Chapter 6

HIGH GAIN K/Ku BAND MIMO ANTENNA FOR SATELLITE APPLICATIONS

Lower frequency spectrum possess low bandwidth. K/Ku band are high frequency bands and are considered to be potential bands for upcoming research. Lot of work is going on in the field of antenna design for satellite application (K/Ku band) using techniques like array antenna, slot,defected ground structures, parasitic element etc.

6.1 Compact, high Gain, low Profile, square slot diversity antenna for K/Ku band application

Evolution of 3-element diversity antenna

The development of geometry and final configuration for 3-element diversity antenna is represented in Figure 6.1. The parametric study shows the improvement of gain of the antenna and finally, Figure 6.1(d) is chosen for fabrication of prototype on the basis of maximum gain value. The optimized dimensions for designed structure (All values in mm) are given in Table 6.1. All the three radiating antenna elements are shared on the common ground plane. Initially, simulation for single element antenna was carried out and broadside simulated gain for single radiator is found as 4.7 dBi. To achieve more the gain of antenna, number of elliptical radiators are increased and

Parameter	L_g	W_g	L_s	W_S	L_q
Dimensions(mm)	27.4	27.4	2.4	2.4	3
Parameter	W_q	L_f	W_f	major R	minor R
Dimensions(mm)	0.5	5.9	2	2.025	2.2275

Table 6.1: Dimensions of 3-element slotted MIMO antenna

the gain becomes 5.35 dBi. After increasing number of slotted radiators the gain

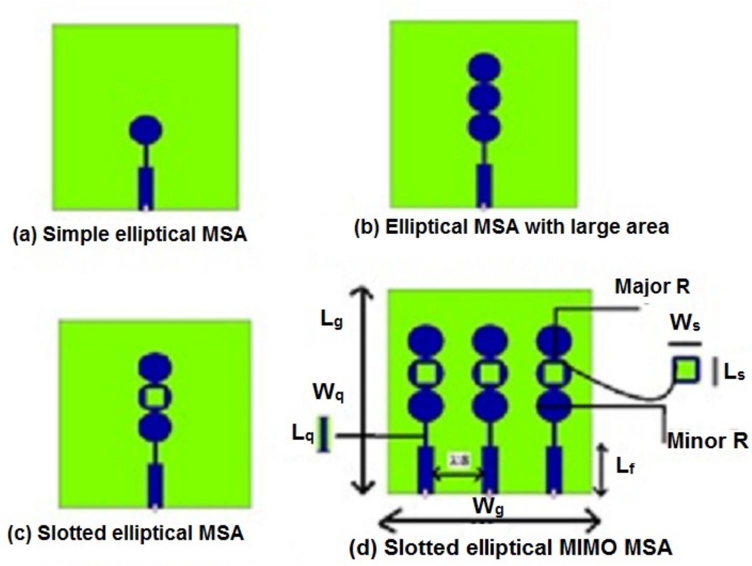

Figure 6.1: Structure of 3-element MIMO antenna

of 10.94 dBi can be achieved. Good isolation between radiating elements can be achieved by placing each elements $\lambda/8$ apart. Planar FR4 substrate with $\epsilon_r = 4.4$ and $tan\delta = 0.02$ is used for fabrication. The final dimensions of three element antenna is $27.4mm \times 27.4mm$. Quarter wave transformer is used as matching element with dimensions $[L_q \times W_q]$. The slot with dimensions $[L_s \times W_s]$ has been etched in the middle antenna element to achieve large impedance bandwidth. The feeding line and the ground plane are directly connected with the SMA connector. Small variation in the simulation and measurement result was observed due to cables and connector losses and due to properties of material used for fabrication. Figure 6.2 shows hardware of the same.

