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Switchable Planar Monopole Antenna between Ultra-Wideband and Narrow Band Behavior

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Abstract—In this paper, we propose a novel compact switchable monopole CPW-fed antenna which has the ability to be used for narrowband as well as UWB applications. A single element antenna to be used for wireless local area network (WLAN) applications is first proposed in this article having overall dimensions of $24 \times 30.5\,\mathrm{mm}^2$. The corresponding antenna has been transformed to UWB frequency range just by utilizing two variable capacitors within the designed structure. The proposed small size, variable, low cost as well as low weight antenna with good propagation characteristics performs well in the WLAN as well as in the UWB frequency band. The proposed antenna is simulated using Ansoft HFSS, and results are validated in CST Microwave Studio suite. The proposed antenna has also been fabricated, and the measured response is correlated with the simulated ones.

1. INTRODUCTION

The rapid development of wireless communications has demanded that antennas for moveable devices must be low profile and wide-band to tolerate operation at multiple frequency ranges, disregarding the requirement for isolated antennas for each application [1]. Recently there has been a lot of interest in this regard, and a reconfigurable antenna for Bluetooth and wireless local-area network (WLAN) applications has been designed in [2]. Also, due to demand of increased speed for wireless communication devices an Ultra-Wideband (UWB) technology got a huge amount of interest among the researchers. UWB communication covers a frequency range of 3.1 GHz to 10.6 GHz and possesses a high data rate, short-range low-power communication within a tightly specified range of frequencies.

Formerly, wideband antennas have been used in applications. For example, [2, 3] proposed antennas for ground penetrating radar (GPR) applications. In [4], the authors propose some applications of UWB technology like radio frequency identity tags, impulse radar and position finders. Variable antennas can resolve the demands of complex systems without any change in the shape or electrical behavior. Variations of the polarization, frequency band, bandwidth or radiation pattern are some of the important features in modern antenna design [5].

Current development in UWB technology requires a UWB device to be small, planar and compact which can support much larger bandwidth than required bandwidth for current mobile communications systems such as global system for mobile communications (GSM) and code division multiple access (CDMA) [3]. A huge amount of research in this regard has been performed, and various antennas have been developed in the past decade. Researchers also tried to integrate antennas, RF components, and microstrip filters as filtering antennas for multi-functionalities in the same structure. So, by the combination of reconfigurable antennas and filtering antennas, we can achieve a wideband-to-narrowband reconfigurable filtering antenna. In this regard, the reconfigurable antenna between WLAN

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and UWB applications has been developed in [4], However, the size of the presented antenna is very large; its structure is complex; the technique of integration is very complex; its implementation is quite difficult.

In this paper, a novel compact CPW-fed switchable monopole antenna is implemented for narrowband (WLAN) as well as wideband (UWB) applications. The transformation of the antenna from narrowband to wideband does not require any specific change in the geometry of the antenna. The conversion of the antenna from WLAN to UWB frequency band is made by placing two variable capacitors at the open end of the resonators. The size of the antenna is $24 \times 30.5\,\text{mm}^2$ including the partial ground plane, and the antenna is fabricated as well. The simulation and measurement of the antennas are carried out, and the responses are correlated very well.

The paper is arranged in the following manner. Section 2 contains a brief description and experiments of the related work in this area. Section 3 contains the configuration of the proposed antenna including dimensions and fabrication pictures. Section 4 presents the simulated results of the proposed antenna at capacitor values of 0.1 pF and 0.8 pF for corresponding WLAN and UWB applications, respectively. Section 5 deals with the experimental results. Section 6 sums up the paper with conclusions on performance enhancements.

2. RELATED WORK

The technique for designing an antenna for narrowband (WLAN) and wideband (UWB) has first been proposed in [6, 7]. The authors in [6] propose a narrowband antenna by utilizing an inverted F-shaped resonator printed on the opposite side of a coplanar waveguide (CPW) fed UWB antenna. It uses the radiator of the UWB antenna as its own ground plane, and in this regard a matching circuit is used to tune the proposed antenna in three operating frequencies centered at 4, 8, and 10 GHz. This technique is very complex to implement and further leads to larger dimensions of the antenna.

In [7], an egg-shaped UWB antenna with five different patch radiators within a circular section is designed on the same substrate. By physically rotating the circular part using a stepper motor, the operating frequency of the antenna can be made adjustable. Various frequency ranges can be achieved by each rotation step while feeding the distinct patch radiator. However, such an antenna is also very complex to implement, and using stepper motor consumes a lot of space and makes the antenna dimensions large.

