FilterViewer

A simple tool for visualizing the layout and analyzing the responses of Microwave filters.

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About the software

FilterViewer is a JAVA and MATLAB based software for visualizing the layout and analyzing the responses of various types of microwave filters including Interdigital Filters, Tchebychev Low Pass and Butterworth Low Pass Filters.

It is developed by Abhishek Shrivastava and Amey Dharwadker, 3rd Year undergraduate students of Electronics and Communications Engineering Department of National Institute of Technology Trichy, 2007-2011, as an assignment project under Prof. Raghavan of the ECE Department.

Motivation:

In the future, learning in modern format will tend to combine theoretical instruction together with the experiment by using computer program, which can make undergraduate student to understand the principle or the theory quickly and effectively. The computer program is an important tool [1], [2], [3], [4] that helps undergraduate student in electrical engineering, especially in telecommunications major to learn the theory to test and develop new ideas. Future more the computer program will assist students to be able to working on more complicated research efficiently. Many courses in electromagnetic and microwave are considered to be the most difficult subjects in the electrical engineering curriculum because the nature of theory courses in which it is usually taught, refer to inform of an abstract and mathematical model. The problem is found in many universities by lacking of modern microwave and simulation program. Thus, we are interested in developing a new computer simulation program to be an education tool [5], [6] for engineering courses.

We have developed a simulation program with an interactive graphical interface for analyzing the characteristics and the layout of microwave band-pass filters using interdigital arrays of resonator line elements between parallel ground planes.

Interdigital Filters

Introduction:

A recent study has shown that interdigital line structures have very interesting band-pass filter characteristics. In that study, various image-impedance and image-propagation phase properties of interdigital line structures were determined, and the results were verified by experimental tests on an interdigital line structure. In this present discussion a different point of view is utilized to obtain approximate design equations for interdigital filters with specified pass-band and cut-off characteristics.

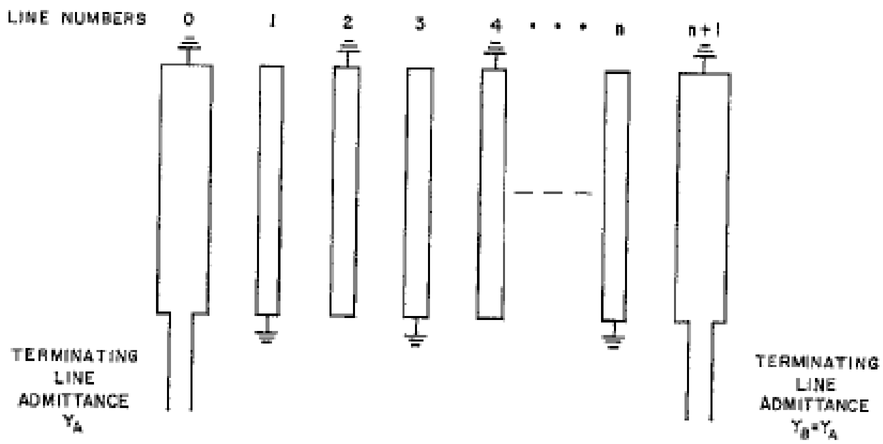


Fig. 1—Interdigital filter with short-circuited lines at the ends.

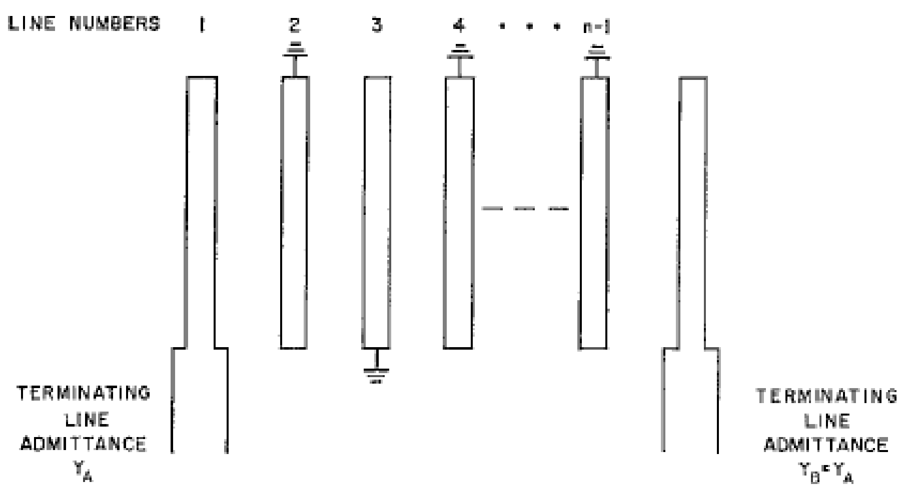


Fig. 2—Interdigital filter with open-circuited lines at the ends.

Our design structure of interdigital filter consists of TEM-mode strip-line resonators between parallel ground planes. Each resonator element is a quarter-wavelength long at the midband frequency and is short-circuited at one end and open-circuited at the other end. Coupling is achieved by way of the fields fringing between adjacent resonator elements. The design equations to be presented for this case (for which the terminating lines are short-circuited) give filter structural dimensions that will be most practical when the filter is of narrow or moderate bandwidth (say, 30 per cent bandwidth or less). In this structure each line element serves as a resonator, except for the input and output line elements which have an impedance-matching function.

Low Pass Prototype Filters and Low pass-to-band pass Transformation:

The design procedures to be described are based on the use of low-pass prototype filter element values to give the band-pass filter its desired characteristics. Notice that n is the number of reactive elements and that, including the resistor terminations, the element values range from g_o to g_{n+1}. A low-pass prototype with n reactive elements leads to a band-pass filter with n resonators.

