Signal Cable Selection for the VERITAS Observatory

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Abstract

We describe electrical and mechanical tests performed on various coaxial cables to characterize their electrical properties and reliabilities. We use these properties, combined with additional information concerning weight, diameter, and cost, to select the optimum signal cables for the VERITAS observatory. We find significant advantages in using RG-59 Coaxial cable over traditional RG-58 cable. Stranded core RG-59 results in an 30-50% increase in effective mirror area over RG 58; solid core RG59 would result in a 84% increase in effective mirror area. Reliability tests demonstrate that although RG59 solid core will fatigue and fail after repeated twisting, this fatigue would result in a loss of approximately 10 cables over the lifetime of the VERITAS array.

1. Introduction

The VERITAS observatory [1,2] is a next generation facility for Gamma Ray Astronomy in the 50 GeV-50 TeV energy range. The energy threshold of the observatory depends critically on the high frequency performance of the 130 ft long signal cables which transmit the PMT signals to the system trigger and recording electronics. Electrical and mechanical tests are performed to select the optimal signal cables.

2. Cable Electrical Tests

Cable electrical tests consisted of passing a 150 psec risetime pulse generated by a Berkley Nucleonics 6040 signal generator though 100-130 ft sections of the candidate cables. Cables ends were electrically terminated to their characteristic impedance, and the waveform of the signal transmitted through the cable was then recorded by a LeCroy LC560 1 Ghz oscilloscope(Figure 1).

Each measured waveform was fitted to the theoretical waveform $V(t) = \int_0^t G(\tau - t) f(\tau) d\tau$ where $G(t) = \sqrt{\frac{\pi}{\alpha}} e^{-t/\alpha} t^{-3/2}$ is the Green's function of the cable and $f(t) = U(t) - U(t-8)$ is the input pulse waveform. Here $U(t)$ is the Heaviside (step) function . This determines α for the cable. α defines

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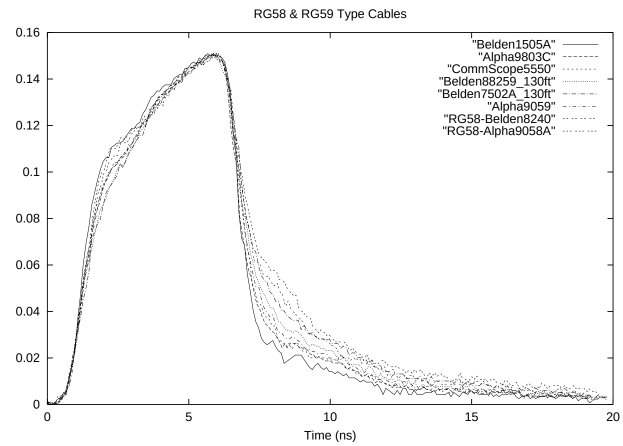

Fig. 1. 8 nsec Square Pulse signal after passing through 130 ft lengths of various cable types. Waveform voltages are renormalized to a common peak voltage.

the optimal charge integration window and the Signal/Noise Ratio (S/N) for the cable. A smaller α gives a faster rise time and a shorter waveform tail, thereby giving a larger S/N. A similar S/N increase could also be gained by increasing the number of mirrors in the VERITAS telescope while using less expensive cables. lower bandwidth cables (with a larger α).

Table 2 lists α for various cables as well as the optimal S/N ratios for each cable. Table 2 also lists the Equivalent Mirror Area and equivalent Cable length. Equivalent Cable Length is the cable length that achieves the same S/N as 130 ft of 9803C cable. Equivalent Mirror Area is the effective gain in S/N using the cable type as compared to using standard 9803C cable, at the same total cost per telescope (any additional cable/connector costs are offset by eliminating mirror area).

The optimal cable solution is to use Belden 1505A solid Core RG59; this results in an 20% effective gain in mirror area compared to a standard telescope instrumented with 9803 (stranded core RG59). Note that stranded core RG58 (9085A) effectively reduces mirror area by 30% compared with the 9803C. The 1505A will net a 84% increase in effective detection area compared to standard RG58 stranded core coax.

