DESIGN OF A MICROSTRIP SQUARE-RING SLOT ANTENNA FILLED BY AN H-SHAPE SLOT FOR UWB APPLICATIONS

S. Sadat and M. Houshmand

Iran Telecommunication Research Center
Tehran, Iran

M. Roshandel

Mobile Communication Company of Iran
Tehran, Iran

Abstract—A novel microstrip slot antenna for UWB (Ultra Wideband) applications is proposed. A square ring slot antenna is filled by an H shape slot as a parasitic element. This structure is fed by a single microstrip line with a fork like-tuning stub. Experiments are carried out to investigate its return loss, its radiation and its time domain behavior, which exhibit good radiation pattern and impedance bandwidth over the entire band of frequency. Time domain consideration also exhibits that this antenna can be used with short pulses. Extended from the proposed antenna, one advanced band-notched (5.5–7 GHz) design is also presented as a desirable feature for UWB applications.

1. INTRODUCTION

The ultra wideband (UWB) technology promotes the communication system particularly wireless multimedia system with high data rate. A UWB antenna should provide a gain and impedance bandwidth from 3.1 to 10.6 GHz. For numerous applications, these antennas must be compact, low cost, and must present omnidirectional radiation patterns. The microstrip slot antenna may be a good choice as it is compact, low profile and easy to integrate with monolithic microwave integrated circuits (MMICs). A new design of a microstrip-line fed printed wide slot antenna with a fork-like tuning stub for bandwidth

enhancement and suitable radiation is studied in [1–3]. The square-ring slot antenna (SRSA) is one of the most beneficial wideband slot antennas. In [4] a circular slot antenna is fed by a circular open ended microstrip line to provide UWB impedance bandwidth. Also in [5] an ultra wideband SRSA is proposed which is fed by a microstrip line with forklike tuning stub. However SRSA is split inside the fork like feed, so it is called split square ring slot antenna (SSRSA). A printed rectangular slot antenna with fork like tuning stub backed with reflector for improves the impedance bandwidth and unidirectional radiation patterns in [6]. In this paper we propose a novel structures driven by [5] with improvement in impedance and gain bandwidth. In this structure an Hshape slot located inside the SSRSA. Measured and simulation results of impedance bandwidth indicate the good agreement with each other. This structure improves the impedance bandwidth and relatively constant radiation pattern in comparison with [5] and successful band-rejection capability in 5.5–7 GHz band. The time domain consideration is also applied which exhibits good performance with short pulses.

2. ANTENNA GEOMETRY AND IMPEDANCE MATCHING

The proposed antenna topology is SSRSA fabricated on a 0.5 mm RO4003B substrate with a dielectric constant equal to 3.4, and is depicted in Fig. 1. The proposed antenna includes a microstrip feed line with fork like tuning stub. The ground plane size is $Lg \times Wg =$
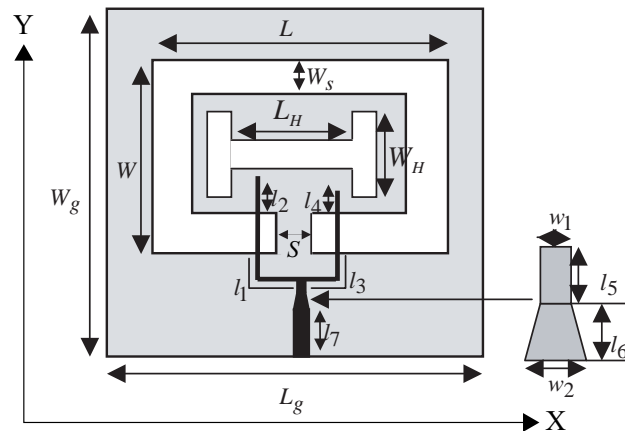

Figure 1. Geometry of the proposed antenna.

120 mm × 100 mm and the length of split (S) is one of the most significant parameters to obtain the required impedance bandwidth indicated in [5]. An SSRSA could be considered as a combination of a number of narrow slot radiators which are connected to each other, so it can provide a couple of resonances at different frequencies. The split in one arm actually increases the number of resonances by introducing new resonant lengths. An H slot is located inside the square ring. It behaves as a parasitic element. Actually the H slot can resonate at the very square ring slot resonant frequencies. So it improves the impedance matching rather than [5]. Also the WH resonates at high frequencies and cancels the spurious radiation of feed line. Then the radiation pattern improves at high frequencies.