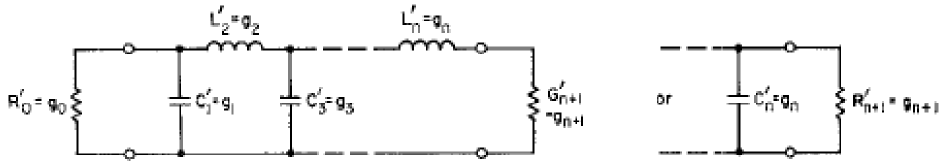
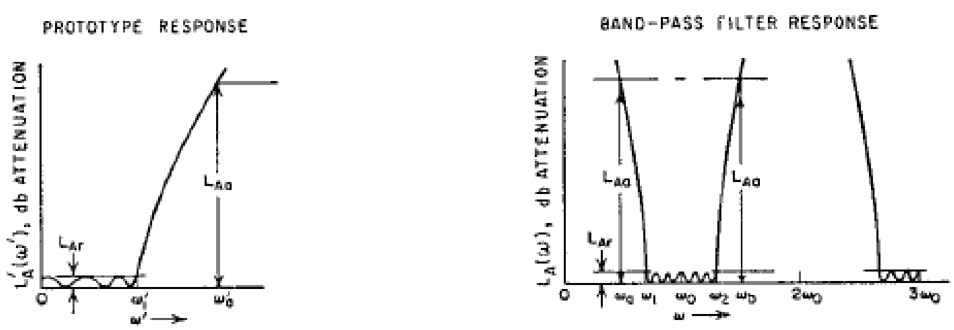


Fig. 3—Definition of prototype filter parameters g_0, g_1, g_2, $\cdots$, g_n, g_{n+1}. An additional prototype parameter ω_1' is defined in Fig. 4.



$$L_A(\omega) = L_A'(\omega') \text{ db} \qquad \omega_0 = \frac{\omega_2 + \omega_1}{2}$$

where

$$\omega' = \frac{2\omega_1'}{w}\left|\frac{\omega - \omega_0}{\omega_0}\right| \quad \text{and} \quad w = \frac{\omega_2 - \omega_1}{\omega_0}.$$

Fig: Relation between the low-pass prototype response and the band-pass filter response

Design Equations for the Interdigital Band-pass Filter:

The type of design simulated in our software is most practical for filters having narrow or moderate bandwidth. The main drawback in applying the design procedure in this section to filters of wide bandwidth is that the gaps between Lines 0 and 1 and between Lines n and n+ 1 tend to become inconveniently small when the bandwidth is large, and the widths of Bars 1 and n tend to become very small.
Select a low-pass prototype with the required value of n. The input and output lines in this filter do not count as resonators, so that there are n+2 lines for an n-reactive element prototype.

Compute

$$\theta_1 = \frac{\pi}{2}\frac{\omega_1}{\omega_0} = \frac{\pi}{2}\left(1 - \frac{w}{2}\right)$$

$$\frac{J_{01}}{Y_A} = \frac{1}{\sqrt{g_0 g_1 \omega_1'}}, \qquad \left.\frac{J_{k,k+1}}{Y_A}\right|_{k=1 \text{ to } n-1} = \frac{1}{\omega_1' \sqrt{g_k g_{k+1}}}$$

$$\frac{J_{n,n+1}}{Y_A} = \frac{1}{\sqrt{g_n g_{n+1} \omega_1'}},$$

$$\left.N_{k,k+1}\right|_{k=1 \text{ to } n-1} = \sqrt{\left(\frac{J_{k,k+1}}{Y_A}\right)^2 + \frac{\tan^2\theta_1}{4}},$$

$$M_1 = Y_A\left[\frac{J_{01}}{Y_A}\sqrt{h} + 1\right], \qquad M_n = Y_A\left[\frac{J_{n,n+1}}{Y_A}\sqrt{h} + 1\right]$$

where h is a dimensionless admittance scale factor to be specified arbitrarily so as to give a convenient admittance level in the filter. The normalized self-capacitances C_k/ε per unit length for the line elements are:

$$\frac{C_0}{\epsilon} = \frac{376.7}{\sqrt{\epsilon_r}}\left[2Y_A - M_1\right]$$

$$\frac{C_1}{\epsilon} = \frac{376.7}{\sqrt{\epsilon_r}}\left[Y_A - M_1 + hY_A\left[\frac{\tan\theta_1}{2} + \left(\frac{J_{01}}{Y_A}\right)^2 + N_{12} - \frac{J_{12}}{Y_A}\right]\right]$$

$$\left.\frac{C_k}{\epsilon}\right|_{k=2 \text{ to } n-1} = \frac{376.7}{\sqrt{\epsilon_r}}\, hY_A\left[N_{k-1,k} + N_{k,k+1} - \frac{J_{k-1,k}}{Y_A} - \frac{J_{k,k+1}}{Y_A}\right]$$

$$\frac{C_n}{\epsilon} = \frac{376.7}{\sqrt{\epsilon_r}}\left[Y_A - M_n + hY_A\left[\frac{\tan\theta_1}{2} + \left(\frac{J_{n,n+1}}{Y_A}\right)^2 + N_{n-1,n} - \frac{J_{n-1,n}}{Y_A}\right]\right]$$

$$\frac{C_{n+1}}{\epsilon} = \frac{376.7}{\sqrt{\epsilon_r}}\left[2Y_A - M_n\right]$$

where ε is the dielectric constant and ε_r is the relative dielectric constant in the medium of propagation.

