

# High Performance Broadband Polarizer for KA Band Applications

M. Richitha<sup>1\*</sup>, V. Senthil Kumar<sup>2</sup> and Ravi Prakash Dwivedi<sup>1</sup>

<sup>1</sup>VIT University, Chennai - 600 127, Tamilnadu, India; richitha.m2013@vit.ac.in, raviprakash.dwivedi@vit.ac.in

<sup>2</sup>ISRO Satellite Centre, Bangalore - 560 017, Karnataka, India; senthil@isac.gov.in

## Abstract

**Aim of Findings:** A modified mirror shaped waveguide-type stepped septum polarizer is suggested and verified using Ansoft HFSS. Mirror profile performs better than the conventional varying thickness polarizer in terms of phase-angle, reflection loss and isolation. **Methodology Employed:** The 3D structure has been simulated using HFSS. The parameters are initially optimized using a WASPNET tool and later implemented in HFSS. WASPNET is a specially designed tool which automatically adjusts the dimensions according to the specifications thus reducing mathematical computations. By performing a number of simulations regarding the thickness and dimension profiles, it is concluded that the performance parameters are not degraded. **Final Results:** FEM based simulations on the device suggest that mirror shaped waveguide-type profile performs better than the varying thickness profile waveguide-type septum. Initially the thickness of the septum has to be decided to construct an effective septum according to its requirements. Thickness of 0.3 mm performs better than the profiles greater than 0.5 mm thickness. Similarly, the varying thickness profile was simulated and set to 0.2–0.6 mm as it gives better performance. The axial ratio is measured in terms of the angle between the  $TE_{10}$  and  $TE_{01}$  modes, is seen to be 89.75/90.44 between  $S_{31}$  and  $S_{32}$  respectively, ideal value being 90 degrees. The  $S_{11}$  of mirror shaped septum gives reflection coefficient which is found to be greater than -31dB for the entire band compared to that of varying profile. The performance is found to exist over the entire band and not restricted to the center frequency. The isolation characteristics is >25dB which is better than the conventional design. This shows that a good isolation is maintained between both the ports.

**Keywords:** Mirror Shaped Septum Waveguide Polarizer, Square Waveguide Polarizer, Stepped Septum Polarizer

## 1. Introduction

Nowadays, there is a great demand for high data rate. In order to fulfill these never ending demands, it is necessary to provide a reliable data transfer between the satellite and the ground station. One of the ways to do this is to implement circular polarization for signal communication. The major advantage of circular polarization is that it emits radiation along all the planes which is needed for alignment<sup>1</sup>. As the signal travels through the atmosphere, it is prone to undergo attenuation and also a change in its direction, such waves can be easily detected by using a circularly polarized antenna over a linearly polarized one. In case of linear polarization, a good cross polarization response is difficult to obtain due to the non-alignment between transmitter and receiver.

The lower end of the RF spectrum is crowded with commercial and government traffic and has not been used by satellite communications. Wider bandwidths are available at high frequencies, but signals transmitted in this range suffer atmospheric reflection during satellite to ground station communication. In order to meet this demand for high data rate, frequency reuse concept is employed at different polarizations. This involves simultaneous transmission (or reception) of two independent streams of data using Left Hand Circular Polarization (LHCP) and Right Hand Circular Polarization (RHCP). This is referred to as dual polarization.

Septum Polarizer is a microwave device capable of producing circular polarization from input linear excitations and vice-versa. The unique feature of the polarizer is that an RHCP or LHCP wave given as input at the square port is

\*Author for correspondence

coupled to the respective rectangular port with the output at the other port being equal to zero<sup>2</sup>. Similarly, a circular wave can be generated by providing two waves equal magnitude and at rectangular port they have a difference of 90°. As per the result analysis, in comparison to sloping septum the stepped septum provides better bandwidth performance, phase orthogonality and an ease for optimization<sup>3</sup>.

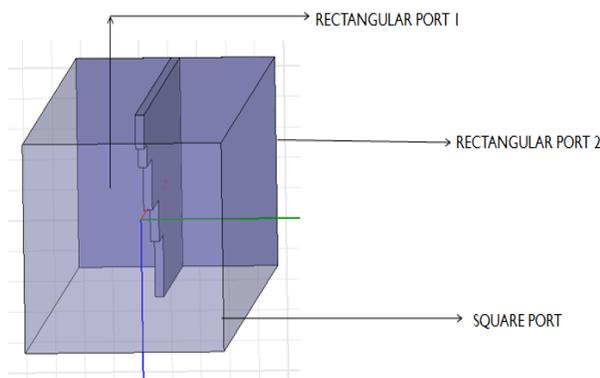
The efficiency of a polarizer can be determined by measuring its axial ratio and S parameters. These parameters solely depend on the dimensions of the septum i.e. the length and Width of the Septum Polarizer. The dimensions are further optimized using the WASP-NET tool.

