RF Band Pass Filter Design

Filter Specification:

Filter Type	Chebyshev
Center Frequency	2.4GHz
3dB Bandwidth	10%
Maximum Ripple	< 0.1 dB
Stop band Bandwidth	2 x 3dB
Stop band attenuation	≥36dB
Source Impedance	50 ohms
Load Impedance	50 ohms
Implementation	Quarter wavelength Coupled lines
Relative Permittivity of Substrate (ε)	2.31
Thickness of the Substrate (h)	31.5 mil
Thickness of the conductor	1.2 mil

Design Procedure:

a) Normalize filter requirements. Compute geometric center frequency,

$F_0 = \sqrt{F_1 * F_2}$

b) For each stop band frequency (F_a, F_b), compute new frequencies ($F_{a'}$, $F_{b'}$)

where $F_{a'} = (F_0\text{^}2) / F_b$, $F_{b'} = (F_0\text{^}2) / F_a$.

c) Calculate the difference $(F_{b'} - F_a)$ and $(F_b - F_{a'})$

Select the one having the smallest frequency separation (most severe requirement) and compute the Steepness Factor, A_s

$$A_s = \frac{\text{most severe stopband BW}}{\text{BW}_{3\text{dB}}}$$

d) With A_s and Stop band attenuation, select the filter order n from the Attenuation characteristics graph for Chebyshev filter

e) With Filter order n, Pass band ripple and ratio (Rs/Rl) choose Chebyshev low pass prototype element values ($g_1 \ldots g_n$) from the corresponding look up table.

f) Use equations given below to find *ZoJn* for

n=1,2,…N+1

$$Z_o J_1 = \sqrt{\frac{\pi\Delta}{2g_1}}$$

$$Z_o J_n = \frac{\pi\Delta}{2\sqrt{g_{n-1}g_n}} \quad for\, n = 2,3,\ldots,N$$

$$Z_o J_{N+1} = \sqrt{\frac{\pi\Delta}{2g_N g_{N+1}}}$$

$$Z_{oe} = Z_o\left[1 + JZ_o + (JZ_o)^2\right]$$

$$Z_{oo} = Z_o\left[1 - JZ_o + (JZ_o)^2\right]$$

Where $\Delta = (F_2 - F_1)/F_0$

g) Find the even and odd mode impedances Z0o and Z0e from which the Width, Length, Separation of each coupled line can be synthesized.

Calculated parameters:

1) Most severe stop band BW = 458 MHz

2) Steepness Factor $A_s = 1.92$

3) Characteristic Impedance $Z_0 = 50$ Ohms

4) (Rs/Rl) = 1

5) Filter Order was chosen to be 5 for stop band attenuation ≥36dB

6) The low pass prototype element values were found to be

$g_1 = 1.301$

$g_2 = 1.556$

$g_3 = 2.241$

$g_4 = 1.556$

$g_5 = 1.301$

7) The corresponding even mode and odd mode impedances were calculated as given in the table below.

n	*Z*0*Jn*	*Z*0e (W)	*Z*0o(W)
1	0.347473	73.41052	38.66322
2	0.110402	56.12953	45.08933
3	0.084119	54.55975	46.14785
4	0.084119	54.55975	46.14785
5	0.110402	56.12953	45.08933
6	0.347473	73.41052	38.66322

8) From the above table the dimensions of the coupled microstrip lines were synthesized using Linecalc - an ADS utility tool. The Dimensions are as given below

n	**Width** (mil)	**Separation** (mil)	**Length** (mil)
1	69.2315	6.232	904.465
2	89.4	36.96	884.252
3	90.572	49.82	883.063
4	90.572	49.82	883.063
5	89.4	36.96	884.252
6	69.2315	6.232	904.465

Filter Simulation, Implementation, Results

Schematics and Layout

The Coupled Microstrip lines can implemented in ADS using MCLIN component as shown in the figure below.

