Bandwidth Enhancement of Compact Planar Microstrip Antenna

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Abstract **−** A novel monopole antenna is presented for ultra-wideband (UWB) applications. Enhancement in the antenna's bandwidth was obtained by using a new radiating patch structure that includes a q-shaped slots in the ground plane. UWB performance is achieved without increasing the overall size of the antenna's structure. The antenna operates between 2.4 GHz – 13.9 GHz for $S_{11} \leq$ -10 dB. The antenna radiates omni-directionally over its operating band. The antenna occupies an area of about 25 × 25 mm^2 when fabricated on FR4 substrate with thickness of 1 mm and relative permittivity of $\varepsilon_r = 4.4$.

Index Terms **−** Microstrip antenna, monopole antenna, and ultra-wide band antenna.

I. INTRODUCTION

Nowadays there is a great demand for antennas that are capable of operating over an ultra-wideband frequency range. Over the past few years many broadband monopole antennas have been proposed consisting of various geometries [1-21]. This type of antenna is the most widely used in the architecture of mobile communications systems as it provides the desired radiation patterns and can be easily integrated within mobile handsets. Wide band technology is becoming increasingly attractive in wireless communication as it allows greater system capacity and data exchange. Since the U.S Federal Communication Commission (FCC) has specified 3.1 GHz – 10.6 GHz frequency band for ultra-wideband usage, the UWB technology has become the preferred candidate for future short range and high rate indoor data communication systems.

Research on printed planar antennas is growing because this type of antenna implementation offers desirable characteristic like ease in fabrication, low cost, and integration [7-10]. Due to these features the planar antenna is considered the best choice for the use in UWB systems. However, one serious disadvantage of patch antennas is their narrow bandwidth. Therefore researchers are investigating the utilization of different methods and techniques for designing wideband patch antennas. Various techniques have been used in order to increase the bandwidth of the monopole antenna, for instance, fractal structures [7-9], embedding a dielectric slot in the radiating patch or in the ground surface [9], employing several radiating elements to form an array antenna [10-11], employing capacitive coupling between the radiating element and the ground plane [12], addition of slots in the radiating element [13-14], using a tapered feed line [15], notching the ground plane and/or the patch [16-17], modifying the shape of the radiating element and adding a shorting pin [18], and modifying the top side of the ground plane [19-20].

In this paper, an UWB antenna is described as compact in size and exhibits good radiation characteristics. It is shown that by increasing the number of dielectric slots and by finely tuning the dimensions of slots, additional resonance

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responses can be generated to realize enhanced impedance matching. The performance of the UWB antenna was simulated and optimized using HFSS ver. 11.1 [21].

II. ANTENNA STRUCTURE

The geometry and dimensions of the proposed monopole antenna are shown in Fig. 1. The antenna is created from a hollowed rectangular patch structure that forms a loop, and within this is embedded another loop structure. The antenna's ground plane is defected to enhance its impedance bandwidth. The actual size of the antenna is 25 × 25 × 1 mm^3, which was constructed on an inexpensive FR4 substrate with relative permittivity of 4.4 and loss of tangent of 0.024. The antenna is fed through a microstrip line of width Wf = 1.875 mm corresponding to a 50 Ω characteristic impedance. The optimized dimensions (in mm) of the antenna, which were obtained through parametric study using HFSS, are: W1 = 1, L1 = 1.5 ,W5 = 1.5, W4 = 1, L4 = 2.2, Lp = 11.4, Wp = 9, W2 = 1.6, W3 = 1, L2 = 2, L3 = 3.5, L5 = 0.4, L6 = 1, W7 = 1.5, and W8 = 0.5, while the ground plane parameters are: Lg = 5.5, W6 = 2.5, W9 = 2.5, and feed-line parameters are: Wf = 1.875 and Lf = 6.6. The antenna is made using two steps: firstly, the ground plane is essentially a rectangle containing two q-shaped slots, which are rotated by ± 90^o and located at the two sides of the ground plane, as shown in Fig. 1.

