MIL-STD-188-318
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MILITARY STANDARD

SYSTEM AND SUBSYSTEM DESIGN AND ENGINEERING AND EQUIPMENT TECHNICAL STANDARDS FOR CLOSED CIRCUIT TELEVISION (CCTV) SYSTEMS

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DEPARTMENT OF DEFENSE

Washington, D.C. 20301

System and Subsystem Design and Engineering and Equipment Technical Standards for Closed Circuit Television (CCTV) Systems.

MIL-STD-188-318

1. This Military Standard is approved and mandatory for use by all Departments and Agencies of the Department of Defense in accordance with the Under Secretary of Defense (Research and Engineering) Memorandum of 16 Aug 1983 (Appendix A).

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Space and Naval Warfare Systems Command, ATTN: SPAWAR 8111, Washington, D.C. 20363-5100 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FOREWORD

1. Originally, Military Standard 188 (MIL-STD-188) covered technical standards for tactical and long haul communications, but later evolved through revisions (MIL-STD-188A, MIL-STD-188B) into a document applicable to tactical communications only (MIL-STD-188C).

2. The Defense Communications Agency (DCA) published DCA Circulars (DCAC) promulgating standards and engineering criteria applicable to the long haul Defense Communications System (DCS) and to the technical support of the National Military Command System (NMCS).

3. As a result of a Joint Chiefs of Staff (JCS) action, standards for all military communications are now being published in a MIL-STD-188 series of documents. The MIL-STD-188 series is subdivided into a MIL-STD-188-100 series covering common standards for tactical and long haul communications, a MIL-STD-188-200 series covering standards for tactical communications only, and a MIL-STD-188-300 series covering standards for long haul communications only. Emphasis is being placed on developing common standards for tactical and long haul communications published in the MIL-STD-188-100 series.

4. This document contains technical standards and design objectives for U.S. standard 525 line closed circuit television (CCTV) systems and subsystems.

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ACKNOWLEDGEMENT

The Electronic Industries Association (EIA) is the copyright holder of material used in this standard. Their permission to reproduce portions of EIA Standard RS-170 is gratefully acknowledged. This EIA standard is referenced in Section 2 and may be purchased from the address given on page 2.

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FIGURES

TABLE

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1. SCOPE

1.1 Purpose. The purpose of this document is to establish system and subsystem design and engineering and equipment technical standards for closed circuit television (CCTV) systems.

This standard addresses the non-tactical, non-weapon systems related television specified in a through f:

a. Command, Control, Communications and Intelligence systems
b. Security systems
c. Hospital systems
d. Entertainment systems
e. Education and Training systems
f. Weather Briefing systems

1.2 Application. This document is applicable to the design and development of new systems, subsystems, and assemblages used in CCTV applications. It is not intended that the standards contained herein inhibit advances in CCTV technology, nor that existing CCTV facilities be immediately converted to comply with the standards contained in this document. New facilities and those undergoing major modification or rehabilitation shall comply with standards contained herein subject to applicable requirements of current procurement regulations. This standard is mandatory for use (see APPENDIX A).

1.3 Objectives. The main objectives of this document are to provide a degree of system performance acceptable to the majority of users of CCTV systems, to ensure compatibility and interoperability of equipment, subsystems, and systems consistent with military requirements, and to achieve the necessary degree of performance and interoperation in the most economical way.

1.4 System/subsystem standards and design objectives. If the word "shall" is used in connection with a parameter value, that value is a mandatory standard. If the word "should" is used, the value is a design objective.

2. REFERENCE DOCUMENTS

2.1 Issues of documents The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of this standard to the extent specified herein.

STANDARDS

FEDERAL

FED-STD-359	Tape, Video, Magnetic, Recording, Formats for
FED-STD-1037	Glossary of Telecommunication Terms

MILITARY

MIL-STD-1680	Installation Criteria for Shipboard Secure Electrical Information Processing Systems (U)

HANDBOOKS

MILITARY

MIL-HDBK-419	Grounding, Bonding, and Shielding for Electric Equipments and Facilities

(Copies of standards and handbooks required by contractors in connection with a specific procurement function should be obtained from the procuring activity or as directed by the contracting officer.)

PUBLICATIONS

NATIONAL SECURITY AGENCY

NACSIM 5100A	Compromising Emanations Laboratory Test Requirements, Electromagnetics (U)
NACSIM 5203	Guidelines for Facility Design and RED/BLACK Installation (U)

(Application for copies should be addressed to Director, National Security Agency, Fort George G. Meade, MD 20755.)

2.2 Other publications. The following forms a part of this document to the extent specified herein. Unless otherwise indicated, the issue in effect on the date of invitation for bids or request for proposal shall apply.

ELECTRONIC INDUSTRIES ASSOCIATION

EIA RS 170-57	Electrical Performance Standards - Monochrome Television Studio Facilities

(Application for copies should be addressed to EIA, 2001 Eye Street, N.W., Washington, DC 20006, telephone (202) 457-4900.)

FEDERAL COMMUNICATIONS COMMISSION

FCC RULES, Part 73	Radio Broadcast Services of March 1980

(Copies required by contractors in connection with a specific procurement function should be obtained from the procuring activity or as directed by the contracting officer.)

3. DEFINITIONS

3.1 Definition of terms. The following Closed Circuit Television terms are used herein. Acronyms and abbreviations are specified in APPENDIX B.

3.1.1 Average picture level (APL). A time average of the voltage waveform of the video signal.

3.1.2 B-Y signal. A signal derived from the blue sensitive pickup tube in a color television camera, with the luminance signal subtracted. This may also be called the blue color-difference signal.

3.1.3 Chrominance. That quality of a light stimulus which describes its color. This term is also used to mean the electrical signal or signals which describe only the color of some element in a video signal stream. For example, the combination of the three color difference signals R-Y, B-Y, and G-Y may be called collectively the Chrominance signal. Also, this term is used to mean the modulated subcarrier signal, in which the relative phase carries the Hue and the amplitude carries the Saturation information.

3.1.4 Equiband. A characteristic of certain circuits designed to demodulate the chrominance subcarrier, in which the various baseband color difference signals derived from the demodulation are given equal bandwidth.

3.1.5 Gamma and gamma correction. Gamma means the slope of the characteristic curve of a camera or of a kinescope. Gamma correction refers to a means of altering the shape of the camera's characteristic curve so as to make the system's response more nearly linear.

3.1.6 Geometric distortion. A measure of the degree to which a television system displaces objects in the reproduced scene relative to their positions in the original scene.

3.1.7 G-Y signal. A signal derived from the green sensitive pickup tube in a color television camera, with the luminance signal subtracted. This may also be called the green color-difference signal.

3.1.8 IRE unit. An arbitrary scale measuring unit used in the measurement of television waveform voltages. Relationship to volts is: 140 IRE units equals 1.00 volt.

3.1.9 I signal. The wideband color-difference signal, derived by a weighted summation of the B-Y and R-Y signals, and corresponding to the color-difference axis for which the human eye has greater resolving power.

3.1.10 Kinescope. The cathode ray tube used for displaying the output of a television system's video.

3.1.11 Luminance. The brightness of objects in the scene. In monochrome television, the video signal. In color television, the weighted sum of the red, green, and blue signal voltages which represents the relative brightness of objects in the scene, irrespective of color.

3.1.12 Monochromatic. Light which consists entirely of one wavelength. A maximally saturated color.

3.1.13 Monochrome. A process or system which presents the brightness values of a scene in white light, ranging from white through shades of grey to black.

3.1.14 Q signal. The narrowband color-difference signal, derived by a weighted summation of the B-Y and R-Y signals, and corresponding to the color-difference axis for which the eye has approximately its least resolving power.

3.1.15 RGB. A system of color reproduction in which all of the primary colors are passed along on separate circuits of equal bandwidth.

3.1.16 Resolution. The ability of a system to permit the observer to detect the presence of two separated elements in the scene.

3.1.17 R-Y signal. A signal derived from the red sensitive pickup tube in a color television camera, with the luminance signal subtracted. This may also be called the red color-difference signal.

3.1.18 Shading correction. A means for correcting evenness of response over the area of the picture in camera pickup tubes.

3.1.19 Triad. A group of three spots of phosphor, arranged in an equilateral triangle. The three phosphor spots emit light in the three primary colors red, green, and blue.

3.1.20 Tricolor kinescope. Any television display cathode ray tube which displays color pictures by combined outputs of three primary color phosphors, in red, green and blue.

3.1.21 Y signal. In color television systems, the weighted sum of the red, green, and blue pickup tubes' signals which corresponds to the relative brightness of elements in the picture only.

3.1.22 Zone 1. A circular area centered at the center of the raster, and with diameter equal to 0.8 times the height of the raster.

3.1.23 Zone 2. A circular ring concentric to zone one, extending from the outside of zone one to a circle of diameter 1.0 times the raster height.

3.1.24 Zone 3. All parts of the raster not included in Zones 1 and 2.

3.2 Other telecommunication terms. Other standard telecommunications terms used herein shall be as specified in FED-STD-1037.

4. GENERAL REQUIREMENTS

4.1 Introduction. This section of the standard will deal primarily in those requirements which are sufficiently broad so as to cover all types of closed circuit television systems. Basic principles of operation of closed circuit television systems are provided in APPENDIX C.

4.2 Basic television systems. For purposes of this standard, a basic television system shall consist of a source of analog signals in raster scanned form representing a visual stimulus, a set of equipments to process and transmit those signals over a circuit to another place, and a set of equipment to receive and display the representation of the original scene. The system may include analog audio signals associated with the visual scene. These audio signals may be sent over a separate circuit, or may be combined with the video signals on a common circuit. Two types of basic television systems are specified in a and b:

a. Baseband systems
b. Radio Frequency (RF) modulated systems

4.3 System security standards. Television systems which handle classified traffic shall be installed in a manner to protect the classified traffic from disclosure through electrical or electronic emanation of signals. Commercial equipment shall be tested and modified to provide protection in accordance with applicable standards as stated in a and b:

a. For all fixed installations, NACSIM 5100A and NACSIM 5203
b. For shipboard applications, MIL-STD-1680

Grounding, bonding and shielding for these systems shall be in accordance with MIL-HDBK-419.

4.4 Video and audio recording subsystems. The kinds of subsystems to be used for video and audio recording shall be limited to the specific types which use tape formats specified by FED-STD-359.

5. DETAILED REQUIREMENTS

5.1 Monochrome systems. All monochrome systems shall conform to EIA Standard RS-170-57, except that the 4.5 megahertz (MHz) video signal bandwidth in baseband systems may be extended to 10 MHz.

5.1.1 Synchronization requirements. The synchronizing waveforms used in monochrome systems shall conform to the requirements of the recommended synchronizing generator waveform of EIA standard RS-170-57.

NOTE: Additional tutorial is contained in APPENDIX C.

5.1.2 Camera subsystem requirements. Cameras in the monochrome system shall produce video waveforms which conform to the requirements of EIA Standard RS-170-57. Three major types of monochrome cameras are specified in a through c:

a. Type I - Standard monochrome cameras
b. Type II - Low light level cameras
c. Type III - Intensified low light level cameras

5.1.2.1 Type I camera requirements. The minimum essential requirements for a Type I camera shall be as specified in 5.1.2.1.1 through 5.1.2.1.7.

5.1.2.1.1 Sensitivity. The camera shall produce a 100 IRE unit output with a minimum face-plate illumination of 5 x 10^{-2} foot-candles.

5.1.2.1.2 Signal-to-noise ratio. The camera shall show a signal-to-noise ratio of not less than 40 decibels (dB) when preset at the sensitivity specified in 5.1.2.1.1 and measured at 1.0 gamma.

5.1.2.1.3 Resolution. The camera shall provide a horizontal resolution of at least 750 lines in Zone 1 with automatic gain and bandwidth at the sensitivity specified in 5.1.2.1.1.

5.1.2.1.4 Grey scale. The camera shall be capable of producing at least ten shades of grey at the minimum sensitivity specified in 5.1.2.1.1 and at 1.0 gamma, using the EIA standard grey scale chart.

5.1.2.1.5 Bandwidth. The camera bandwidth shall be a minimum of 10 MHz +0, -0.5dB.

5.1.2.1.6 Gamma. The camera shall provide gamma selections of not less than 1.0 and 0.7.

5.1.2.1.7 Geometric distortion. The camera shall be accurate to within a maximum 1.5 percent geometric distortion in Zone 1 and to within two percent in Zones 2 and 3.

5.1.2.2 Type II camera requirements. The minimum essential characteristics for a Type II camera shall be as specified in 5.1.2.2.1 through 5.1.2.2.7.

5.1.2.2.1 Sensitivity. The camera shall produce a 100 IRE unit output with a minimum face-plate illumination of 5 x 10^{-3} foot-candles.

5.1.2.2.2 Signal-to-noise ratio. The camera shall show a signal-to-noise ratio of not less than 40 dB when preset at sensitivity specified in 5.1.2.2.1 and measured at 1.0 gamma.

5.1.2.2.3 Resolution. The camera shall provide a horizontal resolution of at least 700 lines in Zone 1 with automatic gain and bandwidth at the sensitivity specified in 5.1.2.2.1.

5.1.2.2.4 Grey scale. The camera shall be capable of producing at least ten shades of grey at the minimum sensitivity specified in 5.1.2.2.1 and at 1.0 gamma, using the EIA standard grey scale chart.

5.1.2.2.5 Bandwidth. The camera bandwidth shall be a minimum of 10 MHz +0, -0.5dB.

5.1.2.2.6 Gamma. The camera shall provide gamma selections of not less than 1.0 and 0.7.

5.1.2.2.7 Geometric distortion. The camera shall be accurate to within a maximum 1.5 percent geometric distortion in Zone 1 and to within two percent in Zones 2 and 3.

5.1.2.3 Type III camera requirements. The minimum essential characteristics for a Type III camera shall be as specified in 5.1.2.3.1 through 5.1.2.3.7.

5.1.2.3.1 Sensitivity. The camera shall produce a 100 IRE unit output with a minimum face-plate illumination of 8 x 10^{-5} foot-candles.

5.1.2.3.2 Signal-to-noise ratio. The camera shall show a signal-to-noise ratio of not less than 40 dB when preset at the sensitivity specified in 5.2.3.1 and measured at 1.0 gamma.

5.1.2.3.3 Resolution. The camera shall provide a horizontal resolution of at least 500 lines in Zone 1 with automatic gain and bandwidth at the sensitivity specified in 5.1.2.3.1.

5.1.2.3.4 Grey scale. The camera shall be capable of producing at least ten shades of grey at the minimum sensitivity specified in 5.1.2.3.1 and at 1.0 gamma, using the EIA standard grey scale chart.

5.1.2.3.5 Bandwidth. The camera bandwidth shall be a minimum of 8 MHz +0, -0.5 dB.

5.1.2.3.6 Gamma. The camera shall provide gamma selections of 1.0 and 0.7.

5.1.2.3.7 Geometric distortion. The camera shall be accurate to within one percent distortion in Zone 1, and within three percent in Zones 2 and 3.

5.1.3 Video switching subsystem standards. The switching subsystem may vary considerably in configuration and requirements. The treatment of switchers shall be broken into the types specified in a through e:

a. Type I - Program/effects switchers
b. Type II - Digital remote/local controlled distribution
c. Type III - Local controlled distribution
d. Type IV - Engineering/bridging switchers
e. Type V - Passive switchers

5.1.3.1 Type I switcher requirements. Basic program switching requirements shall be as specified in 5.1.3.1.1 through 5.1.3.1.1.9. If optional features are required for particular applications, addition of these options shall not change the performance requirements for the basic program switching capability. (Also, see APPENDIX D.)

5.1.3.1.1 Basic switcher requirements. The program switcher shall provide the means to select from a number of video inputs and route the selected input to either of at least two output busses. Selection of an input shall cause the corresponding crosspoint switch to make the requested connection during the next available vertical interval of the video waveform.

5.1.3.1.1.1 Inputs. Inputs for video, sync, and subcarrier shall all be of the bridging type, on a 75 ohm line, with provisions for loop through operation. The input impedance for the bridging input shall be not less than 50,000 ohms resistive. Input levels shall be as follows: Composite video, 1.0 volt in peak-to-peak (p-p), Pulse (sync and blanking) 4.0 V p-p and subcarrier 2.0 V p-p.

NOTE: Sync, subcarrier inputs and non-composite video (0.714 V p-p) may not be required, depending on the make and model, and the options selected.

5.1.3.1.1.2 Outputs. There shall be at least one output provided for each switching bus. Each output shall be composite video at 1.0 V p-p with 75 ohm line driving capability.

5.1.3.1.1.3 Frequency response. The video circuit, from any input to any output, shall have a frequency response of not less than 30 Hz to 10 MHz ±0.5 dB.

5.1.3.1.1.4 Direct current (DC) on output. No DC voltage shall appear on any open output under conditions of no signal input.

5.1.3.1.1.5 Differential gain. The differential gain at all frequencies within the video passband shall be less than one percent.

5.1.3.1.1.6 Low-frequency tilt. The low-frequency tilt superinduced on a 60 hertz (Hz) square wave input signal shall be less than one percent.

5.1.3.1.1.7 Overshoot. Overshoot superinduced on a square wave input signal having a rise time of 0.1 microsecond shall be less than one percent.

5.1.3.1.1.8 Crosstalk. Crosstalk between any two inputs, any two outputs, and any non-switched input to output shall be less than -50 dB.

5.1.3.1.1.9 Signal-to-noise ratio. Signal-to-noise ratio for a 1.0 V p-p input signal, measured at either output, shall be greater than 60 dB for the frequency band from 50 Hz to 5 MHz.

5.1.3.2 Type II switcher requirements. The overall input and output performance requirements for Type II switchers shall be as specified in 5.1.3.1.1 through 5.1.3.1.1.9 and as stated in 5.1.3.2.1 through 5.1.3.2.2.1. (Also, see APPENDIX D.)

5.1.3.2.1 Number of inputs and outputs. The number of inputs and outputs shall be determined by the application.

5.1.3.2.2 Digital control. Type II switchers shall be capable of having all crosspoint actions controlled by a digital control subsystem. As a minimum, each Type II switcher shall have a master control terminal capable of making input to output routing selections for each crosspoint in the switching matrix.

5.1.3.2.2.1 Remote control. Type II switchers shall be capable of accepting control instructions from remote stations through the digital control subsystem.

5.1.3.3 Type III switcher requirements. The requirements for Type III switchers shall be as specified in 5.1.3.2 for Type II except that no remote control shall be possible.

5.1.3.4 Type IV switcher requirements. Performance of the Type IV switcher shall be as specified in 5.1.3.1 except that there shall be only one switching bus, and one or two isolated outputs of the selected input shall be provided.

5.1.3.5 Type V switcher requirements. The Type V switcher shall provide 75 ohm termination for all unswitched input lines and shall pass the switched input unterminated to the load. Switching shall occur when activated, and shall not require synchronization to vertical interval.

5.1.4 Audio switching subsystem requirements. In many television systems, an audio system is required. This standard covers audio systems associated with television installations. Requirements specified in 5.1.4.1 through 5.1.4.3 shall serve as minimum criteria for selecting the basic audio components for these audio systems.

5.1.4.1 Audio mixers. Audio mixers shall perform as required in paragraphs 5.1.4.1.1 through 5.1.4.1.11. The number of inputs to the audio mixer shall be determined by the required audio sources in each application.

5.1.4.1.1 Input signal characteristics. Inputs to the audio mixer shall be in one of the forms specified in a through c:

a. 600 ohm balanced line, at a nominal level of 0 decibels referenced to one milliwatt (dBm)
b. Low level microphone
c. High impedance unbalanced line

5.1.4.1.2 Isolation. Each input to the audio mixer shall be isolated from any and all other inputs so that a 0 dBm input at one port shall not be present at any other input port at more than -60 dBm, at 1 kilohertz (kHz).

5.1.4.1.3 Mixing. Each input to the audio mixer shall be capable of being introduced to the mixing point through a fading device capable of varying the relative level of the input by at least 40 dB. There shall be no measurable interaction among the input faders.

5.1.4.1.4 Master level. The audio mixer shall be provided with a master level control which controls the level of the mixed output signal. This control shall have a range of not less than 40 dB.

5.1.4.1.5 Output level monitoring. The audio mixer shall be provided with a means of monitoring the output level. The monitoring device shall have a range extending at least from -20 volume units (VU) + 3 VU.

5.1.4.1.6 Frequency response. The audio mixer shall have frequency response extending from 30 Hz to 15 kHz +0, -1 dB.

5.1.4.1.7 Distortion. Total harmonic distortion for a 1 kHz input signal shall not be greater than 0.5 percent, at an output level of +10 dBm. Intermodulation distortion, for combined inputs at 50 Hz and 10 kHz, mixed 4:1; where the 50 Hz input is at 0 dBm, shall not be greater than 1.0 percent.

5.1.4.1.8 Output power. The output power level shall be adjustable at least over the range of 0 dBm to + 10 dBm. The VU meter shall be capable of calibration to a 0 VU reading for the selected output level.

5.1.4.1.9 Output line. The output line shall be capable of providing one of the forms specified in a through c:

a. 600 ohm balanced
b. 150 ohm balanced
c. High impedance unbalanced

5.1.4.1.10 Monitor output. The mixer shall be provided with a monitor output which shall provide the same audio signal as the program output line, into either a speaker or headphone or both. Level of signal on this output shall be controlled by a separate level control.

5.1.4.1.11 Signal-to-noise ratio. The audio mixer shall have a signal-to-noise ratio of not less than 65 dB, relative to 1 kHz at 0 dBm output when reference signal is injected into the lowest level input available. Hum at the power line frequency and harmonics thereof shall not be greater than -70 dBm for maximum output settings on all controls with inputs terminated.

5.1.4.2 Audio distribution switchers. Audio distribution switchers shall perform as specified in 5.1.4.2.1 through 5.1.4.2.5. The audio switcher shall be capable of operating in two basic modes: Audio follow video and audio breakaway. In the first of these, the audio cross-points shall be made connections when the corresponding video crosspoint is activated. In the second mode, the control mechanism shall make possible the selection of audio sources independent of the video selected.

5.1.4.2.1 Overall performance. The requirements for input signal characteristics, isolation, frequency response, distortion, output power, output line and signal-to-noise ratio shall be as specified on 5.1.4.1.

5.1.4.2.2 Inputs and outputs. The number of inputs and outputs shall be determined by the application.

5.1.4.2.3 Switching noise. Switching noise when crosspoints are activated or deactivated shall not be greater than -60 dBm.

5.1.4.2.4 Gain uniformity. The gain of the audio distribution switcher shall be unity for any combination of input to output connections, within ±1 dB.

5.1.4.2.5 Audio distribution switcher crosstalk. Crosstalk between any input line and any output line not selected to that input shall be less than -70 dB.

5.1.4.3 Audio talkback systems. An audio talkback system shall provide the capability for any output station on the distribution switcher to send audio signals back to the audio source to which that output station is connected. Performance requirements for the talkback system shall be as specified in 5.1.4.2.

5.1.5 Monitors. Monitors in monochrome systems shall be of either type specified in a or b:

a. Type I - Control room monitors
b. Type II - Distribution monitors

The performance requirements for the two types are different. Type I monitors shall perform as specified in 5.1.5.1 through 5.1.5.1.5. Type II monitors shall perform as specified in paragraphs 5.1.5.2 through 5.1.5.2.5.

5.1.5.1 Type I monitors. Type I monitors should be used principally for picture quality control and input monitoring in the central control facility. These monitors are also used in color systems, but they are covered here because they are in fact monochrome devices.

5.1.5.1.1 Picture sizes. These monitors are normally mounted in standard 19 inch racks, and viewed at close distance. Their diagonal picture size shall be not less than four inches.

5.1.5.1.2 Underscan. Type I monitors shall be capable of being operated with sufficient underscan so that all parts of each active line in the raster shall be visible.

5.1.5.1.3 Resolution. Type I monitors shall have a horizontal resolution of not less than 700 Television (TV) lines, at 50 foot-lamberts brightness, within Zone 1.

5.1.5.1.4 Geometry. No point in the active raster area shall deviate from its correct position by more than two percent of raster height.

5.1.5.1.5 Grey scale. The monitor shall reproduce no less than ten discernible shades of grey.

5.1.5.2 Type II monitors. Distribution monitors shall have the minimum essential requirements specified in 5.1.5.2.1 through 5.1.5.2.5.

5.1.5.2.1 Picture sizes. Picture size for Type II monitors shall be determined as required by the application.

5.1.5.2.2 Underscan. Underscan operation may be required for Type II monitors if necessary for the application.

5.1.5.2.3 Resolution. Type II monitors shall have a horizontal resolution of not less than 450 TV lines, at 50 foot lamberts brightness.

5.1.5.2.4 Geometry. No point in the active raster shall deviate from its correct position by more than two percent of raster height.

5.1.5.2.5 Grey scale. The monitor shall reproduce not less than ten discernible shades of grey.

5.1.5.3 Waveform monitors. Waveform monitors shall be used as a signal quality control device in all control or master switching centers for both monochrome and color CCTV systems. Waveform monitors shall be capable of synchronizing at both horizontal and vertical rates, and shall provide capability to expand the time scale of their displays.

5.1.6 Monochrome character generators. The minimum performance requirements for monochrome character generators shall be as specified in paragraphs 5.1.6.1 through 5.1.6.4.

5.1.6.1 Font. Characters shall be formed from either dot matrix or line segments, in at least two sizes of upper case characters. Style shall be simple block letters.

5.1.6.2 Mixing or keying. The character generator shall be capable of either mixing or keying its characters with input RS 170-57 monochrome video.

5.1.6.3 Storage. The character generator shall provide internal storage for at least one page of characters.

5.1.6.4 Page content. A page of characters shall consist of not less than ten nor more than twenty lines of characters. Each line shall consist of not less than sixteen nor more than forty characters and spaces.

5.1.7 System resolution. The overall monochrome system shall have a minimum resolution of 450 lines in the horizontal direction, and 350 lines in the vertical direction. System resolution is measured in the manner prescribed by EIA Standard RS-170-57, using the camera as the input for the resolution test chart, and using a Type II monitor as the output device upon which resolution is measured.

5.1.8 System signal-to-noise. The system signal-to-noise ratio, measured at the output of the distribution switcher, and using 60-foot candles illumination on a 60 percent reflectance Munsell white surface, shall not be less than 42 dB. (Recommended illumination color temperature is 3150 degrees Kelvin (K)).

5.2 National Television System Committee (NTSC) color systems. Color systems shall use the methodology and shall comply with the signal standards established for compatible color broadcasting in the United States by the NTSC. (See APPENDIX C). The vital salient features of the signal standards are specified in APPENDIX C.

5.2.1 Synchronization requirements. The synchronization standards for NTSC color systems are similar to the standards for monochrome systems (RS-170-57) except for the following: The base line rate, field rate, and frame rate are different and the color subcarrier reference signal (color burst) is added to the back porch of the horizontal sync pulse. The horizontal scanning line rate shall be 15,734.264 ±0.047 lines per second.

The field rate shall be 59.94 fields per second, and the frame rate shall be 29.97 frames per second. The subcarrier frequency shall be 3.579545 MHz ±10 Hz. Rate of change for the subcarrier shall not be greater than 0.1 Hz per second. The horizontal and vertical synchronizing signals shall be derived from the subcarrier by the relationships:

$$\text{Line rate} = \frac{3.579545 \text{ MHz} \times 2}{455} = 15{,}734.264 \text{ Hz}$$

$$\text{Field rate} = \frac{15{,}734.264 \text{ Hz}}{262.5} = 59.94 \text{ Hz}$$

$$\text{Frame rate} = \frac{15{,}734.264 \text{ Hz}}{525} = 29.97 \text{ Hz}$$

Through the remainder of this standard, the subcarrier will be referred to by its nominal value of 3.58 MHz, and the line rate for color systems will be referred to by its nominal value of 15,734 Hz. The frame and field rates will be treated as 30 and 60 Hz, respectively. (This rounding of values is for convenience only). The required rates for actually operating a system shall be the exact rates and tolerance given above.

5.2.2 Camera subsystem requirements. The requirements for color cameras are divided into two separate parts, dealing with single tube and three tube cameras as specified in 5.2.2.1 through 5.2.2.2.3.6.

