A Broadband Stepped-Slot Antenna

Leena Vershney, Jibendu Sekhar Roy

Abstract –**The design of a broadband printed slot antenna is reported here. First, the CPW-fed conventional rectangular slot antenna is designed and then the rectangular shape is modified by a stepped configuration to achieve higher bandwidth. The simulated results using IE3D software are verified by measurement and the results show that the printed stepped-slot antenna can be used for UWB communication in the frequency range of 3.1GHz – 5.7GHz.**

Keywords – **Stepped-slot antenna, broadband, constant group delay.**

I. INTRODUCTION

In recent years, printed antennas becoming attractive for use in wireless communication systems [1-10] including ultra wideband (UWB) systems [11-15] due to their attractive merits of simple structure and low profile. The basic form of a printed slot antenna consists of a slot on a metallic patch etched on a dielectric substrate. This type of antenna can take various configurations such as rectangle, circle etc. Printed slot antennas are able to radiate bi-directional radiation pattern with larger bandwidth. But the microstrip feed for slot antennas needs the proper alignment of the etching on the two sides of the board and also the microstrip line is not very compatible with monolithic integrated circuits [2,4,5]. For those reasons printed slot antennas are often fed by coplanar waveguide (CPW). CPW-fed slot antennas have been studied extensively [2]. The electric field lines in the two CPW apertures excites the two slots of the antenna (Fig. 1) and the radiated field of the antenna is linearly polarized along the width of the slot. Most of the slot antennas have bigger size.

In this paper, the design of a CPW-fed printed slot antenna is described, where the slot is of stepped rectangular shape. The bandwidth of this stepped printed slot antenna is more than twice that of CPW-fed printed rectangular slot antenna and the size of the stepped-slot antenna is comparatively smaller. The antenna can be operated in the frequency range of 3.1GHz –5.7GHz which is nearly 60% of the centre frequency. The good agreement between simulated results, using IE3D software, and measured results are achieved.

Here, the bandwidth of the antenna is defined as the frequency range in which the return loss of the antenna is –10 dB and the gain of the antenna is at least 2 dB. The antenna may be used for UWB communication. The recommended bandwidth for UWB communication is 3.1GHz – 10.6GHz, but in many cases instead of using the whole bandwidth, part of the above bandwidth is used [13 – 15].

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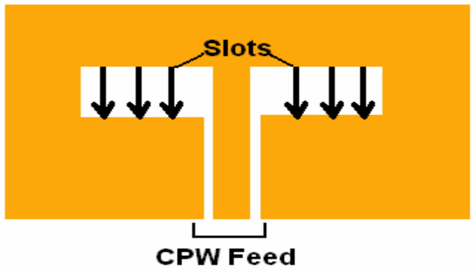

Fig. 1. CPW-fed Rectangular Slot Antenna

II. GEOMETRY OF THE PRINTED STEPPED-SLOT ANTENNA

The total length of slot (L1+L2) is 80mm, whereas L1 = L2, and the width of the slot at extreme ends (H1 = H2) is 10.5mm.(Fig.2). The gap (W2) and the width of the center strip (W1) are 0.5mm and 2.4mm respectively. The total length of the antenna (L) is 88mm and the width of the antenna (W) is 45mm. Lengths H3, H4 and H5 are 15mm, 11mm and 7mm respectively. L3 and L4 are 20mm and 8mm respectively. The length of the CPW line (H3) is 15mm. In order to reduce the overall size of the antenna, in two corners of the patch, saw-tooth geometry (of 3 mm.) was produced (Fig.2).

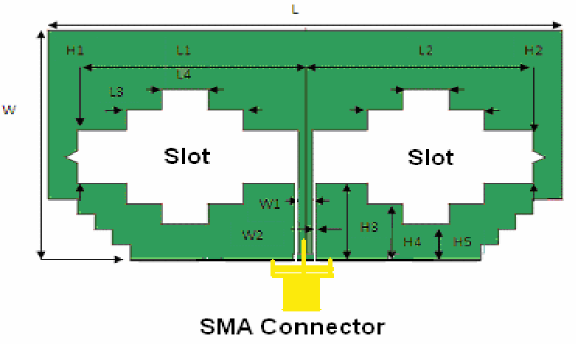

Fig. 2. CPW-fed Stepped-slot Antenna

Cutting four or two corners of the antenna smoothly, size reduction is possible but the performance of the antenna parameters degrades. Two small triangular-shaped slot extensions are used for good impedance matching without which it was not possible to achieve –10dB return loss in the frequency band of 3.1GHz – 5.7GHz. Due to these two small triangular-shaped slot extensions, other properties of antenna do not change. The dimensions of the arms of the triangles are 2mm each. The Glass Epoxy substrate of dielectric constant 4.36, height 1.57 mm, loss tangent 0.01 was used for the simulation and fabrication of the antenna.

