COMPUTER-AIDED DESIGN (CAD) AND FABRICATION OF MICROSTRIP FILTER

Zulkifli b. Hj. Mohd Sidi **Dr. Zaiki b. Hj. Awang**
Bachelor of Engineering (Hon's.) Electrical,
Faculty of Electrical Engineering,
Institut Teknologi Mara, SHAH ALAM.

Abstract

This paper will present on 'Designing and Fabrication of Microstrip Low-Pass Filter' it's a microwave components operating at very high frequency helping by Computer-Aided Design (CAD). This Low-Pass filter should has a minimum *'Return Loss'* 15dB over the frequency range of 0~2 GHz with minimum *'Attenuation'* 15dB at 3 GHz. The type of this microwave filter are called *'Maximally Flat' (Butterworth)*, which is having often been reputed to have less delay distortion than other type of microwave filter, *'Chebyshev (Equal-Ripple)*'.

Material has been used are *'Duroid/Rogers 5870'* with a 0.5mm thickness and *'relative permitivity'* (ϵ_r) 2.33. CAD *'HP Eesof TouchStone' (Libra)* simulator, the simulation will eliminate many tedious steps and safe a time to draw an actual stripline before doing fabrication when conventional method was compared.

With a great vision from Faculty of Electrical Engineering, ITM, Shah Alam to develop the microwave fabrication facilities, they provides all of designing, fabricating and measuring facilities.[1] 'Wiltron 562 Vector Analyser' is used for measurement analysis purposes.

Introduction

Computer-Aided Design (CAD) is powerful tools for microwave designers getting high reliability standard, precisely characterised and less error. CAD also gives a fastest and cheapest solution to eliminate trial and error, reduce a times and laborious mathematical calculation. [2]

CAD is used to replacing a conventional method, such as trial and error and manually mathematical calculation. Because of these reasons CAD suitable for:

- The complexity of modern systems with demanding in precision and accurate of circuit design.
- Incorporate any changing in circuits fabrication by 'Microwave Integrated Circuit' (MIC) in today technology.
- Variety of active and passive devices is new available for achieving a circuit function. Some difficulties in selective the appropriate devices when conventional method was eliminated.

The configuration of microstrip is parallels to the *ground plane*, which is copper or aluminium, as in figure 1.

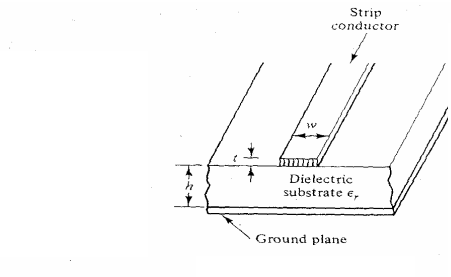

Fig. 1, Microstrip with ground plane (Metal: Copper or Aluminium)

Microstrip is lowest-cost media because all the circuitry is *'photolithographically'* etched on the one side of substrate. Launching energy from coaxial to microstrip is done by connecting the coaxial centre conductor to the circuit conductor to the ground plane. [2]

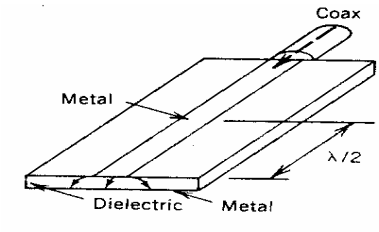

Fig. 1a, Coaxial to microstrip.

Microstrip has the advantages of allowing lumped elements, both active and passive easily mounted directly on the substrate.

With large of dielectric constant will confines the signals and hence less-loss. Due to the planar structure, it's suitable to use in solid state circuitry, low power application and easily to fabricate.

Filters are used for rejecting harmonics and excluding out of band signals. It's a two-port device that plays important role of controlling the frequencies response at some cross section in microwave systems. Letting a band(s) of frequencies pass through while rejecting frequencies in another band(s).

'Insertion-Loss Method' is a modern procedure to designing low-pass filter comparing with conventional method, 'Image Parameters Method'. It is using a 'Network Synthesis Techniques' which is compatible to forward design with other type of microwave filters such as Band-pass filter, High-pass filter, Band-stop Filter etc. By starting with low-pass filter, other type of filters will be designed using 'Insertion-Loss Method'.

This papers is reports the designing microwave low-pass filter (Butterworth type) at 0~2GHz which is above than 2GHz will be rejected, whereby HP Eesof TouchStone is used for simulation process before fabrication.
Photoresist and microstrip etching process will be done afterward at the Fabrication Laboratory.

