ENB440 RF Techniques and Modern Applications

ENB440 - Filter Design

Design Milestone 1

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Executive Summary

In this report a 70Ω microstrip is characterised through mathematic calculation, then designed and modeled within the CST Design Suite software environment.

Transmission and reflection characteristics are first calculated in section 2.1 in terms of ABCD parameters, from which the geometry of the system is calculated. The microstrip geometries are then independently found by using TX-Line software in section 2.3.

CST modeling methods and S parameters are evaluated in section 3. Passband, return loss and transmission are discussed in terms of the microstrip S parameters.

talk about conclusion

Contents

1 Scope

2 Line Impedance Calculations

2.1 Hand Calculations

First we found the ABCD parameters for the circuit shown in Figure 1. Once found they were converted to scattering parameters.

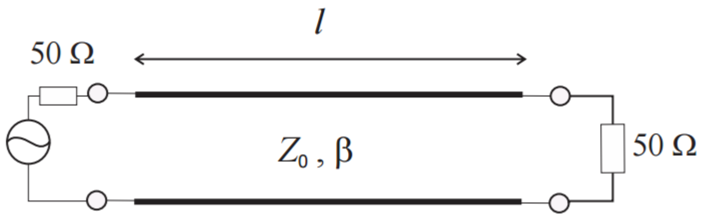

Fig. 1: Theoretical stripline circuit

This circuit consists of two 50Ω loads and two sections of transmission line with an electrical length of λ and an impedence(Z_0) of 70Ω. The wave number (β) is given by:

$$\beta = \frac{2\pi}{\lambda}$$

The unsimplified ABCD representation for this circuit is the following:

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 50 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} cos(\beta l) & j70sin(\beta l) \\ \frac{jsin(\beta l)}{70} & cos(\beta l) \end{bmatrix} \begin{bmatrix} 1 & 50 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} cos(\beta l) & j70sin(\beta l) \\ \frac{jsin(\beta l)}{70} & cos(\beta l) \end{bmatrix}$$

As $\beta l = 2\pi$ the sin terms are 0 and the cos terms become 1. The results for the ABCD matrix are as follows:

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 100 \\ 0 & 1 \end{bmatrix}$$

The conversion from ABCD to scattering parameters is shown here:

$$S_{11} = \frac{A + B/Z_0 - CZ_0 - D}{A + B/Z_0 + CZ_0 + D} \tag{1}$$

$$S_{11} = \frac{1 + 100/70 - 0 - 1}{1 + 100/70 + 0 + 1} \tag{2}$$

$$S_{11} = \frac{5}{12} \tag{3}$$

$$= 20log(S_{11}) = -7.6042dB \tag{4}$$

$$S_{12} = \frac{2(AD - BC)}{A + B/Z_0 + CZ_0 + D} \tag{5}$$

$$S_{12} = \frac{2(1 - 0)}{1 + 100/70 + 0 + 1} \tag{6}$$

$$S_{12} = \frac{7}{12} \tag{7}$$

$$= 20log(S_{12}) = -4.6817dB \tag{8}$$

$$S_{21} = \frac{2}{A + B/Z_0 + CZ_0 + D} \tag{9}$$
$$S_{21} = \frac{2}{1 + 100/70 + 0 + 1} \tag{10}$$
$$S_{21} = \frac{7}{12} \tag{11}$$
$$= 20log(S_{21}) = -4.6817dB \tag{12}$$

$$S_{22} = \frac{-A + B/Z_0 - CZ_0 + D}{A + B/Z_0 + CZ_0 + D} \tag{13}$$
$$S_{22} = \frac{-1 + 100/70 - 0 + 1}{1 + 100/70 + 0 + 1} \tag{14}$$
$$S_{22} = \frac{5}{12} \tag{15}$$
$$= 20log(S_{22}) = -7.6042dB \tag{16}$$

2.2 Matlab Results

We attempted to replicate the hand calculations in Matlab in order to model the S paramaters over the 2-4 GHz range where length was constant. The code to perform the calculations is noted in the APPENDIX and Figure 2 was generated.

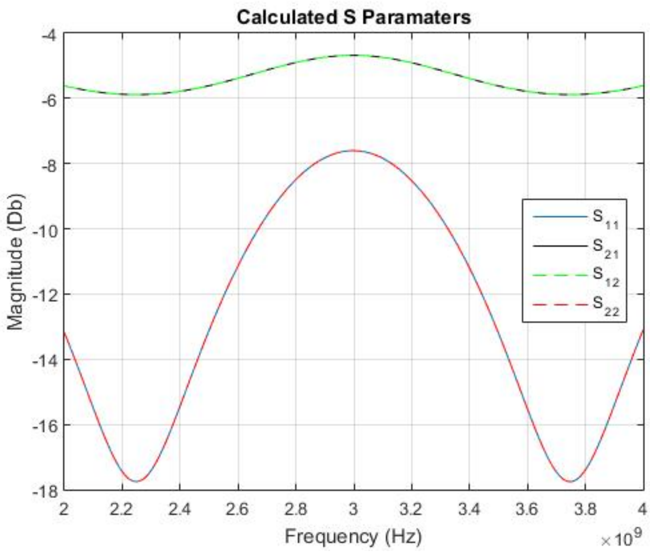

Fig. 2: S Paramaters from 2-4 GHz

This plot did not satisfactorily match our expectations for an ideal sweep of the circuits scattering parameters. This is because it shows the attenuation of reflection decreasing towards the design frequency. Our expectation was for the opposite to happen as is seen in the section on Computer Generated Results.