This paper shows an improvisation of the above mentioned parameters by altering the shape of the metallic septum as it is dimension dependent. A comparison has been done between the existing varying thickness profile and the newly simulated mirror shaped septum.

## 2. Device Structure

The 3D structure is modeled using the FEM based design tool High Frequency Structure Simulator (HFSS). The septum is designed for the desired operating frequency of 26.5 GHz<sup>4</sup>. The conventional septum polarizer is shown in Figure 1. The dimensions are later optimized using the WASP-NET tool in order to meet the design specifications as shown in Table 1. This tool provides a new set of values with a slight variation according to the specifications indicated and the structure is reconstructed with these values.

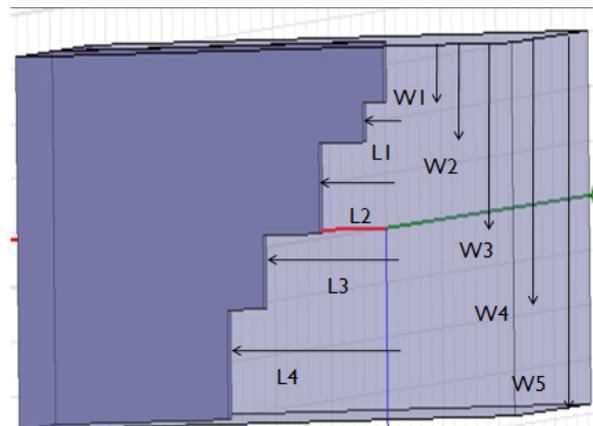
Septum polarizer along with its dimensions is shown in Figure 2. The L1-L5 refers to the lengths and W1-W5 refers to the widths of the septum polarizer.



**Figure 1.** Conventional stepped septum polarizer in HFSS.

**Table 1.** Dimensions of the septum

Length	Width
0.851λ	0.082 λ
0.749 λ	0.182 λ
0.497 λ	0.281 λ
0.243 λ	0.443 λ
MISSING DATA	0.6 λ



**Figure 2.** Conventional polarizer with dimensions.

Each step of the septum is provided with a different thickness varying from 0.2 mm to 0.6 mm. This range of thickness has been selected mainly for the reason that the axial ratio performance in this range is better than other thickness ranges. Sensitivity analysis was also performed to confirm this. The results are summarized in Table 2.  $S_{11}$  gives the measure of the reflection loss,  $S_{21}$  gives the isolation measurement between the two ports and the axial ratio cannot be measured directly using HFSS and hence the phase angle between the two modes is measured. A 90° phase difference between the two ensures a good axial ratio. The thickness increases step by step with the thinnest septum facing the square port to the thickest separating the two rectangular ports, as shown in Figure 3.

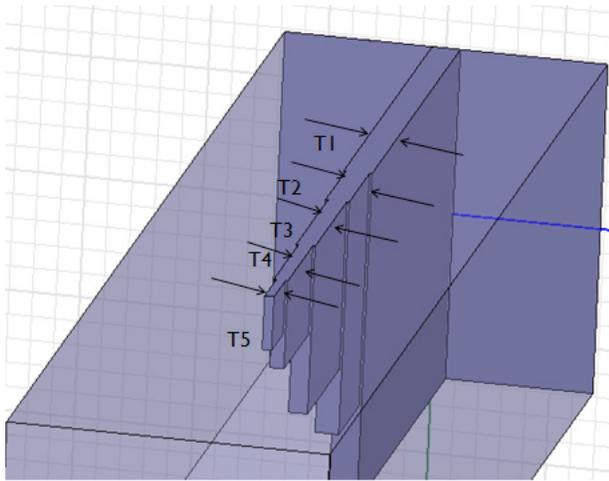
The proposed novel design consists of a mirror profile which includes back to back connections of the septum with thickness varying from 0.2 mm to 0.6 mm and again from 0.6 mm to 0.2 mm.

## 3. Design Procedure

The dimension of the septum plays a vital role in deciding the performance of polarizer. The initial design has been obtained from<sup>5-6</sup>.

