APPLICATION OF DIGITAL VIDEO IN MODERN TELEMETRY SYSTEMS

Author: David Druif
LORAL/CONIC
9020 Balboa Avenue
San Diego, California 92123

ABSTRACT

This paper addresses the system issues of applying digital video to modern telemetry systems and problems. Comparison of typical link budgets, block diagrams, as well as improvements and limitations for both analog and digital video are included. Encryption issues are covered from a generic unclassified point of view.

INTRODUCTION

In most telemetry video systems three things are of importance: resolution, signal-to-noise ratio, and bandwidth. When analog techniques are used, these three elements are highly interrelated. More resolution requires higher telemetry channel frequency response, and higher channel response generally requires more transmission bandwidth to send the signal out. This in turn lowers the signal-to-noise ratio of the received signal unless a comparable increase in signal strength is achieved through added transmit power or through reduction in signal attenuation (shorter range). As a rule, analog video systems are designed to achieve a minimum signal-to-noise ratio of 30 db and, with normal 525 line RS-170 video (the most common case in the US), have a bandwidth of 4.5 MHz. With normal narrowband FM this signal occupies an RF bandwidth of about 10 MHz. This FM system is probably the most common method of transmitting video on US test ranges today.

The drawbacks of this type of analog FM transmission system are many, but the major problem is the difficulty of reliably encrypting the video signal. Additional considerations are the difficulty of efficiently mixing other, more classical telemetry data with the video, the wide bandwidth required to transmit this signal, and the vulnerability of this signal to noise. But these problems are not insurmountable; a reasonable solution can be found through the use of digital video.

ADVANTAGES OF DIGITAL VIDEO

Signal-to Noise Ratio and Link Budget

Digitizing 525-line RS-170 (4.5 MHz) video image into an 8-bit pixel array 512x512 at 30 arrays per second closely approximates the original image quality. Without any overhead or other processing, this raw video image will result in a serial bit stream of 62,914,569 bits per second (bps). Using the recommendations contained in the PMTC Telemetry Applications Handbook, a link budget can be constructed for each type of TM link and a direct performance comparison can be made. Figure 1 illustrates the block diagram of a simple PCM/FM digital video encryption and telemetry system. Table I illustrates the link budget of the classic analog video FM telemetry system, and Table 11 illustrates the link budget of the comparable digital PCM/FM transmission system.

A quick comparison of Table I and Table II shows that even without any sort of compression, the PCM/FM system has about 7.5 db more margin than the analog FM system. With no further changes to the configuaration, the PCM system would have 2.4 times the range of the analog FM system with equivalent margin. The PCM system does have the drawback of requiring significantly more bandwidth (approximately 7 times, or 8.5 db more,) but it also offers 16 db more noise immunity.

The VCS-500 system hardware provided by LORAL/CONIC will compress this video into a PCM stream of 8.8 Mbps. Table III illustrates the link budget for this system. In this configuration, the system is capable of transmitting video in a 1.1 Mbps PCM bit stream at a reduced frame rate of 3.25 Fps. Table IV illustrates this case. New hardware under development will soon be available and will employ two- or three- dimensional compression techniques with compression ratios as high as 85:1. These new techniques should allow full frame rate, 512x512 pixels per frame, eight bits per pixel, RS-170 video in a bit stream of less than 800 Kbps. This is very close to the 740 Kbps maximum bit rate recommendation of the PMTC Telemetry Applications Handbook for an IRIG 106-86 1 MHz telemetry channel. A table illustrating the link budget for this potential system would be similar to Table IV, but the margin would be 1.2 db greater. Whenever possible the nearest standard IF bandwidth was used for link calculations as recommended in IRIG-106-86.

Encryption

Encryption of analog video signals is an unreliable process at best, and requires very special encryption equipment. This problem is most easily solved by digitizing the video and compressing the resulting PCM stream. Most ranges support the KG-66 Nobleman algorithm with commonly available NSA decryption hardware. Although highly reliable, this low-cost digital encryption hardware is not capable of securing video signals without digitizing and compression to less than 10 Mbps. The VCS-500 hardware operates at a wide range of user-programmable output bit rates--all of which are below 10 Mbps. This hardware allows the use of this class of encryptor and as an option has the KGV-68 built into the unit. This equipment has been tested for Tempest requirements and found satisfactory by NSA. The use of compression will allow the implementation of a wide variety of encryptors which were formerly used only for telemetry.

