Modification of Signal Propagation Velocity Through Printed Circuit Boards Using High Dielectric Constant Materials

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The NSF NNCI Multi-Scale Manufacturing & Nano Integration Node

Motivation

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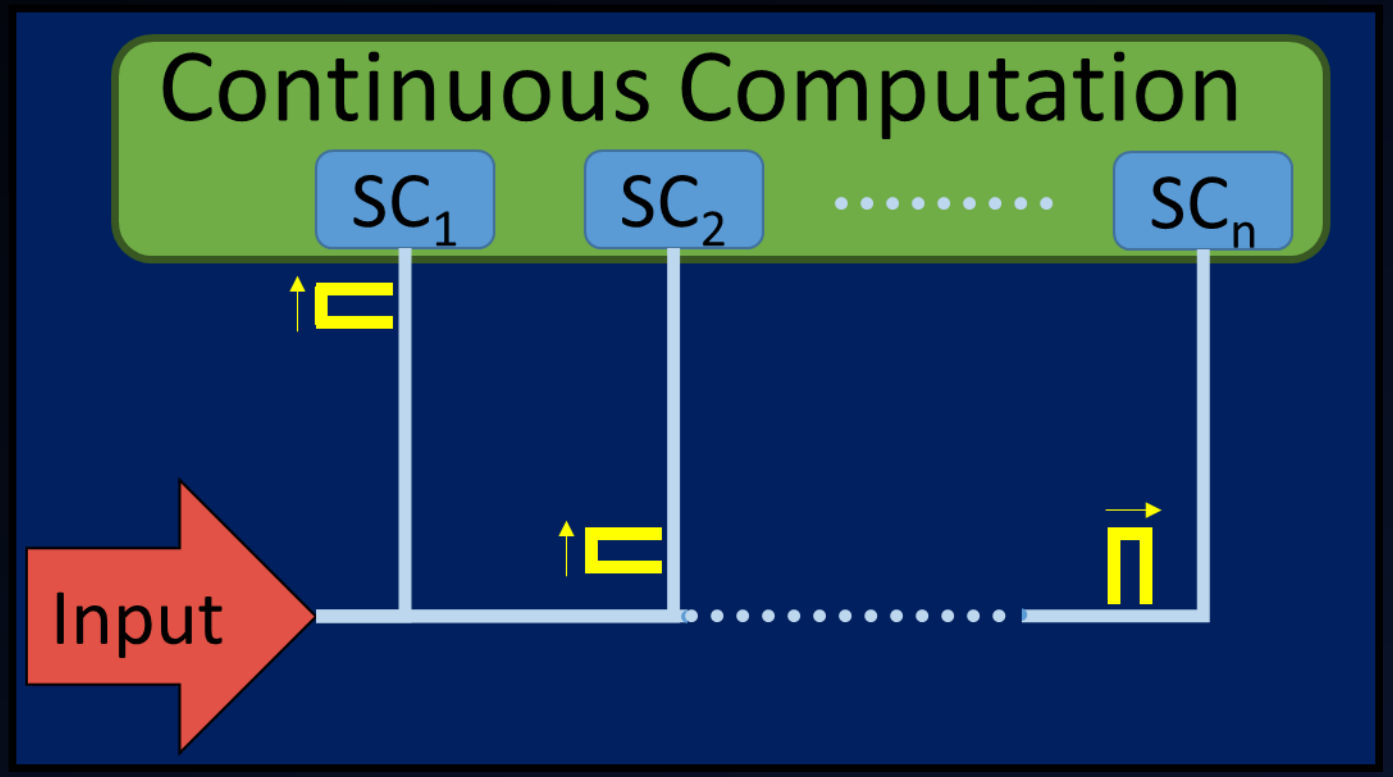

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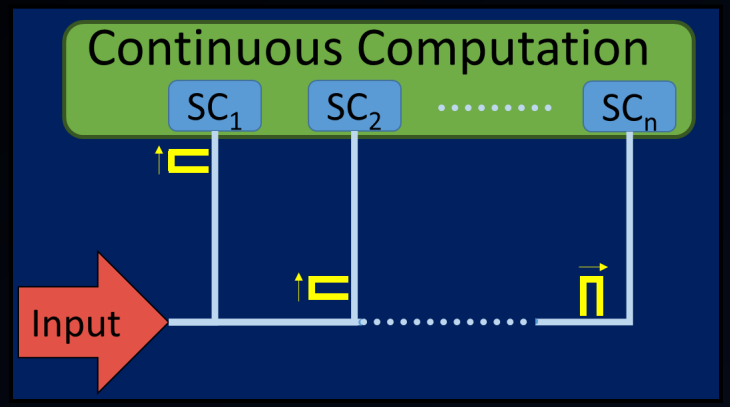

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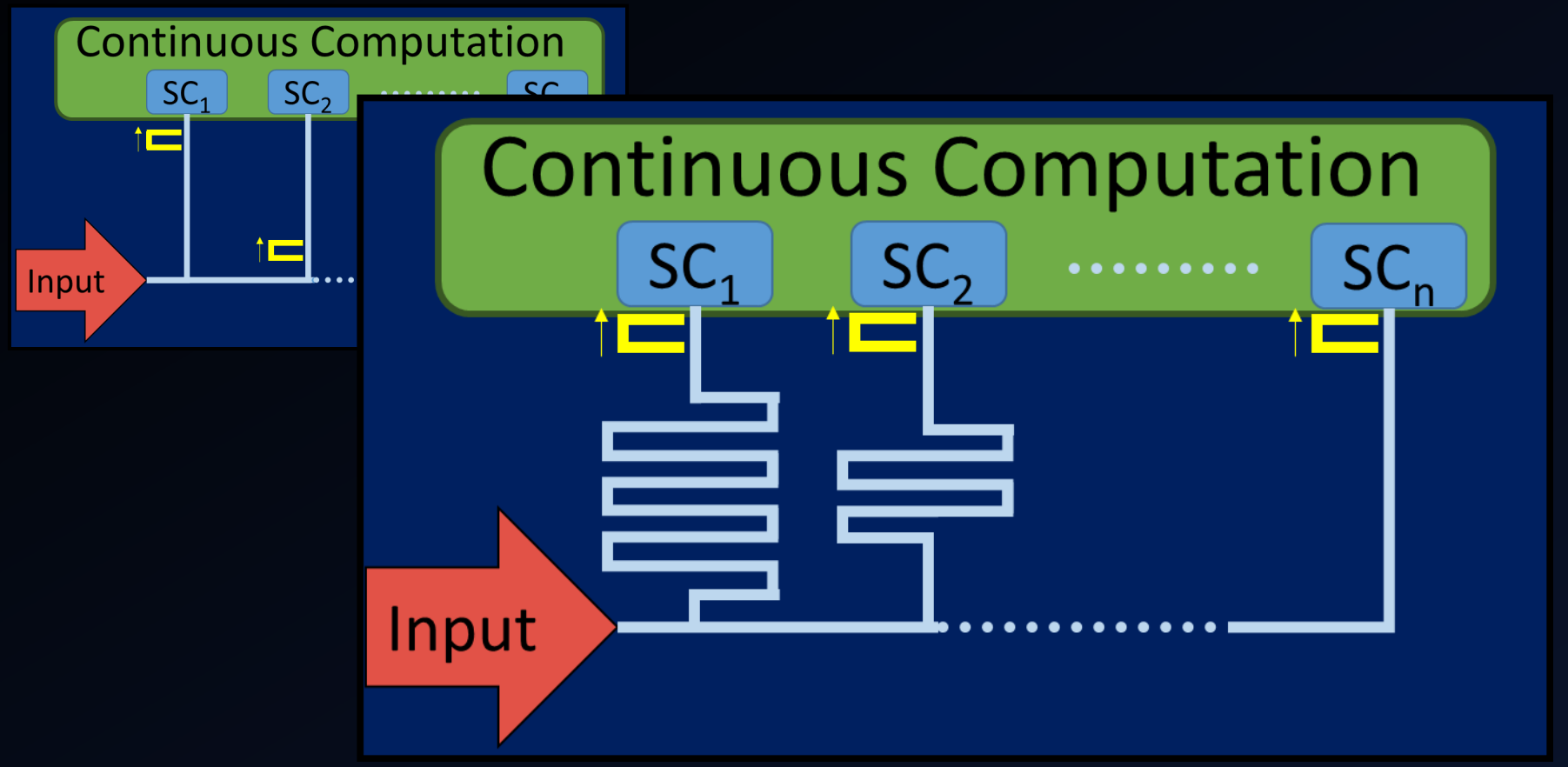
Continuous Computation
SC1
SC2
Input
Continuous Computation
SC1
SC2
SCn
Input