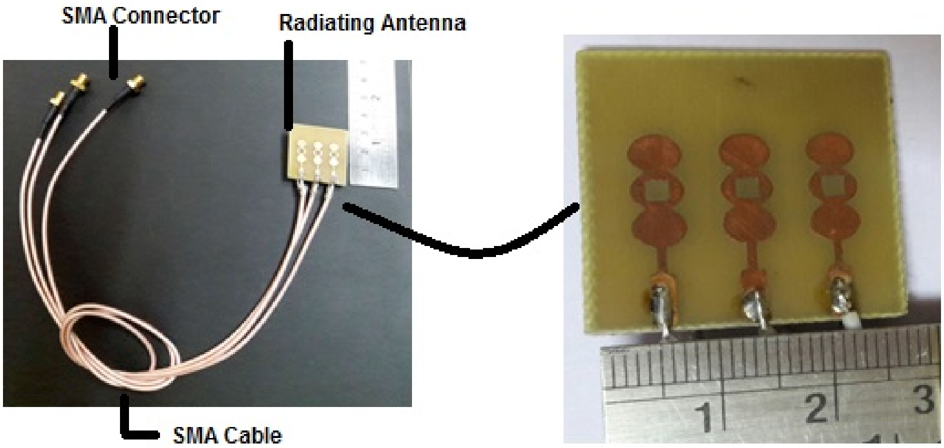

Figure 6.2: Fabricated prototype of 3-element slotted diversity antenna

6.1.1 Results and discussion

A. Impedance and isolation characteristics

The simulation for basic antenna characteristics were carried out using IE3D mentor graphics software. S- Parameter (S_{11}) and isolation characteristics (S_{12}/S_{13}) measurements were carried out using an Agilent-N9918A vector network analyzer as shown [Figure 6.3]. Figure 6.4 and Figure 6.5 respectively shows comparison of simulated

Figure 6.3: Testing using vector network analyzer (S_{11} and S_{12}/S_{13})

and measured characteristics for impedance bandwidth and isolation loss.

The three element structure has return loss i.e. $|S_{11}| <$ -10 dB for frequency bands of 14.8 GHz to 16.76 GHz, 18.44 GHz to 19.28 GHz, which is shown in Figure 6.4. Since

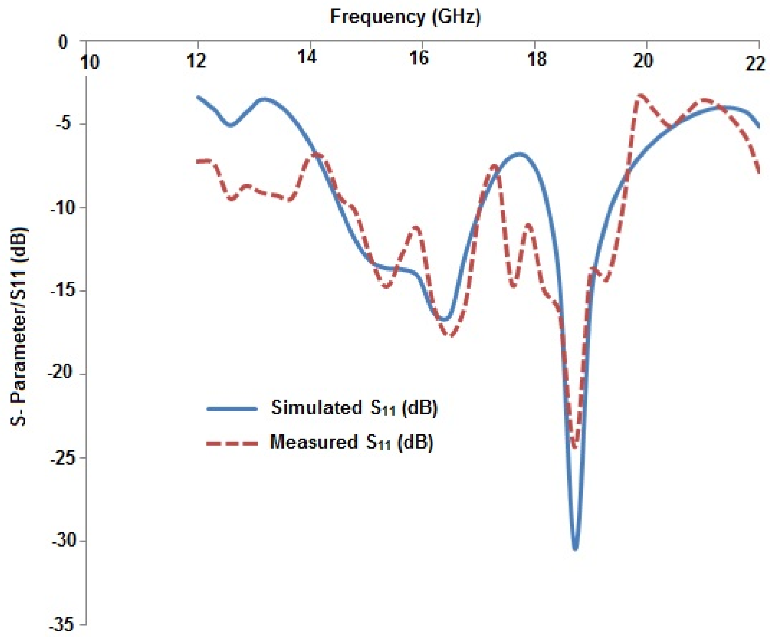

Figure 6.4: Comparative study of simulated and hardware results of S_{11} for 3-element slotted diversity antenna

all the radiating elements are similar in structure and placed at equal distance, hence $S_{11} = S_{22} = S_{33}$. While performing measurement with respect to one port, the other two ports are terminated with 50Ω matched load. The bandwidth obtained for each band is 1.96 GHz, 840 MHz respectively. The isolation characteristic is shown in Figure 6.5 for the proposed MIMO antenna between port 2 and port 3 with respect to port 1. To achieve high isolation, two radiating elements are kept $\lambda/8$ apart. Fabrication and calibration errors lead to variation in the simulated and measured results but results are acceptable for Ku band communication.

B. Radiation and gain characteristics

The radiation characteristics in E-plane and H-plane were measured with respect to port 1 in a semi-anechoic chamber. The co-polarized (Co-Pol) and cross polarized (Cross-Pol) patterns were measured for 15 GHz and 16.5 GHz frequency and are shown in Figure 6.6. While measuring E-plane and H-plane patterns with respect to port 1, port 2 and port 3 were terminated with matched load of 50Ω. Omnidirectional patterns are observed in H-plane and bidirectional pattern in E-plane. Higher order modes on radiating planes generates small amount of cross polarization in both the planes. Figure 6.7 shows simulated antenna gain for frequency range from 12 GHz to

