A Low Profile, UWB Circular Patch Antenna with Monopole-Like Radiation Characteristics

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***Abstract*— a simple ultra-wideband antenna with monopole-like radiation pattern is presented in this paper. The structure of this low profile antenna with height of the 7 mm (0.65 λ_{min}) is based on annular-ring circular patch. To improve the antenna's bandwidth, the main annular-ring circular patch is loaded with two concentric rings and two rectangular slots. The result shows the antenna achieves a 10 dB return loss bandwidth from 2.85 GHz to 8.6 GHz. The monopole-like radiation pattern is maintained throughout the frequency bands by combining four propagation modes of TM_{01}, TM_{02}, and TM_{03}.**

Keywords*— Annular-ring patch, circular patch, low profile antenna, microstrip antenna, monopole-like radiation patterns, ultra-wideband (UWB).

I. INTRODUCTION

The rapid advances in broadband wireless communication and extensive demands for higher speed data necessitates ultra-wideband (UWB) antennas, which can support higher bit rates. Increased research efforts have been dedicated to UWB technology over the last decade, largely due to its versatile benefits of low power consumption, immunity against multipath, and high data rate transmission for short distances [1], [2]. UWB antennas with omnidirectional radiation in the azimuthal plane are often desired in wireless sensor network applications in surveillance, structural-health monitoring in building structures, automation, Vehicle-to-Vehicle (V2V) communications. Such antennas are also very interesting for Wireless Body Area Network (WBAN), where various sensing nodes distributed across the body can communicate with each other by making use of such monopole-like radiation patterns [3], [4].

Despite of extensive research on size and bandwidth of monopole antenna, they are not suitable for aforementioned applications due to their high height and low [5]. A low-profile antenna with monopole-like radiation patterns for UWB applications have been previously proposed in [6-9]. In [6], a small cylinder is added on the top of a monocone antenna to enhance the bandwidth of 3.06 to 12 GHz and reduce the height of structure to 0.086 λ_{min}. The structure needs to have a radome to protect its delicate pins. In [7], two bent diamond shape radiators are employed for increasing antenna bandwidth while the smaller radiator is embedded in the middle of the bigger radiator in order to decrease the antenna size. The antenna bandwidth is 0.66–5.6 GHz and the height of the antenna is 0.046 λ_{min}. A very low profile (0.09 λ_{min}) UWB top-hat loaded loops which used feed network to improve the antenna bandwidth (0.69 to 2.84 GHz) is also presented in [8]. In [9], the proposed UWB and antenna which consists of the monocone and a shorted ring patch with profile of the 0.07 λ_{min}, thin and delicate shorted pins are also employed.

For all of the applications, especially in WBANs, a low profile and conformal antenna is preferred due to the capability to be mounted on or embedded in a curved surface. The monocone antennas are not proper options due to the conductive conical shape whichare fabricated from conductive rigid materials. The low profile structure with the potential of fabrication with flexible material is a promising candidate for aforementioned applications [10]. The low profile circular patch antenna which is fed in the center and has a monopole-like radiation pattern without any extra pins, has a potential for this fabrication method.

In this paper, we presented an UWB circular patch antenna with a monopole-like radiation pattern. The proposed circular patch covers the frequency band from 2.85 GHz to 8.7 GHz with the height of 0.65 λ_{min}. This low profile achieved without using any extra feed network and pins whereas the lateral size is kept small as well (0.72 λ_{min} ×0.72 λ_{min}).

II. ANTENNA DESIGN

Fig. 1 and Table I show the proposed antenna geometry and designed parameters. The design of the proposed structure is based on a center fed circular patch. The antenna contains a main circular patch in which radius is calculated from the [11]. A circular patch which fed in the center has a conical pattern shape, a null in the center and is inherently narrowband. As Fig. 2 shows the circular patch with the radius of the 22 mm with the mode of TM_{01} resonates at the 3.3 GHz, regarding the presented formula in [12]. The inner slot with the radius of the r_m and width of the d in the center of circular patch improves the frequency matching and the other resonance 5 GHz with the mode of TM_{02} is produced.

