Analysis of Frequency Reconfigurable Annular Slot Antenna for 3 to 7GHz

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ABSTRACT
A new kind of double short strip and single-side micro strip type antenna architecture to develop a frequency reconfigurable annular slot antenna. The design and characterization of this "reconfigurable antenna (RA) annular slot" which was built on a microwave laminate TMM10i Rogers (permittivity=9.8, loss tangent=0.002), are presented in this paper. By increasing and decreasing the length of ground micro strip feeding line strategically located within the antenna geometry the operating frequency band is changed. The RA annular slot has two reconfigurable frequencies of operation with center frequencies f_{high}=6.733GHz, f_{low}=3.0GHz compatible with F and H band standards. The S_{11} and VSWR characteristics of the antenna along with the RF performance are presented and discussed.

Keywords
Annular slot antenna, reconfigurable antenna, microstrip feeding line, short strip, cpw

1. INTRODUCTION
The reconfigurable antenna (RA) concept has significant interest as a result of two main points. One is single RA performs many functions by changing its operating frequency, polarization, and radiation pattern. This result in significant reduction in the overall size of multi-mode multi-band wireless communication systems and replace multiple single-function antennas. Next is reconfigurable properties of a RA can be used as important degrees of freedom in an adaptive system.

The design of slot-ring antennas was previously studied in [11].The design is made on substrate rogers (permitivity=9.8, loss tangent=0.0002) on dimensions WXW=40x40mm^2.Multi-frequency operation was presented in several papers. The multi-band operation is done by using multiple concentric annular-ring slots with cooper conductivity which are excited by either a micro strip. Micro strip-fed slot-ring antennas, which contains a single slot-ring of various geometries, that produce multi-frequency operation were also studied in [14].These antennas support multiple frequencies and gain values corresponding to each frequency can be appropriately different. The same problem applies to a broadband antenna, where the degradation in gain can be significant over a broad frequency band. This might be a problem for multi-mode multi-band wireless communications applications where the radiation characteristics and gain performance are required to be similar over multiple frequencies. Recent efforts have been focusing on the tunable slot-ring antennas [15], [16].The analysis and design of annular slot presented in this paper maintains at f_{high}=6.73GHz and GHz f_{low}=3.0 GHz.This design shows the reconfigurability at different frequencies by changing the length k from 11 mm to 18 mm of microstrip feeding line.

