Sample Technical Memorandum

Memorandum

DATE: November 12, 2002

TO: Dr. Keith W. Whites

FROM: Dan Palecek and Jeremy Fejfar (Revised by KWW)

SUBJECT: EE 481 Laboratory Assignment #1 – Single Stub Tuner on Microstrip

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INTRODUCTION

In Homework #6, a single stub tuner was designed for implementation in microstrip on GML 1000 laminate (30 mil, 1-oz copper). This tuner circuit is shown below in Fig. 1.

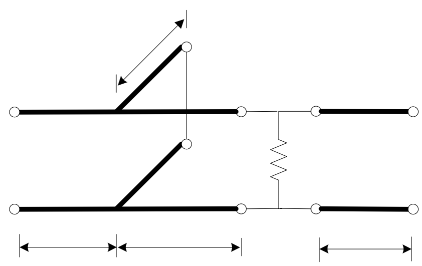

Figure 1 Schematic diagram of the designed single stub, short circuit tuner.

This circuit was fabricated and *S*-parameter measurements were taken for comparison with calculated values and *Advanced Design System* (ADS) simulation results.

PROCEDURE

The vector network analyzer (VNA) was calibrated using the Thru-Reflect Line (TRL) technique and the supplied Thru, Reflect and Line standards. The tuned circuit was connected to the calibrated VNA and measurements of the *S* parameters were taken from 0.9 to 1.8 GHz.

Secondly, the *S* parameters of the singe-stub tuner and TRL calibration standards were measured at 1.0 and 1.6 GHz with the VNA correction off, allowing for manual calculation of the error box coefficients. These calculations are summarized below.

After measuring L_{11}, L_{12}, T_{11}, T_{12} and R_{11}, the S matrix of the error boxes was determined using equations (1)-(4) below (Pozar, 1998) and the fact that, by reciprocity, $S_{12} = S_{21}$

$$e^{-\gamma\ell} = \frac{L_{12}^2 + T_{12}^2 - (T_{11} - L_{11})^2 \pm \sqrt{[L_{12}^2 + T_{12}^2 - (T_{11} - L_{11})^2]^2 - 4L_{12}^2 T_{12}^2}}{2L_{12}T_{12}} \tag{1}$$

$$S_{22} = \frac{T_{11} - L_{11}}{T_{12} - L_{12} e^{-\gamma \ell}}, \quad S_{11} = T_{11} - S_{22} T_{12}, \quad \text{and} \quad S_{12} = \sqrt{T_{12}(1 - S_{22}^2)} \tag{2),(3),(4}$$

The *ABCD* matrix of the error boxes was determined using relations from Table 4.2 in the text, as was the uncorrected *S* matrix of the DUT. It is quite easy to show that the corrected DUT *S* matrix is given by (Pozar, 1998)

$$\begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}^{-1} \cdot \begin{bmatrix} A_m & B_m \\ C_m & D_m \end{bmatrix} \cdot \begin{bmatrix} A & B \\ C & D \end{bmatrix} \tag{5}$$

where A, B, C and D are the error box coefficients; A_m, B_m, C_m and D_m are the measured and uncorrected DUT coefficients; and A', B', C' and D' are the corrected DUT coefficients. The corrected DUT matrix was converted to *S* parameters using the conversion relations in Table 4.2 of the text. These calculations were performed numerically using MATLAB.

RESULTS

Table 1 lists our system error coefficients calculated from (1)-(4) when converted to *ABCD* parameters. Both measured and manually corrected DUT *S* parameters are listed in Table 2 at 1.0 and 1.6 GHz. Finally, Figs. 1 and 2 contain plots of the predicted, simulated and measured *S* parameters from 0.9 to 1.8 GHz.

Table 1 Computed error box coefficients from (5).

	***f* = 1.0 GHz**	***f* = 1.6 GHz**
A	0.1776∠-5.007°	0.9495∠-89.59°
B	49.8∠-89.51°	14.84∠1.045°
C	0.1930∠-90.00°	0.006083∠-170.5°
D	0.2361∠-7.251°	0.9601∠88.52°

Table 2 Corrected *S* parameters of the DUT.

	***f* = 1.0 GHz**		***f* = 1.6 GHz**	
	Calculated	Measured	Calculated	Measured
S_{11}	0.6633∠104.18°	0.6792∠102°	0.2926∠-175.17°	0.2971∠94.8°
S_{12}	0.4894∠90.59°	0.5107∠-51.9°	0.6180∠-127.15°	0.6432∠-141°
S_{21}	0.5047∠103.59°	0.5279∠-52.4°	0.6190∠-105.95°	0.6446∠-141°
S_{22}	0.2494∠134.46°	0.2840∠-146°	0.4730∠-145.93°	0.5077∠169°

