DESIGN AND ANALYSIS OF REFLECTARRAY ELEMENT IN KU BAND FOR SATELLITE APPLICATIONS

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Abstract

The paper discusses the design and study of a reflect array antenna element in Ku band using a novel tilted concave patch unit cell. Conventional microstrip patches are small in size but their gain is quite low for most applications. Hence, a reflectarray element in the shape of a tilted concave structure is proposed. The reflectarray can be constructed using the proposed elements to achieve high gain. Different configurations like extended port, bent port have been analysed.

Keywords: reflectarray antenna, tilted concave structure, port excitation

I. INTRODUCTION

Long distance communication requires high gain antennas. Conventionally, applications that require high-gain mostly depended on parabolic antennas and arrays. Manufacturing parabolic antennas becomes complex at high frequencies because of its bent geometry. The parabolic reflector does not provide extensive beam scanning whereas, high-gain arrays provide extensive beam scanning but are complex and highpriced. In order to resolve the above mentioned concerns, a new conception called "reflect-array" has been developed which adds the advantages of both parabolic-antennas and arrays [1].
The proposed design is for satellite applications.

A microstrip reflectarray antenna encompasses a slim reflecting surface with elements printed on it in an array manner and a feeding antenna in front of it. The array elements are illumed by the feed element. The signals incident on it are radiated back by the array elements which forms an even planar phase front. The length of the path between the centre element and feed is smaller than the path length between the corner elements and the feed. In order to achieve a planar wave front path lengths difference should be compensated, arrays with variable size elements are reported in [2]. Phase Difference can also be compensated with stubs of variable lengths [3].

For many applications like personal mobile communications and portable communication systems the size of the microstrip antenna (MSA) needs to be small [4]. The size of a MSA of regular shapewhich is operating in the Ultra High Frequency (UHF) band is quite large because the frequency is inversely propotional to its resonant length . Therefore modifications in conventional MSAs are reqired in order to design a smaller or a compact antenna at these frequencies [4]. One way of designing a compact antenna is to cut a whole ellipse into a tilted concave shaped patch. The tilted concave structure is smaller in size compared to the full-ellipse structure. Usually, the unit cell has a low gain, but when used in an array the resultant gain could be sufficient. Hence, three elements are proposed for the formation of an array.

The paper is structured as follows. Initially, the details of the array elements are provided. Next, the simulations of three modified unit cells are presented, and the last section consists of analysis of the simulated results and proof of their credibility. Reflectarrays and several other unit elements are thoroughly learned in literatures [6-12]. A diversity of reflect array unit elements with different designs for several applications are available in the literature. Each unit cell had a unique gain and phase response. One major factor in designing a reflect array unit cell is the phase characteristics. The square patch is most widely used and has a phase variation equivalent to 360^0 [3]. All the Koch and Minkowski unit-cells showed a phase difference of 300^0 only [1]. The reflect array using dielectric resonator was also proposed and had a phase difference of 360^0 only [8]. The proposed novel tilted concave unit-cell displays an extensice phase difference of nearly 400 degrees.

II. UNIT CELL DESIGN

1. Proposed Structures

The proposed geometry of the unit cells shown are derived from cutting the full-ellipse structure into a tilted concave structure to work at 12GHz. Unsophisticated structure enrichment is the idea here. This idea is realized using intricate structures. The tilted concave element with thickness 0.5mm is designed on a Rogers substrate with εr =3.5. Fig.1 explains the formation of the three tilted concave patches. Initially, a full ellipse is formed, then it is cut into half and a novel tilted concave structure is obtained. The port length and positions are varied and the three structures are analysed for phase, gain and return loss.

