TELEVISION RADIO ELECTRONICS

UNITED TELEVISION LABORATORIES

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LOUISVILLE, KENTUCKY

ASSIGNMENT 99

TELEVISION STATION EQUIPMENT

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This assignment will be devoted to a general discussion of some of the pieces of equipment used at a television station to develop the composite video signal and to transmit it to the television receiver. In addition to the equipment used to develop the composite video signal, a television station, of course, employs equipment for developing and broadcasting the audio frequency signal. However, this equipment is the same type as that used in standard F-M broadcast stations and, since this equipment has been discussed in previous assignments, no further discussion will be required at this point.

Before proceeding with this assignment, it is suggested that the Associate review carefully Assignment 66 which explains, in a rather basic manner, the operation of a television broadcast system. With this overall picture well in mind, it will be possible to proceed with the general discussion included in this assignment.

Station Layout

Station equipment will be considered under five categories for this discussion. These categories are: 1. Studio equipment; 2. Control room equipment; 3. Film projection equipment; 4. Field pickup equipment; and 5. Transmitting equipment.

Figure 1 illustrates by block diagram the layout of a standard television station equipped to handle studio, remote, film, and network programs. The studio, control room, and film projection room will ordinarily be at the same location. The transmitter may or may not be located at the same place as the studio. The remote pickup point can be any site from which a "live" show originates such as a sports arena, theater, site of a special news event, or a studio located at some distance from the main studio. Network programs will come to the station by means of special coaxial cables installed by the telephone and telegraph companies.

Figure 2 illustrates the layout of a large television station having several local studios. Centralized control of the station is maintained in the master control room. The equipment used in a large station will in general be of the same type as that used in a small station but it is obvious that more of the equipment will be required.

Studio Equipment

The basic studio equipment will consist of television cameras, microphones, and lighting equipment. The studio cameras normally employ image orthicon pickup tubes. These cameras are generally mounted on special dollies or booms so that they may be easily and quietly moved during a telecast in order that a scene may be picked up from different angles or so that special effects may be produced.

Studio microphones are of the same type as those used in standard broadcast studios. Some of the microphones will be mounted on special booms so that they may be moved freely during a telecast since microphones are generally kept out of the range of the cameras. In some cases microphones are placed in the camera range but are concealed so their presence is unknown to the telecast viewer.

The studio lighting system must be very flexible to provide sufficient lighting for the television cameras and yet allow the creation of special lighting effects which may be required for some scenes. The lighting system may consist of controlled overhead lights plus movable lights mounted on dollies or suspended from special tracks on the ceiling for front and side lighting of a scene.

Control Room Equipment

Control room equipment will consist basically of a video console, director's console, audio console, synchronizing generator, and auxiliary equipment. The video console is the position from which the studio cameras are monitored and controlled. Film cameras may also be controlled from this position. The equipment in the video console will consist of a camera control for each studio or film camera.

The director's console has provisions for monitoring the picture being fed to the transmitter for previewing of pictures before they are actually "put on the air" to check picture quality and signal amplitude, and switching of video signals.

The audio console will be of the same type as used in standard broadcast stations and will provide for monitoring of the sound portion of the telecast as to quality and signal level. Transcription turntables and announce microphones may also be included with the audio console.

Figure 3 illustrates a typical television studio and the control positions of the control room. In the studio are shown two cameras on tripod mountings, two microphones on boom mounts, and studio props. Three control positions are shown; these are, left to right, the audio control position, the director's control position, and the camera control position. At the audio control position is the turntable, announce microphone, and audio console. At the director's position are two pictures and video signal waveform monitors (video control switches are in front of the monitors but below desktop level), and at the camera control position the camera controls for the two studio cameras are shown.

The synchronizing generator which is in the control room, provides the signals which make possible the synchronization of the television cameras and the receiver at the telecast viewer's home so that the transmitted picture can be reproduced. One type of sync generator has been discussed in an earlier assignment. A sync generator designed for operation at a fixed location is shown in Figure 4.

The auxiliary equipment in the control room will consist of such units as regulated power supplies for the studio cameras, camera controls, switching systems, monitors, etc., video and audio amplifiers, and video and audio jack panels and patch cords. Additional equipment may include monoscope camera, relay receiver and transmitter controls, relay equipment antenna controls, and terminal equipment for network and remote video and audio transmission lines. Some of this auxiliary equipment is illustrated in Figure 4.

Film Projection Equipment

Film projection room equipment will include film cameras, special film projectors, slide projectors, multiplexer, and balopticon. Some stations are also equipped to process and edit their own motion picture film so that local programs or special events may be filmed and telecast later.

Film cameras will differ from the studio cameras mainly in that a different type of camera tube is used; the iconoscope being employed widely for this application. The film cameras are mounted so that the picture produced by the film or slide projectors is focused directly on the mosaic of the camera tube.

The film projectors are similar to those used for standard motion picture projection and use standard 16mm or 35mm film. The principle difference lies in the shutter opening and film pull-down rates. Standard motion picture film is projected at a rate of 24 pictures per second, whereas a television picture is produced at a rate of 30 pictures per second. To compensate for the picture rate difference the film camera tube is exposed to light from the projector at a rate equivalent to 30 pictures per second, but the film speed through the projector is still at the average rate of 24 pictures per second.

The slide projectors are used for the projection of transparent still pictures onto the film camera tube and are of the conventional types used in homes and schools for showing slides.

The balopticon is a device used to project a picture from a non-transparent surface onto the film camera. This makes it possible to project still pictures without having them prepared in the form of slides.

The multiplexer is a device using an arrangement of mirrors so that two projectors may be used with one film camera. The projector is focused on the multiplexer and the light is then reflected by the multiplexer at right angles and onto the film camera tube. Two projectors are mounted on opposite sides of the multiplexer as illustrated in Figure 5. In Figure 5 the multiplexer is mounted on the tubular stand in front of the film camera. A slide projector is also shown mounted on the stand with the multiplexer and focused on the camera tube.

Figure 6 illustrates in a block diagram the studio, control room and film projection room equipment, showing the general paths of the picture and sound signals. Analyze this figure carefully to determine the manner in which the various signals are handled.

Field Pickup (Remote) Equipment

Field pickup equipment will differ from corresponding studio and control equipment mainly in that it is designed for portability. The basic units required are field cameras, field camera controls, power supplies, field synchronizing generator, field monitor, field video switching system, r-f equipment, and audio equipment. It is obvious that the equipment types are essentially the same as required at the studio location. In many cases stations use field equipment at the studio location. This is more economical for small stations since the equipment may be used interchangeably for studio or remote pickups, thereby reducing the actual amount of equipment required.

The picture signal generated at the remote pickup point is usually sent to the main studio or transmitter location by means of transmitting and receiving equipment operating in the 2000 mc or 7000 mc band. This method is used because the type of coaxial cable required to carry the wide-band picture signal is ordinarily not available between the remote pickup point and the station. The audio signal will generally be transmitted to the station location by telephone lines rented from the telephone company.

A field pickup layout employing two cameras is illustrated in Figure 7. Compare this layout with the block diagram illustrated in Figure 6 and it can be seen that fundamentally the field equipment is similar to the studio equipment. However, the field equipment is in most cases considerably simpler and is designed for portability. To facilitate the movement of this equipment from one place to another the units are customarily mounted in conveniently sized cases which have suit-case handles on them. This permits the equipment to be moved and set up as desired.

Transmitting Equipment

The transmitting equipment includes a sound and picture transmitter, transmitter-to-antenna coupling system, antenna, transmitter control console, and auxiliary equipment. Additional equipment may include turntables, microphones, and sideband filter. Figure 8 illustrates, in block form, a typical transmitter layout.

The television transmitter actually consists of two separate transmitters; an F-M transmitter for the sound and an A-M transmitter for the picture signal. These transmitters are coupled to the antenna through a special coupling network so that both the sound and picture signals can be radiated by the same antenna, yet isolation is maintained between the two transmitters.

The television transmitting antenna is designed to concentrate signal radiation along the earth's surface since, at the high frequencies used for transmission, energy which is radiated skyward is rarely returned to the earth and is consequently wasted. By concentrating the radiation along the surface of the earth, the effective radiated power of a station is increased. The antenna will be mounted on some high point of the terrain from which the desired coverage can be obtained or on a self supporting or guyed tower several hundred feet high. Figure 9 shows a photograph of a typical television tower and antenna.

The transmitter console contains the power switches for controlling the transmitters, a picture and video signal waveform monitor for checking the picture signal at input, output, and in various stages of the transmitter, and audio signal monitoring facilities.

Auxiliary equipment at the transmitter location may include video and audio amplifiers, power supplies, frequency monitors for the transmitters, watercooling system for transmitter tubes, and test equipment. Turntables and announce microphones will generally be available at the transmitter location for test purposes and for station breaks during periods when studio programs are not being presented. Television stations transmit a test pattern and tone signal during certain hours of the day for the convenience of television receiver servicemen and users in adjusting the receivers. During these periods, station breaks and special announcements can be made directly from the transmitter location.

Another unit which is used with some picture transmitters is the sideband filter. According to the present transmission standards only a part of the lower sideband frequencies produced in modulating the picture signal carrier are transmitted. Different transmitter manufacturers use different methods to remove the portion of the lower sideband. In some transmitters it is done by the tuned circuits of the transmitter. With other transmitters the frequencies are removed after the signal leaves the transmitter proper by feeding the signal through a filter circuit which removes the undesired frequencies and passes the remaining frequencies on to the antenna coupling system. The filter is commonly called a sideband filter.

At this point it will be apparent to the Associate that many types of equipment are used by a television station to generate and transmit signals which are to be picked up by the television receiver and converted into a picture and sound. The discussion to follow will treat in somewhat more detail the basic functions and theory of operation of circuits which are used in connection with the handling of the picture signal. It has been pointed out that the pickup and transmission of the sound portion of the telecast is basically the same as that used in F-M broadcasting. The Associate may refer to the assignments on broadcast practice and F-M transmitters for this information.

Synchronizing Generator

The synchronizing generator is located in the control room of a television station and is a key piece of equipment for a television system since it produces the signals which control the scanning beams of the camera tubes in the television cameras and the picture tubes of the television receivers. The scanning beam in the camera tube effectively converts various light intensities into electrical impulses in a particular order and the scanning beam of the receiver picture tubes must reproduce these variations in light in the same order.

The output signals of a typical sync generator will consist of a composite sync signal which becomes part of the transmitted signal to control the TV receivers; a composite blanking signal which becomes part of the transmitted signal to blank out the TV receiver beam during the vertical and horizontal retrace intervals; horizontal and vertical driving pulses which are used to control the sweep circuits of the studio, field, or film cameras and monitors and as blanking signals for cameras and some types of monitors. Additional output signals may include pulses having frequencies of one-half the horizontal and vertical sweep frequencies. These pulses are used to synchronize oscilloscopes or monitors for waveform observations and test purposes.

Sync generators are made in two general types, one for operation at a fixed location (see Figure 4) such as at the station, the other for portable operation since a sync generator must be in the vicinity of the cameras and associated controls.

The basic units comprising a sync generator are shown in Figure 10 (A); and consist of a timer or pulse former, pulse shaper and power supply. The output signals are generated in the pulse shaper circuits, but since the output pulses must be accurately controlled with respect to frequency ratios and time relations, the timer or pulse former supplies trigger pulses of the correct frequency ratios to the shaper for the control of the shaper circuits.

Pulse Former

A pulse former is illustrated in simplified block diagram form in Figure 10(B). A master oscillator operates at a frequency of 31,500 cps. The sine wave output of the oscillator is fed to a clipper circuit which is an overdriven amplifier and the resulting waveform is essentially a square wave. The 31,500 pps (pulses per second) output of the pulse former is used to control shaper circuits operating at this rate such as the equalizing pulse and vertical sync block generating circuits.

The 31,500 pps square wave is also fed to several frequency dividing circuits in order to obtain the other required frequencies. A 2 to 1 frequency divider produces output pulses of 15,750 pps to control several shaper circuits such as the horizontal sync pulses and horizontal blanking pulse generating circuits. A 525 to 1 frequency divider produces a 60 pps output for the control of such shaper circuits as the vertical blanking pulse generator. Actually the 525 to 1 divider consists of four cascaded frequency dividers operating at division ratios of 7 to 1, 5 to 1, 5 to 1, and 3 to 1. Thus the 31,500 pps signal is divided by 7 to give 4500 pps, 4500 pps divided by 5 gives 900 pps, 900 divided by 5 gives 180 pps, and dividing this by 3 gives the 60 pps output. The three frequencies 31,500, 15,750, and 60 are the basic frequencies necessary to produce the sync, blanking, and driving signals.

The test signal, 30 and 7875 pps, may be produced by additional frequency dividers as shown in Figure 10(B). These two frequencies are then exactly one-half of the vertical and horizontal sweep frequencies. Their use has been previously pointed out.

Since all of the frequencies have been obtained from the frequency of the master oscillator a fixed ratio between all of the frequencies can be maintained even though the frequencies are not of the exact values specified. If the master oscillator is slightly off frequency all other frequencies will be off by a proportional amount, their ratios remaining the same. A fixed ratio between frequencies is absolutely necessary in order to produce the composite sync, blanking and driving signals in proper time relations.

In order to improve the stability of the sync generator, the master oscillator is frequency controlled. One method of frequency control is to lock-in the master oscillator with another oscillator which is crystal controlled. Another method, which is commonly used, is to compare the 60 pps output of the pulse former with the 60 cps power line frequency which is generally maintained at a stable frequency by the power companies. The pulse former output and line frequencies are compared by a discriminator circuit which produces a change in d-c output voltage if the pulse former output is not of the same frequency as the power line voltage. The d-c output voltage of the discriminator is applied to the grid of a reactance tube as a control voltage causing the reactance tube to change its effective reactance by the amount required to bring the master oscillator to its correct frequency. In principle, the action is the same as that used in AFC circuits explained in a previous discussion on the sync generator.

Pulse Shaper

The pulse shaper actually produces the pulses which are the output signals of the sync generator. Figure 11 illustrates the shaper circuits in a simplified block diagram.

Before considering the general operation of the circuits, it will be advisable to study the various signals which are to be produced by the circuit, to get in mind the wave shapes and timing of various output pulses. The output signals of the sync generator are shown in Figure 12(A) as waveforms A, B, G, and H, which are the horizontal driving pulses, vertical driving pulses, composite sync signal, and composite blanking signal respectively. The composite sync and blanking signals together with picture signals from the cameras produce the composite television signal.

The standard composite television signal which is used at the present time is illustrated in Figure 11 of Assignment 77. This figure shows the general appearance of the signal immediately preceding, during, and immediately following the vertical blanking period for successive fields. The composite signal is also shown in Figure 12(B) of this assignment in proper time relation with respect to all the other waveforms of Figures 12(A) and 12(B). The composite video signal should be carefully reviewed at this point in order to visualize the timing that must exist between the parts of the signal. The three basic parts of the signal, sync, blanking, and picture information are generated separately and then added together to form the standard signal.

It will be noted that the leading edges of the horizontal blanking pulses occur slightly before the leading edges of the horizontal sync pulses. This is to insure that the receiver scanning beam is blanked out before the horizontal retrace begins. The small interval of time between the leading edges of the two pulses is called the "front porch" interval. A front porch interval also appears between the leading edge of the vertical blanking pulse and the first equalizing pulse. It will also be noted that there is a specific interval between the leading edge of the vertical blanking pulse and the last preceding horizontal blanking pulse in each field. A specific time interval also exists between the leading edge of the vertical blanking pulse and the first vertical sync block. It becomes obvious that exact timing must be maintained between the circuits which generate the various parts of the composite signal.

Of the signals produced by the sync generator, the most comolex is the composite sync signal. There are several methods of producing this signal but only one typical method will be discussed in this assignment. In this case the sync signal is produced by mixing four different signals together. These signals are illustrated by waveforms C, D, E, and F of Figure 12(A). The addition of these signals, point for point, will result in waveform G. The portions of waveform G above and below the dotted lines are clipped off in overdriven amplifiers, and the resulting waveform will be standard composite sync signal. The resulting waveform may be more easily visualized if the clipped off portions of waveform G are covered by slips of paper.

To get a more complete picture of how the sync signal is generated, it will be necessary at this point to study the block diagram of the pulse shaper (Figure 11), in conjunction with the waveforms of Figure 12(A). The four signals, C, D, E, and F of Figure 12(A) are individually fed to four mixer tubes labeled to correspond with the particular waveform handled by each mixer. These mixer tubes employ the same plate load resistor so that the resulting output signal becomes that of G which is fed to a clipping circuit. The sync output stage is designed to operate into a low impedance load such as a coaxial cable which is generally used to convey the signal to the next unit of equipment.

Next consider the source of the four signals C, D, E, and F. The equalizing pulses, C, are generated by a pulse generating circuit, such as a multivibrator, which is triggered by the 31,500 pps output from the pulse former. The equalizing pulse generator operates continuously and the pulses appear in the common plate circuit of the four mixers at all times.

Vertical sync blocks are also generated continuously by a vertical sync block generator triggered by the 31,500 pps signal from the pulse former. Although both the equalizing pulse generator and sync block generator are effectively triggered by the same pulses from the pulse former, they are not triggered at the same instants. The trigger pulses are fed to a delay circuit before being applied to the pulse generator in order to "time" the circuits.

The equalizing pulse generator is triggered slightly before the vertical pulse generator. The result of this timing is shown by adding waveforms C and E. A portion of an equalizing pulse forms the leading edge of each vertical sync block that appears in waveform G. The remaining part of the equalizing pulse occurs at the time when the vertical block begins to appear and the addition of the two pulses produces the "pip" which rides on top of the vertical sync blocks. The equalizing and vertical pulses are also timed in respect to the 60 pps output of the pulse former by means of the delay circuits. As it has been pointed out, the vertical sync blocks are generated continuously. However, examination of the composite sync signals shows that only six pulses are actually needed every sixtieth of a second. The six pulses are inserted by the vertical pulse insertion circuit which, although it uses several vacuum tube circuits, may be considered as a switch which closes sixty times per second for periods just long enough to allow six vertical blocks to be fed from the vertical pulse generator to the mixer E. A 60 pps trigger pulse for the vertical pulse insertion circuit is obtained from the pulse former.

The pulses in waveform D of Figure 12(A) are generated by the horizontal sync pulse generator which is triggered by the 15,750 pps output of the pulse former through another delay circuit for proper timing. The horizontal sync pulses are also timed in respect to the equalizing pulses so that every other equalizing pulse will form the leading edge of a horizontal sync pulse. This results in a "pip" on each horizontal sync pulse as in the case of the vertical sync blocks.

Examination of the composite sync signal will show that horizontal sync pulses do not appear for a period of nine lines during each field. The nine pulses are removed by a 60 pps signal for the 9-line keyer circuit in conjunction with electronic switch number 1. The electronic switch is simply a tube having two signal grids. The output from the horizontal sync pulse generator is fed to one grid and the signal from the 9-line keyer is fed to the other grid. The electronic switch tube is normally in conduction allowing the horizontal sync pulses to appear in the output and be fed to mixer D. When the nine pulses are to be removed, the 60 pps signal triggers the 9-line keyer, causing it to apply a negative going voltage to one grid of the electronic switch tube cutting the tube off and thus preventing the horizontal pulses from appearing at the input of the mixer D.

The notching pulses, waveform F, are used as a means of removing every other equalizing pulse during the periods when only horizontal sync pulses are to be present in the composite sync signal. The notching pulses are timed so that the unwanted equalizing pulses fall into the notches as shown in waveform G. The notching pulses are produced by the notching pulse generator which is triggered from the 15,750 pps delay circuit. The output of the notching pulse generator is fed to electronic switch number 2 which is controlled by the 9-line keyer. Nine notching pulses are removed at the time that the nine horizontal sync pulses are removed, in order to allow the six equalizing pulses to appear before and after the group of vertical sync blocks and for six other equalizing pulses to form the leading edges of the vertical blocks. This completes the generation of the composite sync signal.

The blanking pulses are generated by separate horizontal and vertical blanking pulse generators, which are triggered by 15,750 and 60 pps signals respectively and fed to a blanking mixer. The mixing action will result in a waveform similar to H of Figure 12(A) except that horizontal blanking pulses would appear on top of the vertical blanking pulse. The blanking mixer output is fed to a clipper which removes the unwanted portion of the signal and produces the composite blanking signal H. The signal then goes to the output circuit and terminals.

The driving signals which are used as trigger signals for sweep circuits of station equipment are generated by separate pulse generators and fed to separate output terminals. The timing of these pulses, waveform A and B, is shown in Figure 12(A). The leading edges of the horizontal driving pulses coincide with the leading edges of the horizontal blanking pulses. The width of the horizontal driving pulses can be equal to or less than that of the corresponding blanking pulses. The leading edges of the vertical driving pulses occur at the same time as the leading edges of the vertical blanking pulses. The vertical driving pulses cannot be greater in width than the vertical blanking pulses.

In the case of the fixed-location type of sync generator the pulse output circuits will generally be provided with two output terminals for each signal so that a signal may be obtained with either positive or negative going pulses. Portable sync generators are used with a specific group of equipment and will usually have only one polarity of output for each signal.

The Camera Chain

The camera chain consists of three main pieces of equipment; namely, the camera, camera control, and associated power supplies. The camera is, of course, located in the television studio. The camera control and the associated power supplies are located in the control room.

The camera consists of two units, the actual television camera or pickup head as it is sometimes called and a view finder. The camera tube together with the necessary deflection circuit and video amplifiers makes up the pickup head which operates independently of the view finder. The view finder consists of a small picture together with deflection and amplifier circuits for reproducing the camera signal as a picture. The view finder chassis is mounted on top of the pickup head chassis thus essentially becoming part of the camera, enabling the camera operator to see the picture being picked up by his camera and to adjust his camera for best picture quality.

The camera control unit may be located many feet from the camera and provides means for several electrical adjustments of the camera tube circuit, monitoring of picture and addition of composite blanking signal to camera signal.

The power supplies used in conjunction with this equipment are of the voltage regulated type having high current capacity. The number of power supplies required with a camera chain depends on the type of equipment used, whether it is portable or of the studio type. Portable equipment power is obtained from a single power supply, whereas, studio type camera chains may require several power supplies. High voltages for picture tubes and camera tubes are obtained from high voltage supplies built into each particular unit using such high voltages.

Basically there is little difference between studio and field camera chain equipment. Principle differences are in the mechanical construction and in the size of camera control monitor picture tubes and waveform monitor tubes.

The Image Orthicon Pickup Head

Studio and field cameras used at the present time employ the image orthicon camera tube which has been described in Assignment 94. The pickup head of a camera is relatively simple as shown by the block diagram in Figure 13. The heart of the unit is, of course, the camera tube which converts light energy into electrical impulses which are fed to a video amplifier. The video amplifier consists of several stages which are compensated so as to give a frequency response of about 8 megacycles. These amplifiers are of the same type that are used in television receivers except that they are designed to handle a very low level signal and have a greater frequency response. A typical amplifier requires four stages feeding a cathode follower output tube which is connected through low impedance coaxial cables to the camera control and view finder. The amplitude of the signal developed at the cathode follower is normally approximately 2 volts peak-to-peak.

Blanking signals must be applied to the image orthicon tube during the vertical and horizontal retrace periods to prevent the scanning beam from touching the target. If the scanning beam scans the target during the retraces, the original charge produced on the target by light from the scene would be disturbed and dark lines would tend to appear in the picture. Blanking of the image orthicon is obtained by applying sufficient negative going signal to the target to prevent the scanning beam from reaching the target. As shown in Figure 13, the driving pulses are fed to a blanking mixer to produce a blanking signal which is fed to the image orthicon target with negative polarity. Scanning of the target plus the effect of the blanking signals will produce a camera output signal similar to that shown in Figure 16(A). Although blanking pulses are thus introduced, they are not satisfactory as the final blanking signal of the composite video signal. The composite blanking signal produced by the sync generator will be added later in the camera control.

The deflection circuits used with the camera tube are of the conventional magnetic type. The discharge tubes are triggered by the respective driving pulses. High voltage for the camera tube is obtained by amplifying and rectifying the high voltage pulses developed in the horizontal deflection circuit during the horizontal retrace. This is much the same as the methods used in receiver high voltage supplies.

Several of the voltages applied to elements in the image orthicon tube are remotely controlled from the camera control. This system reduces the number of adjustments that the camera man has to make during operation when he may be kept busy focusing the camera on a scene. There are numerous electrical adjustments on the pickup head but these do not require adjustment during normal operation.

Optical focusing of the camera is generally carried out by a combination of lens adjustments and positioning of the camera tube. The lenses used are of the types used with high quality cameras and the adjustments are similar. Fine control of the focusing is obtained by mounting the camera tube on a track so that the tube can be moved a greater or lesser distance from the lens by means of a gear assembly in connection with the control knob or handle on the side of the camera. Various types of lenses are available for different pickup distances. A camera is generally provided with four different lenses mounted on a turret on the front of the camera. The desired lens may be selected by means of a handle at the back of the camera so the operator can quickly change lenses to meet various pickup conditions.

To show the camera operator that the signal from his camera is being transmitted, a small light on the camera panel will glow. Lights may also be provided at the front of the camera so that the performers can tell which camera is being used at any given time to pick up the scene. These are called "tally lights."

The View Finder

A typical electronic view finder is illustrated in Figure 14. It consists of a picture tube with a video amplifier which amplifies the camera signal to sufficient amplitude to drive the picture tube and deflection circuits. These circuits are of the same type as those used in receivers. The signal fed to the input of the video amplifier is about 2 volts peak-to-peak and is taken from the output terminal (A), Figure 13, of the camera amplifier output stage. To insure that the picture tube is properly blanked during retrace intervals, a blanking signal is fed to the video amplifier in the view finder and mixed with the camera signal. These blanking pulses are the mixed driving signals obtained from the output of the blanking mixer in the pickup head, terminal (B) of Figure 13.

The deflection circuits and high voltage supply circuit of the view finder are of the conventional type found in receivers using magnetic deflection except that the discharge tubes in the saw-tooth voltage generators may be driven directly by the driving pulses rather than by horizontal and vertical oscillators.

The view finder unit is compact and clamps to the top of the pickup head in such a position that the picture tube is directly in front of the camera operator so that he can constantly check the output quality of his camera. This enables the camera operator to correctly focus his camera on the scene and also to properly position the viewed scene. The view finder can be removed from the camera without affecting the operation of the pickup head.

The Camera Control

A camera control unit is required for each camera. The camera control unit is equipped with two picture tubes. A large one used for monitoring the picture and a smaller picture tube is used in an oscilloscope circuit for the purpose of observing the waveform. The oscilloscope used for viewing the waveform is called a waveform monitor. In the camera control units used with portable equipment the picture monitor tube is generally 7 inches and the waveform monitor is a 3 inch tube while in the camera control units used with studio equipment the picture monitor is a ten inch tube and a five inch tube is used for the waveform monitor.

