Transmission of a PCM Telemetry Subcarrier with a Baseband TV Signal

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Abstract

An FM television system using a baseband color TV signal with a 100 kB/s PCM data FM subcarrier is described. Techniques used are based more like those for satellite transmission of TV images than those used for telemetry or broadcast TV. Discussion of optimization of transmission bandwidth, deviation, and subcarrier injection levels are discussed, along with the philosopy and application of such designs in instrumentation systems.

1 Introduction

Recent progress in manufacture of miniature, all solid-state television cameras make possible transmission of video from platforms not previously accessible. While tube-type cameras suffered from microphonics and other unpleasant effects not encountered in a TV studio, cameras are now available in packages as small as a cigarette pack or a cocktail weenie—including the lens and often including no-moving-parts electronic shutter to freeze fast action and adjust light levels more quickly than a mechanical iris. Telemetry transmitters have long been available in the small package sizes needed for airborne applications, and can be (and have been) used for transmission of television images in some TV-based weapons systems over the last twenty years or so. These older systems were always black-and-white, and many used nonstandard video formats beholden only to a limited number of monitors and often no videotape recorders at all. The smaller size, higher reliability, and lower costs of solid-state cameras make transmission of black-and-white or color TV signals for things like miss distance measurement, bomb release, parachute systems, etc., practical where they really werent previously. For those systems that previously had, or would benefit from, a telemetry link as well, it is generally appropriate to combine those functions on a single RF link.

2 RF System Considerations

The system described in this paper is a standard color TV signal with telemetry data sent as an FM subcarrier carrying a pulse-code modulated [PCM] digital signal. Transmitting a video signal with an auxiliary subcarrier isn't new—while early commercial TV system designs had a separate transmitter for sound and video, newer designs transmit the audio as a subcarrier 4½ MHZ above the AM video carrier. The receiver doesn't care—it treats the received audio carrier as a subcarrier in either case, at least if the receiver was manufactured after about 1950. The commercial sound subcarrier is FM, and uses a deviation for the normal audio of ±25 kHz. The broadcast audio subcarrier may contain other services such as stereo, second-language programming, intercom service for remotes, and telemetry for the TV transmitter, all on subcarriers of the audio track. One common form of satellite transmission involves sending the baseband video and one or more FM audio tracks together on an FM transponder. In such a system, the audio subcarriers are spaced at a greater distance above the video baseband than in commercial AM transmission, at reasonably standard frequencies of 5.5, 6.2, 6.8, 7.5, and 8.2 MHZ. Even when the audio related to the picture transmitted is sent through other means (such as subscription TV services are now transmitted), as many as a few dozen FM subcarriers may be present.

3 Implementation

The system described in this paper resembles more closely the system used for satellite TV transmission than that used for standard TV broadcast in that the carrier is FM and the subcarrier center frequency is 7.5 MHZ. [1] An FM system is used not for its bandwidth efficiency (it isn't the most compact), but for its relative insensitivity to rapid and slow fades that are often present in telemetry signals sent from moving vehicles. The baseband video signal is a standard NTSC composite color signal, whose bandwidth is a mixture of a typical black-and-white ("luminance") signal and a color subcarrier signal centered about 3.58 MHZ. Because of the limitations caused by the scanning system, the luminance signal can contain no important information nor spectral energy beyond about 6 MHZ, much of which is lost in the receiving and recording process. [2] As a consequence of this frequency limitation, significant sideband energy in the data subcarrier can extend as far down as 6 MHZ, as long as no intermodulation products create other frequencies within the video passband; any energy below 6 MHZ may be visible in the television picture. If an FM subcarrier is used (as we do here), a symmetrical signal would thus extend from 6 to 9

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[1]Actual selection of 7.5 MHZ as the subcarrier frequency was somewhat arbitrary, determined by the commercial discriminators used in the first experiment.

[2]A broadcast NTSC color picture is limited to a bandwidth of about 4.2 MHZ; a typical VHS, Beta, or U-Matic recorder is limited to about 2.5 MHZ.

MHZ. A “noiseless” television picture needs a signal-to-noise ratio of 46 dB or so. [3] The sideband energy limitation determines the envelope shape of the subcarrier and the maximum injection that can be used. The minimum injection level for the data subcarrier is determined by other factors that well examine shortly, as is the total carrier deviation for the video-plus-subcarrier composite.