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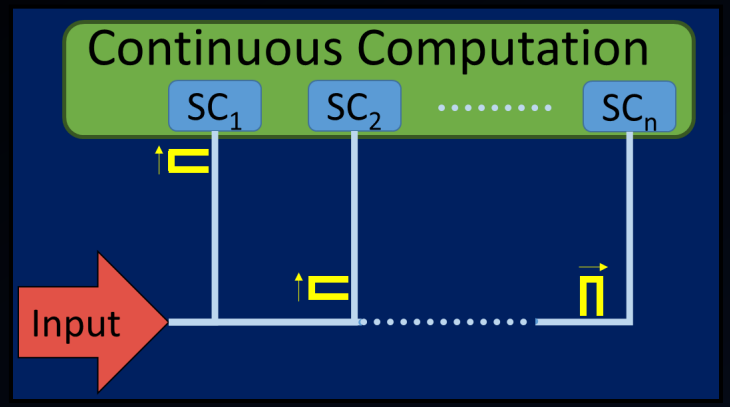
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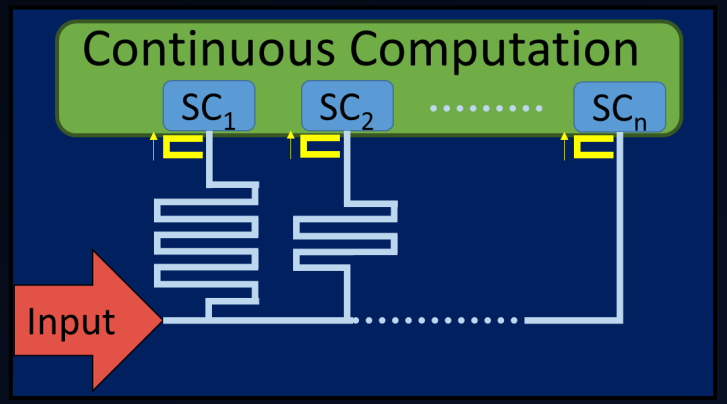
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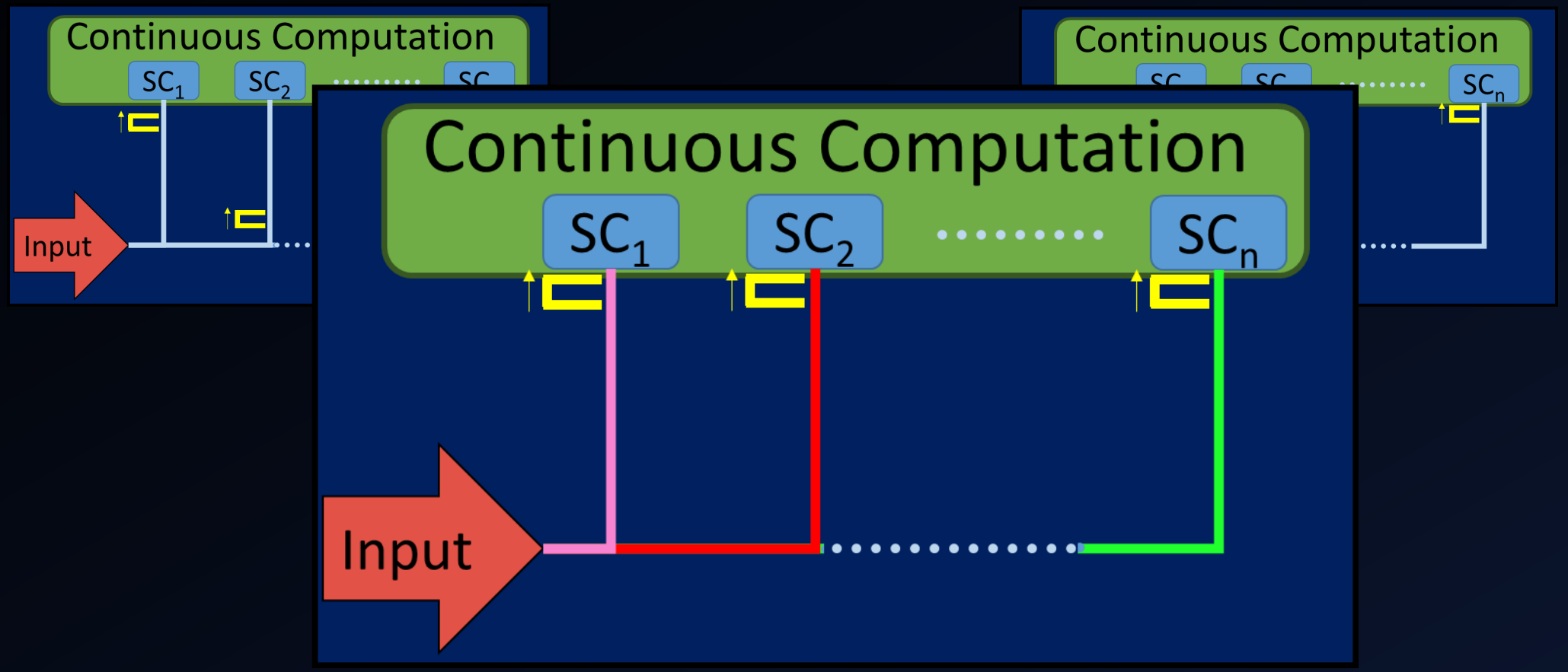

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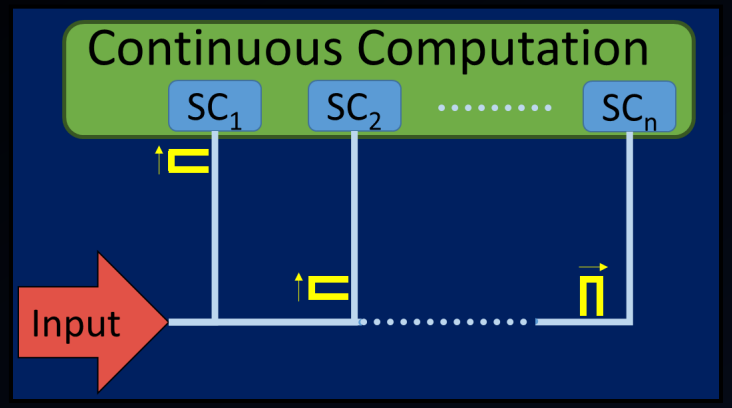
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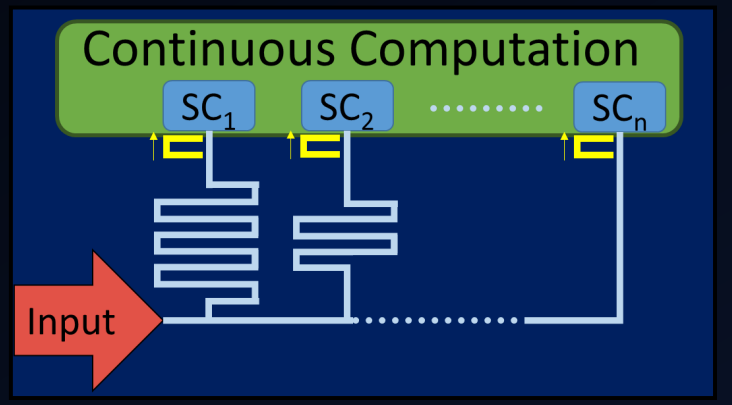
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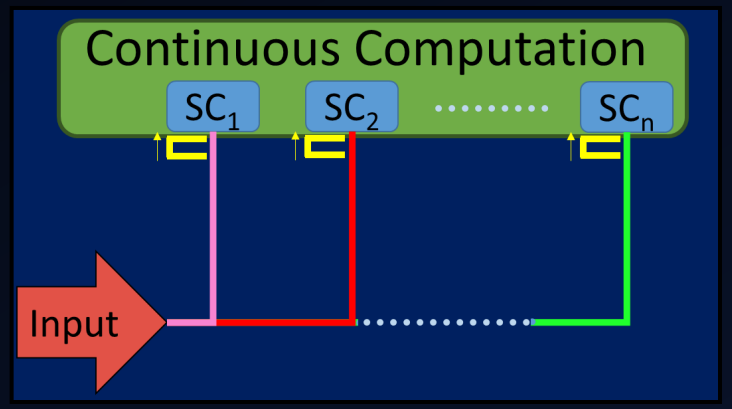
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Background

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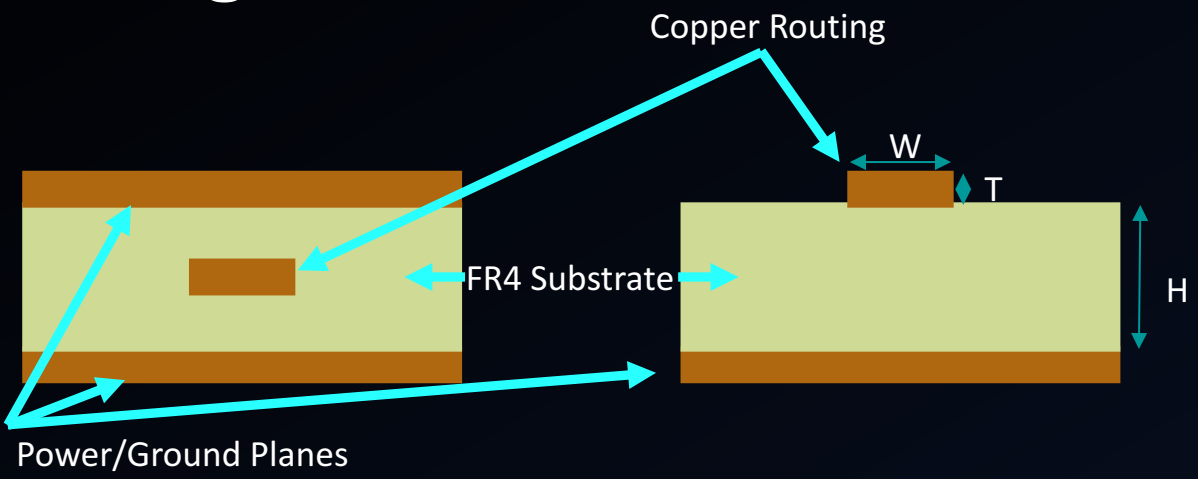

