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FEASIBILITY STUDY OF TRANSMISSION OF OTV CAMERA CONTROL INFORMATION IN THE VIDEO VERTICAL BLANKING INTERVAL

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Please allow the author to add a personal note to Dr. Anderson: Loren, you'll be missed, have a great retirement.

ABSTRACT

The Operational Television system at Kennedy Space Center operates hundreds of video cameras, many remotely controllable, in support of the operations at the center. This study was undertaken to determine if commercial NABTS teletext transmission in the vertical blanking interval of the genlock signals distributed to the cameras could be used to send remote control commands to the cameras and the associated pan and tilt platforms. Wavelength division multiplexed fiberoptic links are being installed in the OTV system to obtain RS-250 short-haul quality. It was demonstrated that the NABTS transmission could be sent over the fiberoptic cable plant without excessive video quality degradation and that video cameras could be controlled using NABTS transmissions over multimode fiberoptic paths as long as 18.2 km.

SUMMARY

The Operational Television network at Kennedy Space Center is tasked with supporting all of the operations at the center. There are approximately 150 OTV cameras at pads 39A and 39B. These cameras and their associated pan and tilt platforms are remotely controllable from the OTV control room which is located 8-km distant in the Lanuch Control Center. The OTV network is currently being upgraded to wideband multimode fiberoptic video transmission. It is desirable to upgrade the camera and pan and tilt control loops as well. Previous work has shown that electrical multiplexing of the control data and the camera video had some unattractive characteristics.

This study was undertaken to explore the feasibility of using commercial teletext equipment to insert the camera control commands and camera environment telemetry in the vertical blanking interval (VBI) of the OTV video signals. It was determined that the North American Basic Teletext System standard (NABTS) was the most appropriate standard for this application. A data encoder and a decoder that conform to NABTS were obtained for these studies. These devices possess RS-232 ports to interface with the source and user of the teletext data.

It was found that the encoder and decoder could be used to send data from one personal computer to another, both through coaxial cable and over OTV wideband fiberoptic links.

An Ikegami color camera and associated remote control unit were obtained for camera-control over VBI tests. After some problems, unique to the devices under test were found and rectified, it was shown that the video camera-could be controlled using data transported by VBI-teletext equipment over coaxial cable or through OTV wideband fiberoptic links.

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[1] ANSI/EIA. *Recommended Practice for Teletext: North American Basic Teletext Specification (NABTS)*. EIA-Standard 516. May 1988

ABBREVIATIONS AND ACRONYMS LIST

ANSI /EIA .... American National Standards InstituteElectronic Industries Association
ASCII .... American Standard Code for Information Interchange
BS .... Byte Synchronization sequence, the third byte in NABTS synchronization sequence
CATV................ Community Antenna Television
CCTV................ Closed Circuit Television
CDSC .... Communications Distribution and Switching Center building
CS .... Clock Synchronization sequence of two bytes which begins a NABTS data line
CSA .... Canadian Standards Association
DTR .... Data Terminal Ready line in RS232
EDL .... Engineering Development Laboratory building
FEC .... Foward Error Control (or Correction)
HC240 .... model number for an Ikegami color video camera
IRE .... units used to measure video signal amplitudes
I/O .... input/output
LAN .... Local Area Network
LCC .... Launch Control Center building
MAC .... Multiplexed Analog Components, a type of video signal
NABTS .... North American Basic Teletext Specification (ANSI/EIA 516)
NAPLPS .... North American Videotext/Teletext Presentation Level Protocol Syntax
NTSC .... National Television Systems Committee, a television standard used in N. America and Japan
OTV .... Operational Television at KSC
OSI .... Open Systems Interconnect, the standard reference model for data communications
P1, P2, P3 .... Prefix bytes 1, 2 and 3 in the NABTS data packet, specify the data channel number
PAL .... Phase Alternating Line, a television standard used in Europe
PC .... Personal Computer
PDC .... Programme Delivery Control, a UK teletext-like service for controlling VCRs
PROM .... Programmable Read-Only Memory
PS .... Packet Structure byte, the last byte in the NABTS data line prefix
PTCR .... Pad Terminal Connection Room
P/T .... Pan and Tilt
RCU240 .... model number for the remote control unit for the Ikegami HC240 camera
SECAM .... Sequential Avec Memoire, a television standard used in France
SID .... Station Identification Code sometimes transmitted in the USA on line 20
SS .... Synchronization Sequence which begins a NABTS data line
TM10-9 .... model number for an Ikegami video monitor
TSG100 .... model number for a Tektronix NTSC video generator
TTX645 .... model number for a Norpak NABTS decoder
UDE400 .... model number for an Ultech NABTS encoder
VBI .... Vertical Blanking Interval, the first 21 lines of an NTSC video field
VABR .... Vehicle Assembly Building Repeater building
VIRS .... Vertical Interval Reference Signal
VITS .... Vertical Interval Test Signal
VM700A .... model number for a Tektronix Video Parameter Measuring Set
VPS .... Video Program System, a teletext-like service used in Germany to control VCRs
WDM .... Wavelength Division Multiplexer
WST .... World System Teletext
5000RX ,TX...... model number for the receiver, transmitter modules used in the OTV wideband fiberoptic transmission system

I

INTRODUCTION

1.1 OPERATIONAL TELEVISION AT KSC

The operational television (OTV) system is used to support the operations at Kennedy Space Center (KSC). The OTV network consists of more than two hundred cameras which feed images to the control room in the Launch Control Center (LCC). Within the control room, a 196x512 video switcher allows easy reconfiguration of the network to meet the changing needs of the users. A genlock signal is distributed to the OTV cameras to synchronize the video streams and the switch. Many of the cameras, particularly the 150 cameras at pads 39A and 39B, are remotely controllable from the control room where operators can adjust camera settings such as exposure, zoom and focus and can move the camera's pan and tilt (P/T) platform.

At present the camera and P/T control data is sent from the control room to the pads using modems and dated telephone technology. The control data is converted to discrete electrical signals in room 204 in the pad base and are fed to the cameras on separate wire pairs. Coaxial cables carry the genlock to the camera and the video from the camera. The numerous video streams originating at the pad cameras are multiplexed and carried to the control room using conventional coaxial-cable CATV frequency-division-multiplexing broadband equipment located in the PTCR. The distance from the pads to the control room (8-km maximum) necessitates that the broadband signals be amplified several times along the path.

1.2 OTV UPGRADE

KSC has begun an OTV upgrade that will improve the video quality available from the pad cameras and will reduce maintenance by simplifying the OTV network. Camera video will be migrated to multimode fiberoptic paths that will transport two video streams per fiber using 1300/1550-nm wavelength division multiplexing (WDM). Wideband (12-MHz) fiberoptic transmitter and receiver modules have been installed in pad room 204 and the LCC. The wide bandwidth of the optical fiber equipment can be used to transport more than the video; so it would be very desirable to be able to include the camera control data (and perhaps camera environment telemetry) along the existent fiberoptic paths.