4 RF Bandwidth

RF bandwidth can be defined in several ways, so it’s necessary to define terms first. The RF bandwidth that is to be optimized (not necessarily minimized) is that bandwidth which is necessary in the IF section(s) of the receiver to allow reception of the signal without significant distortion. For an FM signal, as is the one here, the bandwidth has a minimum of twice the bandwidth of the modulation, so with an unmodulated subcarrier, the bandwidth required would be <u>at least</u> 15 MHZ, and with the assumption that the subcarrier contains modulation, that bandwidth would be more like 17-18 MHZ. The actual bandwidth will be somewhat larger than these numbers, though, because these estimates assume zero carrier deviation of the actual FM composite carrier, but will never be as great as the result predicted from Carson’s rule (bandwidth is approximately twice the sum of peak devition and the modulation bandwidth). In satellite transmission, signals of the type under consideration here are sent in a 40 MHZ passband transponder, and normally detected with a receiver bandwidth of 20-28 MHZ. In the system described here, a 141-IRE television signal feeding a transmitter with a sensitivity of 4 MHZ per peak volt produces approximately 4 MHZ of overall deviation. Since the system is AC coupled to the asymmetrical video, the average center frequency varies with picture content. [4]

5 Data Subcarrier

The data subcarrier center frequency is selected to be 7.5 MHZ, somewhat arbitarily because of available equipment, as mentioned earlier. The data to be sent is a binarydigital code, with a bit rate of 100 kilobits per second. [5] Theoretically, a subcarrier with a

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[3] The actual appearance of interference in a television picture depends in large measure on the harmonic relationship between the energy and harmonics of the horizontal repetition rate and to a lesser extent the color subcarrier frequency. The number used here is based on a worst-case assumption.

[4] On the PAE transmitter used, the transmitter is capable of ±6 MHZ deviation, which can accommodate the video signal and several subcarriers.

[5] The original customer request (for the Naval Research Laboratories, White Oak, MD) was for a multiplexer bit rate of at least 19 kB/s. The Altera chip used in this implementation has been tested at rates in excess of 100 kB/s, and will be used at 50 kB/s in this particular application.

bandwidth of 3 MHZ could carry a binary NRZ signal at bit rates of up to 3 Mb/sec, although some filtering of sideband energy would no doubt be necessary to reduce picture interference. The bit rate used thus comes nowhere close to straining the capability of the bandwidth available on the system baseband, even when using the less spectrally-efficient BIΦ code used for the first tests.[6] Deviation of the 7.5 MHZ carrier is set at ±75 to ±80 kHz for the 100 kB/s data rate; deviation would be set at 0.35-0.4 times the clock rate for NRZ and twice that for BI Φ. Subcarrier injection level is set at ±750 kHz; if more than one subcarrier is used, the lower subcarrier is set for ±500 kHz injection and the higher ones tapered in accordance with their relative frequencies and data bandwidths. The subcarrier could also be used for high-fidelity audio transmission, again not unlike standard broadcast or satellite TV.

6 Signal Path

The digital signal to be transmitted is from an RS422 source external to the telemetry unit. "Multiplexing" thus consists at the transmitting end of converting the two-wire balanced source to a single-ended TTL signal, lowpass (premodulation) filtering, and feeding the signal to a properly-scaled voltage-controlled oscillator, as shown in Figure 1, for mixing with the video signal for transmission.

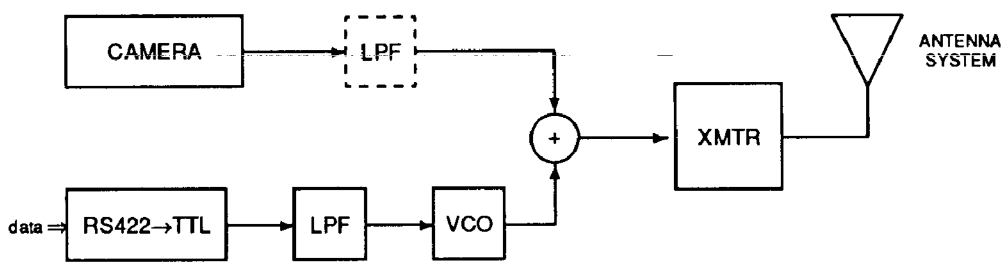

Figure 1: Block Diagram, Sending End

The lowpass filter in the video line isn't absolutely necessary, but when used assures that the video signal produces no interference to the FM subcarrier spectrum space. The lowpass filter would definitely be necessary if an AM subcarrier were used.