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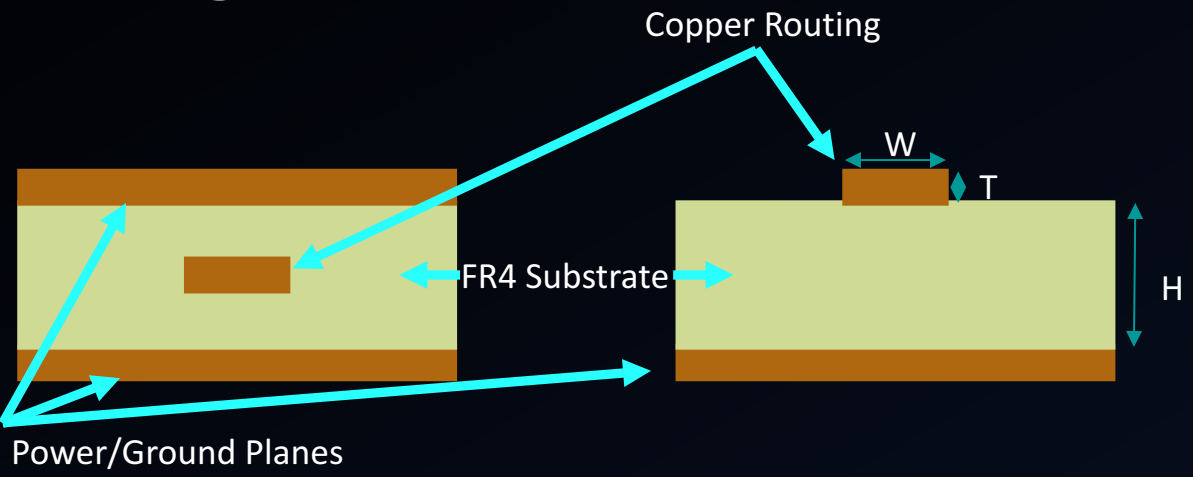

$$V_s = \frac{c}{sqrt(dK_{eff})}$$

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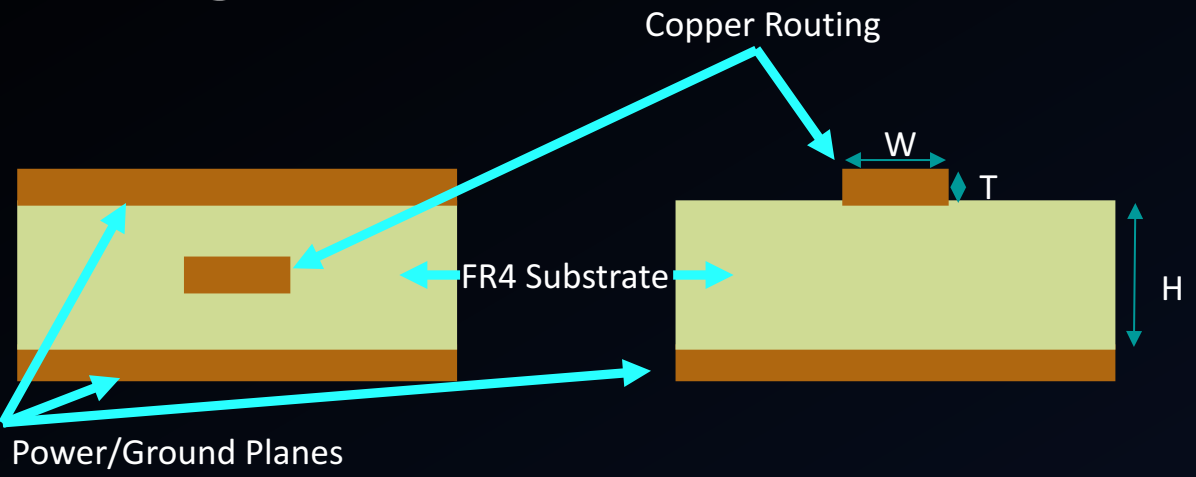

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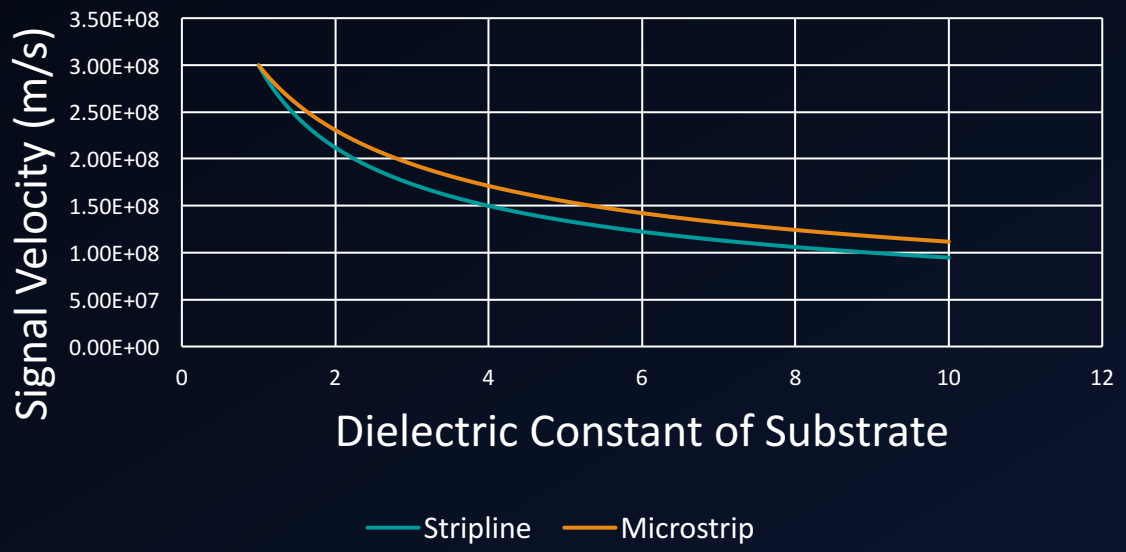
Signal Velocity for Stripline vs Microstrip for W/H = 2



Methods

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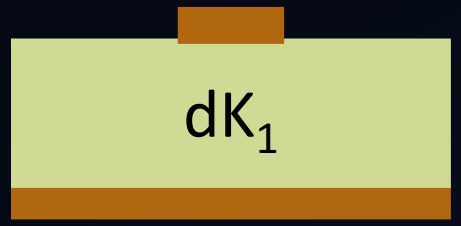
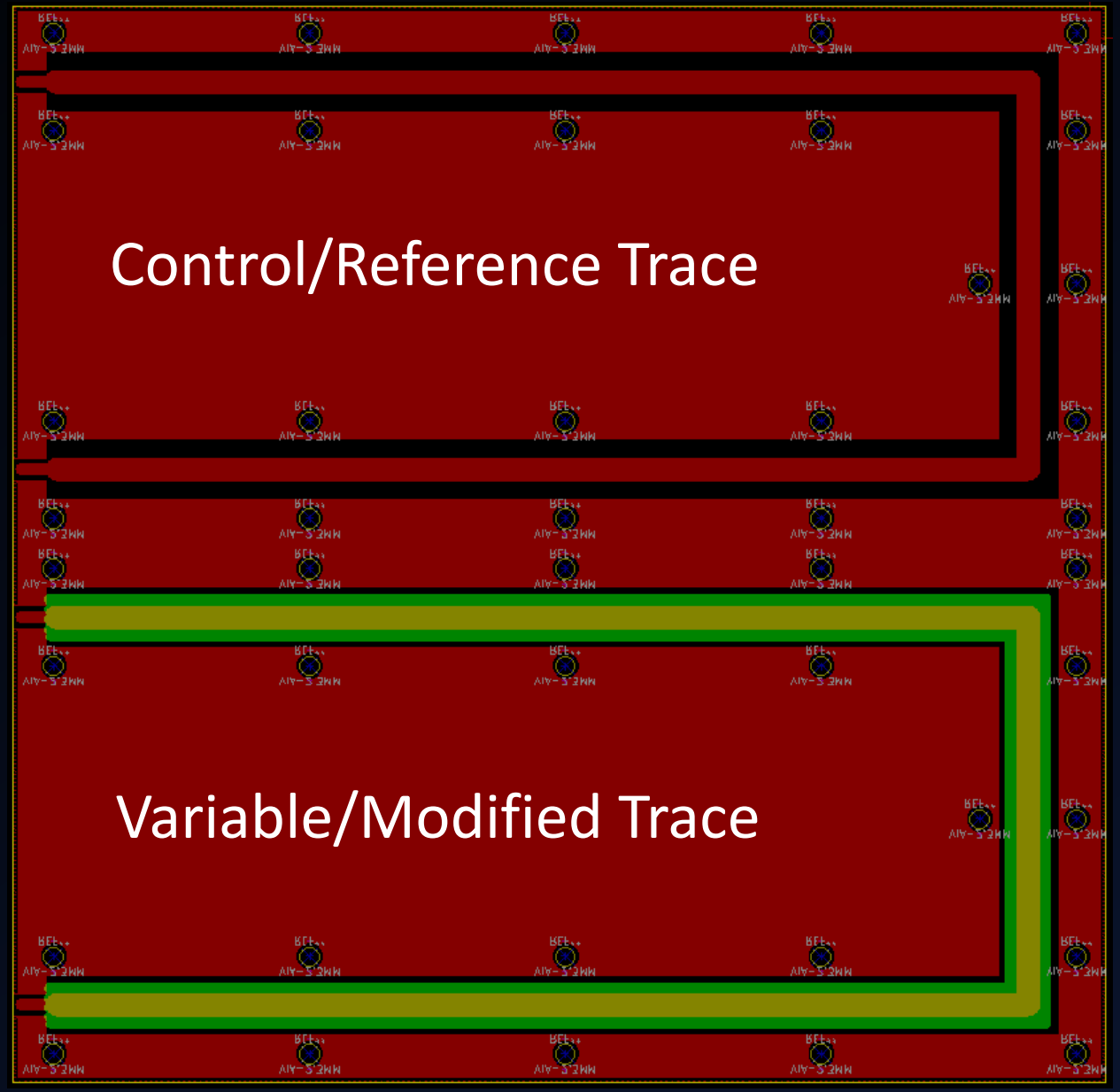


$$V_{s1} = \frac{c}{sqrt(dK_{eff1})}$$

$$V_{s2} = \frac{c}{sqrt(dK_{eff2})}$$

Methods



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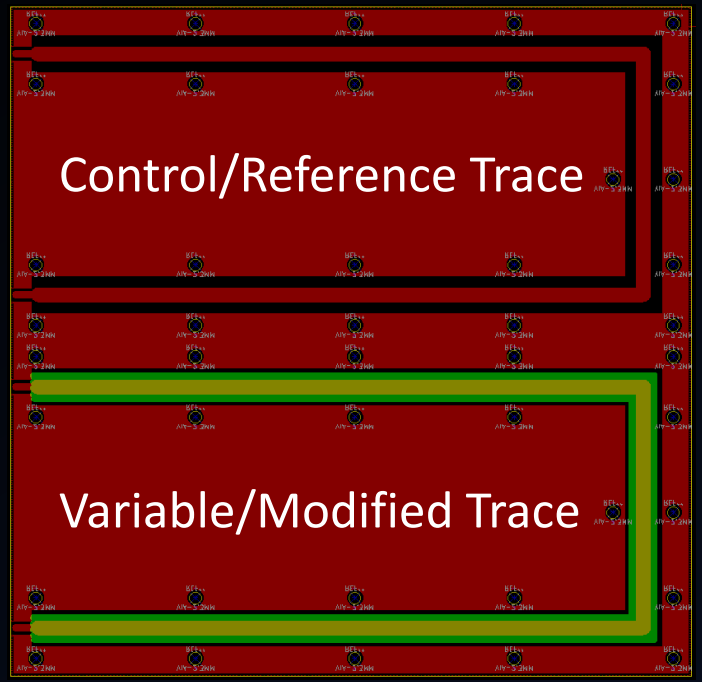

