RF Lab Module #7 — RF Filters

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***Abstract*—RF filters are of immense importantance in today's RF dependent world. Nearly every consumer electronic device utilized RF filters to communicate and connect with the internet. In this lab, several RF filters were designed, characterized, and analyzed. Specifically, a 0.5dB equal ripple low pass filter was implemented using the stepped impedance method.**

I. Introduction

IMPLEMENTING Implementing a stepped impedance low pass filter requires a desired filter order and cutoff frequency. In this lab, we designed 2 5th order low pass filters with a cutoff frequency of 600Mhz and 1.2GHz. The e design made use of the low-pass filter prototype charts. This made choosing component values as simple as calculating an equation. These filters where chartered by measuring the S parameters across frequency.

II. Procedure

1) Compute Design Parameters
   a) Determine Z_{low}, Z_{high}
   b) Use prototype elements to determine desired inductor and capacitor values
   c) Determine the TX line length required to realize the passives
2) Manufacture Filter
   a) Cut copper tape strips to width determined by Z_{low}, Z_{high} and length determined by length needed by passives
   b) Adhere the copper strips to blank side of copper-plated FR4 board to realize the stepped impedance configuration
   c) Solder SMA connectors to either end adding 50Ohm microstrip line to extend where necessary
3) Characterize Filter
   a) Calibrate VNA with 201 points from 50k-3GHz

III. Analysis

Record the observations and conclusions from the lab. The 600Mhz filter behaved as expected with a cutoff frequency around 600Mhz; however, the effects of the transmission line properties of the stepped impedance were exposed. After $\tilde{1}$.4GHz the filter started to pass the signal once again with ripples following after the resurgence. The milled stepped impedance filter proved to have an exceptionally flat pass bad; however, due to the limited calibration frequencies the filter gave poor results outside of 3GHz. The lack of calibration outside of 3GHz is cited for the apparent chaotic transfer charactistics for the milled stepped impedance filter.

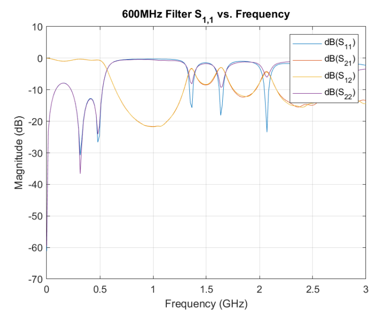

Fig. 1. Measured S Parameters of DIY $f_c = 600$MHz Stepped Impedance Low Pass Filter

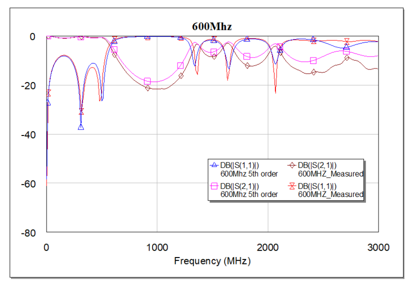

Fig. 2. Theoretical S Parameters of 600Mhz filter compared with Measured S Parameters

How do your measured values compare with the simulated responses (% error). What might be causing the error?

There are several factors that could contribute to the error between the simulated and measured values. For example, the manufacturing accuracy, differences between the different board parameters such as $\tan(\delta)$ or board height, and systematic measurement error.

How long did it take you to complete the lab?

1 hour 15 minutes

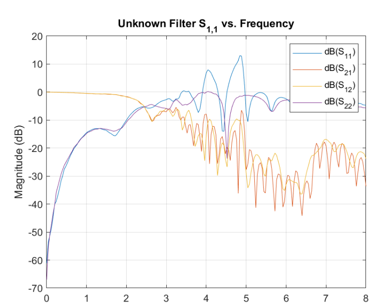

Fig. 3. Measured S Parameters of Unknown Cutoff frequency Milled Stepped Impedance Low Pass Filter

IV. Discussion and Summary

Overall, this lab exposed the tradeoffs leveraged when designing RF filters including the properties of TX lines, accuracy of manufacturing processes, and difference between passives realized by lumped vs. distributed methods. Experience as gained using the stepped impedance method to realize a 0.5dB Chebyshev 5th low pass filter.

Appendix A
Extra Photos

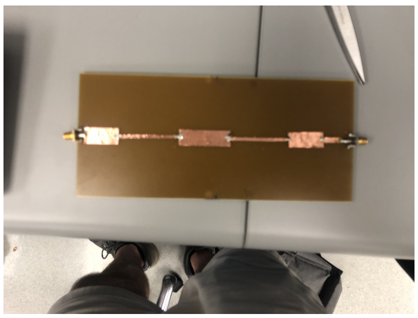

Fig. 4. Copper Tape 600MHz Filter

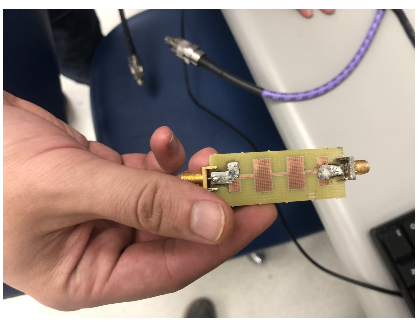

Fig. 5. Milled Filter

Parameter	TX line (0.6 GHz)	TX Line (1.2 GHz)	Measured 0.6 GHz	Milled T line
Ripple	0.885dB	0.8782 dB	0.96dB	N/A
Cutoff frequency (3dB)	574MHz	1135MHz	557.7MHz	2273MHz
Rejection at 1.2 GHz	12.72dB	1.6dB	15.14dB	In Passband
Min. Return loss (dB) across the band	-58.42dB	-64.48	-58.42dB	-61.1dB

TABLE I
Recorded Values of Simulated and Measured Filters

600 MHz Filter		
Measured	Actual	% Error
0.96 dB	0.885 dB	8.474576
557.7 MHz	574MHz	2.839721
15.14 dB	12.72 dB	19.02516
58.42 dB	58.42 dB	0

TABLE II
Percent Error of Measured vs. Simulated Values for the 600MHz filter

Z0 (Ohm)	Width (mil)	Width (cm)
20	474.84	1.20609
50	132.87	0.33749
55	113.13	0.28735

TABLE III
Width of microstrip transmission lines

g_1	1.7058
g_2	1.2296
g_3	2.5408
g_4	1.2296
g_5	1.7058
g_6	1

TABLE IV
Prototype Parameters of 0.5dB Equal Ripple Low pass Filter

Component	Electrical Length in Radians	Length (cm) of MS TX Line 600MHz	Length (cm) of MS TX Line 1.2GHz
C1	0.68232	2.85605	1.42423
L1	1.2296	4.9972	2.48582
C2	1.01632	4.2541	2.1214
L2	1.2296	4.9972	2.48582
C3	0.68232	2.85605	1.42423

TABLE V
Filter Components and Corresponding TX line lengths