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(A)

MIXED VIDEO/DATA NETWORK USING CATV TECHNIQUES*

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Introduction

SLAC is undertaking an Accelerator improvement program using a new injector and the first 300 feet of the accelerator. Very short, high current beams are being injected and will be accelerated in the front end of the machine. This requires an upgrade of the existing control and monitoring system in that area. We are installing a new data/video system to control and monitor this new injector and the additional beam line magnetic elements, beam monitoring and other associated equipment. The computers which will be used for these tests, are 2.5 miles to the east. The local control room which is adjacent to the new injector, will have touch panels and remote terminals which interface to the existing MCC PDP11/34 computer system and to the PEP PDP11/780 VAX computer. We have decided to use a Frequency Division Multiplexed CATV system in order to provide the video/data communications required for these tests.

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System Implementation

The new control area has two touch panels (computer generated displays overlaid by cross-wire controls), a plotter video channel and three remote 9600 baud terminals to communicate with the VAX. The injector and first sector (300 feet) of the linac will have five CAMAC crates to provide the new control and monitoring facilities. Each CAMAC crate has a 6800 microprocessor system to interface the control and monitoring modules with the 1 Mbps CATV Modems. This system communicates with the VAX computer. In addition, the CATV system carries eight additional 6 MHz video channels for transmitting camera and computer generated video signals for general purpose monitoring in the Klystron Gallery and between the Klystron Gallery, the control area and the Control buildings which contain the PDP11/34 and PDP11/780 systems.

The CATV system utilizes mid-split frequency amplifiers with west-bound signals being sent in the frequency range of 5 to 110 MHz and east-bound signals transmitted in the frequency range of 170 to 300 MHz (see Fig. 1). The mid-split system provides roughly equal spectrum space above and below the split (110 to 170 MHz) with only a slight inconvenience in that TV video channels 2-6 are constrained to go west-bound and channels 7-13 constrained to go east-bound. The cable is configured as a Frequency Division Multiplex system where dedicated channels are assigned to transmit a certain video or data signal from one location to another, i.e., this is a multidrop system with an assigned routing for each information channel as opposed to a Time-Division Multiple access system which will permit information to be routed dynamically between drops. This latter system will be required when the remainder of the accelerator is modified. The TDMA mode will make it possible to establish efficient local control loops. The present multidrop system provides ingress and egress to the "cable" at PEP Control, Main Control, Sector 10, Sector 9, Sector 1, Sector 0 and in the new Control Room adjacent to the new injector (see Fig. 1).

Three modem systems were used to implement this information system. Video is sent and received using CATV modulators and demodulators. A block diagram of these units is shown in Fig. 2. The 9600 baud data is sent and received by a FSK Modulator-Demodulator system. This block diagram is shown in Fig. 3. The 1 Mbps data system block diagram is shown in Fig. 4. We chose a Video Modulator-Demodulator to interface high speed data to the cable. This FM Video system had been originally designed to be used on a dedicated cable and required 14 MHz bandwidth to send a high quality video signal. We reduced the bandwidth to 7 MHz and can successfully pass a 300 ns pulse with acceptable rise-time.

Our 1 Mbps system uses a pulse duration modulation scheme with pulse lengths of 300 ns ("0") and 700 ns ("1"). The effective speed of transmission using a 300 ns pulse is about 4.5 Mbps. We have written checkout and maintenance software for the 1 Mbps system which runs on the VAX computer. The software sends out a message to a CAMAC crate and looks for a response. It tabulates outgoing errors, incoming errors and time-out errors (generated by lack of CAMAC response). The remote terminals, of course, allow us to run these tests from either end of the cable system.

Determination of the carrier spacing and the channel spacing of the 9600 baud modems has been a problem. In fact, the operational date of the system was late because of incorrect spacing. We initially spaced the two FSK carriers at 30 kHz (based on the best available information and a bit rate of 9600). This was later widened to 100 kHz spacing giving an effective modulation index of 10. Channel to channel spacing of 200 kHz also proved to be too close (as evidenced by crosstalk). The spacing was later widened to about 500 kHz. We devised a method to measure proper spacing which involved the spectrum of the modulator and the acceptance bandwidth of the demodulator. We found that our sweep generator could be FM modulated by a 5 kHz square wave and that the spectrum produced was sufficiently representative of our FSK system modulated by a 5 kHz square wave. Since the modulated generator could be moved toward the adjacent channel's demodulator, a measure of receiver acceptance could be obtained where crosstalk just started. We could also adjust modulated generator amplitude and a family of amplitude vs frequency curves could be determined for each receiver. As extra insurance, we also decided to sharpen the bandpass of the demodulators with a ceramic filter in the IF stage.