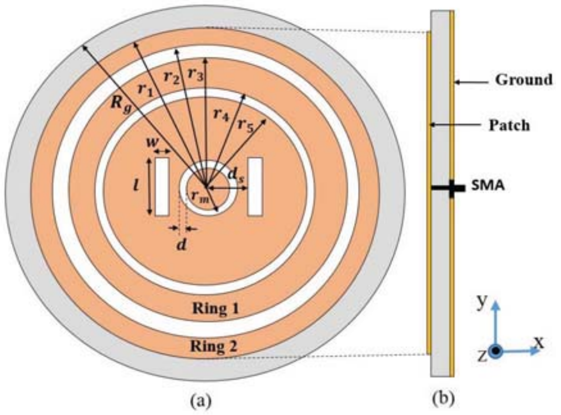

Fig. 1. Proposed antenna geometry: (a) front view; (b) side view.

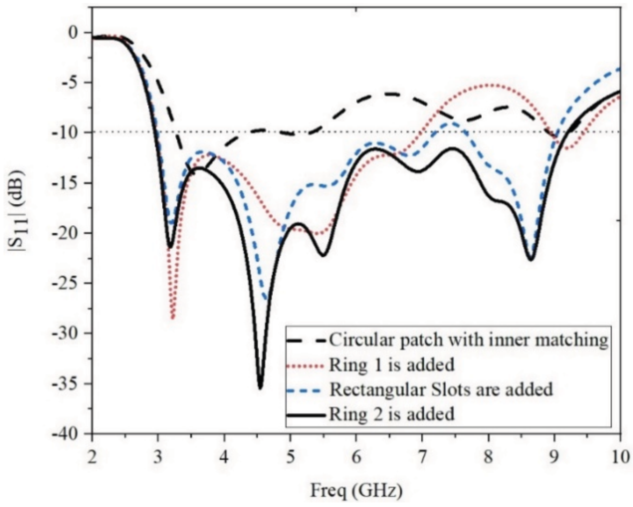

Fig. 2. Simulation of reflection coefficient of antenna in the different values.

TABLE I VALUES OF THE PARAMETERS FOR THE DESIGNED ANTENNA

Parameter	r_1	r_2	r_3	r_4	r_5	r_6	d	l	w	R_g
Value (mm)	37	34	31	23	22	1.5	0.5	11	3	38

The ring 1 with the outer radius of the r_3 and inner radius of the r_4 is added to shift the two resonances and the modes to the lower frequency due to coupling effects of this ring and circular patch. Two resonances of the 3.3 GHz and 5 GHz are merged and shifted to the lower frequencies, 3 GHz and 4.8 GHz. The other resonance at the 5.5 GHz at the TM_{03} mode is also merged to the frequency band. To improve the higher frequency bands, two slots with the dimension of the $\lambda_g/2$ at the highest frequency bands, 8.5 GHz, are added on the main circular patch. The places of the slots and their distances to the center of the patch are optimized to not affect the antenna mode, TM_{03}. Finally, for improving the impedance matching for the whole of the frequency band, the loading effects of the ring 2 with the outer radius of the r_1 and inner radius of the r_2 are employed for the whole of the structure. Hence, the proposed structure covers the frequency bands from 2.85 GHz to 8.5 GHz. The steps of design are depicted in Fig. 2.

In circular patch, in Modes TM_{0n}, surface current is evenly distributed in the radial direction, which result in having monopole-like radiation pattern [12], [13], [14]. In each of the modes shown in Fig. 3, at the frequencies of 3.5 GHz, 6 GHz and 7 GH, TM_{01}, TM_{02} and TM_{03}, it can be seen that the surface current is evenly distributed in the radial direction, therefore, yielding monopole like radiation patterns shown in Fig. 4.

I. RESULTS AND DISCUSSION

The simulated results reflection coefficient are shown in Fig. 2. The matched bandwidth of the antenna (|S11<-10dB) extends from 2.85 GHz to 8.7 GHz. Simulated far-field radiation patterns of the proposed antenna at three frequency of the 3.5 GHz, 6 GHz, and 7.2 GHz in the *xz*-plane and *xy*-plane are shown at the Fig. 4. As it is shown, the antenna has the monopole-like radiation pattern in the whole of the designed frequency. The results show the omnidirectional patterns in the *xy*-plane and a monopole-like radiation pattern in *yz*-plane. The radiation patterns were computed by using HFSS. The antenna peak gain of antenna is from 2.9 dBi to 6.9 dBi.

