FM TRANSMISSION OF VIDEO SIGNALS

Michael M. McMahon
Loral Conic Inc.
9020 Balboa Avenue
San Diego, Ca 92193

ABSTRACT

Analog video telemetry links are generally realized with an FM video transmitter and an FM video receiver. Various standards specify characteristics of both the baseband video signal and the transmitted modulation characteristics. This paper summarizes and clarifies these standards so that the video/transmitter interface may be specified and correctly set up. Monochrome and color video signal levels are described. Required deviation and pre-emphasis characteristics of the transmitter are also clarified.

INTRODUCTION

Virtually all transmission of ground and airborne video telemetry is accomplished by means of frequency modulated (FM) links. In the case of analog video, the baseband video waveform and resultant frequency modulation characteristics are well defined by several standards. In order specify or to set up the video transmission end of the FM analog video link, baseband video signal levels and transmitter deviation sensitivity and pre-emphasis must be well understood.

In many cases, confusion between standards and misunderstanding of standards has led to improperly specified characteristics and incorrect hardware. The following paragraphs summarize standard video specifications which drive definition of the video transmission hardware. A significant number of video systems conform to these standard signal levels even though the waveforms are tailored in terms of lines per frame, timing, or insertion of digital data in blanking intervals.

THE VIDEO AND SYNC WAVEFORM

Video signals used in the United States form the basis of many analog video telemetry systems. Sometimes referred to as standard NTSC video, 525 line video, RS-170 video, or standard 1 volt peak to peak video, waveforms are strictly specified by EIA standard RS-170 for monochrome video and by NTSC standards for color video.

As shown in Figure 1, RS-170 video is defined as a 1.0 V p-p picture signal which covers the full monochrome luminance range from black to white (positive voltage is white). The lowest level is called "blanking" and the highest level is called "reference white". Periodic horizontal synchronization pulses go "blacker than black" to a level 0.4 volts below the blanking level. This waveform is sometimes called "one volt peak to peak video", but it is clear the full waveform is 1.4 V p-p with the sync signal added to the picture signal.

The resultant video signal is AC coupled, and so no absolute waveform voltages are specified. Waveform voltages are referenced to the sync tip, blanking, and reference white levels.

As shown in Figure 1, a special scale in IRE units is used for specifying video signal levels. The video luminance signal runs from 0 to 100 IRE. IRE corresponds to the blanking level and 100 IRE corresponds to reference white. Sync tips are below the luminance range at -40 IRE. Most video quality specifications are specified in terms of these IRE units.

SETUP

Actual camera scenes are adjusted such that 100 IRE represents full (reference) white and 7.5 IRE represents full (reference) black. This ensures that the 0 IRE signals provided immediately before and after each horizontal sync pulse fully blank the receiver display at the start and finish of each horizontal line. This provides crisp black edges on the sides of the picture and ensures that circuit transients due to the sync pulse do not show as dots or lines at the screen edges. The horizontal sync waveform always includes these 0 IRE edge blanking levels, referred to as the "front porch" and "back porch" (see Figure 1). The offset between reference black and blanking is called "setup" and is set at a standard level of 7.5 IRE. Note that the 1.0 V p-p video signal is measured from blanking to reference white, not just from reference black to reference white.

THE USE OF COLOR VIDEO

Color adds greatly to visual perception and is standard in almost all video entertainment applications. Identification of objects is greatly enhanced in scenes which appear flat in black and white (uniform luminance), but contain colored objects. Such can be the case for aerial observation in forested areas. However, common practice for most surveillance applications is to use monochrome for four major reasons. First, color is more expensive and complicated than monochrome. Second, color pictures are more susceptible to noise than black and white. Third, color can be distracting in scenes where color camouflaging is being used. Fourth, today's IR sensors are monochrome only with no ability to differentiate between wavelengths.

THE COLOR VIDEO WAVEFORM

The addition of color to the picture adds a 3.58 MHZ sine wave to the monochrome luminance signal as shown in Figure 2. In a color TV, three guns (red, green, and blue) provide the picture. If all three are increased in unison, the screen may be run from black through gray, and to white. In this way, a 3-gun TV creates a black and white picture. By unbalancing the guns, the color may be changed from gray toward red, green, or blue. Other colors are created by unbalancing toward two guns, as is the case for yellow which appears when the red and green guns are turned on.

