Design and Analysis of Concentric Reflectarray Element

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1. Introduction

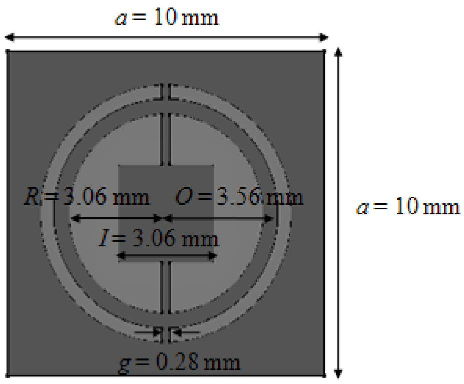
In some wireless communication systems like satellite communication due to the long distance between the transmitter and the receiver high gain antennas are required. Parabolic reflector antenna is a conventional candidate for high gain radiation patterns. However, it is bulky in size and large in mass which makes it unsuitable for the applications like satellite communication. Microstrip reflectarray antennas are good alternatives for parabolic reflector antenna due to their lightness and small size. A reflectarray antenna consists of a reflecting surface and a feed antenna which illuminates the reflecting surface. The reflecting surface is a two dimensional array of radiating elements. The principle of reflectarray antennas using the waveguide technology was first introduced by Berry [1]. Emerging the printed circuit technology and consequently microstrip antennas paved the way for developing microstrip version of reflectarrays [2]. There are three approaches for designing a reflectarray. In the first approach, identical patch elements with different-length stubs are used for obtaining the phase difference required for designing the reflectarray [3, 4]. The second method makes use of the elements with different dimensions to provide the desired phase difference [5–7]. In the third method, for circular polarization only, the circularly polarized elements are all identical, but with different angular rotations [8].

In this paper the second approach mentioned above is employed to design a reflectarray made of microstrip concentric ring square elements. The reflection phase of the element versus the size element is obtained by using the CST Microstripes software. The design of the element is simulated in CST Microstripes and also measured. The simulation of reflection phase versus size element shows good agreement with the measurement.

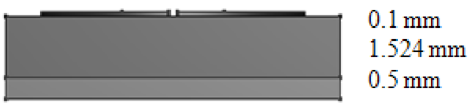
2. Design and Analysis

This paper discusses a series of phase response of element namely concentric split ring square with variation dimensions. Phase response is a value to measure the bandwidth performance of a reflectarray element. The wider phase range and less steep phase graph will leads to the broader bandwidth and high efficiency due to the less phase error.

RF-35 with dielectric constant of 3.54 and loss tangent of 0.0018 at 1.9 GHz is used as the substrate material while copper metal is used as the element and ground plane material. 1.524 mm is chose for substrate thickness while 0.1 mm for element thickness and 0.5 mm for ground plane thickness. The unit cell size is 10 mm x 10 mm. In Figure 1, R is the square ring element radius with dimensions of 3.06 mm while O is the outer ring radius of 3.56 mm. Gap, g is the size of the split introduced in elements with dimensions of 0.28 mm. The size of square hole, I is identical with R. The ratio of R/O value is 0.86 while I/R is 1.



(a)



(b)

Figure 1. The (a) top-view and (b) side-view of concentric split ring square reflectarray element

Figure 2 shows the phase and return loss graph versus frequencies of the concentric split ring square element. This result shows that for less steep phase graph gives the lower return loss. The element developed in this paper can operate in dual frequency operation at 13.44 GHz and 18.36 GHz. From Figure 2, the phase curve at first resonance is less steep and has less plateau region. The return loss is around -0.2dB. While the phase curve at second resonance is steeper with the return loss -0.65dB. In reflectarray antenna concept, the less return loss is better due to the objective of the antenna itself which is to reflect the power instead of to transmit it.

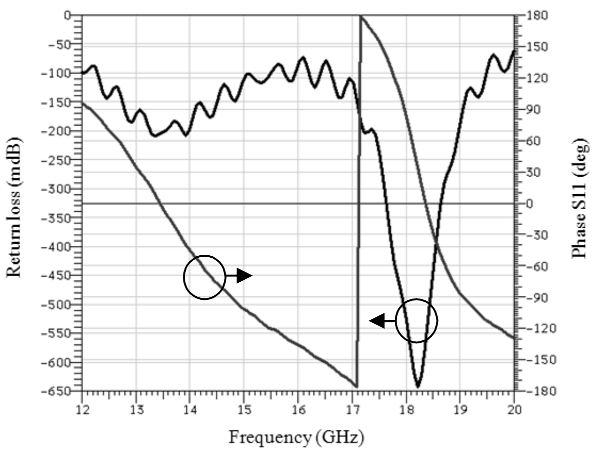


Figure 2. Return loss and phase S_{11} versus frequency for concentric split ring square element

It is clearly shown in Figure 2 that the proposed element can operate in dual frequency operation. The frequencies are in Ku-band range (12-18 GHz).

