Reconfigurable RF Filter for Mobile Device

Abiramasundari S[1], Meenakshi Sundaram V[2], Logeshwari A[3]
[1,3]*Assistant Professor, Department of ECE, VSBCETC, Coimbatore, Tamilnadu, India*
[2]*Assosiate Professor, Department of ECE, VSBCETC, Coimbatore, Tamilnadu, India*

***Abstract* - Multistandard devices have increased demand for smart phones with global coverage and the spare allocation of wireless spectrum for cellular applications. The increasing demand of wireless communication applications necessitates RF filters operating in various separated frequency bands such that users can access various services with a single terminal. As the amount of wireless standards and frequency bands grows, the costs, complexity and standards become significant. Tunable filters are aimed at addressing the multiband problem by permitting a single component to handle multiple bands so as to combine multiple frontend signal chains into one. In this paper we proposed a special topology to design reconfigurable RF filters using dual behaviour resonators (DBR) filter topology. A tunable filter is able to switch between GSM, Wi-Fi and LTE reception bands. S-parameter value show good filter performances in terms of insertion loss return loss and bandwidth.**

***Index Terms* - SDR ; wireless communication; dual behavior resonators; multistandard; varactor diode.**

I.INTRODUCTION

The Wireless system of future generation will be based on the Software Defined Ratio technology, which provides an prominent solution between old technologies and software radio. Hence to operate with both classical and future technology, the whole system must be flexible.

In receiver module, the tunable filters play very significant roles in minimizing the noise and also it reduces the consumption of power.

In existing method, there are different papers investigating the design of tunable filters. In [2], the filter which is presented has an insertion loss up to 6 dB. In [3], the existing filter has a good performance but its insertion loss and return loss is high. It presents a wide frequency tuning range of 6 GHz with a constant bandwidth, which makes frequencies unreachable. In [4], the classical filter exhibits a high insertion loss and deviation in center frequencies.

As well as some other filter which is proposed in existing method have not concentrated on wireless standards, and they also have some handicaps: performances of insertion los and return loss, power consumption, cost, tuning speed, complexity [1]-[7].

Indeed to gather a good performances from existing method. So we have investigated a DBR topology which permits to control central frequency and other parameters like bandwidth, attenuation band etc., and our main idea is to propose a design a reconfigurable filter for GSM, WIFI and LTE. The paper is ordered as follows: after the introduction about tunable filter, the overview of DBR topology and the synthesis of topology are presented in section II. Proposed reconfigurable RF filter design steps are described in section III. In next section, brief methodology of CMDA/GSM/ WIFI/LTE tunable filter is presented in section IV. Before conclusion varactor diodes are found and the simulation results are presented.

II.SYNTHESIS OF DBR TOPOLOGY

Dual Behavior Resonator (DBR) technology has been receiving a great attention from scholars in modern years, due to its applications in planar microwave filters. These filters are based on the parallel association of two stubs which is said to be elementary cells. These cells has two stubs where the top of the stub is used to control the low transmission zeros and bottom of the stub is used to control the high transmission zeros. This structure looks like a notch structure. It has a very narrow band pass response and 2n transmission zeros where n represents the order of the filter [10].

DBR allows controlling central frequency and bandwidth independently and it has a major disadvantage of spurious resonances and parasitic response in the lower and upper sides of the central frequency. These drawbacks can be overcome by Capacitive- Coupled Dual Behavior Resonator; n order filter involves n DBR resonators and n+1 j inverters (quarter wave admittance inverters). These resonators help to achieve 2n transmission zero.

The prominent tuning elements are magnetic and micro- Electromechanical Systems (MEMS).Electric techniques are easily implementable in circuits. This technique includes tunable elements such as PIN diodes, ferroelectric techniques. The magnetic technique includes MEMS switches and MEMS varicaps.

An electric technique is preferred for tunable filter due to high tuning speed and easy implementation in circuits. PIN diode allows to tune between two bands. Hence we tune using varactor diode. We prefer varactor diode for their small size and less cost. Table I shows the comparison of reconfiguration techniques.

