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NATIONAL RADIO ASTRONOMY OBSERVATORY
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MEMORANDUM

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To: GBT Memo Series

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Subj: Cable Specifications for GBT Cable Wrap

I. Introduction

Specifications of cables determines the cable wrap design criteria for the GBT. Specifically the size of the cables, the flexibility and whether the cables can withstand twisting of +/- 270 degrees is needed. Two types of cables will pass through the cable wrap, fiber optic cable for electronic signals and copper cable for power distribution. Two types of fiber optic cables are needed, single mode for LO distribution and analog distribution with multimode for digital data distribution. The three phase power will be distributed over several cables where the number will depend on the current carrying capability of the cables.

II. Fiber Optic Cable

Fiber optic cable is superior to coaxial cable in bandwidth specifications, temperature coefficient, and RFI immunity. JPL has demonstrated the improvements in LO distribution for the Deep Space Network which has round trip signal paths of 850 meters with group delay changes of 0.03 ps when the cable is subjected to flexing. To achieve this performance, the semiconductor laser diode must be isolated from the fiber using commercial bulk optical isolators where a isolation of 70 dB and a 1.3 dB forward loss is obtainable.[1] Future developments of laser diodes with integral dual isolators may eliminate the need for the the external bulk optical isolators. The distance from the GBT site to the electronics lab is approximately 2.6 km which is the maximum distance from the GBT for a control room. Passive stabilization of single mode fiber, such as burial, results in a stability of one part in 10^{15}. The hydrogen maser has a frequency stability of 1×10^{-15} for an averaging time of 1000 seconds.[2] With active stabilization, improvements of least 40 times reduction over a 4 Km link are obtainable with theoretical predictions of 500 times improvement obtainable by reducing optical losses and leakage.[3]

Another important consideration for the single mode fibers is analog signal transmission. With the bandwidth capabilities of fiber optics, RF signal bandwidths of several GHZ are obtainable. JPL has demonstrated X-band signal transmission with a frequency range from 100 MHZ to 18 GHZ with a 150 dB dynamic range. Ortel has available a system cable of 12 GHZ of bandwidth as an off the shelf item for ~$15,000. They are planning to develop a system with a bandwidth of 20 GHZ. Today's technology of single mode fibers is capable of achieving this performance, the limitations is in the RF modulators. Therefore, installation of single mode fiber will not hinder future improvements in RF transmission. Also, this fiber is available with 72 conductors per cable in a loose tube construction by Belden and AT&T allowing for expansion of signal paths and redundancy. The cost of the fiber is approximately $0.08/ft-fiber.

Multimode fibers are available with 94 conductors per cable. Current technology, for instance an FDDI bus, is capable of transmitting 100Mbit/s. The FDDI also will have the capability of dynamically allocating bandwidth to data where varying time delays are intolerable along with data where varying delays are acceptable. This capability may reduce the complexity of the electronics at the telescope. The FDDI system has a maximum distance of 2 km between nodes with a total network distance of 100 km. Therefore, a node would be necessary between a control room located at the Jansky lab and the telescope. Future developments will enable voice and video transmissions over the network.

II. Power Cable

The power cable must be able to supply three phase power to the telescope through a cable wrap. Therefore, the cable must withstand twisting and flexing. The type of commercially available cable which meets these requirements is miner's cable. The conductors are rope-lay stranded annealed copper, which gives the desired flexibility. These cables are OSHA acceptable and MSHA approved for safety. Table 1 gives the required ampacity of the conductors. Because the converters in DC motors are very noisy, separate power lines for the motors is necessary to improve isolation from the electronics. The DC converters usually operate from a 480 V three phase power delta configuration. Therefore, a Y to delta isolation transformer is needed. In order to reduce the current load of each conductor, the transformer is located on the telescope side of the cable wrap. American Insulated Wire Corporation manufactures a 3-conductor portable power cable with a ground conductor. The 2/0 size is rated at 215 A in 40 C ambient temperature and 90 C conductor temperature. A similar cable is also manufactured by Rome Cable Corporation. The cable has an approximate outside diameter of 1.630 inches and a weight of 2660 lbs./M'. Therefore, a minimum of three cables is needed for the motor power. The active surfaces requires approximately 50 kW and the electronic power is estimated at 20% of the motor power, which gives a total of 200 kW. From Table 2, a single cable of the type mentioned above can supply the remainder of the power.