The normalized mutual capacitances $C_{k,k+1}/\varepsilon$ per unit length between adjacent line elements are:

$$\frac{C_{01}}{\epsilon} = \frac{376.7}{\sqrt{\epsilon_r}}\left[M_1 - Y_A\right],$$

$$\left.\frac{C_{k,k+1}}{\epsilon}\right|_{k=1 \text{ to } n-1} = \frac{376.7 h Y_A}{\sqrt{\epsilon_r}}\left(\frac{J_{k,k+1}}{Y_A}\right)$$

$$\frac{C_{n,n+1}}{\epsilon} = \frac{376.7}{\sqrt{\epsilon_r}}\left[M_n - Y_A\right].$$

The choice of the value h is made such that the quantity

$$\left.\frac{2C_{k-1,k}}{\epsilon} + \frac{C_k}{\epsilon} + \frac{2C_{k,k+1}}{\epsilon}\right|_{\substack{k=n/2 \text{ for } n \text{ even} \\ =(n+1)/2 \text{ for } n \text{ odd}}}$$

$$= (\text{around } 5.4)$$

After calculating all these parameters, the layout was designed for the filter with desired input specifications and the frequency response curve (Attenuation in dB versus the normalized frequency) was also plotted.

Graphical User Interface (GUI) Details

Main Features:

- New Project Wizard for creating new projects
- Open Project Wizard can open existing projects saved anywhere in the harddisk
- Save Project Wizard can save a project after modifying anywhere in the harddisk
- The main windows consist of tabs for handling multiple projects at the same time.
- The graphs and layouts are generated using MATLAB and hence incorporates all the features like 3-D viewing, rotating, zooming, labeling, coloring, etc
- At most 15 projects can be opened and worked with simultaneously.

Requirements:

- MATLAB (7.6 or above) must be installed and working properly.
- Eclipse IDE for JAVA.
- FilterViewer software source codes.

Installation:

Assumptions:

- *MATLAB installation directory*
  `C:\Program Files\MATLAB\R2008a`
- *Eclipse IDE installation directory*
  `C:\Eclipse`
- *FilterViewer codes directory*
  `C:\FilterViewer`

Note: Please change the above directories in the following steps depending on where you installed the required programs.

- Make sure the following lines are in the MATLAB Java CLASSPATH.

```
C:\FilterViewer\java\micfilter
C:\FilterViewer\java
C:\Eclipse\plugins
C:\Eclipse\plugins\org.eclipse.swt.win32.win32.x86_3.2.
2.v3236.jar
C:\Eclipse\plugins\org.eclipse.swt_3.2.2.v3236b.jar
C:\Eclipse\configuration\org.eclipse.osgi\bundles
C:\Eclipse\configuration\org.eclipse.osgi\bundles\79\1\
.cp
```

To add the above lines, in the MATLAB prompt, type

```
edit classpath.txt
```

and add those lines in the editor which opened.

- Make sure the following lines are in the MATLAB Current Directory Path.

```
C:\FilterViewer\matlab
```

Execute this command with the above directory path:

```
addpath C:\FilterViewer\matlab
```

- Make sure the following lines are in your operating systems PATH environment variable.

```
C:\Program Files\MATLAB\R2008a\bin;
C:\Program Files\MATLAB\R2008a\bin\win32;
C:\Program Files\MATLAB\R2008a\java\jar;
C:\Eclipse\configuration\org.eclipse.osgi\bundles\79\1\
.cp;
C:\Eclipse\configuration\org.eclipse.osgi\bundles;
```

How to do it in Windows:

1) Right-click on “My Computer” icon in Desktop or “Computer” icon from Start Menu and go to “Properties”.
2) Go to “Advanced System Settings” or click on “Advanced tab”, whichever exists.
3) Click on “Environment Variables” button and from the “System variables” list select the variable called “Path”.
4) Then click on “Edit” and then append the above lines (separated by semi-colon) in “Variable value” field.

Running the application:

- Open MATLAB and type the following in the MATLAB prompt:

```
micfilter.MICFilter.main({});
```

About GUI:

The GUI has been entirely written using the JAVA programming language. Specifically, the SWT (Standard Widget Toolkit) Technology is used, which can be found in the Eclipse IDE by default. It was written with the help of Eclipse IDE and was interfaced with the MATLAB software for backend computations, using the MATLAB’s *com.mathworks.jmi* package. This package comes installed with the MATLAB software already.

References

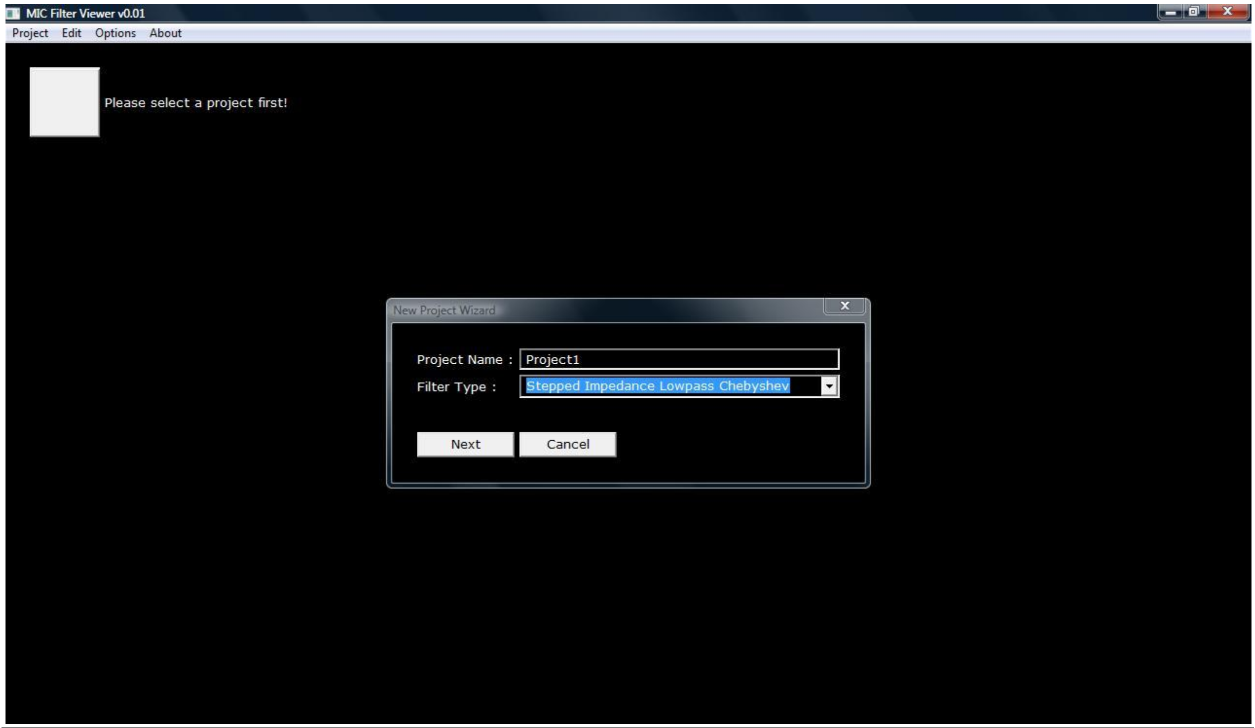
[1] George L. Mathei, “**Interdigital Band-Pass Filters**”. IRE Transactions on Microwave Theory and Techniques.

