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DESIGN AND SIMULATION OF A TUNABLE BANDPASS FILTER USING VARACTOR DIODES FOR WIRELESS AND RADAR APPLICATIONS

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ABSTRACT

This article discusses the development of an electronically tunable filter capable of a wide frequency tuning range. Variation of bias (0-5V) changes the center frequency of the filter within 10% while achieving a 1-dB of typical insertion loss. The concept of tuning a filter's 3-dB bandwidth with voltage is demonstrated and the effect of the bandwidth tuning elements on the tunable filter performance is discussed. The designed filter has a simple structure and the characteristics of wide tuning range of 1800MHz to 2000MHz and low insertion loss of less than -1.20 dB. The tunable bandpass filter can be scaled to the commercial frequencies up to 2.5GHz, offering advantages for most ISM and cellular band applications.
Keywords: Bandpass filter, varactor, tunable filter.

VARAKTOR DİYOT KULLANILARAK KABLOSUZ HABERLEŞME VE RADAR UYGULAMALARI İÇİN AYARLANABİLİR BAND GEÇİREN FİLİTRE TASARIM VE SİMÜLASYONU

ÖZET

Bu çalışmada, varaktör diyotlar kullanılarak elektronik olarak ayarlanabilen geniş bantlı mikroşerit filtre tasarımı anlatılmaktadır. Benzetimi yapılan mikroşerit filtre 0-5V bias değişimine sahiptir, genel kullanımdaki sistemlere benzer bir ekleme kaybı ile frekans bandı %10 değiştirebilmektedir.-3dBlik filtreleme bandının gerilim ile değişimi çalışma içinde anlatılmıştır. Tasarlanan filtrenin basit bir yapısı ve karakteristiği olup 1800 ile 2000MHz frekans bandı boyunca 1.2 dB düşük ekleme kaybına sahiptir. Tasarlanan filtrenin çalışma frekansı 2.5 GHz'e kadar yükseltilebildiği için birçok ISM bandı uygulaması için avantaj sağlamaktadır.
Anahtar Sözcükler: Bant geçiren filtre, varaktor, ayarlanabilir, filtre.

1. INTRODUCTION

Advances in many microwave systems and applications with multifunction capabilities means that there is an increasing demand to develop reconfigurable filters. Thus reconfigurable filters are essential for future wireless communication systems across commercial, defense, and civil sectors. In all these systems reconfigurable filter technologies hold the key to controlling the spectrum of RF signals, eliminating interference and preserving the dynamic range under any signal receiving condition. Reconfigurable filters can be realized in a variety of ways, but no

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matter what method of tuning is used they must conserve their transmission and reflection coefficient over the tuning range specified. They offer many advantages over traditional filter banks, the main being size and flexibility.

Microwave filter plays an important role in modern wireless and mobile communication systems. Planar filters are particularly popular structures because they can be fabricated using printed circuit technology and are suitable for commercial applications due to their compact size and low-cost integration [1]. Therefore, many applications to planar filters such as parallel-band and multiband band pass filters have been used in microwave communication systems due to their high performance and simple synthesis procedures [2]–[5]. It is well known that a band pass filter with transmission zeros can be designed using a stub-loaded resonator [6]–[9]. The open stubs in these papers are close to a quarter-wavelength at the center frequency. The transmission zero can be located at the upper or lower side of the pass band by adjusting the open stub length. In [6], two stub-loaded resonators with different stub lengths were used to design the band pass filter with two transmission zeros. In [7] and [8], a resonator with two loaded stubs was used to designed elliptic filters, also the equivalent circuit of the filter using a stub-loaded resonator was given in [6] and [8]. Recently, it has been popular to design an ultra-wideband (UWB) filter and a dual-band filter using a stub-loaded. In [10] and [11], the multiple-mode resonator is formed by loading three open stubs in shunt to a simple stepped-impedance resonator. In [12] and [13], centrally loaded resonators were presented for dual-band filter application. Theoretical analysis shows that the even-mode resonance of the centrally loaded resonator can be conveniently controlled without affecting the response at the odd-mode resonant frequency. In [14], open-loop resonators loaded by shunt open stubs were proposed to design compact dual-band filter with improved stop band rejection characteristics. However, only the open stub was used in these papers. It is interesting to find that the open and short stubs loaded resonator can be a good candidate for the tri-band filter design [19]. Usually, tri-band filters can be realized with the stepped-impedance resonators because of their multiband behavior [15]–[18]. In [15], the tri-band filter was realized by cascaded multiband resonators. In [16], the tri-band band pass filter was designed using a combined quarter-wavelength resonator. A tri-section stepped-impedance resonator [17], [18] could also be used to design the tri-band filter; by properly determining the impedance ratio, three pass bands at any desired frequencies can be obtained. However, the resonance frequencies of the stepped-impedance resonator are dependent, complicating the filter design [19-24].