System levels were set to various levels but the most satisfactory, i.e., the least intermodulation distortion was obtained using the recommended input/output specifications of the trunk amplifiers. This also produced the best signal to noise ratio in the system. We operate the system so a +5 dBmV level is delivered to all demodulators and that all modulators provide about +40 dBmV to their input taps. In our system, the data demodulators will receive signals at -10 dBmV. Their levels were finally adjusted to between 0 and +5 dBmV.

The system has been designed with adequate trunk gain so that extra taps can be added at a later date. The trunk gain will have to be readjusted but this should be accomplished rather quickly. The spectrum plan is shown in Fig. 5.

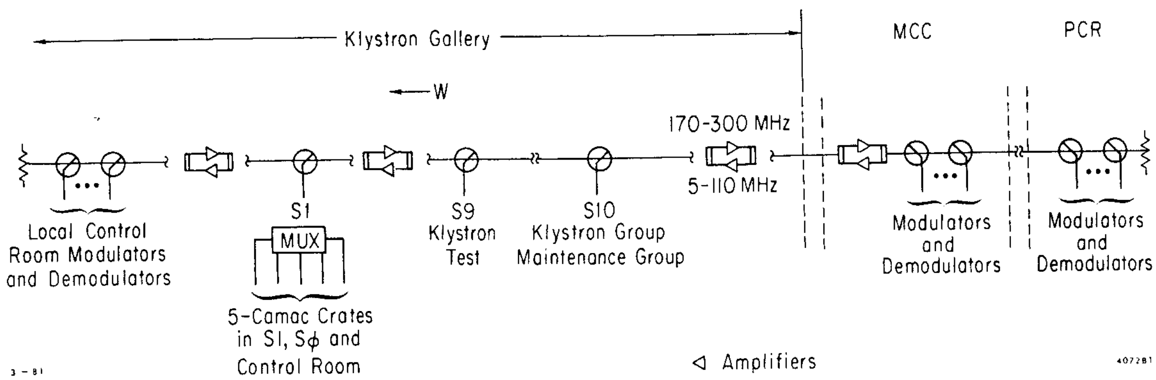
Operational Experience

The CATV system has been up since late January 1981, and the reliability has been very good. One 1 Mbps demodulator had to be retuned. The modulator frequency is not controlled and some drift probably occurred. The 7 MHz bandwidth for our 1 Mbps seems adequate, the error rate is less than 1 bit in 10^8. It is probably much higher (we have not had the computer time to measure it). In general, the system is either go or no-go. When something happens, it is immediately obvious and repair can be initiated.

This system proves the original premise that you can mix video, high speed data and low speed data on a bi-directional cable system if you pay particular attention to system levels and to channel spacing.

Acknowledgements

I wish to thank Bill Pioske for much of the development, installation and tune-up of the system. Bob Melen and Ken Crook provided support and much needed information as the project progressed.



Klystron Gallery
MCC
PCR
W
170-300 MHz
5-110 MHz
Local Control Room Modulators and Demodulators
S1
MUX
5-Camac Crates in S1, Sϕ and Control Room
S9 Klystron Test
S10 Klystron Group Maintenance Group
Modulators and Demodulators
Modulators and Demodulators
Amplifiers
3-81
4072B1

