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Design of Tunable Microstrip Bandpass Cascaded Quadruplet Filter for SDR(Software Defined Radio)

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Abstract—*The proposed filter is an advanced microstrip bandpass filter in which many shortcomings of the traditional BPF is tried to fix. We proposed an eight- pole half-wavelength microstrip bandpass cascaded quadruplet filter. It has two transmission zeros at finite frequencies due to two cross couplings. High selectivity is achieved by introducing the cross coupling between the resonators. Speciality of the proposed filter is, its easy and simple tunability which has a demand in high-speed digital transmission systems. Bandwidth of the filter can be easily controlled by changing the position of the tapped line Proposed filter is realized for centre frequency 0.850 GHz on substrate RT/Duroid of thickness 1.27 mm and 10.8 relative dielectric constant. Design is simulated on IE3D.*

1. INTRODUCTION

In this modern era of communication systems high speed digital transmission systems are in great demand. Traditional microstrip filters can't satisfy the stringent demand for wireless RF/microwave systems. In the past years variety of bandpass filters are proposed and fabricated but in those filters channel selection was not an easy task. In one quadruplet four open loop microstrip resonators are comprised as shown in fig.1. These four open loop resonators are coupled directly and cross coupled depending upon the orientation of the open-loop resonator with respect to the position of gap. These quadruplet can be cascaded in any number known as cascaded quadruplet (CQ) as shown in fig. 2. In any fashion CQ can be coupled, cross coupled or direct coupled and higher order filter can be realized[1-2]. Filters with single pair transmission zeros have a very good selectivity characteristic but its fabrication is not easy[3]. By using a cross coupled resonator high selectivity criterion can be obtained. In cascaded quadruplet (CQ) resonator filter many transmission zeros are taken into account to improved selectivity[4]. The cross coupling is implemented in such a way that it gives transmission zeros at finite frequencies to get high selectivity or it can be set in such a way to provide group delay self-equalization. Fig.3 shows the coupling structure of CQ eight-pole bandpass filter where node represent a resonator. M_{ij} is coefficient of coupling and Q_{e1} and Q_{e8} are the external quality factors of input and output couplings. Speciality of the proposed CQ filter is its easy tunability which is independent of cross-coupling.

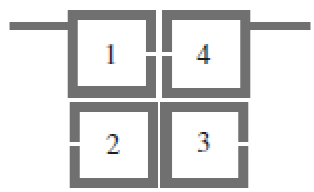

Fig. 1: Quadruplet comprised of four open-loop resonator.

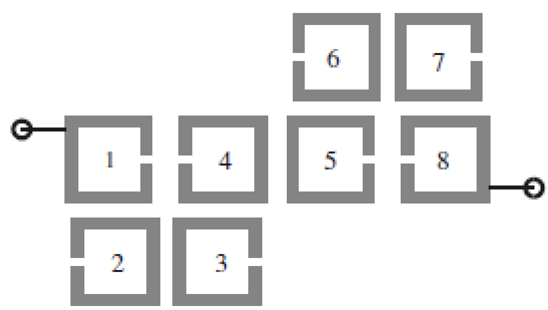

Fig. 2: Configuration of open-loop eight-pole microstrip bandpass cascaded quadruplet filter.

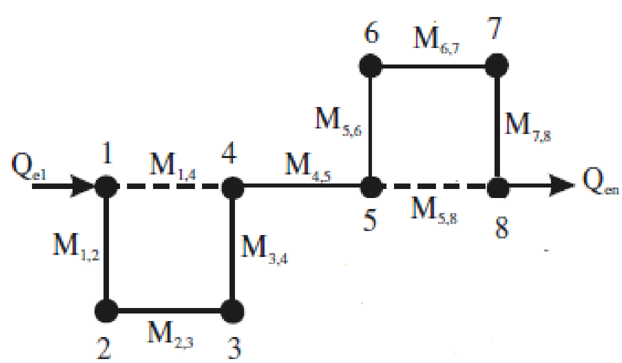

Fig. 3: Coupling diagram of CQ eight-pole bandpass filter

2. COUPLING BETWEEN RESONATORS

To find the physical dimensions of the filter, value of coefficient of coupling, M and external quality factor, Q associated with input and output coupling of the filter are necessary to obtain first[5]. Secondly relationship between each value of coupling coefficient and physical dimension has to establish. There is no closed form expressions are available to obtain physical dimensions of filter. The only way is to perform full-wave EM simulation of the design to match the coefficient of coupling and external quality factor.[6]