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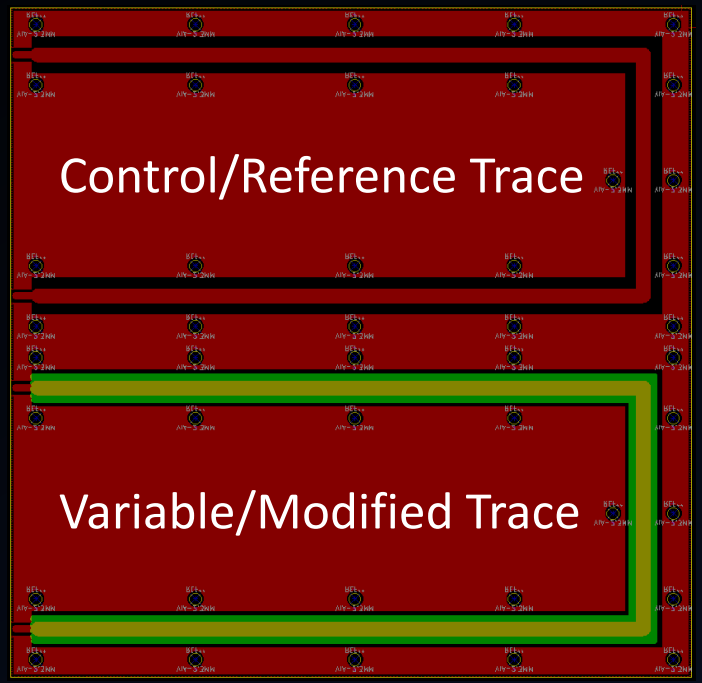
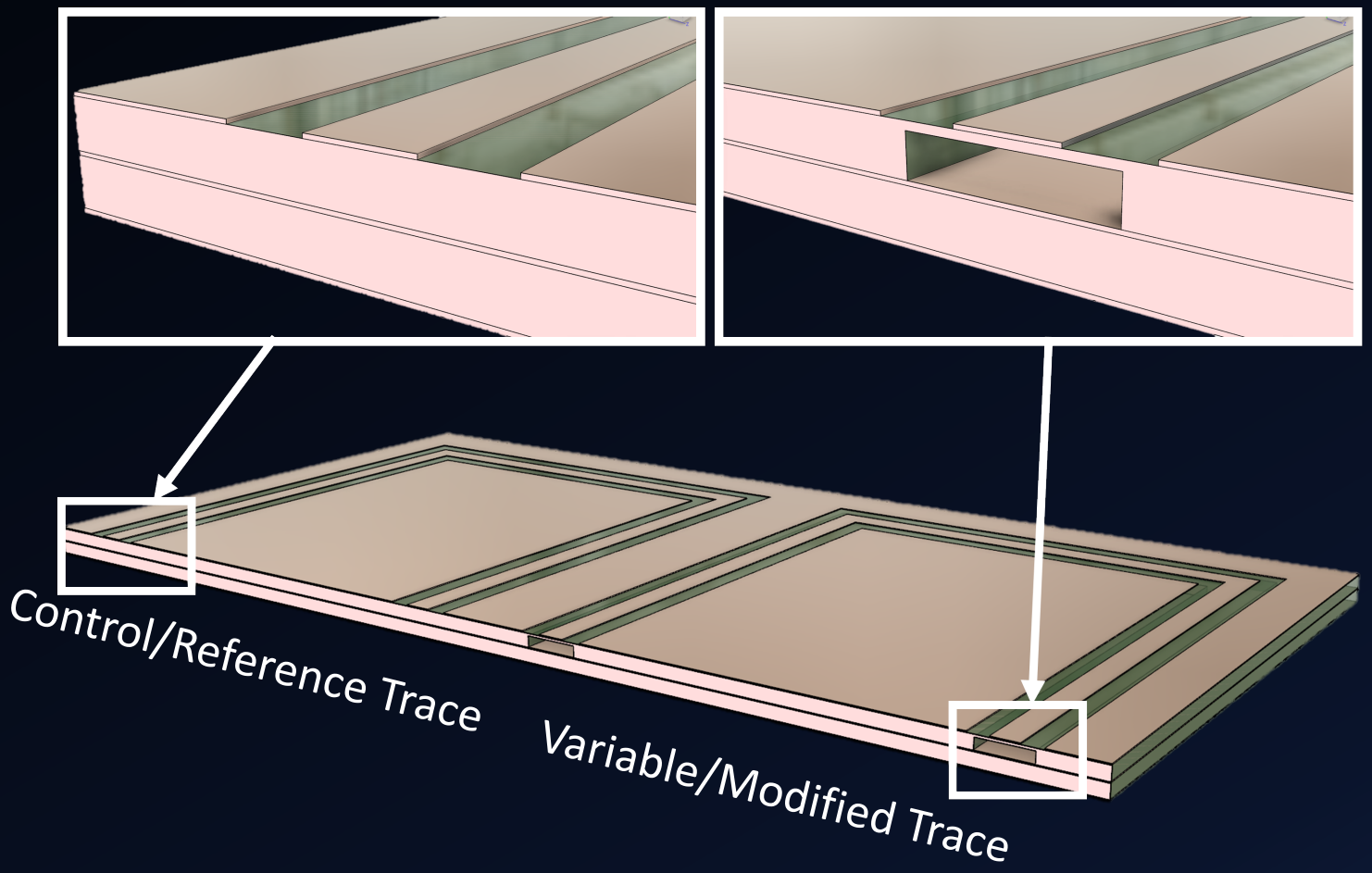

Control/Reference Trace
Variable/Modified Trace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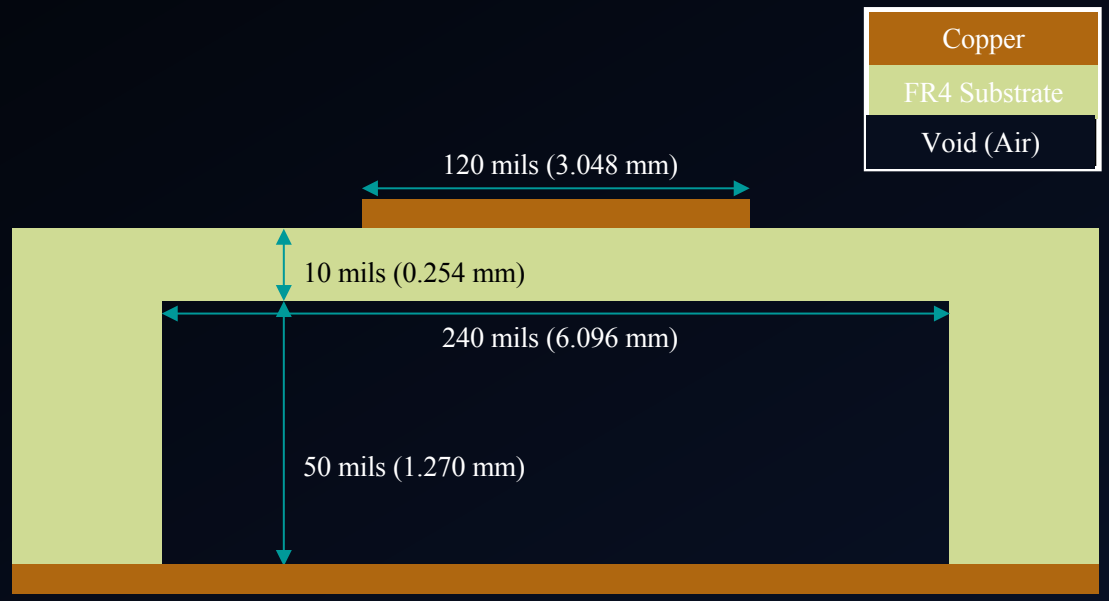
Copper
FR4 Substrate
Void (Air)
120 mils (3.048 mm)
10 mils (0.254 mm)
240 mils (6.096 mm)
50 mils (1.270 mm)

Methods

Tested Materials

Considerations:

- Range
- Ease of Application
- Safety
- Mechanical Integrity

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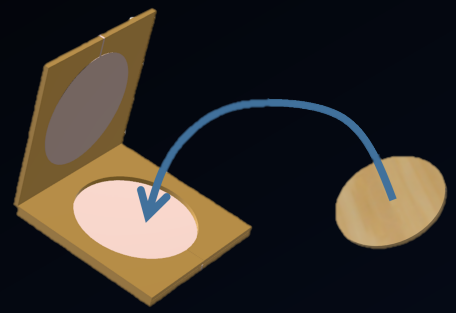
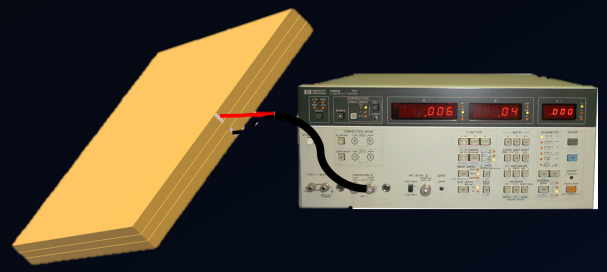
Material	Reported dK
FR4	4.2
Air	1
PVDF (Polyvinylidene Fluoride)	8.4
Barium Titanate	2000
Water*	80.4
Silicon Nitride	7
Titanium Dioxide	10
Mica	7

Methods





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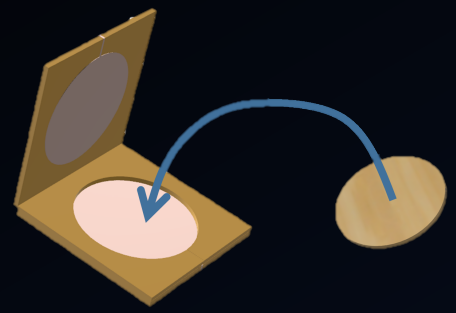

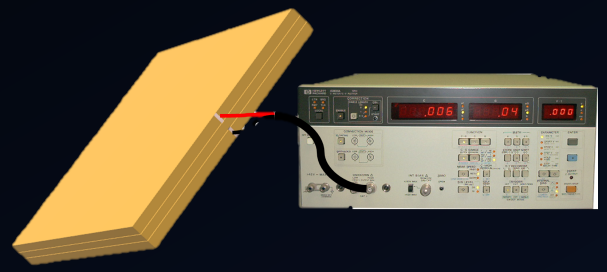

Material	Capacitance (pf) / k	Reported k	Notes
FR4	20.7 / 4.17	4.2	Reference material
Air	7.9 / 1.59	1	Lowest dielectric
PVDF (polyvinylidene difluoride)	26.6 / 5.36	8.4	3 layers of film
Barium Titanate	48.5 / 9.77	2000	Dried but not sintered
Water*	63.0 / 12.69	80.4	Water & cornstarch mixture
Silicon Nitride	15.3 / 3.08	7	Research grade
Titanium Dioxide	19.0 / 3.83	10	Consumer grade
Mica	11.5 / 2.32	7	Consumer grade

Experimentation

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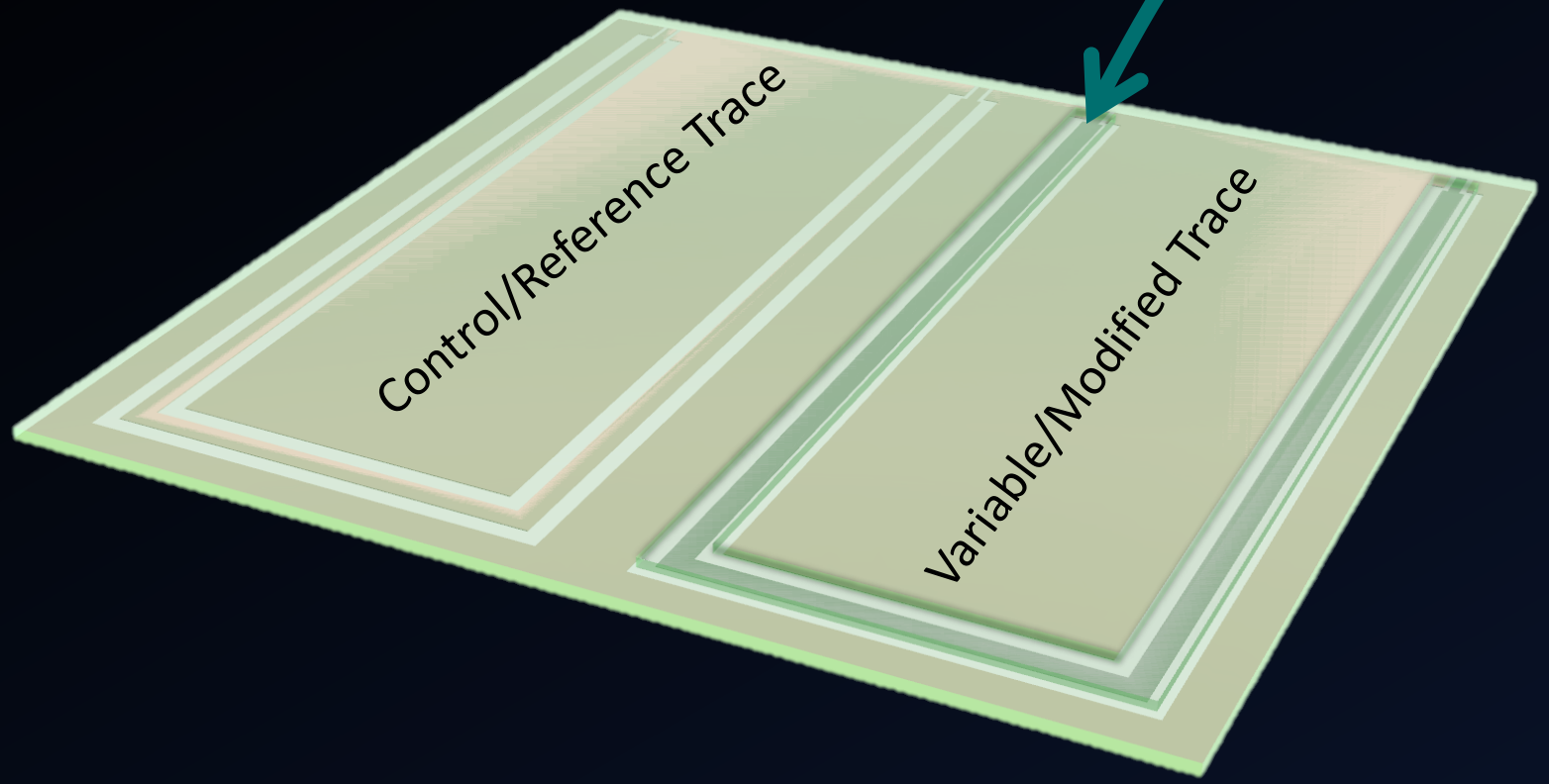

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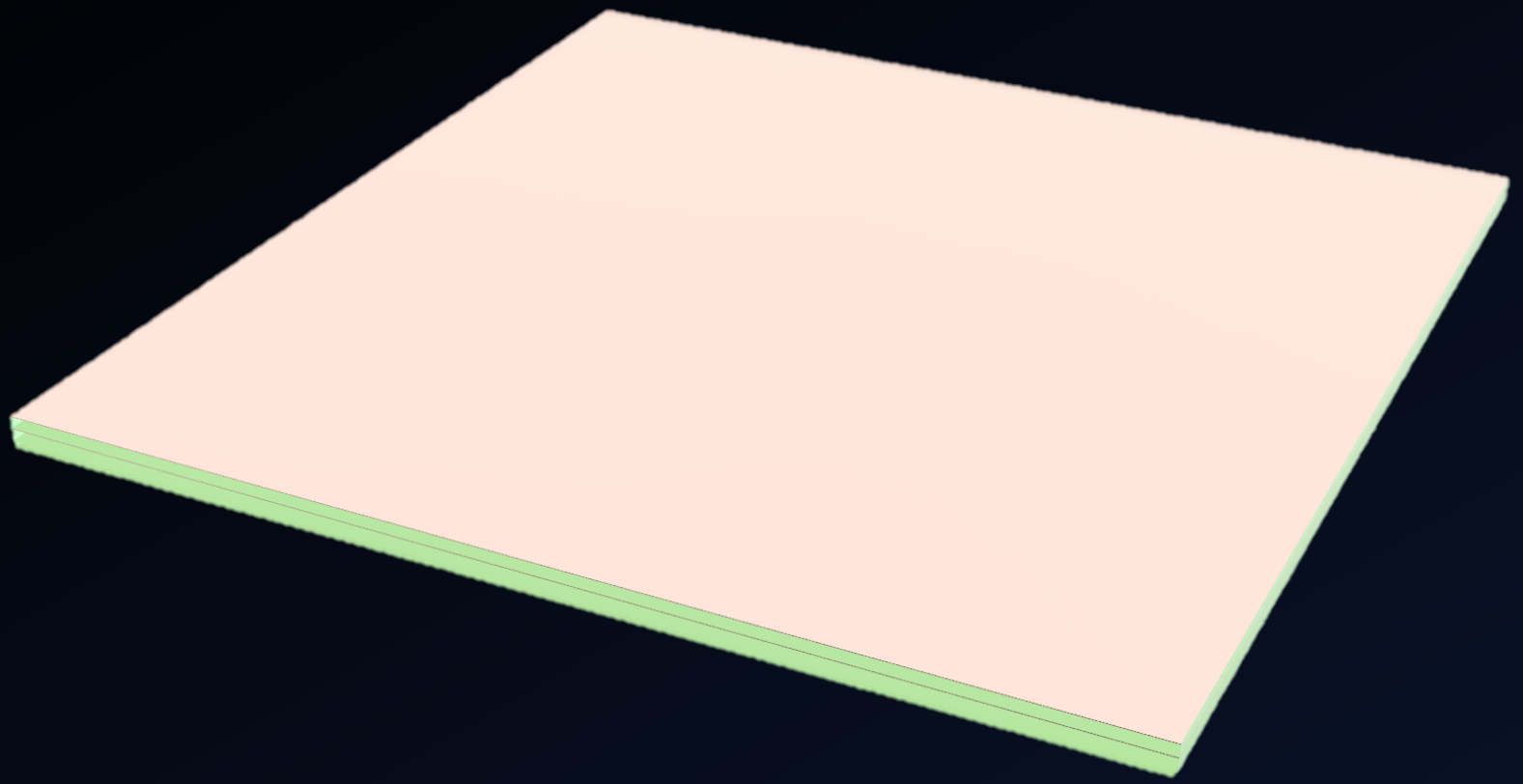

