ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 10, October 2016

Optimization of Horn Antenna using various Techniques: A Review

Anku Bala[1], Garima Saini[2]

ME Student, National Institute of Technical Teachers Training and Research, Chandigarh, India[1]

Assistant Professor, National Institute of Technical Teachers Training and Research, Chandigarh, India [2]

ABSTRACT: Horn antenna is flaring of open end of the waveguide. It is most widely used antenna at UHF and at microwave range. These are widely used transmitting and receiving antenna in the laboratory. Horn antenna provides a gradual transition of EM energy to the free space and prevent reflection of energy. The horn antennas are not always of small size, the world's largest conical horn antenna is about 14 feet.In this review paper, various techniques of antenna have been proposed. This paper is a review for optimization of gain performance of an antenna. The different type of material has different effects on horn antenna. The Particle Swarm Optimization technique is also discussed here to optimize the results.

KEYWORDS: Horn antenna, Artificial neural network, Corrugated horn antenna, Ridges, Particle swarm optimization.

I.INTRODUCTION

Horn antenna is the most important part of communication system because it is widely used antenna at UHF frequency and microwave frequency. It is a type of aperture antenna used for various applications. Horn antenna is used as a feed element in large antennas. It is also used as a standard antenna to compare it with other antennas. In this paper various techniques have been studied to design a horn antenna and to improve its gain [1]. There are a number of materials used for designing a horn antenna, one of them is carbon based composite materials. These materials are widely used for aerospace, car industry, etc. In horn antenna manufacturing composite materials are used. If carbon based polymer material is used for antenna. The electric conduction is ensured by surface containing metal particles. Using these materials one can improve radiation pattern, reflection and scattering properties.

Corrugated horn antennas have been known since the 1960s. These antennas are used in many applications because of their low sidelobe, low return loss and broad bandwidth. After some time a new type of profile was introduced which is known as a Gaussian profiled horn antenna. This type of profile has very low side lobes and very low cross polar levels. The main disadvantage of this type of horn antenna is heavy weight and big size.it also has difficulty in fabrication [2]. After some time horizontal and vertical corrugations have been combined to achieve the high performance of horn antenna. These types of antennas are easier to manufacture as compared to earlier one [3].

The ridges in the waveguide were adopted by Walton and Sundberg in 1990. The purpose of the ridges in horn is to introduce the capacitance effect and to decrease the cutoff frequency of propagating mode [4]. In 2003 it is reported that double ridge horn antenna suffers from a major problem of radiation pattern and gain at high frequency in [5].

The artificial neural network is commonly used to optimize the parameters of an antenna. The supervised feed forward type of network is used. In an ANN a nonlinear function (·), also known as activation function is used with weights to calculate the output signal. The ANN network learns the information by an error signal and weight updating is done accordingly. By doing this iteratively optimum results are obtained [6].
Meta-materials are the growing interest which is being utilized in antenna community. Some metamaterials are such as photonic crystals, double negative materials, electromagnetic band gap and many more depend upon applications. The low refractive metamaterials are used for improving the directivity [7].

The paper consists of section II of the literature survey, section III consists of discussion and section IV consists of a conclusion.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 10, October 2016

II.LITERATURE REVIEW

Teniente et al. in [3] proposed a horn antenna based on the combined horizontal and vertical corrugations. The designed horn antenna using these techniques has high gain with short profiles. The corrugated horn antenna has been designed with 24dB of gain and a return loss of -25dB. The simulation is done on Mician microwave software. The corrugated horn has been designed in this paper is because of its broad bandwidth and low return loss.

Fedi et al in [6] described a method using an artificial neural network to design a horn. The supervised feed forward type of neural network has been used in this paper. A non linear function is applied to the weighted sum of inputs to produce output. The network learns by getting information from error signal. A number of artificial neural network is required to speed up the learning process. This paper explains the process by which training to ANN is carried out to map the electromagnetic characterstics Y into the geometrical parameter X. The ANN approach for synthesis and analysis for corrugated horn is much faster than full analysis and it is very accurate. This solution gives a good level of accuracy for synthesis problem

Xiao et al. in [7] proposed a horn antenna for gain enhancement using low refractive metamaterial. Metamaterials are the materials with unique feature not existing in nature. The metamaterial (MTM) consists of two layers, one of them is slices of foam and another one is metallic grids. The permitivity of metamaterial is positive and less than equal to one approx zero. MTM slab is designed from two layers, and is placed above flange of horn antenna. The MTM horn is then compared with conventional horn of 12dB in 11.8 GHz-12.8 GHz frequency range and metallic flange horn. It has a little lower gain as compared to MTM horn. The gain of MTM horn is 16dB in the same frequency range. The designed MTM horn has a narrow main lobe and side lobes are not much higher.

