Dimensional Variation Effects on the Performance of Slotted Millimeter Wave Antenna

R. Rahul, D. S. Ram Kiran, D. Ujwala, B. Harish, N. Anand Ratnesh

Abstract:- A compact slotted micro strip patch antenna is proposed and designed in this paper for millimeter wave Radar applications. The antenna is designed on Quartz glass substrate of dielectric constant 3.78 with thickness of 0.8mm. The size of the proposed antenna is 4mm x 9mm x 0.8mm. The proposed antenna resonates at three frequencies 24.42 GHz (24.17-24.69), 27.02 GHz (26.74 – 27.32) and 34.67 GHz (33.89 – 35.47). A comparative analysis is done by varying the dimensions of the slots in antenna. The proposed model is simulated using Finite Element Method based High Frequency Structure Simulator (HFSS).

Keywords:- Dimensional variation, slot, millimeter wave antenna.

I. INTRODUCTION

Microstrip Antenna technology has been a rapidly developing technology over the past decades. Low profile antennas, allowing operation at multiple frequency bands are in demand. The most popular among miniature antenna is the microstrip patch antenna. It is also light weight and easy to install [1-4]. The main challenge of antenna design in a planar technology is the trade off between radiation efficiency and bandwidth. To obtain a large bandwidth, a relatively thick dielectric layer is needed. However, a thicker dielectric layer introduces higher loss due to surface-wave excitation in the dielectric. A lot of work has been done to improve the radiation efficiency of planar antennas while maintaining a large bandwidth particularly, the use of electromagnetic band gap (EBG) materials that suppress the surface-wave excitation has received a lot of attention. However, EBG materials are either difficult to manufacture, or too large to be used in planar array configurations. Another approach to improve the radiation efficiency is presented in, where a superstrate antenna is used [5-6]. This solution shows good performance but is more complicated to realize since the superstrate antenna is a separate component that has to be placed partly on top of the integrated circuit. As an alternative, a balanced antenna design is proposed here. In this design, the antenna element itself cancels part of the surface- wave excitation. Because of the reduced surface-wave excitation, a simulated radiation efficiency of over 80% is obtained throughout the band of operation. On top of that, an antenna bandwidth of more than 10% is realized by using two resonant elements. Placing of slots is one alternative to design compact antennas [7-8]. The present work carries the performance evaluation of antenna with dimensional variation of slots operating at millimetre wave frequency.

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II. ANTENNA GEOMETRY

The Geometry of the proposed antenna is as shown in figure 1. The antenna is realized on Quartz glass with a dielectric constant of 3.78 and a thickness of 0.8mm. The antenna is fed by a coaxial cable with impedance matching of 50Ω.

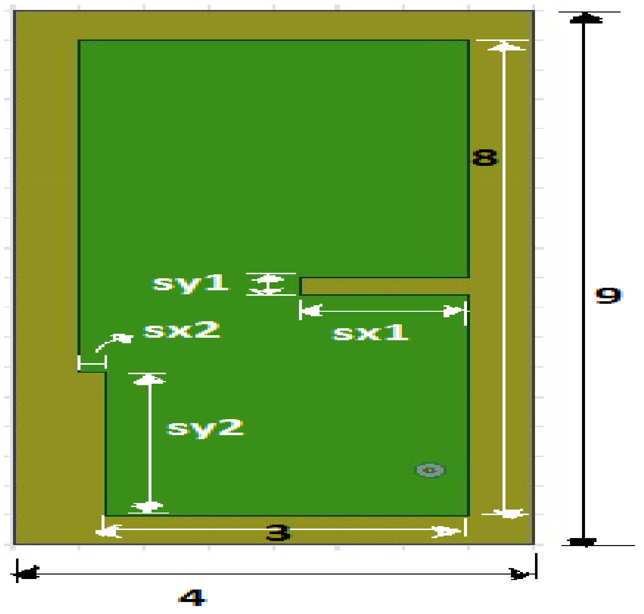

Figure 1: Slot Antenna Model

The substrate dimensions are 4mm x 9mm x 0.8mm. The patch dimensions are 3mm x 8 mm with two slots. The lengths and widths of the two slots are sx1=1.3mm, sy1= 0.3mm, sx2=0.2mm and sy2=2.4mm. The coaxial feed location is (3.2mm, 1.25mm). The diameter of the feed is 0.12mm and feed length is 0.8mm. By varying the slot dimensions sy1 and sx2, a comparative analysis of Return Loss is made. The designed antenna structure is simulated using FEM based Ansoft High Frequency Structure Simulator vs. 13.

