Coplanar Waveguide Fed Coplanar Patch Antenna for Nanorectifiers at 2.45 GHz

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Abstract— The reduction in device dimensions due to lateral scaling, increase in circuit complexity, and saturation of Moore's law motivated researchers to explore novel concepts of planar nanoelectronic devices including Self-Switching Device and Ballistic rectifier. To implement these technologies for futuristic applications coplanar interconnects integrated with planar antennas are required. Here, we report the design and fabrication of coplanar waveguide fed coplanar patch antenna to integrate such devices at Unlicensed Industrial, Scientific and Medical band frequency of 2.45 GHz for radio frequency identification systems.

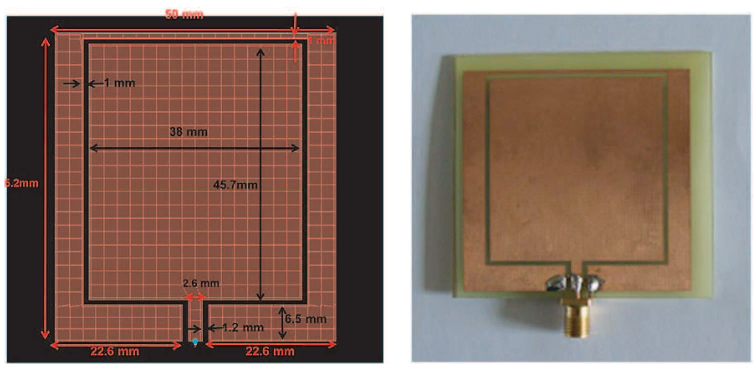
1. INTRODUCTION

The recent developments in semiconductor industry have demonstrated the pervasive use of digital broadband communication handling a huge data to be processed and transmitted at the faster speed. In order to increase the operating speed, the device dimensions have been scaled down following the Moore's Law and reached at the verge of saturation [1]. Therefore, researchers have proposed a wide variety of novel nanoelectronic devices such as Self-Switching Device (SSD) [2] and Ballistic rectifier [3] which can be fabricated in two-dimensional electron gas (2-DEG) heterostructures by using standard nanolithography followed by a wet chemical or dry etching. The SSD is a two terminal device and it consists of two L-shaped trenches that ensures the flow of current only through the channel. The surface states accumulated around the etched channel trenches allow the device to conduct only in a particular direction similar to a diode. On the other hand, ballistic rectifier is four terminal (source, drain, lower and upper) device and behaves like a bridge rectifier. The device geometry consists of two cross junctions with or without an antidot located at the centre enabling the flow of charge carriers in the desired direction. The AC and/or DC current is applied between source and drain terminals, and the rectified output is measured simultaneously across the lower and upper terminals. Both the devices can be used as a rectifier to convert microwave signals into DC signals, however, they don't require any *pn* and/or Schottky barrier when compared to conventional multi-layered rectifiers. Due to their planar device architecture, they have shown very small internal capacitance meaning that their frequency response doesn't have RC charging time limitations as convention electronic devices and can be used for various applications starting from radio frequency (RF) to terahertz (THz) frequencies [4–6]. Such devices can easily be integrated to outside macroscopic world using coplanar transmission lines and planar antennas demonstrating very low parasitic capacitances.

Here, we report the design and fabrication of coplanar waveguide (CPW) fed coplanar patch antenna (CPA) to integrate with SSD and ballistic rectifier at Unlicensed Industrial, Scientific and Medical (ISM) band frequency of 2.45 GHz for radio frequency identification (RFID) systems.

2. DESIGN AND SIMULATION

Coplanar patch antenna consisting of a patch surrounded by a closely spaced ground conductor on the same side of substrate was first introduced by Greiser [7]. It has been demonstrated that this structure of antenna behaves more like a patch antenna rather than a loop slot antenna. Less radiation loss, less dispersion, wide bandwidth, lower cross polarization, uniplanar configuration, and ease of integration are few of the advantages of CPAs [8–10]. In addition, they can easily be fed using coplanar lines. The patch length of about half wavelength, i.e., $L = c/(2f_r\sqrt{\varepsilon_r})$, instead of total loop size determines the resonating frequency (f_r) of the antenna, here c and ε_r represents the speed of light and dielectric constant of substrate, respectively. On the other hand, width of the patch, $W = c/(2f_r\sqrt{(\varepsilon_r+1)/2})$, determines the impedance of antenna. The equivalent width and length of the slot at the outer side is designed to be around $1.6\lambda_0/\sqrt{\varepsilon_r}$ (more than one and half wavelength) and $0.52\lambda_0/\sqrt{\varepsilon_r}$ (close to half wavelength), respectively, where λ_0 is the wavelength at 2.45 GHz [10]. The conventional design of CPAs generally has a back ground conductor to achieve unidirectional radiation pattern. However, here we designed and introduced a new concept of CPA without a back ground conductor exhibiting a unidirectional radiation pattern. In order to avoid the impedance mismatch between designed antenna and commercially available measurement systems, a CPW feed line with an impedance of 50 Ω is connected at the edge of patch to feed the antenna. The dimensions of CPW feed lines are calculated theoretically by considering closed loop empirical relations. The gap between center patch and surrounded ground plane is taken 1 mm to match the impedance of antenna to CPW. The detailed device dimensions of the designed antenna as discussed above are shown in Fig. 1(a). The method of moments based Agilent's Advanced Design Systems (ADS) software is used to simulate the electrical and radiation properties of CPA. The full wave electromagnetic simulations based on Maxwell's equations including substrate and space wave radiation effects have been carried out for the complete analysis. These results are later validated by performing the measurements as discussed in the following section.



