SYNTHESIS, DESIGN AND SIMULATION OF A DIPLEXER

BY

JAGJEET PAL SINGH-031014

PRABHJOT SINGH -031016

SUCHIT BOORA-031105

Submitted in partial fulfillment of the Degree of

Bachelor of Technology

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY-WAKNAGHAT.

MAY-2007

CERTIFICATE

I hereby certify that the work which is being presented in the project entitled "**SYNTHESIS, DESIGN AND SIMULATION OF A DIPLEXER**" by **Jagjeet Pal Singh, Prabhjot Singh, Suchit Boora** in partial fulfillment of requirements for the award of degree of B.Tech. (E.C.E) submitted in the Department of (Electronics & Communication Engineering) at JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY is an authentic record of our own work under the supervision of **Dr. Tapas Charkravarty**. The matter presented in this project has not been submitted by us in any other University / Institute for the award of B.Tech. Degree.

This is to certify that the above statement made by the candidate is correct to the best of my knowledge

Dr. Tapas Charkravarty

ACKNOWLEDGMENT

We wish to express our earnest gratitude to **Dr Tapas Chakravarty**, for providing us invaluable guidance and timely suggestions by the help of which we successfully completed our project. We'd also like to thank her for her moral support in times when the project was losing pace.

We would like to the thank the faculty of the Electronic & Communication Engineering Department of Jaypee University of Information Technology, Waknaghat for their valuable suggestions that made helped us improve our project.

We would like to thank all the staff members of the Computing facilities of **Jaypee University of Information Technology**, Waknaghat, for providing us with support and facilities required for the completion of this project.

TABLE OF CONTENTS

CHAPTER I
INTRODUCTION

1-1 Diplexer

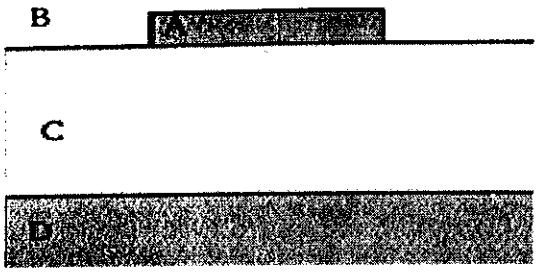
It's a network that splits a signal to two or more loads, dependent on frequency. It is the simplest form of a multiplexer, which can split a signal into many different signal bands. Often a diplexer is used to route signals, based on frequency, to two different receivers. A diplexer can also be used to create a "matched" filter that is non-reflective outside of the intended passband. It can also be used as a bias tee, to feed your favorite active device with DC power.

It is the network that permits a transmitter and receiver to use the same antenna, at or very near the same frequency. This is not used in radar, where the returned signal is going to be very close to the transmitted frequency. In a diplexer, the signals have to be offset in frequency by an appreciable percentage so the filters can do their job sorting them out.

Diplexers are generally used to separate whole frequency ranges. For example, a certain **Diplexer** may have two output ports, and one input port. Port A (Input), port B (Output 1) and port C (output port 2). Port A may be connected to a device that produces multiple frequency ranges, for example HF (High Frequency - Less then 30 MHz) and say VHF (Very High Frequency - 130 MHz - 174 MHz). The **Diplexer** might be used to separate these two "bands" (HF & VHF) into to different antenna.

1-2 Microstrip

Cross-section of microstrip geometry:-



Conductor (A) is separated from ground plane (D) by dielectric substrate (C). Upper dielectric (B) is typically air.

A **microstrip** is a thin, flat electrical conductor separated from a ground plane by a dielectric layer. Microstrips are used in printed circuit designs where high frequency signals need to be routed from one part of the assembly to another with high efficiency and minimal signal loss due to radiation. They are of a class of electrical conductors called transmission lines, having specific electrical properties that are determined by conductor width and resistivity, spacing from the ground plane, and dielectric properties of the insulating layer. A microstrip transmission line is similar to a stripline, except that the stripline is sandwiched between two ground planes and respective insulating layers.

1-2-1 Inhomogeneity

The electromagnetic wave carried by a microstrip line, exists partly in the dielectric substrate, and partly in the air above it. In general, the dielectric constant of the substrate will be greater than that of the air, so that the wave is travelling in an inhomogeneous medium. In consequence, the propagation velocity is somewhere between the speed of radio waves in the substrate, and the speed of radio waves in air. This behaviour is commonly described by stating the **effective dielectric constant** (or **effective relative permittivity**) of the microstrip; this

being the dielectric constant of an equivalent homogeneous medium (i.e. one resulting in the same propagation velocity).

Further consequences of an inhomogeneous medium include:

- The line will not support a true TEM wave; at non-zero frequencies, both the E and H fields will have longitudinal components (a hybrid mode). The longitudinal components are small however, and so the dominant mode is referred to as **quasi-TEM**.

- The line is dispersive. With increasing frequency, the effective dielectric constant gradually climbs towards that of the substrate, so that the phase velocity gradually decreases. This is true even with a non-dispersive substrate material (the substrate dielectric constant will usually fall with increasing frequency).

- The characteristic impedance of the line changes slightly with frequency (again, even with a non-dispersive substrate material). The characteristic impedance of non-TEM modes is not uniquely defined, and depending on the precise definition used, the impedance of microstrip either rises, falls, or falls then rises with increasing frequency. The low-frequency limit of the characteristic impedance is referred to as the **quasi-static characteristic impedance**, and is the same for all definitions of characteristic impedance.

- The wave impedance varies over the cross-section of the line.

1-2-2 Characteristic Impedance

A closed-form approximate expression for the quasi-static characteristic impedence of a microstrip line was developed by Wheeler

$$Z_{\text{microstrip}} = \frac{Z_0}{2\pi\sqrt{2(1+\varepsilon_r)}} \ln\left(1 + \frac{4h}{w_{\text{eff}}}\left(\frac{14+\frac{8}{\varepsilon_r}}{11}\frac{4h}{w_{\text{eff}}} + \sqrt{\left(\frac{14+\frac{8}{\varepsilon_r}}{11}\frac{4h}{w_{\text{eff}}}\right)^2 + \pi^2\frac{1+\frac{1}{\varepsilon_r}}{2}}\right)\right)$$

where w_{eff} is the *effective width*, which is the actual width of the strip, plus a correction to account for the non-zero thickness of the metallization. The effective width is given by

$$w_{\text{eff}} = w + t\frac{1+\frac{1}{\varepsilon_r}}{2\pi}\ln\left(\frac{4e}{\sqrt{\left(\frac{t}{h}\right)^2+\left(\frac{1}{\pi}\frac{1}{\frac{w}{t}+\frac{11}{10}}\right)^2}}\right)$$

with

Z_0 = impedance of free space,

ε_r = dielectric constant of substrate,

w = width of strip,

h = thickness ('height') of substrate and

t = thickness of strip metallization.

This formula is asymptotic to an exact solution in three different cases

1. $w \gg h$, any ε_r (parallel plate transmission line),
2. $w \ll h$, $\varepsilon_r = 1$ (wire above a ground-plane) and
3. $w \ll h$, $\varepsilon_r \gg 1$.

CHAPTER II
MODEL DESIGN AND ANALYSIS

2-1 Designing steps

The four main designing steps :

1) Determine the one type resonator network, to realize the specification, from the original prototype.

2) From the network parameters, evaluate the even and odd ordered characteristics impedances, Z_{oe} and Z_{oo}, applicable to the parallel-coupled microstrip.

   The quantities 'g' refer to the prototype element values, for example g_o=1(the normalized termination value) and g1 =0.781 from the table for a fourth order chebyshev prototype which is standard data available in many references . The admittance inverter parameters (J) are then given by:

   For the first coupling structure:

   $$J_{01}/Y_0 = \sqrt{\Pi\delta \;/\; 2g_1g_0}$$

   For the intermediate coupling structure :

   $$J_{j,j+1}/Y_0 \;\big|_{j=1to(n-1)} = \Pi\delta \;/\; 2\omega_c\sqrt{g_jg_{j+1}}$$

   For the final coupling structure :

   $$J_{n,n+1}/Y_0 = \sqrt{\Pi\delta \;/\; 2g_ng_{n+1}}$$

In these three equations, δ is the fractional bandwidth

$$\delta = f_2 - f_1 / f_0$$

The frequency transformation from the low pass prototype filter to the bandpass microwave filter is then

$$\omega_i / \omega_c = 2/\delta \, (f_i - f_o / f_0)$$

where ω_c is the prototype cut off frequency (it equals 1.0) and ω_i has to be defined in the filter specifications.

3) Relate the values of Z_{oe} and Z_{oo} to microstrip widths and separations (w, s).

$$(Z_{oe})_{j,j+1} = Z_0 (1 + aZ_0 + a^2 Z_0^2)$$

$$(Z_{oo})_{j,j+1} = Z_0 (1 - aZ_0 + a^2 Z_0^2)$$

where $a = J_{j,j+1}$

4) Calculate the whole resonator length 2l', slightly less than $\lambda_g /2$, and therefore of the coupled-section length l', which is slightly less than $\lambda_g /4$.

Here λ_g is the mid-band and average microstrip line wavelength.

Filter 1 specifications

Transmission media :- Stripline

Filter center frequency :- 2.25 GHz

Filter bandwidth :- 0.1 GHz

Ripple :- 0.5

Out of band attenuation :- 2.6 GHz

Attenuation at that frequency :- 40 dB

Input Impedence :- 50 ohm

Output Impedence :- 50 ohm

Internal impedence :- 60 ohm

Relative dielectric constants :- 3.5

Dielectric :- GaAs

Filter 2 specifications

Transmission media :- Stripline

Filter center frequency :- 2.5 GHz

Filter bandwidth :- 0.1 GHz

Ripple :- 0.5

Out of band attenuation :- 2.9GHz

Attenuation at that frequency :- 40 dB

Input Impedence :- 50 ohm

Output Impedence :- 50 ohm

Internal impedence :- 60 ohm

Relative dielectric constants :- 3.5

Even and Odd Impedances of the Edge coupled band pass filter with center frequency 2.5 GHz

N (order)	$Z^{even}(\Omega)$	$Z^{odd}(\Omega)$
1)	63.077	39.832
2)	52.360	47.354
3)	51.969	48.174
4)	52.360	47.354
5)	63.077	39.832

Even and Odd Impedancies of the Edge coupled band pass filter with center frequency 2.25 GHz

N (order)	$Z^{even}(\Omega)$	$Z^{odd}(\Omega)$
1)	63.160	39.851
2)	52.639	47.227
3)	52.200	47.977
4)	52.639	47.227
5)	63.160	39.851

:

2.2 Tools used

2-2-1 Tx Line software

It's a software used to calculate the Length , Width , Height, Gap and thickness of Coupled Microstrip Lines which we need to realize Edge coupled filters and finally diplexers.
Here we input even and odd impedances which we calculated manually by using formulae.