2. ANTENNA DESIGN
2.1 Antenna Structure
Figs from 1 to 3 are showing the design of the annular slot antenna.

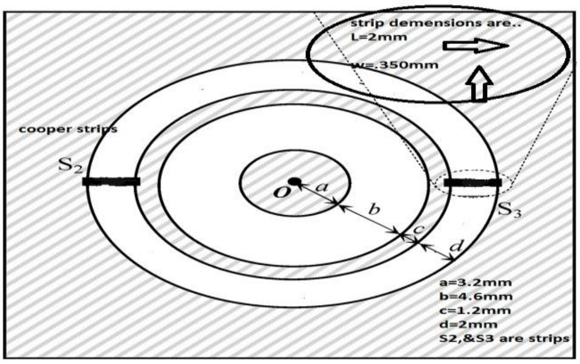

Fig.1.shows the geometry and top view of the given antenna

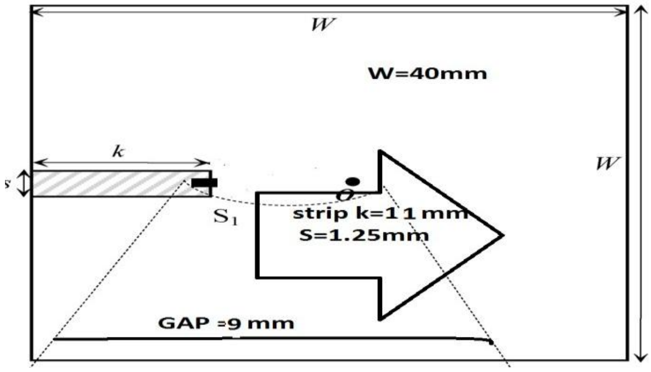

Fig.2 shows the geometry and bottom view of the given antenna

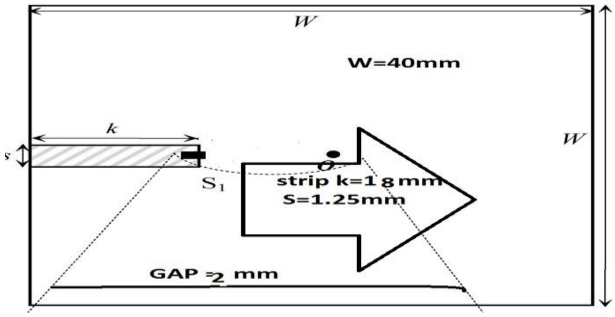

Fig.3 shows the geometry and bottom view of the given antenna at k=18mm

Since the feeding structure are not implemented on the same plane with antenna. the feeding is performed at lower substrate of height 0.635mm and upper substrate having slot antenna design with cilcular slots. Total height of the substrate is 1.27mm with dimensions of 40x40mm^2.The wave port is used for micro strip feeding. Design of aperture is determined by reducing the aperture area while satisfying the input impedance matched especially for the lower frequencies. Here figure 1 shows the top view with slots and figure 2&3 shows the bottom view with feeding micro strip line.

2.2 Working

The architecture and a image of the micro strip-fed RA annular slot are shown in Figs.1,2 and 3. The antenna is built on two separate layers of TMM10i (permitivity=9.8, loss tangent=0.002) microwave laminate each with 0.635 mm thickness. The micro strip feed line is fixed on upper layer and the annular slot is placed on the lower layer, which are bonded together having a total thickness of 1.27 mm. This Antenna has two concentric circular slots each can be excited individually by increasing the length of microstrip feeding line in order to achieve frequency reconfigurability.

The outer slot is fed; the operation frequency is f_{low}=3.0 GHz.When the microstrip segments line is increased upto 18mm (k=18mm), then the inner slot is fed; the operation frequency is f_{high}=6.73GHz. This microstrip feeding line length (ground) enable the metallic annular ring, which stays between the outer and inner slots, to be shorted to RF ground so that when the inner slot is excited, it has a continuous ground plane. Therefore the operation of the inner slot is not adversely impacted by the presence of the outer slot. We also observed that when the outer slot is excited for the influence of the presence of the inner slot combined with the central metallic circular island on the outer slot produces only a minor resonant effect, which is out of the operation range of the higher frequency, so no need to shorted the inner slot to be shorted.

The simulation tool Ansoft HFSS is used in the paper for design and optimization. Fig.5 and 6 shows S parameter v/s frequency graph of the proposed antenna Fig 6 shows the first resonance at the approximate frequency 3.0GHz (MODE-1),when outer slot is excited by keeping k=11mm. And resonance also can be obtained at the 6.733GHz (MODE-2) when inner slot is excited by keeping k=18mm but at these frequencies the S parameter and VSWR value are not sharp. So depending on the sensitivity corresponding to the aperture parameters of the antenna the return loss performance of the antenna can be increased. To obtain maximum bandwidth with minimum dimensions, the mode called fundamental mode. Considering the annular slot as a transmission line, the fundamental resonance appears around the frequency at which the circumference of the annular slot becomes one guided wavelength of the slot (λ/4mm). The slot guided wavelength for the frequency and dielectric permittivity ranges of interest can be expressed by equation number 1

$$\frac{\lambda_{gs}}{\lambda_o} = 0.9217 - 0.277\ln\varepsilon_r + 0.0322\left(\frac{w}{h}\right)\left[\frac{\varepsilon_r}{\frac{w}{h}+0.435}\right]^{1/2}$$
$$-0.01\ln\left(\frac{\mathrm{h}}{\lambda_o}\right)\left[4.6 - \frac{3.65}{\varepsilon_r^2\sqrt{\frac{w}{\lambda_o}}\left(9.06 - 100\left(\frac{w}{\lambda_o}\right)\right)}\right] \quad (1)$$

Here λ_{gs} is guided wavelength, h is thickness of substrate, λ_0 is operating wavelength and ξr is relative permittivity that used in above equation number 1.

