

# A Septum Polarizer by Inserting Additional Stubs for its Applications in the CP Horn Antennas

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## 1. Introduction

A polarizer structure is studied, which is motivated in designing multi-beam reflector antennas [1,2] with circularly polarized (CP) radiations for multi-satellite digital TV receptions[3] as illustrated in Figure 1. These have narrow beam separations due to crowded satellite placements, and results in insufficient spaces to place isolated feed horns. Co-structured horns are required and degrade their radiation performances.

A septum polarizer[4] is investigated and used to compensate the deficiency of the horns' radiations. Due to its symmetry, an ordinary septum polarizer is not able to compensate the radiation deficiency of both right-handed (RH) and left-handed (LH) CPs simultaneously because the cross-polarized component of a linearly excited horn plays an opposite role for RHCP and LHCP. This paper investigates the possibility of resolving this problem by inserting stubs inside the polarizer to create unequal ARs. Thus several configurations shown in Figure 2 are numerically investigated to exhibit their physical behaviors in influencing the polarizer's characteristics. In particular, characteristics of return loss (RL), axial ratio (AR) and phase difference (PD) will be examined as described in the following sections.

## 2. Antenna Structure and Simulation Setup

### 2.1. Reflector Antenna System and Problem Statement

As exemplified in Figure 1, one considers the satellites at 99.2, 101 and 102.8 degrees west, operated at Ku- and Ka-bands by DirecTV [3]. These triple beams are separated by  $1.8^\circ$ , and can be radiated by placing three feeds with a  $\cos^{4.5} \theta$  radiation taper on a line perpendicular to the reflector's axis, where the reflector has roughly a  $73 \times 91 \text{cm}^2$  aperture with a 15" focal length. The feeds are separated by 1.8cm that is not sufficient to place independent horns, and cause co-structured horns as also illustrated in Figure 1, which results in deficiency in horns' radiation patterns as well as the subsequent triple beams.

### 2.2. The Polarizer Design

An ordinary septum polarizer is illustrated in Figure 2(a). The septum divides the waveguide into two parts exciting RHCP and LHCP by cutting the shape of septum to create another fundamental mode, perpendicular to the one produced by a linear excitation, with ideally equal amplitudes and a  $90^\circ$  phase difference. These two modes will make the horns to radiate good CP fields if they are complete in structure.

The polarizer is modified from Figure 2(a) by inserting additional stubs in these two tunnels as shown in Figure 2(b). The structure provides additional freedoms to optimize the polarizer. As a result, the AR as well as the PD for RHCP and LHCP may be relatively independently adjusted to compensate the polarization degradation arising from the breakage of the horn structure.

### 2.3. Simulation Setup

Ansoft HFSS has been shown very reliable and relatively accurate, and is used to compute the results. To effectively perform the simulation, particularly in a fashion of optimum polarizer design, an external add-on optimization procedure was established, which uses this software as a computational engine within the framework of the genetic algorithm (GA)[5]. This add-on procedure has been shown significantly extending the application scopes of the simulation tool since a variety of new features may be developed with more optimization functions. The fitness function is minimized by estimating AR and PD of the polarizer or horn's radiation.

## 3. Numerical Performance Examination

### 3.1. Bilateral Stub Insertion

An additional stub is symmetrically placed in the part of port 1 with respect to the septum with a same size as illustrated in Figure 2(b). They thus result in same influences to port 1 and 2. As shown in Figure 3 that within moderate sizes of  $S_x < 7\text{mm}$ , the RL has been improved. The dynamic ranges of the PD and AR are  $20^\circ$  and 1.5dB, respectively, which is very useful for its applications of horn antennas. One further examines the performance with respect to the frequency variations. In this case,  $S_x = 8\text{mm}$ . In the frequencies between 12.1 and 12.75GHz, the PD is within  $12^\circ$  ( $\pm 6^\circ$  variation if it is referenced to PD at 12.45GHz). AR varies within 1dB.

### 3.2. Radiation Characteristics

The studied polarizer is combined with a horn structure to investigate its performance over its radiation. The horn's structure is shown on Figure 4, which has a RL of -20.97dB at 12.45GHz. First, one examines the case of an ideal polarizer, whose radiation is shown in Figure 4. It is found that the radiation pattern has an AR of 2.36dB and PD of  $142.70^\circ$ , which results in a cross-polarized component of -7.14dB compared to its co-polarized component. The -10 dB beam-widths are  $66^\circ \times 103^\circ$ .

The structure of Figure 2(b) is employed with this horn structure, whose radiation is also shown in Figure 4. It is found that the polarizer has an AR and PD of 2.58dB and  $58.78^\circ$ , respectively, which gives the radiation patterns with an AR and PD of 0.53dB and  $96.68^\circ$ , respectively. The cross-polarized component is -23.6dB down from its co-polarized component, which exhibits a 16.5dB improvement. The beam widths are  $76^\circ \times 111^\circ$ .

Experimental measurements were performed, and shown in Table 2 and Figure 5 to validate this implementation. In particular, Table 2 compares the characteristics of polarizers designed with and without inserting stubs which are used to feed the co-structured horn antenna for good performances. The case without stubs is designed and exhibited a good cross-polarized component if a good horn structure is used. In the current case, as shown in Figure 5 for RHCP radiation, it results in a cross-polarized level of -5.43 dB down from its co-polarized component. On the other hand, the proposed stubbed polarizer results in a cross-polarized level of -22.23 dB. Also in this case, the -10 dB

beam widths are  $80^\circ \times 140^\circ$ , respectively.