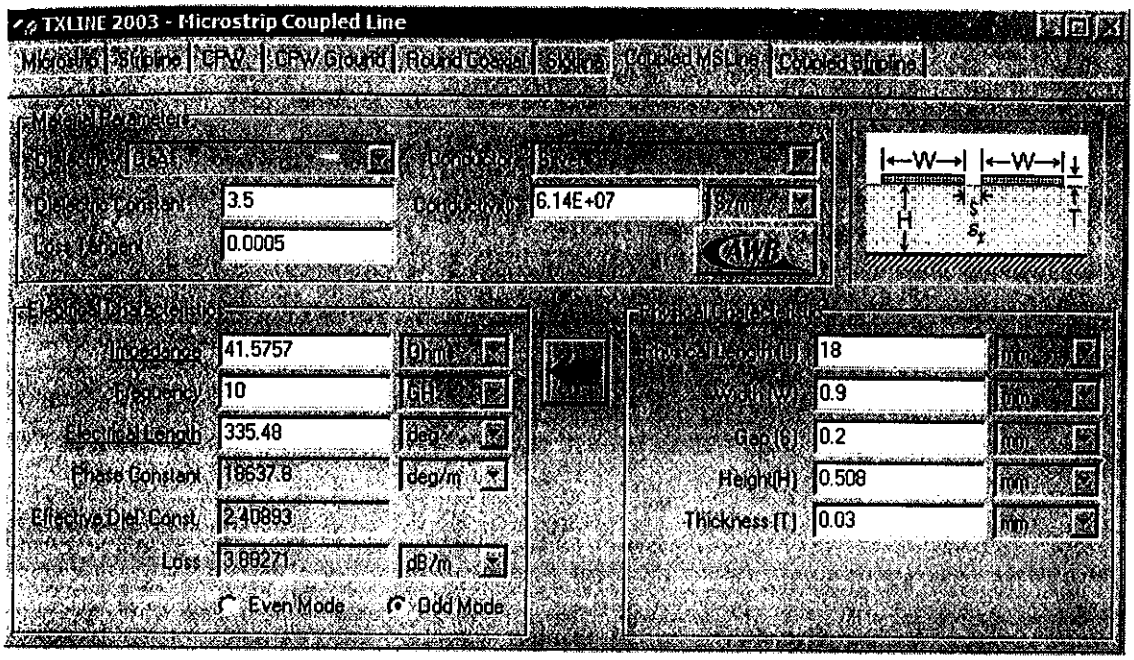
2-2-2 AWR software

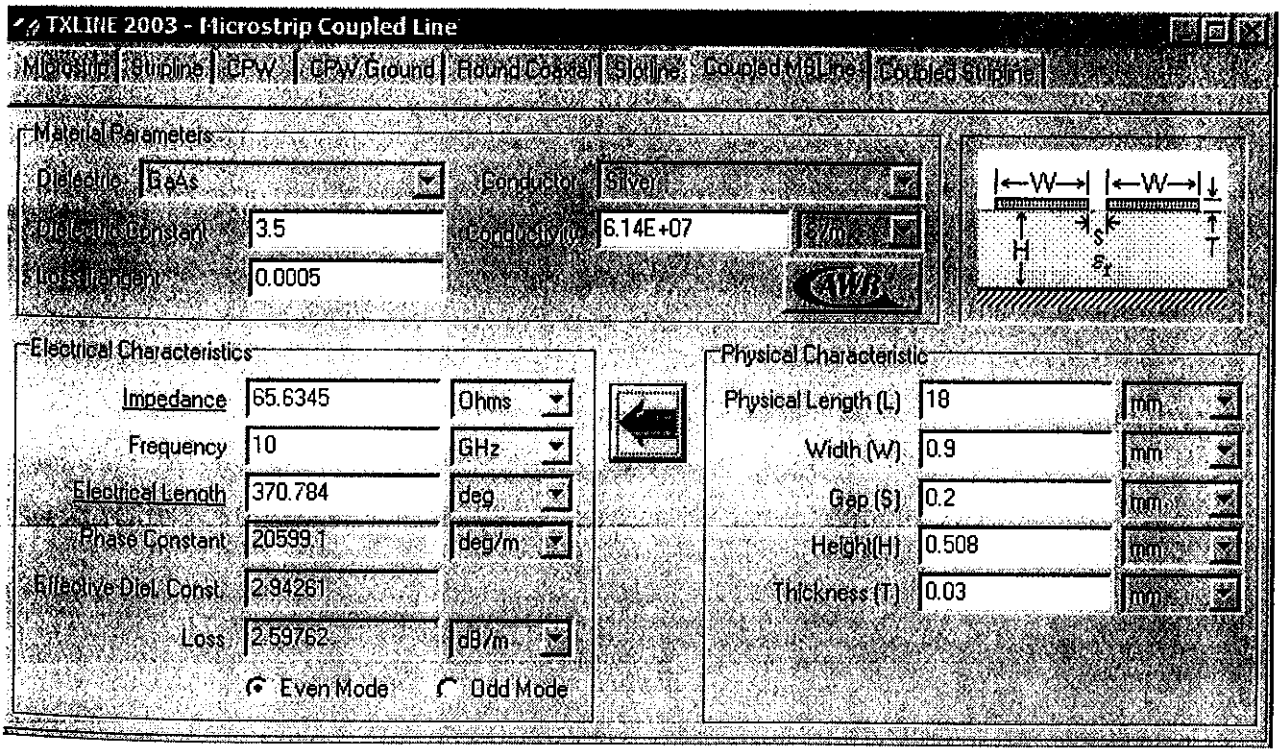
This software is used to simulate the final result of the edge coupled filters and the diplexer.

2-3 Edge coupled band pass filter 1

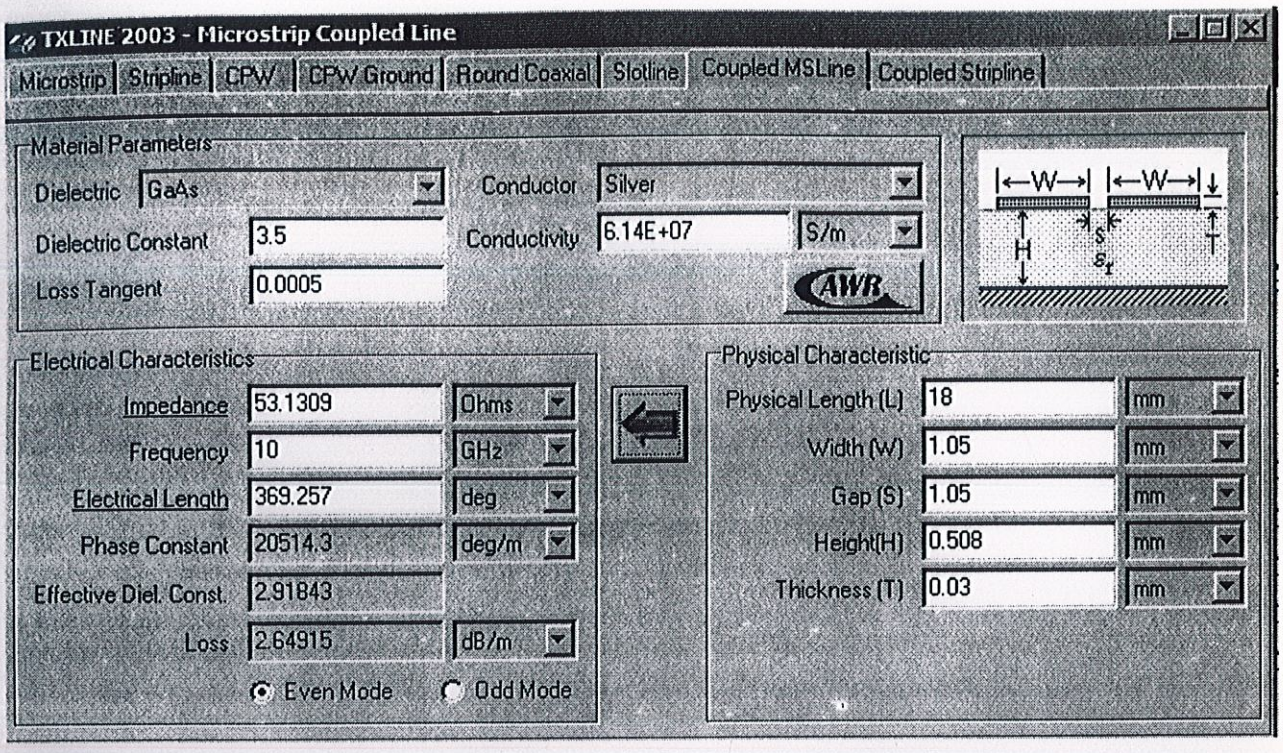
Results obtained using Txline for filter 1 with center frequency 2.25 GHz