**Table 2.** Sensitivity analysis

Thickness [in mm]	$S_{11}$ [in dB]	$S_{21}$ [in dB]	Phase Shift ( $S_{31}$ in degrees)	Phase Shift ( $S_{32}$ in degrees)
0.16	-30.98	-30.98	-89.97	89.85
0.3	-44.07	-31.99	89.91	90.11
0.5	-33	-33.32	90.05	90.07



**Figure 3.** Varying thickness profile in HFSS.

The dimensions in Table 1 can be used in order to scale the values depending on the frequency of application. In our case it has been scaled for 26.25 GHz. The thickness of the septum is decided by performing simulations for different thickness profiles<sup>7</sup>, starting from 0.16 mm, 0.3 mm and 0.5 mm.

This shows that 0.3 mm thickness of the septum provides a better performance than the other two. Hence the structure is modeled using 0.3 mm septum thickness. Also, 0.16 mm thickness can cause fabrication issues.

### 3.1 Polarizer with Varying Thickness

The septum is constructed with each step having varying thickness. The thickness range is from 0.2 mm to 0.6 mm. The thickest step (0.6 mm) is separating the two ports and the thinnest step (0.2 mm) is facing the square port as shown in Figure 3. The thickness is not allowed to go below 0.2 mm as it may lead to difficulty in fabrication. The thickness range was decided by simulating various profiles and checking their performances. This is summarized in Table 3.

Axial ratio plays a very important role in deciding the effectiveness of the polarizer. Hence it is given

**Table 3** Thickness profile comparison

Thickness (in mm)	$S_{11}$ (in decibels)	$S_{21}$ (in decibels)	Phase Shift (in degrees)
0.2–0.6	-34.96	-26.84	89.22/90.88
0.3–0.7	-42.24	-28.39	91.57/88.45
0.4–0.8	-39.98	-27.16	92.11/87.98

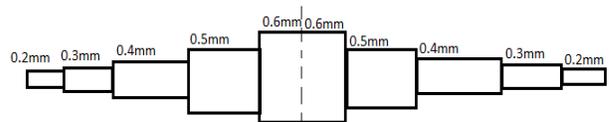
more importance than the other. From Table 3 it can be concluded that 0.2 mm to 0.6 mm thickness performs better than the other two thickness profiles.

### 3.2 Polarizer having Mirror Septum

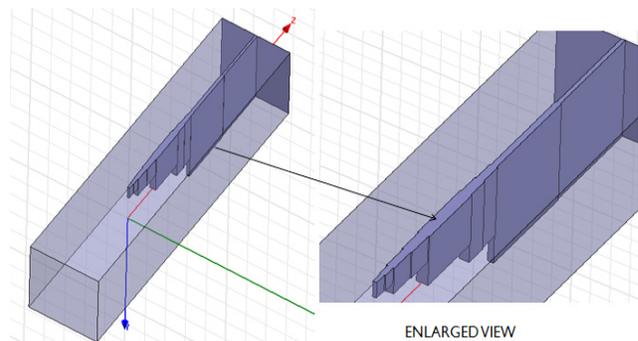
The name mirror septum is due to the reason that the thickness increases and further decreases thus forming a replica. Figure 4 shows how the thickness of the stepped septum is varying with the thinnest septum present at both the front of the waveguide and also separating the two rectangular ports. Hence it is referred to as mirror profile. Figure 5 shows the same modeled using Ansoft HFSS.

## 4. RF Simulation

Both the mirror profile and the varying thickness structures are simulated in HFSS. Figure 6 shows the return loss ( $S_{11}$ ) measurement in the varying thickness profile having bandwidth of 25 GHz to 28 GHz. Figure 7 shows the isolation measure between the two ports. Figures 8–9 shows the same with mirror profile septum.



**Figure 4.** Top view of the septum.



**Figure 5.** Mirror profile in HFSS.

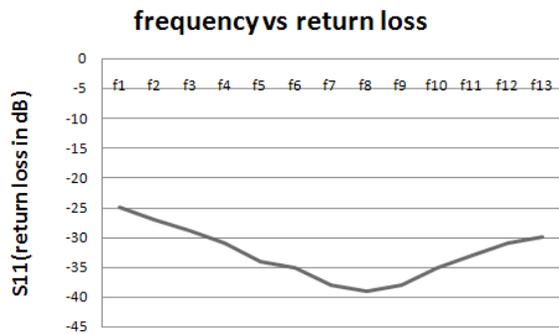


Figure 6. Return loss-varying thickness.

