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Influence of Iterative Parameter Calculations on the Response of Micro-strip Band-pass Filter with Parallel-Line Couplings

Fatema Itarsiwala[1], Sushruta Shetty[2], Ameem Khan[3], Awij A.R. Shaikh[4]
Department of E&TC, M.H. Saboo Siddik College of Engineering, Mumbai

Abstract: Band-pass filter is the important part of communication system. Transmitted and received signals have to be filtered to a certain centre frequency with a specific bandwidth. A band-pass filter is an important component must be found in transmitter and receiver. Band-pass filter is a passive component which is able to select signals inside a specific bandwidth at a center frequency and reject signals in another frequency region, especially in frequency regions, which have the potential to interfere with the information signals

I. INTRODUCTION

Band-pass filters are widely used in wireless transmitters and receivers. The main function of such filter in a transmitter and receiver is to identify and transmit the desired signal. This prevents the transmitter and receiver from interfering with other stations. A band-pass filter optimizes the signal-to-noise ratio. For the guidance in the design of integrated microwave circuit components, data are required on the parameters of symmetrical coupled pairs of micro strip transmission lines. The parameters needed to characterize this structure are the characteristic impedances and velocities of propagation of the two normal modes.

Micro-strip is a type of electrical transmission line that can be fabricated using printed circuit board technology and is used to convey micro-wave frequency signals. It consists of conducting strip separated from the ground plane by a dielectric layer called the substrate. Microwave components such as antennas, couplers, filters, power dividers, etc can be formed from microstrip with the entire device existing as the pattern of metallization on the substrate. Modification is necessary to reduce loss, reflections and spurious coupling but retaining advantages in simplicity, size, reliability, and cost which such production techniques afford.[1][2][3]

In order to build a complete circuit in micro strip, it is often necessary for the path of a strip to turn through a large angle. An abrupt 90° bend in a micro strip will cause a significant portion of the signal on the strip to be reflected back towards its source, with only part of the signal transmitted on around the bend. One means of affecting a low-reflection bend, is to curve the path of the strip in an arc of radius at least 3 times the strip-width. However, a far more common technique, and one which consumes a smaller area of substrate, is to use a mitered.

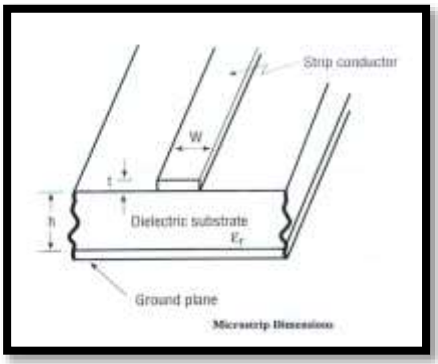

Figure. 1:. Micro-strip transmission line

As for the planar microwave band-pass filters, there are normally four different types: the combline filters, the interdigital filters, the parallel coupled filters and the hairpin-line filters. In modern RF/microwave communication systems, the size of the planar microwave filters is one of the major concerns, especially when these filters are applied in the monolithic microwave integrated circuits (MMIC). As alternative, micro-strip filter based on printed circuit board (PCB) offers the advantages easy and cheap in mass production of designing micro-strip band pass filters for the LTE applications at the frequency 1.7GHz with parallel coupled micro-strips.

II. DESIGN OF MICROSTRIP BANDPASS FILTER

Designing band-pass filter: the physical construction configuration is conventionally specified by parameters W/H and S/H, together with ε_r, where W is the width of the strip, H is the substrate height, and S is the spacing between the adjacent edges of the strips. ε_r is the permittivity of the material.