1.3 PREVIOUS TRIALS WITH MULTIPLEXED VIDEO AND DATA

1.3.1 DATA ON AURAL SUBCARRIERS. Several trials, aimed at transmitting some combination of multiplexed video and data, preceded this work. In one case, audio carrier transmission modules from the same manufacturer that produces the OTV wideband fiberoptic transmitters and receivers were obtained. These devices are used to combine two audio channels with one video channel video for transmission. Laboratory adjustments to these audio modules placed the aural carrier frequencies above 9 MHz and a 8.5 MHz low pass filter was used to further isolate the video. Modems were used to insert data streams on the aural carriers. This trial successfully resulted in two full-duplex data channels operating at or above 2400 bit/s multiplexed with one bidirectional video channel. Further testing confirmed that the video still met short-haul specifications. Although technically successful, it was thought that this solution was not appropriate for field installation since it required too much equipment and exhibited unacceptable drift in the aural subcarrier frequencies.

Equipment from other vendors, designed to combine video and data for fiberoptic transport, was tested but found unacceptable usually due to the inability of the video to meet short-haul standards.

II

VERTICAL BLANKING INTERVAL

2.1 STRUCTURE OF THE VBI

The NTSC video standard used in North America has 525 horizontal scan lines divided equally into two fields. The first 21 lines in each field make up an area that does not carry any video information and is not shown on video receivers. Together, these lines are known as the vertical blanking interval (VBI). The first nine lines in the vertical blanking interval transmit special pulses which are used to synchronize the vertical scanning of the video receiver with the top of the transmitted image. Lines 10 through 21 of the vertical interval are unused for either vertical sync or for the video image and are therefore available to carry other information. Neither the USA nor Canada regulates the usage of the VBI. The structure of the VBI can be seen in the figure in Appendix A.

2.2 DATA IN THE VBI

Worldwide, several standards have been developed and are currently in use for transporting signals of various types in the VBI. These standards were developed to meet a wide range of needs of and market opportunities for TV originators, broadcasters, CATV and CCTV operators. Beginning in the late 1970s and expanding since then, many different types of information have been transmitted in the VBI.

Some of the first signals to have been inserted in the VBI are the vertical interval test signal and the vertical interval reference signal (VITS & VIRS). These are analog test signals, normally transmitted on lines 17, 18 and 19 in both fields, enable receiving equipment to assess transmission degradation.

A digital VBI signal that is now ubiquitous in the USA is *closed-captioning* (for the hearing impaired). In 1991 the FCC ordered that all TV receivers sold in the USA after July 1, 1993 must be capable of decoding and displaying closed-caption data. Closed-captioning transmits a NRZ signal, on line 21, field 1, of the VBI. To meet this limited need and to keep costs low, closed-captioning uses a low data rate, transmitting a synchronizing preamble and 2 bytes (7 data bits, 1 parity bit) of information per line. This gives a maximum data rate of ≈840 bit/s. Figure 2-1 shows an example of closed-caption data on line 21.

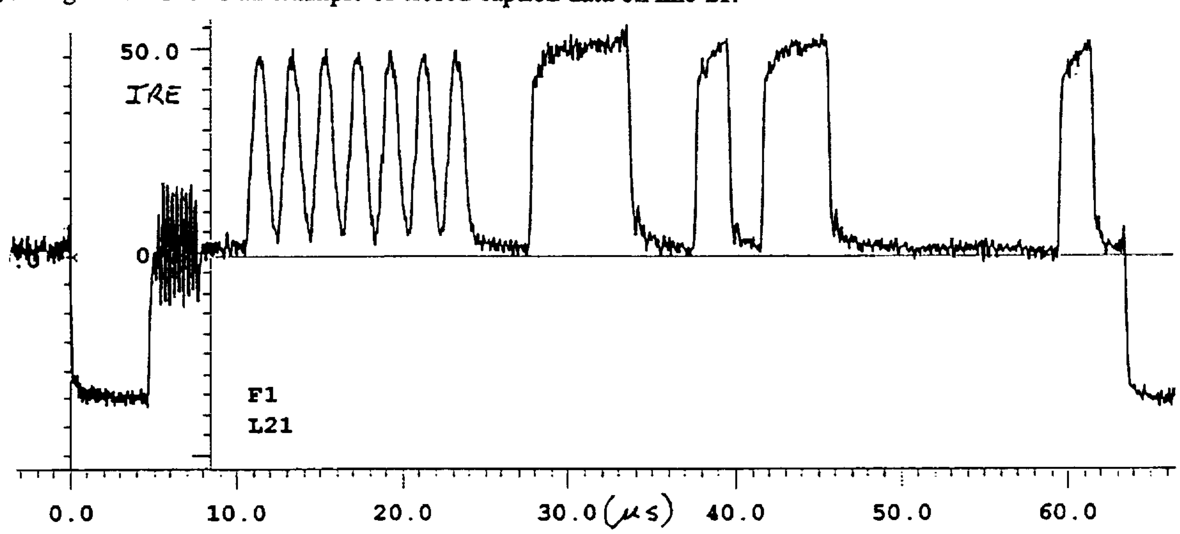

Figure 2-1 Closed Caption Data

Another example of a specialized digital VBI signal that is sometimes broadcast in the USA is the station identification code (SID). This is a 48-bit code that is transmitted on line 20, field 1.

Teletext is a general term used to refer to various digital data broadcasting methods developed over the past decade. Incompatible variations on the teletext theme have been standardized in Europe and in North America. Either variety is highly flexible, allowing the transmission of one or many data streams on video lines in the VBI and even extending up to full field teletext where data is transmitted in the video portion of all lines. Teletext in some form in the VBI has become widely used since it becomes part of the video signal, is carried wherever the video reaches and is transported transparently through all of the video equipment and media (although it is often not recorded on VCRs).

In 1988 ANSI/EIA and CSA (Canadian Standards Association) jointly published the *North American Basic Teletext Specification* (NABTS) which specifies the essential technical details for a very robust and flexible high-speed teletext system for use on NTSC signals. NABTS systems have become widely deployed throughout broadcast and CATV systems. It is this system that appears to be most adaptable to KSC's OTV use and will be detailed in the next section of this report.