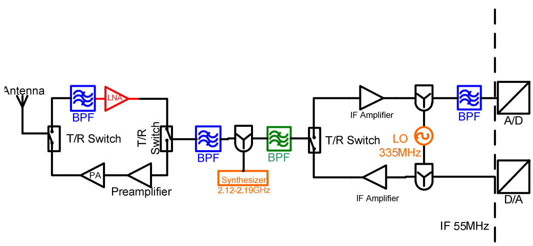


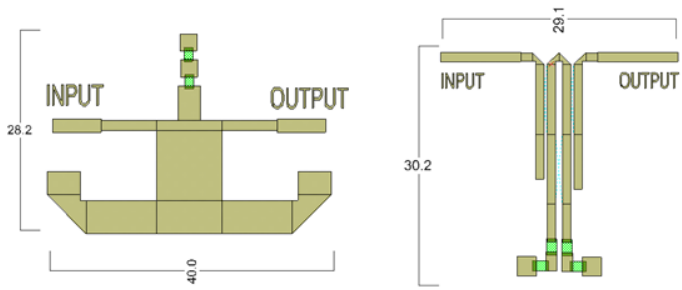
Figure 1. An example schematic for Radio System Architecture

In this article, the design and simulation performance of wide tunable range, variable bandwidth, varactor diode voltage-tuned filters using printed are presented. In this article, a varactor-tuned microstrip band pass filter with wide tuning range is proposed. The design goal of the proposed filter is to have a tuning range and to maintain a difference between the insertion loss at the lowest frequency and that at the highest frequency below 3 dB for GSM applications.

2. TUNABLE FILTER DESIGN TUN

The objective of developing an electronically tuned filter is to exploit a common filter, which will reduce the number and types of RF/IF filters used to process RF signals from UHF to the ISM band, in a given radio system architecture at Fig. 1. Since the filter may also be placed in the front-end of a receiver, it is desirable to develop a filter that has small size and low loss, and is easy to produce as well.

A tunable filter is designed by using the hairpin line resonator loaded with capacitors at the ends. In this resonator, as the loading capacitance is increased, the resonant frequency is decreased. Therefore, a compact size and wide tuning range can be achieved by using the proposed filter.



Filter 1 Filter 2

Figure 2. Simple tunable filter structure

Table 1. Filter Parameter

Parameter	Filter-1	Filter-2
Resonance Frequency (GHz)	1.8-2.0	1.7-2.0
Substrate Thickness (mm)	1.6	1.6
Substrate Permittivity	4.6	4.6
Loss Tangent	0.0035	0.0035
Patch Width, Length	W=28,L=40	W=30.2,L=29.1

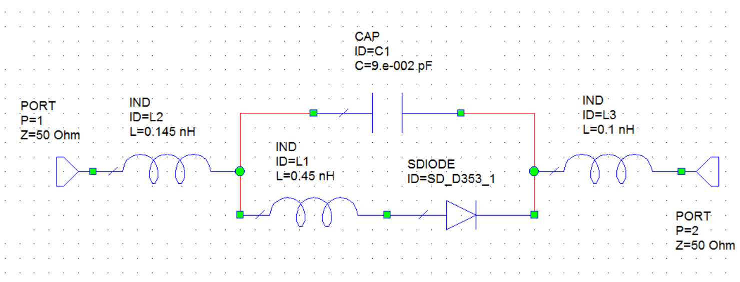


Figure 3. Lumped model of the varactor (BBY58-02)

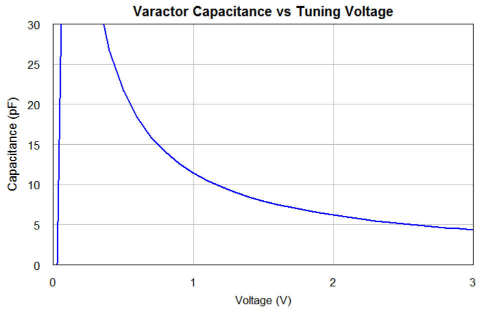


Figure 4. Varactor capacitance vs. tuning voltage

3. SIMULATION RESULTS OF THE DESIGNED FILTER

The simulations were performed using Microwave Office AWR DE Software tool to validate the filter's performance . Variable capacitors were used in the models for the varactor diode used for varying center frequency tuning and a varactor used in series with fixed capacitors between the resonators to change the coupling, which in effect changes the filter bandwidth at a given center frequency.

