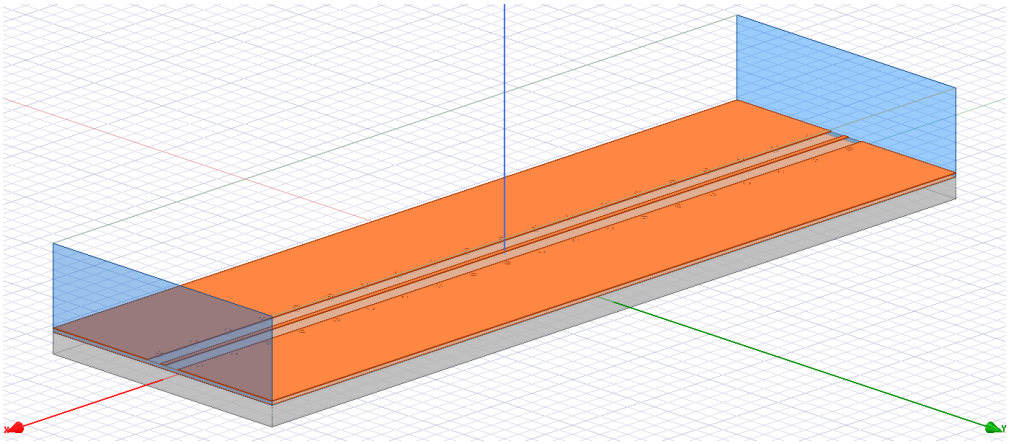
Microstrip TDR Analysis of OSH Park's 4-Layer Stackup with HFSS

Evangelos Mastrogiannis – 2019-07-08



This report analyzes a simple microstrip on OSH Park's 4-layer stackup using HFSS (high-frequency structure simulator); part of Ansys Electromagnetics Suite. Time-domain reflectometry, TDR, impedance plots are used to compare varying microstrip widths. In addition, the FR408 prepreg's thickness and relative permittivity specifications from OSH Park's stackup and FR408 datasheet are compared to Harmon Instruments' measurements. Unmasked and masked board versions are also compared.

HFSS uses the inverse fast Fourier transform, IFFT, to simulate a step response for time-domain reflectometry, TDR. The rise time of the step response is inversely related to the maximum evaluated frequency in the frequency sweep; E.g. a maximum of 10 GHz corresponds to 100 ps step response. TDR resolution increases with decreasing step response rise time.

HFSS's manual defines the TDR impedance by:

$$TDRZ(t) = Z_{ref}\frac{\left(1 + IFFT(S_{11} \cdot input)\right)}{\left(1 - IFFT(S_{11} \cdot input)\right)}$$

OSH Park 4 Layer Stackup (layers 1 & 2):

1 mil (0.0254 mm)	Solder mask
1.4 mil (0.0356 mm)	1 oz copper
6.7 mil (0.1702 mm)	FR408 prepreg (Er = 3.66, Loss Tan. = 0.012 @ 1GHz)
0.7 mil (0.0178 mm)	0.5 oz copper
47 mil (1.1938 mm)	FR408 core

