

# TRANSMITTING ANTENNA WITH DUAL CIRCULAR POLARISATION FOR INDOOR ANTENNA MEASUREMENT RANGE

Michal Mrnka, Jan Vélím

Doctoral Degree Programme (2), FEEC BUT

E-mail: xmrnka01@stud.feec.vutbr.cz, velim@phd.feec.vutbr.cz

Supervised by: Zbyněk Raida

E-mail: raida@feec.vutbr.cz

**Abstract:** The presented paper describes design of an original transmitting antenna for specific indoor far-field measurement range. The antenna is able to generate both senses of the circular polarization with high polarization purity by using stepped septum polarizer inside a waveguide. Very high suppression of the side lobes is achieved by utilization of the higher order modes in the aperture of the final horn antenna which is directly connected to the septum polarizer. The antenna was simulated and optimized in CST Microwave studio, measured and the data compared. Excellent agreement between simulation and experiment was achieved.

**Keywords:** measurement range, septum polarizer, dual mode horn, axial ratio, waveguide

## 1. INTRODUCTION

The motivation for the work described in this paper was the need for the reference antenna (transmitting antenna) for specific indoor measurement range in ERA a.s. company. The antenna was intended to serve as a reference radiator for radiation pattern measurements of GPS L1 antennas developed in the above mentioned company. The ability to generate both circular polarization senses with high polarization purity (low axial ratio) and the maximum suppression of the sidelobes were of most importance.

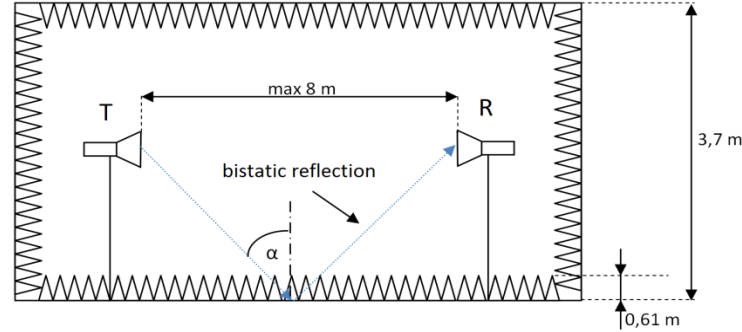
Circularly polarized (CP) electromagnetic wave can be generated by different antenna elements, e.g. microstrip, helix, horns or simple orthogonal dipole antennas. Two orthogonal components of the E-field must be generated with the same amplitudes in every point of the desired space with phase shift  $\pi/2$  rad. The most suitable solution for building the reference antenna with high polarization purity is the horn antenna and generation of the CP inside the waveguide. For this purpose septum polarizer device was used; the device enabled us to excite both CP senses with high polarization purity. To suppress the sidelobes in the radiation pattern and to provide sufficient gain, dual mode horn antenna was developed.

In designing the reference antenna for specific test range it is very important to analyze the reflections inside the range. The parameters of the reference antenna must comply with the geometry of the test range as well as with the parameters of the antennas to be measured with our reference antenna. This analysis lead to the formulation of more specific requirements (Section 2) the resultant device had to meet. Sections 3 and 4 briefly describe the operation and design of the stepped septum polarizer and the dual mode horn, respectively. Finally, the simulation and measurement results are compared in Section 5 and the paper is concluded by Section 6.

## 2. PERFORMANCE SPECIFICATION

The transmitting antenna had to be designed for specific far-field antenna measurement range; simplified sketch with some parameters is shown in Fig. 1. The maximum required gain was determined by the minimum distance from the reference antenna aperture to the GPS antenna under test (AUT) which was 4 m. The gain was calculated, so that at the minimum distance, the amplitude

variation of the electromagnetic wave along the AUT was not more than 0.2 dB (we consider the maximum aperture of the AUT 0.5 m x 0.5 m). The maximum distance between transmitting and receiving antenna inside the test range was 8 m; at this distance the amplitude error would be decreased compared to the previously mentioned case. Ideally, the gain of our transmitting antenna should lie somewhere between 16 and 17 dBi. The height of the transmitting and receiving antennas according to the Fig.1 was 1.85 m.



**Figure 1:** Simplified geometry of the indoor measurement range

Detailed analysis of the internal reflections inside the measurement range is very crucial when setting up the requirements for the transmitting antenna to be designed. Internal reflections inside the test range occur since the absorption coefficient of the absorbers that cover the walls of the range is a function of the incident angle  $\alpha$  and frequency  $f$ . The absorption is mostly effective when  $\alpha = 0^\circ$ , on the other hand if  $\alpha > 0^\circ$ , the absorption becomes less effective as the angle of incidence increases. Similarly, the absorption is most effective, when the electrical size of the absorbers is at given frequency at least  $4\lambda$ . In our case the height of the absorbers (i.e. 0.61 m) was about  $3.2\lambda$ .

