LIGO-T890065-00-R

#79

List of 5/01/89

FILE:INTERCON.TEX

TO: W.Althouse

FROM:R.W. (April 20, 1989)

CONCERNING: LIGO requirements for intrasite communication and data links

FUNCTIONS OF DATA AND COMMUNICATION LINKS

The document is concerned with data and communication links between buildings within a LIGO site. The communication and data links between sites and between sites and home laboratories are discussed in section XX. The data and communication links serve several functions.

1) Send housekeeping signals to the vertex building to monitor the state of the facilities: state of valves, state of entries into buildings, state of the HVAC system etc. These are simple one bit signals associated with 16 bit addresses to indicate their location but with a data rate less than one word per second.

2) Send instrumentation housekeeping signals to the vertex building to monitor low data rate environmental variables: temperture, barometric pressure, average power dissipation from the mains distribution, average residual gas pressure of different molecular constituents at different points in the vacuum system, ion currents in the ion pumps etc. These are low data rate signals, a data word per second or less, but with large dynamic range, 16 bit words, to monitor small changes.

3) Send facility state changing control signals from the vertex building to other locations: open valve, turn heater on, etc. The information has 16 bit addresses but with a data rate less than one word per second.

4) Send high bandwidth, 1Kword/sec, environmental monitoring signals to the vertex building on command for diagnostic studies (Remote oscilloscope mode). Examples are: accelerometer signals, acoustic pressure variations, fluctuations in local magnetic field etc.

5) Send (receiver) interferometer signals to the vertex building. A two mode system is envisaged. One mode has low bandwidth, 1 word/sec, large dynamic range, 16 bits/word, to monitor the average state of mass damping loops, pointing loops and transmitted laser power, the other mode has large bandwidth, 1Kword/sec and large dynamic range on commanded interferometer variables,the remote oscilloscope mode.

6) Send interferometer servo control signals from the vertex building to the remote masses. In all of the Fabry - Perot interferometer servo systems presently envisaged, it will be necessary to servo control the position of the remote masses from optical signals developed in the vertex building to acquire and control cavity lock. The bandwidth of these control loops is limited by the transit time from the vertex building to the remote mass. The propagation delay time is $20\mu sec$ for a 4 km path in either optical or coaxial cable. In order to obtain maximum permitted servo loop gain, the data link for the control signals should have a minimum bandwidth of 50K words/second per interferometer with a dynamic range of 90db (16 bit word). This application of the data links places the most severe demands on them, a dedicated line per interferometer is recommended for this purpose.

7) Send commands from the vertex building to the local interferometer control systems to set gains and servo filter characteristics, a low bandwidth function using 16 bit addresses.

8) Send signals from the vertex building to graphics terminals at remote locations with the display information available at the vertex building. The utility of this became apparent on a visit to Fermi lab where it is possible, at any location in the laboratory, to monitor the state of the accelerator. The operator page displays are available to all users of the facility. The capability should help to speed up diagnostics during interferometer installation and debugging.

9) Send/receive voice signals between vertex building and other fixed locations on the site, an internal intercom system; 8 bit words at 3kwords/sec suffice for a single channel.

10) A luxury, but it may be advantageous to have a computer link to the archives from remote locations outside of the vertex building to facilitate diagnosis from a remote location.

REQUIREMENTS

1) All instrumentation,data and communication links will be digital except those special wideband width ($\Delta B > 1MHz$) analog links used in:

a) impressing RF subcarriers on the laser light,

b) frequency and amplitude stabilization servo loops of the lasers

c) photodetector signals with RF carriers.

The wideband analog links are expected to be restricted to the vertex building.

2) The requirements on the digital links are:

a) Maximum dynamic range 90db (16bit data words)

The quantization noise limits the dynamic range as

$$V_{rms} = \frac{\cdot\ \Delta V_{LSB}}{\sqrt{6}(f_{sample}t_{int})^{1/2}}$$

so that with 16 bit words and a 10kHz sampling rate, the amplitude signal to noise is 144db at an integration time of 1 second.

b) Estimated data rates are: (this needs more thinking)

Function	bits/sec	number/int.	number of int.	total bits/sec
cavity and fringe control	800K	1	6 (site 1)	4.8M
cavity and fringe control	800K	1	3 (site 2)	2.4M
mass monitors	6X16K	2	6 (site 1)	1.2M
mass monitors	6X16K	2	3 (site 2)	560K
pointing monitors	3X16K	1	6 (site 1)	288K
pointing monitors	3X16K	1	3 (site 2)	144K
oscilloscope mode	3X160K	intermittent, duty cycle 1/10		48K
facility housekeeping	10K			10K
facility commands	10K			10K
voice link	24K			24K
computer link	20K			20K
TOTAL (site 1)				6.4M (no continge
TOTAL (site 2)				3.2M (no continge

Recommend a factor of 3 contingency even after a proper count is made of the anticipated signals.