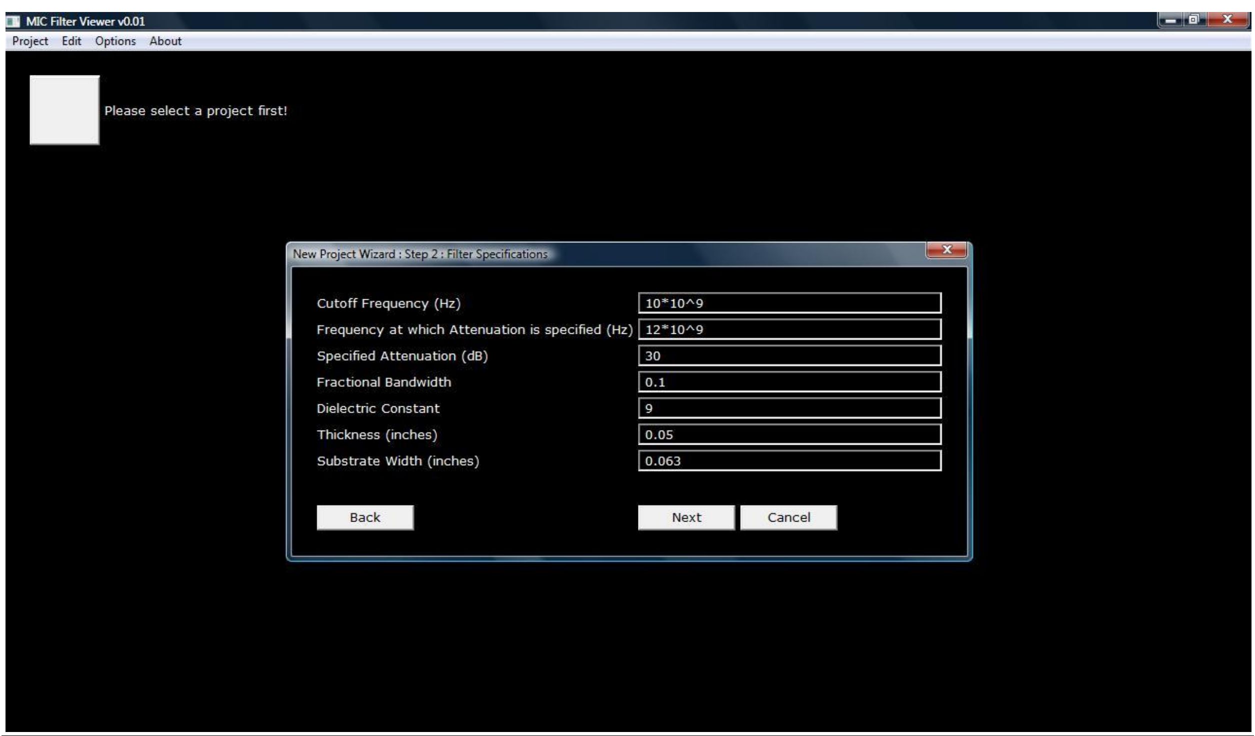
[2] Chen Chao, Wu Qon, “**Fast Design and Optimization of Bandpass Tapped-Line Interdigital Filters Using GENESYS**”, IEEE Transactions.

