Final Project

ANSYS HFSS Port, Microstrip and Stripline Simulation Modeling

Fields and Wave Propagation

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Course: ECE 4703-001

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Fall, 2022

Introduction:

Using ANSYS HFSS software ports, Microstrip and Striplines will be simulated and the accuracy of hand calculations and TXLine software for characteristic impedances will be tested.

Task 1:

Task 1 Calculations:

$b = 30\text{mil} = 0.0762\text{cm}, \quad t = 18\mu\text{m} = 0.0018\text{cm}, \quad Z_0 = 50, \quad \varepsilon_r = 3.66$

$$\frac{W}{h} = \frac{8e^{A}}{e^{2A} - 2}$$

$$A = \frac{Z_0}{60}\left(\frac{\varepsilon_r + 1}{2}\right)^{1/2} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right) \quad \therefore \varepsilon_r = 3.66, \; Z_0 = 50\Omega$$

$A = 1.42047$ Since $A < 1.52$

$$\frac{W}{h} = \frac{2}{\pi}\left\{B - 1 - \ln(2B-1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left[\ln(B-1) + 0.39 - \frac{0.61}{\varepsilon_r}\right]\right\}$$

$$\therefore \varepsilon_r = 3.66 \quad B = \frac{60\pi^2}{Z_0\sqrt{\varepsilon_r}} = 6.190709$$

$$\frac{W}{h} = 2.18891 \Rightarrow W = 2.18891 \cdot h \quad \therefore h = 30\text{mil}$$

$$W = 65.6674\text{mil} = \boxed{0.166795\text{cm} = \text{width}}$$

Figure 1: Task 1 calculations for width of microstrip trace.

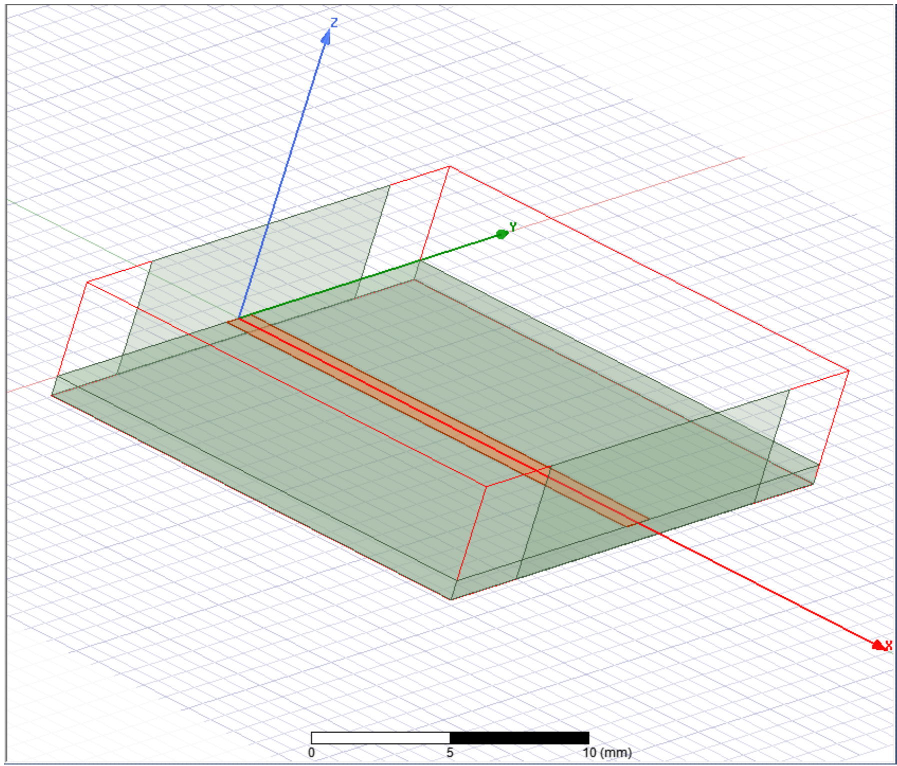

Figure 2: Screen snip of 700mil by 1000mil HFSS microstrip transmission line.