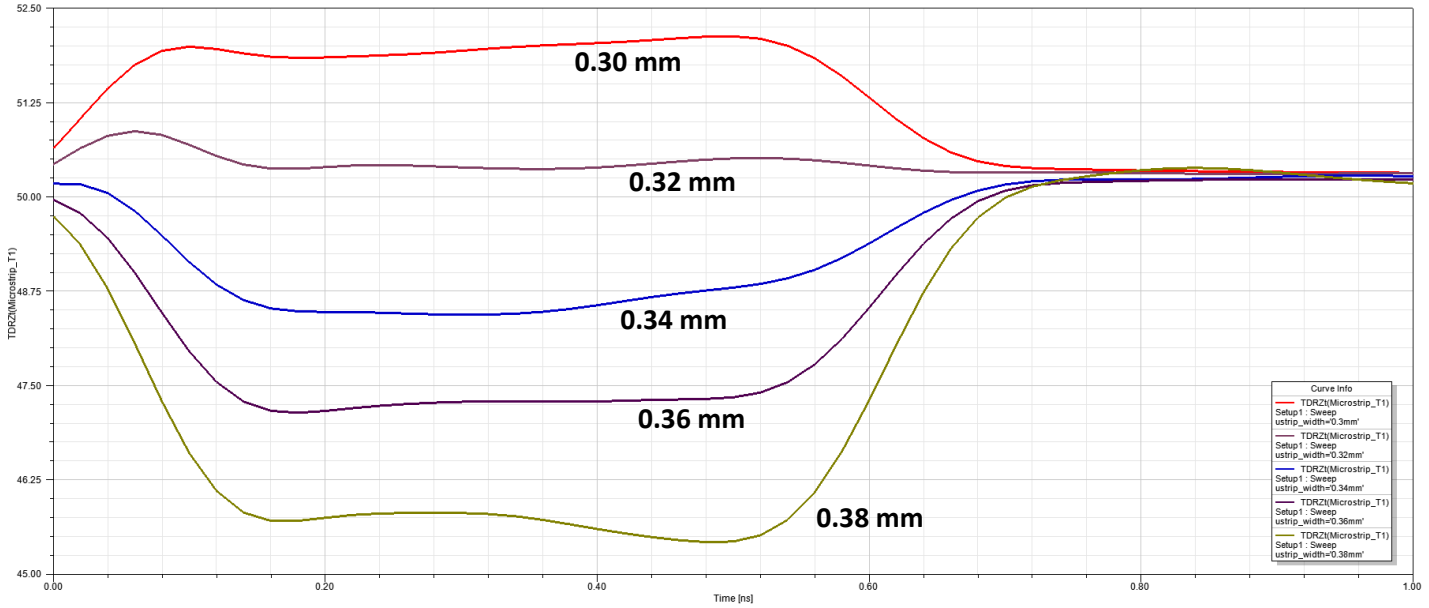
Microstrip Board Dimensions:

50 mm	PCB Length
16 mm	PCB Width
5x prepreg	Microstrip Gap
0.35 mm / 5 mm x 10	Via Diameter / Spacing

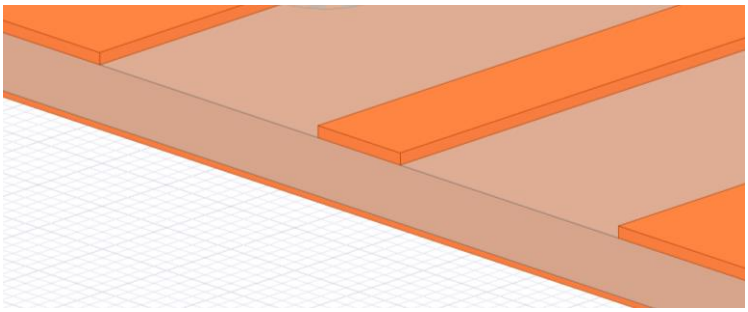
HFSS Solution and Sweep Setup:

Terminal with Wave Ports	Solution Type
1 GHz	Solution Frequency
40	Max # of Passes
0.01	Maximum Delta S
1%	Maximum Delta Zo
Interpolating Linear Step	Sweep Type
100 MHz / 10 GHz / 25 MHz	Sweep Start, End, Step
1000	Sweep Max Solutions

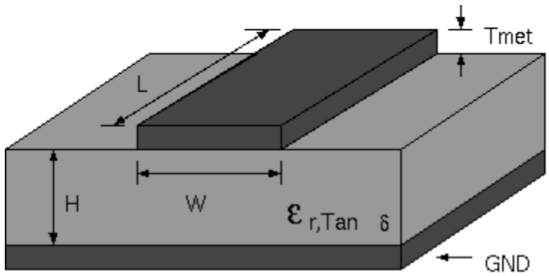
Unmasked Microstrip TDR Plot (parametric sweep of microstrip width w/ datasheet spec):