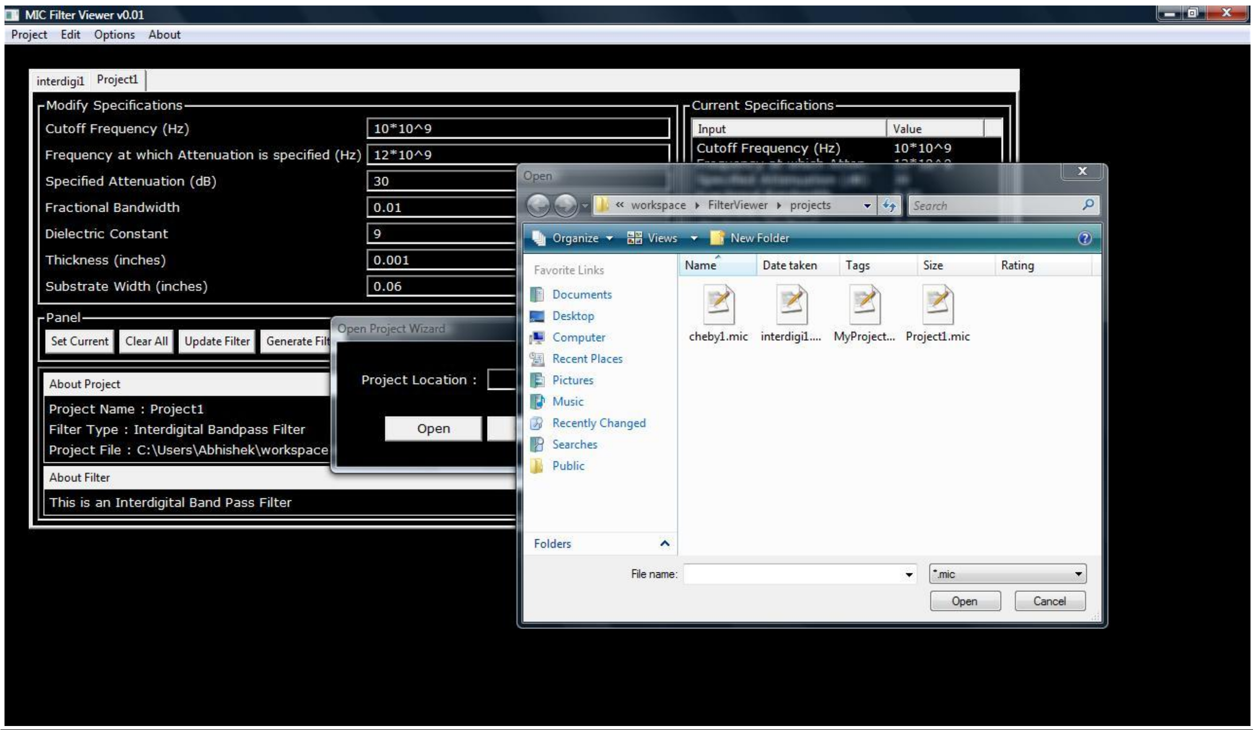
[3] “**Reference Data for Radio Engineers**”, Federal Telephone and Radio Corporation.

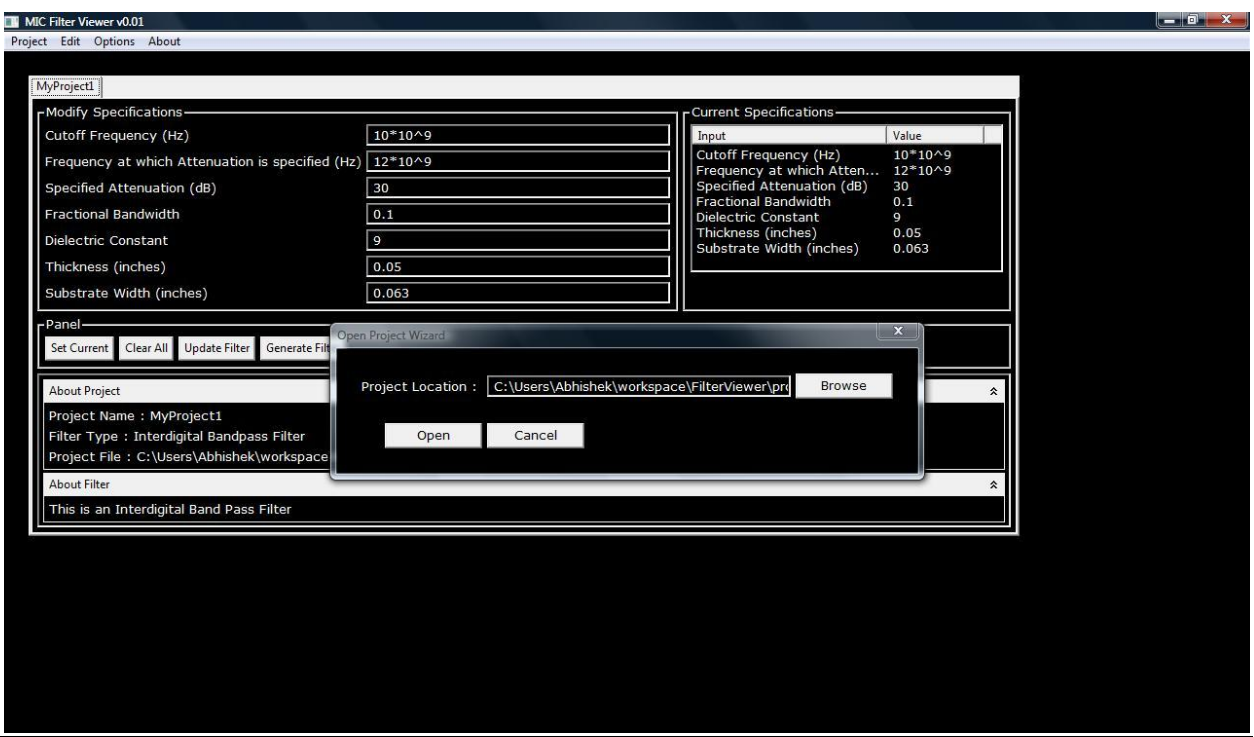
[4] A.M. Nassar, A.M. Moselhy, M.A. El Gazzar, “**Design and Simulation of Microwave Filter**”, IEEE Journal

