Novel Ku Band Reflect array Antenna for Satellite Communication

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Abstract - This paper focuses on the design and analysis of Ku band reflect array antenna using a novel crossed dumbbell(clover) patch unit cell. The reflect array proposed is to pave way for a new generation miniaturized satellite communication, finding an important application in the Satellite newsgathering (12.5 GHz-13.75 GHz) .The clover shaped unit cell is designed for 13.07 GHz and the suitability of the unit cell is validated using the phase characteristics analysis. The effect of the elements on the performance represented by the range of the reflection phase is of prime importance. From the observation, Clover unit cell has large phase variation compared to minkowski and koch unit cells. Therefore, the main purpose of this paper is to investigate and validate the novel unit cell with a wide phase characteristics and the reflect array constructed.

Keywords: — Microstrip antenna, Phase characteristics Reflect array antenna, Satellite communication.

1. INTRODUCTION

RADAR and long distance communications demands high gain antennas. Traditionally, high - gain applications have relied upon parabolic reflectors or arrays. At high frequencies parabolic reflectors poses complexity in manufacturing due to its curved geometry, added to this parabolic reflectors lacks wide - angle beam scanning. On the other hand, the high - gain array antenna provides wide angle beam scanning at the cost of complexity and expensiveness. In order to sort out the aforementioned issues, a new concept of "reflect array" has been evolved and combines the advantages of reflectors and array antennas [1]. The Proposed design is to work for the satellite communication- satellite newsgathering(12.5 GHz- 13.75 GHz), Fixed links(13.25 GHz-13.75 GHz) and Aeronautical Radio navigation (13.25 GHz- 13.4 GHz) in the Ku band centered at 13.07 GHz in a miniaturized dimensions of 13.8 cm x 13.8 cm with 117 elements present in the reflect array.

The paper is presented in the following manner. First the details of the unit cell is furnished, second the simulation of an unit cell , thirdly the construction of the reflect array and the last section the simulated results are analyzed to prove the credibility. Reflect array and various unit cells used, are extensively studied in the literature [2-9]. Variety of reflect array unit cells are available in literature for different applications and with different phase characteristics. Phase characteristics is one of the prime factor in designing the reflect array unit cell. The frontier of its kind is a square patch having a phase variation less than 360 deg [3]. The unit cells of various configurations of koch and minkowski elements gave a phase of 300 degrees only [2]. The reflect array using dielectric resonator was also proposed and gave a phase of 360 degrees only [4]. The novel crossed dumbbell (clover) patch unit cell proposed has a wide phase characteristics of more than 410 degrees which is greater than the unit cells proposed in [2-5][7]. The novelty is addressed in terms of unit cell geometry and its excellent phase characteristics.

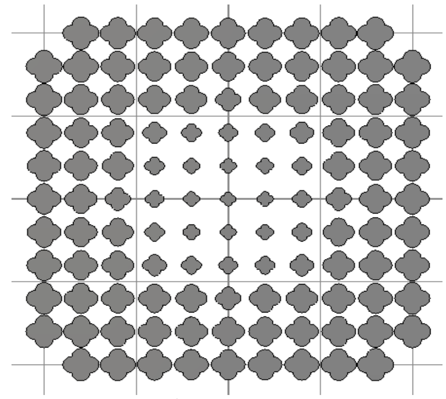

Fig. 3 Reflect array constructed.

2. UNIT CELL DESIGN

2.1. Proposed Structure

The proposed unit cell geometry shown in Fig.1 is derived from combining the four circles of equal radii R=2.875 mm to work at 13.07 GHz with a dimension of 1.15 cm x 1.15cm (L=4R). Simple structure enhancement is the notion here, which is achieved by means of convoluted structures. Multitudes of structures were tried out and the best of it is used to satisfy the application and the phase response characteristics. The clover patch (thickness of 0.035mm) is designed on a Rogers RT6002 substrate [with ε_r=2.94 and loss tangent of 0.0023] over a height of 0.05mm. Fig.1 explains the formation of the crossed dumbbell(clover) shape. Initially a dumbbell is formed, then another dumbbell perpendicular to it, is fused to the initial dumbbell and hence a novel crossed dumbbell(clover) shape is obtained.