POSSIBLE IMPLEMENTATION AND SOME COSTS

The state of the art in April 1989 includes coaxial lines, microwave links and optical fiber links. The clear choice, considering the high reliability requirements, data rates, the potential problems associated with large baseline ground currents, (and weighted by the costs), are optical fiber links. At present two types of systems are available. The first uses LED light sources and multimode fibers at 1.3 microns. The fibers have a loss of 3db/km. The system reliability and bandwith is maintained with an 18 to 20db loss in transmission, so that repeaters will not be necessary in a 4km link. A single multimode fiber receiver/transmitter combination is used at 20Mbits/sec. Half of the data rate is used up in housekeeping- timing signals and periodic checks of the line-in an interleaved format with the data, the so called Manchester encoding. A useful rule of thumb to estimate fiber installation costs is $0.5/cabled meter of fiber. A typical cost of a 8 fiber system with multiplexer and demultiplexer, transmit modulator, receive signal electronics and 4 km cabled fibers is $42K. The system includes a microcomputer for decommutation and housekeeping and spares to maintain system continuity.

The second type of system uses single mode fibers and laser diode light sources at 1.3 microns. The advantage of these systems is the reduced dispersion in the fiber which will allow data rates of 550Mbits/sec. The electronics uses ECL logic. The laser diodes are more expensive than the LEDs and the fiber connectors are more difficult to install. A crude estimate is that this system is 3 times more expensive, at present, than the multimode system. Clearly the data rate per link is greater than the factor of 3 but to arrive at a reasoned choice; a detailed trade off study of reliability vs cost of single mode systems vs multiple multimode systems will be needed to make a decision.

See note: Data on fiber optical links April 4,1989.

FILE:fiberoptcom.tex

FROM: R.Weiss (April 4,1989)

TO: W. Althouse

CONCERNING: Data on fiber optical links

People talked to:

ATT Framingham Mass 508-626-2161

Dan Yasi ext 3726 Account Manager

Pat Mosher ext 3702 Technical

Typical interaction with ATT, no one person knows enough. Receiver/transmitter pairs ODL 50 $600 good for 1km in 20Mbit/sec link using multimode fiber. ODL 200 $1K good for 4 km in 20Mbit/sec link with multimode fibers. No information on complete systems and none on what are called passive components, the fibers and couplers.

FOCS, 15 Midstate Drive, Auburn Mass,01501. 508-832-6208

Ken Coons

Use multimode fibers with LED drivers and avalanche photodetectors at 1.3 micron. Allow for 20 db loss before repeaters are needed. Good multimode fiber should have 3db/km. Single fiber system should give 20Mbits/sec. Multiplexer made with 8 channels to drive and receive. Signals are Manchester encoded- data word interleaved with timing word. Cost of a system consisting of a fiber cable 4 km long including 8 fibers. Fiber $16K, multiplexers receive and send $24K, test of system $2K. Total system cost $42K. System includes microprocessor to maintain system and spare receivers and transmitters on the link to maintain continuity if components fail.

If broader bandwidth is needed, the industrial state of the art is 550Mbits/sec. These systems use laser diodes at 1.3 microns and single mode fibers in the optics and ECL in the electronics. More costly by a factor of 10 but one could pull deals where the factor is only 3.

TRELLIS Salem New Hampshire 603-898-3434

Allen Kasiewicz. Company does not manufacture components but installs and tests optical links. Has done this for Lincoln Lab between buildings and remote installations.

100Mbit/sec systems use LED transmitters and avalanche diode detectors at 1.3 microns. Systems easily sustain 18 db loss without repeaters. Typical good multimode fibers have 3 db loss/km. Uses rule of thumb of $0.5/cabled meter of fiber. Estimate $15K/end for multiplexers and $9K per transmiter-receiver pair. Claims state of the art is system with 565Mbits/sec using laser and single mode fiber. Single mode fiber costs $0.4/cabled meter of fiber but laser is more expensive than LED by $5-10K if coolers and power supplies are included. Installation costs typically $1/ft if trenched specifically for the optical link and 1 man day per end which costs $500 per man day.