In Europe teletext standards and systems have generally reached a higher level of development and deployment and been adapted to a wider range of applications than in the USA. *World System Teletext*, WST is the most flexible specification and is widely used to transmit text and graphics. WST can be carried on PAL, SECAM, NTSC and also can be included in MAC systems (either in the VBI or as packet data). In addition, teletext-like automatic VCR programming data is transmitted in Germany as *Video Program System* (VPS) and in the United Kingdom as *Programme Delivery Control* (PDC) codes.

Table 2-1 compares some of the North American and European teletext standards.

Table 2-1 Comparison of Some VBI Data Transmission Standards

Characteristic	Closed Caption	NABTS	WST	VPS/PDC
Data Rate (Mbit/s)	0.00084	5.7273	6.9375	2.5
Data Amplitude	0.5 V	0.7 V	0.46 V	0.5 V
Data Coding	NRZ	NRZ	NRZ	biphase
TV line(s)	21 field 1	VBI or full field	VBI or full field	16 field 1

III

NORTH AMERICAN BASIC TELETEXT SYSTEM

3.1 NABTS

For the application under investigation, NABTS appears to be the most applicable; therefore, this section will present some of the details of this specification. Published as EIA-516, this specification provides the technical description, transmission technique, coding language, and user interface for one-way teletext service applications in North America, As Table 3-1 shows, the first seven chapters of the standards document generally correspond to the seven layers of the open system interconnect (OSI) reference model for data communications.

Table 3-1 Correspondance Between OSI and NABTS

OSI LAYER NAME	NABTS CHAPTER	SPECIFIES
Physical	Data transmission	NTSC physical transmission parameters: timing, bit rate, waveforms, etc.
Data Link	Data Line	structure of 288-bit data line into 24-bit sync sequence, 264-bit data packet
Network	Data Packet	structure of 264-bit (33-byte) data packet into prefix, data block and suffix
Transport	Data Group	structure of data groups (long messages): a series of related data packets
Session	Teletext Record	structure of presentation or application data records
Presentation	Coding of Teletext Record	coding of presentation records (usually 7-bit ASCII)
Application	Application	organizes sets of records (usually into magazines and pages)

For this application, each camera-control message is thought to be short enough to fit in one data line, so that the parameters affecting data transmission of OTV camera-control information are found in the first three chapters of the standards document and will be detailed in the following sections.

3.2 NABTS DATA TRANSMISSION

Data may be transmitted in the video portion of any or all of lines 10 through 21 in the VBI of both fields; thus, the teletext data may use any of the VBI lines not already occupied by VITS, VIR, SID or closed-captioning. Therefore, lines 10 through 16 and 20 are most likely to be used in broadcast applications. In addition, all active lines of both fields of the 525-line NTSC signal may be used when full-field teletext transmission is desired. The transmission data rate is fixed at 5,727,272 bit/s (8/5 times the color sub-carrier frequency). The data are NRZ-coded with nominal amplitudes of 70 IRE for a *1* and 0 IRE for a *0*. The timing and amplitudes of the of the data signal are shown in Figure 3-1.

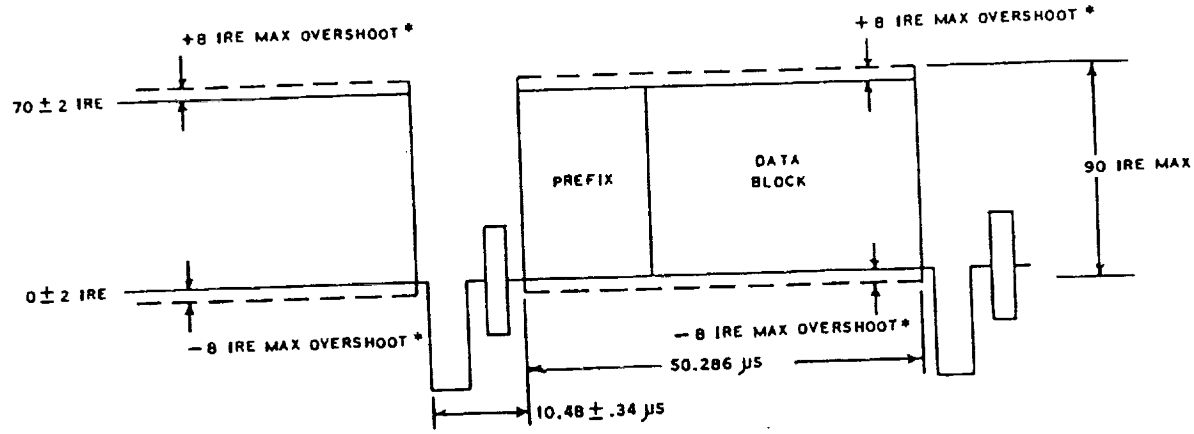

Figure 3-1 NABTS Timing and Amplitudes

3.2.1 NABTS DATA LINE. A teletext *data line* consists of a sequence of 288 bits (36 bytes) which is subdivided into four fields known as the 1) synchronization sequence, 2) prefix, 3) data block and 4) suffix (the suffix may be omitted in some applications). The data line structure is shown in Figure 3-2 and Figure 3-3 shows an example of actual an NABTS transmission.

The synchronization sequence (SS) field consists of a 2-byte clock sync (CS) and a 1-byte framing code (also called the byte-sync, BS). The SS essentially performs the same function as the preamble and start flags that are often used asynchronous LANs. The three remaining fields are known collectively as the *data packet*.