Moreover, [8–10] utilized two different techniques for the realization of narrowband and UWB resonators for sensing applications. The techniques used for integrating narrowband within UWB antennas is achieved by two ways.

(1) Integrating bandpass filter with UWB antenna [8, 9].
(2) Changing the complete design of the UWB antenna and ground plane via multiple switches [10].

A novel tunable monopole antenna with switchable integrated feed network for UWB and WLAN (2.4 GHz and 5.8 GHz) has been proposed in [11]. The frequency reconfiguration is realized by integrating two bandpass filters with UWB antenna circuit. Recently, [12] proposed a novel reconfigurable monopole switchable antenna for UWB/WLAN having filtering characteristics by utilizing three switchable states. The antenna operates in three states with three independent ports for UWB, WLAN (2.4 GHz), and WLAN (5.8 GHz) frequency bands. The first narrowband (2.4 GHz) is produced by using a microstrip filter of first order with an open loop resonator (OLR), and the second narrowband (5.8 GHz) is generated by including hairpin bandpass filter of third order in RF path. The reconfiguration is performed using dc-controlled PIN diodes, and the overall dimensions of the antenna are $38 \times 40\,\text{mm}^2$.

3. CONFIGURATIONS OF THE PROPOSED ANTENNA

The designed antenna geometry is shown in Figure 1 while its fabricated monograph is shown in Figure 2. This antenna is constructed on a Rogers RO4003 substrate with a thickness of 1.5 mm and relative dielectric constant of $\varepsilon_r = 3.38$, which has a dimension of $24 \times 30.5\,\text{mm}^2$ (i.e., $w_{sub} \times l_{sub}$). The parameters of the proposed antenna are mentioned in Table 1.

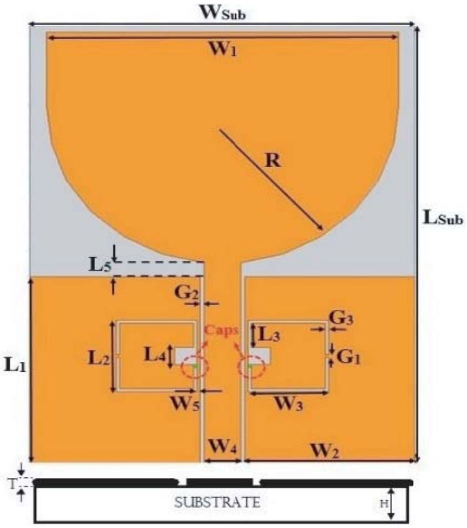

Figure 1. Geometrical parameters of the proposed antenna.

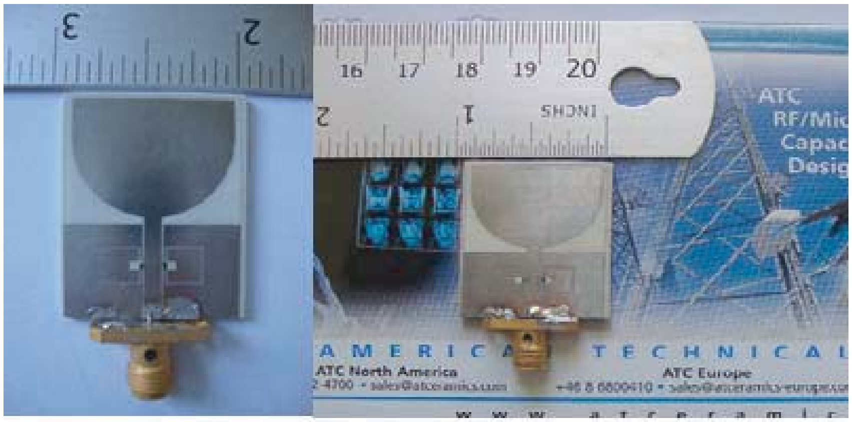

Figure 2. Fabricated pictures of the proposed antenna.

Table 1. Dimensions (in Millimeters) of the proposed antenna.

Parameters	L_{sub}	W_{sub}	L_1	L_2	L_3	L_4
Value (mm)	30.5	24	13	5	1.7	1.2
Parameters	L_5	W_1	W_2	W_3	W_4	W_5
Value (mm)	0.96	22	10.6	5	2.3	0.2
Parameters	G_1	G_2	G_3	T	H	R
Value (mm)	0.2	0.25	0.2	0.017	1.5	11

Simulation of the proposed designed antenna has been performed with Ansoft HFSS and validated using CST Microwave Studio suite. The antenna is also fabricated as shown in Figure 2. Good agreement has been observed between the simulated and measured results. The slight discrepancy between the simulated and measured results is because of hand-welding inaccuracy and connector losses.