III. RESULTS AND DISCUSSIONS

The proposed antenna resonates at three frequencies 24.42 GHz, 27.02 GHz and 34.67 GHz. The first Resonant Frequency has a bandwidth of 24.17 GHz to 24.69 GHz centered at 24.42 GHz. The second resonant frequency has a bandwidth of 26.74 GHz to 27.32 GHz with a center frequency of 27.02 GHz and the third resonant frequency has a bandwidth of 33.89 GHz to 35.47 GHz centered at 34.67 GHz.

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The Return Loss of the proposed millimeter wave antenna at the three resonating frequencies is as shown in figure 2. The Return Loss values are -26.02 dB, -21.89 dB and-35.85 dB at the corresponding resonant frequencies 24.42 GHz, 27.02 GHz and 34.67 GHz.

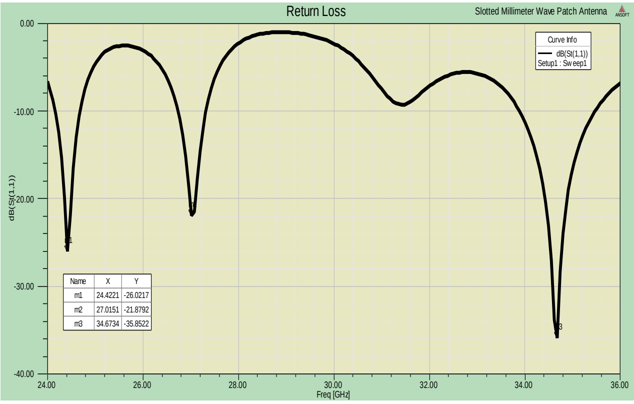

Figure 2: Return loss Vs Frequency

By varying the dimensions of the two slots in the patch antenna, the variations in the Return Loss are observed as follows. The first slot has a length sx1=1.3mm and width sy1=0.3mm. The width sy1 of the first slot is varied and the Return Loss for different sy1=0.2mm, 0.3mm, 0.4mm, 0.5mm is as shown in figure 3.

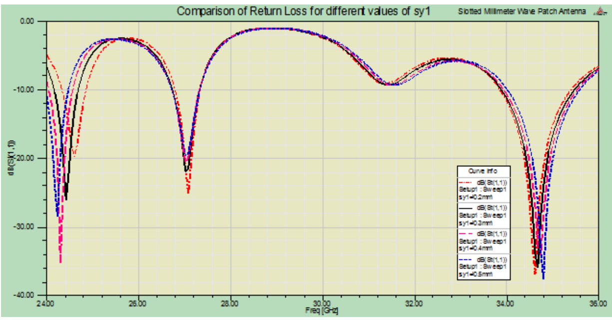

Figure 3: Return loss Vs Slot sy1 dimension

The second slot has a length sx2=0.2mm and width sy2=2.4mm. By varying the length sx2, a comparative analysis of Return Loss is done and it is shown in figure 4 for sx2=0.2mm, 0.3mm,0.4mm, 0.5mm.

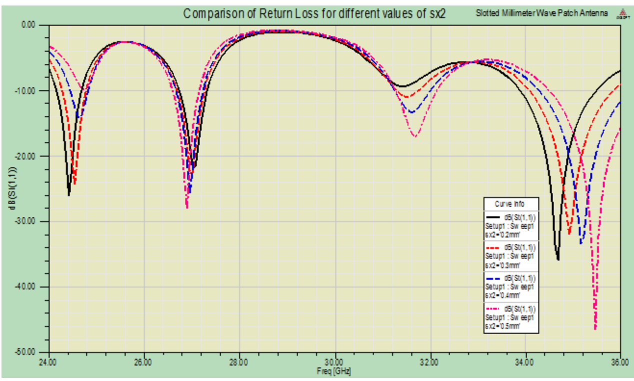

Figure 4: Return loss Vs Slot sx2 dimensions

The VSWR plot is shown in figure 5. The VSWR is 1.11, 1.19, 1.03 at resonating frequencies 24.42 GHz, 27.02 GHz, 34.67GHz respectively.

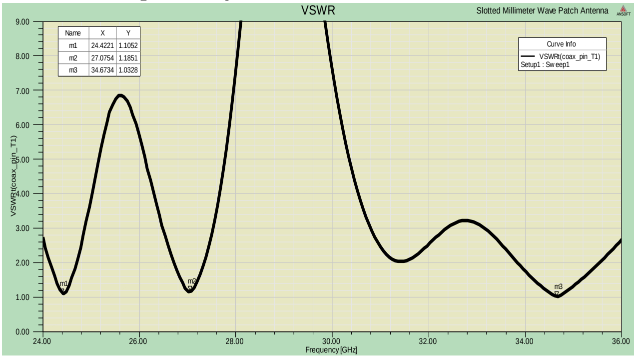

Figure 5: VSWR Vs Frequency

The Input Impedance plot is shown in figure 6. The Impedance bandwidth is obtained as 98.28%.