Fig. 1

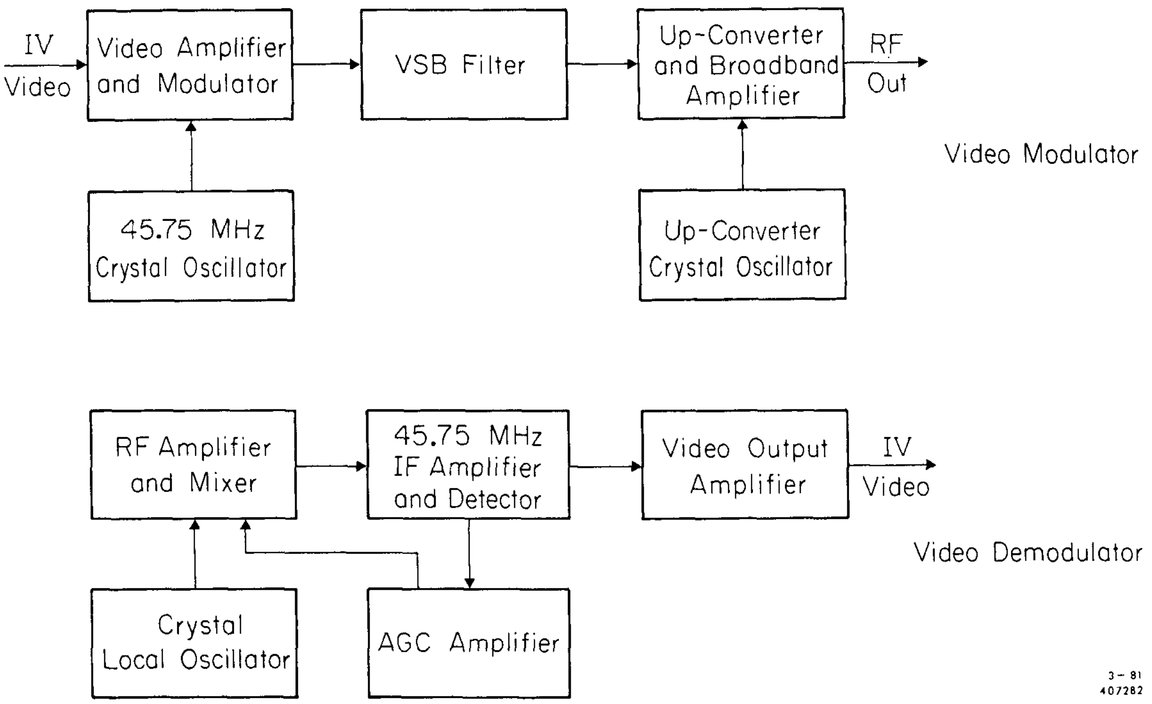

IV
Video
Video Amplifier and Modulator
VSB Filter
Up-Converter and Broadband Amplifier
RF
Out
Video Modulator
45.75 MHz Crystal Oscillator
Up-Converter Crystal Oscillator
RF Amplifier and Mixer
45.75 MHz IF Amplifier and Detector
Video Output Amplifier
IV
Video
Video Demodulator
Crystal Local Oscillator
AGC Amplifier
3-81
407282

