CPW-Fed Wideband Printed Spiral Slot Antenna Design for Multiband Applications

Nasr Gad[1], Leon Pavlovic[2], Tomaz Korosec[3], and Matjaz Vidmar[4]

Radiation and Optics Laboratory, Faculty of Electrical Engineering, University of Ljubljana, tržaška 25, SI-1000 Ljubljana, Slovenia.

nasr.gad@fe.uni-lj.si; Leon.Pavlovic@fe.uni-lj.si; Tomaz.Korosec@fe.uni-lj.si; Matjaz.Vidmar@fe.uni-lj.si

Abstract. *In this paper, the design of a wideband printed slot antenna for multiband applications is presented. The proposed antenna consists of two square spiral slot elements with 180° out of phase excitation and external feeding by a coplanar wave guide (CPW). The antenna is designed on a single-sided low cost FR4 substrate. Spiral antenna and its feeding circuit are compact in size with overall dimensions 40 mm × 65 mm × 1.6 mm. The antenna was simulated and measured in frequency range from 2-17 GHz and it exhibits multiple wide band operation within this range. The antenna was firstly simulated using electromagnetic simulation software based on method of moments (MoM) and later on fabricated and measured. The measured return loss and radiation pattern results are in good agreement with the simulated results. The proposed antenna can be embedded in wireless systems and integrated with microwave circuits to lower the manufacturing cost. The obtained results for return loss and gain show that the proposed CPW-fed printed slot antenna is suitable for WLAN and UWB applications.*

1 INTRODUCTION

Nowadays, wireless communications have progressed very rapidly which increases the need to provide antennas with a large bandwidth for multiband applications. Besides that, devices are getting smaller and smaller with integrated and as small as possible antennas. Therefore, the wideband printed antenna design has become very important. Printed antenna is the type of antenna which can be used both for transmitting and receiving signals. Printed antennas are low-profile, lightweight, compact in size, simple and inexpensive to fabricate and have pretty good performances. They are quite popular and widely used in wireless and mobile communications, as well as in radar applications.

Wideband printed antennas can be mainly classified into three basic types by structure: printed dipole, printed slot and printed monopole antennas. These are the most popular in wireless communication systems [1]-[3]. Microstrip line and coplanar waveguide are the most suitable feeding solutions for wideband printed antennas [4], [5]. CPW feeding is supposed to be a better candidate over a microstrip line because of its simple single-layer configuration, low radiation loss, manufacturing advantages, repeatability, and low cost. The advantage of the CPW-fed printed slot antenna is its wide frequency band which encourages many researchers to introduce various shapes of printed slot antenna for different wideband applications without any difficulties in fabrication.

Spiral antennas fall under the category of frequency independent antennas. This class of antennas includes antennas for which radiation pattern, impedance and polarization remain virtually unchanged over large bandwidth [6], [7]. Spiral antennas gained a lot of popularity due to their circularly polarized radiation with relatively constant input impedance and radiation over wide frequency range. The spiral radiator shape can be classified as equiangular, Archimedean, logarithmic, rectangular, etc. Spiral antennas may be configured with a single arm, double arms, or multiple arms [8]. In case of connecting the two-arm spiral antenna with balanced input and coaxial cable with unbalanced structure, and in order to compensate for impedance difference between the spiral antenna input impedance and the coaxial cable impedance, a balance–to–unbalance (balun) circuit and an impedance transformer are usually added to the feeding structure of the spiral antenna [9]. Two arm circular spiral slot antenna with modified CPW feed for multiband applications in the frequency range from 2.5 GHz to 9.5 GHz is studied in [10]. Its overall size is 100mm × 110 mm. Our previous work on square spiral slot antenna consisted of two phase-shifted corner truncated square spiral slots, fabricated on low cost FR4 substrate (45 mm× 70 mm) is presented in [11].

In this paper, we studied a novel approach of square spiral slot antenna consisted of two phase-shifted square spiral slot elements and fed by inductively coupled CPW connected to the end terminal of spiral slots. Applying corner truncation to the spiral slots improved the impedance bandwidth. We compared antenna configurations with different corner truncations. The proposed antenna was simulated and measured to investigate the practical parameters in the frequency band between 2 and 17 GHz. The antenna prototypes were fabricated on FR4 substrate with thickness of 1.6 mm and relative permittivity (εr) of 4.4. The frequency bandwidth of this antenna is defined as a bandwidth within which the return loss is greater than 10 dB or voltage standing wave ratio (VSWR) is less than 2. Analysis of the proposed antenna was done by IE3D Simulator based on the method of moments [12]. The measurements of the return loss and radiation pattern were obtained for all four types of the square spiral slots and compared with the calculated results for the proposed antenna.