Pereira et al. in [8] described the method for optimum design of horn antenna. Pyramidal horn antenna finds its application in microwave range because of its better gain, low VSWR and low bandwidth. Exact phase errors are not considered for usual methods to calculate the gain as given in (Gonzalez). There are many factors that influence the gain of pyramidal horn antenna. While designing the pyramidal horn antenna, the assumption is that the only dominant mode will exist, but higher modes will appear due to larger dimensions of horn antenna. Wave reflections occur due to increase in aperture of the antenna, hence increasing VSWR. The reflections can be lower when smooth transition occurs from waveguide in free space. So a new method has been proposed by considering all these parameters. The optimal solution has been designed relating the four dimensions by given the operating frequency, waveguide and gain. The results calculated by this method were compared with Cozzen's method and original design. The dimensions of aperture of optimum design are closer to Cozzen's method whereas axial length is closer to the traditional design. The advantage of optimum design is stable gain with aperture dimension.

Dayal et al in [9] optimized the horn antenna to achieve 20dB gain by using WIPL-D microwave package. It is powerful and easy to use tool for designing of microwave circuits, and for accurate simulation. The S parameters are calculated during simulation. EM Solver is a component which is used from WIPL-D software package. EM solver is based on the method of moments. EM modelling in WIPL-D is divided into two parts, the one is geometrical modelling in which metallic structure is considered as interconnection of wires and plates whereas in the current modelling, the current is calculated by a polynomial expansion across wires and plates. In the design of pyramidal horn section, first of all the design of waveguide is given, whose dimensions are calculated using IEEE standard of waveguides.
The choice of dimensions is done by considering:

1. Operating frequency
2. Power to transfer
3. Transmission loss which can be tolerated.

The dimensions of flared part of the horn are first calculated and then optimized using a genetic algorithm, which is the global optimization algorithm. The parameter range is also decided so that the dimensions of horn can't exceed up to some limit. After optimizing the horn the simulation results are shown and compared with the horn in which genetic algorithm is not used to optimize the dimensions. After optimizing the gain of horn antenna is increased to 20dB. The

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 10, October 2016

comparison of simulated horn and optimized horn is also given. The gain of horn antenna can be increased from 15dB to 20dB by slightly increasing the dimensions, which are optimized using A Genetic algorithm.

Yogita et al. in [10] designed an antenna with a gain of 20dB and centre frequency 9.5GHz. The design of horn antenna is reduced from 4 order equation. For horn antenna, $R_E = R_H$ Whereas R_E is the length of the horn aperture in E- field and R_H is the length of the horn aperture in H-field. The design procedure includes, first calculate A, the first approximate
$A = 0.45\lambda\sqrt{G}$, Then calculate B

$$B = \frac{1}{4\pi}\frac{G\lambda^2}{0.51A}$$

$$R_1 = \frac{A^2}{3\lambda}$$

$$R_2 = \frac{B^2}{2\lambda}$$

$R_E = R_2\left(1 - \frac{a}{A}\right)$ and $R_H = R_1\left(1 - \frac{b}{B}\right)$
Finally, check $R_E = R_H$. If $R_E = R_H$ Then the horn can be realizable. The directivity of horn antenna is calculated as 21.8dB. The horn is fabricated and practical value of gain is 19.49dB, which is less than the specification of 20dB.

Odendaal et al. in [11] presented a wave diffraction model for calculation of directivity of near field of horn antenna. To verify the range of standard gain antenna for directivity, the method of moments is used. The edge wave diffraction model used in this paper to calculate the gain of near field of the pyramidal horn antenna and this model was compared with various techniques and gain data. The predicted value of gain at 1m from aperture is 16.1dB and at 3m it is 16.8dB. The gain is calculated at various frequencies and compared with theoretical values. This difference is quite small. In this paper theoretical models are presented such as moment of method, schelkunoff approximation to find the radiated field strength from standard antenna and provide the accurate results. The model for horn antenna is not very expensive as compared to method of moments and easy to apply for large standard gain antenna for frequency above 2.5GHz.

Najjar et al. in [12] designed a method for optimal gain horn antenna by just improving the existing design equation by using the particle swarm optimization technique. Optimum gain pyramidal horn antenna provides maximum gain. In the design of horn antenna the first known parameters are gain, wavelength and the dimension of the waveguide. On the basis of these parameters, the other parameters are determined. The maximum gain occurs when:

1. $B = \sqrt{2\lambda L_1}$ Where B is the dimension of the aperture
2. $A = \sqrt{3\lambda L_2}$

The above equations are obtained by curve fitting for maximum gain. The Particle Swarm Optimization Technique has been applied to antenna design for effective results. The results drawn from PSO are similar to a genetic algorithm, but it requires less computation and few code lines. In this paper improved formulas were given for optimum design such as

$$B_1 = \sqrt{2.1060\lambda L_1}$$
$$A_1 = \sqrt{3.1831\lambda L_2}$$

The horn is designed using both improved formulas for A_1 and B_1 and approximate formulas to have a fair comparison. The improved formula explained in this paper does not approximate the path length error and thus by using formula, more accurate results are obtained. Using a particle swarm technique better accuracy is obtained as compared to previous design methods.