Properties	Varactor diode	YIG	DTC	MEMS
Tunability(Q)	good	High	high	low
RF loss	Moderate Q<60	Very good Q>200	moderate	Very good
Control voltage	< 10 v	< 28 v	<20v	<60v
Tuning speed	Fast 1-5 nano seconds	Slow>1 milliseconds	Fast 1-5 nano seconds	Slow > 5 nano seconds
Power	poor	excellent	excellent	excellent
Insertion loss	moderate	Low	low	low
Cost	less	Low	low	moderate
Circuit integration	easy	difficult	high	difficult

Table I: Shows the comparison of reconfiguration techniques

III.RECONFIGURABLE DBR TOPOLOGY

For controlling the bandwidth and central frequency independently, Variable capacitances are inserted at the end of the stub. The capacitances are placed at the top stub which provides control over the frequency on low transmission zeros and it is denoted as CA. The capacitances at the bottom of the stub is used to control the frequency of high transmission zero and it is denoted as CB.

By changing the value of capacitor, the electrical length of the corresponding stub will increase which results in the decrease in the frequency of transmission zero.

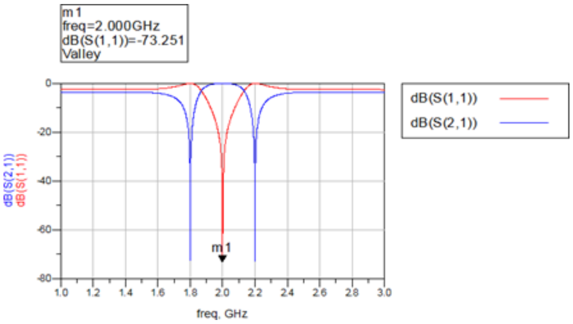

Fig.1. S parameters simulation of the first order filter

Figure 1 describes the S parameters simulation of the first order filter

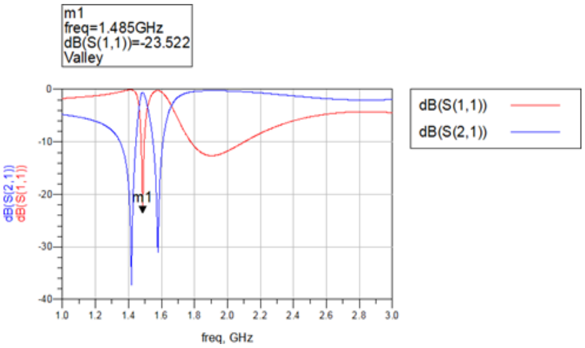

Fig.2.DBR filter with capacitances as tuning element

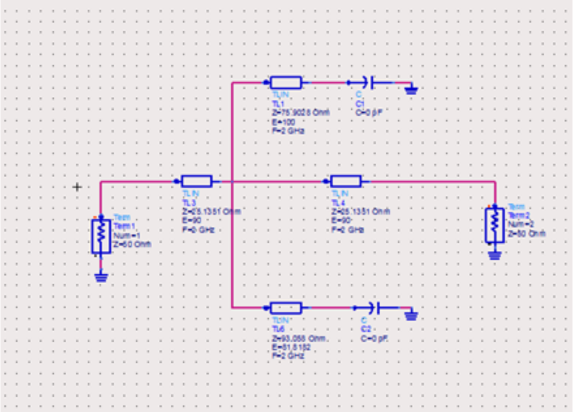

Fig 3: simulation parameter result on tuning

Figure 3 it shows the s parameters value on changing the capacitance value to 0.35 the frequency is shifted to 1.4GHz

IV.STEPS TO DESIGN TUNABLE RF FILTER

In this section, we use different steps to design a tunable filter .the filter design steps as follows.

Step 1: Filter specifications and choice of design

In first step, we use the specification of different parameters for synthesizing the filter. Fcx is the center frequency for xth RF band which is given in equation (1).

$Fcx=\sqrt{F_{p1X}.\,F_{p2}}$ ---------------(1)

Where Fp1X, Fp2X are pass band edge frequencies. Consider Fcx should be ordered i.e. Fc1<Fc2<….<FcN. where x varies from 1 to N.