Mixing with TM Data

Quite often when Video telemetry is required, some “other” telemetry is also needed. When analog video is transmitted, the most common method of transmitting this “other” telemetry is by way of a subcarrier oscillator which allows both signals to be transmitted on the same carrier. This FDM method of combining signals wastes the telemetry spectrum, since spacing is required to prevent mutual interference between the analog video and the “other” telemetry. When digitized and compressed PCM video is used, however, it is a simple matter to digitally merge these two PCM streams into a single composite stream. This composite stream, if properly formatted to comply with the requirements of IRIG 106-86 type I formats, could easily be decommutated using existing decommutators in place on most ranges today. The use of “in-place” equipment would require the paralleling of the video data expansion unit with the existing range decommutator; this parallel patching would occur after the decryption hardware. This approach to mixing TM data would minimize equipment costs, while using existing IRIG specifications to standardize data formats.

Securing Video Tapes Through the Use of Compressed Digital Video

Great strides in airborne video tape recorders have been made in the last few years. Today both VHS and 8 mm formats are available in packages reinforced for use in high performance aircraft or unmanned vehicles. Recording this video on tape (when classified information is contained in the video images) classifies the tape to the level of the classified information. This means, of course, that the tape must be controlled and treated with all the normal precautions granted other classified information. Electronics are available today to use these same analog video tape recorders to record digital data up to 1 Mbps. This will allow 3.25 frames per second (decimated RS-170) encrypted video to be recorded today and full frame rate video to be recorded in the future. Within 2 years full frame rate video will compress to less than 1.0 Mbps in airborne hardware.

CONCLUSION

The application of digital video in modern telemetry systems is a promising concept. Not only does it offer a solution to the problem of reliable encryption of the video signal, it also offers significantly higher margin and link reliability, a less expensive and more effective way to mix TM data, and a better method of securing video tapes--for today-and for the future.

