Analysis of Concentric Bridge Ring Circular and Square Element for Reflectarray Antenna.

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Abstract - This paper presents a study of phase slope, phase range and return loss for concentric bridge ring circular and square element for reflectarray antenna by using single layer of substrate. The study has been done to find the best dimensions that suit the reflectarray antenna criteria for both elements. Comparison of simulated results shows that concentric bridge ring circular element performs a better performance compare with concentric bridge ring square element that can be covered two frequency operation. All the process and development is done using CST MWS.

Keywords: Concentric bridge ring circular, concentric bridge ring square, CST MWS.

I. INTRODUCTION

Recently, reflectarray antenna has been studied to replace the conventional parabolic antenna for satellite applications. The microstrip reflectarray antenna has characteristics of low profiles and light weight compared to heavy and "big dish" of the conventional parabolic antenna. However the design of reflectarray antenna becomes more complicated due to this advantage. Another main disadvantage of printed microstrip reflectarray is narrow bandwidth of the microstrip patch elements on the reflectarray surface and it also having a differential spatial phase delay. They usually are employed at UHF and higher frequency because the size of the antenna is directly tied to the wavelength at the resonant frequency. A reflectarray antenna consists of a flat or slightly curved reflecting surface and a feed antenna which illuminates the reflecting surface. There are many radiating element on the reflecting surface has been reported.

Using identical patch elements with different length of stubs (variable length phase delay lines attached/different length microstrip transmission line) the reflectarray antenna can be designed with a good result of the phase difference. This approach has been discussed as in [1,2]. Variable size of patches also is one of the approach has been used in designing reflectarray antenna as in [3,4]. Variable size of patches can have different scattering impedances and thus, different phases to compensate for the different path delay.

[5,6] reported that different rotation angles or different angular rotation can be used to compensate the feed path-length differences. For this method the patch element size and attached stub-line length was fixed in dimensions.

The most common patches shape of the microstrip reflectarray antenna is rectangular and circular due to its simple and easy design. Comparison of the characteristic of square and circular patches has been discussed in [7]. With same dielectric substrate, both patches shape will produce an approximately equal phase range. However, the phase characteristic gradient is smaller for the circular patch. The phase range of thinner substrate is much bigger compared to thicker substrate [8,7,9] and at the same time it will give the broader band. However, in both cases mentioned the phase range is below 360° range.

This paper presents an analysis of physical parameter of concentric bridge ring circular and concentric bridge ring square for reflecatarray elements by using single layer of substrate. Variation of parameter will be studied in term of phase and return loss characteristic.

II. ANTENNA STRUCTURE AND DESIGN

For all the proposed structure, the periodicity of the element is a = 18 mm. The material of the substrate is Roger RT5870 with the dielectric constant of the substrate is εr=2.33 and the thickness of the substrate is h = 1.524 mm, thickness of the ground copper is Gt = 0.035 mm and thickness of the element is t = 0.1 mm.

A. Concentric Bridge Ring Circular Element

The design proposed in this section is concentric bridge ring circular element for reflectarray antenna. First, geometrical structure as shown in figure 1(a) is analyzed as to achieve the performance of phase variations (phase slope, phase range) and return loss. In figure 1(a), A is radius of the outer ring and B is radius of inner ring.

The purposes of this investigation is to review the performance of the proposed structure and its relation to phase variations. Values for A has been set at 5.74 mm, 5.44 mm and 5.14 mm. While B is set fixed at 4.8 mm.

Second, geometrical structure as shown in figure 1(b) is analyzed. In figure 1 (b), C is a radius of concentric circular element and it has been set at 4.2 mm, 3.9 mm and 3.6 mm.

Value for A and B is fixed to the value that had given a better simulation result as in figure 1(a).

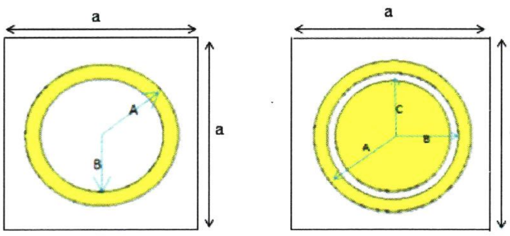

Figure 1: The geometrical view of (a) a single circular ring element and (b) concentric solid ring circular element.

