Progress In Electromagnetics Research, PIER 67, 173–179, 2007

A COMPACT MICROSTRIP SQUARE-RING SLOT ANTENNA FOR UWB APPLICATIONS

S. Sadat, M. Fardis, F. Geran, and G. Dadashzadeh

Iran Telecommunication Research Center
Iran Telecommunication Research Center
Kargar St., Tehran, Iran

Abstract—A microstrip square-ring slot antenna (MSRSA) for UWB (Ultra Wideband) antenna applications is proposed and improved by compaction. This structure is fed by a single microstrip line with a fork like-tuning stub. By splitting the square-ring slot antenna (SRSA) and optimization of the feeding network, the required impedance bandwidth is achieved over the UWB frequency range (3.1 to 10.6 GHz). The experimental and simulation results exhibit good agreement together. Parametric study is applied to compaction of structure. This compaction provides a good radiation pattern and a relatively constant gain over the entire band of frequency.

1. INTRODUCTION

In 2002 the Federal Communications Commission (FCC) issued a ruling for UWB implementation in data communication as well [1]. In antenna terminology, an antenna with a bandwidth equal to 6:1 or more is defined as a UWB antenna while according to FCC; a UWB antenna should provide a gain and impedance bandwidth from 3.1 to 10.6 GHz. 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). It is usually implemented in two forms of wide and narrow slots. Wide slot antennas have more bandwidth compared to the narrow slots while they suffer from more x-polar components and larger dimensions. Microstrip-fed wide slot antenna has been theoretically studied in [2]. A new design of microstrip-line-fed printed wide slot antenna with a fork-like tuning stub for bandwidth enhancement and suitable radiation is studied in [3, 4]. The most important limitation of a narrow microstrip slot antenna is the single frequency and narrowband operation; there are some investigations to enhance the bandwidth and at the same time preserve the compactness of narrow slot antenna [5–8]. But these methods do not satisfy the desired gain and impedance bandwidth for UWB requirements. The square-ring slot antenna (SRSA) is one of the major wideband slot antennas. It benefits from a more compact size and lower level of x-polar compared to the wide slot antenna and at the same could provide good bandwidth. Recently, an "island like" space filling curves has been used for the development of broadband and circularly polarized square-ring slot antenna [9]. Also in [10] a circular slot antenna is fed by a circular open ended microstrip line to provide UWB impedance bandwidth. In this paper, we propose an ultra wideband SRSA which is fed by a microstrip line with fork-like tuning stub while splitting the square slot ring inside of fork like feed. Furthermore with compression of square-ring slot, the antenna exhibits a relatively constant radiation pattern and gain over the band of UWB. Measured and simulated results of impedance bandwidth indicate the good agreement with each other. This structure creates more radiation pattern bandwidth than [3] and more impedance bandwidth than [8, 9].

2. ANTENNA STRUCTURE

The proposed antenna topology is a split square-ring slot in the ground plane of dielectric substrate. A SSRSA could be considered as a combination of a number of narrow slot radiators which are connected together, so it could provide a couple of resonances at different frequencies. The split in one arm actually increase the number of resonances by introducing new resonant lengths. This structure is fed by a single microstrip line with fork-like tuning stub. This feed mechanism also produces more resonant frequencies due to the fictitious short circuits which appear near the microstrip feed [8]. In order to validate this concept, a SSRSA is designed, simulated, optimized and measured. Fig. 1 shows the proposed antenna geometry. It is a SRSA which has been split on the feed side of slot ring. The SSRSA is considered on a 0.5 mm RO4003B substrate with a dielectric constant equal to 3.4. The ground plane size is $L_g \times W_g = 120\,\text{mm} \times 100\,\text{mm}$ and the length of split (S) is one of significant parameters to obtain the required impedance bandwidth.

3. PARAMETRIC STUDY

The broad-band behavior of the antenna is followed by parametric study. Fig. 2 shows the effect of S changes on the return loss of antenna, which is evaluated by IE3D software. The required impedance

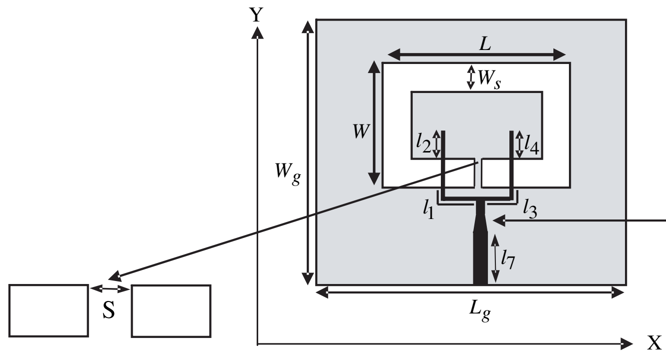

Figure 1. Geometry of the SSRSA antenna.