III. DESIGN OF THE BROADBAND STEPPED-SLOT ANTENNA

For the proposed antenna design, IE3D simulation software is used, which is a full wave electromagnetic simulation software for the microwave and millimeter wave integrated circuits. The primary formulation of the IE3D software is an integral equation obtained through the use of Green's function. The simulation using IE3D, takes into account, the effect of co-axial SMA connector, by which the antenna was fed. First, the simulation was started with a CPW-fed rectangular slot antenna, like Fig. 1. Then in order to achieve broad bandwidth, the rectangular slot is modified to rectangular stepped-slot. The best performance of the antenna was obtained after a large number of simulations where dimensions of stepped slot (L1, L2, L3, L4, W1, W2, W3, W4, H1, H2, H3, H4), width of the feed strip (W2) and dimensions of the radiating patch (L, W), are varied to achieve the maximum bandwidth (in terms of impedance bandwidth and gain) of the antenna. The fabricated antenna prototype is shown in Fig.3.

Fig. 3. Stepped-slot Antenna Prototype

The simulated radiation patterns, antenna efficiency of the slot antenna are shown in Fig.4, Fig.5, Fig.6 respectively.

The radiation patterns are bi-directional and linearly polarized. In Fig. 4 and Fig. 5, the frequency difference is about 1.9 GHz. The radiation patterns of a simple dipole antenna are different for different lengths of the dipole (in terms of wavelength λ). In the present structure also the lengths of the radiating edges become different (in terms of wavelength λ) at different frequencies and therefore, radiation patters at Fig. 4 and Fig.5 are different.