Experimental Procedures

Following the specification given, with minimum 15dB attenuation, the elements value (*n*) was founded, there is five-elements (*n=5*) lumped circuit microwave filter and Butterworth prototyped was created after denormalised procedure was done. [3]

The next step is to simulate the five-elements (n=5) with lumped circuit using Eesof TouchStone (Libra). Transformation from *'lumped elements'* (L and C) to *'distributed element'* (Width and Length) gives more detail the actual microwave filter design. The formulae are use here to get an accurate Length (L) and Width (W).

The input data such as substrate relative permitivity ($\in_r$), thickness and operation frequencies are important to know before simulate.

With an accessories of Eesof TouchStone called *'Acad'* can be translate the programme type of Eesof TouchStone to the line drawing file of .DXF or .DXG (AutoCAD File). The drawing will be printed in actual scale after converted into *Visio Technical* software. The printer output will be a actual image on transparency film and as a mask for *'photoresist'* process.

Element	Normalise Element Value	Actual Element Value	Width (W) mm	Length (L) mm
C_1	0.618	*0.9836 pF*	*5.93*	*5.09*
L_2	1.618	*6.4378 nH*	*0.81*	*15.77*
C_3	2.000	*3.1831 pF*	*5.94*	*16.49*
L_4	1.618	*6.4378 nH*	*0.81*	*15.77*
C_5	0.618	*0.9836 pF*	*5.93*	*5.09*

Table 1, Respectively element values

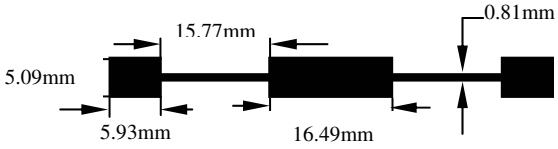

Fig. 2, The two-port network stripline (5th Element Low-Pass Filter-Butterworth)

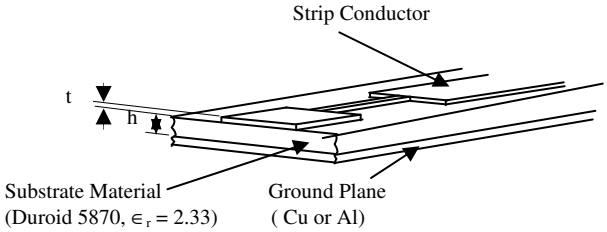

Fig. 3, Butterworth Microwave Low-Pass Filter Microstrip

Photoresist process is to expose substrate Duroid/Rogers 5870 Microwave Integrated Circuit (MIC) into ultraviolet (UV) light. The pattern of microstrip will appear on the substrate after agitation process into *'photoresist developer'*

Actual stripline (Fig.2) will apply into photoresist processes and afterward to making microstrip onto Duroid 5870 MIC.

Results

Figure 4, is a complete Low-Pass Filter Butterworth type with an Aluminium plane ground. Two-port network symmetrical microstrip could be any input or output between two ports.

Figure 5, shown us the distributed simulation program that is consists of parameter "MLIN" in HP EESOF TouchStone Libra. Through this HP Simulator program; bring us to the Figure 5a, this graph (decibel Vs. Frequency) show us 'Insertion Loss' and 'Return Loss' of the Low-Pass Filter

microwave circuit design, we can see the cut-off frequency at 2 GHz. Simulation program will transpose into the actual stripline as shown in Figure 2.

This report also includes the Low-Pass Filter measurement using Wiltron 562 Scalar Network Analyser shown on Figure 6.

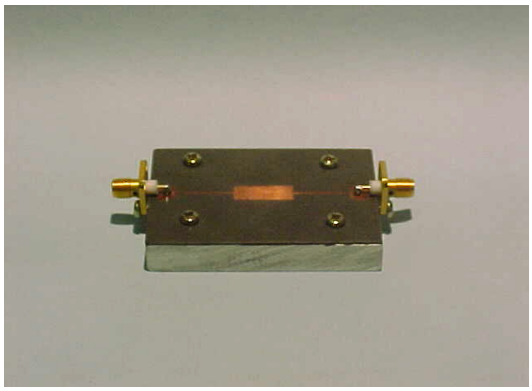

Figure 4, Low-Pass Filter (Zulkifli Mohd Sidi ©)

Conclusion

The simulation software is a tool for me as a designer in this decade. Making design much easy and reducing a time during early design process. Electromagnetic energy is most virtual condition than real world that is can see; Computers-Aided Design (CAD) can solve our microwave circuits during a second.

We have reported almost Low-Pass (Butterworth type) Filter are symmetrical shapes. When we know clearly the length (L) and width (W) of the microstrip, the roughly microstrip shaping can be identified. By using AutoCad or Visio Technical software, the stripline layout will be pictured it.

The fabrication facilities of microstrip design almost reached their targets, making successfully fabricated at Electrical Faculty, Institut Teknologi MARA (ITM).