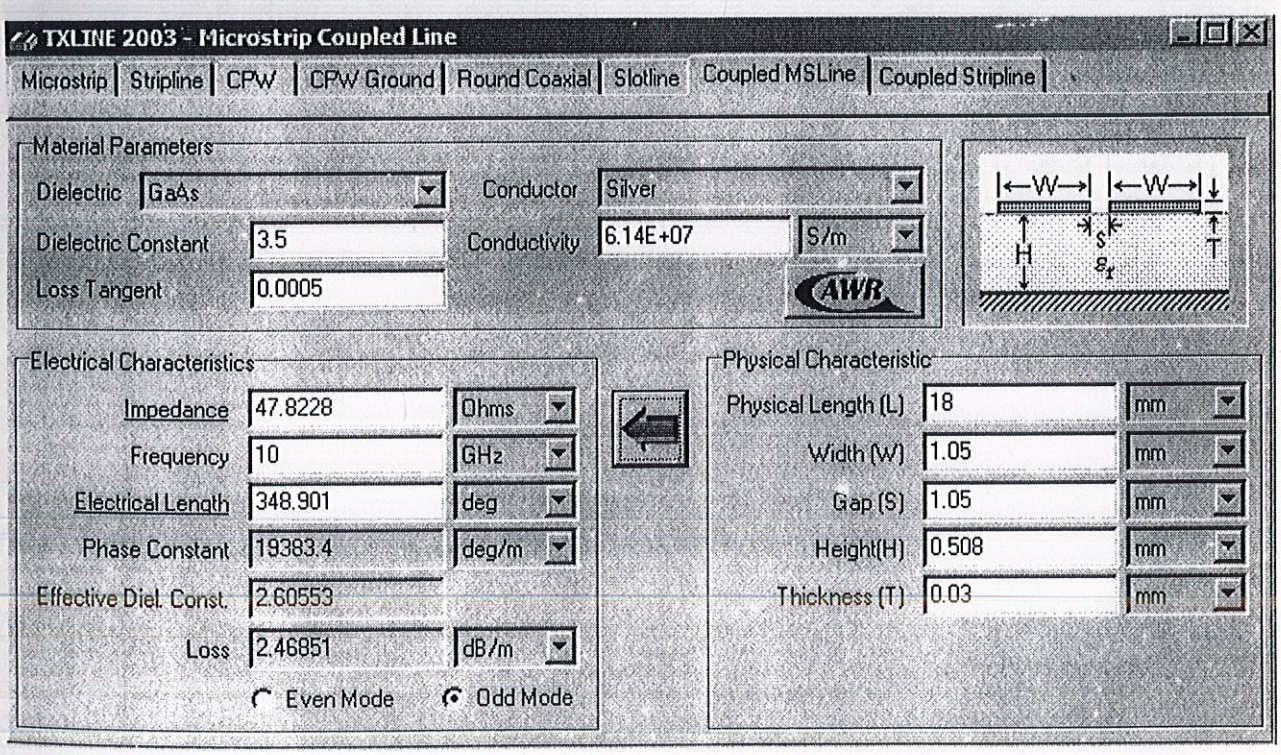
For order (n) = 1



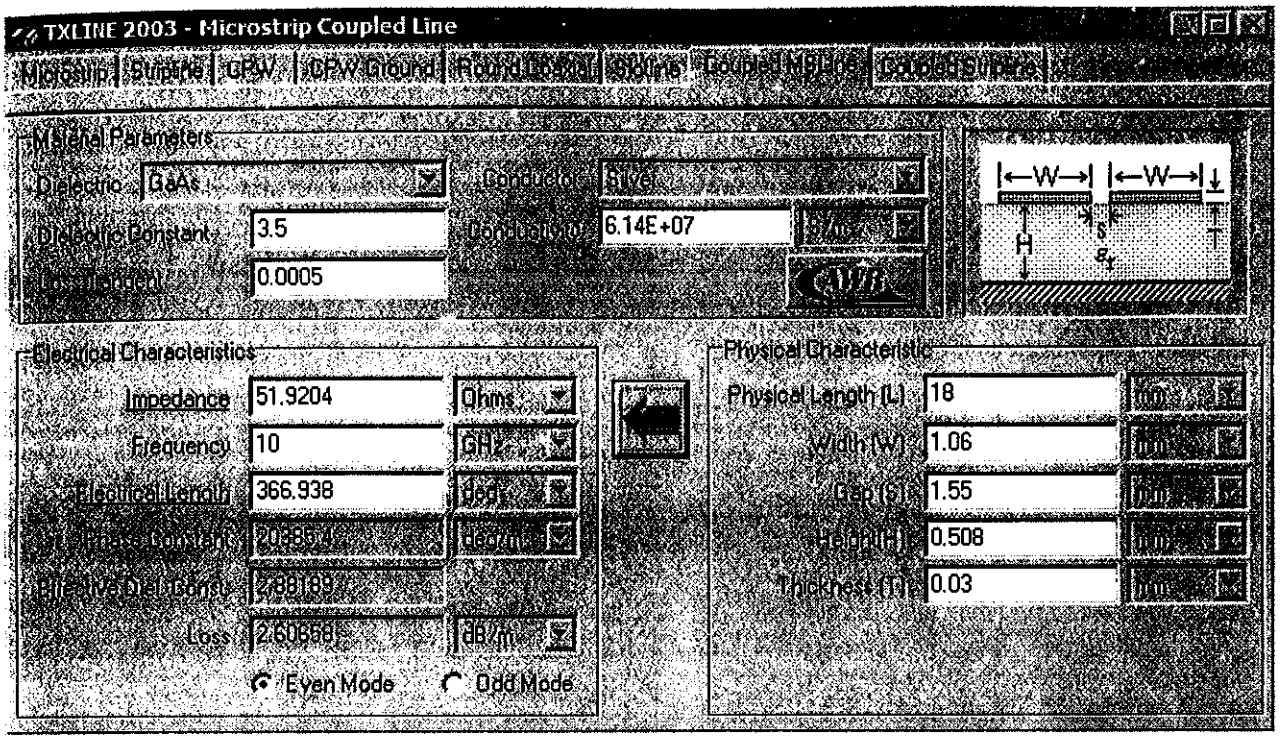


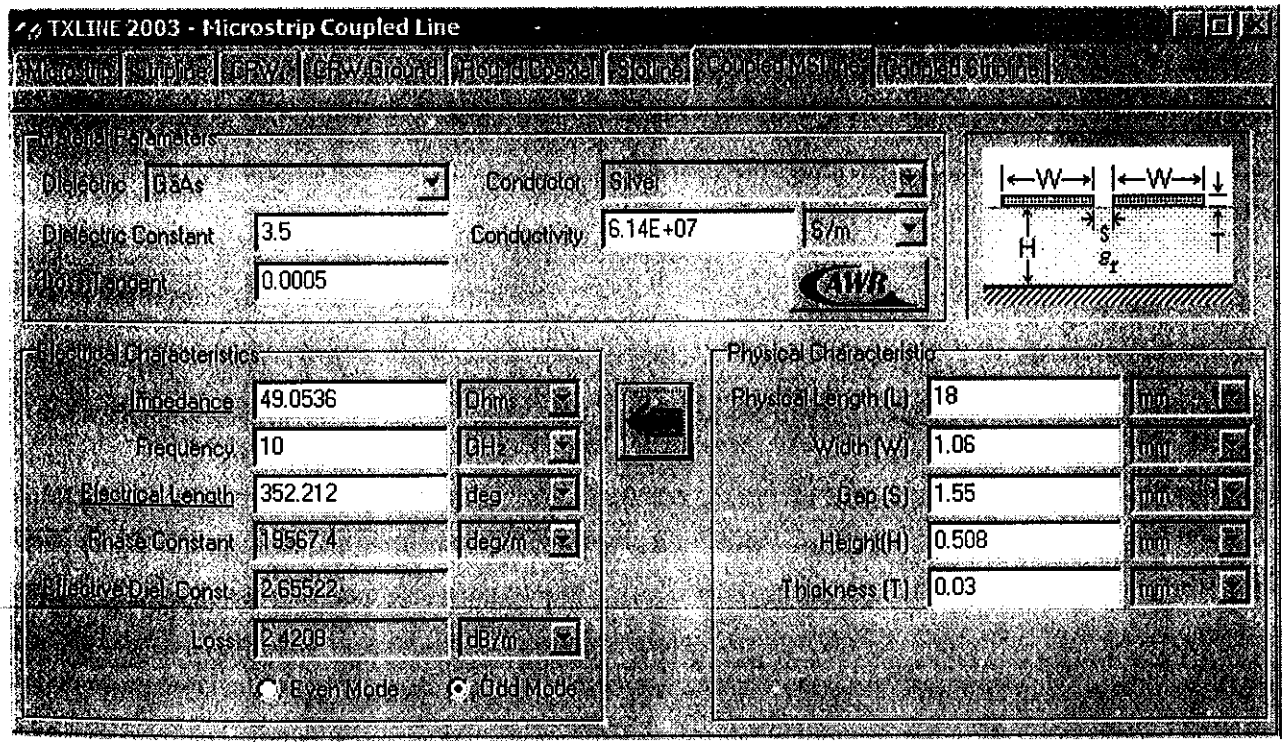
For order (n) = 2


TXLINE 2003 - Microstrip Coupled Line
Microstrip
Stripline
CPW
CPW Ground
Round Coaxial
Slotline
Coupled MSLine
Coupled Stripline
Material Parameters
Dielectric
GaAs
Conductor
Silver
Dielectric Constant
3.5
Conductivity
6.14E+07
S/m
Loss Tangent
0.0005
AWR
W
S
T
H
Electrical Characteristics
Impedance
53.1309
Ohms
Frequency
10
GHz
Electrical Length
369.257
deg
Phase Constant
20514.3
deg/m
Effective Diel. Const.
2.91843
Loss
2.64915
dB/m
Even Mode
Odd Mode
Physical Characteristic
Physical Length (L)
18
mm
Width (W)
1.05
mm
Gap (S)
1.05
mm
Height(H)
0.508
mm
Thickness (T)
0.03
mm

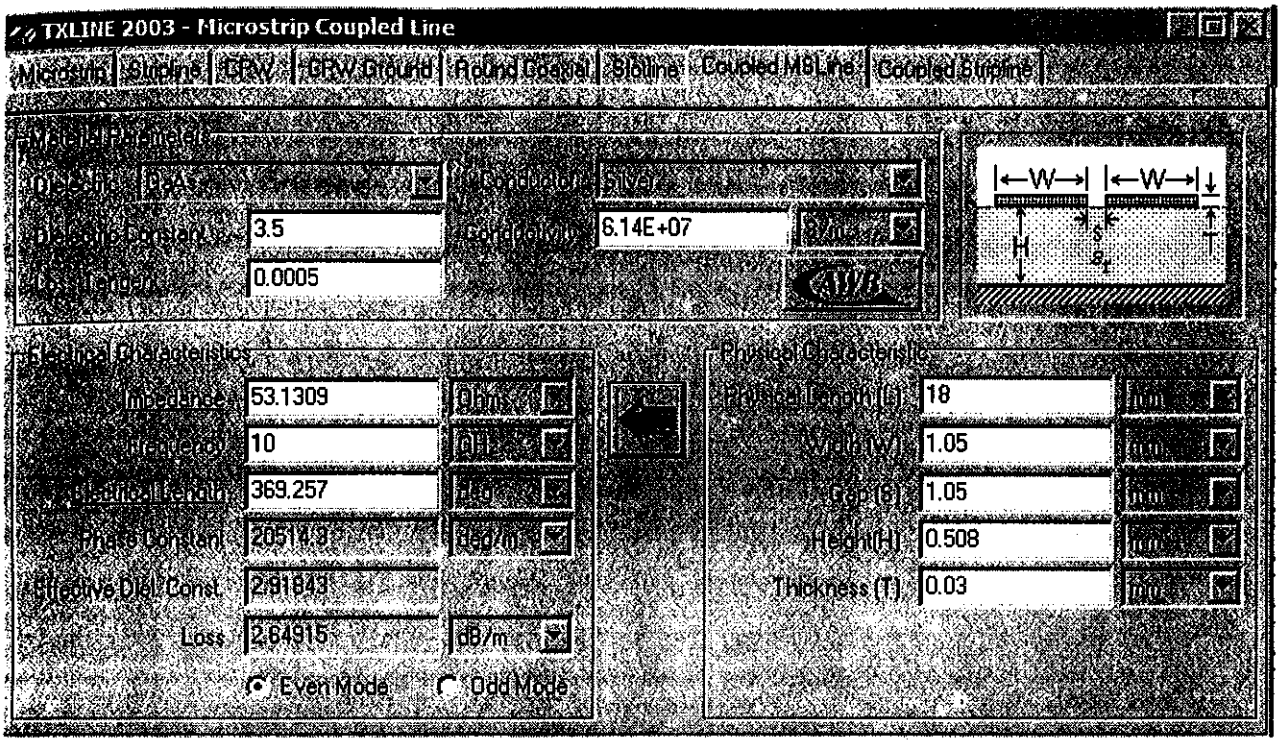

TXLINE 2003 - Microstrip Coupled Line
Microstrip
Stripline
CPW
CPW Ground
Round Coaxial
Slotline
Coupled MSLine
Coupled Stripline
Material Parameters
Dielectric
GaAs
Conductor
Silver
Dielectric Constant
3.5
Conductivity
6.14E+07
S/m
Loss Tangent
0.0005
AWR
W
S
T
H
Electrical Characteristics
Impedance
47.8228
Ohms
Frequency
10
GHz
Electrical Length
348.901
deg
Phase Constant
19383.4
deg/m
Effective Diel. Const.
2.60553
Loss
2.46851
dB/m
Even Mode
Odd Mode
Physical Characteristic
Physical Length (L)
18
mm
Width (W)
1.05
mm
Gap (S)
1.05
mm
Height(H)
0.508
mm
Thickness (T)
0.03
mm

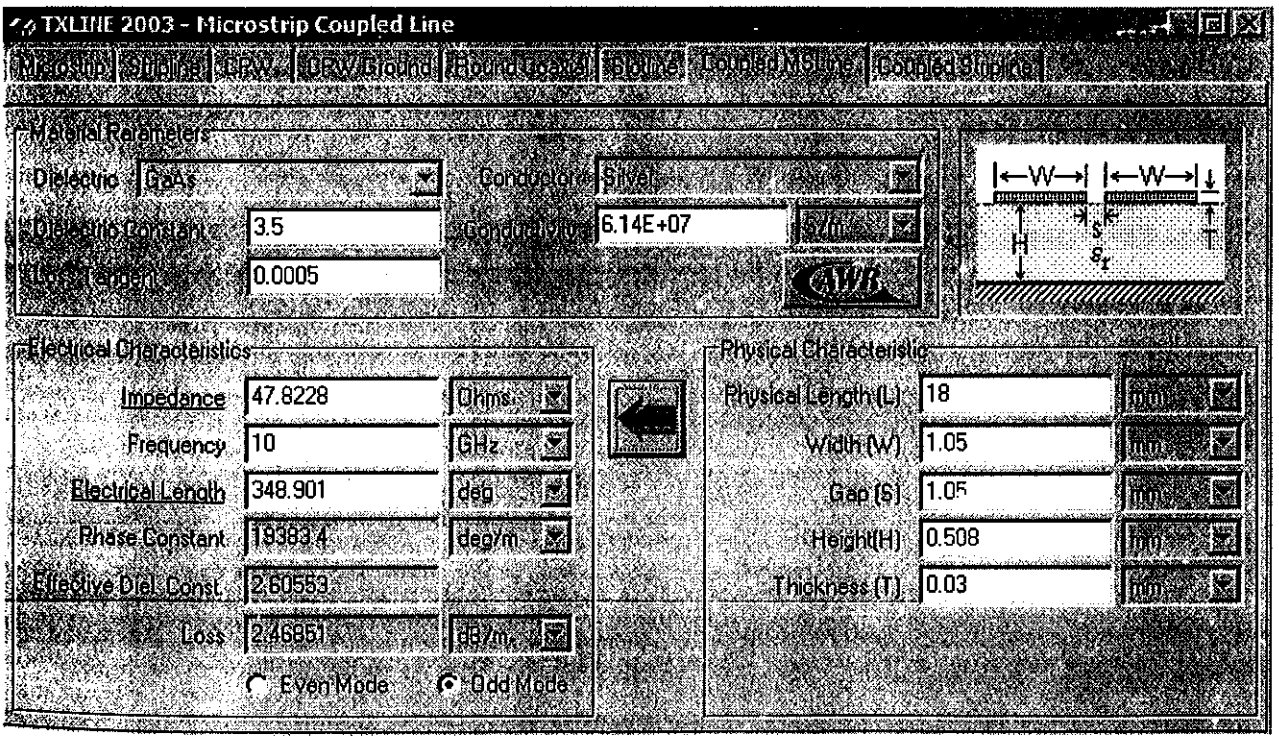
For order (n) = 3


TXLINE 2003 - Microstrip Coupled Line
Material Parameters
Dielectric
GaAs
Conductor
Silver
Dielectric Constant
3.5
Conductivity
6.14E+07
S/m
Loss Tangent
0.0005
Electrical Characteristics
Impedance
51.9204
Ohms
Frequency
10
GHz
Electrical Length
366.938
deg
Phase Constant
20986.4
deg/m
Effective Diel Const
2.88189
Loss
2.60858
dB/m
Even Mode
Odd Mode
Physical Characteristic
Physical Length (L)
18
mm
Width (W)
1.06
Gap (S)
1.55
Height(H)
0.508
Thickness (T)
0.03

