Integrated Cognitive Radio Antenna Using Reconfigurable Band Pass Filters

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Abstract— **This paper discusses the design of a reconfigurable band pass filter integrated with an UWB antenna. The presented filter is a reconfigurable T-Shaped DMS structure. The filter reconfigurability is achieved by incorporating switches within the filter structure. The integration of the filter with the antenna makes it suitable for cognitive radio applications. A prototype structure is fabricated and tested. A good agreement is noticed between the simulated and the measured data.**

I. Introduction

Recent developments in software–defined radio (SDR) and dynamic spectrum allocation offer new challenges in reconfigurable antenna design and RF front ends in general. Reconfigurable antennas are gaining lot of attention due to their ability to tune their operating frequency and keep the same radiation and gain characteristics.

Maintaining a constant gain at different resonant modes of a reconfigurable antenna structure is a major challenge in real applications. One possible solution to this problem is to integrate a reconfigurable filter with the antenna structure. This technique will not alter the antenna surface current distribution and hence the radiation pattern will be less affected by the frequency tuning of the filter.

Some research has been done on the design of reconfigurable antenna for cognitive radio communication. In [1], the authors present a reconfigurable antenna based on photoconductive switches. An UWB antenna is also incorporated for channel sensing. A reconfigurable slot antenna for cognitive radio applications is presented in [2]. The antenna can be switched between any one of three discrete states. A rotatable reconfigurable cognitive radio antenna is presented in [3-4]. A coupling of less than -20 dB was observed throughout the whole band of the UWB antenna.

In this paper, we propose a new technique to achieve frequency reconfigurable antenna for a cognitive radio environment. The reconfigurability is obtained by integrating a reconfigurable filter within the antenna structure. The tuning of the filter is based on the incorporated switches with the filter structure.

II. Design

A. DMS Band-Pass Filter Configuration

In this work, a reconfigurable defected microstrip structure (DMS) band pass filter is investigated and integrated with a broadband antenna. The filter has a T-shape slot of dimension 2.25 mm x 2.8 mm and two coupling gaps of dimension 0.25 mm each. The purpose of the gap is to allow the filter to have the "band-pass" feature by functioning as a parallel-series resonance.

The proposed design is printed on the Taconic TLY substrate with a dielectric constant ε_r=2.2 and a thickness 1.6 mm. The fabricated prototype and the dimensions of the T-shape DMS band pass filter are shown in Fig. 1.

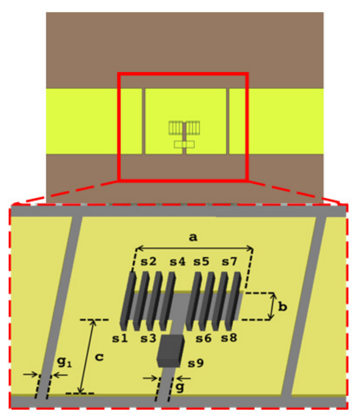


Fig. 1 Dimensions of the DMS filter; a= 2.25mm, b=0.8mm, c=2mm, g=0.25mm, and g1=0.2mm and its fabricated prototype consisting of nine switches

The reconfigurability in the filter is achieved by integrating 9 switches within the T-slot. The switches are activated in pairs of two from the two edges of the T-slot. The purpose of the switches is to change the length of the slot (labelled 'a' in Fig. 1) in order to produce a reconfigurable band pass filter. The different combination for the switches is summarized in Table 1.