The filter to be designed is a parallel coupled filter. The strips are arranged parallel close to each other, so that they are coupled with certain coupling factors. We use the following equations for designing the parallel-coupled filter.[5][6][7]

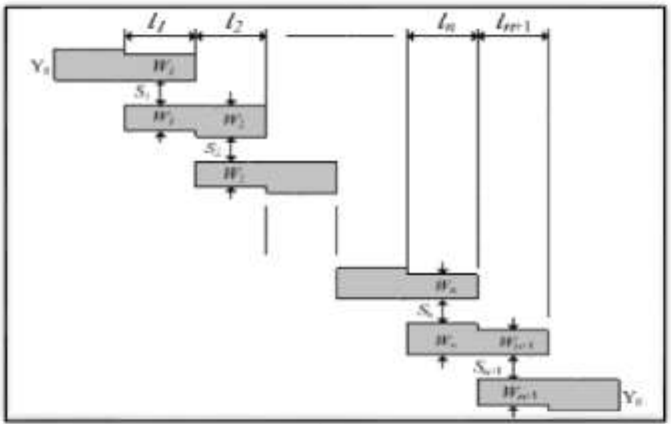

Figure.2: General structure of parallel(edge)-coupled microstrip band-pass filter with lengths(l), width(w), and spacings(s)

$$\frac{J_{01}}{Y_0} = \sqrt{\frac{\pi FBW}{2g_0 g_1}} \qquad (1) \qquad (1)$$

$$\frac{J_{j,j+1}}{Y_0} = \frac{\pi FBW}{2}\frac{1}{\sqrt{g_j g_{j+1}}} \qquad (2) \qquad (2)$$

For j= 1 to n-1

$$\frac{J_{n,n+1}}{Y_0} = \sqrt{\frac{\pi FBW}{2g_n g_{n+1}}} \qquad (3) \qquad (3)$$

g_0 ,g_1 ..... g_n can be taken from (4)(5)(6), FBW is the relative bandwidth , $J_{j,j+1}$ is the characteristic admittance of J inverter and Y_0 is the characteristic admittance of the connecting transmission line.

$$g_0=1 \qquad (4)$$

$$g_1 = \frac{2}{\gamma}\sin\left(\frac{\pi}{2n}\right) \qquad (5)$$

$$g_i = \frac{1}{g_{i-1}}\,\frac{4\sin\left(\frac{(2i-1)\pi}{2n}\right)\sin\left(\frac{(2i-3)\pi}{2n}\right)}{\gamma^2+\sin^2\left(\frac{(i-1)\pi}{n}\right)}\sin\left(\frac{(2i-1)\pi}{2n}\right) \text{ For i = 1 to n} \qquad (6)$$

$$g_{n+1} = \begin{cases} 1 & \text{for odd n} \\ \coth^2\left(\frac{\beta}{4}\right) & \text{for even n} \end{cases} \qquad (7)$$

Where

$$\beta = \ln\left[\coth\left(\frac{L_{Ar}}{17.37}\right)\right] \text{and } \gamma = \sin\left(\frac{\beta}{2n}\right) \qquad (8)$$

With the data of characteristic admittance of the inverter, we can calculate the characteristic impedances of even-mode and odd-mode of the parallel-coupled micro-strip transmission line, as follows [9,10].

$$(Z_{0e})_{j,j+1} = \frac{1}{Y_0}\left[1+\frac{J_{j,j+1}}{Y_0}+\left(\frac{J_{j,j+1}}{Y_0}\right)^2\right] \qquad (9)$$

For j = 0 to n and

$$(Z_{0o})_{j,j+1} = \frac{1}{Y_0}\left[1-\frac{J_{j,j+1}}{Y_0}+\left(\frac{J_{j,j+1}}{Y_0}\right)^2\right] \qquad (10)$$

$$g = \cosh\left[\frac{1}{2}\pi(s/h)\right]$$

$$h = \cosh\left[\pi(W/h)+\frac{1}{2}\pi(s/h)\right] \qquad (11)$$

We can determine the width of parallel-coupled micro-strip lines W and the distance between them s. The first step is to find the two single-line shape ratios $(W/H)_{se}$ and $(W/H)_{so}$ corresponding to the impedance $Z_{Oe}/2$ and $Z_{OO}/2$, respectively. By Wheelers Theory [16]

