A GENERAL PURPOSE FIBER OPTIC LINK WITH RADIATION RESISTANCE*

Edward R. Beadle
AGS Department, Brookhaven National Laboratory
Upton, New York 11973-5000 USA

Abstract

A general purpose analog fiber optic link transmitting a 2 Vp-p input over a passband of .05 Hz to over 25 MHz with a > 50 db dynamic range and < 1 % THD has been developed using previously identified and high volume commercially available radiation resistant components. With few component changes the passband can be extended to over 50 MHz. The basic design, trade-offs, and performance characteristics are presented.

I. INTRODUCTION

In some applications it is necessary to send wide-band analog data, with good fidelity, between two stations separated by several hundred feet. This is particularly true for instrumentation in an accelerator environment, where the sensing equipment can be inside the tunnel, and the processing equipment outside. Aside from the distortion and loss introduced by low cost coaxial cables, this case is further complicated by the possibility of pick-up from environmental noise, and the possible radiation damage of the transmitting electronics. Fiber optics is be a viable alterative to the standard coaxial driver, particularly where video bandwidths are concerned. This paper discusses basic design, trade-offs, and performance of one such link developed primarily for the AGS-to-RHIC (ATR) Transfer line profile monitors[1].

II. REQUIREMENTS

For the ATR line profile monitors, 12 complete links are required. The fiber lengths vary from approximately 60 m - 500 m. For each link, the transmission specifications are to provide unity gain over a bandwidth of approximately 6 Hz - 6.5 MHz, with a gain flatness over that band of < +/- 1 db. Further, dynamic range of 50 db, and low THD are also required. Also, because the front end video system of each profile monitor is inside the tunnel, the fiber optic transmitter and fiber must be radiation resistant.

III. BASIC DESIGN

The basic design of the link used components previously found to be radiation in previous testing at the AGS[2]. The cable selected is Spectran Specialty Optics HCR-series with a 200 micron core. This cable was used in the beam position monitoring system in the AGS Booster and has performed very well over the last 5 years. The fiber has a length-bandwidth product (LBP) of 17 MHz/km at 820 nm. Given worst case fiber length, 500 m, the fiber bandwidth will be about 34 MHz and hence not degrade the video signal. The attenuation introduced by the cable is minimal at 6 db/km as compared to coaxial solutions. The connectors used are SMA in and do not require epoxy polishing to get low loss connections.

The transmit and receive diodes selected are the Hewlett-Packard HFBR 1404/2406 pair ($40/pr). They are based on InGaAs technology and operate in the 820 nm window. These diodes have also been radiation tested at the AGS and have been used in the Booster for over 5 years. The receiver diode (HFBR2406) has a small signal bandwidth of over 125 MHz.

The transmitter schematic is shown in figure 1. The 75 ohm input resistor is for matching to the source impedance of a video driver. This circuit however can be used with most any matching impedance. The basic circuit is a voltage-to-current (transimpedance amplifier). The RCA CA3083 is used to implement a Wilson current source which provides the dc-bias required by the LED for analog data transmission. Dynamic range and bandwidth are optimized for bias currents of 20 - 25 mA range. The current source is adjusted with a pot in the programming leg of the current source. Since the ideal current source has infinite AC impedance, all of the (low frequency) signal current flows through the resistor R4. The input voltage is scaled to a current by Vi/R4. This is where the voltage-to-current conversion occurs. Depending on the application, some peaking across R4 may be desired. The value of R4 can be selected to scale the input voltages of >2 Vp-p to fit within the LED current dynamic range. In the system built for the ATR line, R4=100 ohms, the peaking circuit is a series combination of an 820 ohm resistor and 1200 pf capacitor. The opamp selected is the AD847. It was selected based on bandwidth and stability considerations.

To power the transmitter circuit, raw AC is brought into the package, and converted to DC analog rails using a CALEX AC/DC supply. The output is then filtered for use by the circuitry. The CALEX supply is also a proven device in the AGS tunnel, as withstanding radiation doses. However, no quantitative testing has been performed, in qualitative studies they seem to be the power supply of choice based on cost and lifetime. They provide the necessary DC power and require only an AC input which is readily available inside the tunnel at a variety of locations.

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Work performed under the auspices of US Dept. of Energy under contract No. DE-AC02-76CH00016.

Packaging the transmitter has been accomplished using a small all aluminum 7"x 7" x 2" chassis. The package concept is such that it is a line replaceable unit (LRU). The chassis is sized such that the entire transmitter assembly can be placed inside a "cubby-hole" along with other instrumentation. The package has been designed to provide indicator lights and test points for quick status checks. Also, access to the control and value of the LED bias current is available without opening the chassis.