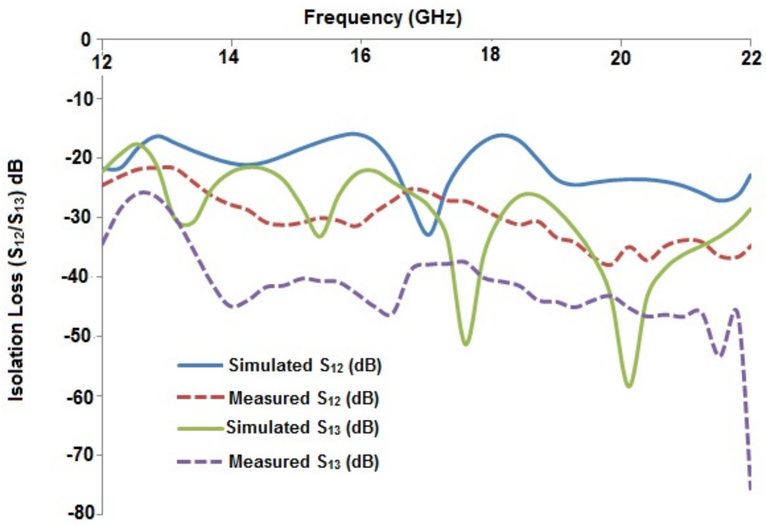

Figure 6.5: Comparative study of simulated and hardware results of S_{12} / S_{13} for 3-element slotted diversity antenna

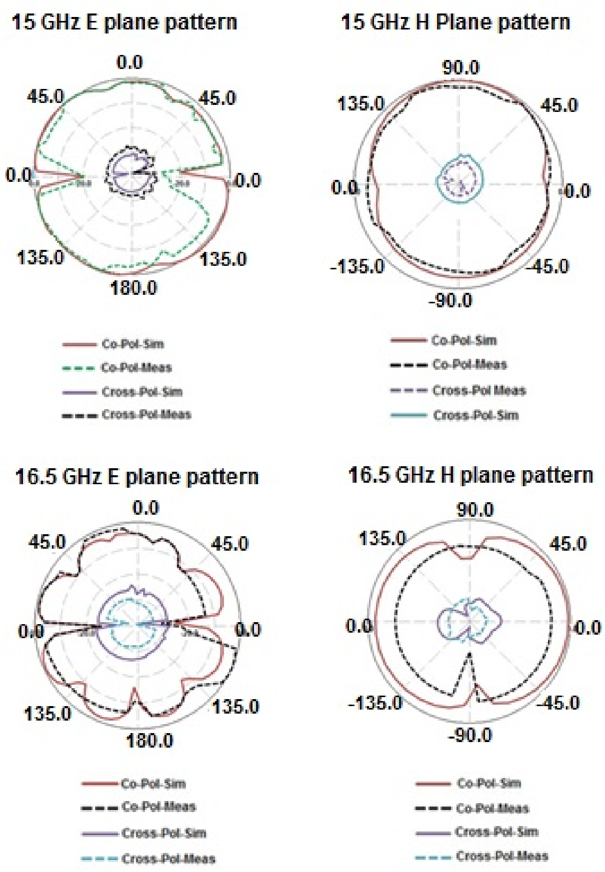

Figure 6.6: Comparison of radiation characteristics for 3-element slotted diversity antenna

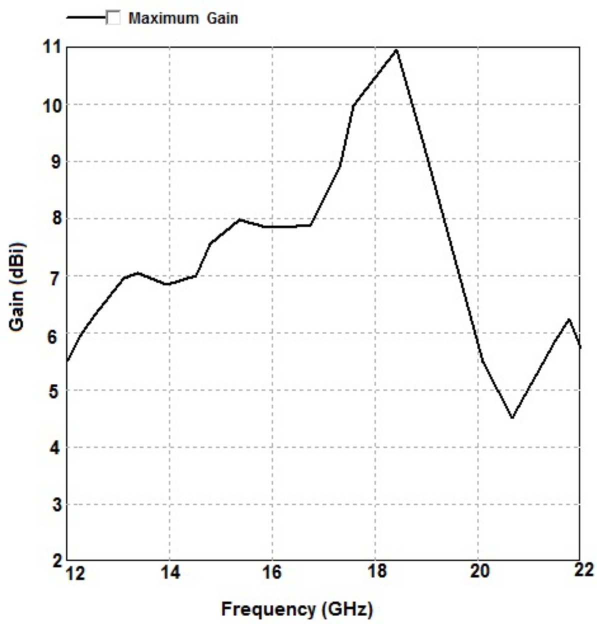

Figure 6.7: Simulated maximum gain of for 3-element slotted diversity antenna

22 GHz and it is is greater than 3.6 dBi with the maximum gain of 10.94 dBi at 18.5 GHz frequency.

C. Current Distribution Characteristics

Figure 6.8 demonstrates surface current distribution for 16.5 GHz, 18.5 GHz and 22 GHz. The surface current distribution with respect to port 1 shows strong current is seen near square slot and at the excited port. Current distribution is comparatively weak near ports other than excited ports leads for decoupling characteristics. The suppression in the surface waves improves the isolation between two radiating elements.

