MATHUSLA Fiber Management and SiPM Cooling

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Scintillator Module Assembly Issues

Wavelength Shifting Fiber Management

- Minimum Bend Radius
- Losses: Attenuation Length, Curvature
- Differential Length Issues
- Housekeeping: Messy bundles of delicate fibers; Optical and mechanical shielding

Cabling

- Fast Signal
- SiPM control voltage, temperature signals, etc.,
- Amplifier power

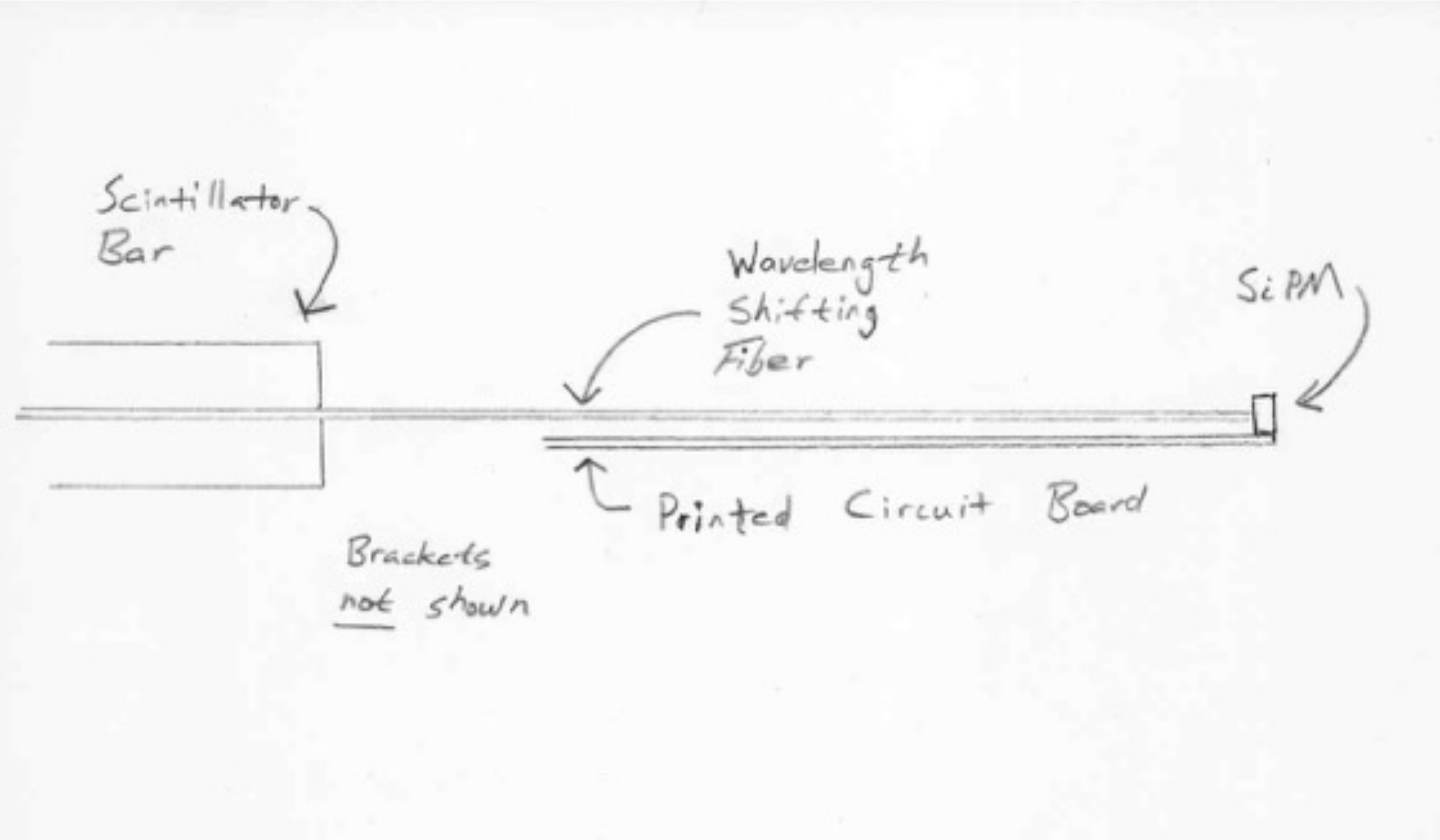
Cooling (if desired)