The composite blanking signal developed by the sync generator is added to the camera signal in the camera control unit. The composite sync signal may also be added in this unit, however, this is done only in the case of a single camera-chain when switching from one camera to another is not done during a telecast. The amplitude of the blanking pulse in the video signal is adjusted to the desired value in this unit. The amplitude of the blanking pulse with respect to the picture information between the pulses will determine the background illumination of the reproduced picture, that is, whether the picture appears light or dark. The blanking amplitude is adjustable by means of a manual control and is set by the camera control operator. Correct adjustment is determined by observing the reproduced scene on the picture monitor and the signal waveform on the waveform monitor.

Several voltages for electrodes in the image orthicon tube of the camera are adjusted by means of controls in the camera control unit. Voltages that are adjusted at this unit are the grid voltage (beam current control), beam focus electrode voltage (orthicon focus), target voltage (target control), multiplier focus voltage (multiplier focus control), and the photo-cathode voltage (image focus control). These voltages may require adjustment during operation, so by placing the controls in the camera control unit, the number of adjustments that the camera operator must make during a telecast is reduced, enabling him to concentrate on the optical focus of the camera and to follow a moving scene more easily.

Figure 15 illustrates a typical camera control unit in simplified form. Let us first consider the path of the video signal through this unit and the addition of the composite blanking signal. The output signal of the camera is brought to the input of the control video amplifier by means of a coaxial cable. This cable is generally of the 75 ohm type and is terminated at the control input. The length of the cable may be up to several hundred feet in some installations. The signal is amplified by several conventional compensated video amplifiers and the composite blanking signal is added in one of these stages. The addition of the two signals is illustrated in Figure 16, waveforms A, B, and C. This results in a blanking pulse which is too great in amplitude and may have some irregularities which are not suitable for transmission. The unwanted part of the resultant blanking pulse has to be clipped off leaving a blanking pulse of the correct amplitude and with a flat top so that the composite sync signal can be added later.

A clamper circuit at the input of one video amplifier clamps all of the blanking pulse tips to a set reference point (as in d-c restorer action) and the proper amount of the blanking pulse is clipped off in the clipper circuit. The amount of the blanking pulse that is clipped off is such that the remaining blanking pulse amplitude will be approximately equal to that of the blanking pulses which appear in the camera signal (waveform A) which were produced by applying the driving pulses to the camera tube target. The waveform D of Figure 16 results after clipping, and the dotted lines indicate the position of sync pulses which must be added. The output of the clipper is then fed to a video output stage and the picture output terminal of the camera control.

If the composite sync is to be added in the camera control, it is fed to a sync amplifier which passes the signal to a video amplifier following the clipper for mixing.

The clamper circuit differs from a conventional d-c restorer in that a keying or triggering signal must be applied to it in order for it to function, whereas d-c restorer circuits generally use the video signal itself as a keying signal. The horizontal driving pulses are used as the keying pulses for the clamper. When the clamper circuit is triggered, it causes the grid of the clamped amplifier to go to a specific voltage each time and since the driving pulses appear at the same time as the blanking pulses, these pulses are all effectively clamped to the same level.

The video signal output from the camera control will generally be connected to a switching system in the control room at the studio or in the case of a remote setup to a field type of switching system. The video output signal is also fed to the grid of the camera control monitor and to the vertical deflection plates of the waveform monitor so the picture can be monitored and the waveform observed.

Secondly, consider the path of the driving pulses through the control unit. The horizontal driving pulses coming from the sync generator are supplied to four circuits; to the clamper through a clamp keying amplifier, to the horizontal deflection circuits of the picture monitor, to the horizontal deflection circuits of the waveform monitor, and to the camera through a cable. With the driving pulses fed to the deflection plates of the waveform monitor through switch SW, two lines of the video signal waveform can be observed on the CRO.

The vertical driving pulses are fed to three circuits; to the vertical deflection circuits of the viewing monitor, to the horizontal deflection plates of the waveform monitor tube, and to the camera. With the vertical driving pulses supplied to the deflection plates of the waveform monitor, an entire frame of the video signal may be observed.

A tally light is provided on the camera control panel to indicate that the signal from the unit is being transmitted. This tally light will work in conjunction with the lights on the camera. The tally lights are controlled from the switching system.

The units of equipment discussed so far, namely the sync generator, camera, and camera control, can produce a composite video signal providing the sync is added in the camera control. However, many other types of equipment are required to provide a flexible system for the handling of the video signal and pulses which control these units.

Video Switching System

The video switching systems in use at television stations are of many types. The system used will depend upon the size of the station and the flexibility that is desired. Simple studio and field types will now be discussed which provide for switching between several cameras and other sources of video signals.

A general idea of a typical switching system and associated equipment may be obtained by referring to Figure 17. The system consists of the actual switching circuits, a picture and video signal waveform monitor and, of course, necessary power supplies. A typical switcher has inputs for handling video signals from six different sources, for example, from four studio and film cameras, network, and remote sources. The output of the switcher is fed to additional switching circuits in the master control room of a large installation, to a stabilizing amplifier and then to the transmitter in the case of smaller installations, or to the relay transmitter in the case of a field setup. The exact arrangement used will depend on each particular station layout. The output signal is also fed to necessary monitors.

Provisions are generally made so that the composite sync signal may be added in the switcher if desired. In the case of remote or field equipment, the sync is added in the switcher. At the station location, sync is generally added in a stabilizing amplifier. The sync signal is always added to a camera signal at a point in the system following the switches which are used to change from one camera to another. This is done to prevent interruption of the sync signal during switching which may cause undesired pulses to appear in the composite video signal and cause television receivers to lose sync momentarily each time the station changes from one camera to another. In many instances during a telecast the scene picked up by one camera is faded out and the scene from another camera is faded in to produce an effect like that used in motion pictures for scene changes. This is done by merely reducing the amplitude of the signal from one camera and increasing the amplitude of the signal from the second camera. If the sync pulses were present on the signal from each camera, for example, if the sync had been added at the camera controls, the sync pulse amplitude would also change with the result that sync pulses transmitted to the television receivers would tend to vary in amplitude and cause loss of synchronization to occur.

Power for the tally lights of the cameras and camera controls is also supplied from the switcher through switches interlocked with the video signal selector switches.

The type of monitor used in conjunction with the switcher is sometimes referred to as a master monitor. The picture tube will generally be of the 10 inch size and the waveform monitor tube of the 5 inch type. Switches are provided in the switcher so that the monitor can be used to monitor the signal leaving the switcher or signals coming to the switcher which are not actually being fed to the output of the system. Thus, picture quality of a signal can be previewed before it is switched to the transmitting circuits.

Switching circuits for the intercommunication system used by operating personnel during a telecast are sometimes included as part of a field or studio switching system.

Field Switching System

One type of field switching unit is illustrated in Figure 18(A). This diagram considers only the video and monitor switching circuits. Four camera inputs and two auxiliary inputs are provided. Each input terminal provides a terminating resistor for the coaxial cable which connects the switcher to a camera or other signal source. Camera selector switches and auxiliary switches are provided for each input but are interlocked so that only one signal can be selected at a time. As shown in Figure 18(A), the selector switch for the Camera-2 input would be closed and the signal would be fed to the input of the video amplifier and the sync separator and amplifier. Also, the tally light switch would permit tally light power to be applied to the tally lights on the camera control and camera which is connected to the Camera-2 terminals, indicating to the camera man, camera control operator, and other personnel that the signal from this particular camera is being transmitted.

The video signal goes through a video amplifier to a clamper circuit of the type used in the camera control. The clamper reinserts the d-c component of the video signal and passes the signal on to the video output amplifier. The video output terminal will generally be connected to a relay transmitter in the case of a remote pickup, however, in some cases suitable cable may be available to carry the signal to the station location. If the switching system is used in place of the studio type at the station, the video output would be connected to master control circuits, a stabilizing video amplifier or other video amplifiers.

A signal from the camera control would not have composite sync added when fed to the switcher. Composite sync would be fed to the sync amplifier and with the switch SW in the position shown in Figure 18(A), sync would be mixed with the incoming signal in the video output amplifier. The composite sync pulses are also fed to the clamp keying amplifier to trigger the clamper circuits. (In the case of the camera control, horizontal driving pulses were used to control the clamper.)

If a signal already having the sync added comes in to the switching system, SW is turned to the INT SYNC position. This disconnects the sync amplifier from the clamp keying amplifier and connects the sync separator and amplifier to the clamp keying amplifier. Sync pulses present on the incoming signal are separated from the picture information in the sync separating circuit and are used to trigger the clamper circuit. (NOTE: The sync separator does not remove the sync pulses from the signal passing through the video amplifiers). Signals having sync already added will normally be brought in to the auxiliary inputs.

The video signal is also fed to an auxiliary monitor output amplifier and to one terminal of the monitor selector switch.

The monitor selector switch permits one monitor to be used for monitoring of the switching system output signal (signal to be transmitted), the signal at the output of the relay transmitter, a signal which is not passed through the switching circuits such as a cue signal from the station, and the two auxiliary input signals. Thus, the quality of the picture can be checked as it leaves the switcher and again at the output of the relay transmitter so that if trouble develops between the switcher and the relay transmitter it can be quickly localized. Also, signals fed to the auxiliary inputs can be previewed before being switched in. If desired, a second master monitor can be connected to the auxiliary monitor output for constant monitoring of the signal at the output of the switching system.

Some types of field switching systems also provide circuits for fading and superimposing pictures.

Studio Switching System

An example of a studio type of switcher is shown in Figure 18(B) in simplified form. Four camera inputs are provided plus two auxiliary inputs, each terminal being terminated in a resistance of correct value for the type of coaxial cable used. The camera and auxiliary selector switching is different than that used in the field switcher. Two selector switches, which are labeled A and B in the diagram, are used in conjunction with each input. Each signal can be fed to either of two video amplifiers called "Channel A" and "Channel B" amplifiers. The output of the two amplifiers is common so the output signal of each amplifier is fed to one output terminal. At the input of the amplifiers there are controls by which the amplitude of the signal to each amplifier can be controlled, (fading controls). In the diagram, the Channel A amplifier is connected to the Cam-3 input and the Channel B amplifier is connected to the Cam-1 input. With the fading controls set as shown, full signal amplitude would be applied to the Channel B amplifier and the picture signal of Camera 1 would be fed to the video output terminal. By moving the fading controls in the direction corresponding to the left-hand direction on the diagram, the picture from Camera 1 can be faded out and then the picture from Camera 3 faded in.

An effect called a "dissolve" is produced when one camera is faded out at the same time that another is faded in. This causes the pictures from the two cameras to appear on the screen at the same time and one picture appears to dissolve or fade into the other as the changeover is made. The rate at which the changeover is made can be controlled by the speed at which the fader controls are moved. Instantaneous changeover can be made by releasing the selector switch for one input and depressing the selector switch for the desired input. Many special effects can be produced by the proper manipulation of the selector switches and fader controls.

A monitor selector switch is also incorporated in the switching system, so that one monitor may be used to monitor the signal to be transmitted, or to preview the signals fed to the auxiliary inputs. However, generally at least two monitors are used in connection with the switching system, one to constantly monitor the transmitted signal and one to preview pictures which are to be transmitted. The picture signal to be transmitted is obtained from the output of the stabilizing amplifier which follows the switching system.

The automatic sync control circuits shown in the block diagram will be considered under the discussion of the stabilizing amplifier. Although not shown in the diagram, tally light switches are operated in connection with the camera switches as in the case of the field switching circuit.

Stabilizing Amplifier

One of the most important of the video amplifiers listed as part of the station equipment in the first part of this assignment is the stabilizing amplifier. The main purpose for this amplifier is to minimize noise and distortion which may have been introduced into the video signal as a result of the signal having to pass through many circuits between the originating point and the video transmitter, to suppress surges in the signal which are a result of switching, to add the composite sync signal to picture and blanking or to correct sync pulses to the desired shape and amplitude. The amplifier may be used at several points in the station system such as at the input to the transmitter, at the output of video switchers, at the terminating end of the network or long studio-to-transmitter cables. Some installations may require several stabilizing amplifiers.

A typical stabilizing amplifier is shown in block form in Figure 19. The way in which the amplifier removes noise and distortion from the video signal would require a discussion of the actual circuits used and so will not be considered here. However, the path of the video signal and the addition of the sync signal can be considered with little difficulty.

The video signal is brought to the "PICT IN" terminal from a source such as the studio switching system. The composite sync may or may not be present on the incoming signal. A signal originating at a remote pickup point or from a network will have sync pulses already added. Signals originating at the studio may not have the sync added until it is added in the stabilizing amplifier. Thus it becomes necessary to discuss the action of the amplifier for two different input signal conditions.

First let us assume that a signal without sync pulses is fed to the stabilizing amplifier. The incoming signal is then amplified by picture amplifier number 1 and fed to amplifier number 2. Local sync from the sync generator is fed through a sync amplifier and to the input of picture amplifier number 2 which results in the addition of the sync signal to the incoming signal. However, the addition of the sync signal at this point is only for the purpose of controlling a clamper circuit as will be obvious later.

The output of picture amplifier number 2 goes to a clamped picture amplifier and clipper circuit which operates on the same principle as the clamper and clipper circuits used in the camera control and field switching system. The clipper is adjusted so that the signal is clipped at the black level (level of the blanking pulses) and the sync pulses are removed. The signal goes through picture amplifier number 3 and to a sync mixer in which the composite sync is finally added. The signal goes to the picture output circuit which is designed to work into a low impedance cable as a load.

The video signal with sync added is also fed to picture amplifier number 4 from the output of the clamped picture amplifier. The signal goes to a sync separator and clipper in which the picture and blanking portion of the signal is removed and only the sync pulses are retained. (This action is similar to that used in receivers). The sync separator and clipper circuits have two outputs, one to a cable terminal so that the sync pulses may be supplied to any unit requiring a composite sync signal, and the other to a pulse former circuit. This pulse former must not be confused with the pulse former discussed in connection with the sync generator. It is merely a differentiating circuit plus a vacuum tube clipper which produces an output consisting of pulses which coincide with the trailing edges of the sync pulses. The pulses produced are fed to the clamp keying amplifier and then to the clamper as trigger pulses. The only time that the clamper (d-c restorer) circuit is in operation, then, is for a short period beginning with the trailing edges of the sync pulses. Thus it is seen that the addition of the sync at the input of picture amplifier number 2 merely provides a keying signal for the clamper.

With the sync selector switch in position 2 as shown in the diagram, the sync pulses from the sync separator and clipper are also fed through another clipper and output circuit to the sync mixer for final addition of the composite sync to the outgoing video signal. A sync amplitude control is incorporated in the sync output circuit so that the added sync pulses will be of the desired amplitude. If the stabilizing amplifier is at the input to the transmitter, the sync amplitude control must be adjusted so that the sync amplitude in the transmitted signal is of the standard amplitude. (See Figure 12(B), waveform J).

An output terminal is provided on the amplifier for connection to a monitor so that picture quality and signal waveform may be checked at the output of the stabilizing amplifier.

The switching-transient suppressor circuit is used to remove surges which may be introduced into the video signal as a result of switching between cameras or signal sources.

Secondly, assume that the incoming signal includes the composite sync. In this case the automatic sync-control circuits in the studio switching system will prevent the sync amplifier from feeding local sync into the input of picture amplifier number 2 and the addition of any local sync to the signal. The sync is removed from the blanking pedestals in the same manner as for the preceding case. The sync pulses from the output of the sync separator and clipper stage are amplified and clipped again by the sync clipper and output circuit. This arrangement is employed so that, if the sync pulses on the original signal at the input of the stabilizing amplifier have become distorted in preceding stages of the station system or in the transmission from a remote point or network, they will be completely reshaped when added to the signal again in the sync mixer stage. In other respects the amplifier works as described for a signal without sync.

When the signal is changed from one with sync to one without sync at the switching system, such as switching from a remote signal controlled by a sync generator at the pickup point to a signal from the studio which is controlled by the station sync generator, the automatic sync control circuit will permit the sync amplifier to function and the local sync will be added.

In some cases it may be desirable to add local sync to a signal controlled by remote or network sync generator. This will require additional equipment in the way of a system which will control the local sync generator to the same frequency and phase as the remote or network generator. The selector switch is then operated in position number 1 and the local sync is fed from the "SYNC INPUT" terminal to the sync mixer. The sync pulses present on the incoming signal will appear at the "SYNC OUT" terminal of the stabilizing amplifier and can be used in conjunction with additional control equipment to "lock in" the local sync generator to the frequency and phase of the remote generator.

Distribution Amplifier

Another type of amplifier which finds considerable use in a station is the distribution amplifier. It will consist of several, for example, five, low gain amplifiers mounted on one chassis. Each of the five amplifiers will have a gain of about 1 and a bandwidth up to 8 mc. Each amplifier will also be designed to have a high input impedance so that it will not load the circuit to which it is connected and will have a low output impedance for operation into a low impedance coaxial cable. Each of the five amplifiers may be operated as a separate unit.

A distribution amplifier may be used to distribute one signal to several load circuits; to feed several signals to one load circuit; to mix sync signals with the picture and blanking signals; to operate as a straightforward amplifier by connecting 2 or more stages in parallel.

Several example applications of distribution amplifiers are shown in Figures 20(A), 20(B), 20(C), and 20(D). Figure 20(A) shows how the vertical or horizontal driving pulses or the composite blanking signal from the sync generator may be distributed to four camera controls and a monoscope. This method of distribution permits isolation of the five output circuits from the sync generator output. For example, if a short circuit should occur in one of the output cables, the sync generator output and the other four outputs would not be effected.

Figure 20(B) illustrates how the composite sync signal could be distributed to the switching system stabilizing amplifiers for three studios, to the film projection room, and to the station repair shop.

A method of adding composite sync to a signal is shown in Figure 20(C). Picture signals from two studio switching systems are fed to amplifier sections one and two of the distribution amplifier and the outputs of sections one and two are paralleled with the output of section four which has sync pulses applied to the input. Thus, the combined outputs of amplifier sections 1 and 4 or 2 and 4 will be a composite video signal. The picture signal from the film room is fed to amplifier section 3, the output of which is paralleled with the sync output of section 5 to produce a composite video signal.

If it is necessary to produce a gain of more than one, the amplifier sections may be paralleled as shown in Figure 20(D). The inputs and outputs are paralleled and a single signal may be handled by the amplifier.

Pulse Distribution Box

Another unit used for the distribution of driving and blanking signals from the sync generator to camera controls or other devices requiring these pulses is called a pulse distribution box. The distribution box is used primarily for pulse distribution to camera control units. This unit is illustrated in Figure 21. The three outputs of the sync generator may be connected directly to the input terminals of the distribution amplifiers if several distribution boxes or other sync generator outputs are required. The distribution box is provided with four output sockets, each socket furnishing vertical drive, horizontal drive, and blanking signals. If it is desired to operate more than four units from the output of the box, the units may be series connected in sets of two so that a total of eight units may be operated from the four outputs.

The cables connected to the inputs of the distribution box are terminated by resistors corresponding to the impedance of the cable. This means that the circuits connected to the outputs of the box must be of the high impedance and low capacity type such as the grid circuit of a vacuum tube. The distribution box must also be located in the vicinity of the units to which its output is supplied because long cables connected to the output would have too much capacity and would distort the pulses.

Film Projection Room Equipment

Basic projection room equipment is illustrated in Figure 22. One film camera is shown which is used to pick up the pictures from two film projectors and one slide projector. Film cameras are generally designed to use the iconoscope type of camera tube. The iconoscope requires high illumination for satisfactory pickup, but this disadvantage is overcome in the case of pickup from film because the projector can be focused directly on the mosaic of the camera tube and sufficient illumination is thus easily obtained. The film camera requires no lens system because the lens on the film projectors or slide projectors will take care of adjusting the projected picture to the proper size and focus on the camera tube mosaic. A camera control is required for the film camera as in the case of studio or field cameras. This unit may be placed in the control room alongside the studio camera controls as part of the video console. However, the film camera control may be located at any convenient point.

The film projectors used are standard projectors with certain modifications required to change the 24 frames per second rate of projection to an effective 30 frames per second to conform to the television standards. (This will be discussed in greater detail presently). Stations may be equipped to project 16mm, 35mm, or both types of movie film. Small stations will generally use 16mm film because it is readily available, and it can be stored safely without special storage vaults and handled with less precaution than the 35mm type. At least two film projectors are generally used so that full length movies or more than one short film can be run without interruption for the changing of film reels.

To limit the number of film cameras needed in the projection room, a unit (sometimes called a multiplexer) having an arrangement of fixed or movable mirrors is used to reflect the light from the projectors onto the camera tube. An example of this arrangement is shown in Figure 22. Two fixed mirrors are placed so that the picture from either projector is reflected on the mosaic of the camera tube even though the film projectors are placed at right angles with respect to the film-camera. The slide projector is mounted above the multiplexer so it is focused directly on the camera tube. In some installations the mirrors are movable and can be quickly adjusted by means of a lever to permit the use of one camera with several projectors.

Accessory equipment in the projection room may include a control and monitoring panel. Picture and sound monitors are used to check picture and sound quality of the film during program transmission or during the pre-running of a film which is to be telecast later. The control panel will include the necessary start, stop, and changeover controls for the film projectors, and slide projector lamp controls. A picture and sound monitor will also be available so that portions of the telecast not originating in the film room may be observed by the film room personnel, especially for cue purposes.

Principles of Film Projection

The basic principles of film projection and the difference in standard and television film projection may be described with the aid of Figures 23 and 24. A movie film actually consists of a series of still pictures, each picture differing slightly from the preceding one. By presenting this series of still pictures on a screen at a rapid enough rate, the illusion of motion is obtained. In standard movie projectors, each still picture on the film is projected onto the screen twice and then the succeeding still picture is shown twice, etc., at a rate of 24 pictures (frames) per second. By showing the series of still pictures at this rate, the illusion of smooth motion is produced by the eye. The showing of each picture twice is done to reduce the effect of light flicker.

The principle of film projection is illustrated in Figure 23. The film passes in front of an aperture or opening which is the same size as each of the still pictures (frames) on the film. Each frame is held motionless in front of the aperture and light from the projector lamp passes through the lens, the film, and through the projection lens and to the screen. In order to bring the succeeding still picture in front of the aperture, it is first necessary to prevent the light from passing through the film. This is done by means of the shutter which usually consists of a circular disc with one or more notches cut in it. The shutter rotates allowing light to reach the film only when a notch is in front of the aperture. While the light to the film is cut off by the shutter, the pull-down claw engages the small holes along the edge of the film and pulls the film down until the next frame is in front of the aperture. The shutter then allows light to pass through the film to the screen to present a picture. If the shutter opens only once for each frame the human eye will detect a flickering effect because of the light interruption. To overcome this condition, which would be tiring and undesirable, the shutter is rotated so that two notches pass by the aperture for each frame. The timing of the light flashes through the film with respect to each frame and film pull-down is illustrated in Figure 24(A) and (B). This shows that the light is interrupted for each pull-down and once during the period that a frame is held stationary at the aperture.

It would seem at first that a television camera could simply be focused on a movie screen, or the projector focused directly on the camera tube, without any changes being made in the projection system. However, the television camera is more sensitive to sudden light changes than the eye. Although the sudden changes of illumination produced by the shutter in the projector are not readily noticed by the eye, these changes of illumination on a camera tube will produce variations in the electrical output of the camera which consequently results in variations of the beam intensity of the picture tube in the TV receiver. The changes in illumination occurring 48 times per second, plus the visual effects of blanking out the receiver picture tube 60 times per second for vertical retrace, produces a noticeable flickering of the reproduced scene which would be annoying to the television viewer. It is possible to overcome the flickering effect by interrupting the light through the film at the projector 60 times per second instead of 48, and by phasing these light interruptions properly in respect to the vertical blanking pulse of the composite video signal. This change must be done in such a manner that the standard film speed can be maintained so as to permit the televising of standard movie film.

The proper time relations between film pull-down, film and camera tube illumination, scanning fields, and vertical blanking pulses are illustrated by Figures 24(C), (D), (E), and (F). From Figure 24(C), it will be noted that the time allotted for film pull-down has been reduced in comparison with the standard pull-down time. This requires modification of the pull-down mechanism of the projector. The shutter may also be changed so that it produces light pulses through the film and to the camera tube as shown by Figure 24(D). (Some systems use a pulsed light source in the projector instead of the shutter). It will be noted that the light pulses occur during the vertical blanking pulse interval and that the camera tube is scanned during the interval between the light pulses; hence, there is no sudden change of illumination on the camera tube during the scanning periods which would tend to produce flicker in the received picture. The storage action of the iconoscope camera tube makes this system possible. The tube stores the picture information obtained during the light pulses so that it can be scanned in the absence of light.

Frame number 1 is shown to be exposed twice, frame number 2 is exposed three times, frame number 3 twice, frame number 4 three times and so on. The average scanning rate is, then, two and one-half scannings per frame, and since the film speed is 24 frames per second, 60 scanned fields are produced for the 24 frames. This effectively changes the 48 "fields" per second of the standard film to the 60 fields per second required by the television system.

Video Equipment

So far in this assignment the individual units used in the studio, control room, and projection room to produce a composite video signal have been discussed. At this point it will be desirable to get a more complete mental picture of how all of these units are interconnected as far as the various signals in the TV system are concerned.

The distribution of the composite sync, composite blanking, and driving signals is illustrated in Figure 25. The composite sync signal from the sync generator is fed to the stabilizing amplifier where it will be added to the picture and blanking signals from studio and film cameras. The blanking pulses and the vertical and horizontal driving pulses are fed to a pulse distribution box (or to distribution amplifiers) and then to each of the four camera controls. The blanking signal, as previously explained, will be added to the signal from a camera in the respective camera control. The vertical and horizontal driving pulses, however, must be fed to the camera to control the sweep circuits and provide blanking pulses for the camera tubes.

Although not shown, two sync generators are generally available at the studio location, one in use and one as a spare because if this unit becomes inoperative the station cannot operate.

The path of the camera signals through the control room equipment is shown in Figure 26. For an example, consider the path of the signal from camera number 1. The signal first goes to the camera control where it is mixed with the composite blanking signal, the correct blanking amplitude being adjusted by the camera control operator. The signal with blanking added is fed to the camera monitor so that the picture quality and signal waveform may be observed. The signal must also go to the switching system being fed to the camera control number 1 input on the studio switcher. When the camera number 1 switch on the switching system is depressed, the signal will be fed to the picture signal input on the stabilizing amplifier where the composite sync is added producing the composite video signal.