Furthermore, geometrical structure as shown in figure 2 has been analyzed. This section will investigate the performance of the bridge with 3 bridge size (g) set at g = 1.0 mm, g = 0.7 mm and g = 0.28 mm.

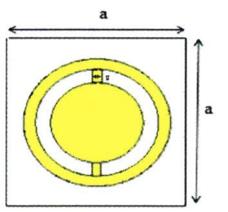

Figure 2: The geometrical view of concentric bridge ring circular element.

B. Concentric Bridge Ring Square Element

The design proposed in this section is a concentric bridge ring square element for reflectarray antenna. Geometrical structure as shown in figure 3(a) is analyzed as to achieve the performance of phase variations (phase slope, phase range) and return loss. In figure 3(a), M is the width and length of the outer ring and N is the width and length of the inner ring.

The purposes of this investigation is to review the performance of the proposed structure and its relation to phase variations. Values for M has been set at 11.48 mm, 10.88 mm and 10.28 mm. While N is set fixed at 9.6 mm.

Geometrical structure as shown in figure 3(b) is analyzed as to achieve the performance of phase slope, phase range and return loss. In figure 3(b), P is a width and length of concentric square element and it has been set at 8.4 mm, 7.8 mm and 7.2 mm. Value for M and N is fixed to the value that had given a better simulation result for a proposed structure in figure 3(a). It has been reported [12] the smaller value of concentric square element will give better performance.

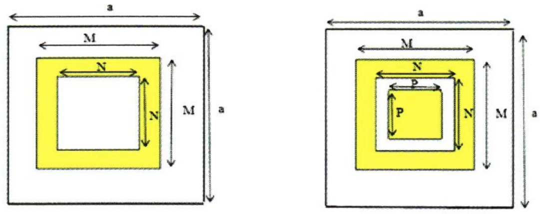

Figure 3: The geometrical view of (a) single square ring element and (b) concentric solid ring square element.

Furthermore, geometrical structure as shown in figure 4 has been analyzed. This section will investigate the performance of the bridge with 3 bridge size (g) set at g = 1.0 mm, g = 0.7 mm and g = 0.28 mm.

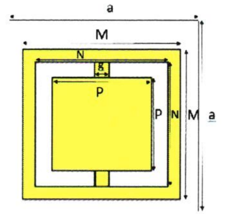

Figure 4: The geometrical view of view of concentric bridge ring square element.

III. RESULT AND DISCUSSION

The relationship between the width of the ring, radius of circular ring and bridge size is investigated for concentric bridge ring circular element in order to find the best dimensions that suit the criteria of less steep of phase slope, greater phase range and low return loss.

On the other hand, a concentric bridge ring square element also was investigated. The relationship between the length and width for square ring (M), square element (P) and bridge size (g) is investigated to find best dimensions. For both designs the dielectric constant of the substrate is 2.33, thickness of the substrate is 1.524 mm, thickness of the ground material is 0.035 mm, thickness of the copper material is 0.1 mm and the periodicity is 18 mm.

A. Concentric Bridge Ring Circular Element

Figure 5 shows the phase to frequency graph for a single ring elements and concentric solid ring circular element. As shown in Figure 5, the first resonant frequency is not affected by introducing a concentric circular element.

It also clearly shows that concentric circular elements will determine the second resonant frequency. However, there is no significant change can be observed from the aspect of improving of phase gradient or phase range.

For return loss analysis as shown in figure 6, the loss is less for concentric solid ring circular element. This indicates that the element having a better performance of reflection coefficient as the element is reflected instead of the transmitter.