The in-phase and quadrature components of the 3.58 MHZ sine wave control the amount of gun imbalance. For a black and white scene, the guns are always perfectly balanced and the I and Q channels are both zero, resulting in a zero amplitude sine wave. For highly colored images, much imbalance is used, and the 3.58 MHZ sine wave can grow as large as 60 IRE p-p. Because the 3.58 MHZ sine wave controls the coloring (gun imbalance), it is called the chroma, or chrominance signal. To properly separate the I and Q signals, a phase reference "color burst" consisting of about 10 cycles of 3.58 MHZ is included on the back porch after each horizonal sync pulse when transmitting color.

SIGNAL SWING OF COLOR VIDEO

One interesting property of the 3.58 MHZ chroma signal is that it goes to zero amplitude for full black or full white luminance. To achieve full white, all 3 guns are at maximum, and there is no difference between guns, causing the chroma signal to go to zero near white levels. Consequently, the combined luminance plus chrominance peaks can never exceed 100 IRE for valid pictures. Likewise, black is formed with all 3 guns at zero and therefore no gun imbalance, forcing the chroma signal to zero near black levels. As a result, the combined luminance plus chrominance waveforms do not extend much past the 0 to 100 IRE (1.0 V p-p) range for valid camera scenes.

Of course, test signals can be generated which combine large 3.58 MHZ chrominance signals on top of full 0 to 100 IRE video signals, thus overdriving the guns. This is actually done with some standard color test signals. However, even standard test signals limit the combined signal to the -20 to 110 IRE range to control overdrive.

FM TRANSMISSION OF VIDEO

Transmission of FM video is described by CCIR Recommendation 405 (sometimes called CCIR405). This document also references CCIR Recommendation 276. Ground microwave links for commercial television follow this FM standard, as do many current video links for military UAV’s and video guided ordnance. The three major characteristics controlled by these documents are polarity, deviation, and pre-emphasis.

Polarity is defined as increasing frequency for increasing (white-going) video voltage. Standard RS-170 or NTSC video signals are assumed.

Deviation is defined as 8 MHZ p-p (4 MHZ peak) for a 1 V p-p sine wave. This applies at a reference frequency of 761.6 kHz for standard 525 line NTSC video. Of course, video is not a sine wave, but the standard 1 V p-p sine wave at the reference frequency is the most convenient signal to use to set up modulation sensitivity of the transmitter.

CCIR-405 dictates the FM transmitter deviation be set with a 1.0 V p-p sinewave at the 0 dB reference frequency and assumes that RS-170 or NTSC video is applied. If the video source provides the lower amplitude RS-330 video, FM transmitter deviation should be set with a .714 V p-p sine wave at the 0 dB reference frequency. If a 1 V p-p sinewave is used to set up an RS-330 driven FM transmitter, the transmitter will be undermodulated.

Pre-emphasis provides an upslope response to boost the high end of the video spectrum where there is poorer SNR but usually little video luminance energy. Figure 3 shows the actual pre-emphasis curve. Note that chroma signals (if used) around 3.58 MHZ are transmitted with nearly maximum gain. Down at low frequencies, signals are attenuated to reduce deviation caused by the large low-frequency components of normal video. Likewise, the slow sync signals are reduced in amplitude. Figure 3 shows how signals below the 761.6 kHz reference frequency are attenuated up to 10.00 dB (.3162 times). Signals above the reference are augmented up to 3.40 dB (1.4791 times). This standard 525 line video pre-emphasis curve is a single zero/pole pair with upslope breakpoint around 150 kHz, leveled off by a pole at around 1.1 MHZ.

Figure 3 shows other pre-emphasis curves for video standards beyond the standard Unites States 525 line NTSC video. Europe and other countries use 625 line PAL and 819 line SECAM systems with pre-emphasis curves as specified in CCIR-405 for, 625, and 819 line systems. The four pre-emphasis curves are similar and all use a 0 dB reference around 1 MHZ. In all cases, magnitude of deviation is specified with a 1 V p-p sine wave at the reference frequency, with the transmitter adjusted for 8 MHZ p-p (4 MHZ peak) deviation.

