Microstrip reflect-array antenna using second iteration Murkowski-like radiating element

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Abstract— A new class of reflect array unit cell with increased phase-shift using single-layer second iteration Murkowski-like with triangles at the four corners of radiating element at frequency of 14GHz is proposed. The structure provides increased number of edges which contributes to increased reflection phase of the element. Using this method, the proposed structure was found to have wide phase-range of 393˚.A centre-fed reflect array antenna is designed and from simulation results, the structure is found to have low SLL -15dB, realized gain of 28dB, and overall efficiency of 94.85% at operating frequency 14GHz.

Index Terms— *Micro strip reflect array antenna, single-layer, second iteration Murkowski.*

1 Introduction

Traditionally for radar and long distance wireless communications, high-gain antennas play a vital role. Therefore, in such application parabolic reflectors or arrays are mostly relied on [1]. However, parabolic reflectors are difficult to manufacture due to its curved surface especially at high microwave frequencies; as there are significant increase in size at higher frequency [2]. On the other hand, array antenna requires complicated electronic circuit and expensive amplifier module to achieve wider beam scanning which may add losses to the antenna itself [3]. As a result, reflect arrays are being evolved in the field of scientific research to lessen the problems associated with the parabolic reflector and conventional array. Micro strip Reflect-array Antenna reutilizes some of the basic features of the parabolic reflector and conventional array. Plus, it also consists of a very thin printed conducting elements separated by a dielectric substrate to the ground plane. The feed (mostly horn) illuminates the Radiating surface of the reflect array which are designed to re-radiate the incident field to form a pencil beam in a required direction. Unlike the parabolic reflector, micro strip reflect array is flat and phase compensation is vital in designing micro strip reflect array antenna. However, due to the flat nature of the reflecting surface, the re-radiated field appeared to be out of phase from the centre-feed to the reflecting elements, each of which is designed to reflect an incident wave with a phase shift proportional to the phase centre of the feed, the distance travelled by the reflected waves to the none centred element is more than that of the centred, hence each element will propagate and presents a different phase from one element to another, which makes phase compensation very essential in reflect array design [4].

As a result, a few methods of phase compensation for reflect array are available which includes reflect array with variable patches size [5], variable stub lengths [6], reflect array with variable size slots on ground plane [7], as well as reflect array with variable rotation angles [8]. The stubs in [6] produce some dissipative losses and addition radiation of their own when bent. Varying resonant dimensions to achieve proper phase control as used in [5], produces lower dissipative losses and cross-polarization levels than the stubs. However, this method [9, 10] requires a miniature or micro machined motor placed under each micro strip element to achieve the required beam scanning in a particular direction which will certainly add difficulty in fabrication.

All of the above phase compensation methods mentioned were unable to provide the acceptable phase range (360˚), as generating multiple resonances, enhancing bandwidth, side lobe level (SLL), and phase-shift are among the major concerns to be considered in reflect array design.

To achieve a higher phase range using only single layer substrate, complicated radiating elements are needed to be worked on. These factors are the reason why fractal geometry was introduced as the term fractal is a recursively generated object.

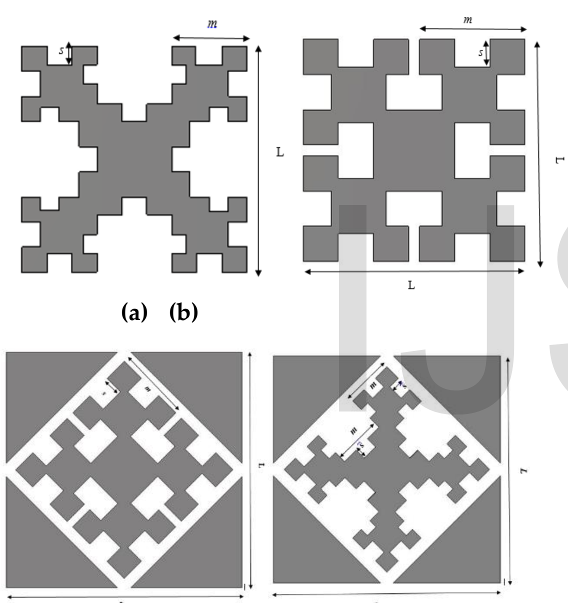
Recently, the first iteration Murkowski patch element has been proposed as demonstrated by [11], however the configuration suffers limitations. The phase range obtained is around 300˚, this is probably due to the inability to properly exploit the miniaturization capability of the radiating element, following the same trend,[12] and [13] introduced a second iteration Murkowski patch element in which phase compensation technique used was of variable slot length and fixed patch length and varying scaling factor respectively. However, the phase-range produced by this configuration in [12] is around 324˚, this is likely due to the additional reflection loss as a result of unwanted back-lobe radiation produced by slot in the ground plane.

