

Evaluation of Shielded Cable at LIGO

LIGO-T080097-00-C

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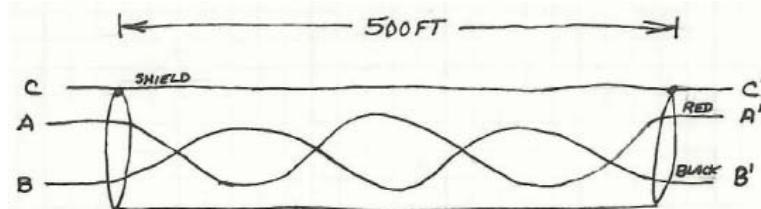
15 April 2008

1. **Overview:** LIGO has informally adopted the standard of amplifying analog signals above a $100\text{nV}/\sqrt{\text{Hz}}$ minimum signal level prior to transmission on a cable. This practice is valid to the extent that interfering noise sources are significantly smaller than this minimum signal level.

The placement of electronics racks for Advanced LIGO will require long cable runs, which raises the concern that electrical noise may become troublesome. This note shows the results of a measurement performed on 500 feet of shielded twisted pair. There is nothing particularly special about the cable used for this test; it is merely what was on hand. The cable uses an overall foil shield with a drain-wire. The datasheet for the cable is included at the end of this report.

2. **Test Setup:** 500 feet of cable was haphazardly strewn around the office and into the parking lot. Figure 1 shows the various connection points for reference.

Figure 1



Connecting only point A' to the input of a Stanford Research SR785 Dynamic Signal Analyzer allows a sample of the unshielded ambient noise to be recorded. For all measurements, the SR785 analyzer's noise floor was recorded and compared to the data to ensure sufficient signal to noise ratio. Many different connection scenarios were analyzed, but the results of the most favorable LIGO-like connections are presented. There were no surprises in the data that point to a new mindset; essentially a shielded twisted pair with the shield free from ground loops is the best choice. Figure 2 shows the results of the measurements. The essence of the message is that a properly terminated and shielded 500 foot cable draped around an electrically cacophonous Los Angeles office building, yields reasonable results. The data shows better than 100dB of shielding at 60Hz. Much of the results are beyond the dynamic range of the SR785 to measure without using a low noise preamplifier.