2 ANTENNA DESIGN

The overall main structure of the proposed square spiral slot antenna is shown in figure 1. As can be seen from the figure, the proposed antenna consists of two square spiral slot elements. Spiral slots are wound in clockwise direction and one spiral element is shifted with 180° comparing to the other. This is similar to the concept of two arm spiral antenna but with out of phase excitation. The spiral antenna is fed with a coplanar waveguide structure. The square spiral slot elements and its CPW feed were fabricated on a single metallic layer and etched on an inexpensive FR4 substrate with relative dielectric constant 4.4, loss tangent 0.02 and height 1.6 mm. The overall dimensions of the proposed antenna including ground plane are width x length = 40 mm× 65 mm. The spiral slots of the antenna are based on the self-complementary structure with the strip width P between the spiral slots and the slot width S of the same dimensions, i.e. P = S = 2 mm. Each spiral slot element wound with N = 2.5 turns with total spiral slot length Lslot = 180 mm. The two spiral slots have the same size and shape but they are excited out of phase and separated by a distance to improve the impedance matching and to reduce the mutual coupling. The gap g and the width Wf of the central feeding CPW conductor are 0.5 mm and 3 mm respectively. The printed spiral slot was designed to achieve wide bandwidth for multiband applications such as WLAN and UWB.

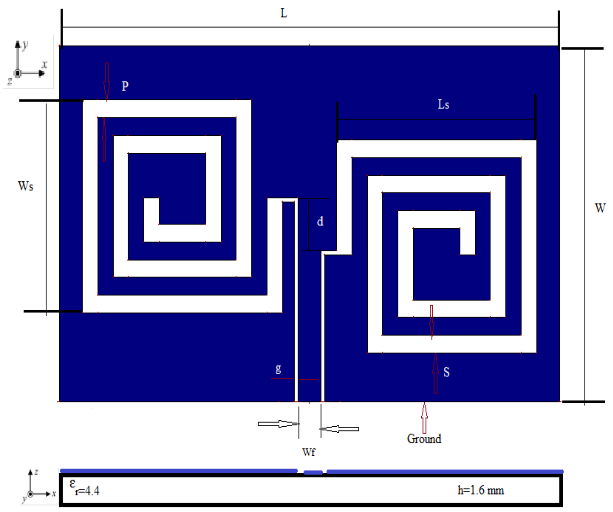


Fig. 1: Square spiral slot antenna.

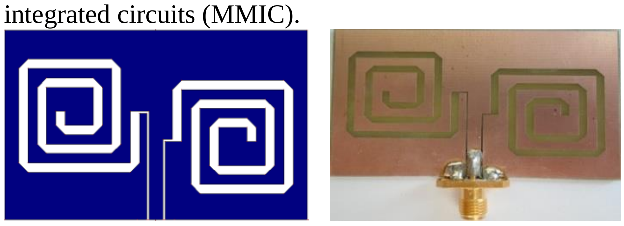
The parameters shown in table 1 represent values of the fabricated square spiral slot antenna structure.

TABLE 1: Parameters of the proposed square spiral slot antenna.

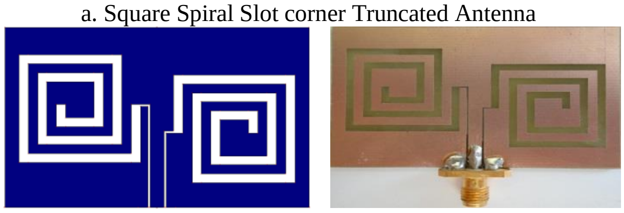
Parameter	*L*	*W*	*S*	*P*	*Ls*	*Ws*	*d*	W_f	*g*
Value (mm)	65	40	2	2	26	24	6	3	0.5