0.17 mm	FR408 prepreg (Er = 3.66)
0.32 mm	50 Ω Microstrip width



Online Microstrip Calculator

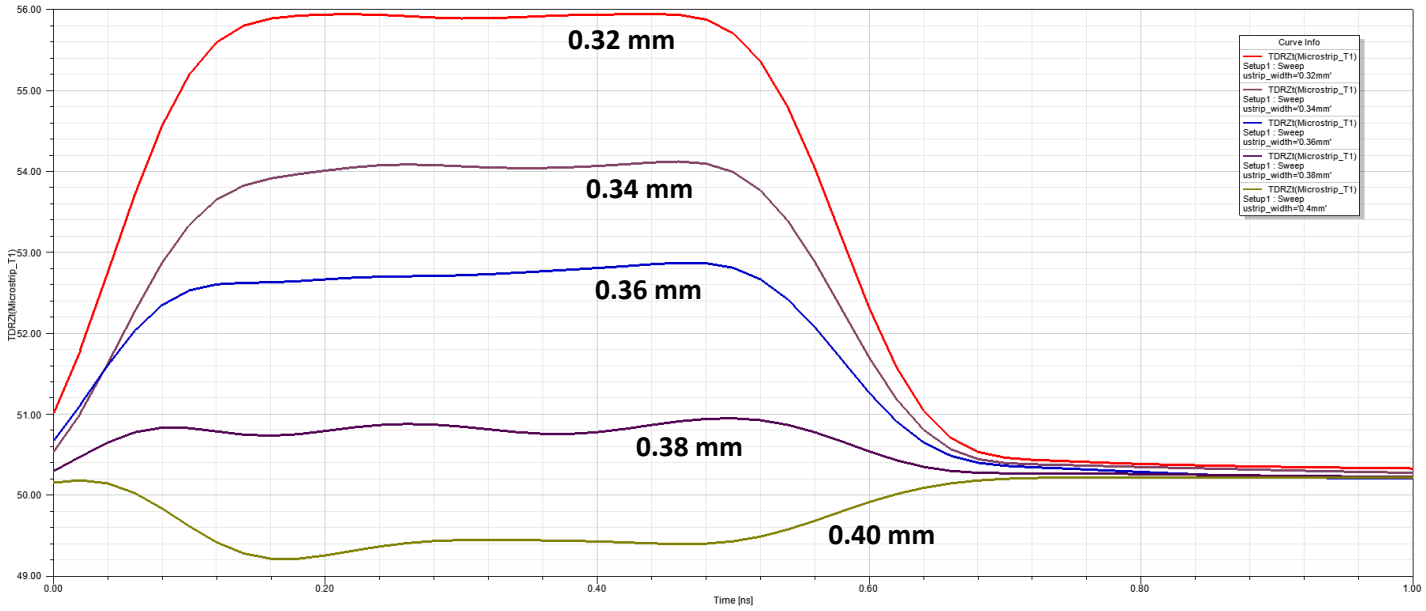


Metal width (W)	0.32	mm	calc
Trace length (L)	50	mm	calc
Metal thickness (Tmet)	0.0356	mm	
Metal resistivity (RHO)	1.72e-08	Ohm - m	
Metal surface roughness (RGH)	0.001	mil -rms	
Substrate thickness (H)	0.1702	mm	calc
Substrate relative dielectric constant (Er)	3.66		calc
Substrate loss tangent (tand)	0.012		
Frequency	1	GHz	

Analyze Reset

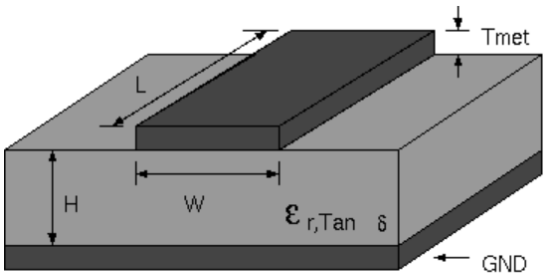
Characteristic Impedance	51.8818	[ohms]
Electrical Length	99.0153	[degrees]