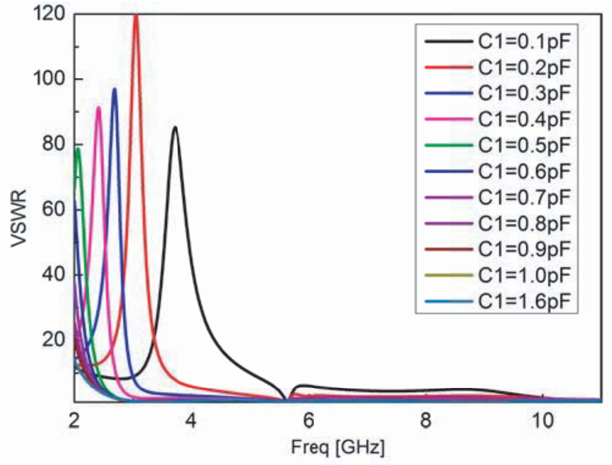

Figure 3. Simulated VSWR plot of the antenna at different values of capacitors.

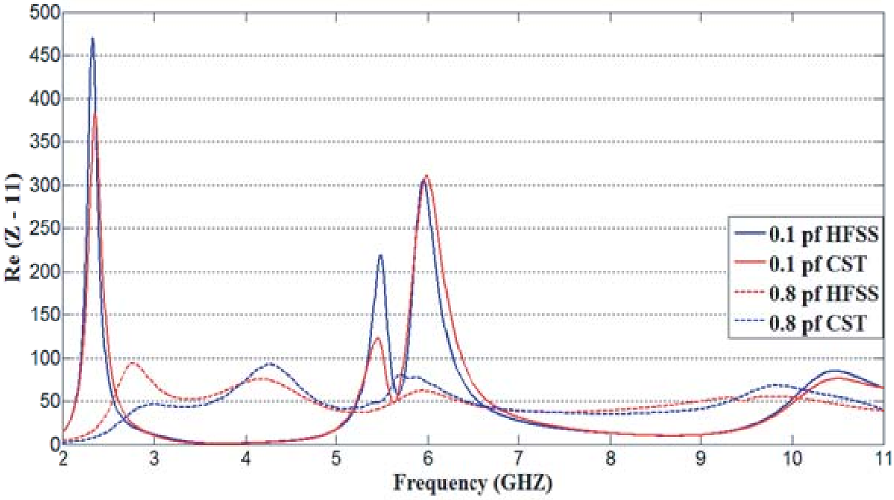

Figure 4. Input real part of resistance for 0.1 PF and 0.8 PF capacitors in Ansoft HFSS and CST.

4. SIMULATIONS OF THE PROPOSED ANTENNA

The antenna has been simulated at Ansoft HFSS, and the results have been validated using CST Microwave studio suite. The VSWR plot at different values of capacitors is shown in Figure 3. By analyzing Figure 3, it is clear that the antenna operates at WLAN frequency band at a capacitor value of 0.1 pF. By increasing the capacitor value, the antenna response is changed, and at 1.0 pF and 1.6 pF the antenna can be used for UWB applications (3.1–10.6 GHz). Figure 3 plots also reveal how the antenna can be made switchable between the narrow-band (WLAN) and wide-band (UWB) frequency bands.

Figure 4 and Figure 5 show the input real and imaginary parts of resistance at 0.1 PF and 0.8 PF capacitors in Ansoft HFSS and CST, respectively. Both plots reveal that the antenna can be easily made switchable between WLAN and UWB frequency ranges just by changing the capacitor value. In this way, we can design an antenna for multiple applications with the same structure.

The peak gain (dBi) of antennae in CST Microwave studio suite and Ansoft HFSS for Capacitor value of 0.1 pf are depicted in Figure 6. It is revealed that the peak gain is very stable over most of the required frequency band. At 0.1 pF the antenna operates at WLAN frequency band having operating bandwidth of 0.2 GHz with fractional bandwidth (%) of 3.50% referred from Figure 7. Also, at 0.8 pF

