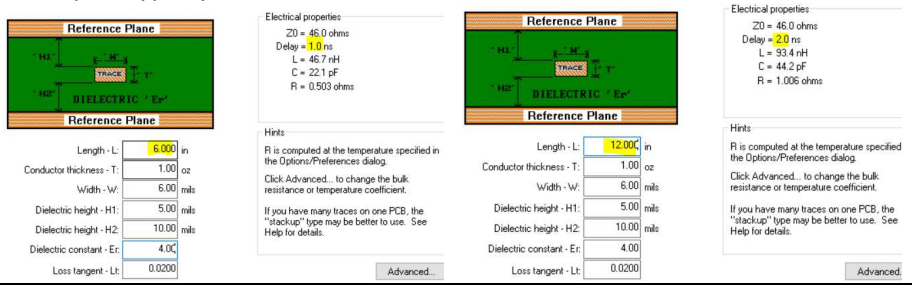
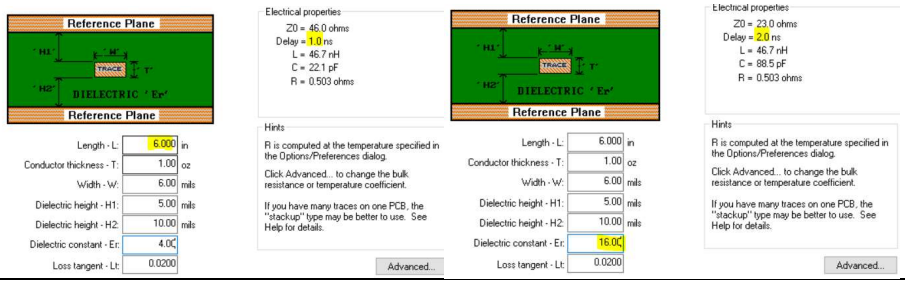
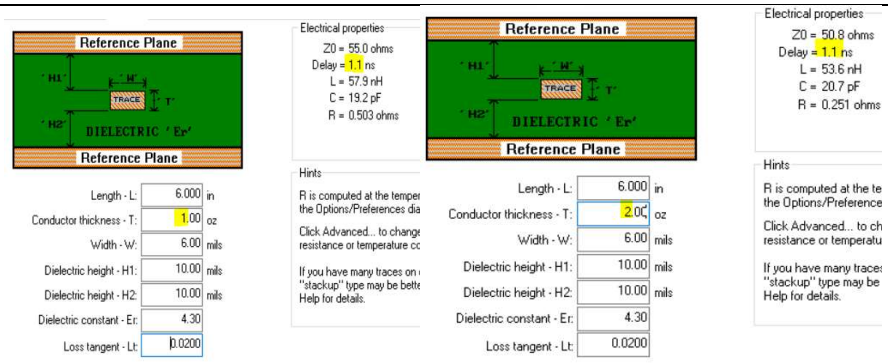
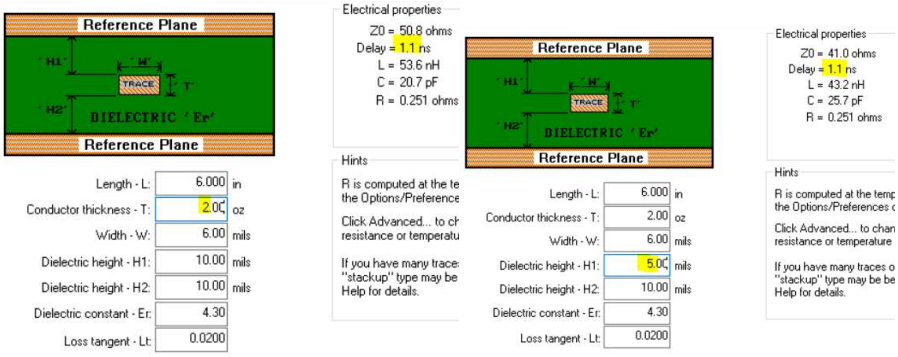
Goal: The goal of this lab is to get a hands-on experience to examine the parameters of a Transmission Line which decide the Time Delay and Characteristic Impedance. Tool used is Hyperlynx.

Plan: The plan is to theoretically anticipate the effects of variation in Transmission line parameters like Length, Width, Dielectric constant, Dielectric thickness etc. and verify the anticipated results in Hyperlynx 2D Solver.