The calibration of Wiltron Scalar Network Analyser is most important to measure more accurately. This calibration is to define the actual references port and attenuation causes by connectors will be eliminated. Calibration is the process whereby losses inherent in a transmission or return loss measurement system are measured, and the result given are minus residual losses. But we still have losses; this may be created from extra connection or dioxides of components Adapter, Rf Detector or SWR Autotester, but these losses cannot be avoided and not in serious situation. Others losses may be from device under test itself, sometime the manually fabrication exposed to the human error with unbalance edge of stripline. Without problems mentioned above, the ripples on the result could be reduced.

This Low-Pass Filter allowed 0 ~ 2 GHz pass through and rejected others than that. 'Cut-off frequency' (f_c) is almost 2 GHz. Lastly, the project was successfully conducted.

Acknowledgement

I wish to acknowledge the advice and help of Dr. Zaiki b. Hj. Awang and former SIRIM staff Dr.

Nafizah Goriman Khan who is my supervisor and advisor respectively giving me an ideas, progress comments and suggestion.
Appreciation also should be given to my friends who is support with pleasant ideas.

References

[1] Rahani Bt Abdullah, "CAD & Characterisation of Microstrip Low-Pass Filter", Bachelor of Eng. (Hons.) Electrical, ITM, Shah Alam. Oct 1997.

[2] Edward A. Wolff and Roger Kaul, "Microwave Engineering and System Applications," pp. 167-169.

[3] Samuel Y. Liao, "Microwave Devices and Circuits," Prentice Hall International Editions, pp. 472-473.

[4] D.M. Pozar, "Microwave Engineering", pp. 477-478.

[5] Matthael, George L., "Microwave Filter, Impedance Matching Network, and Coupling Structure", Mc Graw HillBook Company.

```
            Libra(R) for Windows, Version 2.100.105.0425R

Date: 22 December 1998  Time: 12:09

                    Design File Name: A:\JADIFIL.CKT

Printout of EditFile

DIM
   FREQ GHZ
   COND /OH
   IND NH
   CAP PF
   LNG MM
   ANG DEG
   VOL V
   CUR MA
   PWR DBM

CKT
   MSUB ER=2.33 H=0.79 T=0.02 RHO=1.0 RGH=0.015
   TAND TAND=0.0001
   MLIN 1 2 W=5.93 L=5.09
   MLIN 2 3 W=0.81 L=15.77
   MLIN 3 4 W=5.94 L=16.49
   MLIN 4 5 W=0.81 L=15.77
   MLIN 5 6 W=5.93 L=5.09
   DEF2P 1 6 LPF


OUTVAR
   L=LPF MAG[S11]
   S=LPF MAG[S21]

OUTEQN
   I=20*LOG(L) ! INSERTION LOSS FORMULAE
   R=20*LOG(S)  ! RETURN LOSS FORMULAE

FREQ
   SWEEP 0 6 0.2

OUT
   LPF DB[S11] GR1
   LPF DB[S21] GR1
   OUTEQN MAG[I] GR2
   OUTEQN MAG[R] GR2
   LPF VSWR1 GR3

GRID
   FREQ 0 6 0.2
   GR1  -70 0 10
   GR2  -10 70 10
   GR3  0 6 1

OPT
   FREQ 0 6 1
```

Fig. 5, The output of HP EESof TouchStone Simulation programs.

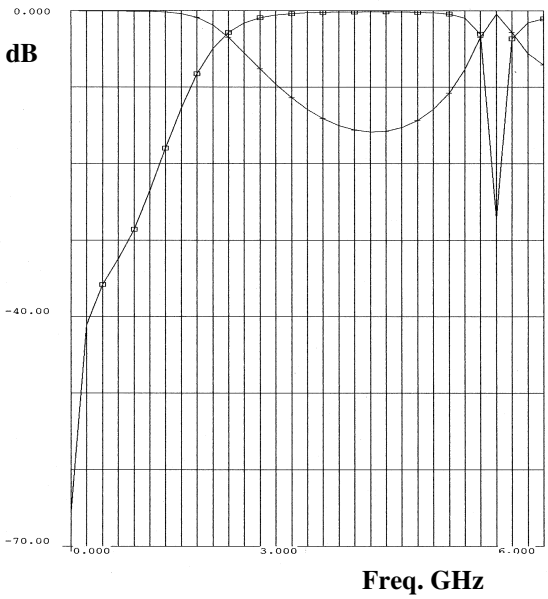

Fig. 5a, The simulation results in distributed elements (dB).

Fig. 6, Low-Pass Filter Microstrip measurements using Wiltron Scalar Network Analyser