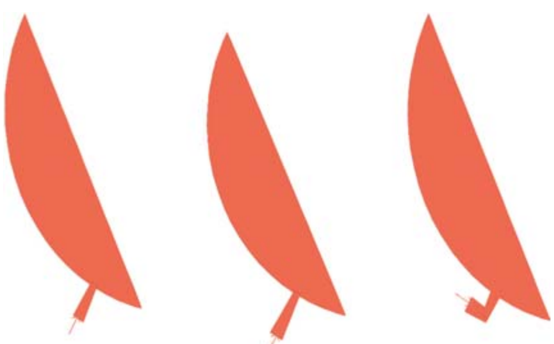

Figure1: Three Unit Cell Structures

2. Reflectarray Element Simulation Scenario

The unit cell of the reflect array element is designed using factors like permittivity, substrate, thickness of patch, and the radiating element's shape. The element is designed by means of an offset fed setup such that high directivity is achieved in the desired direction. The simulation is carried out using Agilent ADS Software using Method of Momentum technique.

One of the prime factors that have a key influence on the precision and simulation speed is the size of the mesh cell. The port location and the mode of the port are other factors to be considered. The location of the port, which acts as an illuminating source during simulation, plays a vital role in capturing the reflection. In this analysis, the port length, size, and position are varied and the elements are studied for each variation.

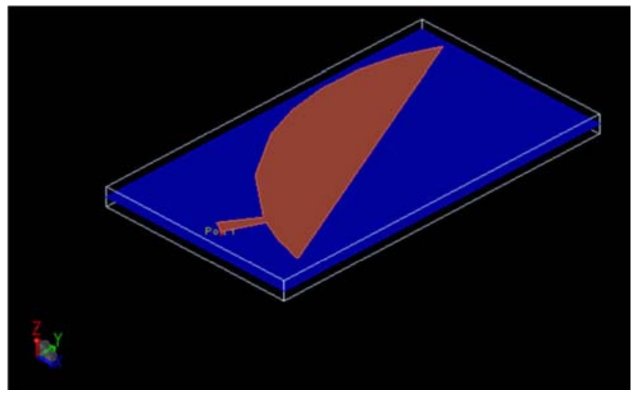

Figure 2: Isometric view of the unit cell

3. Simulation Results

The structure which was simulated is shown in Fig. 2 demonstrating the plane of symmetry, the conductor, and the substrate layers. The reflectarray element's performance characteristics are shown in Fig. 3. Reflection coefficients of 2.8dB, 2.5dB and 2.7dB are observed at 12GHz, 12.1GHz and 12.1GHz respectively. This return loss will be suitable for designing a reflector. By using a thin substrate, the element also displays good performance with respect to bandwidth. The bandwidth can be modified by varying the substrate thickness, altering the port size, rotating the element etc. A ground plane is kept to minimize the radiation due to back lobes. Fig. 4 shows the phase variation of the three elements. The phase change achieved is 360 degrees which is much more than the variations observed in other papers [2-4].

The gain plot of the designed reflectarray elements are shown in Fig 5, 6 and 7. A high gain of 5.808 dBi is achieved at 12GHz using element 1, the gain performance is increased to 6.428 dBi for the second element and the gain performance of the third element is found to be 6.647 dBi for the same operating frequency. This gain can be further improved by constructing an array of elements. It can be concluded that the tilted concave structure can be considered as a good reflector due to its good return loss characteristics and high gain performance. Table: 1 summarizes the performance characteristics of all the three elements designed.