3. PARAMETRIC STUDY

The broad-band behavior of the antenna is known by a parametric study. Fig. 2 shows the effect of L_H variations on the return loss of antenna, which is evaluated by IE3D software [7]. The longer L_H leads to the better impedance matching, for the coupling between the square ring and the H slot. It is obvious that the upper resonances are created by off-center microstrip feed, explained in [3].
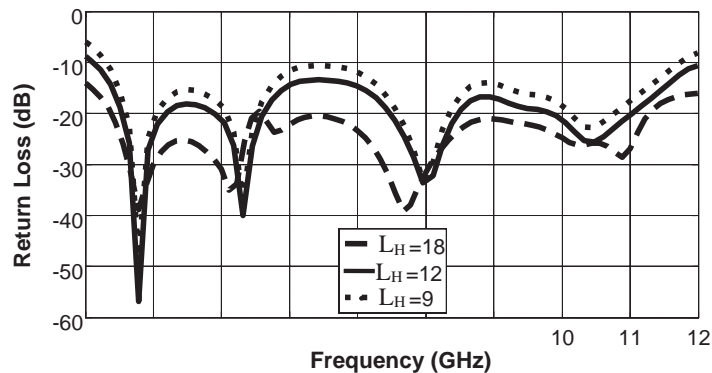

Figure 2. Effect of L_H changes on the return loss of antenna.

4. THE UWB ANTENNA

With $L_H = 18$ mm and $W_H = 10$ mm, a prototype antenna is simulated by IE3D software and is also fabricated. The simulation and measurement results are shown in Fig. 3. There is a good agreement in resonant frequencies between the simulation and measurement results.

The antenna has a VSWR of lower than 2 ($S_{11} < -10\,\text{dB}$) from 3 to 11 GHz. This structure is more compact than [4]. The other parameter dimensions are identified in Table 1. These dimensions are obtained after performing an optimization. Fig. 4 shows the relatively constant gain of optimized antenna at broadside ($\varphi = 0$, $\theta = 0$) with
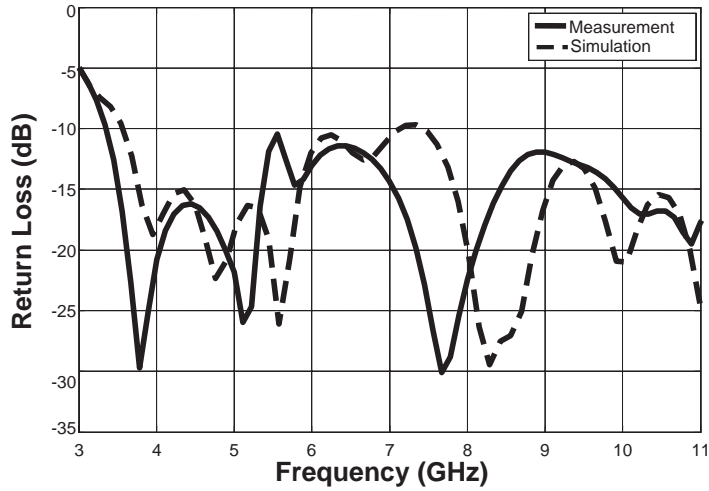

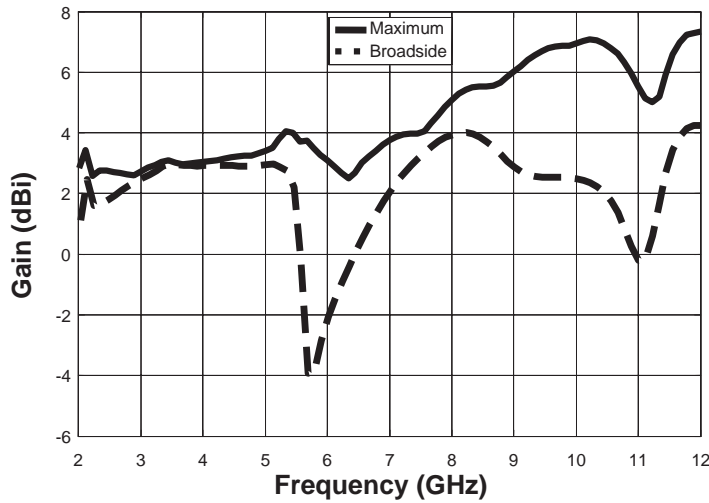**Figure 3.** Measured and simulated return loss of antenna.