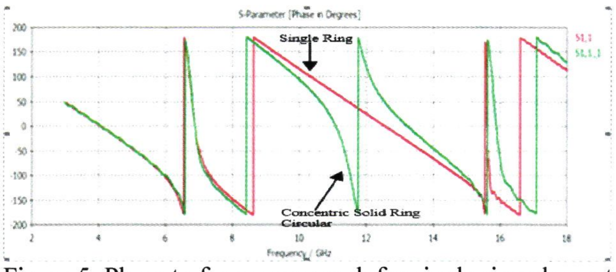

Figure 5: Phase to frequency graph for single ring element and concentric solid ring circular element.

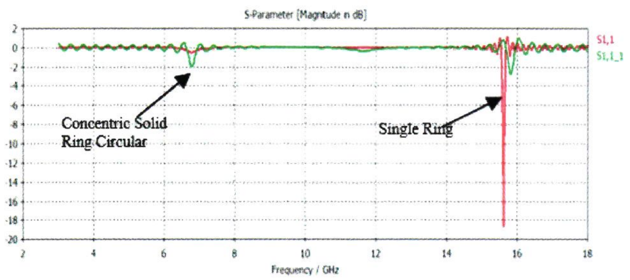

Figure 6: Return loss to frequency graph for single ring element and concentric solid ring circular element.

In order to review any changes that might occur due to changes in the size of the width of the ring element, value A has been set at, A = 5.74 mm, 5.44 mm and 5.14 mm. While B is set at a fixed value B = 4.8 mm. This investigation is to find the best dimension that suit the criteria for the reflectarray antenna element for further analysis. Other parameters are unchanged as stated before.

It is shown in Figure 7 that the first resonant frequency has shifted from 6.92 GHz to 7.11 GHz and to 7.37 GHz for A set at 5.74 mm, 5.44 mm and 5.14 mm respectively. First resonant depending on the thickness of the ring. The thinner ring value will lead to higher resonant frequency. While the thicker ring value will lead to lower resonant frequency. The phase range of all values is similar and full fill requirement, which is minimum 360°. It also observed that the thicker ring value produces, the less steep of phase slope and its leads to bandwidth improvement.

For return loss analysis as shown in figure 8, the loss is less for the thicker ring compared to thinner ring. This represents the best performance of reflection coefficient as the element is reflected instead of the transmitter. The loss for outer ring set at 5.74 mm, 5.44 mm and 5.14 mm are 1.96 dB, 2.24 dB and 2.65 dB respectively. For further analysis thicker ring size was chosen because it produces less steep of phase slope.

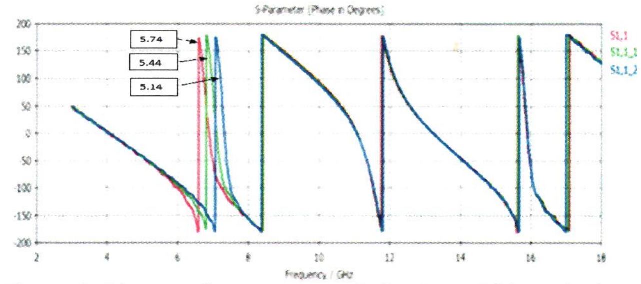

Figure 7: Phase to frequency graph for ring width analysis.

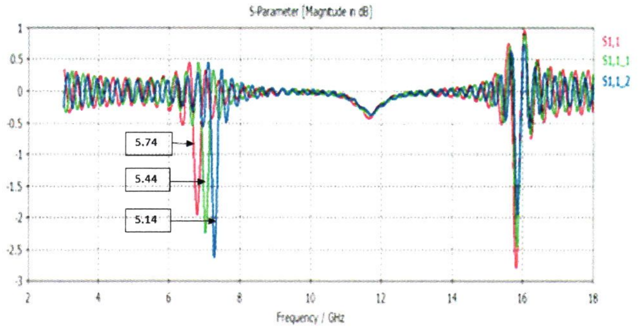

Figure 8: Return loss to frequency graph for ring width analysis.

For circular element radius investigation purposes, the value is analyzed at C = 4.2 mm, C = 3.9 mm and C = 3.6 mm. Value A and B is set at fixed value which is A = 5.74 mm and B = 4.8 mm. This investigation is to configure out which circular radius is suitable for further analysis of the reflectarray antenna element. The others parameter has remained unchanged as stated before.