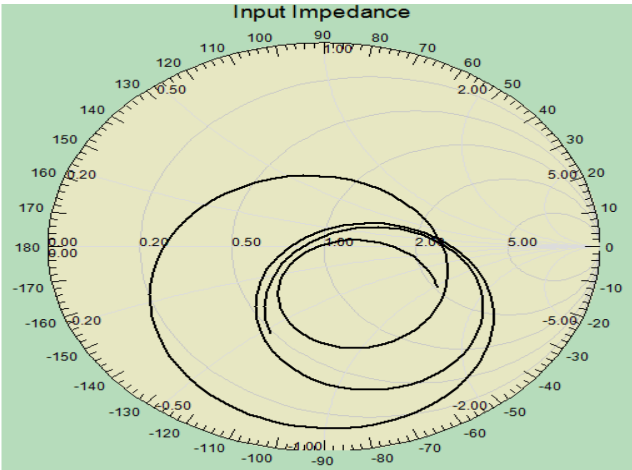

Figure 6: Input impedance smith chart

The E-Plane and H-Plane Radiation Patterns at resonant frequencies is shown in figures 7 and 8.

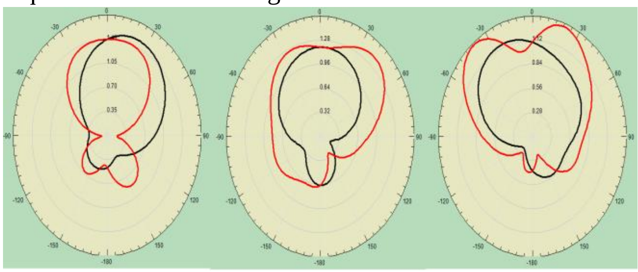

Figure 7: E-Plane Radiation Pattern for Phi=0 deg and Phi=90 deg

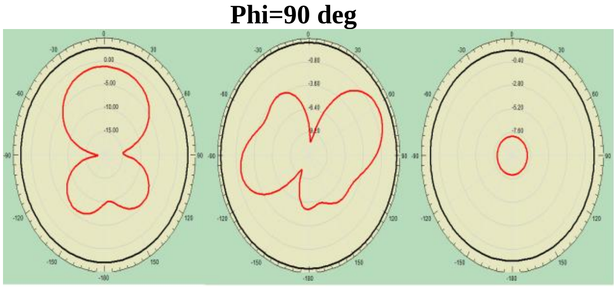

Figure 8: H-Plane Radiation Pattern for Theta=0 deg and Theta=90 deg

The polarization of an antenna of an electromagnetic wave is defined as the orientation of the electric field vector. It is described by the geometric figure traced by the electric field vector upon a stationary plane perpendicular to the direction of propagation, as the wave travels through that plane. An electromagnetic wave is frequently composed of two orthogonal components in the directions of x and y axis. The sense of antenna polarization is defined from a viewer positioned behind an antenna looking in the direction of propagation. The polarization is specified as a transmitting, not receiving antenna regardless of the intended use. The radiation pattern is taken both for a co- polarized and cross-polarized response. The polarization quality is expressed by the ratio of these two responses. The E-Plane Radiation pattern is directional from figure 7 and H-Plane Radiation Pattern is Omni-direction from figure 8.

The Electric field, Magnetic field, Surface Current distribution and Mesh Plot at 27.02 GHz are shown in figures 9-11.