Fig. 2

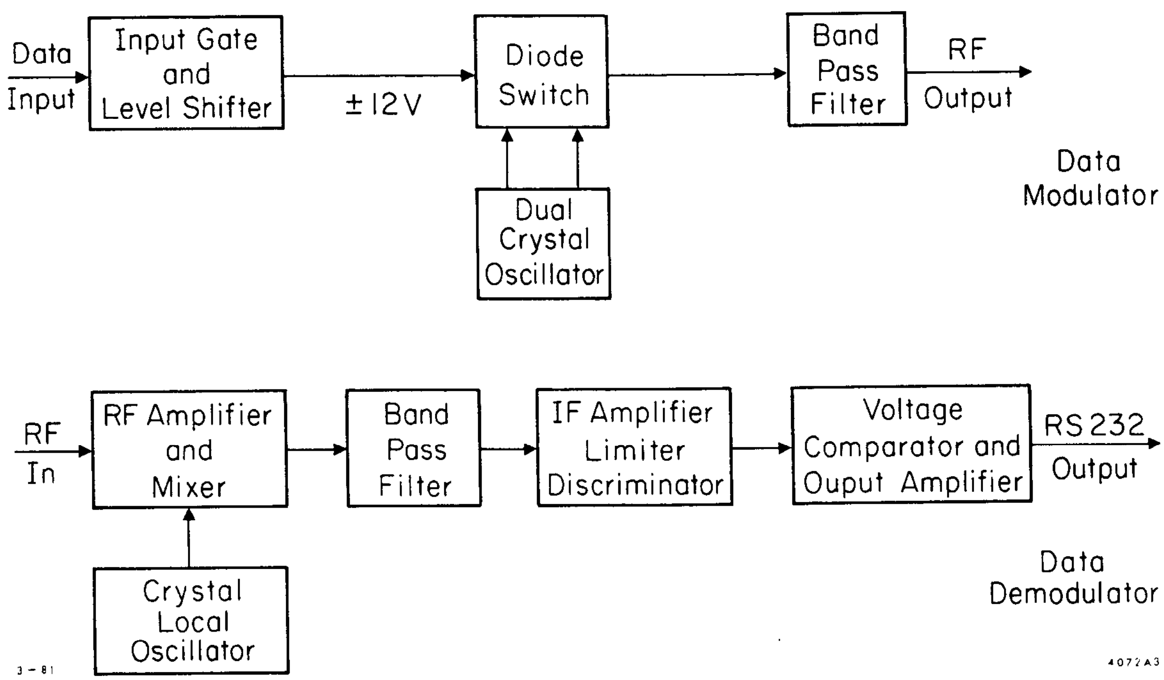

Data
Input
Input Gate
and
Level Shifter
±12V
Diode
Switch
Band
Pass
Filter
RF
Output
Dual
Crystal
Oscillator
Data
Modulator
RF
In
RF Amplifier
and
Mixer
Band
Pass
Filter
IF Amplifier
Limiter
Discriminator
Voltage
Comparator and
Ouput Amplifier
RS 232
Output
Crystal
Local
Oscillator
Data
Demodulator
3-81
4072A3

Fig. 3

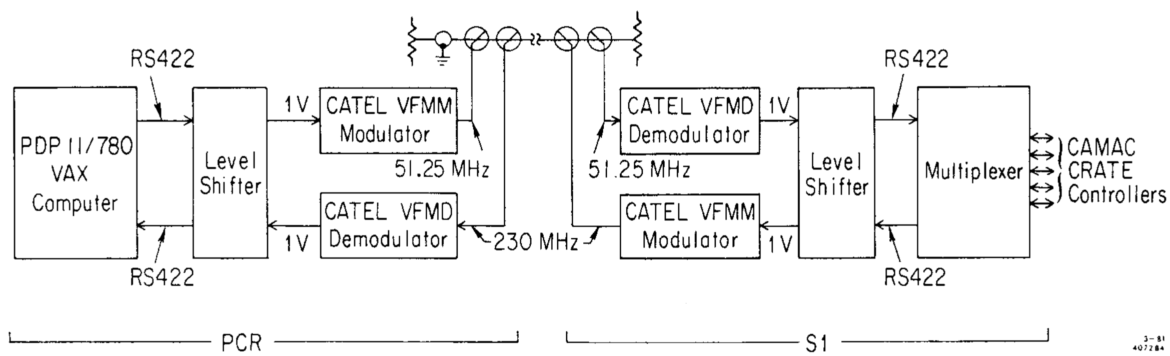

RS422
PDP 11/780
VAX
Computer
Level
Shifter
1 V
CATEL VFMM
Modulator
51.25 MHz
CATEL VFMD
Demodulator
1 V
RS422
230 MHz
CATEL VFMD
Demodulator
1V
51.25 MHz
CATEL VFMM
Modulator
1 V
Level
Shifter
RS422
Multiplexer
CAMAC
CRATE
Controllers
RS422
PCR
S1