Figure 4. Simulated gain of optimized antenna.

successful band rejection in the 5.5–7 GHz band. The notch-band function is desirable in the UWB system to reduce the interferences with the IEEE802.11 and HIPERLAN/2 WLAN systems. This figure also shows how much the pattern rotates from broadside especially at high frequencies. Figs. 5 and 6 show the measured co- and cross polarized radiation patterns across the entire frequency band in the H-plane (xz-plane) and the E-plane (yz-plane) respectively. To use the antenna as a linearly polarized antenna the radiation pattern in the E-plane seems to be better than the H-plane. In the E-plane the cross-polar radiation is at least -10 dB less than the co-polar radiation. However, the radiation patterns start to change in high frequencies and show higher directivities in other directions. In higher frequencies (i.e., from 7 GHz), it seems that the fork-like stub length almost equals to the half wavelength and starts to introduce spurious radiation. However it is omitted by the legs of H (W_H).
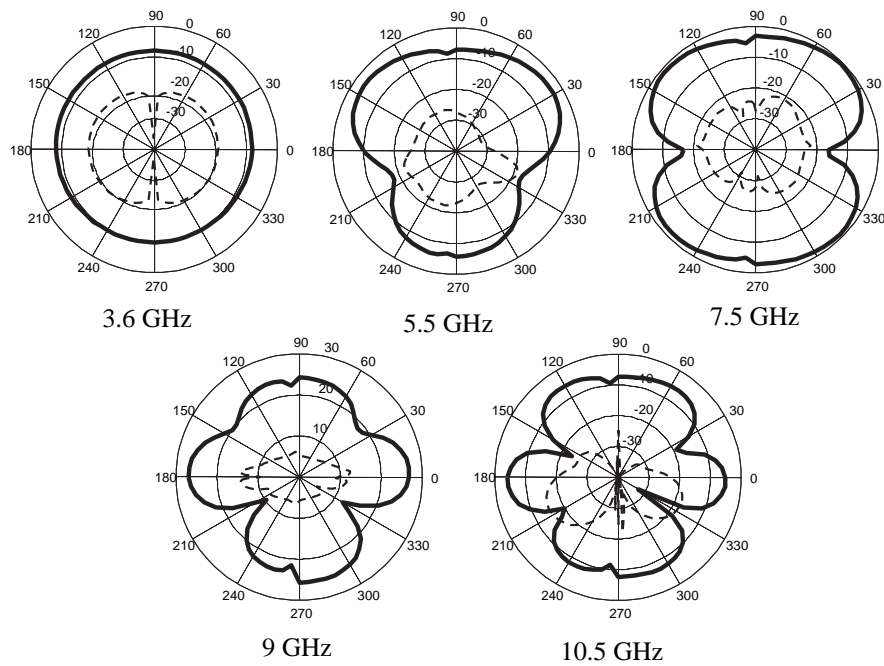

3.6 GHz   5.5 GHz   7.5 GHz

9 GHz   10.5 GHz

Figure 5. Measured radiation pattern of SSRSA in H-plane ($\phi = 0°$). The solid line is co-polar and the dash line is cross-polar component.

Table 1. The dimensions of proposed antenna. All dimensions are in millimeters.

