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ANALYSIS OF ELECTRONICALLY TUNABLE DIPLEXER FOR WIMAX FRONT-END MODULES

G.Kingsley, S.Prabhakaran, M.Pravin

Department of Electronics and Communication

CMS College of Engineering and Technology

Abstract- This paper presents a systematic approach for the design of electronically tunable diplexers for frequency agile WiMAX based applications. Integration of front-end modules with tunable characteristics is generally recognized in reducing size complexity and cost constraints inherent to conventional transceiver architecture design and implementation. A compact diplexer using microstrip ring resonator properties that incorporates two bandpass filters and microstrip T-junction is presented and analyzed. The proposed varactor tuned diplexer has the advantages good frequency tunability characteristics of its constituent filters, simplicity and compactness. Advance Design Systems software (ADS) software is used for the simulation of the proposed varactor tuned microstrip filters and results are analyzed. Finally the design of the diplexer is presented for the WiMAX front-end modules.

1 Introduction

Wireless RF and microwave communication systems are a rapidly expanding market and strict requirements on size, weight and power necessitate the use of low power low loss components. Reconfigurable radio system represents a potential solution for interferences, cost, size and power consumption problems encountered by wireless communication industry as frequency agility tends to be more important. Such systems commonly employ Diplexers in their front-ends as channel separators. The diplexer is generally composed of two bandpass filters with different operation frequencies, and they are seen electrically open over their passbands with respect to each other. These devices can be used to connect single antenna with several receivers or transmitters or to provide the coexistence of different wireless systems in multiservice and multiband communication systems.

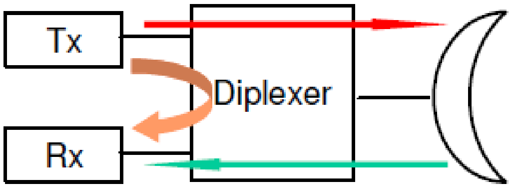

Fig. 1: General view of a Diplexer

Indeed, it is still a challenging task to design a tunable diplexer with tuning range wide enough to cover operating frequencies needed for practical applications. Interferences among actual standard communication radios systems are one of the major problems encountered by wireless communication industry. Systems are equipped with more and more radios in a single chip, and are susceptible to mutually interfered with each other if operate simultaneously close enough in a common frequency band. On the other hand, the wireless frequency band spectra are almost occupied by those systems, specifically around 2.4 GHz frequency band. Consequently, there are no completely “free” frequency bands for the next generation of wireless systems.

Microwave filters have important role in many wireless and communication systems such as satellite and cellular mobile organizations. It is expected that a single filter is able to support multiple information channels simultaneously. This kind of filters can reduce the overall size and cost of transreceivers. Either a bank of fixed-frequency filter or a single reconfigurable filter with variable frequency characteristics is needed in order to fulfill this function. A lot of research and investigations have been done in developing a reconfigurable filter. These reconfiguring effects are achieved by changing the coupling between resonators with devices that have tunable properties: PIN diode MEMS switches and varactor diodes. This paper demonstrates the use of the varactor tuned dual-mode microstrip ring resonator properties in order to achieve miniaturization of microstrip bandpass filters for diplexer and multiplexer applications.

The proposed filters and diplexers have advantages of simplicity and compactness. Simulation results for microstrip filters and analysis and design of the proposed diplexer are presented. The important specifications for the proposed Diplexer are given in Table 1.

Parameters	**Specification**
Center Frequency (Transmitter filter)	2.5 GHz
Center Frequency (Receiver filter)	~ 3 GHz
Passband Insertion Loss	Less than 5 dB
Passband Return Loss	Better than -10 dB

Table 1: Filter Specifications for proposed Diplexer

Section II will describe the architecture of the proposed tunable diplexer and EM modeling analysis of both tunable dual mode bandpass filters using ADS software. Finally, section III presents the experimental results of a tunable diplexer prototype.