2.2. Simulation of the unit cell

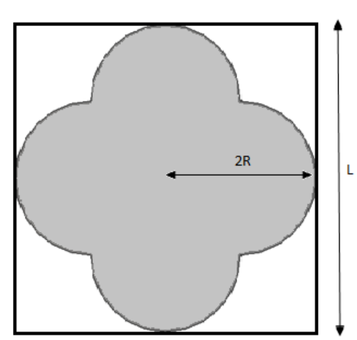

Fig. 1 Proposed unit cell.

Clover unit cell of the reflect array is modeled and parameters such as permittivity which is dielectric constant, substrate and copper thickness, tangential loss and geometry of radiating element are defined. Perfect Magnetic Conductor (PMC) boundary condition was

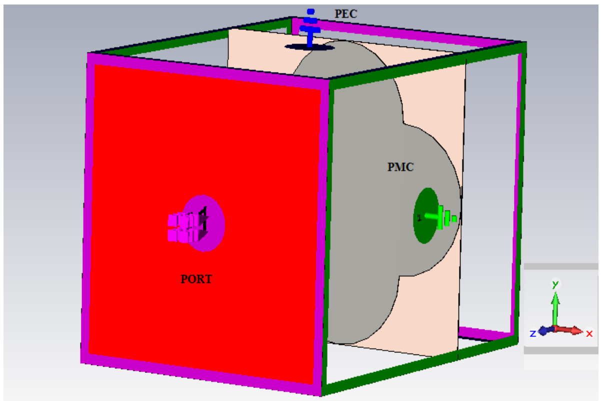

Fig. 2 Boundary conditions for the simulation of the unit cell.

setup on the left and right hand side of a unit cell reflect array in x-axis and Perfect Electric Conductor (PEC) boundary condition was setup on the bottom and top of a unit cell in y-axis. The incident wave will propagates along z-axis whereas the E-field of the incident energy is polarized in y-axis and the H-field of the incident energy is polarized in x-axis. These boundary conditions are to make sure the unit cell receives an incident energy from a plane wave. Figure 2 illustrates the example of simulated unit cell reflect array with clover patch as a reflect element.

Mesh cell or meshing size is very important parameter and has an impact on the accuracy and speed of the simulation. Another point of consideration is the port location and port mode. The port in the simulation will play an important role as an excitation source to capture the reflection, it is required to be located at least 0.25λ from the unit cell in order to ensure reception of a normal incident wave (0 degree) .The first mode or dominant mode which is TE_{10} will be chosen to propagate and excite that unit cell of reflect array [2].

2.3 Reflect Array and Simulation Results

Fig. 3 shows the reflect array constructed using the novel clover patch elements of variable sizes in order to overcome the individual path differences which leads to the phase differences when fed by a horn antenna. The interelement distance between the two clover elements is taken to be equal to 0.5 times the free space wavelength which is equal to 1.15 mm. The dimensions of the reflect array constructed is 13.8 cm x 13.8 cm. A ground plane of thickness 0.5mm is kept in order to reduce the back lobe radiation.

Full wave simulation is performed using EM solver. The reflection characteristics of the clover shape unit cell are illustrated in Fig.4. The reflection coefficient of -0.693 dB is observed at 13.07 GHz. It can be concluded that the clover unit cell has a good return loss and therefore they can be considered as a good reflector as the reflection is more than 90%. Fig.5 shows the phase characteristics that is phase vs radius parameter of the clover element. This witnesses the phase response obtained is more than 360 deg. and the reflection phase ranges from 52 deg. to -362 deg. leading to a reflection phase of 414 deg.

Fig.6 illustrates the excitation of the reflect array using a horn antenna which is placed at a distance of 0.97 times the reflect array dimensions that is at 13.386 cm (f/D=0.97).

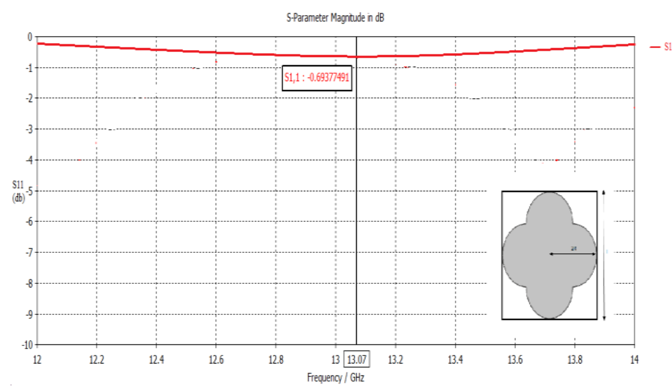

Fig. 4 Reflection coefficient S_{11} of the clover unit cell.