On the receiving end, the process is reversed—the composite signal is fed to a lowpass filter to allow the television signal to be displayed on a standard NTSC monitor, recorded, and/or rebroadcast as a standard NTSC television signal, and fed as well to a discriminator

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[6]The BIΦ code was selected for convenient use with existing equipment. Future designs using higher bit rates will use randomized NRZ, and bit rates greater than a few hundred kHz will by synchronized to multiples of the television horizontal rate (≈ 15, 734 kHz) to minimize picture interference.

which recovers the analog version of the data signal. A comparator is used to resquare the signal and a translator is used to reproduce the desired output signal, as shown in Figure 2.

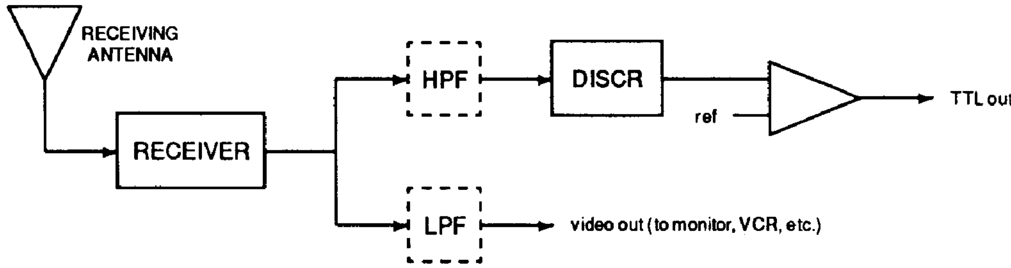

Figure 2: Block Diagram, Receiving End

At the receiving end, a lowpass filter is needed if the bandwidth of the monitor, VCR, microwave system, etc., is great enough that the subcarrier energy might interfere with the picture (it would appear as a fine herringbone pattern). The highpass filter for the discriminator may not be necessary in any case. The TTL output produced by the system is normally fed to a bit synchronizer/signal conditioner [BSSC] to recover the data clock and convert logic levels as required; in some cases the comparator function is provided by the BSSC. If the recovered data is fed to a computer, the comparator output may be ±12 V_{dc} for RS-232 compatibility, etc., as determined by the use and the user.

7 Packaging

A transmitter with integral subcarrier VCO is shown in Figure 3. Size of the package is less than 4" x 4" x 12" inches, dictated by the user, in this case a parachute recovery project.

8 System Power

The transmitting system is powered by a 28-volt NiCd battery pack, which allows an operating time of around 20 minutes for the 5-watt transmitter shown. A two-watt system runs about twice as long on the same battery package. In use, the system is turned on at takeoff time, and the battery need not last longer than the maximum amount of time that the airplane can fly on a single tank of fuel, but this assumption can backfire if the aircraft doesn't take off immediately after the power is turned on. Depending on the use, a system such as this could be operated by thermal batteries or power "stolen" from the host, or a pin enabling the on-board batteries can be pulled by the launching sequence. Actual curent draw at 28 volts is around 2 amperes, or 56 watts, mainly due to the efficiency (or more accurately, inefficiency of the transmitter.