#### 4. Discussions

This paper examines the utilization of stubs for polarizer to compensate the discrepancy of polarization due to the diffraction of co-structured horn antenna feeds. Numerical examples indicate that with slight sacrifice of RL the cross-polarized component can be significantly reduced.

#### References

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Table 1: Dimensions of the septum for case A of Figure 2 (unit: mm).

H <sub>1</sub>	H <sub>2</sub>	H <sub>3</sub>	H <sub>4</sub>	H <sub>5</sub>	H <sub>6</sub>
1.45	3.22	6.73	10.1	12.1	15.2
L <sub>1</sub>	L <sub>2</sub>	L <sub>3</sub>	L <sub>3</sub>	L <sub>5</sub>	L <sub>6</sub>
11.35	13.65	19.16	22.35	26.15	33.88

Table 2: Measured characteristics of polarizers with and without inserting stubs.

Stubbed polarizer	12.2GHz		12.45GHz		12.7GHz	
	LHCP	RHCP	LHCP	RHCP	LHCP	RHCP
AR	3.6	3.3	6.6	5.6	11.4	8.4
PD	-40.6	135.9	-39.6	136.5	-66.1	131.7
Ideal polarizer	12.2GHz		12.45GHz		12.7GHz	
	LHCP	RHCP	LHCP	RHCP	LHCP	RHCP
AR	-0.27	-0.88	-0.74	-2.42	-0.05	-0.4
PD	-107.1	71.13	-100.9	79.9	-89.8	91.6

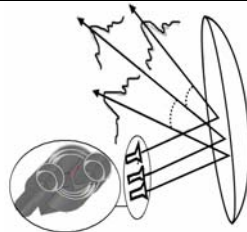
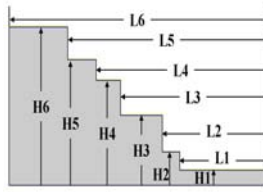
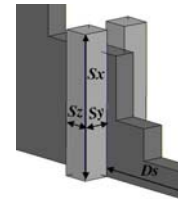


Figure 1: Illustration of triple beam reflector antenna system and its co-structured Ku-Ka band feed horn antennas.

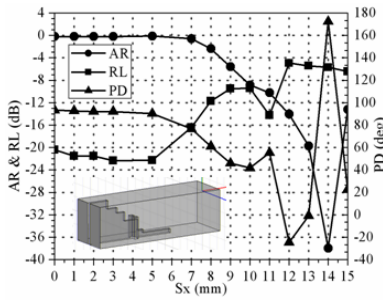


(a) Septum

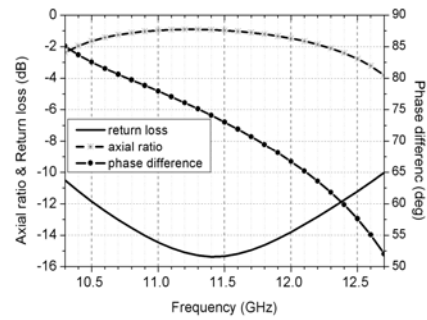


(b) Insert stubs

Figure 2: Polarizer structure

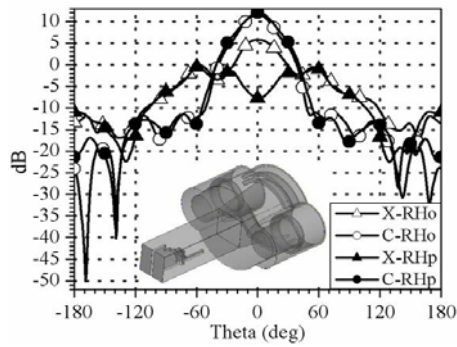


(a)  $S_x$  sweep

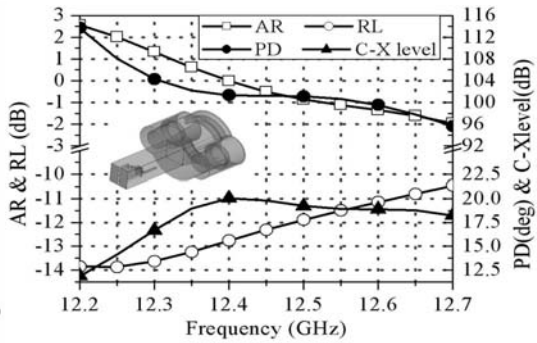


(b) Frequency sweep

Figure 3: Polarizer's performance for Figure 2(b).



(a) Radiation



(b) Electric Performance

Figure 4: Performance of a horn antenna with polarizer inserted additional stubs in these two tunnels

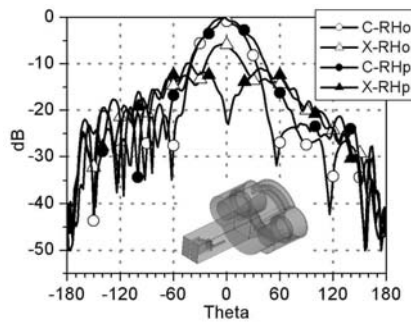


Figure 5: Measured radiation patterns of a horn antenna as shown in Figure 4.