2.3 Feeding

The feeding or excitation is given by wave port which having dimension of dx=7.5mm and dy=6.35mm.Cooper is used as the radiating element in top and bottom both sides with it properties. The vacuum box is made to cover its all the radiations when antenna works and its length and width both are same as the dimension of the substrate but the height or thickness of the vacuum box is λ/4mm where λ is wavelength of the center frequency.

To get the desired results we have simulated antenna at different length of the micro strip feeding line. The feeding concept is given below by fig 4 in which excitation is applied by wave ports

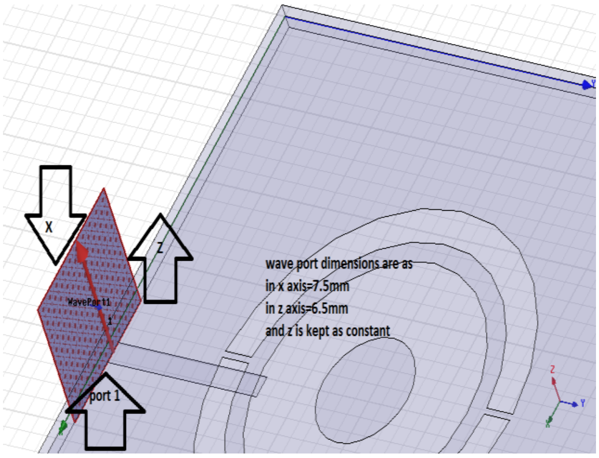

Fig.4 Wave port design of antenna (feeding concept)

2.4 Results

2.4.1 Reflection Coefficient at 3.0 and 6.73 GHz

The reflection coefficients at 3.0 GHz and 6.733 GHz are given after simulation. In range of 3.0 GHz and 6.733 GHz we have found the VSWR between 0 and 2 but at theses two given frequencies the S_{11} and VSWR are showing the best results.S_{11} at 3.0 GHz are represented by the fig 5 and S_{11} at 6.733 GHz are represented by the fig 6. At these frequencies gain is <-10db which we needed for better results. we increases the length of micro strip, k=18 mm then our antenna works on next reconfigured frequency (6.733GHz). Reconfiguration is also performed by micro strip length (k) return losses and VSWR can also be shown at 3GHz when outer slot is excited (k=11mm).Reconfiguration is also performed by micro strip length (k) return losses and VSWR can also be shown at 3GHz when inner slot is excited (k=18mm).We have simulated all the results depending on the variation of size of micro strip feeding line. Figures from 7, 8 shows the results at k=11mm when outer slot is excited and Figures 5. Shows the results at k=18mm when inner is slot excited.

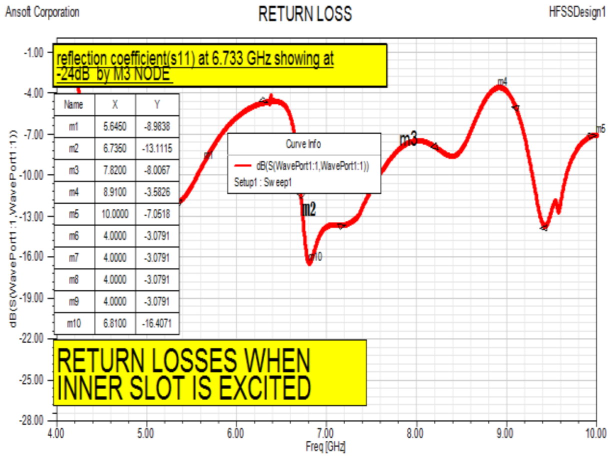

Fig 5 Simulated reflection coefficients for f_{high}=6.733 GHz (Mode 2 operation, outer slot is excited).