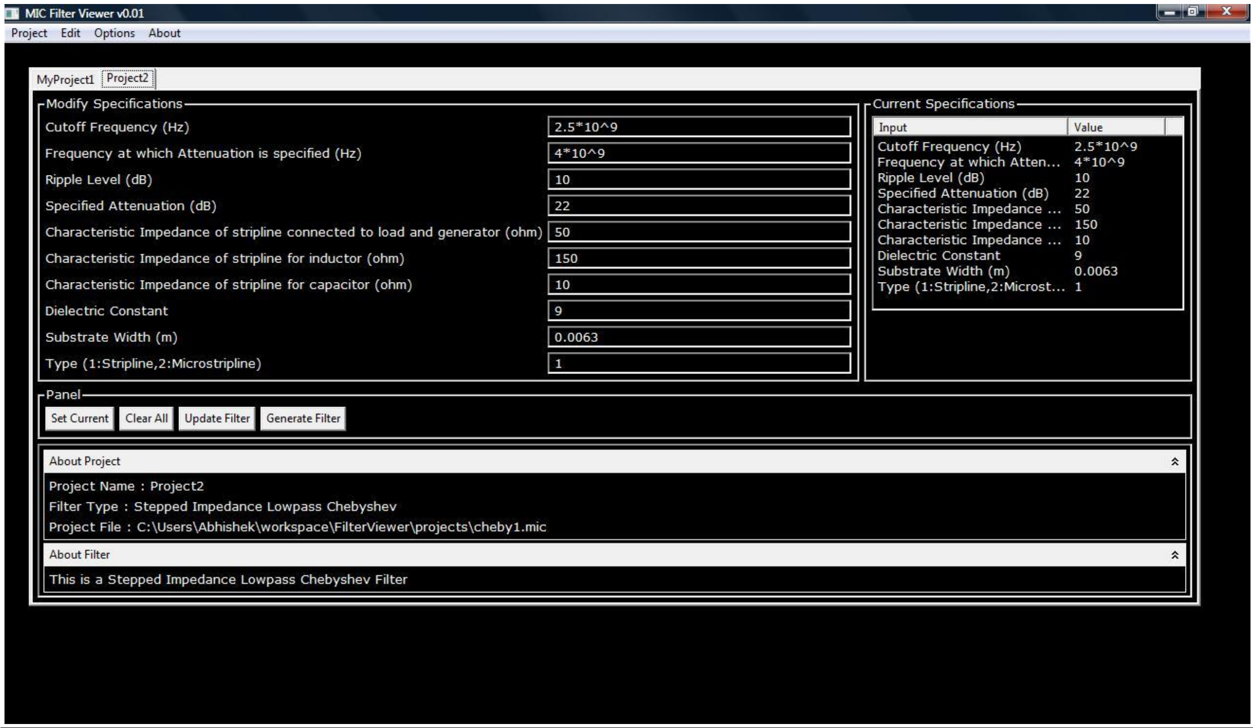
Screen Shots

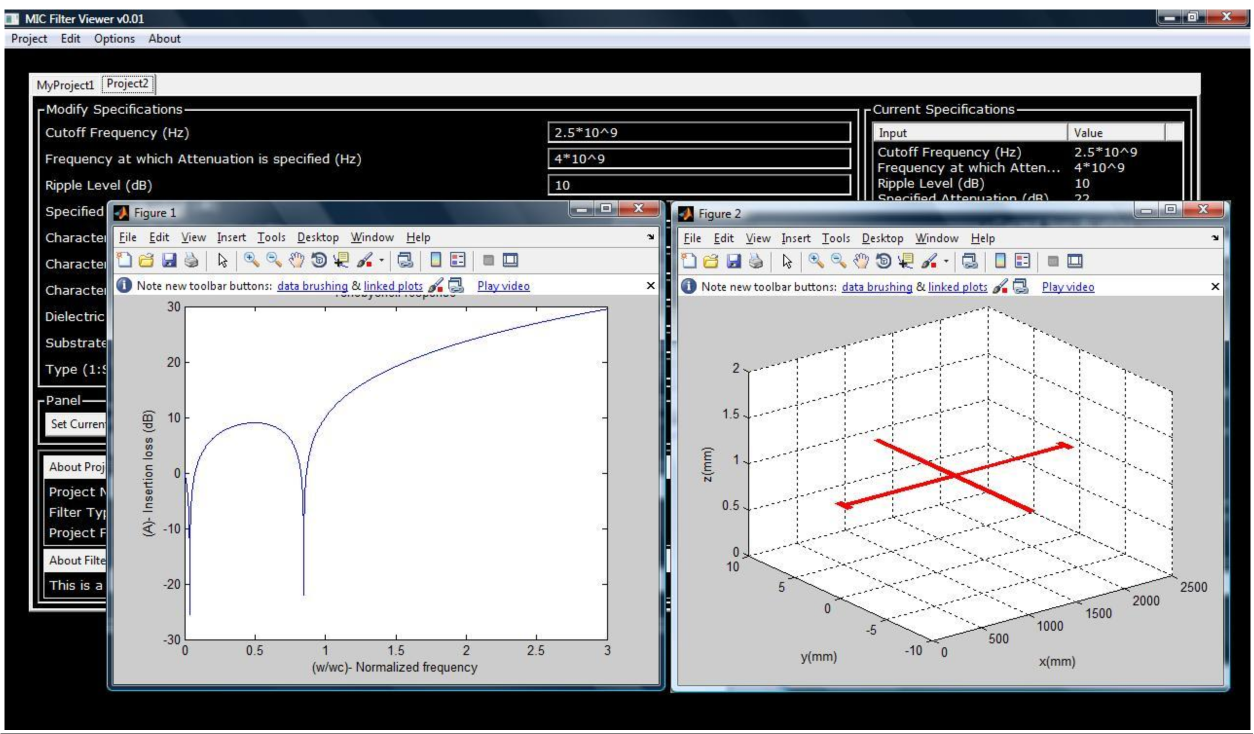


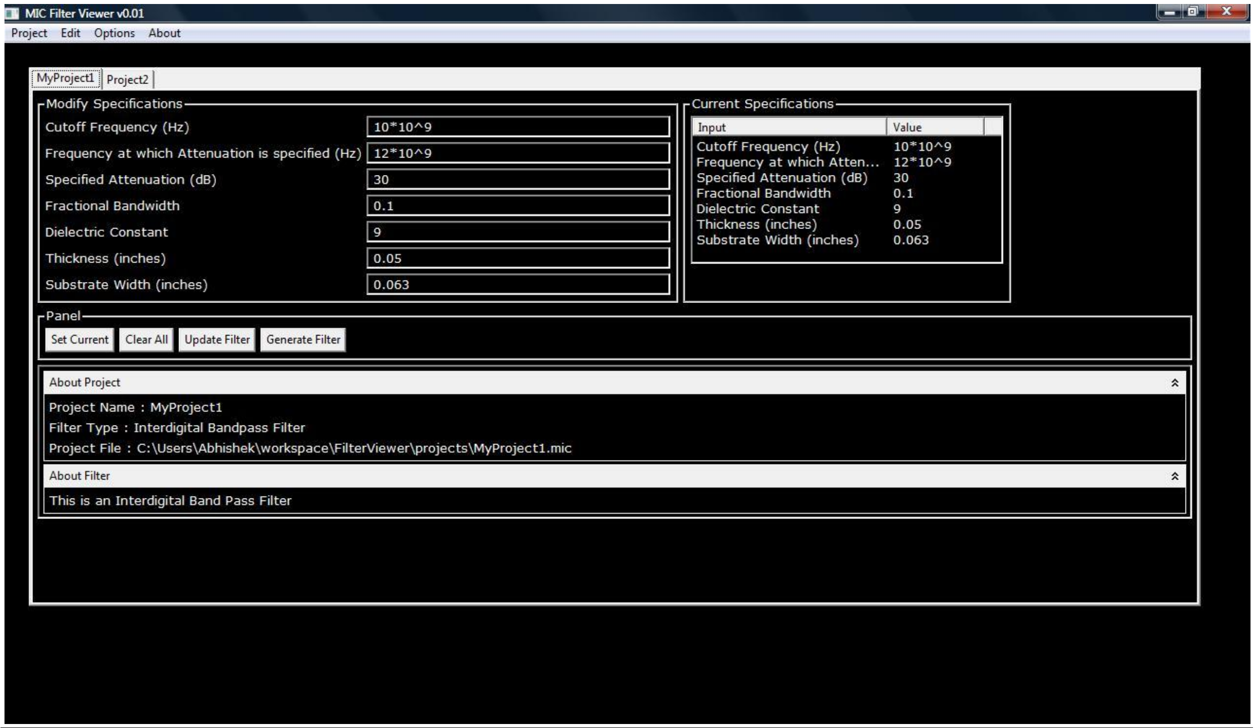



MIC Filter Viewer v0.01
Project Edit Options About
interdigi1 Project1
Modify Specifications
Cutoff Frequency (Hz) 10*10^9
Frequency at which Attenuation is specified (Hz) 12*10^9
Specified Attenuation (dB) 30
Fractional Bandwidth 0.01
Dielectric Constant 9
Thickness (inches) 0.001
Substrate Width (inches) 0.06
Current Specifications
Input Value
Cutoff Frequency (Hz) 10*10^9
Panel
Set Current Clear All Update Filter Generate Filt
Open Project Wizard
Project Location :
Open
About Project
Project Name : Project1
Filter Type : Interdigital Bandpass Filter
Project File : C:\Users\Abhishek\workspace
About Filter
This is an Interdigital Band Pass Filter
Open
workspace FilterViewer projects
Search
Organize Views New Folder
Favorite Links
Documents
Desktop
Computer
Recent Places
Pictures
Music
Recently Changed
Searches
Public
Folders
Name Date taken Tags Size Rating
cheby1.mic interdigi1.... MyProject... Project1.mic
File name:
*.mic
Open Cancel


MIC Filter Viewer v0.01
Project Edit Options About
MyProject1
Modify Specifications
Cutoff Frequency (Hz) 10*10^9
Frequency at which Attenuation is specified (Hz) 12*10^9
Specified Attenuation (dB) 30
Fractional Bandwidth 0.1
Dielectric Constant 9
Thickness (inches) 0.05
Substrate Width (inches) 0.063
Current Specifications
Input Value
Cutoff Frequency (Hz) 10*10^9
Frequency at which Atten... 12*10^9
Specified Attenuation (dB) 30
Fractional Bandwidth 0.1