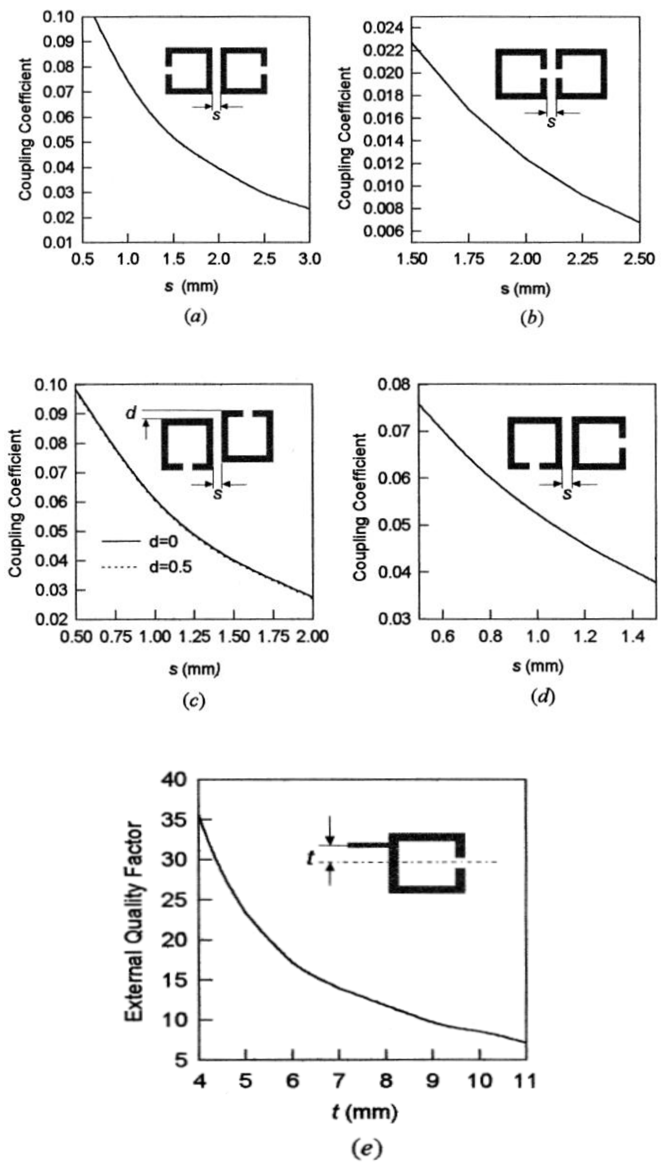

Fig. 4: Design curve. (*a*) Magnetic coupling. (*b*) Electric coupling. (*c*) Mixed coupling I. (*d*)Mixed coupling II. (*e*) External quality factor. (All resonators have a line width of 1.5 mm and a size of 20 mm × 20 mm on a 1.27 mm thick substrate with a relative dielectric constant of 10.8.)

The response of EM simulation is presented in the fig. 4. Coupling spacing, s can be determined from fig.4 against different types of coupling and size. These values are scaled and optimized.

3. DESIGN EQUATIONS

Design parameters of the bandpass filters, i.e., coupling coefficient and external quality factor can be determined by the following formulas

$$Q_{ei} = Q_{eo} = \frac{g_1}{FBW} \dots \quad (1)$$

$$M_{i,i+1} = M_{n-i,n-i+1} = \frac{FBW}{\sqrt{g_i g_{i+1}}} \dots \quad (2)$$

For i=1 to m-1

$$M_{m,m+1} = \frac{FBW.J_m}{g_m} \dots \quad (3)$$

$$M_{m-1,m+2} = \frac{FBW.J_{m-1}}{g_{m-1}} \dots \quad (4)$$

Where Q_{ei} and Q_{eo} are external quality factor for input and output couplings. $g_i \dots\dots\dots g_{i+1} \dots\dots.. g_n$ are the elements of prototype lowpass filter. Where n is the order of filter. Where m is any integer. FBW is fraction bandwidth. $M_{i,i+1}$ is the coefficient of coupling. J is admittance inverter.

4. DESIGN AND ANALYSIS OF THE FILTER

4.1 Design Specification

Type : cascaded quadruplet bandpass filter

Order of filter : 8

Function : Chebychev

Centre frequency : 0.850 GHz

Relative Dielectric constant: 10.8

Substrate height : 1.27 mm

FBW: 0.07063

Coefficient of coupling and external quality factor are calculated by using equations (1), (2), (3), (4)

M_{12} = 0.058(Mixed coupling) M_{56} = 0.035(Mixed coupling)

M_{23} = 0.047 (Magnetic coupling) M_{67} = 0.053(Mag. coupling)

M_{34} = 0.038(Mixed coupling) M_{78} = 0.056(Mixed coupling)

M_{14} = –0.0072(Electric coupling) M_{58} = –0.017(Elec. coupling)

M_{45} = 0.038(Mixed coupling) Q_{ei} = Q_{eo} = 13.56

4.2 Design Analysis

CQ bandpass filter shows direct coupling and cross coupling both[7]. The inter-resonator couplings are realized through the fringe fields of the microstrip open-loop resonators. Design shows two pairs of transmission zeros at finite frequencies[8]. One pair of transmission zeros is due to magnetic and electric coupling M_{23} and M_{14} respectively. Second pair of transmission zeros is due to magnetic and electric coupling M_{67} and M_{58}. These two types of couplings have opposite sign. This opposite sign nature of the couplings gives highly selective frequency characteristic. Filter also exhibits group delay self-equalization.