3. Mechanical Tests

Cables were tested using a computer controlled screw drive with programmable acceleration and rotation range. Two meter sections were bound together with wire ties to make a thick bundle of 6-12 cables; most of the cables in the bundle were solid core Belden 1505A, but 2 or 3 cables in each bundle were stranded core Alpha 9803C cable. Each cable was electrically monitored to

Table 1. RG58 and RG 59 Cable Physical Properties

Cable Name	Mfgr Name	RG Type	Impedance (Ω)	Core Wire	Diameter (in)	Weight (lb/100 ft)
1505A	Belden	RG59	75	Solid	0.235	3.4
9062A	Alpha	RG62	93	Solid	0.242	4
9803C	Alpha	RG59	75	Stranded	0.242	3.5
5550	CommScope	RG59	75	Stranded	0.242	3.5
82259	Alpha	RG59	75	Stranded	0.193	3.2
9059	Alpha	RG59	75	Solid	0.242	4.1
9055B	Alpha	RG55B	53	Solid	0.206	3.5
8240	Belden	RG58	50	Solid	0.193	2.7
9085A	Alpha	RG58A	50	Stranded	0.195	2.8

record the number of rotations experienced before failure. One end of the cable bundle was tied to the screw drive, which the other was tied to a fixed mounting point.The cable was tested while laying flat on a table. The cable bundle was never placed under tension during any part of the rotation cycle.

A single test cycle consists of rotating the cable bundle axially through 270° and then back again at a fixed acceleration rate. A full test consisted of recording the number of cables breaking as a function of number of elapsed cycles for several million cycles. This data measures the survival probability P of the solid core cables as a function of number of elapsed cycles for given acceleration rate. Typical test time was approximately 2-4 months, depending upon selected acceleration rates.

The survival probability data for number of cycles $c < 1.2 \times 10^6$ is well fitted by $P = 100 \times e^{-c/\lambda}$. Similar tests and data fitting were performed for angular accelerations of 0.4, 1.1 and 2.7 rev/sec^2, yielding $\lambda = 1.1 \times 10^7$, 3.9×10^6, and 5.5×10^5 respectively. During all these tests all Alpha 9803C cables survived without failure.

We find the primary survival exponent λ is proportional to the applied force (angular acceleration). Using a linear fit, we extrapolate zero force, similar to the slow angular acceleration expected for the VERITAS Telescopes . This extrapolation gives an expected survival exponent of $\lambda = 1.78 \times 10^7$ Cycles.

Assuming a single cable will experience 20 rotations per night with 200 nights of operation per year and a 10 year operational lifetime, we expect a 99.77% survival rate (40000 cycles). For the entire VERITAS observatory (7 telescopes * 499 cables/telescope) we expect 9 Belden 1505A cables to fail during the 10 year operational period. No Alpha 9803c cables are expected to fail.

Table 2. RG58 and RG59 Cable Measured/Calculated Properties

Cable bane	α (130 ft)	Max S/N	Equivalent Length	Equivalent Mirrors	Mirror Area Gain(Loss)
1505A	0.07	0.264	205.5	361	20.3%
9062A	0.17	0.239	130.0	300	1.0%
9803C	0.17	0.239	130.0	300	0.0%
5550	0.19	0.236	124.0	293	0.0%
82259	0.20	0.234	119.5	288	(-13.0%)
9059	0.25	0.227	106.9	271	(-8.3%)
9055B	0.42	0.207	82.2	225	(-31.0%)
8240	0.42	0.207	82.2	225	(-25%)
9085A	0.59	0.193	69.5	196	(-34.6%)

4. Cable Selection

Based upon the electrical tests, the best cable for use with VERITAS is the Belden 1505A cable. Mechanical tests indicate that there is a finite risk of core conductor breakage due to rotation fatigue, although the number of broken cables for the entire experiment should be negligible. In order to be conservative, and also due to bandwidth limitations of the front end preamplifier, at the present time VERITAS has chosen to employ the stranded core RG59 (9803C) for signal cables with VERITAS. With additional bandwidth improvements in the preamplifier, it should be possible to effectively increase the mirror area by 20% through use of the Belden 1505A cables with only a small risk of breakage. A manuscript is under preparation which provides a fuller description of these tests, including additional data for additional cable types (RG6, RG8, RG213, etc)[3].

5. Acknowledgment

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6. References

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