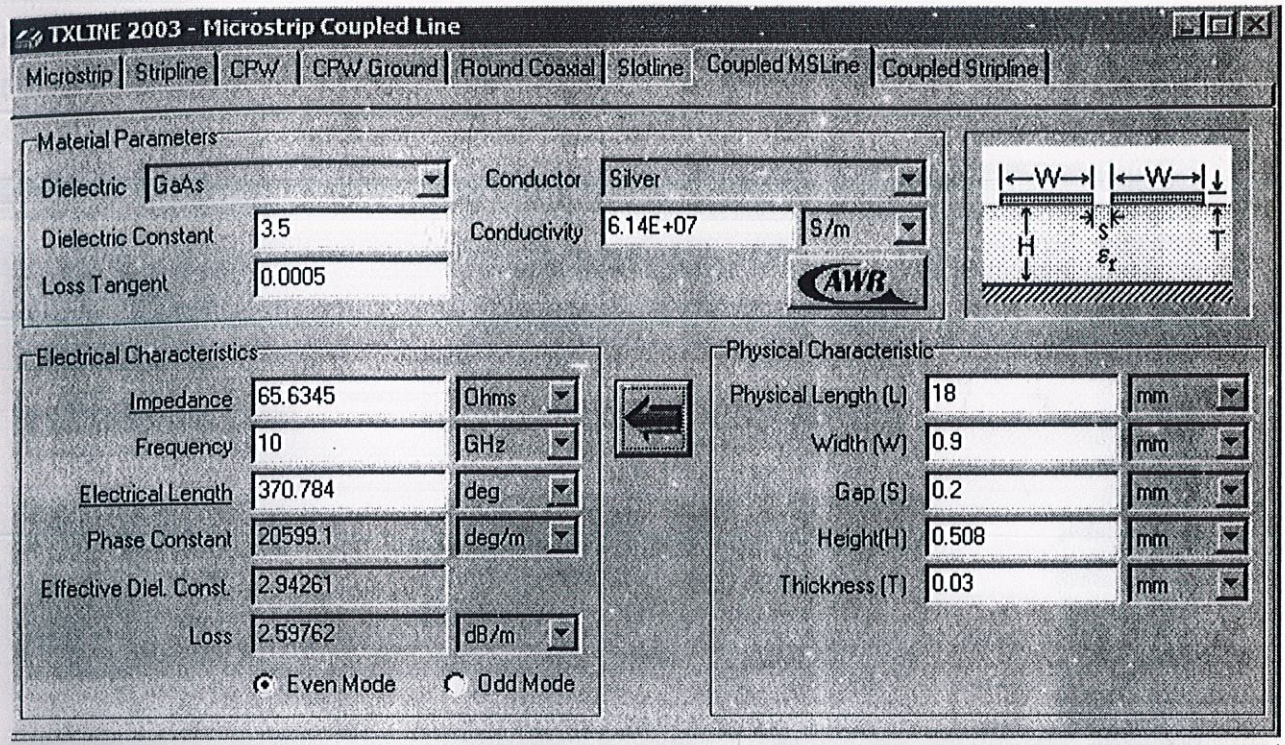

TXLINE 2003 - Microstrip Coupled Line
Material Parameters
Dielectric
GaAs
Conductor
Silver
Dielectric Constant
3.5
Conductivity
6.14E+07
S/m
Loss Tangent
0.0005
Electrical Characteristics
Impedance
49.0536
Ohms
Frequency
10
GHz
Electrical Length
352.212
deg
Phase Constant
19567.4
deg/m
Effective Diel Const
2.65522
Loss
2.4208
dB/m
Even Mode
Odd Mode
Physical Characteristic
Physical Length (L)
18
mm
Width (W)
1.06
Gap (S)
1.55
Height(H)
0.508
Thickness (T)
0.03

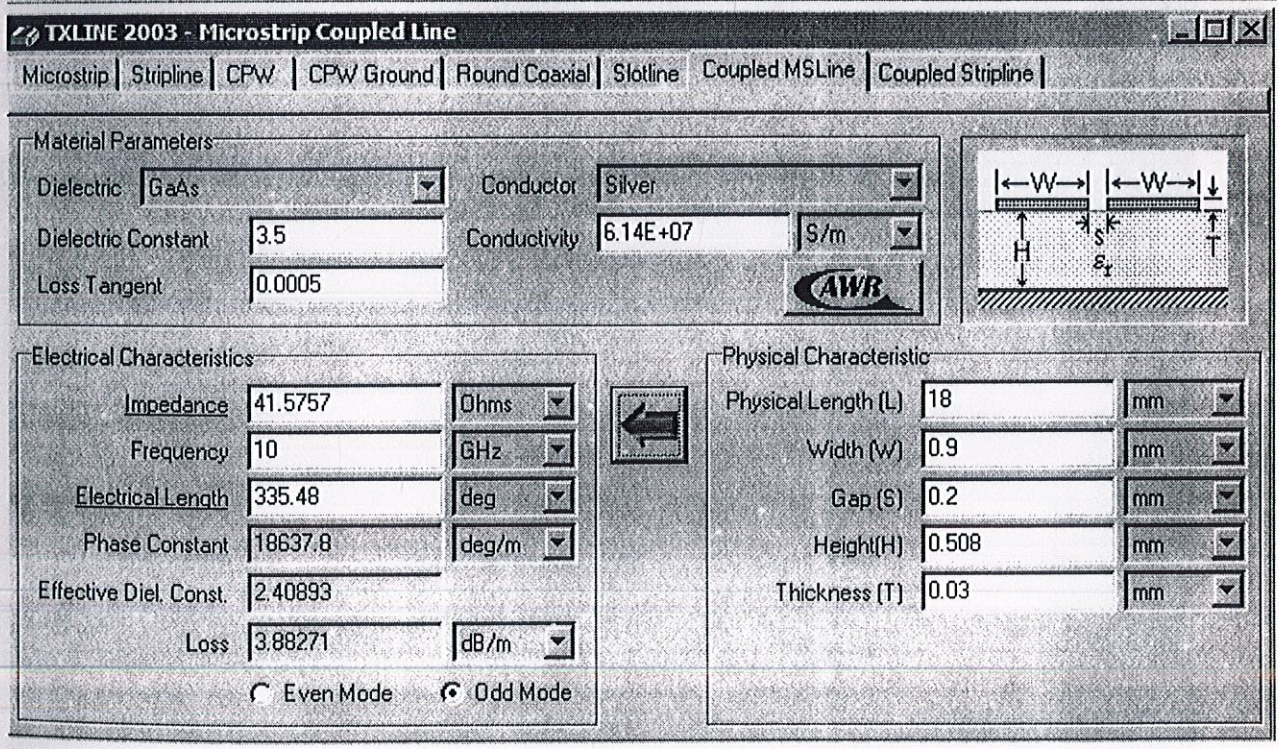
For order (n) = 4


TXLINE 2003 - Microstrip Coupled Line
Microstrip
Stripline
CPW
CPW/Ground
Round Coaxial
Slotline
Coupled MSLine
Coupled Stripline
Material Parameters
Dielectric
GaAs
Conductor
Silver
Dielectric Constant
3.5
Conductivity
6.14E+07
S/m
Loss Tangent
0.0005
AWR
Electrical Characteristics
Impedance
53.1309
Ohms
Frequency
10
GHz
Electrical Length
369.257
deg
Phase Constant
20514.3
deg/m
Effective Diel. Const.
2.91843
Loss
2.64915
dB/m
Even Mode
Odd Mode
Physical Characteristic
Physical Length (L)
18
mm
Width (W)
1.05
Gap (S)
1.05
Height (H)
0.508
Thickness (T)
0.03
W
S
H
T
ε_r


TXLINE 2003 - Microstrip Coupled Line
Microstrip
Stripline
CPW
CPW/Ground
Round Coaxial
Slotline
Coupled MSLine
Coupled Stripline
Material Parameters
Dielectric
GaAs
Conductor
Silver
Dielectric Constant
3.5
Conductivity
6.14E+07
S/m
Loss Tangent
0.0005
AWR
Electrical Characteristics
Impedance
47.8228
Ohms
Frequency
10
GHz
Electrical Length
348.901
deg
Phase Constant
19383.4
deg/m
Effective Diel. Const.
2.60553
Loss
2.46851
dB/m
Even Mode
Odd Mode
Physical Characteristic
Physical Length (L)
18
mm
Width (W)
1.05
Gap (S)
1.05
Height (H)
0.508
Thickness (T)
0.03
W
S
H
T
ε_r