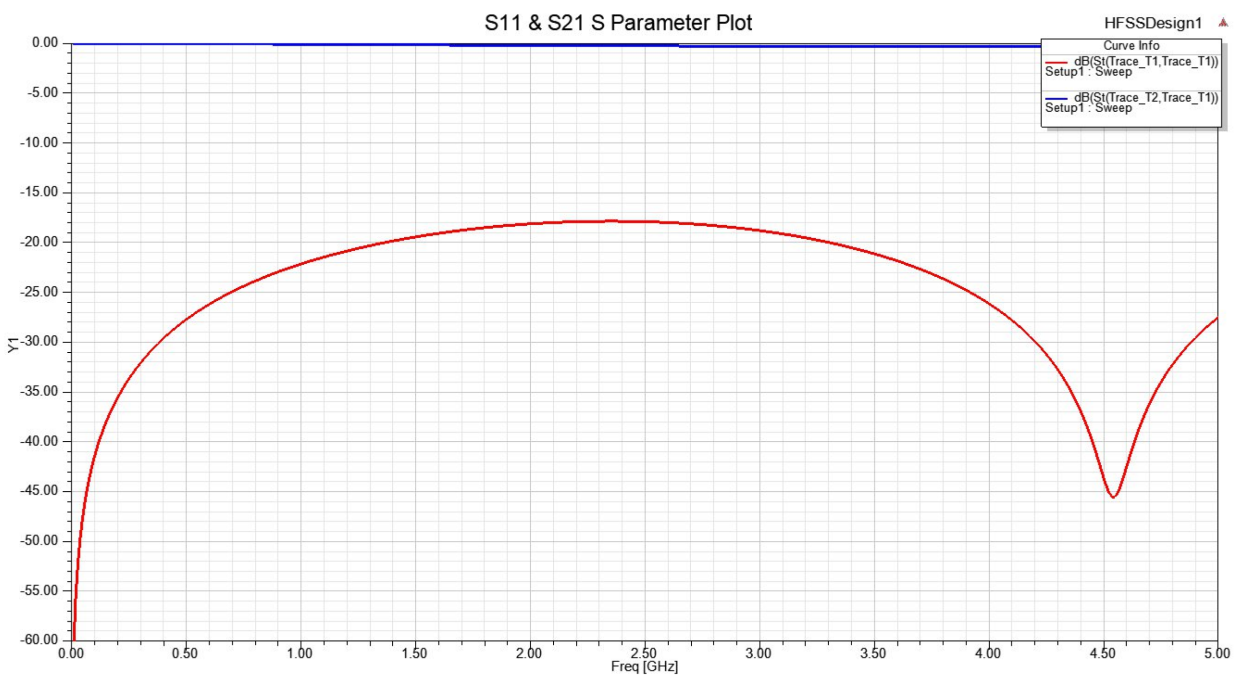

Figure 3: HFSS S11 and S21 microstrip S parameter plot.

Task 2:

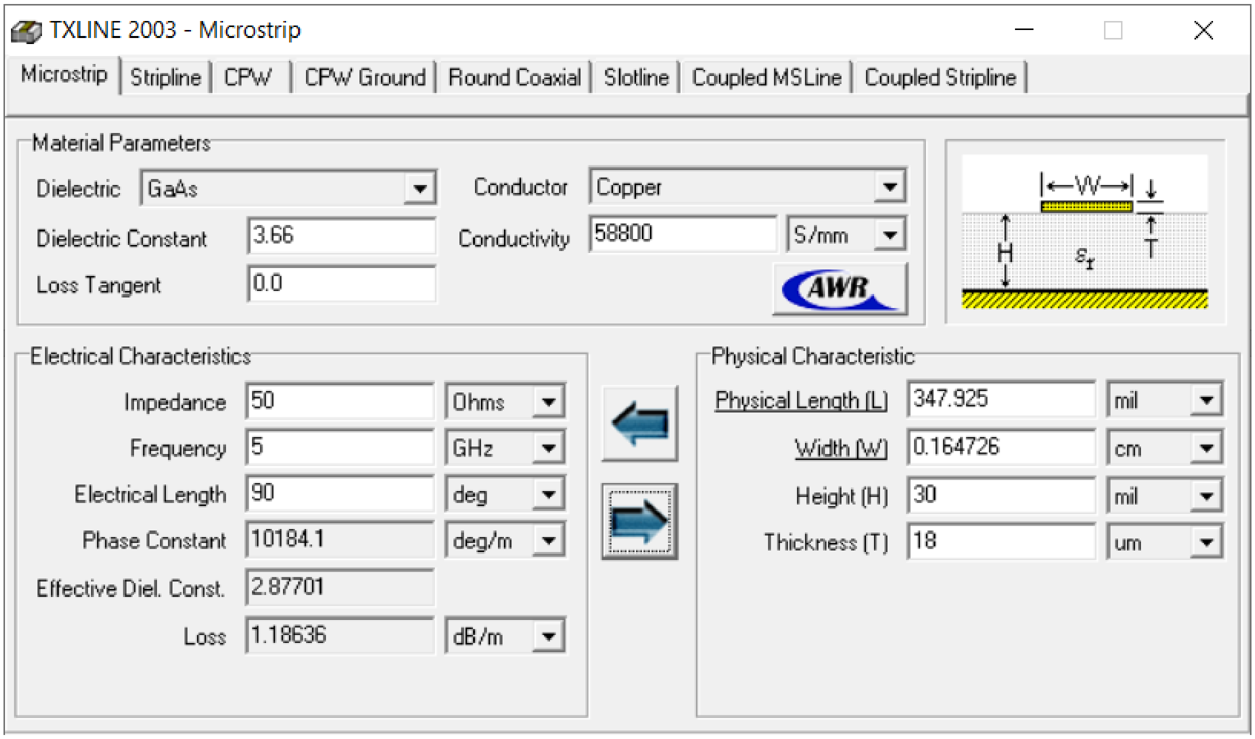

Figure 4: TXLine calculation of trace width. The width is 0.1647cm.

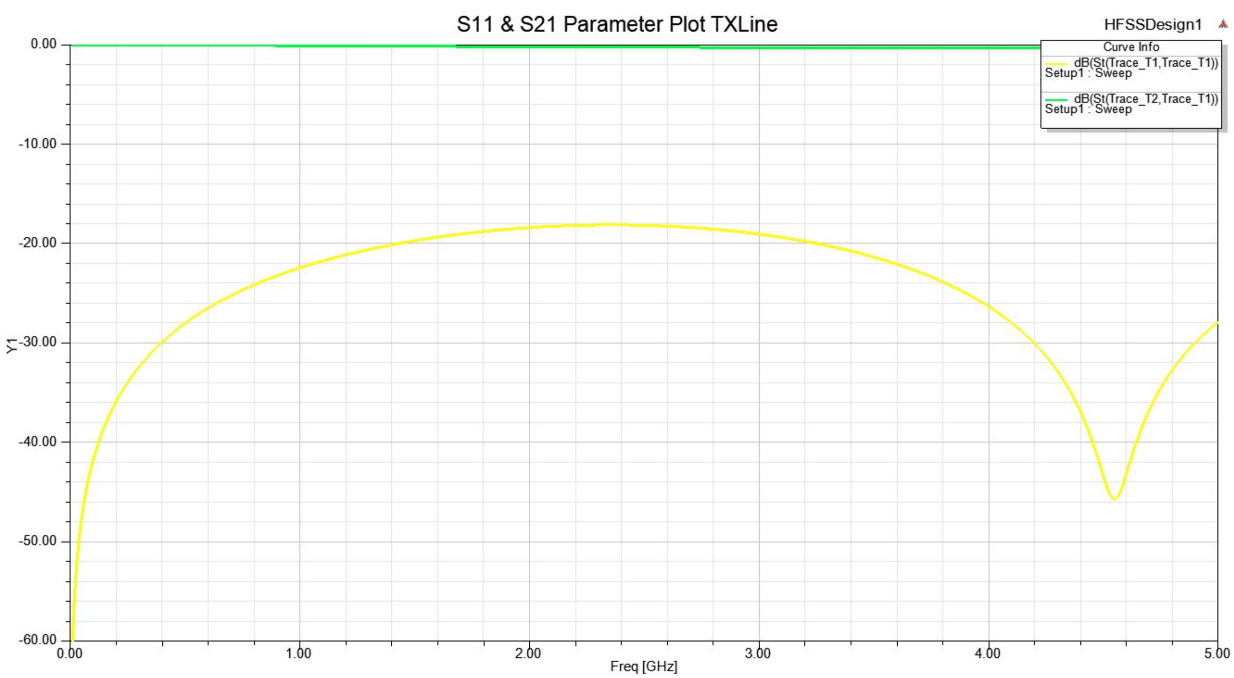

Figure 5: TXLine calculated width S Parameter simulation.