Therefore, by adopting variable patch size approach, provides wider phase-range and allows a significant reduction in size. Hence, provide small inter-element spacing giving opportunity to obtain wide scan-angle, as inspired by [12] and [13], a new class of unit cell using second iteration "Murkowski-like" fractal-shape patch with triangles at the four corners of radiating element is proposed.

2 UNIT CELL DESIGN

One of the most essential step in reflect array design is its proper elements characterization. If the element is properly optimized, the reflect array will re-radiate the incident signal from the feed (horn) to the intended direction effectively. The proposed single-layer second iteration Murkowski-like unit cell is obtained from the basic square patch element. Based on figure 1 below, we can the space between shapes like a gap between two conducting surfaces. The small distance between them is seen as a 'slit'. This can cause high current density with increased number of edges progressively from one element to another and hence the discontinuity between element's edges. This effect causes the surface current distributions and electrical dimensions on the element to produce shift in resonance frequency and higher phase range of a reflectarray. This can be seen from the phase response graph in figure 2 (a), it can be observed that the phase range obtained for second iteration Murkowski & Murkowski-like is around (330˚) & (335˚) respectively. While figure 2 (b) presents the phase response for the second iteration Murkowski & Murkowski-like with triangles having higher radiating edges hence provides higher phase agility range of about (390˚) and (393˚) respectively.

However, these characteristics seize to add any significant influence as the number of 'slit' and number of edges is further increased. Moreover, it all depends on the operational wavelength. If we are designing it at higher frequency like 30GHz or more, then the smallest edges and 'slits' counts.



(a) (b)

(c) (d)

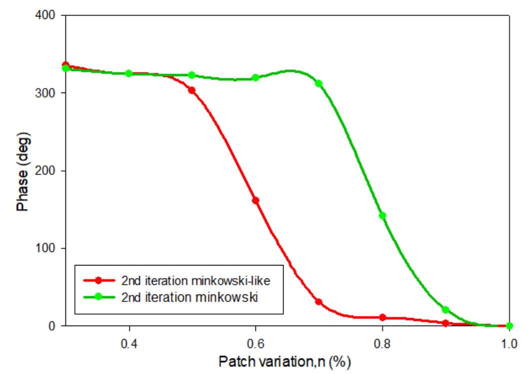
Figure 1. Second iteration (a) Murkowski (b) Murkowski-like (c) Murkowski-like with triangle (d) Murkowski with triangles

The relationship between the element parameters is formulated based on the following equation

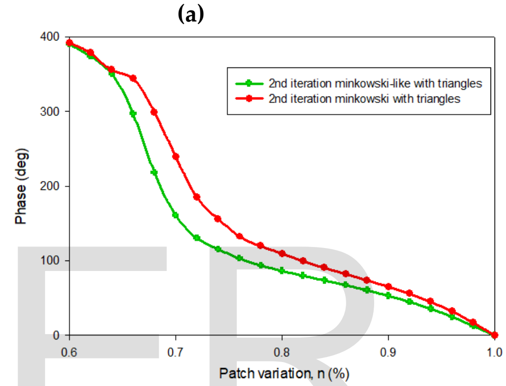
$\eta=\frac{s}{m}$, $0<\eta<1$ (1)

Where η is the iteration factor as the ratio of element dimensions whose value is usually taken to be less than one[14]. The value iteration factor chosen for this work is η= 0.79, for the design of proposed structure, $s$is the cavity of the patch, $l$is patch length. The scattering parameters magnitude/phase are considered as the guide for the development of an individual unit cell at desired frequency 14GHz. Which are generated from the theoretical analysis implemented using waveguide simulator for the available full-wave Computer Simulation Technology Microwave Studio tool (CST MWS).