For order (n) = 5

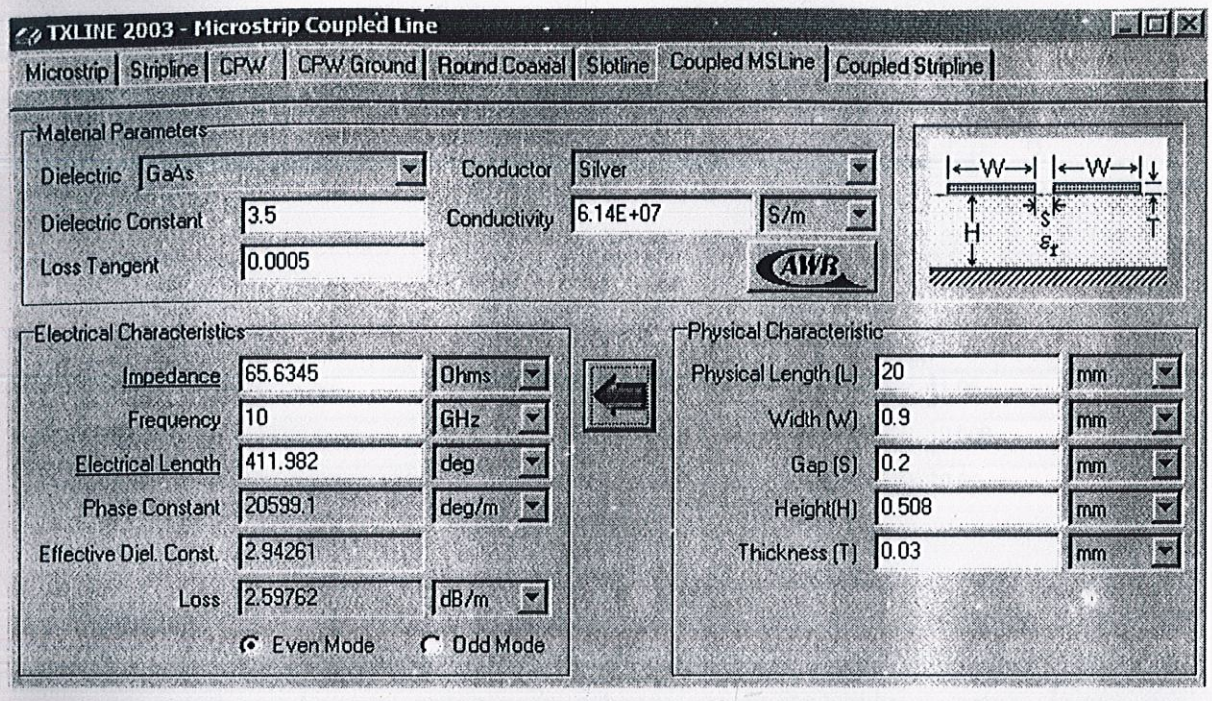

TXLINE 2003 - Microstrip Coupled Line
Microstrip
Stripline
CPW
CPW Ground
Round Coaxial
Slotline
Coupled MSLine
Coupled Stripline
Material Parameters
Dielectric
GaAs
Conductor
Silver
Dielectric Constant
3.5
Conductivity
6.14E+07
S/m
Loss Tangent
0.0005
AWR
W
W
S
H
T
Electrical Characteristics
Impedance
65.6345
Ohms
Frequency
10
GHz
Electrical Length
370.784
deg
Phase Constant
20599.1
deg/m
Effective Diel. Const.
2.94261
Loss
2.59762
dB/m
Even Mode
Odd Mode
Physical Characteristic
Physical Length (L)
18
mm
Width (W)
0.9
mm
Gap (S)
0.2
mm
Height(H)
0.508
mm
Thickness (T)
0.03
mm

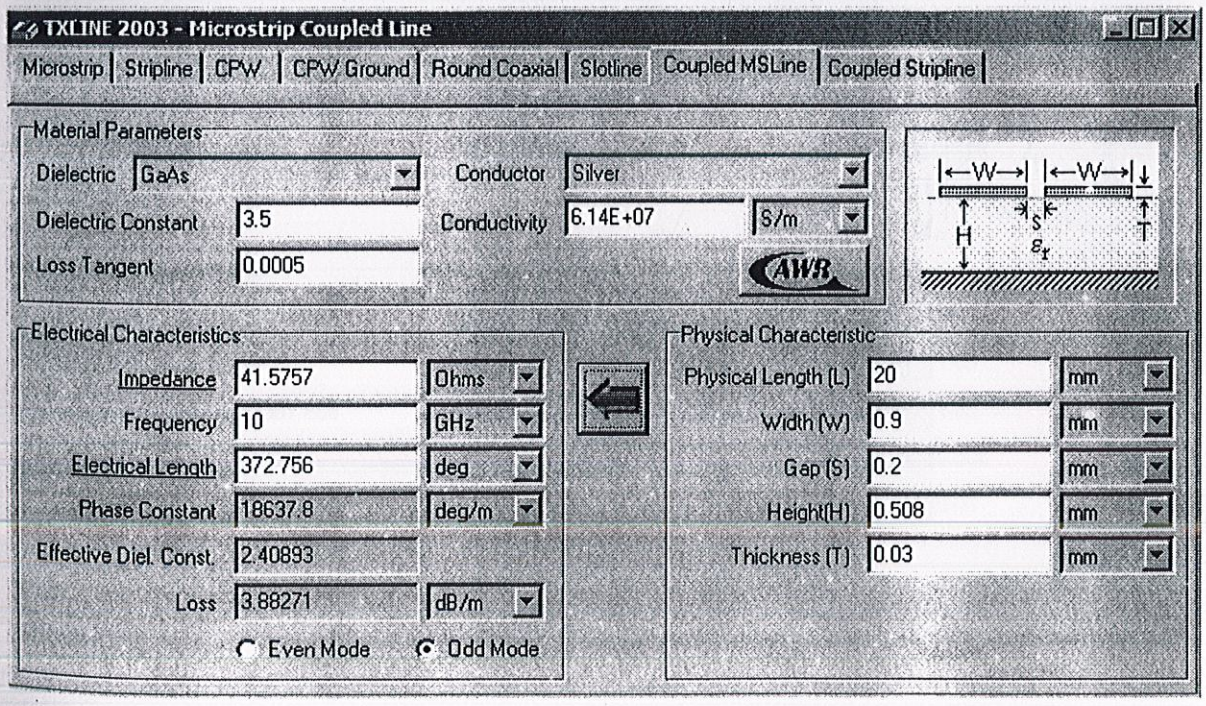

TXLINE 2003 - Microstrip Coupled Line
Microstrip
Stripline
CPW
CPW Ground
Round Coaxial
Slotline
Coupled MSLine
Coupled Stripline
Material Parameters
Dielectric
GaAs
Conductor
Silver
Dielectric Constant
3.5
Conductivity
6.14E+07
S/m
Loss Tangent
0.0005
AWR
W
W
S
H
T
Electrical Characteristics
Impedance
41.5757
Ohms
Frequency
10
GHz
Electrical Length
335.48
deg
Phase Constant
18637.8
deg/m
Effective Diel. Const.
2.40893
Loss
3.88271
dB/m
Even Mode
Odd Mode
Physical Characteristic
Physical Length (L)
18
mm
Width (W)
0.9
mm
Gap (S)
0.2
mm
Height(H)
0.508
mm
Thickness (T)
0.03
mm

2-4 Edge coupled band pass filter 2

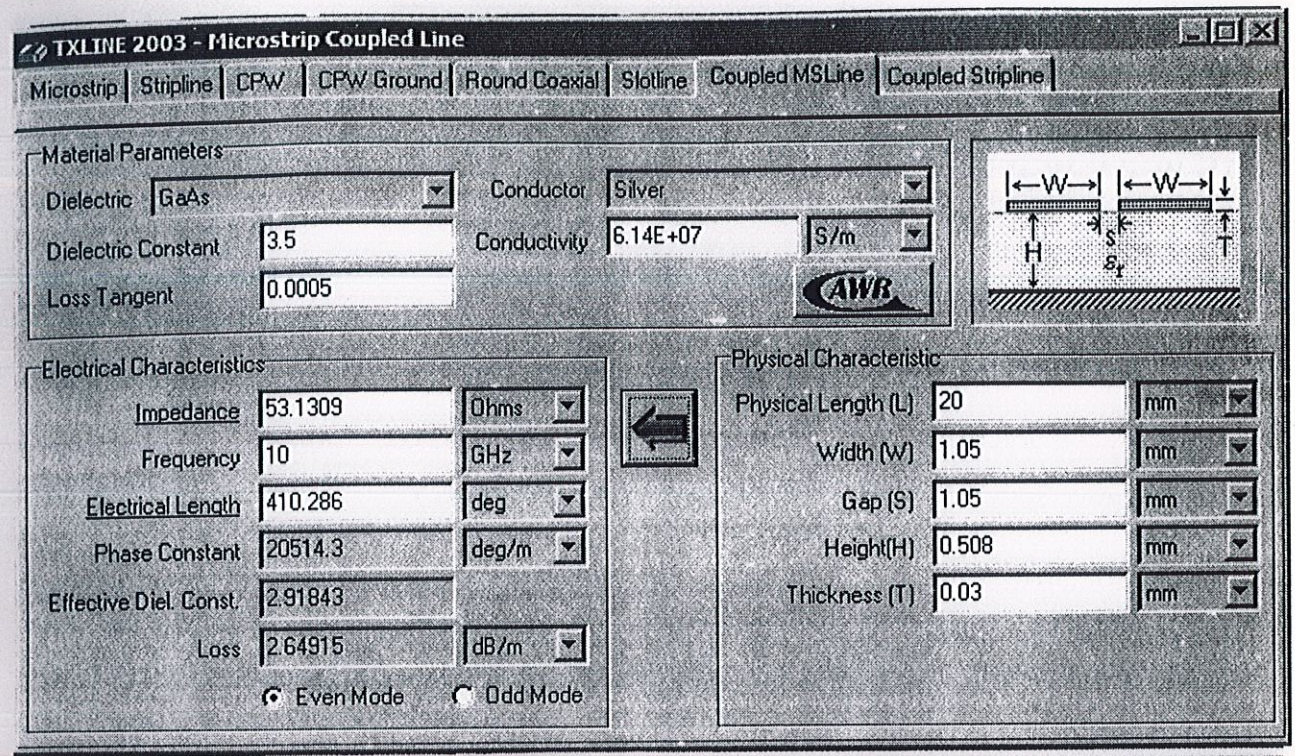
Results for filter 2 with center frequency 2.5 GHz