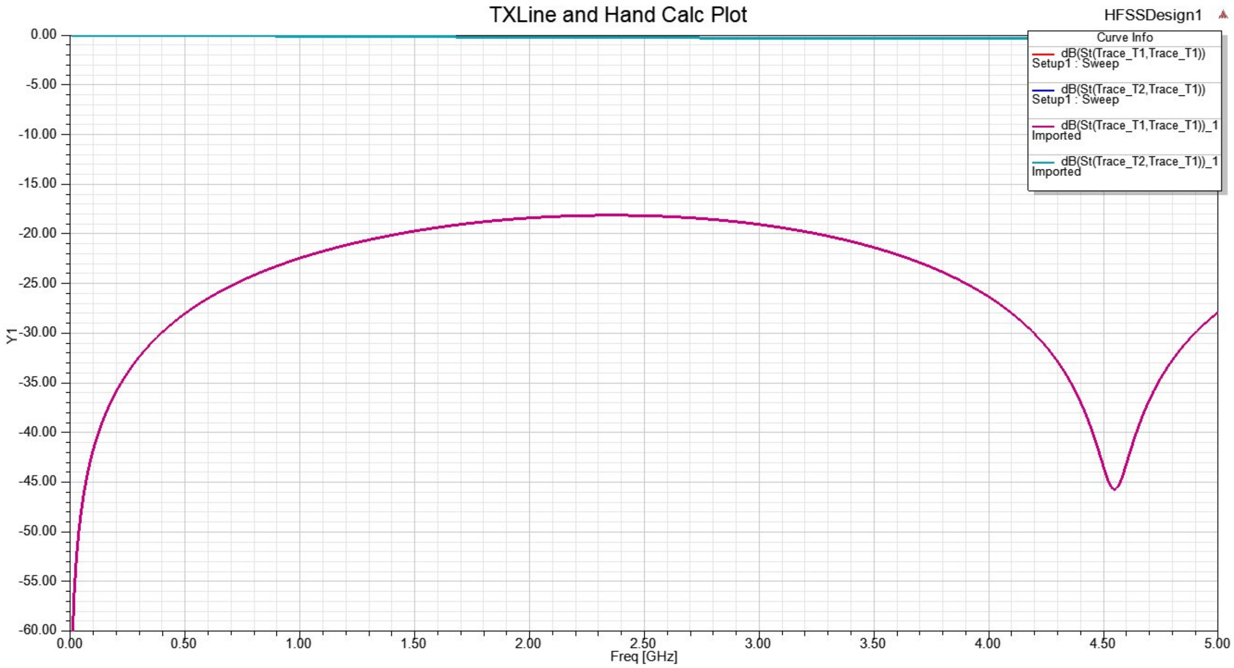

Figure 6: Hand calculations and TXLine calculation compared.

The results of the microstrip simulation comparing the hand calculations for trace width versus TXLine trace width calculations demonstrate the accuracy of microstrip design equations. The difference between the computer calculation and the hand calculation is negligible and not decipherable from the data analyzed.

Task 3:

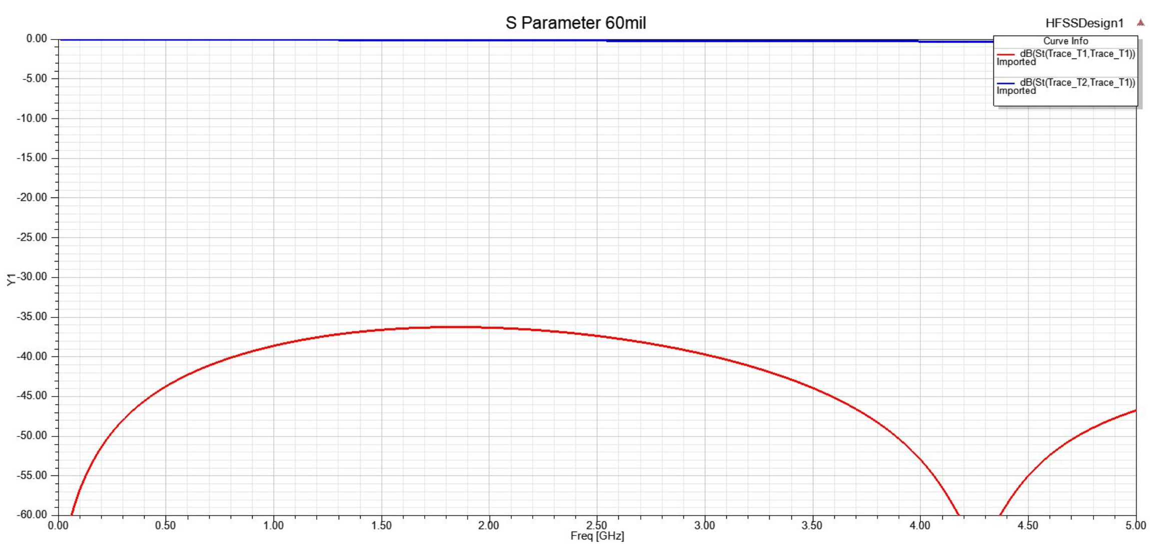

Figure 7: 60mil trace width microstrip S-Parameter simulation data.

