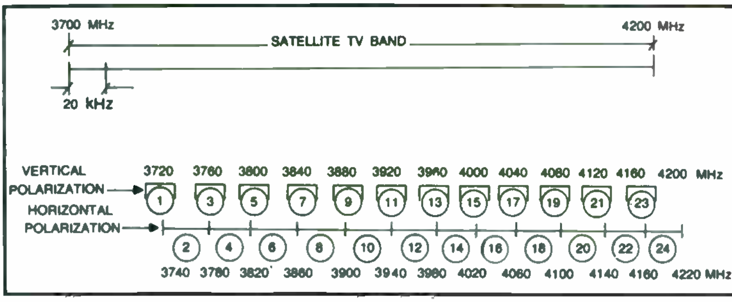


Fig. 10-7. Concept of frequency reuse employing vertical and horizontal polarization of signals transmitting in the 3.7 to 4.2 GHz range. Example shown is for SatCom I and similar "workhorse" birds. Video format is FM, 30-kHz bandwidth with 10-kHz guardbands. Audio subcarrier is also FM; center frequency is 6.2 or 6.8 MHz.

subcarrier on either 6.2 or 6.8 MHz, depending on the particular transponder being received (6.8 MHz is presently used on 75 percent of the transponders). Because clusters of signal energy are produced near the carrier frequency, transponders are "offset" 20 kHz between vertical and horizontal polarizations. Thus, earth-based stations receiving a particular satellite would change both polarization and frequency when shifting transponders. The prime "workhorse" of TV satellites is SatCom 1, which is placed approximately 135 degrees west (in reference to the Zero Meridian), and carries almost full transponder loads 24 hours a day.

TVROS: CALCULATING EQUIPMENT NEEDS

Because satellite-TV pictures are weak and masked by noise, an efficient and high-gain "front end" is necessary for their reception. Precisely how much gain is required is determined by parabolic-dish size, LNA gain/noise figure, and the receiving location in respect to the satellites. "Overkill" in the form of excessive gain for satellite reception isn't totally unknown, but the results are quite noticeable in an otherwise healthy bankroll! The problem, then, is in achieving the necessary 10 dB signal-to-noise ratio and then aiming the antenna.

TV satellite users use signal-strength charts (known as "footprints") to evaluate an area and determine system requirements. See Fig. 10-8. Although signal variations for most U.S. areas are a couple of dB, those variations are directly translated to currency when setting up a TVRO. The dB figures shown in footprints are signal levels referenced to 1 watt, and do not consider path loss (approximately 196 dB at 4 GHz). The footprint center in Fig. 10-8

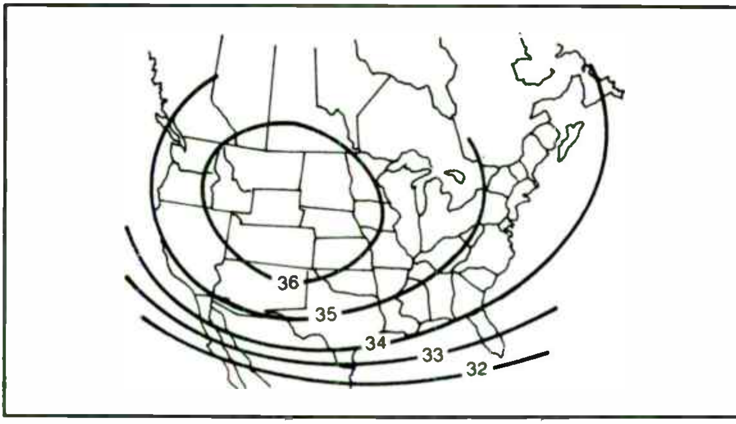


Fig. 10-8. Footprints of a typical TV satellite. More detailed footprints for all satellites are available from cable-TV suppliers.

is +35 dB, thus +35 and −196 = −161 dB. Weak, indeed! That −161 dB figure is too weak for even the best 4-GHz receiver. A high-gain antenna is thus mandatory; however, it still doesn't provide the necessary margin over noise. An antenna-mounted 4-GHz preamplifier is also required. The preamplifier must exhibit a very low noise figure, otherwise the antenna gain is meaningless. Selection of the parabolic dish and LNA thus go hand in hand. A list of typical 4-GHz parabolic dishes and their approximate gains are shown in Table 10-1. Assuming the use of a 15-foot dish, we acquire −161 dB (path losses) +43 dB (dish gain) or −118 dB to be overcome by LNA and receiver figures. Assuming the figure is split between 50 dB LNA and an 80 dB receiver, the signal should be above the noise level. These figures do not take into account receiver bandwidth or terrestrial noises. Some examples of dish and LNA relationships are presented in Table 10-2. Careful examination will indicate that a typical 120-degree-Kelvin LNA and 10- to 12-foot dish should serve for most 32- to 36- dB footprint areas, provided extraneous noises and receiver bandwidths are held to acceptable values. These comparisons should clarify visions of using a small dish and low-temperature LNA (financially crippling),

Table 10-1. Typical Gain Figures for Parabolic Dishes Used In Satellite-TV Service.

6 Foot	35 dB
8 Foot	37 dB
10 Foot	39 dB
12 Foot	41 dB
15 Foot	43 dB

Table 10-2. Relation of Dish Sizes to LNA Figures for Achieving 10 dB or Higher Signal Strengths. Bipolar Transistors Are Usually Rated Above 250 Degrees Kelvin. GaAsFET Transistors Are Usually Rated Below 200 Degrees Kelvin. Lower Temperatures Indicate Lower Noise Figures.

Appx. Minimum Footprint	Dish Size		LNA (Appx. Gain: 50-60 DB)
37 DB	6 Ft	———	50°K = 0.8 DB Noise
36 DB	8 Ft	———	100°K = 1.3 DB Noise
36 DB	10 Ft	———	120°K = 1.5 DB Noise
35 DB	12 Ft	———	180°K = 2.3 DB Noise

Note: Noise figure of LNA in degrees Kelvin.
0°K = −273°C

or using a very large dish and high-temperature LNA (physically impractical). Relatively large parabolic dishes and relatively low-noise LNAs plus a good receiver bandwidth (30 MHz typical) are the basic TVRO ingredients, with 12- to 16-foot dishes and 120-degree-Kelvin LNAs being "standard references."

THE PARABOLIC DISH

The first signal-encountering item in a TV-satellite receiving system is the dish antenna—that colossal item found perched atop cable-TV buildings and dotting landscapes across the country. The dishes are sometimes constructed of aluminum sheeting which is usually arranged in strips, or an aluminum mesh is encapsulated in glass fiber. Dishes thus enclosed often use two-layer metallic construction, the "rear" dish being insulated and grounded separately to reduce noise pickup.

All dishes are not created equal—indeed, some 10-foot dishes perform like 12-foot dishes and some 12-foot dishes perform like 8-foot dishes. The deciding factors seem to center around overall accuracy of parabola design and focal point. Here is an interesting and interrelated factor: A parabolic dish should be made flatter for maximum gain but deeper for maximum selectivity and lower noise pickup (we need both). Typically, the focal-length-to-diameter ratio is between 0.5 and 1.0. The prospective TVRO enthusiast should thus seek a quality dish, free of surface flaws exceeding ⅛ inch, and a shallow curvature producing a focal point at more than one-half the dish diameter.

The high cost of parabolic dishes has inspired many TVRO enthusiast to build their own. Some work successfully and some fail. The home constructor would be well advised to learn from Radio Amateur microwave enthusiasts and their many technical publications. Amateur Radio operators have, for many years, constructed large parabolic dishes for moonbounce and similar "exotic" forms of communications. Using various types of lumber for the framework, heavy rope for bending the surface, and fine-screen mesh for the dish proper, these Amateurs have constructed antennas which should perform well in a TVRO setup.

Assuming a parabolic dish suitable for satellite-TV operation is obtained, it can then be mounted in a manner which provides rotation and elevation as required. The setup is usually referenced to SatCom 1 for position, and its overall beamwidth is often measured with sun noise. The dish is secured to prevent wind movement and a small rotor is placed at its focal point for changing LNA polarization as required.

THE LNA

The next link in a TVRO system is the low-noise amplifier. This unit performs the vital function of boosting the received signal above ambient noise and thus "uncovering" the rf energy. Although the signal loss of a few dB when using a small receiving dish may be compensated with the LNA, the additional noise in that arrangement would render LNA noise figures useless. The LNA determines overall system noise figure, and following stages amplify both the signal and noises.

The LNA consists of two to four 500-MHz-wide (3.7- to 4.2-GHz) stages of rf amplification. A horn collects rf energy at the dish focal point and directs it to a small antenna. The antenna carries rf to the first amplifier stage. Special transistors known as GaAsFETs are used in at least the first two of the LNA. These devices are quite small (gate size approximately 0.5 micron) and quite expensive ($75 to $125, typical). Once the signal has been amplified by these ultra-low-noise devices, less expensive transistors may be used in following stages. GaAsFETs typically exhibit different operating points for maximum gain and minimum noise. The first LNA stages are thus set for minimum noise while subsequent stages are set for maximum gain.

The noise figures for GaAsFETs (and LNAs) are measured in degrees Kelvin rather than more common decibels. Kelvin is a measure of temperature; −273 degrees centigrade equalling zero Kelvin, or absolute zero—a theoretical point where all molecular motion stops. Since all movement would stop at that hypothetical point, all noise would also cease. Zero degrees Kelvin thus represents absolutely no noise, while higher Kelvin temperatures repre-

Table 10-3. Comparison of Kelvin and dB For Noise Measurements In GaAsFETs and LNAs.

Temperature	Equivalent Noise Figure In
0°K	0
75°K	1.0
100°K	1.3
120°K	1.5
170°K	2.0
225°K	2.5
285°K	3.0

sent higher noise levels. A brief comparison of noise temperatures and decibels is shown in Table 10-3. When considering that conventional (bipolar) uhf transistors operate in the 300-degree-Kelvin, and higher, range, the capabilities of state-of-the-art GaAsFET devices become readily apparent. Unfortunately, there are few ways to get around the signal 4 GHz reception. Due to their internal construction, GaAsFETs are difficult to work with and properly bias. The devices are also sensitive to voltage spikes and transients—a situation which almost makes one want to run out and protect the LNA during thunderstorms! GaAsFETs are not the only consideration in LNAs; several other sensitive parameters must also be considered: board material, lead lengths, and component types.

The circuit board material used at 4 GHz must have Teflon as a dielectric, and double-sided. Grounds must connect to all sides and through the board with very short leads. Additionally, small capacitors without leads (called chip capacitors) and small resistors (with leads cut at ends) must be used and precisely positioned.

Finally, the LNA must be enclosed in a well-shielded and weather-proof enclosure. Any leakage or gasket seepage can allow moisture to destroy it's performance. If all these requirements seem an impossibility, remember that cable-TV companies have used them for years.

Some enterprising individuals have constructed LNAs with good results. Soldering requires patience and a steady hand, plus experience in microwave techniques. Individuals feeling uncomfortable in this respect are well advised to purchase rather than construct low-noise amplifiers. As this book is being written, typical costs of 120-degree LNAs range from $600 to $800.

Low-loss hardline coaxial cable is used for carrying LNA output to the indoor receiver. This cable should be as short as possible in order to minimize losses. Likewise, high-quality cable is mandatory, and good connectors must be used. Any signal loss at this point would destroy the effect of both the dish and the LNA. Voltages for LNA operation may also be carried via this cable, or via a separate cable, depending on the particular LNA used.

THE RECEIVER

The final link in TVRO makeup is the indoor receiver, or tuning unit. The first generation of receivers featured expensive microwave-type design front ends, and continuous tuning of the 3.7- to 4.2-GHz range. As technology advanced, receiver designs improved and digital concepts were used. Today's receivers have switchable transponder selection by digital divide-by-N circuits, phase-locked-loop ICs, etc. The overall results are quality items which may be purchased for prices between $700 and $1200, or they may be home constructed for approximately half that amount.

The block diagram of a basic receiver is shown in Fig. 10-9. Signals in the 3.7-4.2 GHz range arrive via cable from the LNA, and are applied to a bandpass-filter network. The purpose of this filter is to eliminate extraneous signals, producing a clean spectrum for processing. Although one might think the microwave range is relatively free of outside interference, that simply isn't the case—particularly during the modern age with its numerous microwave links, microwave appliances, etc. Additionally, this stage rejects signals which the TVRO could generate and recirculate within itself. After the input filter, an rf preselector stage is used to amplify the 3.7-to 4.2-GHz spectrum and provide additional bandpass filtering. This stage has relatively high gain and low noise. Signals from the rf preselector are then combined in the mixer with signals from the local oscillator, producing the i-f signal. The most commonly used i-f is 70 MHz, and the bandwidth is 30 MHz. A point of interest is the 30-MHz bandwidth; excessive bandwidth will produce additional noise while a more narrow bandwidth will not pass all video information.

The next stage is a basic limiter inserted between i-f stages to maintain constant signal strength. Following additional stages of i-f amplification, a limiter is employed. Its purpose is to clean up the incoming signal. The resultant single-channel information is then directed to an FM demodulator for retrieving video information and the audio subcarrier. The demodulated video frequencies are next

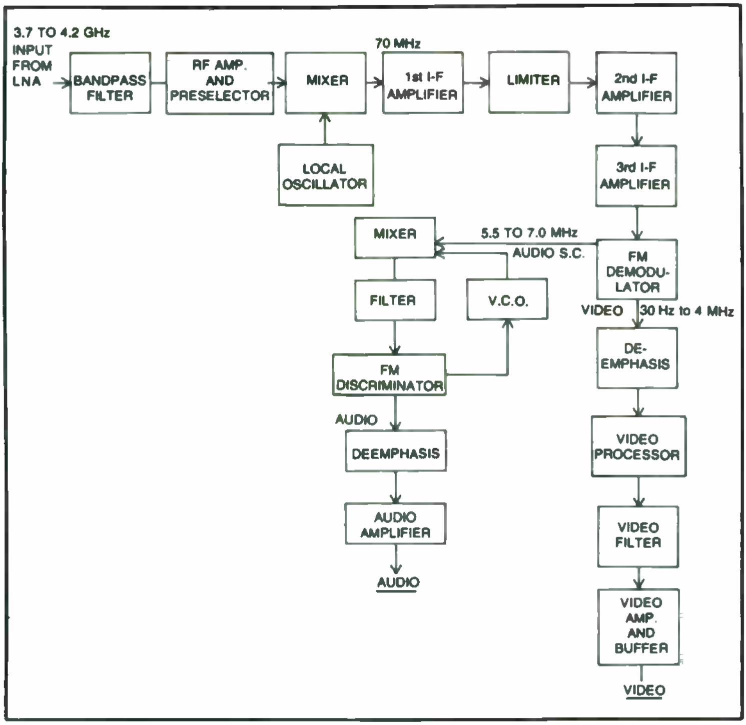


Fig. 10-9. Block diagram of a basic "first generation" satellite-TV receiver, indicating usual circuits and their functions (see text). Although single conversion is shown, some units may feature dual-conversion principles.

directed through a de-emphasis circuit and applied to a video processor. This processor may consist of a sample-and-hold setup, or it may simply remove remaining effects of FM video action. An additional video filter is often used to further ensure a "clean output." Finally, a video amplifier and buffer stage are used to boost the video level and to permit connection to an external unit. That resultant baseband output can be directed to a video tape recorder, connected to a video monitor, or directed to a simple modulated oscillator which would feed the signal into the antenna terminals of a conventional television receiver.

Refer to the FM demodulator. Another line carrying audio i-f signals will be noted running to a mixer. The mixer heterodynes this signal with that of the voltage-controlled oscillator (VCO), producing a 6.8 or 6.2 MHz signal (depending on vco selection according to satellite transponder). The resultant signal is then directed to a narrowband FM discriminator for recovery of baseband audio. The resultant audio is then de-emphasized and applied to a conventional audio amplifier. The audio output may be applied to a stereo amplifier, if desired, or some of the newer modulated oscillators which radiate both audio and video may be employed. Now let's look back at some additional consideration in various stages of the receiver.

The use of 4-GHz input requires microwave design techniques and devices which, although substantially less expensive than GaAsFET's, cost more than common TV-receiver items. As we will see in upcoming designs, placing the microwave sections at the dish feedpoint is more cost effective and efficient. The mixer should be narrowband to achieve high signal gain and low noise figure. The i-f section is relatively conventional in design and in operation (the 70-MHz range is relatively easy to handle, compared to 4 GHz). Since the signal-to-noise ratio has been established in previous stages, i-f noise figures as high as 10 dB are acceptable in the receiver. Hard-limiting stages must be used in at least one point within the receiver to provide clean video and accurate waveforms for subsequent stages. The FM discriminator circuits are particularly adaptable to the use of modern integrated circuits such as the 564, 567, LM3065, etc. The baseband stages are conventional and work well with modern solid-state devices.

EVOLUTION

Approximately three generations of downlink receiving systems have taken place during the years of satellite TV communications. First-generation systems used straight analog concepts and routed 4 GHz signals from the dish antenna to the indoor tuner. The second-generation TVROs included sophisticated afc systems, digital frequency control with divide-by-N circuits, etc. As this book is being written, the third-generation of TVROs is becoming popular. In addition to including digital concepts and state-of-the-art devices, the new generation features microprocessor-controlled scanners for both the tuning unit and the antenna system. There's also much interest in a clever new concept nicknamed "ampliverter." Essentially, this technique involves mounting a 3.7- to 4.2-GHz downconverter behind the LNA at the dish feed, and directing the resultant 70-MHz i-f signal to the indoor tuner via conventional coaxial cable. The advantages and benefits of this arrangement are numerous, including better quality video without the cost of expensive hardline cable, and less expensive (higher temperature) LNAs can be used.

One of the prime considerations for manufacturers of TVRO systems and related items involves protecting their latest schematics and ideas from duplication. That is why it is so unbelievably difficult to secure exact schematics and layouts of TV-satellite equipment (particularly LNAs). Every new schematic, every new antenna design, etc., reflects a potentially high revenue to their designer. Naturally, such "trade secrets" are protected to a relatively high degree. Realizing this difficulty, we are quite grateful to KLM Electronics of Morgan Hill, California, for sharing schematics of their system. These schematics are presented in the next chapter.

TVROS: ANOTHER APPROACH

As explained during the first part of this chapter, a conventional TV-satellite receiving setup consists of a large parabolic-dish antenna, a dish-mounted LNA, a length of low-loss cable, and an indoor tuning unit. That arrangement has been used for many years in a basic "follow the leader" (or beginner) manner. Indeed, newly-introduced TVROs continued to follow similar layouts while including more narrow-beamwidth (lower noise) dishes, less-expensive GaAsFET LNAs, and indoor tuners of better design. The concept of transfering full 3.7- to 4.2-GHz bandwidth signals from outdoor dish to indoor tuner was inefficient and expensive, but the arrangement was accepted as "normal."

Being an avid Radio Amateur operator and microwave enthusiast, the author also wanted to join the TVRO craze but couldn't justify the necessary financial expenditure. A full-blown new ham-radio setup with its worldwide audio and visual communications capabilities held substantially more merit than a super-TV-receive-only setup, yet the "challenge of TVRO" had merit if its funding could be reduced.

The resultant cut rate project began with a study of minimum acceptable reception from existing systems, and a re-evaluation of known TVRO practices. It seemed that the LNA could be replaced with a high-gain, low-noise downconverter mounted at the dish, and the resultant i-f signal could be transferred to the indoor unit via conventional cable. Pursuing that arrangement, an inexpensive black-and-white television receiver could be modified to serve as an indoor tuning unit. The use of 70 MHz, as the i-f was not mandatory; it merely became popular and that popularity was maintained as a compatibility measure. A "homebrew" system, however, need not be influenced by such compatability considerations. Finally, additional stages for audio and video processing were included in the modified TV receiver, and their outputs were directed to a mod-

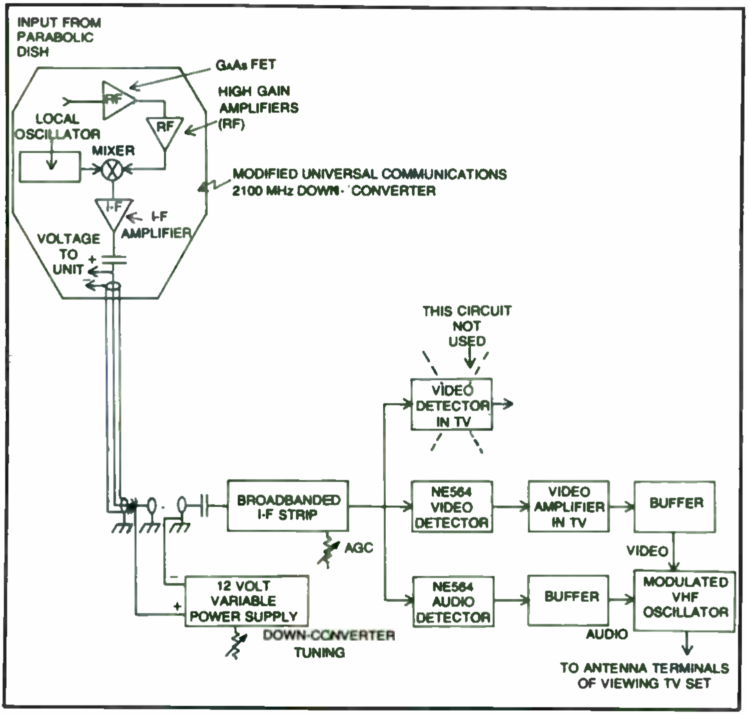


Fig. 10-10. The first approach to an inexpensive, home-constructed TVRO featured a modified MDS downconverter and highly modified television receiver. A separate receiver was required for viewing satellite-relayed pictures.

ulated oscillator for radiation into an unmodified television receiver. An outline of this system is shown in Fig. 10-10.

THE UNIVERSAL COMMUNICATIONS TVRO SYSTEM

Another approach to good performance in a TVRO, shown in Figs. 10-11 and 10-12, has been developed by Universal Communications. They have used the latest design techniques to obtain good performance at a reasonable cost.

The downconverter applies incoming signals to a 90-degree phase shifter to produce two phase-shifted signals for application to the quadrature mixers. The mixers are fed from a local oscillator which is operating at one-half the desired output frequency. Each mixer's i-f output is then amplified and applied to a hybrid combiner before going to a composite i-f amplifier and to the indoor tuning unit. The use of 90-degree hybrid mixers and in-phase recombining reduces spurious signals and images which otherwise appear as

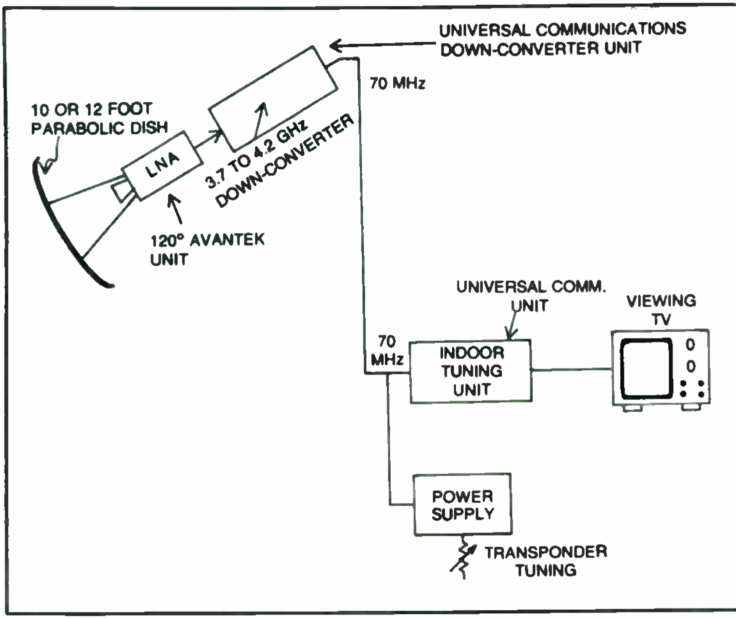


Fig. 10-11. The professional TVRO system developed by Universal Communications, Arlington, Texas, features many concepts destined to lead the way in future designs.

interference to a TVRO "front end." Output signals from the downconverter are conveyed to the indoor unit via a non-critical length of RG-59u cable.

A block diagram of the indoor tuning unit is shown in Fig. 10-13. Incoming 70-MHz signals are band filtered and limited before being applied to an FM discriminator. The output signal is then buffered and split for application to audio and video processing channels. Another output from the discriminator drives the afc which, in turn, provides a correction voltage to the dish-mounted downconverter and maintains a steady i-f. The audio signal is filtered and limited before being applied to a phase-locked-loop detector. A manual "correction adjustment" is provided for setting either 6.2- or 6.8-MHz sound i-f signal detection. The video signal undergoes de-emphasis before being applied to the video amplifier. The sync stripper, pulse detector, and ramp sample hold the timing of each cycle of video and provide exact voltage-equivalent outputs for the video buffer. The output audio and video signals are then applied to a conventional modulated oscillator which radiates the satellite TV signal to a conventional TV receiver.