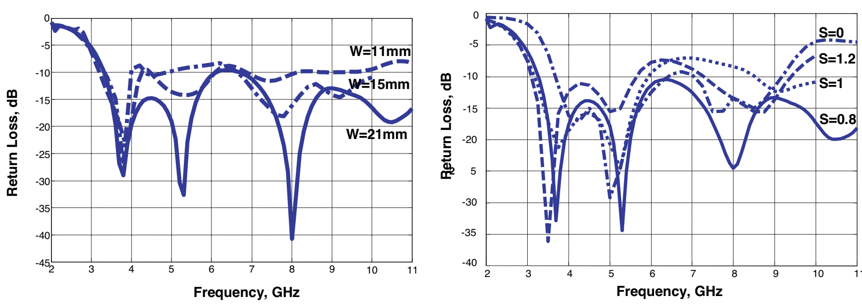

Figure 2. Effect of W and S changes on the return loss of antenna.

bandwidth is observed in S equal to 0.8 mm, it is obvious that the upper resonances are created by off-center microstrip feed which has been expressed in [8]. Also Fig. 2 shows the effect of W changes on the return loss. It's observed that although the reduction of W makes compact the antenna structure, however the upper frequency resonances would be removed.

4. THE UWB ANTENNA

With $S = 0.8$ mm, a prototype antenna is fabricated, simulated by IE3D [11] and HFSS [12] software and the return loss is measured which has been shown in Fig. 3. There is good agreement in resonant frequencies between the simulations and measurement results. The antenna has a VSWR of lower than 2.2 ($S_{11} < -8.5$ dB) from 3 to 11 GHz (Fig. 3). The resonant frequencies are created in respect to

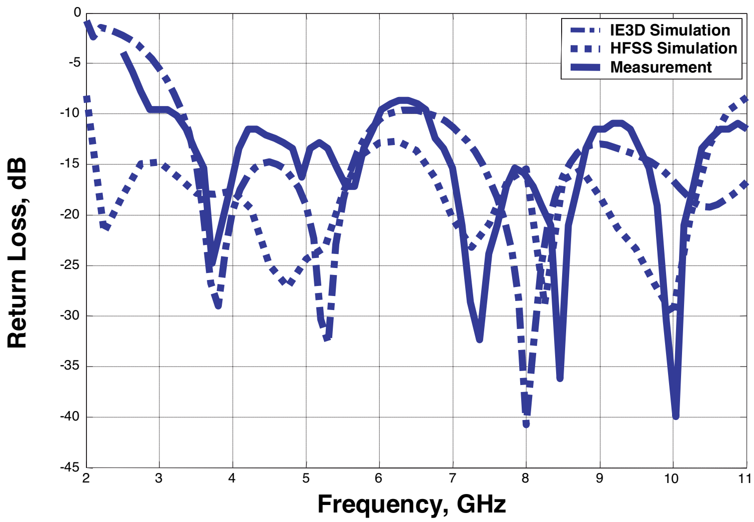

Figure 3. Measured and simulated return loss of antenna.

resonant length of narrow slots which connected together and produced the SSRSA. This structure could also be designed more compact than [9]. The other SSRSA dimensions are identified in Table 1. These dimensions are obtained by performing an optimization for improving the impedance bandwidth by ADS software [13]. Fig. 4 shows the relatively constant gain of optimized antenna at Broadside ($\varphi = 0,\ \theta = 0$) from 3 to 9 GHz with some changes about 6 GHz. This figure also shows how much pattern rotates from broadside especially at high frequencies. Figs. 5 and 6 shows the measured co- and cross polarized radiation pattern across the entire frequency band in H-plane (xz-plane) and E-plane (yz-plane) respectively. If we want to use the antenna as a linearly polarized antenna the radiation pattern in E-plane seems to be better than H-plane. In E-plane the cross-polar radiation is almost -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. It seems that the fork-like stub