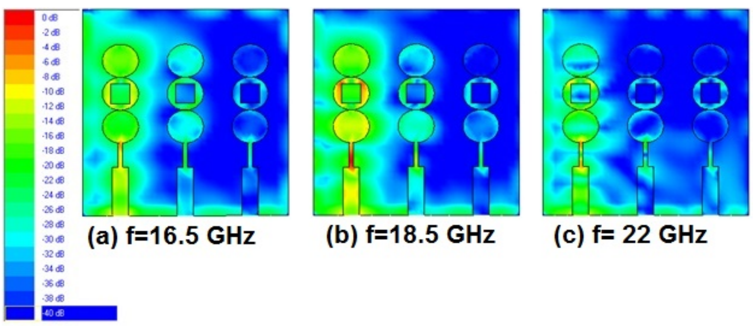

Figure 6.8: Simulated surface current distribution of for 3-element slotted diversity antenna

D. Diversity Characteristics

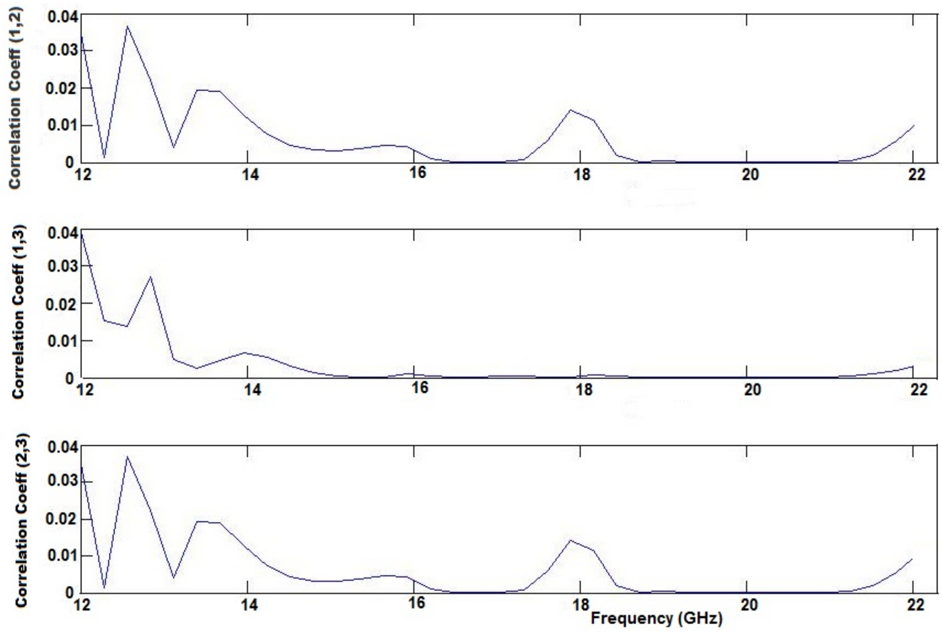

Figure 6.9: Simulated ECC (Envelope Correlation Coefficient) of for 3-element slotted diversity antenna

Channel capacity is very important parameters for MIMO systems. Channel capacity depends on number of elements used in transmitter as well as receiver side of MIMO systems. At the same time diversity behaviour of the system also plays important role.Envelope correlation coefficient (ECC) characteristics decides the diversified behavior of the MIMO systems. The correlation coefficient must have small value for efficient diversity characteristics. The relation between envelope correlation and diversity gain is found in [67]. Figure 6.9 represents the ECC values obtained for three element antenna using eqn. (2.7) between port 1 and port 2, between port 3 and port 1 and between port 2 and port 3. A very small value of ECC with respect to all ports are nearer to zero, hence three element antenna is more suitable for MIMO communications. The approximate diversity gain for the proposed antenna is calculated by eqn. (6.7) [68]. All measured and simulated results prove that the proposed three element slot antenna with high gain, compact size is suitable for MIMO systems for Ku band application.

Three element diversity antennas are suitable for Ku band applications. High gain is achieved by increasing number of antenna radiators. Quarter wave transformer is *used for reducing mismatching of impedance generated at feed line. Very low value of ECC with high diversity gain makes antenna suitable for diversity applications. Most of the antennas investigated in previous chapters are linearly polarized. To achieve dual polarization with high gain, more number of radiating elements oriented in different directions must be used. Next chapter includes design of MIMO antenna for multiband application possessing dual polarization and high gain.*