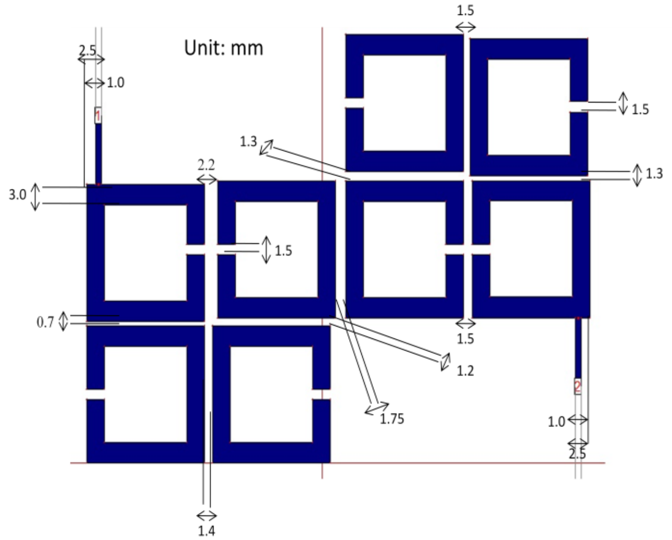

Fig. 5: Layout of the designed microstrip CQ filter with all the dimensions shown.RT/D 1.27mm thick substrate with a relative dielectric constant of 10.8.

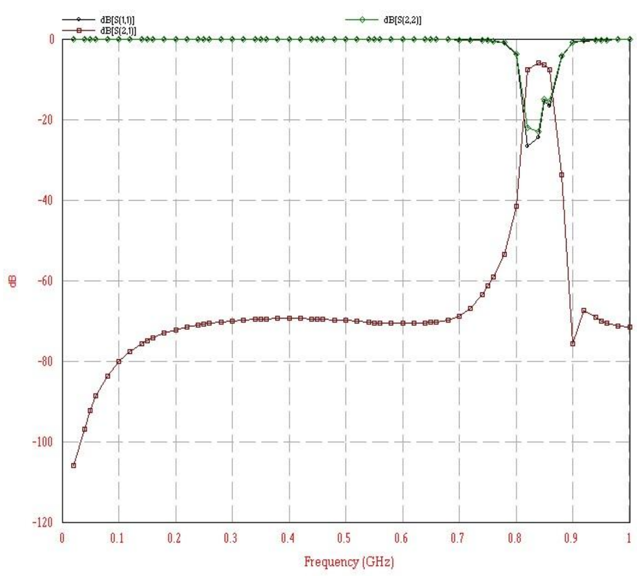

Fig. 6: Simulated performance of the microstrip CQ bandpass filter.

To increase the power handling capability and to minimize the conductor losses width of the microstrip is increased to 3mm. Eventually the size of the microstrip is increased in the same ratio. For a fixed gap 1.5 mm and square loop of side 20 mm which is constant for all the square loop resonators used to design the filter, other dimensions are extracted from the EM simulation performed on IE3D. Selectivity and frequency response of the filter can be improved by designing higher order filter. In fig.4 different types of couplings between the open loop resonator is shown with respect to constant microstrip width 1.5 mm and 20 mm size of loop.

5. SIMULATION

Proposed filter 'cascaded quadruplet bandpass filter' for centre frequency 0.850 GHz is designed and simulated on zeland software IE3D. Layout of the design is shown in fig.5 and all the dimensions are indicated in the layout. Simulated response of the design shown in fig.5 is shown in fig.6. Return loss is -22 dB. Insertion loss is -5 dB. In the simulation one pair of the transmission zero is not clearly visible. This is due to the effect of mixed coupling. In designing the filter exact value of coefficient of mixed coupling is required to get the desired frequency response. We designed a filter for two pairs of transmission zeros on either edge of the passband. In the simulation two pairs of transmission zeroes are visible but it is visible only upper side of the centre frequency, lower side of the centre frequency transmission poles are not clearly visible.

6. CONCLUSION

The proposed cascaded quadruplet bandpass filter has sharp and flat passband and passband is flat without any appreciable spurious frequencies. It is designed for two pairs of transmission zeros but due to the use of coupling values obtained by simulation, transmission zeros are present only on the upper side of passband near the edge. By using the more exact values of the coefficient of coupling desired transmission zeroes can be obtained. Filter is designed for 0.850 GHz but in the simulation centre frequency is 0.827 GHz. In the proposed filter gap of the open loop resonator g = 1.5 mm is used and this is constant for all the resonators used to design CQ bandpass filter. Centre frequency can be shifted to upper side by decreasing the value of gap, g. Moreover by using the different gap values in different resonators centre frequency can be shifted. Return loss is -22 dB. Insertion loss is -5 dB.

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