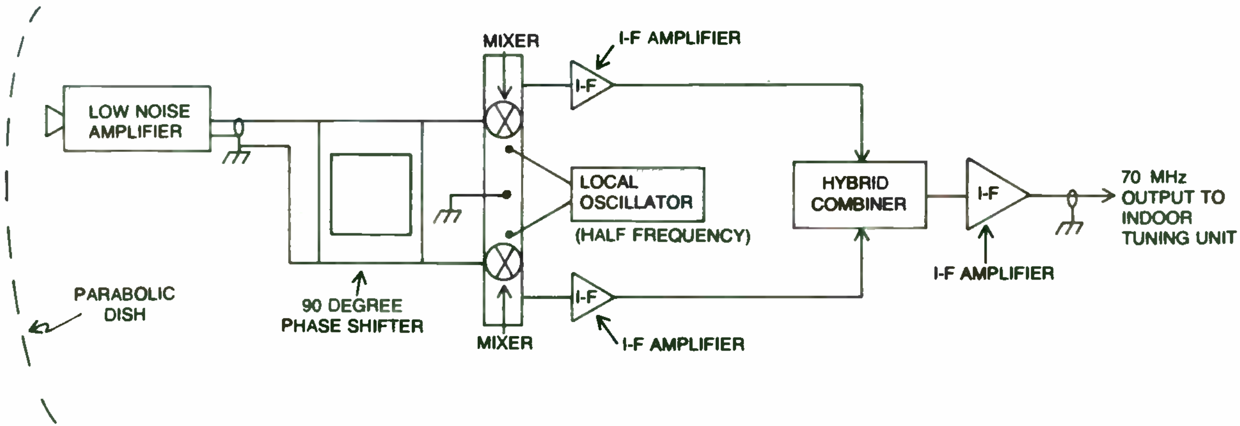


Fig. 10-12. Block diagram of internal design used in the Universal Communications 3.7 to 4.2 GHz downconverter. Note 90-degree-shifted mixing, amplification, and recombination.

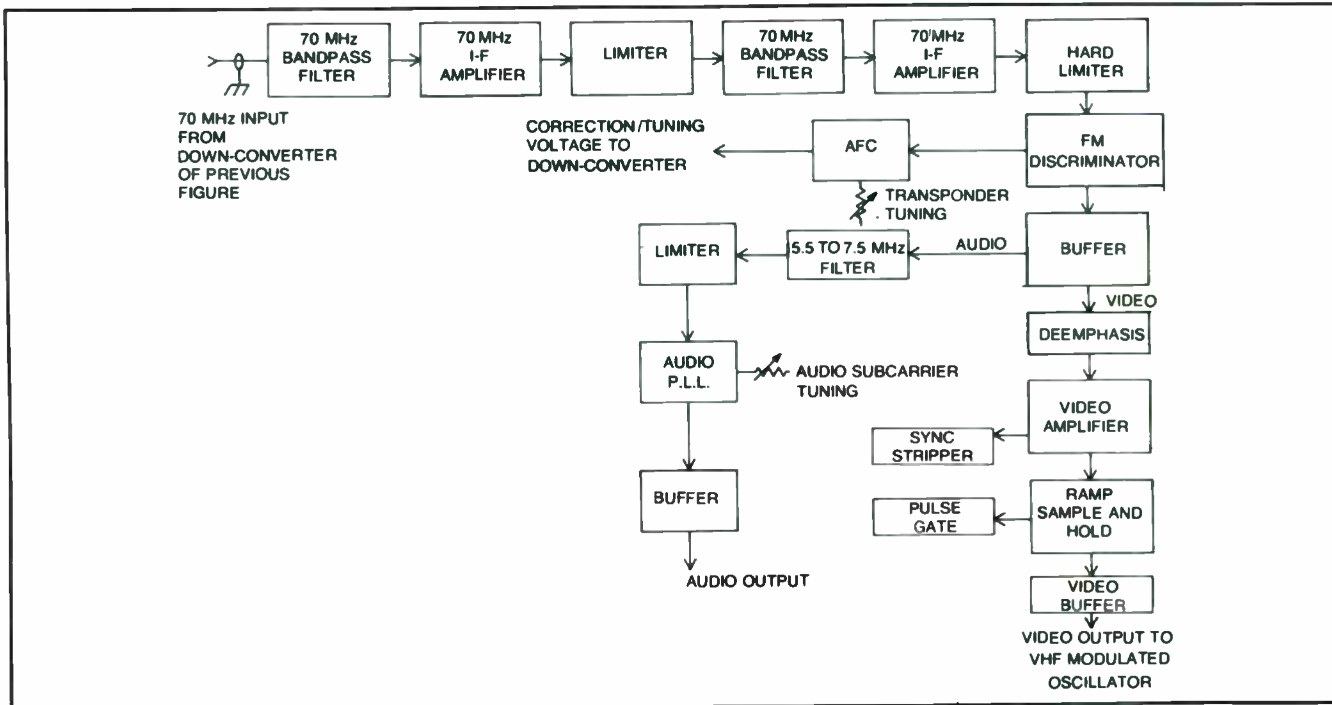


Fig. 10-13. Mating indoor tuning unit for the Universal Communications TVRO.

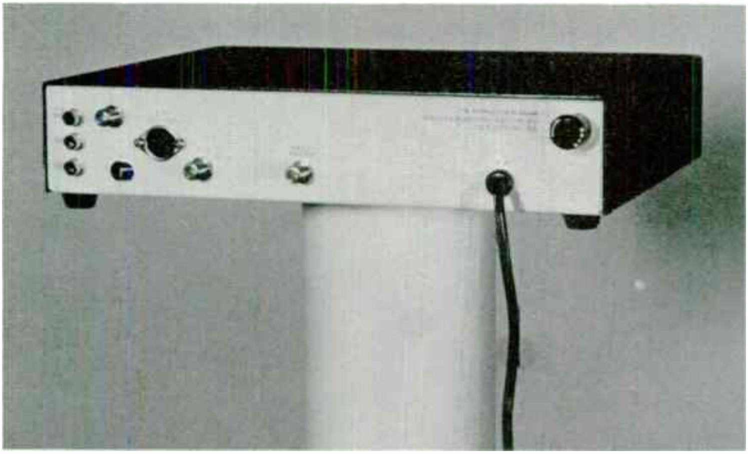


Fig. 10-14. The Universal Communications DL-2000 satellite-TV receiving system, completed and available for public consumption at a very reasonable cost.

The LNA/downconverter concept appears to hold much merit in the TVRO field, and several companies have recently adapted this approach. The requirements of an LNA may never be fully bypassed, but the use of a less-sophisticated unit can decrease costs and that's a major consideration in all TVRO designs. See Figs. 10-14 through 10-17.

Fig. 10-15. Rear view of Universal Communications unit reveals simplicity of hookup and use.

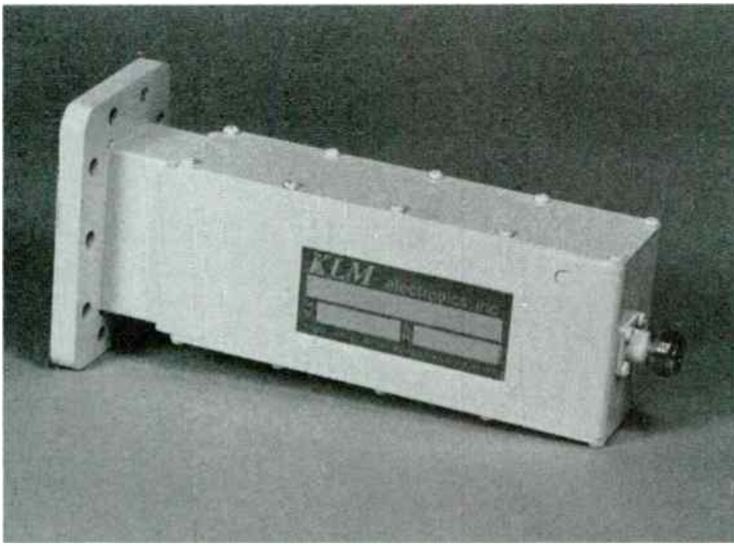


Fig. 10-16. A 120-degree LNA suitable for use with the Universal Communications or equivalent satellite-TV receiver.

Fig. 10-17. A typical TVRO dish of fiberglass design performs extremely well with the Universal Communications system.

THE FUTURE OF SATELLITE TV

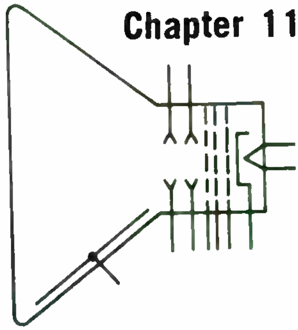
Predicting future developments or happenings in the satellite TV field is precarious. By reviewing past happenings, however, one can logically surmise obvious paths which constantly influence satellite-TV systems.

The concept of two-way, or interactive, cable is destined to gain a major foothold in almost every American home. Increasing energy costs and inflation will tend to reduce unnecessary travel, therefore interactive cable will permit on-screen shopping, purchasing, and community activities right from a home. Visualize, for example, the ability to query cable-linked computers concerning brands of cameras. Each camera's functions can be critiqued, compared, and evaluated while a personal home computer keeps tally of desired features, and extras of each unit. The selected camera can be purchased and billed via on-screen light-pen signatures. Groceries and other goods can be selected by the home computer and programmed into "daily happenings" listed on the TV screen. If all this sounds as if functions in tomorrow's homes will center around personal computers and cable-linked television receivers, you're right.

Commercial advertisements are also bidding for a place in the cable-TV market, and their acceptance appears to only be a matter of time. The cable-TV market is not restricted by FCC provisions affecting commercial-TV broadcasting stations, consequently, advertisements of any length are possible. Visualize a daily hour-long program for the "Kitchen Shopper," "The Golf Enthusiast," "The Home Artist and his Paints," etc., and the impact of combination program/advertisement becomes quite apparent. Cable-TV operators are constantly seeking low-priced but interesting programming and these information/sales arrangements serve those needs perfectly. Advertizers are pressuring cable networks to include commercials, and the amount of money being offered is staggering. The outcome of such offers is not yet predictable, but the tastefully-prepared results should prove informative and personally beneficial. The home TVRO, however, will provide a logical alternative for viewers: They simply switch to another satellite! Cable-TV companies (providing special services) and home TVROs will peacefully co-exist, along with another satellite-TV service planned for the 10- and 12-GHz bands. These super-satellites will act as "TV stations in the sky," broadcasting to homes around the country. Their relatively inexpensive and small receiving terminals will be readily available through larger department stores, but special "descramblers" may be required.

Chapter 11

Home TVRO Equipment and Concepts



One of the most logical ways of becoming familiar with satellite-TV receiving systems and home TVROs involves getting involved with a complete system. This may best be accomplished by following a typical installation from dish assembly through system theory of operation and use.

The following pages of this chapter will thus present details of a TVRO system, compliments of KLM Electronics. P.O. Box 816, Morgan Hill, California 95037. All items discussed are available from KLM.

THE KLM PARABOLIC DISH ANTENNA

KLM produces two parabolic dishes; one 12-foot diameter and one 16-foot diameter. The following details are primarily directed toward the 12-foot dish. We will bypass unpacking/general parts layout and begin with assembly:

1. Remove the two Allen-head hinge bolts and the elevation-screw-mounting lock nut from the motorized AZ-EL mount. Lift off the EL (elevation) plate and place it on a support that provides a convenient working height. (A Black & Decker "Work-mate" works well. An old table or overturned garbage can, padded with cardboard or a blanket, are also suitable.) Replace the bolts and nut on the mount to avoid loss. See Fig. 11-1.

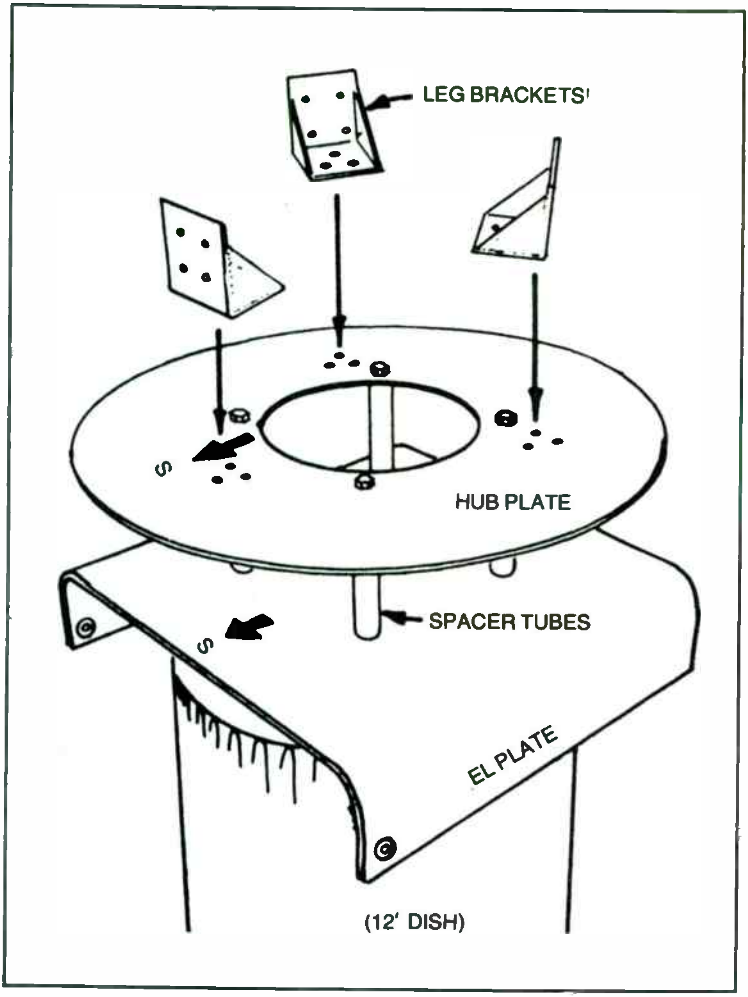


Fig. 11-1. Dish assembly begins with pedestal subassembly. An inverted garbage can serves as a workbench.

2. Attach the round flat HUB plate to the EL plate with the 1″ O.D. spacer tubes and the ½-13 bolts, nuts, and lockwashers. Orient "S" (south arrows on both plates the same way (one set of three holes on the hub plate, for the leg brackets, will be facing the hinged end of the EL plate).

3. Install the three LNA leg brackets to the hub plate using the ¼-20×1-¼″ hardware (bolt heads inside bracket).

4. Loosely attach a 1-½" U-BOLT to the bottom set of holes in each bracket. The cradle and "U" section mount *inside* the bracket on the 12′ dish; *outside* the bracket on the 16′ dish. See Fig. 11-2.

5. Attach Fiberglass legs to the LNA feed assembly using the ¼-20×2-½" hardware (finger-tight only). Use the *middle* hole in each leg. See Fig. 11-3.

6. Lift the LNA/leg assembly up over the EL plate and place legs into U-bolts. Be sure legs are firmly resting on the bracket

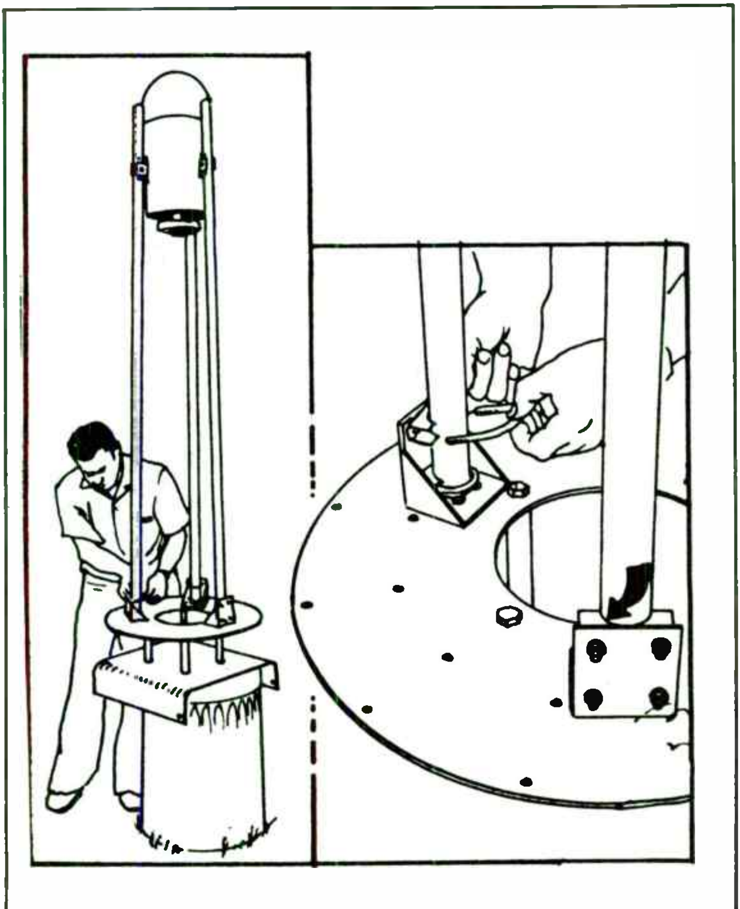


Fig. 11-2. Center cradle is installed on pedestal.

Fig. 11-3. Fiber-glass legs are secured to LNA housing assembly.

mounting-bolt heads before tightening U-bolts. After legs are secure, loosely add upper 1-½" U-bolts to each bracket. Before tightening U-bolts, check that legs are straight to the LNA. (Any two legs must be parallel when sighting across them.) If they are not, twist leg assemblies until they are parallel and then securely tighten all U-bolts. See Fig. 11-4.

7. Tilt the feed/leg/plate assembly to a horizontal position. Measure the distance between the face of the hub plate and the closest lip of the feedhorn. Check against figures:

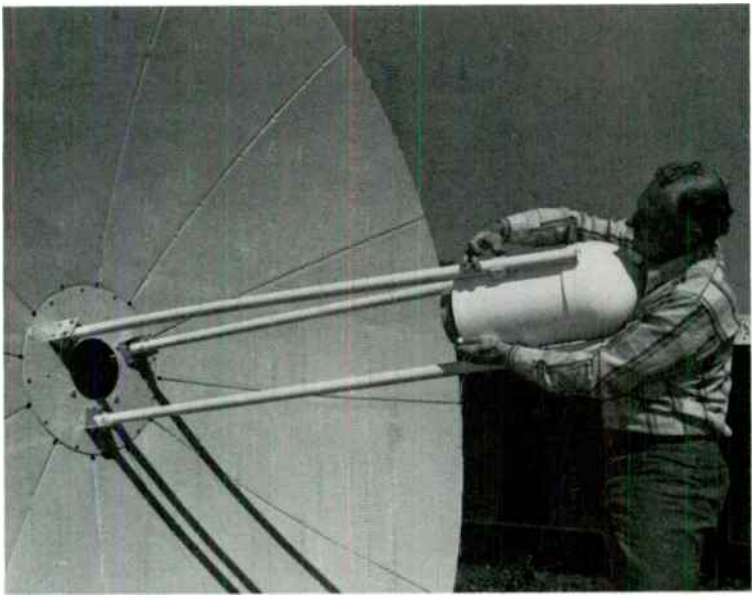


Fig. 11-4. Aligning LNA housing and support-leg assembly.

12′ Dish = 56-½″ (4′ 8-½″) ± ½″

If distance is not correct, LNA/feed assembly can be remounted using alternate holes. See Fig. 11-5.

8. Remove the LNA/feed assembly from the legs and set aside at this time. Replace bolts in feed-assembly brackets to avoid loss.
   Experience has shown the dish is much easier to handle and install on the motorized mount *without* the LNA/feed assembly attached.
   Remove the plate/leg assembly from the support and set aside.

CAUTION!

DO NOT ATTEMPT PETAL/DISH ASSEMBLY OR INSTALLATION DURING WINDY PERIODS. INJURY AND/OR COMPONENT DAMAGE COULD RESULT.

Petal Assembly:

1. Lay two petals of the dish together on the support. Loosely secure mating flanges at three or four points, avoiding the holes

to be used for backribs (12′ dish, ¼-20×¾″ hardware; 16′ dish, 8-32×1″ hardware). See Fig. 11-6. Lay up a backrib to the mating flanges *from the side shown in the drawing*—orientation is important for correct mating to EL plate later in assembly. Loosely secure backribs with appropriate hardware (12′ dish, ¼-20×1-¼″ hardware; 16′ dish, 8-32×1-¾″ hardware).
Install remaining ¾″/1″ hardware.

2. Install anti-crush insert into the butt end of each backrib.

3. Repeat steps 1 and 2 until all 6 petal pairs are completed.

4. Replace plate leg assembly on the support. Attach a petal pair to the hub and EL plate (petal tabs go underneath hub). Secure tabs with ¼-20×¾″ hardware (12′ dish) or 1″ hardware (16′ dish, then jockey the petal until the backrib butt-hole aligns with hole in EL plate. Secure with ¼-20×1-½″ hardware, finger tight.
Place a chair or short ladder under the petal to maintain balance until another petal-pair can be added. See Fig. 11-7.

5. Install another petal pair on the opposite side of the hub and EL plate. Always secure petal tabs first, then backrib butt. Finger tighten the hardware.

6. Install another petal pair and support the assembly with a chair or ladder. See Fig. 11-8.

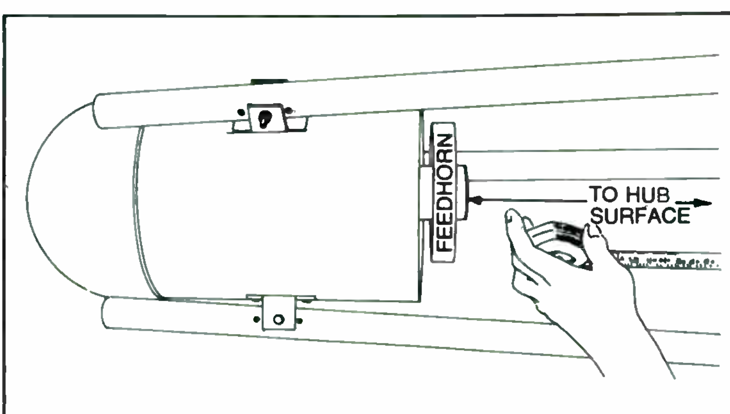


Fig. 11-5. Measuring pedestal-hub to LNA-feed distance.

Fig. 11-6. Pedals of dish are affixed to backribs using garbage can for support. Note assembled center assembly in rear.

7. Secure adjacent petal-pairs together with the ¾″ or 1″ hardware.
   Start in close to the hub and work out to the rim. Leave backrib holes clear. Use a punch or other tapered-shank tool to align holes (as necessary).

8. Install backribs to adjacent petal pairs, oriented to the same side of the flanges as those previously installed. Start with arm

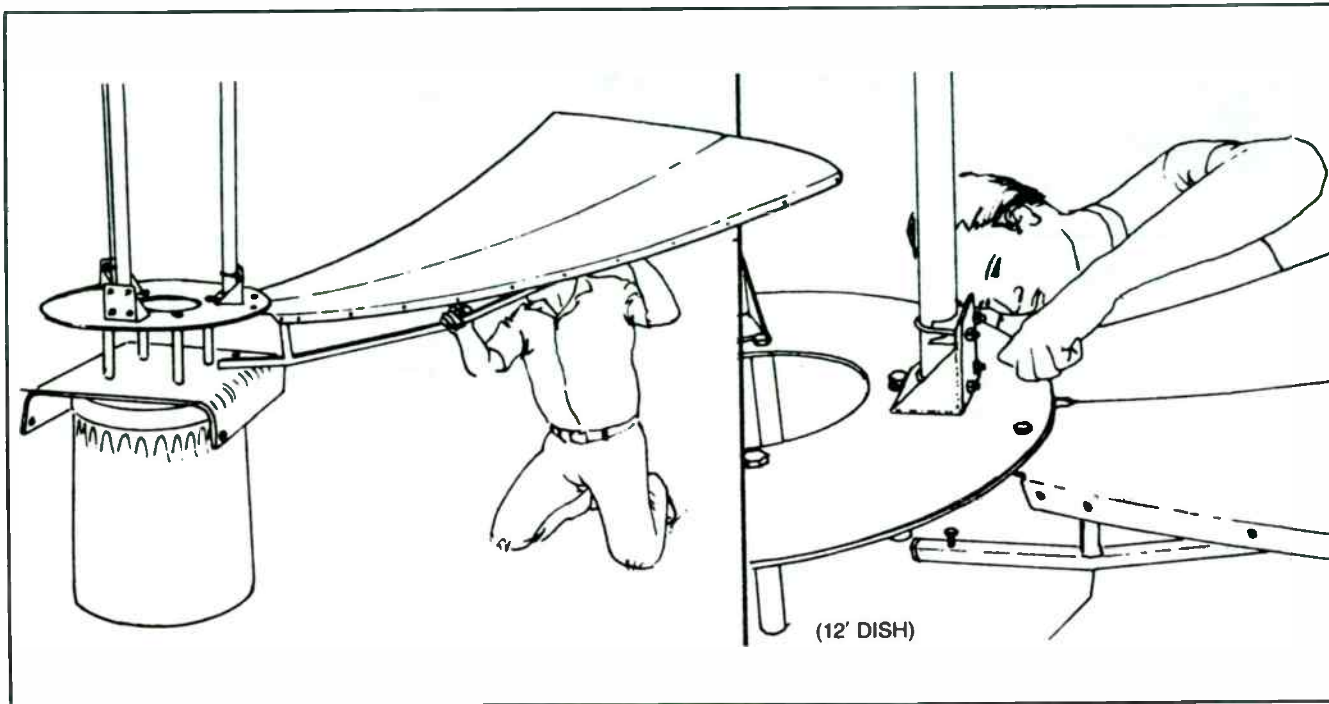


Fig. 11-7. Petal pairs are affixed to hub and backribs are secured.

