A Varactor-based Tunable Microstrip Band Pass Filter

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Abstract— This paper presents a novel design of a varactor-based tunable microstrip band pass filter suitable for several applications such as LTE, UMTS, WiFi and others. The proposed filter is designed on a Rogers RO3203 substrate over a full ground plane. The filter is based on a PI(π)-shaped slot incorporated in a microstrip line between a pair of gaps. The designed filter operates in the frequency band from 1.8 to 3 GHz. Frequency tunability is obtained by inserting a varactor in the design and modifying its capacitance using DC bias lines.

1. INTRODUCTION

TV Broadband wireless access communication systems are undergoing a rapid expanding growth. Such RF systems employ RF filters which are important components in their transceivers. Therefore, there is an increasing demand for low cost, compact size and high performance filters [1]. These filters are widely studied and different kinds have been proposed via different methods and structures in recent years. Future mobile communication systems will require wideband transmission in order to support high-speed and high-capacity data transmission. This has led to an increasing demand for dual-band band pass filters and tri-band band pass filters. However, tunability of these filters is a better solution.

In recent years, the demands of the multi-standard wireless communication industry have forced filters to be increasingly adaptable due to various constraints, such as size, geometry, impedance bandwidth and operating frequency. Such design constraints have forced filter designers to consider tunable filters, so that their behavior can adapt with changing system requirements or environmental conditions, and they can tune to several frequencies and operate for different applications. Therefore, tunability is a required feature in these wireless communication systems.

Due to the significant increase in the demand of tunable filters in modern multiband communication systems, several tunable band pass filters have been recently proposed with good tuning characteristics. There are many strategies and technologies to achieve tuning, including the use microelectromechanical systems (MEMS), ferroelectric components, liquid crystals and split ring resonators and complementary split ring resonators among others [2–8]. Some of these strategies have been applied to the design of tunable filters by implementing varactor diodes [9]. The RFMEMS switched capacitor array reported in [2] as a RF component to achieve various kinds of tunable RF filters consists of RFMEMS direct contact switches and metal-insulator-metal capacitors. In [3], a band-pass tunable filter within frequency ranges of 13–20 GHz showing good stop rejection and sharp roll off frequency is designed using a novel design to turn the resonant frequency by micro-electromechanical systems (MEMS) switch and coplanar-waveguide (CPW) structures. A tunable filter in the Ku-band, which is realized in multilayer ferrite LTCC substrate with embedded bias windings and negating the need of a large electromagnet, is presented in [4]. In [5], a band-pass filter using ferrite nanoparticles as the active element in microstrip geometry is designed. The filter is based on ferromagnetic resonance and it is very compact and has wide frequency tunability. In [6], an MMIC active band-pass filter is designed for the implementation of a tunable RF filter in a 0.35 μm SiGe BiCMOS technology. This filter structure is proposed for operation in the S-band applications and BiCMOS MMICs applications for wireless personal communication. The authors in [7] show that open split ring resonators (OSRRs) and open complementary split ring resonators (OCSRRs) can be used to implement tunable filters in coplanar waveguide (CPW) technology. By loading a CPW with shunt-connected varactor-loaded OSRRs, a band-stop filter with tunable central frequency results. A compact tunable band pass filter using a vertical stepped-impedance resonator (SIR) based on the conventional multi-layer printed circuit board (PCB), exhibiting high unloaded quality factor, compact size and low electromagnetic coupling to nearby RF circuits is reported in [8]. In [9], a compact electrical tunable microstrip band pass filter, realized by coupling two Hairpin-DGS resonators, is proposed. The tunability is achieved by embedding varactor diodes to the Hairpin-DGS resonators.

In this paper, a simpler and a highly effective tuning approach is introduced. A simple varactor-based tunable microstrip band pass filter based on a PI(π)-shaped slot integrated in a microstrip line between a pair of gaps, is presented. Frequency tunability is achieved through inserting a varactor in the design and modifying its capacitance using DC bias lines. The designed filter operates in the frequency band from 1.8 to 3 GHz. The geometry and the design guidelines of the proposed antenna structures are presented in Section 2. The results are presented in Section 3. In Section 4 a brief conclusion is given.