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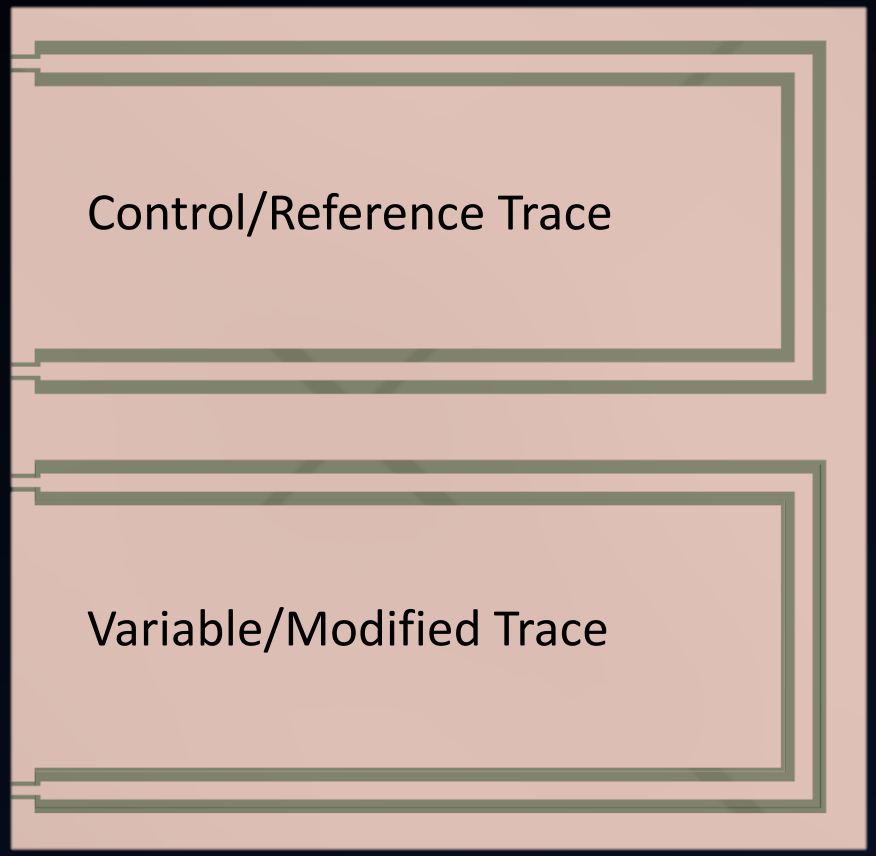

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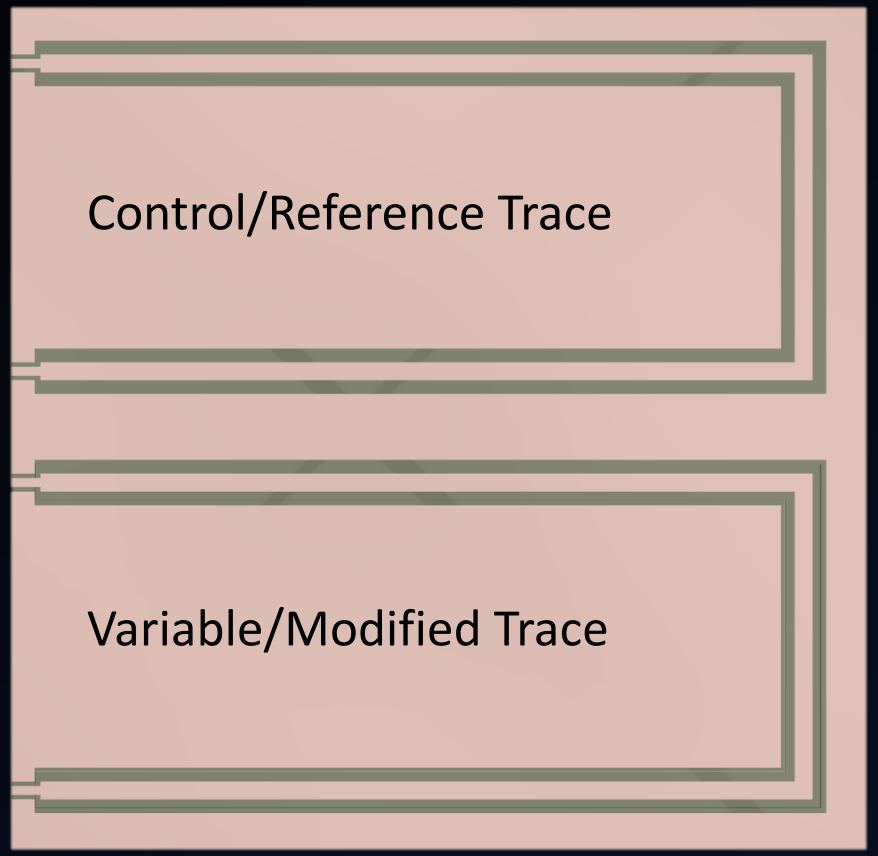

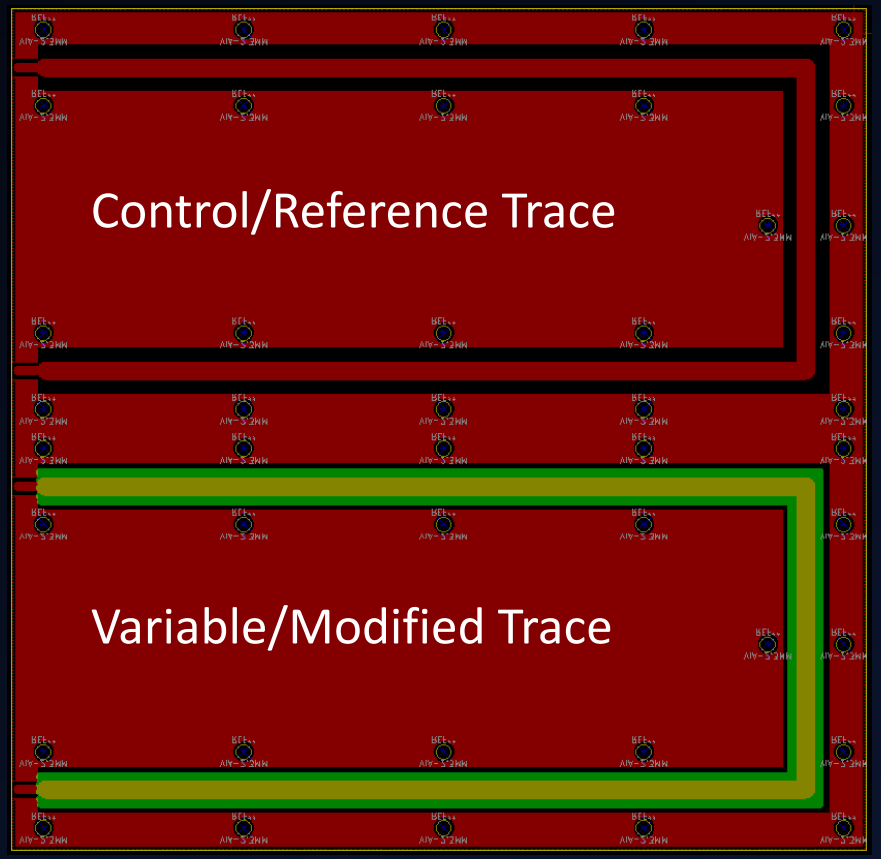

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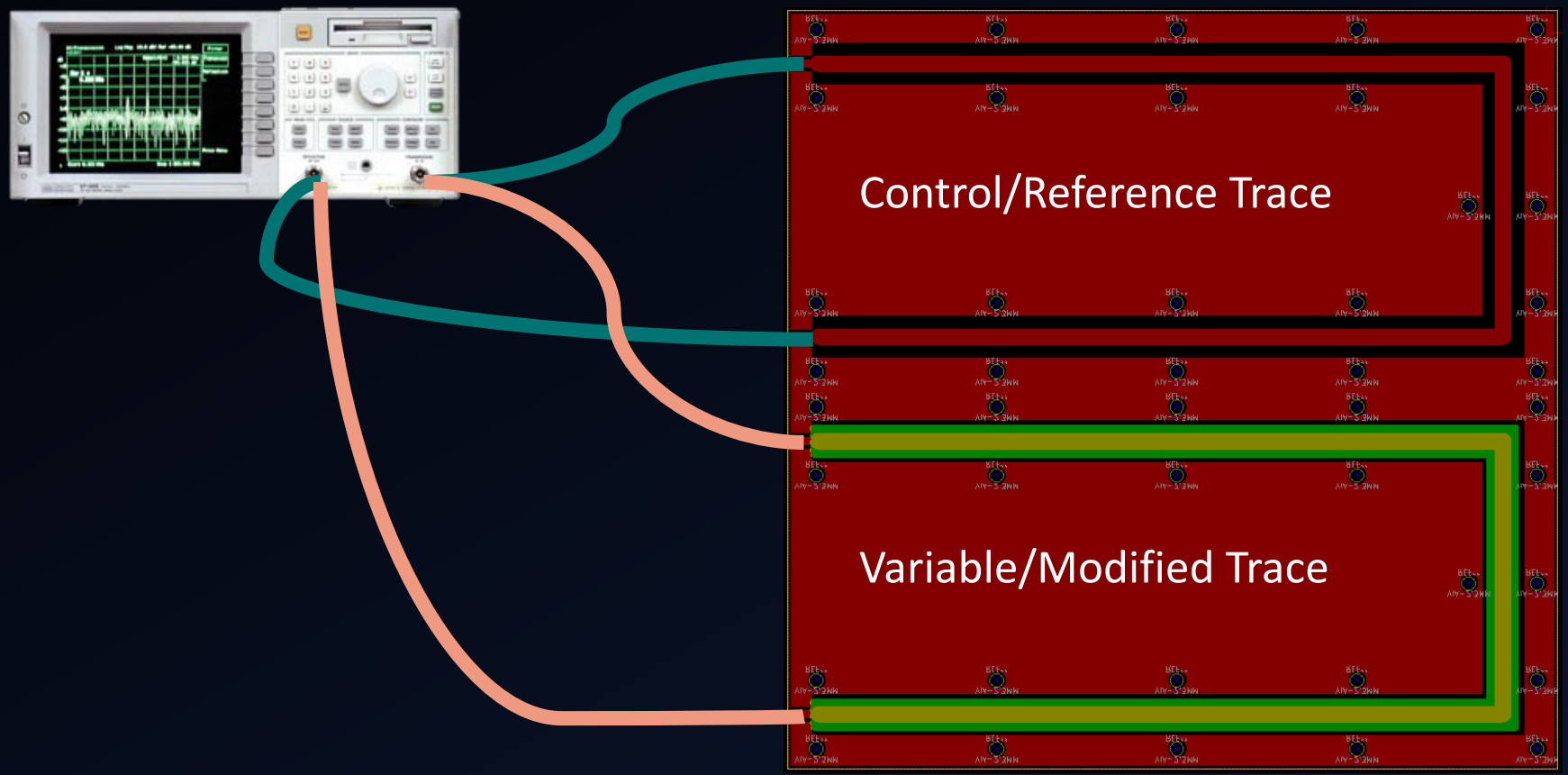