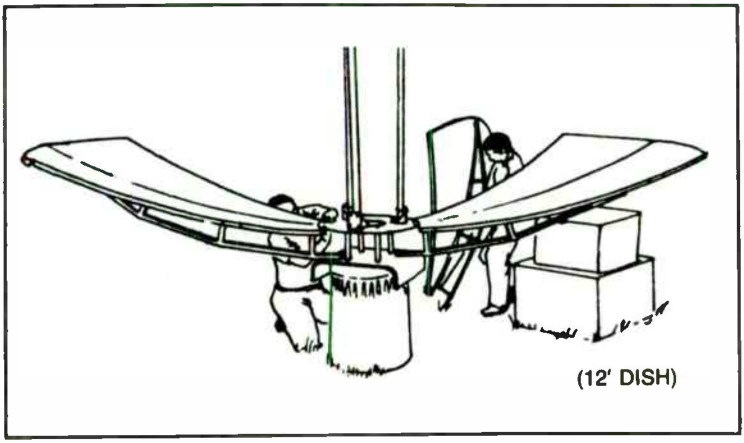


Fig. 11-8. Additional petals are added and dish antenna begins to take form.

nearest hub and work out to rim. Secure the backrib butt to the EL plate last.

9. Install all petal pairs and backribs as described above. Check dish assembly for any missing hardware. Backrib arms are perpendicular to EL plate. If a backrib has arms that lean, viewed from rim, remove and reinstall on other side of petal flanges. See Fig. 11-9.

10. At this point, all petal/backrib assembly hardware has been finger tightened only. Walk around the dish once, gently wig-

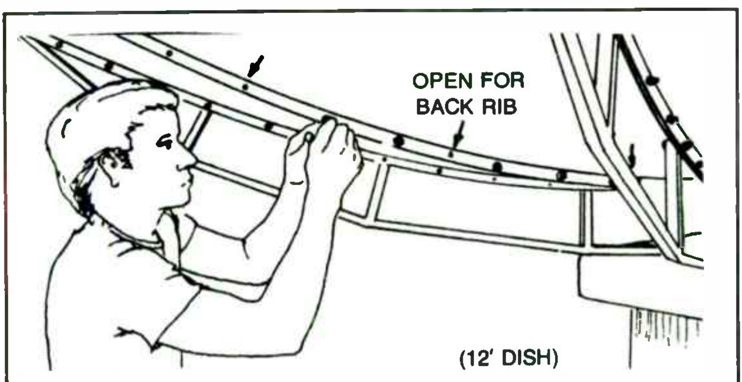


Fig. 11-9. Petals and backribs are checked and aligned for dish symmetry, and bolts are tightened.

gling the petals up and down slightly. This allows them to take a loose "set" with one another and helps balance any unequal stresses and strains. Next, follow the steps outlined below for tightening up the whole dish assembly:

- Tighten innermost backrib arm hardware (nearest hub) only, working your way around the dish. Tighten carefully to avoid crushing or bending rib material.

- Tighten the next two outer ¾″ or 1″ bolts on each petal flange, all the way around the dish.

- Tighten the next backrib arm and the next two ¾″ bolts, all the way around the dish.

- Tighten the remaining outermost backrib and flange bolts, all the way around.

- The last bolts to be tightened are the ¼-20×1-½″ bolts securing the backrib butts to the EL plate. Sight across the rim of the dish from several sides as you go. If a petal junction seems a little high or low, adjust it to level at the rim *before* tightening the butt bolt. Rim of the dish should be straight and even when you have completed this step.
  The butt bolts are important in keeping the dish straight and strong. Anti-crush inserts permit them to be tightened firmly, but watch carefully to avoid damage. See Fig. 11-10.

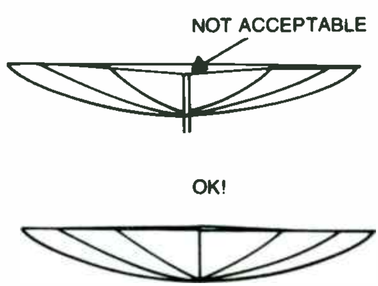


Fig. 11-10. Method of checking the parabola of the dish for accuracy.

Base, Pedestal, and Final Dish Assembly:

1. Place a ½" flatwasher on each of the five ½-13×7" bolts and install through the 6"×6"×10' redwood beams.

2. Assemble the two beams, notch into notch, and secure the flatwasher, lockwasher, and nut on the center bolt.

3. Orient the X-frame base at the site to face true South (not magnetic) by aligning two of the leg mounting studs as shown at left.

4. Start here with prepoured base. Bring the legs, AZ-EL motor mount, and hardware to the south side of the base.

5. Lay the motorized mount unit on its hinged end. Tilt out the EL screw for support as shown in Fig. 11-11.

6. Attach the legs to the mount using ⅜-16×2-½" hardware. Keep legs and bolt heads inside the side plates. Keep leg feet turned out to sit flat on base. The small welded tabs for the sag rods are located between the legs.

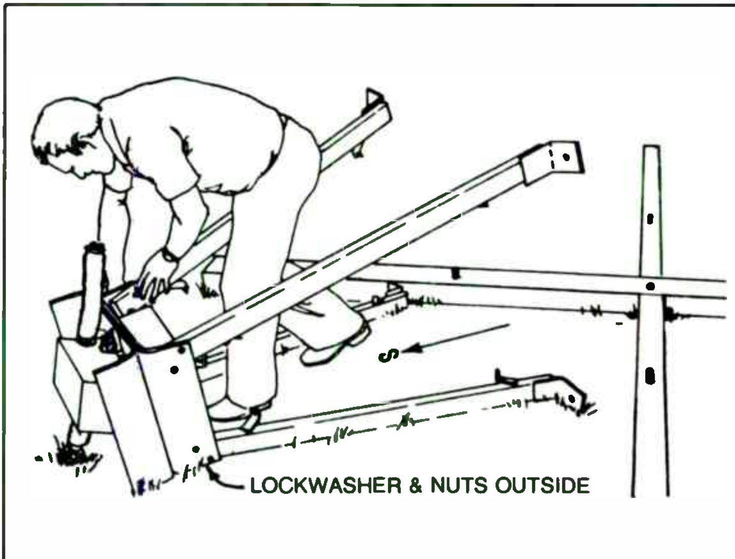


Fig. 11-11. The final step approaches.

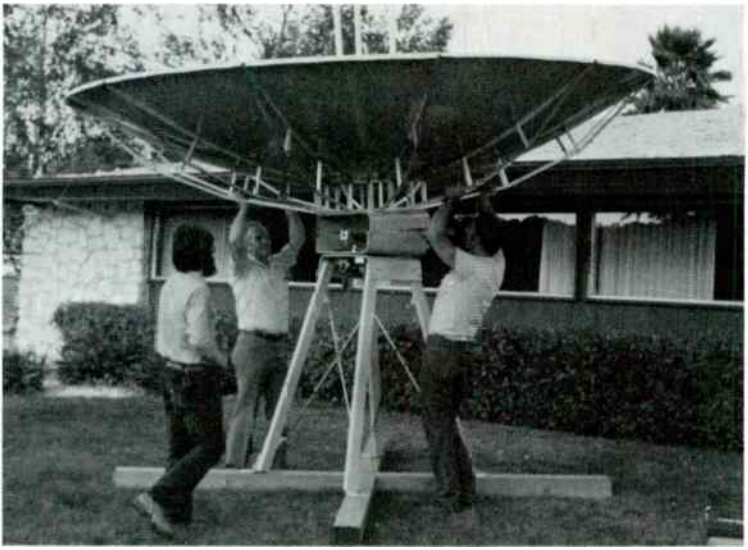


Fig. 11-12. Dish is lifted by backribs and placed on the mount.

7. Raise the mount/leg assembly upright and place feet onto the base studs. Secure feet wtih ½-13 lockwashers and nuts.

8. Place a lockwasher and nut on one end of each sag rod and install rods through leg tabs. Add lockwashers and nuts to the bottom end of each rod. Tighten all sag-rod nuts to provide equal tension to legs.

9. The motor mount is now ready to receive the dish. Place a 2- or 3-foot length of "1×4" type wood across the northern end of the mount to prevent damage to the motor cover and provide a point on which to place some of the weight of the dish while aligning hinge holes. Two or three men can raise and carry the dish to the mount. Keep the hinge points correctly oriented for easy placement on the mount. Lift the dish by the backribs, closer to the hub than the rim, and near the arms running to the petals. See Fig. 11-12.

10. Place the dish onto the mount, allowing the 1×4 to bear some of the weight.

11. One man should hold the dish in front of the hinge points and adjust the height until his partner can install the hinge bolts. Do

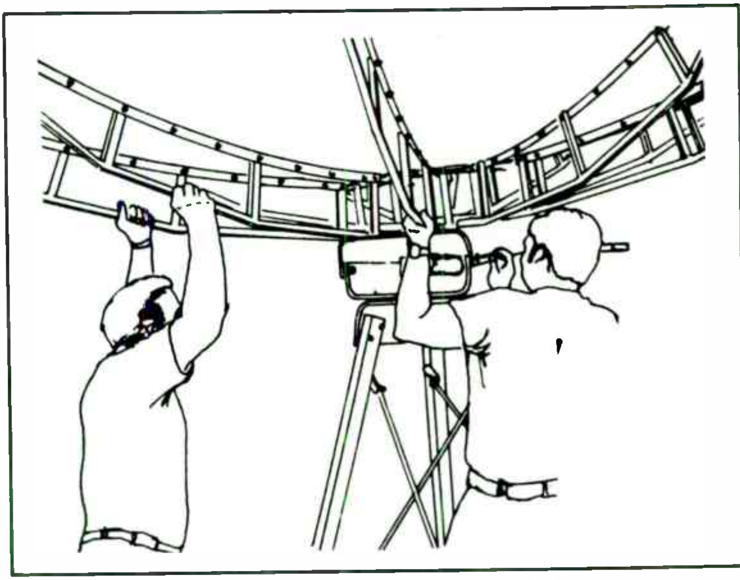


Fig. 11-13. Securing dish and mount is a two-man project.

not tighten one side until a flatwasher, lockwasher, and nut has been installed on the other. Balance the tightening of each. See Fig. 11-13.

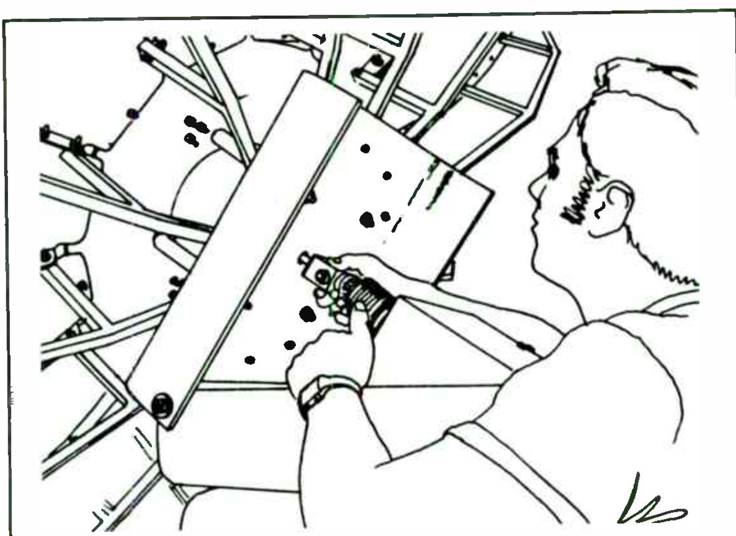


Fig. 11-14. Tightening the complete assembly with dish tilted forward again requires two people.

12. Tilt the dish forward, raise the elevation screw, and insert the U-joint stud through the center hole in the EL plate. Secure with a locknut.
Hold U-joint square with EL plate while tightening nut—do not allow the U-joint to twist. See Fig. 11-14.

13. Most of the dish assembly is now complete. The LNA/feed assembly is to be reinstalled after the Moto-trak Control Console has been connected and the dish can be safely lowered for easy access.

THE KLM SR-3/SRC-3 RECEIVING SYSTEM

The KLM satellite TV receiving system uses the latest microwave technology to provide superior performance, easy operation, and convenient installation. This system is actually composed of two units: The indoor tuning unit which is used in conjunction with the viewing TV receiver, and the remote downconverter/LNA (Ampliverter) which is used in conjunction with the parabolic dish antenna. A sketch of the system is shown in Fig. 11-15.

The SRC-3 is a remote controlled downconverter. This converter should be installed as close to the LNA as possible for optimum performance. The i-f signal, dc power, and tuning voltage for the vco are all transmitted by the single RG58 coax cable. Refer to the block diagram of Fig. 11-16 for theory of operation.

The downconverter is made up of an image-rejection mixer, a voltage-controlled oscillator, an i-f amplifier and dc control circuits. A diagram of this unit is shown in Fig. 11-17.

The image-rejection mixer converts the incoming signal in the 3.7-4.2 GHz band to a 70-MHz intermediate frequency. The overall conversion gain is about 20 dB with a noise figure of less than 10 dB. The mixer is optimized for the 3.7-4.2 GHz band, but does not contain a preselector filter. The broadband i-f amplifier sets the overall gain of the module and establishes the proper source impedance for the i-f port. Dc supply voltage is fed to the downconverter by the coax line. This voltage varies from about 18 to 28 volts. Tuning voltage is recovered by subtracting 18 volts, yielding 0 to 10 volts. A regulator generates the 15 Vdc for the B + requirement, and the unprocessed dc is fed on to the LNA. Output signals from this unit are directed to the SR-3 indoor unit.

I-f System

The i-f system consists of three cascaded amplifier assemblies.

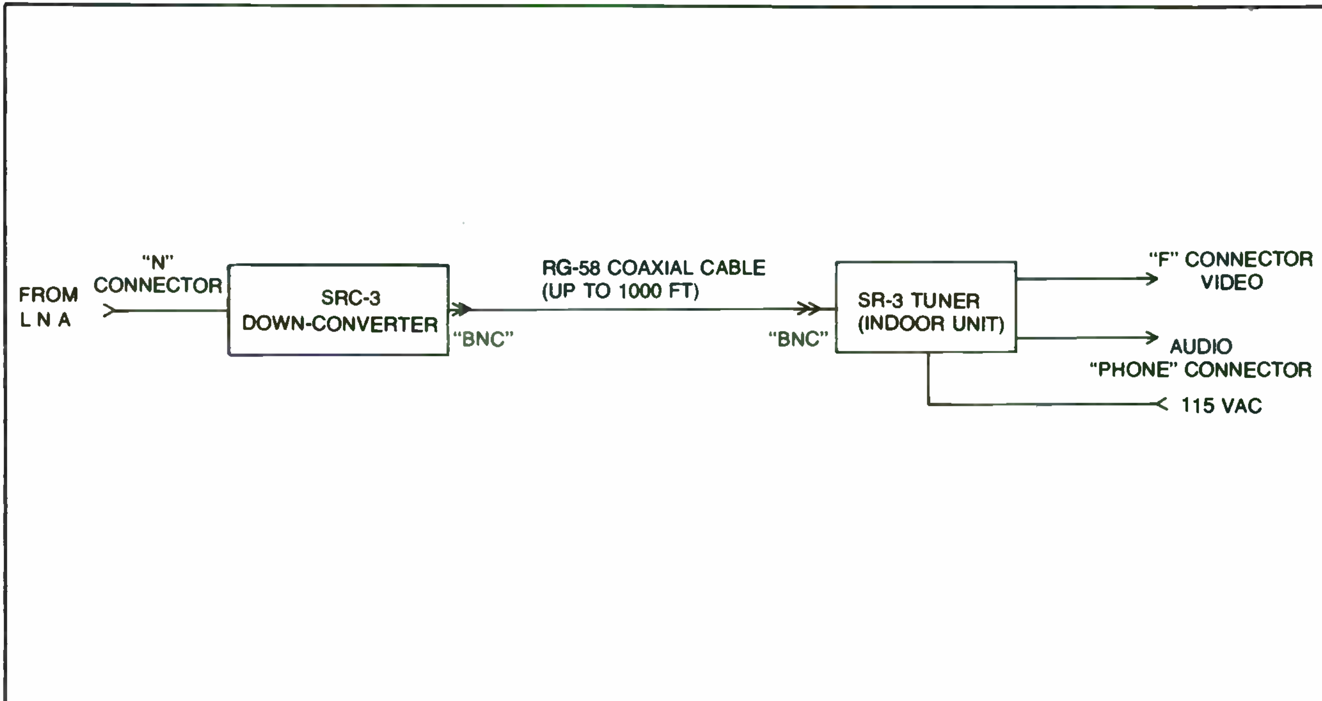


Fig. 11-15. Basic arrangement of the KLM SR-C/SRC-3 TVRO system.

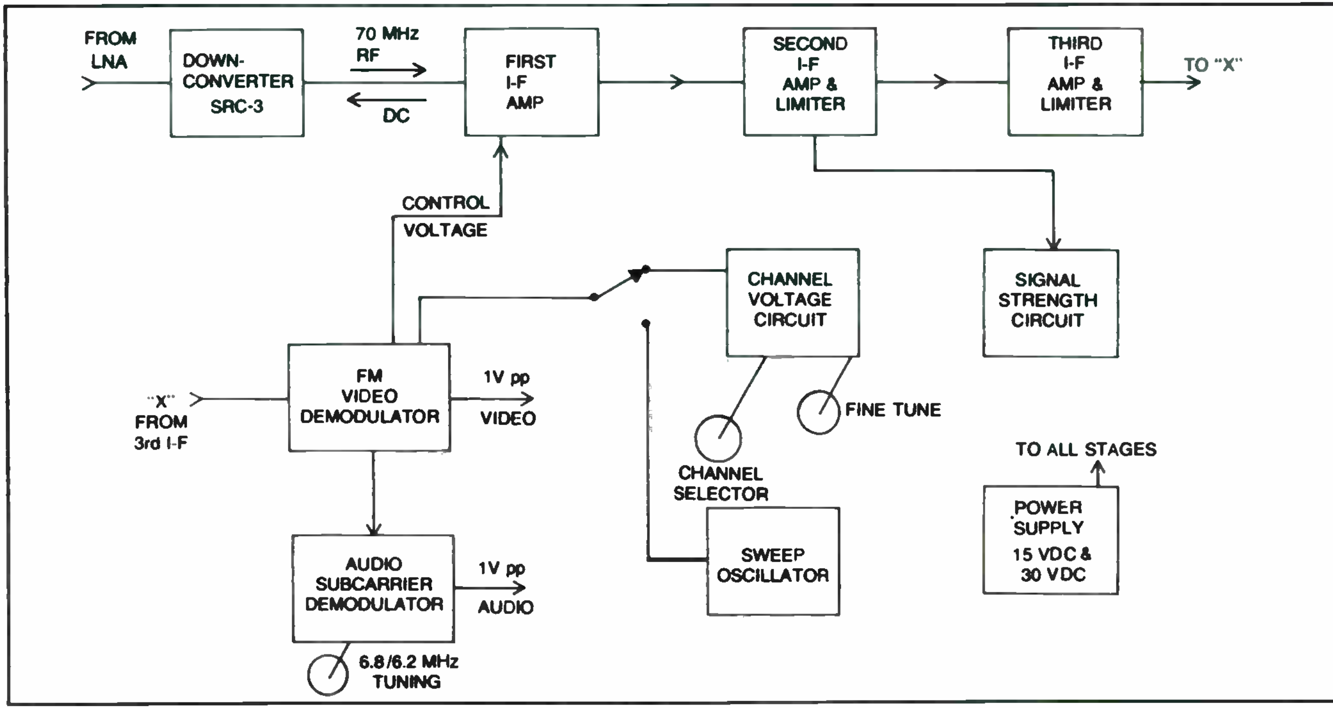


Fig. 11-16. Block diagram of the KLM SR-3/SRC-3 Satellite Receiver System.

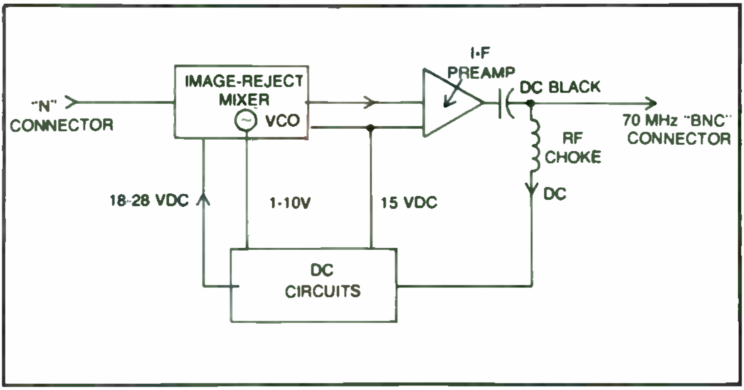


Fig. 11-17. Expanded diagram of SRC-3 downconverter unit.

The first assembly has 30 dB gain, 30-MHz bandwidth, and establishes an i-f noise figure of about 4 dB. The second and third assemblies have 14 dB gain, 25-MHz bandwidth, and are limiters. The overall gain for an unlimited signal is, therefore, about 58 dB. See Fig. 11-18.

The SR-3 uses a frequency discriminator as an FM detector. This discriminator exhibits high linearity and maintains full baseband bandwidth under marginal signal conditions. The baseband signal-to-noise ratio for 9 dB C/N is about 48 dB. Frequency-error voltage is derived from the discriminator detectors. Reference voltage for the error amplifier is derived from the channel-tuning circuit. The error-amplifier output is used as a reference voltage for the control-voltage regulator in the power supply. See Fig. 11-19.

Audio subcarrier frequency is usually 6.2 or 6.8 MHz. However, some other frequencies are used, therefore the KLM SR-3

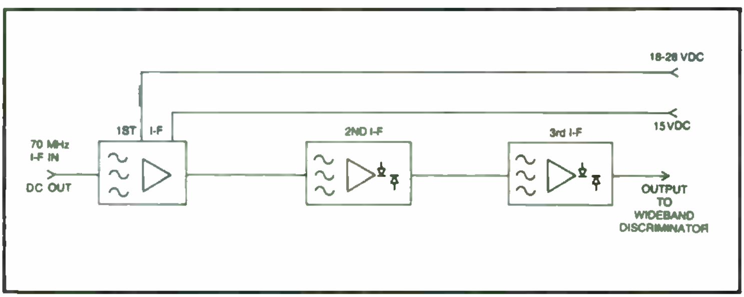


Fig. 11-18. The KLM i-f section is composed of three stages, yielding an overall gain of approximately 58 dB.

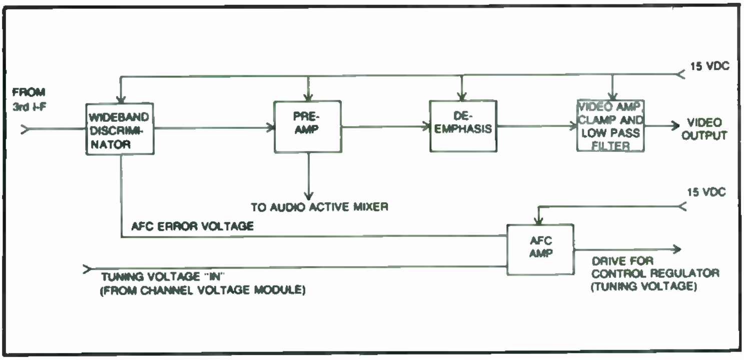


Fig. 11-19. FM detector used for retrieving video information.

features a continuously tunable audio, able to tune subcarriers from 5.5 to 7.5 MHz. See Fig. 11-20.