TABLE I

COMBINATIONS OF THE SWITCHES

Mode	Switches ON
0	*None*
1	*{S1, S8}*
2	*{S1, S8}, {S2,S7}*
3	*{S1, S8}, {S2,S7}, {S3, S6}*
4	*{S1, S8}, {S2,S7}, {S3, S6}, {S4, S5}*

The corresponding circuit model for the DMS filter is shown in Fig. 2. The two gaps are modeled by the inductor Ls and the capacitor Cs. The T-slot is modelled by Lp and Cp. The corresponding equations to determine the values of the inductors and the capacitors are as follows [5]:

$$C_{s,p} = \frac{f_c}{200\pi\left(f_0^2 - f_c^2\right)},\quad L_{s,p} = \frac{1}{4\pi^2 f_0^2 C_{s,p}}$$

Where f_o is the resonant frequency and f_c is the cut-off frequency of the designed filter. The change in the filter operating frequency will change the values of C and L as summarized in Table 2. This data corresponds to all the different states of the switches. The tuning in the filter return loss is shown in Fig. 3.

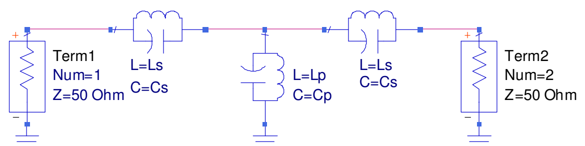


Fig 2 Circuit model of the DMS filter

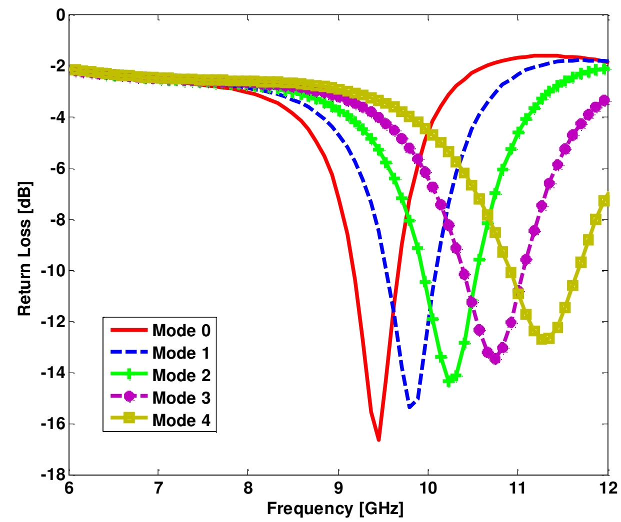


Fig 3 Tuning of the filter

TABLE II

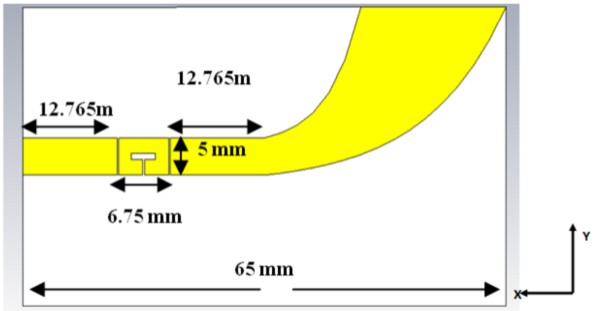
L AND C VALUES FOR THE EQUIVALENT CIRCUIT

Cs [pF]	Ls [nH]	Cp [pF]	Lp [nH]	Frequency [GHz]
0.778	*61.10*	*0.09913*	*1.142*	*9.4*
0.1772	*98.37*	*0.1064*	*1.064*	*9.78*
0.1675	*1.254*	*0.113*	*0.999*	*10.23*
0.1592	*1.188*	*0.1286*	*0.880*	*10.61*
0.1516	*1.239*	*0.147*	*0.7691*	*11.18*
0.1326	*1.288*	*0.2393*	*4.729*	*12.3077*

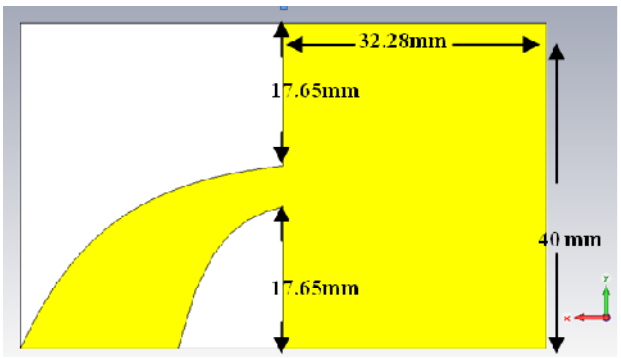
III. DUAL-SIDED TAPERED SLOT ANTENNA CONFIGURATION

A dual-sided tapered slot antenna (DTSA) is integrated with the reconfigurable DMS band pass filter discussed previously. The DMS filter is integrated on the microstrip feed line of the antenna structure. Such configuration allows the antenna to be reconfigurable based on the mode of operation of the filter.