Unmasked Microstrip TDR Plot (parametric sweep of microstrip width w/ Harmon Instruments spec):



0.19 mm	FR408 prepreg (Er = 3.30)
0.39 mm	50 Ω Microstrip width

Online Microstrip Calculator

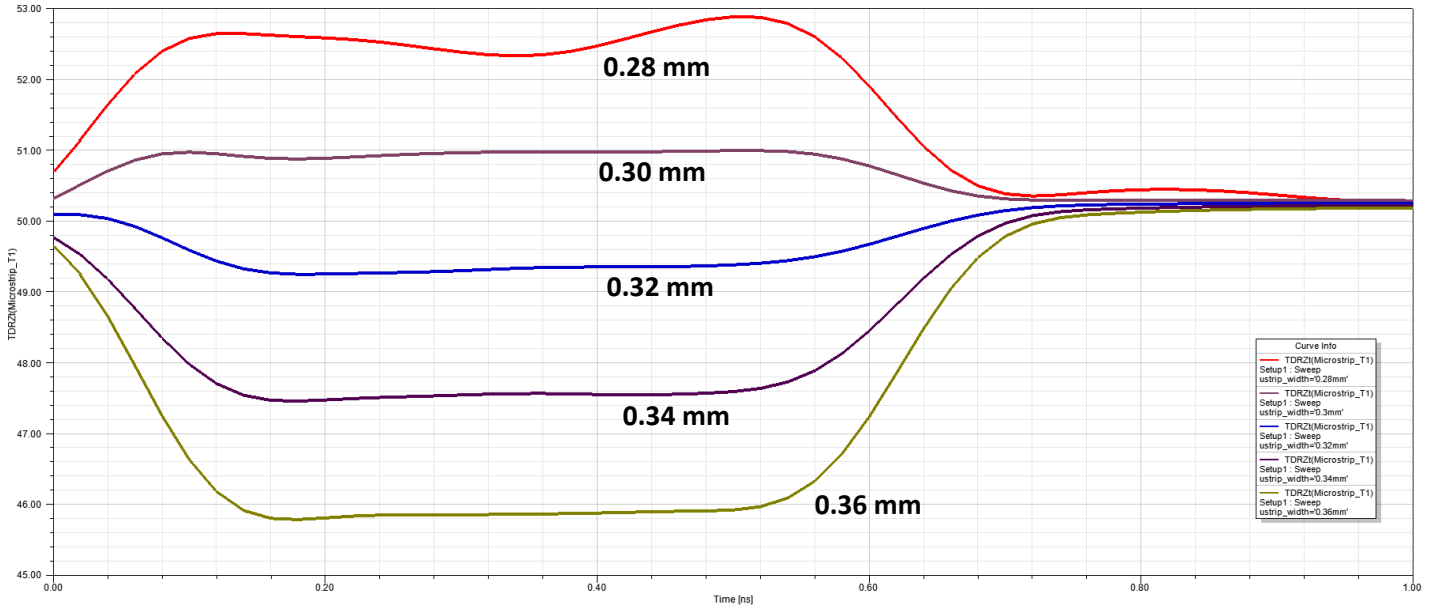


Metal width (W)	0.39	mm	calc
Trace length (L)	50	mm	calc
Metal thickness (Tmet)	0.0356	mm	
Metal resistivity (RHO)	1.72e-08	Ohm - m	
Metal surface roughness (RGH)	0.001	mil -rms	
Substrate thickness (H)	0.1905	mm	calc
Substrate relative dielectric constant (Er)	3.3		calc
Substrate loss tangent (tand)	0.012		
Frequency	1	GHz	