3 RESULTS AND DISCUSSIONS

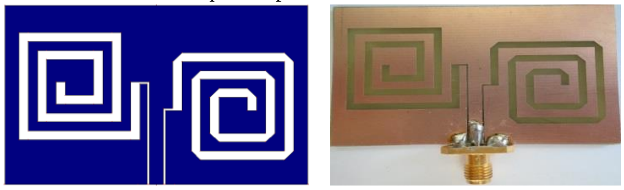
The proposed antenna design was slightly modified into four different variations. All of them were simulated and prototyped. All four layouts and fabricated prototypes of the proposed square spiral slot antenna are shown in figure 2. All parameters which affect the antenna performance were simulated based on the method of moments. Simulated models were printed and fabricated on a single metallic layer on FR4 substrate. Because of the balanced structure of the two-arm spiral antenna and the unbalanced structure of the coaxial cable, and the difference between the input impedance of the spiral antenna and the line impedance of the coaxial cable, a balun and an impedance transformer are usually added to the feeding structure of the spiral antenna. In our design applying the CPW feeding eliminates the need for balun and impedance transformer and make the spiral antenna easy for fabrication and integration with monolithic microwave integrated circuits (MMIC).



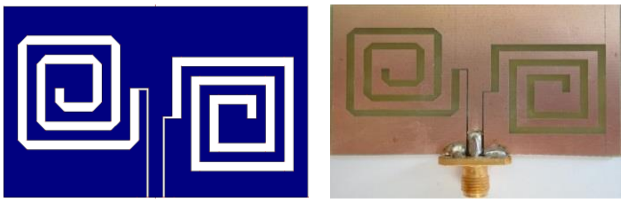
a. Square Spiral Slot corner Truncated Antenna



b. Square Spiral Slot Antenna



c. Square Spiral Slot Lower Corner Truncated Antenna



d. Square Spiral Slot Upper Corner Truncated Antenna

Figure 2: Four variations of fabricated prototypes of square spiral slot antenna.

Frequency bandwidth of the simulated and fabricated antennas was evaluated as an impedance bandwidth, where return loss is greater than 10 dB. We measured return loss as a S11 parameter using R&S ZVA Vector Network Analyzer (VNA up to 67 GHz). The measured and simulated results for S11 for all four types of antenna are shown in figure 3. The antennas were simulated and measured in the frequency range from 2 to 17 GHz. As can be seen from figure, lower operated frequency for all prototypes are the same, i.e. at 2.5 GHz, with best S11 for the square spiral slot corner truncated. Antennas radiate in multiple wideband frequency bands (suitable for different applications, such as UWB and WLAN) within the observed frequency range. Simulated and measured results are in good accordance at the lower and upper frequency limits. However, due to imperfect simulated model, especially at the excitation port, some deviations between simulated and measured results are observed.