The most important reflections inside the test range are called bistatic reflections (Fig. 1) - in our scenario, these reflections represent the reflections from the top and the bottom wall of the range and from left and right wall of the range. As mentioned earlier, the bistatic reflections become more pronounced as the angle of incidence becomes larger. Considering our simplified geometry and the absorption coefficient data provided by the datasheet [1] and also taking into consideration different path losses for signals travelling along different trajectories we were able to calculate the attenuation of the reflected wave - for distance 8 m between apertures, the reflected signals were about 22 dB below the line-of-sight component and for distance 4 m the attenuation of reflected signals was about 36 dB. The multipath propagation can be dealt with at the transmitting antenna level as well, simply by reducing the side lobe level. The maximum suppression of the side lobes in the radiation pattern was thus extremely desirable.

Since the designed antenna should serve as a reference antenna for measuring the radiation patterns of circularly polarized antennas, high purity of generated circular polarizations was needed. The maximum value of the axial ratio in the main beam axis was to be at most 0.4 dB

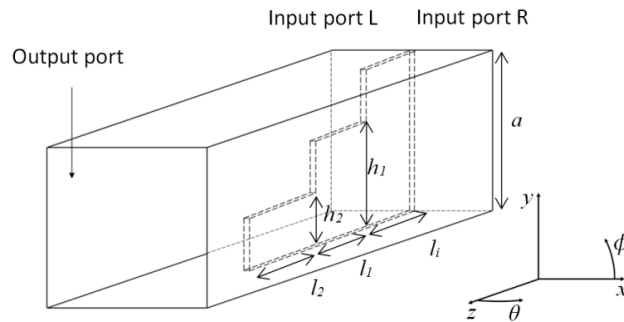
The central frequency of the transmitter antenna was to be the L1 frequency of the GPS system, which is 1.57542 GHz (free space wavelength  $\lambda_0 = 0.1904$  m), with relative bandwidth only 0.13 % which made our antenna a narrow band radiator.

Reflection coefficient at both the input ports was required to be at least -15 dB, ideally even below -20 dB. Isolation between the input ports was not so critical. Poor isolation performance could have been dealt with by simply terminating the unused input port with matched  $50\Omega$  termination. In that case, the reflection at the unused input port due to the poor isolation is minimized due to the suitable termination.

### 3. SEPTUM POLARIZER

For generating circularly polarized radiation so-called septum polarizer device was used. 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.2).

Usually, such a polarizer is designed with 4 or 5 steps [2-3], nevertheless, if relatively narrowband operation is desired, two-step geometry might be sufficient as shown in [4]. The design process in the open literature is mostly based on brute-force optimization [2-3]; however, by following quite straightforward guidelines already reported in [4], the whole process can be simplified. The process is based on proper determination of phase shifts at step discontinuities and avoiding the excitation of higher order modes that would deteriorate the performance.



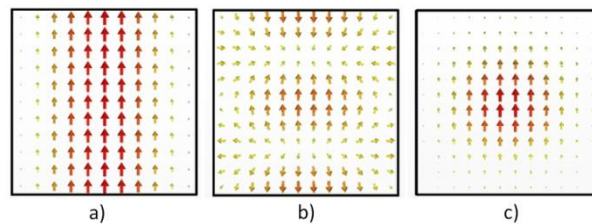
**Figure 2:** Septum polarizer geometry

### 4. DUAL MODE PYRAMIDAL HORN

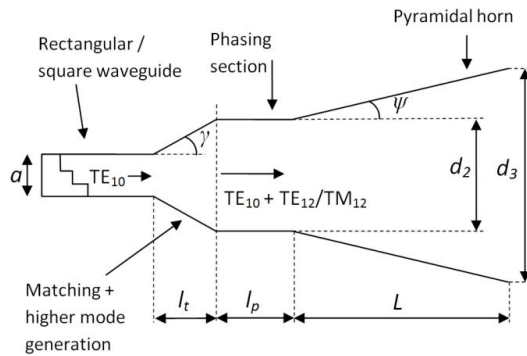
It was necessary to use a horn antenna to increase the gain (16-17 dBi). To provide high side lobe level suppression, we used a dual mode horn. Due to the construction limitations, it was not possible to utilize circular shapes in the design; in fact the whole antenna had to be built from aluminum sheets.

Operation principle of a dual mode horn antenna lies in the cancelation of the E-field near the edges of the aperture. The cancelation is done by excitation of higher order  $TM_{12}$  mode in addition to the dominant  $TE_{10}$  mode. The modes are added together in phase near the center of the aperture and out of phase near the edges. The field distribution is thus tapered in both principal planes (Fig. 3) and side lobes in the E-plane are reduced.

First, the optimum amplitude ratio of both the modes in terms of the side-lobe level performance had to be found. Then, the angle  $\gamma$  (Fig.4) which generated the higher order mode with desired amplitude was determined. The open aperture of the phasing section provided gain only about 11 dBi. In order to accomplish sufficient gain and at the same time keep the dimensions of the device as small as possible, we had to work with quite large angles of the pyramidal horn  $\psi$  [5]. If the classical design method had been used [8], the resultant device would have been at least 1m longer.