PEAK DEVIATION OF PRE-EMPHASIZED FM VIDEO

Peak deviations of an actual pre-emphasized video scene depend on picture content. Luminance may have high frequency components, causing higher deviations. Highly saturated color pictures have large 3.58 MHZ chrominance signal components. Dark scenes create the smallest peak deviations, since the sync-to-luminance swing is small and the chroma signal (if used) is small. Actual peak deviations may be important in determining how closely video channels may be spaced without objectionable interference. Because the signal is AC coupled, the transmitted signal centers the average video value on the transmitter carrier frequencies, greatly affecting peak deviation. As an example, predominantly black scene with small white spots center on the black value, with the white spots causing quick impulses upward in frequency, interfering with the upper adjacent channel but not the lower. Interference tests are best performed using actual scenes from the intended viewing environment.

CONCLUSION

Analog video is often transmitted using frequency modulation (FM). The use of standard pre-emphasis provides better picture quality, but makes setup of transmitter deviation difficult when looking at time domain waveforms. Accordingly, a frequency domain approach is used with a 1.0 V p-p sine wave at the reference frequency applied to the transmitter and the deviation set to 8.0 MHZ p-p, or 4.0 MHZ peak. The transmitter is then driven with RS-170 video which is 1.0 V of video and .4 V of sync, an overall 1.4 V p-p swing.

RS-330 video is only .714 V of video, and .286 V of sync, an overall 1.0 V p-p swing. However, frequency deviation of the transmitter should be the same for identical scenes and not dependent on the video source/transmitter interface definition. For RS-330 video, transmitter deviation is set up with a .714 V p-p sinewave at the reference frequency to ensure the correct deviation sensitivity.

The addition of color superimposes a 3.58 MHZ (for NTSC)component on the video waveform, but does not change the luminance or sync portions of waveform. Transmitter pre-emphasis and deviation setup are identical to monochrome operation.

Peak deviation of the transmitter is strongly dependent on picture content and the presence or absence of the chroma signal. Adjacent channel interference is best determined subjectively with the expected types of desired and interfering video scenes.