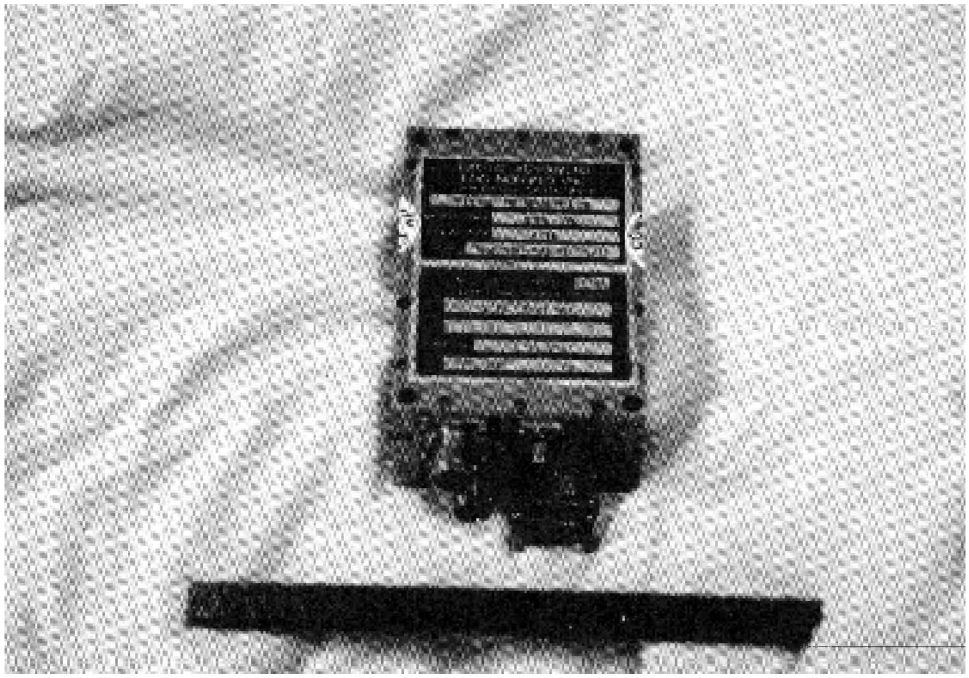

Figure 3: Television-Telemetry Transmitting System

9 Transmitting Antenna

The transmitting antenna used for this application was a blade type, which produces a linearly-polarized signal with a gain of essentially zero dB over isotropic. The advantages of a blade antenna include low cost and broad bandwidth (the latter essential if different frequencies are provided on a frequency-agile transmitter); disadvantages include a very un-omnidirectional pattern and being relatively easily broken off. If a different type of antenna is used, the antenna bandwidth must be sufficient to pass the wideband signal, which means at least a 2% bandwidth, not always attainable with wraparound units.

10 Receiver Package

A receiver system made for field use is shown in Figure 4. Satisfactory results have been obtained with a UHF spiral antenna attached to a gunstock in the parachute recovery system.

The receiver package can also be attached to any tracking antenna system available at the test facility. Ground stations may also already have the capability of receiving and demodulating a signal of this type, but that is not assured.

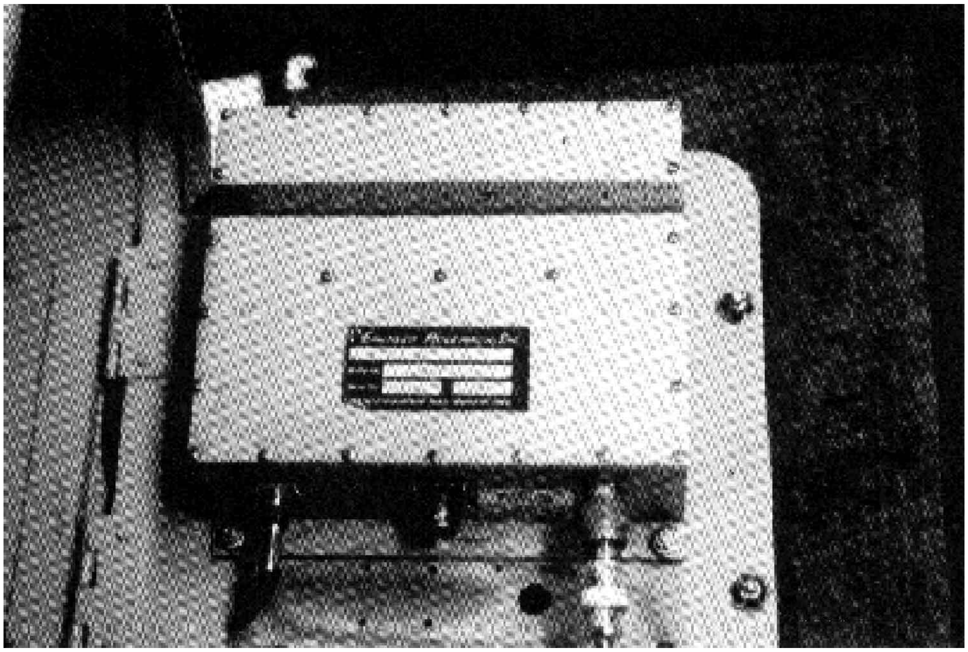

Figure 4: Television-Telemetry Receiving System

11 Ground Station Considerations

Ground stations at most test ranges have antennas and receivers that operate in the frequency ranges used for the television-telemetry system. A typical telemetry receiver has adjustable IF and baseband bandwidths, but many ground station receivers may not be adjustable enough to allow the required bandwidths for this purpose. Many telemetry receivers also do not use the 160- and 70 MHZ IF frequencies common in television systems, and thus cannot be used as a downconverter feeding external equipment. Receivers capable of these bandwidths can be obtained from several manufacturers, however, and retrofit kits for modification of some existing telemetry receivers are available.

12 Conclusion

Television pictures produced by miniature cameras are a cost-effective replacement or supplement to methods currently in use. If a picture is worth a thousand words, producing the proper pictures can be very verbose indeed.