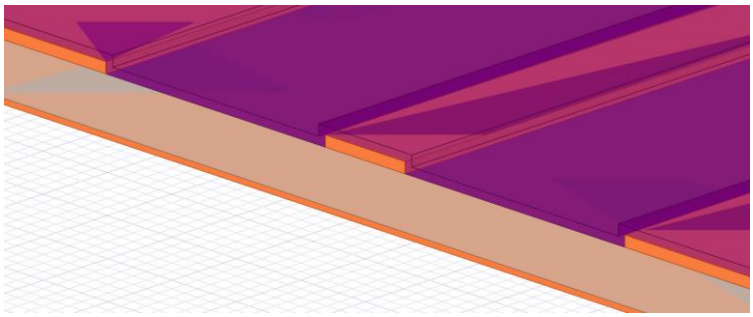
Analyze Reset

Characteristic Impedance	51.8966	[ohms]
Electrical Length	95.2647	[degrees]

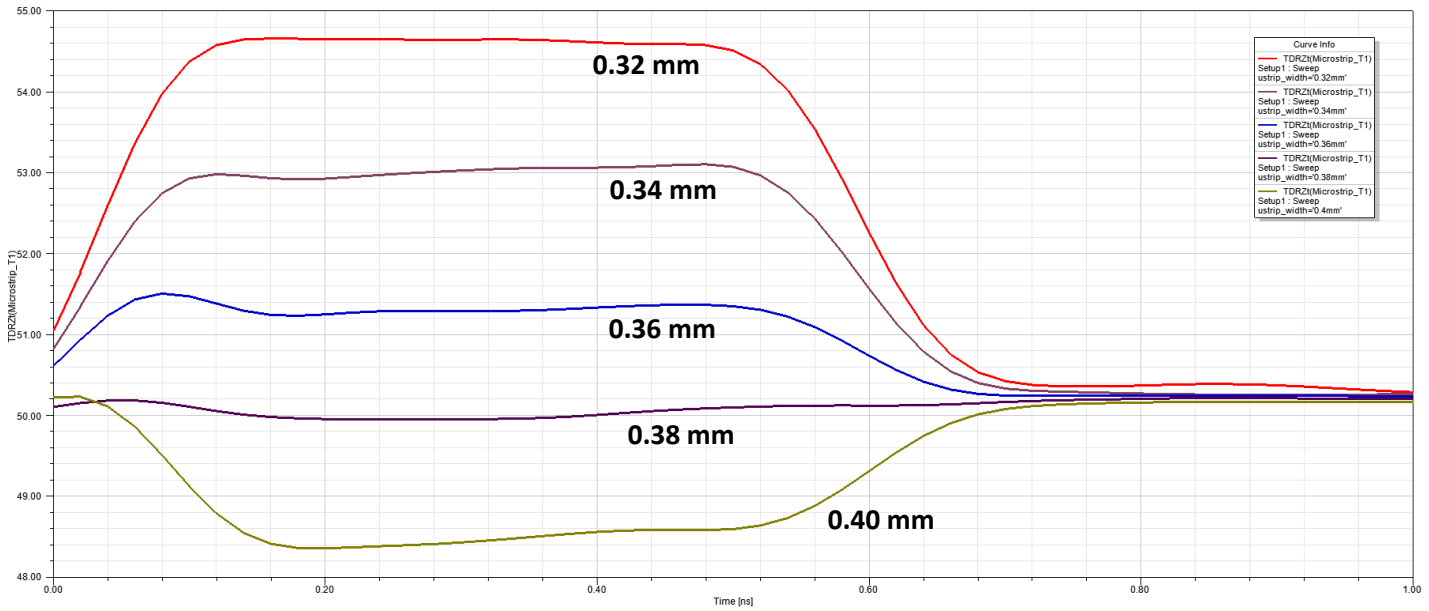
Masked Microstrip TDR Plot (parametric sweep of microstrip width w/ datasheet spec):