The video output from the stabilizing amplifier goes to the transmitter location. The monitor output of the stabilizing amplifier is shown going to the input of a distribution amplifier. The signal is thus distributed to several monitors. Section 1 of the distribution amplifier feeds the video signal to the "line" monitor input on the switcher so that the outgoing signal may be viewed on the preview monitor for monitor adjustments when there is no signal on the auxiliary positions of the monitor selector switch. Section 2 of the distribution amplifier supplies the outgoing signal to a line monitor which is generally used for constant monitoring of the signal being fed to the transmitter. Amplifier section 3 and 4 are shown as being used to feed the signal to a monitor in the announcer's booth and to an office monitor. Amplifier section 5 supplies the video signal to a monitor in the projection room.

It may appear that only the auxiliary input signal can be previewed with the system shown. However, the camera controls can be used to preview films or studio rehearsals. With the simple system shown, the camera controls would be placed side by side and the line and preview monitor would be placed near the switcher in such a position that the person operating the switching system can observe the pictures on the camera controls also. Therefore, any picture can be previewed before it is switched to the transmitter input.

The pulse distribution and video signal path diagrams show only one possible way of interconnecting the principal units of equipment used at the studio, control room, and projection room. A very simple system has been shown in order to get a general picture of this part of station equipment layout. Probably no two television stations would use the same equipment layout since the layout must meet the requirements presented by a station's size, building arrangement, studio and transmitter location, etc. The units discussed are generally designed to handle standard pulse and video signals of amplitudes ranging from about 1 to 4 volts peak-to-peak, thus making it possible to interconnect the various units into almost any desired combination.

Television Relay Equipment

A television station is frequently called upon to televise a program, such as a sports event, which originated at a location outside of the main studios. In such cases the picture and sound signals must be sent to the station location for transmission. The sound signals may be sent to the station by means of telephone lines which are readily available in most cases. However, ordinary telephone company circuits are not suitable for the transmission of the picture signal because of the high frequency components contained in the picture signal. Coaxial cables are required to handle the picture signal and such cables are generally not available from telephone companies except the network coaxial cables, and in some cases, a short, permanent link between the program pickup point and the station. In order to provide a means for relaying the picture signal to the station location, TV stations are equipped with a relay transmitter and receiver operating at very high frequencies.

A relay system is illustrated in Figure 27 and includes a transmitter control unit, a relay transmitter and antenna, and a relay receiver with antenna and control unit. The FCC has allotted three frequency bands for the operation of such equipment, namely, 13,000 mc, 7000 mc, and 2000 mc. Commercial equipment is available at the present time for the 7000 mc and 2000 mc bands, the former band probably being the more commonly used.

Frequency modulation is used and the transmission range is limited to approximately the line of sight between the transmitter and receiver. The antenna systems consist of parabolic reflectors and are highly directional so as to concentrate the transmission and pickup of the signal to an effective beam along the line of sight. Because of the highly directional antennas used, a transmitter operating with an actual output of a fraction of a watt can produce a signal at the receiving point equivalent to that produced by a transmitter having an output of several hundred watts using a non-directional antenna. The antenna system for the transmitter consists of a wave guide which serves to convey the r-f signal from the transmitter output to a point in front of the reflector (the focal point of the reflector).

The receiving antenna is usually identical to the transmitting antenna. R-F energy striking the reflector is reflected into the end of the wave guide which carries the signal to the input of the receiver. The reflectors are generally four feet or greater in diameter and are bolted directly to the transmitter or receiver housing.

Because the relay transmitter or receiver is generally mounted on a high point such as the top of a building or on the station antenna tower a control is used in conjunction with the transmitter and receiver so that electrical adjustments may be made at a remote point. For example, the relay receiver is frequently mounted on the antenna tower at the station transmitter location several hundred feet above the ground. The receiver control is then rack mounted as part of the auxiliary equipment in the transmitter room or in the station control room and normal adjustments are easily made.

The transmitter and receiver are mounted so that they can be rotated and tilted to obtain maximum signal transfer. In some installations, an electrical rotating and tilting mechanism is provided so that the unit can be remotely adjusted for proper direction and elevation from the station control room.

The video signal fed to the remote transmitter control is taken from the output of a unit such as the field switching system, or from a camera control if a single camera is used at the pickup point. In order to check the quality of the remote transmitter output, a sample of the r-f signal is taken at the input to the waveguide, detected, and amplified to produce a signal for a monitor.

The signal output from the receiver control is the composite video signal and is fed to the switching circuits at the control room or transmitter room. As an example, the signal could be fed to one of the auxiliary inputs on the studio switching system.

Several applications of relay equipment are illustrated in Figure 28. In Figure 28(A), the normal application of remote equipment is illustrated. In this case, the remote equipment is used to transmit the video signal from the remote pickup point to the TV station for rebroadcast. Figure 28(B) illustrates the manner in which the remote equipment may be used as a link between the station studios and the main TV transmitter if they are located in different buildings. In Figure 28(C), relay units are used as repeater stations by connecting the output of a relay receiver to the input of a second relay transmitter. Such an arrangement must be employed if line of sight transmission is not possible between the remote pickup point and the TV station.

Field Pickup Equipment

A three-camera-chain field pickup system is illustrated in Figure 29 showing pulse distribution from the sync generator to units in the system and the path of the picture signal from cameras to relay transmitter. It will be noted that the pulse and signal distribution is nearly the same as for the studio and control room system.

The blanking signal is added to the picture signal in the camera control and the composite sync is added in the field switcher. The signal output of the switcher, then, is a composite video signal and is fed to the relay transmitter through the relay transmitter control. (The video signal shown going from the relay transmitter back to the switcher is the video signal as it is obtained from the output of the relay transmitter for monitoring purposes.)

An ordinary TV receiver is often used to monitor the signal from the station transmitter. This provides the remote operations crew with a visual cue from the main station when they are to go on the air. Telephone circuits are also used between the remote point and the station by operations personnel to provide communications which are necessary for successful operation and coordination between station and remote crews.

Video Transmitters

Video transmitters are very similar in principle to ordinary broadcast transmitters, that is, they require an oscillator and amplifiers to develop the carrier frequency, a modulator and power amplifiers to develop enough modulated r-f energy for satisfactory transmission, and of course the power supplies and controls for the equipment. Since the Associate has studied transmitters earlier in this training program, it will be necessary only to consider the main differences between video transmitters and conventional broadcast transmitters.

The block diagram of a typical video transmitter is shown in Figure 30. This transmitter consists of three basic sections; the carrier frequency generator, video amplifiers (these correspond to the speech amplifiers in a standard broadcast transmitter), and r-f power amplifiers, the first of which is the modulated amplifier.

Carrier Frequency Generator

The carrier frequency generator incorporates a crystal controlled oscillator which operates at a frequency of less than 10 mc. The oscillator is operated at such a low frequency because crystals are not available for satisfactory operation at higher frequencies. The carrier frequency of the transmitter must be within 0.002% of the assigned frequency, consequently, sufficient frequency stability can be obtained only by means of a crystal controlled oscillator. In order to produce the desired carrier frequency, the oscillator frequency is multiplied by means of frequency doublers and triplers. In the transmitter of Figure 30, the oscillator plate circuit serves as a doubler and is followed by two doubler stages. If the transmitter is to be operated in the low television band, the oscillator frequency is thus multiplied eight times. For example, if channel 5 is to be used, the carrier frequency must be 77.25 mc and the oscillator frequency will be one-eighth of this or 9656.25 kc. The output of the last doubler drives an r-f amplifier which in turn supplies the r-f signal for the modulated amplifier. For operation in the high television band, the last doubler is followed by a tripler giving a total multiplication of the oscillator frequency of twenty-four times so that the oscillator frequency can be kept below 10 mc. In this case an additional stage of r-f amplification is also added following the tripler to produce the required power output since the tripler is comparatively inefficient at the high frequencies.

The circuits of the carrier frequency generator are conventional. The frequency multipliers and r-f amplifiers are generally operated class C. The latter stages of the carrier generator, where the frequency is high, employ tuned lines as tank circuits rather than the inductance and capacity components used at lower frequencies. (The principles of tuned lines as tank circuits was discussed in Assignment 62, Ultra-High Frequency Techniques).

Video Amplifiers

The video amplifiers in the transmitter must amplify the composite video signal to the amplitude required to properly modulate the transmitter. These amplifiers are conventional compensated amplifiers providing the necessary bandwidth for the handling of the video signal.

The input signal for the video amplifiers is obtained from a stabilizing amplifier such as the one shown earlier in this assignment in connection with the studio and control room equipment. The amplitude of the video signal at the input will be about 1 to 2 volts peak-to-peak and this must be increased to an amplitude as high as 150 volts in some cases to modulate the transmitter.

A d-c restorer is used in the grid circuit of the last video amplifier stage to reinsert the d-c component of the signal, and the plate circuit of the last video stage is directly coupled to the grid circuit of the modulated r-f amplifier to avoid losing the d-c component again. The simplified circuit of Figure 31 illustrates the final video stage and the method of coupling to the grid circuit of the modulated amplifier. (Compare this circuit with the circuits used for grid modulation as shown in Assignment 53).

The waveforms marked (A) in Figure 31 represent a scene with a high average brightness and the waveforms labeled (B) represent a scene with low average brightness. When the signal appears at the grid circuit of the video amplifier it will be noted that the blanking pulses, which represent the same picture information (black), do not reach the same voltage level. The d-c restorer corrects this, and the blanking pulse levels in the plate circuit of the video amplifier are the same for the two scene brightnesses, a condition which is necessary in order to properly modulate the transmitter according to the present television standards. (This is also true of the sync pulse levels).

Modulation and the Modulated Amplifier

Although amplitude modulation is used in the video transmitter, it differs in some respects from the conventional amplitude modulation which has been described in preceding assignments. In Figure 32 the amplitude modulation as employed by a standard broadcast station is illustrated. In this figure it will be noted that the amplitude of the output signal varies to both greater and lesser values than the unmodulated amplitude of the carrier when that modulation takes place.

Now compare this with the amplitude modulation system employed in television transmission as illustrated in Figure 33. Notice that in this case the carrier amplitude is greatest for the unmodulated condition and that the carrier is only reduced when modulated. In other words, the amplitude of the carrier is greatest for the unmodulated condition. To clearly illustrate this condition let us consider the effect produced under two conditions. Waveform (B) of Figure 33 illustrates the composite video signal when only the sync pulses are being transmitted. It will be recalled that this represents a condition for a black picture. Waveform (D) illustrates the modulated carrier in this case and it can be seen that the carrier amplitude reaches the unmodulated level during each sync pulse. During the time that the black picture information is being presented, the amplitude of the carrier is reduced to 75% of the maximum value.

Waveform (C) illustrates the composite video signal (modulating signal) which would be present if a white picture was being scanned. Once again the carrier amplitude reaches the unmodulated level only during the sync pulses. During the blanking pulses the amplitude of the carrier is 75% of its maximum value and during the interval between the blanking pulses (when the white picture information is being transmitted), the carrier is reduced to a very low value as illustrated by waveform (E). In accordance with the FCC standards, the carrier should be reduced to 15% or less of the peak amplitude during modulation by white picture information.

It should be noted that the amplitude of the r-f signal is the same for the sync or blanking pulses regardless of the picture brightness. Also, as the amplitude of the r-f signal increases (an increase in transmitted power), the brightness produced by the beam on the picture tube of a TV receiver decreases. Transmission of a video signal according to these standards is known as "negative transmission." In order to modulate the transmitter so that the standard r-f signal will be developed, the d-c component of the signal must be present and the signal must have the correct polarity at the input to the modulated amplifier.

At this point the Associate should review the principles and waveforms of grid modulation as described in Assignment 53. It will be noticed that the modulating signal is applied to the grid circuit of the modulated amplifier in such a manner that it effectively causes the bias on the modulated amplifier to vary according to the modulating signal waveform. At the same time a constant amplitude r-f carrier voltage is coupled into the grid circuit and the result of the two voltages acting on the grid is to produce current pulses in the plate circuit of the tube, the amplitude of which vary according to the modulating signal. It should be noted that the modulating signal can cause the bias to vary to more or less than the value when no modulation is applied.

Now consider grid modulation when a standard TV r-f signal is to be developed. Figures 34(A), (B), and (C) illustrate the grid voltage and plate current variations of the modulated amplifier. Figure 34(A) shows the condition when no modulation is present. Assuming the amplifier is operated class B, it will be biased near cutoff. The amplitude of the r-f carrier voltage is adjusted so that the grid swings to the maximum permissible amplitude in the positive direction. The plate current pulses will then have the maximum amplitude and the transmitter will consequently be delivering maximum output power. (In the conventional system the r-f grid voltage amplitude is adjusted to produce plate current pulses one-half the maximum amplitude. See Figure 21(A) of Assignment 53).

The composite video signal is applied, as illustrated in Figure 31, in such a manner that the tips of the synchronizing pulses are clamped at the operating bias point of the tube and the picture signal causes the instantaneous bias to become more negative. This is illustrated for a white picture signal in Figure 34(B). Notice that with this arrangement the maximum allowable grid swing in the positive direction occurs only during the synchronizing pulses, and during the remaining portions of the signal the instantaneous grid bias is more negative thereby reducing the plate current pulses in the modulated amplifier. When the blanking pedestal is being transmitted, the plate current pulses are 75% of their maximum amplitude (when the sync pulse is being transmitted), and during the white picture information the plate current pulses are reduced to a very low value (less than 15% of the maximum value).

Figure 34(C) represents the modulation conditions when the modulating signal contains black picture information. Once again it can be seen that the synchronizing pulses produce an output signal which is equal to the no-modulated value of the carrier and during the remaining portion of the signal (the blanking pulse interval and the black information which is at the same level as the blanking pulse) the plate current pulses represent 75% of the maximum output. If these figures are examined carefully it can be seen that to secure this type of modulation, the modulating signal must be clamped at the synchronizing level. That is, regardless of the average brightness of the scene, the grid of the modulated amplifier must never reach an instantaneous value less negative than it does when no modulation is present.

Modulation in this manner is made possible by the action of the d-c restorer in the grid circuit of the final video amplifier (see Figure 31). The d-c restorer causes the grid of the video amplifier to reach the same voltage each time a sync pulse appears in the signal. This will of course cause the same value of plate current to flow through the video amplifier tube and its load resistor R for each sync pulse and the same voltage value will be developed across the load R. The modulated amplifier may then be considered as operating with a bias voltage which is the sum of the source voltage and the drop across R during the presence of the sync pulses in the modulating signal. Direct coupling must be used between the final video amplifier plate circuit and the grid of the modulated amplifier in order to retain the d-c component. In order to prevent the plate supply voltage of the amplifier tube from appearing in the cathode-to-grid circuit of the modulated amplifier a separate supply is used for the last video amplifier with the positive side grounded. The cathode of the video amplifier tube will then be at a negative potential with respect to ground by the amount of the plate supply voltage.

The modulated amplifier is generally of the push-pull type and develops a peak power output of several hundred watts. The amplifier must be of the broadband type to accomodate the sideband frequencies produced in modulation. A typical bandwidth for this amplifier is 7 mc. Such bandwidth is obtained by resistance loading of the tuned circuits and by overcoupling to the following stage, which is the same principle as that used in some television receivers to produce the desired bandwidth.

R-F Power Amplifiers

It has been pointed out in an earlier section of the training program that an r-f power amplifier which is to handle a modulated signal must be operated either Class A or Class B in order to prevent distortion of the signal. Since the Class B amplifier is more efficient, it is usually employed in this application. Such amplifiers are also referred to as linear amplifiers. The circuit of such an amplifier would basically be the same as that of the modulated amplifier shown in Figure 31 except, of course, the only applied signal is the modulated r-f signal. The tuned-line tank circuits are tuned by means of a shorting bar which changes the length of the tuned-line and its resonant frequency. These amplifiers must also be of the broad band type so as to provide an overall bandwidth of 4 or 5 megacycles.

It will be recalled that, under the present television transmission standard, the upper sidebands and only a portion of the lower sidebands are transmitted. Since both sidebands are produced during modulation some method must be used to eliminate the unwanted portion of the lower sideband. Figure 35 shows the transmission charateristic of an ideal transmitter, the minimum transmission characteristic accepted by the FCC, and the characteristics obtained from practical transmitters.

The output of the transmitter, for frequencies of 1.25 mc or more below the carrier frequency, must be at least 20 db below the maximum output to meet the FCC specifications. This is to insure that the video signal output of the transmitter will not interfere with the sound channel of the next lower TV channel. At frequencies above the carrier the output of the transmitter must not fall below the FCC specifications. It will be noted that typical transmitters can provide greater than specified output at frequencies above 2 mc. The transmitter output must also be reduced sufficiently at frequencies above 4 mc so that the video signal output will not interfere with the sound carrier of the station. The sound carrier has a center frequency 4.5 mc above the video carrier frequency.

With the required transmission characteristic in mind it is now possible to consider how this is obtained with the transmitter under discussion. Lower sideband elimination is obtained by tuning the linear amplifiers so that the video carrier frequency falls near the low-frequency side of the amplifier pass-band. Examination of Figure 36 will show this principle of sideband elimination. The solid-line curve shows the response that can be obtained from a signal r-f amplifier designed for broadband operation. If an additional r-f amplifier is added, the overall response of the two stages would be similar to that shown for 2 stages in Figure 36. The effect of additional stages on the over-all response characteristic is to steepen its sides. Then by tuning these amplifiers so that the video carrier frequency falls near the low-frequency side of the band-pass, the low-frequency sidebands will be attenuated by the amplifier tuned circuit but the upper sidebands will be passed. Thus, in a low-level modulated transmitter the desired output characteristic can be obtained by the proper tuning and broadbanding of the r-f amplifiers which pass the modulated signal.

Antenna Equipment

Diplexer

The diplexer is a unit which permits the video transmitter and the sound transmitter to operate into the same antenna by isolating the two transmitter outputs from one another but yet allows the output from both transmitters to reach the antenna. A diplexer is shown schematically in Figure 37. Inductive elements make up two arms of a bridge circuit and the antenna radiators form the other two arms of the bridge. The transmitters feed power to opposite terminals of the bridge circuit.

When balanced, the bridge circuit effectively isolates the two transmitter outputs because according to balanced-bridge theory a difference of potential between one set of bridge terminals cannot cause a difference between the other set of terminals.

Physically, the diplexer unit is made up of sections of coaxial transmission line which, because of their length, will appear as inductive elements at the frequencies for a particular TV Channel and will permit the connection of the antenna radiators and transmitter output to the unit by means of coaxial lines.

Transmitting Antenna

There are several types of TV transmitting antennas but the one most commonly used at present is the "super turnstile." This antenna is illustrated in the two views of Figure 38. Each section of the antenna consists of four radiators arranged at 90° angles about the supporting mast. Pairs of radiators are often referred to as the E-W (east-west) and N-S (north-south) radiators. Each radiator is made of metal in the form of an open framework. The open construction reduces wind resistance and permits less rugged mounting. The radiators are mounted directly on the supporting mast which is grounded.

The N-S and E-W radiators of each section are fed 90° out of phase which produced a radiation pattern which is essentially circular. The N-S radiators of each section are fed from one output terminal on the diplexer and the E-W radiators of each section are fed from the second output terminal of the diplexer. This is illustrated in Figure 39. All transmission lines used are of the coaxial type made of copper tubing. The 90° phase displacement necessary for feeding the radiators is obtained by making the transmission lines feeding one set of radiators in each section a quarter-wavelength longer than the lines feeding the sections which are mounted at right angles.

The number of sections used determines the gain of the antenna system. An effective gain in transmitted power is obtained from such an antenna system because the radiated energy is concentrated along the surface of the earth by the antenna system and little energy is lost to sky radiation. (Remember that at the high frequencies used in television, skyward radiation is not returned to the earth from the ionosphere.) Two or more sections, or bays, are used with super turnstile installations. A three section antenna operated in the low TV channels will have a power gain of about 4. For the high TV band, 6 or more sections are generally used with a resulting gain of 7 to 8, depending on the channel used. Thus, if the peak power reaching the antenna from the transmitter is 500 watts and the antenna has a gain of 7, the effective peak power radiated will be 3500 watts. The WHAS-TV antenna installation, illustrated in Figure 9, has 12 bays or sections on the vertical element at the top of the tower although these bays are not discernable in the photograph due to the height (600 feet).

Auxiliary Equipment

Power supplies are obviously part of the equipment required in conjunction with the transmitter and associated equipment. D-C voltages ranging up to 5000 volts must be furnished for the transmitter. The power consumption of a typical 5000 watt video and 2500 watt sound transmitter will be over 30,000 watts.

Many of the tubes in a TV transmitter are water cooled as in standard broadcast transmitters. Water cooling equipment is often located in a room adjacent to the transmitter room.

The video and sound transmitter are both controlled from a transmitter control console placed in front of the transmitters where the operator has full view of the transmitters. The control console will contain the switches for controlling the power supplies for the transmitters. Meters are provided for checking the sound level to the sound transmitter. A video monitor and oscilloscope are used for monitoring the video transmitter. By means of a selector switch the video monitor can be connected to various points in the transmitter such as the input to the video transmitter, the input to the modulated amplifier, the transmission line between the transmitter and the diplexer. When the video signal is to be monitored at the output of the transmitter the signal must, of course, be demodulated before it is fed to the monitor.

Other equipment, which may be part of the control console or may be placed on equipment racks in the transmitter room, are modulation percentage indicators and frequency meters for both transmitters.

High-Level Modulated Video Transmitters

Video transmitters using high-level modulation are also in wide use by TV stations. A simplified block diagram of such a transmitter is shown in Figure 40. The advantage of such a transmitter is that linear r-f power amplifiers are not required, which simplifies tuning of the r-f stages. At the same time, however, greater output must be obtained from the video amplifiers for a given transmitter power rating than from the video amplifiers of a low-level modulated transmitter. Hence, it becomes difficult to say that one type of modulation system is better, when all things are taken into consideration.

The r-f carrier generator of this transmitter is similar to that used in the transmitter previously discussed. The power output of the last stage in the carrier generator must develop more power to drive the modulated r-f amplifier since the modulated amplifier is the last stage in this type of transmitter. For a typical 5000 watt video transmitter the output of the carrier generator is about 400 watts.

The video amplifiers must accept a signal level of the standard 1 to 2.5 volts peak-to-peak, and amplify this to more than 600 volts in order to grid modulate a 5000 watt transmitter. A d-c restorer must be used in the grid circuit of the last video stage as previously explained.

The modulated amplifier is grid modulated according to the same principles used in the low-level modulated transmitter. The amplifier is tuned so that the video carrier frequency falls near the low frequency end of the amplifier bandpass so that the lower sidebands developed during modulation will be partially attenuated. One of the methods used to tune the modulated amplifier is to use a "tune" crystal which is cut for a frequency which, when multiplied by the stages of the carrier generator, will produce the center frequency for the modulated amplifier bandpass. After the modulated amplifier has been tuned, the "operate" crystal is switched in and the carrier frequency generator stages are retuned to produce the proper video carrier frequency; however, the modulated amplifier is not retuned, and a reduction in the output of the lower sideband is obtained.

Sideband Filter

A unit which is required in conjunction with a high-level modulated transmitter is the sideband filter. Sufficient attenuation of the lower sideband frequencies is not obtained in the modulated amplifier; hence, further attenuation must be provided. The principles of the sideband filter are illustrated in block form in Figure 41. The filter may be considered as being made up of two filter sections; a high-pass filter which passes the desired sideband frequencies to the diplexer and antenna system, and a low-pass filter which passes only the undesired sideband frequencies. The load for the low-pass filter is a water-cooled resistor which dissipates the energy left at the lower sideband frequencies in the output of the transmitter. The transmission characteristic of a high-level modulated transmitter is that obtained at the output of the sideband filter and must conform to the FCC standards.

Sections of coaxial transmission lines are used in the construction of a sideband filter to form the L and C components that make up a filter. At the high frequencies used for TV transmission, sections of transmission line make more practical L and C components than conventional coils and condensers.

Summary

This discussion of television station equipment has revealed that many different pieces of equipment are used even in a simple station installation, which offers moderate flexibility for handling of the picture signal. A more detailed discussion of the circuits used in this equipment would further reveal that the theory of the majority of the circuits would be based on circuits with which the Associate is already familiar. Station equipment is merely another application of the fundamental electronic components, vacuum tubes, resistors, coils, and capacitors. The Associate will find that a good background of fundamental theory and circuits will enable him to quickly learn the circuit theory of station equipment if necessary. Practical experience in the operation and servicing of any electronic equipment would also provide an invaluable background for the operation, maintenance, or servicing of television station equipment.

Test Questions

Be sure to number your Answer Sheet Assignment 99.
Place your Name and Associate Number on every Answer Sheet.
Send in your answers for this assignment immediately after you finish them. This will give you the greatest possible benefit from our personal grading service.

1. Why is the composite sync signal normally added to the video signal after the switcher?

2. Why is it that the pick-up tube used in the film cameras is normally an iconoscope when this tube is rarely used as a pick-up device in modern studio cameras?

3. What is the purpose of a stabilizing amplifier?

4. Why are many of the camera adjustments made accessible at the camera control unit in addition to being available at the camera itself?

5. Explain two fundamental differences between a normal movie projector and the film projector used in a television station.

6. What frequencies are used for the television relay transmitters?

7. Explain briefly the modulation system employed in a video transmitter.

8. Explain the purpose of a diplexer.

9. What are tally lights and why are they used?

10. Two types of monitors are used very widely in television broadcast stations. What are these two monitors and what are their uses?