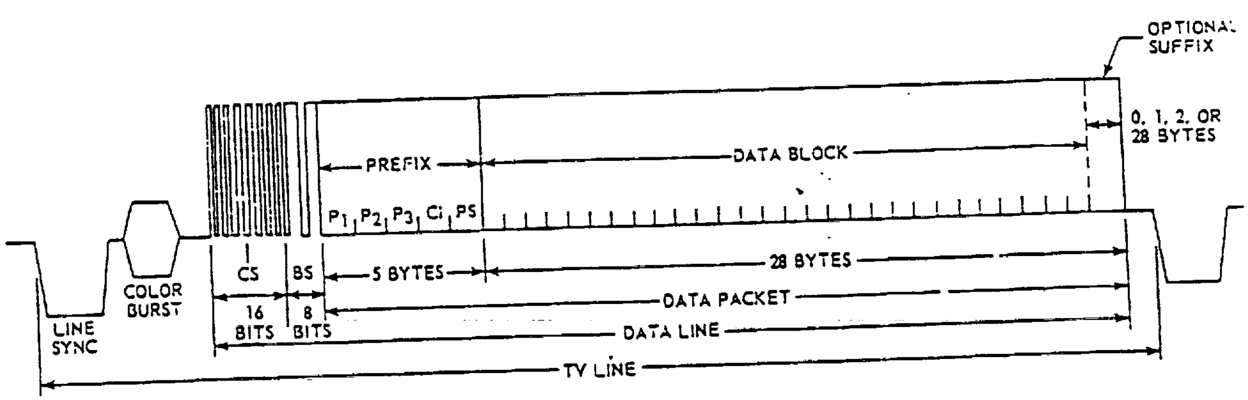

Figure 3-2 NABTS Data Line Structure

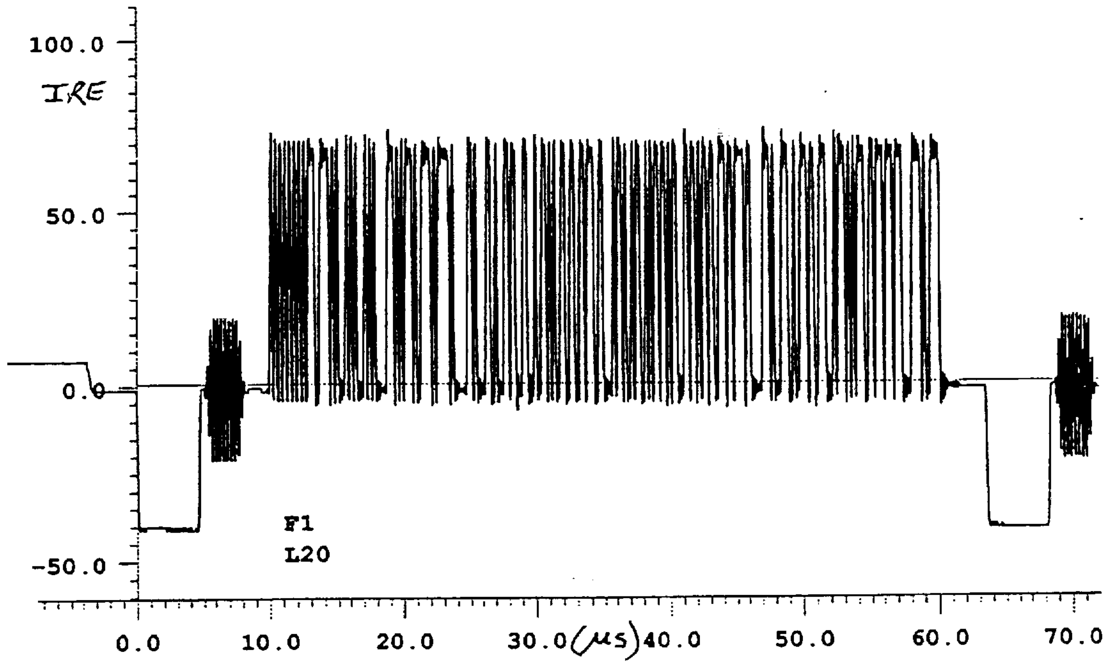

Figure 3-3 Actual NABTS Transmission

3.2.2 NABTS DATA PACKET. The first five bytes of the data packet are reserved for the *prefix*. Each prefix byte is Hamming coded, resulting in 4-bits (1 hex digit) of data and robust error correction capability as shown in Figure 3-4. The first three prefix digits (P1, P2 and P3) combine to form the *data channel* which is essentially similar to a LAN address. Therefore, NABTS supports 4096 distinct data channel addresses (000h - FFFh). The fourth prefix byte is the *continuity index* (CI) which is a modulo-16 sequence number used to detect lost packets in a data channel message stream. The final byte is the *packet structure* byte (PS) which consists of three flags denoting a) if the packet is the first, or *synchronizing*, packet of a multi-packet message (called a *data group*) or a standard packet within a data group, b) if the packet is full of data or not and c) the length of the suffix which can be 0, 1, 2 or 28 bytes.

The *data block* field of the data packet transports the information payload. Depending on the length of the suffix, the data block can carry 28, 27, 26 or 0 bytes per data line. All data-block bytes are transmitted with odd parity. For 26 bytes of payload the resulting data rate is 6240 bit/s/TV line. The payload can consist of upper-layer protocol headers, trailers and information. The suffix, when present, follows the data block and is always positioned at the end of the data line. The suffix is used for error protection of the information payload in the data block or, for a 28-byte suffix, a series of data blocks.

3.2.3 HIGHER LEVEL PROTOCOLS. Much more detail regarding the structure of data groups and the protocols for coding presentation layer records and application layer records are contained in chapters 4 through 7 of the specification document. A related standard document ANSI BSR X3.110 (1983) North American Videotext/Teletext Presentation Level Protocol Syntax (NAPLPS) is used to structure long messages or complex data bases. No further information on these topics is presented in this report since they are not thought to apply to the OTV camera control use addressed in this study.

3.2.4 FORWARD ERROR CONTROL. Since NABTS and other teletext systems are intended to transmit information in only one direction, forward error correction (FEC) is an essential capability since, unlike other data networks, in ordinary teletext applications the destination cannot request retransmission of erroneous information.

As noted above, the basic NABTS specification provides robust error protection for the 5-byte data packet prefix by the use of Hamming codes. This scheme allows forward error correction of all single-bit errors and detection of multiple errors within a prefix byte. In this way, packets with uncorrectable errors in the critical information in the prefix can be recognized and discarded. However, the error protection afforded to the data block by the small (1 or 2 byte) suffix can provide only error detection. In commercial applications, teletext data robustness is often assured by multiple transmissions of the information streams and programming the receiver to respond only after a predetermined number of identical records have been received. Alternative, proprietary, forward-error-control mechanisms are offered by several NABTS equipment vendors and promise to realize virtually error-free transmission. If one-way NABTS transmissions are used in this OTV application, KSC may need to consider some FEC mechanism to ensure data transmission integrity. However, if two-way transmissions (up-stream camera control and down-stream camera-environment telemetry) are used, then it would be possible for the camera to acknowledge correct transmissions. Further work will need to be performed to assess the probability of NABTS data transmission errors in the field OTV systems

ENCODING

INFORMATION BITS

HEXADECIMAL										
INFORMATION NUMBER	HAMMING VALUE	DECIMAL NUMBER	b8	b7	b6	b5	b4	b3	b2	b1
0	15	0	0	0	0	1	0	1	0	1
1	02	1	0	0	0	0	0	0	1	0
2	49	2	0	1	0	0	1	0	0	1
3	5E	3	0	1	0	1	1	1	1	0
4	64	4	0	1	1	0	0	1	0	0
5	73	5	0	1	1	1	0	0	1	1
6	38	6	0	0	1	1	1	0	0	0
7	2F	7	0	0	1	0	1	1	1	1
8	D0	8	1	1	0	1	0	0	0	0
9	C7	9	1	1	0	0	0	1	1	1
A	8C	10	1	0	0	0	1	1	0	0
B	9B	11	1	0	0	1	1	0	1	1
C	A1	12	1	0	1	0	0	0	0	1
D	B6	13	1	0	1	1	0	1	1	0
E	F0	14	1	1	1	1	1	1	0	1
F	EA	15	1	1	1	0	1	0	1	0