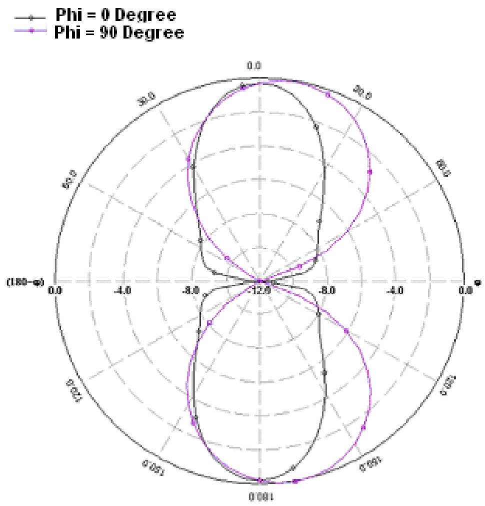

Fig. 4. Radiation Pattern at 3.63 GHz

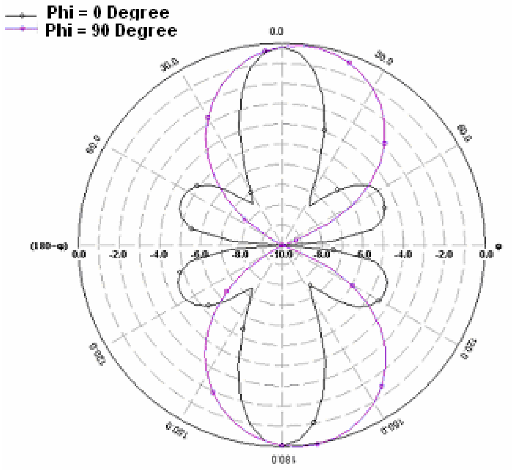

Fig. 5. Radiation Pattern at 5.4 GHz

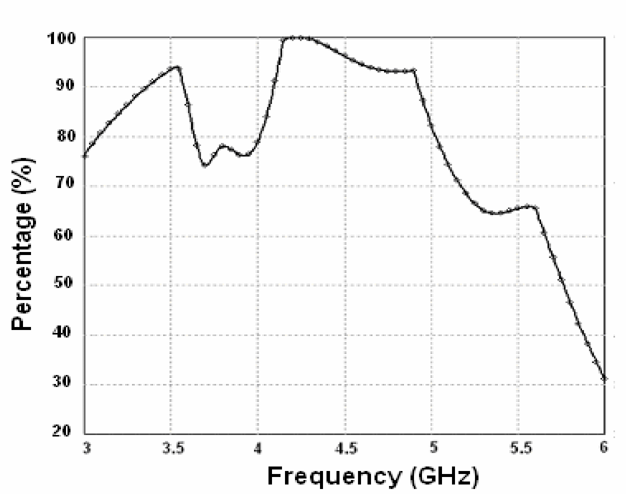

Fig. 6. Simulated Antenna Efficiency

After fabrication of the antenna, measurement was done using vector network analyser (VNA N5230A, Agilent Technologies). The simulated and measured return losses of the antenna are compared in Fig. 7. The real(Rin) and imaginary parts(Xin) of the input impedance are plotted in Fig. 8.

The simulated and measured gains of the antenna are compared in Fig. 9. The maximum simulated gain of the antenna is 6.5 dB and minimum gain is 2.4 dB over the frequency range of 3.1 – 5.7 GHz. The gain of the antenna was measured at discrete frequencies over the band of the antenna.

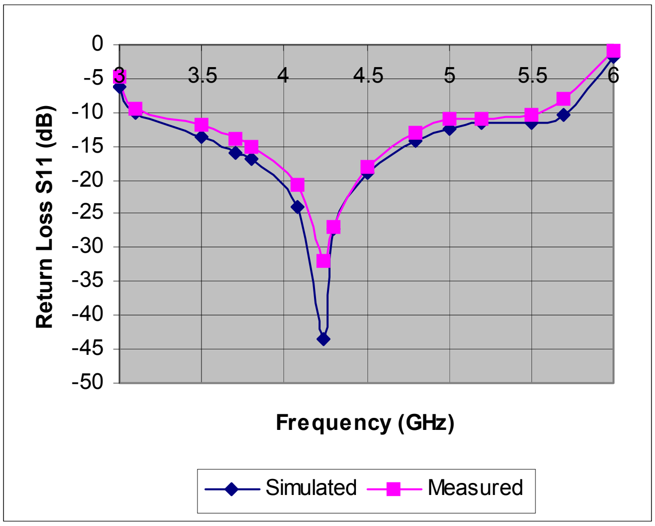

Fig. 7. Comparison Between Simulated and Measured Return Losses (S_{11})