2. Design description of tunable diplexer

The topology of the proposed tunable second-order microstrip dual-mode bandpass filters is presented in Fig.2. The microstrip dual-mode resonator is widely used to design bandpass filters due to its compact size. A tunable dual-mode bandpass filter has been realized in [2]. However, very little effort has been focused on detailed theoretical analysis.

To validate the proposed model, the transmit (Tx) channel dual-mode bandpass filter with center operation frequency f_i= 2.4 GHz is designed by using ADS software The substrate used is Rogers RT/duroid_5880 with thickness of 0.635 mm and relative permittivity ε_r = 10.2. Geometrical dimensions for the layout in Fig.2 are w_p = 0.593 mm, w_1 = 0.1523 mm, w = 0.3 mm, l_1 = 2.55 mm, l_2 = 2 mm, l_3 = 1 mm, l_4 = 2.5 mm, l_5 = 3.5 mm, h = 8.6 mm, s_1 = 0.1524 mm, w_n= 0.15 mm, l_n = 2.5 mm and C_{var} = 0.45 pF .

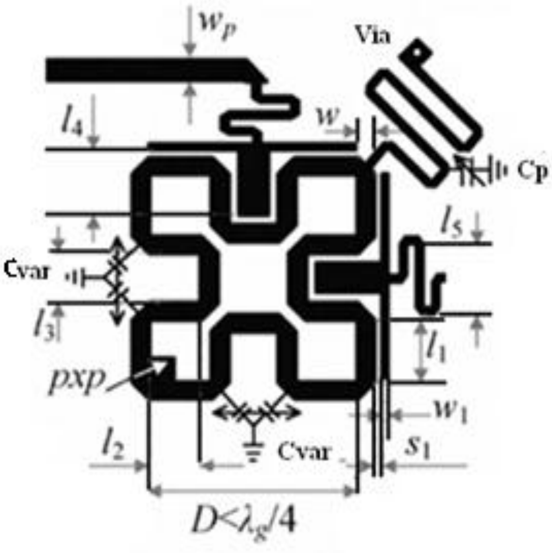

Fig 2: Proposed Tunable Dual-mode Bandpass filter

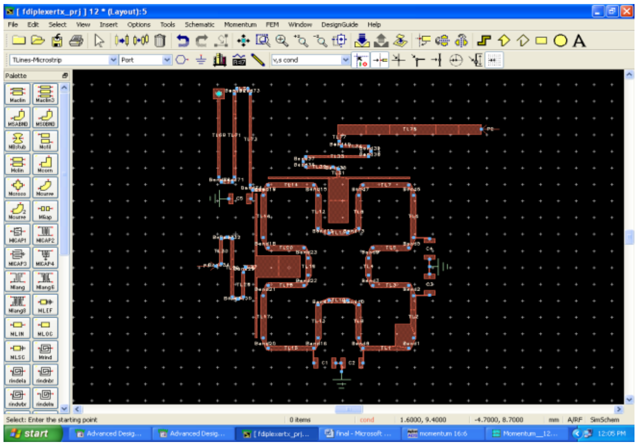

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Fig. 3: Simulated model of the filter layout

Fig.3 shows the simulated layout for the transmitter channel dual-mode bandpass filter as per the dimensions mentioned above. When the value of C increases, the upper and lower stopband transmission zeros will be closer to the passband edges with the stable passband insertion loss that is essentially not degraded. As C_p increase, the split between the two degenerated frequencies modes will increase (filter bandwidth increases). The (Tx) channel filter presents ~2.5 dB insertion loss at the center operation frequency 1(2.4 GHz). This insertion loss is mainly due to the substrate dielectric loss.