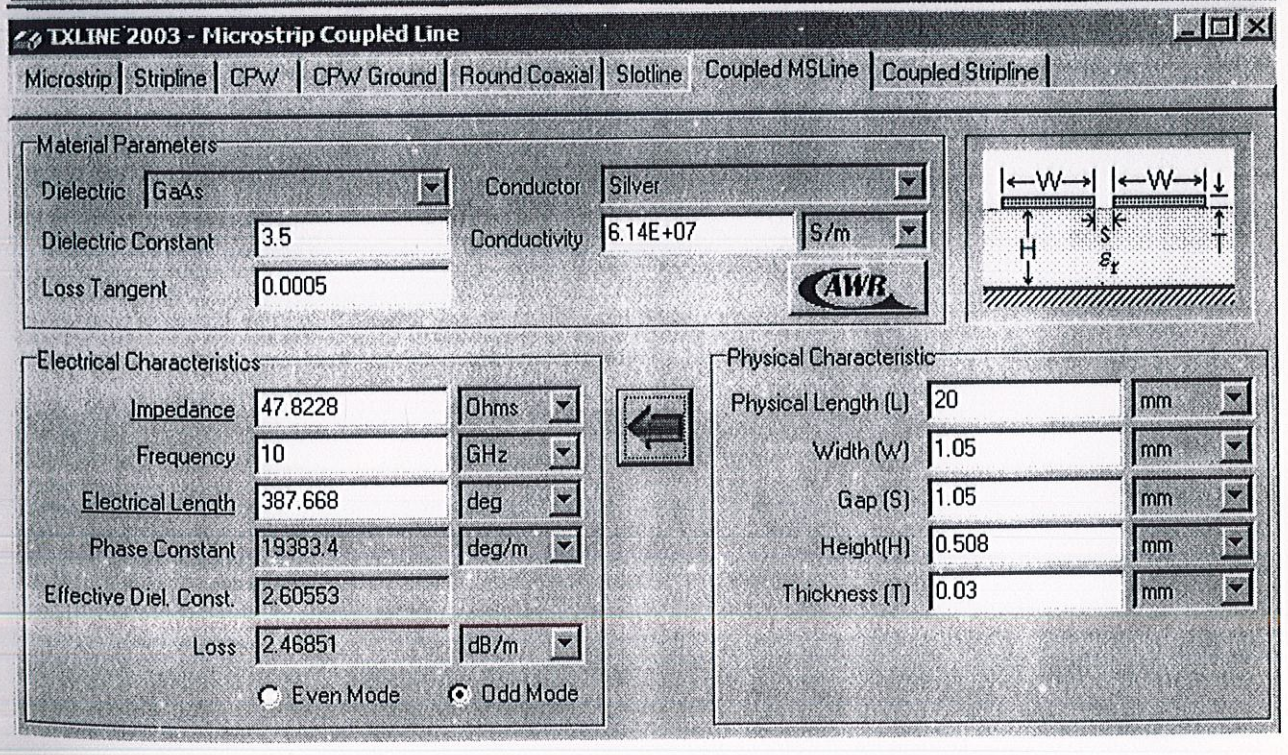
For order (n) = 1



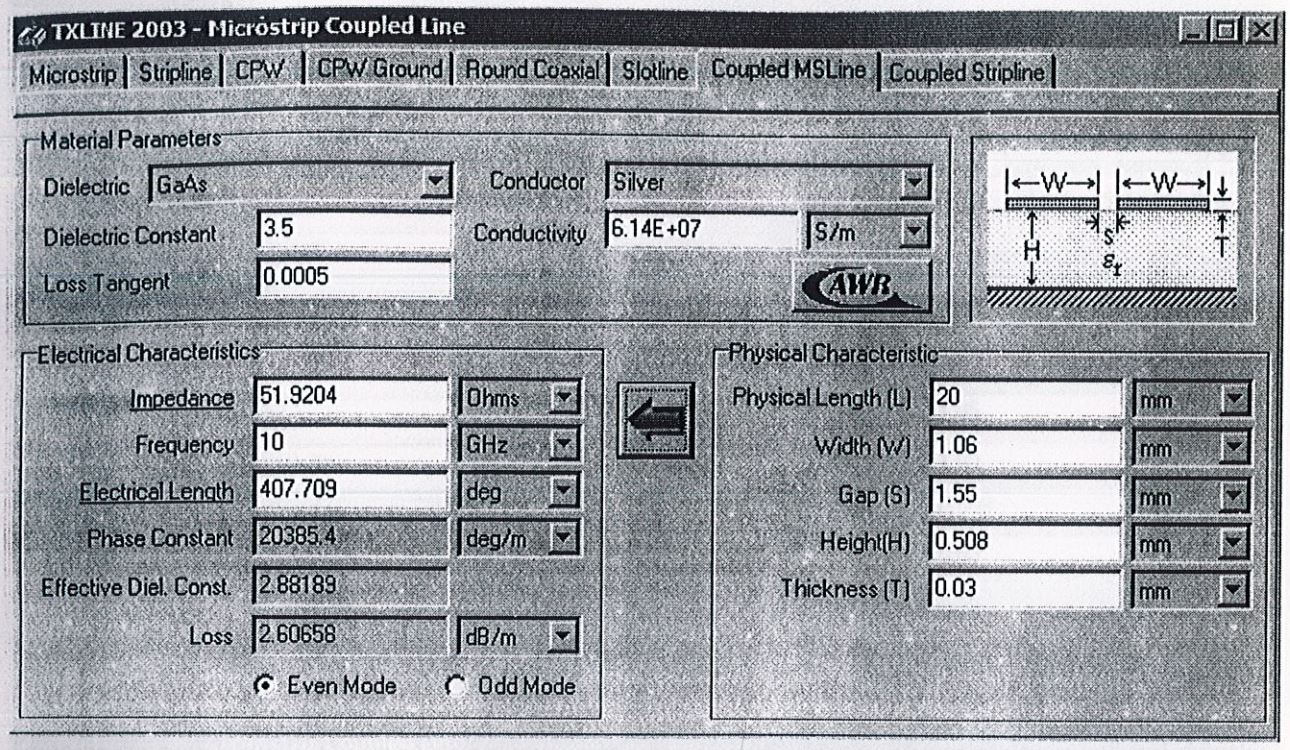


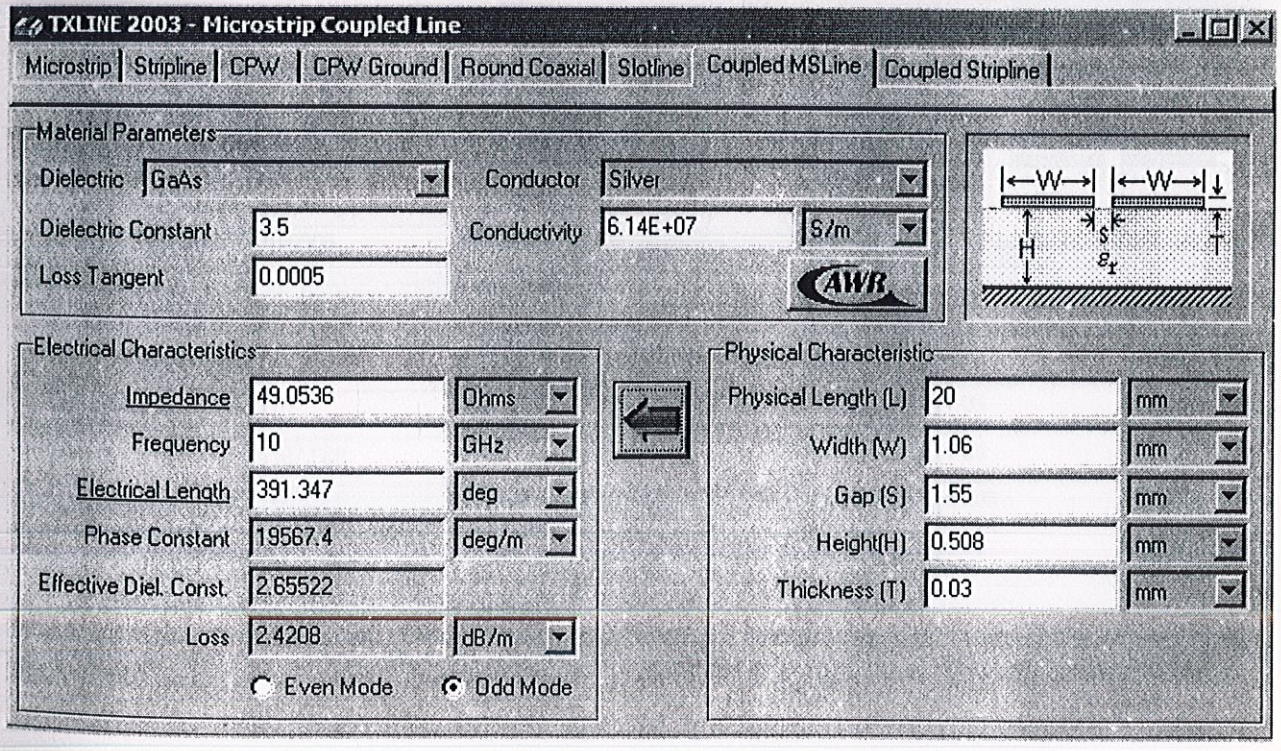
For order (n) = 2



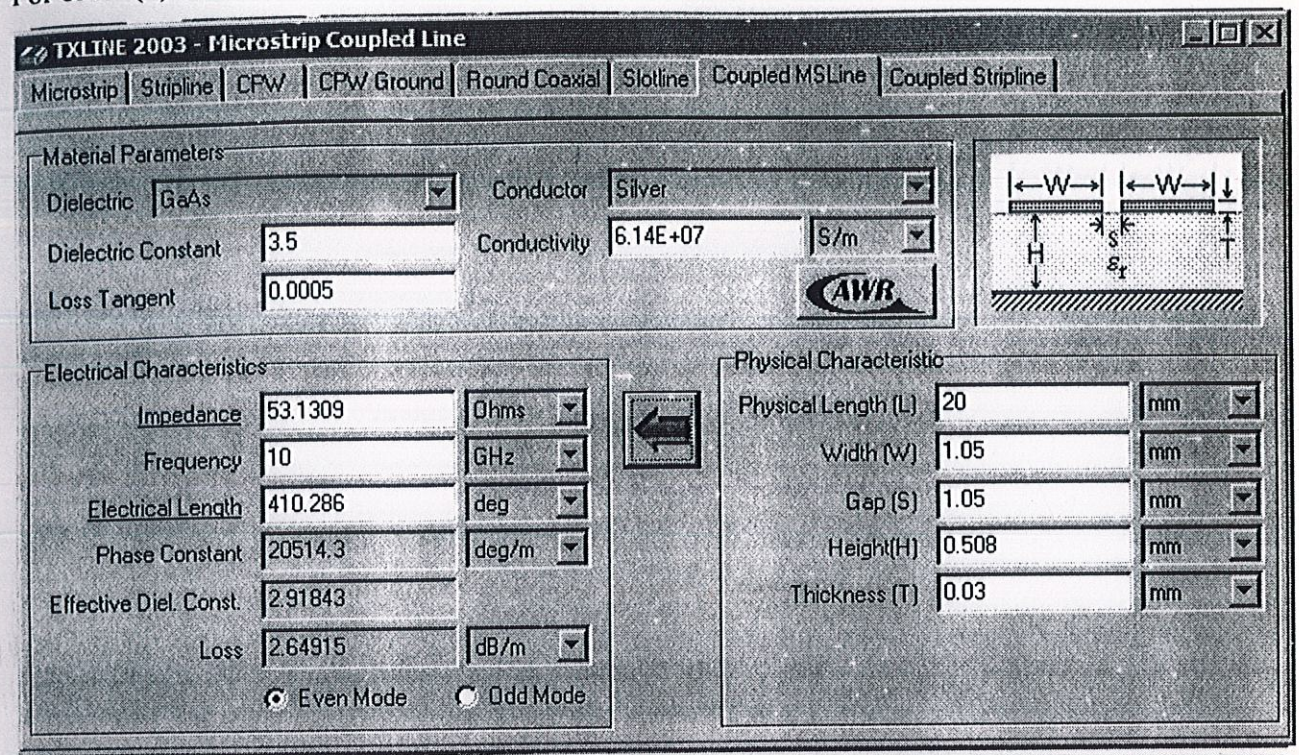


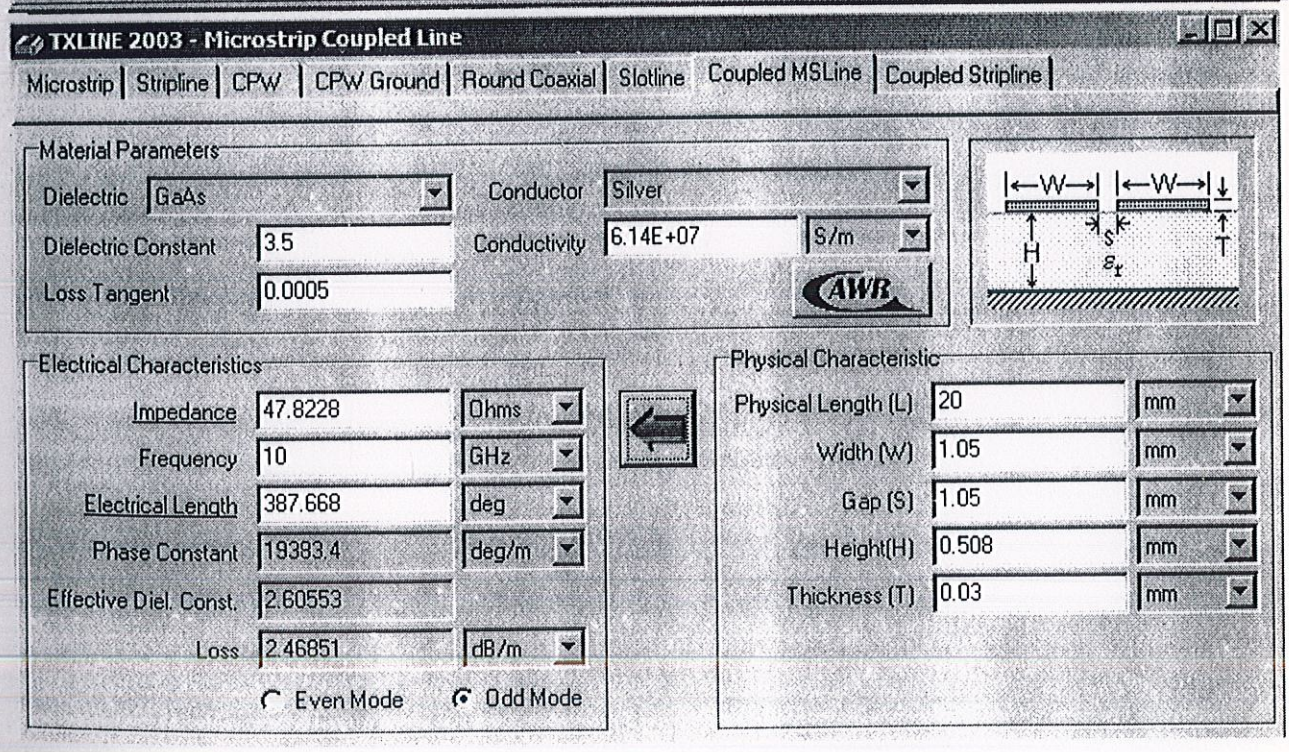
For order (n) = 3


TXLINE 2003 - Microstrip Coupled Line
Microstrip
Stripline
CPW
CPW Ground
Round Coaxial
Slotline
Coupled MSLine
Coupled Stripline
Material Parameters
Dielectric
GaAs
Conductor
Silver
Dielectric Constant
3.5
Conductivity
6.14E+07
S/m
Loss Tangent
0.0005
AWR
W
W
S
H
T
Electrical Characteristics
Impedance
51.9204
Ohms
Frequency
10
GHz
Electrical Length
407.709
deg
Phase Constant
20385.4
deg/m
Effective Diel. Const.
2.88189
Loss
2.60658
dB/m
Even Mode
Odd Mode
Physical Characteristic
Physical Length (L)
20
mm
Width (W)
1.06
mm
Gap (S)
1.55
mm
Height(H)
0.508
mm
Thickness (T)
0.03
mm