III. Summary

The minimum number of fiber optic cables needed is two, one for single mode fiber and one for multimode fiber. Each can contain as many as 72 fibers in today's technology. The cables are approximately 0.7 inches in outside diameter and can withstand twisting as specified in EIA 455-85. The minimum number of power cables needed is four 3-conductor 2/0 AWG cable. The cable is designed to be portable; therefore, flexing and bending is not a problem. If a cable length of 3 km is considered for analog and data transmission with 15 single mode fibers and 10 multimode fibers, the cost for the single mode fiber is ~$22,000 with the cost of the mulitmode fiber being ~$15,000 . This is for armor protected fiber.

References

1. G. Lutes, "High Stability Frequency and Timing Distribution using Semiconductor Lasers and Fiber Optic Links." JPL Publication.

2. A. Kirk, P. Kuhnle, and R.Sydnor, "Evaluation of moder hydrogen masers," Proc. 14th Ann. Precise Time and Time Interval (PTTI) Applications and Planning Meeting, pp. 359-392, NASA Conference Publication 2265, Nov./Dec. 1982.

3. L. Primas, G. Lutes, R. Sydnor, "Stabilized Fiber Optic Frequency Distriburtion System." JPL Publication.

Horse Power = 898		Efficiency = 0.9		Total Power[kW] = 744.34		
Line Voltage		Amps/Phase		# cond/Phase	Amps/Cond.	
delta	Y	delta	Y	...	delta	Y
440	440	976.72	563.93	1	976.72	563.93
440	440	976.72	563.93	2	488.36	281.96
440	440	976.72	563.93	3	325.57	187.98
440	440	976.72	563.93	4	244.18	140.98
440	440	976.72	563.93	5	195.34	112.79
480	480	895.33	516.93	1	895.33	516.93
480	480	895.33	516.93	2	447.67	258.47
480	480	895.33	516.93	3	298.44	172.31
480	480	895.33	516.93	4	223.83	129.23
480	480	895.33	516.93	5	179.07	103.39
600	600	716.26	413.55	1	716.26	413.55
600	600	716.26	413.55	2	358.13	206.77
600	600	716.26	413.55	3	238.75	137.85
800	800	537.20	310.16	1	537.20	310.16
800	800	537.20	310.16	2	268.60	155.08
800	800	537.20	310.16	3	179.07	103.39
1000	1000	429.76	248.13	1	429.76	248.13
1000	1000	429.76	248.13	2	214.88	124.06
1000	1000	429.76	248.13	3	143.25	82.71
2400	2400	179.07	103.39	1	179.07	103.39
2400	2400	179.07	103.39	2	89.53	51.69
2400	2400	179.07	103.39	3	59.69	34.46

Table 1. Estimated DC Motor Power Consumption.

Total Power[kW] = 200.00						
Line Voltage		Amps/Phase		# cond/Phase	Amps/Cond.	
delta	Y	delta	Y	...	delta	Y
440	440	262.44	151.52	1	262.44	151.52
440	440	262.44	151.52	2	131.22	75.76
440	440	262.44	151.52	3	87.48	50.51
440	440	262.44	151.52	4	65.61	37.88
440	440	262.44	151.52	5	52.49	30.30
480	480	240.57	138.90	1	240.57	138.90
480	480	240.57	138.90	2	120.28	69.45
480	480	240.57	138.90	3	80.19	46.30
480	480	240.57	138.90	4	60.14	34.72
480	480	240.57	138.90	5	48.11	27.78

Table 2 Estimated Electronic Power Consumption.