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
Value	35	21	6	0.7	1.25	17.3	2.7	12.7	4.1	0.6	1.8	30

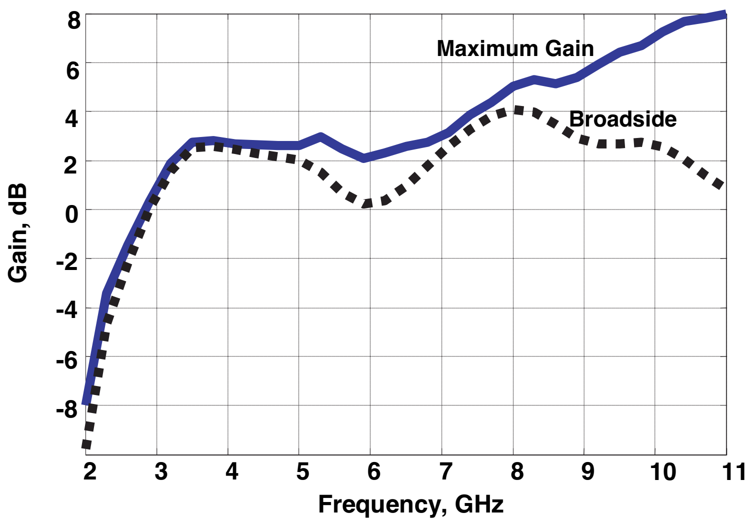

Figure 4. Simulated gain of optimized antenna.

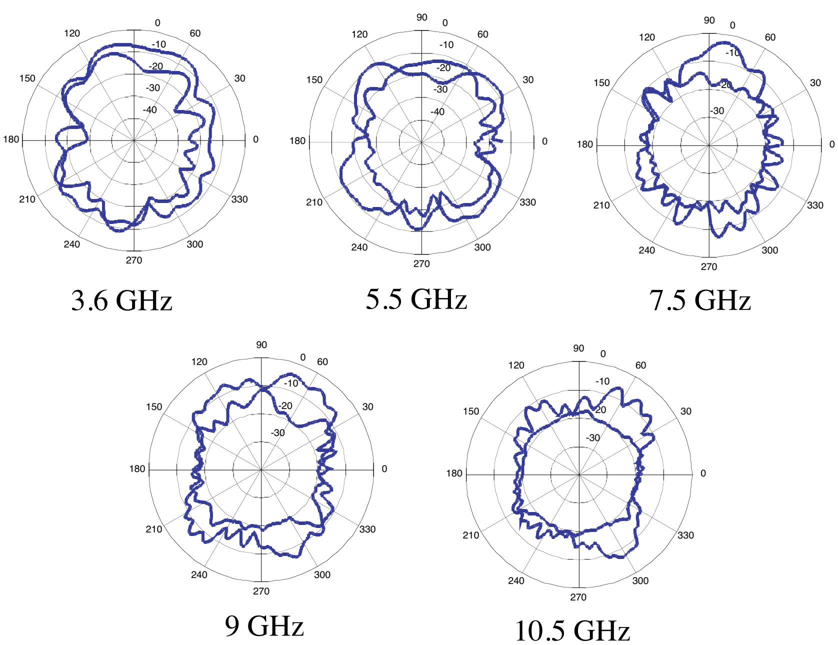

Figure 5. Measured radiation pattern of SSRSA in H-plane ($\phi = 0°$). The solid line is co-polar and the dash line is cross-polar component.