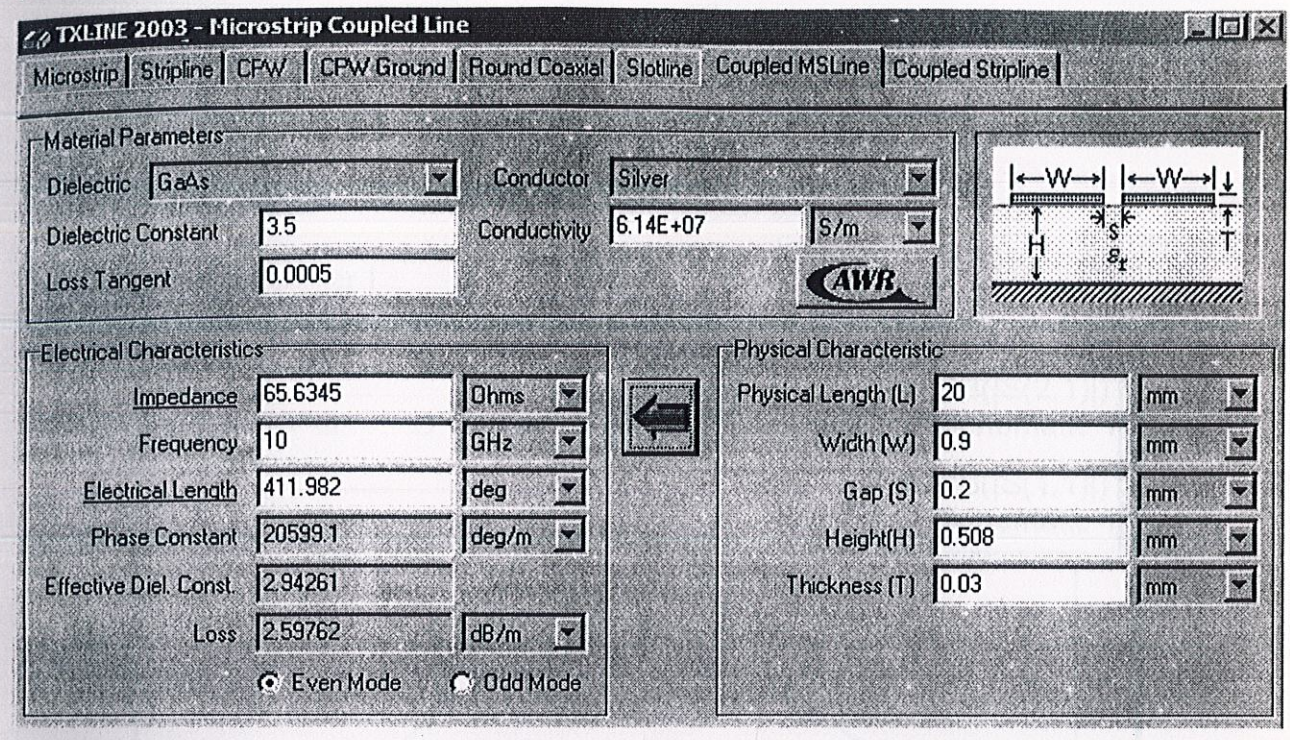

TXLINE 2003 - Microstrip Coupled Line
Microstrip
Stripline
CPW
CPW Ground
Round Coaxial
Slotline
Coupled MSLine
Coupled Stripline
Material Parameters
Dielectric
GaAs
Conductor
Silver
Dielectric Constant
3.5
Conductivity
6.14E+07
S/m
Loss Tangent
0.0005
AWR
W
W
S
H
T
Electrical Characteristics
Impedance
49.0536
Ohms
Frequency
10
GHz
Electrical Length
391.347
deg
Phase Constant
19567.4
deg/m
Effective Diel. Const.
2.65522
Loss
2.4208
dB/m
Even Mode
Odd Mode
Physical Characteristic
Physical Length (L)
20
mm
Width (W)
1.06
mm
Gap (S)
1.55
mm
Height(H)
0.508
mm
Thickness (T)
0.03
mm

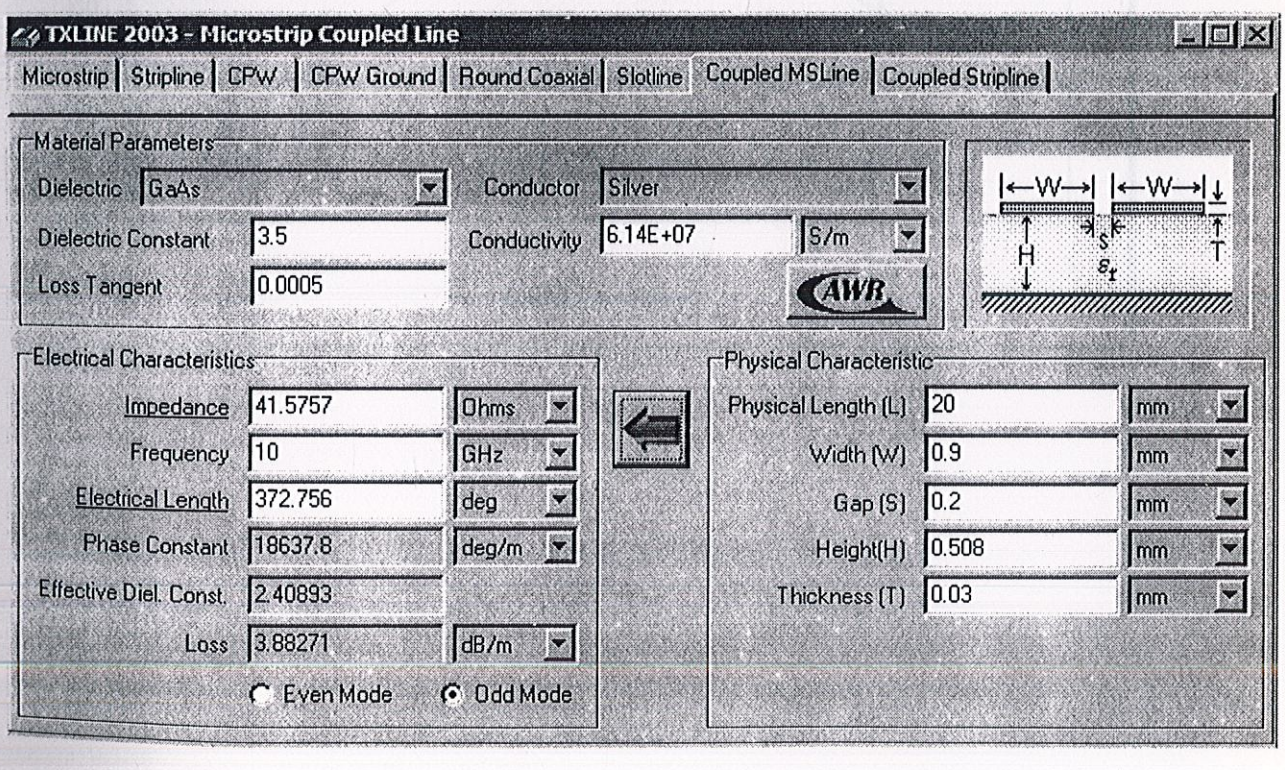
For order (n) = 4


TXLINE 2003 - Microstrip Coupled Line
Microstrip
Stripline
CPW
CPW Ground
Round Coaxial
Slotline
Coupled MSLine
Coupled Stripline
Material Parameters
Dielectric
GaAs
Conductor
Silver
Dielectric Constant
3.5
Conductivity
6.14E+07
S/m
Loss Tangent
0.0005
AWR
W
S
T
H
Electrical Characteristics
Impedance
53.1309
Ohms
Frequency
10
GHz
Electrical Length
410.286
deg
Phase Constant
20514.3
deg/m
Effective Diel. Const.
2.91843
Loss
2.64915
dB/m
Even Mode
Odd Mode
Physical Characteristic
Physical Length (L)
20
mm
Width (W)
1.05
mm
Gap (S)
1.05
mm
Height(H)
0.508
mm
Thickness (T)
0.03
mm


TXLINE 2003 - Microstrip Coupled Line
Microstrip
Stripline
CPW
CPW Ground
Round Coaxial
Slotline
Coupled MSLine
Coupled Stripline
Material Parameters
Dielectric
GaAs
Conductor
Silver
Dielectric Constant
3.5
Conductivity
6.14E+07
S/m
Loss Tangent
0.0005
AWR
W
S
T
H
Electrical Characteristics
Impedance
47.8228
Ohms
Frequency
10
GHz
Electrical Length
387.668
deg
Phase Constant
19393.4
deg/m
Effective Diel. Const.
2.60553
Loss
2.46851
dB/m
Even Mode
Odd Mode
Physical Characteristic
Physical Length (L)
20
mm
Width (W)
1.05
mm
Gap (S)
1.05
mm
Height(H)
0.508
mm
Thickness (T)
0.03
mm

For order (n) = 5


TXLINE 2003 - Microstrip Coupled Line
Microstrip
Stripline
CPW
CPW Ground
Round Coaxial
Slotline
Coupled MSLine
Coupled Stripline
Material Parameters
Dielectric
GaAs
Conductor
Silver
Dielectric Constant
3.5
Conductivity
6.14E+07
S/m
Loss Tangent
0.0005
AWR
W
W
S
H
T
Electrical Characteristics
Impedance
65.6345
Ohms
Frequency
10
GHz
Electrical Length
411.982
deg
Phase Constant
20599.1
deg/m
Effective Diel. Const.
2.94261
Loss
2.59762
dB/m
Even Mode
Odd Mode
Physical Characteristic
Physical Length (L)
20
mm
Width (W)
0.9
mm
Gap (S)
0.2
mm
Height(H)
0.508
mm
Thickness (T)
0.03
mm