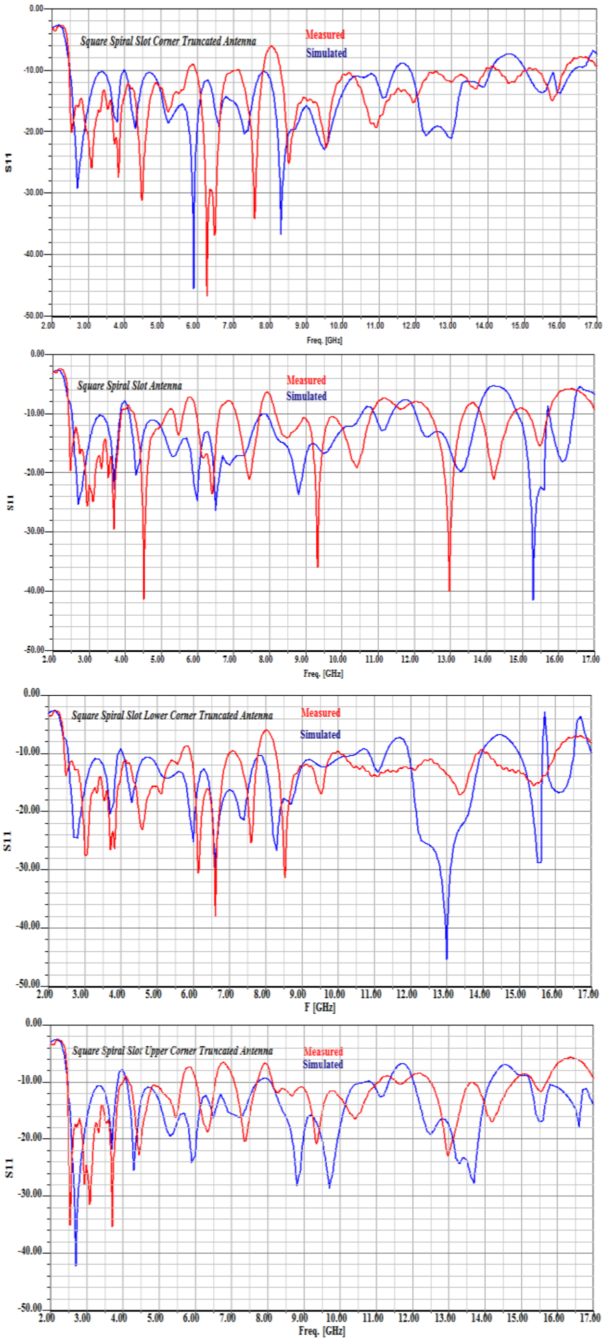
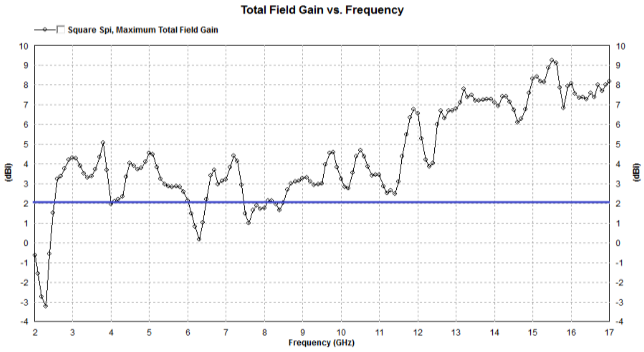
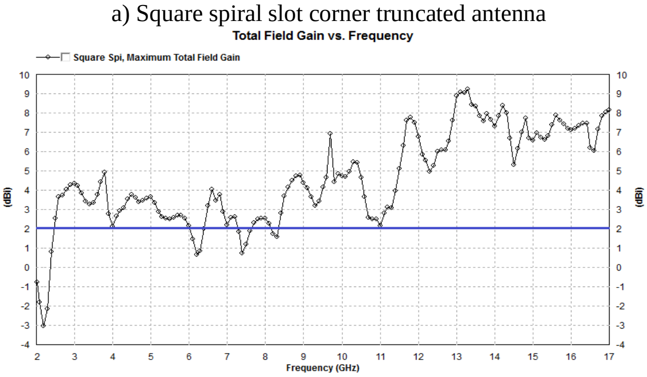


Figure 3: Measured & simulated S11 for four variations of square spiral slot antenna.

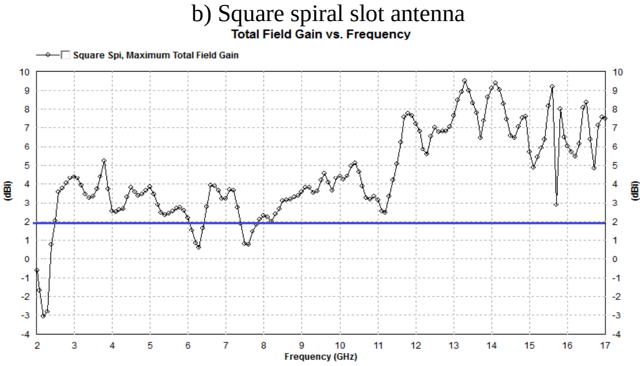
The gain versus frequency for all four proposed spiral slot antennas was also simulated and the results are shown in figure 4. In the frequency range from 2-17 GHz, the antenna gain values fluctuates between (2-5) dBi in the UWB (3.1-10.6 GHz) and WLAN (5.15-5.825 GHz) frequency bands.



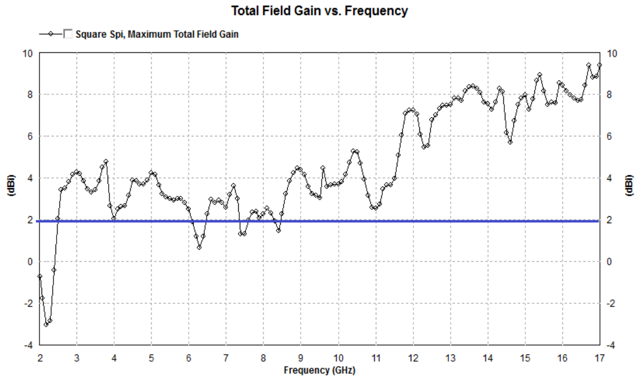
a) Square spiral slot corner truncated antenna