Figure 2

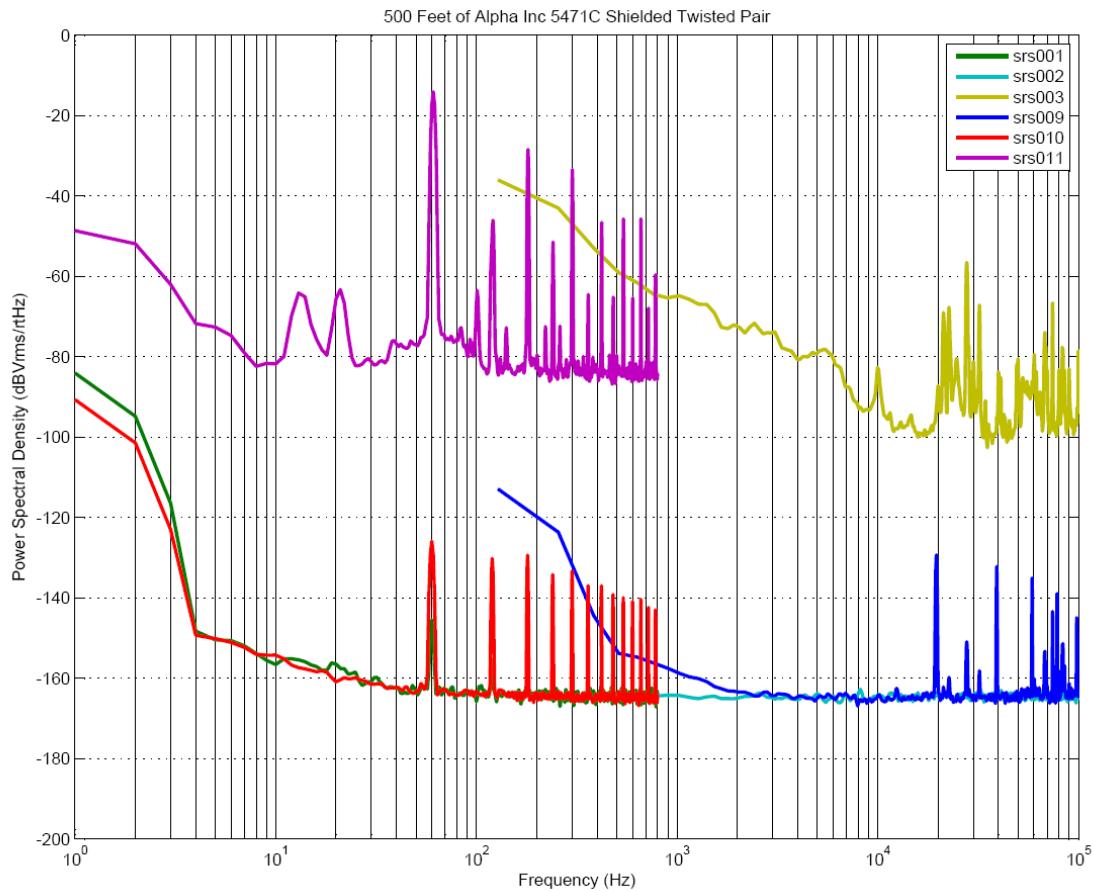


Table 1

Trace Name	Description (Connections refer to Figure 1)
SRS001	Low frequency analyzer noise floor
SRS002	High frequency analyzer noise floor
SRS003	High frequency ambient noise measured at A' with no other connections
SRS009	High frequency noise measured differentially (A' - B') across the fully shielded twisted pair. Signal wires and shield (A, B and C) shorted. Shield C' terminated to analyzer. See Figure 4 for test details.
SRS010	Low frequency portion of SRS009
SRS011	Low frequency ambient noise same as SRS003

3. **Conclusion:** Transmission of analog signals with amplitudes greater than $100\text{nV}/\sqrt{\text{Hz}}$ does not seem unreasonable at LIGO even over 500 feet of cable. Shielding performance in excess of 100dB seems routinely achievable from the standpoint of the cable. These measurements don't address radio frequency interference, nor the degradation associated with finite common-mode balance in differential transmitters and receivers at LIGO.

Figure 3, Alpha Wire Datasheet

ALPHA WIRE COMPANY CUSTOMER PRODUCT SPECIFICATION					
Part Number: 5471C		Issue:	5		
Page 1 of 2 Pages		Issue Date:	5/23/2005		
		Effective Date:	8/1/2005		
A. Construction					Diameters
1) Component 1	1 X 1 PAIR				
a) Conductor	24 (7/32) AWG TC				
b) Insulation	0.010" Wall, Nom. PVC, Semi Rigid				0.044
(1) Color Code	Alpha Wire Color Code K				
		Pair	Color	Pair	Color
		1	BLACK-RED		
c) Pair	2/Cond Cabled Together				
(1) Twists:	9.6 Twists/foot (min)				
2) Shield:	Alum/Mylar Tape, 25% Overlap, Min.				
a) Foil Direction	Foil Facing In				
b) Drain Wire	24 (7/32) AWG TC				
3) Jacket	0.032" Wall, Nom.,PVC				0.156 (0.166 Max.)
a) Color(s)	GRAY				
b) Print	ALPHA WIRE-* P/N 5471C 1PR 24 AWG SHIELDED 75C (UL) TYPE CM OR AWM 2464 --- LLXXXXXX CSA TYPE CMG FT4 ROHS				
	* = Factory Code				
<i>[Note: Product may have c(UL) or CSA markings depending upon plant of manufacture.]</i>					
B. Industry Approvals					
1) UL	AWM/STYLE2464				80°C / 300V
	CM				75°C
2) CSA International	CIMG				60°C
	FT4				
3) EU Directive 2002/95/EC(RoHS):	All materials used in the manufacture of this part are in compliance with EU Directive 2002/95/EU regarding the restriction of use of certain hazardous substances in electrical and electronic equipment. Consult Alpha Wire's web site for compliance Date of Manufacture.				
4) California Proposition 65: The outer surface materials used in the manufacture of this part meet the requirements of California Proposition 65.					
C. Physical & Mechanical Properties					
1) Temperature Range	-20 to 80°C				
2) Bend Radius	10X Cable Diameter				
3) Pull Tension	10.6 Lbs. Maximum				
D. Electrical Properties (For Engineering purposes only)					
1) Voltage Rating	300 V _{RMS}				
2) Mutual Capacitance	35 pf/ft @1 kHz, Nominal				
3) Ground Capacitance	63 pf/ft @1 kHz, Nominal				
4) Characteristic Impedance	54 Ω				
5) Inductance	0.19 μH/ft, Nominal				
6) Conductor DCR	25 Ω/1000ft @20°C, Nominal				
7) OA Shield DCR	23.7 Ω/1000ft @20°C, Nominal				