It is shown in Figure 9 that the second resonant frequency has shifted from 11.11 GHz to 11.61 GHz and to 11.91 GHz for C set to 4.2 mm, 3.9 mm and 3.6 mm respectively. Second resonant depends on the radius of the circular element. The smaller radius value will lead to higher resonant frequency. Smaller radius value also will produce slower slope and bigger bandwidth. However the bigger radius value will lead to lower resonant frequency. The phase range of all values is similar and fulfill requirement, which is minimum 360°.

For return loss analysis as shown in figure 10, the loss is less for the smaller radius compared to a bigger radius. The smaller radius was chosen to further investigate due to it's less steep slope and bigger bandwidth.

Figure 11 shown the analysis results for different size of the bridge. In order to investigate the effect of the bridge, the value is analyzed at g = 1.0 mm, g = 0.7 mm and g = 0.28 mm. The larger size of the bridge shows a smooth phase curve with a less steep phase slope that will provide improvements of the bandwidth for first resonant. From figure 13, clearly shown that by introducing the bridge the phase response is improved.

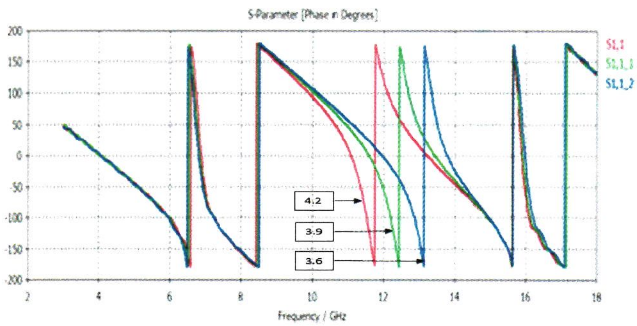

Figure 9: Phase to frequency graph for circular radius analysis.

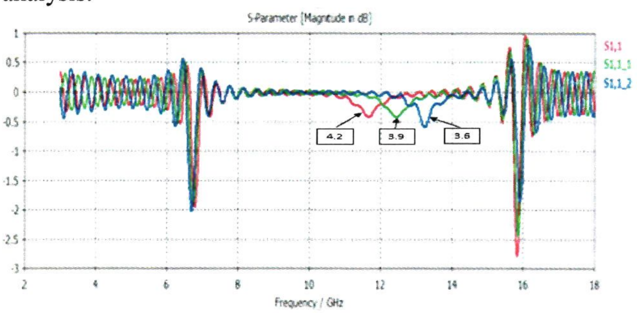

Figure 10: Return loss to frequency graph for circular radius analysis

For return loss analysis as shown in figure 12, the loss is less for the larger size of bridge compared to a smaller size.

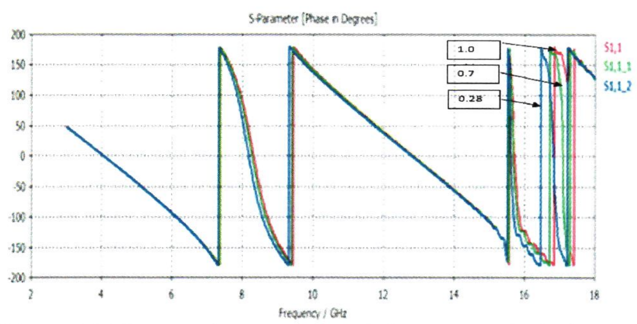

Figure 11: Phase to frequency graph for gap analysis for concentric bridge ring circular element.