Similarly the receiver (R_x) channel dual-mode bandpass filter with center operation frequency f_i = 2.75 GHz is designed by using (EM) software ADS. The substrate used is Rogers RT/duroid_5880 with thickness of 0.635 mm and relative permittivity ε_r = 10.2 The same procedure is used to design the (R_x) channel filter with the center frequency = 2.7 GHz. Optimized geometrical parameter values are given as follows: w_p = 0.593 mm, w_1 = 0.1523 mm, w = 0.3 mm, l_1 = 2.15 mm, l_2 = 1.6 mm, l_3 = 1 mm, l_4 = 2 mm, l_5 = 3.5 mm, l_6 = 8.6 mm, s_1 = 0.1524 mm, w_n= 0.15 mm, l_n = 2.3 mm and C_{var}= 0.45 pf. The (R_x) channel filter presents ~4 dB insertion loss at the center operation frequency 2 (2.7 GHz). This insertion loss is mainly due to the substrate dielectric loss.

The tunable diplexer is obtained by the interconnection of the (Tx) and (Rx) dual-mode bandpass filters using a simple microstrip T junction as shown in Fig.4.

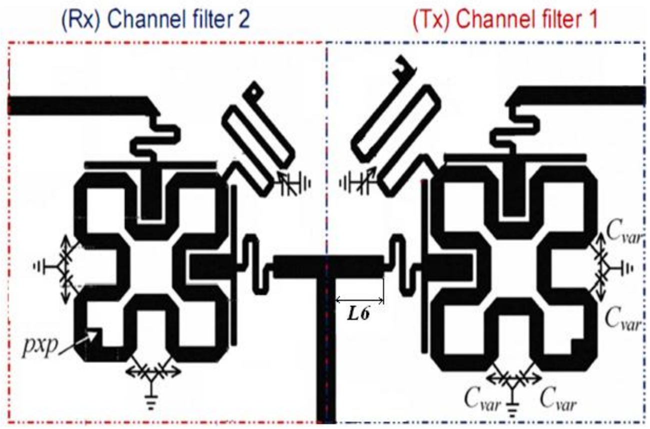
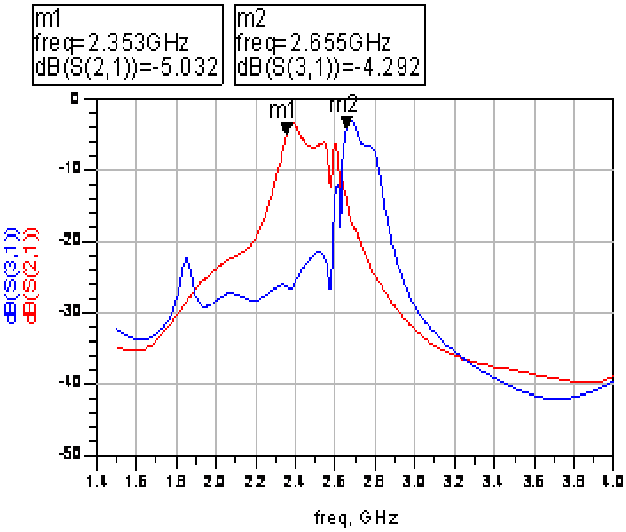