The proposed structure is printed on the single-layer Taconic RF-35 substrate material with thickness (t=1.524mm), tangential loss (tan δ= 0.0018), and relative permittivity (εr= 3.54). For the phase compensation, the geometry of the patch element is swept within (0.6 – 1) in 2% step width, where n=1 is the resonant size (l=7.40mm). Figure 2 below shows the phase-range obtained for the proposed element to be 393˚.



(a)



(b)

Figure 3. Phase response (a) for 2nd iteration Murkowski & Murkowski-like. (b) 2nd iteration Murkowski & Murkowski-like with triangles.

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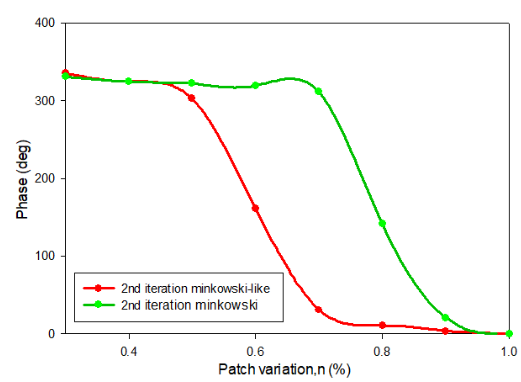

(a)

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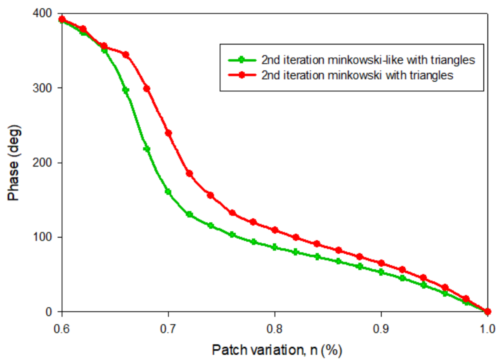
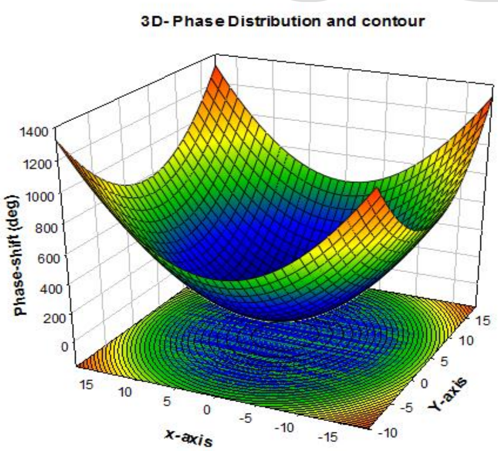


(b)

Figure 3. Phase response (a) for 2nd iteration Murkowski & Murkowski-like. (b) 2nd iteration Murkowski & Murkowski-like with triangles.