This receiver also features a scan function which can be used as an aid in system alignment. The receiver will continuously tune through all channels at a rate of about 2 seconds per sweep. The afc will keep a station in tune long enough for the viewer to evaluate the picture quality before lock is lost and the next station is tuned in. The oscillator circuit is mounted on the power-supply board.

Relative signal strength is indicated by a bar of LEDs. The circuit is made up of a diode detector on the second i-f assembly,

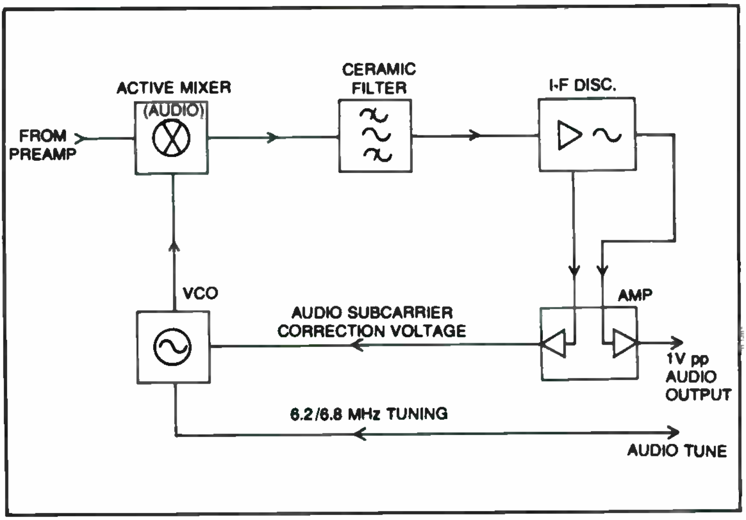


Fig. 11-20. Audio detector arrangement for recovering 6.2 or 6.8 MHz subcarrier information.

driving an analog-to-LED converter. This circuit is for relative readings only and is not calibrated for a specific input power level. Indications may vary if a different antenna/LNA system is used.

The power supply uses full-wave-bridge rectification and integrated regulators to produce the 15 Vdc and the control voltage. The control-voltage regulator derives its reference from the afc amplifier, hence the tuning voltage/afc is stacked on top of an 18-volt supply so that the control voltage varies from 18 to 28 volts when the receiver is tuned from 3.7 to 4.2 GHz. This voltage is fed to the downconverter via the i-f coax. The indoor tuning unit is shown in Fig. 11-21.

The SR-3 front-panel controls are simple and direct. The large central knob selects the satellite channel desired. It is calibrated to the 24 channels found on SatCom I, the most popular entertainment satellite, and, of course, it tunes the channels on the other satellites too.

The small "Fine-Tune" knob to the right is for optimizing the picture quality. Since the SR-3 is aligned at the factory, adjustment of the fine-tune knob is seldom required.

The small "Audio" knob is for optimizing the sound accompanying the programming. Again, it usually needs no adjustment once set unless you desire to tune for other audio programming that is broadcast simultaneously on some channels (5.5-7.5 MHz).

The bottom push-button at the far left of the panel, "Power," turns on the SCR-3 Receiver, supplies tuning voltages to the remote downconverter, and dc power to the LNA.

Fig. 11-21. The KLM SR-3 indoor tuning unit.

The "Video Inversion" button permits viewing programs that have been transmitted with reversed video signals.

The "Scan" button is used as an aid in antenna alignment. When activated, the receiver will continuously tune through all channels at a rate of about 2 seconds per sweep.

The bar of red LEDs across the upper right section of the front panel indicate relative signal strength as an aid in tuning. They are not calibrated to specific input power levels and will vary with different antenna/LNA systems.

Rear Panel Connections: At the lower left is the Rf-In connector. RG-58 cable connects here from the remote downconverter.

Next to the right end is the Rf-Out connector for the internal modulator is used. RG-59 cable connects this terminal to the home TV set. Some receivers may have a 75-ohm antenna input for direct access. Otherwise, the standard 300-ohm antenna terminals require a cable-TV-type impedance transformer (300 ohm to 75 ohm).

On the right, next to the Rf-Out connector, are two female type "F" connectors. The top one is "Audio Out; bottom is "Video Out." These connect, via 75-ohm cable, directly to a TV monitor, VTR, or VCR. These terminals can also feed an external modulator and provide satellite programming on Channel 3 or 4 of a standard home TV set. Modulators built into a VTR or VCR are also usually suitable for this purpose.

Right next to the heatsink are the two RCA phono jacks. These supply stereo audio signals on receivers ordered with the stereo option. Otherwise, they are unwired. The fuse holder and the power cord are at the far right.

Installation

The special design of the SR-3 receiver greatly simplifies installation and reduces cable costs dramatically. The remote downconverter is mounted as close to the dish antenna as possible. In many cases, this means just beneath the hub of the dish or in the support framework. RG-142 coax, with type "N" connectors, connects the downconverter to the LNA located at the focal point of the antenna. This coax carries microwave frequencies and is expensive. Short runs mean less signal loss and reduced expense. If necessary, the downconverter can be mounted farther from the dish. With cable runs of 75 feet or less, the maximum threshold sensitivity of the receiver can still be fully utilized.

Use care in attaching connectors and installing the cable. Carefully mate connectors to components and allow cable to form its own natural bends. Avoid areas where it might be pinched by machinery. Bent connector pins and/or crushed or kinked cable will result in signal losses and a less-than-optimum picture.

RG-58 (50 ohm) coax is used to connect the downconverter to the tuner. Runs up to 1000 feet can be used, permitting a variety of installations (buried out of sight in PVC pipe, etc). BNC-type connectors are used with the RG-58 cable.

RG-59 coax (75 ohm) with type "F" connectors is used between the Video-out and Audio-out connectors on the tuner and a TV monitor, VTR, or VCR. When used with a standard home-type TV set, a modulator is required. This unit places satellite programming on an unused channel of a TV set (usually Channel 3 or 4). If you own a VTR or VCR, it may have a built in modulator suitable for this purpose. Check your owner's manual. RG-59 is normally used for modulator connections, as well as the cable to the TV set.

Alignment of the Tuner

The SR-3 is factory aligned to tune the satellite channels. Occasionally, shipping vibration or installation variations may disturb alignment of the tuner, *i.e.*, best picture is beyond reach of the "fine-tune" adjustment or absent completely. Realignment should be referred to a qualified electronics service technician or the system installer.

Before realignment, be sure the other system components (dish, LNA, etc.) are correctly positioned and functioning properly, and that a picture should be present on the given channel (some SatCom I channels are blank, etc.).

Realignment Procedure is as follows:

1. Check programming so individual channels can be correctly identified.

2. Remove the top cover of the tuner and let the receiver warm up for 10 to 15 minutes.

3. The channel-tuning assembly with wafer switch is mounted on the inside center area of the front panel. Viewing the assembly from the rear, the individual channel alignment potentiometers are identified.

4. Set the channel selector to the desired position and set the

"Fine Tune" to neutral (12:00 O'clock). With a small screwdriver, adjust the appropriate potentiometer to the best picture for the chosen channel.

5. Repeat for all channels to be aligned. There should be no interaction between individual alignments. See Figs. 11-22 and 11-23.

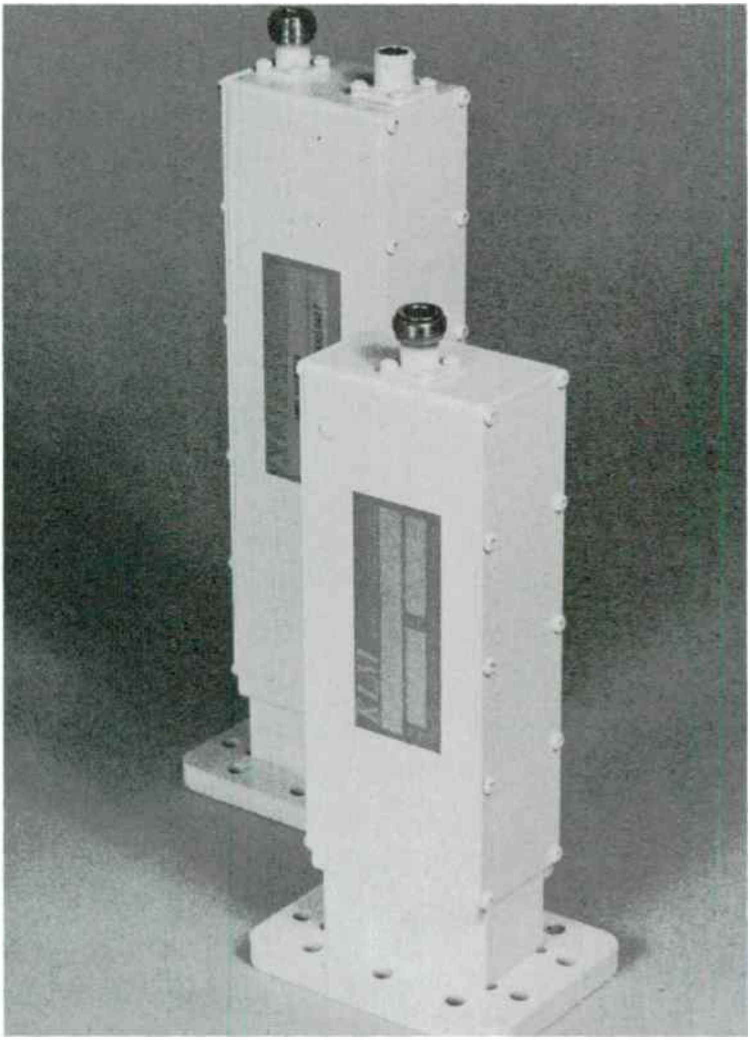


Fig. 11-22. The KLM SRC "Ampliverter" (left) and regular KLM LNA (right). Both units are 120° K.

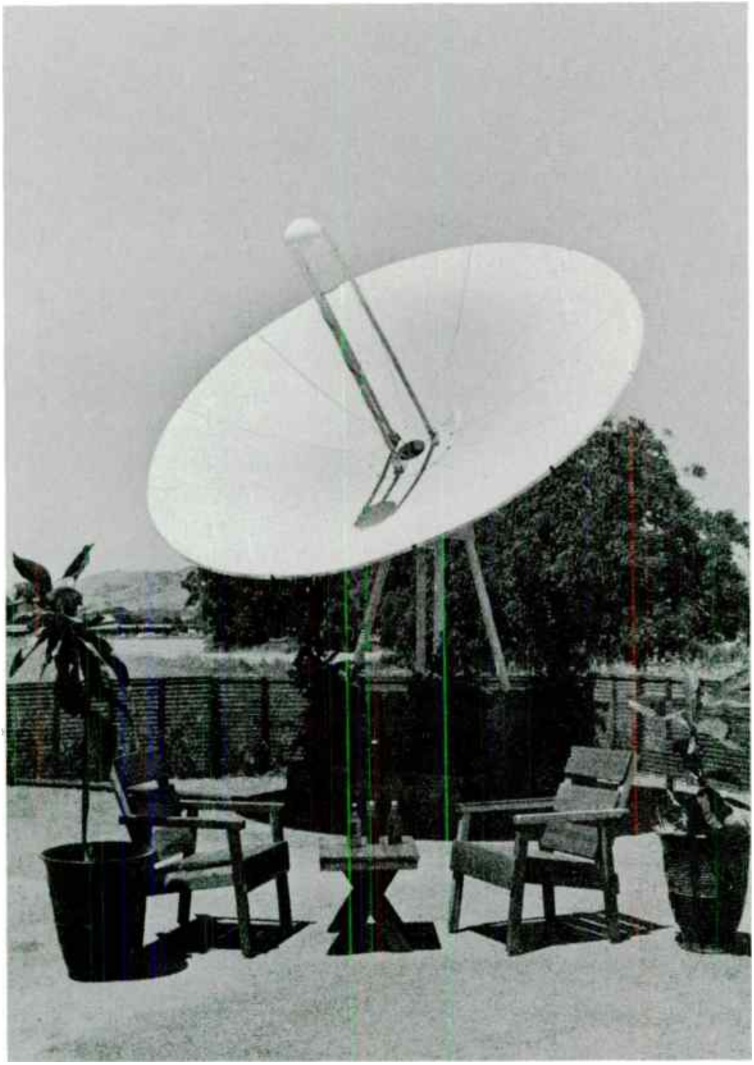


Fig. 11-23. The complete outdoor KLM setup. Ampliverter/SRC-3 is enclosed in waterproof housing.

THE KLM SKY EYE I RECEIVING SYSTEM

This TVRO kit is a two-component system: the control console and the receiver unit. The two units are linked by cables.

The compact Control Console puts picture (video) and sound (audio) tuning at your command. Located at or near your TV receiver, it is the only part of the satellite receiving system you need in your home.

All the channels from SatCom I, Westar III, Comstar D-2, etc., are available within the full rotation of the "Channel" tuning dial. The "Audio Tuning" dial is for optimizing the sound accompanying the picture (although once the sound is set for one channel, the others will need little or no adjustment). Thanks to wide-range audio tuning on the Sky Eye I, you can also tune for other audio entertainment programs (called "subcarriers") on the same channel. These generally present various types of music or news programs.

The other controls on the Sky Eye I are equally simple. The "Power" switch activates the Sky Eye I receiver system. The "Polarity" switch supplies control to the motorized polarity-change unit and allows reception of either horizontally (H) or vertically (V) polarized channels on each satellite. It is designed specifically for use with the KLM parabolic-dish antenna system.

The receiver unit is supplied with a weatherproof case for mounting at or near the dish. As directed by the Control Console, it covers the satellite signals from the LNA on the dish and sends them to the TV set. The receiver unit has no external controls and, under normal circumstances, requires no adjustment.

For safety's sake, all cables except the ac power cord to the Control Center carry only harmless, low voltages.

The complete KLM Sky Eye I receiver system consists of the Sky Eye I receiver, described above, a parabolic-dish antenna, LNA (KLM with 120°K or better performance), motorized polarity control, and all cabling—everything necessary to put the satellite channels into your home except for the TV set.

Two different parabolic dishes are offered with the Sky Eye I receiver system. The 12-foot diameter model is suitable for the greater part of the U.S., where the signals are the strongest.

The 5-Meter dish is designed for the perimeter areas of the U.S. where the satellite signals are slightly weaker. The dish is made up of 12 aluminum-frame petals and the surface is screened to reduce weight, windload, and visibility.

Both models require a simple 4×4-foot concrete base, two-feet deep. The pedestal for the dish is nearly identical for both models, with separate, geared, azimuth and elevation controls. A two- or three-man crew will find assembly and installation of the dishes quite simple, with no heavy equipment necessary. At this time, the dishes are available only with the complete Sky Eye I receiver system, and are not sold separately.

The high adaptability of the Sky Eye I modules means your TV set and parabolic dish antenna are the essential factors in determining the placement of the Control Center and receiver unit. Your TV set should be located where cable access from outside the house is reasonably convenient. Placement of the dish is subject to many factors, including the space available, aesthetics, neighbors, and manufacturers specifications. The dish must have an unobstructed, line-of-sight path to the desired satellites, and be within a reasonable distance of the other components.

The best place for the receiver is right at the dish, close to the LNA. If this is not practical, it can be located up to 100-feet away using the RG-142 cable specified. Greater distances are possible, if necessary. The heavy aluminum channel on the receiver provides ample surface for most any type of mounting hardware (bolts, U-bolts, lag bolts, screws, etc.).

Control Console Placement

The control console can be placed at the TV set or within reach of the viewer. Its ac-power cord is plugged into a standard wall socket. With the cables supplied, the Control Console can be up to 100 feet from the receiver unit.

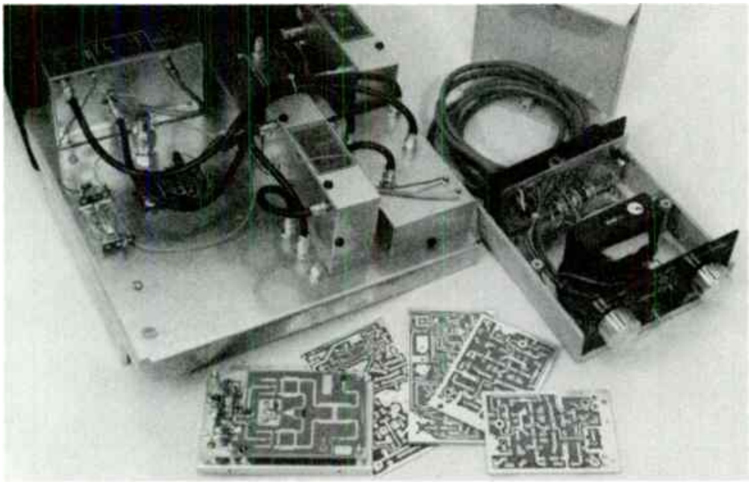


Fig. 11-24. The KLM Sky Eye I TVRO Kit contains all parts, boards, hardware, etc., plus very elaborate instruction manual.

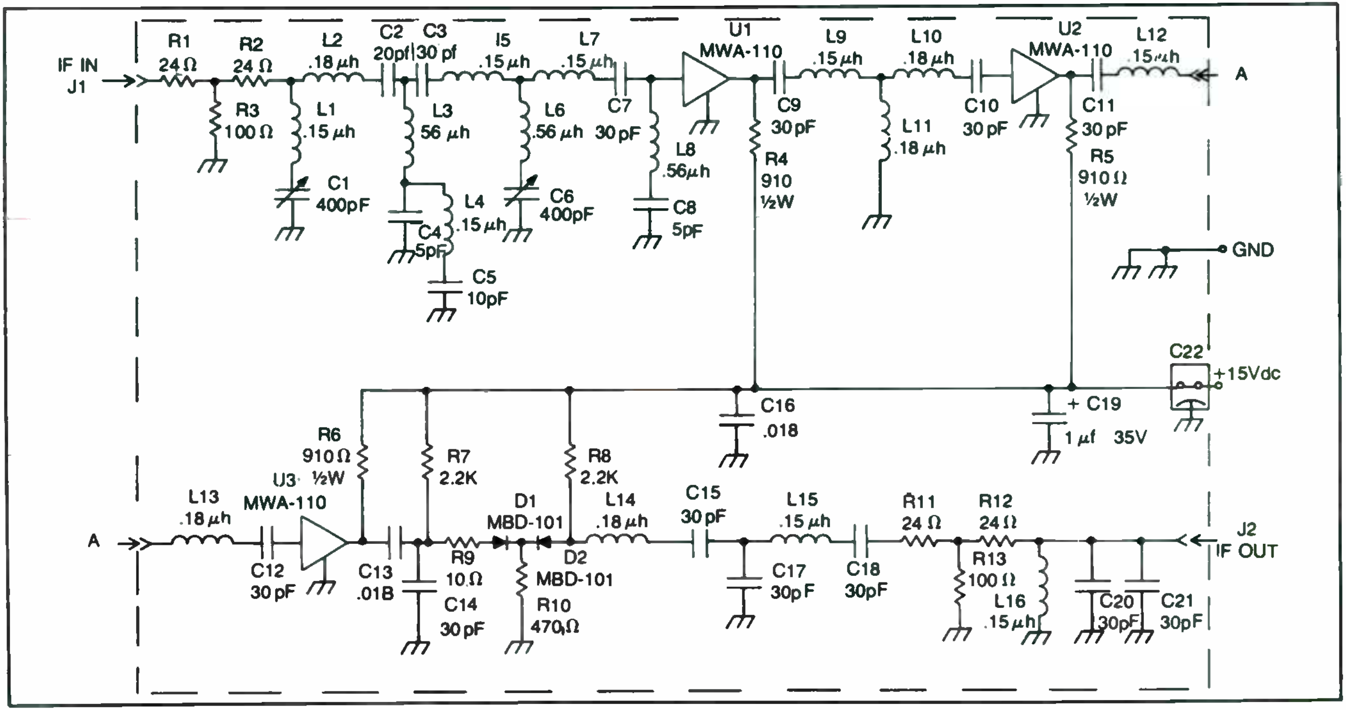


Fig. 11-25. The KLM Sky Eye first i-f amplifier-limiter.

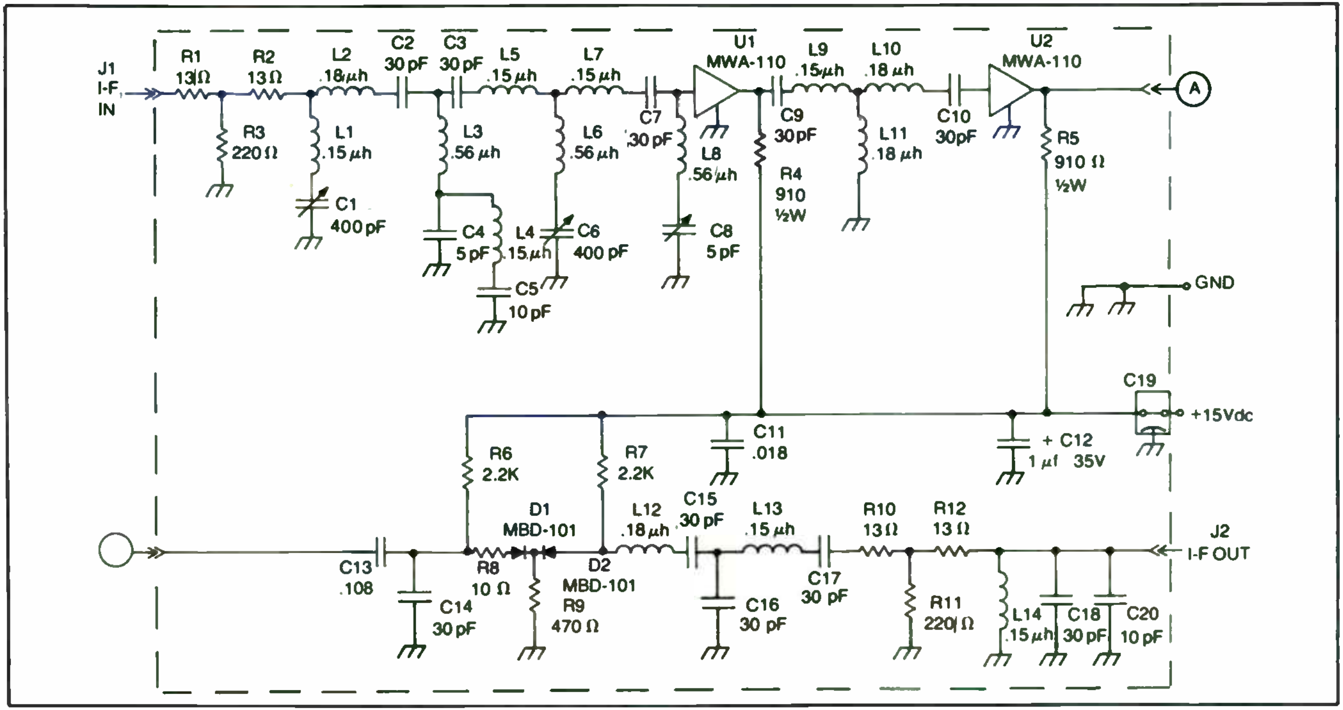


Fig. 11-26. The KLM Sky Eye second i-f amplifier-limiter.