5.2.2.1 Single tube color cameras. The required minimum characteristics for single tube cameras shall be as specified in 5.2.2.1 through 5.2.2.1.6.

5.2.2.1.1 Synchronization. Single tube cameras shall be capable of external and internal synchronization. Internal synchronization shall meet the NTSC tolerances specified in 5.2.1.

5.2.2.1.2 Resolution. Single tube cameras shall have a minimum horizontal resolution of 300 TV lines.

5.2.2.1.3 Sensitivity. Single tube cameras shall produce a 100 IRE unit video output with 100 foot-candles scene illumination on an EIA grey scale test chart, at f 4 lens aperture.

5.2.2.1.4 Signal-to-noise. Single tube cameras shall have a minimum signal-to-noise ratio of 40 dB when preset to the sensitivity specified in 5.2.2.1.3.

5.2.2.1.5 Video output. Video output from the single tube color camera shall be standard NTSC, 1 volt p-p, sync negative, 75 ohms unbalanced.

5.2.2.1.6 White balance. The single tube camera shall have a white balance control capable of handling light sources over the range of 2850 through 6500 degrees K. White balance shall be achieved using a white test object.

5.2.2.2 Three tube color cameras. Three major types are as specified in a through c:

a. Type I - Broadcast Studio Camera
b. Type II - Broadcast Electronic News Gathering (ENG) camera
c. Type III - Miniature Industrial Camera

5.2.2.2.1 Type I color cameras requirements. Type I cameras shall be full broadcast quality studio cameras. The minimum essential characteristics shall be as specified in 5.2.2.2.1.1 through 5.2.2.2.1.10.

5.2.2.2.1.1 Resolution. Resolution shall be at least 400 TV lines per picture height at 100 percent modulation depth for the luminance signal with aperture correction, and not less than 600 lines at 30 percent modulation depth. Resolution shall be measured within Zone 1.

5.2.2.2.1.2 Registration. Registration of the images from the three pickup tubes shall be within .08 percent of picture height in Zone 1, within .16 percent of picture height in Zone 2, and within .30 percent of picture height in Zone 3.

5.2.2.2.1.3 Sensitivity. The camera shall produce a 100 IRE unit output at f 2.8 from a 125 foot-candle incident light on a 60 percent reflectance Munsell white surface where illuminant color temperature is 3200 degrees K.

5.2.2.2.1.4 Signal-to-noise ratio. The camera shall show a signal-to-noise ratio of not less than 51 dB, when preset to the sensitivity specified in 5.2.2.2.1.3, measured at 1.0 gamma and without aperture correction.

5.2.2.2.1.5 Picture geometry. Geometry of the raster shall be accurate to within 0.5 percent in Zone 1, within 1.0 percent in Zone 2, and within two percent in Zone 3.

5.2.2.2.1.6 Shading correction. The camera shall have correction circuits to provide both sawtooth and parabolic corrections in both horizontal and vertical axes.

5.2.2.2.1.7 Contrast compression. The camera shall provide means to stretch the contrast between shades of grey at the black end of the video range. Stretch shall be continuously adjustable over the range of 1:1 to 4:1 as measured on the darkest step of the EIA Grey Scale chart.

5.2.2.2.1.8 Interphone. The camera head shall provide for a plug-in interphone cable of bringing at least one channel of audio to and from the camera operator's headset.

5.2.2.2.1.9 Gamma. The camera shall provide a means of controlling gamma over the range of 0.5 to 1.

5.2.2.2.1.10 Synchronization. Type I cameras shall be capable of operation with external synchronization.

5.2.2.2.2 Type II color camera requirements. Type II cameras shall be the broadcast quality Electronic News Gathering (ENG) type. The minimum essential characteristics for a type II camera shall be as specified in 5.2.2.2.2.1 through 5.2.2.2.2.8.

5.2.2.2.2.1 Resolution. Resolution shall be at least 400 TV lines per picture height at 100 percent modulation depth for the luminance signal with aperture correction, and not less than 600 lines at 30 percent modulation depth. Resolution shall be measured within Zone 1.

5.2.2.2.2.2 Registration. Registration of the images from the three pickup tubes shall be within 0.5 percent in Zone 1, within 1.0 percent in Zone 2, and within two percent in Zone 3.

5.2.2.2.2.3 Sensitivity. The camera shall produce a 100 IRE unit output at f 2.8 from a 100 foot-candle incident light at 3200 degrees K on a 60 percent reflectance Munsell white surface.

5.2.2.2.2.4 Signal-to-noise ratio. The camera shall show a signal-to-noise ratio of not less than 48 dB, when preset to the above sensitivity, and measured at 1.0 gamma without aperture correction.

5.2.2.2.2.5 Picture geometry. Geometry of the raster shall be accurate to within 0.5 percent in Zone 1, within 1.0 percent in Zone 2, and two percent in Zone 3.

5.2.2.2.2.6 Shading correction. The camera shall have correction circuits to provide sawtooth correction in both horizontal and vertical directions, and parabola correction in the horizontal direction.

5.2.2.2.2.7 Gamma. The camera shall provide means of adjusting gamma over the range of 0.7 to 1.0, in steps not larger than 0.05.

5.2.2.2.2.8 Synchronization. Type II cameras shall be capable of operating with internal and external synchronization.

5.2.2.2.3 Type III color camera requirements. A camera meeting the minimum essential characteristics specified in 5.2.2.2.3.1 through 5.2.2.2.3.5 shall qualify as a Type III camera.

5.2.2.2.3.1 Resolution. The camera shall provide resolution of at least 400 TV lines per picture height at 80 percent modulation depth, and not less than 500 lines at 40 percent modulation depth. Resolution shall be measured in Zone 1.

5.2.2.2.3.2 Registration. The camera shall register the images from the three pickup tubes within 0.7 percent in Zone 1, to within 1.5 percent in Zone 2, and to within two percent in Zone 3.

5.2.2.2.3.3 Sensitivity. The camera shall produce a 100 IRE unit output at f 2.8 from a 100 foot-candle incident light at 3200 degrees K on a 60 percent reflectance Munsell white surface.

5.2.2.2.3.4 Signal-to-noise ratio. When preset to the sensitivity specified in 5.2.2.2.3.3, the camera shall show a signal-to-noise ratio of not less than 46 dB.

5.2.2.2.3.5 Picture geometry. Picture geometry shall be accurate within one percent in Zone 1, to within 1.5 percent in Zone 2, and to within 2.5 percent in Zone 3.

5.2.2.2.3.6 Synchronization. Type III cameras shall be capable of operating with internal and external synchronization.

5.2.3 Video switching subsystem requirements. The switching subsystem will vary considerably in configuration and requirements. For convenience, the treatment of switchers shall be broken into types specified in a through e:

a. Type I - Program/effects switchers
b. Type II - Digital remote/local controlled distribution
c. Type III - Local controlled distribution
d. Type IV - Engineering/bridging switchers
e. Type V - Passive switchers

Switchers shall perform as specified in paragraphs 5.2.3.1 through 5.2.3.5.

5.2.3.1 Type I switcher requirements. Basic program switching requirements are stated in paragraphs 5.2.3.1.1 through 5.2.3.1.1.13. If optional features are required for particular applications, addition of these options shall not change the performance requirements for the basic switching capability. (See APPENDIX D for optional features.)

5.2.3.1.1 Basic switching requirements. The program switcher shall provide the means to select from a number of video inputs and route the selected input to either of at least two output busses. Selection of an input shall cause the corresponding crosspoint switch to make the requested connection during the next available vertical interval of the video waveform.

5.2.3.1.1.1 Inputs. Inputs for video, sync, and subcarrier shall all be of the bridging type, on a 75-ohm line, with provisions for loop through operation. The input impedance for the bridging input shall be not less than 50,000 ohms resistive minimum. Input levels should be as follows: Composite video, 1.0 V p-p; Pulse (sync and blanking) 4.0 V p-p; subcarrier 2.0 V p-p.

NOTE: Sync subcarrier inputs and non-composite 0.714 V p-p video may not be required, depending on the make and model, and the options selected.

5.2.3.1.1.2 Outputs. There shall be at least one output provided for each switching bus. Each output shall be composite video at 1.0 V p-p, with 75 ohm line driving capability.

5.2.3.1.1.3 Frequency response. The video circuit, from any input to any output, shall have a frequency response of not less than 30 Hz to 10 MHz ±0.5 dB.

5.2.3.1.1.4 Differential phase. Differential phase response for the 3.58 MHz subcarrier portion of the composite video signal shall be no greater than 5 degrees between ten percent and 90 percent Average Picture Level (APL).

5.2.3.1.1.5 Delay inequality. Inequality of signal delay between the luminance and the subcarrier from any input to any output shall be less than 10 nanoseconds (ns).

5.2.3.1.1.6 Gain inequality. Inequality of gain between the luminance and subcarrier shall be less than 0.1 dB.

5.2.3.1.1.7 Crosstalk. Crosstalk between any two inputs, any two outputs, and any non-switched input to output shall be less than -50 dB, measured at the 3.58 MHz subcarrier frequency.

5.2.3.1.1.8 Signal-to-noise ratio. Signal-to-noise ratio for a 1.0 V p-p input signal, measured at either output, shall be not less than 60 dB for the frequency band from 50 Hz to 5 MHz.

5.2.3.1.1.9 Path length matching. The electrical path lengths through the switcher for all combinations of input to output shall be matched to within the equivalent of 1.0 degree of phase at the 3.58 MHz subcarrier frequency.

5.2.3.1.1.10 DC on output. No DC voltage shall appear on any open output under conditions of no signal input.

5.2.3.1.1.11 Differential gain. The differential gain at all frequencies within the video passband shall be less than one percent.

5.2.3.1.1.12 Low-frequency tilt. The low frequency tilt superinduced on a 60 Hz square wave input shall be less than one percent.

5.2.3.1.1.13 Overshoot. Overshoot superinduced on a square wave input signal having a rise-time of 0.1 microsecond shall be less than one percent.

5.2.3.2 Type II switcher requirements. The overall input and output performance requirements for Type II switchers shall be as specified in 5.2.3.1.1 through 5.2.3.1.1.13 and as stated in 5.2.3.2.1 through 5.2.3.2.2.1. (See APPENDIX D for optional features.)

5.2.3.2.1 Number of inputs and outputs. The number of inputs and outputs shall be determined by the application.

5.2.3.2.2 Digital control. Type II switchers shall be capable of having all crosspoint actions controlled by a digital control subsystem. As a minimum, each Type II switcher shall have a master control terminal capable of making input to output routing selections for each crosspoint in the switching matrix.

5.2.3.2.2.1 Remote control. Type II switchers shall be capable of accepting control instructions from remote stations through the digital control subsystem.

5.2.3.3 Type III switcher requirements. The requirements for Type III switchers shall be the same as those for Type II except that no remote control shall be possible.

5.2.3.4 Type IV switcher requirements. Performance of the Type IV switcher shall be as specified in 5.2.3.1 except that there shall be only one switching bus, and one or two isolated outputs of the selected input shall be provided.

5.2.3.5 Type V switcher requirements. The Type V switcher shall provide 75-ohm termination for all unswitched input lines and shall pass the switched input unterminated to the load. Switching shall occur when activated and shall not require synchronization to vertical interval.

5.2.4 Audio switching subsystem requirements. In many television systems, an audio system is required. This standard covers audio systems associated with television installations. Requirements specified in 5.2.4.1 through 5.2.4.3 shall serve as minimum criteria for selecting the basic audio components for these audio systems.

5.2.4.1 Audio mixers. The number of inputs to the audio mixer shall be determined by the required audio sources in each application.

5.2.4.1.1 Input signal characteristics. Inputs to the audio mixer shall be in one of the forms specified in a through c:

a. 600 ohm balanced line, at a nominal level of 0 dBm
b. Low level microphone
c. High impedance unbalanced line

5.2.4.1.2 Isolation. Each input to the audio mixer shall be isolated from any and all other inputs so that a 0 dBm input at one port shall not be present at any other input port at more than -60 dBm, at 1 kHz.

5.2.4.1.3 Mixing. Each input to the audio mixer shall be capable of being introduced to the mixing point through a fading device capable of varying the relative level of the input by at least 40 dB. There shall be no measurable interaction among the input faders.

5.2.4.1.4 Master level. The audio mixer shall be provided with a master level control which controls the level of the mixed output signal. This control shall have a range of not less than 40 dB.

5.2.4.1.5 Output level monitoring. The audio mixer shall be provided with a means of monitoring the output level. The monitoring device shall have a range extending at least from -20 VU to +3 VU.

5.2.4.1.6 Frequency response. The audio mixer shall have frequency response extending from 30 Hz to 15 kHz +0, -1 dB.

5.2.4.1.7 Distortion. Total harmonic distortion for a 1 kHz input signal shall not be greater than 0.5 percent, at an output level of +10 dBm. Intermodulation distortion, for combined inputs at 50 Hz and 10 kHz, mixed 4:1, where the 50 Hz input is at 0 dBm, shall not be greater than one percent.

5.2.4.1.8 Output power. The output power level shall be adjustable at least over the range of 0 dBm to +10 dBm. The VU meter shall be capable of calibration to a 0 VU reading for the selected output level.

5.2.4.1.9 Output line. The output line shall be capable of providing one of the forms specified in a through c:

a. 600 ohm balanced
b. 150 ohm balanced
c. High impedance unbalanced

5.2.4.1.10 Monitor output. The mixer shall be provided with a monitor output which shall provide the same audio signal as the program output line, into either a speaker or headphone or both. Level of signal on this output shall be controlled by a separate level control.

5.2.4.1.11 Signal-to-noise ratio. The audio mixer shall have a signal-to-noise ratio of not less than 65 dB, relative to 1 kHz at 0 dBm output when reference signal is injected into the lowest level input available. Hum at the power line frequency and harmonics thereof shall not be greater than -70 dBm for maximum output settings on all controls with inputs terminated.

5.2.4.2 Audio distribution switchers. The audio switcher shall be capable of operating in two basic modes: Audio follow video and audio breakaway. In the first of these, the audio crosspoints shall be made connections when the corresponding video crosspoint is activated. In the second mode, the control mechanism shall make possible the selection of audio sources independent of the video selected. Requirements for audio distribution switchers are stated in 5.2.4.2.1 through 5.2.4.2.5.

5.2.4.2.1 Overall performance. The requirements for input signal characteristics, isolation, frequency response, distortion, output power, output line and signal-to-noise ratio shall be as specified in 5.2.4.1.

5.2.4.2.2 Inputs and outputs. The number of inputs and outputs shall be determined by the application.

5.2.4.2.3 Switching noise. Switching noise when crosspoints are activated or deactivated shall not be greater than -60 dBm.

5.2.4.2.4 Gain uniformity. The gain of the audio distribution switcher shall be unity for any combination of input to output connections, within ±1 dB.

5.2.4.2.5 Crosstalk. Crosstalk between any input line and any output line not selected to that input shall be less than -70 dB.

5.2.4.3 Audio talkback systems. An audio talkback system shall provide the capability for any output station on the distribution switcher to send audio signals back to the audio source to which that output station is connected. Performance characteristics for the talkback system shall be as specified in 5.2.4.2.

5.2.5 Modulated RF systems. Modulated RF systems shall be used for unclassified or encrypted traffic only. They may be used for distribution of multi-channel entertainment and training materials originating from videotape or videocassette sources.

5.2.5.1 Modulators. Modulators used in RF distribution systems shall accept standard NTSC video from a 75 ohm line and standard television audio from either a 600 ohm balanced line or as a 4.5 MHz modulated subcarrier, and shall produce modulated RF signals in accordance with the Transmission standards paragraph of FCC Rules, Part 73.

5.2.6 Color monitor subsystem standards. The studio monitor shall have seven types of monitors covered herein as specified in a through g:

a. Type I: Studio monitors
b. Type II: Color match monitors
c. Type III: High resolution monitors
d. Type IV: Receiver/monitors
e. Type V: Modified Receiver/monitors
f. Type VI: Receivers
g. Type VII: Large screen projectors
h. Chrominance vector monitors

5.2.6.1 Type I monitor requirements. The Type I monitor shall be used in the central control station of a system, and shall serve as the final quality control check on the video signal being sent to the consumers on the system. This monitor should be set up with its raster in a normal overscan, so that it serves as a final check on picture composition. It shall conform to the requirements specified in 5.2.6.1.1 through 5.2.6.1.5.

5.2.6.1.1 Brightness. The studio monitor shall have a maximum highlight brightness of not less than 25 foot-lamberts.

5.2.6.1.2 Resolution. The studio monitor shall have a minimum horizontal resolution of not less than 350 lines, for luminance in Zone 1. Resolution in Zone 2 shall be not less than 280 lines.

5.2.6.1.3 Contrast. At maximum brightness, the studio monitor shall have a contrast ratio of not less than 40:1.

5.2.6.1.4 Color rendition. The studio monitor, where possible, shall use the same type phosphors as the Type IV monitors.

5.2.6.1.5 Video input. The studio monitor shall accept the standard NTSC composite video, 1.0 V p-p. It shall provide means for terminating the video signal in 75 ohms.

5.2.6.2 Type II (color match) monitor requirements. The color match monitor shall conform to the requirements specified in 5.2.6.2.1 through 5.2.6.2.4.

5.2.6.2.1 Brightness. The color-match monitor shall have a minimum highlight brightness of not less than 20 foot lamberts. The brightness control shall have a detented factory calibrated position for color matching purposes.

5.2.6.2.2 Resolution. The color-match monitor shall have a minimum horizontal resolution not less than 300 lines for luminance in Zone 1.

5.2.6.2.3 Contrast. At maximum brightness, the color-match monitor shall have a contrast of not less than 50:1. The contrast control shall have a detent position factory calibrated to optimum setting for color matching purposes.

5.2.6.2.4 Color rendition. The color-match monitor shall have the normal controls for color saturation and hue, but these shall each be provided with detented factory calibrated settings to match the optimum color reproduction characteristics of the system. The phosphor set used shall be chosen to optimize the ability to discriminate small changes in hue. A switch setting shall be provided to cause the chrominance circuits to match the overall color rendition of the original NTSC phosphor set.

5.2.6.3 Type III monitor requirements. The high resolution monitor shall be as specified in 5.2.6.1, except that its minimum horizontal resolution shall be not less than 500 lines, for luminance as measured in Zone 1. Resolution in Zone 2 shall be at least 80 percent of that in Zone 1.

5.2.6.4 Type IV receiver/monitor requirements. The receiver/monitors shall be capable of operating either as a baseband video monitor or as an RF receiver, by operation of a single switch control. When operated as a monitor, they shall conform to the performance requirements specified in 5.2.6.1, except that minimum horizontal resolution shall be not less than 300 lines for luminance in Zone 1, and they shall be capable of reproducing audio through a self-contained audio amplifier and speaker. As a receiver, the receiver/monitor shall be capable of accepting RF input for at least the twelve Very High Frequency (VHF) broadcast channels. They shall be provided with the capability to demodulate and reproduce the audio carrier signals through a self-contained speaker.

5.2.6.5 Type V modified receiver/monitor requirements. Type IV receiver/monitors shall be modified to Type V by having their receiver circuits removed or disabled. Except for the inability to receive RF modulated signals, performance of Type V shall be identical to Type IV (see 5.2.6.4).

5.2.6.6 Type VI receiver requirements. Receivers shall conform to the requirements specified in 5.2.6.4, except that they shall not accept baseband video and audio, and they shall have the ability to accept both the twelve VHF channels and the Ultra-high Frequency (UHF) channels (14 through 83).

5.2.6.7 Type VII large-screen projector monitor requirements. The large screen projector monitor shall be used only where the size of the viewing group, or the maximum viewing distance makes it impossible to use the largest non-projection monitors. Large screen projectors shall be divided into two classes specified in a and b:

a. Class 1: For entertainment and training purposes, where screen size is less than or equal to 6.5 feet, and the viewing area is illuminated to not more than 5 foot candles.

b. Class 2: For all other purposes, where screen size exceeds 6.5 feet, and viewing area illumination is greater than 5 foot-candles.

5.2.6.7.1 Class 1 projector requirements. The class 1 projector shall serve in the system as either a receiver or receiver/monitor. The projector and screen may be either permanently attached to a common base, or they may be separately installed. Performance characteristics shall be as specified in 5.2.7.7.1.1 through 5.2.7.7.1.4.

5.2.6.7.1.1 Brightness. The projector shall have a total light output of not less than 50 lumens.

5.2.6.7.1.2 Resolution. The projector and screen shall have an overall horizontal resolution of not less than 300 lines for luminance.

5.2.6.7.1.3 Contrast. The projector and screen shall provide a contrast ratio of not less than 25:1 with five foot candles incident lighting in the viewing area, for on-axis viewers. (NOTE: This assumes that no incident light strikes the screen directly.) Contrast for off-axis viewers, at a 20 degree angle from the intersection of the axis with the screen surface, shall not be less than 10:1, under the same incident light conditions.

5.2.6.7.1.4 Audio output. The projector shall include an audio amplifier and speaker with an output power of at least 5 watts Root-mean-square (RMS) at 1 kHz, with less than one percent Total Harmonic Distortion (THD) and less than two percent Intermodulation Distortion (IM) over the frequency range of 40 Hz to 10 kHz, and a frequency response of not less than ±3 dB from 40 Hz to 10 kHz.

5.2.6.7.2 Class 2 projector requirements. The class 2 projector shall be a stand-alone unit, designed for use with a user-supplied screen, either front or rear projection type. Class 2 projectors shall perform as specified in 5.2.6.7.2.1 thru 5.2.6.7.2.5 (NOTE: This standard does not cover the screen materials for class 2 projectors. Guidance for selection and employment of class 2 projectors is contained in APPENDIX C.)

5.2.6.7.2.1 Brightness. Class 2 projectors shall have a minimum total light output of 650 lumens.

5.2.6.7.2.2 Resolution. Class 2 projectors shall have a minimum horizontal resolution of 450 lines for luminance in Zone 1. Resolution in Zone 2 shall be at least 80 percent of the resolution in Zone 1.

5.2.6.7.2.3 Contrast. Class 2 projectors shall have a minimum contrast ratio of 50:1 between peak white and black. NOTE: This standard covers the projector only. In most installations, the achieved contrast of the projector at the viewing position will be governed by factors other than the projector.

5.2.6.7.2.4 Registration The projector shall provide registration of its red, green, and blue rasters within 1 percent at all parts of the raster. Registration should be maintained without requiring adjustments over a 24 hour period.

5.2.6.7.2.5 Video input. The projector shall accept NTSC composite video at 1.0 V P-P terminated in 75 ohms, unbalanced.

5.2.6.8 Chrominance vector monitors. Chrominance vector monitors shall be used in the control room or central switching facility of all color CCTV systems, as a quality control device. The chrominance vector monitor shall decode the chrominance component of the composite NTSC signal and produce a polar plot of that signal in which direction from the center of the display is representative of the instantaneous hue values in the video and distance from the center of the display is proportional to saturation. The display shall have a fixed graticule with calibrated positions corresponding to I signal, Q signal, the six principal colors of the standard color bar test signal, and the burst signal.

5.2.7 Video character generators. A video character generator shall consist, as a minimum, of an alphanumeric keyboard and the necessary electronic memory and video generating circuits to produce one raster page of typed material. They will be divided into two types as specified in a and b:

a. Type I: Broadcast quality color, with variable type fonts.
b. Type II: Industrial quality monochrome.

It should be noted that, although Type II character generators are monochrome, in that they produce only white characters, they may be used in color systems.

5.2.7.1 Type I character generator performance requirements. The requirements specified in 5.2.7.1.1 through 5.2.7.1.7 shall characterize Type I character generators. (See APPENDIX D for option features).

5.2.7.1.1 Font selection. At least two different fonts shall be available for selection from the front panel (keyboard) of the Type I character generator. Fonts shall be capable of being mixed within any page of characters.

5.2.7.1.2 Type sizes. At least two type sizes shall be available for each font selectable on a character-by-character basis.

5.2.7.1.3 Upper case and lower case. Both upper and lower case characters shall be available for each font.

5.2.7.1.4 Colors. Characters shall be capable of being generated in any of eight colors, selectable on a character-by-character basis.

5.2.7.1.5 Bordering. Characters shall be capable of being surrounded by borders in at least a selection of Black, White, and Grey.

5.2.7.1.6 Self-keying. Characters, with or without borders, shall be capable of self-keying over any NTSC color video input. Insertion or deletion of the characters shall cause no measurable change in the APL, chrominance signal levels, or hue of the input video.

5.2.7.1.7 Character formation. Characters shall be formed entirely of variable-length line segments in the raster. Video signal level shall be constant within ±3 IRE units during the duration of any character line segment.

5.2.7.2 Type II character generator performance requirements. The minimum performance requirements for Type II character generators shall be as specified in 5.2.7.2.1 through 5.2.7.2.4.

5.2.7.2.1 Font. Characters shall be formed from either dot matrix or line segments, in at least two sizes of upper case characters. Style shall be simple block letters.

5.2.7.2.2 Mixing and keying. The character generator shall be capable of either mixing or keying its characters with input NTSC color or RS 170-57 monochrome video. When used with NTSC color video inputs, the character generator shall cause no measurable change in the hue or saturation of the colors in the input video.

5.2.7.2.3 Storage. The character generator shall provide internal storage for at least one page of characters.

5.2.7.2.4 Page content. A page of characters shall consist of not less than ten nor more than twenty lines of characters. Each line shall consist of not less than sixteen nor more than forty characters and spaces.

5.2.8 Digital video processing. Standards for digital video processing are not included herein. Industry standards in this area have not been firmly established. Once established, appropriate standards will be incorporated. Guidance for the use of digital processing equipment is contained in APPENDIX E.

Custodians:
Army-SC
Navy-EC
Air Force-90

Preparing Activity
NAVY-EC

(Project Number SLHC-3180)

User activities:
Navy-SH

APPENDIX A
THIS APPENDIX IS MANDATORY FOR USE

THE UNDER SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

RESEARCH AND
ENGINEERING

16 AUG 1983

MEMORANDUM FOR ASSISTANT SECRETARY OF THE ARMY (INSTALLATIONS, LOGISTICS & FINANCIAL MANAGEMENT)
ASSISTANT SECRETARY OF THE NAVY (SHIPBUILDING & LOGISTICS)
ASSISTANT SECRETARY OF THE AIR FORCE (RESEARCH DEVELOPMENT & LOGISTICS)
COMMANDANT OF THE MARINE CORPS
DIRECTOR, DEFENSE COMMUNICATIONS AGENCY
DIRECTOR, NATIONAL SECURITY AGENCY

SUBJECT: Mandatory Use of Military Telecommunications Standards in the MIL-STD-188 Series

On May 10, 1977, Dr. Gerald Dinneen, then Assistant Secretary of Defense(C^3I), issued the following policy statement regarding the mandatory nature of the MIL-STD-188 series telecommunications standards:

"...standards as a general rule are now cited as 'approved for use' rather than 'mandatory for use' in the Department of Defense.

This deference to the judgment of the designing and procuring agencies is clearly appropriate to standards dealing with process, component ruggedness and reliability, paint finishes, and the like. It is clearly not appropriate to standards such as those in the MIL-STD-188 series which address telecommunication design parameters. These influence the functional integrity of telecommunication systems and their ability to efficiently interoperate with other functionally similar Government and commercial systems. Therefore, relevant military standards in the 188 series will continue to be mandatory for use within the Department of Defense.

To minimize the probability of misapplication of these standards, it is incumbent upon the developers of the MIL-STD-188 series to insure that each standard is not only essential but of uniformly high quality, clear and concise as to application, and wherever possible compatible with existing or proposed national, international and Federal telecommunication standards. It is also incumbent upon the users of these standards to cite in their procurement specifications only those standards which are clearly necessary to the proper functioning of the device or systems over its projected lifetime."

This statement has been reviewed by this office and continues to be the policy of the Department of Defense.

APPENDIX B
ACRONYMS AND ABBREVIATIONS

10. SCOPE

10.1 Scope. This appendix provides explanations of acronyms and abbreviations used in this standard and is not mandatory.