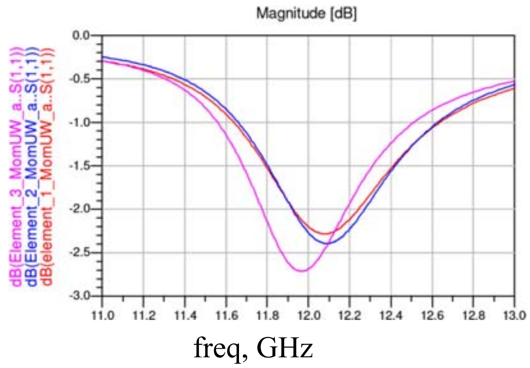

Figure 3: S11 comparison of the 3 unit cells

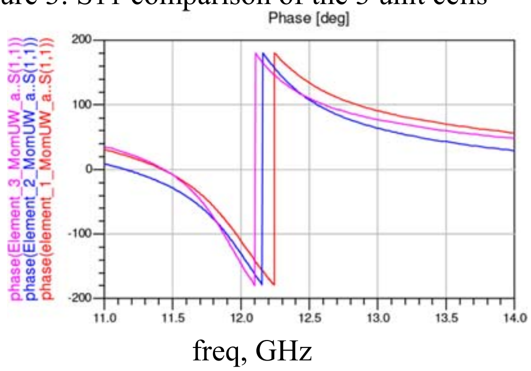

Figure 4: Phase comparison of the 3 unit cells

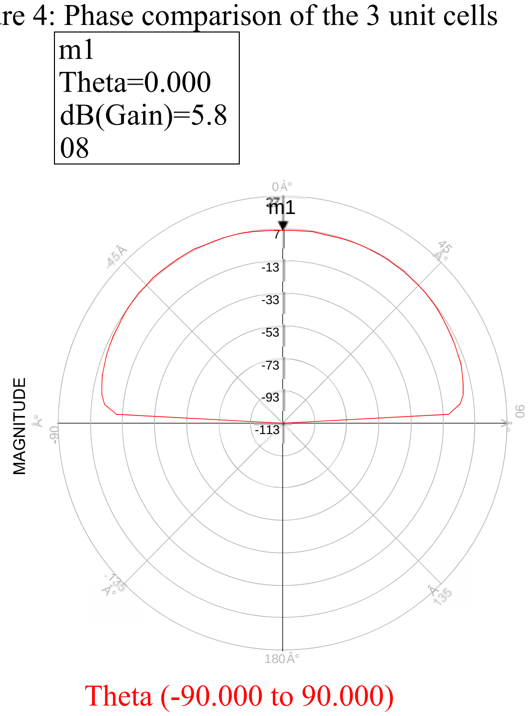

Figure 5: Gain plot for cell 1

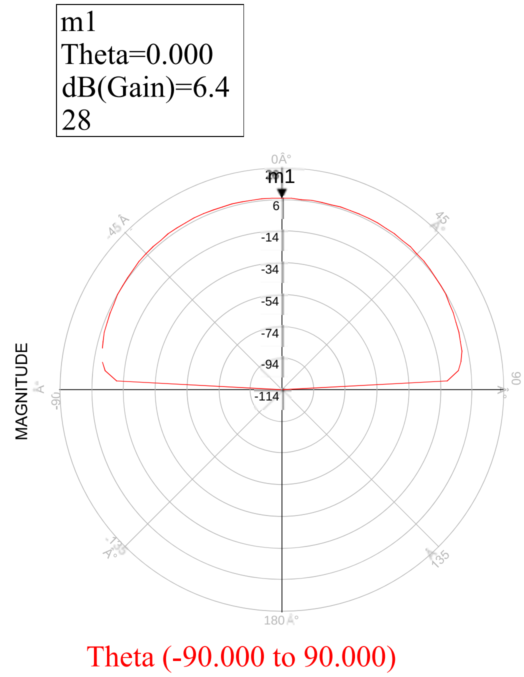

Figure 6: Gain plot for Cell 2

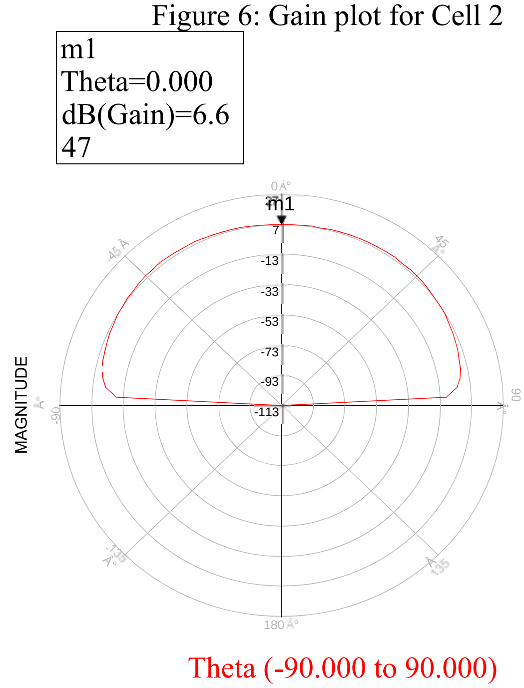

Figure 7: Gain Plot for Cell 3

CELL	PORT LENGTH (mm)	RETURN LOSS (dB)	GAIN (dBi)
1	0.817	-2.8	5.808
2	2.511	-2.5	6.428
3	Bent at 0.367	-2.7	6.647

Table 1: Comparison between the 3 cells

III. CONCLUSION

A novel tilted concave reflectarray element has been proposed.