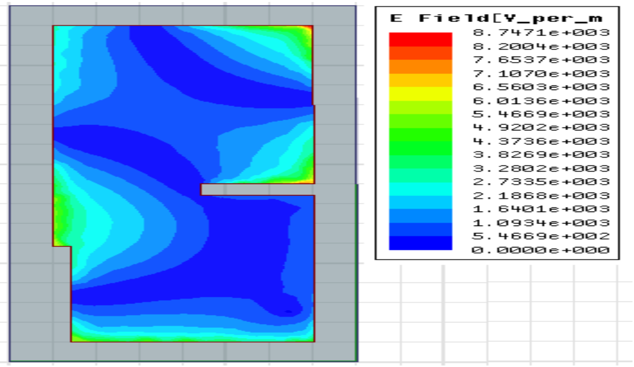

Figure 9: E-Field distribution

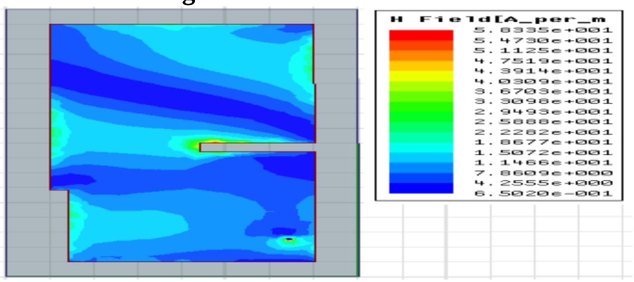

Figure 10: H-Field distribution

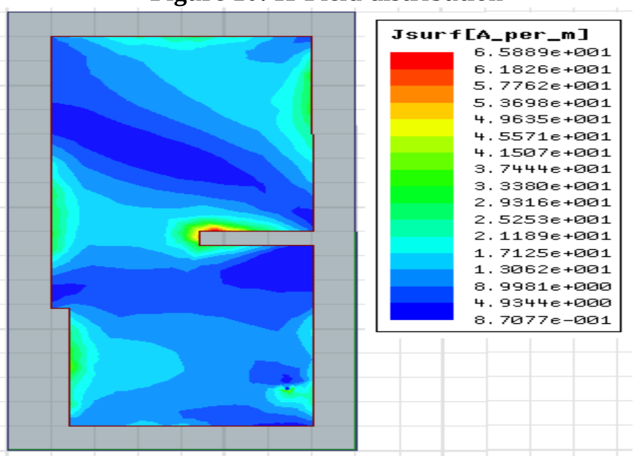

Figure 11: Surface Current distribution

Gain is another measure to describe the performance of an antenna. Directivity and gain are used interchangeably. The difference is that directivity neglects antenna losses such as dielectric, resistance, polarization and VSWR losses. Is these losses of antennas are quite small, the directivity and gain will be approximately equal. Gain is defined as the ratio of the radiation intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropic ally. The peak gain of the proposed antenna is 5.8 dBi as shown in figure 12.

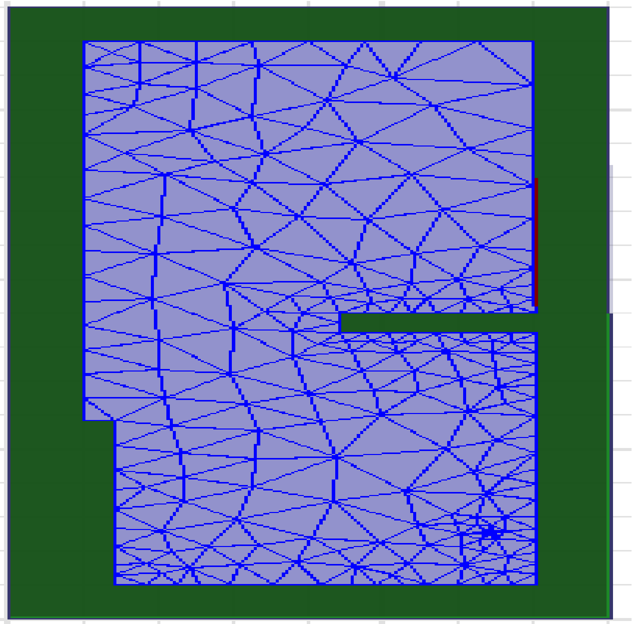

Figure 12: Mesh generation plot

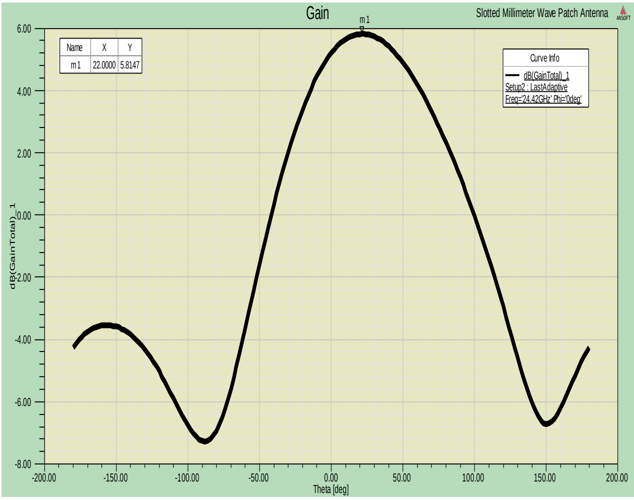

Figure 12: Two dimensional Gain

IV. CONCLUSION

A novel multiband slot antenna was designed and simulation results are presented in this paper. By changing the dimensions of the slot the performance characterization of the antenna was studied with respect to its output parameters.

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When we change the dimensions of the slot y1, the antenna is resonating at triple band and by changing the dimensions of the slot x2, the antenna is resonating at quad band. Bandwidth of 0.98% is achieved by adjusting the slot dimensions to optimum values. Gain of almost 5.8 dB and radiation efficiency of 0.98 is attained from the current model.

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