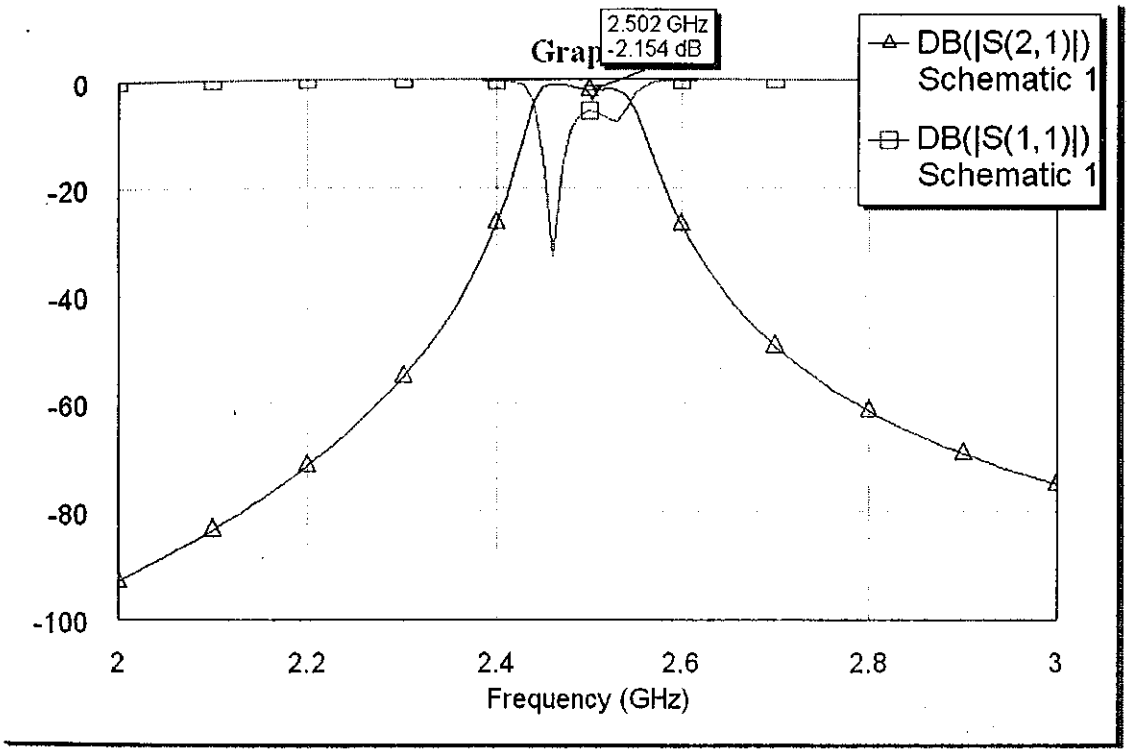

TXLINE 2003 - Microstrip Coupled Line
Microstrip
Stripline
CPW
CPW Ground
Round Coaxial
Slotline
Coupled MSLine
Coupled Stripline
Material Parameters
Dielectric
GaAs
Conductor
Silver
Dielectric Constant
3.5
Conductivity
6.14E+07
S/m
Loss Tangent
0.0005
AWR
W
W
S
H
T
Electrical Characteristics
Impedance
41.5757
Ohms
Frequency
10
GHz
Electrical Length
372.756
deg
Phase Constant
18637.8
deg/m
Effective Diel. Const.
2.40893
Loss
3.88271
dB/m
Even Mode
Odd Mode
Physical Characteristic
Physical Length (L)
20
mm
Width (W)
0.9
mm
Gap (S)
0.2
mm
Height(H)
0.508
mm
Thickness (T)
0.03
mm

CHAPTER III

SIMULATION AND FINAL RESULTS

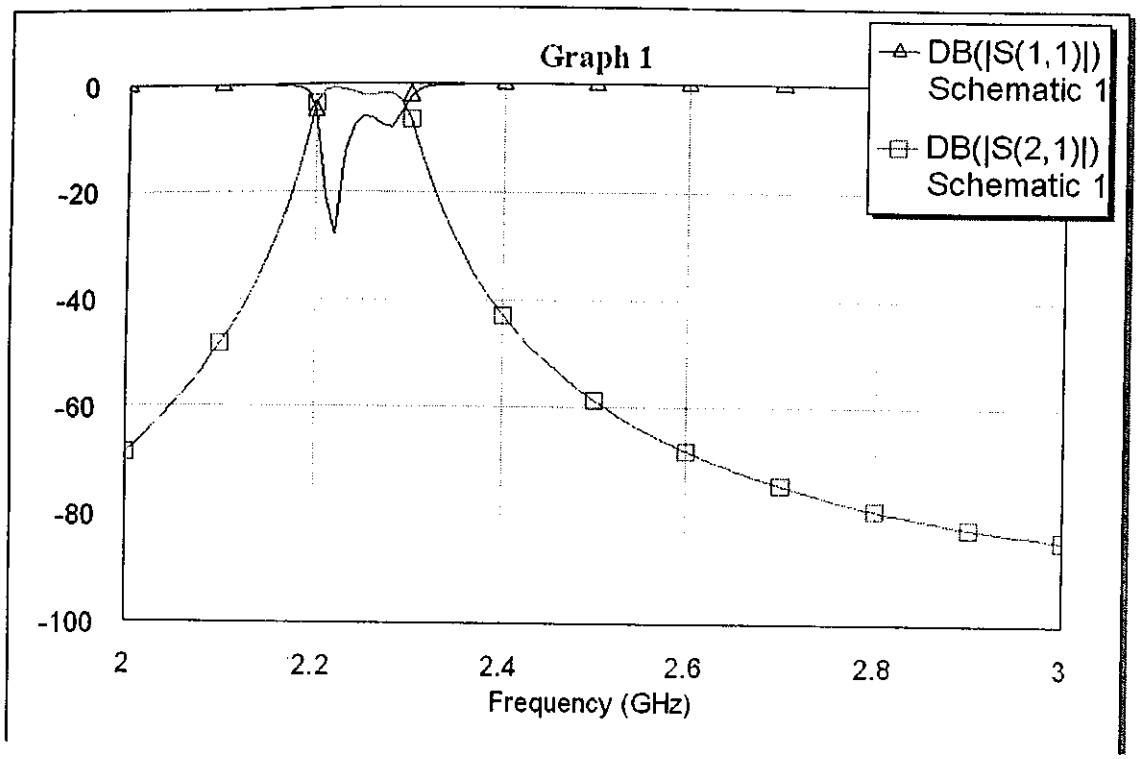
3.1 Microstrip Edge coupled band pass filter 1

Final output graph of filter 1 :



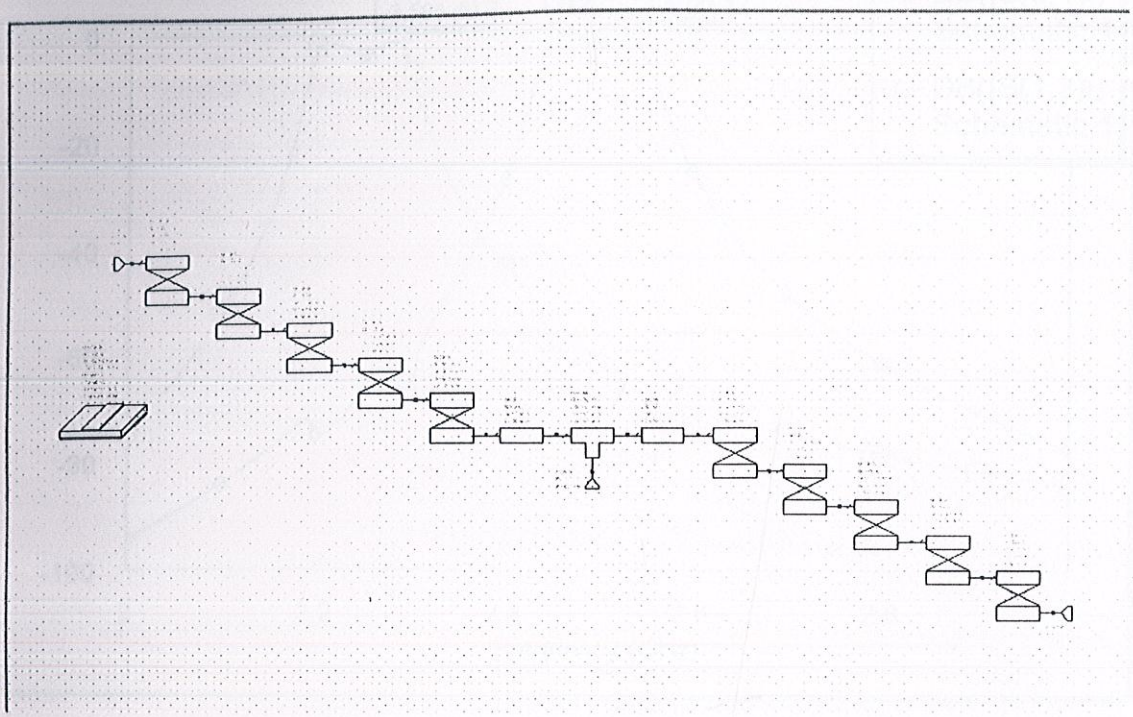
3.2 Microstrip Edge coupled band pass filter 2

Final output graph of filter 2 :

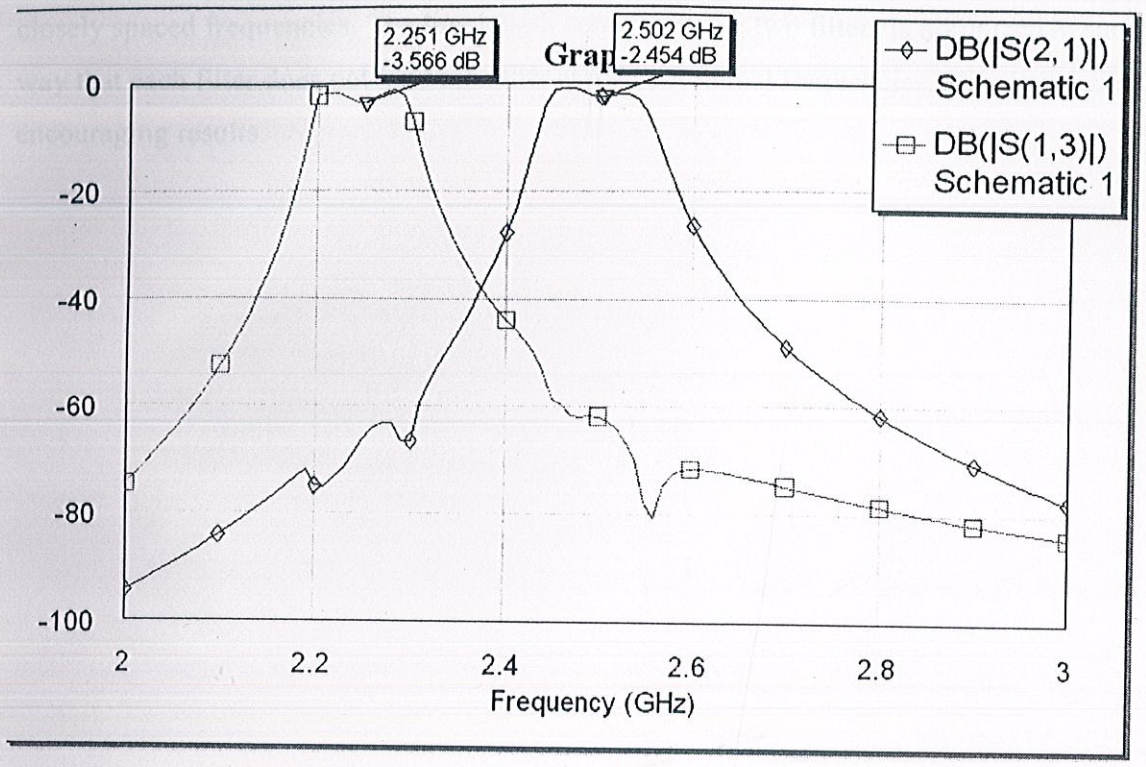


3.3 Final outlay of diplexer

Outlay circuit of the Diplexer :



3.4 Final output of diplexer



CONCLUSION

In this project we have demonstrated a design methodology for microstrip diplexers working at closely spaced frequencies. The line length connecting the two filters is optimized in such a way that each filter does not load the other at the operational frequencies. Simulation show encouraging results.

BIBLIOGRAPHY

- Edwards T C, Foundation of interconnect and microstrip design .
- Bharathi Bhat , S K Koul , Stripline like transmission lines for microwave integrated circuits
- www.circuitsage.com
- www.rfdude.com