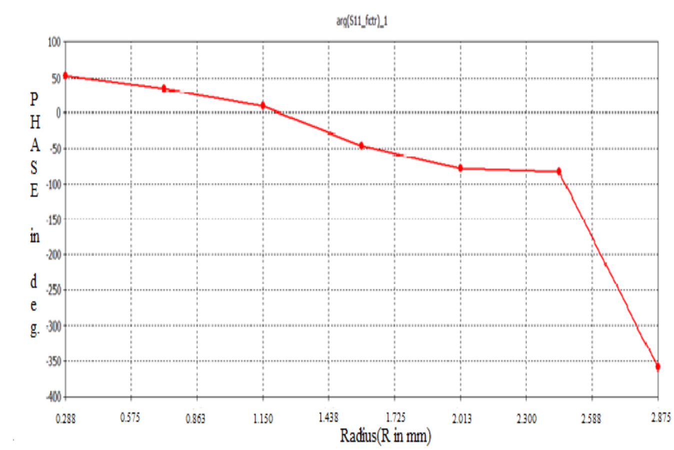

Fig. 5 Reflection phase vs radius of the clover unit cell.

Fig. 7 shows the normalized E-Field pattern and it is noted that the side lobe level(SLL) is -18.5 dB, Angular width is 5.6 deg. and from the analysis it is found that

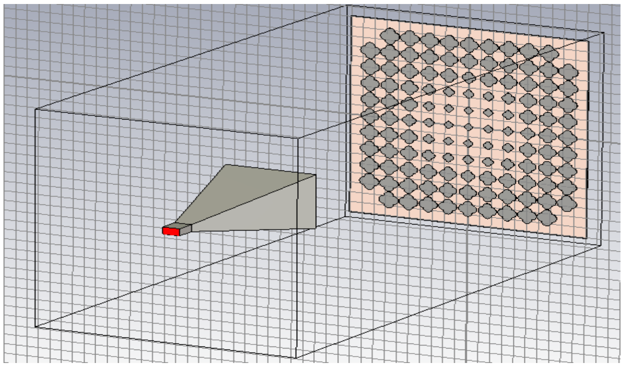

Fig. 6 Reflect array setup fed by horn.

the directivity is 24.5 dBi and the gain is 24.03 dB. Table 1 summarizes the characteristics and features of the novel clover reflect array.

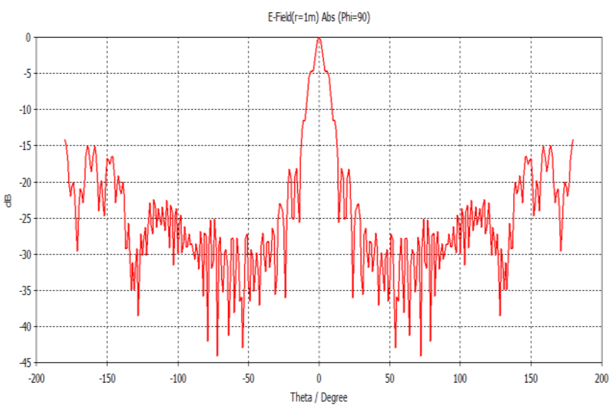

Fig. 7 E-Field radiation pattern.

TABLE I
PERFORMANCE OF CLOVER REFLECTARRAY

Parameters	Value
Phase range (deg.)	414
Gain (dB)	24.03
Side lobe level (SLL)	< -18.5 dB
-3 dB beam width (deg.)	5.6
E field (dBV/m)	39.14

3. CONCLUSION

A Ku band reflect array antenna which has the features of novel unit cell and wide phase characteristics is discussed in this paper. From the results, investigating the clover unit cell , it can be validated and may be called as a good reflector for the reflect array with reflection more than 90% and provides a wide reflection phase greater than 410 deg. compared to the phase obtained in [2-5] . The feed arrays show deep SLL suppression, high gain and directivity which is suitable for the satellite communication. Further study should focus on improving the - 3 dB Beam width, rigidity, reduction in the cost of the construction of the reflect array and also the reduction of the back lobes using frequency selective surface as proposed in [8].

V . REFERENCES

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