Using port design tools in the HFSS design suite, microstrip ports can be automatically designed for a specified characteristic impedance. The software can be represented by the characteristic impedance formula:

$$Z_0 = \left(\frac{\eta}{2\pi\sqrt{\varepsilon_{re}}} ln\left(\frac{8h}{W} + 0.25\frac{W}{h} \right) \right)$$

Using the above formula, changes in trace width will alter the characteristic impedance. This allows specific characteristic impedances like 50Ω to easily designed for by changing the width of the trace and/or the height of the substrate. For this design, a trace width of 0.109111cm is required to achieve the characteristic impedance of 50 Ω.

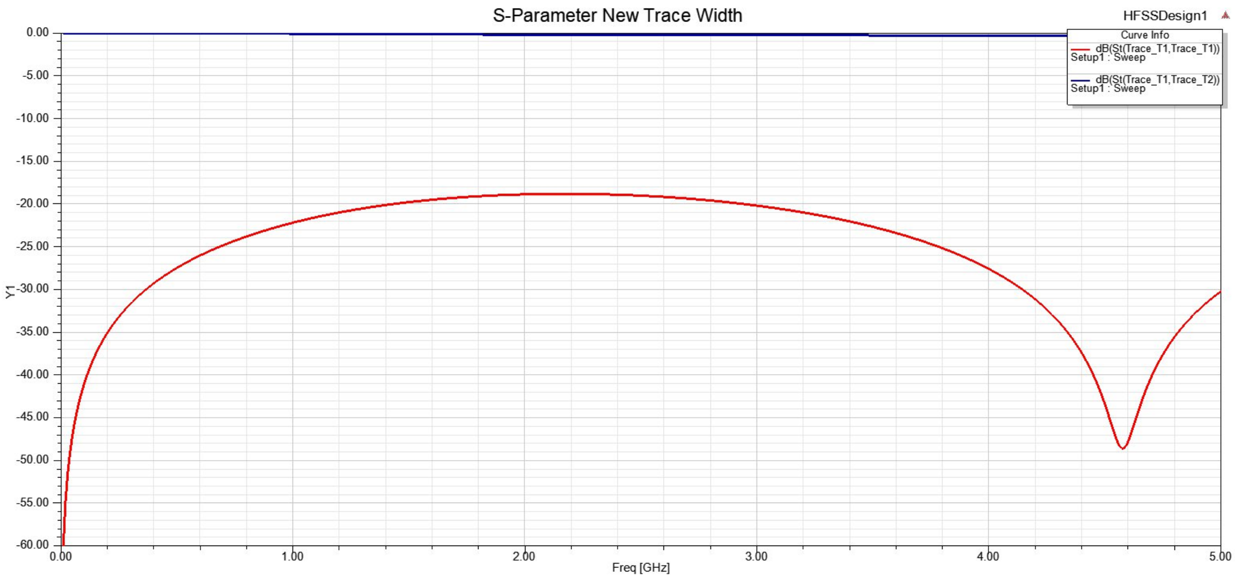

Figure 8: S-Parameter using custom trace width of 0.109111cm.

Task 4:

Task 4 Calculations:

$Z_0 = 50\Omega$, stripline, $H = 60\,\text{mil}$, Rogers 4350b, $T = 18\,\mu m$, DC→5GHz

$$\frac{W_e}{b} = \frac{W}{b} = \begin{cases} x & ; \sqrt{\varepsilon_r}\, Z_0 < 120\Omega \\ 0.85-\sqrt{0.6-x} & \end{cases} \qquad x = \frac{30\pi}{\sqrt{\varepsilon_r}\, Z_0} - 0.441 = 0.54428$$

$$\sqrt{\varepsilon_r}\cdot 50 = 95.655$$

$$\frac{W}{b} = \cancel{0.61395}$$

$$\text{So...}\ \frac{W}{b} = 0.54428 \Rightarrow \boxed{W = 32.6569\,\text{mil} = 0.0829485\,\text{cm}}$$

Figure 8: Hand calculations to determine the width of the Stripline trace.