A/D	- A conversion of an electrical signal from analog to digital form.
APL	- Average Picture Level - A time average over some stated period of the video signal.
B/W	- Black and White.
CCTV	- Closed Circuit Television.
CIE	- Commission Internationale de l'Eclairage.
D/A	- A conversion of the digital representation of an electrical signal to analog form.
ENG	- Electronic News Gathering.
dB	- Decibel.
dBm	- Decibels referenced to one milliwatt.
dBmv	- Decibels referenced to one millivolt.
IRE	- Institute of Radio Engineers.
NAB	- National Association of Broadcasters.
NTSC	- National Television System Committee.
P-P	- Peak to Peak.
R/C	- Remote Control.
SMPTE	- Society of Motion Picture and Television Engineers.
SYNC	- Synchronization signal.
VCR	- Videocassette Recorder.
VHF	- Very High Frequency.
VTR	- Videotape recorder.
VU	- Volume units.

APPENDIX C

TUTORIAL INFORMATION REGARDING CCTV

(THIS APPENDIX IS NOT A MANDATORY PART OF THIS STANDARD).

10. INTRODUCTION

10.1 Historical context. The history of the television systems covered by this standard dates back to the early 1940s. Although, for all practical purposes, television service in this country did not begin until about 1946, the standards for that service were developed much earlier, and published in 1943. Those standards covered a monochrome broadcast service, but the basic characteristics established in those standards are still with us today. The standards for monochrome television service were developed by a group of radio industry, government, and broadcasting people called the National Television System Committee. This fact can be the source of some confusion, because the color television standards used in this country are called the NTSC standards, after the National Television System Committee. Actually, there were two such bodies. The first, which created the monochrome standards, met in the early 1940s. The second, which developed the compatible color broadcasting standards, met about ten years later, in the early 1950s. Throughout this standard, the appellation NTSC is used to mean only this second National Television System Committee, in keeping with common practice in the industry.

10.2 System definition. In its broadest sense, the word Television means anything used to see at a distance. That sense is much too broad for purposes of this tutorial since it could be construed to include purely optical instruments, such as the telescope. Use of the term will be limited to those systems which are all electronic, use visible light as an input, perform a scanning process to convert the electrical image to signals for processing, and combine the synchronization of scanning with the video signals for transmission through wire lines or other transmission media.

20. BASICS OF SYSTEM DESIGN

20.1 Choice of scanning standards. In theory, once an image has been formed in a television camera's light sensitive surface, it may be scanned in any manner one chooses. In present systems, however, all scanning is done on a rectangular basis, in one direction only, with the scanning moving across the image from left to right, and at a slower rate from top to bottom, much the same as the human eye reads a page. This rectangular scanning pattern, or raster, does make it easier to synchronize the scanning between the camera and the receiver, and reduces the cost of receivers.

Once having chosen a rectangular form, and a raster method of scanning, the next choices are of how many frames (or complete scans) are to be sent per second, and how many lines of scanning will constitute one frame. In all, there were three basic criteria to be considered. First, the motion of objects in the image should appear continuous to the human eye; second, the image should not flicker; third, the image should have sufficient resolution to approximately match that of the human eye for the expected screen size and viewing distance.

For the first criterion, a rate of as little as sixteen frames per second would be sufficient. For the second, given the expected image brightness and ambient lighting conditions, a rate of at least 48 per second would be required.

It was desirable to have the rate of taking frames minimized, because that rate is proportional to bandwidth for the signals. A second constraint was the relationship between the frame rate of the system and the power line frequency. For at least two reasons, one being the unwanted patterns generated in the picture by residual hum from the power line, and the second being the relative ease of using the power line as a source of synchronization, it was decided that the frame rate should be an exact submultiple of the power lines' 60 Hz rate. The rate chosen was 30 frames per second. This rate would more than meet the continuity of motion criterion, while keeping the bandwidth within reasonable bounds. (The standards were not of course developed one step at a time. Thirty frames per second at a high line rate is something different in bandwidth from thirty frames per second at a low line rate. The standards were developed together to form a best compromise among competing criteria.)

Now, however, to avoid an appearance of flicker, some means had to be devised to trick the human eye into believing it was seeing more than forty-eight frames per second. To do this, the designers took advantage of the fact that the images flowing through the system would be pictorial in nature, and continuous in tonal variations. Thus, if one examined the actual picture content of two adjacent scanning lines, there would be much greater probability of finding the same value of signal at corresponding points in the two lines than there would be of finding two radically different values. To put that another way, there would be more similarities than dissimilarities between two adjacent lines. Thus, a system of interlaced scanning was devised, whereby the picture would be scanned twice in the one thirtieth of a second period, but the first scan would hit only the odd numbered lines, and the second would hit only the even numbered lines. The eye would perceive this scanning as if it were presenting sixty complete pictures per second, while the system was actually only required to pass thirty pictures per second. It must be noted that this interlace trick works for continuous tone pictorial subjects, and works best for viewing distances greater than four times the width of the picture.

Last in the discussion, though by no means last in the development of the standards, is the question of the resolution of the system. Before the designers were able to settle this question, they had to make some assumptions about how the system would be used. It was, for example, assumed that the television receiver would essentially supplant the radio as a source of family entertainment in the living room of the consumers' homes. It was assumed that three to four people would want to watch the picture, and that given the technically feasible sizes of the picture, on the receiver, that the distance of viewers from the screen would range from about four to about seven times the width of the picture. It was considered essential that, for the picture to be acceptable to home viewers, the individual lines of the raster scanning would merge into an apparently continuous picture at the nearer of those limits. (Actually, a series of tests were run with randomly chosen human subjects). Finally, it was assumed that the system should be balanced in resolution. That is, the number of lines per picture height should be the same in both the horizontal and vertical axes. The number of lines decided upon was 525 lines in the complete scanning cycle, with 488 lines containing the actual picture, and with a 2:1 interlace. Thus the system would scan the odd numbered lines in the first 60th of a second, and the even numbered lines in the second 60th, thus complete scanning of the entire image area in each 30th of a second. (Actually, the scan is divided into two fields, each of which has exactly 262.5 lines).

Having decided the number of scanning lines, and having decided that the resolution of the system would be balanced, the designers now had also decided the horizontal resolution, and with it the bandwidth, of the video signals. (Vertical resolution is typically less than 488 lines overall, primarily because of the Kell factor. The Kell factor is a numerical expression of the loss in resolution due to random misalignment between the scanning lines and the features of the image).

Given the effect of Kell factor, the vertical resolution of the system is about 390 lines. To determine the impact of that resolution on the bandwidth for a balanced system, a rule of thumb factor of 80 lines per MHz, which would therefore mean a video bandwidth of 4.88 MHz is applied. (Note that these figures are in TV lines per picture height. That is, in the system a 4:3 aspect ratio is used so that the total lines across the picture will be 390 x 4/3, or about 520 lines. In any case, the final system design for Broadcast purposes imposed a compromise on bandwidth, alloting only about 4.2 MHz for video, which gave the horizontal resolution as only 336 lines per picture height, or 448 across the entire picture. System designers must bear an important difference in mind when dealing with closed circuit systems, however. In baseband systems, the video bandwidth is not limited to 4.2 MHz, so the achievable resolution in such systems is considerably greater than that which can be achieved in any RF modulated system. It is not unusual for baseband monochrome systems to use overall bandwidths of 6.5 MHz, and corresponding resolution of 520 lines per picture height. This unbalanced situation, where the horizontal resolution is considerably more than the vertical, is very common in the case of computer generated alphanumeric video sources. The imbalance is not so bad as it first appears, however, because the Kell factor for such systems is typically much higher than in systems where a camera is used. (With stable interlacing in the monitor, the Kell factor can be made to closely approach unity.)

20.2 Monochrome system signal structure. The monochrome signal structure is a composite of two major components: The video, or information carrying signal, and the synchronizing signal. The structure will be shown for the baseband case first, then for RF modulated systems.

20.2.1 Baseband video signal. In baseband systems, the video signal is broken up into periods by the line rate. The video signal is present only for the 488 active lines of the picture, and only for 82 percent of the period for each active line. Its polarity is white positive, and its amplitude is 0.714 volts P-P. It appears in increments of about 52 microseconds duration, corresponding to 82 percent of the horizontal scanning lines' period; that is:

$$\frac{1}{15{,}750\text{Hz}} \times .82 = 52.063 \times 10^{6} \text{ seconds}$$

A full cycle, including horizontal synchronizing pulse, is 63.492 microseconds.

NOTE: See 5.2.1.

20.2.2 Synchronizing signal. The synchronizing signal is a series of negative pulses of about 0.25 volts amplitude, at a repetition rate of 15,750 pps, timed to occur between the video increments, except during the vertical interval. During the vertical interval, or vertical retrace period, all video is blanked, and the normal horizontal synchronizing pulses are replaced by a special sequence for vertical synchronization. This special sequence occupies a total of nine horizontal sync periods totalling about 571 microseconds. The sequence is divided into three equal parts. For the first three horizontal periods, a series of narrow equalizing pulses is sent at twice the horizontal repetition rate. In the second period, the vertical synchronizing pulses are sent. These are broad pulses at twice the horizontal repetition rate. In the third period, a second set of equalizing pulses is sent, again at twice the horizontal rate. After these three periods, the normal horizontal sync pulses resume without video, until the first active line of the field, at which time video signals return.

20.2.3 Composite signal. The composite signal, which is the normal means of sending video through the baseband system, consists of the summation of the video signal, the blanking signal, and the sychronizing signal. FIGURE 1 shows this composite signal as it appears on the video lines in a typical monochrome system. Amplitude of the composite signal is 1.0 volt P-P, with the positive peaks representing the highlight white portions of the picture, and the negative peaks representing the peak level of synchronizing signals. FIGURE 1 is of course only a small portion of one complete frame in the television signal, that being the vertical blanking interval and the beginning and ending of the active lines of the raster. Note that the time scales show a stagger of one half line in the relative timing between the odd and even fields. It is this stagger relative to the vertical synchronization which produces the interlace of the two fields. On the FIGURE, the vertical blanking interval is shown as exactly 18.5 lines. (For convenience, common practice in television systems is to reckon timings in terms of the horizontal sweep period and decimals or fractions thereof, using the symbol H to mean one horizontal sweep period.) It has become common practice also for there to be some variation in the actual vertical blanking interval, so that the actual value found in a system may be more than 18.5 H, but will not be less.

For most of the lines of the raster the composite signal does not appear as shown in FIGURE 1 but as a long series of horizontal sweeps containing video. FIGURE 2 shows a typical line of the normal video type. The active portion, containing video information, is supposed to occupy about 82 percent of the time, with horizontal blanking interval taking the rest. Here again, practice in the industry has permitted the interval to frequently be found occupying more than the allotted 0.18 H, but never less. For ease of reference, FIGURE 3 has been included here to show more clearly the detail of the vertical interval's equalizing and sync pulses. Rise and fall times for all synchronizing pulses should be no more than .004 H, measured between ten percent and 90 percent of the pulse amplitude at its peak.

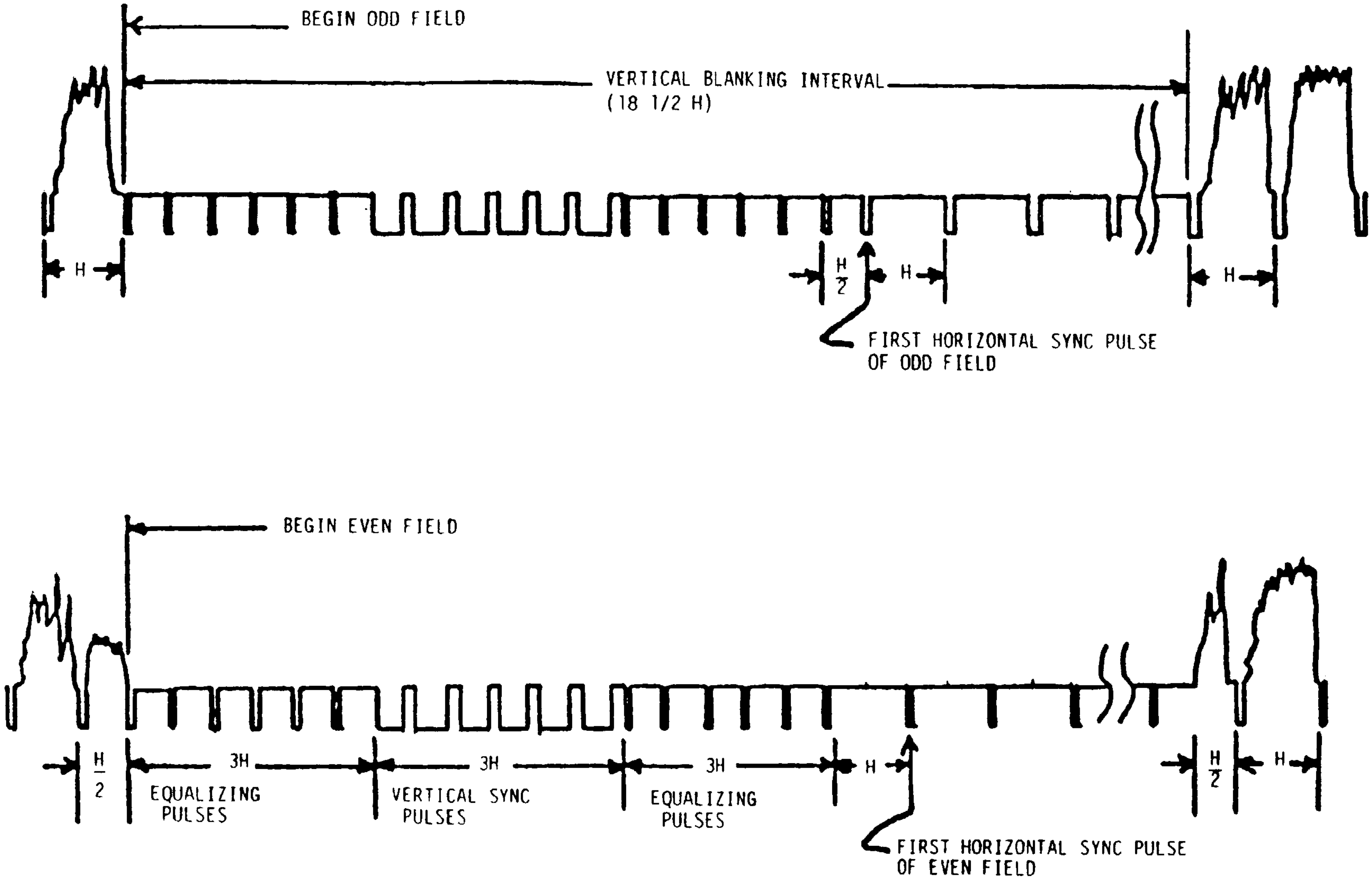

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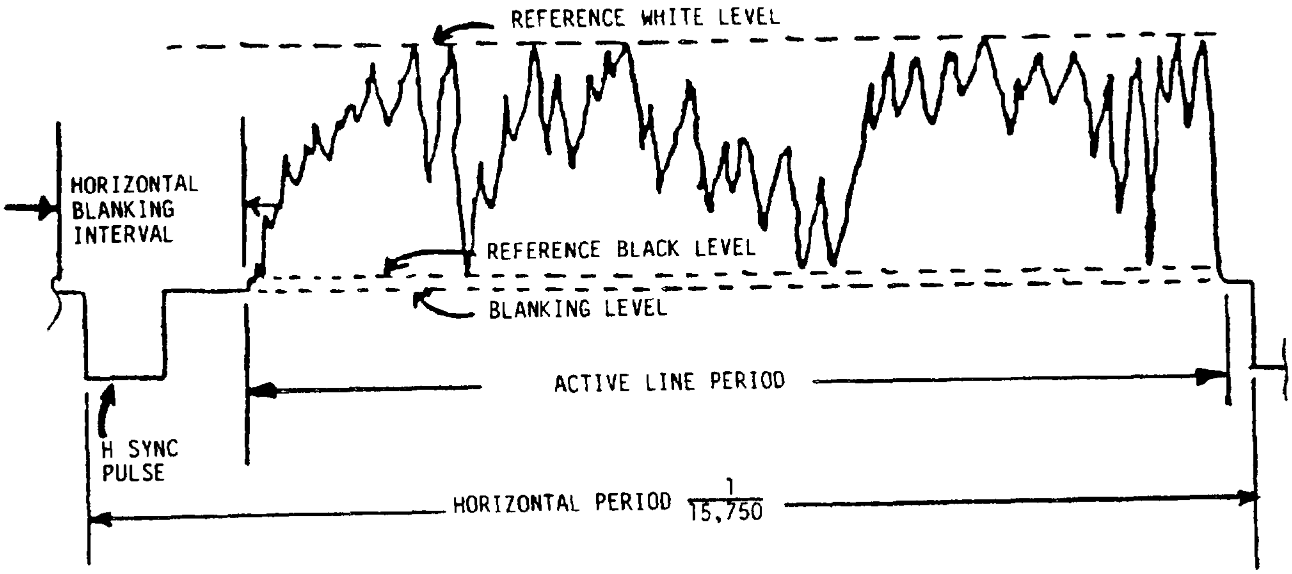
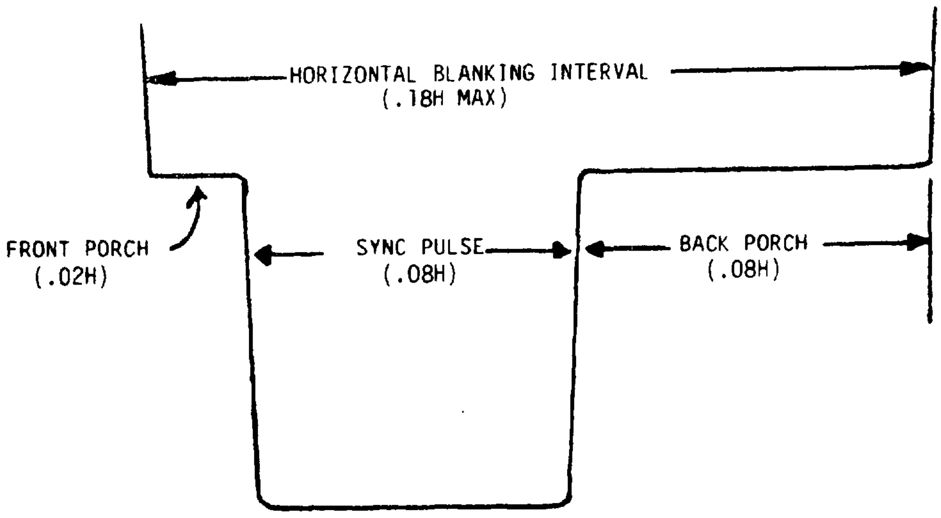
FIGURE 1. Composite video signal structure (vertical interval).

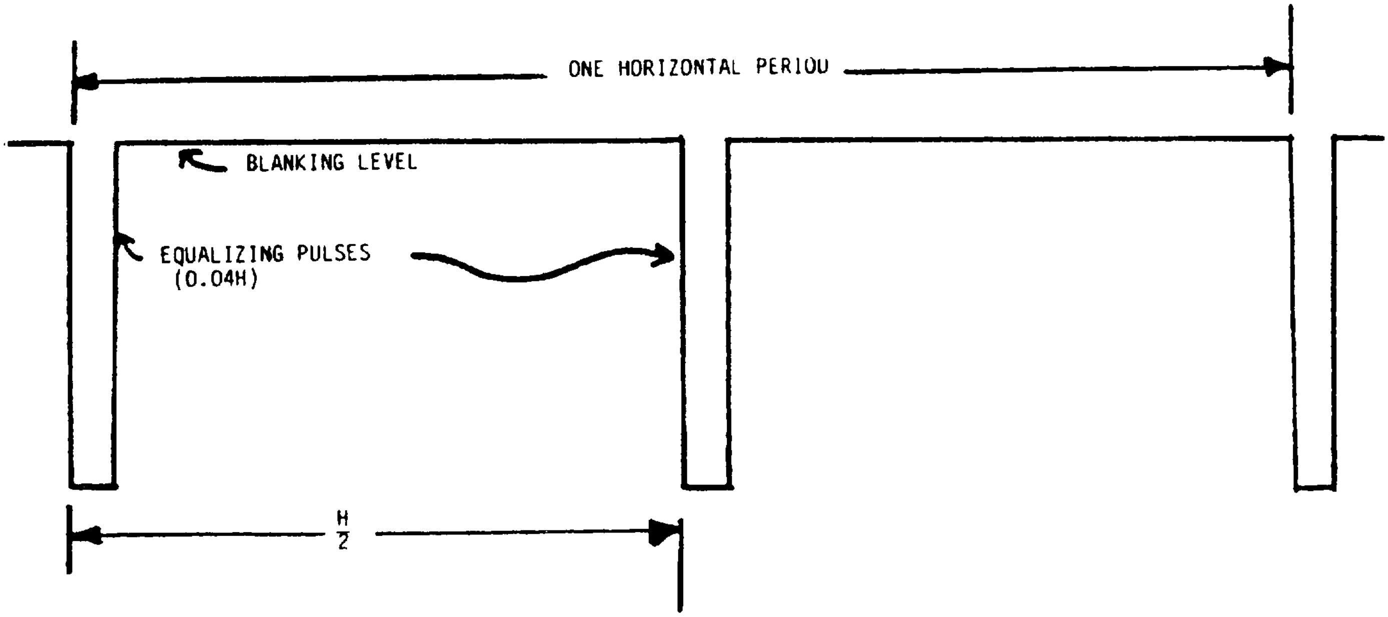


A. COMPOSITE VIDEO DETAIL, ONE HORIZONTAL LINE

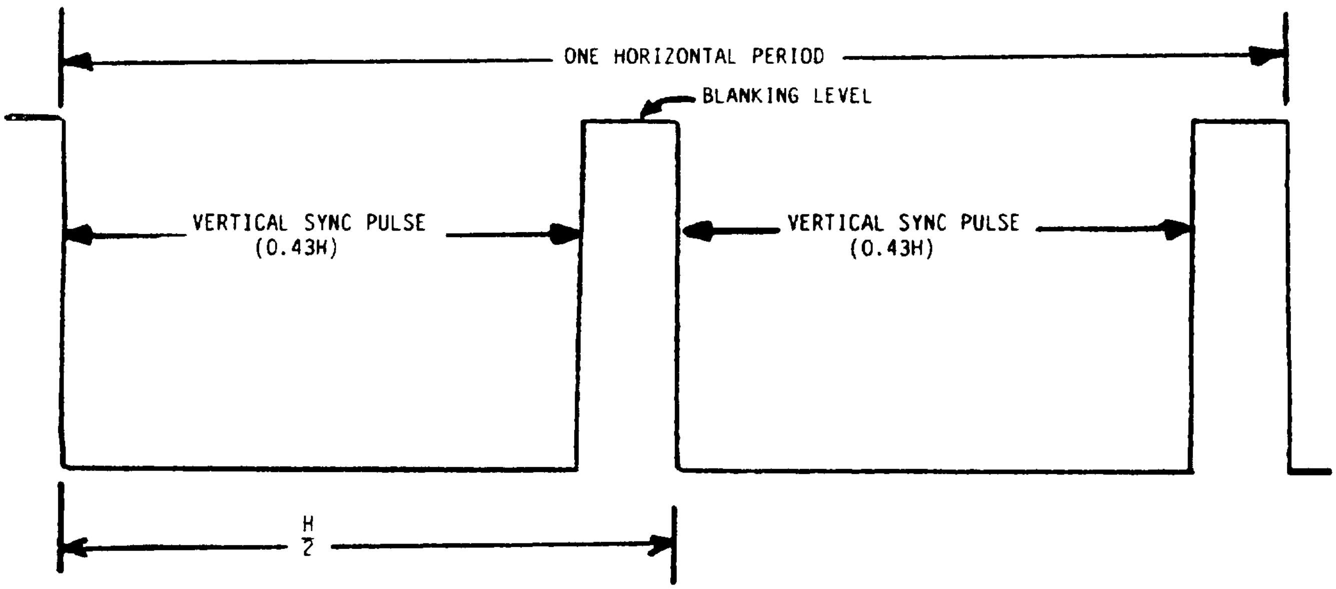


B. HORIZONTAL BLANKING INTERVAL DETAIL

FIGURE 2. Composite video signal, detail of one horizontal line.



A. VERTICAL EQUALIZING PULSE DETAIL



B. VERTICAL SYNCHRONIZING PULSE DETAIL

FIGURE 3. Vertical interval pulses detail.

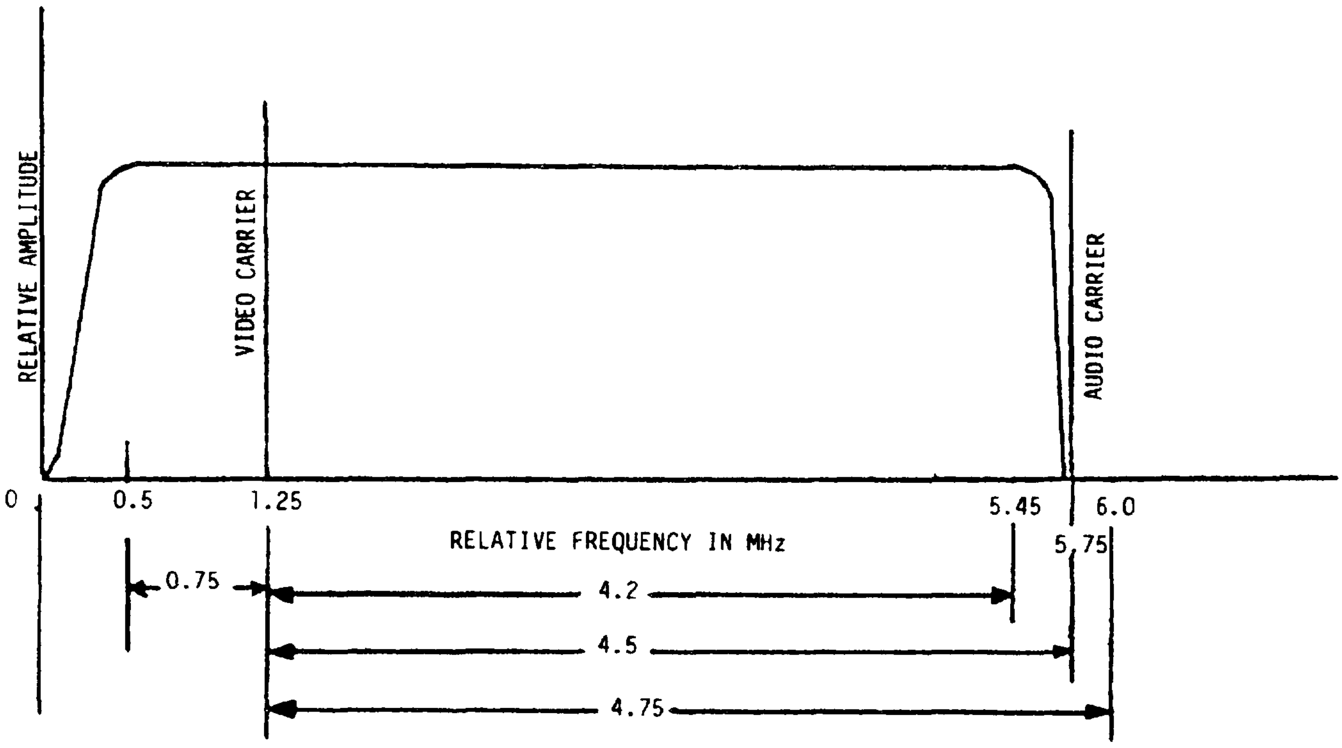


FIGURE 4. Idealized frequency domain representation of monochrome TV channel.

20.2.4 RF modulated signal structure. The first and most striking difference between the baseband composite video signal and a simple detected RF signal is that the latter is inverted from the former. That is, the greatest amplitude of the modulated carrier occurs at the peak of the sync pulses, and the minimum occurs at the peak white portions of the video signal. If FIGURE 1 is viewed in a mirror and upside down, the image is that of a detected RF signal.