The q-shape slots increase the surface currents on the ground plane. This phenomenon occurs because the slots perturb the current distribution over the ground plane structure. Ground plane parameters were fine tuned to optimize the antenna's impedance bandwidth. The second step involves the creation of the patch, which is essentially a rectangular loop that envelopes an inner ring that is connected to the outer rectangular loop at the top and bottom, as shown in Fig. 1.The dimensions of the outer rectangular loop are: Lp = 11.4 mm and Wp = 9 mm. The inner ring resembles a rectangle with the top half being narrower than the bottom half. Inside the inner ring is an inverted T-shaped stub. The resulting antenna structure enables omni-directional radiation and enhanced impedance bandwidth. In addition, the structure provides an effective impedance match and return-loss characteristics with linear phase variation for transmission and reception of narrow pulses used UWB systems [7-9].

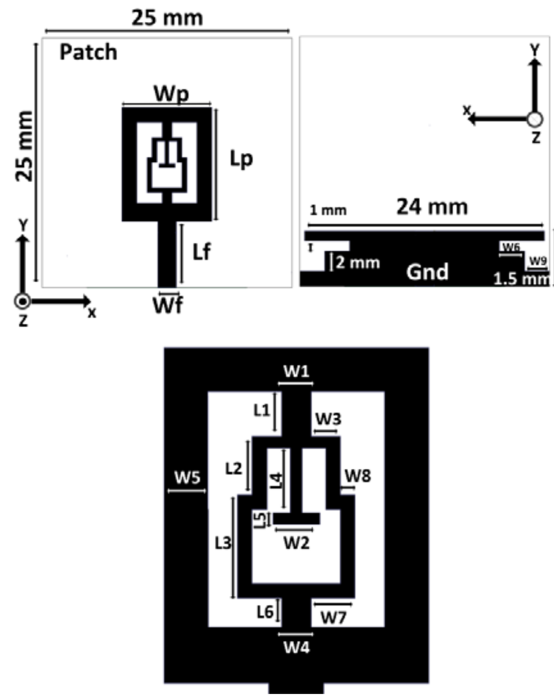

Fig. 1. Structure of the proposed monopole antenna with optimized dimensions.

III. SIMULATION AND MEASUERMENT RESULTS

The proposed antenna was designed using Ansoft HFSS [21]. The optimized design was then realized on printed circuit board. The proposed antenna was fabricated on a common FR4 substrate. Figure 2 shows a photograph of the antenna. The width (Wf) and length (Lf) of the microstrip feed-line are 1.875 mm and 6.6 mm, respectively. The impedance bandwidth of the antenna was measured using Agilent 8722ES vector network analyzer. It is observed from Fig. 3, that the impedance bandwidth is tightly related to W6. The bandwidth decreases when the length of W6 is varied from its optimum value (W6 = 2.5 mm) in either direction. Moreover, as depicted in Fig. 4, the bandwidth is also affected by parameter W5. By increasing W5, the frequency of the upper band edge decreases. Parametric study also showed the operating frequency band of the antenna is affected by the space between the patch and ground plane (Lf). Other parameters such as L3 and W7, have negligible influence on the return-loss (S11) of the antenna. The proposed antenna structure is shown to fulfill the requirements for UWB systems.

The effect of the inner and outer ring parameters on the prototype antenna's response are shown in Fig. 5. It shows five absorption resonances within the antenna's bandwidth at different frequencies. There is good agreement between the measured and simulated results. The antenna's gain between 2 GHz to 11 GHz is plotted in Fig. 6. The antenna's gain figure varies between 1 dBi and 4 dBi over the UWB bandwidth, and the variation is approximately linear. The far field radiation characteristics were also studied. Figure 7 show the co-polarization and cross-polarization radiation patterns in the E- and H-planes at three different spot frequencies 3 GHz, 6 GHz, and 10 GHz. The H-plane pattern is omni-directional over the entire UWB operating band. This antenna performs similarly to conventional printed monopole antennas with the advantage of being significantly smaller in size and possessing enhanced bandwidth.