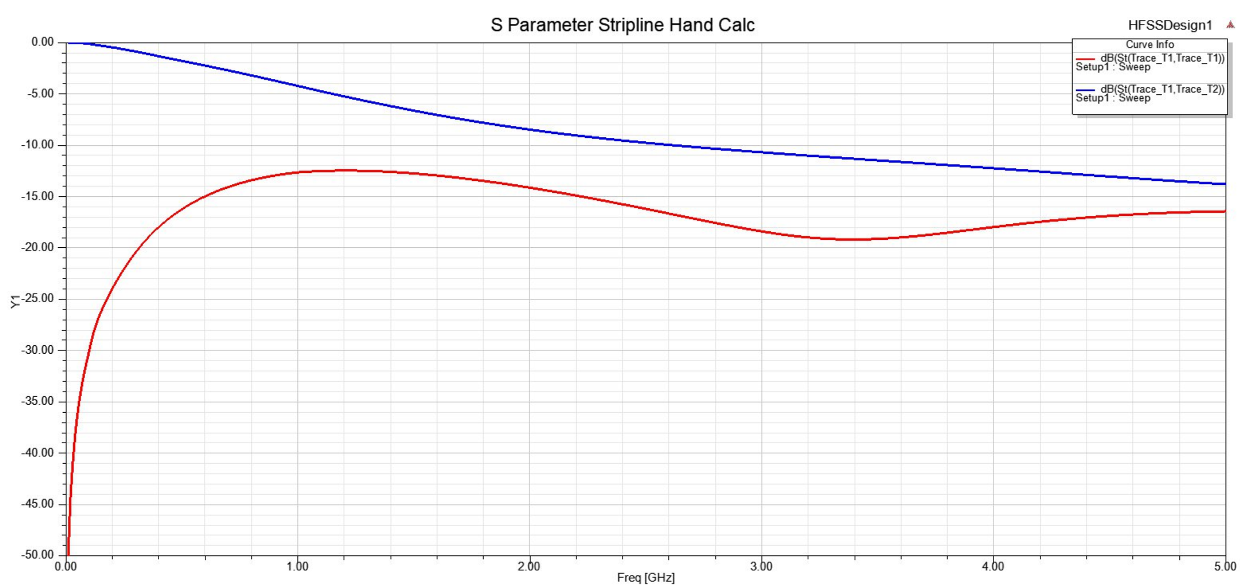

Figure 9: S-Parameter plot of Stripline using hand calculations.

Task 5:

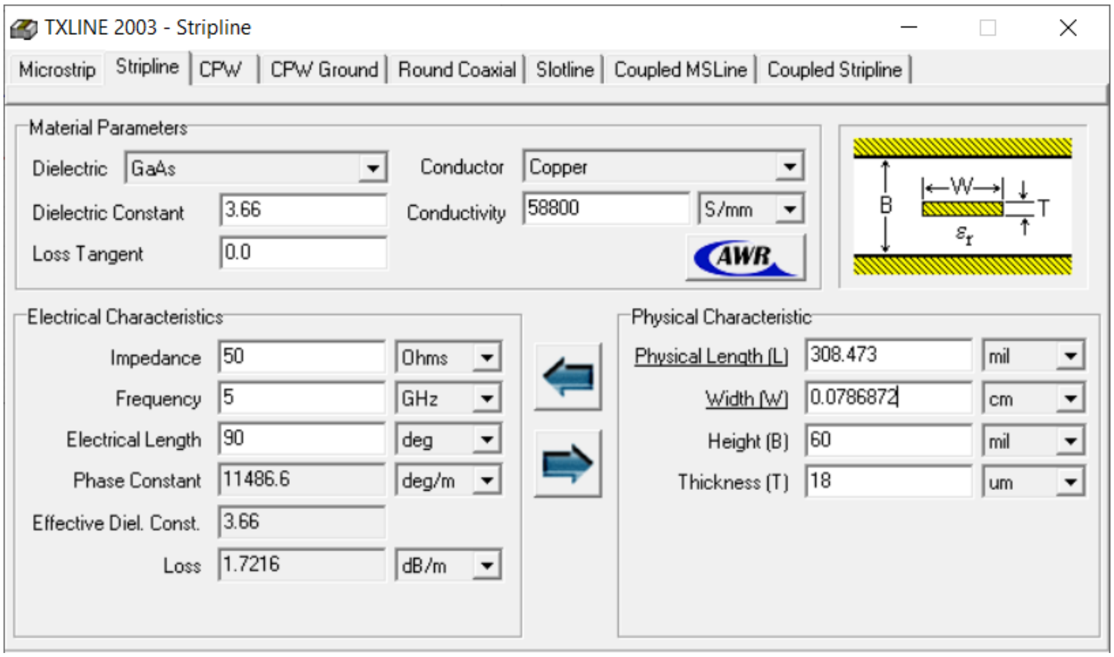

Figure 10: TXLine model for Stripline.