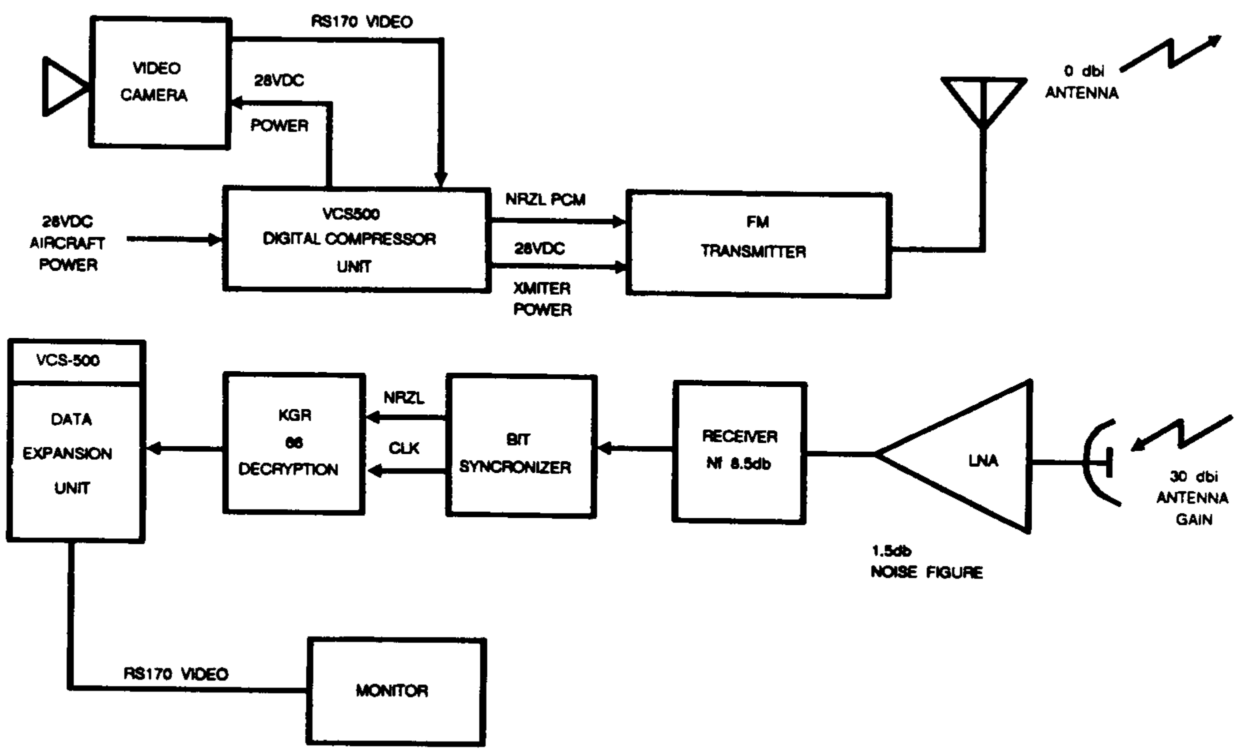

FIGURE 1

PROJECT NAME......ITC 88

DESCRIPTION....... Analog Video 4.5 Mhz

RANGE SOLUTION EQUATION SOLVED FOR MARGIN AND LINK RELIABILITY
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SYSTEM DATA		SYSTEM LOSSES	
FREQUENCY	1700.00 MHZ		
TRANSMIT POWER	2.00 WATTS	TX FEED	-1.00dB
MINIMUM SNR	30.00 dB	POLARIZATION	-3.00 dB
DESIRED RANGE	10.00 MILES	WEATHER	0.00 dB
Max Mod Freq	4500.00 KBS	OTHER	0.00 dB
IF BW	10000.00 KHz		

PEAK DEVIATION	4500.00 KHz	TOTAL LOSSES	-4.00 dB
MODULATION INDEX	1.00		

ANTENNAS		NOISE FIGURE	
TX ANTENNA GAIN	0.00 dB	RX FEED LOSS	-1.00 dB
RX ANTENNA GAIN	30.00 dB	LNA NOISE FIGURE	1.50 dB
------------------		LNA GAIN	25.00 dB
CUM ANTENNA GAIN	30.00 dB	CABLE LOSS	3.00 dB
		OTHER	0.00 dB
		RX NOISE FIGURE	8.50 dB
DIVERSITIES	0.00 dB		---------
		SYSTEM NOISE FIG	2.52 dB

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FREE SPACE ATTEN	-121.21 dB		
TX POWER	33.01 dBm	KTB	-174.00 dB/Hz
ANTENNA GAIN	30.00 dB	IF BANDWIDTH	70.00 dB
SYSTEM LOSSES	-4.00 dB	NOISE FIGURE	2.52 dB
DIVERSITY IMPROVE	0.00 dB	MINIMUM SNR	30.00 dB
	------------		---------
CARRIER POWER	-62.20 dBm	USE THRESHOLD	-71.48 dBm
FM IMPROVEMENT	0.00 dB		
USE THRESHOLD	-71.48 dBm		

MARGIN	9.28 dB		
LINK RELIABILITY	88.19%		

TABLE I

PROJECT NAME......ITC 88
DESCRIPTION.........PCM VIDEO 63 Mbps

RANGE SOLUTION EQUATION SOLVED FOR MARGIN AND LINK RELIABILITY

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SYSTEM DATA		SYSTEM LOSSES	
FREQUENCY	1700.00 MHZ		
TRANSMIT POWER	2.00 WATTS	TX FEED	-1.00 dB
MINIMUM SNR	14.00 dB	POLARIZATION	-3.00 dB
DESIRED RANGE	10.00 MILES	WEATHER	0.00 dB
BIT RATE	62914.00 KBS	OTHER	0.00 dB
IF BW	70000.00 KHz		---------
PEAK DEVIATION	22000.00 KHz	TOTAL LOSSES	-4.00 dB
MODULATION INDEX	0.50		

ANTENNAS		NOISE FIGURE	
TX ANTENNA GAIN	0.00 dB	RX FEED LOSS	-1.00 dB
RX ANTENNA GAIN	30.00 dB	LNA NOISE FIGURE	1.50 dB
	----------	LNA GAIN	25.00 dB
CUM ANTENNA GAIN	30.00 dB	CABLE LOSS	3.00 dB
		OTHER	0.00 dB
		RX NOISE FIGURE	8.50 dB
DIVERSITIES	0.00 dB		---------
		SYSTEM NOISE FIG	2.52 dB

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FREE SPACE ATTEN	-121.21 dB		
TX POWER	33.01 dBm	KTB	-174.00 dB/Hz
ANTENNA GAIN	30.00 dB	IF BANDWIDTH	78.45 dB
SYSTEM LOSSES	-4.00 dB	NOISE FIGURE	2.52 dB
DIVERSITY IMPROVE	0.00 dB	MINIMUM SNR	14.00 dB
	-----------		---------
CARRIER POWER	-62.20 dBm	USE THRESHOLD	-79.03 dBm
FM IMPROVEMENT	0.00 dB		
USE THRESHOLD	-79.03 dBm		

