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TUNABLE FILTENNA USING VARACTOR TUNED RINGS FED WITH AN ULTRA WIDEBAND ANTENNA

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Abstract—A tunable filtering antenna (filtenna) realized using rings fed with an ultra-wideband (UWB) planar, elliptical monopole antenna is proposed. An array of slotted rings with varactors is placed in close proximity of the planar monopole to obtain the low profile tunable filtenna. The array of rings can be viewed as a small tunable frequency selective surface. The design produces a tuning range of about 3.8–4.4 GHz over a varactor reverse bias voltage of 1–4 V.

1. INTRODUCTION

Filtennas are antennas that also perform filtering operations. Filtennas are employed to relieve the necessity of a bandpass (or bandstop) filter in the receiver front end. Ultra-wideband (UWB) frequencies (3.1 to 10.6 GHz) often employ filtennas to notch out the IEEE 802.11a wireless local area network (WLAN). The authors in [1] propose an UWB antenna with slots that provide notching characteristics of the WLAN band.

The primary concern in this paper is to design a new low profile filtenna with tunable frequency band. The filtering aspects of an array of rings with varactors placed on top of an ultra wideband planar antenna are investigated. The array of rings can be viewed as a small frequency selective surface (FSS) The authors in [2] propose placing a band-pass non-tunable FSS in the aperture of a horn antenna to narrow the bandwidth of the antenna. Reference [3] proposes a non-tunable miniaturized FSS on a patch antenna array to create a narrower response from the patch antennas. Non-tunable FSSs placed in the near-field of antennas have also been investigated to improve

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an antenna's directivity and radiation efficiency in [4, 5]. Finally, [6] investigates a multi-layer FSS structure to produce a beam steering application.

The purpose of this research is to create a filtering antenna using a tunable array of slotted rings placed very close to an UWB antenna. Tuning of FSS structures is investigated using varactors in [6–9]. However, none of the varactor tuned FSS structures are placed very close to the antenna to provide tuning of the antenna in a low profile design.

2. DESIGN AND SIMULATION

2.1. Frequency Selective Surface and Varactors

The array of rings used employed in this research can be treated as a small frequency selective surface (FSS) tuned using varactors. The choice of the slotted ring as the FSS element simplifies biasing of the varactors. Vias are placed through the surface to allow the varactors to be biased from underneath the antenna. Bias lines are connected to the disks while the outer surface is connected to ground. Fig. 1 shows the unit cell for the slotted ring array to illustrate varactor biasing. The size of the array is a 3×3 matrix of slotted rings to demonstrate the proposed concept with a relatively small number of varactors. The dimensions of the structure are shown in Fig. 3 and Table 1. The varactors, from Aeroflex Metelics, are MGV-125-08-0805. They are hyperabrupt, gallium arsenide (GaAs) diodes and

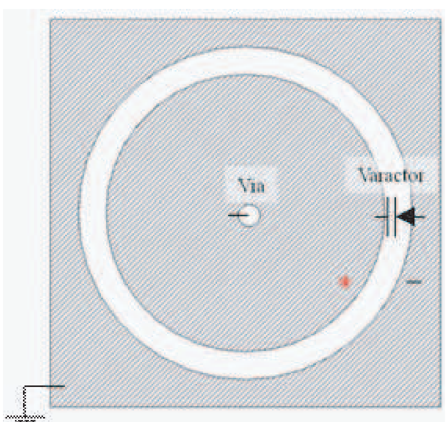

Figure 1. Slotted ring FSS unit cell demonstrating biasing considerations.

Table 1. UWB antenna and array dimensions.

Parameter	Variable	Value
Ring Radius	r_r	6 mm
Ring Thickness	t_r	1 mm
Periodicity (x-direction)	p_x	14 mm
Periodicity (y-direction)	p_y	14 mm
Antenna Radius	r_1	15 mm
Antenna Radial Ratio	α	1.1
Antenna Feed Width	w_T	3 mm
Microstrip Ground width	w_G	25 mm
FSS Distance	u_{FSS}	1 mm
Ground Distance	u_{Ground}	20 mm
Length	l	75 mm
Width	w	75 mm
Substrate Thickness	N/A	62 mil
Substrate Dielectric Constant	N/A	2.33