The corresponding structure is shown in Fig. 4. The fabricated prototype is shown in Fig.5. The dimensions of the entire design are 65x40 mm.



(a)



(b)

Fig 4 Simulated Structure with Dimensions (a) Top Layer, and (b) Bottom Layer

The width of the microstrip feeding line is chosen to achieve the 50-Ω characteristic impedance over the interested frequency range. The inner and outer contours of a TSA are curved based on an exponential function [6-8]. Such antenna architecture produces a very wideband behavior.

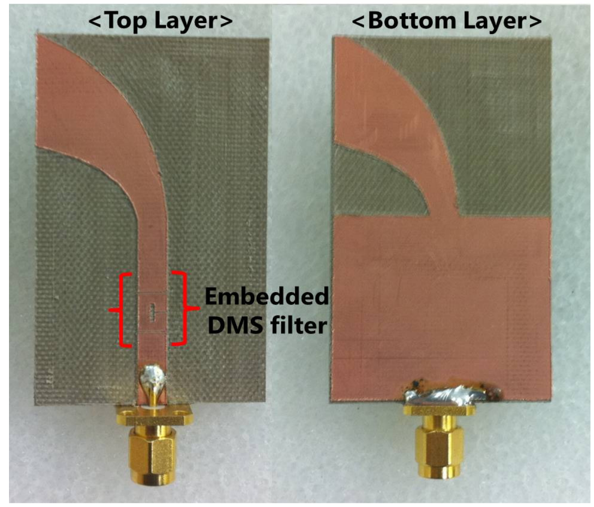


Fig 5 Fabricated prototype of the DMS filter-embedded DTSA

IV. MEASUREMENT

The simulated return loss for the reconfigurable filter integrated with the antenna is shown in Fig 6. This plot corresponds to four cases of the reconfigurable filter shown previously. One can notice how the antenna is able to tune its operating frequency by changing the status of the switches within the T-slot of the reconfigurable filter. Table 2 shows the tunning frequency of the integrated antenna. It is noticed that the integration of the antenna with the filter has the effect of lowering the band-pass frequency of the filter.

The importance of the proposed design in cognitive radio communication is that can be operated as a sensing antenna when the filter is OFF. After band scanning, the antenna can function as a communicating antenna by means of manipulating the switches on the DMS filter

TABLE II

FREQUENCY TUNING FOR EACH MODEL

Switches ON	Frequency
0	7.4 GHz
{S1, S8}, {S2,S7}, {S3, S6}, {S4, S5}	9.3 GHz
All On	10.8 GHz
Filter Off	All Pass