1. **Problem set #1:**

What does TD depend on?

Transmission line	Parameter varied	Effect on TD ? Yes / No	Comments
Stripline	Length	Yes	Speed of the signal in an FR4 medium is 6 inch/ ns neglecting losses. Time taken to travel from Driver to Receiver through a Transmission Line is ratio of length of Transmission Line and signal speed. So, as length increases, the time taken by the signal to reach receiver from driver increases. Hence, the time delay seen at the far end of the Transmission line also increases and vice versa. When length of Transmission line is 6 inch keeping all other parameters constant, the delay for Dk = 4 is 1ns. When length is 12 inch and Dk=4, TD is 4ns as per Hyperlynx 2D solver. 
	Dielectric constant (Dk)	Yes	Speed of signal = speed of signal in vaccum / sqrt(Dk). Hence, there is an inverse relation between signal speed and Dk. For Dk=4, the signal speed = 12inch/ns/ sqrt(4)= 6inch /ns. For a Dk = 16, speed of signal = 3 inch/ns. Hence, for a constant length, as speed varies, the time taken by the taken to reach from one end to other end of transmission line also varies. 
	Conductor Thickness	No	Conductor thickness neither increases the length of Transmission line nor affects Dk. So, TD is independent of Conductor thickness.

			
	Dielectric Height	No	Dielectric Height neither increases the length of Transmission line nor affects Dk. So, TD is independent of Conductor thickness. 
Microstrip	Length	Yes	The dependency reason is same as that of Stripline.
	Dielectric constant (Dk)	Yes	The dependency reason is same as that of Stripline. However, there is a small deviation in the expected change as the fringe field see both air and FR4 in Microstrip compared to only FR4 in Stripline due to which Dk is Microstrip is slightly greater than Stripline.
	Conductor Thickness	No	The dependency reason is same as that of Stripline.
	Dielectric Height	No	The dependency reason is same as that of Stripline.

What is a good rule of thumb for the TD of a 12-inch-long transmission line on FR4??

For FR4, Dk is nearly 4. So, signal speed = speed of signal in vacuum / sqrt(Dk).
So, signal speed = speed of signal in vacuum / sqrt(Dk).
Signal speed =12inch/ns/ sqrt(4)= 6inch /ns.
Time Delay TD = Transmission Line length / Signal speed
TD= 12 inch / 6inch /ns.
TD = 2ns

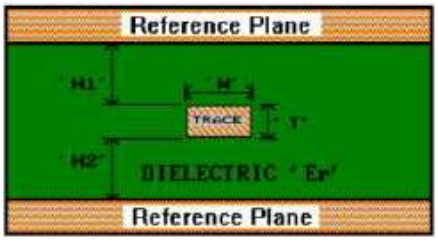
The above logic applies to both Microstrip and stripline.

2. **Problem Set #2:**

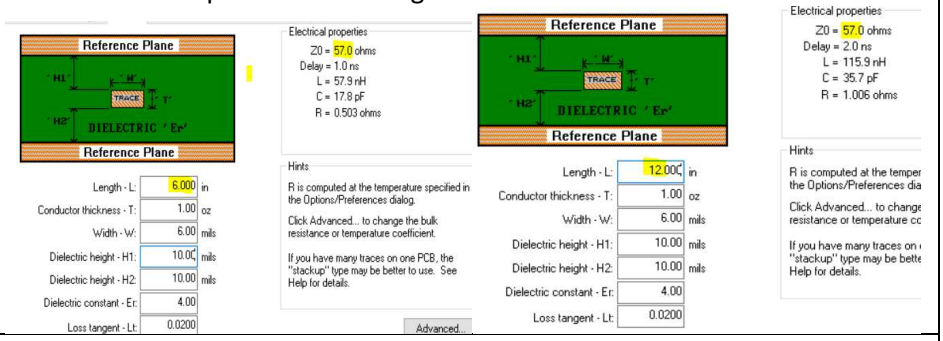
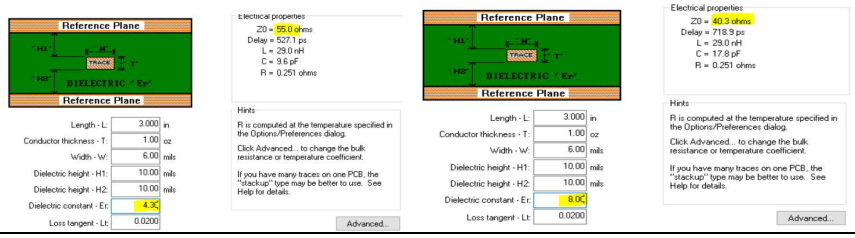
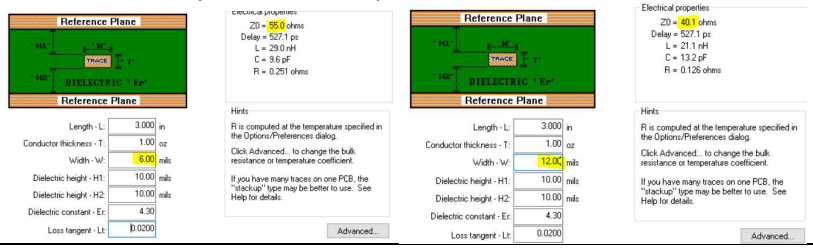
How will Z0 depend on line width, dielectric thickness, Dk, Length? For stripline