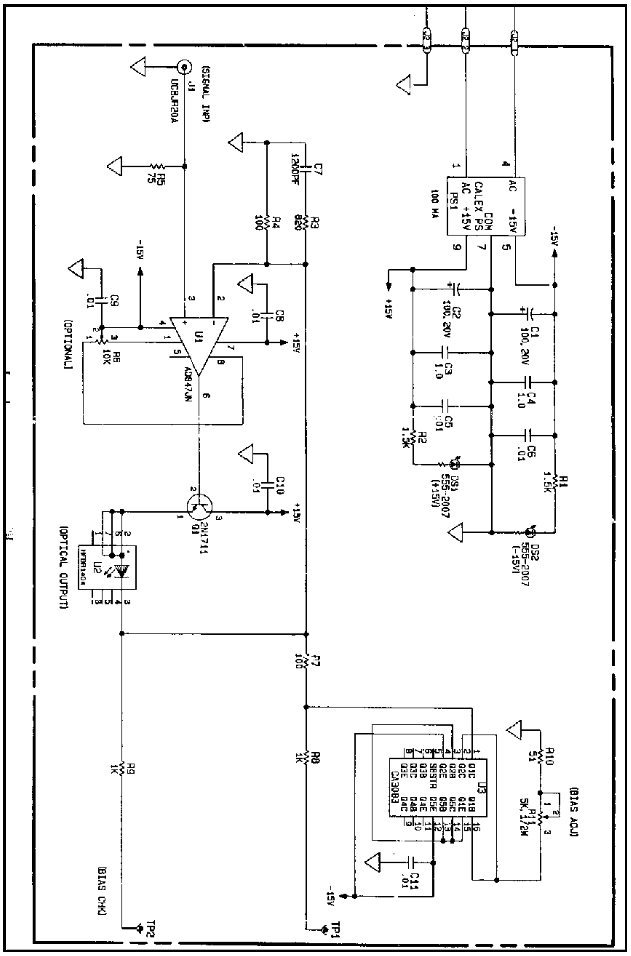


Figure 1. Transmitter schematic.

The receiver circuitry is shown in figure 2. The receivers are centrally located in one of the instrumentation trailers outside the tunnel. Therefore, the receiver circuits have been designed to the more conventional eurocard form factor. Each module is 3 Ux7 HPx220 mm and mates into a slot in a 19" rack mount crate. The crate is powered with a single +/- 15 V DC supply. However, the receivers, unlike the transmitters, require +5 V in addition to the analog rails, so a +5 V regulator has been incorporated onto the board. This lowers the overall part and assembly cost of system, as opposed to adding an additional +5 V supply.

The receiver is the HP HFBR-2406, and is a combination photodiode and analog preamp in one package. The low pass filter following the diode sets the lower corner of the link frequency response, and is used to block the DC offset coming from the receiver photodiode. Across the 330 uF capacitor a good quality rf capacitor has been placed to reduce the non-ideal behavior of the electrolytic to acceptable levels in wide-band applications. The resistor placed in series with the inverting node of the opamp is important as the capacitance of the AD811 degrades the frequency response. The AD811 was chosen because of the large available output current, and the fact that the bandwidth is nearly independent of the gain. The later reason being the overriding factor. In this application the gain will be varied to compensate for the initial link losses caused by the cable and connectors, and variability in photodiode responsivity from unit-to-unit. Later, some adjustment may be necessary to compensate for some of the radiation induced darkening over the lifetime of the system. However, in the Booster applications which have used this fiber, darkening has not been an issue. The receiver gain, as shown, can be varied over the range of 4.4 to 7.25. However larger ratios can be employed if necessary. The output stage shown has a DC impedance of 75 ohms, and the capacitor serves to reduce the output noise bandwidth. Thus at high frequencies, a 56 ohm impedance is presented to a cable. This is not really a problem as for 75 ohms, it represents a VSWR of 1.5:1, and this is usually acceptable.

