SEPTUM POLARIZER - AN ALTERNATIVE DESIGN APPROACH

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Abstract: The presented paper deals with the septum polarizer as an antenna element and describes a simple design method to determine the initial geometry for further optimization. After explaining operation principle and current design approaches an alternative method is proposed. Based on this method stepped septum polarizer in square waveguide for GPS L1 carrier (i.e. 1.57542 GHz) is successfully designed.

Keywords: septum polarizer, axial ratio, waveguide

1. INTRODUCTION

Septum polarizer is a waveguide microwave device, whose function is to transform linearly polarized EM wave at the input port into a circularly polarized EM wave with excellent axial ratio at the output and vice versa. Signal fed into the input port designated R is transformed into RHCP at the aperture, and correspondingly, signal fed into the input port L is transformed into LHCP (Fig.1).

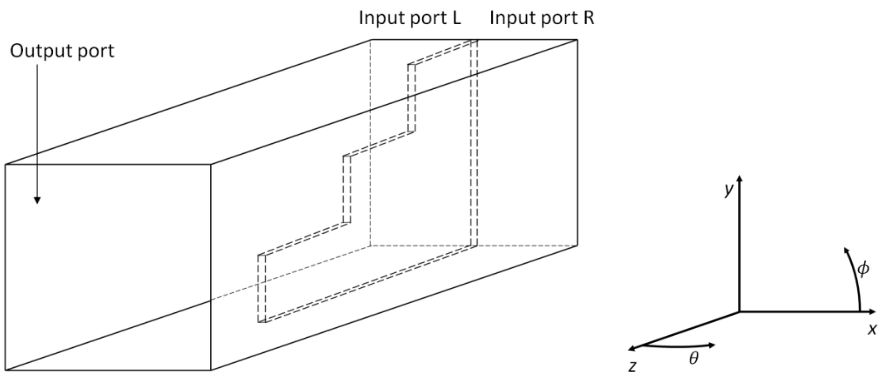

Fig. 1: Septum polarizer geometry

2. DEVICE DESCRIPTION AND CURRENT DESIGN METHODS

Septum polarizer consists of three parts: Input waveguides (rectangular or half circular), ridge septum itself and the output square/circular waveguide. Following text describes only a square type of the polarizer. Description of the circular version is analogous - instead of the modes TE_{10}, TE_{01} two orthogonal circular modes TE_{11} are excited.

Input waveguides represent two input ports (R,L). If one of the ports is excited with the TE_{10} mode, CP wave is generated at the output port. When exciting both of the input ports with signals of different amplitudes/phases it is possible to generate all polarization senses.

Second section can be considered as a series of ridge waveguides (i.e. steps), whose purpose is to generate waveguide mode parallel to the ridge (i.e. TE_{10}) from the mode perpendicular to the ridge (i.e. TE_{01}) with equal amplitude and 90° phase shift. The crucial part of the design is therefore focused on determining the suitable geometry of the steps (i.e. number, heights, lengths).

Third part is a square waveguide, that supports both degenerated perpendicular modes (TE_{10}, TE_{01}) with equal amplitudes and relative phase shift of 90 °. The length of this section is important for sufficient higher modes suppression.

Current design methods:

At the time there exists no general design procedure that would lead on a polarizer geometry. Currently this device is mostly designed by scaling an existing and published polarizer configurations. The first stepped septum polarizer was designed by Chen and Tsandoulas and described in journal paper in 1973 [1]. For illustration, the polarizer was developed, as authors stated, by "trial and error experimental method". Another way is to perform "brute force" optimization using either mode matching techniques [2] or full wave simulator.