Dielectric Constant 9
Thickness (inches) 0.05
Substrate Width (inches) 0.063
Panel
Set Current Clear All Update Filter Generate Filt
Open Project Wizard
Project Location : C:\Users\Abhishek\workspace\FilterViewer\pro
Browse
Open Cancel
About Project
Project Name : MyProject1
Filter Type : Interdigital Bandpass Filter
Project File : C:\Users\Abhishek\workspace
About Filter
This is an Interdigital Band Pass Filter


MIC Filter Viewer v0.01
Project Edit Options About
MyProject1 Project2
Modify Specifications
Cutoff Frequency (Hz) 2.5*10^9
Frequency at which Attenuation is specified (Hz) 4*10^9
Ripple Level (dB) 10
Specified Attenuation (dB) 22
Characteristic Impedance of stripline connected to load and generator (ohm) 50
Characteristic Impedance of stripline for inductor (ohm) 150
Characteristic Impedance of stripline for capacitor (ohm) 10
Dielectric Constant 9
Substrate Width (m) 0.0063
Type (1:Stripline,2:Microstripline) 1
Current Specifications
Input Value
Cutoff Frequency (Hz) 2.5*10^9
Frequency at which Atten... 4*10^9
Ripple Level (dB) 10
Specified Attenuation (dB) 22
Characteristic Impedance ... 50
Characteristic Impedance ... 150
Characteristic Impedance ... 10
Dielectric Constant 9
Substrate Width (m) 0.0063
Type (1:Stripline,2:Microst... 1
Panel
Set Current Clear All Update Filter Generate Filter
About Project
Project Name : Project2
Filter Type : Stepped Impedance Lowpass Chebyshev
Project File : C:\Users\Abhishek\workspace\FilterViewer\projects\cheby1.mic
About Filter
This is a Stepped Impedance Lowpass Chebyshev Filter