The more important distinctions between these two cases arise from the limits imposed by channel bandwidth, and therefore can best be seen in a frequency - domain representation of the signal structure. FIGURE 8 shows an idealized representation of a monochrome television channel, including the video and audio. The audio is frequency modulated, while the video is amplitude modulated. As will be immediately apparent, though, the video is by no means an ordinary amplitude modulated signal. The sidebands are far from symmetrically arranged about the carrier. This form of transmission, in which the lower sideband is limited to about 0.75 MHz width, while the upper sideband extends to about 4.2 MHz, is called Vestigal Sideband Transmission. It is essentially a compromise between the double sideband type, in which the video would have less than 3 MHz bandwidth, and the more efficient single sideband type, in which the video would have about 5.4 MHz bandwidth. This vestigal sideband technique makes reasonably efficient use of the available channel width, but makes receiver design simpler and therefore less costly than would be the case for single sideband transmission. As shown in the diagram, the upper sideband is rolled off sharply beginning at 4.2 MHz above the carrier, in order to minimize interference with the sound signal, whose carrier is at 4.5 MHz above the video carrier.

20.3 Development of color standards. By the early 1950's monochrome television was a well established and rapidly growing broadcast service, and it was against that framework that the second National Television System Committee was formed to develop standards for compatible color television service. The Committee's goal was to develop standards which would: (1) provide good rendition of the colors in the original scene; (2) keep the signal structure within the confines of the 6 MHz channels then allocated for broadcasting; (3) permit all makes and models of monochrome receivers then extant to receive a faithful monochrome representation of the color picture without need for modification.

20.3.1 Characteristics of human color vision. In early investigation of this phenomenon of human color vision, there were two competing theories of the process. The Young-Helmholtz theory held that the eye saw color in terms of three primaries, red, green and blue, and saw white as a combination of all three primaries. The other theory held that the eye saw color as differentiated into two color axis, a yellow-blue and a red-green, plus a third axis for the black-white response, and theorized therefrom only two color receptors. Today, researchers are discovering that both theories are correct to some degree.

The eye does contain three different color dyes, and therefore the process operates to a degree along the Young-Helmholtz theory. The eye does not,however, pass the information from these receptors directly to the brain. There is a matrix of nerves in the retina itself which acts like an analog computer to add and subtract responses from groups of sensitive cells, and in so doing it yields an overall response which closely supports the second theory. That is, the eye encodes its information about color into two color-difference axis and a brightness or luminance axis before sending signals to the brain. This encoding process is important in a number of ways. For example, even though red is generally understood to be a primary color for the eye, the eye does not have a receptor cell which peaks in the red portion of the spectrum. The actual dyes are Yellow-Orange, Green and Blue. The eye sees red by processing signals, in that the yellow dye has a strong response to red, but the green dye has almost none. The eye, then, compares the responses of these two sensors to see the color red as a signal from one in the absence of a signal from the other. This encoding process in the eye, then, uses the sum of the color receptors' responses to sense brightness values in a scene, and uses differences in their responses to differentiate colors.

The eye's ability to resolve objects in the scene varies as a function of their relative brightness values and also as a function of the color differences between objects. The brightness response uses the sum of all three kinds of receptors, and so has the greatest resolving power. The resolving power for color-only differences is far less, and is different depending on the particular color difference to be resolved. This particular fact about human color vision will be very important to the process of encoding color for transmission as designed by the NTSC.

In essence, the NTSC encoding of color-difference signals for transmission closely parallels that performed by the nerves in the human eye. (At the time that the standards were developed, the details of the eye's encoding process were not known, but the empirical results of tests on human subjects led to the NTSC's developing standards which closely parallel that which is now known about the eye's processing.)

20.3.2 Colorimetry and the chromaticity diagram. The word colorimetry means exactly what its name implies, that is, the measurement of color. By international agreement, the standards used in colorimetry are developed and maintained by a body known as the Commission Internationale de l'Eclairage, or the CIE. The CIE has established a standard method using a common cartesian coordinate system with its primaries luminance (y) (or brightness) and a pair of artificial color primaries, X and Z. These X and Z artificial primaries extend well beyond the spectrum of real colors, so that, by properly choosing values of the CIE primaries, any real color can be matched exactly.

Through the CIE system, colors are plotted in a three-dimensional cartesian coordinate system, and for purposes of ease of handling on two-dimensional paper, chromaticity diagrams are drawn as projections into the XY plane of the CIE coordinate system. FIGURE 5 shows a typical CIE chromaticity diagram. The curved line on the diagram is the spectral locus, which represents the set of all maximally saturated colors. The numbers around the periphery of the curve are the wavelengths of the three primaries in namometers. The dots labelled Red, Green, and Blue represent the phosphor primaries used in the NTSC system, and the dot labelled White represents the CIE Illuminant C, or a white light of 5500 degrees K color temperature. (A white light which approximates the color of outdoor daylight when the sun is overhead.) The entire NTSC system was designed around a white balance of Illuminant C. That is, the system should perform correctly in all respects when the receiver's phospors are balanced for a white at 5500 degrees K.

In the NTSC system, the camera splits the incoming light into three paths, each of which passes through a filter corresponding to one of the three primaries as shown on FIGURE 5. Thus the camera's pickup devices produce three separate video signals, which, for convenience, are called simply R, G, and B, after the initials of the primary colors.

In the NTSC system, the first order of business for these signals is to combine them into a suitable monochrome signal, so as to maintain compatibility with the monochrome receiver. This is done by taking a weighted sum of three signals. The monochrome signal is called Y, and is composed from the three primaries as follows: $Y = 0.30R + 0.59G - 0.11B$. This mixture will result in a correct grey tone renderig of the Y signal in a monochrome receiver.

Now, given the fact that a monochrome receiver should receive a color signal and produce a monochrome image no different from that it would produce with a monochrome signal, and given that the channel bandwidth was fixed at 6 MHz, the NTSC's task was to find a way of sending the chrominance information through the communicaiton channel along with the luminance in a manner which would: (1) Cause no interference or other undesirable effects on monochrome receivers; and (2) Produce a full range of colors on a color receiver.

It became evident that only some form of modulated subcarrier added to the monochrome signal could meet both criteria. What was needed was a subcarrier which the monochrome receiver would ignore, but which would carry all of the color information the human eye could handle. Tests were conducted to determine what the resolving power of the eye was for various combination of color differences, and it was determined that there were two axes across the chromaticity diagram which would be significant to the formulation of a scheme for encoding the color information onto a subcarrier. FIGURE 6 shows these two important axes, labelled the I axis and the Q axis. The I axis is that line (approximately) along which the eye has its greatest resolution for color-only differences. The Q axis is that line along which the eye has its least resolution for color-only differences. That is, the eye can best resolve lines of equal brightness if they lie along an axis running from a red-orange to a bluish blue-green color. It can least easily resolve lines of equal brightness if they lie along an axis between a blue purple and yellow-green color. The NTSC system takes advantage of this difference in resolving power in modulating its color information onto a subcarrier.

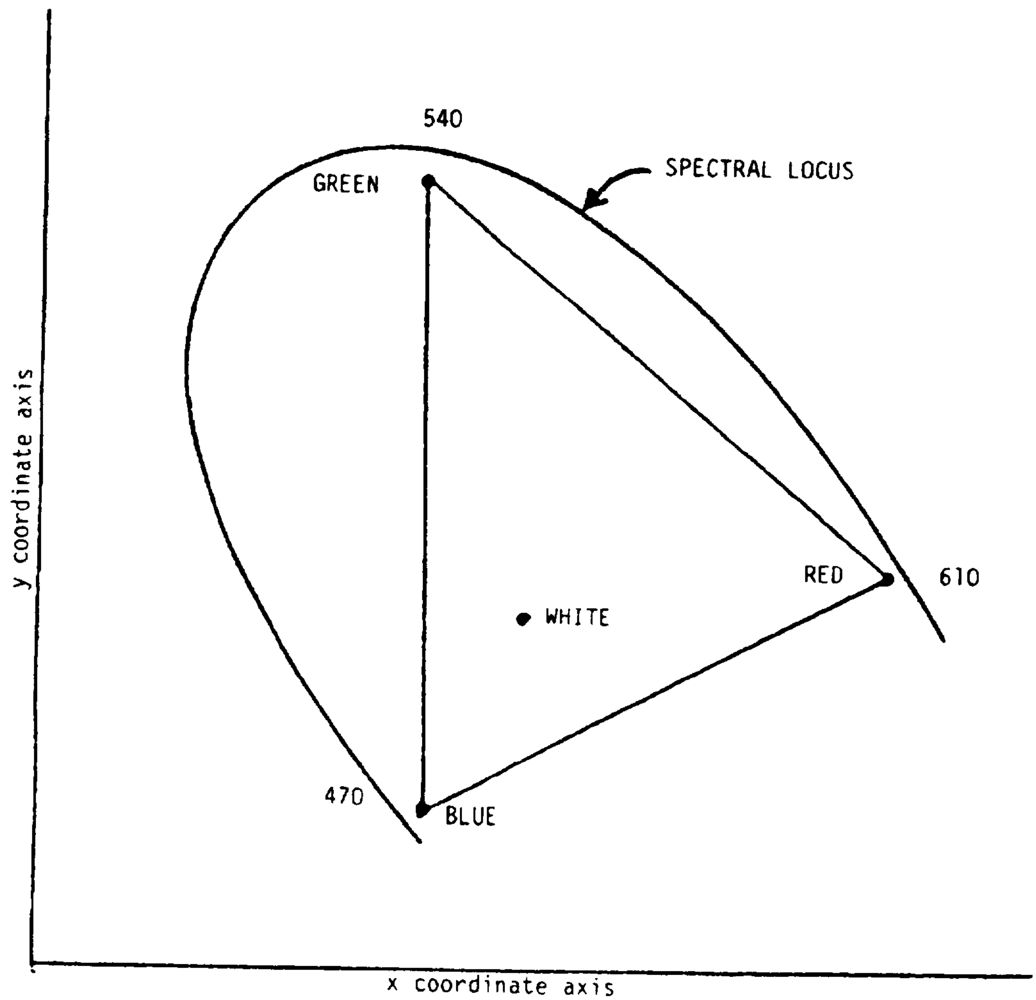


FIGURE 5. Typical CIE chromaticity diagram.

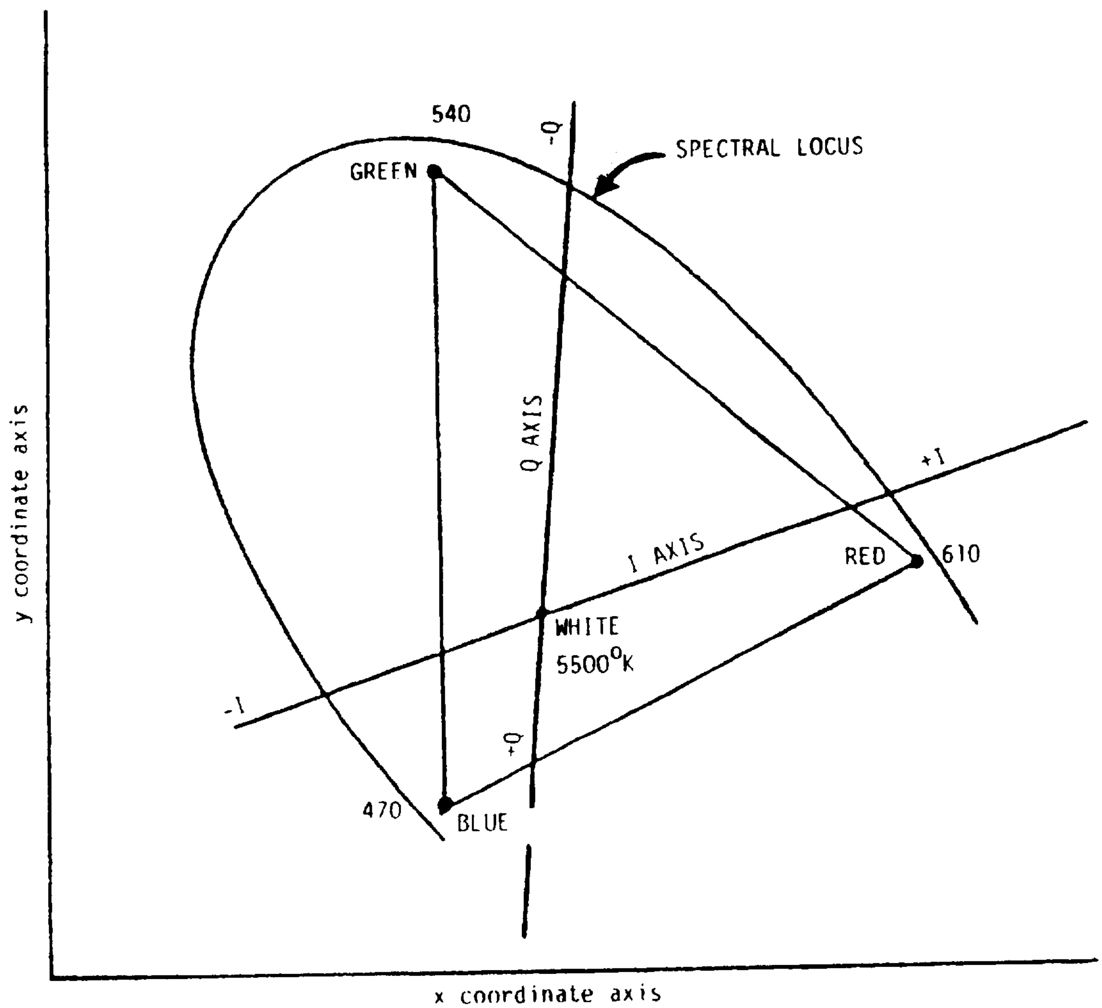


FIGURE 6. Location of the color-difference axes I and Q.

20.3.3 Choice and modulation of the subcarrier. Given that a subcarrier is necessary to carry the color information, it is necessary to select a frequency within the range of 0 to 6 MHz, which can handle the required bandwidth of modulating signal and which will not interfere with either the baseband luminance signal or the sound signal. In order not to interfere with the sound, the subcarrier would have to be below about 4 MHz. In order to carry the required information, it would have to be above 3 MHz. The subcarrier frequency chosen was 3.579545 MHz. That exact frequency allowed all the criteria to be met. For example, that frequency made it relatively easy to divide down in frequency to derive the horizontal and vertical sync rates from the subcarrier, and thereby maintain the required relationships to assure complete compatibility with monochrome receivers.

The required relationship between the subcarrier and the sync is that the subcarrier be an exact odd multiple of half the line rate. The effects of this relationship can be looked at in two ways, from either a frequency domain approach or from a time-domain approach. In the frequency domain, this relationship means that the subcarrier and all its sidebands, when modulated fall between the sidebands arising from the luminance signal. The effect on compatibility is more obvious when viewed in the time domain. FIGURE 7 illustrates the effect when a composite of the luminance and modulated subcarrier are fed through a monochrome receiver's video circuit. In essence, the relationship between the subcarrier and the line rate means that on alternate scans of any given line, the subcarrier becomes 180 degrees out of phase with its previous appearance. Thus in the eye of the viewer, its contribution to the light output in the picture on successive scans is self-cancelling. Note however, as shown in FIGURE 7, that in parts of the picture where the chrominance signal is large in comparison to the luminance, there will be some uncancelled contribution to the light output, since the CRT cannot put out less than zero light.

Having chosen a subcarrier for the color information, then it was necessary to devise a means of modulating the subcarrier with color information.

As the signals emerge from the camera, there are three video streams, representing the Red, Green, and Blue contents of the picture. Each of these video streams carries with it a contribution of the brightness, or luminance signal. (Remember that a weighted sum of the three signals was used to make the luminance signal.) In order for the color channel to transmit only the color information, it is necessary to remove this luminance information from the color signals before further processing, so the encoding equipment forms the color-difference signals by subtracting the luminance signal from each of the three color video signals. These color-difference signals are called R-Y, G-Y, and B-Y, respectively. Now, in order to take full advantage of the human eye's characteristics, these three signals are converted through a matrix into two signals aligned along the I and Q axes of the chromaticity diagram. It will be recalled that the eye's resolving power for color-only differences is less, even along the I axis, than it is for luminance differences. Thus, to make best use of the available bandwidth, the I channel information is limited to a bandwidth of about 1.2 MHz, and the Q channel is limited to about 600 kHz. Each of these video signals is then used to modulate the 3.58 MHz subcarrier in a normal balanced modulator, but in quadrature to one another. The resulting two double sideband suppressed-carrier signals, when combined, become a single subcarrier modulated in both amplitude and phase. The amplitude of this modulated subcarrier then represents the saturation, or amount, of color for each point in the picture, while the relative phase represents the hue, or predominant wavelength, of the same point in the picture. Thus, when this chrominance subcarrier signal is added to the luminance signal, the combination fully describes the characteristics of each point in the picture.

20.3.4 The composite color signal. There are two key differences between the composite monochrome signal and the composite color signal. First, a color subcarrier has been mixed with the video in each active line of the raster. Second, in order to phase lock the receiver's local 3.58 MHz oscillator, a short burst of 3.58 MHz carrier has been added to the back porch, after the horizontal sync pulse and before the end of horizontal blanking. FIGURE 8 shows the detail in one horizontal active line of this composite color signal. The burst is omitted during the vertical sync and equalizing periods. (see FIGURE 9)

20.3.5 RF modulating the composite color signal. Like the monochrome signal, the composite color signal is amplitude modulated onto a video carrier, and the resulting signal must occupy a limited space in the 6 MHz allocated channel. As with the monochrome signal, the carrier is offset from the center of the band, giving the luminance a vestigal sideband characteristic. The color subcarrier is also offset from the band center, at about 620 kHz below the top of the allowed band for video, so it too appears, with its sidebands, as a vestigal sideband transmission, with one sideband extending 1.2 MHz below the subcarrier, and the upper sideband limited to 620 kHz above the subcarrier. FIGURE 10 shows the combined frequency domain effect of a composite color signal RF modulated, and its associated audio carrier.

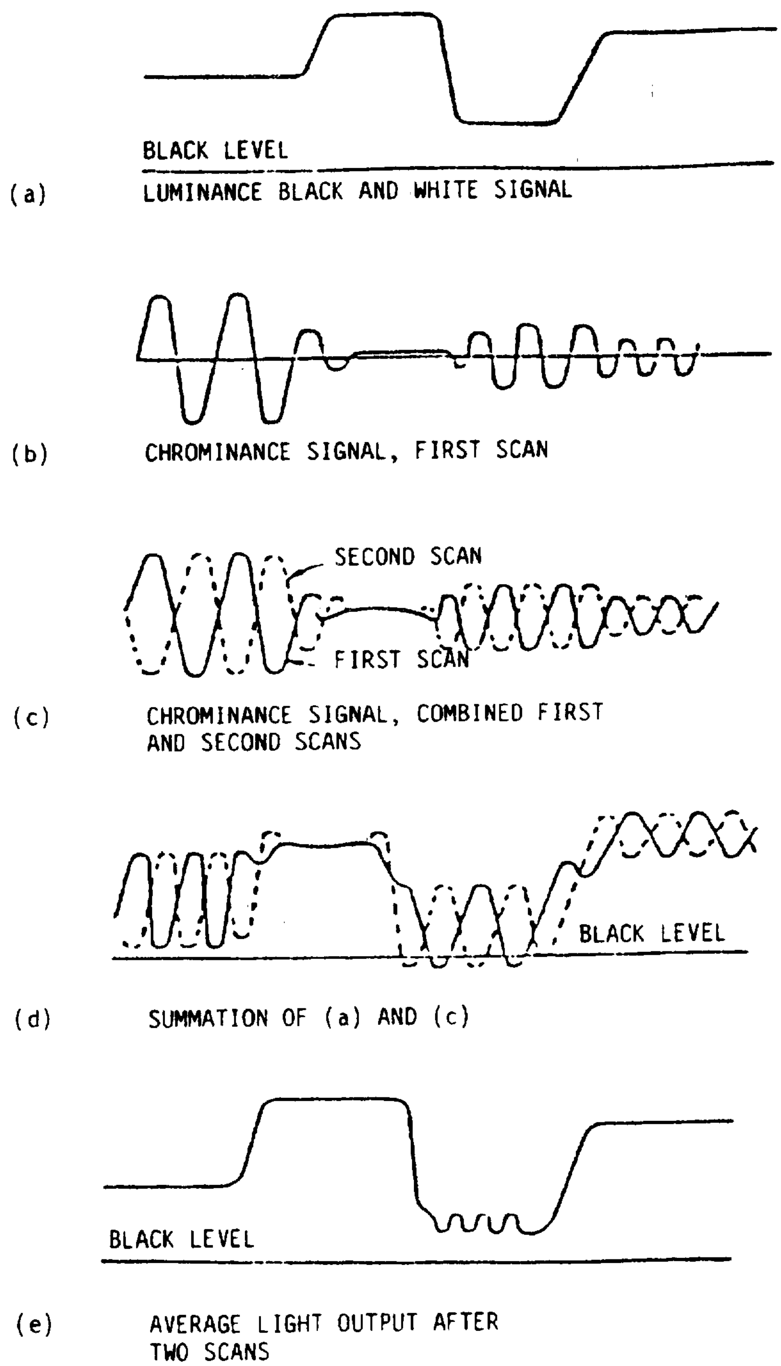
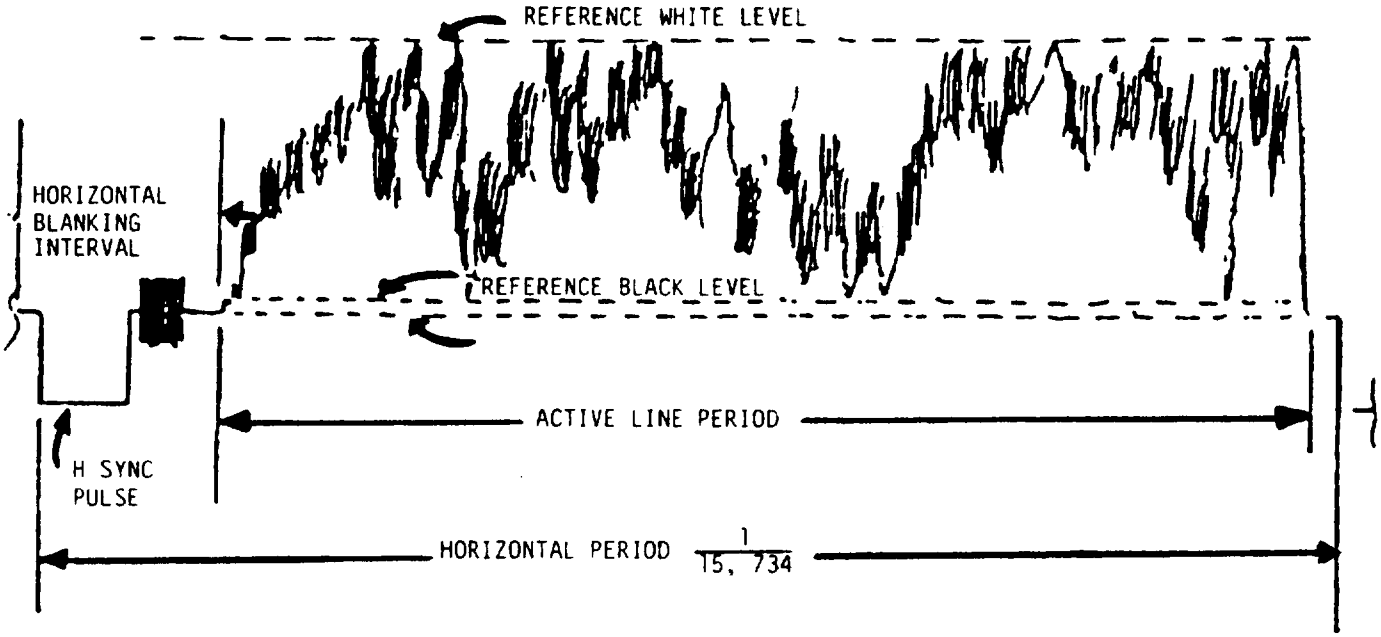
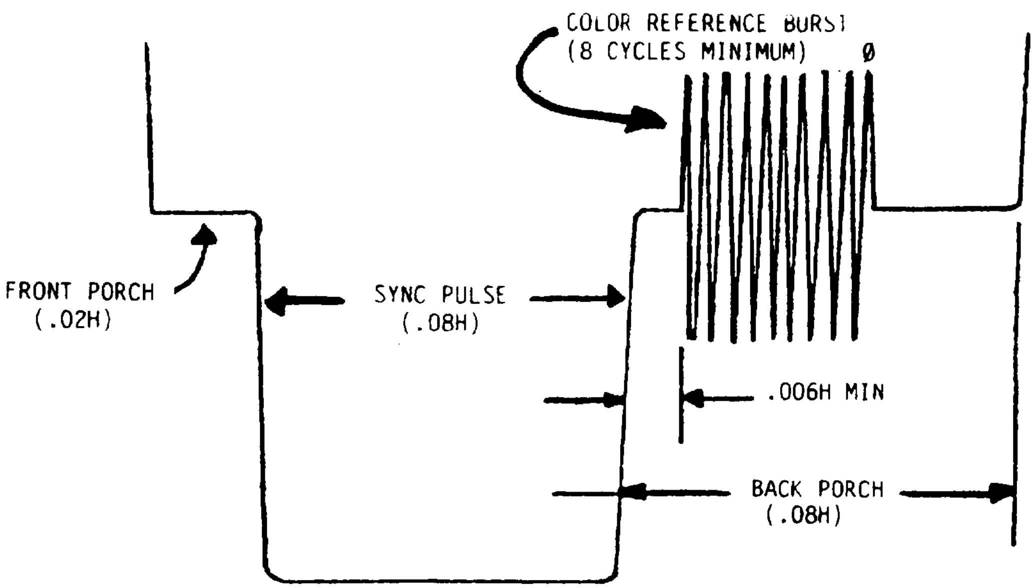


FIGURE 7. Self-cancellation of chrominance signal in successive scans.



A. COMPOSITE VIDEO SIGNAL DETAIL, ONE HORIZONTAL LINE



B. HORIZONTAL BLANKING INTERVAL DETAIL

FIGURE 8. Composite NTSC color video signal, one line detail.

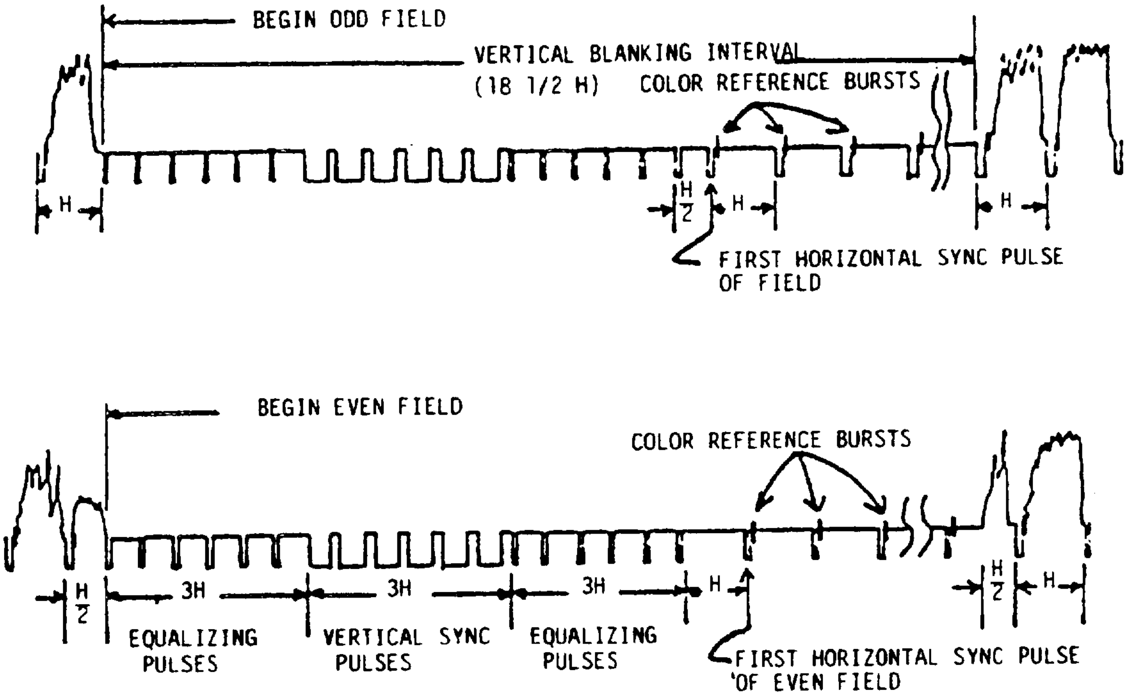


FIGURE 9. Composite video signal structure with color reference bursts.

