Design of Pyramidal Horn Antenna for 2.45GHz in FEKO for Application in Experimental FSO/RF Hybrid System

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Abstract — Communication technologies are growing for day to day because demand on data sharing is unstoppable. Users require availability of approach to network at all time. Implementation of smart technologies allows communication of all type of devices. Capacity of data flow have to grow. Video formats HD or 4K require transmit on high data speed. Based on the demands many types of different communication systems which are suitable for these speeds were designed. One of these systems is FSO (Free Space Optics). FSO system is based on transmission of optical beams which carry the information. This system allow high data speed comparable with standard optical fiber in range to 10km. One of drawbacks of this system is LOS (Light of Sight) between communication points. The other drawback is sensitivity to weather changes. Optical beams interfere with water particles and cause attenuation on transmission path. The solution is in implementation using hybrid FSO/RF system which combines optical communication system with RF (Radio Frequency) backup link. We realized FSO communication link on Technical University of Košice. Our research is focused on design of appropriate type of antenna for our RF backup link. Our results in this area were published.

Keywords— FEKO, FSO/RF, horn antenna

I. INTRODUCTION

Today in the age of smart technologies we have to react to demand of users. Each of them would like to communicate, share data or information, stream or watch high quality video. Young generation is online oriented. On the base of these requirements we have to focus on increasing availabilities of services through growth of parameters of communication systems. Increase of speed of transmission, bandwidth and decrease of latency is one of the main points of research activities in communications field. Invention of optical fiber as transmission medium caused revolutionary change in communication systems. Transmission of light beams which carry information with

possible reach speed of transmission about 40 Gbps was incredible.

Optical fiber was the basic part of many communication systems, but the idea of transmission of light as carrier of information affects all types of communication systems. FSO system is based on transmission of optical beam carrying information through atmospheric channel. In comparison with optical fiber communication system FSO system offers comparable speed of transmission in short range (few km, to 10 km with speed of transmission 1 Gbps) without needs to implementation of optical fiber on transmission path.

Implementation of FSO system is easy regarding to speed of installation. This system could be implemented during one day. We need to place only one optical head on both sides of communication nodes with ensured LOS (Light of Sight) between communication points. Application of these systems is effective in mountain areas or in densely build city, where it is very complicated to install standard optical fibers.

Because the chosen communication medium at atmospheric channel with all inhomogeneities, the FSO system is sensitive to changes in atmosphere. These inhomogeneities are caused by concentration of water particles which are specific for each of type of weather. In case of critical concentration of inhomogeneities in atmosphere, the attenuation of optical beams grows significantly. In boundary cases it is possible to reach outage of services. We have to secure stabile connection at all times. Solution is in design of hybrid FSO/RF system which combines primary optical link and backup RF (Radio Frequency) link. We look for appropriate type of RF antenna operating in non-licensed frequency range with sufficient gain and low radiation power.

Many studies were focused on a design of appropriate type of antenna. We are interested in design of pyramidal horn antenna operating on 2.45 GHz. This is the point of this paper. Our research activities focused on increasing availability of FSO system and analysis, searching

appropriate type of antennas for backup RF link were published in [1-5].

II. DESIGN OF HORN ANTENNA

On the base of our previous research activities was chosen for next analysis pyramidal horn antenna. Horn antennas are characterized with high gain (more than 15dBi), acceptable side lobes level, low power consumption and otherwise relatively low price. We consider operating frequency from non-licensed frequency range [6-8]. With regards to non-licensed frequency range in Slovak Republic was chosen frequency equal to 2.45 GHz. Design of antenna is realized in special programme suite FEKO proposed to analysis of electro-magnetic compatibility. Physical parameters were determined by equations (1 - 8).