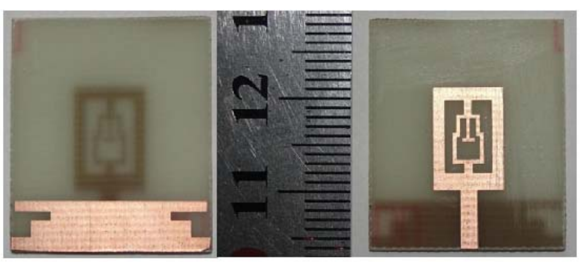

Fig. 2. Photograph of the printed monopole antenna.

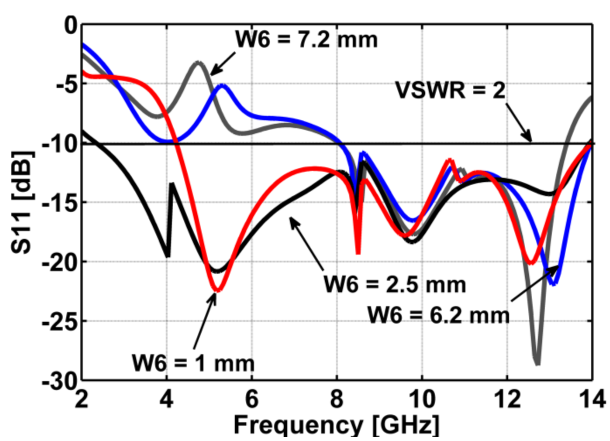

Fig. 3. Simulated return-loss (S11) frequency response as a function of parameter W6.

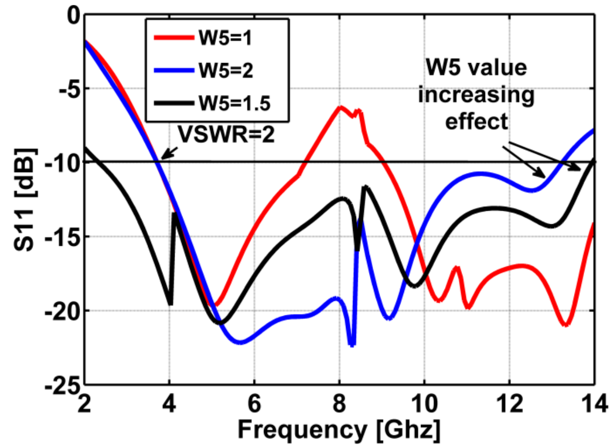

Fig. 4. Return-loss (S11) frequency response as a function of parameter W5 (in mm).

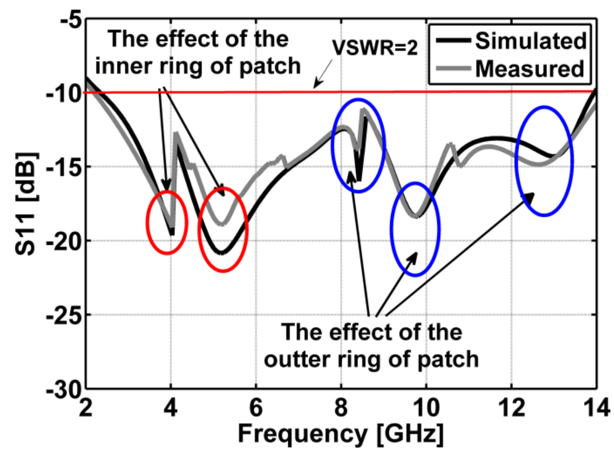

Fig. 5. Measured and simulated return-loss of the antenna using optimized values with embedded slots (inner and outer rings).