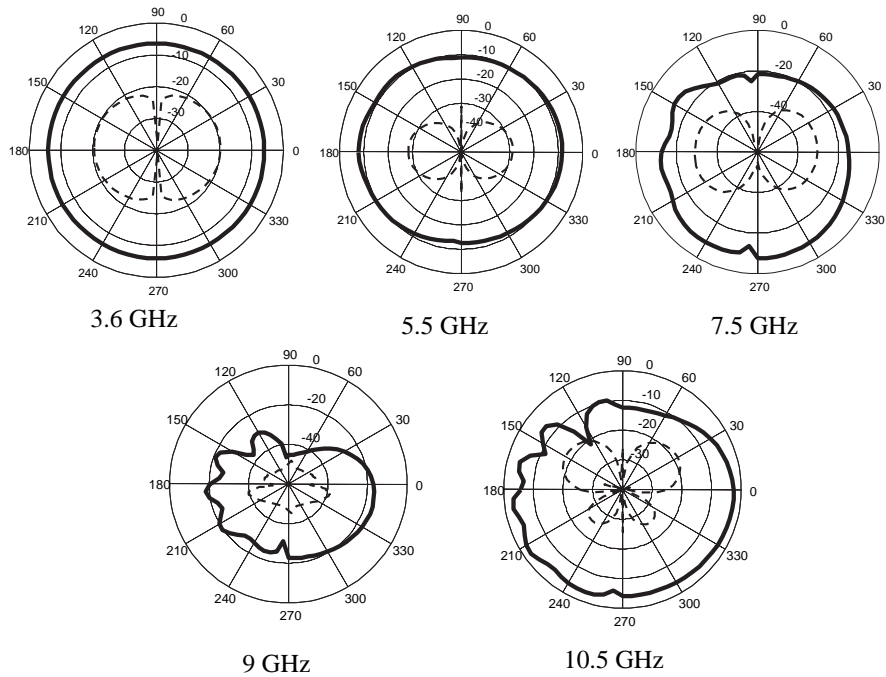| Parameter	L	W	W_s	W_1	W_2	l_1	l_2	l_3	l_4	l_5	l_6	l_7	S
Value	35	21	6	0.7	13	14.3	3	14	4.1	0.6	1.8	30	0.8

Figure 6. Measured radiation pattern of SSRSA in E-plane ($\phi = 90°$). The solid line is co-polar and the dash line is cross-polar component.

5. TIME DOMAIN CONSIDERATION

To study the time-domain antenna behavior, a reference pulse is applied to the terminals of an antenna thanks to a pulse generator. This antenna operates as a transmitting antenna. The other antenna operates as a receiving antenna and is connected to a digital- storage oscilloscope with a 5 ps sampling rate and 20 GHz bandwidth. The received pulse shape is compared with the reference pulse shape in order to know the distortions due to the transmitting and receiving antennas. The reference pulse has 0.43 ns duration and its half-power

width is 0.1 ns. Its spectrum covers a band from 3.3 to 11 GHz. Fig. 7 shows the comparison between the reference and received signal in the E-plane. The received pulse has a magnitude of 0.73 and 0.8 ns duration with a half-power width of 1.1 ns. So the pulse main beam does not change but ripples appear, lengthening the received pulse. So this antenna can be used with short pulses.
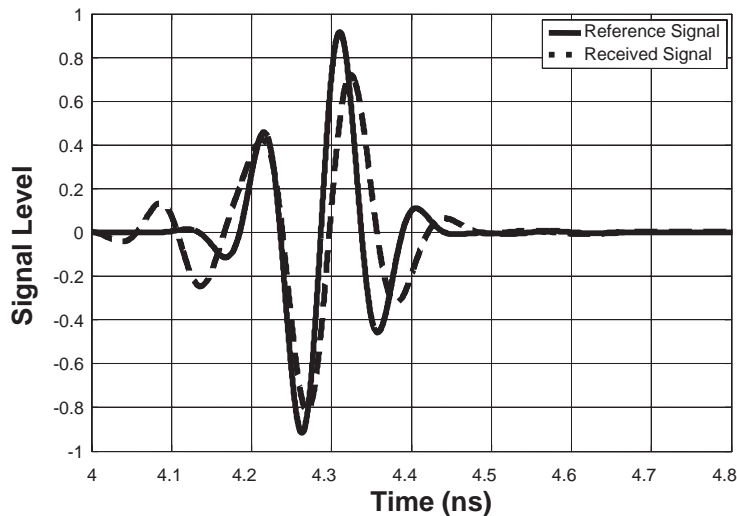

Figure 7. Measured reference and received signal.

6. CONCLUSION

A novel SSRSA antenna filled by an H-shape slot was designed, simulated, optimized, fabricated and measured for UWB applications. Parametric study has been utilized to improve the impedance bandwidth. This structure provides relatively constant radiation pattern and impedance matching rather than [5]. This structure has a good total field gain across the matching band and successful band rejection in 5.5–7 GHz band as a desirable feature for UWB applications. The wide impedance bandwidth was presented with VSWR of less than 2 ($S_{11} < -10$ dB). Time domain consideration exhibited that this antenna could be used with short pulses.

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7. IE3D 9.1 Electromagnetic Simulation Software, Zeland Software, Inc.