**Figure 3:** E-field distribution in the cross section of a square waveguide for  $TE_{10}$  mode (a),  $TM_{12}$  mode (b) and combination of both modes (c)



**Figure 4:** Dual mode horn antenna

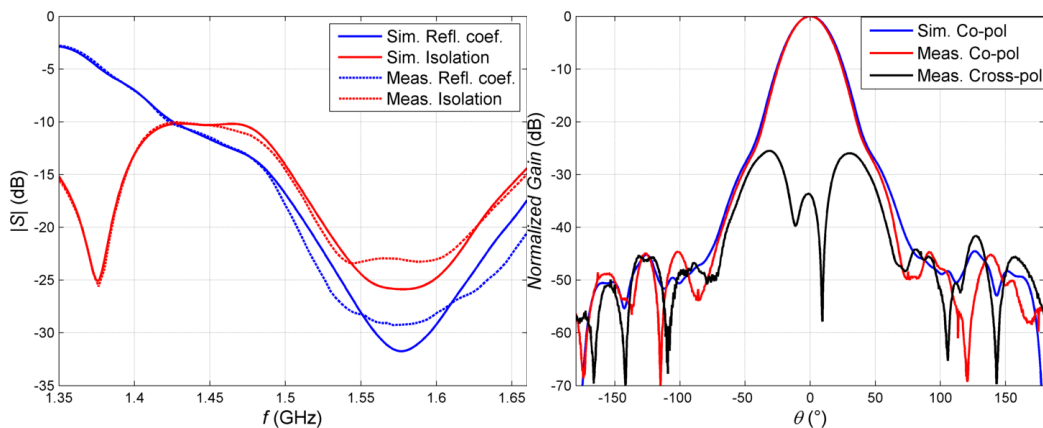
Polarizer		Dual mode horn	
$h_1$	$0.3676 \lambda_0$	$l_t$	$0.2941 \lambda_0$
$h_2$	$0.2101 \lambda_0$	$l_p$	$0.7878 \lambda_0$
$l_1$	$0.2946 \lambda_0$	$L$	$2.6261 \lambda_0$
$l_2$	$0.3036 \lambda_0$	$d_2$	$1.2868 \lambda_0$
$l_i$	$0.3676 \lambda_0$	$d_3$	$0.3676 \lambda_0$
$a$	$0.6303 \lambda_0$		

**Table 1:** Final dimensions

## 5. RESULTS

Simulations and optimization of the suggested structure were performed in the transient solver of CST Microwave Studio. The designed transmitting antenna was manufactured, measured and the data compared with simulation results with very good agreement (Fig.5). The reflection coefficient and input port isolation were measured by placing RF absorbers into the aperture plane. Radiation patterns for co and cross polarizations were measured as well in an anechoic chamber. In Fig. 5 co-polarization corresponds to the right hand CP and the cross-polarization to the left hand CP. If the other input port was fed, the definitions of co and cross polarization would be switched. Manufactured prototype of the antenna is shown in Fig. 6.

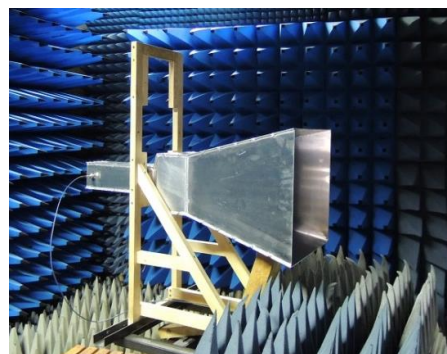
Measured parameters of the design antenna are summarized in Table 2. We can see that the achieved performance fulfilled all the requirements with sufficient margin. Particularly, the side lobe level was decreased to about -42 dB and the final axial ratio at the desired frequency was 0.36 dB.



**Figure 5:** Simulated and measured reflection coefficient and isolation (left), simulated and measured co-polarization radiation patterns and measured cross-polarization pattern (right)

Reflection coefficient	-29.3 dB
Isolation	-23.0 dB
Gain	16.2 dBi
Side lobe level	-42.0 dB
Back lobe level	-56.7 dB
Axial Ratio	0.36 dB

**Table 2:** Measured parameters of the designed antenna at 1.5754 GHz



**Figure 6:** Fabricated transmitting antenna inside the measurement range

## 6. CONCLUSION

Reference transmitting antenna based on the stepped septum polarizer solution and a dual mode horn with a rectangular cross section was proposed. The device was designed for GPS L1 frequency 1.57542 GHz in order to serve as a reference antenna for radiation pattern measurements of GPS antennas developed at ERA a.s. company.

The original contribution of the antenna lies in the utilization only two step polarizer for achieving excellent polarization purity and sufficient impedance bandwidth. Moreover, the dual mode operation of a horn antenna has been so far reported only in the conical horn. However, our device was based on pyramidal horn for simplified construction.

Excellent results of reflection coefficient, input port isolation, side lobe level suppression and axial ratio were obtained. The performance of the antenna was successfully verified by measurement.

## ACKNOWLEDGEMENT

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