b) Square spiral slot antenna



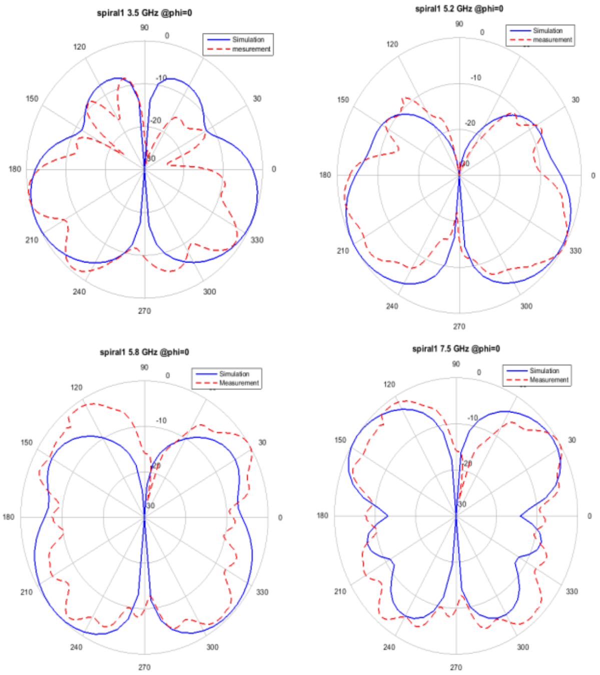
c) Square spiral slot lower corner truncated antenna



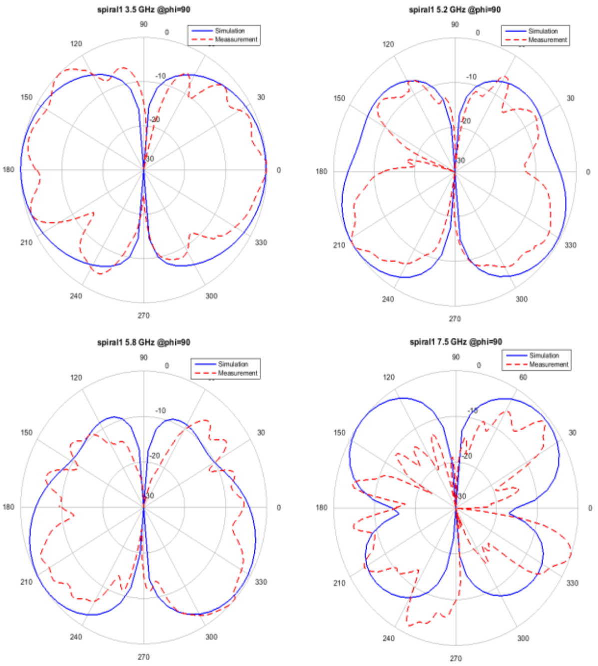
d) Square spiral slot upper corner truncated antenna

Figure 4: Simulated gain for all four spiral slot antenna prototypes.

Far-field radiation patterns for all four antenna types at different frequencies between 2 and 13 GHz were also simulated and measured in the anechoic chamber. For the sake of brevity, simulated and measured results are only presented for square spiral slot corner truncated antenna at four different frequencies and shown in figure 5. Other three types of antennas exhibit almost similar radiation performances.



a) Elevation E-total radiation patterns at four different frequencies for Square Spiral Slot corner Truncated Antenna @ ϕ=0 (xz plane)



b) Elevation E-total radiation patterns at four different frequencies for Square Spiral Slot corner Truncated Antenna @ ϕ=90 (yz plane)

Figure 5: Radiation patterns at four different frequencies for square spiral slot corner truncated antenna.

From figure 5 it can be seen that the proposed antenna exhibits bidirectional pattern and radiates equally in the planes both above and below the spiral radiator elements.

4 CONCLUSIONS

In this papr, CPW-fed wideband printed square spiral slot antenna for multiband applications has been presented. It is inductively coupled with the coplanar wave guide, which acts like short circuit at the end of the slot, and the two spiral slots are separated. The simple CPW-based feeding without the need for balun and impedance transformer, as well as the antenna compact and completely planar structure with wide impedance bandwidth are main advantages of this antenna. The simulation and experimental results show that this antenna is suitable for the WLAN and the UWB applications.

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