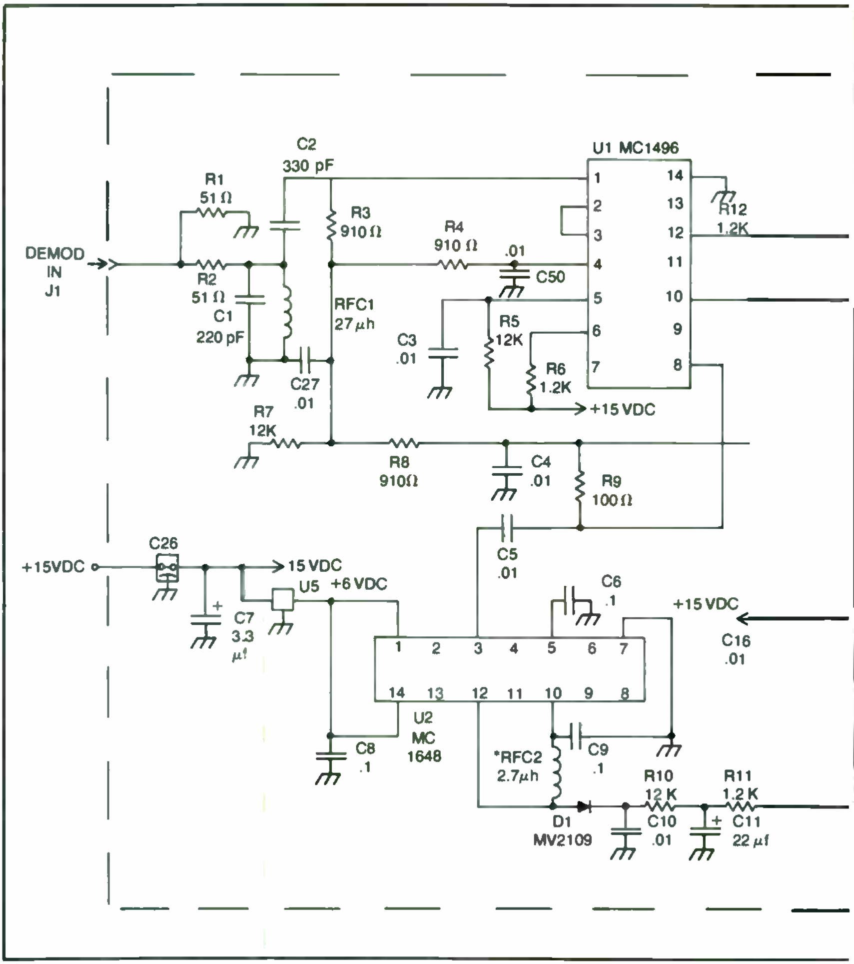
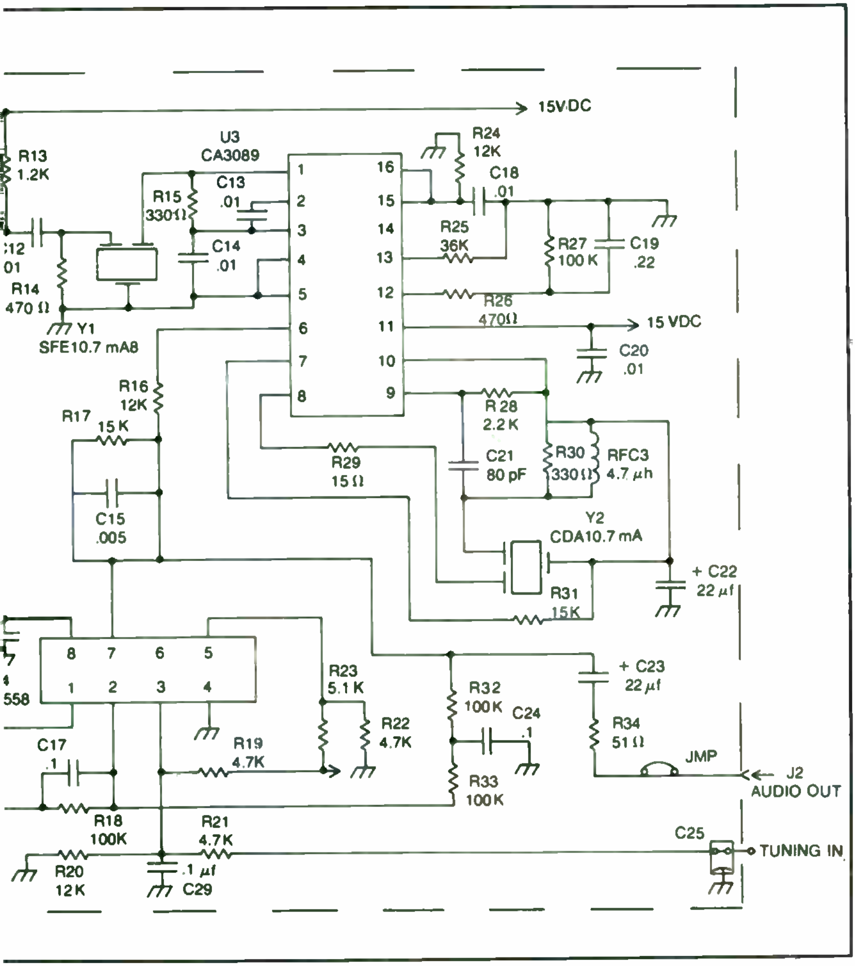


Fig. 11-27. The KLM Sky Eye audio demodulator.

The Sky Eye I kit comes in easy-to-assemble modules that match the modular design of the receiver electronics. Individual steps are kept short and simple, and each must be completed and checked off before continuing. Every module contains just the parts needed. There's no searching through a pile of loose hardware.

The critical mixer module, handling microwave frequencies, is factory assembled and aligned, eliminating the need for exotic test equipment. In addition to the normal tools needed for assembly, testing and aligning the receiver requires only a 60-80 MHz sweep generator, a low-frequency oscilloscope, and a multimeter (VTVM,



VOM, DMM, etc.). If you wish, the kit may be returned to KLM for alignment.

To help you put together a complete satellite receiver system, special discount certificates are included with each kit. They are your opportunity to acquire the other components from KLM (LNA, feedhorn, dish antenna, etc.) at substantial savings. And, they're good insurance that the components you buy will interface perfectly with your Sky Eye I. A complete list of components, options, and accessories is included. See Figs. 11-24 through 11-30.

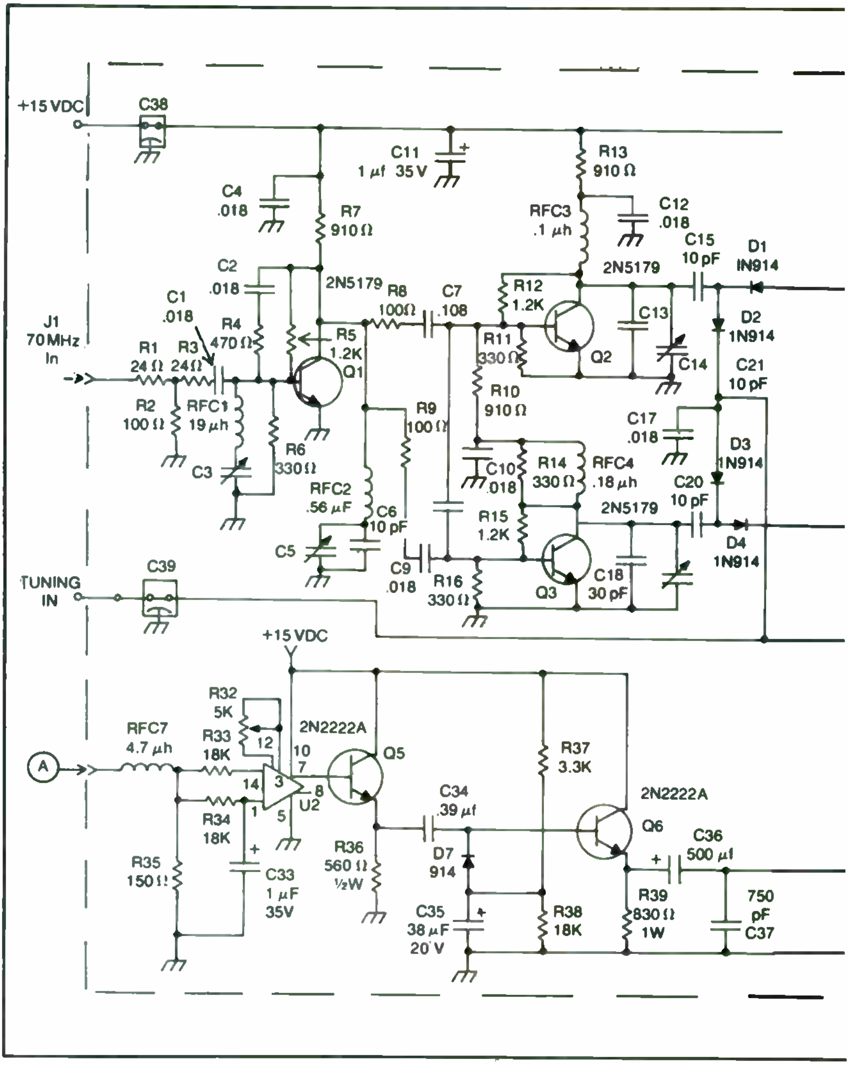
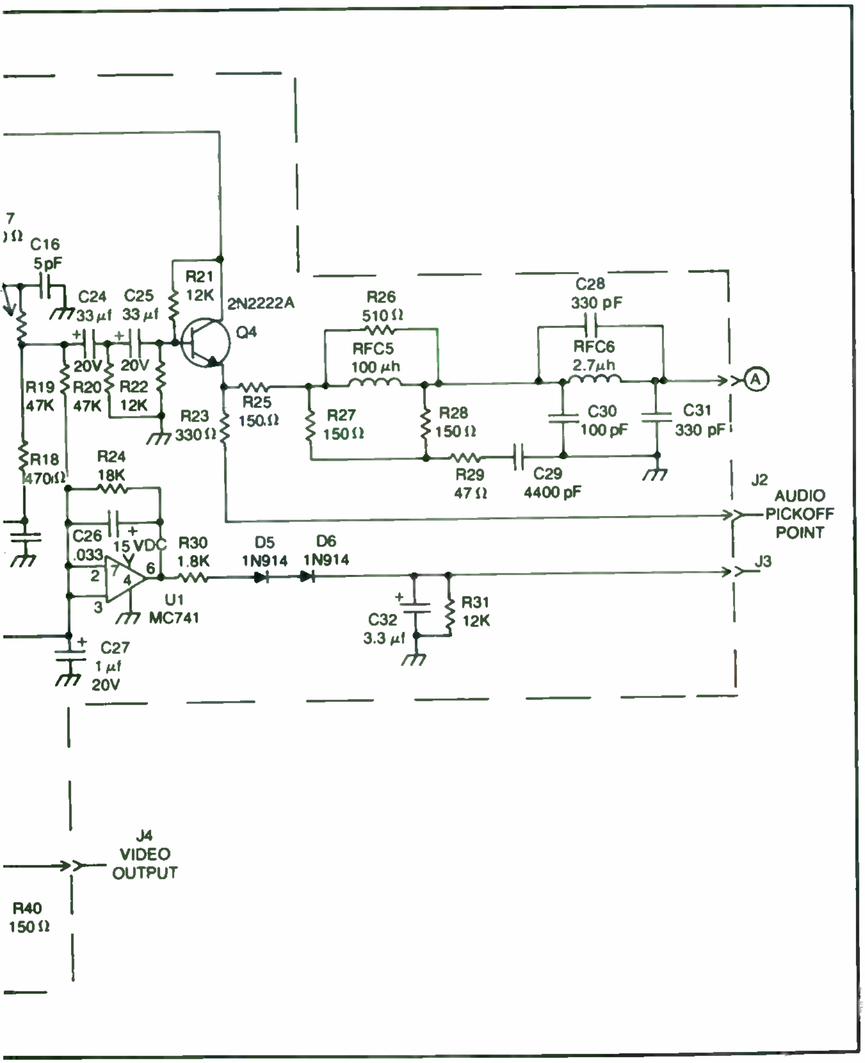


Fig. 11-28. The KLM Sky Eye video demodulator.

THE KLM MOTO-TRAK AUTOMATIC ANTENNA SYSTEM

The KLM Moto-Trak system provides for automatic satellite access in an easy-to-use manner. In the "Auto" mode, the desired satellite is selected with the large dial on the front panel. That's all there is to it! Comparator/logic circuitry and gear motors do the rest. All the programmed satellites (up to 12) are available whenever you want them.



Switch to "Man" (manual) mode, and the azimuth and elevation switches on the Console (or at the dish) provide full control for adjustment, or searching for a new satellite.

In both modes, azimuth/elevation headings are constantly available on the LED display and selectable with the readout switch. The polarity-control switch (optional) permits about 120° of rotation, so horizontal and vertical polarity can be optimized, satellite to satellite. Always turn off the Moto-Trak console when unit is not in use.

When the Moto-Trak is in "Auto" mode and a satellite is selected, comparator circuits sample the voltage from high-resolution potentiometers mechanically coupled to the azimuth and elevation gears. These pots tell the console where the dish is pointed. Their voltages are compared with reference voltages for the satellite, supplied by AZ and EL calibration potentiometers inside the console. If the voltages are not equal, logic circuits activate the green LED "travel" indicators (E, W, UP, DN) and opto-couplers that regulate the triac-controlled-motor action. The motors move the dish until the high resolution pots produce voltages equal to the reference voltages. The comparator circuits sense the balance and shut down the motors. The red LED "auto-lock" lights up to indicate tracking is complete.

In the manual mode, the comparator and reference circuits are bypassed. Full control is transferred to the manual azimuth and elevation switches on the console and at the dish.

The Moto-Trak is supplied with 100 feet of 12-conductor cable. Moto-Trak units with polarity control use all 12 conductors and have a 10-pin Jones plug and an RCA phono plug at each end. Moto-Trak units without polarity control use only 10 of the 12 conductors. The cable requires a single Jones plug at each end.

For initial checkout, it is most convenient to have the Moto-Trak console, satellite receiver, and TV set at the dish site. If this is not possible, another person should be available to relay picture and display information.

The following steps assume you have an operational receiver and TV set installed, and you have the AZ (azimuth) and EL (elevation) headings for all the desired satellites:

- Remove the lower (AZ) motor/gear cover. Connect the 12-conductor cable between the Moto-Trak console and the junction box illustrated in Fig. 11-31. Check that all other plugs are installed. Motor cables are multi-conductor type, sensing-pot cables are smaller. Both EL cables emerge from the center of the AZ rotation shaft.
- Apply power to the Moto-Trak console. Use the manual (Man) EL (elevation) switch on the console or junction box to lower the dish to about 5°. Since the Moto-Trak has not yet been keyed or calibrated, keep

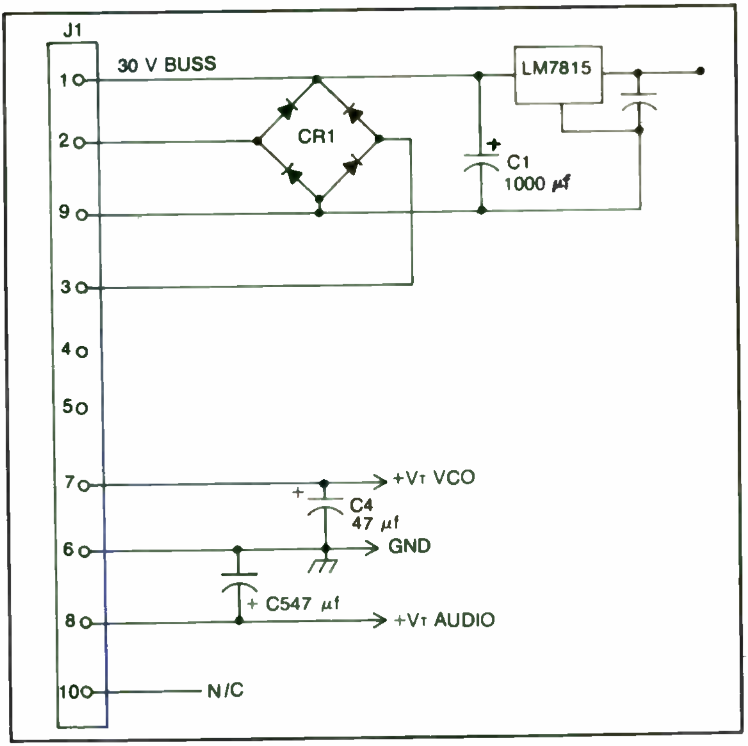


Fig. 11-29. The KLM Sky Eye receiver interface.

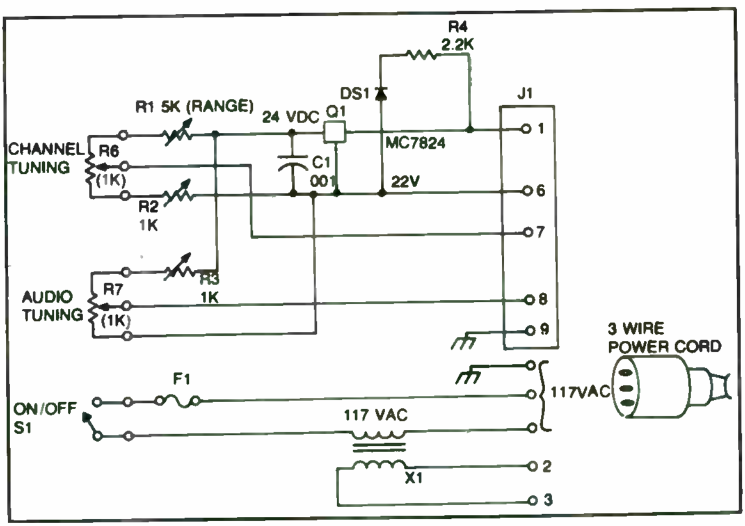


Fig. 11-30. The KLM Sky Eye control-box circuitry.

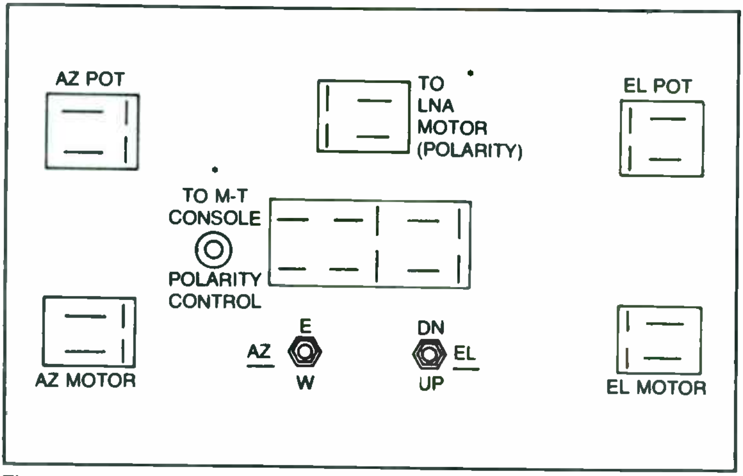


Fig. 11-31. Inside view showing connections to Moto-Trak console and junction box.

a sharp eye on the dish and do not allow the rim to strike the ground.

- Reinstall the LNA/Feed assembly on the legs. Secure the bottom leg in the U-bracket first, then the top two legs. Verify correct distance from the hub plate to the feedhorn lip. Uncoil the LNA feedline and polarity-control line frominside the feed cover. Route them along bottom leg and through the central hole in the hub. Secure every 12 to 18 inches with harness ties. Secure the cables just outside (to leg) and inside (to spacer tube) of the hub hole. Form a loop in the cables so they do not contact any sharp edges on the hub plate.

- Connect polarity-control cable to the junction box or the polarity cable from the receiver. Secure with harness ties but allow enough slack to permit complete dish movement.

- Connect LNA feedline to the downcoverter unit (SR-3 systems, standard), the receiver (SR-3 systems with Ampliverter), or the receiver unit (Sky Eye I systems). Secure with harness ties but allow enough slack to permit complete dish movement.

The Moto-Trak console and motorized mount are matched and calibrated at the factory to a level base, oriented to true South. With the Moto-Trak cabled and "ON," the AZ display will read 180° when the upper and lower AZ plates are parallel. The EL display will read 45° when the EL plate is tilted 45° forward from the upper AZ plate. Errors in base level or alignment (to South) will cause mistracking until the Moto-Trak has been "keyed" to its real base orientation.

The quickest way to check the system is to switch the console to "Man" (manual mode) and use the AZ and EL "Manual Bump" switches, either on the console or junction box, to swing the dish to the true AZ and EL coordinates for SATCOM F1 at the west end of the chain. If base alignment was accurate, you should see a good picture on the TV set. If the picture is poor or absent, use the manual switches to search until it is optimized.

Before continuing, optimize receiver tuning and LNA polarity for the best picture possible. Fine-tune AZ and EL one more time for best picture. You should now have a good picture, but the AZ and EL coordinates on the display will probably be incorrect for SAT-

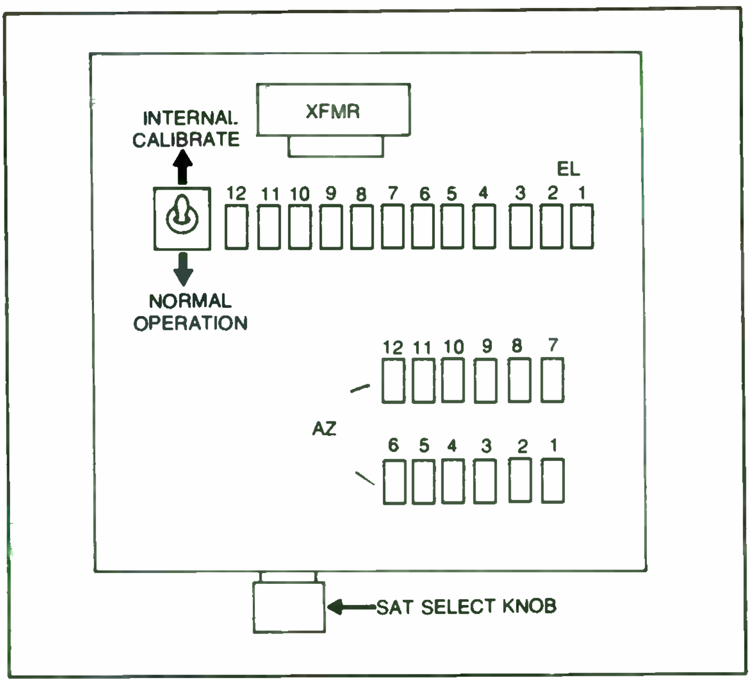


Fig. 11-32. Calibration pots in Moto-Trak console. Each control can be set for automatic satellite selection for truly automatic TVRO operation.

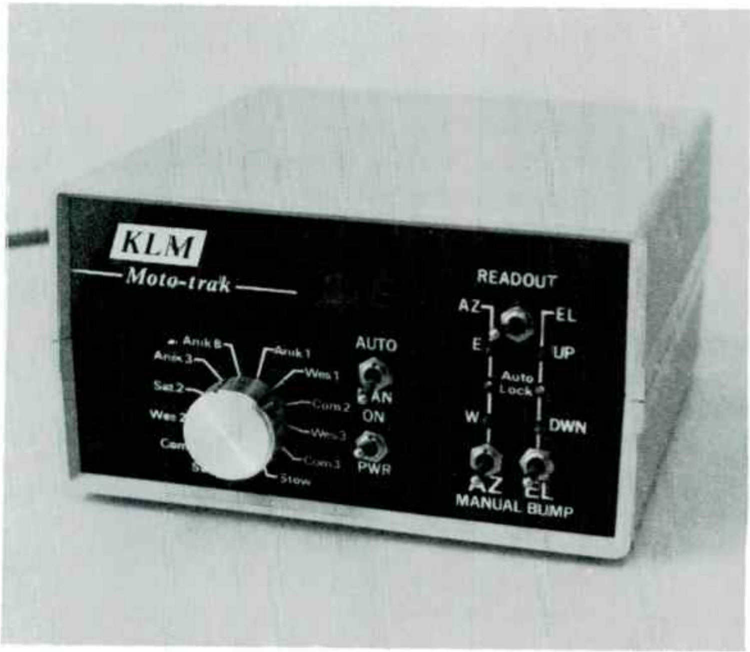


Fig. 11-33. The complete KLM Moto-Trak control console.

COM F1. Now you can "Key" the Moto-Trak system to provide accurate tracking, satellite to satellite.

Switch the display "Readout" to "AZ." Loosen the screws securing the AZ sensing pot and lift the pot away from the small drive gear. Rotate the pot gear until the correct AZ coordinate for SATCOM F1 is produced on the display. Carefully remesh pot and drive gears and retighten the mount screws. Switch readout to "EL".

Remove the EL motor/gear cover. Lift the spring-loaded EL pot gear away from the small drive gear. Rotate the EL pot gear until the correct EL coordinate for SATCOM F1 is produced on the display. Carefully remesh the gears and replace the cover.

The Moto-Trak is now "keyed" to track accurate AZ and EL coordinates. The pairs of individual satellite calibration pots, inside the Console, can now be set to automatically seek the satellite selected by the front-panel knob. Since you are already keyed manually to SATCOM F1, the No. 1 pair of calibration pots should be set first. Remove the two Phillips-head screws at the bottom of the Moto-Trak console and gently lift off the case cover. The calibration pots are lined up as shown in Fig. 11-32.

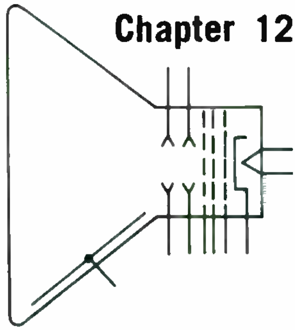
CAUTION, SHOCK HAZARD
EXPOSED AC INSIDE CASE

Rotate the front-panel selector knob to position No. 1, SATCOM. Flip the "Internal Calibration" switch toward the rear of the case. This connects the outputs of the calibration pots to the front panel display.

Switch front panel "readout" to "AZ." Using a small screwdriver, rotate No. 1 AZ calibration pot until the display shows the correct AZ heading for SATCOM F1 (rounding off to the nearest whole number). Now flip the readout switch to "EL." Adjust No. 1 EL calibration pot until the display shows the correct EL heading for SATCOM F1 (rounded off to the nearest whole number).