PROTECTION BITS

FIRST BINARY ELEMENT TRANSMITTED

Figure 3-4 Hamming Code for NABTS Prefix

IV

VBI TRANSMISSION TESTS

4.1 NABTS DATA TRANSMISSION EQUIPMENT

A NABTS teletext encoder and a decoder were obtained for the purpose of proof-of-concept testing of the VBI transmission of camera-control signals. The encoder is the model UDE400 Universal VBI Data Encoder manufactured by Ultech. A sketch and block diagram of the UDE400 are provided in Figure 4-1

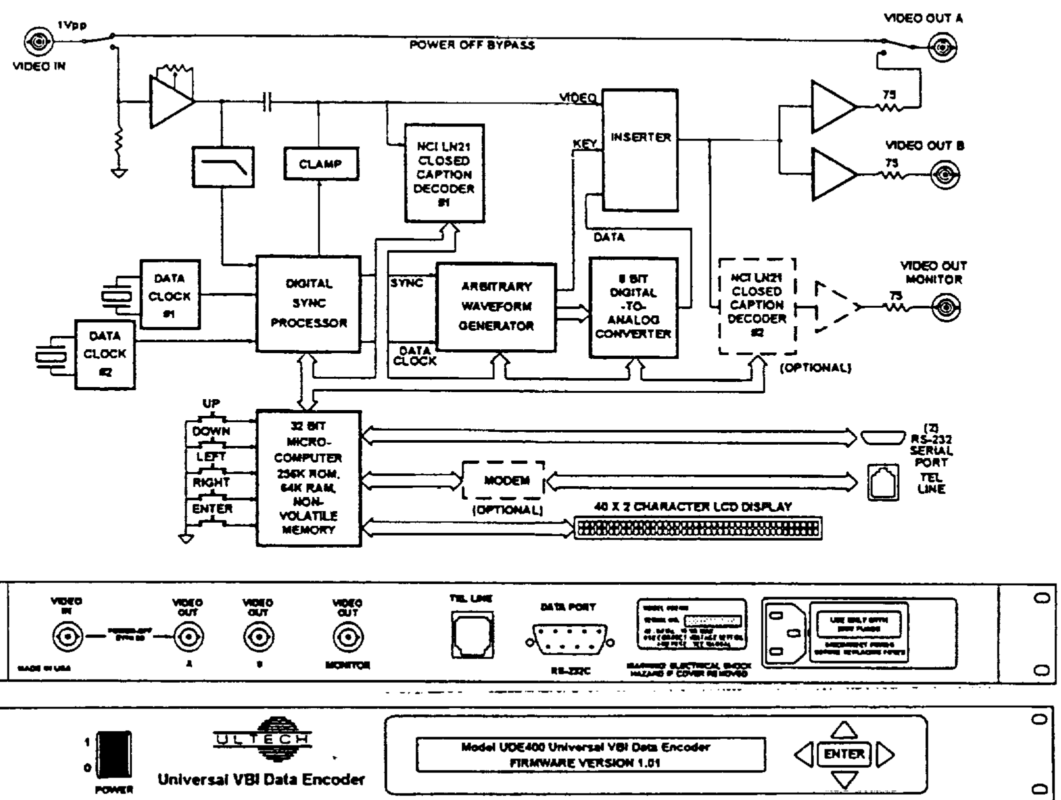

Figure 4-1 Ultech Universal Data Encoder

According to the manufacturer, the UDE400 data encoder is a highly adaptable device. It has the capability of encoding up to 16 unrelated data streams (closed caption, teletext or even arbitrary waveforms) on 16 video lines simultaneously and independently. The device is programmable either from the front panel or by a general purpose personal computer (PC) via its RS232 port, and stores its configuration data in non-volatile memory. Using its powerful internal microprocessor, the device can operate as a stand-alone inserter for one data stream. To utilize 2 to 16 channels, an external PC must be used to input the commands and the data streams. This encoder can also be used to monitor closed caption data on line 21 and to transcode caption data into the teletext format.

The teletext decoder is the model TTX645 NABTS Standard VBI Broadcast Receiver manufactured by Norpak. Front and back views of the device are shown in Figure 4-2.

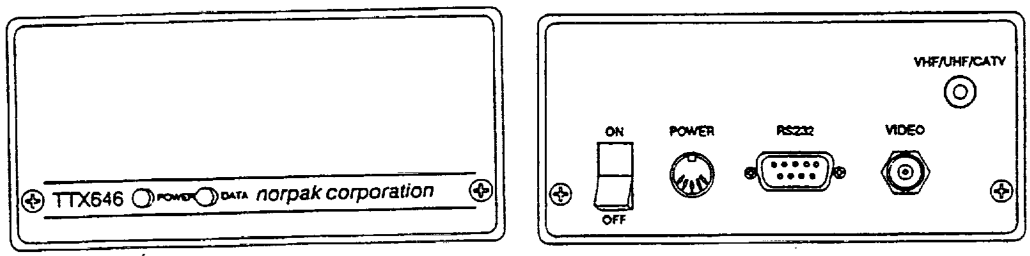

Figure 4-2 Norpak VBI Receiver

According to the manufacturer, the data input to the decoder can be either on baseband video or, by using the device's integral tuner, on an RF-modulated video (off-air or CATV, NTSC or PAL) channel. This receiver/decoder monitors either the VBI or the full field for NABTS data, decodes the data, (optionally) performs forward-error correction on the NABTS data and outputs the information from its RS232 port at bit rates from 50 to 38,400 bit/s. The device is fully programmable via the RS232 connector and stores its configuration information in non-volatile memory.

4.2 NABTS DATA TRANSMISSION TESTS

4.2.1 DATA TRANSPORT. The objective of the first test was to determine that the NABTS encoder and decoder would interoperate and could be used to transport data packets which conform to the NABTS standard. Included with the TTX645 decoder was `SETTTX.EXE`, a program that allowed the use of a PC to configure the decoder. This program did appear to function properly allowing the choice of RS232 port parameters, VBI or full-field data transmission, NABTS data channel number (and two more levels of addressing) and more. The receiver under test could be configured to decode data in one of three modes: 1) process *Alert Records* which are a specialized subset of NABTS complex multipacket records, 2) process NABTS data packets as described in section 3.2.2 of this report and 3) a non-standard *30-byte transparent* mode. All of the tests performed in this study utilized the 30-byte transparent mode which divides the data packet (see Figure 3-2) into a 3-byte Hamming-protected prefix which encodes the data channel number (P1, P2, and P3 bytes), and 30-bytes of transparent (not error-protected) payload. This mode was used due to the fact that the data encoder had been programmed by the manufacturer to utilize this mode exclusively.