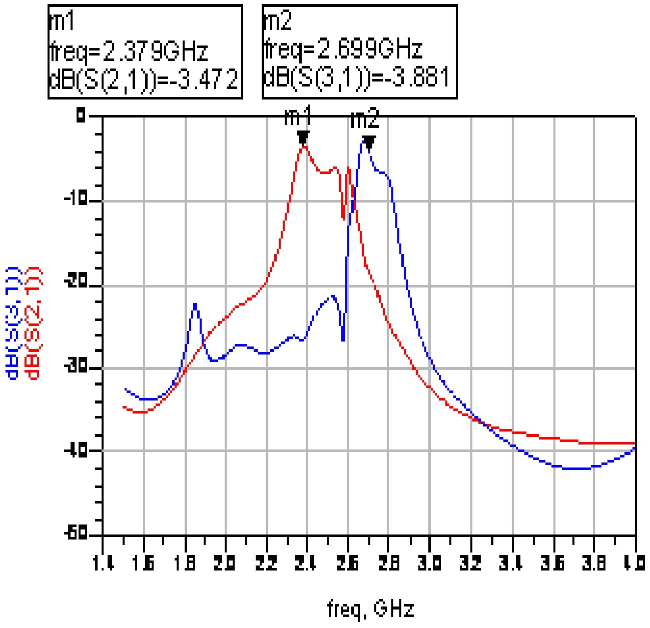
Fig.4: Proposed Diplexer Structure

3. Experimental results of the proposed diplexer model

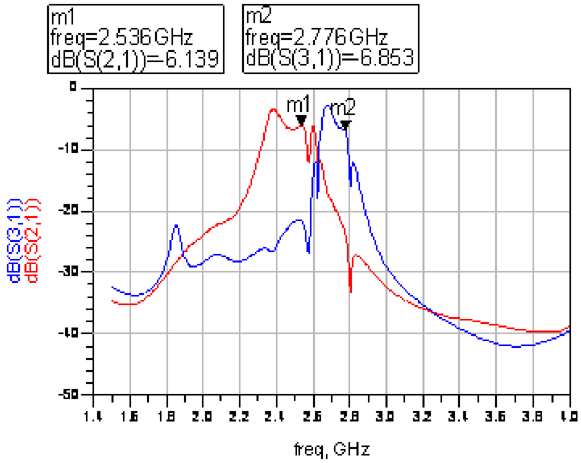
The tunable Tx and Rx channel filters exhibit (fmax-fmin)/(fmax+fmin)/2) center-frequency tunable range from approximately 2.3 to 2.6 GHz, and 2.62 to 2.8 GHz;. As shown in following Fig. 5, the measured insertion losses (S_{31} and S_{21}) at the Tx and Rx filters center operation frequency vary from 6.1 to 3.4 dB and from 6.8 to 3.8 dB, respectively. Such insertion losses are mainly due to the combination of the substrate dielectric loss and the silicon varactor diode loss that increases as the bias voltage decreases (capacitance increases).


m1
freq=2.353GHz
dB(S(2,1))=-5.032
m2
freq=2.655GHz
dB(S(3,1))=-4.292
m1
m2
0
-10
-20
-30
-40
-50
dB(S(3,1))
dB(S(2,1))
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
freq, GHz

(a)


m1
freq=2.379GHz
dB(S(2,1))=-3.472
m2
freq=2.699GHz
dB(S(3,1))=-3.881
m1
m2
0
-10
-20
-30
-40
-50
dB(S(3,1))
dB(S(2,1))
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
freq, GHz

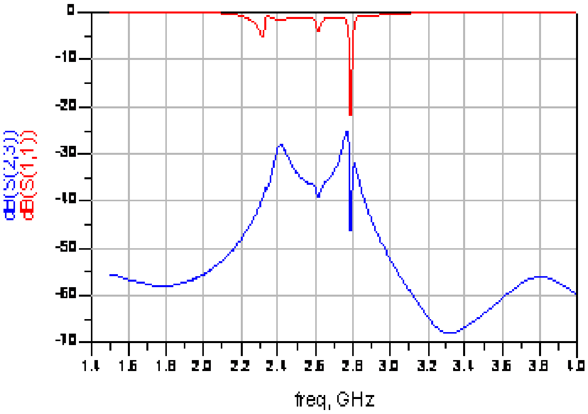
(b)



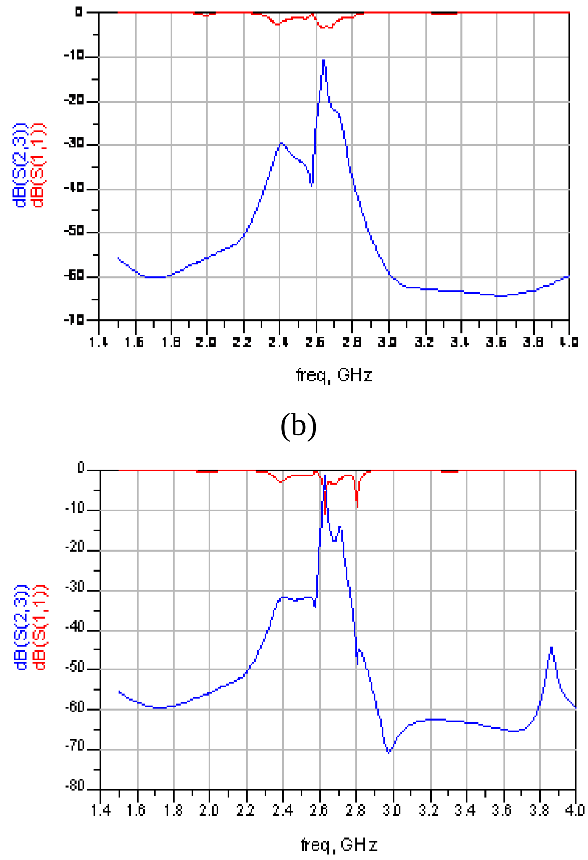
(c)