MARGIN	16.83 dB		
LINK RELIABILITY	97.92%		

TABLE II

PROJECT NAME......ITC 88
DESCRIPTION.........Compressed PCM Video 8.8 Mbps

RANGE SOLUTION EQUATION SOLVED FOR MARGIN AND LINK RELIABILITY

SYSTEM DATA		SYSTEM LOSSES	
FREQUENCY	1700.00 MHZ		
TRANSMIT POWER	2.00 WATTS	TX FEED	-1.00 dB
MINIMUM SNR	14.00 dB	POLARIZATION	-3.00 dB
DESIRED RANGE	10.00 MILES	WEATHER	0.00 dB
BIT RATE	8800.00 KBS	OTHER	0.00 dB
IF BW	10000.00 KHz		---------
PEAK DEVIATION	3080.00 KHz	TOTAL LOSSES	-4.00 dB
MODULATION INDEX	0.50		

ANTENNAS		NOISE FIGURE	
TX ANTENNA GAIN	0.00 dB	RX FEED LOSS	-1.00 dB
RX ANTENNA GAIN	30.00 dB	LNA NOISE FIGURE	1.50 dB
	------------	LNA GAIN	25.00 dB
CUM ANTENNA GAIN\	30.00 dB	CABLE LOSS	3.00 dB
		OTHER	0.00 dB
		RX NOISE FIGURE	8.50 dB
DIVERSITIES	0.00 dB		---------
		SYSTEM NOISE FIG	2.52 dB

FREE SPACE ATTEN	-121.21 dB		
TX POWER	33.01 dBm	KTB	-174.00 dB/Hz
ANTENNA GAIN	30.00 dB	IF BANDWIDTH	70.00 dB
SYSTEM LOSSES	-4.00 dB	NOISE FIGURE	2.52 dB
DIVERSITY IMPROVE	0.00 dB	MINIMUM SNR	14.00 dB
	------------		---------
CARRIER POWER	-62.20 dBm	USE THRESHOLD	-87.48 dBm
FM IMPROVEMENT	0.00 dB		
USE THRESHOLD	-87.48 dBm		

MARGIN	25.28 dB		
LINK RELIABILITY	99.70%		

Table III

PROJECT NAME.....ITC 88
DESCRIPTION.........COMPRESSED VIDEO 1.1 MBPS @ 3.25 Fps

RANGE SOLUTION EQUATION SOLVED FOR MARGIN AND LINK RELIABILITY

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SYSTEM DATA		SYSTEM LOSSES	
FREQUENCY	1700.00 MHZ		
TRANSMIT POWER	2.00 WATTS	TX FEED	-1.00 dB
MINIMUM SNR	14.00 dB	POLARIZATION	-3.00 dB
DESIRED RANGE	10.00 MILES	WEATHER	0.00 dB
BIT RATE	1100.00 KBS	OTHER	0.00 dB
IF BW	1000.00 KHz		---------
PEAK DEVIATION	385.00 KHz	TOTAL LOSSES	-4.00 dB
MODULATION INDEX	0.50		

ANTENNAS		NOISE FIGURE	
TX ANTENNA GAIN	0.00 dB	RX FEED LOSS	-1.00 dB
RX ANTENNA GAIN	30.00 dB	LNA NOISE FIGURE	1.50 dB
	------------	LNA GAIN	25.00 dB
CUM ANTENNA GAIN	30.00 dB	CABLE LOSS	3.00 dB
		OTHER	0.00 dB
		RX NOISE FIGURE	8.50 dB
DIVERSITIES	0.00 dB		---------
		SYSTEM NOISE FIG	2.52 dB

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FREE SPACE ATTEN	-121.21 dB		
TX POWER	33.01 dBm	KTB	-174.00 dB/Hz
ANTENNA GAIN	30.00 dB	IF BANDWIDTH	60.00 dB
SYSTEM LOSSES	-4.00 dB	NOISE FIGURE	2.52 dB
DIVERSITY IMPROVE	0.00 dB	MINIMUM SNR	14.00 dB
	------------		---------
CARRIER POWER	-62.20 dBm	USE THRESHOLD	-97.48 dBm
FM IMPROVEMENT	0.00 dB		
USE THRESHOLD	-97.48 dBm		

MARGIN	35.28 dB		
LINK RELIABILITY	99.97%		

TABLE IV