DIGITAL COLOR TV TELEMETRY

Richard A. Schaphorst
Charles P. Comeau
Delta Information Systems, Inc.
300 Welsh Road, Building 3
Horsham, PA 19044

ABSTRACT

In most of the initial applications of digital TV telemetry the video source signal is monochrome (typically RS-170 standard). However color TV is now employed extensively in many of the government test ranges, and it is likely that it will be required to digitally transmit the NTSC color TV signal for security and other reasons. It is also likely that the bit rates which will be employed for this transmission will range from 1 to 20 mbps depending upon the application.

This paper presents the general issues involved in digitizing color TV signals, describes alternative color coding techniques, compares these alternatives, and describes one particularly promising approach in detail.

Alternative coding techniques that will be discussed and analyzed include direct coding of the composite NTSC signal as well as several component coding concepts - Y, I, Q; Y, R-Y, B-Y; and the transmission of chroma lines on an alternating basis. Specific techniques for multiplexing the digitized color component signals will be presented.

It is desirable that the color coding technique be an incremental expansion relative to existing monochrome coding concepts. One particular technique which shows promise of meeting this objective is presented and discussed.

INTRODUCTION

TV Signals are telemetered for a wide variety of purposes throughout the U.S. Government. In air-to-ground situations, TV sensors are located in missiles and high performance aircraft. In ground-to-ground cases, TV signals are used to precisely measure the performance of aircraft and test. In many cases it is important that these signals be encrypted prior to transmission for security reasons. Encryption requires the use of an encoder at the transmitter to convert the input video to a digital format and a decoder at the
receiver to convert the received digital signal back to the analog TV format. A functional block diagram of a secure video telemetry system is shown in Figure 1. The typical output of the TV camera is a monochrome video signal conforming to the RS-170 specification. However, in some cases there is a need to transmit color TV signals conforming to the NTSC format. The purpose of this paper is to discuss the various techniques to extend the technology which has been developed for the monochrome RS-170 signal to the color NTSC signal.

The bit rate at the output of the encoder varies depending upon the application. For ground-to-ground communications, transmission channels up to 20 mbps are frequently available. For air-to-ground transmission, the bit rate can be as high as 10 mbps and as low as 1 Mbps depending upon a variety of system constraints.

If the input TV signal were to be encoded using conventional PCM, the transmitted bit rate would be in the range of 60 to 80 Mbps (10x10^6 samples/sec.; 6-8 bits/sample). To achieve the required transmission bit rates data compression techniques must be employed which reduce the redundancy inherent in the input picture. The objective of the encoder/decoder is to compress/expand the signal to the required bit rate while maximizing the quality of the output picture.

Many telemetry applications require the transmission of the full 60 fields/sec without reducing frame-to-frame redundancy to insure there is no image smear for a moving object. To achieve an acceptable picture resolution for telemetry the number of pels per line usually varies between 256 and 512. For the common transmission bit rate of 10 Mbps this dictates that the maximum number of bits available to define each pel varies over the corresponding range from 1.3 to 2.6. This is the key figure which defines the data compression requirement.

The NTSC signal may be encoded directly, or it may be first divided into components which are individually encoded. The next two sections of this paper discuss these two alternatives. The final two sections present one particularly promising approach to signal multiplexing and draw overall conclusions on the subject.

**COMPOSITE CODING**

Image compression is possible due to the fact that the brightness of a picture element is usually highly correlated with neighboring pels. By reducing this pel-to-pel redundancy the bit rate can be reduced. Unfortunately the 3.58 mHz subcarrier in the NTSC signal radically reduces this correlation and redundancy. This makes it very difficult to, directly encode the composite NTSC signal to achieve a high compression ratio while maintaining reasonable picture quality.
Some systems have been developed to encode the composite NTSC signal using predictive coding technology. Unfortunately the systems typically require 3 to 4 bits per pixel which is excessive for most telemetry applications. Work has also been done to investigate the application of the Discrete Cosine Transform to the direct coding of the composite signal. Unfortunately, these studies also conclude that approximately 3 bits/pixel are required. The conclusion is that the 3.58 mHz subcarrier reduces the redundancy of the NTSC signal to such a degree that compression below 3 bits/pixel is difficult to achieve, and greater compressions are usually required for the telemetry application.

COMPONENT CODING

For the reasons identified in the previous section virtually all color coding systems encode color components as opposed to the composite NTSC signal. The first step in understanding the component coding process is to define the three components (Y, I, and Q) which make up the NTSC signal. The chromaticity equations and the nominal bandwidths for the three components are listed below where R, G, and B are the three primary colors sensed in the camera and displayed on a monitor.