$$(W/h)_{se} = (2/\pi)\cosh^{-1}\left(\frac{2h-g+1}{g+1}\right)$$

$$(W/h)_{so} = (2/\pi)\cosh^{-1}\left(\frac{2h-g-1}{g-1}\right)$$

Using above equations we can calculate the width and spacing of each coupled micro-strip sections. We can also do the iterative method to calculate the above parameters. The method is as follow. We first calculate the width and spacing as above. Then using $(W/H)_{se}$ and $(W/H)_{so}$ we calculate characteristic impedance Z_0 corresponding to $Z_{Oe}/2$ and $Z_{OO}/2$, respectively.

$$Z_0 = \frac{120\pi(1/\varepsilon_r)^{1/2}}{(W/h)_s + 0.882 + [(\varepsilon_r+1)/\pi\varepsilon_r]\{\ln((W/h)_s + 1.88) + 0.758\} + [(\varepsilon_r - 1)/\varepsilon_r{}^2](0.164)} \qquad (12)$$

So, Characteristics impedances obtained above can be compared with those obtained by (9)(10). If there is difference then slightly change the width and spacing values. Then again we calculate the characteristic impedances. The process is repeated till the values of width and spacing delivers the same value of characteristic impedances as those obtained in (9) and (10).

III. MICROSTRIP BAND PASS FILTER CALCULATIONS

The Fractional Bandwidth(FBW) is set to FBW =0.058 and the specified pass-band ripple to 0.5 dB with the central frequency $f0$ = 1.7 GHz. Considering these specifications, the element values of the prototype Chebyshev low-pass filter with pass-band ripple of 0.5 dB, are selected as shown in the table below.

$g0 = g6$	1
$g1 = g5$	1.1468
$g2 = g4$	1.3712
$g3$	1.9750

$$\frac{J_{01}}{Y_0} = 0.2311 = \frac{J_{56}}{Y_0}$$

$$\frac{J_{12}}{Y_0} = 0.0629 = \frac{J_{45}}{Y_0}$$

$$\frac{J_{23}}{Y_0} = 0.0515 = \frac{J_{34}}{Y_0}$$

0.1 GHz,

Then we calculate the even-mode and odd-mode characteristic impedances of this parallel coupled micro-strip line using eq. (9) and (10), which should lead to (12)

$$(Z_{0e})_{01} = (Z_{0e})_{56} = 64.22\Omega$$
$$(Z_{0o})_{01} = (Z_{0o})_{56} = 41.12\Omega$$
$$(Z_{0e})_{12} = (Z_{0e})_{45} = 53.34\Omega$$
$$(Z_{0o})_{12} = (Z_{0o})_{45} = 47.05\Omega$$
$$(Z_{0e})_{23} = (Z_{0e})_{34} = 52.71\Omega$$
$$(Z_{0o})_{23} = (Z_{0o})_{34} = 47.56\Omega$$

With the procedure explained in [11][13][14], we can determine the width of parallel-coupled micro-strip lines W and the distance between them s. A pair of parallel-coupled micro-strip lines with certain width and separation distance will deliver a pair of characteristic impedances, the even mode and the odd mode ones. W_1 and s_1 are determined such that the resultant even- and odd mode impedances match to $(Z_{0e})_{0,1}$ and $(Z_{0o})_{0,1}$. Assume that the micro-strip filter is constructed on a substrate with a relative dielectric constant of 4.4 and thickness of 1.6 mm. Using the design equations the effective dielectric constants of even mode and odd mode can be determined[12].

The actual lengths of each coupled line section are then determined by

$$l_j = \frac{\lambda_0}{4\left(\sqrt{\varepsilon_{re}\varepsilon_{ro}}\right)^{\frac{1}{2}}} - \Delta j \qquad (13)$$

where Δl_j is the equivalent length of micro-strip open end[18].