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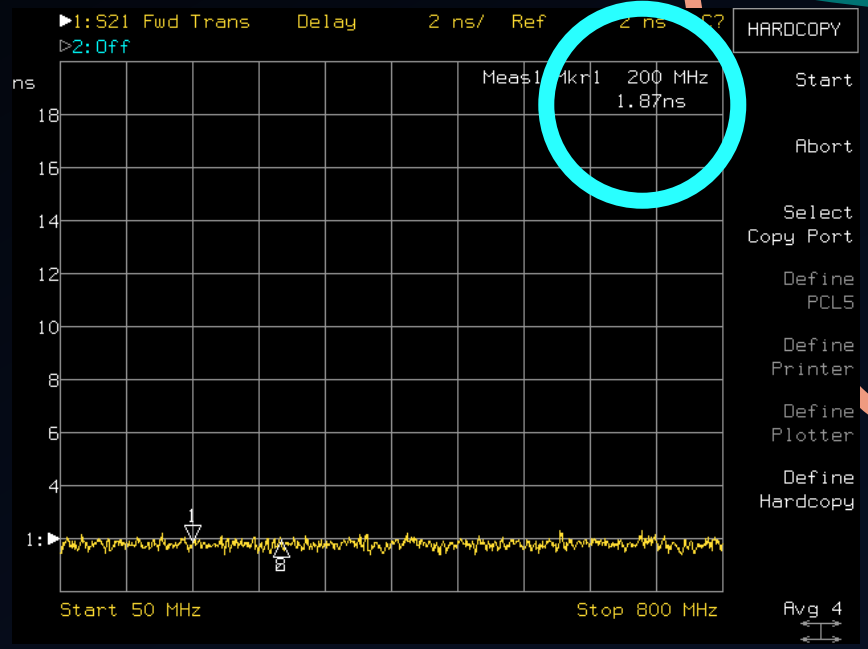

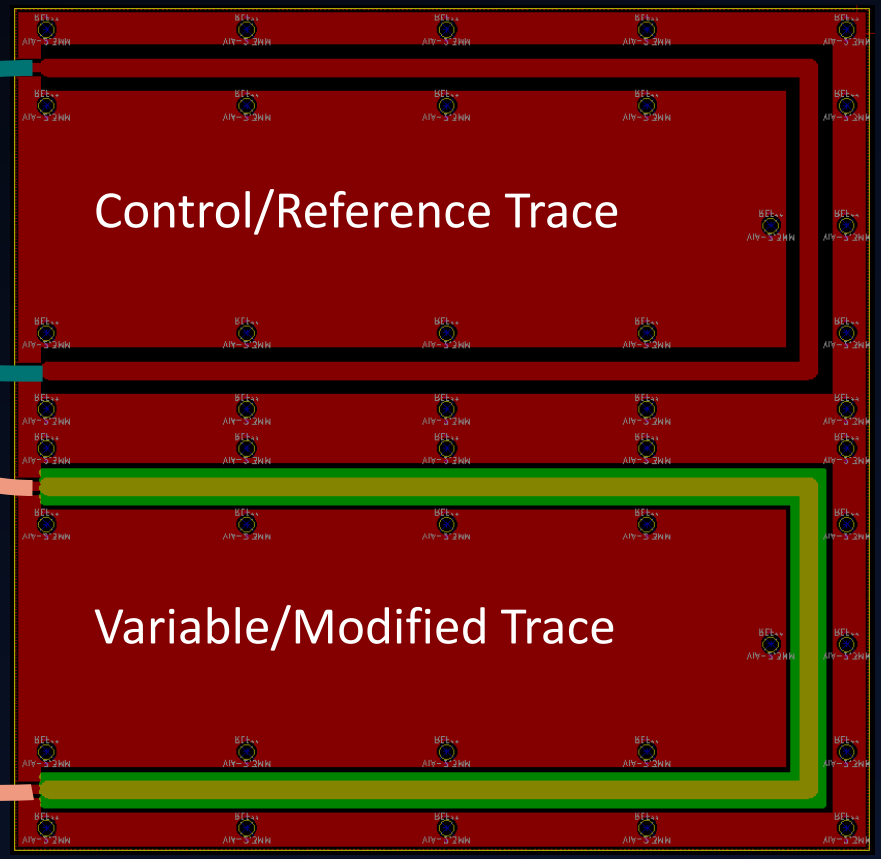

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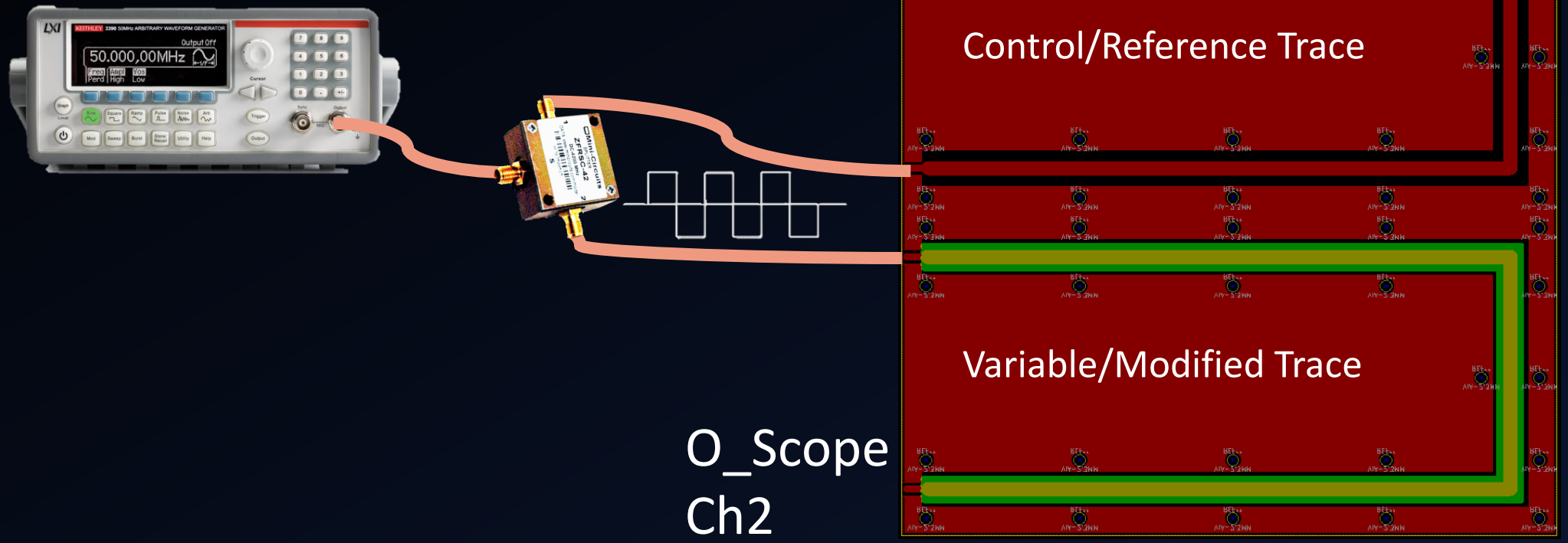