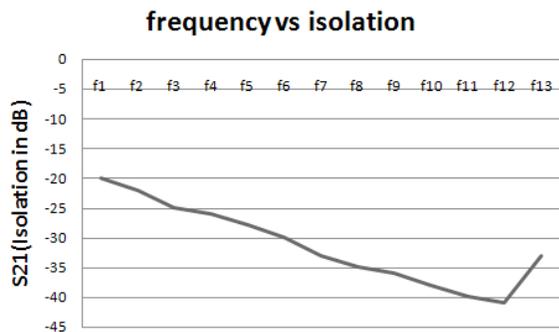


Figure 7. Isolation-varying thickness.

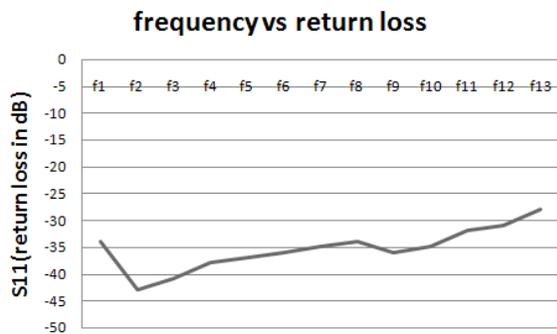


Figure 8. Return loss-mirror profile.

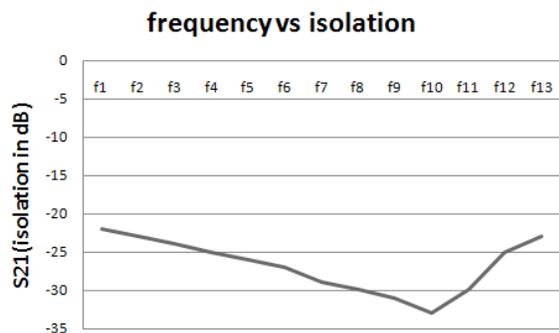


Figure 9. Isolation-mirror profile.

Figures 10–17 show the phase difference between the two modes in varying thickness and the mirror profile.

Table 4 shows that mirror septum provides a good performance as compared to that of varying thickness profile. We see the change in the axial ratio of the device and since this parameter plays a vital role in deciding the septum’s efficiency, mirror septum gives better results.

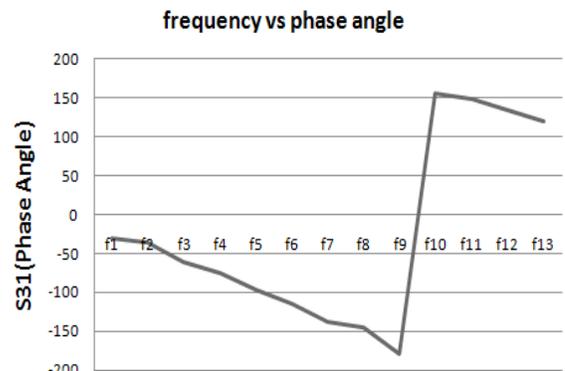


Figure 10.  $S_{31}$  mode 1-varying thickness profile.

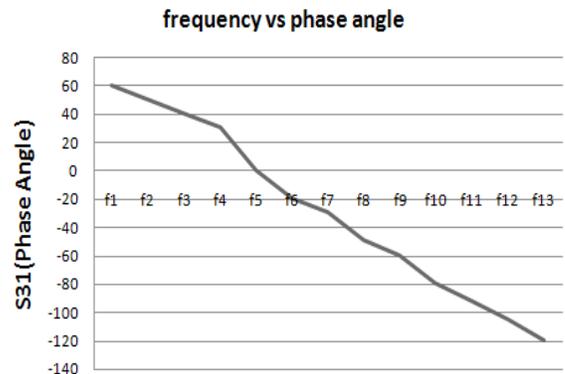


Figure 11.  $S_{31}$  mode 2-varying thickness profile.

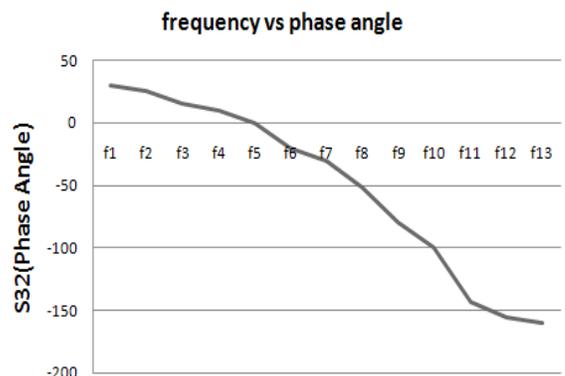


Figure 12.  $S_{32}$  mode 1-varying thickness profile.