Although the UDE400 NABTS encoder is said to be programmable by a PC, this could not be confirmed since neither command protocol information nor interface software were included with the device The encoder was programmed by Ultech to encode data in the 30-byte transparent mode and to transmit 30-byte packets exclusively. Some configuration parameters could be set utilizing the front panel controls. Specifically, the RS232 interface could be set to operate at 9600, 19,200 or 38,400 bit/s, the VBI line utilized for data transmission could be assigned from line 10 to line 21 in both fields. Proper operation at each of these input stream bit-rates was confirmed.

The configuration for the NABTS data transport test is shown in Figure 4-3. The video source used was the Tektronix 1910 Digital Signal Generator. Two PC s were configured as the data source and the data receiver, interfacing with the encoder and decoder through their respective RS232 ports. The encoder and decoder were directly connected using 75-Ω coax. The program TTX_ENC.EXE, included with the Ultech encoder, produced a continuous stream ASCII characters (codes 30-255) for transmission and Procomm's PCPLUS.EXE was used to inspect the decoded data.

It was found that the encoder and decoder would function properly, allowing data transmission at 9600 baud and 19,200 baud (the only data rates accessible using TTX_ENC.EXE). It was confirmed that the UDE400 encoder, as delivered, could place the NABTS data on any one line from line 10 to line 21. No data errors were observed and no bit-error ratio test was performed since the encoder was originally programmed not to transmit any symbol below ASCII 30.

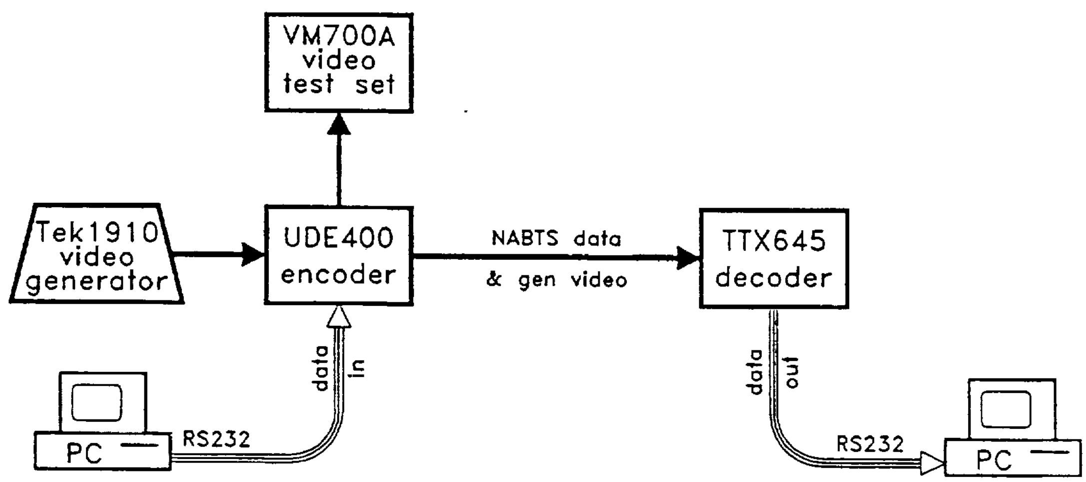

Figure 4-3 VBI Data Transmission Tests

4.2.2 VIDEO IMPAIRMENT TEST. The objective of this test was to measure the degree of video transmission impairment that was due to the insertion and use of the UDE400 VBI data encoder. The test setup was identical to the previous test (Figure 4-3). Video transmission quality was measured utilizing the Tektronix VM-700A Video Measurement Set.

As Table 4-1 summarizes, the insertion of the UDE400 produced no significant quality degradations in the video whether the unit was in bypass mode or was transmitting only the synchronization sequence or inserting data (data inputs at both 9600 and 19,200 baud were tested). Although no test condition violated any preset short-haul limit, there was a noticeable change in the VIRS Chroma Phase and the Relative Burst Phase.

Table 4-1 Video Performance of the UDE400 Encoder

Video Parameter	Encoder Mode: in bypass state	sync sequence alone	9600 baud input	19200 baud input
S/N weighted	81.6 dB	81.2 dB	79.8 dB	82.1 dB
Differential Gain	0.71 %	0.79 %	0.79 %	0.77 %
Differential Phase	0.14°	0.14°	0.13°	0.13°
K-factor distortion	0.2 %	0.2 %	0.2 %	0.2 %
Line time distortion	0.1 %	0.2 %	0.2 %	0.2 %
VIRS chroma phase	-0.3°	-3.0°	-3.0°	-3.0°
Relative burst phase	0.10°	3.25°	3.20°	3.18°

4.2.3 FIBEROPTIC VBI DATA TRANSMISSION TEST. The objective for this test was to affirm that there were no unforeseen problems that would prevent the transmission of VBI data by the OTV wideband fiberoptic transmission equipment now being installed at KSC.

As Figure 4-4 shows, for this test a 1300-nm LED-based 5000TX and a 5000RX wideband fiberoptic video transmission system, similar to those being installed at pads 39A and 39B for OTV transmission, was inserted between the VBI data encoder and decoder. Ten meters of multimode fiberoptic patch cord with wavelength division multiplexer (WDM) at each end was used to interconnect the 5000TX and 5000RX.

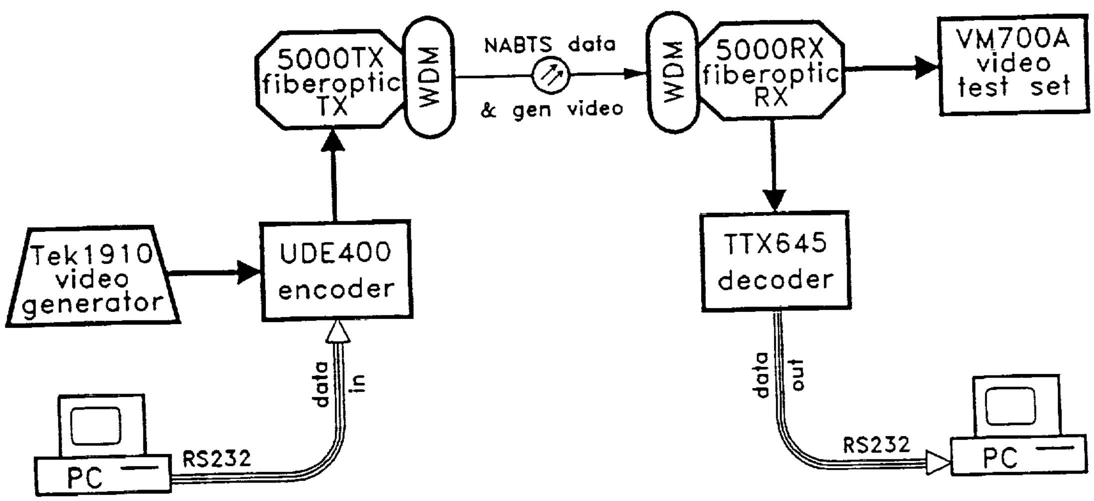

Figure 4-4 Fiberoptic VBI Data Transmission Test

The video performance parameters were measured after passing through the wideband fiberoptic transmission system. Table 4-2 shows the results for these tests with the encoder in one of two states: 1) bypassed and 2) transmitting data continuously using a 9600 baud input. The received data were inspected and no obvious errors were observed; however, no BER test was performed.