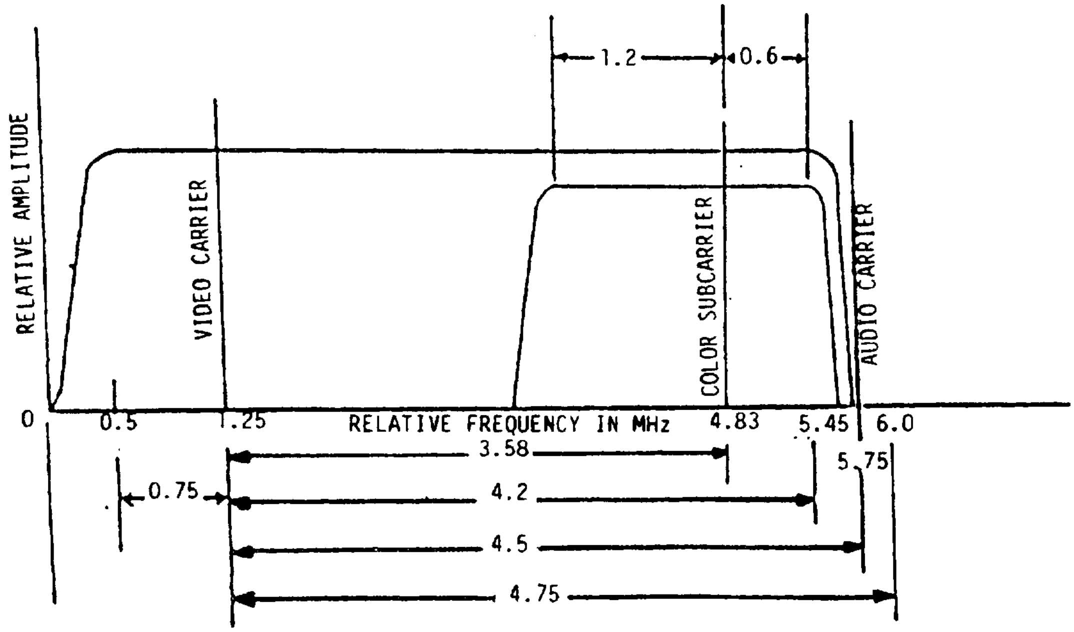


FIGURE 10. Frequency domain representation of RF modulated NTSC color signal.

20.3.6 Reception of the NTSC signal in baseband. To receive the baseband color signal, the receiver must reverse the process used to encode the signal into a luminance signal and a color subcarrier. As a given condition, the final step in the process will be the combining of the luminance and color-difference signals in the tricolor kinescope itself, by simply driving all three guns of the kinescope in parallel with the luminance, and driving another element in each gun with the color difference signals (R-Y, G-Y, and B-Y) in such a way that they add to form R, G, and B signals in the electron beams.

To get the color difference signal the subcarrier must be demodulated. Sychronous detection must be performed using a local oscillator at the exact subcarrier frequency to recover both amplitude and phase information. Further, if the color relationships are to be correctly reproduced, the phase of the local oscillator must be maintained in a constant relationship to the modulated subcarrier. The color burst, or reference signal is used to accurately synchronize the local oscillator for each horizontal scan. The burst is gated out in a synchronous manner to phase lock the local oscillator at the start of each line of video. So long as the frequency stability of the local oscillator is good enough for the 52 microsecond video portion of the line, the phase of the detection will be correct over the entire picture. The simplest way, or at least the most straightforward, to perform the decoding is to use two synchronous detectors with their phases at 90 degrees to each other, and aligned with the I and O modulation axes of the modulated subcarrier. This demodulation will produce two video signals, I and Q. Through a matrix transformation, these signals may be converted into the three color difference video signals R-Y, G-Y, and B-Y. There are however, two possible shortcut methods. Three synchronous demodulators may be used, and by aligning the phase angles of their local oscillator inputs directly to the phase angles corresponding to R-Y, G-Y, and B-Y, the three color difference video signals may be recovered in one step.

The second shortcut takes advantage of the fact that the luminance signal is composed of a weighted sum of the three camera signals. In this method, only two synchronous demodulators are used, and their phases are aligned with the R-Y and B-Y axes. These resulting two video signals are then matrix combined with the luminance signal to derive the G-Y signal.

FIGURE 11 shows a very simplified block diagram of each of the three types of receiver circuits. In FIGURE 11 (a), note that both the luminance and the I signal must pass through delay lines (of unequal length) to align their detected envelopes with the Q signal. These delay lines were a significant cost item in the receiver, so the two shortcut methods shown in (b) and (c) of the Figure were devised principally to reduce the required number of delay lines from two to one. Treatment of the luminance signal for method (b) and (c) of the Figure were devised principally to reduce the required number of delay lines from two to one. Treatment of the luminance signal for method (b) is the same as for method (a), so it has been omitted from the drawing of (b). In the I and Q demodulation method, there is a bandwidth-limiting filter in the Q channel, to limit that channel to about 600 kHz response, while the I channel is permitted the full bandwidth of 1.2 MHz. In both of the other methods, all three color difference signals are bandwidth-limited to 600 kHz or less, therefore earning the name Equiband. The rationale behind using these limitations in the receiver will be better and more meaningful if discussed in the context of rereceiving an RF Modulated signal.

20.3.7 Receiving the RF modulated color signal. If the color subcarrier were a simple amplitude modulated carrier with only one video modulation, the fact of the vestigal sideband method of transmission would cause no ill effects. It is, however, a phase and amplitude modulated signal, with two video sources (I and Q) modulating it in quadrature. When such a signal is subjected to vestigal sideband transmission, however, there is effectively an interaction between the I and Q signals. When demodulated, the Q signal contains spurious sidebands related to the I signal. These crosstalk components show up in the Q signal channel at frequencies above 600 kHz, so a band-limiting filter was used in the receiver's Q channel, thereby eliminating the crosstalk components without in any way deteriorating the desired I and Q signals. In the shortcut methods, I and Q are never demodulated per se; so the only way to eliminate the effects of vestigal sideband quadrature crosstalk is to bandwidth limit all of the chrominance signals after detection. This method saves money in the production of receivers, but at the expense of giving up the additional detail of color rendition carried in the I channel.

This is particularly damaging in the case of baseband systems using receiver-monitors, because in most such cases the bandwidth of the baseband channel is sufficient that no vestigal sideband effect will be present, and therefore no crosstalk would be present. Nevertheless, the receiver-monitor rolls off all the color-difference signals at 600 kHz.

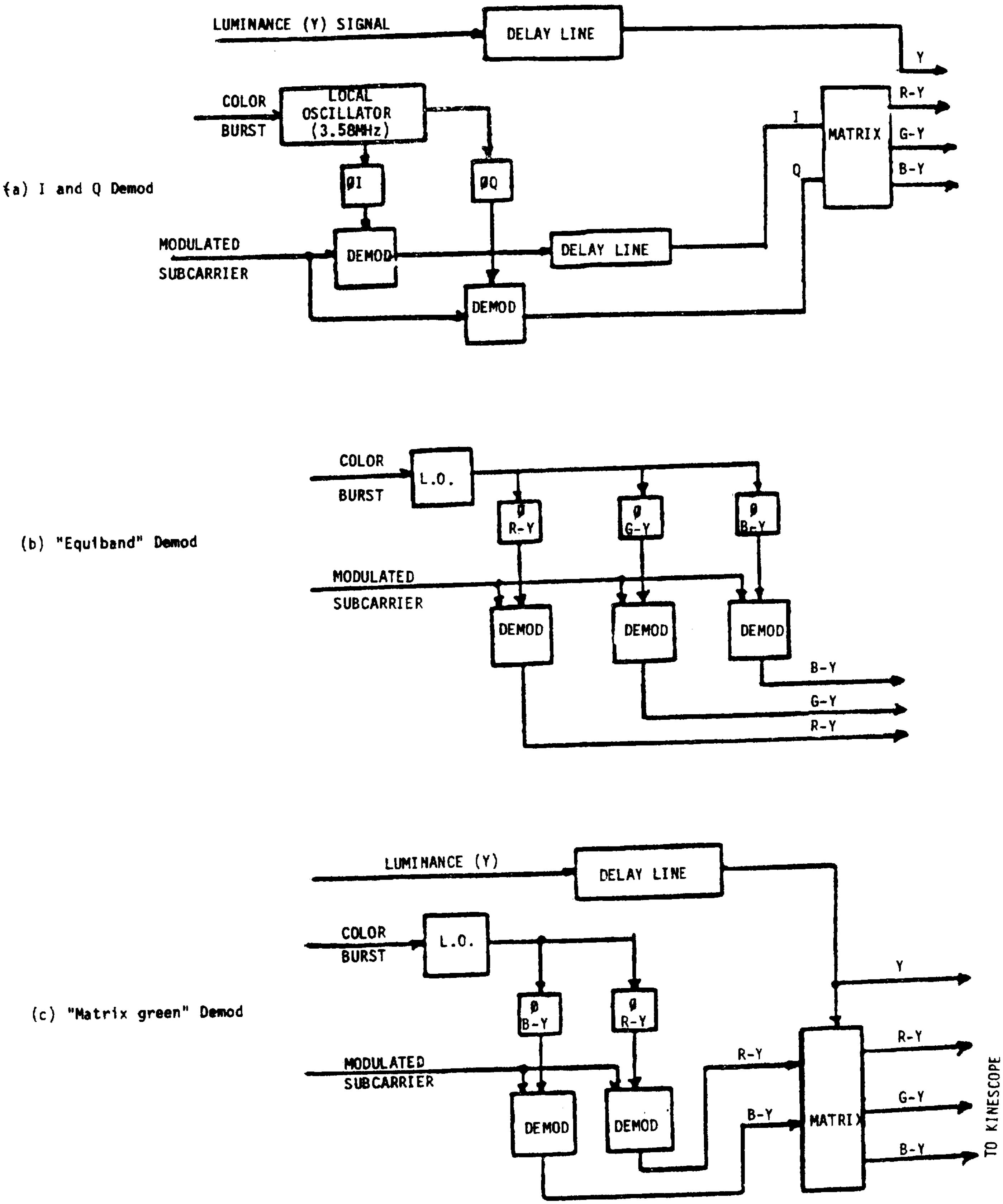


FIGURE 11. Three methods of decoding NTSC color video.

20.3.8 Luminance channel effects. In monochrome receivers, as shown on FIGURE 7, the effect of the chrominance signals in the luminance signal channel was permitted to self-cancel on the viewing surface. In color receivers, however, the discrete spatial distribution of the color phosphor triads would not permit self-cancellation. Two approaches were used to eliminate the majority of the chrominance signal from the luminance channel before sending the signal to the kinescope. In some receivers, a notch filter at the subcarrier frequency was used to eliminate the subcarrier and its near sideband. In other receivers, advantage was taken of the fact that the spatial distribution of the triads would, in and of itself, limit the achievable bandwidth for the luminance, so a simple low-pass filter was used, limiting the luminance channel to about 3 MHz.

Recently, a higher resolution tube has been developed, with about four times the number of triads per unit area. This tube allows the color receiver to achieve much greater bandwidth in the luminance channel, but requires that the subcarrier and its sidebands be selectively eliminated from the luminance channel. For that purpose, advantage is taken of the NTSC system's design, wherein the chrominance subcarrier and its sidebands fall in between those of the luminance signal. A comb filter is used in such receivers to remove the chrominance signal without degrading the luminance. Thus, in baseband applications, the new tube and the comb filter permit luminance bandwidths to about 6 MHz.

30. APPLICATION OF CCTV PROJECTORS, TYPE VII, CLASS 2

30.1 Basic approaches. The most basic consideration in applying projectors is whether to front-project the image or to rear-project the image. In most military applications, rear projection is used.

30.1.1 Front projection. Where a true theater situation exists, and little or no ambient lighting is required in the viewing space, front projection can be used. The major considerations to be taken into account here are the size and shape of the audience which must view the screen. These considerations determine the size of the screen and the type of screen which is suitable. The size of the screen should be determined by the distance from the screen to the farthest observer. The screen width should be not less than 1/10th of the distance to that observer. The width of the audience area determines the type of reflective material which should be used on the screen surface. For very wide audiences, a matte white painted surface is best. For narrow audiences, a high gain screen, of the beaded or lenticular type will offer improved brightness. Figures 12 and 13 show the key room characteristics which are used in designing front projection theaters.

The gain of the screen is measured relative to the reflectance a perfect white diffuse surface would give. Such a surface would have a gain of one. As shown in Figure 14, a matte white surface closely approximates a gain of one even for relatively high viewing angles. A lenticular screen shows a gain of about two for small viewing angles, dropping off to about one at 40 degrees, and dropping rapidly beyond 40 degrees. Still, if the maximum viewing angle will be 40 degrees or less, advantages will be available to most viewers from using a lenticular screen. A glass beaded screen is somewhat more directional than the lenticular, and therefore has even higher gain for small viewing angles, but its gain drops more rapidly as viewing angle increases.

30.1.1.1 Calculating brightness. For matte screens, the gain is sufficiently close to one that viewing angle can in most cases be neglected, and the calculation of brightness becomes its most simple. The brightness from the screen is simply the light output from the projector, in lumens, divided by the area of the image in square feet.

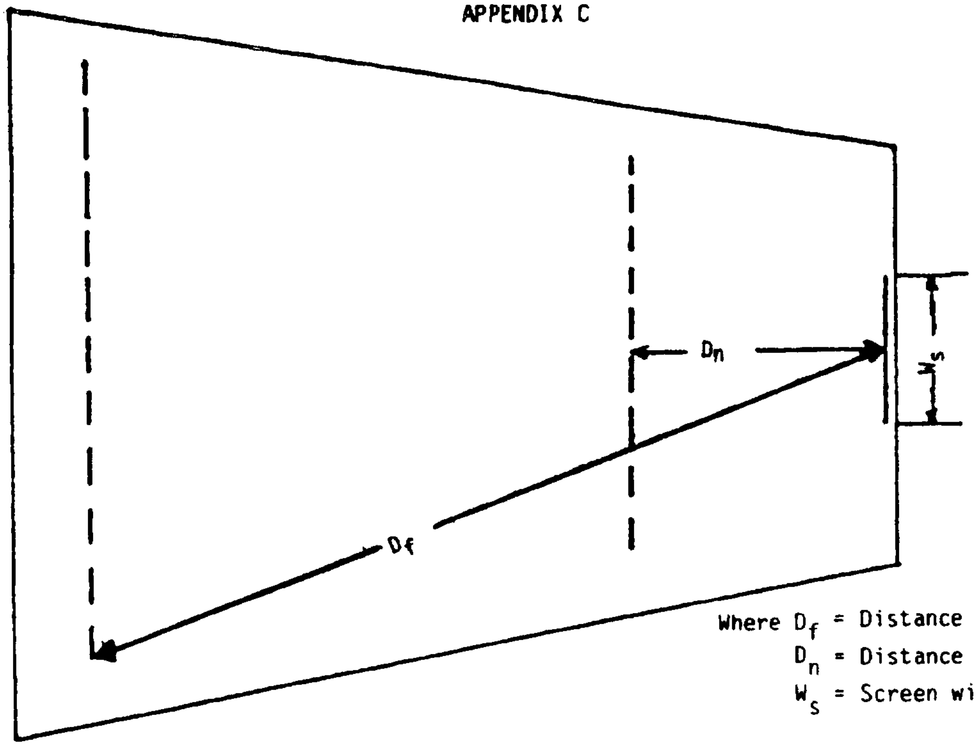
$$B\ (\text{ft-lambert}) = \frac{B_P\ (\text{lumens})}{A_I (\text{ft}^2)}$$

For other screen materials, at least two calculations should be made. First, calculate the brightness for on-axis viewers by taking the projector output in lumens, divided by the image area in square feet, and multiplied by the maximum (or rated) gain of the screen.

$$B_{max} = \frac{B_p\ (\text{lumens}) \times G_{smax}}{A_I\ (\text{ft}^2)}$$

Next, take the maximum viewing angle for the entire audience, as shown in Figure 13 and find from Figure 14 the gain figure for that viewing angle. Repeat the calculation using this second gain figure. (Note that these calculations need not be carried out to three decimal places. The logarithmic response characteristic of the human eye will excuse errors of about ±30 percent).

$$B_{min} = \frac{B_p \times G_\theta}{A_I}$$



Where D_f = Distance farthest
D_n = Distance nearest
W_s = Screen width

Recommended practice: $\frac{D_f}{10} < W_s < \frac{D_n}{4}$

FIGURE 12. Typical theater arrangement.

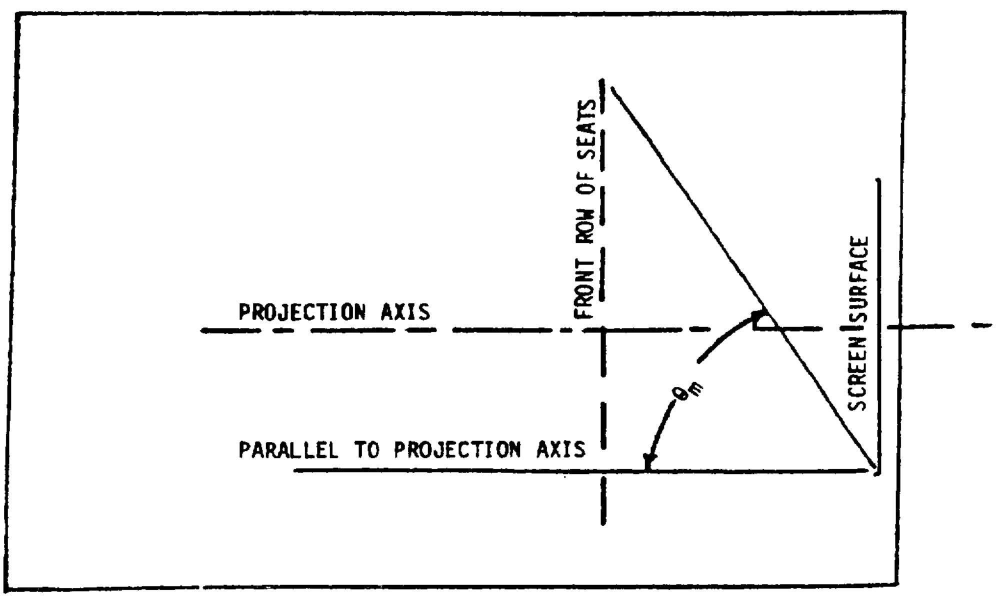


FIGURE 13. Illustration of maximum viewing angle, θ_m.

30.1.1.2 Calculating contrast. Let's simply assume the contrast of the projector to be infinite, so that in areas supposed to be black in the image, no light at all will come from the projector. Contrast of the image on the screen will be the ratio between the maximum highlight brightness and the minimum brightness, where this second quantity is due entirely to the presence of illumination sources other than the projector.

FIGURE 14 shows a typical theater arrangement in elevation view, simplified to show only those things in the room which will be important to our calculation. Assume that some level of illumination will be kept on to allow the audience to take notes, and that some device, such as the baffle shown on FIGURE 15 has been provided to prevent direct illumination of the screen by the overhead fixtures. This means that only reflected light will reach the screen surface from the audience area. The incident light falling on the audience must be measured or approximated. (Normal range for this incident lighting would be 10 to 25 foot candles.) The reflected light reaching the screen would be somewhere between five and twenty percent of this incident light. (Five percent may be used if the majority of the light from the overhead fixtures is concentrated toward the floor, with little or no light striking the walls. Twenty percent is a safer figure, and is more nearly correct when a significant amount of the light from overhead strikes the walls.)

Contrast is expressed as the ratio between the brightest (B_h) and dimmest (B_d) spots on the image:

$$C = \frac{B_h}{B_d}$$

At the highlight spots, the brightness will be the sum of the brightness from the projector and that from the reflected room light. Thus if B_{hp} is defined as the brightness due to the projector alone, then $B_h = B_{hp} + B_d$. Thus the contrast equation may be re-written as:

$$C = \frac{B_{hp} + B_d}{B_d} = \frac{B_{hp}}{B_d} + \frac{B_d}{B_d} = \frac{B_{hp}}{B_d} + 1$$

In this equation, B_{hp} is the highlight brightness of the projector as calculated in a previous equation, and B_d is calculated by taking the measured or approximated room light, multiplied by a reflectance factor, and then multiplied by the screen's rated gain factor:

$$B_d = L_i \times R_a \times G_s$$

Where L_i is the incident light, R_a is the reflectance factor for the audience, and G_s is the gain of the screen. Then, by substitution:

$$C = \frac{B_{hp}}{L_i \times R_a \times G_s} + 1$$

Now, using the maximum and minimum brightness figures calculated earlier, a calculation can be made of the minimum and maximum contrasts by substitution in the last equation.

30.1.1.3 Sample calculations. Use of these equations may be illustrated by using a typical case of a small theater which might be used for briefings at a military installation. The first calculation required is the screen size, where, for example, the farthest observer is 50 feet from the screen. The minimum width for the screen is given by:

$$W_{smin} = \frac{D_f}{10} = \frac{50}{10} = 5 \text{ feet}$$

Given this width, the height is determined by dividing by the aspect ratio, thus giving the height as 3.75 feet. Next some assumed values can be used to calculate the minimum and maximum contrast ratios. Assume a projector brightness of 700 lumens, and a screen of the lenticular type, with a maximum viewing angle of 40 degrees.

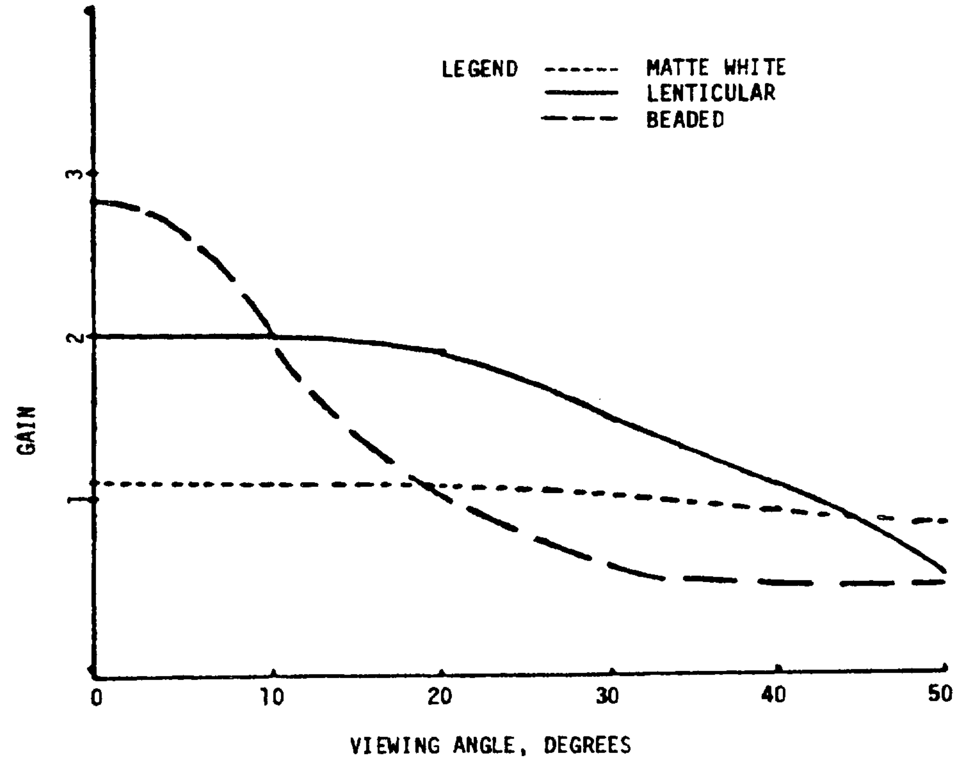


FIGURE 14. Gain versus viewing angle for front projection screens.

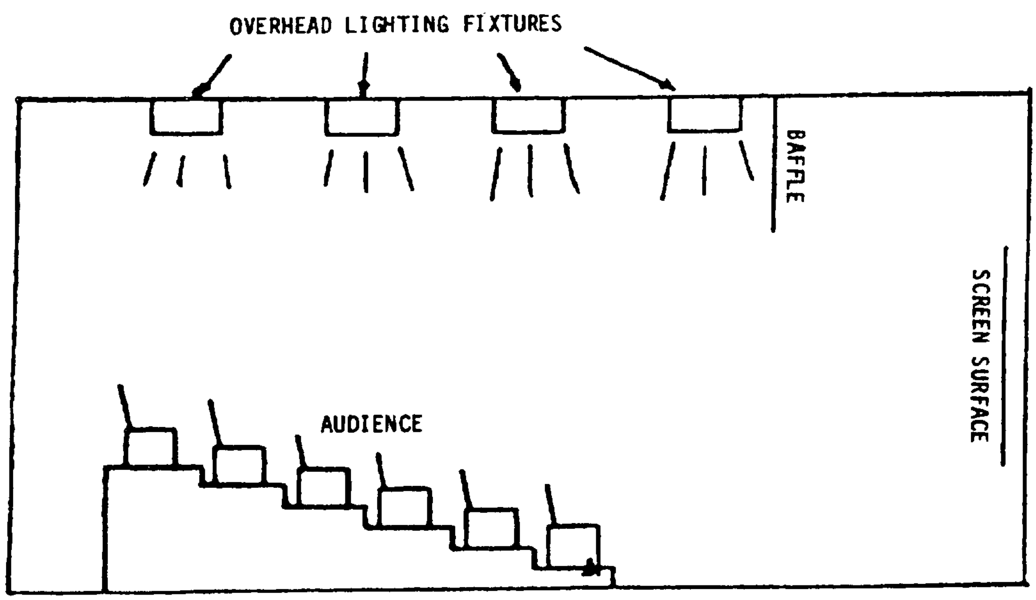


FIGURE 15. Typical theater arrangement, elevation view.

For an on-axis observer, the highlight brightness from the projector only is:

$$B_{hpmax} = \frac{B_p \times G_s}{A_s} = \frac{700 \times 2}{5 \times 3.75} = 74.6 \text{ ft-lamberts}$$

For the "worst seat" viewer, at the far side of the screen, substitute a different value for G_s, derived from FIGURE 14.

$$B_{hpmax} = \frac{B_p \times G_\theta}{A_s} = \frac{700 \times 1.1}{5 \times 3.75} = 41.1 \text{ ft-lamberts}$$

Now assume that our worst seat viewer has a minimum viewing angle of only 20 degrees. Thus at the other side of the screen, that viewer's brightness will be higher by the ratio of the gain values for these two angles, or 41.1 x 1.9/1.1 = 70 foot-lamberts.

Assume that ambient incident lighting on the audience is at 20 foot-candles, and that significant light falls on the walls, so an audience reflectance factor of 20 percent is used. The maximum contrast, then will be:

$$C_{max} = \frac{B_{hpmax}}{L_i \times R_a \times G_s} + 1 = \frac{74.6}{20 \times 0.2 \times 2} + 1 = 10.325$$

Next, the minimum value, which is for our worst seat observer at the extreme far side of the screen is calculated.

$$C_{min} = \frac{B_{hpmin}}{L_i \times R_a \times G_s} + 1 = \frac{41.1}{20 \times 0.2 \times 2} + 1 = 6.14$$

These results would generally be considered unsatisfactory, at least for the worst seat viewer. In most cases, the contrast ratio should be kept at an absolute minimum of 10:1 for the worst seats, 20:1 or better for the best seats. The easiest way to improve this situation is to lower the ambient lighting. For example, if a reduction of 75 percent in the over head lights was made, so that the L_i was five foot-candles, the minimum contrast for the worst seat would be about 21.5:1, and the maximum contrast for the best seats would be over 38:1.

30.1.2 Rear projection. FIGURE 16 shows a typical room configured for rear projection. A projection room has been added behind the screen. The required size for this projection room is governed by the projection lens and the size of the screen. Usually, the room must be at least 1.5 times the screen width deep, not counting the depth of the projector itself.