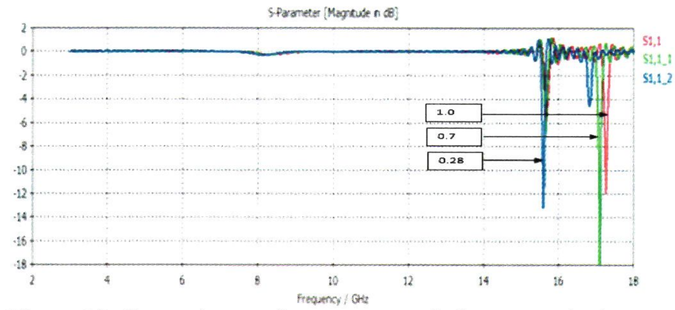

Figure 12: Return loss to frequency graph for gap analysis for concentric bridge ring circular element.

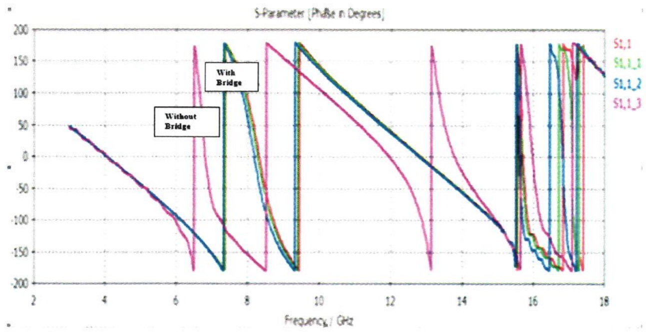

Figure 13: Phase to frequency graph for circular radius analysis and bridge analysis.

For further analysis bigger bridge size was chosen because smaller bridge size is difficult to fabricate (In the future). Another factor that has been considered because the phase range of all values is similar and fulfill requirement, which is minimum 360°.

B. Concentric Bridge Ring Square Element

In order to review any changes that might occur due to changes in the size of the width and length (Value M) of the ring element, value M has been set at, M = 11.48 mm, 10.88 mm and 10.28 mm. While N is set at fixed value N= 9.6 mm This investigation is to configure out which size is suitable for further analysis of reflectarray antenna elements. Other parameters are unchanged as stated before.

It is shown in Figure 14, that the first resonant frequency was shifted from 5.69 GHz to 5.85 GHz and to 6.04GHz for M set at 11.48 mm, 10.88 mm and 10.28 mm respectively. First resonant depending on the thickness of the ring. The thinner ring value will lead to higher resonant frequency. While the thicker ring value will lead to lower resonant frequency. However the phase range of all values does not reach a required minimum value, which is minimum 360°. The phase range is 351.64°, 350.23° and 348.83° for first resonant for M set at 11.48 mm, 10.88 mm and 10.28 mm respectively.

For return loss analysis as shown in figure 15, the loss is less for the thicker ring compared to thinner ring. The loss of thicker value is 2.16 dB and for thinner value is 3.55 dB. Based on a low loss of thicker ring, it was chosen for further analysis.

For square element dimension investigation purposes, the value is analyzed at P = 8.4 mm, P = 7.8 mm and P = 7.2 mm. Value M and N are set at fixed value which is M = 11.48 mm and N = 9.6 mm. This investigation is to configure out which circular radius is suitable for further analysis of the reflectarray antenna element. The others parameter has remained unchanged as stated before.

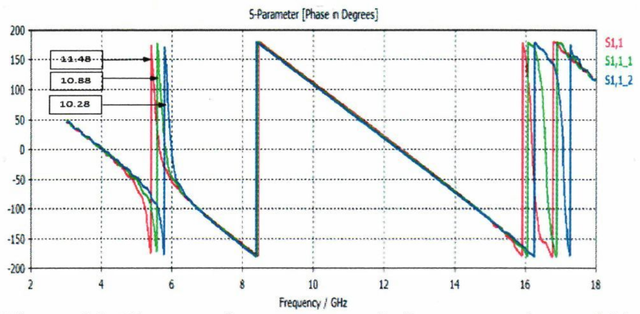

Figure 14: Phase to frequency graph for square ring width and length (Value M) analysis.