Palantei et al. in [13] designed several antennas operating in the ISM bands. The optimization is done using HFSS11 and done by varying the angle of the flare and size of the pyramidal horn. The material used to build the horn antenna is aluminium. The flare angle is varied and the impedance, bandwidth and VSWR are changed accordingly. The optimum angles for large bandwidth and high directivity were in the range of 35-37°. The optimization is done from numerical

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 10, October 2016

computations and for a certain frequency band. The horn antenna at 2.5GHz has very good pattern of directivity, gain, FTBR& beam shape. Some horn antenna has poor performance in terms of directivity and gain, but some antennas with double ridges form has 5.5dB gain 3dB directivity while a quad ridge horn antenna has 7.3dB gain and 4dB directivity.

III.DISCUSSION

Various techniques have been studied which includes a pyramidal horn antenna design for a microwave applications. It has a low VSWR and high gain and moderate bandwidth. The results obtained from this paper were compared with Cozzen's method and traditional design.Another antenna using metamaterials in [2] is discussed and compared with conventional horn. MTM horn has better gain, low side lobe and narrow main lobe.A wave diffraction model is used to design another horn in [5] the horn designed using this model was compared with various techniques.Another horn was designed using particle swarm optimization technique to improve its gain and is compared with previous design methods.The Artificial neural network has been also used to calculate the design parameters and hence horn has been designed using ANN approach. This approach is much faster than full analysis and very accurate.

IV.CONCLUSION

In this review paper basic techniques of antenna are covered. There are many techniques by which one can optimize the gain of an antenna and this paper just introduces the few techniques. A high gain pyramidal horn antenna has been proposed using various techniques and materials make it suitable for various applications like short range communications, microwave imaging applications, GPR applications etc. The horn should have small size and light weight. The overall gain after optimization is 24dB. The maximum gain has been obtained by a vertically and horizontally corrugated horn antenna.

REFERENCES

[1] S. Kampeephat, P. Krachodnok, and R. Wongsan,"A Study of Gain Enhancement of Horn Antenna Using EBG", IEEE Asia-Pacific Conference on Antennas and Propagation, August 27-29, 2012, Singapore.
[2] Jorge Teniente, Ramón Gonzalo, and Carlos del-Río, "Ultra-Wide Band Corrugated Gaussian Profiled Horn Antenna Design", IEEE Micowave and Wireless Cmponents Letters, Vol. 12, No. 1, pp 20-21, Jan 2002
[3] Jorge Teniente, Ramón Gonzalo and Carlos del-Río, "Innovative High-Gain Corrugated Horn Antenna Combining Horizontal and Vertical Corrugations", IEEE Antennas and wireless propagation letters, Vol. 5, pp 380-383, Dec 2006.
[4] M. Abbas-Azimi, F. Arazm and R. Faraji-Dana ,"Design and optimisation of a high-frequency EMC wideband horn antenna", IET Microwave. Antennas Propagation., Vol. 1, No. 3, pp. 580–585, June 2007.
[5] Bruns, C., Leuchtmann, P., and Vahldieck, R.: 'Analysis and simulation of a 1–18-GHz broadband double-ridged horn antenna', IEEE Trans. Electromagnetics. Compat.,Vol 45, pp. 55–60, 2003.
[6] GuilioFedi, Stefano Manetti, Giuseppe Pelosi and Stefano Selleri, "Profiled Corrugated Circular Horns Analysis and Synthesis Via an Artificial Neural Network", IEEE Transactions on Antenna And Propagation, Vol. 49, No. 11, pp 1597-1602, Nov 2009.
[7] Zhinang Xiao and HuiliangXu, "Low Refractive Metamaterials for Gain Enhancement of Horn Antenna", Journal of Infrared MilliTerahz Waves, 2009.
[8] Leandro de Paula Santos Pereira, Macro Antonio Brasil Terada, "New method for optimum design of pyramidal horn antennas", Journal of Microwaves, Optoelectronics and Electromagnetic Applications, vol.10 no1, pp 266-277, June 2011.
[9] Pendurthy A Sunny Dayal, "Design Of X Band Pyramidal Horn Antenna", International Journal of Applied Control, Electrical and Electronics Engineering Vol 3, No.1/2, pp 23-34 May 2015.
[10] G.Abhignya, B.Yogita, C.Abhinay, B.Balaji, MBR Murthy, "Design, fabrication and testing of pyramidal horn antenna",International Journal of Engineering and Applied Sciences, Volume-2, Issue-4, PP 45-47, April 2015.
[11] J. W. Odendaal , J. Joubert and M. J. Prinsloo, "Extended edge wave diffraction model for near-field directivity calculations of horn antennas", IEEE Transactions on Instrumentation and Measurement Vol 54 , Issue: 6 , pp 2469-2473, Dec. 2005.
[12] YahyaNajjar, Mohammad Moneer and Nihad Dib , "Design of optimum gain pyramidal horn with improved formulas using particle swarm optimization", International Journal of RF and Microwave Computer-Aided Engineering, pp 505-511, Aug 2006.
[13] E. Palantei , L. Ramos Emakarim , A. Nugraha and N. K. Subaer, "Optimized wideband horn antennas of high gain and directivity", International Conference on Electromagnetics in Advanced Applications, pp 321-324, Sep 2010