2. FILTER STRUCTURE AND DESIGN

The configuration of the proposed tunable filter is shown in Fig. 1. A simple microstrip line is designed on a 40 mm × 20 mm Rogers RO3203 substrate with dielectric constant of 3.02 and thickness $h = 1.6$ mm over a full ground plane. The filter is based on a PI-shaped slot with two arms incorporated in the microstrip line between a pair of gaps. The detailed dimensions of the PI-slot, its arms and the gaps in the microstrip line are shown in Fig. 1.

The slot itself has bandstop characteristics since it changes the part of the microstrip line around it into an open loop resonator which is known for its bandstop action. The two gaps act as capacitors and transform the bandstop into a bandpass operation.

Frequency tunability is obtained by inserting a varactor (SMV1212) on the microstrip line as shown in Fig. 1 (red color) and modifying its capacitance using the shown DC bias lines. The size of the varactor is compatible with the design and its capacitance ranges between 0.6 and 71 pF. The dimensions of the slot and the gaps are optimized to achieve wider channel bandwidth and better tunability. The filter is designed and simulated using Ansoft HFSS.

3. RESULTS AND DISCUSSION

The simulated reflection coefficient plots of the tunable filter are given in Fig. 2 for the indicated capacitance values of the varactor. It is clear that frequency tunability has been achieved in the frequency band from 1.8 to 3 GHz. Considering several values for the capacitance of the varactor,

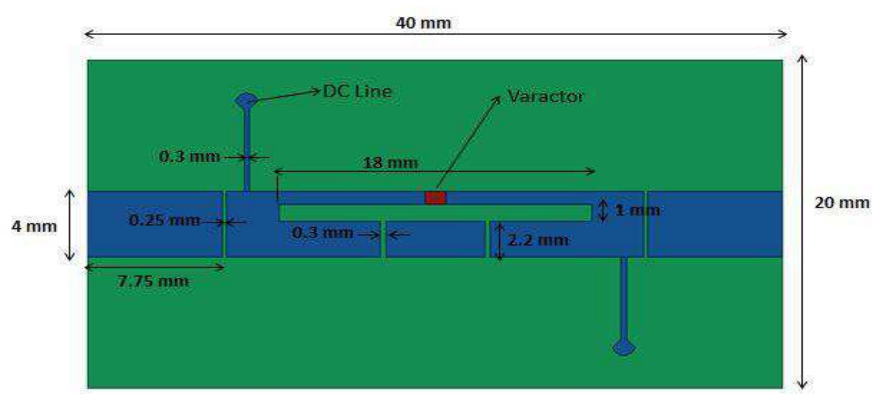

Figure 1: Configuration and dimensions of the proposed microstrip filter.

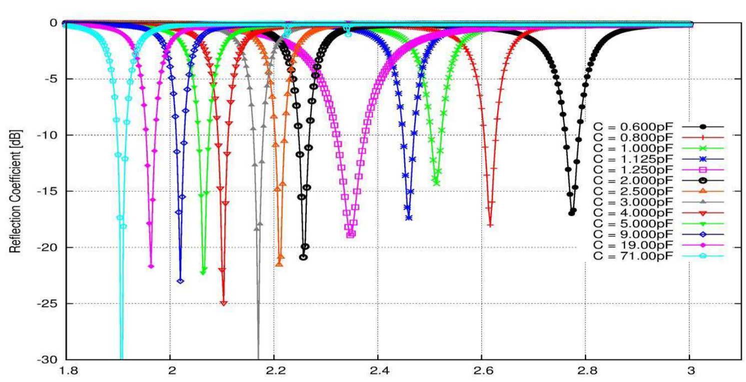

Figure 2: Reflection coefficients for different capacitance values.

the filter can operate on different frequencies in the 1.8–3 GHz band corresponding to different applications such as LTE, UMTS, WiFi, and others.

4. CONCLUSION

A novel design of a varactor-based tunable microstrip band pass filter is proposed in this paper. The designed tunable filter operates in the frequency band from 1.8 to 3 GHz and is suitable for several applications such as LTE, UMTS, WiFi and others. Frequency tunability is attained through inserting a varactor in the design and modifying its capacitance using DC bias lines. The operating bandwidth, the small size, and the frequency tunability make this filter a practical one that can be used for cognitive radio applications.

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