Fig. 5: Field Based Simulation results of magnitude of S_{31} & S_{21} (a) C_p= 1pf, (b) C_p= 0.65pf, (c) C_p= 0.45pf

Fig.6 shows the measured return loss (S_{11}), at the common port 1, from -7 to -20 dB and from - 18 to -14 dB in the (Tx) and (Rx) passbands. In fact, the mismatch in this case is dynamically as a function of the applied voltage, which changes the input condition. The isolation between (Tx) and (Rx) ports (S_{23}) is better than -40 dB over the tuning frequency range.



(a)



(b)

(c)

Fig.6: Field Based Simulation results of magnitude of S_{23} & S_{11} (a) C_p= 1pf, (b) C_p= 0.65pf, (c) C_p= 0.45pf

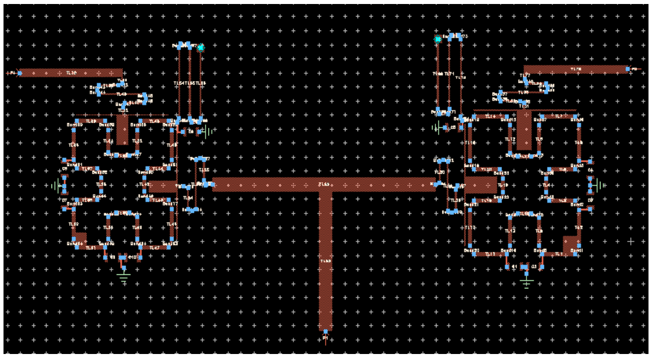


Fig. 7: Simulated model of the proposed Tunable Diplexer structure.

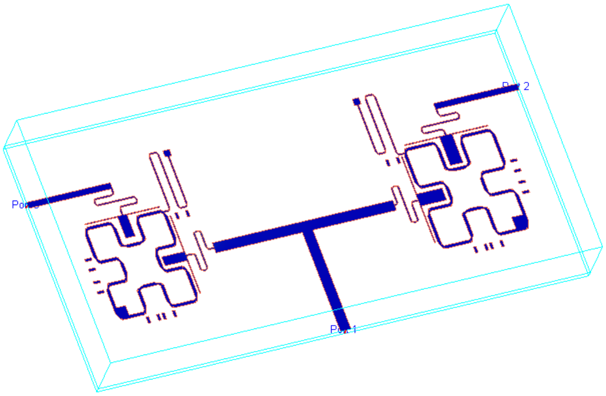


Fig.8: 3-D view of the designed Tunable Diplexer

4. CONCLUSION AND FUTURE WORKS

The proposed electronically tunable Diplexer was implemented and analyzed using the Advanced Design Systems (ADS) software for WiMAX applications. The designed Diplexer showed good tunability characteristics over the range of frequencies of its constituent bandpass filters and their simulated results are provided. Following the analysis of the simulation results described in this paper, two modifications could be involved in the future work. Firstly, improve the loss characteristics of the filters. Secondly, increasing the frequency range of the receiver filter to about 3-3.5 GHz. The Diplexer with above mentioned characteristics would be fabricated and analyzed again. And finally, an antenna design for the required WiMAX application could be explored.

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