Step 2: Synthesis of order of filter

Find the appropriate filter design and the choice is made depending upon the filter order and acceptable response linearity.

Step 3: DBR topology synthesis

Tunable filter order is given P is given in equation (2).

$P=\max_{1\leq X<N} nX$ -----------------------(2)

Use P, the pass band frequencies (Fp1N, Fp2N) and the stop frequencies (FS1N, FS2N) to synthesis the tuning filter structure based on the filter topology.

Step 4: Tuning Element synthesis

Set CA and CBto C=0 in order to fit N^{th} order RF filter, where c is used as central frequency control.

When we change the value of CA and CB the filter response will move around the central frequency, where CA = CB = C.CAcan be increased to alter the bandwidth of the filter.

Where CB can be derived from equation (3)

CB=2C-CA -------------------- (3)

CA and CB outputs are needed for the design of tunable RF filter using DBR filter topology.

STANDARDS	PARAMETERS			
	Fp1(GHz)	Fp2(GHz)	Fs1(GHz)	Fs2(GHz)
GSM	0.935	0.96	0.915	0.98
WI-FI	2.4	2.4835	2	3
LTE	2.62	2.69	2.56	2.75

Table II: Specification of different wireless standards

V.DESIGN OF TUNABLE RF FILTER FOR GSM, WIFI AND LTE

The filter specifications of GSM, WiFi and LTE are taken from the standard specifications which are mentioned in table II. To have a control over central frequency and bandwidth is needed. For this type of application DBR filter topology is suitable.

STANDARDS	DBR PARAMETERS	J INVERTERS
FC = 2.655GHz; FBW=2.63%	Zj1 = 81.65Ω ; E = 100⁰ Zj2 = 93.96Ω ; E=81.81⁰	Zc01=Zc34 = 56.02 ; E=90⁰ Zc12=Zc23=77.97 ; E=90⁰

Table III: Filter physical parameters synthesis

The synthesized filter order is 3 and chebyshev approximation is selected because it is insensitive to tolerances and it is highly selective in nature.

We used the specification of LTE for synthesis of filter. The proposed design is implemented in FR4 substrate with permittivity εr=4.32, thickness h =1.6mm and a tangent loss = 0.001 the synthesized physical parameters values which is given the table III. Figure 4 shows the filter layout and figure 5 represents its S parameters simulation.

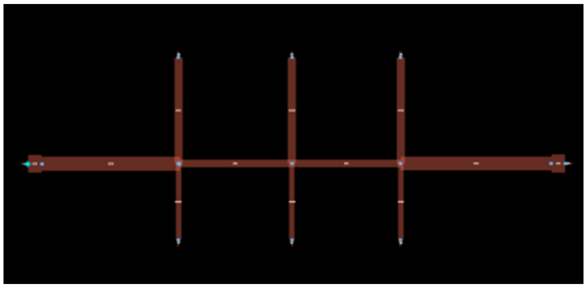

Fig.4. Third Order DBR Filter

Using optimization tool, we optimize the filter response with ideal capacitors.

Figure 5 shows the CO-Simulation circuit which is used to integrate the layout into schematic window and capacitor is connected to control the bandwidth for different standards.

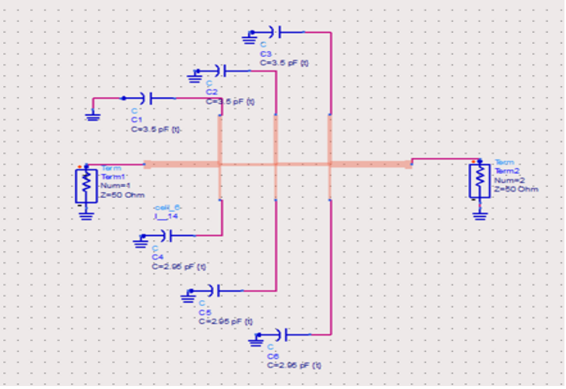

Fig. 5: CO simulation circuit using capacitor as tuning element

Figure 6: Describes the different s parameter simulation for different standards from which the return and insertion loss and bandwidth are measured.