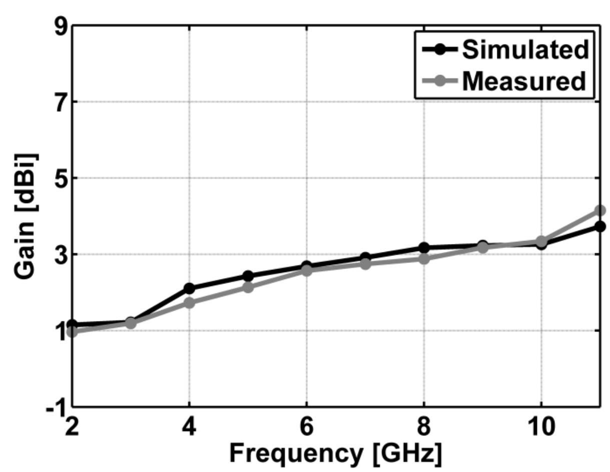

Fig. 6. Measured and simulated antenna gain response of the prototype antenna.

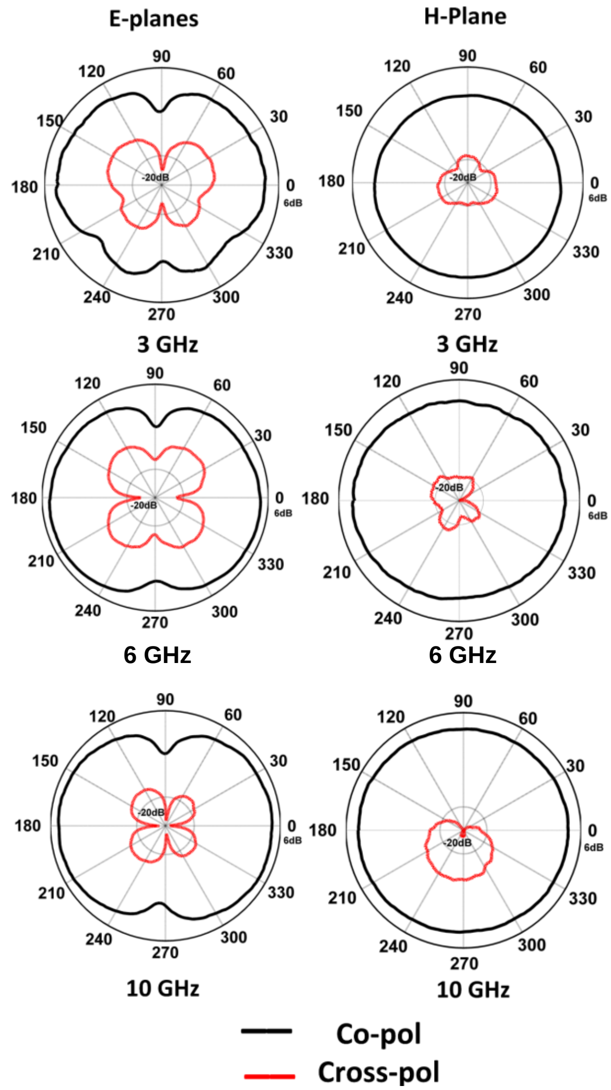

Fig. 7. Measured E- and H-plane patterns at spot frequencies of 3 GHz, 6 GHz, and 10 GHz.

IV. CONCLUSION

A compact and novel monopole antenna was proposed and fabricated for ultra-wideband applications. The antenna's bandwidth performance was enhanced by embedding slots inside the antenna's ground-plane structure. Impedance matching was optimized over the ultra-wideband frequency range by optimizing the current density distribution over the antenna's ground structure. The antenna operated over a frequency range 2.4 GHz to 13.9 GHz, which complies with the UWB specification. The antenna was fed through a microstrip-line. The simulation and measurement results are in good agreement. These results confirm the proposed antenna as a good candidate for UWB wireless technology.

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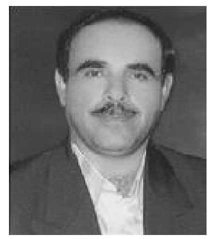

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