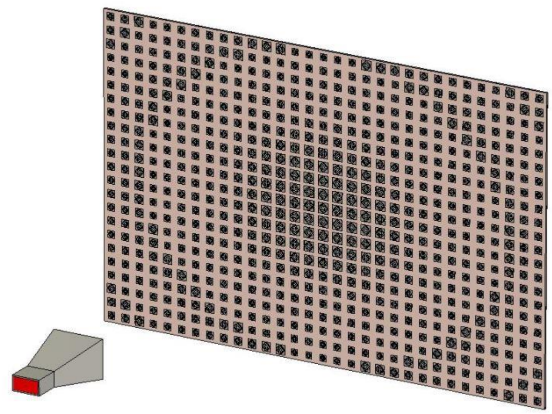
3 REFLECT-ARRAY ANTENNA DESIGN

For reflect array design, the (phase-shift graph) obtained from figure 2 is then used to determine the phase distribution and arranging each unit cell on reflect array surface according to its require phase shift to compensate phase difference based on its distance and position from prime focus reference point of the primary feeding source. Moreover, the equations expressed in [11] have been used to determine the required phase-shift at each element, figure 3 (a) illustrates the 3D and contour phase distribution over the reflect array surface, while (b) shows complete reflect array



with horn.

(a)



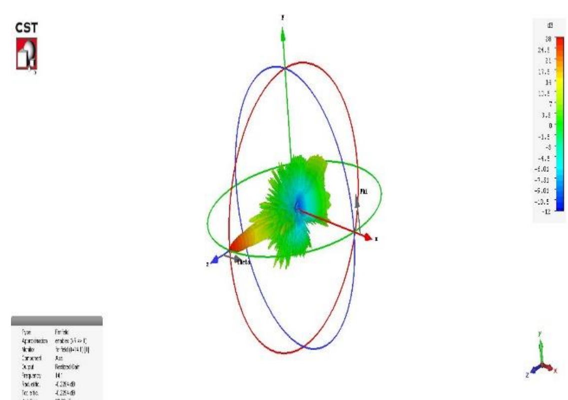
(b)

Figure 3.(a) 3D and contour phase distribution on reflect array surface (b) Complete reflect array with horn

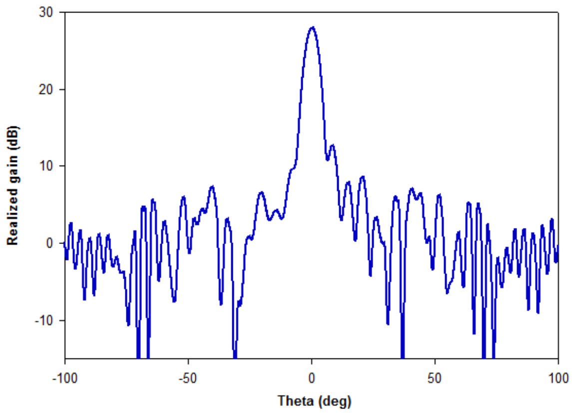
4 RESULT AND DISCUSSION

After obtaining the required phase-shift, the simulation of the complete reflect array incorporated with rectangular x-Ku band feed horn is to investigate the overall performance of the new proposed structure. The analysis is in term of realized gain, half-power beam width (HPBW), side lobe level (SLL) and overall efficiency.

Fig 4(a) and fig 4(b) described the 3D and Cartesian plot of radiation pattern at 14GHz



(a)



(b)

Figure 4. (a) 3D radiation pattern (b) Radiation pattern in Cartesian plane

From figure 4 (a) and (b) shows that the main lobe is in broadside direction with realized gain of 28dB. It can also be observed that the SLL of about -15.4dB which is really appreciable. Besides, the half-power beam width (HPBW) can also be predicted from the same graph, which is about 5.2°and total efficiency of 92.24%. Overall, from the simulation result it is an evident that the proposed structure has significantly increase phase range which in turn improved the performance of the complete reflect array antenna.

Operating frequency	14GHz
Realized gain	28dB
SLL	-15.4dB
HPBW	5.2°
MRA dimension	354.33 x 233.68 mm^2
Total efficiency	94.85%

5 CONCLUSION

This study presents a design, simulation and analysis of micro strip reflect array antenna using second iteration Murkowski-like with triangles radiating element. A phase-range up to 393°achieved and micro strip reflect array antenna is implemented. Based on simulation result, the MRA using the new structure is found to provide a good agreement in term of realized gain low side lobe level at the same time provides good efficiency.

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