Rotate the selector knob to position 2 and repeat these steps, calibrating the pots to the AZ and EL coordinates for COMSTAR 1. Continue this process through position 11. Position 12 can be used for feed-assembly maintenance position, an 80° safety-stop position during high winds, or as an open position for future satellites. Return "internal calibration" switch to the "normal" position, replace AZ and EL motor/gear covers, case cover, and enjoy automatic operation. See Fig. 11-33.

Chapter 12



Video Recording and Playing Systems

There is a trend toward increased use of home video-recorders and players which has opened new avenues of visual communications, and the trend is projected to substantially escalate. As video recorders become commonplace, educational and technological capabilities will expand in a highly beneficial manner. Video recorders, with their preprogrammable capabilities and remote controlling functions, will convert all television viewing time into true "prime time." The home viewer, realizing this flexibility, will no longer be bound to viewing programs during initial network transmissions, thus acquiring the ability to study objects of interest, transact business, or enjoy relaxing entertainment at a time of convenience. Although video recordings acquired their initial recognition and acceptance with only entertainment materials, the use of these units and their peripherals for educational purposes and personal-capability expansion has not yet made a full impact on society.

The ability to move video programs from "transmitted time slot" to "personally beneficial time slot" is a major asset of video recorder/players. The viewer need no longer be concerned about missing a particular broadcast while sleeping, away from home, or watching another program, and he may review the broadcast as desired. Additionally, specific items may be added to a "personal library" which can grow into a full visual educational/entertainment library as time progresses. The information stored in such home libraries can be exchanged with others, and commercial/public library materials may also be combined in these mass-exchange arrangements. There is, however, a slight catch, as different makes of video recorder/player systems are presently used—and they are not fully compatible. This incompatibility is not predicted to improve or stabilize during the near future, thus the video enthusiast is well advised to select a video unit applicable to his particular needs and to set up a basic duplicating process for copying or "dubbing" to the chosen format. Again, we face obstacles, as tape-program manufacturers often include "copylocks" in their tapes which create interference patterns on duplicated copies. However, a growing number of companies are announcing "copylock interference removers" which eliminate such confused signals and reinsert new sync intervals.

Video recordings are an off-the-air form of communication, and thus are not bound to the compatibility requirements of the NTSC. This situation has resulted in the popularity of such incompatible systems as Beta (or Betamax), VHS (Video Home System), Minicassette (a video cassette only slightly larger than conventional audio cassettes) and Videodiscs (there are presently two video-disc systems which are themselves incompatible, and a third video-disc system which is incompatible with the other two is due to be announced in the near future).

There is one particularly distinct difference between videotape systems and video-disc systems, and that is the ability to record and playback or merely playback. The video-tape units perform either function, however video discs are prerecorded programs similar to conventional audio records which can only be replayed. The (relatively) inexpensive methods of manufacturing video discs, however, make these units quite appealing to "straight viewing" video enthusiasts. Video tapes cost, on the average, two to three times as much as video discs. The consideration of selecting either playback-only or record-and-playback capabilities hinges on one's particular needs and applications. Let's take a closer look at these aspects.

Video discs and their associated players are, compared to video tape systems, inexpensive to purchase and maintain. Many people are not concerned with recording their own programs, but rather desire the ability to view their own preference in movies, etc. The video disc fulfills this requirement in fine style, providing movies by disc which could actually turn a profit to an enterprising user. Basically, the cost for two people viewing a theatre movie, plus automobile travel, parking expense, and concessions can equal the cost of a video-disc movie. The disc movie, however, can be viewed more conveniently—and with less concern over personal safety and security. Additionally, disc-exchange groups or clubs can actually turn a profit while reducing costs of disc viewing by members. Any disc viewed by more than four people is thus less expensive than a commercial equivalent. The single drawback to disc at the present time is their "newness" which limits available program material. This situation is due to change substantially during the near future.

Home movies via video tapes are becoming increasingly popular. These video memories can be viewed as they are made, or immediately thereafter, thus eliminating poor shots, inadequate lighting, etc. Unlike film movies, there are no processing costs, and the video tapes maintain their quality indefinitely. Numerous video-tape systems and their associated cameras feature optional battery pack operation, permitting full mobility. "Pause" options are included on most video recorders, permitting their users to bypass unwanted scenes and record only that desired. This feature is also useful for eliminating commercial advertisements when recording conventional TV programs. Older home movies or "slide shows" can easily be moved to video tape with a basic home viewing setup: The slides/movies are directed onto a viewing screen and video taped by using the system's associated camera to also view the screen. Finally, numerous video-exchange groups are becoming popular and can serve as a highly expandable tape library. Recognizing that there is a number of video-tape formats, tape-exchange groups usually maintain an ample supply of patch cords for "dubbing" tapes. This arrangement allows anyone to join the action—even if it means bringing along his own (unusual format) video unit for program copy.

The home video recorder/player, as different as it may be, is a video-technology tool which, like video discs, will realize significant growth. Thoughts of waiting for any "ultimate," or fully compatible, system to evolve into widespread acceptance are, unfortunately, illogical. All systems, however, can be "patched" and "dubbed" (with the obvious exceptions of video disc), and thus allow some degree of compatibility. We will now take a closer look at some presently popular systems, not as a guide to the "best unit" (they are all quality systems), but rather as an understanding of their functions and capabilities.

VIDEO-TAPE SYSTEM FORMATS

The first video recorders were expensive units of colossal proportions. These units used conventional audio-track formats similar to that shown in Fig. 12-1, and fixed-position record/playback heads. In order to reproduce video frequencies (30 Hz to 4 MHz), extremely high tape speeds were required. This required huge tape reels, and their associated inertial problems led to the system's downfall. Evolutions in video-tape recorders created what is known as helical-scanning techniques, a concept which is universally employed in modern video-tape machines. This arrangement is illustrated in Fig. 12-2. The recording/playback head rotates at a high speed, thus saving tape and improving video-frequency response. Tape motion, in conjunction with the rotating head, actually produces diagonal "scanning" of the tape. Slowing or stopping only the tape motion can create "slow motion" or "freeze frame" capabilities. The first video machines with helical scanning were threaded through capstan/pulley assemblies by hand. This "wrap-around, fold-up, twist" procedure was quite cumbersome and thus emphasized the need for cartridge tape systems which could function in a simpler manner. The previously described systems were used in TV-broadcast stations rather than individual homes: The advent of cartridge systems initially opened the door to home-video systems.

Cartivision

One of the first home video-recorder/player systems was produced by Cartivision Company, and employed unusual mechanical/electronic parameters to achieve video reproduction. Tape cartridges of cumbersome style were directed against the helical scanning head, without pulling lengths of tape from the

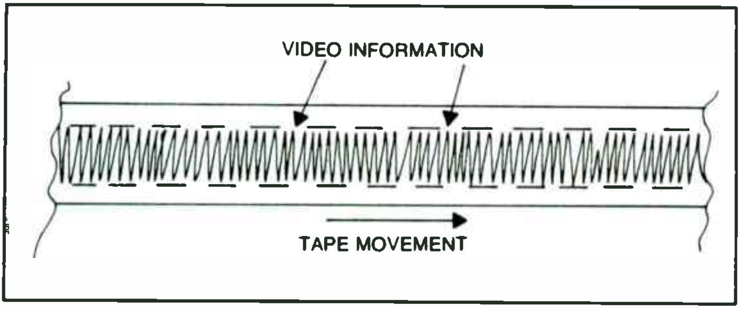


Fig. 12-1. Technique of recording video information on the first generation of video tapes. This concept used long tape lengths with short playing times.

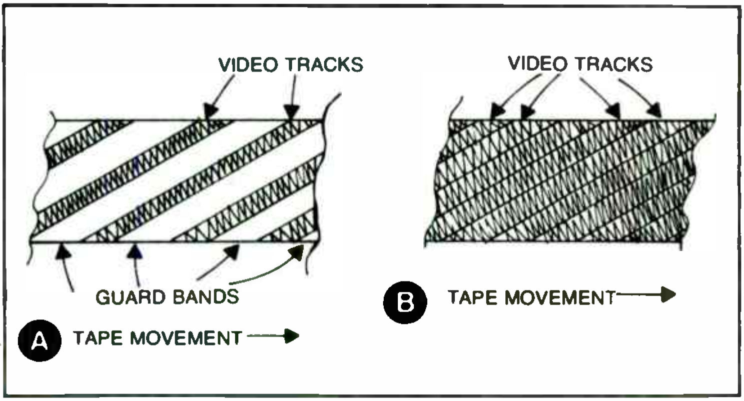


Fig. 12-2. Helical scanning concepts which operate in conjunction with the high-speed rotating head to substantially reduce tape consumption. System A employs guard bands between video tracks while System B merely butts tracks.

cassette proper (as compared to Betamax and VHS which pull tape and thread it around the helican-scan head). Although some Cartivision systems occasionally appear on today's surplus markets, the lack of parts, repair information, and program cassettes restricts their popularity. The individual acquiring one of these units should realize it is only compatible within itself and cannot be adapted to Beta, VHS, or other formats.

Betamax

The next significantly popular video-tape system was the Betamax, or Beta, which is continuing its popularity reign as this book is being written. The first Beta recorder/players were basic one-hour cassette units featuring high speed, helical-scan heads and relatively fast tape movements. Reproduction resolution was very good, setting trends for widespread VCR acceptance and use. Numerous companies were established which provided a wide variety of Betamax-compatible movies, and the world of home-movie viewing expanded manyfold. The early Betamax machines (one hour units) incorporated few "extras," or "frills." They merely recorded and/or played video in a conventional manner. An input jack accepted video (obtained from a closed-circuit TV camera or a TV receiver's video amplifier output), and an "output" jack provided video output for connection to a closed-circuit TV monitor, the video amplifier of a television receiver, or a modulated TV oscillator which radiated the signals into a TV receiver antenna terminals.

VHS

Following close on the heels of Betamax acceptance, another video-cassette recorder known as Video Home System (VHS) was introduced into the market. This unit featured a slightly smaller, high-speed, helical-scan head and slightly larger cassette. A change in tape length and head speed allowed the VHS unit to record and playback at two hour periods—twice the time of Betamax units. Resolution and definition obtained via either VHS or Beta were essentially identical, but the two systems were (and still are) totally incompatible. The video-tape movie market again flourished (and continues to flourish), providing all types, styles, formats and unlimited programming of movies in Beta 1, Beta 2, Beta 3, VHS 2, VHS 4, and VHS 6 movies (numbers indicate hours of play, as will be described presently).

Following the introduction of VHS two-hour machines, Betamax retaliated with a unit which moved tape at one-half the original speed to provide two hours recording/playing per cassette. This unit is known as Beta 2. As a means of maintaining compatibility, speed changes are included on most Beta 2 machines. These units are known as Beta 1 × Beta 2 machines. VHS rataliated with a half-speed unit which provided four hours record/playback per cassette tape. These units are designated VHS 4, and they also include speed change capabilities for VHS 2 or VHS 4. Finally, Betamax has retaliated with a slightly slower cassette-speed unit which provides three hours of recording/playback. This unit is designated Beta 3. Not to be outdone, VHS has again followed suit with a six-hour unit known as VHS 6. How do all these units with their speeds affect the home video enthusiasts? Favorably, we suspect, providing he or she keeps track of formats and speeds, and can afford financial "updates" occasionally along the way. Some additional considerations should be pointed out at this time: All *unrecorded* Beta cassettes and all *unrecorded* VHS cassettes are compatible with their respective machines, however *recorded* cassettes in either format may not be compatible with various models of each machine. A VHS 6 tape, for example, will not replay at correct speed on a VHS 4 or VHS 2—unless that machine includes VHS 6 replay capability. Likewise, Beta 3 tapes will not replay at correct speed on an (early) Beta 1 or Beta 2 machine. One is thus well advised to check speeds plus formats and compare them against the video units before making substantial investments. During recent times, new VHS and Betamax units of "skip-speed record" have become popular. These units often record at "standard speed" only (1 hour Beta, 2 hour VHS), but playback at the two and two-and-a-half speeds. These units provide good results, and afford the capability of viewing any prerecorded tape, however they require time-keeping when recording. Another consideration worthy of mention is their need to "split" extended time movies onto two cassettes when "dubbing" tapes.

FRILLS AND THEIR USE

Following the widespread acceptance and use of video recorders, additional features or "frills," began making their debut in these units. These expansions included, among other things, programmable timers, separate uhf and vhf tuners, modulated oscillators which permitted direct connection to a TV receiver antenna terminals, and various types of automatic cassette-tape changers. These presently popular setups permit almost unlimited taping/viewing capabilities, providing the video enthusiast with true "dream-machine" capabilities. Video recordings featuring built-in TV tuners and programmable timers, for example, can automatically switch on and record programs during periods when the owner is away. Recorders boasting their own tuners can also be used for taping one channel's programs while viewing programs on another channel. This arrangement is shown in Fig. 12-3. The VCR used features a tuner, i-f, and video-detector stages, permitting signal detection and application to the VCR video input. The television receiver functions in a stand-alone manner for conventional reception, or the VCR output can be switched to the TV-receiver input for tape viewing.

The VCR may be used as a remote control for a television receiver using the arrangement shown in Fig. 12-4. The antenna lead-in is directed to the VCR input, while the television receiver is tuned to the VCR output. Using this arrangement, the television's tuner thus acts as an extra stage i-f amplification while the VCR tuner output feeds both that unit and the television receiver. Note that, using this arrangement, it is not possible to view one channel while recording another. Additional examples of performing these functions for cable-TV use are shown in Figs. 12-5 and 12-6.

Finally, a technique for copying or "dubbing" tapes of one format to tapes of another format is shown in Fig. 12-7. Remember that playing/recording times of both tapes should be similar (VHS 2 hour and Beta 2 hour, for example), or tapes will require changing during periods of the dubbing process. Legal implications recording and/or dubbing of video programs are presently unsettled and

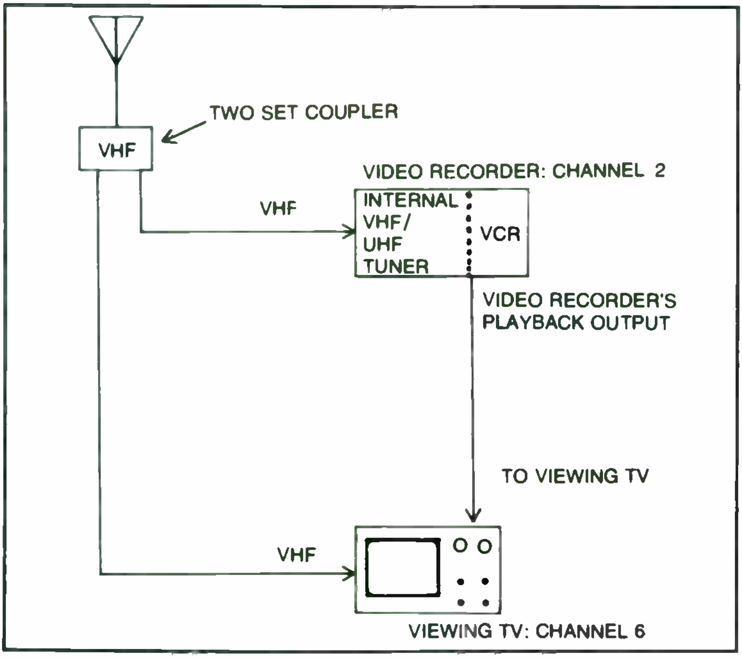


Fig. 12-3. Technique for setting up a VCR for recording one TV channel while viewing a separate TV channel. Note that VCR and viewing TV share a common antenna.

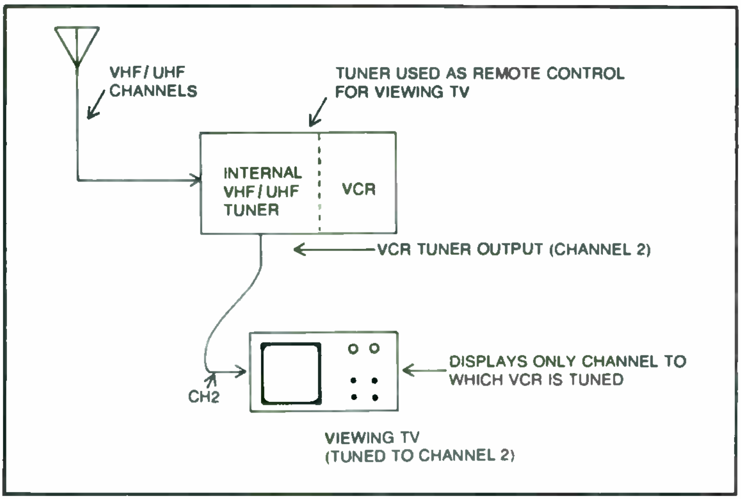


Fig. 12-4. Method of using VCR equipped with vhf and uhf tuners for remote control of conventional TV receiver. Note that TV must be tuned to output channel of VCR.

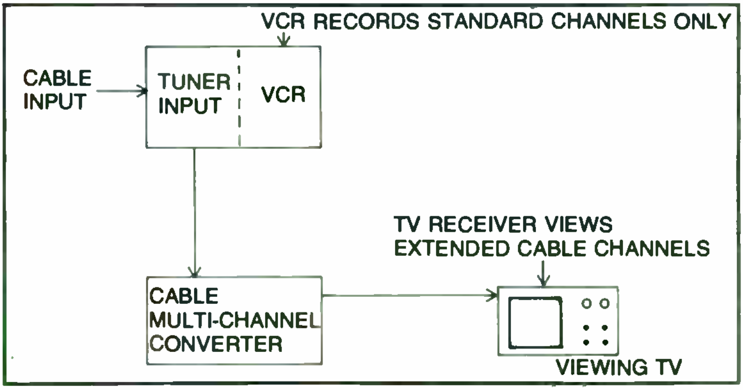


Fig. 12-5. Method of using VCR with cable system for recording standard TV channels while viewing special "extended channels."

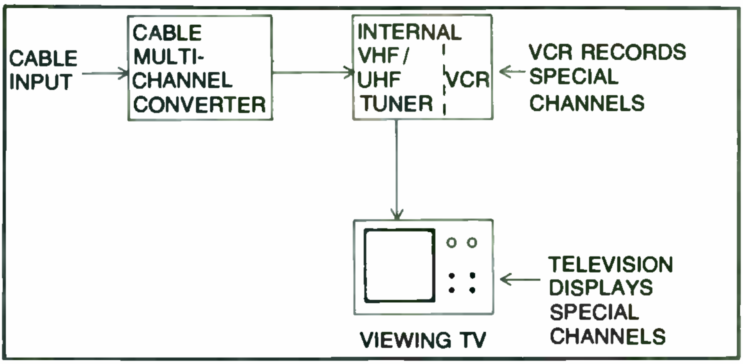


Fig. 12-6. Method of viewing and recording both standard and extended TV-cable channels. Note placement of cable converter box "before" VCR.

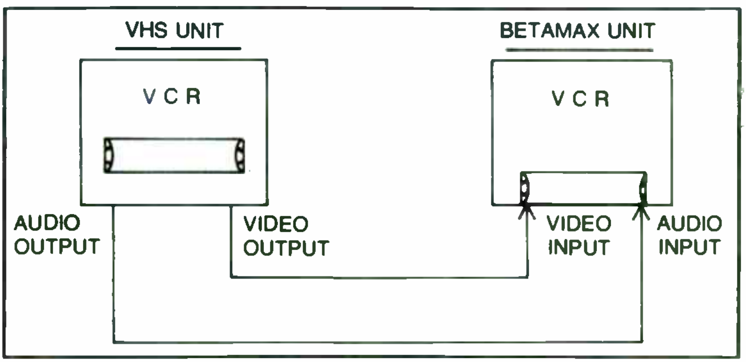


Fig. 12-7. Arrangement for dubbing tapes of different formats. Note that only baseband video and audio signals are used.

Fig. 12-8. This VHS recorder features vhf/uhf tuners with AFT and programmable timer.

unsure. The video enthusiast is encouraged to check reliable video-information sources and recent publications for the latest news in this area. See Figs. 12-8 and 12-9.

VIDEO TAPES

The era of video tapes and their applications is almost as sophisticated and involved as the area of Video Cassette Recorders.

Fig. 12-9. Push button VHS unit is compact and efficient.

Fortunately, however, one can become relatively familiar with this area within a reasonable period of time.

The early Betamax tapes were designated with numbers corresponding to their period of playing time. Cassettes such as T30, T60 and T120, for example, provided record/playing times of 30 minutes, 60 minutes, and 120 minutes respectively (at Beta 1 speed). Recent equivalent tapes are designated in foot lengths, however, their playing times are similar. As an example, L 250 tape is 250 feet, and capable of 30 minutes play, L 500 tape is 500 feet and capable of 60 minutes play, L 750 is 750 feet and capable of 90 minutes play, etc. Another very thin tape, L 83, has been introduced recently; it is capable of 3 hours and 20 minutes play. This thin tape, if subjected to heat, is prone to stretching, etc., such as was experienced in "triple length" audio tapes. All previous examples were Beta 1 speeds. Bear in mind Beta 2 speeds provide double-length record/play periods.

VHS tapes are, as one might suspect, designated in a different way. The standard-play VHS machine or tape is 2 hours, the long-play VHS is 4 hours and the extended-play VHS is 6 hours. A long play VHS tape (500 feet for example) if run at VHS 4 (4 hours) speed could thus provide up to 8 hours recording/playing time. Likewise, an extended-length VHS tape at VHS 2 speed could provide 5 hours recording time. The new long-time, thin tapes are not suggested for VHS 6 hour use, as heat build-up over that period may cause tape stretching.

As this book is being written, there are rumors of more tapes with new designations and thickness which will be introduced. Armed with the basic data presented here, the reader should experience few problems while exploring the eventual tape jungle.

VIDEODISCS AND PLAYERS

A recent development which has acquired widespread acceptance and has a rather promising future is the videodisc player systems. The videodisc units appear somewhat similar to conventional record players; however, their operation is quite different and the machines are far more sophisticated in design and performance. Although originally introduced for public use over 15 years ago, the first videodisc units employed modified audio-type discs which noticeably restricted their playing time. The cost of those early units led to their rapid downfall. Videodisc units are strictly video players; they do not record programs. The prime advantage of these units is their convenience of use and low cost. The videodisc must be put into perspective and analyzed for its capabilities and benefits. Audio tape recorders, for example, are more sophisticated and expensive than audio record players. Likewise videodisc players must reflect substantially lower purchase prices than video tape recorders if the units are to gain widespread acceptance. The recently introduced videodisc systems seem to fulfill this criteria: they employ very high speed disc transports, a vast number of individual grooves (over 30,000 on one disc side), and their cost is approximately half that of video tape units. As this book is being written, the question of whether videodisc systems will become successful is unpredictable. Extensive promotional campaigns have been launched and several large corporations have geared up for producing libraries of videodisc programs. The material thus far available via videodisc is limited—"family" type movies and children's entertainment appear to dominate the scene. Possibly this confinement will be removed, and programs/movies available on videodisc will equal or (hopefully) surpass those available on video cassettes. Meanwhile, owners of videodisc systems will remain confined to the scope of movies available from commercial suppliers.

An increasing number of video clubs and video-equipment outlets are building libraries for both sales and rentals of videodiscs. Although prices vary widely, the usual cost of discs is slightly less than half that of video tapes, and weekend disc rentals are less than the two-person cost of attending a theatre.

There are presently two popular forms of videodisc players, and the two forms are not interchangeable. One system (the Pioneer and Magnavox system) uses an optical-information disc and laser-beam pickup, while the other system (RCA) uses a capacitance information disc and precision-capacitor stylus pickup. A sketch of the RCA disc concept is shown in Fig. 12-10. The videodisc is connected to ground though its transport assembly which the pickup stylus conveys capacitance changes (corresponding to sync, video, etc.) to the detector/amplifier stages. Disc-rotation rate is approximately 450 rpm, and the approximately 30,000 grooves on one side of a disc provide an hour's playing time. Following conversion of videodisc capacitance variations to voltage levels, both video and audio signals are handled in a conventional manner. The audio signal may be directed to the television set or a nearby stereo amplifier, if desired, while the video signal modulates a basic TV Channel 3 or 4 oscillator. The resultant signal is then radiated into the TV set antenna terminals.