In figures 5a and 5b return loss variation of filter 1 and 2 are shown for different DC voltage values. In figures 5c and 5d for 2 V Dc voltage value return loss, insertion loss and the -12 dB bandwidth had been shown. The goals for these simulations are to analyze the performance of active filter with the variation of DC voltage value.

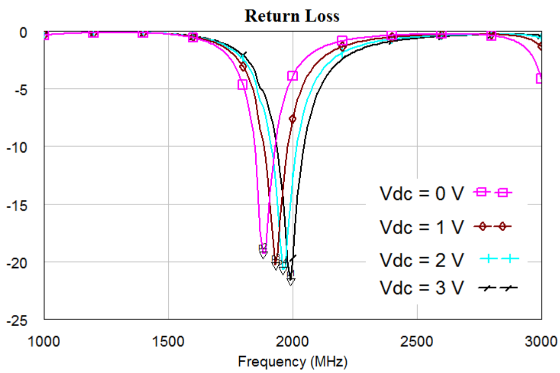


Figure 5a. Varactor capacitance vs. tuning voltage Return Loss Response of Filter 1 by variation of DC Voltage.

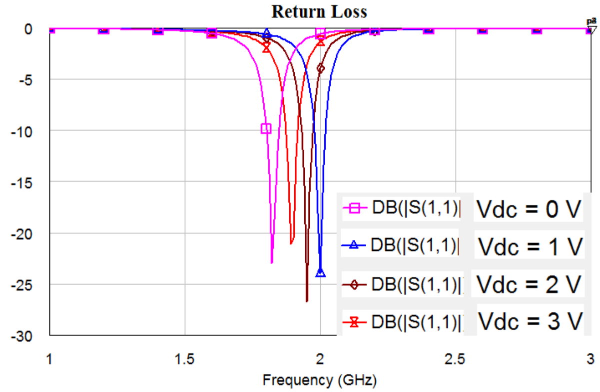


Figure 5b. Return Loss Response of Filter 2 by variation of DC Voltage.