Fig. 4

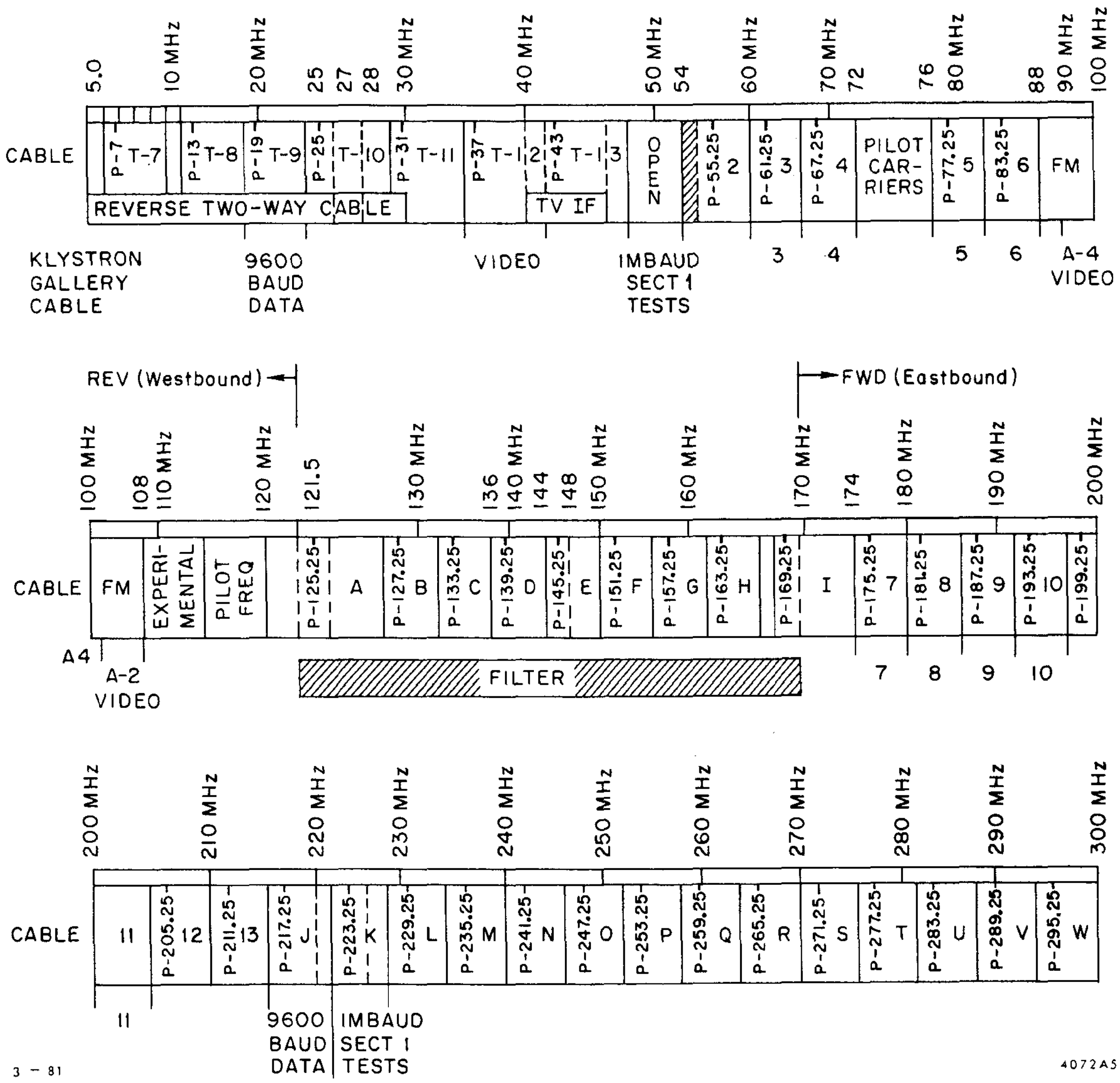

5.0
10 MHz
20 MHz
25
27
28
30 MHz
40 MHz
50 MHz
54
60 MHz
70 MHz
72
76
80 MHz
88
90 MHz
100 MHz
CABLE
P-7 T-7
P-13 T-8
P-19 T-9
P-25 T-10
P-31 T-11
P-37 T-12
P-43 T-13
DOMEZ
P-55.25 2
P-61.25 3
P-67.25 4
PILOT CARRIERS
P-77.25 5
P-83.25 6
FM
REVERSE TWO-WAY CABLE
TV IF
KLYSTRON GALLERY CABLE
9600 BAUD DATA
VIDEO
IMBAUD SECT 1 TESTS
3
4
5
6
A-4 VIDEO
REV (Westbound)
FWD (Eastbound)
100 MHz
108
110 MHz
120 MHz
121.5
130 MHz
136
140 MHz
144
148
150 MHz
160 MHz
170 MHz
174
180 MHz
190 MHz
200 MHz
CABLE
FM
EXPERIMENTAL
PILOT FREQ
P-125.25 A
P-127.25 B
P-133.25 C
P-139.25 D
P-145.25 E
P-151.25 F
P-157.25 G
P-163.25 H
P-169.25 I
P-175.25 7
P-181.25 8
P-187.25 9
P-193.25 10
P-199.25
A4
A-2 VIDEO
FILTER
7
8
9
10
200 MHz
210 MHz
220 MHz
230 MHz
240 MHz
250 MHz
260 MHz
270 MHz
280 MHz
290 MHz
300 MHz
CABLE
11
P-205.25 12
P-211.25 13
P-217.25 J
P-223.25 K
P-229.25 L
P-235.25 M
P-241.25 N
P-247.25 O
P-253.25 P
P-259.25 Q
P-265.25 R
P-271.25 S
P-277.25 T
P-283.25 U
P-289.25 V
P-295.25 W
11
9600 BAUD DATA
IMBAUD SECT 1 TESTS
3 – 81
4072A5

Fig. 5