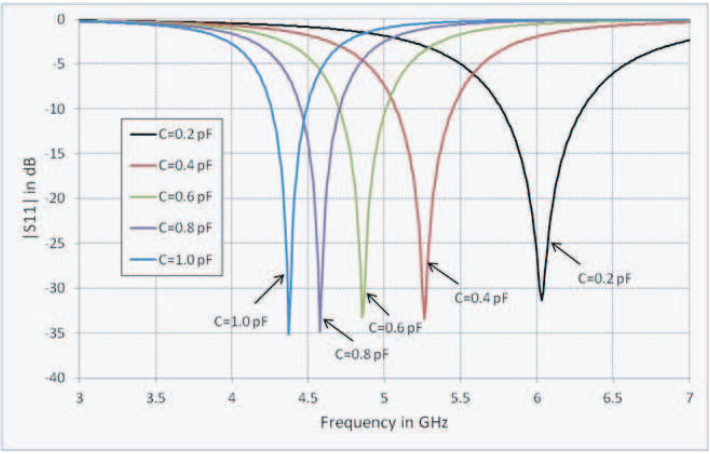

Figure 2. Simulated reflection coefficient of FSS with various capacitance values.

provide a capacitance range of 0.1–1 pF. To investigate the tuning range of an array of rings with varactors, an FSS with capacitors representing the varactors was simulated using Ansys HFSS [10]. The reflection coefficient in dBs of the FSS with various capacitance values is shown in Fig. 2. As the figure shows, a tuning range of more than 1.5 GHz is obtained with capacitance range of 0.2–1 pF demonstrating the feasibility of the proposed concept.