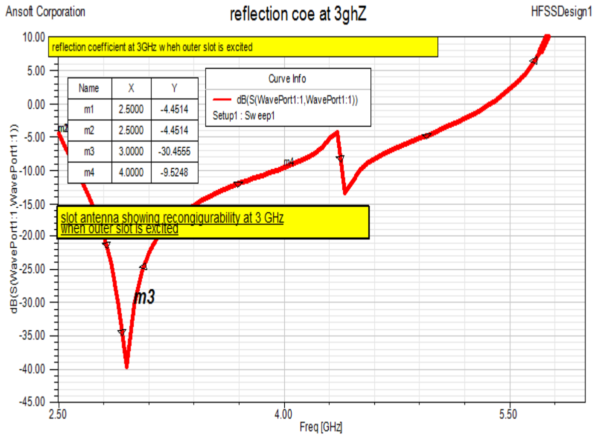

Fig 6 Simulated reflection coefficients for f_{low}=3.0 GHz (Mode 1 operation, outer slot is excited)

2.4.2 VSWR at 3.0 and 6.73 GHz

The voltage standing wave ratio is best simulated at 3 GHz and 6.733 GHz. VSWR at 3.0 GHz are represented by the fig 8 and VSWR at 6.733 GHz are represented by the fig 7.

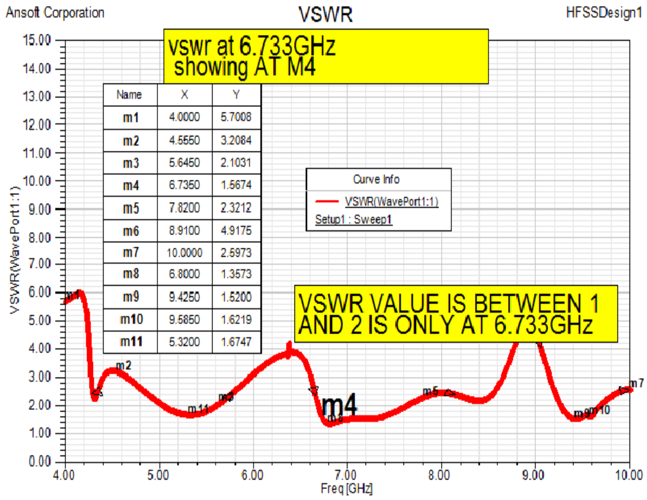

Fig 7 Simulated VSWR for fhigh= 6.733 GHz (Mode 2 operation, inner slot is excited, k=18mm)

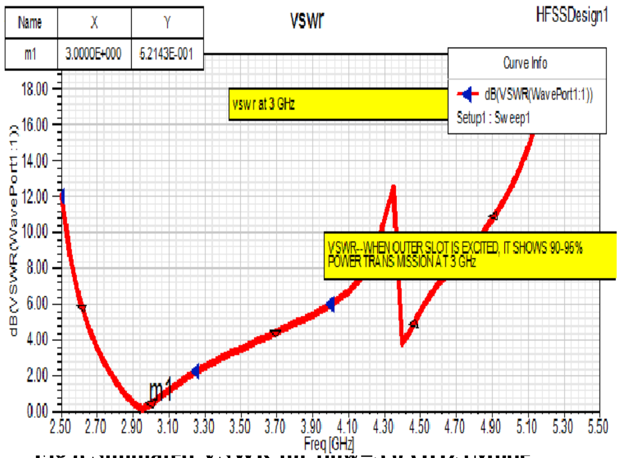

Fig.8 Simulated VSWR for flow=3.0 GHz (Mode 1operation, inner slot is excited, k=11.45mm).

3. CONCLUSION

A frequency reconfigurable ($f_{low=}$ 3 GHz and $f_{high=}$ 6.733 GHz) annular slot antenna has been designed and characterized. The reconfigurability is achieved by varying the length of the microstrip feeding line (k).The antenna showed that it can transmit more power at 3.0 GHz and 6.733 GHz by analyzing the VSWR and S_{11}.

4. IMPROVEMENT

We can make our antenna reconfigurable by own itself that antenna could reconfigure after applying DC voltage to the MEMS switches. Which can be designed between the inner and outer slot of the top design of given annular slot antenna and at lower design also we can make a switch to increases the length of the misco strip feeding line, by help of which by simply applying the actuation voltages to the switches they will perform like the connecting elements then our design may work for the new range of frequencies.

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