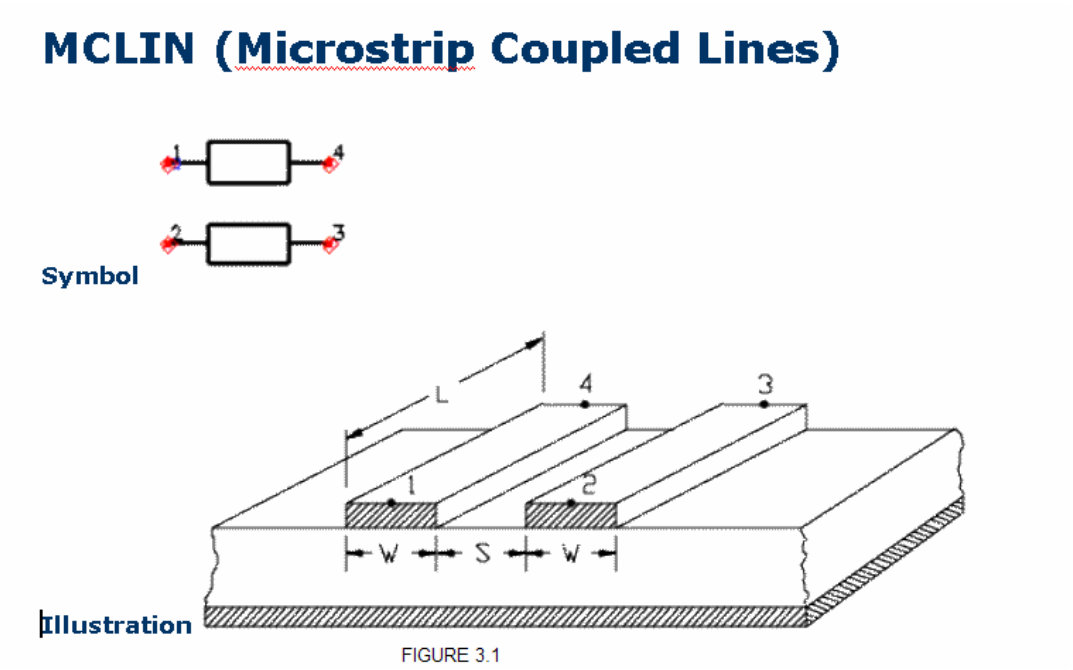

FIGURE 3.1

The Schematic in ADS for the filter is shown below. Then it was converted to layout using ADS Layout tool.