LAYOUT OF SMALL TV STATION

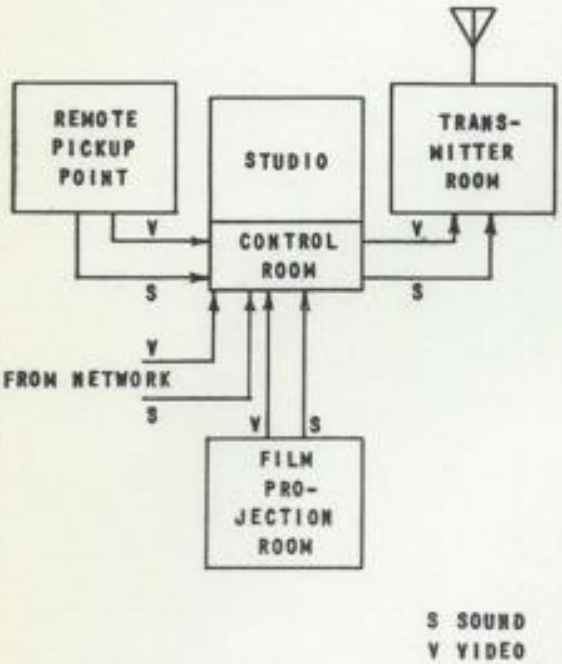


FIGURE 1

LAYOUT OF LARGE TV STATION

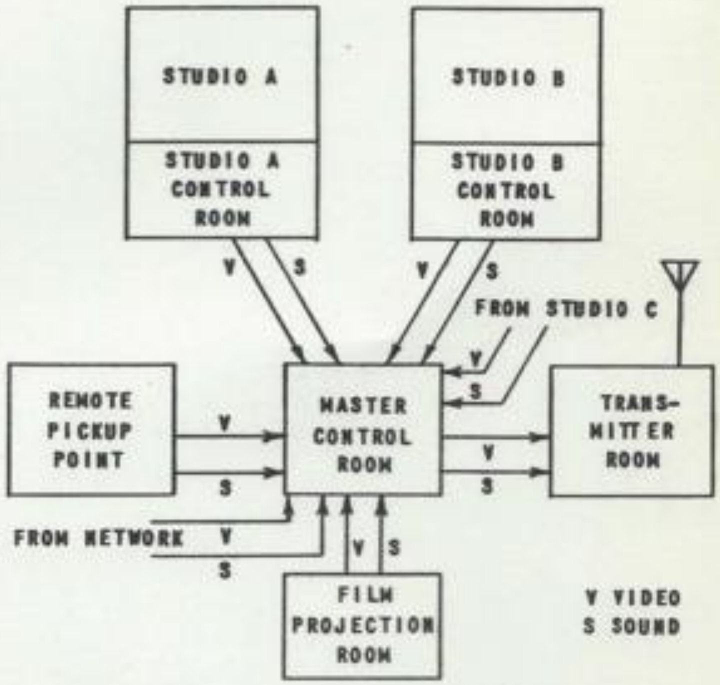


FIGURE 2

TELEVISION CONTROL ROOM

FIGURE 3

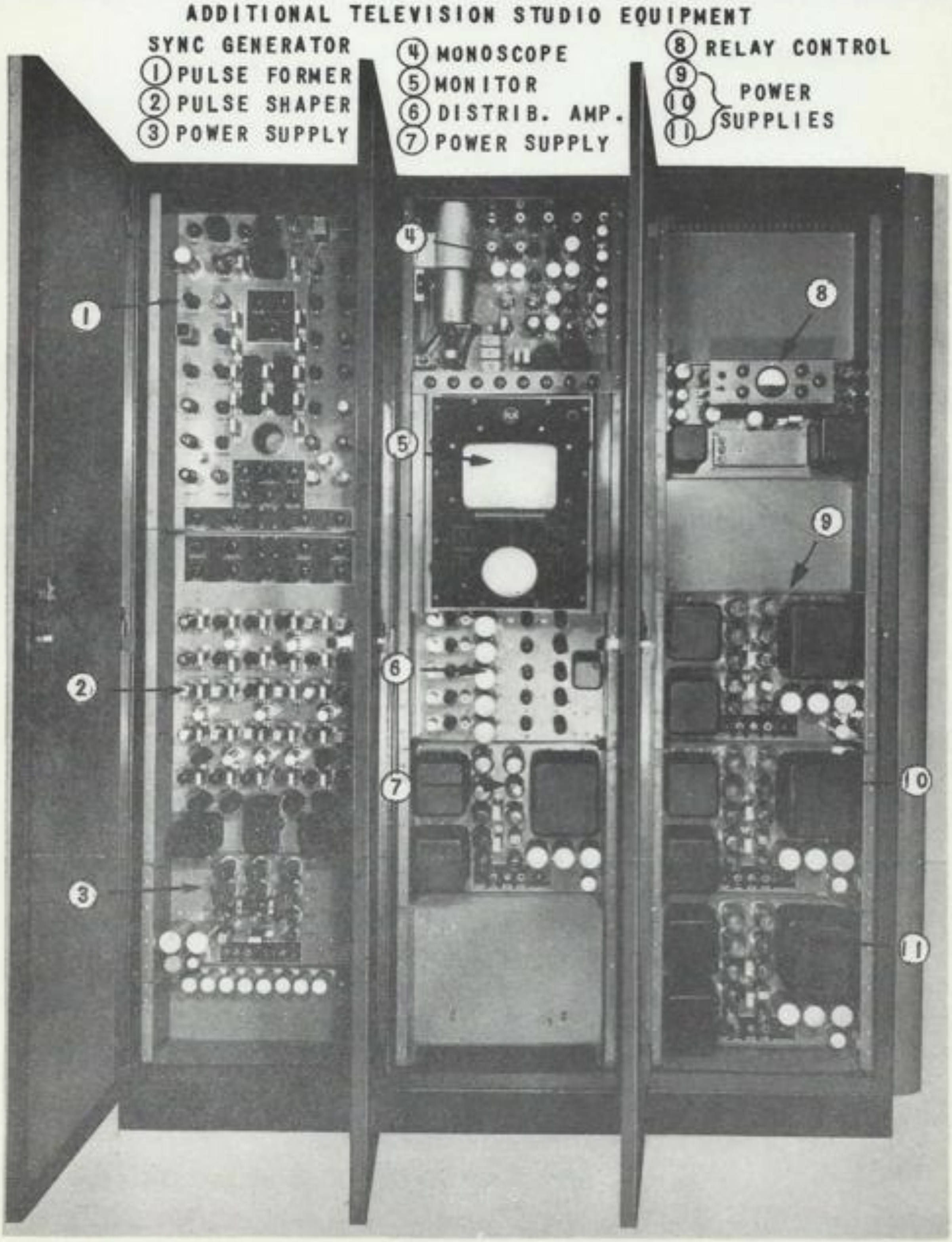
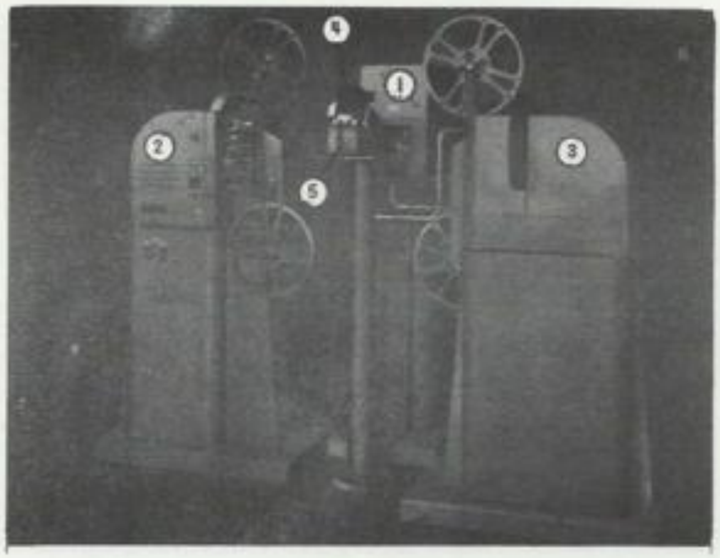

ADDITIONAL TELEVISION STUDIO EQUIPMENT
SYNC GENERATOR
1 PULSE FORMER
2 PULSE SHAPER
3 POWER SUPPLY
4 MONOSCOPE
5 MONITOR
6 DISTRIB. AMP.
7 POWER SUPPLY
8 RELAY CONTROL
9
10 POWER
11 SUPPLIES
1
2
3
4
5
6
7
8
9
10
11

FIGURE 4

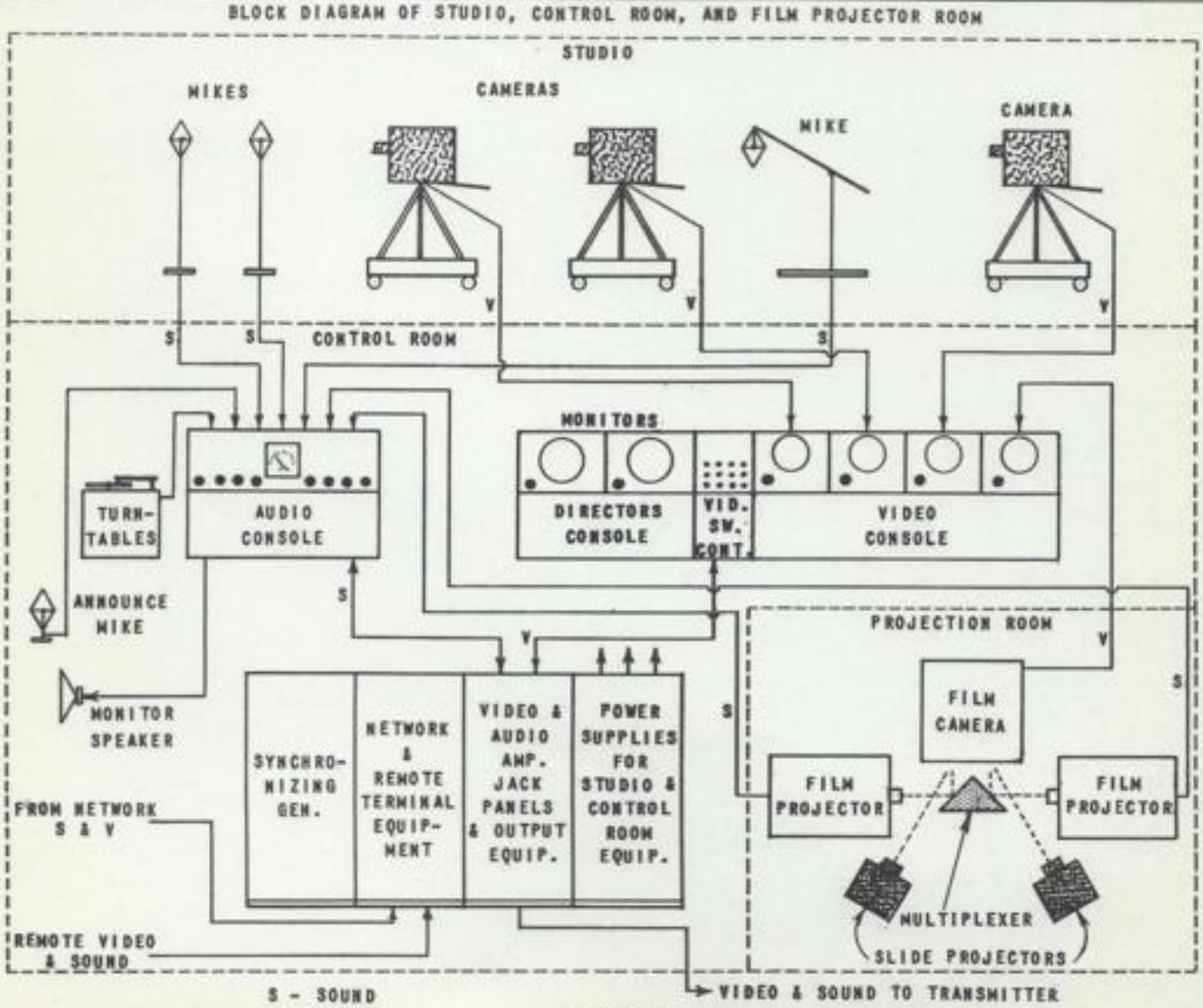
FILM PROJECTORS AND FILM CAMERA



(1) FILM CAMERA
(2) FILM PROJECTORS
(3)
(4) SLIDE PROJECTOR
(5) MULTIPLEXER

FIGURE 5

BLOCK DIAGRAM OF STUDIO, CONTROL ROOM, AND FILM PROJECTOR ROOM



S - SOUND
V - VIDEO

FIGURE 6

TWO-CAMERA FIELD PICKUP LAYOUT

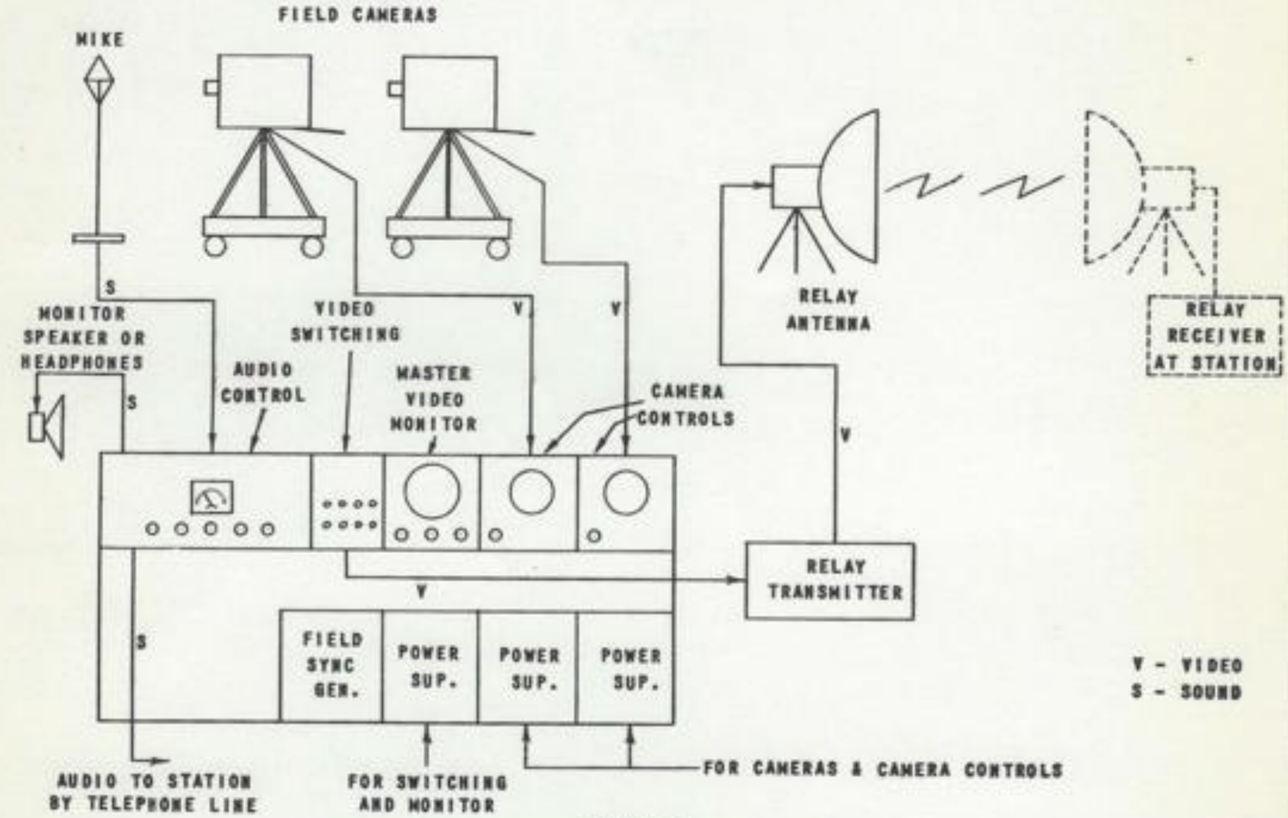


FIGURE 7

TELEVISION STATION TRANSMITTING EQUIPMENT

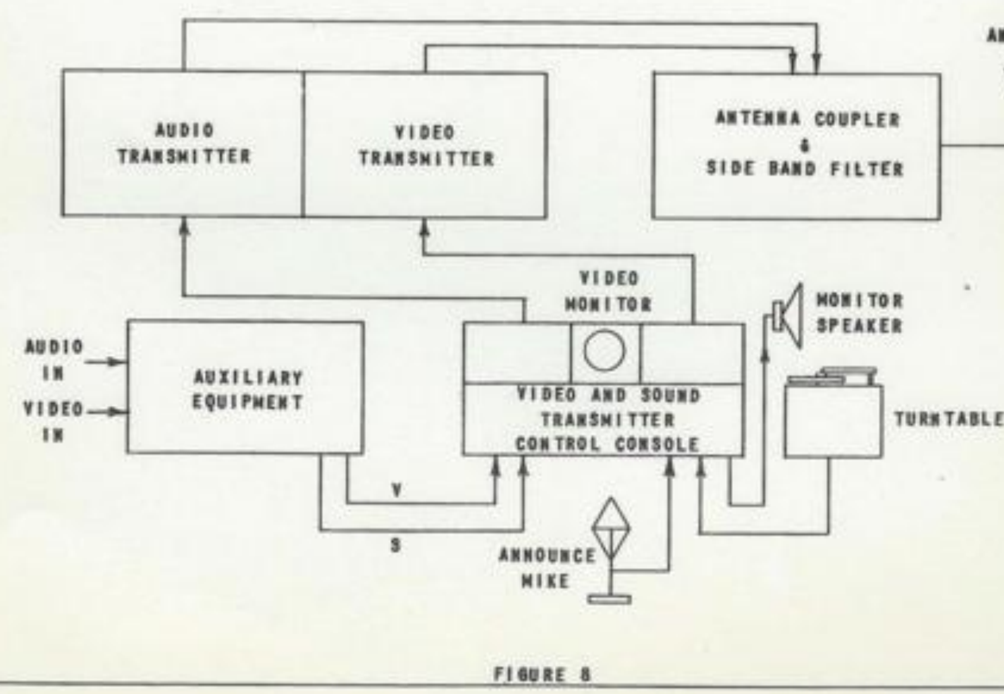


FIGURE 8

TELEVISION ANTENNA AND TOWER - WHAS-TV - LOUISVILLE, KY.

(Courtesy WHAS Inc.)

FIGURE 9

SYNCHRONIZING GENERATOR

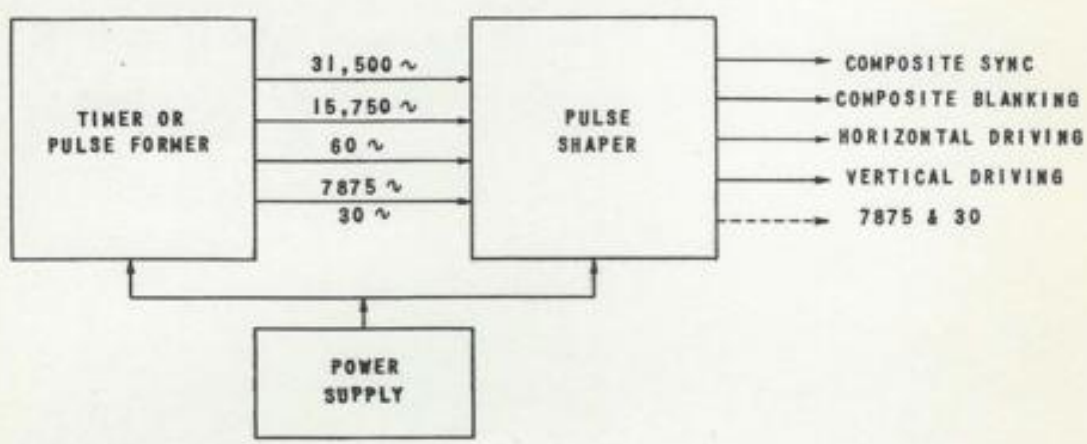


FIGURE 10-A

PULSE FORMER

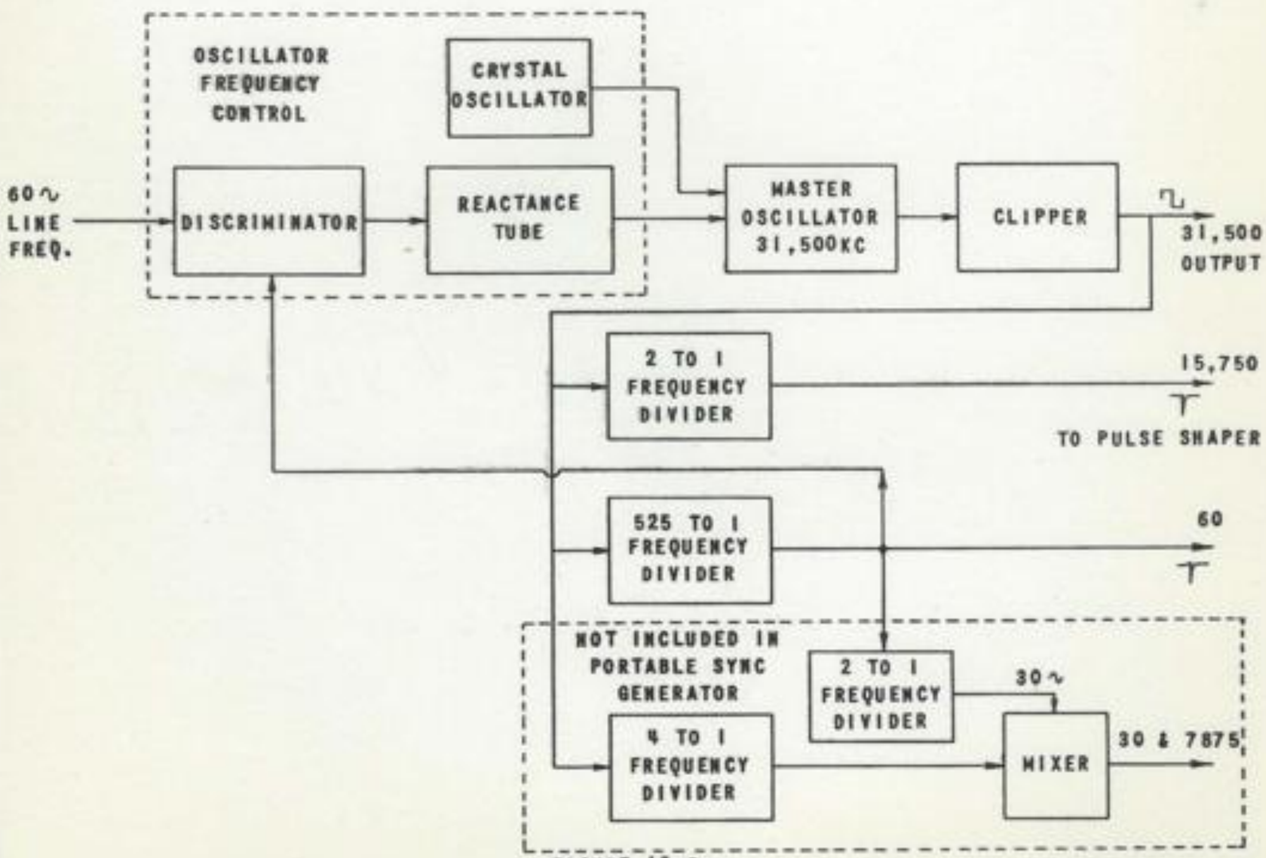


FIGURE 10-B

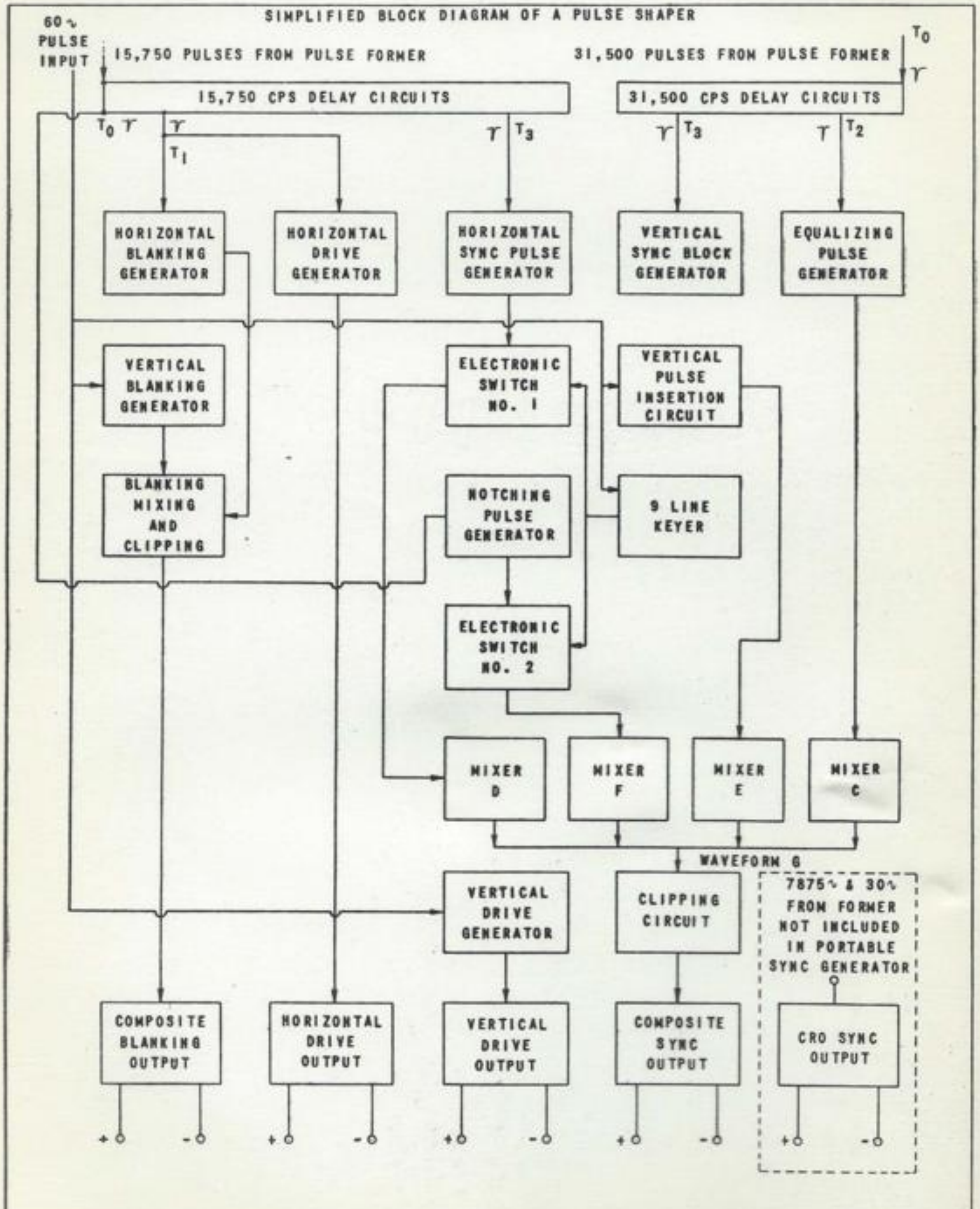

SIMPLIFIED BLOCK DIAGRAM OF A PULSE SHAPER
60 ~ PULSE INPUT
15,750 PULSES FROM PULSE FORMER
31,500 PULSES FROM PULSE FORMER
15,750 CPS DELAY CIRCUITS
31,500 CPS DELAY CIRCUITS
T0
T1
T3
T3
T2
T0
HORIZONTAL BLANKING GENERATOR
HORIZONTAL DRIVE GENERATOR
HORIZONTAL SYNC PULSE GENERATOR
VERTICAL SYNC BLOCK GENERATOR
EQUALIZING PULSE GENERATOR
VERTICAL BLANKING GENERATOR
ELECTRONIC SWITCH NO. 1
VERTICAL PULSE INSERTION CIRCUIT
BLANKING MIXING AND CLIPPING
NOTCHING PULSE GENERATOR
9 LINE KEYER
ELECTRONIC SWITCH NO. 2
MIXER D
MIXER F
MIXER E
MIXER C
WAVEFORM G
VERTICAL DRIVE GENERATOR
CLIPPING CIRCUIT
7875~ & 30~ FROM FORMER NOT INCLUDED IN PORTABLE SYNC GENERATOR
COMPOSITE BLANKING OUTPUT
HORIZONTAL DRIVE OUTPUT
VERTICAL DRIVE OUTPUT
COMPOSITE SYNC OUTPUT
CRO SYNC OUTPUT
+
-