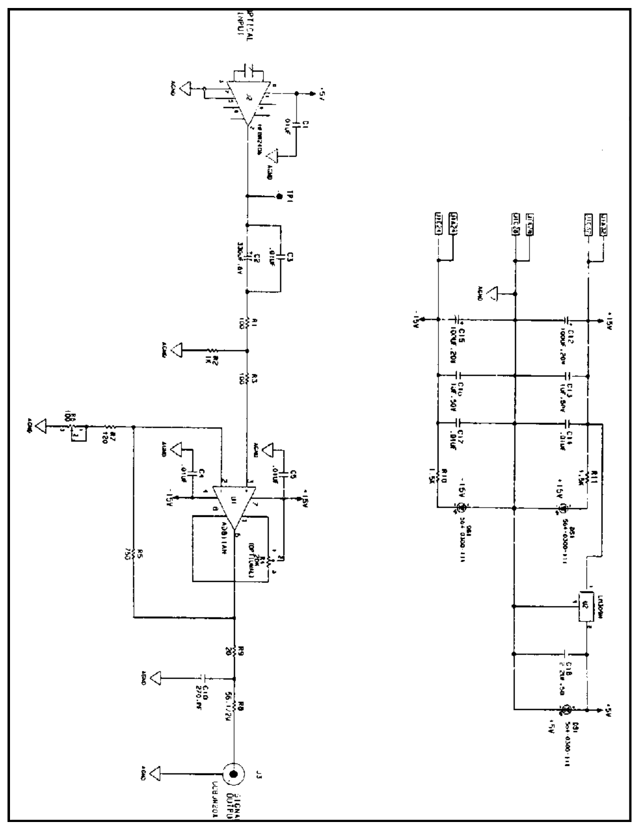


Figure 2. Receiver schematic

IV. PERFORMANCE

The overall system was tested with fibers of lengths 20m, 200 m, 600 m. The frequency response shown in figure 3 is for a 200 m length using 2 Vp-p signal. The receiver was configured with an HFRB-2406 , the transmitter bias was 25 mA, and the value of R6 in the receiver was 67 ohms. The passband is flat (<+/-.5 db) over 6 Hz - 12 MHz. The two traces shown are for two samples from the first lot. The difference in the 3 db points (shown as circles) has to do with the parasitics caused by the individual receiver diode packaging and socketing. Since the required bandwidth is below 10 MHz for this application, these effects were not studied further.

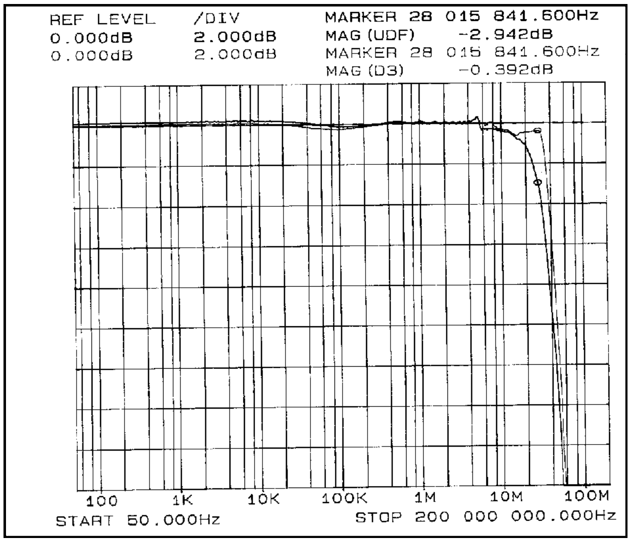
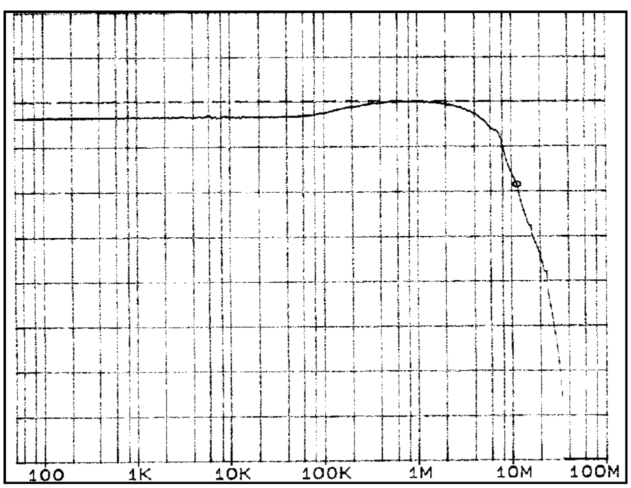


Figure 3. Freq. response of two sample links (L=200 m).

In addition we have found that the dc-power level reaching the receiver diode has an effect on the link bandwidth. For example, changing to a 600 m fiber (figure 4) from the 200 m fiber, and using the same transmit and receive pair, the system bandwidth dropped to about 11.5 Mhz. However the gain flatness



to the 6 Mhz stays within the +/- .5 db range. Note that the scale for figure 4 is the same as figure 3. We believe the cause of this to be the dc-power in the light reaching the receiver causing different capacitance values in the receiver. The dc-power dropped from 75 uW to 46 uW. With less dc-power biasing the PIN receiver, the diode capacitance is larger, and the causes a lower bandwidth than predicted by the LBP of the fiber alone.

To test the total harmonic distortion (THD) a single tone at 1 Mhz and 2 Vp-p was applied to the transmitter circuit and the receiver output was measured. The resulting THD measured was below .5 %, which corresponds to approximately 50 db dynamic range.

The noise floor was also measured. For this test the transmitter input was terminated in 75 ohms, and the receiver output was measured on an oscilloscope. The gain of the receiver was set such that unity link gain was achieved at 1 Mhz using a 200 m fiber. The tests showed the noise output was less than 2 mV(rms). This minimum signal dynamic range is approximately 53 db. Thus the THD and noise limited dynamic ranges are comparable, implying neither parameter is overdesigned.

As stated in the abstract, the link is capable of providing frequency response beyond 50 Mhz. This assumes adequate illumination of the receiver photodiode. However the peaking has been allowed to increase to about 6-8 db and the passband ripple specification relaxed to +/- 1 db. This response was achieved by using the peaking components in the transmitter, and shunting the gain control resistor in the receiver with a capacitor.

V. REFERENCES

1. Witkover, R., "Design of the Beam Profile Monitor for the RHIC Injection Line", see this proceedings.

2. Beadle, E.,"Fiber Optics in the BNL Booster Radition Enviroment", 1991 PAC Proceedings.