The calculations required to determine performance of rear screen projectors are more complex and more difficult to understand than those illustrated above for front projection. In addition, there are two basically different kinds of screen materials available, and the approaches to performance calculations for the two are quite different. The most commonly used screens are the simple diffusion type. These consist of a large transparent substrate (usually glass) and a thin layer of coating material which is translucent. Gain of the screen is determined by the thickness of this coating and its composition. In general, thinner coatings yield higher gain and lower front reflectance than do thicker coatings. The coating material is on the side facing the audience, and in most cases is extremely susceptible to damage, most particularly from briefers touching its surface with wooden or metal pointers.

The less common type of screen material is a relatively new product which is called the lens-let type. This screen is all plastic, and has an extremely durable front surface. The principle of operation is quite different from the diffusion type, and in many instances it can offer significantly better performance than the diffusion type.

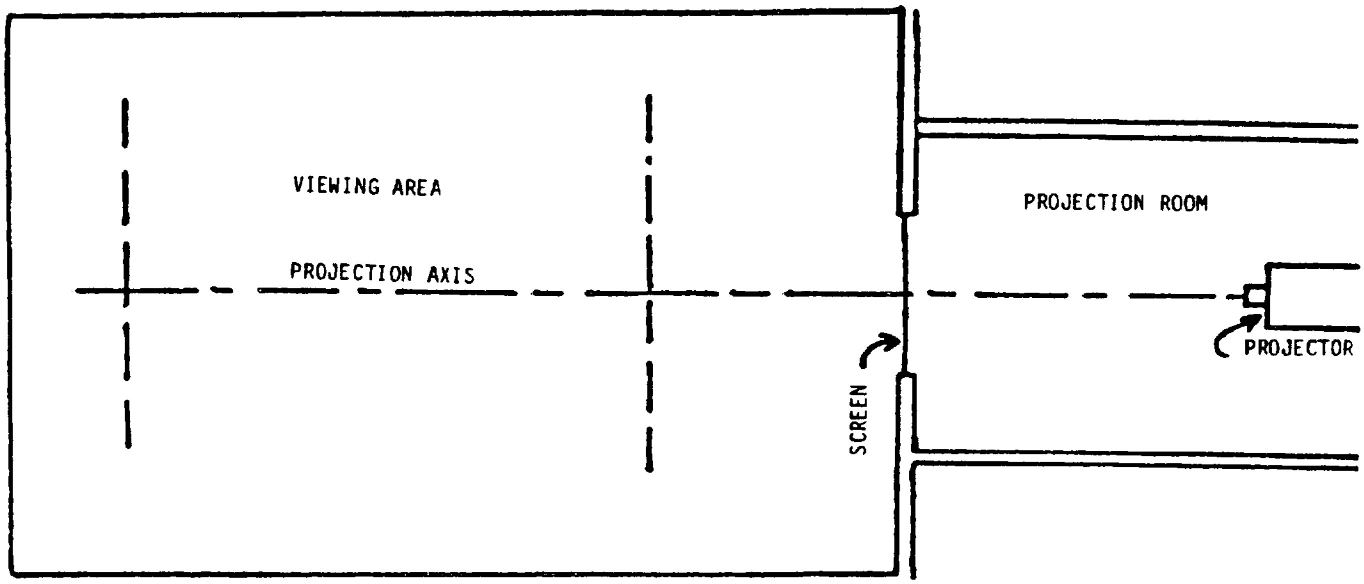


FIGURE 16. Typical rear projection theater arrangement.

30.1.2.1 Brightness and contrast calculations for diffusion screens. A diffusion screen operates by intercepting the incident rays from the projector at its front surface and scattering them through a limited angular wedge in the viewing area. The scattering is by no means uniform over the viewing area. In fact, the majority of the energy from any incident ray is concentrated into a relatively narrow solid angle around the path which the ray was traveling on before hitting the screen. The width of that solid angle is a function of the gain of the screen. For high gain screens more of the light goes into the direct ray, and less into the wider angles. Conversely, for lower gain screens, more of the light is scattered into a wide angle of coverage, and proportionately less is concentrated into the direct ray. The rated gain for a diffusion screen is a measure of the ratio between the light energy in the direct ray and the energy which would be reflected from that same beam by a perfectly diffusing white surface.

The diffused light from a given ray, measured away from its direct path, is a function of the screen gain and the bend angle. To make this concept of bend angle comprehensible, look at FIGURE 17. On that figure, the observer seated to the far side of the front row of seats is labelled Observer O_w. When the observer looks at the far side of the screen, light rays from the projector must be "bent" from their direct path through an angle θ1, in order to reach the eyes. When the observer looks at the near side of the screen, the rays of the projector must be bent through a much smaller angle, θ2, to reach his eye. This difference in bend angles for that observer to look at different parts of the screen surface will mean that the screen's brightness and contrast will not appear uniform. The near edge of the screen will appear much brighter than the far edge and will show greater contrast. The effect will get worse as the screen's gain is increased. In rear projection the diffusion screens, the non-uniform brightness effect will be different for each observer in the audience. On FIGURE 18, we've shown an observer at the rear of the room. For this observer, the maximum bend angle θ1, is far less than for the previous observer, and the minimum bend angle θ2 is zero. This means that this observer will, at one point on the screen see the maximum brightness for that projector and screen and this brightness will fall off in all directions away from that hot spot. For high gain diffusion screens, this hot spot effect will be at its worst for an observer near either end of the first row of seats, where he can see the direct ray at the near side of the screen, and at the other side of the screen sees through a large bend angle. (see FIGURE 19).

Because of the wide variation in performance for different seating positions, it is usually necessary to calculate brightness and contrast for more than one observer, and to calculate the values for each selected observer at more than one point on the screen surface. For the sake of illustration, using the observers O_w and O_r from FIGURES 17 and 18, and we'll calculate brightness and contrast for each of them at the brightness and dimmest spots on the screen for those observers.

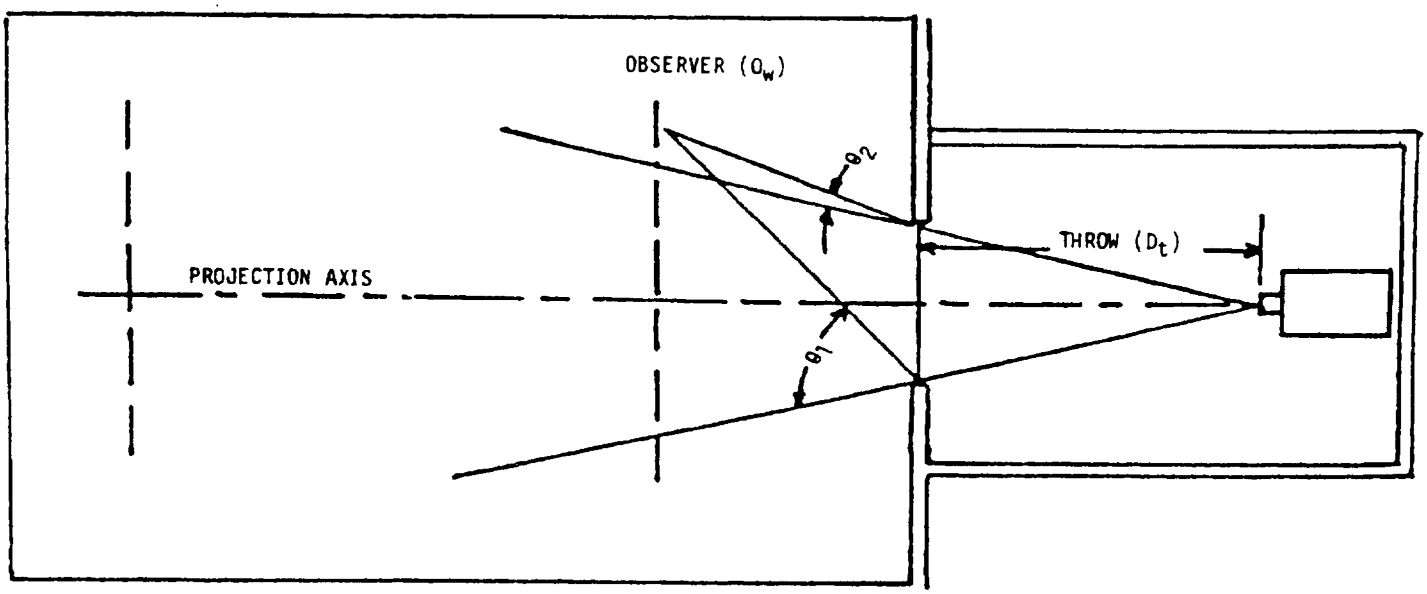


FIGURE 17. Illustration of the concept of bend angle.

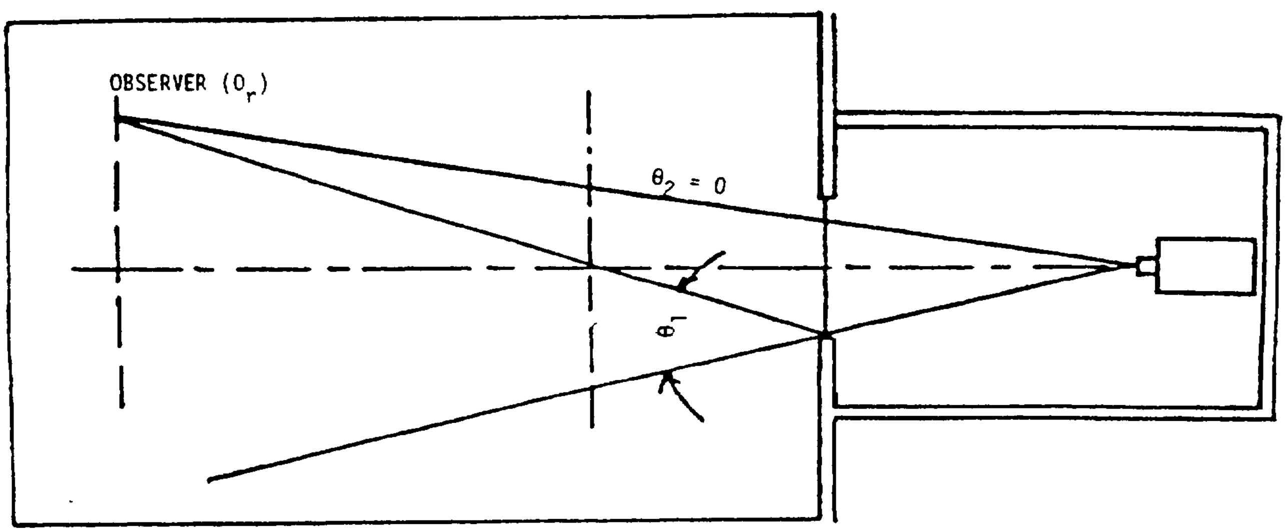


FIGURE 18. Illustration of the concept of hot spot effect.

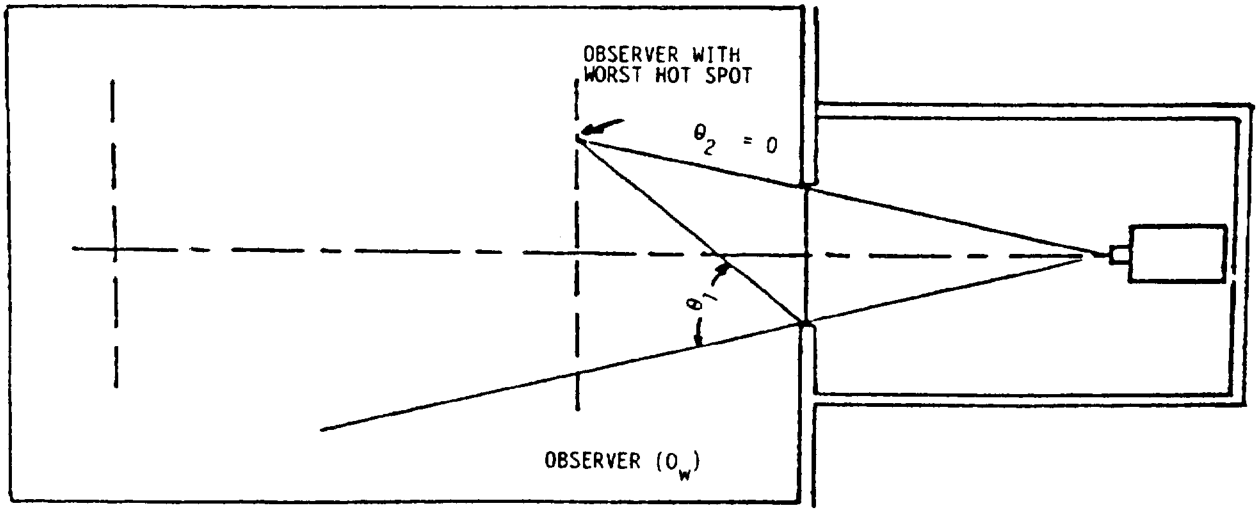


FIGURE 19. Illustration of maximum hot spot condition.

The general equation for the brightness of a spot on the screen for a selected observer is:

$$B_0 = \frac{B_p \times G_\theta \times \cos^2 \phi}{A_I}$$

Where B_p is the brightness of the projector in lumens, G_θ is the gain factor for this screen at the particular bend angle θ, $\cos^2 \phi$ is a factor to account for the angle between the projection axis and the direct ray from the projector to the screen surface, and A_I is the area of the image in square feet.

Of these quantities, B_p is of course found among the salient features given by the projector manufacturer, and A_I is simply the product of the height and width of the image in feet. G_θ is found by taking the rated gain for the screen and the bend angle θ into a chart such as FIGURE 20, moving up the chart from the bend angle to the appropriate member of the family of gain curves, and reading off the number from the ordinate axis. That number is G_θ for that screen at that bend angle. The angle ϕ is found by simple trigonometry, as shown on FIGURE 21.

It should be noted that the gain curves shown on FIGURE 20 are quite different from those for front projection surfaces. In that previous case, a gain factor of 1 meant that the gain was almost constant over a wide range of viewing angles. In this case, even a gain of 1 screen shows a rapid falloff in G_θ as θ increases.

Contrast may be calculated for any observer and screen point combination from the equation:

$$C_o = \frac{B_o}{L_r} + 1$$

Where B_0 is the calculater brightness for that observer at that point on the screen, L_r is the ambient room light reflected off the front of the screen, and the +1 is used to account for the fact that the reflected light adds to the brightness in the highlight areas.

The quantity L_r is calculated in a manner similar to the way in which B_d was calculated for front projection:

$$L_r = L_i \times R_a \times R_s$$

Where L_i is the light incident upon the audience, R_a is the average reflectance factor for the audience, and R_s is the front reflectance of the screen material. (R_s is usually obtained from the manufacturer's specification sheet for the screen. R_a is a figure somewhere between five percent and twenty percent, depending on circumstances and distribution of overhead lights.)

30.1.2.1.1 Sample calculation. For the sake of convenience, consider our viewer O_w to have the same viewing angle as in the previous case (40 degrees). Now, it must be noted that viewing angle and bend angle are not the same. In the front projection case, viewing angle may be considered as the angle between the viewer's sight line and the normal to the screen. The bend angle θ is greater than that in this case, by an amount equal to the projection angle $\emptyset$ (see FIGURE 22). The angle $\emptyset$ can be calculated from the throw distance and half of the screen width (quantity a from FIGURE 21), as follows:

$$\emptyset = \arctan \frac{2.5}{7.5} = 18.4 \text{ degrees}$$

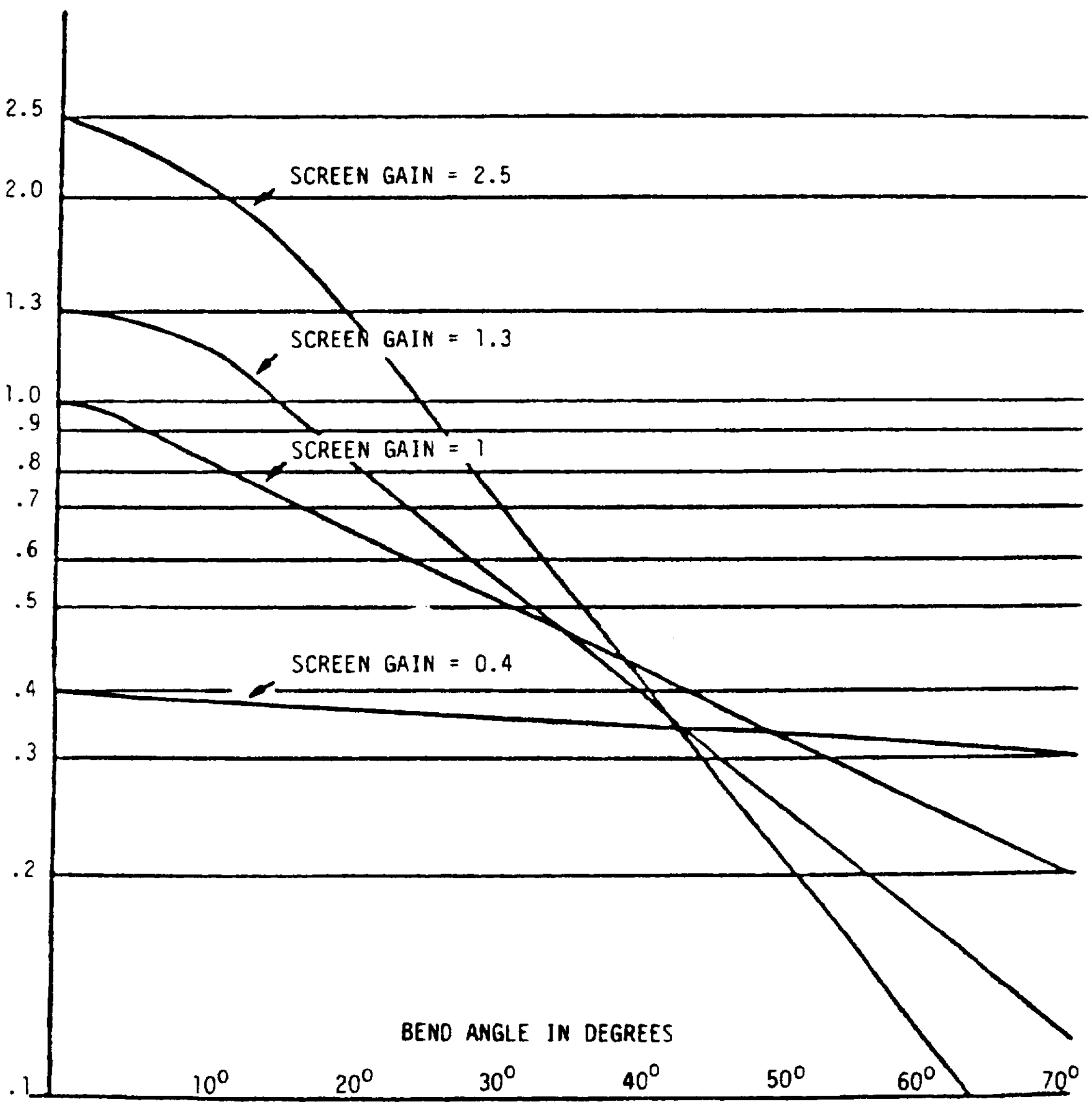


FIGURE 20. Relative gain (G_θ) versus bend angle ($\emptyset$) for diffusion screens.

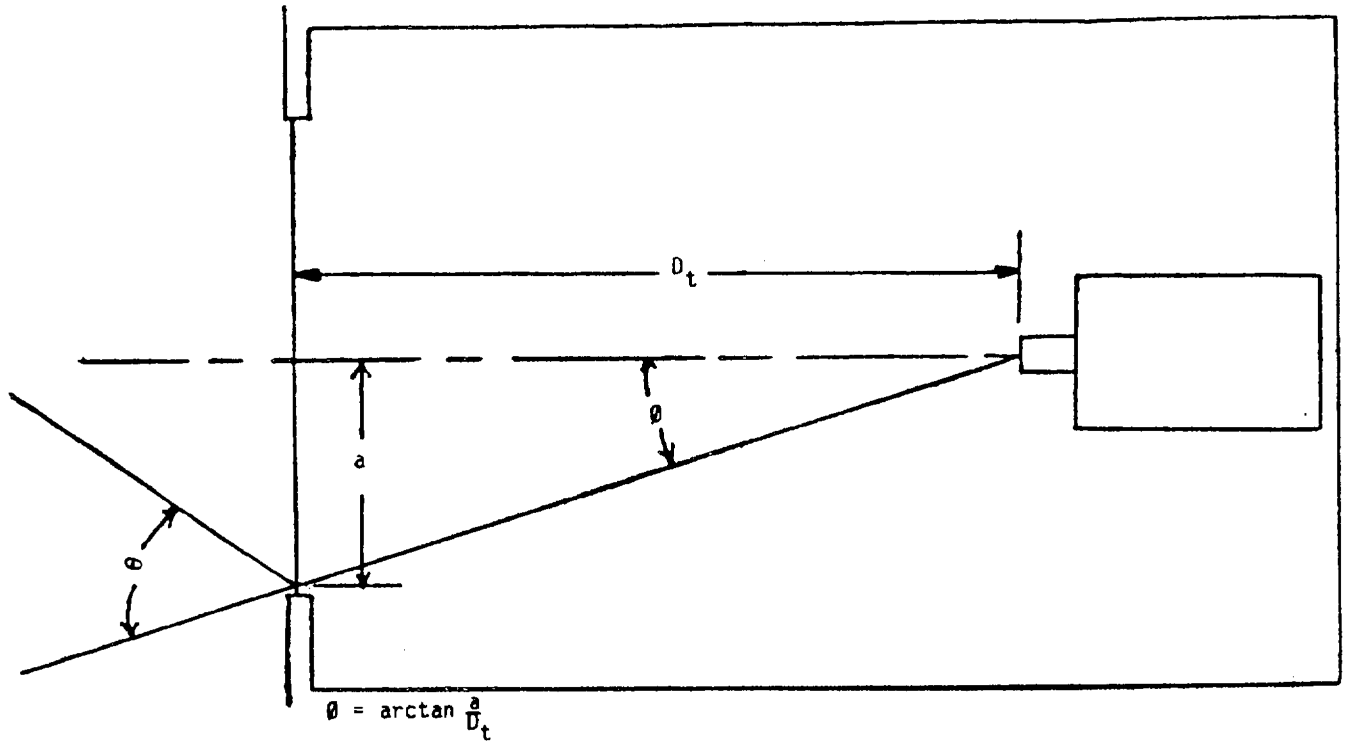


FIGURE 21. Definition of the projection angle Ø.

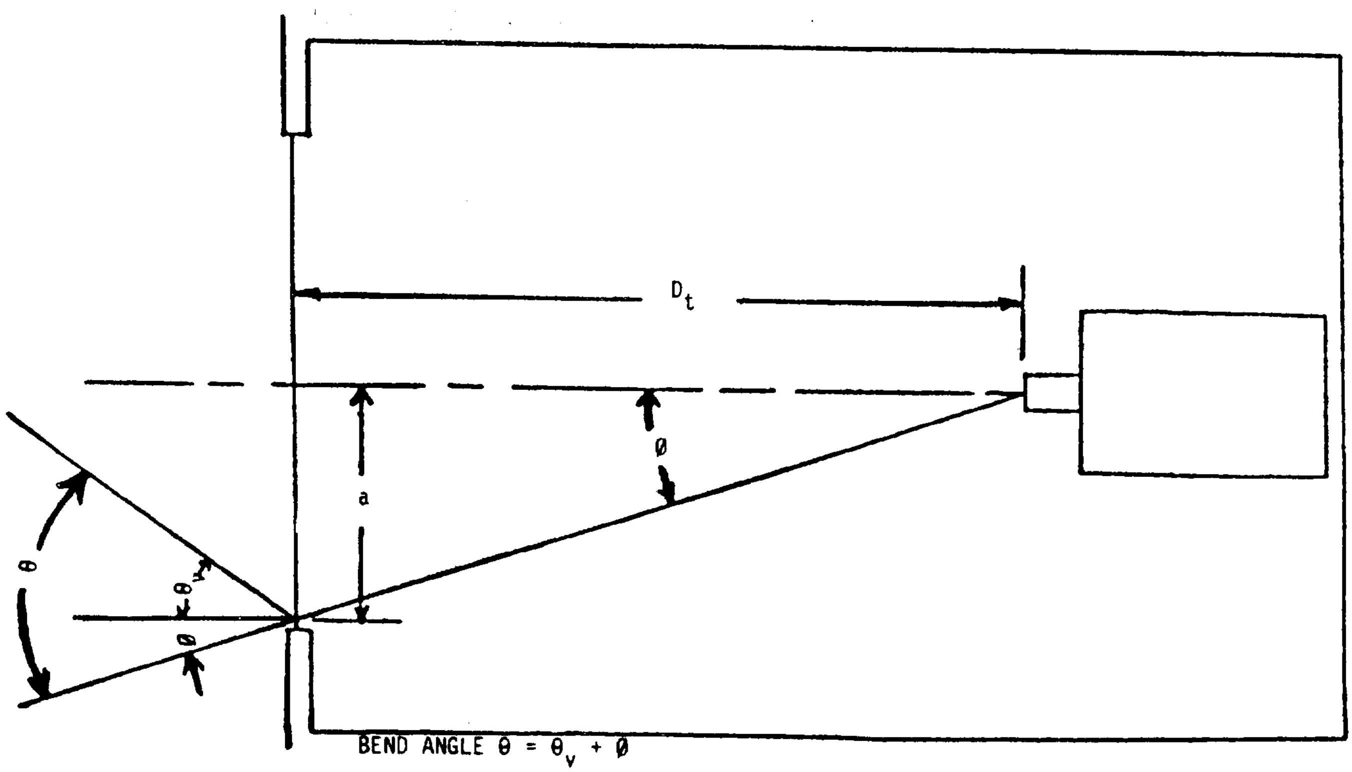


FIGURE 22. Finding bend angle for observer O_W.

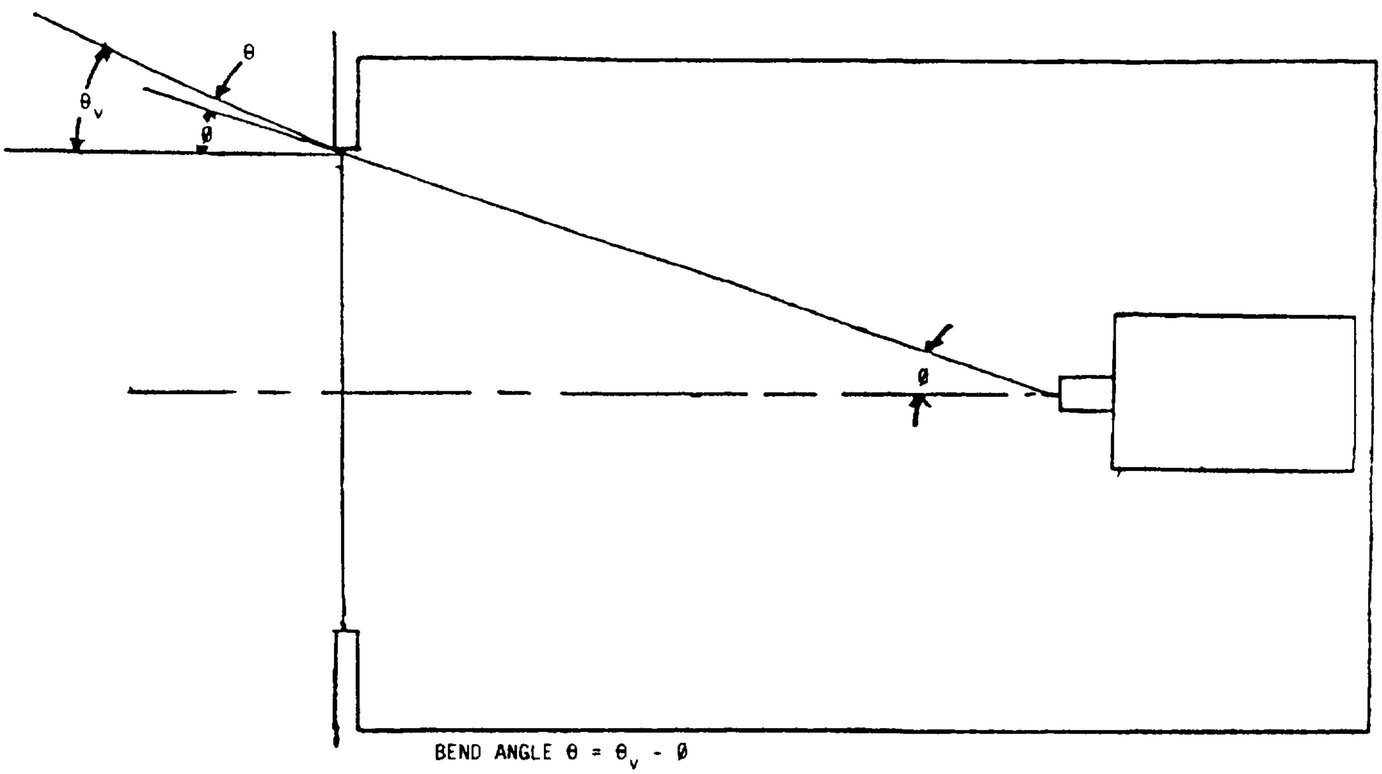


FIGURE 23. Finding near-side bend angle for observer O_W.