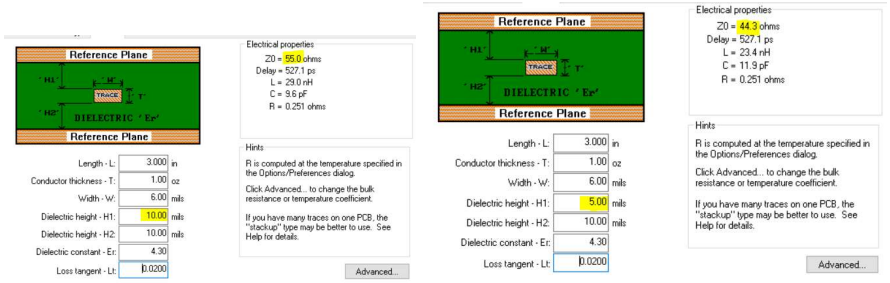
ECEN 5224 **HIGH SPEED DIGITAL DESIGN** **NAGARAJ SIDDESHWAR**

HW1 **DATE – 29TH JAN 2018**



Test your expectations with built in 2D field solver in HyperLynx to calc Z0.

Parameter varied	Effect on Z0? Yes / No	Comments
Length	No	Characteristic Impedance is independent of length of Transmission line. This is because varying the length would vary the time of travel for the signal and wouldn't change the cross-sectional area. Hence, this would never change the Characteristic Impedance of the signal. 
Dielectric constant (Dk)	Yes	Dielectric constant is directly proportional to Capacitance of the material (C= Dk *A/d). Characteristic impedance of a Lossless transmission line is proportional to square root of Capacitance of the trace (Z0 = sqrt(L/C). So, as Dk increases, Capacitance per unit length increases keeping Inductance per unit length constant which decreases Characteristic impedance in a square root manner. 
Conductor width	Yes	Width is directly proportional to Capacitance per unit Length. Increase in width increases Capacitance per unit length which further decreases the Characteristic impedance in a square root manner and vice versa. 

Dielectric thickness	Yes	Varying the Dielectric thickness varies the distance between trace and its reference. If we move the conductors farther apart, the capacitance will decrease, and the characteristic impedance will increase and vice versa. 

What consistency tests did you do?

Consistency Tests are done on 2D Field Solver on Hyperlynx and are found to be in alignment with expectations.

So, what? How will what you learned, influence design decisions?

The following shall influence the design decisions:

1. The first parameter needed to vary to change the Time delay of a Transmission line is its length. But, care should be taken that the length does not exceed the dimensions of the PCB which will be practical to implement. Also, length shouldn't be too small so that it leads to DFM issues.
2. Changing the Dielectric material itself to change the Time Delay is not encouraged as it may lead the designers to recalculate the Z0.
3. Conductor thickness and Dielectric thickness have no influence in varying Time Delay.
4. Decreasing the Dielectric thickness to decrease Z0 increasess the cost of PCB fabrication and should be avoided.
5. Varying the conductor width must be the top priority to vary the Z0 of Transmission line.