3. Results and Discussions

The parametric studies of the proposed element have been analyzed and optimized using CST Microstripes software. Through a series of simulations of varying the design parameters, the optimized results are obtained for the required phase responses. Simulated reflection phase of the proposed element is shown in Figure 3.

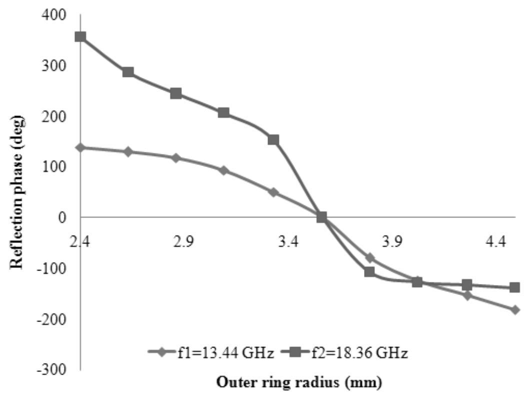


Figure 3. Reflection phase versus outer ring radius for concentric split ring square element

The dimension of outer ring radius is nominal at 3.56 mm in the variation range of 2.40 to 4.49 mm of elements size. At the first resonance of 13.44 GHz, it is observed that the phase range is 320° with the less steep phase curve (or gradient) of 0.15°/µm. The phase range value shows the practicality of the element and is acceptable for the value more than 300°. While the gradient value shows the bandwidth performance of the element with the less value leads to the broader bandwidth and high efficiency. While at the second resonance of 18.36 GHz, it is observed that the phase range is 464° with steeper phase curve of 0.33°/µm. It is normally found that for a higher range of reflection phase will resulted in steeper phase gradient, vice versa.

The phase response of the design is measured using waveguide techniques and shown in Figure 4. The phase responses measured is varied for the dimensions of elements between 2.86 to 4.49 mm of outer ring radius. It is shown in Figure 4 that both simulation and measurement phase response shows good agreement.

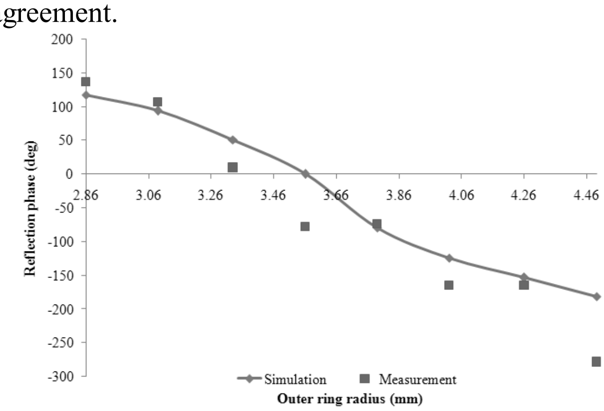


Figure 4. The simulation and measurement of reflection phase versus outer ring radius for concentric split ring square element

The resonant frequency of simulation is 13.44 GHz while for measurement is 13.91 GHz. While Table 1 shows the measured resonant frequencies and return losses for varied dimensions of elements.

Table 1: Resonant frequencies and return losses for varied dimensions of concentric split ring square element

Outer ring radius (mm)	Measured resonant frequency (GHz)	Return loss (dB)	Simulated resonant frequency (GHz)
2.86	18.95	-6.3	16.20
3.09	16.71	-6.4	15.00
3.33	15.17	-6.7	14.20
3.56	13.91	-14.4	13.44
3.79	11.95	-7.8	12.40
4.02	11.46	-5.9	11.50
4.26	10.69	-3.2	10.60
4.49	10.27	-3.6	10.00

It is shown in Table 1 that for the bigger size of element resulted in lower frequency, vice versa. The higher return loss is observed at resonance of 13.91 GHz with the value -14.4 dB. The measured loss is significantly different from the simulation due to the loss in waveguide equipment and the setup of the measurement procedure.

4. Conclusion

A design of a concentric split ring square reflectarray element is presented in this paper. The broader bandwidth is achieved by exploiting the physical dimensional of elements and through the using of RF-35 as the substrate. Both simulation and measurement of phase response for the proposed element shows good agreement. The study shows that the proposed element can be operated in dual frequency. The concentric element concept is used to achieve the dual frequency operation.

Acknowledgments

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