Then the angle θ is:

$$\theta = 40 + \phi = 58.4 \text{ degrees}$$

Assuming a screen-gain FIGURE of 1.3 (a commonly used value) and using Figure 20, the value of G_θ is found as 0.17. Taking the projector's output as 700 lumens, and the area of the screen as 5 feet x 3.75 feet, the brightness for this spot as seen by this observer may be calculated as follows:

$$B_o = \frac{B_p \times G_\theta \times \cos^2 \phi}{A_I} = \frac{700 \times 0.17 \times 0.90}{5 \times 3.75} = 5.71 \text{ foot-lamberts}$$

At the other side of the screen, the brightness for this observer will be greater. In this case, the bend angle becomes less than the viewing angle by ϕ degrees. Thus, taking the viewing angle as 20 degrees and the angle ϕ as 18.4 degrees, the angle θ is 1.6 degrees. Using FIGURE 20 yields a gain G_θ of 1.29, so the brightness may be calculated:

$$B_o = \frac{B_p \times G_\theta \times \cos^2 \phi}{A_1} = \frac{700 \times 1.29 \times 0.90}{5 \times 3.75} = 43.3 \text{ foot-lamberts}$$

Obviously, the uniformity of brightness for this observer will not be good. The ratio between brightest and dimmest highlights will be 7.58:1.

Minimum and maximum contrast ratios for this observer may be calculated as follows, assuming the same lighting conditions as for the front projection example:

$$C_{max} = \frac{43.3}{20 \times .2 \times .2} + 1 = 55.1:1$$

$$C_{min} = \frac{5.71}{20 \times .2 \times .2} + 1 = 8.13:1$$

That's really too wide a variation in brightness and contrast to make viewing comfortable for this viewer. This example shows that, where diffusion screens are used, great care must be taken in the relationships between the viewer's seating position and the screen. The situation could be helped in two other ways, however, without changing his seating position. Making the throw distance longer would lessen the angle ϕ, and so cut down somewhat on the variation of θ. Using a lower gain screen would also help, since the variation of G_ϕ as a function of θ would be less severe.

To illustrate the effect of different seating positions, run calculations for an observer near the back of the viewing area, using the relationships approximately as shown on FIGURE 18.

At the far side of the screen, this observer has bend angle θ of about 36 degrees, and a corresponding value of G_θ of about 0.43. Therefore:

$$B_f = \frac{700 \times .43 \times .90}{5 \times 3.75} = 14.4$$

At the near side, his bend angle is about 11 degrees and G_θ is about 1.1, so:

$$B_n = \frac{700 \times 1.1 \times .90}{5 \times 3.75} = 37$$

At a spot near the near side, the observer has a hot spot, where $\theta = 0$, and $\cos^2 \phi = .95$, so:

$$B_{hs} = \frac{700 \times 1.3 \times .95}{5 \times 3.75} = 46$$

Contrasts for this observer then can be calculated:

$$C_{max} = \frac{46}{20 \times .2 \times .2} + 1 = 58.5:1$$

$$C_{min} = \frac{14.4}{20 \times .2 \times .2} + 1 = 18:1$$

$$C_n = \frac{37}{20 \times .2 \times .2} + 1 = 46.25:1$$

Thus, for this observer, the image from the screen is far better than it is for the first observer. The uniformity of the image would of course be improved by using a lower gain screen, but in actual practice this observer would probably find his view of the screen quite acceptable.

30.1.2.2 Lenslet rear projection screen. The lenslet type rear projection screen is a relatively new product, and uses an entirely different operating principle from the diffusion screens discussed above. The lenslet screen features a combination of high gain, excellent uniformity, and low front reflectance. It accomplishes this by dividing up the screen area into many very small discrete elements, and using a separate plastic lenslet to distribute the light incident at each of these elements through a controlled dispersion angle. The design of the lenslets permits the angle of dispersion to be different in the vertical and horizontal directions, thus tailoring the distribution of light energy into the audience area.

Figure 24 illustrates in greatly magnified form the action of the lenslet design on one discrete element. (A typical lenslet screen has about 400 such elements per inch in both horizontal and vertical directions, so that at the viewers position, the elements merge into an apparently continuous image.) This drawing shows a horizontal cross-section. The matte black stripes between elements are used to reduce the front reflectance of the screen, and occupy about one third of the total screen area. The lenslets channel all of the incident light out between these stripes, so no brightness is lost by the stripes being present.

With a lenslet screen, bend angle is of no importance. The light emerging from the screen is uniformly distributed over a controlled viewing angle range. Typically, the range is ±45 degrees in the horizontal direction, and ±20 degrees or less in the vertical direction. Over that range of viewing angles, the screen will, typically, show a uniform gain of about 4 to 4.5 for all observers. The cutoff outside that range of viewing angles is quite sharp, and at viewing angles of about ±60 degrees, the apparent gain will rapidly approach 0. For viewers within the ±45 degree horizontal by ±20 degree vertical range, the brightness at any point on the screen will be given by:

$$B_o = \frac{B_p \times G \times \cos^2 \phi}{A_s}$$

Where B_p is again the projector output in lumens, G is a constant, and $\cos^2 \phi$ is the projection angle factor, identical to that which we used in the case of diffusion screens. Contrast is found by the same equation used for diffusion screens:

$$C = \frac{B_o}{L_r} + 1$$

and again,

$$L_r = L_i \times R_A \times R_s$$

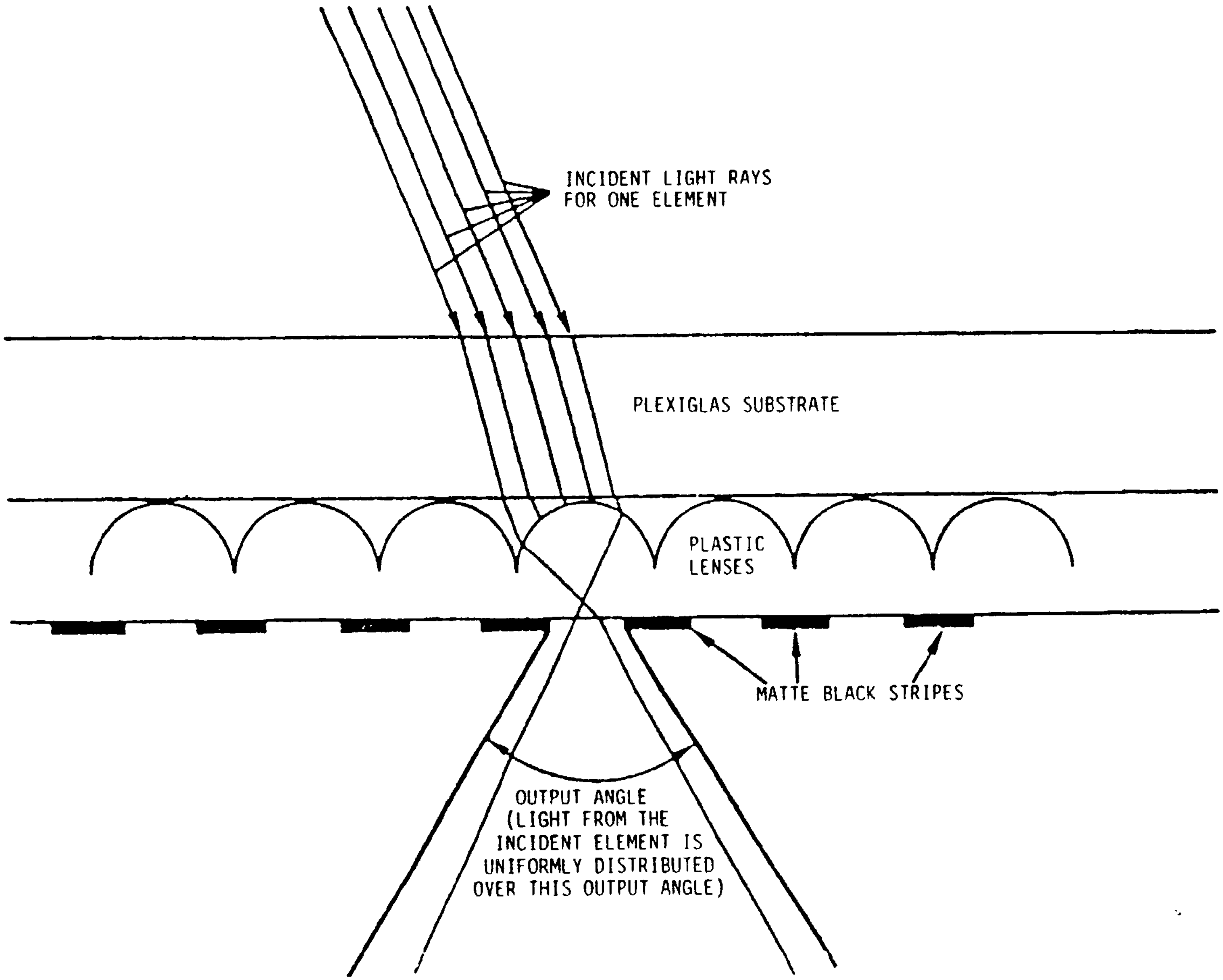


FIGURE 24. Detail of lenslet screen operating principle.

30.1.2.2.1 Sample calculations for lenslet screens. Again, use the observer O_w, and observer O_r, and approximately the same conditions as our previous example. Note that, given the coverage angles for the screen, the only variable needed to be considered in the equation for brightness is $\cos^2 \emptyset$. That variable will cause exactly the same effect for all viewers. Therefore, calculate only the brightness and contrast at the center and the edges of the screen. At the center:

$$B_c = \frac{B_p \times G_s \times \cos^2 \emptyset}{A_s} = \frac{700 \times 4 \times 1}{5 \times 3.75} = 149.33$$

and at the edges:

$$B_e = \frac{700 \times 4 \times 0.9}{5 \times 3.75} = 134.4$$

Thus, all viewers in the viewing area will see a high picture brightness, with only a slight difference between the center and the edges of the image. Contrast calculation is the same as for diffusion screens, but the lenslet screen typically has a front reflectance of 10 percent or less. Thus, at the center of the image:

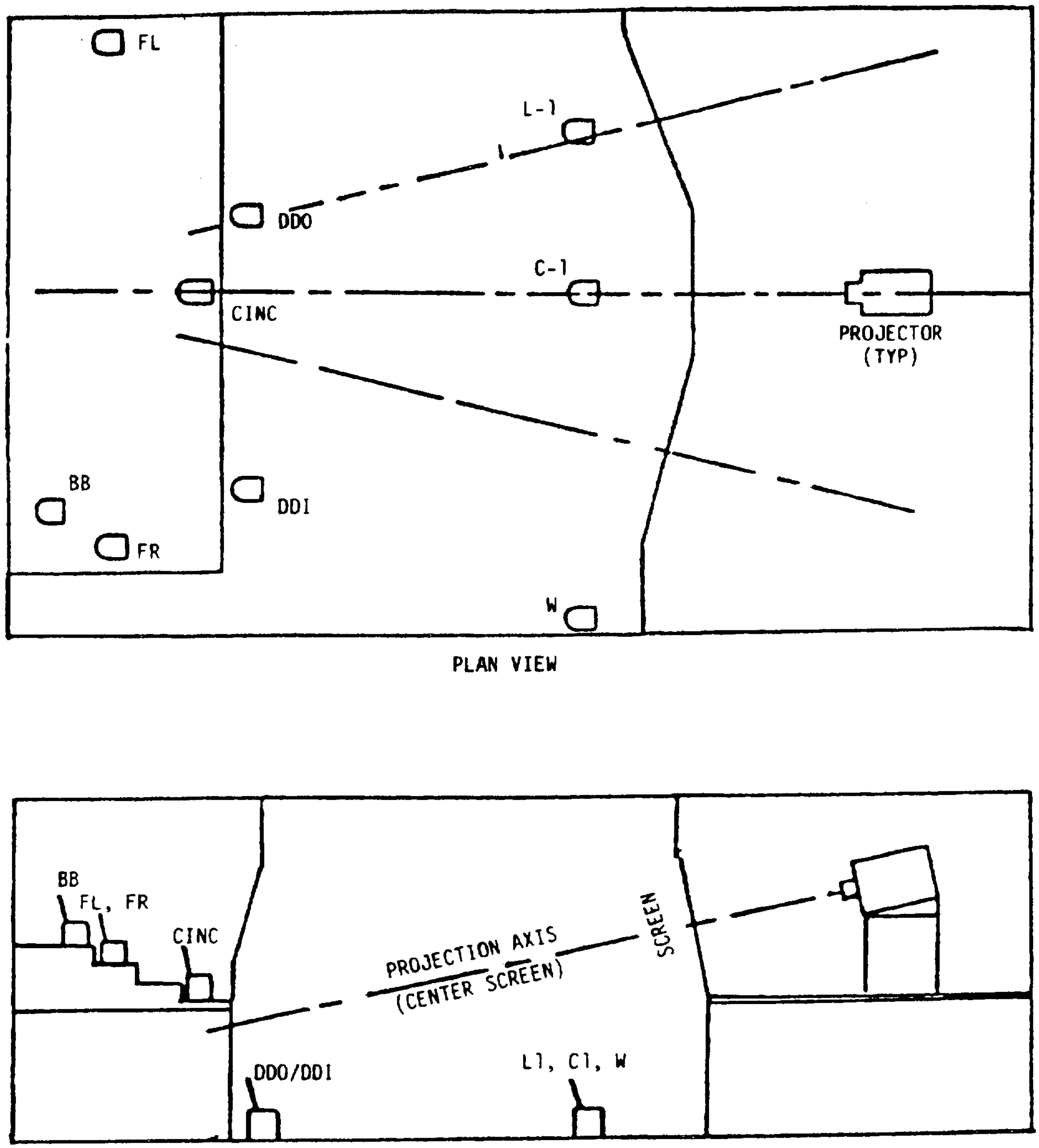
$$C_c = \frac{149.3}{20 \times .2 \times .1} + 1 = 373:1$$

$$C_e = \frac{134.4}{20 \times .2 \times .1} + 1 = 336:1$$

Obviously, with this type screen, much higher light levels could be tolerated without seriously degrading the contrast of the image. In a case such as this, the limiting factor on the contrast might well become the projector itself. For example, the projector might have a maximum contrast of 70:1 which then for all practical purposes would become the overall contrast of the combination. In most cases, any contrast ratio greater than about 25:1 is considered more than adequate. Many large screen displays are in use where the contrast ratio is 10:1 or even less.

30.2 The three-dimensional cases. In the foregoing discussion and in the sample calculations, its assumed that the viewers were at or close to the center of the screen in height. For the relatively flat auditorium layouts shown, that assumption would yield results good enough to make the extra effort in dealing with the vertical dimension a waste of time. In many military applications, however, the vertical displacement of the parts of the audience is far from trivial. For example, FIGURE 25 shows a simplified view of a major Command Center (CINCPAC). In this case, not only is the audience widely distributed in both horizontal and vertical directions, but there are three screens to be considered, and the screens are tilted downward by ten degrees. The outer two screens are also pointed inward toward the center screen's axis. To predict performance in such a case with reasonable accuracy and minimum complications, it is recommended that the designer start with scaled plan and evaluation views of the center, and then pre-select certain key positions in the audience on which to perform detailed analysis.

SIMPLIFIED LAYOUT, CINCPAC COMMAND CENTER



ELEVATION VIEW THROUGH CENTER SCREEN AXIS

FIGURE 25. Case requiring three-dimensional analysis.

It will be readily apparent that the planes in which bend angles will be found are not perpendicular to the projection planes of the two views shown. In order to measure those angles to a reasonably accurate approximation, construct an auxiliary view. By using a combination of the auxiliary view and Pythagoras' Theorem for right triangles, bend angles measurements can be read at least closely enough to be able to judge the quality of view at each selected observer position. FIGURE 26 shows the construction of one such auxiliary view. The purpose of that view is to obtain a true-length view of the ray passing through one corner of one of the screens, and so to calculate the bend angle between that line and the line of view from one of the observers to that corner of the screen. The example shown in FIGURE 26 is that for finding the bend angle where the CINC is looking at the lower left corner of the center screen.

Begin by drawing a straight line on the plan view from the projector through the left edge of the center screen, extending that line beyond the screen for an arbitrary distance into the room. Now construct an auxiliary view using that line to define the projection plane, and using scaled heights from the elevation view to locate the various observers relative to the floor, which is drawn on the auxiliary view parallel to the ray in the plan view. Construct the ray in this auxiliary view by simply running a straight line in the view through the bottom of the screen. In this view, the ray shows in true length because of the way the view is constructed. This line is labelled TLR, for True Length of the Ray. Now, in order to measure the angle θ, construct a right triangle using the lines LV, P, and the ray TLR. The line LV is the line of view, and is simply drawn between the CINC and the bottom corner of the screen. The line P is drawn at right angles to the ray and through the CINC's positions. This line, having been drawn at right angles to a true length view of the ray, will in fact be at right angles to the ray in space. It will not, however, appear in its true length in either of the views shown. To find its true length, construct another auxiliary view, in which the triangle TLR, P, LV, would appear in true size and shape. It is easier, however, to calculate the true length of P by using the views already drawn. First, project the intersection of the P and TLR lines back into the plan view, and then draw the line HPP, which is a horizontal projection of the line P. Next, draw a representation of that line in the auxiliary view, and connect it to the intersection of P and TLR. This new line is HTP, for the height of the perpendicular, or the height between the CINC and the intersection P to TLR, is one ingredient in finding P. Simply scale the lengths HTP and HPP from the auxiliary and plan views respectively, since those lines appear in true length in those views, and apply Pythogoas' Theorem:

$$P = \sqrt{(HPP)^2 + (HTP)^2}$$

Now, to find the angle θ, we take the value of P found above, and scale the distance TLR from the auxiliary view, measuring between the point where TLR leaves the screen to its intersection with P. We'll call this quantity TLR. Now the angle θ is simply:

$$\theta = \arctan \frac{P}{TLR}$$

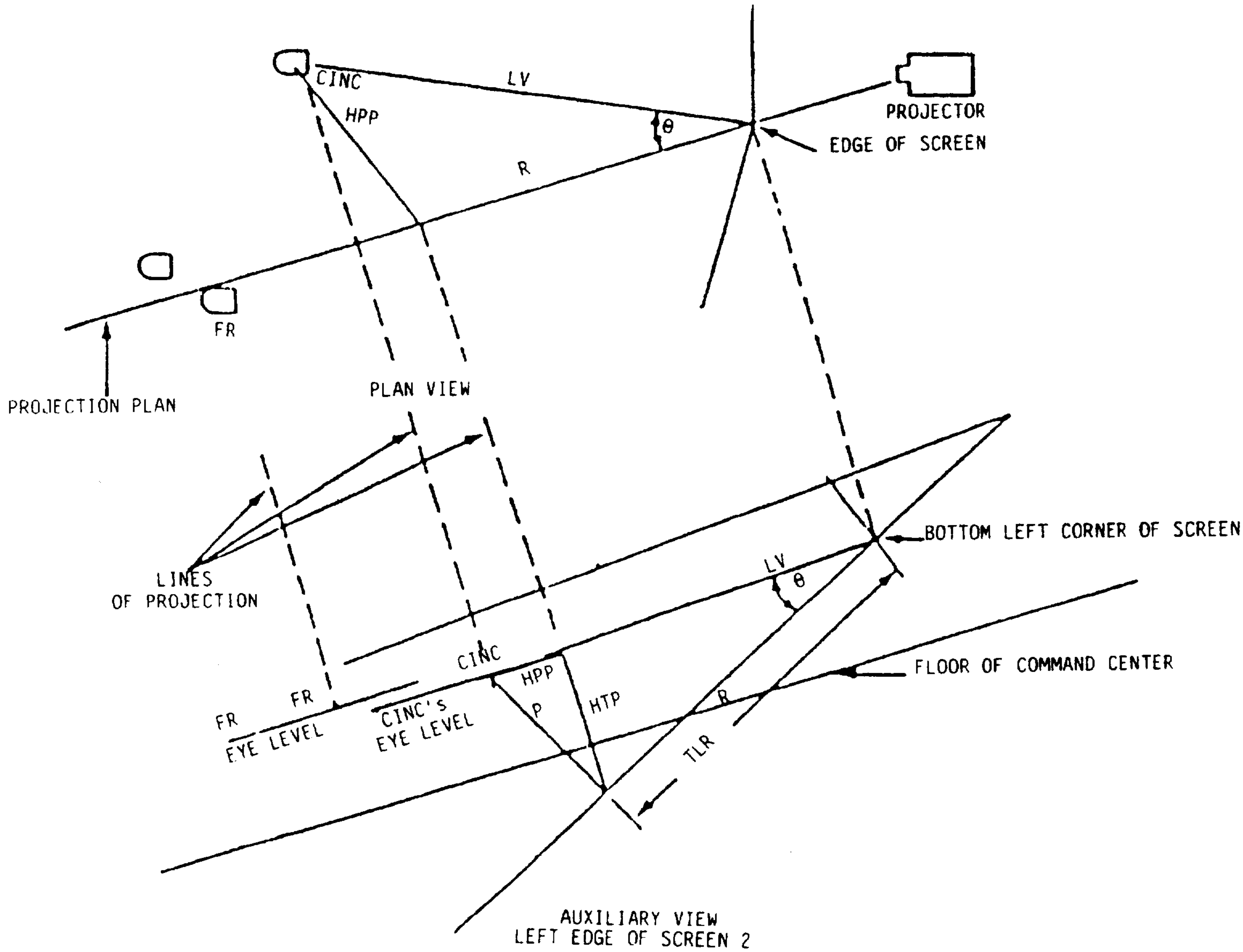


FIGURE 26. Construction and use of auxiliary view.

The same auxiliary view may now be used to find the bend angle for the CINC at the middle of the left edge of the screen, and at the top left corner of the screen. In this case, where the CINC is seated on the projection axis in the plan view, the angles for the left edge of the screen will be the same as those from the right edge, and the bend angles for the center of the screen can be found by using the normal elevation view instead of an auxiliary view. Normally, the bend angles for the four extreme corners, the center points of the top and bottom edges, the center points of the right and left edges, and the dead center of the screen should be found. The hot spot, if any exists for each observer-screen combination should be located. This can be done by simply drawing a straight line through from the observer to the projector in both the plan and elevation views. If that line goes through the screen surface, the observer will have a hot spot at the point where that line pierces the screen (bend angle will be zero). In the case of observers who are not located along the projection axis in either view, such as for example position FR, separate auxiliary views will have to be constructed for the left edge, center, and right edge of each screen. This is a lengthy process, and results in a long series of calculated bend angle values. For example, Table I shows the bend angles for the CINC to all three screens, assuming the screens each have a six by eight foot image on them. (The centers of the right and left edges were omitted in this case simply to reduce the workload involved.) Once the bend angles have been tabulated, a second series of tables may be constructed for the relative brightness levels, using the screen gain curves as shown in the simple two-dimensional case.

The remaining required ingredient to calculate brightness and contrast is the projection angle ϕ, and in turn $\cos^2 \phi$. For the three-dimensional case, this can be done by taking the distances in horizontal and vertical directions from the center of the screen in feet to the point at which the desired ray strikes the screen, and solving for the distance from screen center to the point in question by:

$$D = \sqrt{D_h^2 + D_v^2}$$

Then using the throw distance D_t, is found by:

$$\phi = \arctan \frac{D}{D_t}$$

Advantage may of course be taken of symmetry. The angle ϕ will be the same for all four corners, and the center points of top and bottom edges, and the center points on the two sides, thus requiring only three calculations to find the required values of ϕ for those points for all observers. The calculation of ϕ for the hot spots will of course be unique for each observer, but in most cases a simple linear interpolation would be sufficiently accurate. In most cases the range of values for $\cos^2 \phi$ will not be greater than 0.90 to 1.00 from the extreme corners to the center, and a linear approximation of, say, 0.95 for a point halfway between the center and the corner would not produce unacceptable error in the calculation of brightness or contrast.

TABLE I. Bend Angles.

OBSERVER CINC (Center of first row, mezzanine floor)

Screen 1			
Top Left	Top Center		Top Right
34°	9°		12°
	Dead Center	HOT SPOT	
	16°		
Bottom Left	Bottom Center		Bottom Right
39°	30°		29°

Screen 2		
Top Left	Top Center	Top Right
24°	2°	24°
	HOT SPOT	
	Dead Center	
	13°	
Bottom Left	Bottom Center	Bottom Right
32°	26°	32°

Screen 3			
Top Left		Top Center	Top Right
12°		9°	34°
	HOT SPOT	Dead Center	
		16°	
Bottom Left		Bottom Center	Bottom Right
29°		30°	39°

APPENDIX D

OPTIONAL PERFORMANCE FEATURES

(THIS APPENDIX IS NOT A MANDATORY PART OF THIS STANDARD)

10.1 INTRODUCTION. This standard presents only the minimum essential performance characteristics of television equipments. This Appendix is included to provide guidance toward the selection of various optional features offered by manufacturers. The options listed are by no means intended to be exhaustive, but are those most likely to be found offered by several manufacturers of each of the products covered here. In some instances, it may well be impossible to find products offered without some subset of optional features. For example, in Video Program Switchers, it would be difficult to find one which meets only the basic requirements given in the body of this standard.

20. VIDEO SWITCHING SUBSYSTEMS OPTIONS

20.1 Program switchers. The following are optional features which may be found in video program switchers.

20.1.1 Mixing. This feature provides, by a single lever control, the ability to continuously fade from one image input to any other image input.

20.1.2 Special effects (Effects). The essential element is the ability to cause one input image to replace another in a defined pattern, and in proportion to the movement of a single lever control.

20.1.3 Pattern selection. In addition to the normal wipe process described above, other patterns may be available through use of a set of "pattern select" pushbuttons.

20.1.4 Bordering. The bordering option permits a narrow band of black, white, or a selected color to be interposed between the two images during the effect. The width of the border may be adjustable or fixed.

20.1.5 Soft keying. The line between the two images when soft keying is used is made less distinct, and a gradual mixing or cross fading of the two images appears at the pattern edges. The degree of softening may be fixed or variable.

20.1.6 Pattern modulation. Pattern modulation permits a low frequency signal to modulate the pattern signal. The frequency and amplitude of modulation are variable.

20.1.7 Pattern positioning. This feature provides a joystick which controls the centering of the selected pattern in both horizontal and vertical directions.

20.1.8 Spotlight effect. This effect causes a circular part of the image to be highlighted, or made brighter than the surrounding image. The size and position of the spotlight circle are variable.

20.2 Video distribution switchers. The following optional features may be found in Type II video distribution switchers.

20.2.1 Master control override. The master control station is capable of forcing a particular input to a selected output regardless of any previous selection by the remote control station for that output.

20.2.2 Exclusion. The master control operator is capable of excluding any output station from access to any or all input stations.

20.2.3 Salvo routing. For routine operations in which a single input is always routed to the same outputs (for example, a daily brief), the master control operator is capable of presetting this special multi-station routing into the digital control memory, and then executing that routing by a few keystrokes at the terminal. At the end of the special event, the master control operator is capable of restoring the connections which had been present before the salvo with another small number of keystrokes.

30. AUDIO MIXER OPTION. Audio mixers may be offered with an audition channel which is a second mixing and amplication channel, identical to the normal, or program channel. This channel is capable of being switched into the same input sources and into the same output as the program channel, thereby serving as a backup to the program channel.