FIGURE II

SYNCHRONIZING GENERATOR WAVEFORMS

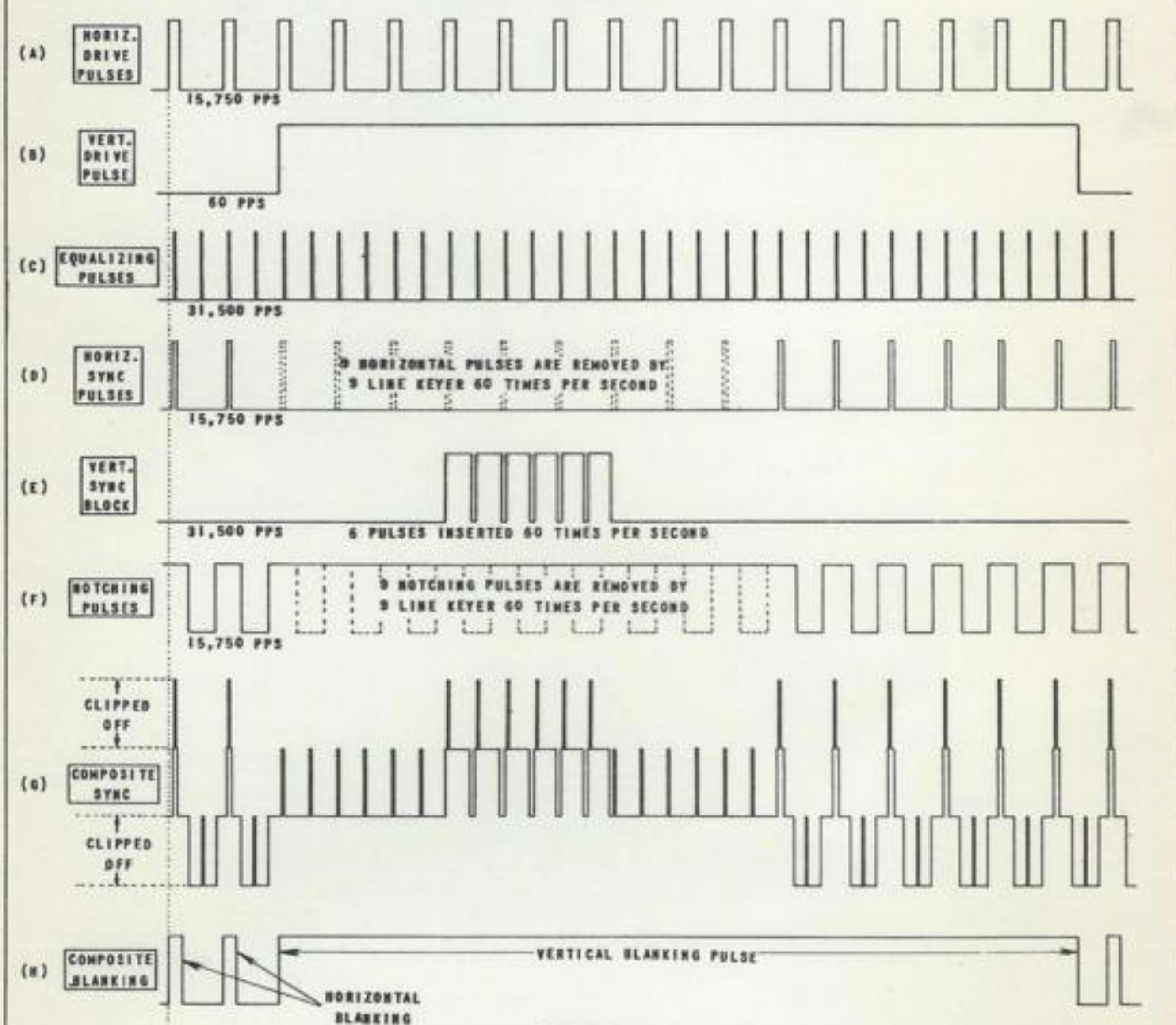


FIGURE 12-A

CAMERA AND COMPOSITE VIDEO SIGNALS

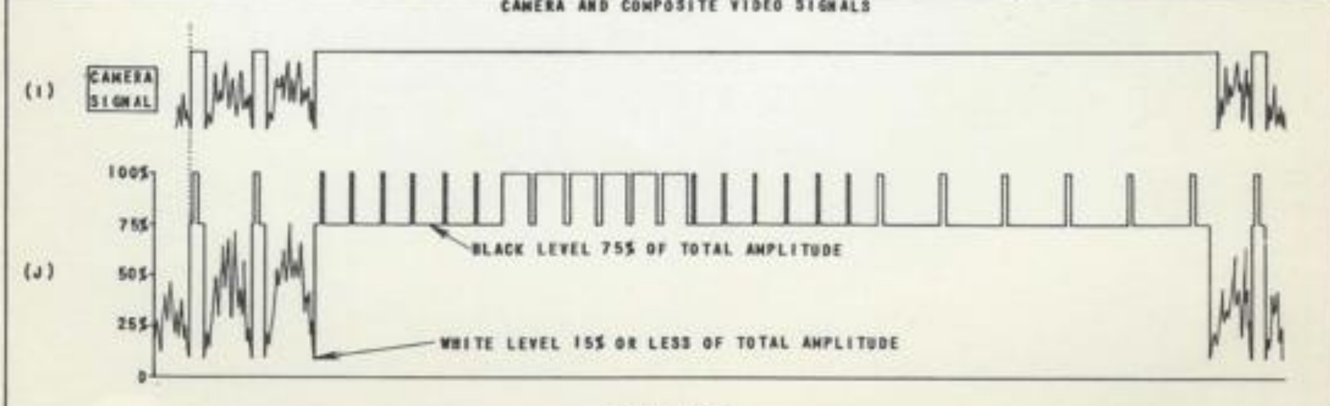


FIGURE 12-B

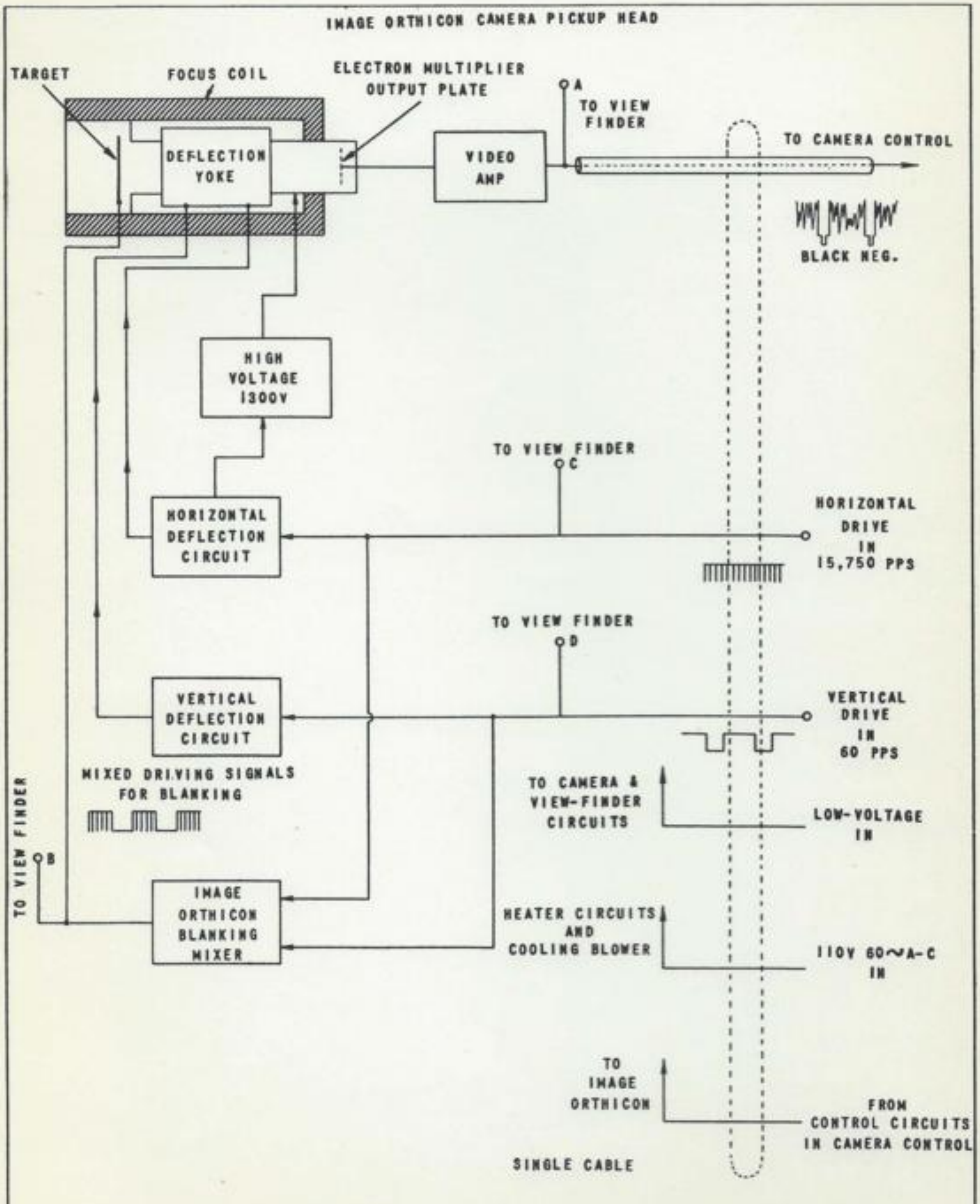


IMAGE ORTHICON CAMERA PICKUP HEAD
TARGET
FOCUS COIL
ELECTRON MULTIPLIER
OUTPUT PLATE
A
TO VIEW
FINDER
DEFLECTION
YOKE
VIDEO
AMP
TO CAMERA CONTROL
BLACK NEG.
HIGH
VOLTAGE
1300V
TO VIEW FINDER
C
HORIZONTAL
DEFLECTION
CIRCUIT
HORIZONTAL
DRIVE
IN
15,750 PPS
TO VIEW FINDER
D
VERTICAL
DEFLECTION
CIRCUIT
VERTICAL
DRIVE
IN
60 PPS
MIXED DRIVING SIGNALS
FOR BLANKING
TO CAMERA &
VIEW-FINDER
CIRCUITS
LOW-VOLTAGE
IN
TO VIEW FINDER
B
IMAGE
ORTHICON
BLANKING
MIXER
HEATER CIRCUITS
AND
COOLING BLOWER
110V 60~A-C
IN
TO
IMAGE
ORTHICON
FROM
CONTROL CIRCUITS
IN CAMERA CONTROL
SINGLE CABLE
FIGURE 13

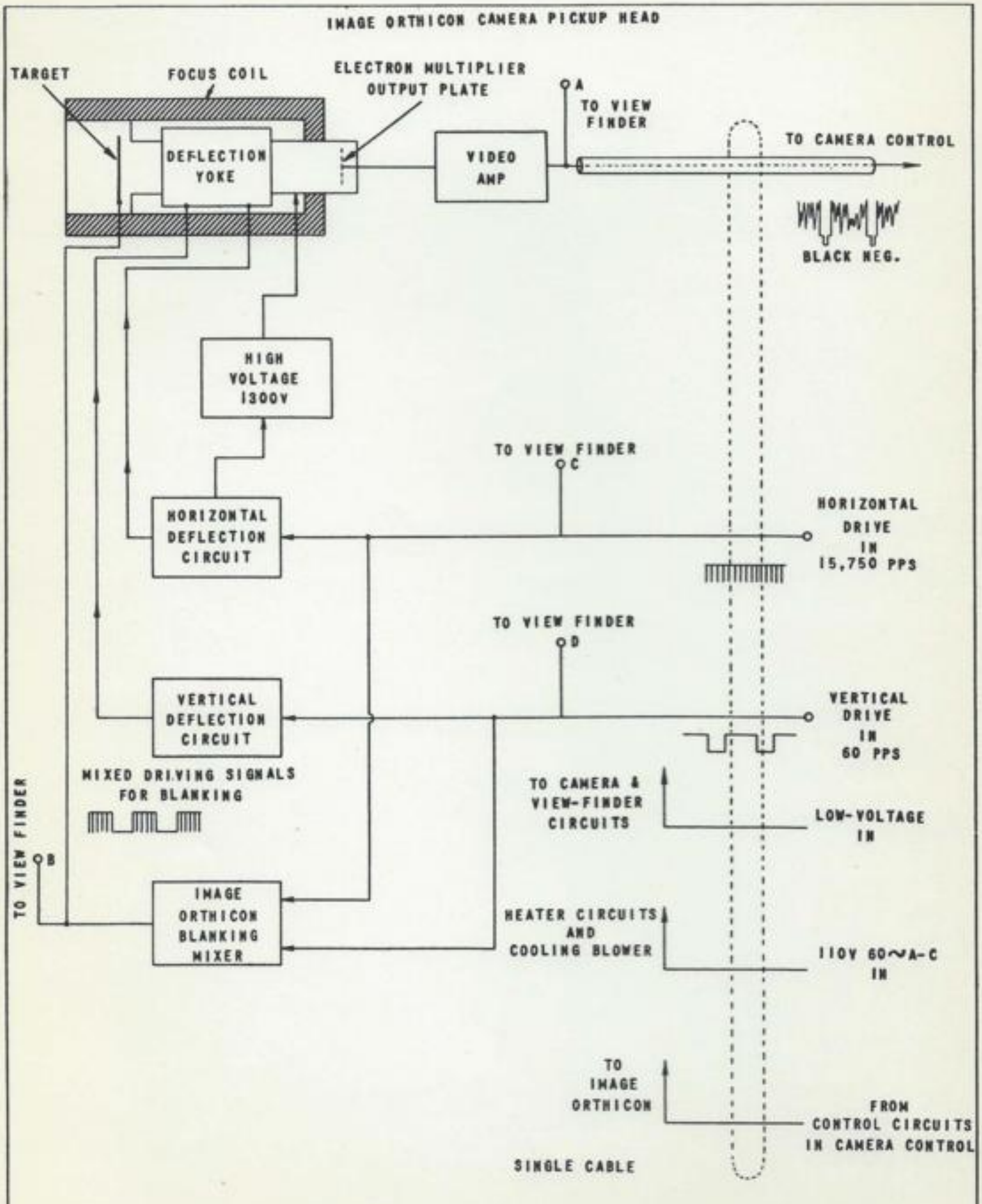


IMAGE ORTHICON CAMERA PICKUP HEAD
TARGET
FOCUS COIL
ELECTRON MULTIPLIER
OUTPUT PLATE
A
TO VIEW
FINDER
DEFLECTION
YOKE
VIDEO
AMP
TO CAMERA CONTROL
BLACK NEG.
HIGH
VOLTAGE
1300V
TO VIEW FINDER
C
HORIZONTAL
DEFLECTION
CIRCUIT
HORIZONTAL
DRIVE
IN
15,750 PPS
TO VIEW FINDER
D
VERTICAL
DEFLECTION
CIRCUIT
VERTICAL
DRIVE
IN
60 PPS
MIXED DRIVING SIGNALS
FOR BLANKING
TO CAMERA &
VIEW-FINDER
CIRCUITS
LOW-VOLTAGE
IN
TO VIEW FINDER
B
IMAGE
ORTHICON
BLANKING
MIXER
HEATER CIRCUITS
AND
COOLING BLOWER
110V 60~A-C
IN
TO
IMAGE
ORTHICON
FROM
CONTROL CIRCUITS
IN CAMERA CONTROL
SINGLE CABLE

FIGURE 13

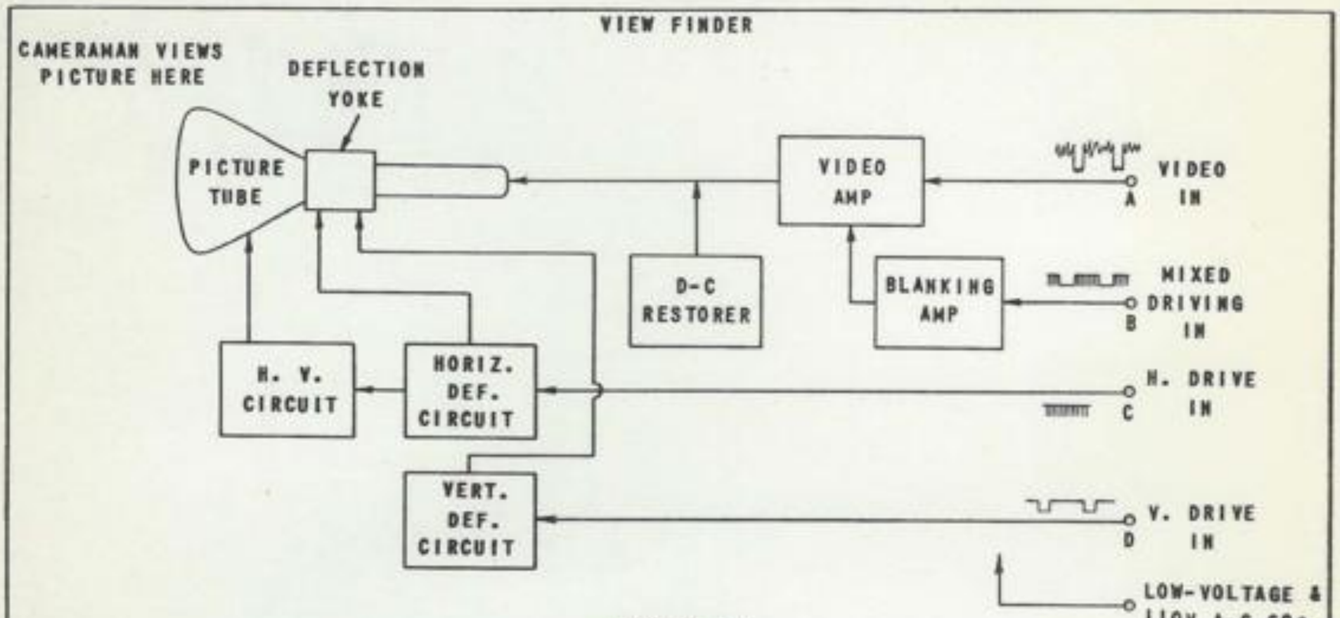


FIGURE 14

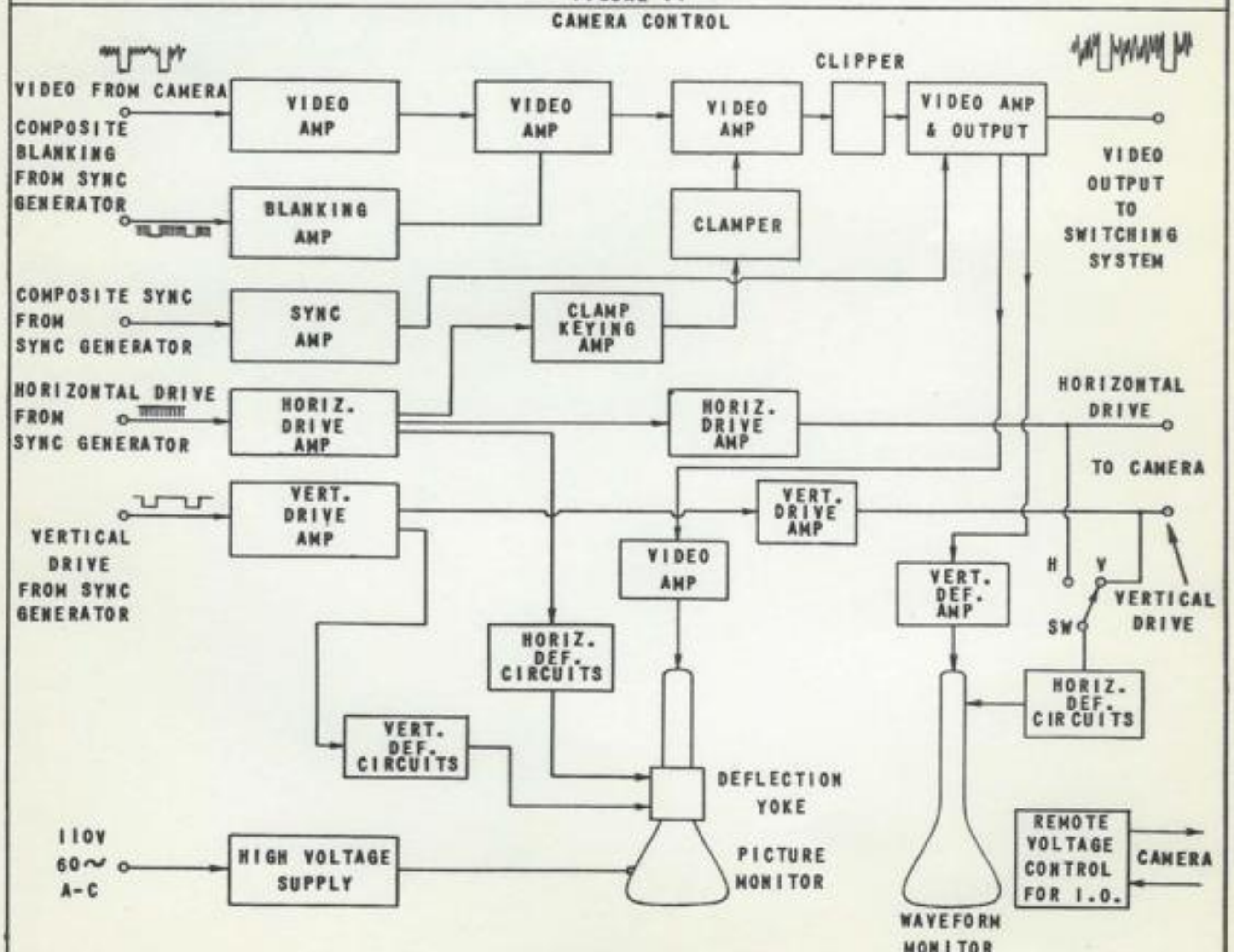


FIGURE 15

ADDITION OF BLANKING TO CAMERA SIGNAL

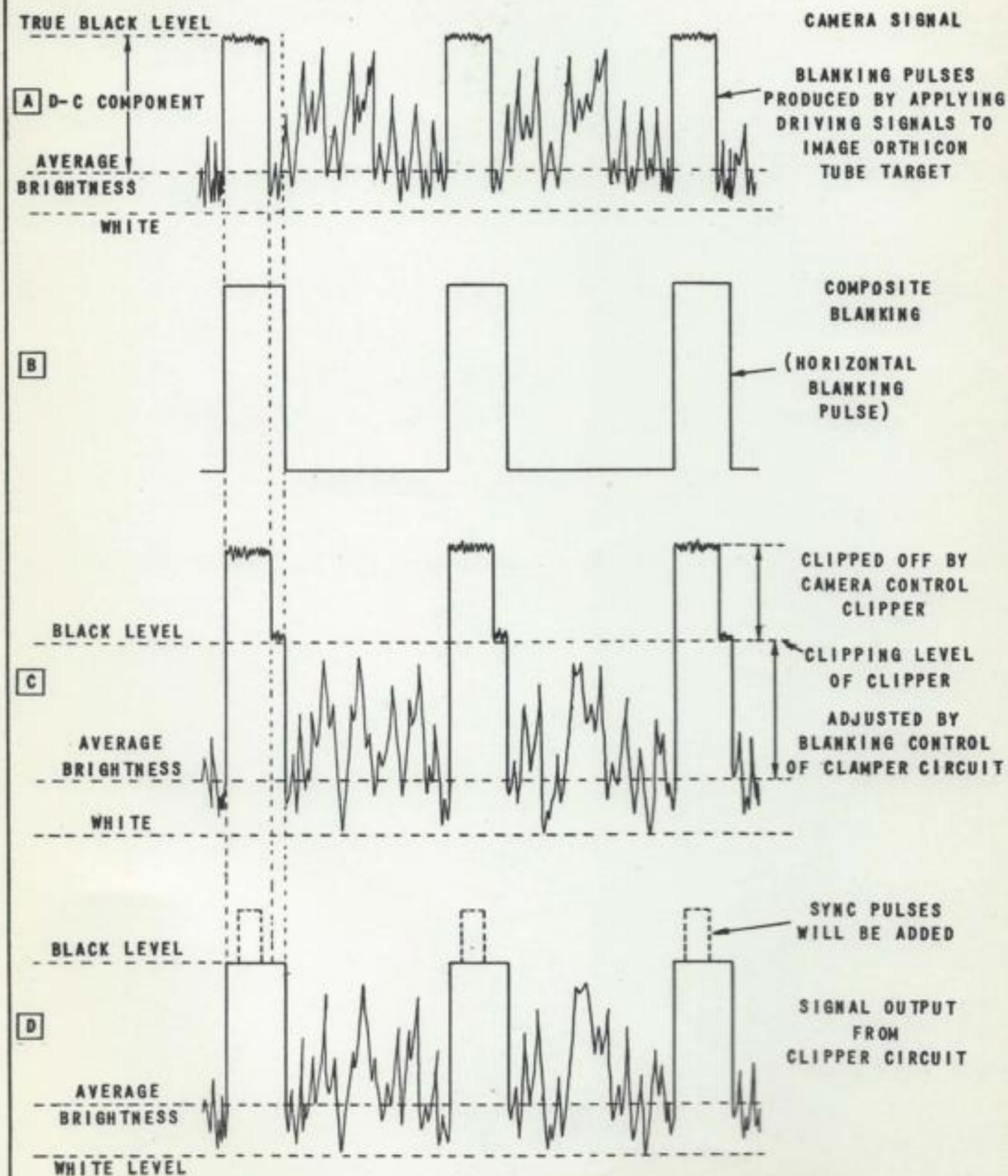


FIGURE 16

SWITCHING SYSTEM AND MASTER MONITOR

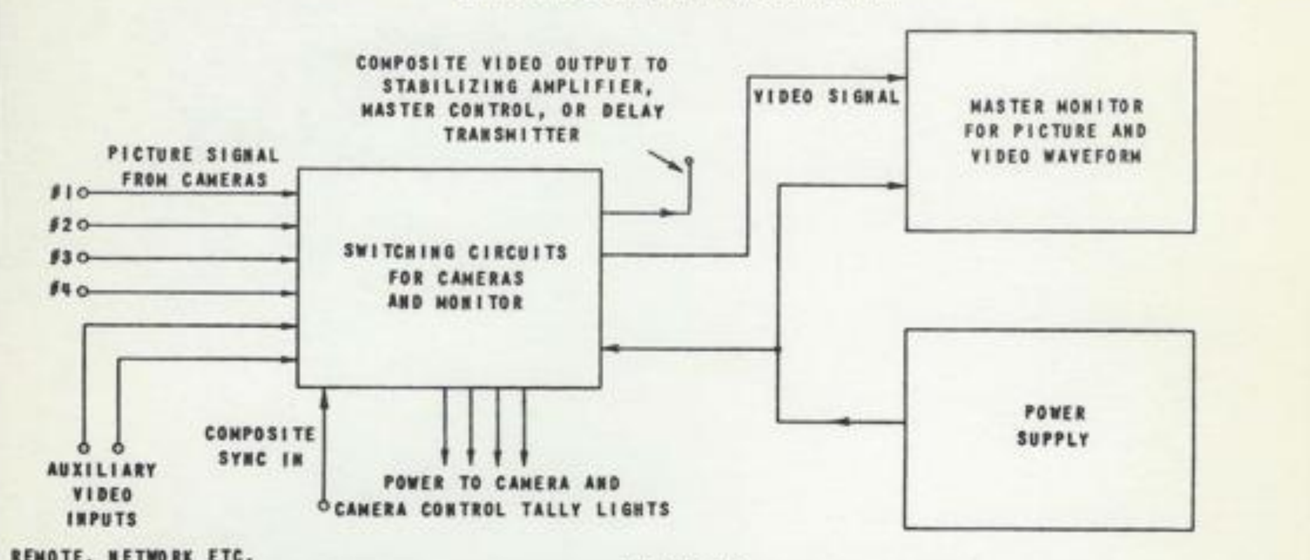


FIGURE 17

VIDEO SIGNAL AND MONITOR SWITCHING CIRCUITS (FIELD TYPE)