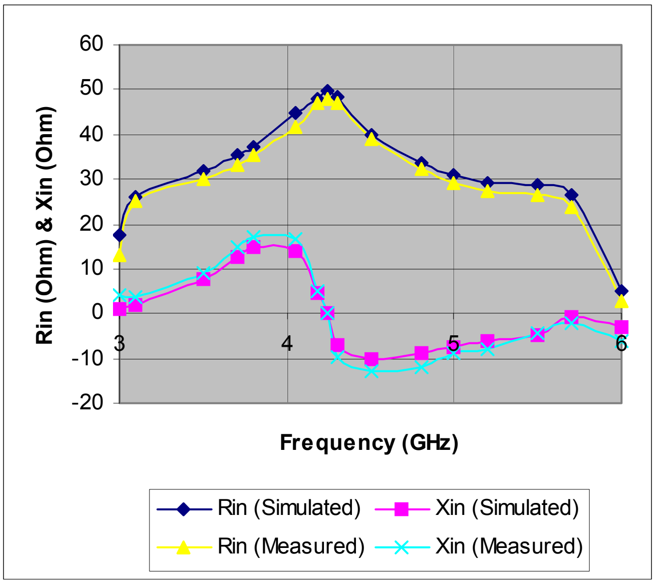

Fig. 8. Real (Rin) and Imaginary (Xin) Parts of Input Impedance of the Antenna

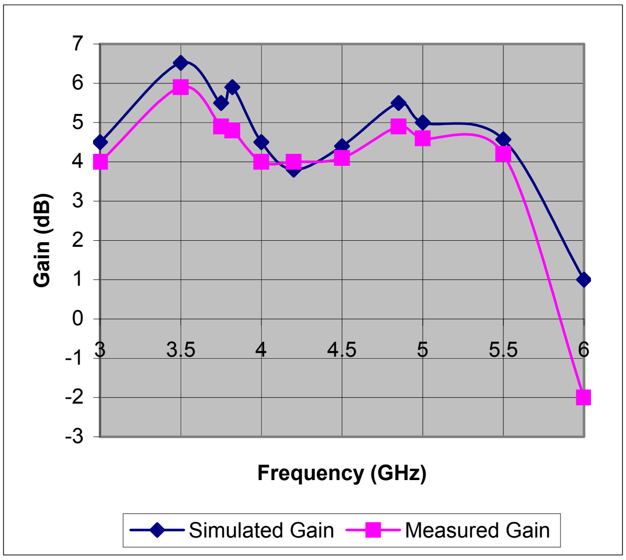

Fig.9. Comparison Between Simulated and Measured Gains

For gain measurement, two identical antennas were fabricated (as shown in Fig.3) and transmission coefficient S12 was measured using vector network analyser without using anechoic chamber. Separation between the two antennas are noted. Then using Friis transmission formula, gain of the antenna was determined. The detailed procedure of gain measurement, using two identical antennas, can be found in [16]. The schematic set up for the measurement of gain using vector network analyser is shown in Fig. 10.

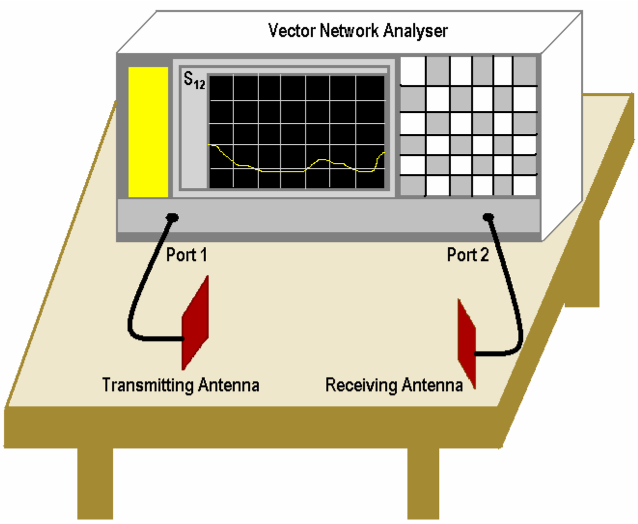

Fig. 10. Experimental Set up for Gain Measurement using Vector Network Analyser

Constant group delay is one of the required characteristics of UWB antenna. Measured Group delay, when the separation between two antennas is 45 cm, is shown in Fig. 11. The average group delay is approximately 2 ns. Group delay is nearly constant over the frequency bandwidth.

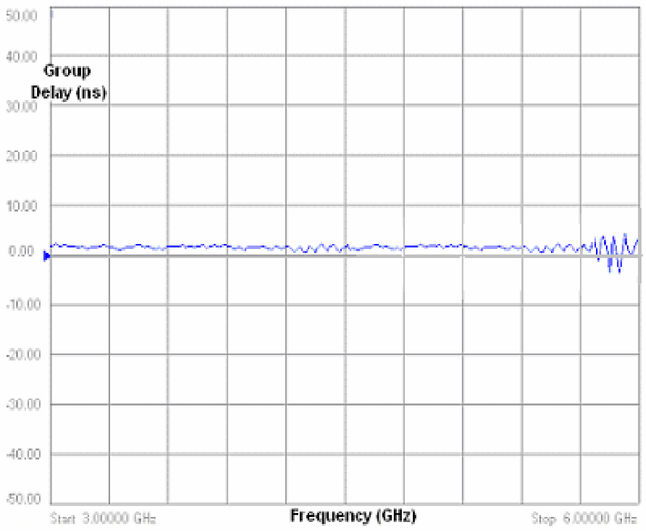

Fig. 11. Measured Group Delay of the Antenna

In figure 11, in some places group delay is negative (near 6GHz). Group delay is determined from the slop (dΦ/df) of the Phase vs. Frequency graph of S21 parameter and expressed as $\tau g = (-1/360)(d\Phi/df)$. In a network analyzer, when calibration is done over a wide range of frequency (specially, if the frequency band is more than 1 GHz), calibration becomes inaccurate. Due to inaccurate calibration, the slope of the phase-frequency curve (dΦ/df) becomes positive at certain frequencies and ultimately, according to above formula, τg becomes negative. For that reason, some parts of the measured group delay curve over a wide frequency range (here it is 2.6GHz), always show negative group delay.

IV. CONCLUSION

A new broadband printed slot antenna with stepped slot is designed for the application in UWB communication. The antenna has small size. For UWB application the gain of the antenna may be low (greater than 2 dB), but the antenna efficiency should be high (greater than 60%), which is almost achieved by simulation and measurement for the proposed antenna, over the bandwidth.

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