IV. RESULTS AND ANALYSIS

The resultant length, width, effective ε and spacing of each microstrip lines can be obtained from equations (9), (10) and (13). It is given in the table below,

J	W_j(mm)	S_j(mm)	ε_{re}	ε_{ro}	l_j(mm)
1 and 6	1.98	0.4	3.5777	2.9424	24.5
2 and 5	2.16	1.6170	3.5777	3.1269	24.12
3 and 4	2.1911	1.409	3.5907	3.1111	23.3112

In the table above, we have used iterative method for calculating length, width and spacing. The final filter layout is illustrated in Figure 3.

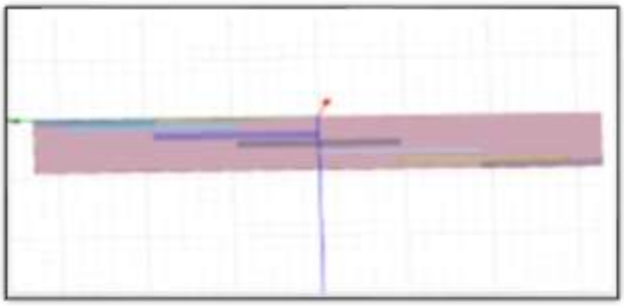

Figure.3:Final layout of microstrip edge-coupled microstrip band pass filter

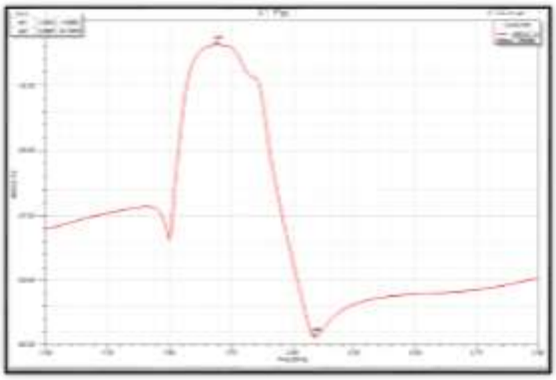

Figure.4:Insertion Loss.S(2,1) of edge-coupled microstrip band pass filter

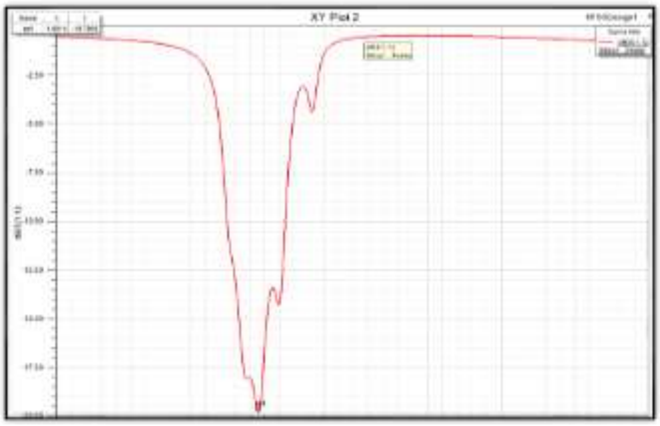

Figure.5:Return Loss.S(1,1) edge-coupled microstrip band pass filter

The Fig.3 shows the actual design of the final bandpass filter with coupled strip lines. It is a filter of order 5 with cutoff frequency of 1.7GHz. The Fig.4 and Fig.5 shows frequency response of the same filter. Fig.4 shows insertion loss i.e.S(2,1) and Fig.5 shows return loss i.e.S(1,1) parameters.

V. CONCLUSION

The designing of band-pass filter using parallel-coupled micro-strip lines with iterative method on HFSS gives very good filter characteristics at the centre frequency 1.7 GHz. The Insertion loss obtained is -4.966dB and Return loss obtained is -19.79dB.

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