One reason the difference may have occurred is that the line was modelled in ABCD as:

$$Load-> Line-> Load-> Line$$

where both loads and lines were considered equal. The ground plain would possibly have differences to the copper strip and could very well account for an error. It is reasonable to conclude that the code may be performing an incorrect process to measure the scattering parameters of this system as it is so different to the result in CST. The amount of work required to make this graph alone shows the usefulness of CST for this task.

Figure 3 shows the S parameters matching the values from the hand calculations. This is due to the length being changed across the frequency range to stay at 1 wavelength.

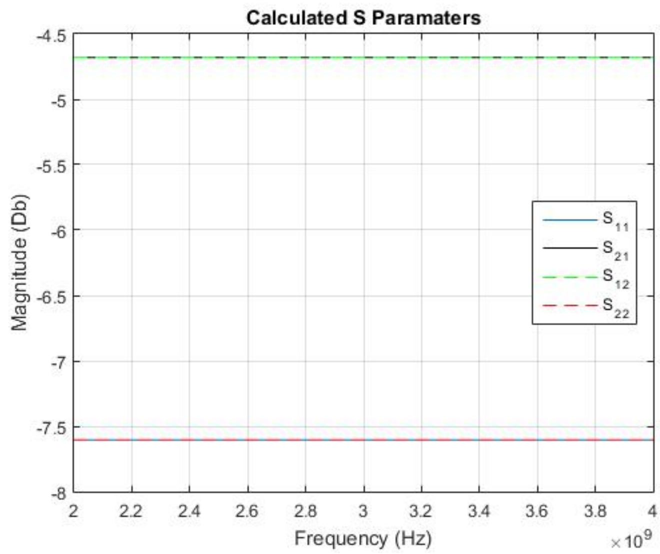

Fig. 3: S Paramaters from 2-4 GHz

This exercise has served to highlight the usefulness of CST for modelling this system.

2.3 Computer Generated Results

The National Instruments (NI) program TX-Line was used to generate an approximation of the microstrip geometry. The given laminate, impedance, frequency and electrical length information were input and the program output the microstrip width and length.

These values can be seen in the TX-Line GUI screenshop in figure 4

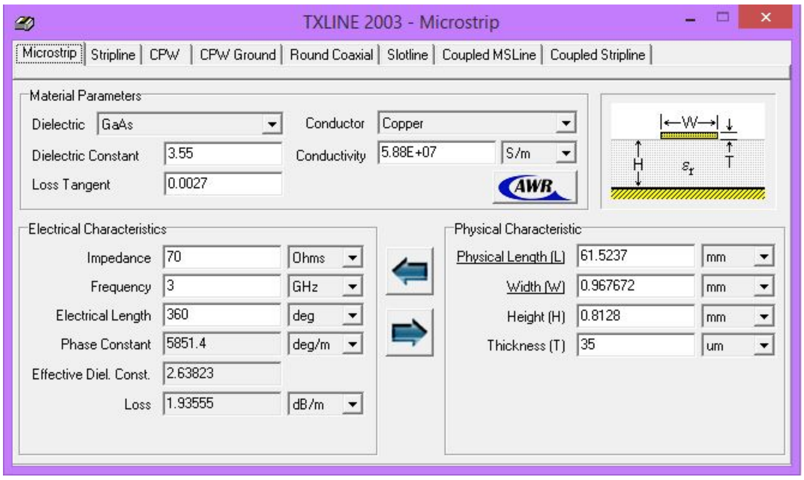

Fig. 4: Screenshot of TX-Line program.

The following data was found from the results:

Characteristic	Result
Phase Constant	0.102126 rad/mm
Physical Length	61.5237 mm
Width	0.967672 mm
Eff. Diel. Const.	2.63823

3 Modeling

The microstrip was modeled in CST, with a frequency range of 2GHz to 4GHz and port information defined at 3GHz. The computer generated results found from TX-Line were initially used and resulted in the model that can be seen below in figure 5.

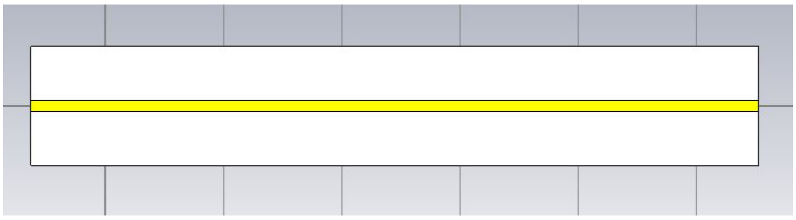

Fig. 5: CST Microstrip model.