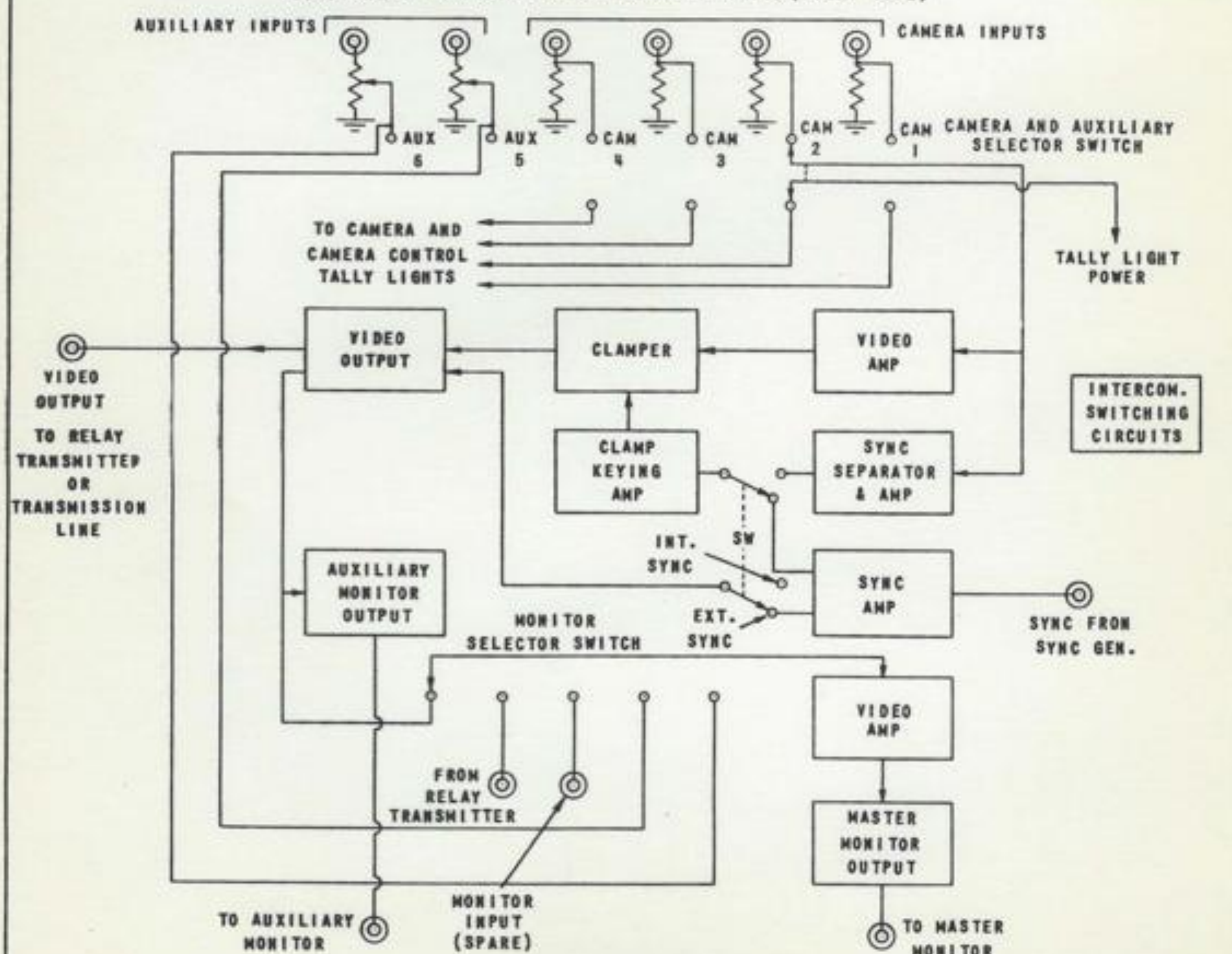
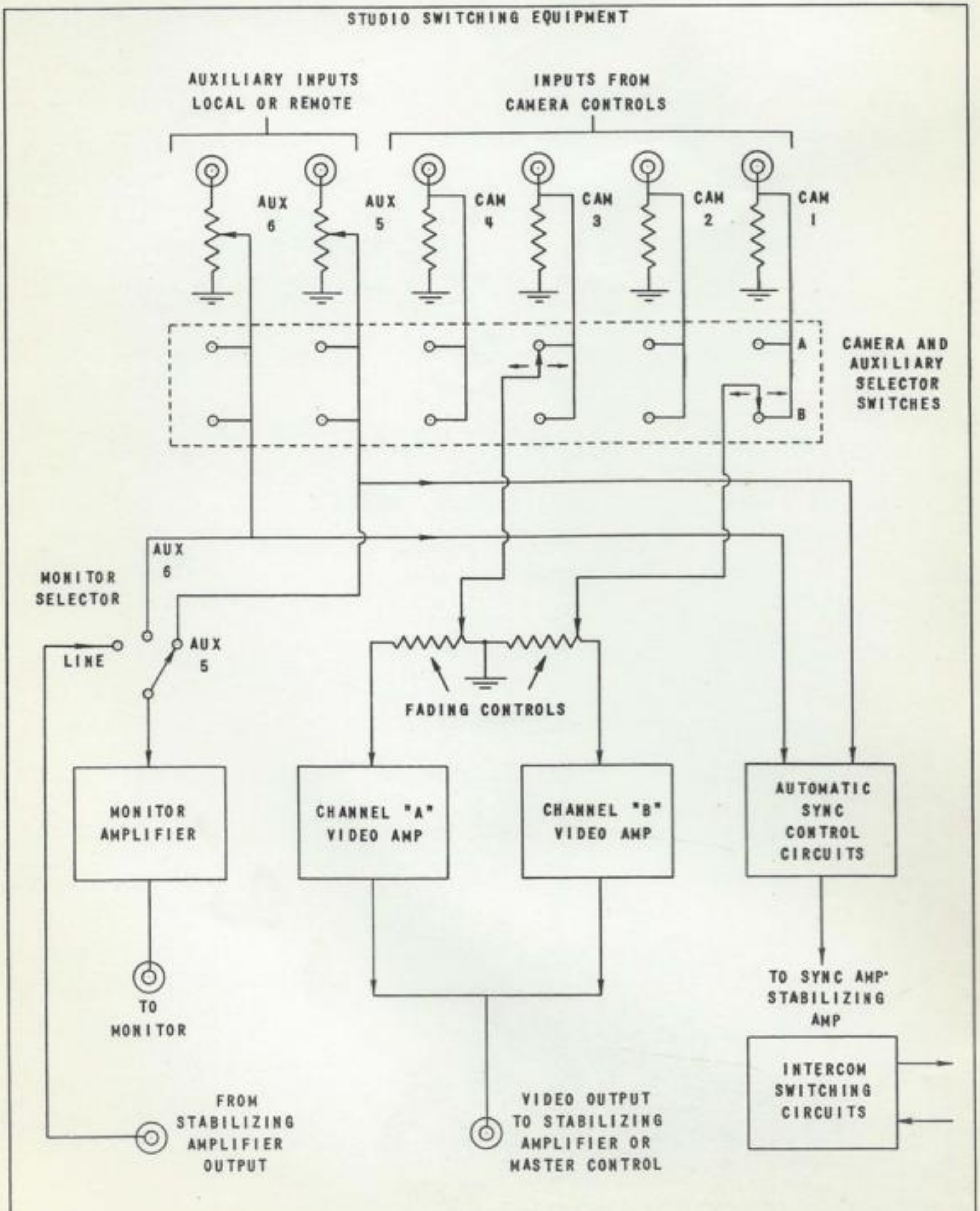
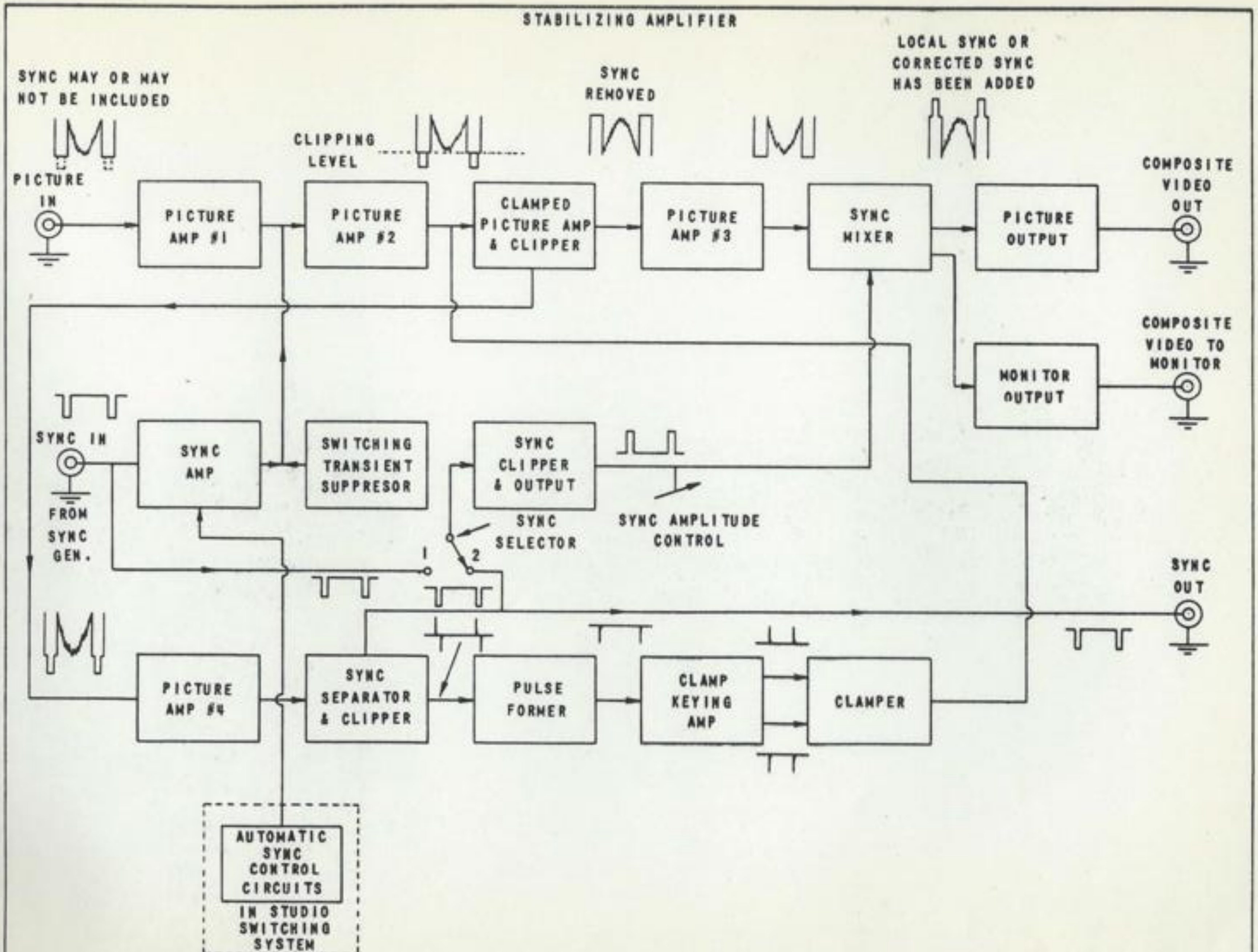


FIGURE 18-A

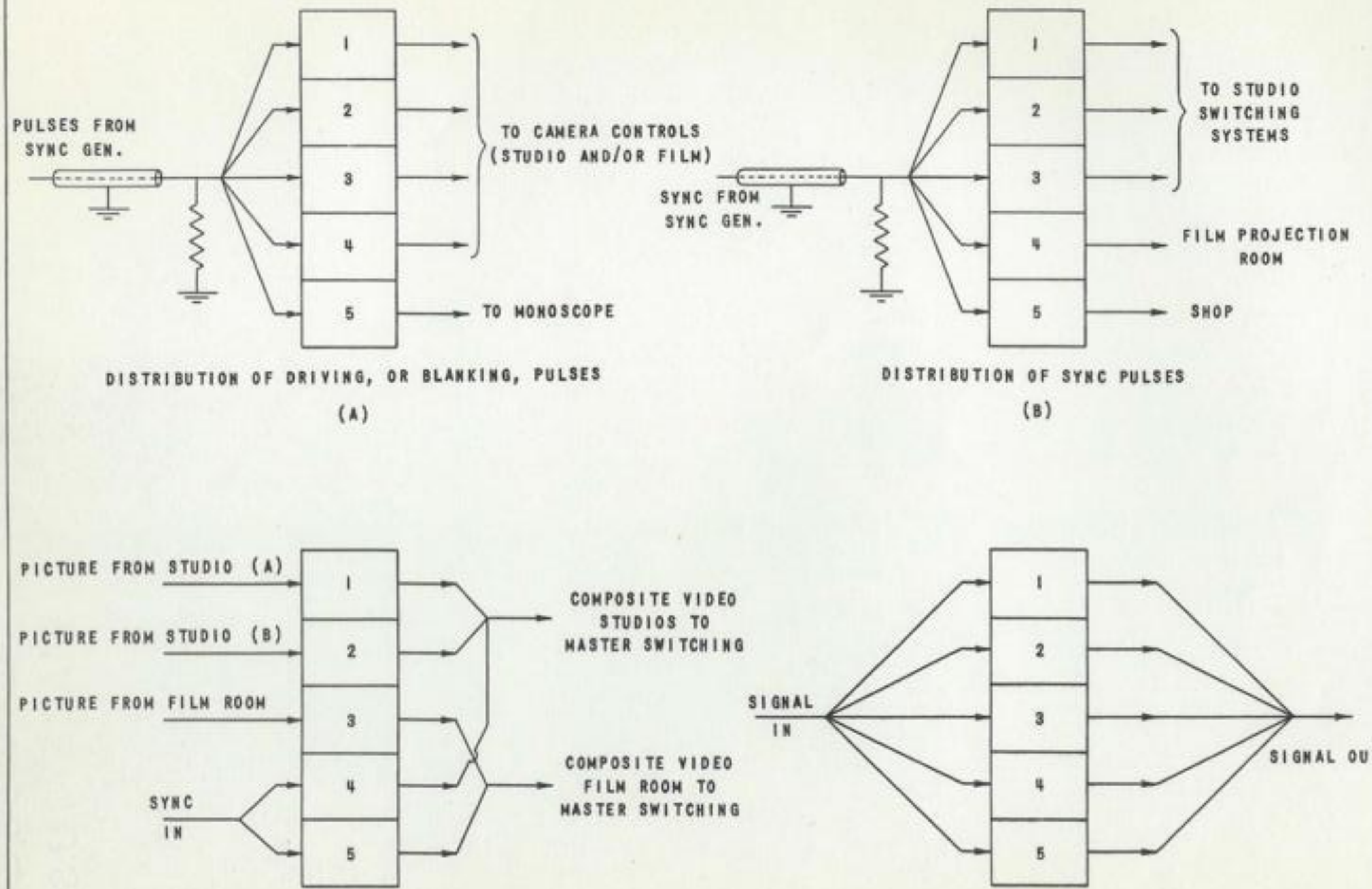


STUDIO SWITCHING EQUIPMENT
AUXILIARY INPUTS
LOCAL OR REMOTE
INPUTS FROM
CAMERA CONTROLS
AUX 6
AUX 5
CAM 4
CAM 3
CAM 2
CAM 1
A
B
CAMERA AND
AUXILIARY
SELECTOR
SWITCHES
AUX 6
MONITOR
SELECTOR
LINE
AUX 5
FADING CONTROLS
MONITOR
AMPLIFIER
CHANNEL "A"
VIDEO AMP
CHANNEL "B"
VIDEO AMP
AUTOMATIC
SYNC
CONTROL
CIRCUITS
TO SYNC AMP'
STABILIZING
AMP
TO
MONITOR
INTERCOM
SWITCHING
CIRCUITS
FROM
STABILIZING
AMPLIFIER
OUTPUT
VIDEO OUTPUT
TO STABILIZING
AMPLIFIER OR
MASTER CONTROL

FIGURE 18-B


STABILIZING AMPLIFIER
SYNC MAY OR MAY NOT BE INCLUDED
PICTURE IN
PICTURE AMP #1
PICTURE AMP #2
CLIPPING LEVEL
CLAMPED PICTURE AMP & CLIPPER
SYNC REMOVED
PICTURE AMP #3
SYNC MIXER
LOCAL SYNC OR CORRECTED SYNC HAS BEEN ADDED
PICTURE OUTPUT
COMPOSITE VIDEO OUT
MONITOR OUTPUT
COMPOSITE VIDEO TO MONITOR
SYNC IN
FROM SYNC GEN.
SYNC AMP
SWITCHING TRANSIENT SUPPRESOR
SYNC CLIPPER & OUTPUT
SYNC SELECTOR
1
2
SYNC AMPLITUDE CONTROL
SYNC OUT
PICTURE AMP #4
SYNC SEPARATOR & CLIPPER
PULSE FORMER
CLAMP KEYING AMP
CLAMPER
AUTOMATIC SYNC CONTROL CIRCUITS
IN STUDIO SWITCHING SYSTEM
FIGURE 19

EXAMPLE APPLICATIONS OF DISTRIBUTION AMPLIFIERS



DISTRIBUTION OF DRIVING, OR BLANKING, PULSES
(A)

DISTRIBUTION OF SYNC PULSES
(B)

MIXING OF SYNC WITH PICTURE SIGNALS
(C)

LOW GAIN AMPLIFIER
(D)