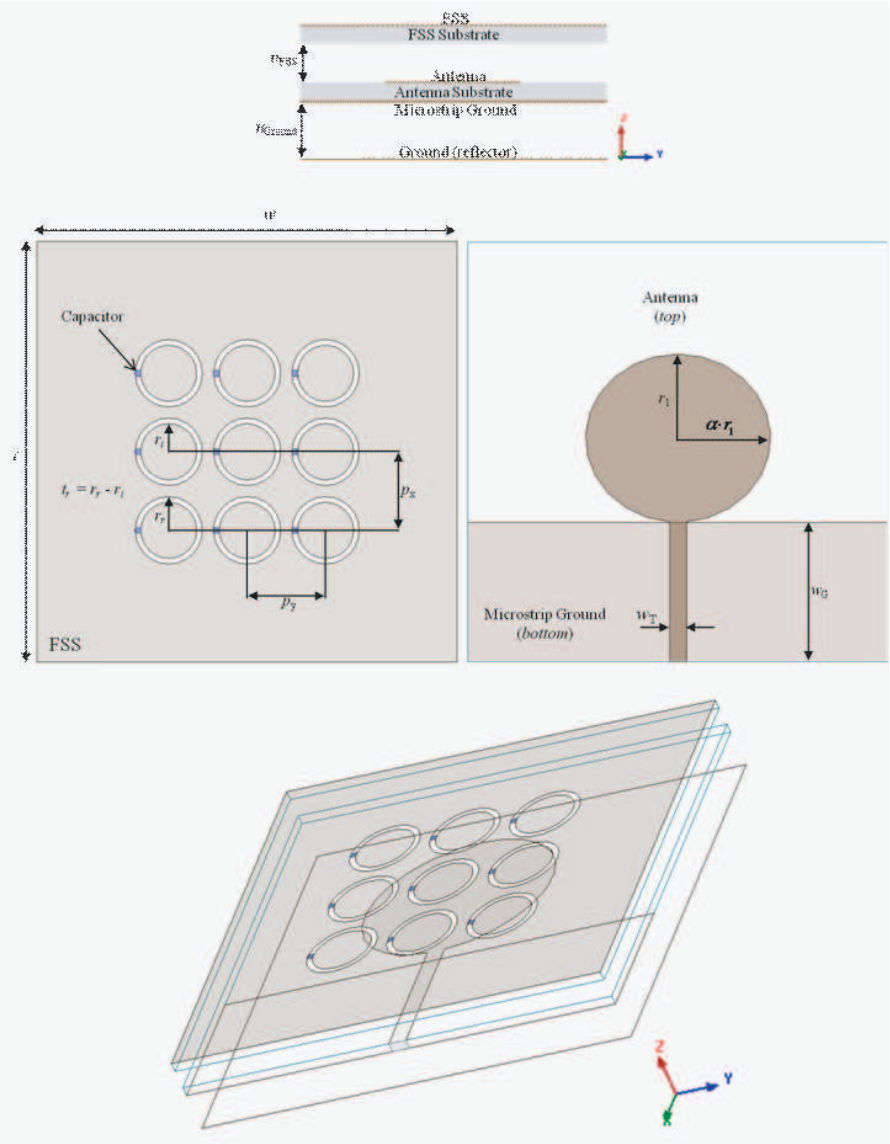

Figure 3. The proposed antenna and varactor tuned array.

2.2. Ultra-wideband Antenna

The UWB antenna used is a coplanar, elliptical, monopole antenna similar to the antenna proposed in [11]. The monopole in this research offers some modifications on the dimensions and the addition of a reflector to reduce back radiation and ease biasing of the varactors. The dimensions of the antenna along with the array of slotted rings are shown in Fig. 3 and Table 1.

The monopole antenna with a reflector was designed using Ansys HFSS. The magnitude of S_{11} in decibels is in shown in Fig. 4. The return loss of the antenna is better than 10 dB for the frequency range needed for the tunable filtenna.

2.3. Radiation Patterns

To obtain the radiation pattern for the complete tunable filtenna shown in Fig. 3, an equivalent capacitance of the varactor for a desired reverse bias voltage was computed using the equivalent circuit model for the varactors used in the fabricated prototype described in the next section. The equivalent capacitor was then used with the filtenna in Ansys HFSS to compute the radiation pattern at the center frequency of the band for this reverse bias voltage. Three bias voltages were assumed

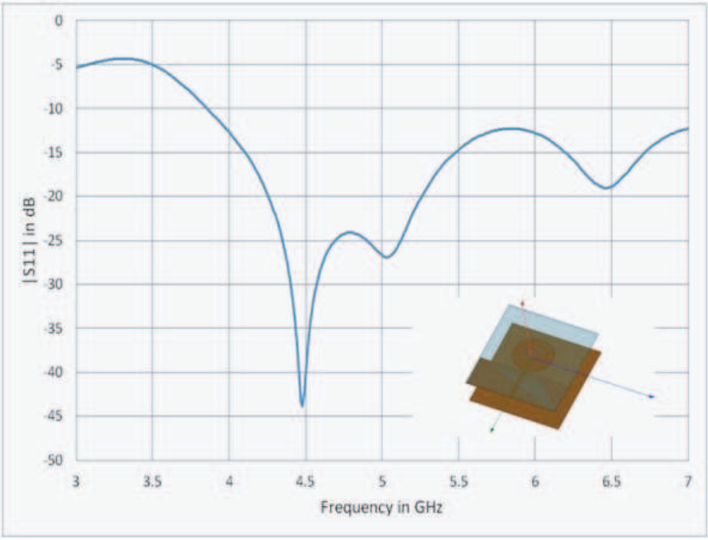

Figure 4. Simulated return loss of the antenna with a reflector (without FSS).

to obtain the radiation patterns at three different frequencies; the resulting patterns are shown in Fig. 5. As shown in the figure, the main beam is tilted and the radiation pattern is somewhat stable with frequency.

3. MEASUREMENT

The fabricated design is shown in Fig. 6 with all of the dimensions shown in Fig. 3. The bias lines are soldered to the copper disks inside

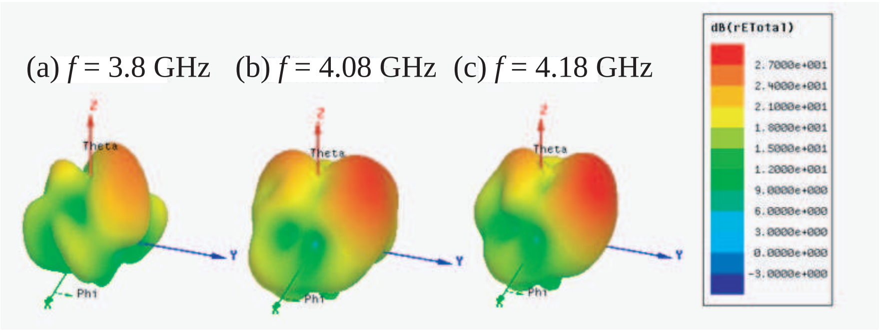

Figure 5. Computed radiation patterns (in dB) of the complete filtenna at different frequencies (corresponding to three reverse bias voltages). (a) $f = 3.8\,\text{GHz}$. (b) $f = 4.08\,\text{GHz}$. (c) $f = 4.18$ GHz.