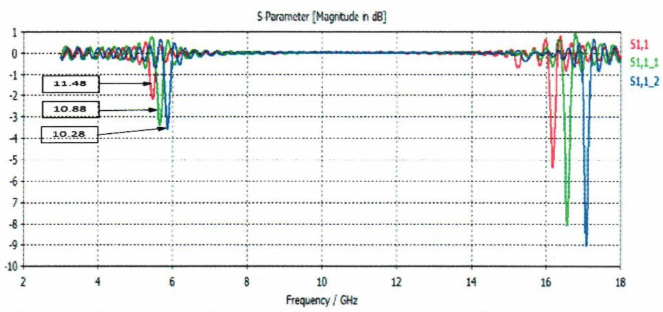

Figure 15: Return loss to frequency graph for square ring width and length (Value M) analysis.

It is shown in Figure 16 that the second resonant frequency has shifted from 9.78GHz to 10.4 GHz and to 11.0GHz for P = 8.4 mm, P = 7.8 mm and P = 7.2 mm respectively. Second resonant depends on the dimension of square element (Value P). The smaller *P* value will lead to higher resonant frequency. Smaller *P* value also will produce slower slope and bigger bandwidth. However the bigger *P* value will lead to lower resonant frequency. The phase range is 358.67°, 358.23° and 357.25° for first resonant for P = 8. 4 mm, P = 7. 8 mm and P = 7.2 mm respectively

For return loss analysis as shown in figure 17, the loss is less for the smaller P value compared to a bigger P Value. The smaller P value was chosen to further investigate due to it's less steep slope and bigger bandwidth.

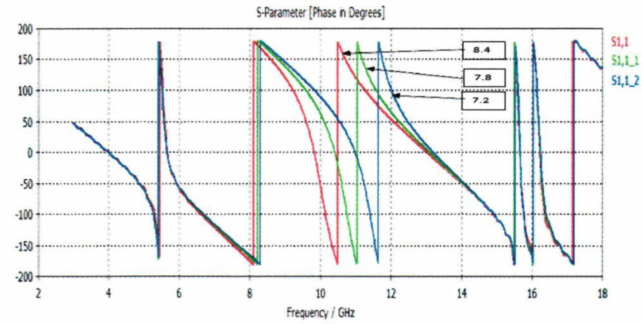

Figure 16 : Phase to frequency graph for square width and length (Value P) analysis.

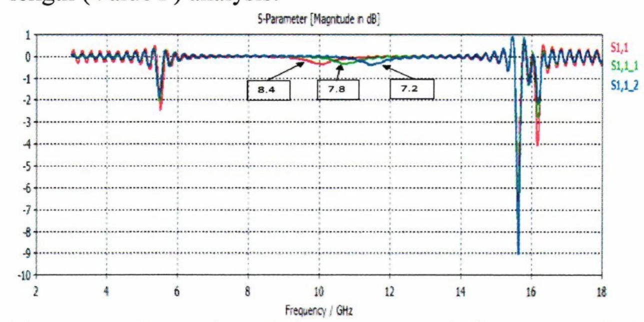

Figure 17: Return loss to frequency graph for square width and length (Value P) analysis.

Figure 18 shown the analysis results for different size of the bridge. In order to investigate the effect of the bridge, the value is analyzed at g = 1.0 mm, g = 0.7 mm and g = 0.28 mm. The larger size of the bridge shows a smooth phase curve with a less steep phase slope that will provide improvements of the bandwidth for first resonant.

For return loss analysis as shown in figure 19, the loss is less for the larger size of bridge compared to a smaller size. Bigger bridge size was chosen because smaller bridge size is difficult to fabricate (In the future). Another factor that has been considered because the phase range of all values is similar and fulfill requirement, which is minimum 360°.

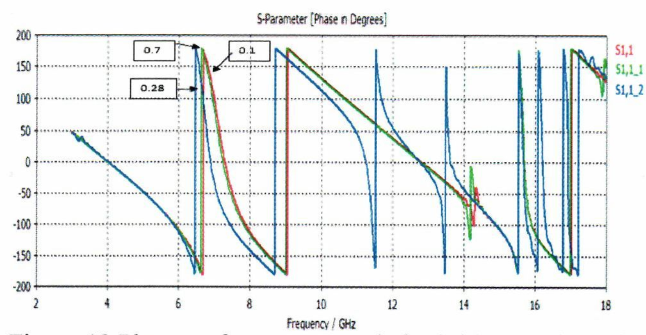

Figure 18:Phase to frequency graph for bridge analysis for concentric bridge ring square element.