Variables R_A and R_B in equations (1), (2) represent perpendicular planes of opened waveguide and plane of horn [9-14].

$$R_a = \frac{A}{A-a} R_A, \quad (1)$$

$$R_b = \frac{B}{B-b} R_B. \quad (2)$$

In equations (3), (4) denote variables L_a and L_b total length of plane of closed waveguide.

$$L_a^2 = R_a^2 + \frac{A^2}{4}, \quad (3)$$

$$L_b^2 = R_b^2 + \frac{B^2}{4}. \quad (4)$$

Angles α and β are defined by related equations:

$$\tan \alpha = \frac{A}{2R_a}, \quad (5)$$

$$\tan \beta = \frac{B}{2R_b}. \quad (6)$$

Lengths denoted as Δ_a and Δ_b in equations (7), (8) represent maximal deviation of radial distance of plane that creates horn part of antenna.

$$\Delta_a = \frac{A^2}{8R_a}, \quad (7)$$

$$\Delta_b = \frac{B^2}{8R_b}. \quad (8)$$

All variables of equations (1 - 8) are shown in the Fig. 1 and Fig. 2.

Fig. 1 YZ cut of model of horn pyramidal antenna

Fig. 2 XZ cut of model of horn pyramidal antenna

The designed model of horn antenna is fed by waveguide port placed on the bottom of waveguide and type of excitation source is waveguide excitation. Parameters of horn antenna shown in Fig. 1 and Fig. 2 are defined in TABLE I.

TABLE I Parameters of designed horn antenna

Horn antenna for 2.45 GHz	
Parameter	Value
Width of waveguide (a)	10.264 cm
Depth of waveguide (b)	4.806 cm
Aperture of horn (A)	42.449 cm
Aperture of horn (B)	34.661 cm
Length of horn ($R_A = R_B$)	39.530 cm
Lengths ($L_a = L_b$)	49.057 cm

The model of horn antenna configured in CAD FEKO (Design environment from program suite FEKO) could be seen in the Fig. 3.

Fig. 3 Designed model of horn antenna

The radiation characteristic of the proposed antenna is shown in Fig. 4 in the decibel scale, the value of the gain is expressed according to the legend in the upper left corner where the largest gain area is the red color, while blue represents the region with the lowest gain value. As it can be seen in Fig. 4 the value of the gain in the main direction of radiation corresponds to 18.315 dBi. The designed antenna is represented by -7.031 dBi in the rear lobe radiator direction.

Fig. 4 Radiation characteristic of designed antenna for frequency 2.45GHz

The most important parameter of antenna is ratio of level of radiation for different directions. Radiation in direction of main lobe is characterized by higher value of radiation. Distance between radiations in main lobe in comparison with second local maximum of radiation determines sidelobe level of radiation (SLL). The value of SLL for simulated antenna reaches value 9.6273 dB. Direction parameters of antenna are affected by value of SLL parameter. Higher value of this parameter ensures potentially low possibility of interference caused by radiation of same signal spreaded out in different direction.

Fig. 5 Sidelobe level of radiation of antenna

The radiation characteristic of the designed antenna shown in polar coordinates in the cut of plane for angle $\phi = 0^\circ$ is illustrated in Fig. 6. The decrease of power value by 3dB causes change of the radiating angle to value 19.1688°.

Change of angle of radiation at half power (-3dB)

Fig. 6 Radiation characteristic in polar graph for $\phi = 0^\circ$

The radiation characteristic of the designed antenna displayed in polar coordinates in the cut of plane for angle $\phi = 90^\circ$ is illustrated in Fig. 7. If the power value would decrease its value by 3dB, the radiating angle would shrink to 21.3157°.

Change of angle of radiation at half power (-3dB)

Fig. 7 Radiation characteristic in polar graph for $\phi = 90^\circ$

III. CONCLUSION

The point of this paper was design of a pyramidal horn antenna working in non-licensed frequency range with chosen operating frequency of 2.45GHz. This type of antenna was chosen regarding to high level of gain, good sidelobe level, low cost and low power consumption. Values of required parameters were reached gain with value 18.315 dBi, the SLL is represented as 9.6273 dB and power reaches value 0.182dBW. Optimisation for purpose of decreasing sidelobe radiation allows increase of radiation in main lobe direction. Type of horn antenna is appropriate for our application and future work is focused on improving its features.

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BIOGRAPHIES

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