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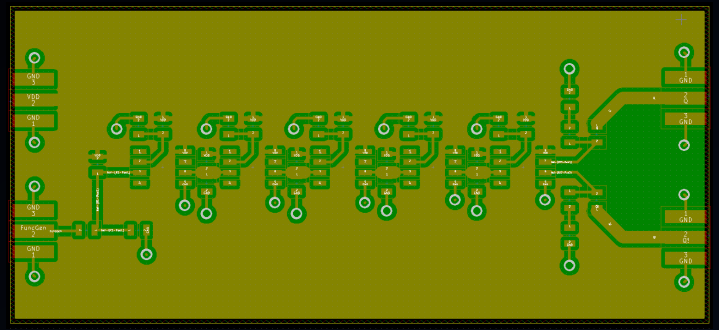
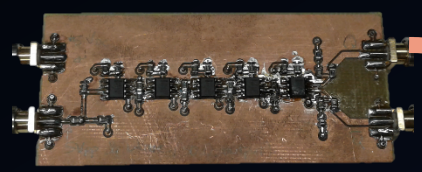
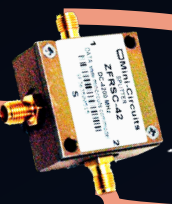
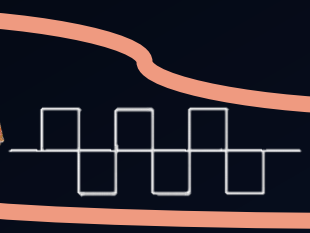
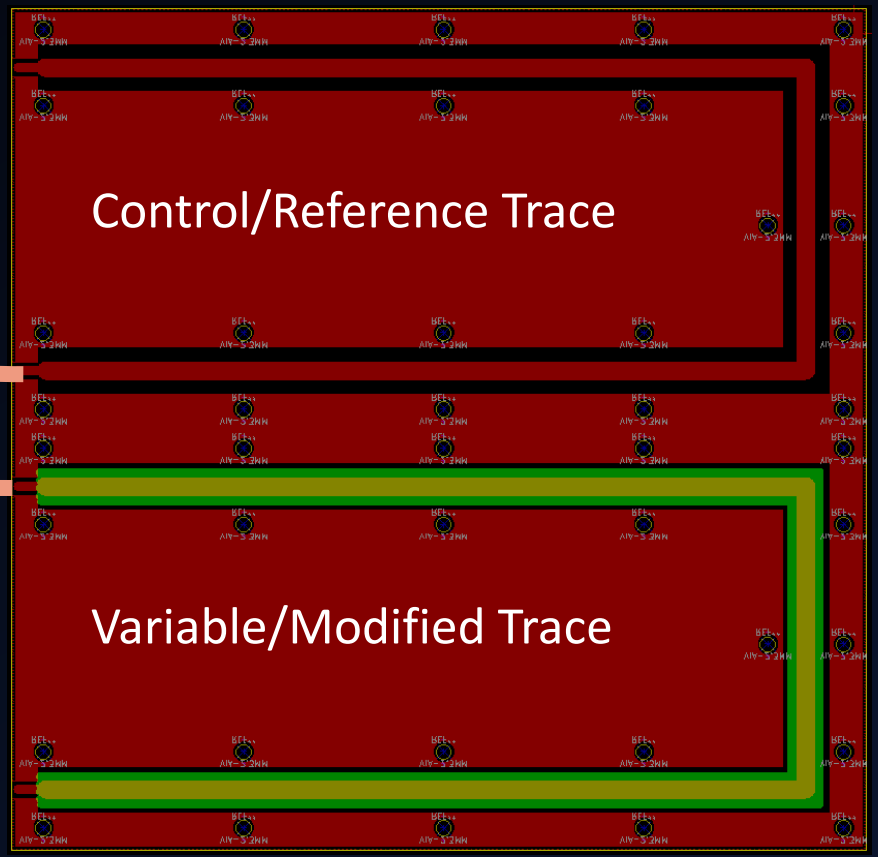






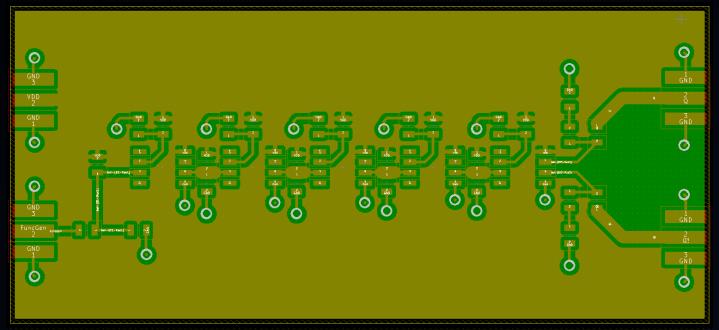


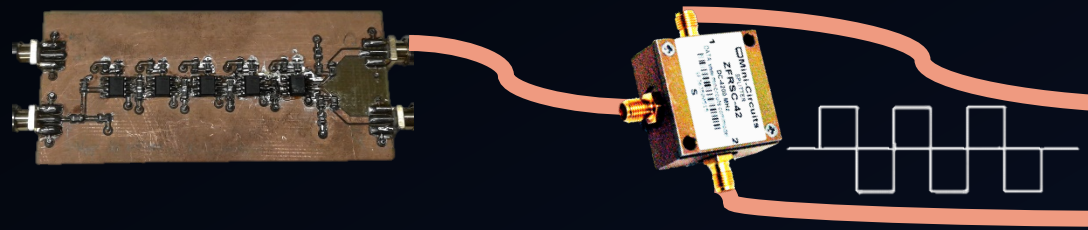
O_Scope Ch1



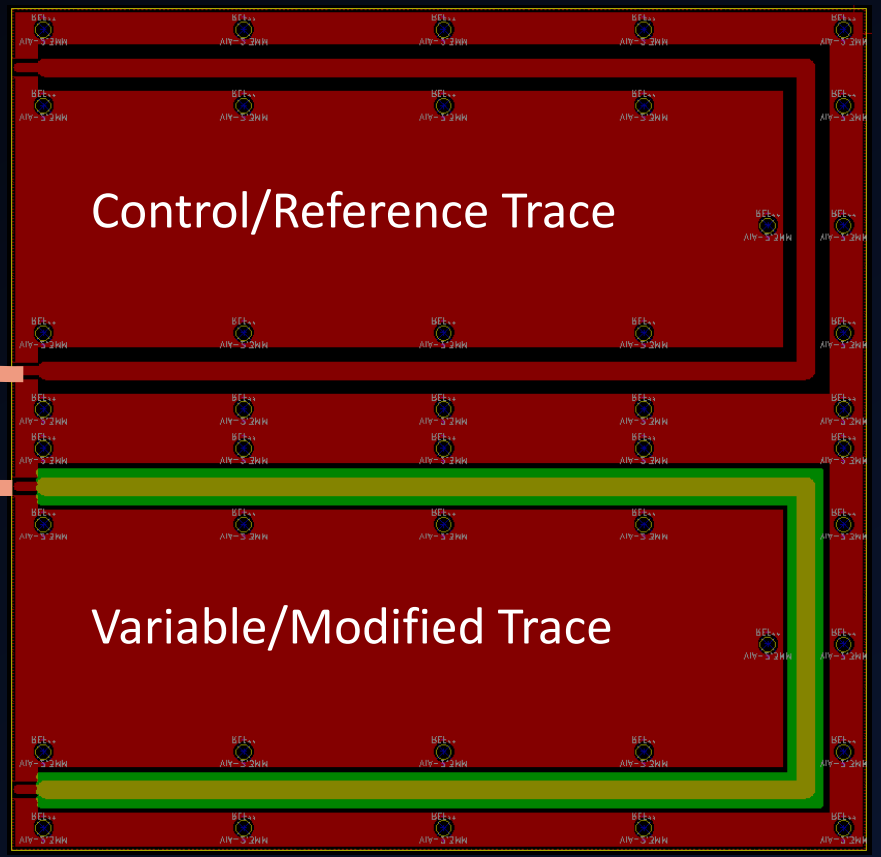
O_Scope Ch2

Experimentation

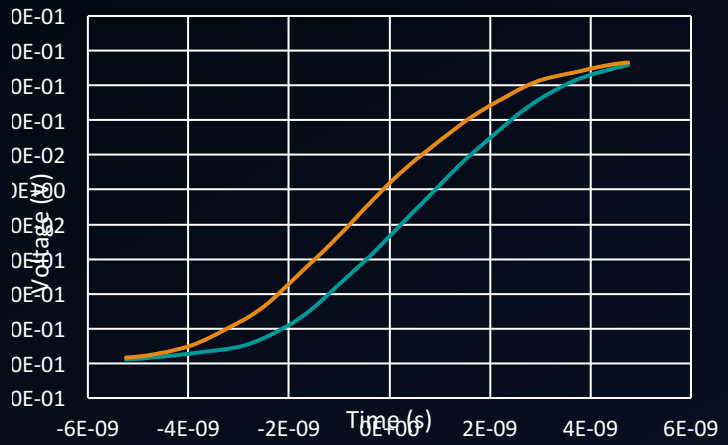




O_Scope Ch1



O_Scope Ch2



Results

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	Measured Tp (ns)	Calculated Tp (ns)	% Error	Measured Td (ns)	Calculated Td (ns)	% Error
FR4	1.87	1.95	4.21	-	-	-
Air	1.21	1.30	6.77	-0.66	-0.65	0.88
PVDF	1.69	2.19	22.79	-0.18	0.24	176.05
Heated BaTiO3	2.30	2.90	20.78	0.43	0.95	54.79
Water*	2.90	3.29	11.91	1.03	1.34	23.13
Silicon Nitride	1.63	1.71	4.51	-0.24	-0.25	2.10
TiO2	1.79	1.88	4.71	-0.08	-0.07	8.52
Mica	1.49	1.51	1.34	-0.38	-0.44	13.89

Results

	|VNA Delay (ns)|	|Oscope Delay (ns)|	% Error
FR4	-	-	-
Air	0.66	0.51	23.11
PVDF	0.18	0.12	31.94
Heated BaTiO3	0.43	0.35	18.61
Water*	1.03	0.94	8.98
Silicon Nitride	0.24	0.16	32.29
TiO2	0.08	0.06	31.25
Mica	0.38	0.32	16.45

Results

	Measured Velocity (10^8m/s)	Calculated Velocity (10^8m/s)	% Error
FR4	1.75	1.68	4.39
Air	2.71	2.53	7.27
PVDF	1.94	1.50	29.52
Heated BaTiO3	1.43	1.13	26.23
Water*	1.13	1.00	13.52
Silicon Nitride	2.01	1.92	4.72
TiO2	1.83	1.75	4.94
Mica	2.20	2.17	1.40

Conclusion

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- Not all measured dielectric constants matched with their reported values, indicating a need for further work in measurement techniques. Measured results agree with calculations with the exception of PVDF.
- Results show that **signal velocities between 4.45 and 10.67 in/ns (11.31 and 27.11 cm/ns) can be obtained.**
- These numbers are promising for increasing the efficiency of PCB area utilization and with further work, this research may find itself within standard PCB processing steps.