FIGURE 20

PULSE DISTRIBUTION BOX

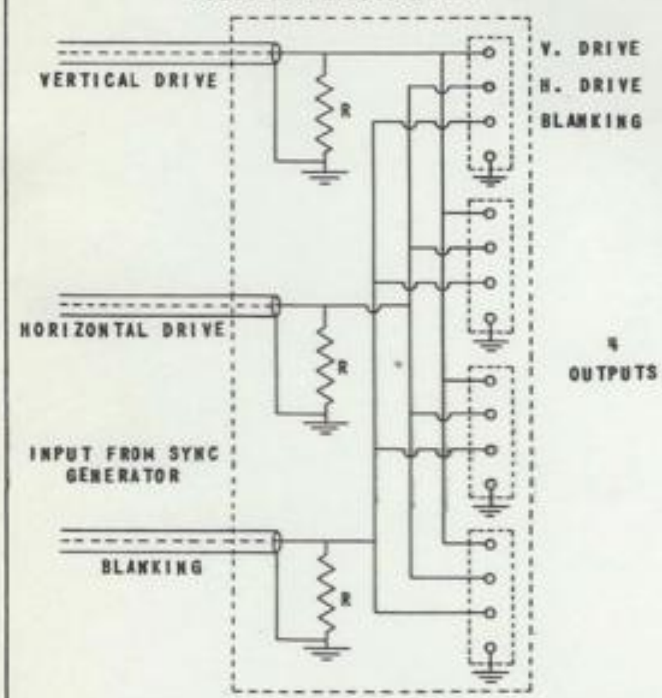


FIGURE 21

FILM PROJECTOR SYSTEM

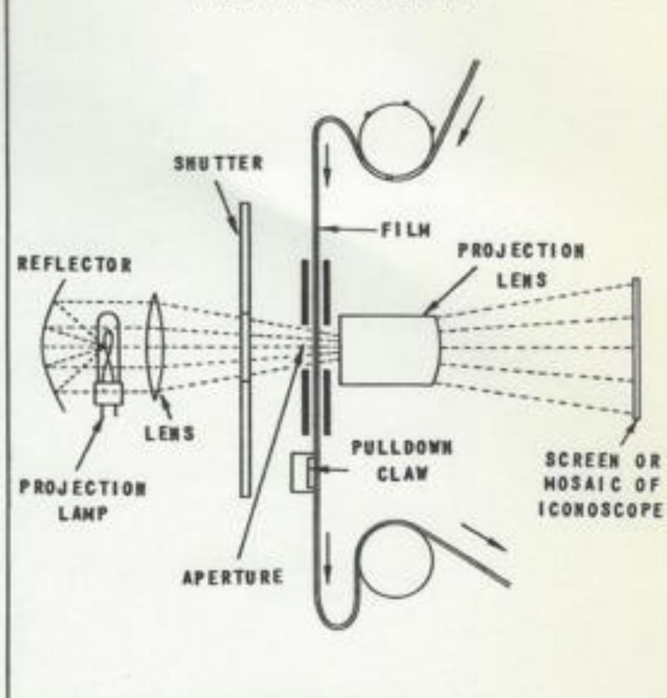


FIGURE 23

PROJECTION ROOM EQUIPMENT

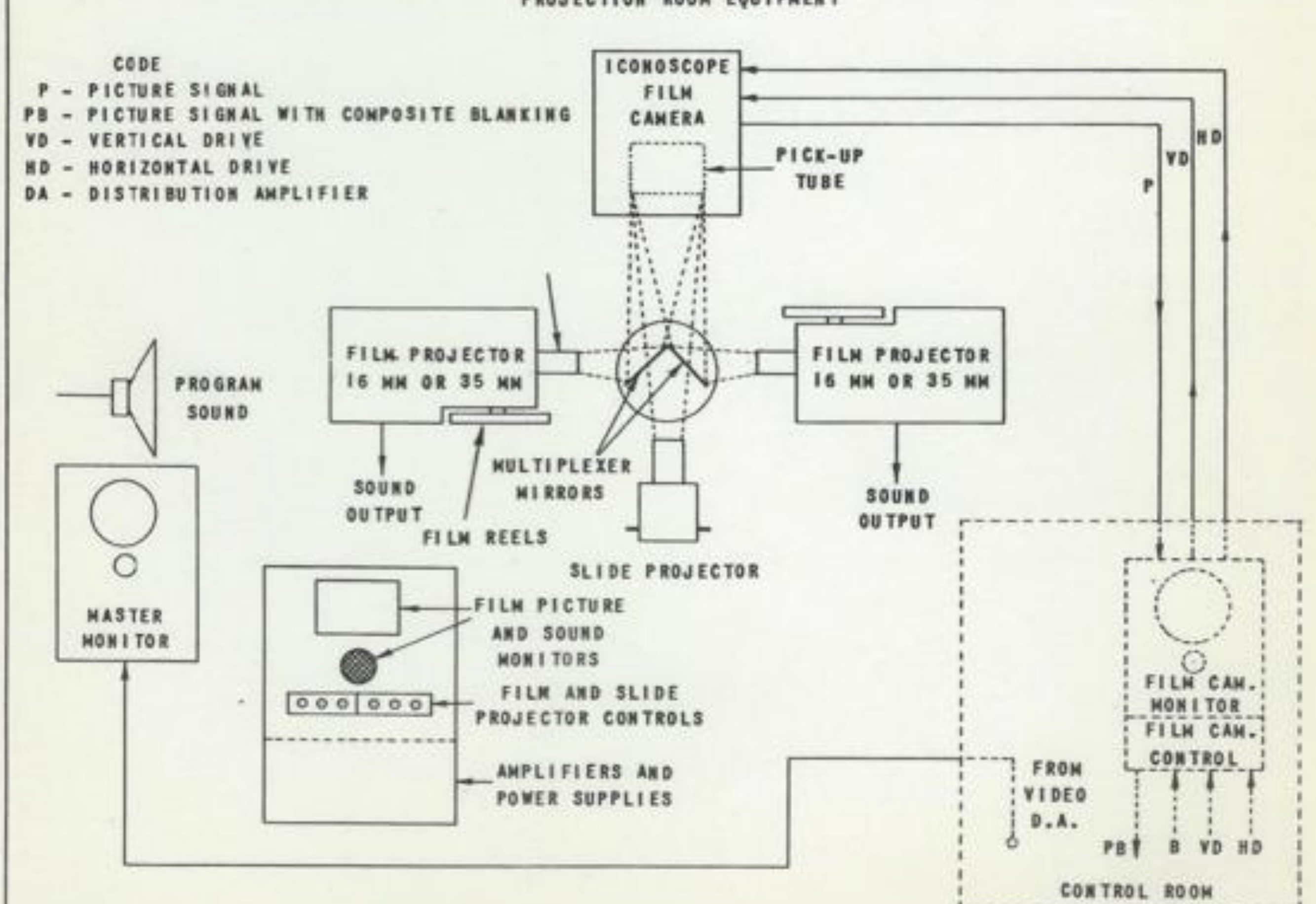


FIGURE 22

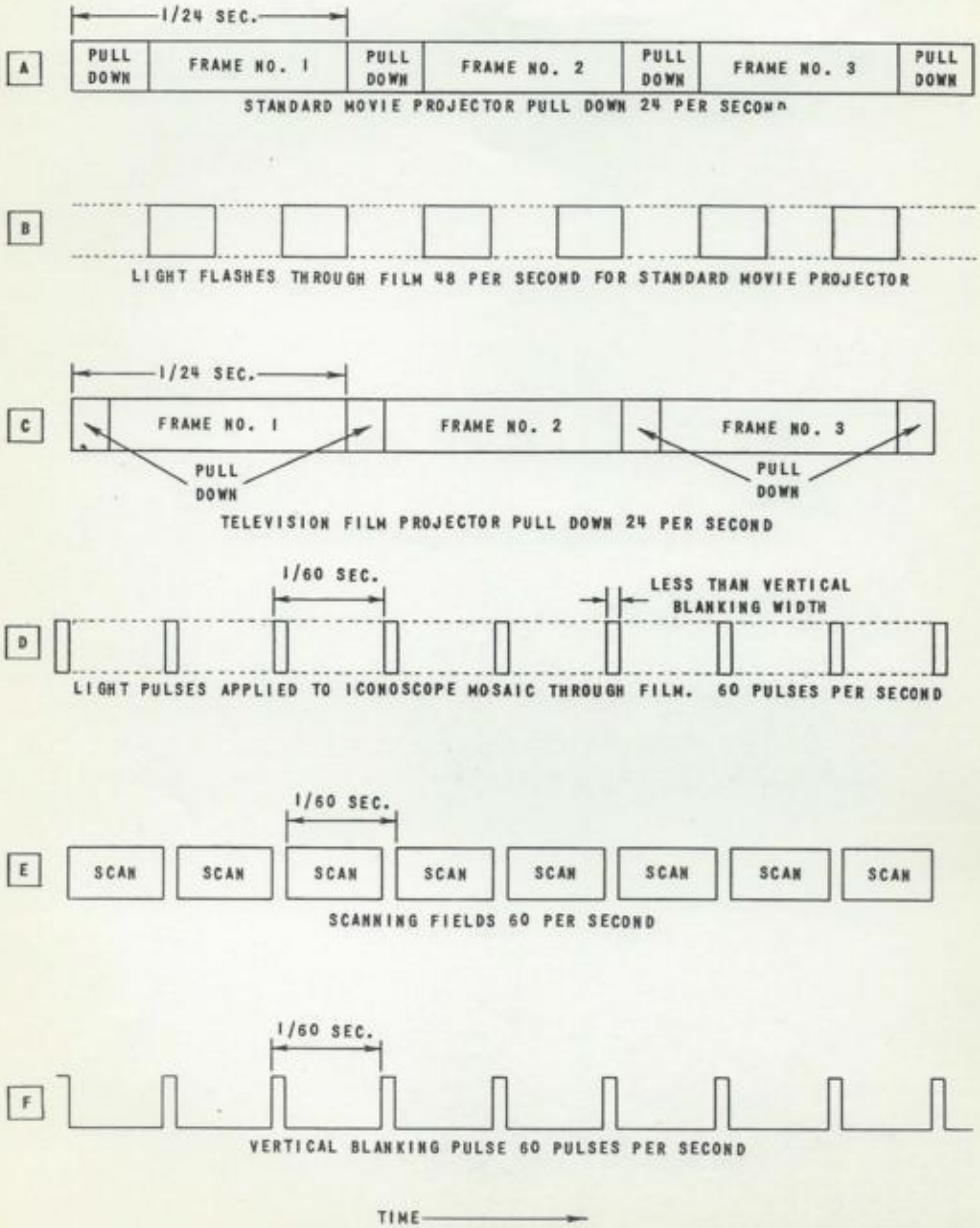
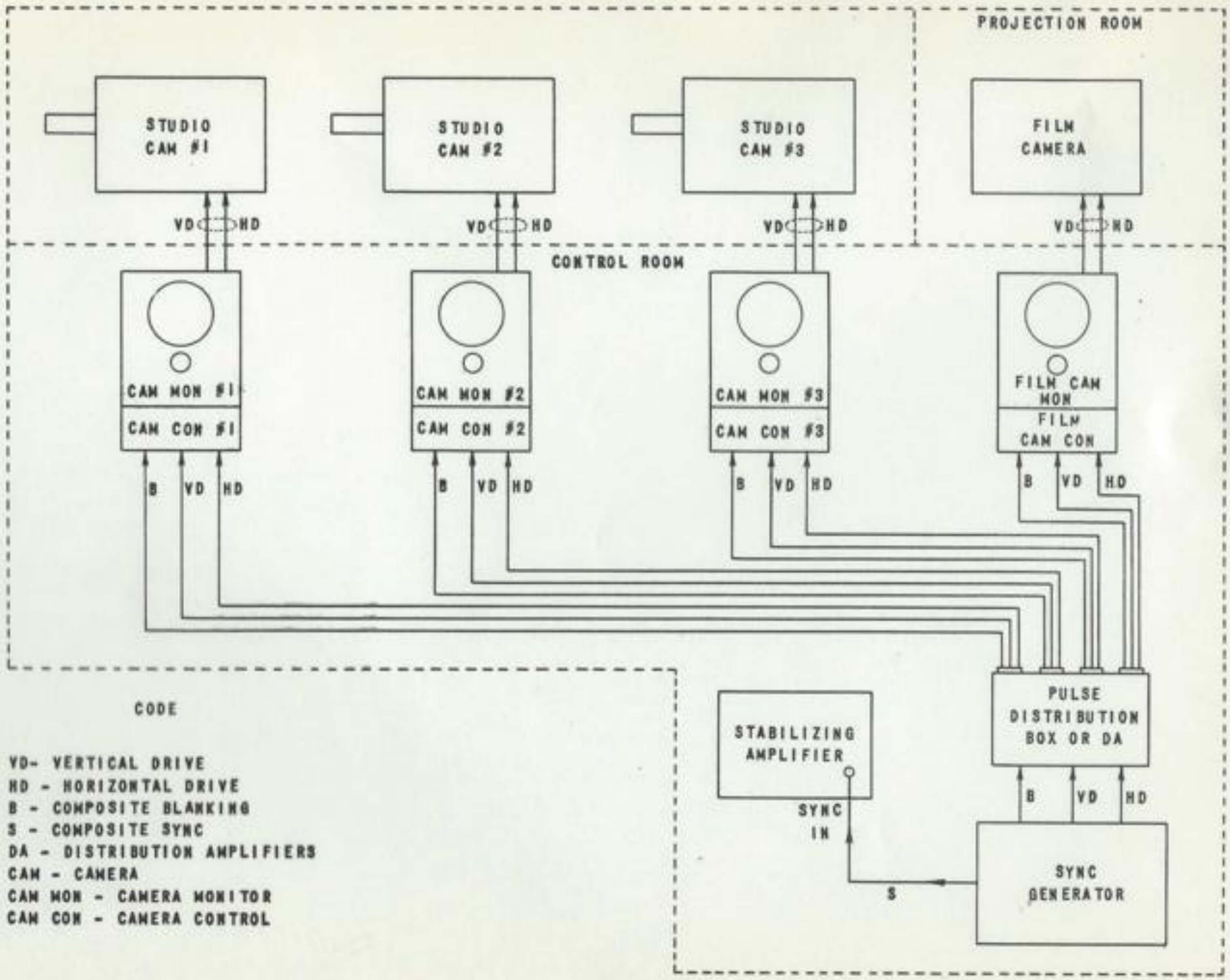

A
1/24 SEC.
PULL DOWN
FRAME NO. 1
PULL DOWN
FRAME NO. 2
PULL DOWN
FRAME NO. 3
PULL DOWN
STANDARD MOVIE PROJECTOR PULL DOWN 24 PER SECOND
B
LIGHT FLASHES THROUGH FILM 48 PER SECOND FOR STANDARD MOVIE PROJECTOR
C
1/24 SEC.
FRAME NO. 1
FRAME NO. 2
FRAME NO. 3
PULL DOWN
PULL DOWN
TELEVISION FILM PROJECTOR PULL DOWN 24 PER SECOND
D
1/60 SEC.
LESS THAN VERTICAL BLANKING WIDTH
LIGHT PULSES APPLIED TO ICONOSCOPE MOSAIC THROUGH FILM. 60 PULSES PER SECOND
E
1/60 SEC.
SCAN
SCAN
SCAN
SCAN
SCAN
SCAN
SCAN
SCAN
SCANNING FIELDS 60 PER SECOND
F
1/60 SEC.
VERTICAL BLANKING PULSE 60 PULSES PER SECOND
TIME

FIGURE 24

DISTRIBUTION OF PULSES TO STUDIO AND CONTROL ROOM EQUIPMENT

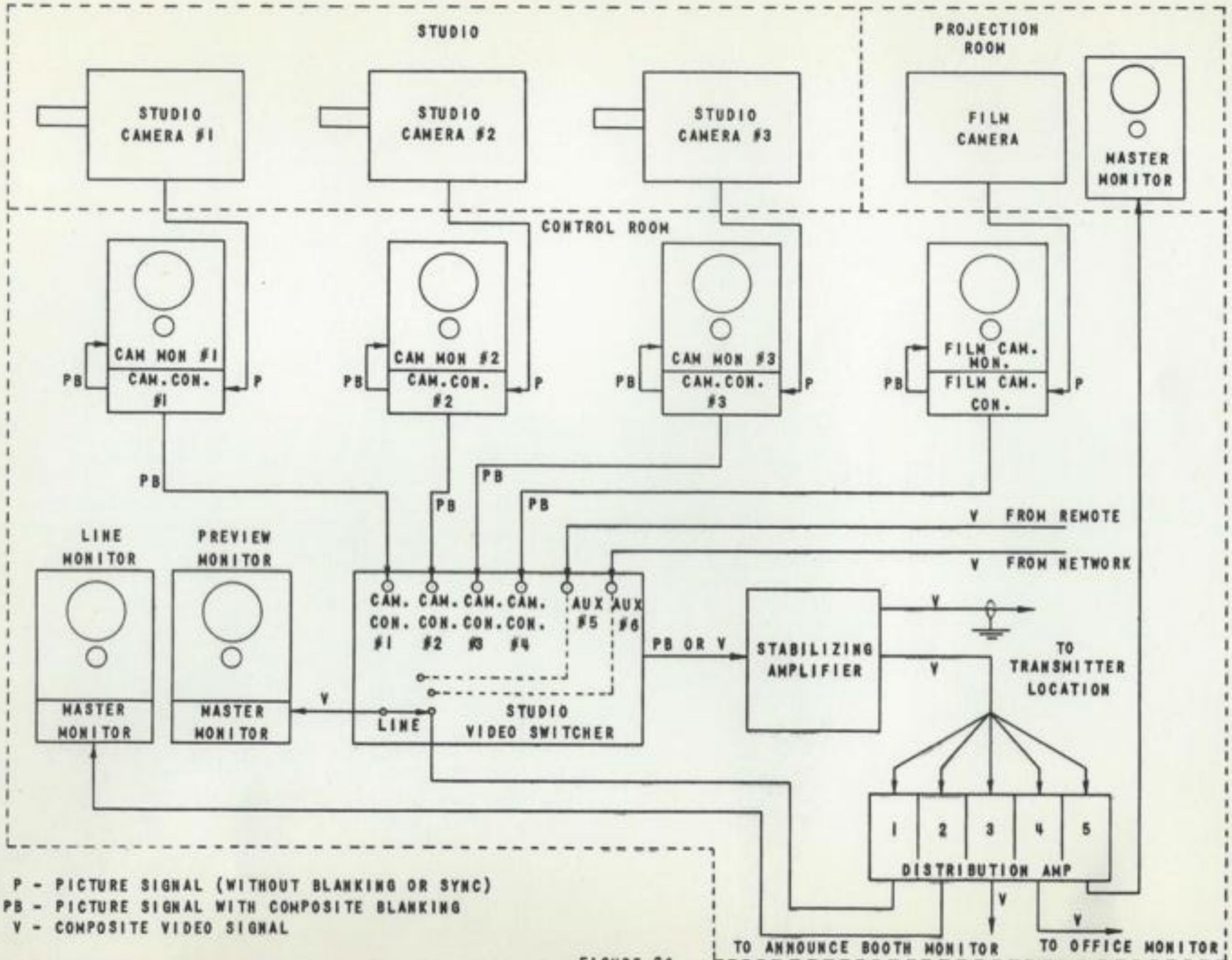


CODE

VD- VERTICAL DRIVE
HD - HORIZONTAL DRIVE
B - COMPOSITE BLANKING
S - COMPOSITE SYNC
DA - DISTRIBUTION AMPLIFIERS
CAM - CAMERA
CAM MON - CAMERA MONITOR
CAM CON - CAMERA CONTROL

FIGURE 25

STUDIO EQUIPMENT PICTURE SIGNAL PATH



P - PICTURE SIGNAL (WITHOUT BLANKING OR SYNC)
PB - PICTURE SIGNAL WITH COMPOSITE BLANKING
V - COMPOSITE VIDEO SIGNAL

FIGURE 26

TELEVISION RELAY EQUIPMENT

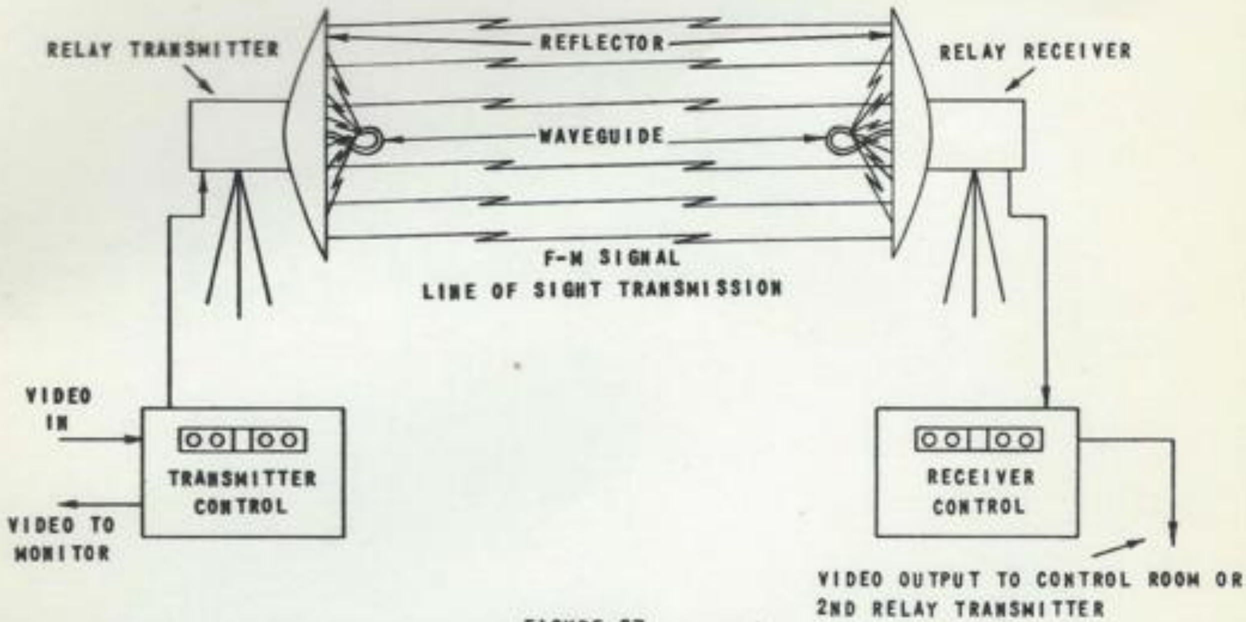


FIGURE 27

APPLICATIONS OF TELEVISION RELAY EQUIPMENT

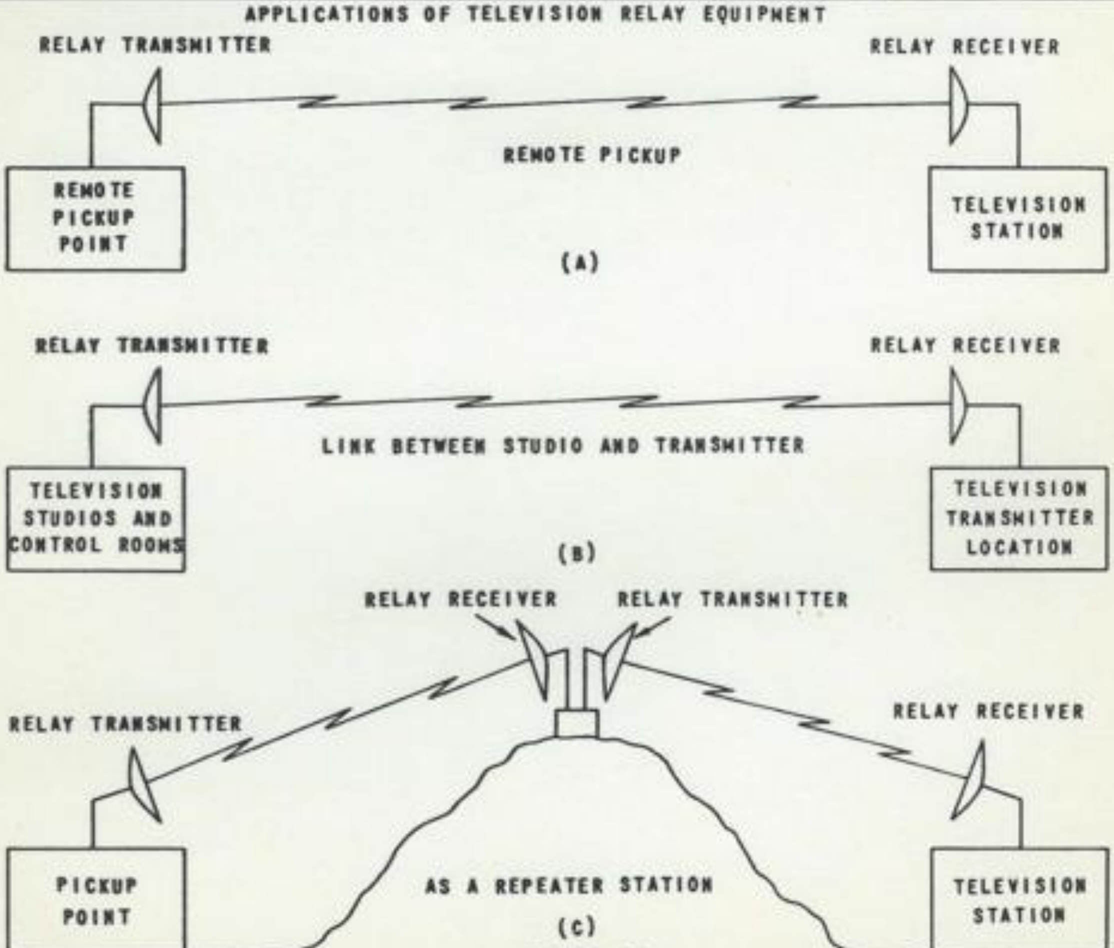
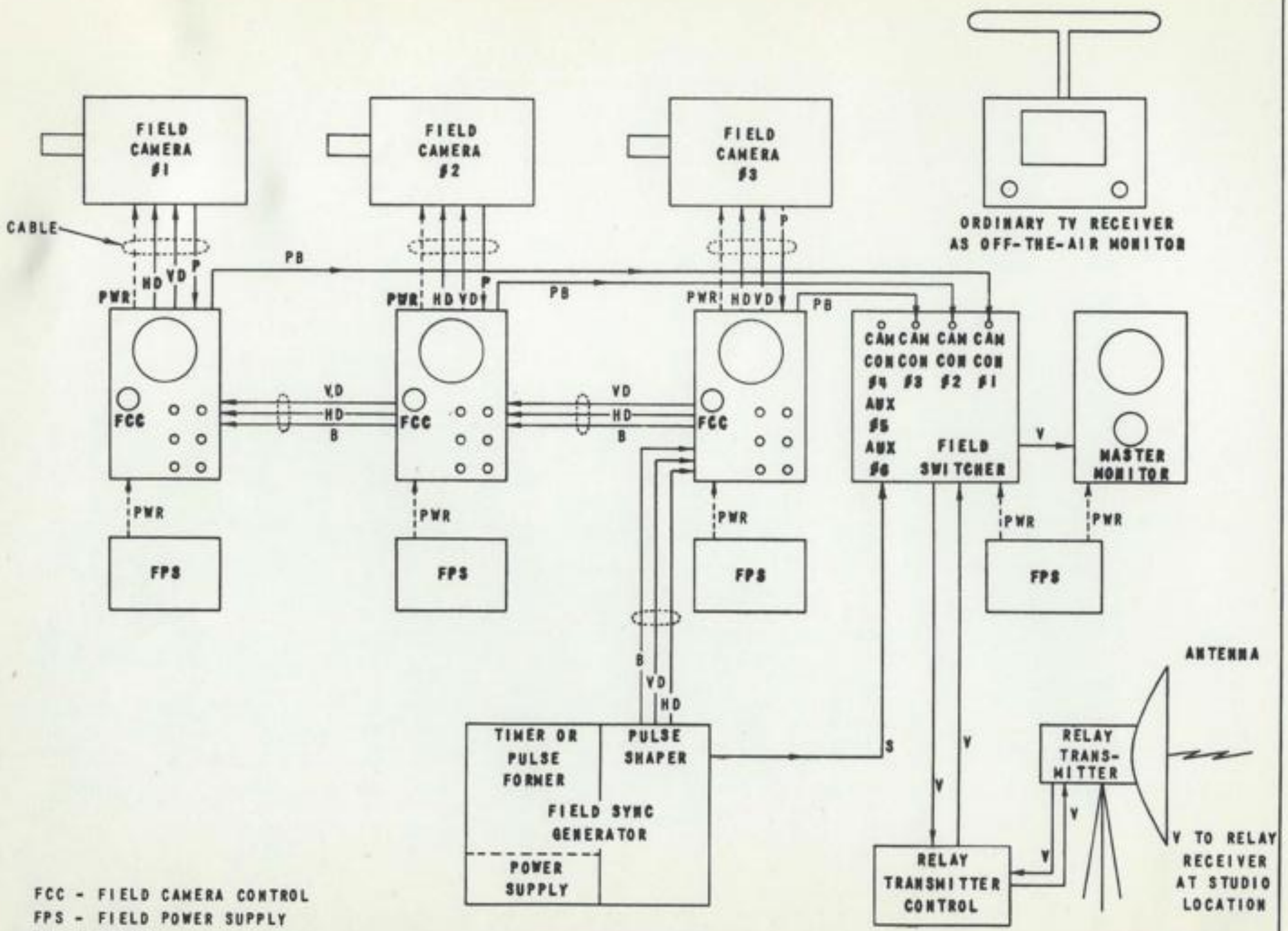