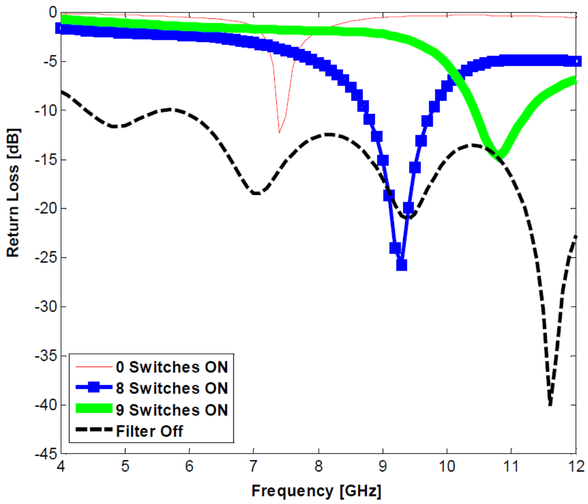
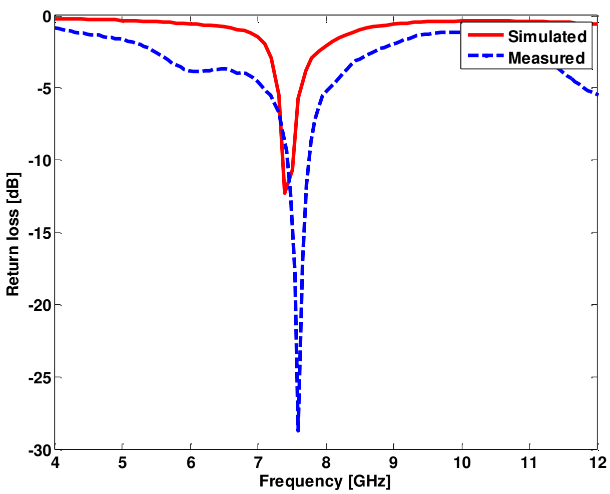


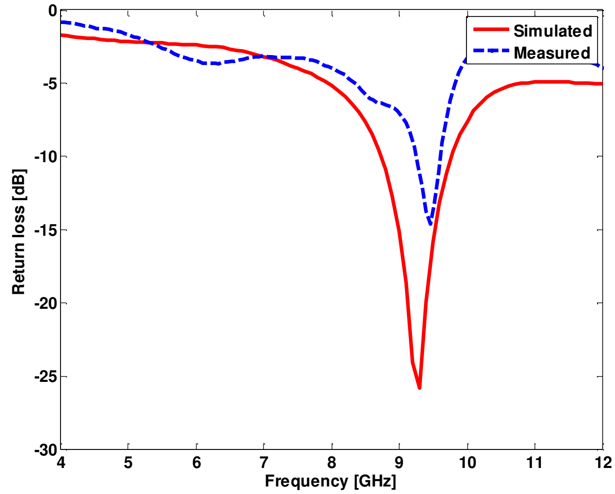
Fig 6 Simulated return losses (S11) of the integrated antenna with the reconfigurable band pass filter

Fig 7 shows the comparison between the simulated and the measured integrated antenna return loss for the different models of the design. A good agreement was obtained between the simulation and the measurement data.

Switches off



8 Switches ON



9 Switches ON

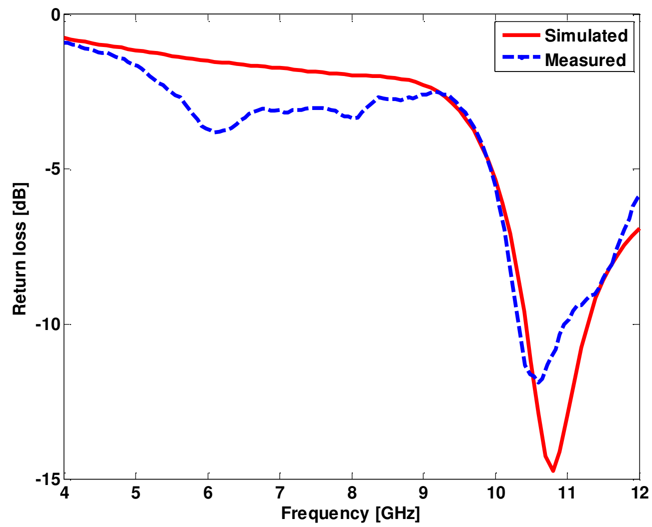


Fig.7 Measured Vs Simulated for three different cases

In the case when the band pass filter is deactivated, the antenna preserves its UWB, and the comparison between simulated and measurement data is shown in Fig 8.