Figure 4, Test setup for best noise performance

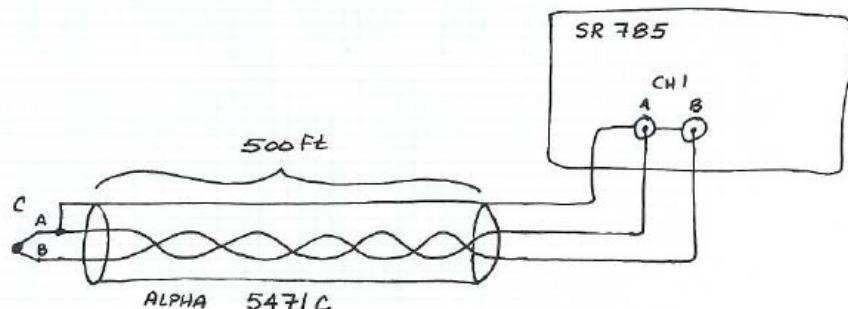
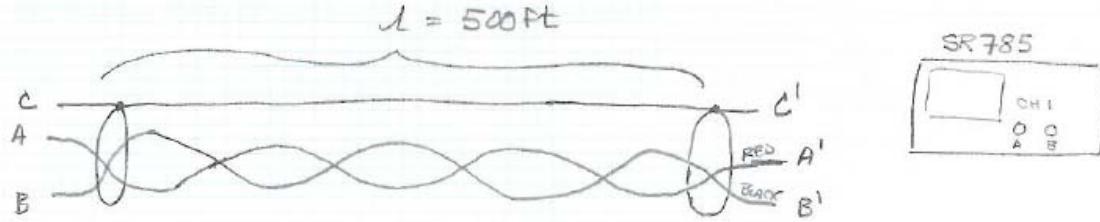


Figure 5. Miscellaneous testing notes. No interest to most people.



File name	Meas. point	Physical Setup	INPUT RANGE	FREQ. RANGE	
SRS001	SR785	50Ω on both inputs. A-B, DC coupl.	-50 dBVpk	1 - 800 Hz	
SRS002	"	"	"	128 - 102,4 kHz	
SRS003	A'	CH1 A INT OUT DECoup GND	Noise baseline using A' as a sense wire. No shield. B' open, A, B, C, C', B' open	-2 dBVpk	"
SRS004	B'	SAME	Noise baseline using B' as a sense wire A, A', B, C, C' open	-2 dBVpk	"
SRS005	SR785	SAME	Analyzer noise floor for SRS003, SRS004. 50Ω on CH1-A. All other parameters same	-2 dBVpk	"
SRS006	A'	SAME	Noise of A' w/ C' to analyzer Shield.	-50 dBVpk	"
SRS007	SR785	SAME	AN. NOISE FLOOR FOR SRS006. 50Ω ON CH1-A.	-50 dBVpk	"
SRS008	A' - B'		SR785 IN A-B, GND MODE C' to AN. SHIELD A, B, C Open.	-50 dBVpk	"
SRS009	A' - B'		SR785 IN A-B, GND MODE C' to AN. SHIELD A, B, C shorted	"	"
SRS010	A' - B'	"	"	1 - 800 Hz	
SRS011	A'	Same as SRS003	"	1 - 800 Hz	