0.17 mm	FR408 prepreg (Er = 3.66)
0.31 mm	50 Ω Microstrip width

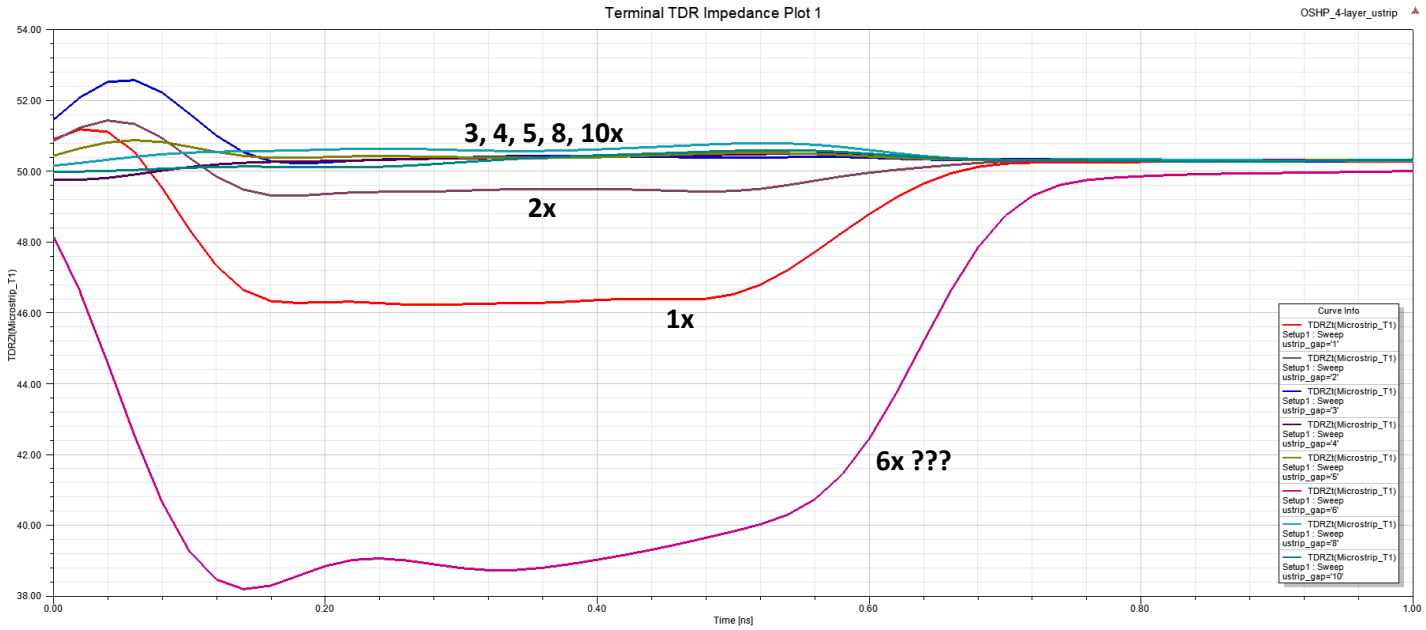


Masked Microstrip TDR Plot (parametric sweep of microstrip width w/ Harmon Instruments spec):



0.19 mm	FR408 prepreg (Er = 3.30)
0.38 mm	50 Ω Microstrip width

Unmasked Microstrip TDR Plot (parametric sweep of microstrip gap – multiple of prepreg height):



0.17 mm	FR408 prepreg (Er = 3.66)
0.32 mm	50 Ω Microstrip width
≥ 3x prepreg	**Microstrip Gap**

The plot above; parametric sweep of the microstrip gap, shows at what relative gap width the microstrip begins to act like a conductor-backed coplanar waveguide, CBCPW. Since only the gap is decreasing the microstrip becomes capacitive which lowers the impedance. The plot shows that a microstrip's impedance with a relative gap width of at least 3x doesn't have any effects from the coplanar ground.

To be continued…