<table>
<thead>
<tr>
<th>Chromaticity Equation</th>
<th>Nominal Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminance Y = 0.3R + 0.59G + 0.11B</td>
<td>3.0 mHz</td>
</tr>
<tr>
<td>Chroma I  I = 0.74(R-Y) - 0.27(B-Y)</td>
<td>1.5 mHz</td>
</tr>
<tr>
<td>Chroma Q  Q = 0.48(R-Y) + 0.41(B-Y)</td>
<td>0.5 mHz</td>
</tr>
</tbody>
</table>

The first step in any component encoding system is to decode the NTSC signal into these Y, I, and Q components. One possible coding system is to digitally encode these three separate components and then multiplex the three digital signals into one stream for transmission. If this were done the combined chroma bandwidth of 2 mHz would occupy 40% of the total transmitted signal bandwidth. This approach has two disadvantages. The 40% is a heavy price to pay, and it is rather complex to encode and multiplex three signals having dissimilar bandwidths.

European countries employ two different color TV standards known as PAL (Phase Alternation Line-Rate) and SECAM. In both of these systems the two transmitted chroma signals are R-Y and B-Y rather than I and Q. In addition the CCIR\(^1\) and CCITT\(^2\) standards organizations have defined digital TV systems which employ the R-Y and B-Y chroma components.

One advantage of the R-Y, B-Y coding over I, Q is that the bandwidths of these two color components are equal. In general, digital coding systems employing R-Y, B-Y components
define each chroma signal with one-half the number of pels which are allocated to luminance. In this situation if all three components were transmitted the color information would occupy 50% of the total bit rate which is a little less efficient than transmitting all three Y, I, Q components.

For the same reason that the horizontal chroma resolution can be reduced relative to the luminance without being perceived by the eye, so the vertical resolution can be, and should be, similarly reduced to effect a bit rate compression. The simplest way to accomplish this reduction of vertical chroma resolution is to transmit R-Y or B-Y on a line alternating basis (similar to SECAM) as shown in Figure 2. Figure 3 is an illustration of the corresponding decoder which operates on the chroma line alternation principle. Important advantages of this approach are that the chroma information occupies only 33% of the total transmitted bit rate, and only two encoders are required at the transmitter. For these reasons this concept is preferred for coding the NTSC signal.

**SIGNAL MULTIPLEXING**

Figure 4 illustrates a recommended framing structure for the line alternating chroma system defined in the previous section. The reader will note that nineteen bits are used to synchronize lines, to define the format of each line, and to provide fill bits if required. This 19 bit field is defined by the Range Commander’s Council Standard 209-88 which will be issued in the near future. One major design issue is the decision on how to multiplex the chroma information with the luminance. The chroma bits could be uniformly interspersed with the luminance bits throughout the line period; or they could be inserted as a burst at the end of the line as shown in Figure 4. The burst approach is preferred to maximize the compatibility of color coding systems with monochrome coding systems. This design approach will permit future color transmissions to be received by RCC 209-88 monochrome decoders which are being deployed today.

The number of bits per line, bits for luminance, and bits for chroma shown in Figure 4 are average figures. The actual number of bits will vary from line to line as the complexity of the line varies. It is noted in Figure 4 that the average number of bits per pixel required for this approach is 1.6. Since the RCC 209-88 standard defines a coding algorithm which achieves this nominal level of compression this overall design concept is recommended as the natural extension from coding the RS-170 monochrome signal to the composite NTSC signal.
CONCLUSION

A design concept has been outlined for the digital coding of the NTSC color TV signal for telemetry applications. Highlights of the proposed system approach are listed below:

- Component coding is preferred to encoding the composite NTSC signal.

- The color components selected are Y, R-Y, and B-Y. This has the advantages of compatibility with CCITT and CCIR standards, and equal bandwidths for the chroma signals.

- The R-Y, B-Y chroma signals are transmitted on a line alternating basis resulting in an allocation of 33% of the transmission capacity to color.

- The chroma signal is transmitted at the end of the line on a burst basis to maximize the compatibility with the forthcoming Range Commanders Council standard 209-88.

REFERENCES


FIGURE 1. - FUNCTIONAL BLOCK DIAGRAM OF A SECURE VIDEO TELEMETRY SYSTEM

FIGURE 2: DIAGRAM OF NTSC VIDEO ENCODER
FIGURE 3: BLOCK DIAGRAM OF NTSC VIDEO DECODER

FIGURE 4:
MULTIPLEX CHARACTERISTICS FOR A TYPICAL NTSC CODING SYSTEM

- LINE SYNCHRONIZATION
- FORMAT DEFINITION
- FILL

BIT RATE = 634 BITS/LINE X 15.750 LINES/SEC = 10^7 BITS/SEC

AVG. BITS/Pixel = 615 BITS = 1.6
384 PIXELS