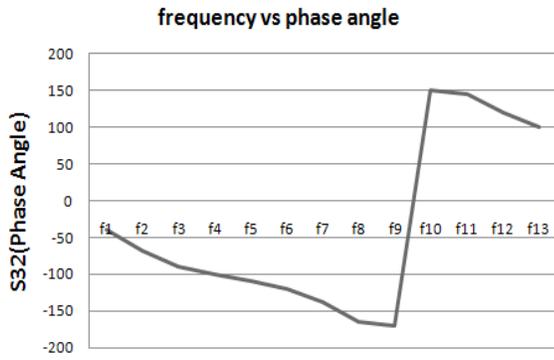


Figure 13.  $S_{32}$  mode 2-varying thickness profile.

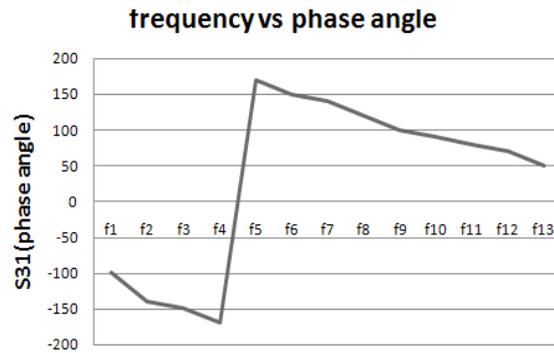


Figure 14.  $S_{31}$  mode 1-mirror profile.

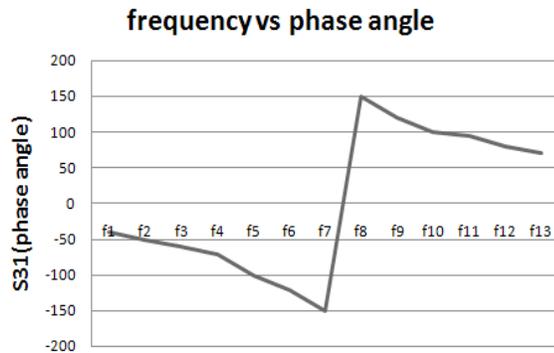


Figure 15.  $S_{31}$  mode 2-mirror profile.

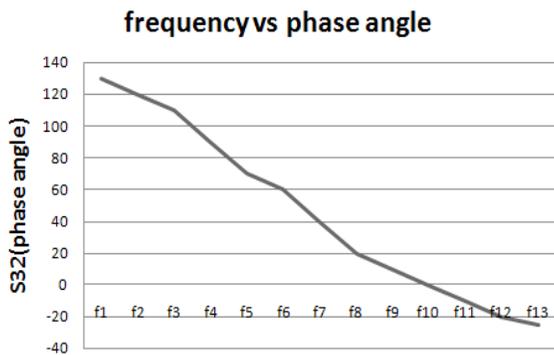


Figure 16.  $S_{32}$  mode 1-mirror profile.

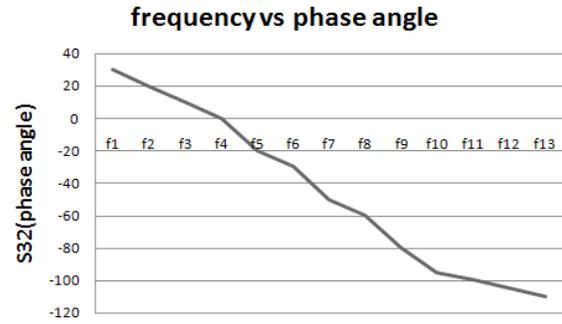


Figure 17.  $S_{32}$  mode 2-mirror profile.

Table 4. Comparison between the mirror profile and the varying thickness septum

Parameters	Varying thickness	Mirror profile
$S_{11}$ (in decibels)	-36.76 dB at 26.25GHz Full band > 28	-32.36 dB at 26.25 GHz Full band > 31
$S_{21}$ (in decibels)	-27.43 dB Full band > 23	28.89 dB Full band > 25
Phase Shift ( $S_{31}/S_{32}$ )	89.22 / 90.88	89.75 / 90.44

## 5. Conclusion

Measurements and comparisons between the two septum designs have shown that mirror shaped septum provides a better performance as compared to that of varying thickness profile. HFSS simulations have been used for validation.

## 6. References

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