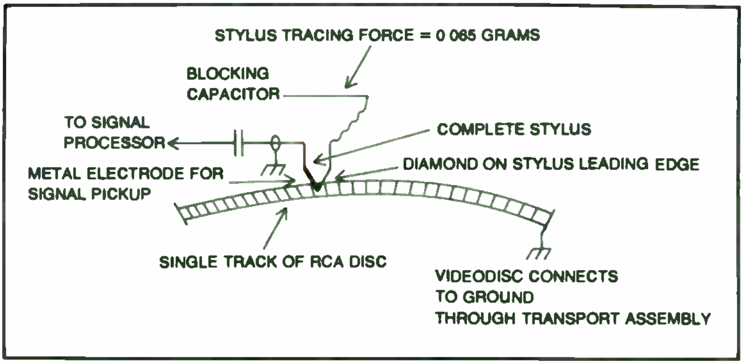


Fig. 12-10. Closeup view of a single track on a RCA Videodisc, illustrating the many separate areas reflecting varying amounts of capacitance. These capacitances are the result of dielectric variations embossed in the disc.

The optical laser videodisc differs from the capacitance-information disc in its method of information storage and pickup. See Fig. 12-11. Thousands of minute surface variations within each disc groove cause microscopic reflections of the scanning laser beam. These reflections are picked up by a photodiode array and converted to voltage variations. The resultant video and audio voltages are then handled in a manner similar to those described with the RCA system. The technique of using a laser-beam probe in a manner similar to pickup stylus has some interesting possibilities. Visualize, for example, the possibilities of measuring animal

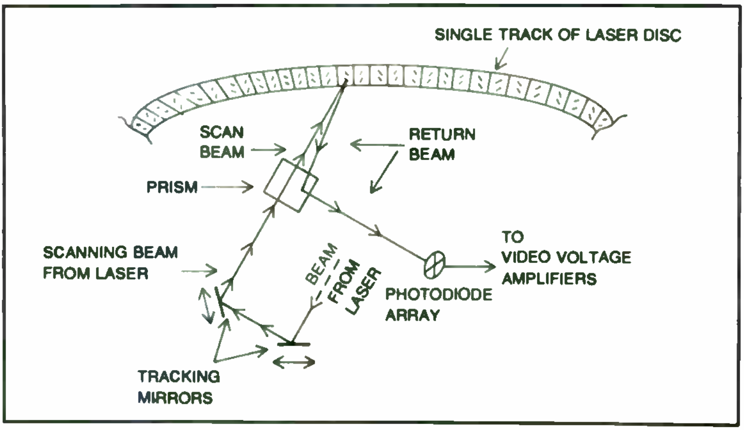


Fig. 12-11. Closeup view of action on a single track of a laser disc, illustrating how thousands of reflective areas defract scanning beam to recreate video signals.

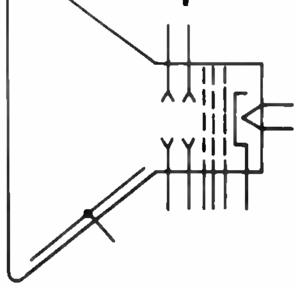
heartbeats or water fluctuations from a distance via laser. Could such optical probes open doors to future electronic devices? We think so, and expect numerous items employing this concept to be introduced in the near future.

Laser-disc systems operate at speeds of 600 rpm, which further illustrates the incompatibility between the RCA and Pioneer systems.

Both of the videodisc systems include numerous "bells and whistles" which truly add to their appeal and usefulness. These features include time-elapse counters (for direct access to specific points in a movie), pause operations (for halting video pickup while the disc continues high-speed rotation) fast forward/reverse picture scanning, etc. All aspects considered, videodiscs are a great idea and serve a worthwhile purpose. Assuming that movies via disc become as popular as audio disc is now, this industry could bloom into the hottest area of knowledge-expansion/entertainment since cable TV. Videodiscs are truly a field worth watching.

Chapter 13

Amateur Television



No book in the video-technology category would be complete without a discussion of Amateur television and its contributions to state-of-the-art advancements. Radio Amateurs have pioneered new communications concepts since "wireless" began during the 1900s; their involvement in television dates back to the early 1920s. Some of the very first scanning-disc "television visors" were home constructed by energetic Amateurs tinkering with ideas in their basements. As time progressed, Amateurs began transmitting and receiving crude pictures by means of electronic scanning. Always striving to give the impossible feat one more try and to pursue projects large companies deem economically unfeasible, today's ham radio operators traditionally continue setting trends and pioneering new techniques, particularly in the exciting world of video communications.

Amateur television is, generally speaking, similar to Amateur (ham) Radio—except the communications are via audio and video rather than audio only. The one-to-one nature of this personal-communication mode has yet to be rivaled for the feeling of accomplishment, particularly when the Radio Amateurs live in different countries or experience social, economic, or political boundaries which otherwise restrict their involvement with the outside world. The capabilities of Amateur television also show promise for future assistance in third world countries, for exchanging knowledge, and for developing numerous other human resources. Technically speaking, Radio Amateurs are presently pioneering new television designs, digital-television concepts, slow- and medium-scan TV systems, new three-dimensional principles, and more. Don't be suprised if the holographic video concepts mentioned in the first part of this book someday evolve from pioneering efforts of Radio Amateurs.

Amateur television appears in many forms, the most popular of which are fast-scan (similar in bandwidth and video quality to conventional commercial television) and slow-scan (an 1100-Hz bandwidth system with slightly reduced video quality and a lack of motion capabilities). Another form of Amateur television presently being explored and showing promise is medium-scan TV. This concept reflects a combination of both fast- and slow-scan methods. Medium-scan TV signals may be transmitted within a 35-kHz bandwidth, and a limited amount of motion is possible. Both slow- and medium-scan television may provide worldwide visual communications on a direct basis, without the need for (broadband) satellite relays.

One of the main reasons Amateur television is able to enjoy unrestricted growth is its freedom from compatibility requirements such as those imposed on commercial television by the National Television System Committee. Pioneered Amateur television systems have compatibility with their own communicating stations. Recognizing the pioneering activities and state-of-the-art advancements provided by Radio Amateurs, the Federal Communications Commission often grants Special Temporary Authorization (STA) to parties involved in such experiments. A substantial amount of pioneering activity in satellite-TV reception has been conducted by ham operators, and this activity is continuing on a daily basis. The future will surely see additional satellite/video/data communication systems being developed by Radio Amateurs. If you haven't investigated the exciting world of Amateur television, please consider this open invitation to join our fabulous world. TAB Books publishes a complete line of books in the Amateur field.

AMATEUR FAST-SCAN TELEVISION

This mode of Amateur communication bears a surprising resemblance to conventional (commercial) television, except it is personal in nature and void of commercial involvement. Amateurs using fast-scan TV share views, opinions, and lifestyles in a "two-way" nature. The video medium provides everything from "scratch-pad noting" to simply showing items under discussion.

Amateur television has also proven its worth during such public service activities as the annual Rose Parade, the Voyager I and Voyager II flyby of Jupiter, Saturn, etc., plus many other events. One particular Radio Amateur even received presidential awards for his work in relaying views (to news media) of storm cells moving across nearby metropolitan areas. This information filled a critical void in that area's weather and tornado watch, providing vital information for the National Weather Service. The capabilities and challenges of Amateur television are, indeed, limited only by one's imagination.

The technical format of Amateur fast-scan television is similar to commercial TV: the carrier is amplitude modulated and contains video frequencies up to 3.5 MHz. The scanned raster consists of 525 lines, field interlaced, with sync time periods also similar to commercial TV. An ordinary television receiver, converted for reception of Amateur rather than commercial broadcast bands, may thus receive Amateur television transmissions (assuming, of course, an Amateur TV setup is within that receiver's range).

The audio signal in Amateur fast-scan communications can be generated by different means. One of these involves using a 4.5-MHz FM subcarrier, similar to commercial-TV systems. Another popular arrangement involves transmitting the audio information as a completely independent signal on a lower frequency Amateur band. The 2-meter (145 MHz) and 6-meter (52 MHz) bands are particularly popular for such audio communications. The logical way to learn which technique and bands are used in a given area is by simply asking local Radio Amateurs. Radio parts stores and radio clubs are usually familiar with these people.

Amateur fast-scan television is affected by the same conditions which influence commercial television: its broad bandwidth requires use of ultra high frequency (UHF) transmissions. A list of the presently popular ATV bands is shown in Table 13-1. The 70-cm

Table 13-1. The Presently Popular Fast-Scan ATV Bands and Most Commonly Used Video Frequencies.

Frequency	Wavelength	Popular ATV Frequency
430 - 470 MHz	70 cm	440 MHz
1260 - 1296 MHz	23 cm	1290 MHz
2300 - 2350 MHz	13 cm	2300 MHz
10,000 - 10,500 MHz	3 cm	10,000 MHz

band is Amateur Radio's most popular ATV band, with a creditable amount of activity being present in most metropolitan areas. This band's proximity to commercial uhf-TV frequency allocations permits use of improved gain and modified uhf tuning setups, plus modification of some uhf antennas for Amateur transmitting and receiving applications. The distance (range) of Amateur communications on 70 cm is usually 30-100 miles: approximately equivalent to conventional uhf television.

Recently the 23-cm band has begun supporting a significant amount of Amateur television activity. In some areas, this is due to "overflow" from 70 cm activity, while at other times band crowding by FM and other activities suggest 23 cm communications as a "privacy measure." A restricted amount of commercially manufactured equipment is available for 23 cm. This usually requires the Amateur home to construct receiving downconverters which convert 1290-MHz signals to 54 MHz, etc., allowing reception by an unmodified television receiver. Transmitters and antennas for 23 cm also reflect home-construction techniques, with power levels of 5 to 10 watts and communication ranges of 25 to 50 miles being typical. A few enterprising Amateurs produce kits fully constructed 23 cm equipment for Amateur-television operation. The introduction of this equipment has been a decidedly beneficial measure in promoting Amateur-television operation and acceptance.

The 13 cm Amateur band is becoming popular for ATV operations in larger metropolitan areas, particularly those supporting a high-degree to lower frequency ATV activity. The equipment used often centers around modified MDS downconverters "in front" of unmodified television receivers, and low-powered, home-constructed transmitters. The most popular antennas for 13 cm are parabolic-dish units and large yagis known as "cigar" antennas. Finally, the 3-cm band is destined to become ATV's major frontier for future development. The large bandwidth allocations in this region permit multiplexed transmissions, plus data links and national relays on a basis similar to telephone-company microwave-network systems. This frontier presently encompasses a wide variety of Amateur communications pioneering, including testing of Amateur weather-radar setups. The popular "Gunnplexers" used for Amateur communications in the 10-GHz range are readily adaptable to television use, providing inexpensive transmitter/downconverter setups.

As one might logically surmise from the previous discussion, Amateur fast-scan setups typically consist of a mixture of home-constructed gear (and possibly some Amateur-manufactured kit equipment), plus a basic closed-circuit camera, an audio link, and the largest antenna that individual can afford or construct. The communication distances are basically restricted by the high frequencies used; however, their range is surprisingly good.

AMATEUR SLOW-SCAN TELEVISION

This unique mode of Amateur visual communications is similar to conventional television, but slowed in scan rate approximately 100 times (hence the term slow-scan TV). An analogy to SSTV would involve playing a regular video recording 1/1000 of its usual speed. The normal 4 MHz bandwidth would reduce to 1100 Hz, while the horizontal frequency would reduce to 15 Hz. The slowly traced picture (8-second vertical scan required for each picture) would require long-persistence, radar-type screens, or digital memories and processing. This narrowband television system, however, provides visual communications over conventional audio channels. In order to fully understand the SSTV impact on the communications world, a brief overview of Amateur Radio activities is beneficial.

Radio Amateurs communicate daily on a person-to-person basis with other Amateurs in nearby cities, states, and in countries throughout the world. The popular mode for these long distance communications is single sideband (SSB) voice. A variety of frequency allocations, known as Amateur bands, are located throughout the high-frequency spectrum (3.5 to 30 MHz), and the SSB communications under discussion are conducted within these bands. During 1958, Copthorne MacDonald, a young engineer attending the University of Kentucky, devised the voice-bandwidth system of slow-scan TV. Being a Radio Amateur, MacDonald acquired special authorization from the Federal Communications Commission to conduct on-the-air tests of SSTV on the then-popular 2-meter Amateur band. An audio subcarrier, amplitude modulated with video, was used. The tests proved that SSTV communications were practical, and launched a new mode of long-distance, visual communications. However, the amplitude-modulated subcarrier's susceptibility to noise interference forced a change to a more beneficial frequency-modulated equivalent. (This change would also prove beneficial to present commercial-television concepts, however their compatibility requirements presently block that path). During the following decade, SSTV grew very slowly as each technical problem was resolved and the overall concept was perfected. Then, during the early 1970s, slow-scan television made its grand debut.

The first SSTV Amateur station used home-constructed cameras and viewing monitors (there were no commercial SSTV equipment manufacturers). The camera's output (audio tones corresponding to video information) was connected to the transmitter audio input, while the monitor input connected to the receiver's speaker output. A limited number of Radio Amateurs involved in this new frontier began exchanging pictures on a national and worldwide basis, and interest and excitement mushroomed. Within the following two-year period, the Amateur SSTV population grew from approximately 250 to over 20,000. Commercial manufacturers jumped on the "bandwagon," providing quality SSTV equipment which Amateurs could use in conjunction with their existing SSB communications equipment. Slow-scan TV had come of age!

The next generation of slow-scan TV growth and innovation encompassed numerous applications of this visual medium, and the inclusion of digital-scan-conversion concepts. The technique of digital-scan conversion permits direct use of conventional, unmodified TV cameras and monitors (or television receivers) with Amateur communications gear. See Figs. 13-1, 13-2, and 13-3. The

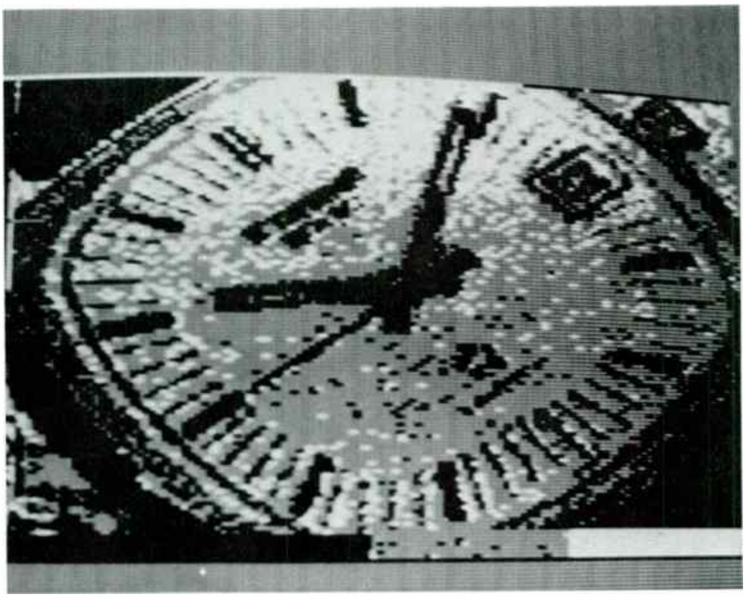


Fig. 13-1. A fast-scan to slow-scan converted picture, showing typical resolution of this narrowband video system.

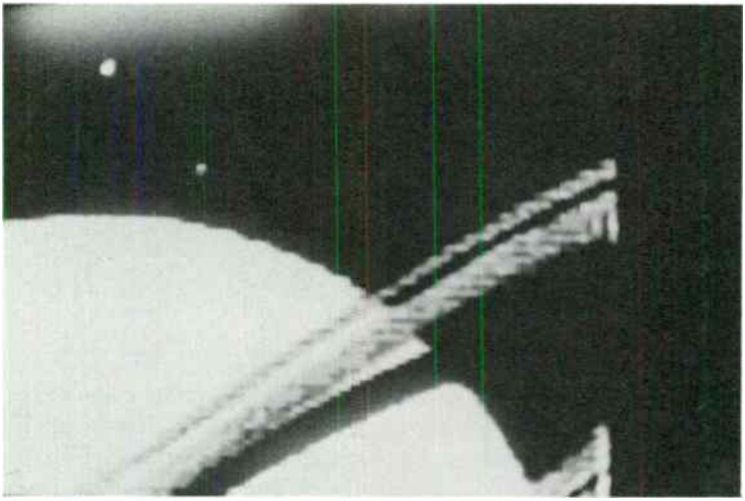


Fig. 13-2. This slow-scan TV picture of Saturn's ring structure was received from Voyager II and relayed to Radio Amateurs around the world by the Jet Propulsion Lab's Amateur Radio station W6VIO. The station is manned by over 40 Radio Amateurs employed at JPL.

scan converter acts as a full-frame time buffer, storing fast-scan video and slowing it 1000 times for slow-scan TV. It also stores slow-scan video and accelerates it 1000 times for fast-scan TV. Analog-to-digital converters, plus additional buffers, "round out" the scan-converter's design.

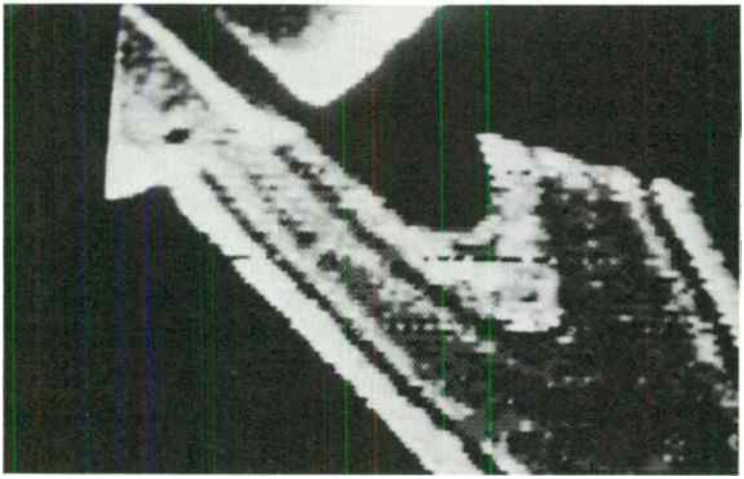


Fig. 13-3. This close-up view of Saturn's ring structure was taken as Voyager II sped past Saturn into the outer reaches of the solar system.

Table 13-2. Amateur Radio Frequency Allocations for Slow-Scan Television Operations Within HF Spectrum. Note than an Advanced Class License Is Required for Operations Within Certain Frequency Ranges.

SSTV Frequency Allocations	Amateur Radio Band	Popular SSTV Frequency
3,800 - 4,000 kHz	80 meters	3845 kHz
7,150 - 7,300 kHz	40 meters	7171 kHz
14,200 - 14,350 kHz	20 meters	14,230 kHz
21,250 - 21,450 kHz	15 meters	21,340 kHz
28,500 - 29,500 kHz	10 meters	28,680 kHz

The present generation of slow-scan TV includes a number of innovations, the most popular of these being color slow-scan TV, 3-D slow-scan TV, computer-processed-and-enhanced SSTV, and several special video-mixing techniques. The future of SSTV looks extremely promising. A list of popular Amateur SSTV frequency allocations is shown in Table 13-2, and the reader is heartily invited to further investigate this exciting mode of long distance communications. TAB Books publishes several books detailing Amateur Radio's many exciting avenues and the new world of Amateur slow-scan television. We particularly suggest reading "The Complete Handbook of Slow-Scan TV," also by this author (TAB Book No. 859).

MEDIUM-SCAN TELEVISION

One of the most recently developed types of visual communications embraces both fast- and slow-scan TV concepts, consequently this mode is designated medium-scan TV. Medium-scan concepts evolved from the desire to span intercontinental distances while maintaining the parameters of motion and high resolution. The system began through efforts of a small group of technically-inclined Amateurs spearheaded by Dr. Don Miller (W9NTP) of Waldron, Indiana. Working with special temporary authorization from the Federal Communications Commission, the group proved limited motion television pictures could be conveyed on an intercontinental basis—and within a 35 kHz bandwidth.

As this is being written, medium-scan TV test transmissions are being conducted primarily on the 29.150-MHz range of ten meters. The signals are medium-band FM in nature. Receiving setups use 29-MHz receivers with modified slow-scan TV monitors or modified forms of digital-scan converters for processing of displayed pictures. The major factor favoring medium-scan TV development is its adaptivity to digital processing techniques. An initial picture, for example, may be received and stored in memory. Subsequent video transmissions may then encompass video information containing differences between previous frames. Dual 65,000-bit memories are used, the output alternating between each information bank as required.

Additional information concerning medium-scan TV may be obtained from W9NTP or through the International Slow-Scan-TV Network which meets each Saturday at 1800 GMT on 14,230 kHz. If you are presently a Radio Amateur involved with video communication, the frontier of medium-scan TV is an area worthy of your efforts and interest.

The world of Amateur Radio/television is an unlimited frontier beckoning every video enthusiast. The challenges and rewards are truly unsurpassed, providing lifetime enjoyment to all pursuing them. Possibly I am somewhat overzealous in my opinions, as I've been involved with Amateur Radio and television most of my life—and I wouldn't give it up for anything!

Additional information concerning all phases of Amateur Radio is available from TAB Books or The American Radio Relay League: (225 Main St., Newington, CT 06111). This superb hobby is open to all technically inclined individuals; it offers ultimate challenges and pleasures which we sincerely invite you to investigate. Two popular statements worthy of note here are: "For more information, ask any Radio Amateur," and "ham operators should be seen" (via Amateur television). See Fig. 13-4.

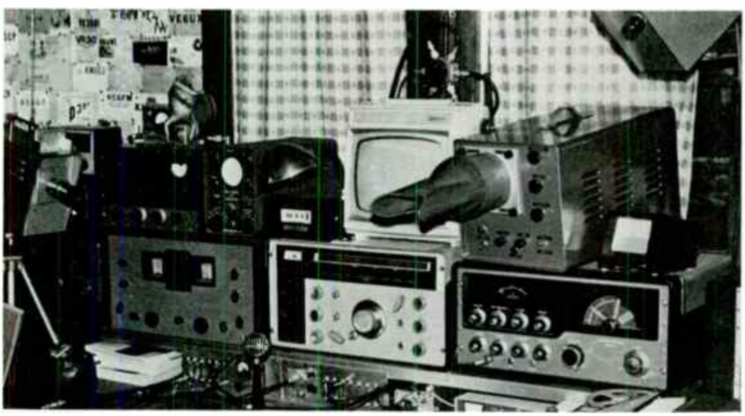
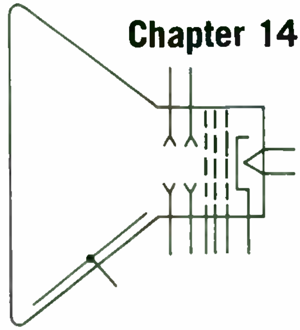


Fig. 13-4. Amateur Radio/fast-scan/medium-scan/slow-scan television setups often reflect the ingenuity of home-construction enthusiasts.

Chapter 14

The Quick TV Troubleshooter



The typical video enthusiast has, over a period of time, acquired an informal label as a mild-mannered type of video technician or troubleshooter. While this may or may not reflect a true identity, it is beneficial for one to be familiar with some of the more typical television problems and their solution. Sooner or later, the occasion will arise when one will be called upon for such "fixits," and this expertise might truly prove priceless. What follows is a general description of the more common or typically experienced television problems and their usual remedies. The "mix and match" format may be used as a quick troubleshooting guide for those occasions.

As a beginning thought, we would like to emphasize the value of logical steps. Don't assume all problems are complex in nature; check out simple and basic situations first. An apparently highly involved problem can often be caused by a simple bugaboo. Likewise, most electronic-equipment failures are usually confined to a single item or component which can be easily replaced. Unless a unit has been hit by lightning, dropped from a three story building, etc., multiple-stage problems are relatively rare. The techniques of video-electronics troubleshooting thus become that of relative simplicity; diagnose the problem as accurately as possible, then direct efforts to locating the defective component within that area. Although "hunt and peck" troubleshooting and general tinkering has worked at times, the technique is slow and costly. Visualize, instead, precisely what functions are performed by each stage and keep track of the overall results. This will direct efforts toward the particular area of concern much sooner than merely stumbling through a unit's electronics until the defective area is discovered.

Some people say an aged technician can also smell a problem and its solution. There are some truths beyond the humor of that statement; using one's natural senses of sight, smell, feel, etc., has been known to trim minutes or hours off a troubleshooting procedure. Hot transformers, for example, indicate excess loads, while cooler-than-normal tubes can indicate low emission or low voltages. Hot resistors indicate too much current flow (is it also charred?) and vibrating an intermittent circuit can help locate poor solder or loose connections. Use all available senses and think logically. Few things are as difficult as they originally seem.

The television receiver is a unique device when describing its symptoms and problems during a failure: the audio and video sections serve double duty in directing one to the troubled area. The difference between an illuminated and dark TV screen usually indicates the presence or absence of high voltage. This voltage, as mentioned in a previous chapter, is acquired from the horizontal-output stage. If the horizontal output stage is inoperative (a common situation, since this stage does more work than any other stage in the television receiver), the TV screen will be dark. If trouble is confined to that horizontal output/high voltage area, the low voltage (B+, or Vcc) will still be present and other stages will operate normally. Continuing, let's assume a TV set has no sound, no picture (dark screen), and its channel-selector pilot lamp is illuminated. A problem in the B+ is indicated, since power is obviously arriving at the television receiver proper. Conversely, a TV set with no sound, no picture (dark screen) and no pilot lamp illumination usually indicates the absence of ac power into the set. Several other examples of such symptom descriptions are given later in this chapter.