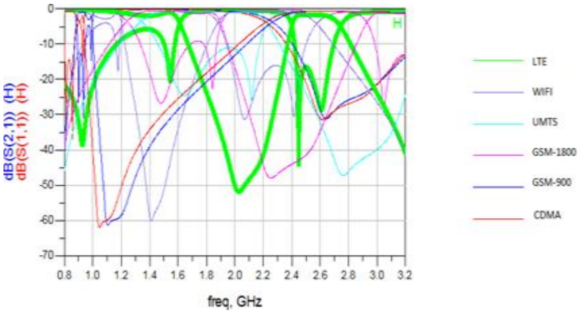

Fig. 6. S parameter simulation of the co-simulation circuit

STANDARDS	PARAMETERS					
	CA (pF)	CB (pF)	F C (GHz)	S 11 (dB)	S 22 (dB)	BW (MHz)
GSM-900	5	2.65	0.933	-0.841	-28.043	98
GSM-1800	5.5	0.4	1.833	-1.108	-19.900	129
WIFI	1	0.001	2.419	-1.067	-30.070	247
LTE	0.25	0.001	2.620	-1.771	-27.442	182

Table IV: S Parameter Simulation Using Capacitor

Table IV shows the simulation performances. Overall desired RF bands, a maximum insertion loss 1.7 dB and minimum reflection loss of 19.9 Db.

VI.IMPLEMENTATION OF TUNABLE FILTER USING VARACTOR DIODE

While tuning the capacitance values using capacitance it covers all RF band is pF. But the choice of choosing the varactor depends upon quality factor which reflects the intrinsic resistive loss, so, we should choose it highly.

We prefer the MA4ST340 varactor diode from MA-COM to be implemented with the filter which has an intrinsic resistance Rs = 0.94 ohms. Which choosed depending upon the filter design. The value of Rs is calculated using the formula:

$$Q = \frac{1}{2\pi . F . R_S . C(V)} \quad ------------ \quad (4)$$

From the above equation frequency is denoted as F and C(V) represents the reverse voltage of 2V. Both the parameers values are specified in the datasheet.

For implementing the variable capacitor, we need to use the basic varactor model which is shown in figure 7

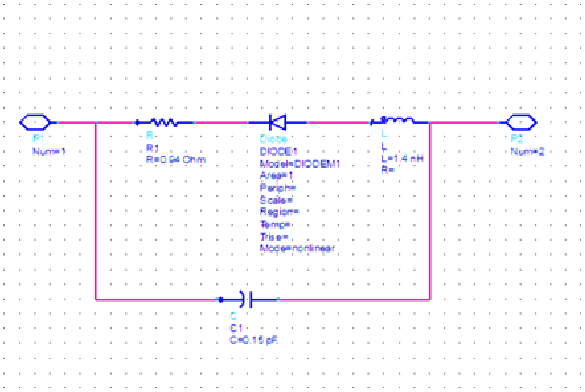

Fig.7. MA4ST340 Varactor model

CSis capacitors added in series with varactor in order to shift the capacitance tuning range. So from the datasheet we mention the value of series capacitances Cs = 8pF.It also used to achieve high tunability.

DC feed is used near the DC bias to protect the DC line from the RF signal, and lower frequency signal to be block from RF signal as it can give feedback and could cause oscillation

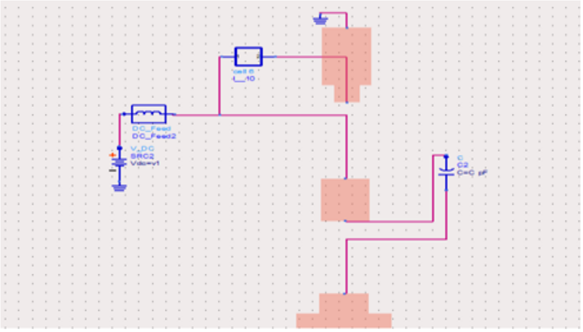

Fig.8. Modified stub using varactor diode

Figure 8 shows the modification made at a single stub in figure 5. The stub is extended by connecting varactor model, dc feed and DC bias in all the six stubs.