The reflection (S_{11} and S_{22}) and transmission S parameters (S_{21} and S_{12}) were then found after simulation. These can be seen below in figure 6.

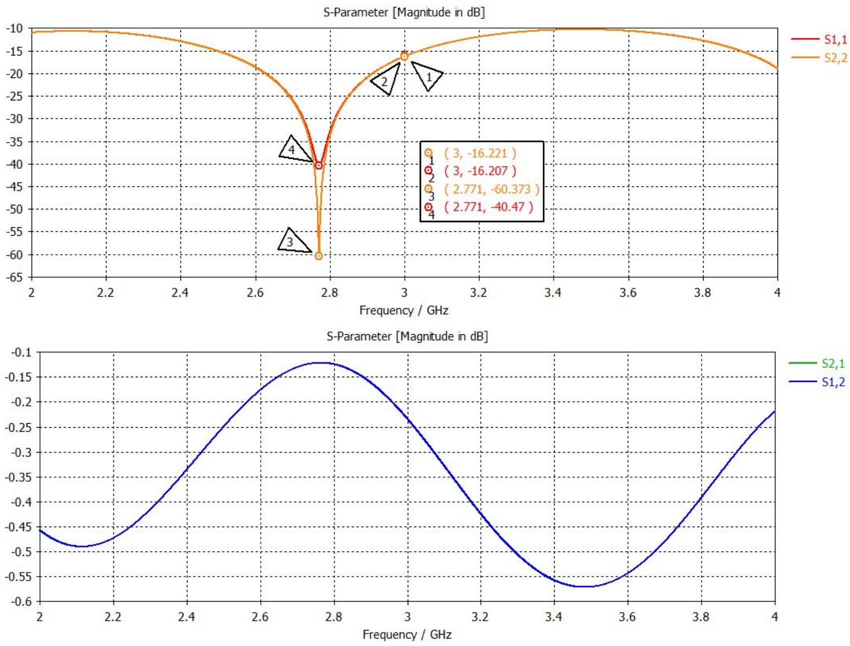

Fig. 6: Top: S_{11} and S_{22} parameters - magnitude. Bottom: S_{21} and S_{12} parameters - magnitude.

It can be seen that the loss of the microstrip along the transmission S parameter S_{21} is 0.239dB. This value is expected - the loss in the copper and dielectric would result in a low loss, especially given the loss tangent of RO4003C being as low as 0.0027.

The passband of the system is seen to peak at 2.771GHz with very little loss (passband at -60dB S_{11} and -40dB S_{22}). At the specified transmission frequency of 3GHz the reflection of the microstrip is -16dB, causing return losses. The cause of this is the mismatch between the 50Ω source port and the 70Ω microstrip.

The phase of all S parameters can be seen below in figure 7.

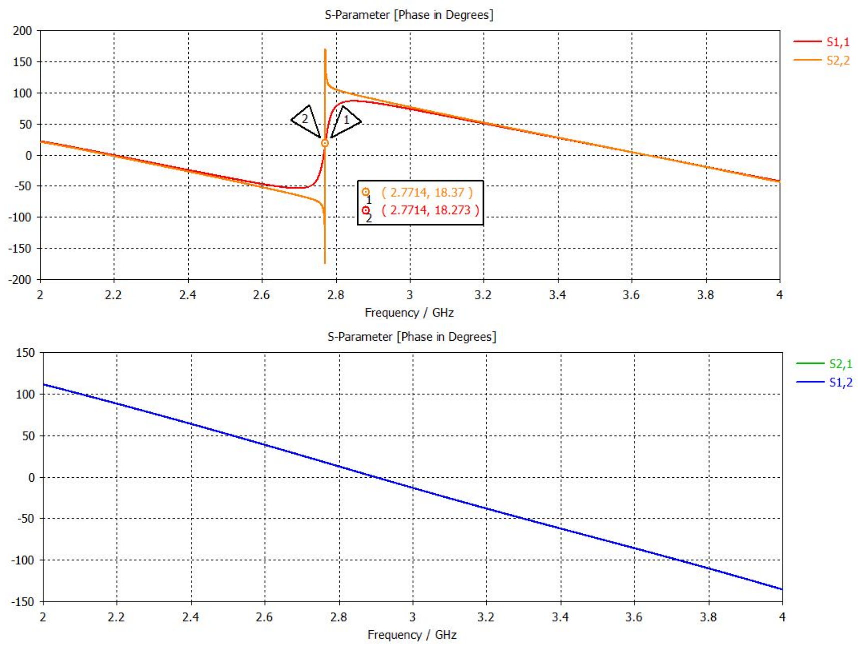

Fig. 7: Top: S_{11} and S_{22} parameters - phase. Bottom: S_{21} and S_{12} parameters - phase.

All S parameter phase plots are linear, as expected.

The S_{11} and S_{22} plots have an abnormality at 2.7714GHz, which is caused by the passband peak.

3.1 CST Optimiser

The CST optimisation software