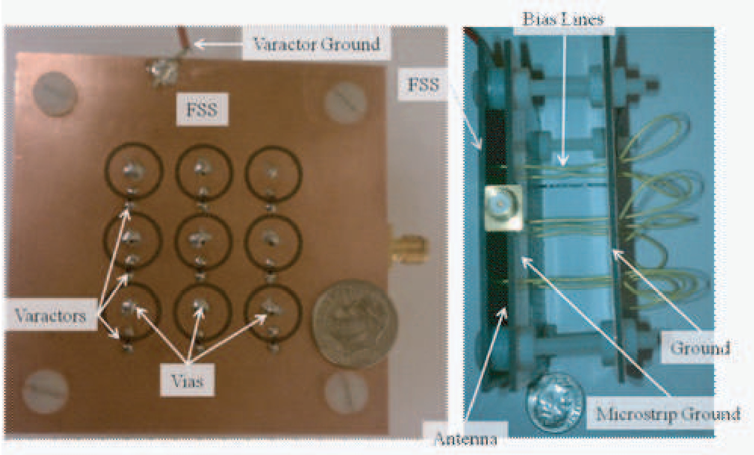

Figure 6. Fabricated design. The bias lines are intentionally kept too long to provide adjustment of the ground and antenna layers.

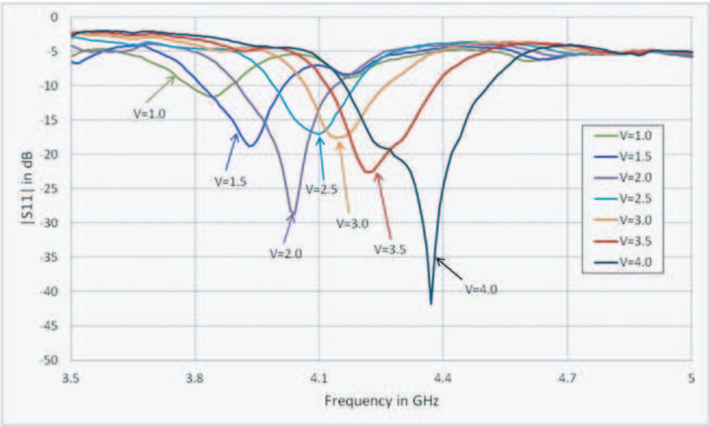

Figure 7. Experimental verification of the tuning range provided by the proposed filtenna. V is the reverse bias voltage of the varactors.

the rings, and they pass through the antenna, microstrip ground, and antenna reflector. The bias lines are soldered to the back side of the reflector so that a DC voltage can easily be applied to all of the rings simultaneously. The varactor ground is connected to the rest of the copper surface of the rings array, as labeled in the figure. The filtenna is fed through an SMA connector.

The measured tuning range is about 3.8–4.4 GHz for bias voltage range of 1–4 V, as shown in Fig. 7 with a 10-dB bandwidth that is much smaller than that of the UWB antenna alone demonstrating the tunable filtering characteristics of the proposed design.

As the reverse voltage increases past 4.5 V, the resonance starts to split and causes undesirable effects in the return loss. However, sufficient tuning is provided within 1–4 V. Improvements in the design may provide a useable tuning range within the full range of the bias voltage of the varactors.

4. CONCLUSION

An array of slotted rings is placed on top of an ultra-wideband (UWB) planar elliptical monopole antenna to realize a filtering antenna (filtenna). The rings are tuned using varactors to provide the filtenna with passband tuning capability. The proposed structure was investigated using simulations and experimental verification. The fabricated design provides a measured tuning range from about 3.8 to 4.4 GHz for a reverse bias voltage range of 1–4 volts.

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