STANDARD	PARAMETERS					
	V1 (V)	V2 (V)	F C (GHz)	S21 (dB)	S 11 (dB)	BW (MHz)
GSM-900	0	5	0.947	-32.65	-2.144	123
GSM-1800	7.9	11.8	1.833	-37.43	-2.102	218
WIFI	6.6	2.7	2.44	-38.30	-1.185	819
LTE	9.5	3.7	2.545	-28.34	-1.281	811

Table V: S Parameter Simulation Using Varactors

Table V shows the simulation performances using the bandwidths and by maintaining acceptable insertion loss (<.2.1 dB) and return loss (>28 dB).

VII.CONCLUSION

A tunable RF filter covering the GSM-900, Wi-Fi and LTE reception bands using DBR topology and ideal capacitor as tuning elements and varactor diode is shown. S parameters simulations show a good agreement with the standards specifications in term of centre frequencies and varactor as tuning element. Overall desired RF bands, a maximum insertion loss 2.1 dB and minimum reflection loss of 28.34dB.

REFERENCE

[1] Brito-Brito.Z. ILlamas-Garro.I. Navarro-Muñoz.G.Perruisseau- Carrier J.C.andPradell.L. (2010), 'Switchable bandpass filter for WiFi–UMTS reception standards', Electronics Letters, Vol. 46, No. 13, pp2-5.

[2] ChaurayaKelly.J.Seager R.D. and Vardaxoglou J.C.(2005), 'Frequency Switchable Microstrip

Filter for Microwave Frequencies', European Microwave Conference.

[3] Courrèges.S. Li.Y.Zhao.Z.Choi.K. Hunt.A. and papolymerou.J.(2009), 'A low loss X-band quasi-elliptic ferroelectric tunable filter', IEEE Microwave and Wireless Components Letters, Vol. 19, No. 4, pp. 203– 205.

[4] Entesari.K. andRebeiz.G.M. (2005), 'A 12 - 18-GHz three-pole RF MEMS tunable filter', IEEE Transactions on Microwave Theory and Techniques, Vol. 53, No. 8, pp. 2566–2571.

[5] Entesari.K. andRebeiz.G.M. (2005), 'A 12 - 18-GHz three-pole RF MEMS tunable filter', IEEE Transactions on Microwave Theory and Techniques, Vol. 53, No. 8, pp. 2566–2571.

[6] Fourn et al.(2002), 'Bandwidth and Central Frequency Tunable Band pass filter', European Microwave Conference,pp.1 – 4.

[7] Hong J.S. and Lancaster M.J.(2001),'Microstrip Filters for RF/Microwave Applications', Wiley Series in Microwave and Optical Engineering," ISBN(International Standard Book Number)0-471-22161-9, pp.1-471.

[8] Hunter.I.Ranson.R.Guyette.A. and Abunjaileh.A. (2007), Microwave Filter Design', From A Systems Perspective, IEEE Microwave Magazine, pp.71-77.

[9] Hussaini.S.Alhameed R.A. and Rodriguez.J. (2011), 'Tunable RF Filters: survey and beyond', 18th IEEE ICECS, pp.512-515.

[10] Manchec.A.Quendo.C. FavennecJ.C.Rius.E. and Person.C.(2006), 'Synthesis of Capacitive-Coupled Dual-Behavior Resonator (CCDBR) Filters',IEEE Transactions on Microwave Theory and Techniques, Vol. 54, No.6, pp.2346-2355.

[11] E. Fourn et al (2002), 'Bandwidth and Central Frequency Tunable Bandpass Filter', European Microwave Conference, pp.1 - 4.

[12] Le Coq.M et al.,(2011), 'Miniature Microstrip Filter Using High-Permittivity Ceramic Substrates (Er = 90)', IEEE International Microwave Symposium Digest (MTT), pp.1-4. [13].Haider.NCaratelli.D and Yarovoy.A.G. (2013), 'Recent Developments in Reconfigurable and Multiband Antenna Technology', Hindawi Publishing Corporation, International Journal of Antennas and Propagation Vol. 2013, Article ID 869170, pp. 1- 14.