(a) (b)

Figure 1: (a) CPW fed coplanar Patch Antenna with optimized dimensions. (b) Fabricated antenna with a SMA connector.

3. RESULTS AND DISCUSSION

The CPW fed coplanar patch antenna is fabricated using a wet chemical etching process considering less than 50 μm tolerance in dimensions as shown in Fig. 1(b). A low material loss dielectric called glass epoxy (FR4) with dielectric constant $\varepsilon_r = 4.4$, loss tangent $(\tan\delta) = 0.0002$, thickness $(h) = 1.2$ mm is used for these experiments. The dielectric constant of material was kept small to keep the fringing fields loosely bound from the edge of microstrip patch for radiation from an antenna. The increase in thickness of substrate results a better surface wave propagation improving the bandwidth of antenna. However, surface waves propagating along the substrate cause a reduction in gain, increase in end fire radiating and cross-polar levels, therefore, it puts an upper limit on the thickness of substrate $h/\lambda_c \leq 0.3/(2\pi\sqrt{\varepsilon_r})$ [11].

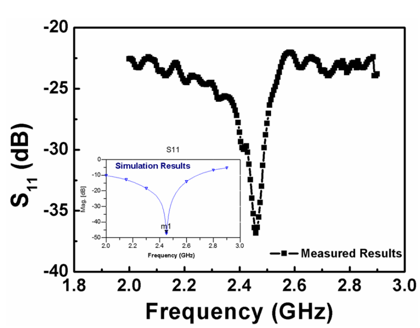
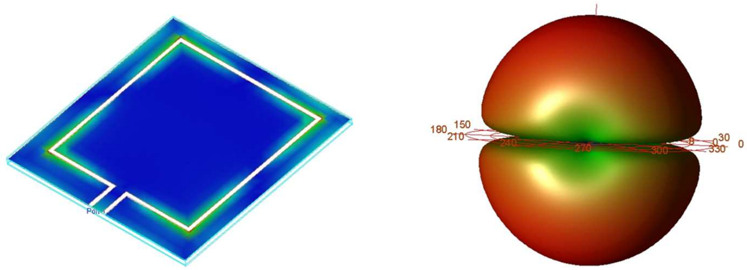


Figure 2: The return loss of 37.24 dB was measured using Agilent's network analyser (model: E 5061B ENA Series) which is in well accordance with the simulated results obtained using ADS software as shown in the inset.

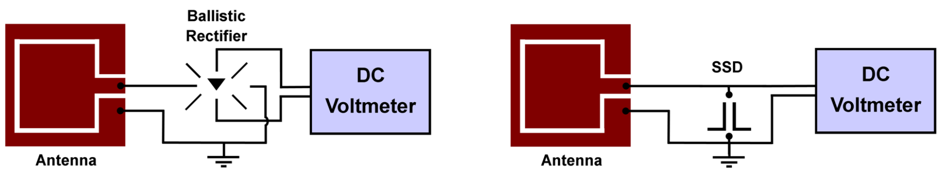
The simulated return loss of 47.4 dB is achieved at the resonating frequency of 2.45 GHz as shown in the inset of Fig. 2. The smith chart (not shown here) demonstrates the impedance matching of



(a) (b)

Figure 3: (a) Current distribution, and (b) 3D radiation pattern of designed antenna at the resonant frequency of 2.45 GHz.

feed with the patch with a VSWR of almost 1. The antenna demonstrated a gain of 3.82 dB. The current distribution and three dimensional radiation pattern of designed antenna at 2.45 GHz is given in Figs. 3(a) and (b), respectively. The S-parameter of fabricated antenna as shown in Fig. 2 is measured in the lab using Agilent's vector network analyser The measured return loss of about 37.24 dB is in reasonable accordance with the simulated values of 47.4 dB.



(a) (b)

Figure 4: Schematic illustration of setup to integrate CPW fed coplanar patch antenna with nanoelectronic devices ballistic rectifier (a) and SSD (b) in rectenna configuration for various RFID applications.

The designed CPW fed coplanar patch antenna can easily be utilised in a rectenna configuration in which it can be coupled with a rectifier to convert microwave signals into DC voltages [12]. Figs. 4(a) and (b) demonstrates the schematic illustrations of such rectenna configurations with ballistic rectifier and SSD, respectively for various applications such as RFID systems, energy harvesting, microwave imaging, etc..

4. CONCLUSION

Here we have presented a novel design of CPW fed CPA without having a ground at another side of substrate making it more suitable to integrate with futuristic novel nenaoelectronic devices for various applications at 2.45 GHz. The planar architecture of antenna and such devices make it easy to fabricate both on the same side of substrate in single step nanolithography for very high speed applications when compared with conventional vertical and multi-layered rectifiers.

ACKNOWLEDGMENT

A. K. S. acknowledges the financial support of the Ministry of Social Justice and Empowerment, Government of India and PEC University of Technology, Chandigarh, India.

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