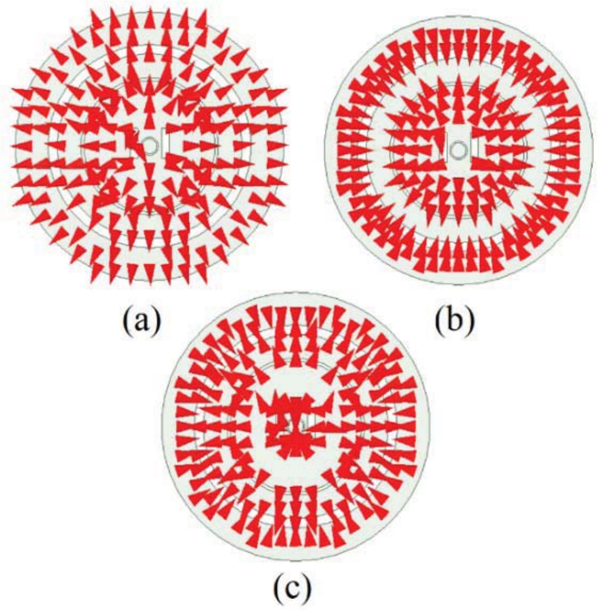

Fig. 3. Simulated current distribution on the proposed patch surface at; (a) 3.5 GHz (TM_{01}); (b) 6 GHz (TM_{02}) and; (c) 7 GHz (TM_{03}).

I. CONCLUSION

In this paper, a simple UWB antenna with a monopole-like radiation pattern is presented. The proposed structure covers the frequency band from 2.85 GHz to 8.7 GHz. To improve the antenna's bandwidth and maintain the monopole-like radiation pattern throughout the entire bandwidth, four modes TM_{01}, TM_{02}, and TM_{03} are combined. This planar and simple antenna has a potential for fabrication based on the PDMS-conductive fabric composite technique due to its low profile and not having any extra components such as pins, feeding points, matching network and divider.

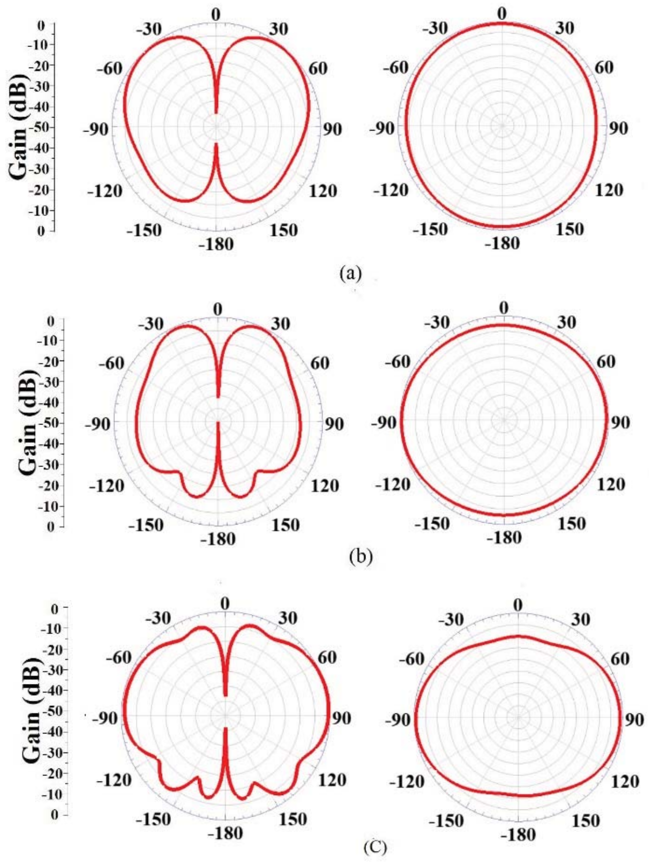

Fig. 4. Simulated radiation patterns of the proposed antenna in in *xz*-plane patterns (left side) and *xy*-plane patterns (right side) at; (a) 3.5 GHz; (b) 6 GHz and; (c) 7.2 GHz.

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