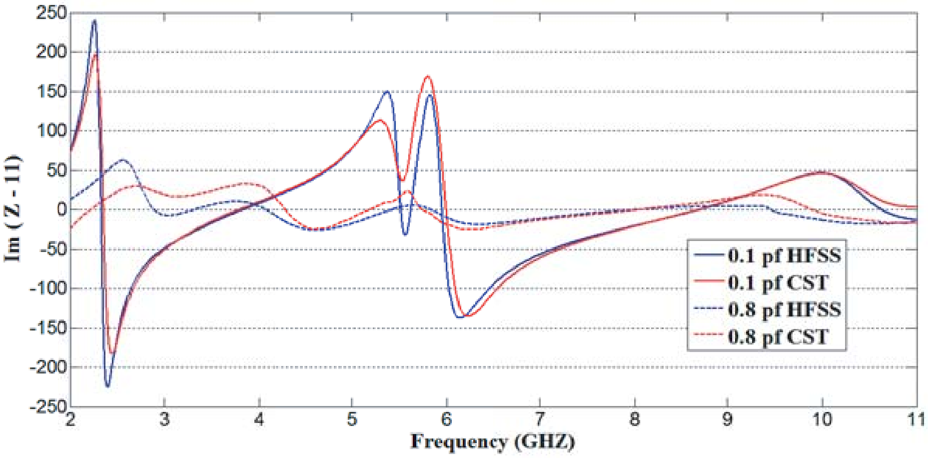

Figure 5. Input imaginary part of resistance for 0.1 PF and 0.8 PF capacitors in Ansoft HFSS and CST.

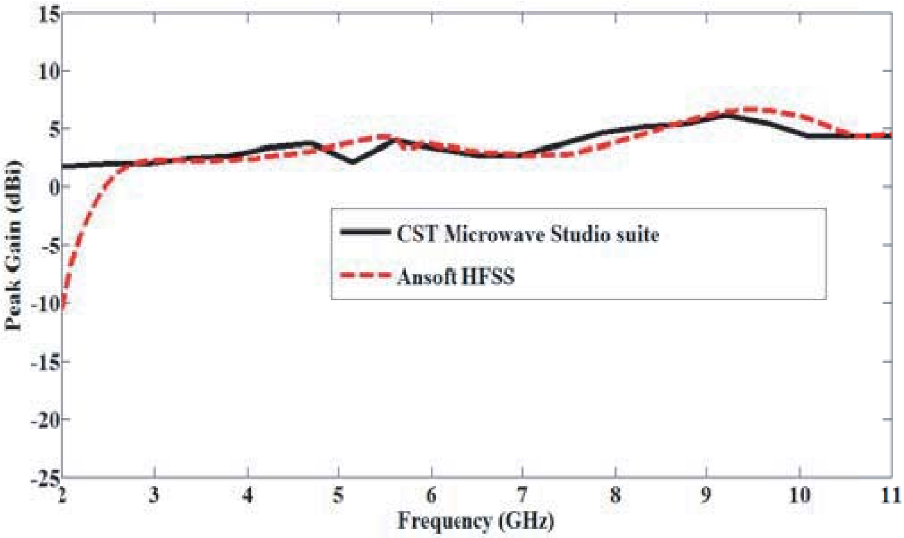

Figure 6. Peak gain of the antenna in dBi. (Cap value = 0.8 pF).

the antenna operates within UWB frequency range having an operating bandwidth of 6.80 GHz with fractional bandwidth (%) of 98% referred from Figure 8.

5. EXPERIMENTAL RESULTS OF THE PROPOSED ANTENNA

The comparison of the S_{11} performances of the antennas at CST, Ansoft HFSS and measured responses at 0.1 pF and 0.8 pF is shown in Figure 7, Figure 8 and Figure 9, respectively. The plots reveal that there is a good resemblance between simulated and measurement results. Tolerance of capacitor, mounting of capacitors and connectors effect are due to mismatching in some frequency bands. The result in Figure 7 shows that the value of S_{11} is lower than -10 dB in 5–6 GHz WLAN frequency range. Also, by increasing the capacitor value to 0.8 pF the antenna is switched and operates within UWB. Figure 8 shows that the value of S_{11} is less than -10 dB from 3.1 to 10.6 GHz UWB frequency range.

The measurement performance of the antenna at 0.1 pF and 0.8 pF is shown in Figure 9, and it is easy to understand the reconfigurability of the proposed antenna between the WLAN and UWB frequency band.