40. VIDEO CHARACTER GENERATORS. Type I color character generators may be offered with the following optional features.

40.1 Color backgrounds. Provides the ability to cover all or part of the input video with a background, selectable in any of the eight colors offered as character colors.

40.2 Color variation. Provides the ability to selectively alter the hue or saturation of any or all of the character or background colors, without affecting the hue or saturation of colors in the input video.

40.3 Additional font entry. Provides the ability to alter the fonts in use, either by adding to those already present in the character generator, or by replacing the standard fonts.

40.4 Font generation. Provides the user the capability to create new fonts directly from artwork, or by manually inserting or deleting line segments or portions thereof. The character generator provides means to store these user generated fonts, both within the character generator and on external storage media for permanent storage. (for example, floppy disk).

40.5 Computer interface. Provides the ability to generate character pages directly upon command from an external computer or word processor.

40.6 Page storage. Provides the ability to store pages of characters in external media, such as floppy disk, for recall at any time.

40.7 Edit/preview/air page operation. With this option, the character generator has three separate outputs. There is an Edit page, upon which typing or changes can be entered without affecting the on-air character page. There is also a preview page, separate from both the edit and air pages, and a preview-to-air pushbutton which causes the contents of the preview page to move to the air page during the next vertical interval following activation of push-button.

40.8 Roll and crawl. Permits the contents of successive pages from storage to be rolled upwards from the bottom of the screen to the top, or crawled from right to left across a single selected line in the picture.

40.9 Speed selection. This option, used with the roll and crawl option, provides the ability to vary the speed of roll or crawl operations.

APPENDIX E

GUIDANCE REGARDING DIGITAL TELEVISION

(THIS APPENDIX IS NOT A MANDATORY PART OF THIS STANDARD)

10.1 INTRODUCTION. In the broadcast industry, there is a growing trend toward the use of digital techniques in the processing of NTSC color video signals. The digital techniques are being introduced for two distinct purposes: first, to perform manipulations of the signal which are virtually impossible to perform with analog techniques; second, to improve upon the performance of functions which are possible through analog techniques, but where the analog techniques lead to undesirable side effects, such as degraded signal to noise ratios. This appendix is intended to offer some guidance for system designers who find need for devices which are being offered for sale, in which digital techniques have been employed. At this time, no comprehensive set of standards has yet emerged in the industry, which means that it would be unfair to both users and producers to incorporate mandatory requirements in this standard. Nevertheless, the growing market for such items makes it advisable to offer some guidance in the selection of devices for those applications which are presently perceived in the broadcast industry.

20. ANALOG TO DIGITAL CONVERSION

20.1 Sampling. For analog to digital conversion of NTSC video, there are presently two sampling standards in use. Both of these standards are related to the chrominance subcarrier. In many systems, a sampling rate of three times the subcarrier frequency is used. In other systems, a rate of four times the subcarrier frequency is used. Obviously, the choice between these rates has impact on system cost. If, for example, digital storage of video is involved, more storage will be required if the 4X rate is used than if the 3X rate is used. For broadcast use, the choice is not too critical, since the luminance signal bandwidth must be limited to 4.2 MHz for transmission. With that limit placed on the video signal, the 3X rate is close enough to the Nyquist criterion for the highest signal frequencies that, at least for the home viewer, the analog to digital and digital to analog transitions will be transparent.

In most military applications, however, the video signal is kept in baseband, and therefore, is not rolled off at 4.2 MHz, but is permitted to extend to 6 or even 8 MHz. In those applications, therefore, the 4X rate may show a significant advantage over the 3X rate, especially where high resolution monitors are used. It is also quite common in military applications to find a high density alphanumeric computer terminal used as a source of video in the system, and processing of that wideband signal (typically over 6 MHz) will require the use of 4X sampling to produce legible output after the digital to analog conversion.

20.2 Bit precision. There appears to be general agreement in the industry on this question, at least for composite conversion systems. Eight bits per sample is the commonly used precision, and yields good results both for broadcast and military applications.

20.3 Composite conversion versus Y, I and Q conversion. There are two basic methods of conversion from analog to digital. In the first, which may be identified as composite conversion, the entire NTSC composite video signal is converted by simply sampling at either the 3X or 4X rate, forming an eight bit digital representation for each sample. In the second method, the NTSC composite signal is split into the luminance (Y) signal and the chrominance subcarrier. The subcarrier is then demodulated into two component video signals, I and Q. The resulting three video signals are then separately converted to digital signals, typically at different sampling and bit precision rates. At first glance, this second method would appear to be much more cumbersome and costly. Its value, however, is in the kinds of image manipulation in the digital domain which this method makes possible. For example, the process of squeezing an image so that it occupies less than the full raster is virtually impossible unless the Y, I and Q conversion method is used. If that were tried using composite converted signals, the necessary relationship between the horizontal timing and the color subcarrier would be altered by the squeeze action, to the degree that no color would be detectable in the output analog signal. In the Y, I and Q method, the squeeze is accomplished on three digital signals, then these are read back into an NTSC encoding process with a new subcarrier signal.

The choice between these two methods should be made on the basis of the uses to which the digital signals will be put. If simple storage and retrieval is required, the composite method is best. If squeezes or other digital special effects are required, then Y, I and Q becomes the best method. (Some manufacturers now accomplish the conversion in composite form, and then digitally process the signals to produce a digital equivalent of Y, I and Q).

20.4 Applications of digital television. The following are applications which are presently being made use of in either military or broadcast service, or both.

20.4.1 Storage and retrieval systems. This system concept was originally developed for broadcasters to serve as a replacement for the 35mm slide projection part of the film chain. Through such systems, any video image may be frozen into a still image in digital form (about 3 million bits) and stored in any digital storage medium, such as a solid-state memory or a computer disk. FIGURE 27 shows a typical arrangement for such a system, in very simplified form. The disk may be actually one or more disk drives, depending on the number of frames to be stored. (Typically, such systems store 150-200 frames on each disk pack.)

In the original broadcast applications, a single control station was provided with a microprocessor actually controlling the actions of the various parts of the system. The microprocessor permitted the operator such features as random sequencing, preview channel operation, and so on.

In the first known military application, a system of remote control stations was added, so that the disk storage could be shared by a number of operators at remote locations. A write-protect was also featured, so that any one operator could have his own private stock of frames into which only he could store frames, but anyone on the system could read all frames stored. Each operator had a pair of solid state framestores, so that, once his frame was retrieved from disk, the disk could go on to serve other users. The solid-state framestore acts as a buffer between the very high data rate required at the A/D and D/A converters and the relatively slow rate at the disk interface.

Some caution is advisable in applications of this kind. Note that, on the diagram, the subcarrier is brought into the input and output converters. Most such systems depend on the presence of that subcarrier input. It is used to synchronize the sampling rate to the subcarrier from the video system on the input side, and to make a synchronous D/A conversion at the output side, so that the phase of the modulated subcarrier is correct for output signals. This can lead to significant problems for monochrome inputs. The system treats all signals as color signals, and so impresses a color burst on the output of monochrome signals, which can lead to unwanted color fringing, or Chroma Crawl effects on monochrome outputs, particularly if these are high density computer terminal alphanumeric or graphic images. (In its broadcast applications, this is never a problem, because all images are color.) In its first military application, a special modification was made, so that incoming monochrome images were recognizable by a white video level on line ten of the raster, and burst was omitted on these at the output.

When such systems are used with color images, it is important that all images arrive synchronously at the input to the A/D converter, so that color reproduction will be the same for all images.

20.4.2 Video transmission systems. In broadcast applications, it is normal to have a system bandwidth of about 6 MHz for long haul circuits. In military applications, this is hardly ever the case. Digital television equipments may be employed to send still frames over slow communications circuits. The technique is similar to the digital storage and retrieval systems, except that instead of going to disk, the digital picture is fed one bit at a time into a low-speed communication circuit. FIGURE 28 shows a typical arrangement, where the pictures are classified, and encryption equipment is used. One significant block has been added, called video compression. This is simply a means of removing redundancies from the image data to improve the transmission time over the link. For higher speed links, particularly over short-haul circuits, this video compression step may safely be omitted, at a significant cost savings. For example, if the link available operates at 12 megabits per second (mb/s) a frame can be transferred in under one second, and compression would not radically affect the operational utility of the link. Conversely, for 2400 bits per second (b/s) circuits, where time to send images without compression is measured in minutes, compression becomes a worthwhile or necessary feature. It should be noted that FIGURE 28 is not the only possible arrangement of functions. It is possible in some cases that the compression step will be accomplished before frame storage, for example. The bit-rate shown as X, for transfer between the frame-storage and the compression could be almost anything, but typically would fall somewhere between the 114 Mb/s rate and the rate over the link. (114 Mb/s is used as the maximum rate for that point in the diagram. It is calculated for a sampling rate of 4 times the subcarrier and eight bits per sample. Thus, 4×3.58 MHz $\times 8 = 114$ Mb/s).

20.4.3 Frame synchronizers. These devices have found an enormous number of uses in the broadcast industry, where feeds of remote video are to be used directly as a program source, and mixed smoothly with local studio produced programming. They permit the remote video to be generated at its own synchronized source rate, and after passing through the device, make these inputs synchronous to the station's synchronizing source.

Basically, the device is the same as the still-storage device, except that the A/D and D/A conversions occur simultaneously, and the frame-memory has the ability to be written to at one randomly selected address and simultaneouly to be read from at another randomly selected address.

FIGURE 29 shows a very simplified block diagram of such a device. The incoming video may be from a videotape, network, or microwave remote from an ENG crew. It is asynchronous to the station's local sync. The A/D converter loads this video into the frame-storage as received. The D/A converter uses the station's sync source to read out the appropriate video from the memory location corresponding to the raster picture-elements at the station, converts this back to analog video synchronous to the station's subcarrier, and provides output video which may be mixed with any local source, or even with other remote sources which have passed through other frame-synchronizers.

In military applications, the most obvious use of these devices is to allow videotape sources to be mixed with live programming.

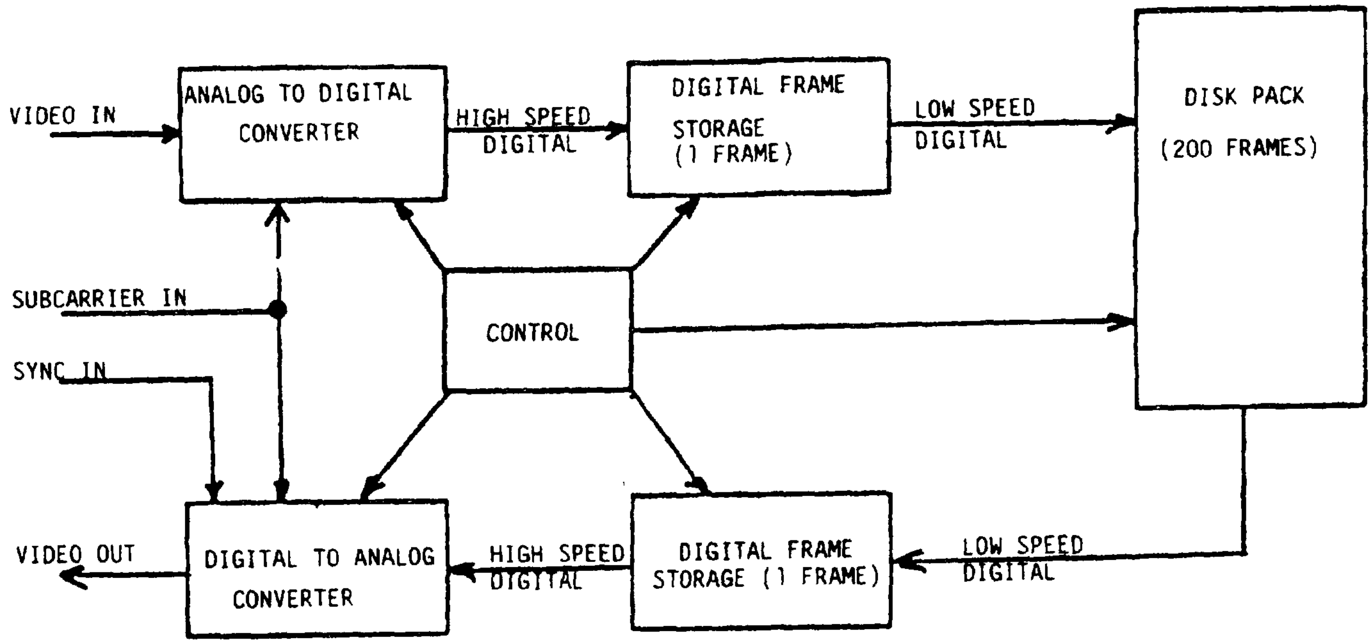
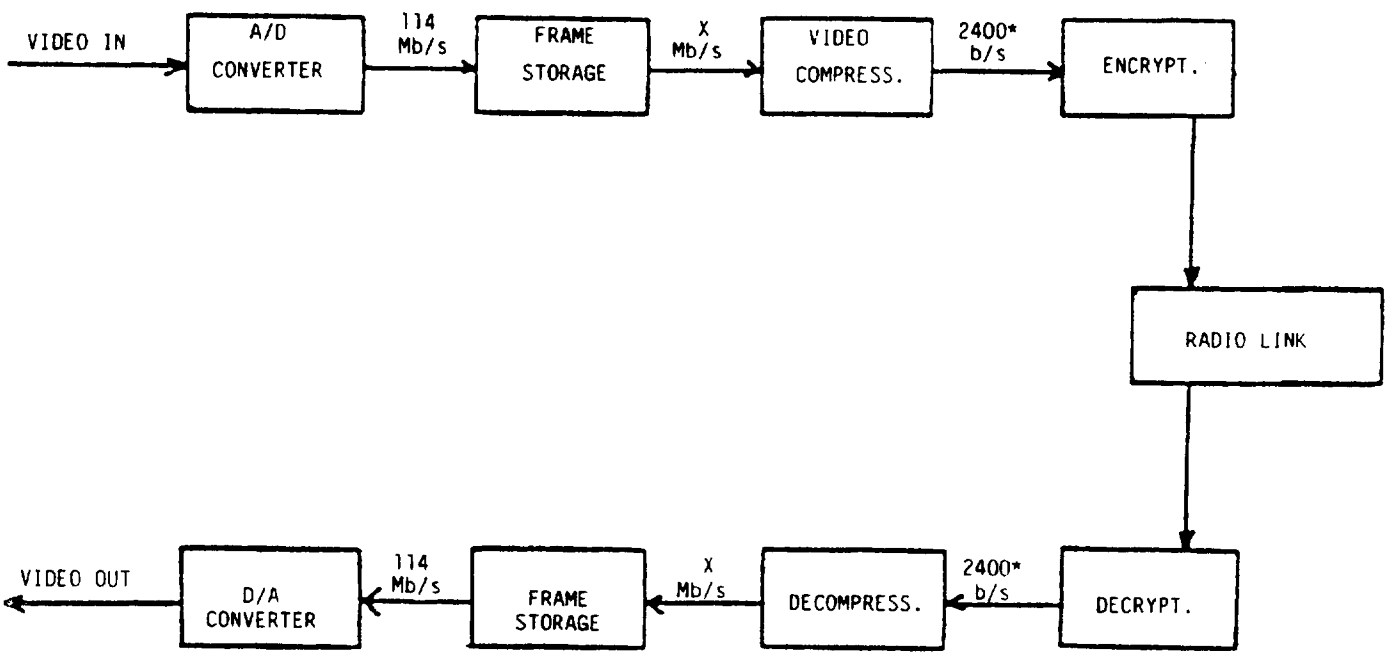


FIGURE 27. Typical digital still frame storage system (simplified).

20.4.4 Digital special effects. In the requirements portion of this standard, the subject of special effects was covered under program switchers. The achievable effects in normal program switchers can be quite interesting and spectacular, but the television broadcasters have always been envious of the range of special optical effects which were available to film producers through the optical printer, many of which were simply not possible in television video. With the addition of digital special effects, however, this has all changed.

In essence, a digital effects device is a special form of frame synchronizer. It allows asynchronous video to be made synchronous, but it also allows upsetting the 1:1 correspondence between a particular picture element in the incoming raster and the same element in the outgoing raster. For example, an incoming raster may be made to occupy only a portion of the outgoing raster. The picture may be shrunk from filling the entire frame down to filling only a small part of the frame. As another example, four pictures may be combined into one, with each of the four occupying only one quarter of the raster, or three may be arranged vertically on one side of the picture, and a fourth will occupy the other half of the picture. A picture may be squeezed horizontally off of the screen (the effect appears like turning the page in a book), to reveal another picture beneath it. The possibilities are too numerous to mention all of them. So far, no particular advantage for military applications seems to be evident from this device. It would constitute a very expensive toy in any military application.



*This rate is governed by the available link, and may vary from 2400 to about 12 Mb/s.

FIGURE 28. Digital television transmission system (simplified).

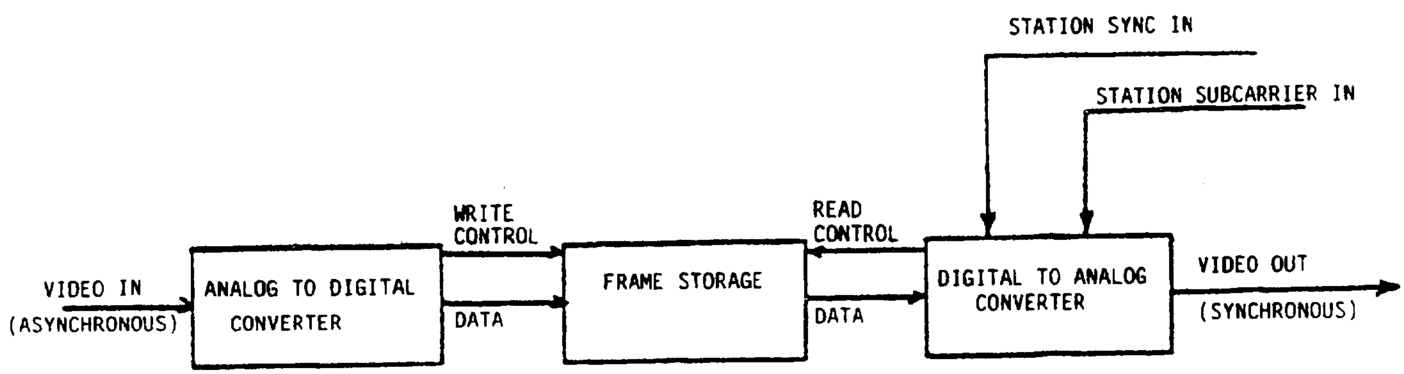


FIGURE 29. Video frame synchronizer (simplified).

20.4.5 Digital noise reducers. This device is related to the frame synchronizer, but is intended to serve yet another purpose. In addition to the function of frame-synchronization, this device uses a feedback from the stored digital signals back to the input side of the memory. A variable weighting is offered to permit more or less noise reduction, depending on the amount of blurring of moving objects which can be tolerated.

The contents of the memory at any given picture element are a weighted average of the current incoming video and the previous contents for that picture element. This process of integrating from frame to frame reduces the signal-to-noise ratio by amounts ranging up to about 10 dB. (For example, an input having 43 dB signal-to-noise could produce an output having 53 dB signal-to-noise ratio (SNR).) The process is most effective for still or slowly moving images. For fast motions, the integration will produce a noticeable blurring, and the amount of feedback will have to be reduced to account for that, thereby lowering the improvement in SNR. These devices are expected to operate with automatic adaptation to motion in the image, so that still objects will show improved SNR to a greater degree than moving objects in the same scene. Figure 30 is a very simplified block diagram of a digital noise-reducer.

30. Future development. The following are descriptions of expected future developments in the field of digital television. None of these appear suitable in the near term for military applications, but all show potential for becoming useful once development is complete and industry standards have been established.

30.1 Digital video tape recorders. Intensive Internal Research and Development (IR&D) programs are underway at a number of current video tape recorder manufacturers' facilities in attempts to develop digital video tape recorders for studio and field use. It is expected that these developments will succeed in providing machines with significantly improved signal-to-noise and inter-operability over present analog video tape recorders.

30.2 All digital studios. At present, the digital processing of video is done in discrete boxes, while the input and output of each box is normal NTSC analog video. This makes for a cumbersome series of A/D and D/A conversions, each of which involves some degree of sampling error and other unmwanted side effects. Manufacturers of video equipment, working under the auspices of industry associations such as the National Association of Broadcasters (NAB), and the Society of Motion Picture and Television Engineers (SMPTE), are attempting to establich uniform guidelines for an ultimate system in which the video is converted to digital form at or near the camera, carried as digital signals throughtout the switching, mixing, distribution, etc., and converted back to analog signals at the transmitter.

40. Computer terminal interfaces. In many military applications, it becomes highly desirable to employ an existing CCTV system to distribute images generated under computer control and displayed on cathode ray tube (CRT) computer terminals. This has often proved difficult to accomplish. There are many techniques employed by the compter terminal designed to present the information on a computer terminal CRT. Terminals employing storage tubes or stroke writing technique cannot be directly interfaced. These require some form of scan conversion such as a television camera to regenerate the image in suitable format for the CCTV system. Other devices using raster writing techniques offer interfacing possibilities, especially those devices that claim to provide a video output that is compatible with EIA RS-170-57 standards.

40.1. Non-EIA RS-170-57 terminals. There are numerous CRT computer terminals offered that claim to be video or television compatible. These devices have a vertical scan rate of 60 Hz (derived from the power line) and a horizontal rate of approximately 15750 Hz. The video will synchronize on standard monochrome monitors and the signal can be distibuted through a typical CCTV distribution system. Usually the video signal can be recorded on video tape with little or no difficulty. However, the video cannot be made syschronous with the existing station timing and hence cannot be integrated into the local programming system unless a frame synchronizer is used to retime the signal.

40.2 EIA RS-170-57 terminals. There are several terminals offered in the commercial markets that meet the EIA RS-170-57 standard. Some are locked to the power line, while others use precision crystal oscillators to develop the horizontal and vertical timing. For example, one such unit commonly encountered in Department of Defense installations is the WWMCCS Visual Information Processor (VIP) Model 7705W. The VIP 7705W does not accept external synchronizing pulses but it does generate a composite video signal, locked to the power line, that meets the EIA RS-170-57 standard. A recent entry into the market place is the WWMCCS Graphics Terminal. This unit delivers an NTSC color video signal. While it will not accept external timing, the internal time base generator is very stable and can be used as a primary timing source to genelock the stations' master sync generator.

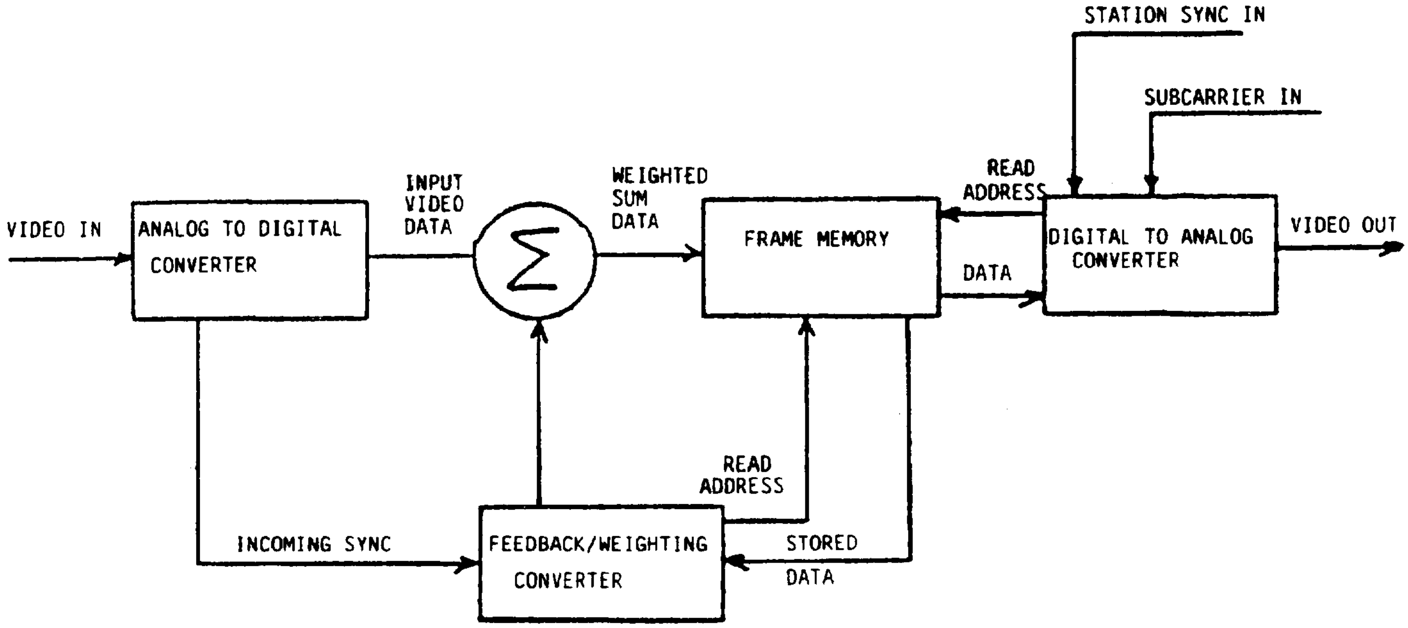


FIGURE 30. Digital noise reducer (simplified).

40.3 WWMCCS Standard ADP Terminal Interfacing. There are presently three CRT terminals that are classified as WWMCCS standard terminals. They are the VIP786W, VIP7705W and the WWMCCS Graphics Terminal WGT 5807.

40.3.1 VIP786W. This is one of the early WWMCCS terminal devices and was neveer intended to produce a video signal for display on external video monitors. However, it is possible to bridge the video feed, preferably with a high impedance input isolation amplifier and extract a video signal that can be used to drive a remote monitor. This practice is not recommended.

40.3.2 VIP7705W. The WWMCCS VIP7705W, when equipped with a video board, delivers a good RS-170-57 signal. The installation of the video board is usually a field modification performed by a field service engineer. The presence of a SO-239 coax connector on the back of the unit will identify it as being modified. The sync pulses and the video levels meet all RS-170-57 requirements. If desired, the signals from the VIP7705W can be used to genelock a monochrome facility or feed through a frame synchronizer for retiming and integration into a color production facility.

40.3.3 WSGT5807. The WWMCCS Standard Graphics Terminal WSGT5807 has recently (late 1981) been added to the standard equipment used by the WWMCCS Automatic Data Processing (ADP) Systems. It is a color graphics terminal that is capable of generating and displaying alpha-numeric characters, symbols, and curves and vectors to generate all forms of graphic displays. It generates the displays in the three primary colors (red, blue, and green) and their complements. It has a very precise time base that is derived from the NTSC color sub-carrier frequency. It delivers red, blue and green (RBG) signals and an NTSC color encoded signal. It will not accept external timing, but its time base is sufficiently stable to permit it to genelock the main station generator.

40.4 High line-rate terminals. Many computer terminals use line-rates above the 525 line-rate which CCTV systems use. These may range all the way from 575 to as many as 1175 lines per frame. In most such cases, some form of scan-rate conversion device may be used to at least create a viable interface to CCTV. This means that one still image at a time is captured from the high line-rate source, then read from a memory at the 525 line rate, synchronous to the CCTV system. Both analog storage tube devices and digital storage devices have been used in this way, with mixed results. In most cases, the best results are obtained where a zoom feature is present in the storage device, so that only a portion of the incoming picture is converted at any one time to a 525 line output.

40.5 Direct-view storage tube and stroke-writing terminals. In some cases, depending on the density of information the terminal produces, it is possible to extract the X, Y, and Z axis signals from such a terminal into a storage tube scan-converter, and so produce a raster-scanned output synchronous to a CCTV system. This approach is definitely not recommended in general, since it usually results in signals which cannot be read on the CCTV system's monitors anyway, and since the extraction of suitable levels of X, Y, and Z signals from the terminal becomes a major custom engineering effect in itself. If CCTV compatibility is important enough to try, then it should be worth the added expense of using a raster-scan terminal in place of one or more of the stroke-written or DVST terminals on the system. Preferably, this raster-scan terminal should be one which is fully compatible with NTSC or RS-170-57 standards, as appropriate.

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