Table 4-2 Video Performance of the UDE400 Encoder and Wideband Fiberoptic Transmission System

Video Parameter	Encoder bypassed	Mode 9600 baud input
S/N weighted	69.5 dB	69.0 dB
Differential Gain	1.29 %	1.08 %
Differential Phase	0.18°	0.13°
K-factor distortion	0.9 %	0.9 %
Line time distortion	9.8 %	8.6 %
VIRS chroma phase	-0.2°	-2.9°
Relative burst phase	0.05°	3.02°

4.3 CAMERA COMMAND TRANSMISSION TESTS.

For these tests the objective was to verify that the NABTS encoder and decoder under study can be used to remotely control a video camera. The NABTS encoder and decoder previously tested were used, set for 9600 baud RS232 I/O and operating on line 20 of both fields. Tektronix TSG100 Television Signal Generator was utilized as the video source. The camera to be controlled was an Ikegami HC240 Compact Color Camera. This camera was connected to a matching Ikegami RCU240 Remote Control Unit. The RCU240 performs two functions important to these tests. First, the RCU240 has a standard RS232 port which is meant to accept control commands from a PC and second it translates the control commands to TTL levels which the camera requires. An Ikegami TM10-9 Color Monitor was used to observe the camera output.

A LabVIEW virtual instrument software module, `IKI_SET.VI` was written to control the shutter speed, the gain, the iris and to turn the camera's color bars on/off. Since 30-byte data packets were required for transmission by the NABTS encoder under test, the camera commands were concatenated and padded to 30-bytes.

All equipment for these tests was located in the Fiberoptics and Communication Laboratory (EDL room 198).

4.3.1 CAMERA CONTROL VIA NABTS. The objective of the first test was to verify that the Ikegami camera could be controlled by commands delivered by the NABTS equipment. The encoder and decoder were directly connected using 75-Ω coax as shown in Figure 4-5.

One handshaking problem between the TTX645 decoder and the RCU240 camera controller was noticed. The RCU240 toggles the DTR pin as data is received but the TTX645 enters a reset state when DTR goes low. In order for the TTX645 to function properly, the DTR line must be held high (<3V).

The Ikegami camera's control protocols required that ASCII 10 (line feed) and 13 (carriage return) terminate all commands. Since the original PROM in the Ultech encoder was programmed not to send any ASCII codes below 30 , the encoder in its original state could not be send camera commands. Therefore, a second PROM was obtained from the manufacturer that excluded only ASCII codes 1, 17 and 19 from encoding, and this PROM was used for the remaining tests.

After the handshake and PROM problems were rectified, it was observed that the camera's shutter, gain, iris and color bars could be controlled over the NABTS link.

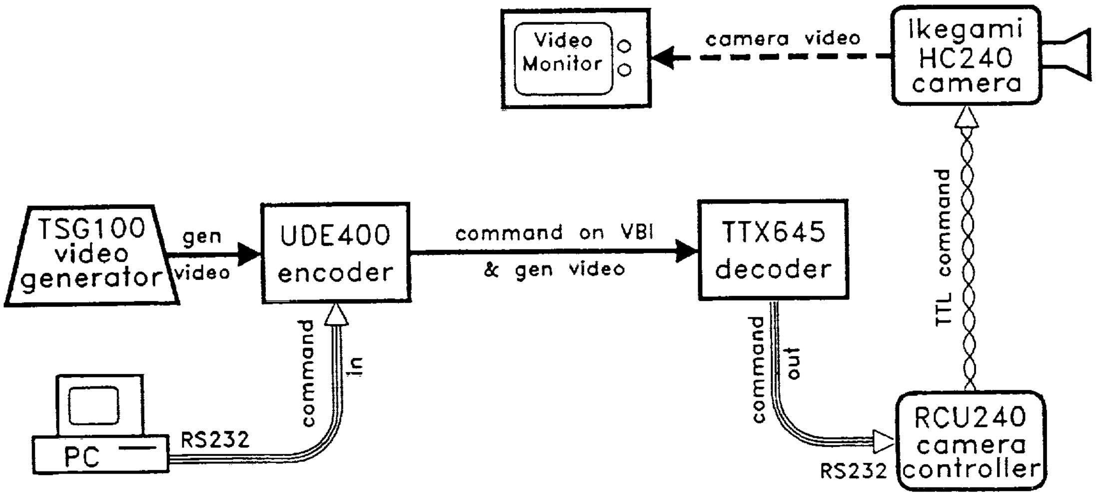

Figure 4-5 Camera Control via NABTS

4.3.2 CAMERA CONTROL ACROSS A FIBEROPTIC LINK. The objective for this test was to determine if the Ikegami camera could be controlled by commands transmitted by VBI data over an OTV wideband fiberoptic link. As Figure 4-6 shows, a 1300-nm LED-based 5000TX and a 5000RX were inserted between the NABTS encoder and decoder. The optical signals were transmitted through a 18.2-km multimode fiber test loop from the from the Fiberoptic Lab through the CDSC to the VABR and return.