ADS SCHEMATIC FOR BAND PASS FILTER

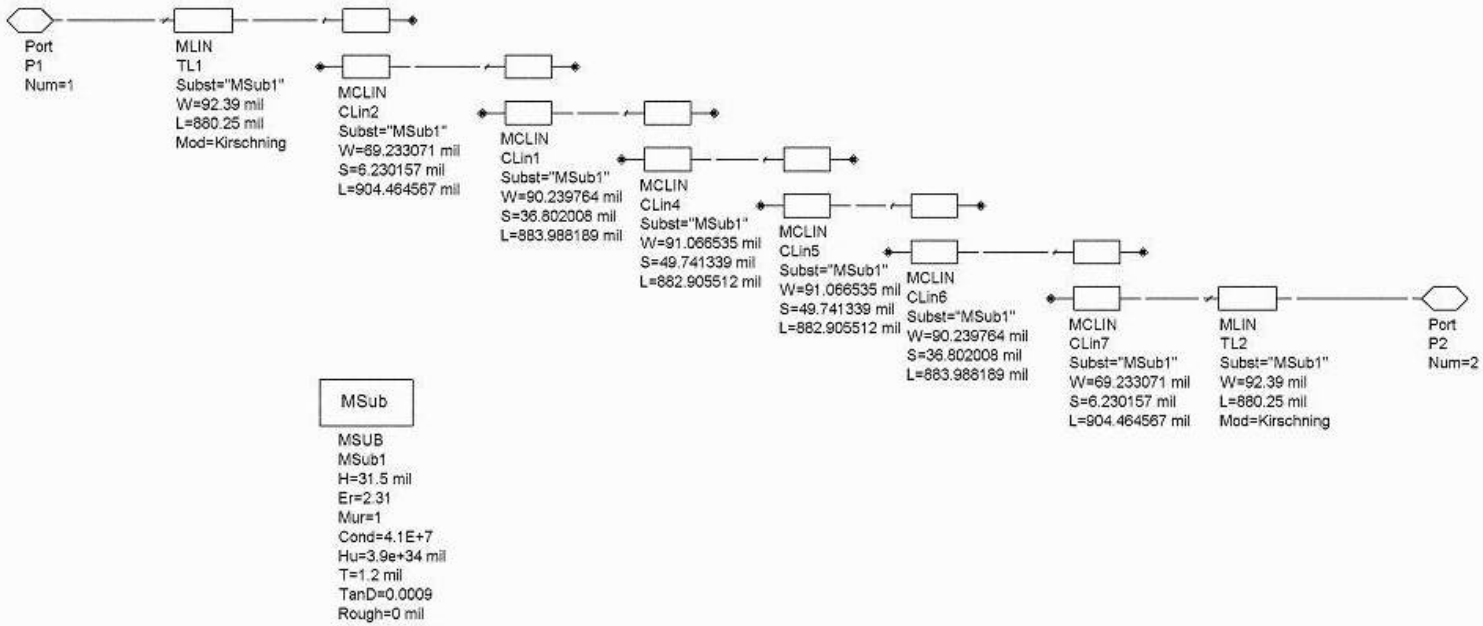

FIGURE 3.2

LAYOUT IN ADS FOR THE FILTER

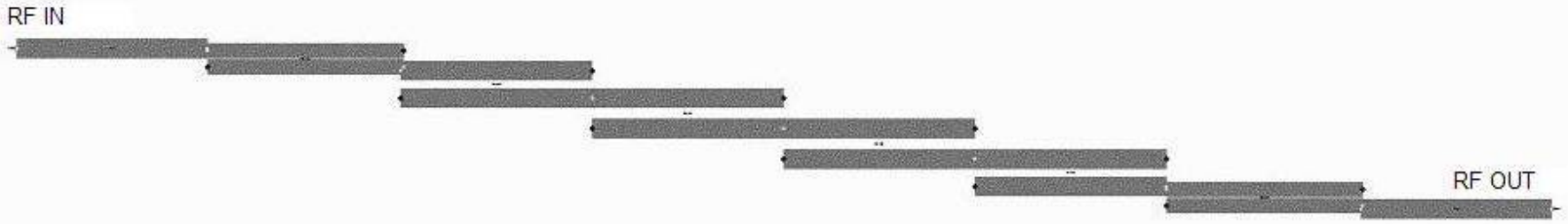

FIGURE 3.3

Simulation Results:

The circuit was simulated for S-parameter simulation using ADS and various parameters and their performances were noted as given below.

S21 , pass band and stop band bandwidth:

TanD = 0.0009

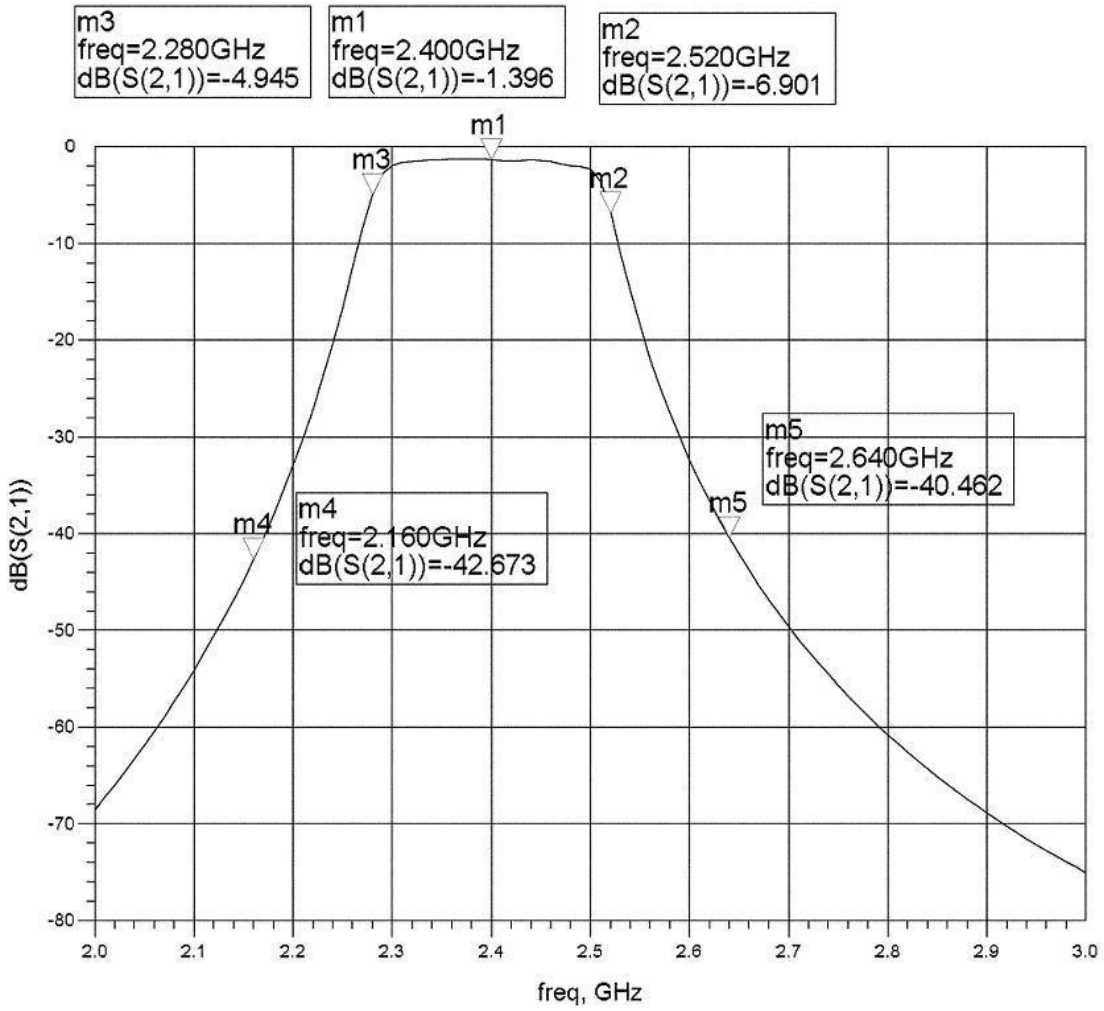

FIGURE 3.4

Return Losses:

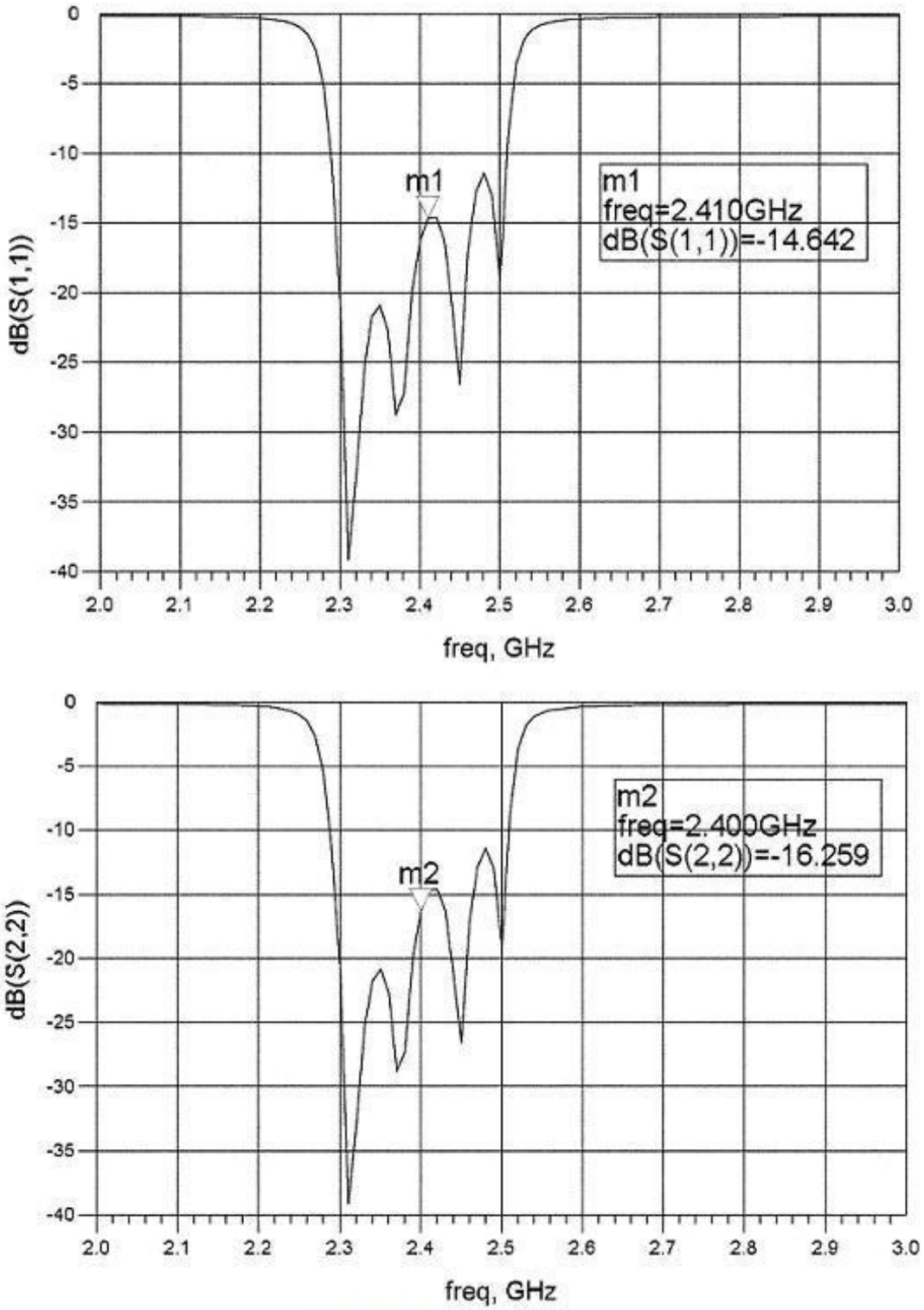

FIGURE 3.5

S21 , pass band and stop band bandwidth:

TanD = 0

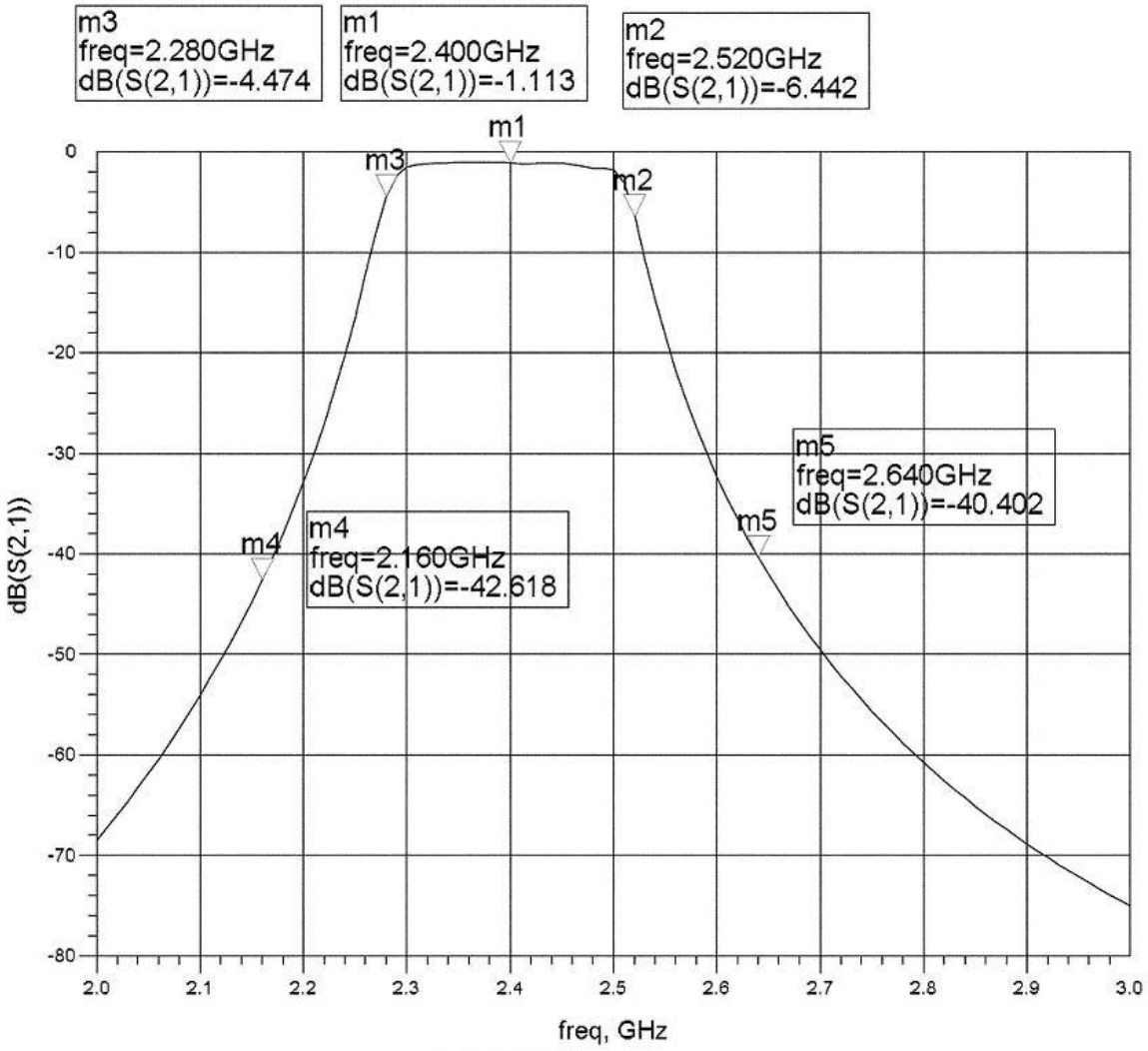

FIGURE 3.6

Measured Results:

S21 , pass band and stop band bandwidth:

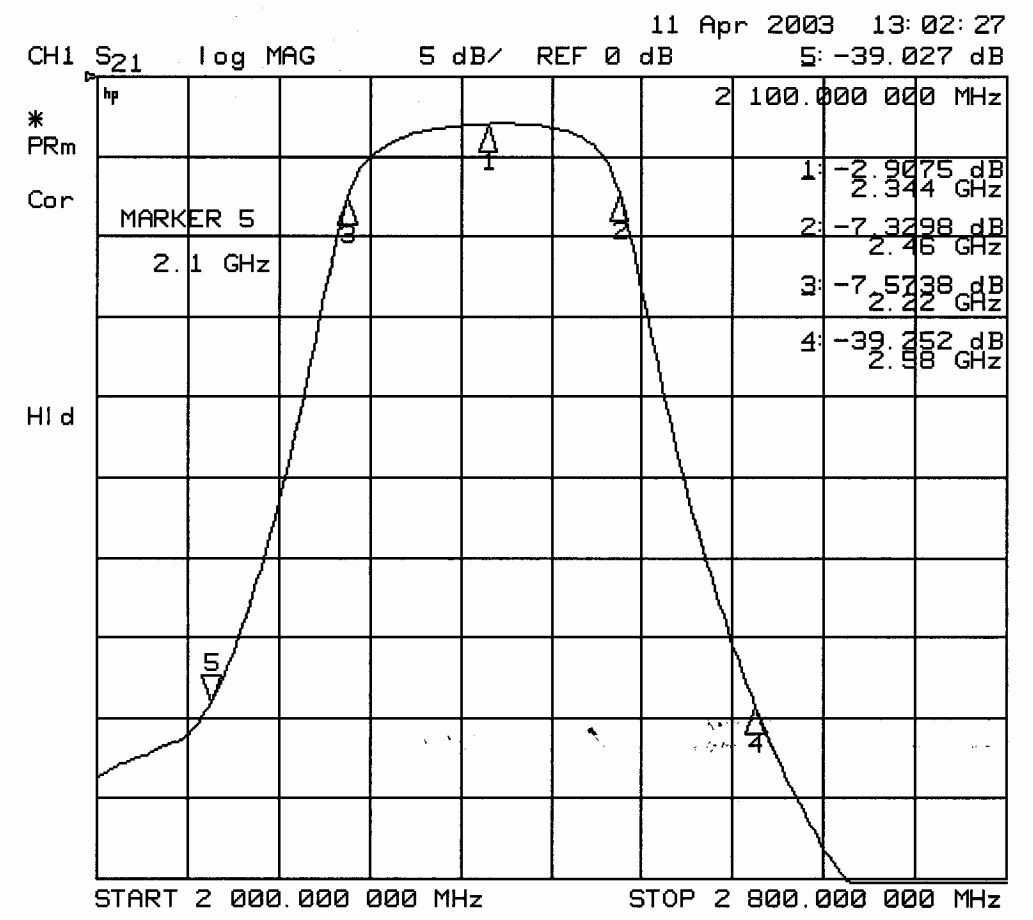

Figure 3.7

Return Loss:

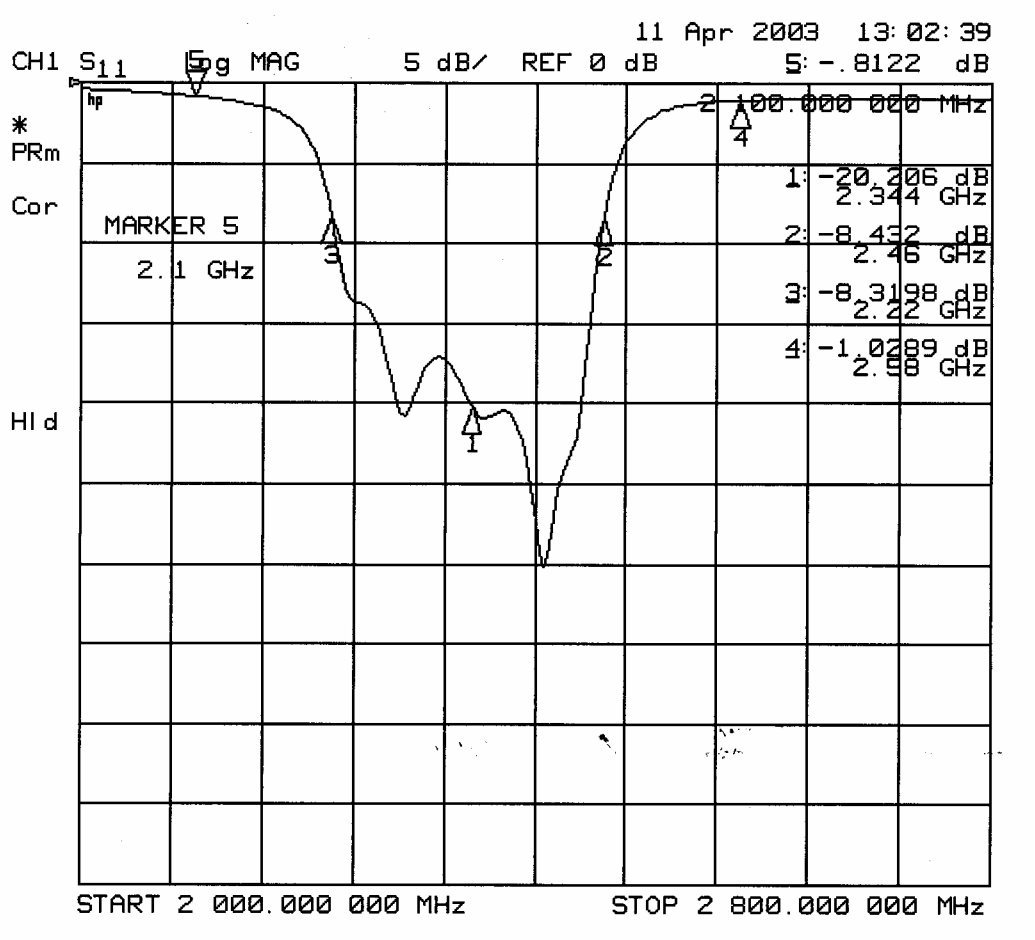

Figure 3.8

Ripple:

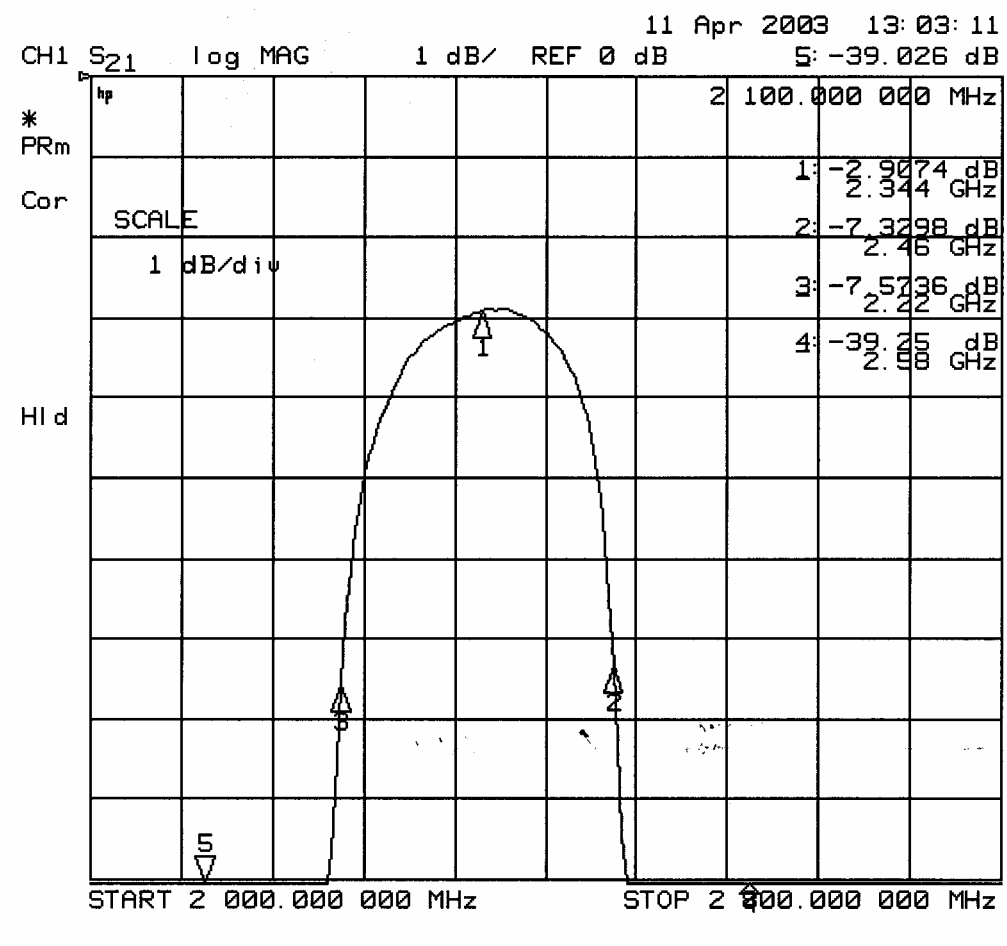

Figure 3.9

The Measured results were poor due to a very narrow separation of 6.232 mils between the 1st and 6th coupled microstrip lines which violated the manufacturing limit of 10 mils.