Three variations are designed to achieve phase compensation. A broadside beam reflectarray antenna with port excitation has been suggested and analyzed centered on the mentioned elements. ADS' Method of Momentum (MoM) was used to simulate the results and to demonstrate good performance of the antenna. The antenna is suitable for applications like satellite communication in which it can be used as a transmitter or a receiver. Moreover, the antenna array can be fabricated at low cost since the antenna element has a single layer structure.

IV. REFERENCES

[1] Sridhar Bilvam, Malathi Kanagasabai, Sandeep Kumar Palaniswamy, Pham Thanh Cong , M. Gulam Nabi Alsath, "*Novel Ku Band Reflectarray Antenna for Satellite Communication*", Research Journal of Applied Sciences, Engineering and Technology, 2014**.**

[2] K. P. Ray, Amit A. Deshmukh and Ameya A. Kadam, "*Linearly Polarized Microstrip Reflectarray with Microstrip Antenna Feed*", IETE Journal of Research, Vol. 59, Issue 4, pp. 294-301, July-August 2013.

[3] Deshmukh, Amit A., Ameya A. Kadam, Kshitij Lele, and K.P. Ray. "*Dual polarized stub loaded microstrip Reflectarray with microstrip antenna feed*", 2015 International Conference on Pervasive Computing (ICPC), 2015.

[4] Amit A. Deshmukh, Kshitij Lele, Ami A. Desai, Saleha A. Shaikh, Sudesh Agrawal, K. P. Ray."*Compact edge shorted microstrip reflectarray antennas*", 2015 IEEE International Conference on Research in Computational Intelligence and Communication Networks (ICRCICN), 2015.

[5] A. A. Deshmukh, G. Kumar, "*Compact Broadband Stacked Microstrip Antennas*", Microwave and Optical Technology Letters, Vol 48, no. 1, January 2006.

[6] Zubir, F., M. K. A. Rahim, O. B. Ayop, and H. A.Majid, "*Design and analysis of microstrip reflect array antenna with Minkowski shape radiation element*," Progress In Electromagnetics Research B, Vol. 24, 2010,pp 317-331.

[7] D. M. Pozar and T. A. Metzler, "*Analysis of a reflect array antenna using microstrip patches of variable size*," Electron. Lett., vol. 29, Apr. 1993,pp. 657–658.

[8] M.G.N.Alsath, M.Kanagasabai and S.Arunkumar," *Dualband dielectric resonator reflect array for c/xbands*," IEEE Antennas and wireless Propag. lett., vol. 11, pp. 1253 – 1256,2012.

[9] D.Oloumi, S.Ebadi, A.Kordzadeh, A.Semnani, P.Mousavi and X.Gong, "*Miniaturized reflect array unit cell using fractalshaped patch-slot configuration*," IEEE Antennas and wireless Propag. lett., vol. 11,2012, pp. 10–13.

[10] Ren, L.-S., Y.-C. Jiao, F. Li, J.-J. Zhao, and G. Zhao, "*A novel dual-petal loop element for broadband reflect array*,"rogress In Electromagnetics Research Letters, Vol. 20, 2011,pp 157-163.

[11] M.E.Bialkowski and K.H.Sayidmarie,"*Phasing characteristics of a single layer microstrip reflect array employing various basic element shapes*," IEEE Procs. iWAT,Chiba,Japan., IT42, 2012 , pp. 79–82.

[12] Ren, L.-S., Y.-C. Jiao, J.-J. Zhao and F.Li, "*RCS Reduction for a FSS-Backed Reflect array using a ring element,"* Progress In Electromagnetics Research Letters, Vol. 26, 2011.,pp 115-123.