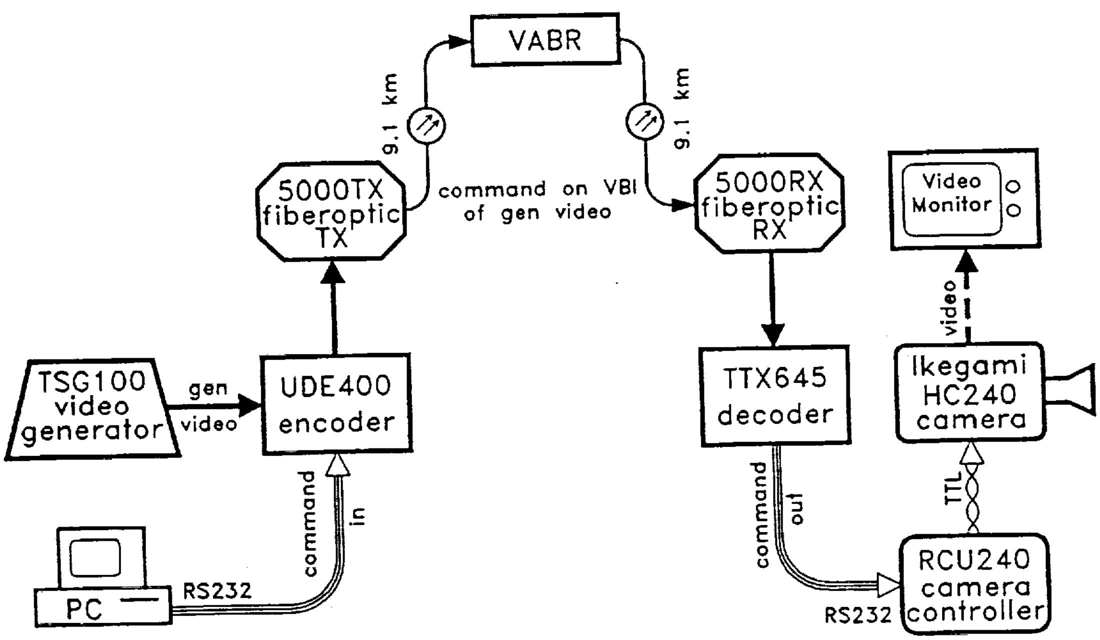

Figure 4-6 Camera Control Across a Fiberoptic Link

It was observed that the camera's shutter, gain, iris and colors bars could be remotely controlled using data transmitted more than 18 km using the OTV fiberoptic equipment.

4.3.3 CAMERA CONTROL AND VIDEO TRANSMISSION USING WDM. The final test in this series required the use of a bidirectional fiberoptic transmission path simulating the OTV WDM wideband fiberoptic links being phased-in at KSC. A 1550-nm LED 5000TX, a second 5000RX and two wavelength division multiplexers (WDMs) were added to allow bidirectional fiberoptic transmission. As Figure 4-7 shows, camera control commands on the VBI of generator video were transmitted using 1550-nm radiation in one direction and camera video was returned at 1300-nm over the same fiber path.

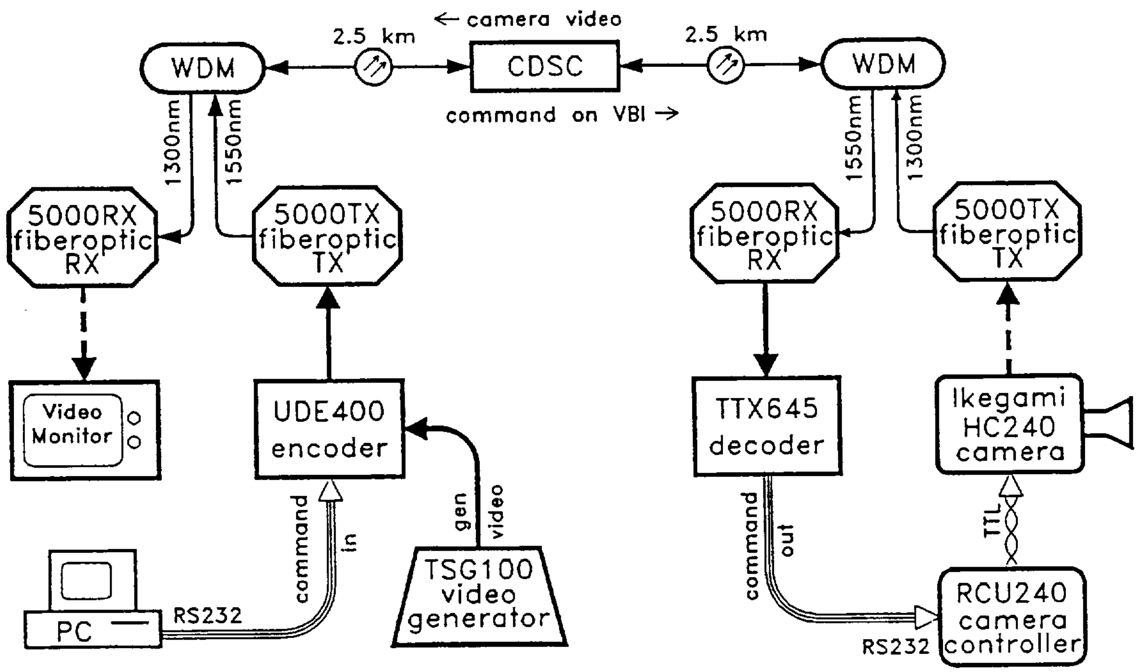

Figure 4-7 Camera Control and Video Transmission Using WDM

At first, an attempt was made to utilize the EDL↔VABR test loops. It was found that the additional loss due to the WDM and additional connectors did not allow that distance. However, it was possible to transmit camera control commands and camera video across the 5.0-km EDL↔CDSC test loops.

V

CONCLUSION

5.1 SUMMARY OF RESULTS

The NABTS encoder and decoder were able to transmit NABTS data with no observable errors at I/O rates of 9600 and 19200 baud. The encoder under test did not cause meaningful degradation of the video signals that were passed through for encoding. The OTV wideband fiberoptic transmission systems were capable of delivering the NABTS encoded video without difficulty, no unusual interactions were found between the OTV wideband system and the encoder or decoder.

Finally, it was demonstrated that an Ikegami video camera could be controlled using commands delivered at 9600 baud in the VBI of a genlock-like signal and that the OTV WDM wideband fiberoptic equipment could be used to transport the camera control commands through the multimode fiber installed at KSC.

5.2 CONCLUDING COMMENTS

These studies demonstrated that camera control using commands transported in the VBI is feasible using commercially available equipment. It seems reasonable to assume that pan and tilt control could also be realized using this method. A logical next step would be to perform a bit-error ratio test on a system that simulates the LCC to pad environment.

If it remains a goal to return camera environment telemetry data in the VBI of the camera video then a redesign of the NABTS encoder is necessary. The commercial unit used in these tests has many more capabilities than are required for this use and, as currently packaged, is not suitable for deployment at the cameras. Also note that the encoder has a closed-caption (a different format from NABTS) receiver already on broad. It seems reasonable to suppose that a NABTS encoder/decoder module with only the limited functions necessary OTV command and telemetry could be economically designed based upon the commercial Ultech encoder.

APPENDIX A

STRUCTURE OF THE VERTICAL BLANKING INTERVAL