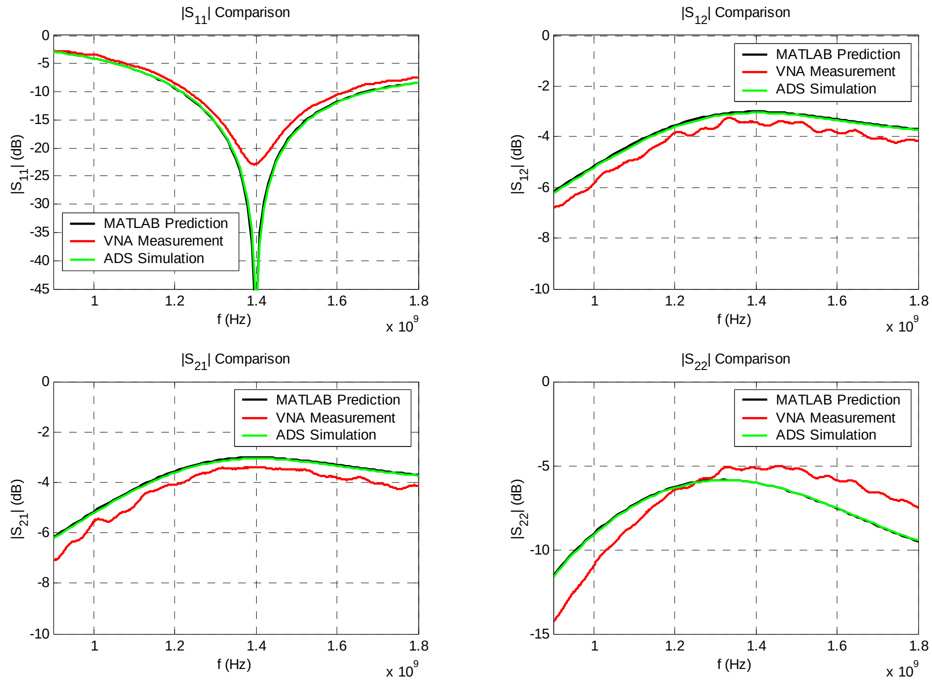

Figure 2 Magnitude comparisons of the predicted, simulated and measured *S* parameters.

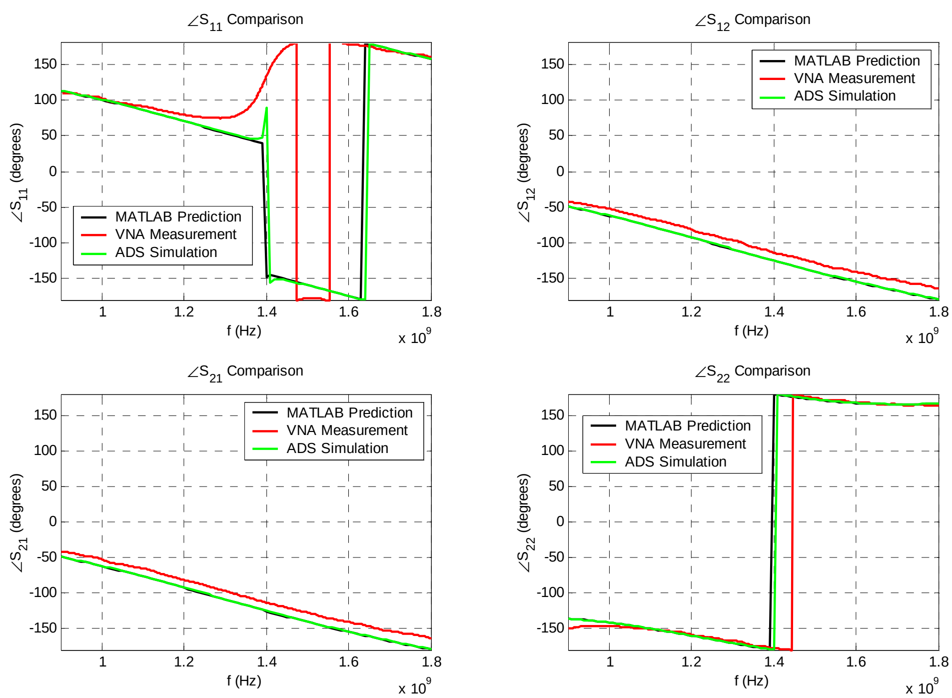

Figure 3 Phase comparisons of the predicted, simulated and measured *S* parameters.

DISCUSSION

The phase planes in the circuit of Fig. 1 were adjusted inward by 2.5 cm in MATLAB to model their locations as defined in the measurements. Specifically, during the TRL calibration the reference planes on the “zero length Thru” are located exactly in the middle of the 5 cm line, while the phase plane at the end of the 2.5 cm Reflect standard is also located there. Consequently, the reference planes for the circuit in Fig. 1 needed to be moved inward by 2.5 cm for location at the stub and resistor positions.

The S parameters were then calculated in MATLAB and simulated in ADS with the proper reference planes. With this adjustment, the magnitude and phase of the calculated, measured and simulated S parameters were quite similar, as shown in Figs. 2 and 3. In particular, the magnitude of S_{11} in Fig. 2 has a dip at 1.4 GHz, just as predicted since the circuit was tuned for a port 1 match at this frequency.

Differences between predicted values and measured data may be attributed to (1) small circuit manufacturing flaws, (2) the fact that the actual microstrip circuit was not lossless, and (3) the inadequacies of the Thru, Reflect and Line standards to satisfy our assumptions in the error model. These standards were manufactured in a simple fashion using GML 1000 laminate and end launchers.

Lastly, referring to Table 2, the magnitudes of the corrected S parameters (calculated and measured) for the DUT at 1.0 and 1.6 GHz match closely. However, the phases do not. The differences between the two sets of data seem too large to be caused just by losses and random measurement errors. Another factor seems to be affecting this difference, though further investigation will be needed to determine the cause.