Modern television receiver design permits troubleshooting and repairs to be performed in a relatively easy manner. Indeed, the majority of electronic items follow similar design trends, and often use printed-circuit-board replacement techniques rather than component-replacement repairs. Expensive? Not necessarily, considering for example, that a trouble-laden horizontal-output board (or other boards) can usually be exchanged for the approximate cost of older-model horizontal-oscillator and output tubes or transistors. Troubles in vertical sections, likewise, can often be cleared merely by exchanging the plug-in board for a new replacement. A "dud fee" is usually allowed on the defective board, while the technician merely exchanges boards to re-establish proper operation. Since inflation has severely devalued money, time itself has the maximum monetary value. Thus rapid board exchange is more logical than time-consuming discrete component troubleshooting. I prefer rapid troubleshooting to the board level, then making a few brief checks on obvious components to ensure that the problem warrants a board exchange. If the problem is found, great. If it isn't, the complete board is swapped before a substantial amount of time is invested in its repair. Each person's techniques, criteria, and opinions differ, so use your own judgment and techniques along with this chapter's ideas as you prefer.

VERTICAL TROUBLES

Vertically rolling pictures, such as that shown in Fig. 14-1, are usually produced by off-frequency vertical-sweep circuits. The first item to suspect for causing this problem is the vertical sweep's active device (tube, transistor, etc.). Assuming a thorough check indicates correct operation of that device, the oscillator's frequency-determining resistance/capacitance network should be suspected. Capacitors in frequency-determining circuits such as the vertical sweep are relatively large in value and can change with

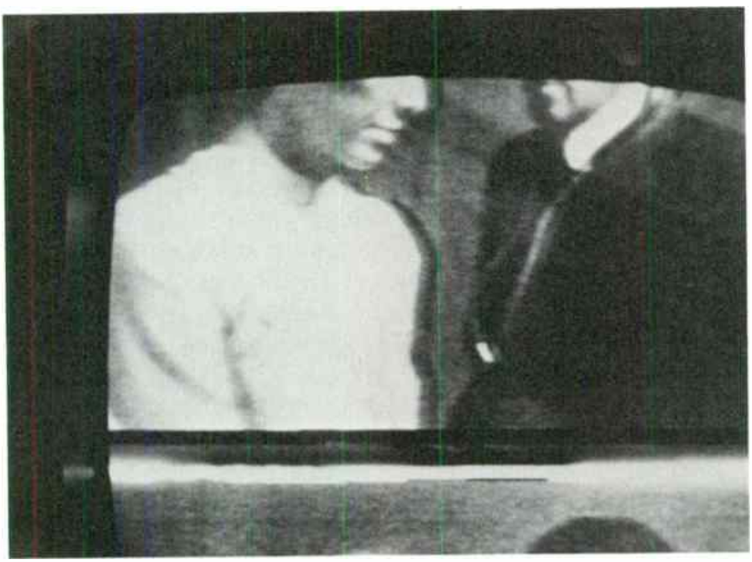


Fig. 14-1. Vertically rolling raster. This problem may be caused by incorrect setting of vertical hold, off-frequency operation of vertical oscillator, or decreased capacitance in vertical-sweep sections.

time. As that capacitance changes, the R/C time-constant changes and produces an off-frequency vertical sweep. A defective vertical-hold control has occasionally been found to cause this trouble. A number of inexpensive portable television sets feature vertical sections with interacting vertical height, linearity, and hold controls. A telltale clue to these particular receivers is a combined vertical height/linearity panel on the back of the receiver. Since all three of the adjustments interact, vertical roll may be caused by misadjustment of one or all of the three controls. Try readjustment before delving into circuitry. As a final note, it's often possible to readjust vertical height and linearity for a slightly smaller picture (small amount of black at screen bottom/top) and consequently permit more stable operation of the vertical-hold circuit.

Problems of shorter than normal rasters, that is, a picture "pulled up from the bottom," may be due to lower-than-normal high voltage or low ac line voltage into the television receiver. When this problem is encountered, check ac power into the receiver.

HORIZONTAL TROUBLES

Horizontal tearing, like vertical roll, is usually caused by an off-frequency operation of the horizontal oscillator section (Fig. 14-2). This stage is slightly more complex than the vertical-oscillator circuit; an APFC type discriminator is used. Should the APFC become defective, the horizontal oscillator will be pulled to an incorrect frequency. Active components in the horizontal section, as well as R/C time constants can be suspected of causing this problem. The reason for horizontal tearing rather than rolling is quite interesting; since the horizontal frequency is 262 times faster than vertical, a 262-times faster roll is produced, which shows up as tearing. Before diving into a television set with horizontal-tearing problems, try adjusting the horizontal-oscillator coil. This coil can be identified by its large number of turns on a slug-tuned form.

A single vertical line on an otherwise blank raster usually indicates a lack of horizontal deflection: this problem could be caused by a horizontal output device, damper, flyback transformer, or yoke. Since the horizontal output device does the most work in a television, its operation should be checked first. The presence of high voltage is indicated by the brightness in the line; looking into that "window," one should thus be able to see video movements. This will confirm the problem's confinement to the horizontal output area, especially the yoke and its connections.

When replacing a horizontal output device (tube, transistor,

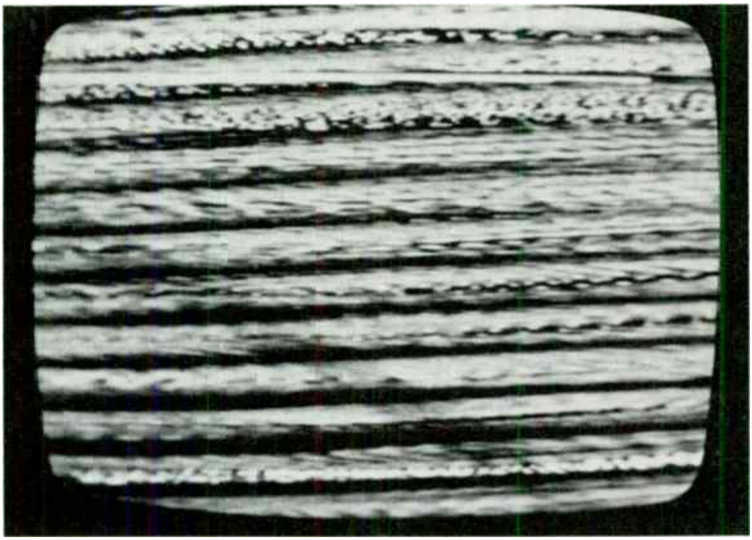


Fig. 14-2. Horizontally tearing picture. This may be caused by incorrect setting of horizontal hold, incorrect horizontal oscillator or discriminator adjustment, or improperly adjusted agc. Remember to check rear panel horizontal-hold control before delving into circuitry.

etc.), be sure to check for proper operation of the horizontal oscillator. A defective horizontal oscillator will quickly destroy a horizontal output device. When replaced, the new horizontal output device will, likewise, be destroyed in rapid time. If in doubt, replace both devices (less expensive in the long run). Many television sets incorporate circuit breakers on the rear panel for protecting the horizontal section. Should excessive current flow, this circuit breaker will remove power from the horizontal section. Remember to check this device when troubleshooting horizontal output sections.

SYNC TROUBLES

Occasionally, a picture will be noted which both rolls vertically and tears horizontally. This situation indicates a loss of synchronization signals. Since the problem is common to both horizontal and vertical, the area in trouble is probably the sync separator circuit and associated components.

RASTER PROBLEMS

Tilted raster is usually caused by a slightly turned yoke. Sometimes television receivers arrive from the factory in this condition,

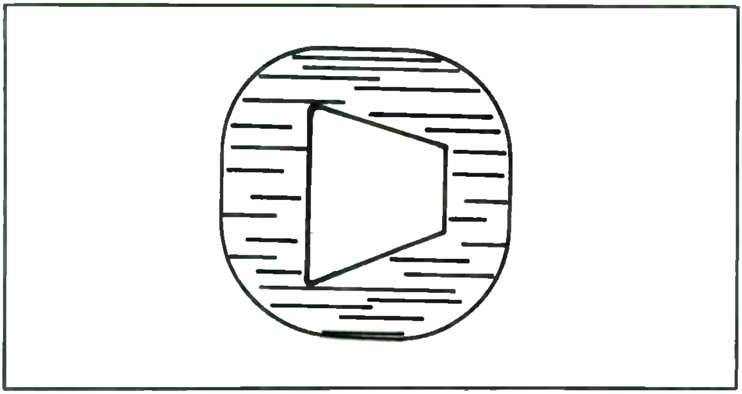


Fig. 14-3. Keystoned raster. A display of this shape is usually caused by an open or shorted coil or yoke.

other times the picture tube's yoke-mounting hardware works loose and permits the yoke to slip. The solution to this minor problem involves simply realigning the yoke for a straight picture, and tightening its mounting hardware.

An unusual problem which is immediately recognized by its unique characteristics is a keystoned raster (Fig. 14-3). This display, which may happen in either a horizontal or vertical direction, is produced by an open or short circuit in one of the deflection coils in the yoke. The solution usually involves simply replacing the yoke assembly. Many times, suitable replacements can be located in discarded or surplus TV receivers. Care should be exercised, however, to ensure that the replacement yoke has the same deflection angle as the original, and that the inside yoke diameter correctly matches the picture tube.

Two small centering rings are often found on the rear of many black-and-white television yokes. An incorrectly centered picture may be readjusted by these rings. Likewise, when replacing a yoke, proper alignment of the raster-centering rings should be checked before replacing the yoke.

Color-television receivers also include centering rings, however their name is changed to purity rings. The rings affect beam alignment with color phosphors on the screen, and require a color-test-bar pattern for proper alignment. Complete details on this procedure were given in Chapter 7.

INTERFERENCE

The condition in Fig. 14-4 is caused by radio interference from a nearby transmitter. Each particular case of television interference is unique in itself; some situations producing only minor herringbone effect in the picture, others totally blanking the picture. The amount of interference is directly related to the nearby transmitter's power frequency, type of antenna, and distance to the television receiver's antenna. Citizens-band transceivers and high-power (illegal) rf amplifiers are particularly notorious for creating television interference. Their proximity to the television receiver's i-f range creates a condition which is quite difficult to relieve. Corrective measures involve using a good antenna, good antenna connections, quality lead-in wire without breaks, good connections on the receiver's antenna terminals, and solid connections to the receiver's tuner input. Additionally, a television high-pass filter may be installed at the television antenna terminals and connected by the shortest possible lead to an external ground. The external ground connection is a vital point in filter operation and must not be overlooked. Many television manufacturers provide high-pass TVI filters free of charge. These devices are usually available from distributors. A move has been proposed in the U.S. Senate for mandatory inclusion of high-pass filters in television receivers; however, that proposal has not yet been accepted.

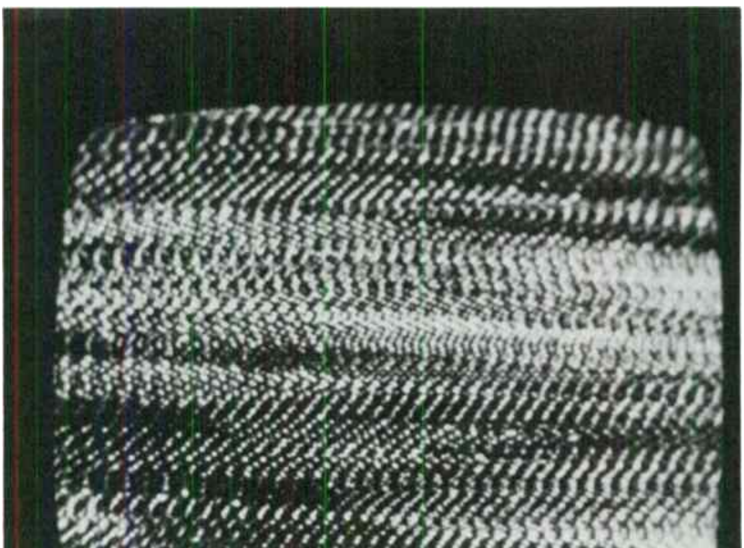


Fig. 14-4. Radio frequency interference. Usually caused by nearby shortwave transmitter. Interference varies from lightly noticeable lines to complete picture obliteration.

POOR PICTURE QUALITY

A low-contrast picture (Fig. 14-5) may be caused by an incorrect setting of the contrast control, incorrect setting of the agc, or a low-output video amplifier stage. Nominal video-modulation output applied to a picture tube ranges from 50 to 85 volts, depending on the particular tube and setting of the contrast control. A weak video amplifier, however, may provide only 10 to 20 volts video output and thus "undermodulate" the picture tube. A quick analysis involves measuring peak-to-peak video signal at the picture-tube base connections while varying contrast level. Assuming that operation is normal, the problem can be traced by applying a 1 to 2 volt peak-to-peak audio signal across the contrast control.

A low contrast or dim picture may be the result of a weak or defective picture tube. This situation is usually indicated, however, by its slow approach. Picture tubes usually deteriorate over a long period of time. As electron-gun emission decreases and the picture becomes dimmer, the viewer usually increases television brightness for compensation. Finally, a point is reached where additional brightness is not available. At this point, the displayed picture exhibits a loss of gray-scale reproduction. Finally, electron-gun output drops to the point that picture-tube replacement is necessary. Many times, picture-tube boosters are effective in delaying the inevitable replacement. The booster is a simple auto-

Fig. 14-5. Low contrast picture. Check settings of brightness, contrast, and agc. If problem persists, check video amplifier and video output stages.

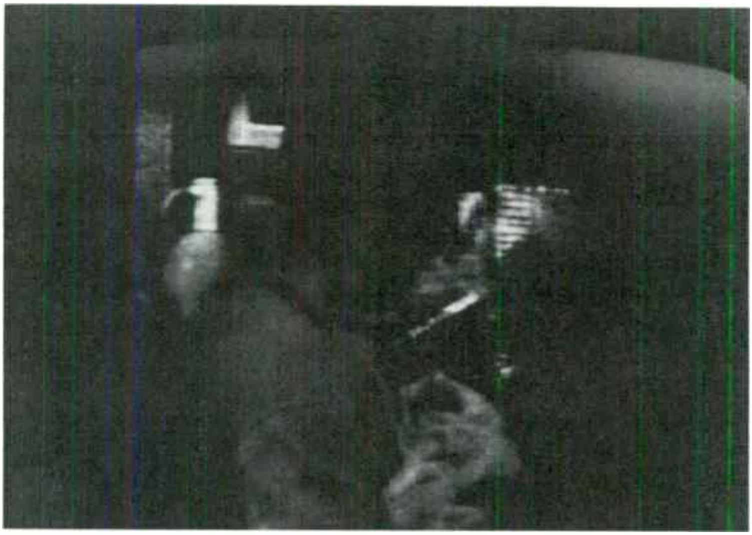


Fig. 14-6. Low brightness. This problem is usually caused by incorrect picture tube bias from video amplifier section or weak picture tube (usually characterized by halos around objects).

transformer for increasing the filament voltage by approximately 15 percent. This increase in filament, or heater, voltage provides increased electron-gun output and consequently brighter pictures. Picture-tube boosters are somewhat of a gamble. The above-normal voltage applied to an older filament creates a risk of causing complete failure, or burn-out, of the rather sensitive filament. Realizing, however, that a picture-tube booster isn't applied to a tube unless satisfactory operation cannot be achieved without it, the use of a booster is thus justified and its calculated risk understood.

Low brightness, or a dim screen (Fig. 14-6), may be the result of a weak picture tube or a defect in the video-amplifier section. As a means of discerning these differences, halos of light often appear around bad-picture-tube displays, while defective video-amplifier stages usually cause problems that develop quickly. Assuming a video-output device develops a change in conductance, the picture tube may be incorrectly biased and video-modulating signals are adversely affected. As a result of this, the picture-tube bias (static condition) may vary tremendously from its established level. Again, the most logical means of tracing this problem involves measuring picture-tube bias and modulating video-signal amplitude at the picture-tube pin connections.

While a situation of high brightness may seem abnormal and seldom encountered, it does happen. High brightness which cannot be controlled by the brightness control may be caused, also, by conductance changes in video-amplifier output devices. A "leaky" video-output transistor, for example, is capable of providing exces-

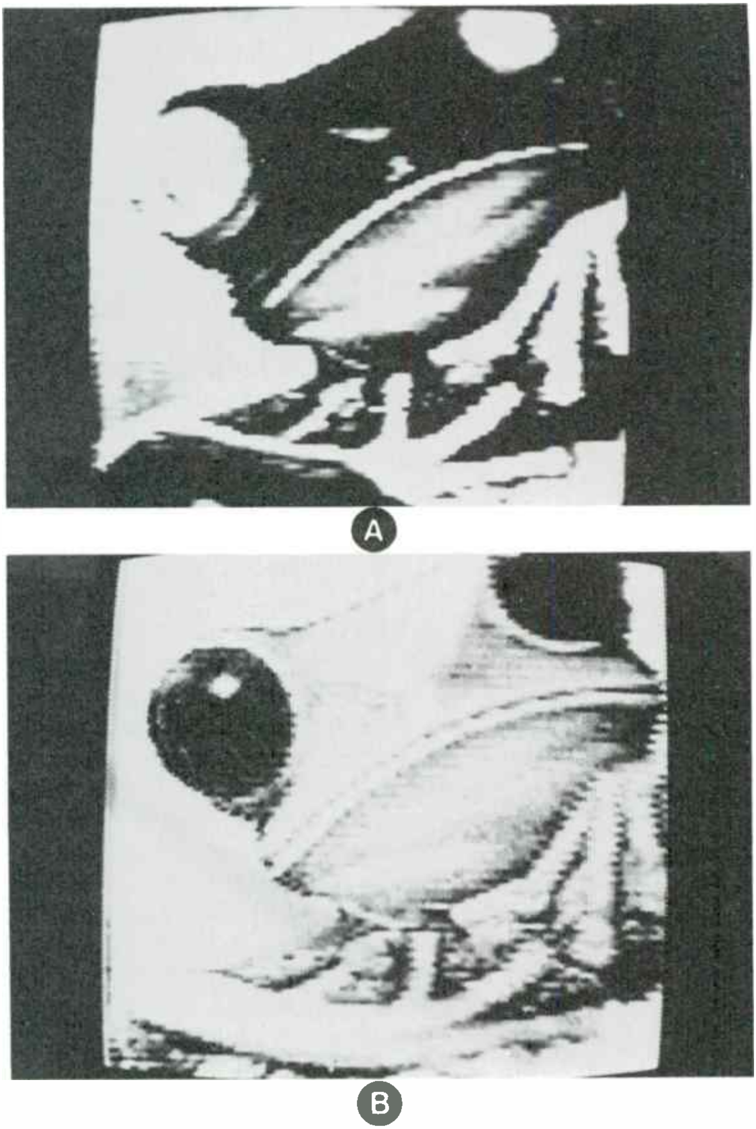


Fig. 14-7. A negative picture (A), and a positive picture (B). The negative picture may be caused by a defective video amplifier or improper agc level.

sive bias to a picture tube while simultaneously reducing video modulation to a significant degree. As before, the best means of localizing these defects involves measuring dc bias and peak-to-peak video levels at the picture tube.

A high-contrast picture, tremendously lacking in gray-scale rendition, is yet another example of a defective video amplifier. This particular situation is created when a higher-than-normal operating bias is applied to the picture tube, and the contrast control is readjusted for compensation. As a result of these maladjustments, an extremely contrasty picture lacking in gray scale is produced. Check brightness and contrast control settings before delving into the circuitry.

A negative picture can be caused by an inoperative stage of video amplification or by agc-level troubles, Fig. 14-9. Bearing in mind that each video amplifier stage inverts the signal, it can be seen that a defective stage might simply couple a signal through without amplification or inversion. The resultant picture should exhibit substantially less than normal contrast because of lack of video amplification in the defective stage. A strong TV signal, mated with low agc levels, may overload the i-f and video detector stages, also producing a negative picture. This situation is usually recognized by its normal or above-normal contrast amplitude, as compared to lower-than-normal levels created by video-amplifier defects. Suggested troubleshooting techniques involve the use of oscilloscope measurements of video levels and/or measurements or substitution of agc bias levels.

FOCUS TROUBLES

A number of situations may cause an out-of-focus picture. Remember to check simple and obvious problems first, and progress to more involved remedies as required. An initial investigation to discern if individual scanning lines (indication of sharp focus) or a small picture element can be seen will prove beneficial. If individual lines cannot be resolved, check set focus and high voltage (along with the voltage divider string which feeds the contrast control). It should be possible to adjust picture clarity from a soft blur to a sharp focus and again to a soft blur as the focus control is rotated through its range. If a small picture element cannot be resolved, and only larger picture elements are apparent, the problem may be due to loss of high-frequency response in i-f amplifier stages. I-f amplifier is a time-consuming and involved procedure. It is thus advisable to thoroughly check other sections (antenna, tuner, agc, etc.,) before investing time in a bandpass and sweep analysis of i-f stages. If alignment is required, a sweep generator, a wideband oscilloscope, and an agc bias box are necessary. A fully detailed explanation for i-f alignment is indeed far beyond the scope of this book. The best source of these instructions is the manufacturer's instructions and service aids.

Light sparkles, or dots, in the video display is usually the result of noise affecting received signals. Sparkles occur whenever noise levels rise above incoming signal levels. This may result from either a high noise level or a low signal level. Out-of-town stations will produce sparkled displays because of low incoming signal amplitude, whereas high power-line or appliance noise level will create noise pulses which can override the signal. The solutions to noise interference are quite varied. Indeed, eliminating a high noise level may be almost impossible—and a "happy medium" may be all that can be achieved. Beginning steps should include checking antenna connections, lead in, and connections to the television antenna terminal. Shielded twin lead or coaxial cables (with associated balun transformers) are suggested as noise-reduction techniques. Twisted lead-in wire often helps in noise reduction. Highly directional antennas are particularly effective in minimizing power-line noises, assuming the antenna can be orientated with its "back" to the noise source, and its "front" toward the transmitting station.

COLOR PROBLEMS

An extremely low output or defective 3.58 MHz oscillator may cause intermittent color, incorrect colors, or a form of barber-pole striping (colors streak through picture but do not lock into proper location). Either bandpass-amplifier discrepancies or 3.58-MHz oscillator troubles may cause these displays. Adjustment of the receiver's fine tuning may help pinpoint which of these two is defective. Likewise, a check of input level to the color-demodulator circuit is advisable. The 3.58-MHz signal may be checked with an oscilloscope: its output should be clean and of relatively high amplitude. The other signal applied to color demodulators, the color-difference signals, should also be discernible at demodulator inputs. If the trouble is still elusive, check phase-shifting networks associated with the 3.58-MHz reference signal and the phase shifters associated with bandpass-amplifier output.

The lack of a single color is a somewhat common problem in many color receivers. This can usually be traced to open resistors or diodes (depending on receiver design) at red, green, or blue video amplifier output. These relatively high-wattage components may be located in a hard-to-reach place, but their track record makes them highly suspect. Assuming that diode/resistor checks reveal proper operation, active circuit devices in each color amplifier should next be suspected.

Although a rather unusual condition, too much color is not an unknown situation. Assuming a Y amplifier stage between the color-take off point and the picture tube becomes defective, no brightness information will be available for diluting the color signal. As a result, pure color will be produced. This condition is usually recognized by a lack of fine detail, or small picture elements, since this information is conveyed via the Y signal. A close examination should reveal improper picture-tube adjustment or defective Y amplifiers.

Color fringing can be somewhat tricky in analysis and remedy. Assuming color fringes appear on objects, check to discern if this happens only in the middle of the screen, or anywhere on the screen. Specific-area fringing usually indicates convergence problems, while fringing independent of screen area usually indicates antenna lead-in, or ghost problems. The most logical means of locating the cause, involves reducing the front-panel color level to zero, and viewing the resultant black and white display. If color fringing is still evident, the problems are in convergence circuitry (dynamic or static, depending on screen area). If color fringing disappears, the problems are associated with the antenna system. Refer to the antenna chapter (Chapter 8) for more details.

Intermittent color with occasional loss of picture and consequent dark screen may be associated with tuner defects. Voltages applied to solid-state tuners can vary due to oxidation and dirt accumulation on contacts. As a result, tuner operation becomes somewhat erratic. This results in occasional "drop out" of received signals, and consequent loss of color or of all video (and sound) information.

Index