3. SUGGESTED DESIGN APPROACH

In order to design an original septum polarizer effectively using limited computational power, following procedure was employed. The procedure applies to both square and circular waveguide.

a) Selecting number of the steps (for speeding up optimization, 2 step geometry was selected)

b) Selecting heights of the steps, h_1, h_2

- the highest step should not be high enough to support propagation of higher modes
- height of the steps is approximately equal

c) Determining phase shifts due to the discontinuities between the steps, $\Delta\phi_D$

d) Since the desired phase shift between modes is 90 °, the remaining shift $\Delta\phi = 90\,° - \Delta\phi_D$ is equally divided between the two steps, hence lengths of the steps l_1,l_2 are calculated from following equation.

$$\Delta\phi_x = 2\pi\, l_x \left(\frac{1}{\lambda_{v_\parallel}} - \frac{1}{\lambda_{v_\perp}}\right), \tag{1}$$

where $\Delta\phi_x$ is the relative phase shift between the two orthogonal modes due to the step with length l_x. $\lambda_{v_\parallel}$ and $\lambda_{v_\perp}$ are the waveguide wavelengths of the two orthogonal modes.

e) All the four design parameters (i.e. h_1, h_2, l_1, l_2) can be now optimized by means of local optimization. The goal function includes the following:

$$\phi_\perp = \phi_\parallel \mp 90\,°, \tag{2}$$

$$|\mathbf{E}_\perp| = |\mathbf{E}_\parallel|, \tag{3}$$

$$Return\ Loss\ \&\ Isolation < -20\ \mathrm{dB}, \tag{4}$$

where $\phi_\perp$, $\phi_\parallel$ are phase shifts and $|\mathbf{E}_\perp|$, $|\mathbf{E}_\parallel|$ magnitudes of the orthogonal electric field vectors corresponding to the perpendicular and parallel mode respectively.

f) The length of the waveguide after the polarizer is determined. This section serves as a mode filter and its length is given by the requirements on the mode purity at the polarizer aperture.

The advantages of the above described method:

- it gives a rough initial approximation of the geometry for subsequent optimization
- local optimization techniques can be employed

– simulation time for one run can be kept very short - i.e. calculation of the radiation characteristics is not part of the optimization

4. RESULTS AND CONCLUSION

Simple procedure for designing septum polarizer was proposed. Based on this method a two step polarizer was designed using full wave EM simulator CST MWS. The result is a polarizer with excellent parameters as listed in Tab.1. Axial ratio in the main lobe is shown in Fig.2. The radiation pattern was identical in both principal planes $\phi = 0\,°$ and $\phi = 90\,°$ (given by circular polarization property) and for both polarization senses. Such a polarizer can be directly deployed as a parabolic reflector feed, after careful horn design as a reference source for anechoic chamber measurements or as a duplexer in wireless communication systems.

	RHCP	**LHCP**
$\Delta\, \phi$ [°]	-89.99	90.02
$\lvert E_{\perp}\rvert / \lvert E_{\parallel}\rvert$	1.0003	1.0003
Axial Ratio [dB]	**0.01**	**0.01**
Return Loss [dB]	-35.72	-35.71
Isolation [dB]	-37.18	-37.20
Bandwidth (Isol. & RL < -20 dB) [%]	10.5	10.5

Tab. 1: Polarizer parameters

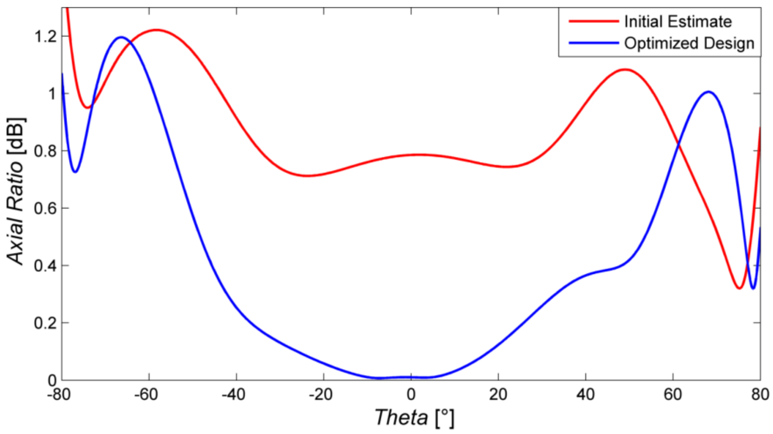

Fig. 2: Axial Ratio vs. elevation (azimuth) angle

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