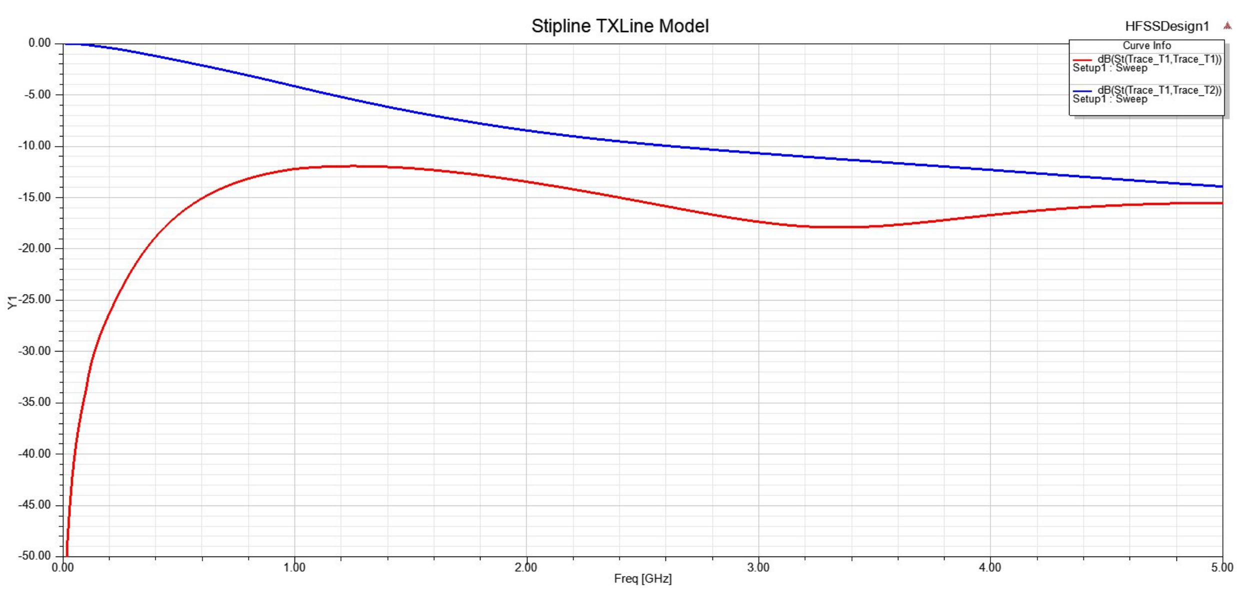

Figure 11: S-Parameter plot of Stripline using TXLine software.

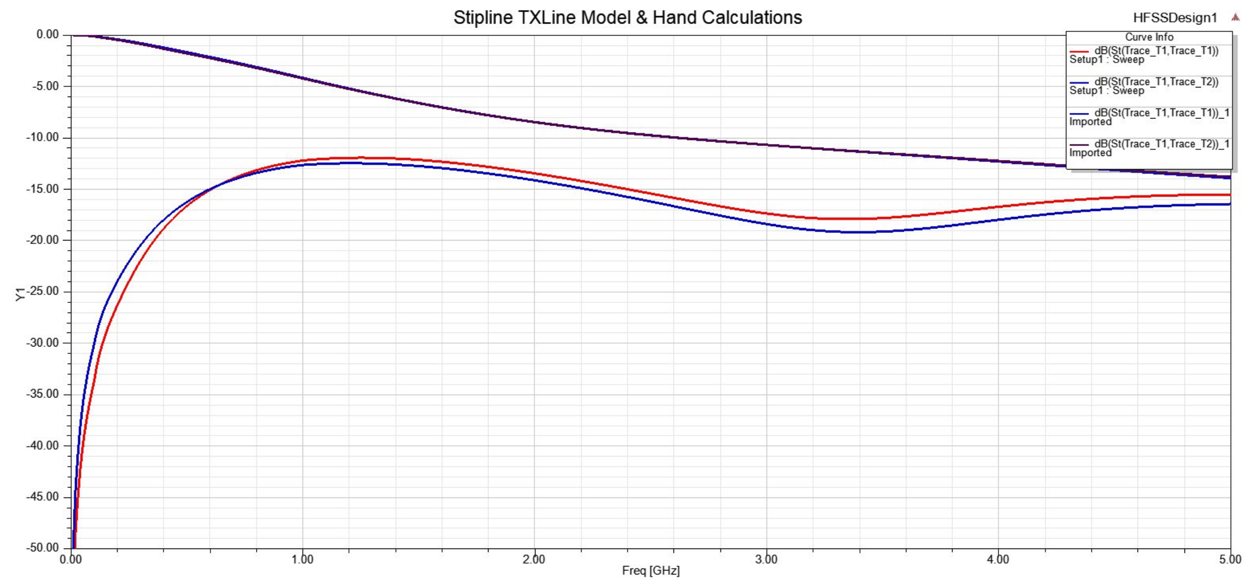

Figure 12: S-Parameter plot of Stripline hand and TXLine calculations.