MIC Filter Viewer v0.01
Project Edit Options About
MyProject1 Project2
Modify Specifications
Cutoff Frequency (Hz) 2.5*10^9
Frequency at which Attenuation is specified (Hz) 4*10^9
Ripple Level (dB) 10
Current Specifications
Input Value
Cutoff Frequency (Hz) 2.5*10^9
Frequency at which Atten... 4*10^9
Ripple Level (dB) 10
Figure 1
File Edit View Insert Tools Desktop Window Help
Note new toolbar buttons: data brushing & linked plots Play video
(A)- Insertion loss (dB)
(w/wc)- Normalized frequency
30
20
10
0
-10
-20
-30
0 0.5 1 1.5 2 2.5 3
Figure 2
File Edit View Insert Tools Desktop Window Help
Note new toolbar buttons: data brushing & linked plots Play video
z(mm)
y(mm)
x(mm)
2
1.5
1
0.5
0
10 5 0 -5 -10
0 500 1000 1500 2000 2500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Fractional Bandwidth 0.1
Dielectric Constant 9
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Current Specifications
Input Value
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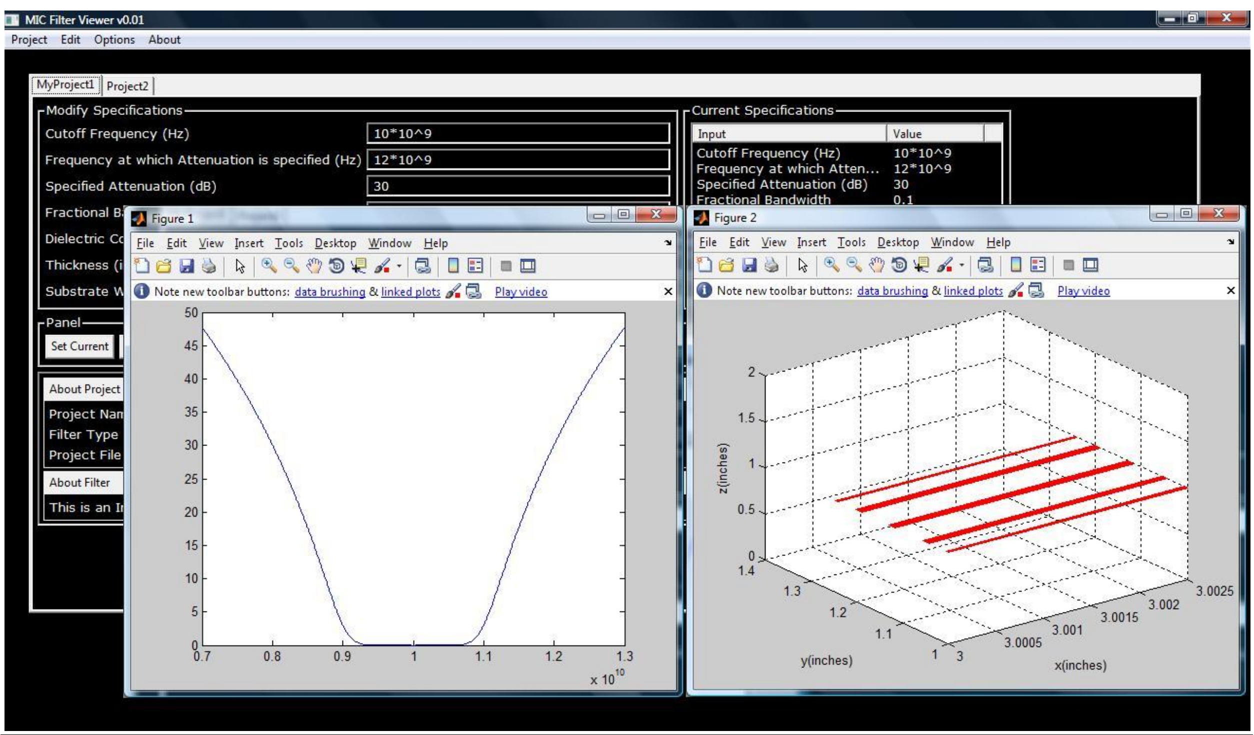
Frequency at which Atten... 12*10^9
Specified Attenuation (dB) 30
Fractional Bandwidth 0.1
Dielectric Constant 9
Thickness (inches) 0.05
Substrate Width (inches) 0.063
Panel
Set Current Clear All Update Filter Generate Filter
About Project
Project Name : MyProject1
Filter Type : Interdigital Bandpass Filter
Project File : C:\Users\Abhishek\workspace\FilterViewer\projects\MyProject1.mic
About Filter
This is an Interdigital Band Pass Filter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Cutoff Frequency (Hz) 10*10^9
Frequency at which Atten... 12*10^9
Specified Attenuation (dB) 30
Fractional Bandwidth 0.1
Panel
Set Current
About Project
About Filter
Figure 1
File Edit View Insert Tools Desktop Window Help
Note new toolbar buttons: data brushing & linked plots Play video
50 45 40 35 30 25 20 15 10 5 0
0.7 0.8 0.9 1 1.1 1.2 1.3
x 10^10
Figure 2
File Edit View Insert Tools Desktop Window Help
Note new toolbar buttons: data brushing & linked plots Play video
z(inches)
2 1.5 1 0.5 0
y(inches)
1.4 1.3 1.2 1.1 1
x(inches)
3 3.0005 3.001 3.0015 3.002 3.0025