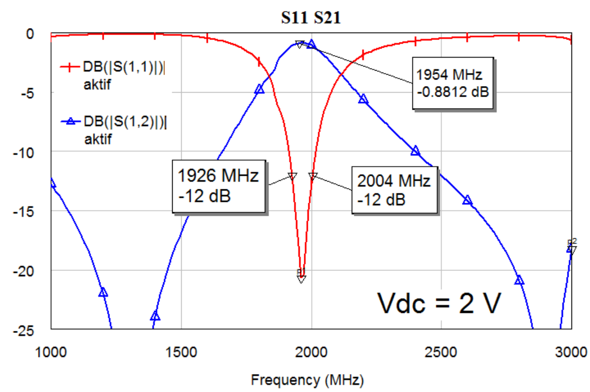


Figure 5c. Bandwidth of filter 1, V_{DC}=2V with reference of -12dB

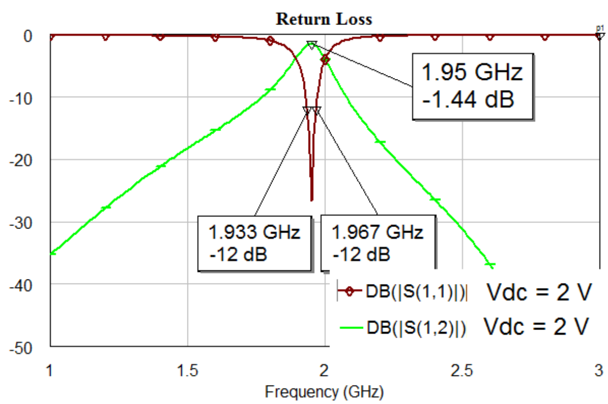


Figure 5d. Bandwidth of filter 2, V_{DC}=2V with reference of -12dB

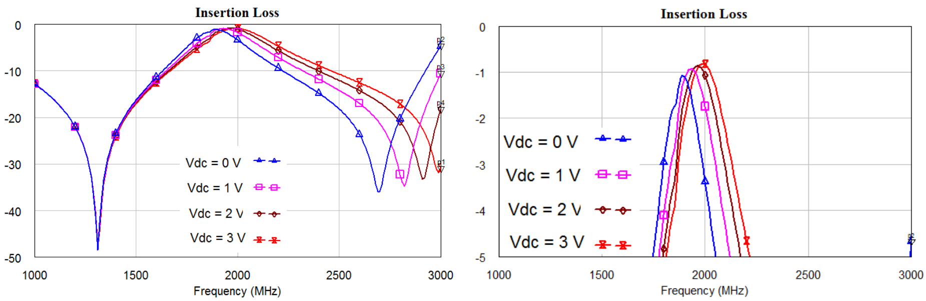


Figure 5e. Insertion loss Response of Filter 1 with Variation of V_{DC}

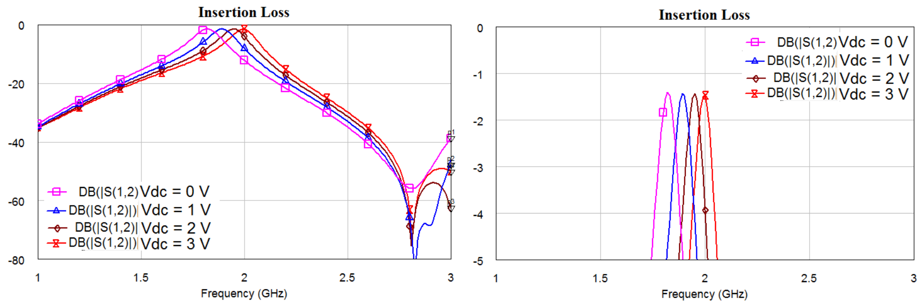


Figure 5f. Insertion loss Response of Filter 2 with Variation of V_{DC}

In figures 5e-5f insertion loss of the designed filters for different DC voltage values are shown S_{21} values are between -1 and -1.5 dB

The simulation results of the designed filters are summarized and compared with similar designs. For values of 0-3 V for varactor diode Filter 1has a -18 dB insertion loss with an active bandwidth of 200 MHz while Filter 2 has a -18 dB insertion loss with an active bandwidth of 300 MHz.

Table 2. Benchmarking of Filters

Parameter	**This study**	**A Tunable Band Pass Filter Based on Varactor Loaded Split-Ring Resonators[20]**
Resonance Frequency(GHz)	1800-2000 1700-2000	2.11 to 2.34
Low Insertion loss (dB)	-0.524 -1.182	2.11 GHz is 11.65 dB and 1.98 dB at 2.34 GHz
Return Loss	<-18	---
Diode	Infenion BB58	Infenion BB833
Voltage (V)	0-3V	0 to 25 V
Substrate: relative permittivity / thickness	4.6/1.6	3.38/ 1.524

4. CONCLUSIONS

In this article, varactor-tuned microstrip bandpass filters with wide tuning range is proposed. The design goal of the proposed filter is to have a tuning range and to maintain a difference between the insertion loss at the lowest frequency and that at the highest frequency below 3 dB. The open stub enables to reduce the filter size as well as improve characteristics at the skirt frequencies. The attenuation pole can be located near the passband by adjusting the stub length. By using varactor at the end of the hairpin resonator and open stub for compensating reduced open microstrip lines, the center frequencies are made tunable within the tuning bandwidth, while the passband bandwidth remains nearly constant. When the voltage across the varactor diode is 4 V, the filter has a 1.95 GHz resonant frequency with a -1.20dB insertion loss. The measurement return values of designed filter and the loading varactor diodes effects. The resonance frequency tuning range remained at approximately 200MHz. Since the proposed bandpass filter is not only compact in size but also has a wide tuning range it can be applicable to wideband wireless systems.. The filter topologies in this paper can be modified to produce other frequencies and bandwidths which can be controlled by choosing adequate resonator extensions.This gives an opportunity to scale the operating frequency up to 2.5GHz with the same fractional bandwidth.

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