- Liquid cooling likely option
- Condensation will be a problem

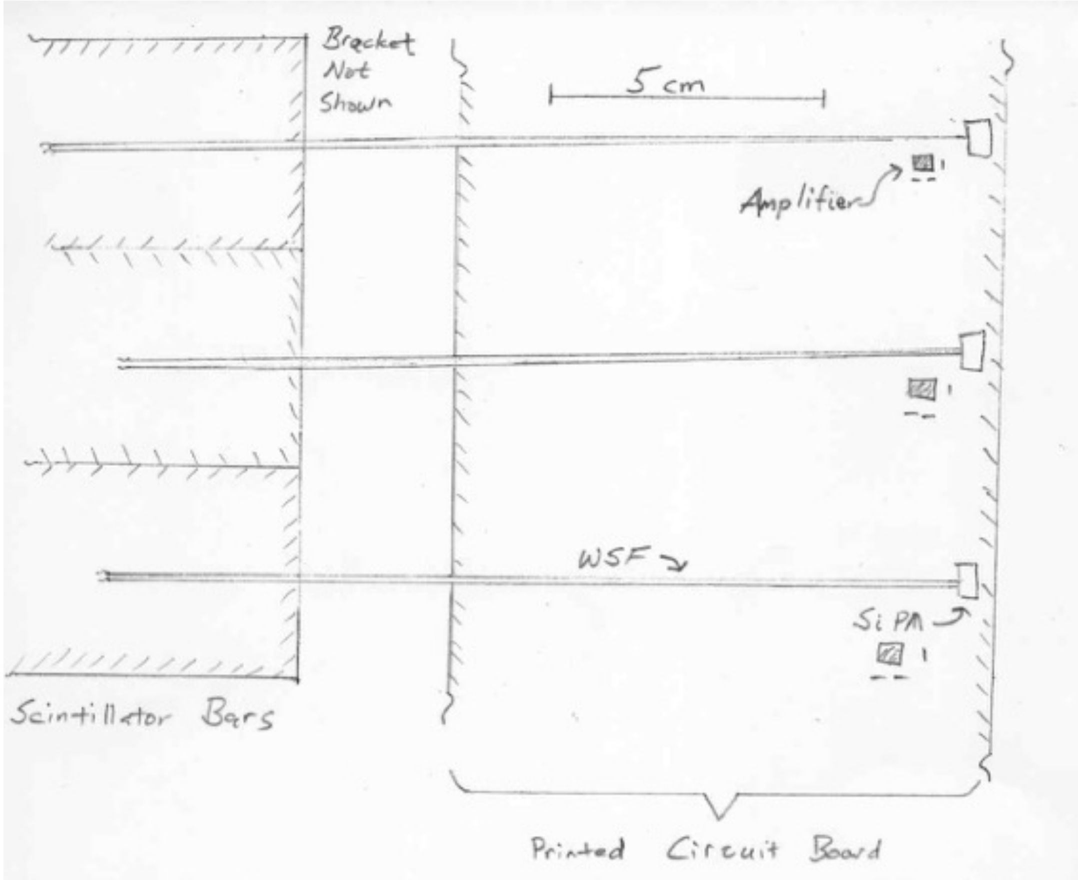
An Approach: Long Printed Circuit Boards
→ Carry all electrical signals and power

- Long Circuit Boards run along business end(s) of Scintillator Modules
- SiPMs are mounted at the scintillator bar horizontal pitch (e.g., 4 cm)
- Amplifier circuitry adjacent to each SiPM
- Amplified analog signals transmitted by embedded *striplines*, a conventional transmission line geometry in PCBs
- Next stage electronics couples to terminated striplines at end of board
- Long (2.25 m) boards available from manufacturers
- Issues include costs, board bending stability, yield

PCB: Side View



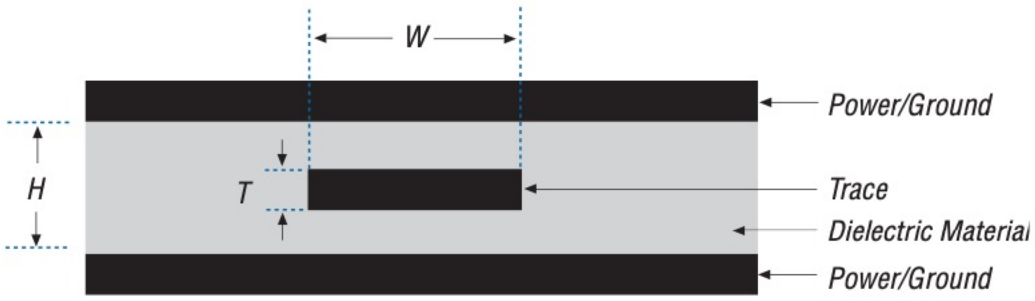
PCB: Top View



Bracket
Not
Shown
5 cm
Amplifier
WSF
Si PM
Scintillator Bars
Printed Circuit Board

Stripline Geometry

Figure 2. Stripline Transmission Line Layout Note (2)



Notes to Figures 1 & 2:

(1) W = width of trace, T = thickness of trace, and H = height between trace and reference plane.

(2) W = width of trace, T = thickness of trace, and H = height between trace and two reference planes.

Typical FR-4 Board Stripline Dimensions: Z_0 = 50 Ohms:

W = 0.22 mm H = 0.6 mm

Variables include dielectric constant, copper surface roughness

Stripline Impedance

A circuit trace routed on the inside layer of the PCB with two low-voltage reference planes (i.e., power and/or GND) constitutes a stripline layout. You can use Equation 4 to calculate the impedance of a stripline trace layout.