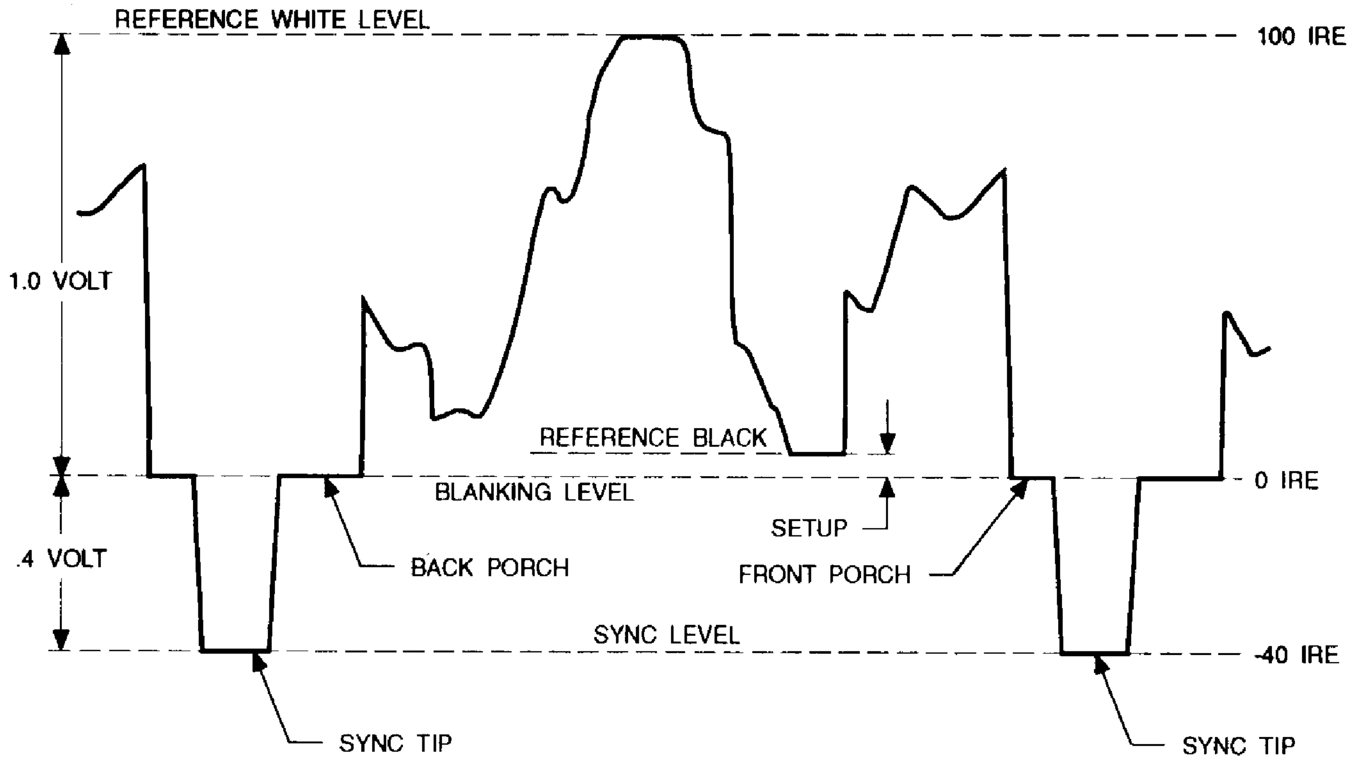

FIG. 1, MONOCHROME VIDEO WAVEFORM

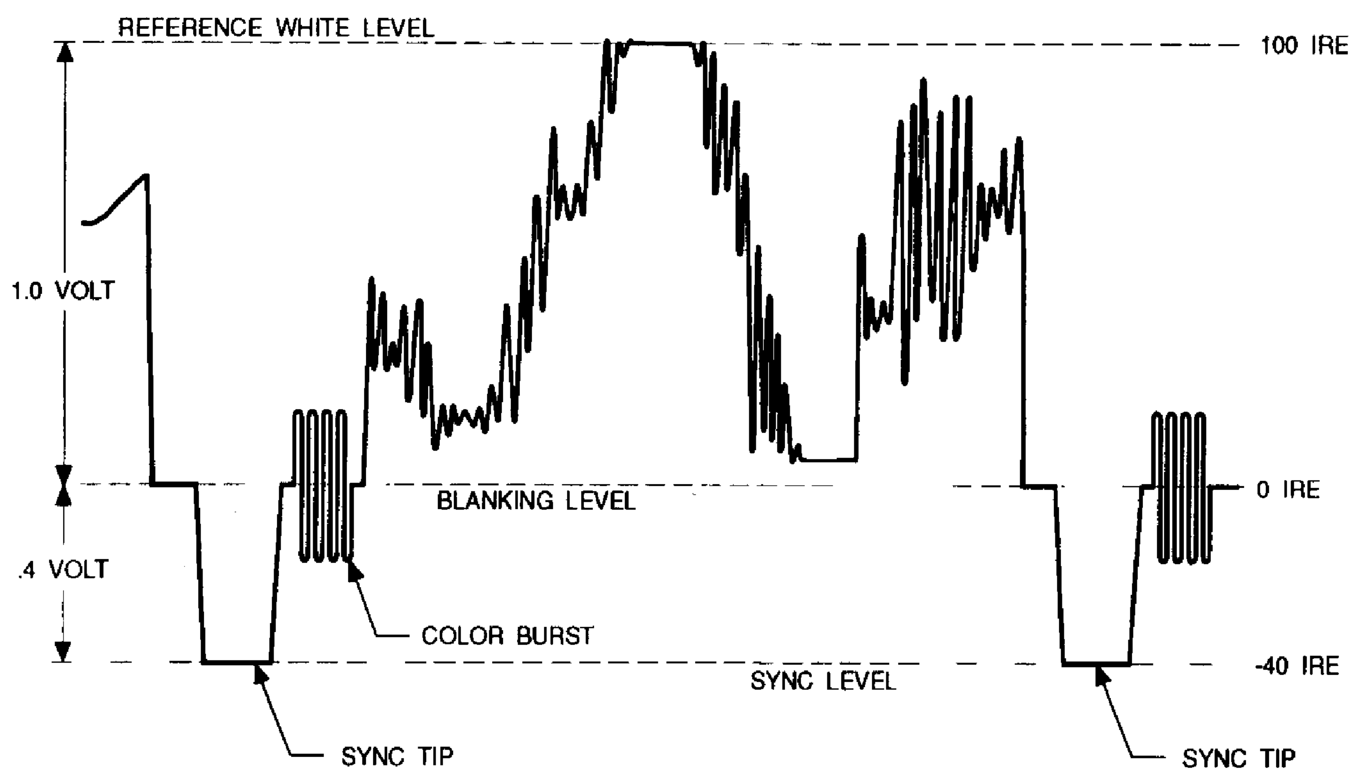

FIG. 2, COLOR VIDEO WAVEFORM

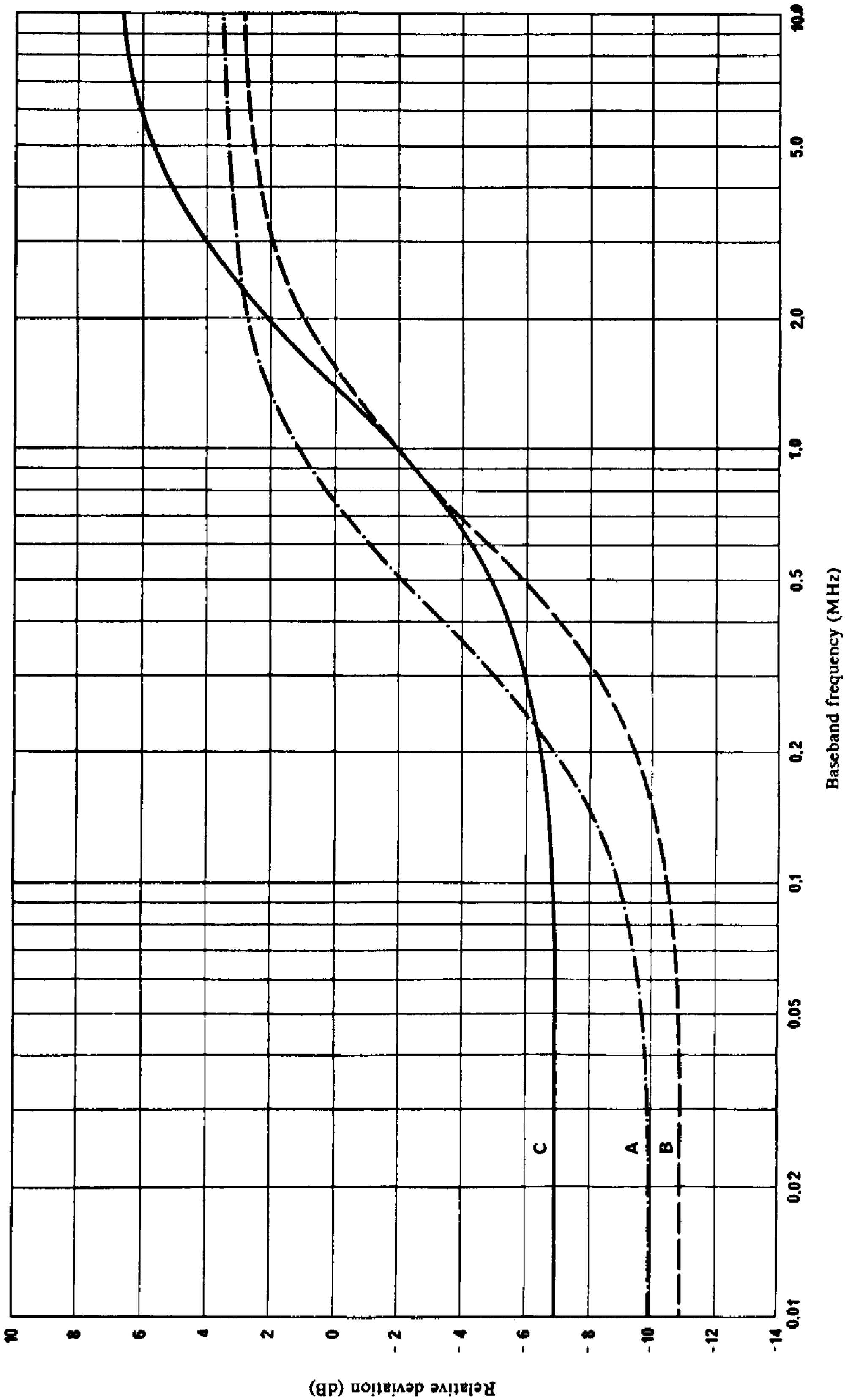

FIGURE 1

Pre-emphasis characteristic for television on 525-, 625-, and 819-line systems

Curve A: 525-line system
B: 625-line system
C: 819-line system

Source: Recommendations and Reports of the CCIR, Vol. IX, Pt. 1, 1986