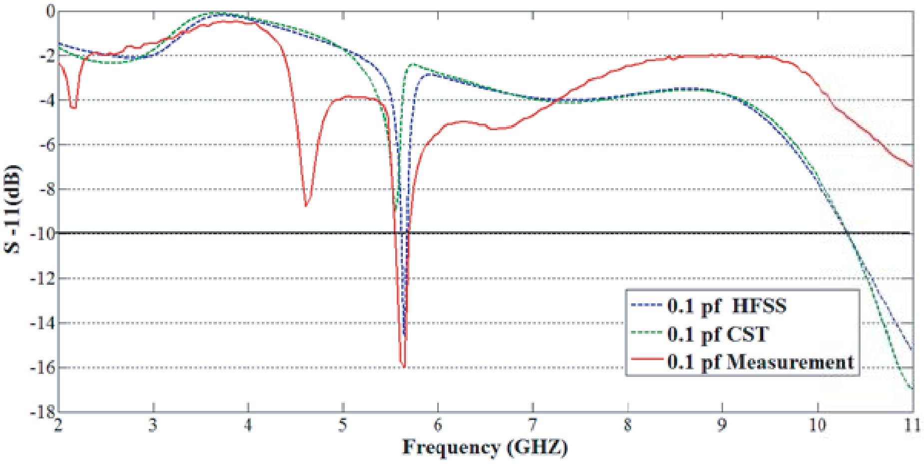

Figure 7. Simulation and measurement magnitude of S_{11} in dB at 0.1 pf (Continuous line) measurement and (dash-line) simulation.

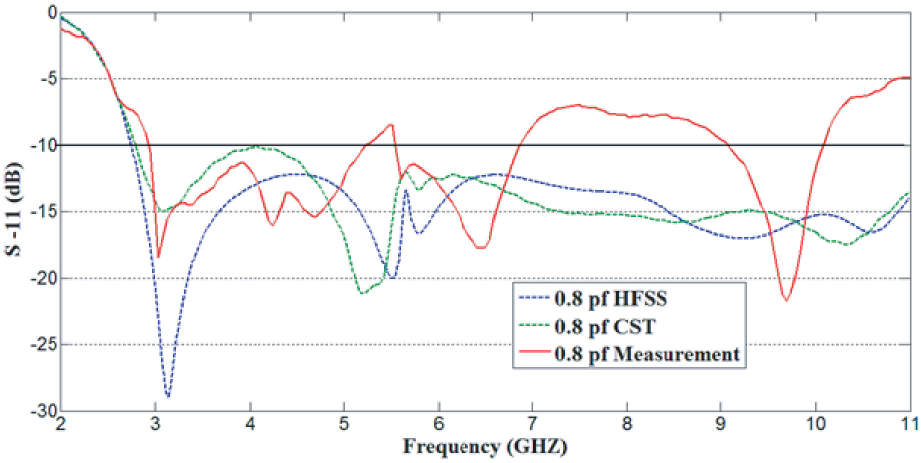

Figure 8. Simulation and measurement magnitude of S_{11} in dB at 0.8 pf (Continuous line) measurement and (dash-line) simulation.

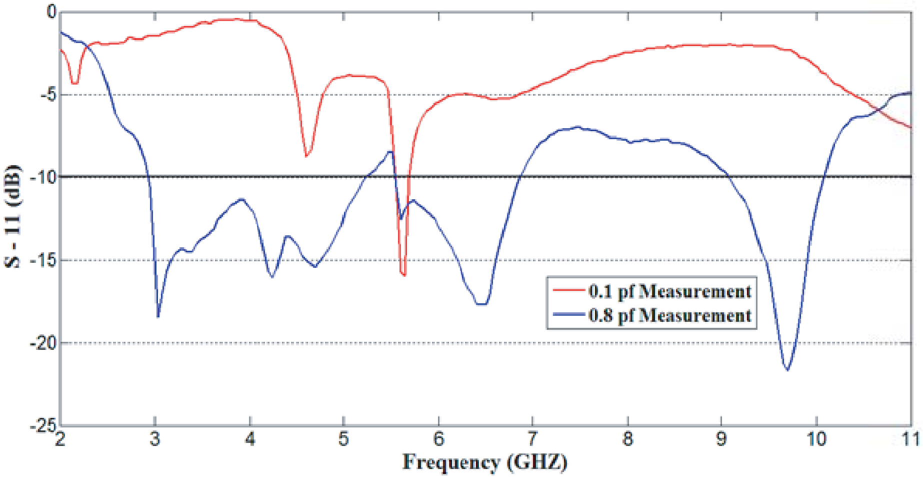

Figure 9. Measurement magnitude of S_{11} in dB at 0.1 pF and 0.8 pF.

6. CONCLUSION

A novel compact CPW-fed switchable monopole antenna having the ability to be used for narrowband (WLAN) and wideband (UWB) applications is presented. The proposed antenna is advantageous in the behavior that it can be easily reconfigured between WLAN and UWB frequency bands without any huge alteration in the fundamental structure of the antenna. The antenna operates well in the WLAN frequency band at 0.1 pF while it can be made switchable in UWB by increasing the capacitor value to 0.8 pF. In this way, two types of antennas can be designed within the same structure and can be utilized in different modes.

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