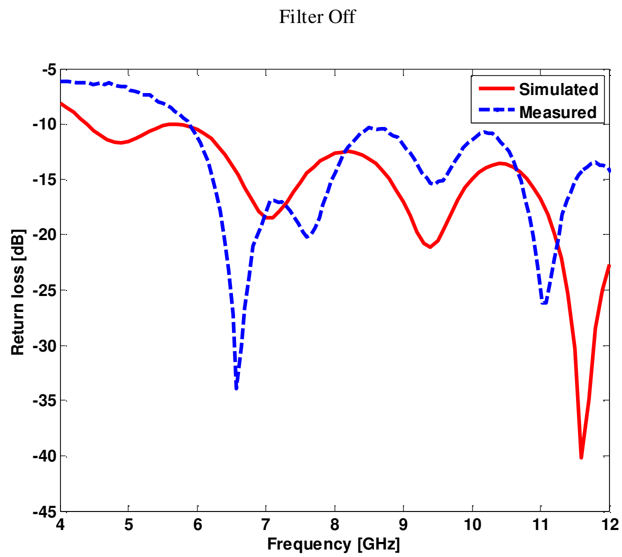
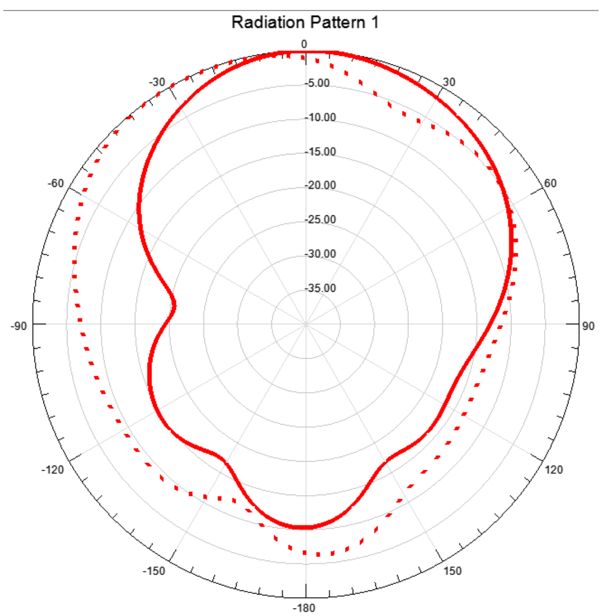
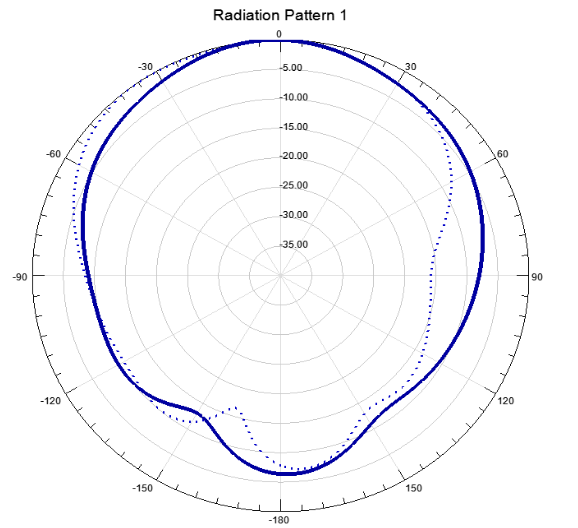


Fig. 8 Simulated Vs Measured when the filter is off

The normalized antenna radiation pattern for the different modes in the YZ plane is shown in Fig 9. An almost omni-directional radiation pattern is obtained.



(a)



(b)

Fig 9 Normalized Radiation Pattern for (a) 0 Switches ON(Solid) and 8 Switches ON (Dotted). (b) 9 Switches ON (Solid) Filter Off (Dotted)

V. CONCLUSION

In this work, a DMS based reconfigurable band pass filter is integrated with a dual-sided TSA. By manipulating the slots in the DMS, the filter can be used for frequency tuning. Such hybrid module can be a possible candidate for RF-front component in a cognitive system. A prototype was fabricated and tested..

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