Task 6:

Task 6 calculations:

$$A = \frac{Z_0\sqrt{\varepsilon_r}}{30} = \frac{\sqrt{3.66}\cdot 50}{30} = 3.18852$$

$$x = \frac{t}{b} = \frac{18\mu m}{h} = 0.0177$$
$$= 1.976$$

$$\frac{W_0}{b} = \frac{8(1-x)}{\pi}\cdot\frac{\sqrt{e^A + 0.568}}{e^A - 1} \Rightarrow \frac{W_0}{b} = 0.5358$$

$$\frac{\Delta W}{b} = \frac{x}{\pi}\left(1 - \frac{1}{2}\ln\left[\left(\frac{x}{2-x}\right)^2 + \left(\frac{.0796x}{W_0/b - .26x}\right)^m\right]\right]\Big\}$$

$$\lambda = \frac{c}{4f\sqrt{\varepsilon_r}} = 1.31\,cm = 515.748\,mil$$

$$\frac{\Delta W}{b} = \cancel{(\ldots)(.5358)} \approx 0.03195\,cm$$

$$W = 0.0536638 - 0.0218265$$

Figure 13: Hand calculations to find width of Stripline Quarter Wave Model.

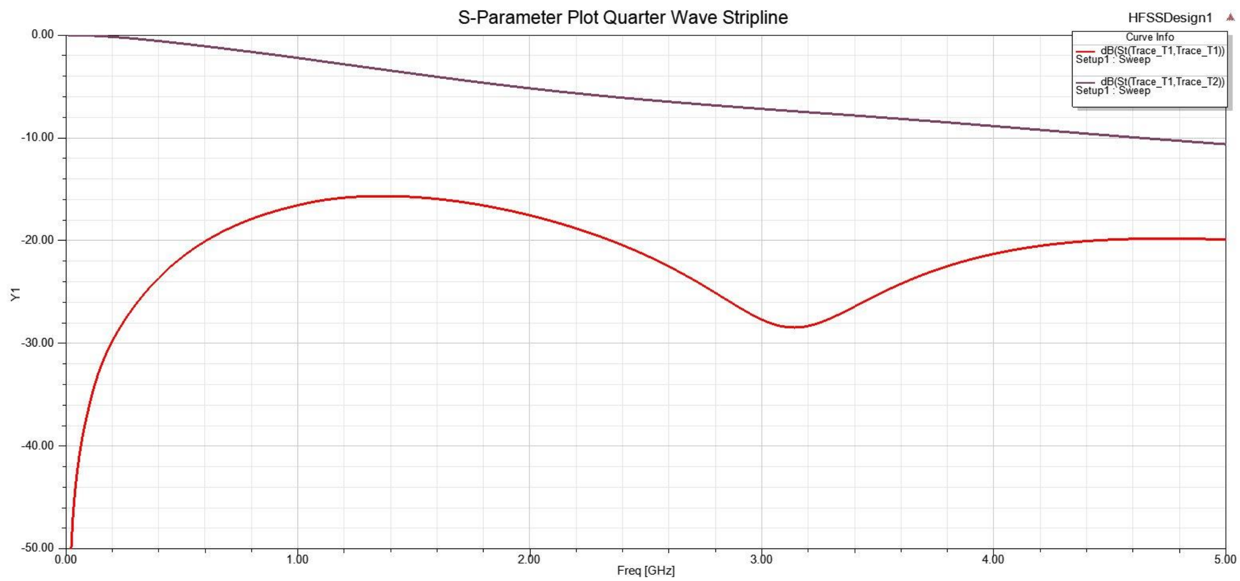

Figure 14: S-Parameter plot for Stripline Quarter Wave Model.

The plot described above does make sense since characteristic impedance and width of the Stripline have greatly changed, so how the frequency to dB ratio. Limitations of a 50Ω to 75Ω Stripline would be the width of the trace and also the substrate.

Conclusion:

Using HFSS to describe and simulate Microstrip and Stripline systems is an effective way to produce verifiable models. The experiment demonstrates the relationship between chacteristic impedance and the width of copper traces. The accuracy of the software TXLine and hand calculation equations has also been shown to be very accurate and reliable for creating models.