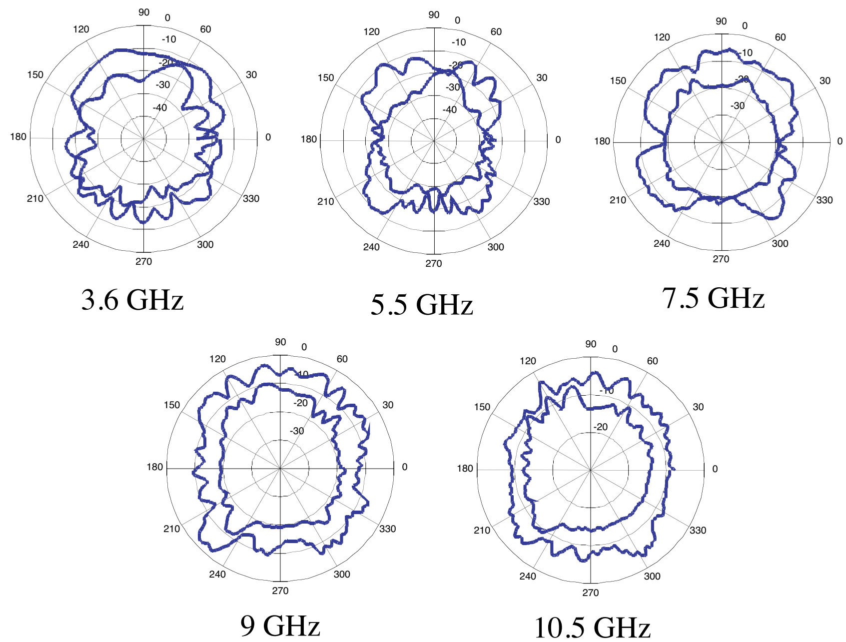

Figure 6. Measured radiation pattern of SSRSA in E-plane ($\phi = 90°$). The solid line is co-polar and the dash line is cross-polar component.

length is almost half wavelength in higher frequencies (i.e., from 7 GHz) and starts to introduce spurious radiation.

5. CONCLUSION

A novel SSRSA antenna was designed, fabricated, optimized and measured for UWB applications. Parametric study was applied to compaction of antenna. Although the reduction of W makes compact the antenna structure, however the upper frequency resonances would be removed. This structure provides relatively constant radiation pattern. Although in H-plane it changes in upper frequencies. This structure has a good total field gain across the matching band. The wide impedance bandwidth is created by $W = 0.8$ mm and provides VSWR of less than 2.2 ($S_{11} < -8.5$ dB) was achieved by using slot radiators which connect vertically together and resonate at certain frequency. The radiation pattern is consistent over the entire frequency range although in H-plane it changes in upper frequencies.

REFERENCES

1. FCC report and order for part 15 acceptance of ultra wideband (UWB) systems from 3.1–10.6 GHz, Washington, DC, 2002.
2. Kahrizi, M., T. Sarkar, and Z. Maricevic, "Analysis of a wide radiating slot in the ground plane of a microstrip line," *IEEE Trans. Microwave Theory Tech.*, Vol. 41, 29–37, January 1993.
3. Chair, R., A. A. Kishk, and K. F. Lee, "Ultrawide-band coplanar Waveguide-fed rectangular slot antenna," *IEEE Antennas and Wireless Propagation Lett.*, Vol. 3, 227–229, 2004.
4. Sze, J. and K. Wong, "Bandwidth enhancement of a microstrip-line-fed printed wide-slot antenna," *IEEE Trans. Antennas and Propagation*, Vol. 49, 1020–1024, July 2001.
5. Sharma, S. K., L. Shafai, and N. Jacob, "Investigation of wideband microstrip slot antenna," *IEEE Trans. Antenna and Propagation*, Vol. 52, No. 3, 865–872, March 2004.
6. Latif, S. I., L. Shafai, and S. K. Sharma, "Bandwidth enhancement and size reduction of microstrip slot antenna," *IEEE Trans. Antenna and Propagation*, Vol. 53, No. 3, 994–1003, March 2005.
7. Behdad, N. and K. Sarabnadi, "A multiresonant single element wideband slot antenna," *IEEE Antennas and Wireless Propagation Lett.*, Vol. 3, 5–8, 2004.
8. Behdad, N. and K. Sarabandi, "A wide-band slot antenna design employing a fictitious short circuit concept," *IEEE Trans. Antennas and Propagation*, Vol. 53, 475–482, January 2005.
9. Ghali, H. A. and T. A Moselhy, "Broad-band circularly polarized space-filling-based slot antennas," *IEEE Trans. Microwave Theory and Techniques*, Vol. 53, No. 6, 1946–1950, June 2005.
10. Kharakhili, F. G., M. Fardis, G. Dadashzadeh, A. Ahmadi, and N. Hojjat, "Circular slot with a novel circular microstrip open ended microstrip feed for UWB applications," *Progress In Electromagnetics Research*, PIER 68, 161–167, 2007.
11. IE3D 9.1 Electromagnetic simulation Software, Zeland software, Inc.
12. HFSS 9.1 Software, Ansoft Corporation.
13. Advanced Design System, Agilent Technologies.