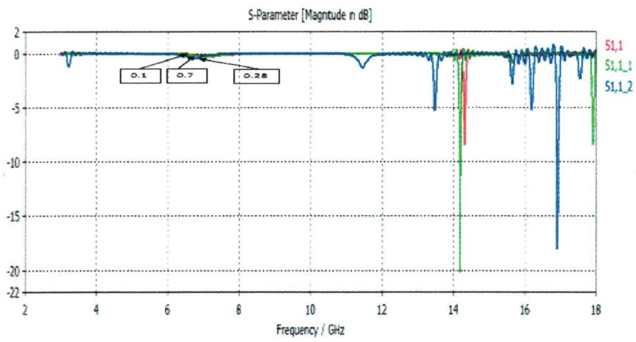

Figure 19: Return loss to frequency graph for bridge analysis for concentric bridge ring square element.

E. Comparison Between Concentric Bridge Ring Circular Element and Concentric Bridge Ring Square Element.

Figure 20 shows the comparison of simulated results for concentric bridge ring circular element and concentric split square element. Referring to figure 20, it's shown that the concentric bridge ring circular element performances a better result with less steep phase slope that that will provide bigger bandwidth. The first resonant frequency is 8.35 GHz and second resonant frequency is 12.91 GHz.

For return loss analysis, referring in figure 21, the lowest return loss is achieved for concentric bridge ring circular element. Low return loss is needed for better reflection performances.

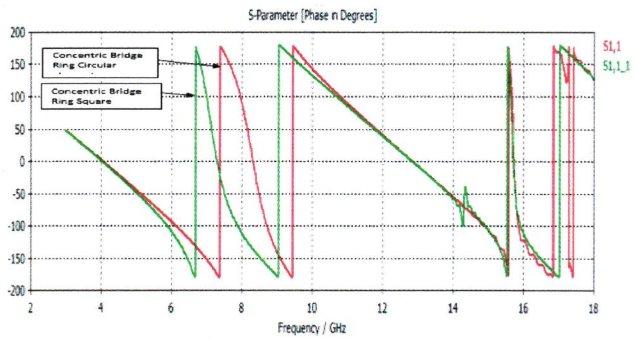

Figure 20:Phase to frequency graph for concentric bridge ring circular element and concentric bridge ring square element.

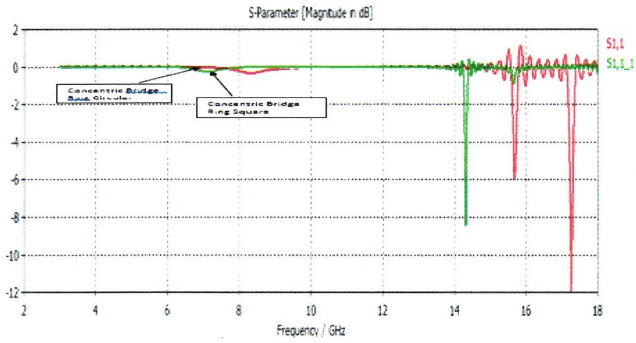

Figure 21: Return loss to frequency graph for concentric bridge ring circular element and concentric bridge ring square element.

VI. CONCLUSION

Analysis carried out shows that with the same value of permittivity εr = 2.33, substrate thickness h = 1.524 mm, material thickness t = 0.1 mm and ground material thickness Gt = 0.5 mm, concentric bridge ring circular element performance a better phase slope and phase range and low loss compare to concentric bridge ring square element.

Concentric bridge ring circular element performs a good result for the dimension of outer ring A = 5.74 mm, inner ring B = 4. 8 mm, circular radius R = 3. 6 mm and bridge g = 1.0 mm.

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