Equation 4:

$$Z_o = \frac{60}{\sqrt{\varepsilon_r}} \ln\left(\frac{4H}{0.67\pi(T + 0.8W)}\right) \Omega$$

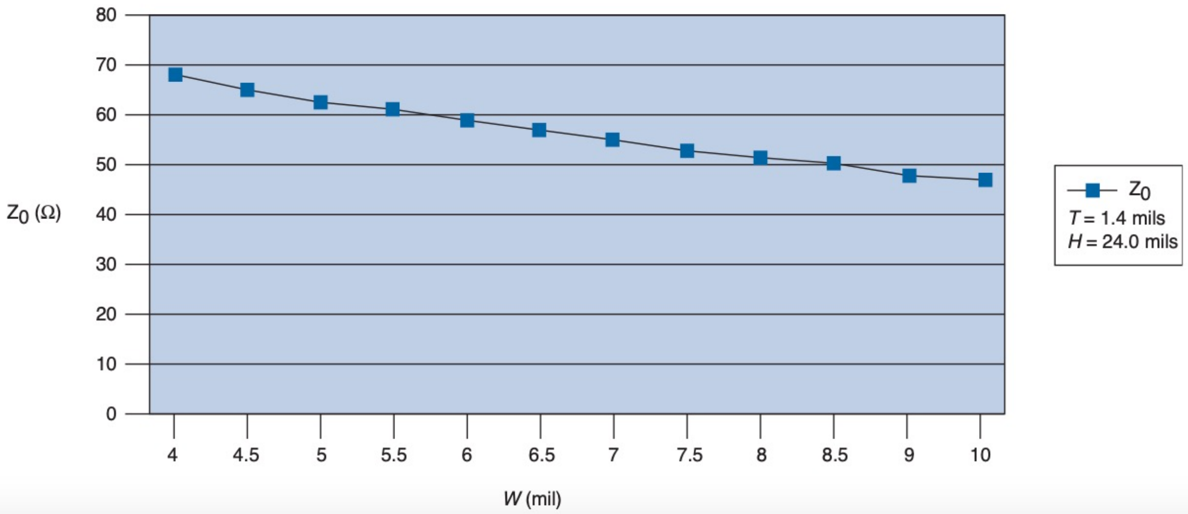
Using typical values of $W = 9$ mil, $H = 24$ mil, $T = 1.4$ mil, ε_r and (FR-4) = 4.1 with Equation 4 and solving for stripline impedance (Z_o) yields:

$$Z_o = \frac{60}{\sqrt{4.1}} \ln\left(\frac{4\,(24)}{0.67\pi\,(1.4) + 0.8(9)}\right) \Omega$$

$$Z_o \sim 50\ \Omega$$

Figure 6 shows impedance vs. trace width using Equation 4, keeping height and thickness constant for stripline trace.

Figure 6. Stripline Trace Impedance with Changing Trace Width



Striplines are commonly used (e.g., online calculators)

Substrate Parameters

εr: Relative permittivity of the substrate.

Tanδ: Loss tangent of the substrate. This parameter is used for the loss calculations. The higher the value, the larger the loss.

Rho: Conductor resistivity relative to copper. This parameter is used for the loss calculations. When in doubt, use 1 for copper, .946 for silver, or 1.45 for gold.

Height: Height of the substrate.

Thickness: Thickness of the microstrip conductor. This can be set to zero, but the calculated loss will not include conductor losses.

Frequency: Frequency at which the microstrip transmission line is analyzed or synthesized.

εr:	4.1		Tanδ:	0.002		Rho:	1	
Height:	0.60960	mm	Thickness:	0.03556	mm	Frequency:	1.0	GHz

Analysis/Synthesis Values

Width:	0.23346	mm	Zo:	49.88	Ω
Length:	1000.001	mm	Angle:	2431.50	**deg.**
	Analyze			Synthesize	
Loss:	2.577	dB			

Board Width

- Stripline Separation Typ. : 3W .. 10 W (crosstalk)
- @ 5W, our stripline pitch is 1.0 mm
- Loss: 2.6 dB/m at 1 GHz
- Maximum length = 96 SiPMs → single stripline layer = 10 cm wide
- 4-layer PCB covers all functions?

Cooling Considerations

- Cooling reduces dark rate and increases gain stability
- Insulated Cooling Losses ~ 10 W/m at delta T = 40 C
- Non-toxic, cheap water-glycol solution would work
- Total cooling requirements order 100 kW thermal, 25 “tons”
  Dallas NFL football stadium summer AC peak load: 750 MW
- Dry air surrounding components <u>a must</u> to prevent condensation
- Unfortunately, chilled-air-only cooling will not work
- Requirements easily within industrial capabilities

Cooling concept: Enclosed liquid channel parallel to PCB