FIGURE 28

FIELD PICKUP EQUIPMENT



FCC - FIELD CAMERA CONTROL
FPS - FIELD POWER SUPPLY
PWR - POWER

FIGURE 29

BLOCK DIAGRAM OF VIDEO TRANSMITTER EMPLOYING LOW LEVEL MODULATION

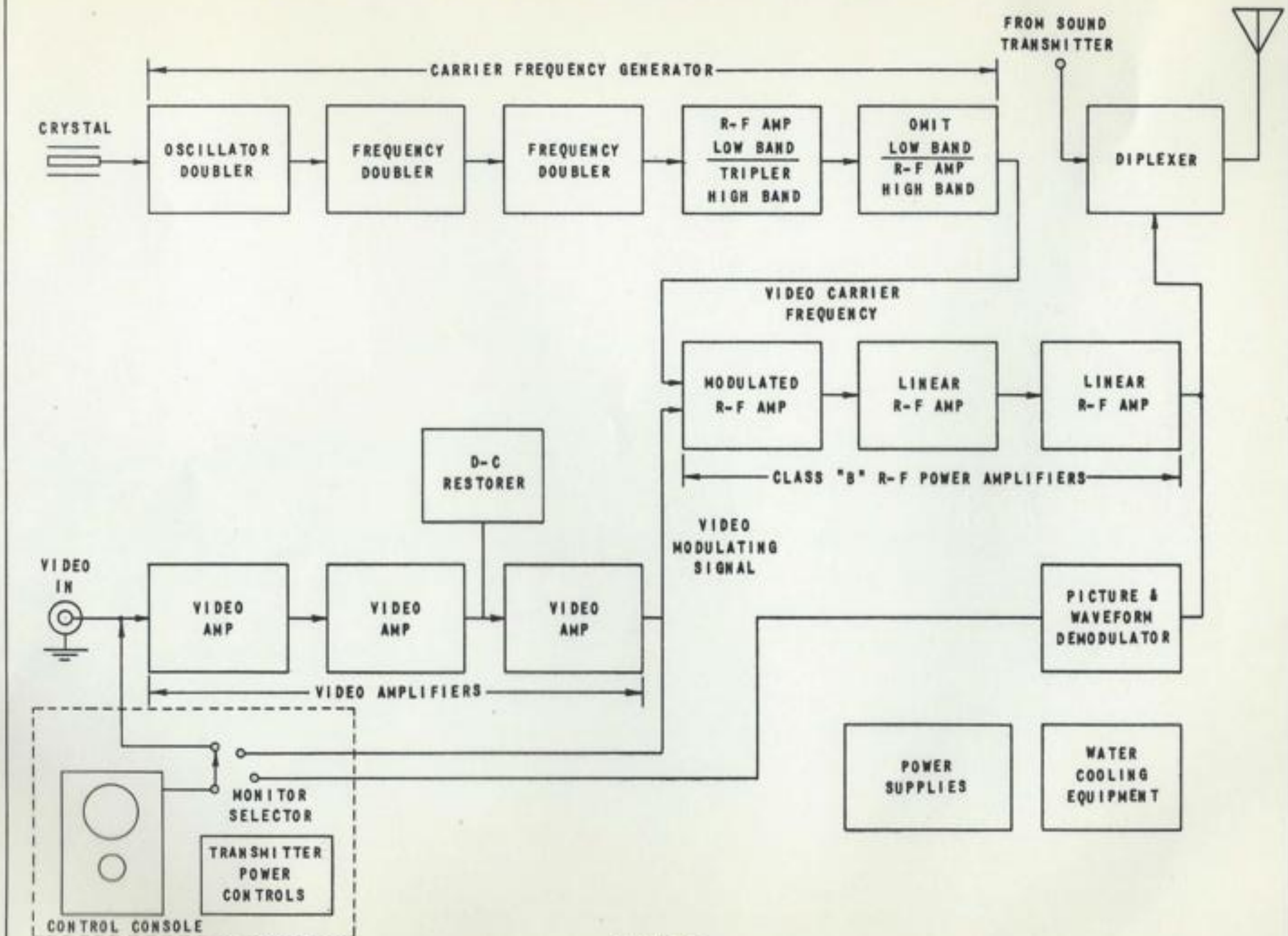


FIGURE 30

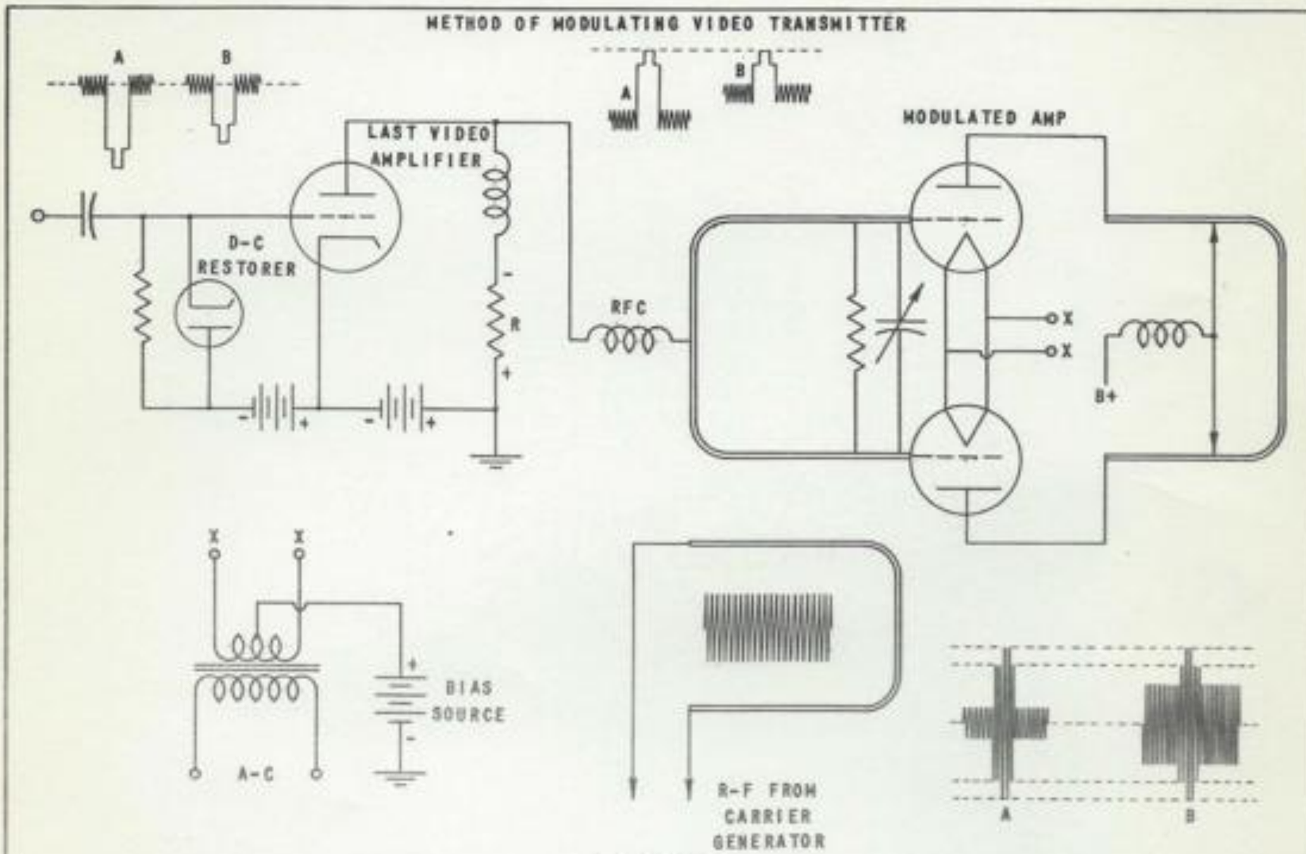


FIGURE 31

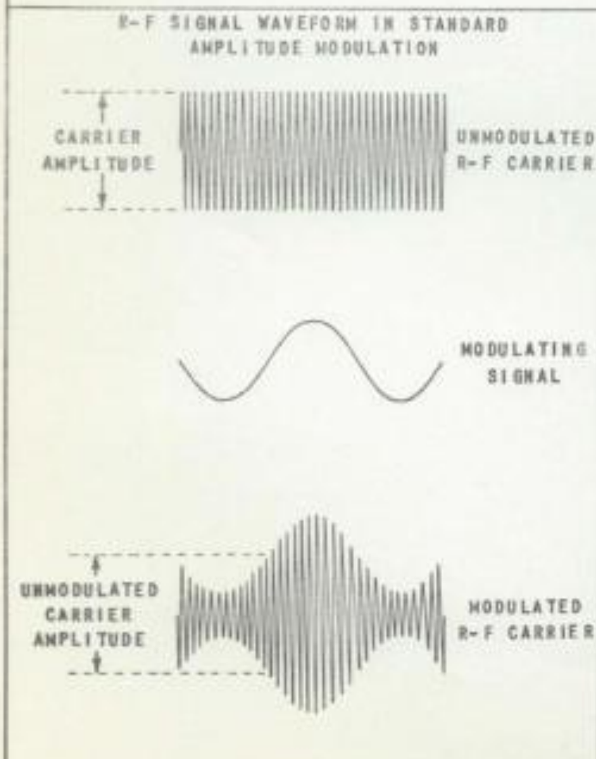


FIGURE 32

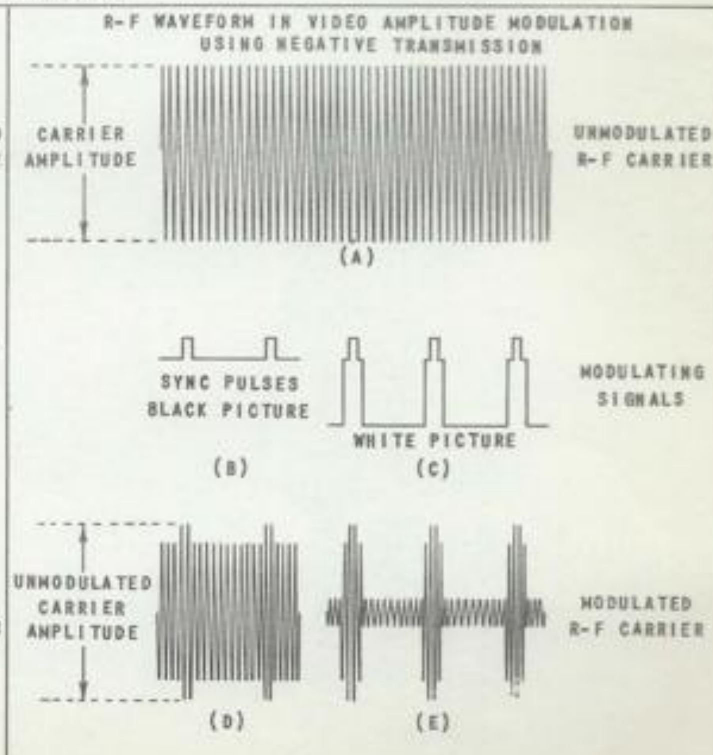


FIGURE 33

UNMODULATED CARRIER

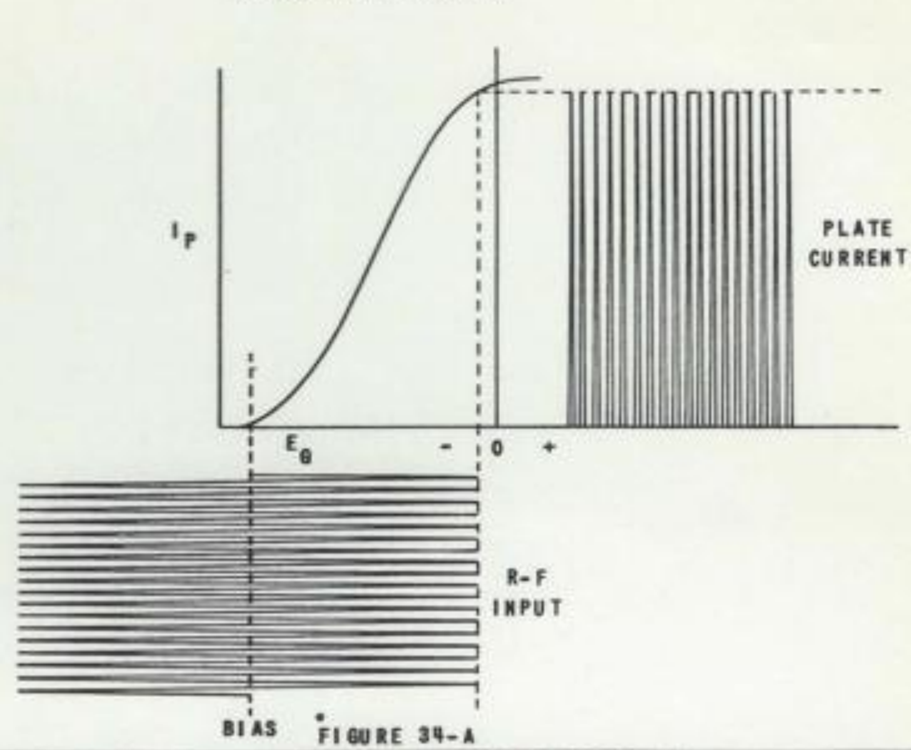


FIGURE 34-A

CARRIER MODULATED WITH WHITE PICTURE SIGNAL

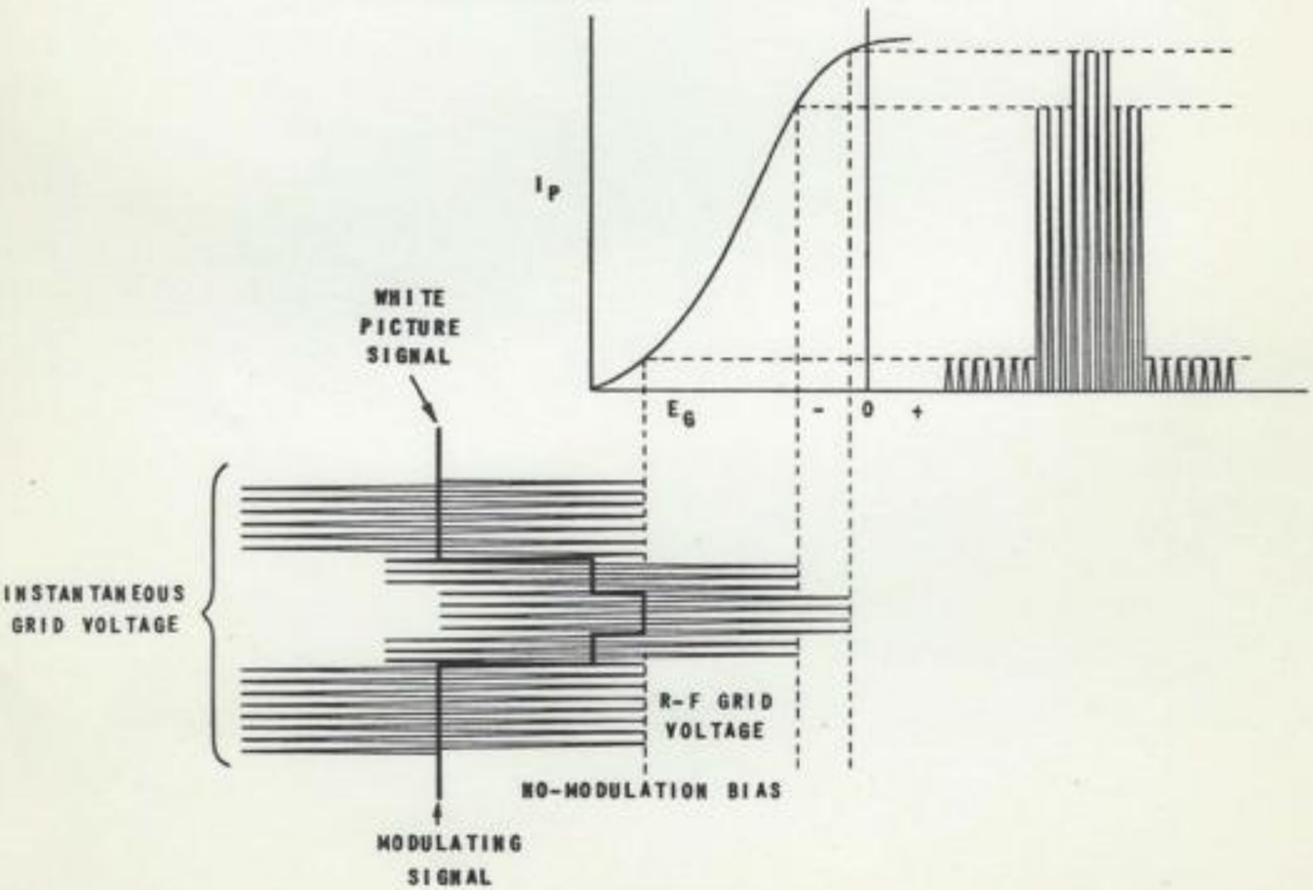


FIGURE 34-B

CARRIER MODULATED WITH BLACK PICTURE SIGNAL

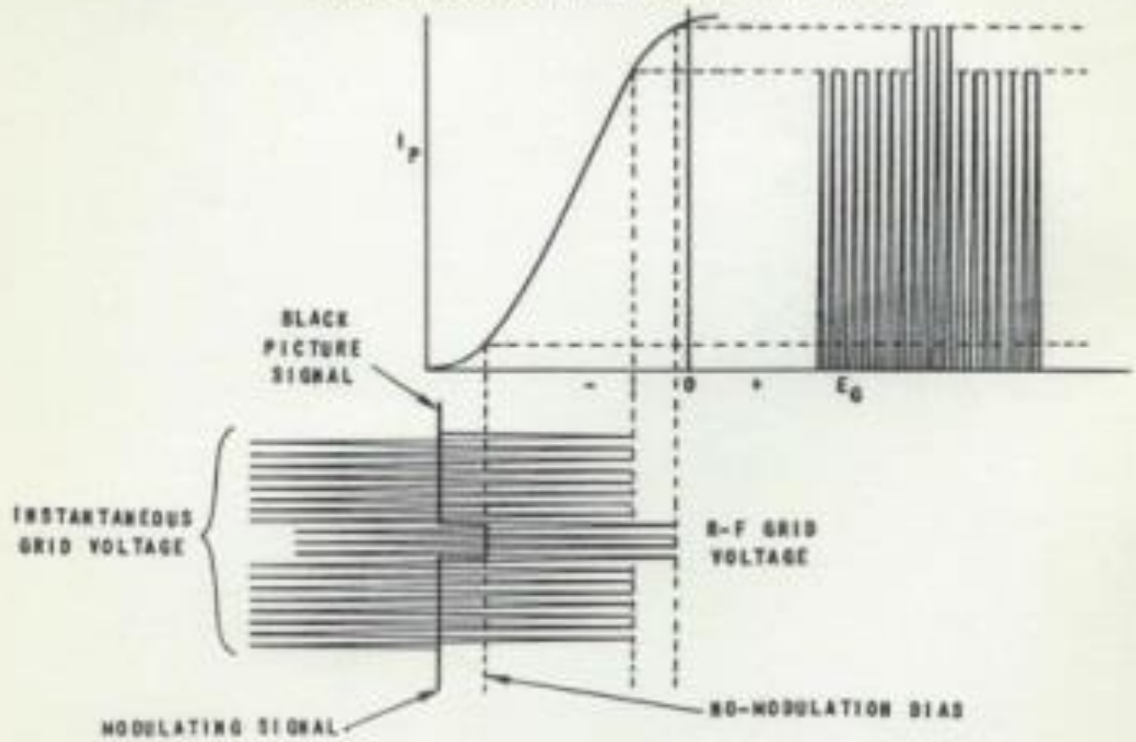


FIGURE 34-C

TRANSMITTER RESPONSE CHARACTERISTICS

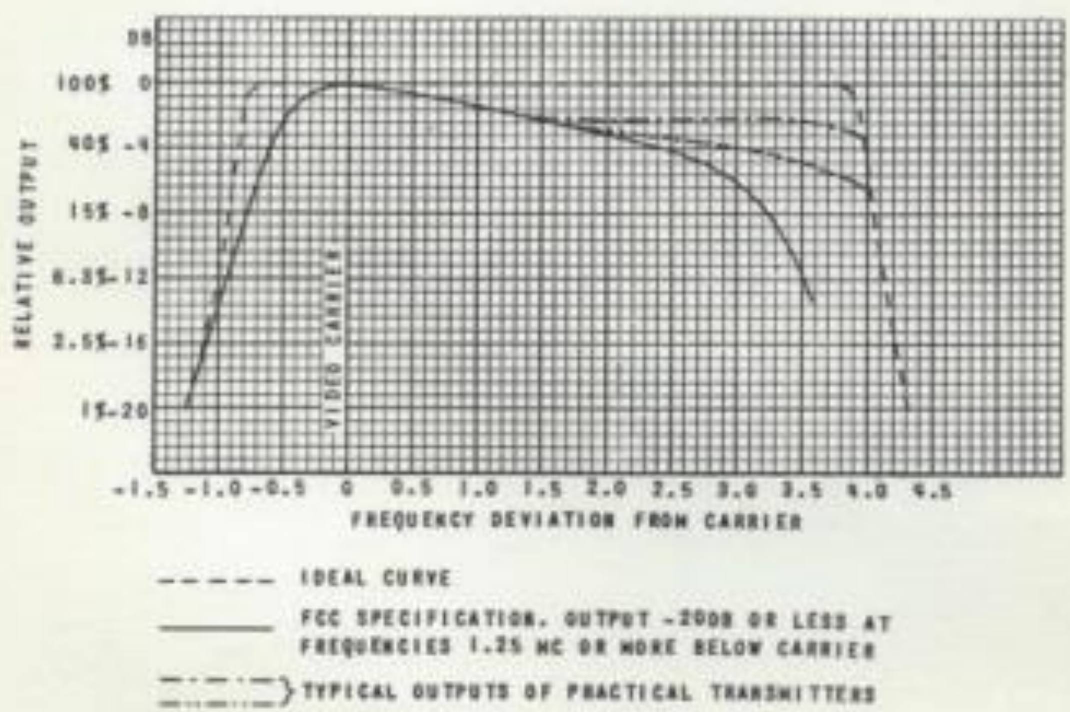


FIGURE 35

BAND PASS CHARACTERISTICS OF LINEAR R-F AMPLIFIERS

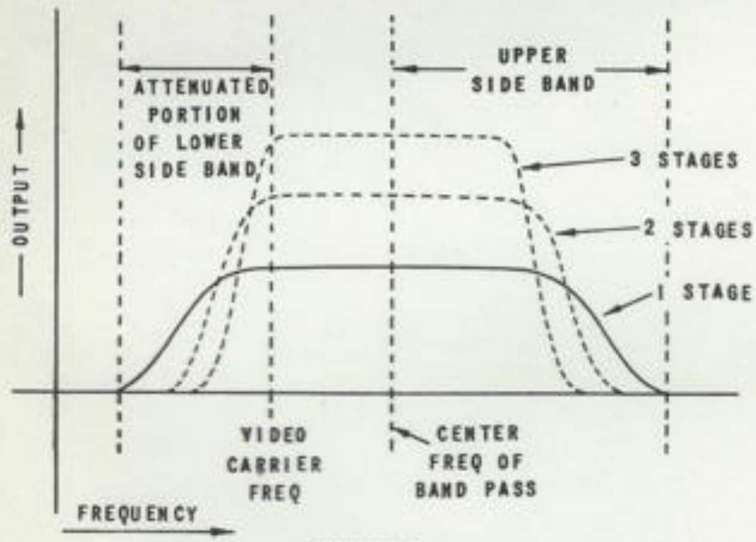


FIGURE 36

DIPLEXER

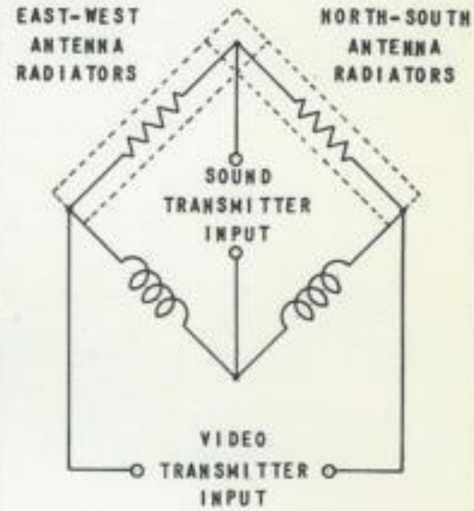
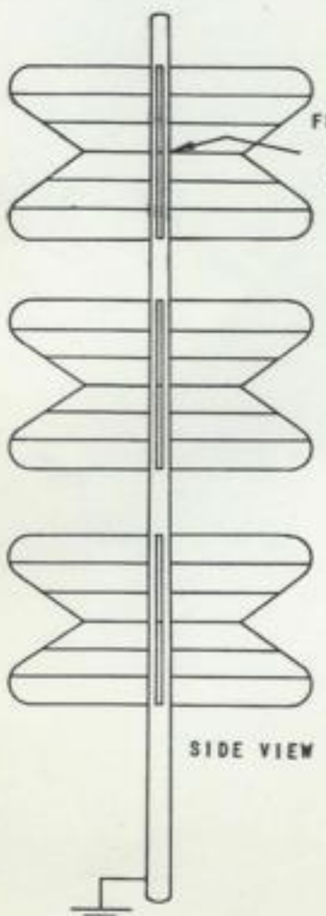


FIGURE 37

3 SECTION SUPER TURNSTILE ANTENNA



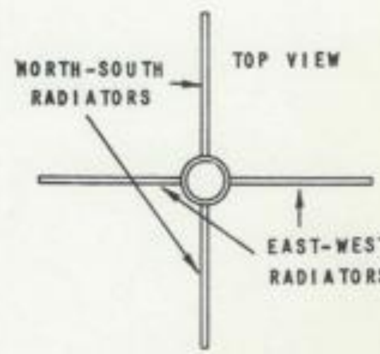


FIGURE 38

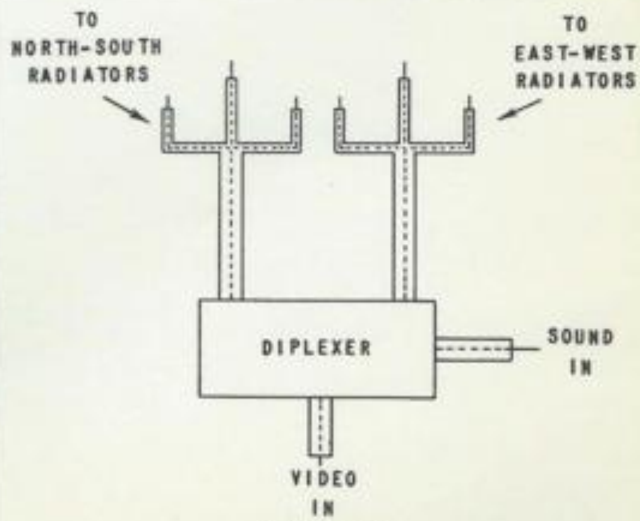


FIGURE 39

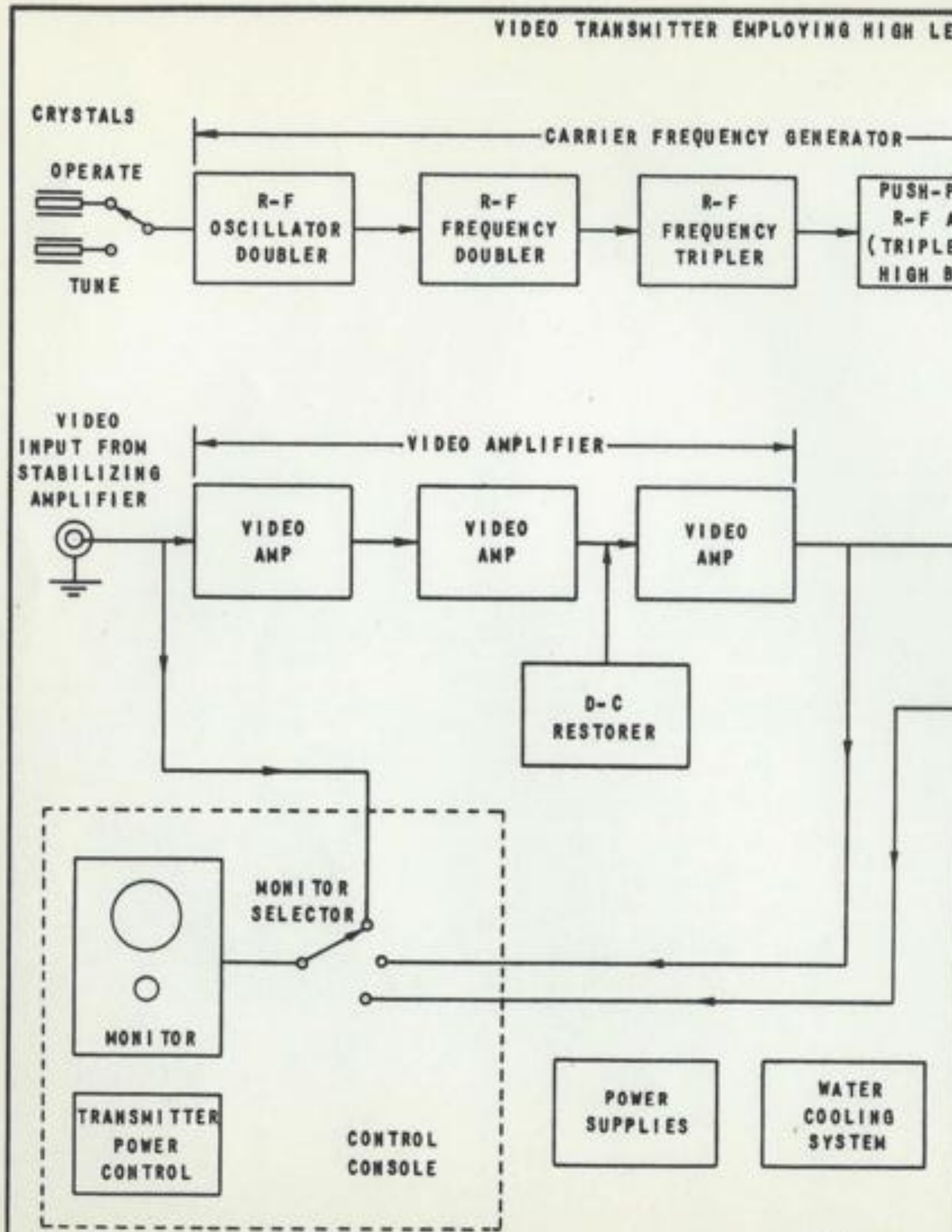


FIGURE 40

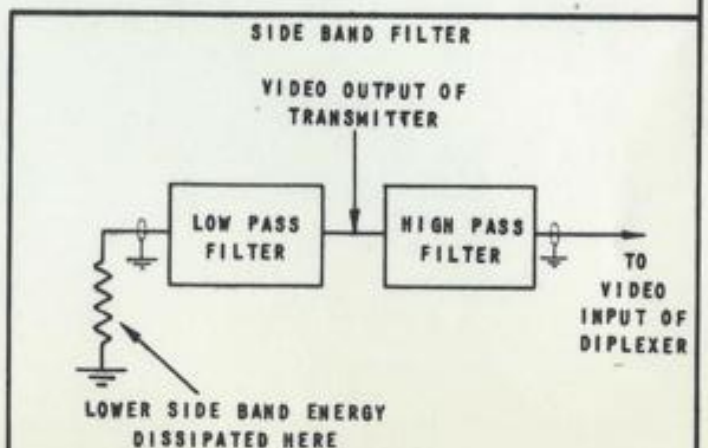


FIGURE 41