J. Basic. Appl. Sci. Res., 3(7)701-707, 2013
© 2013, TextRoad Publication

ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Design and Optimization of an UWB Antenna with 5.8 GHz Band Suppression Using Genetic Algorithm

M. Talha Asghar[1], M. Farhan Shafique[2], Imran Usman[2], Nayab Gogosh[3], Mahmood Ashraf Khan[2]

[1]Department of Electrical Engineering, HITEC University, Taxila, Pakistan.
[2]Center for Advance Studies in Telecommunications, COMSATS Institute of Information Technology, Park Road, Chak Shahzad, Islamabad, Pakistan.
[3]Department of Electrical Engineering, COMSATS Institute of Information Technology, Park Road, Chak Shahzad, Islamabad, Pakistan.

ABSTRACT

This paper reports the optimization of a staircase ultra wideband antenna with an inverted U shaped structure for 5.8 GHz ISM band suppression. Conventionally antennas are optimized on trial and error techniques, which are time consuming and even after a number of iterations there is no guarantee of achieving optimum result. To address the optimization of microwave antenna with a large number of dependent variables genetic algorithm techniques has been proposed. The optimum band suppression has been achieved by using the algorithm. Twelve dependent antenna variables were optimized in a very efficient way by exploiting dependencies among them in terms of bandwidth, notch band selection and return loss. The optimization procedure was elaborated and the optimized antenna results are presented. The antenna covers frequencies from 2.2 to 8.5 GHz and is immune to 5.8 GHz communication by rejecting the frequency. The optimized antenna design prototype was fabricated and the measured results are verified with the simulated results.
KEYWORDS: Design optimization; Genetic algorithms; microstrip antenna; notched band; patch antenna; planar antennas; slot antenna; ultra wideband antennas

I. INTRODUCTION

One of the fundamental attributes of current short-range wireless technologies is the use of high bandwidth to achieve the desired data rates. Since wireless devices are battery operated in general therefore, high transmission power is not a feasible option to achieve the required high data rates. This limitation of short range communication devices, such as Wireless Personal Area Networks (WPANS), has been addressed by transmitting the information over a wide frequency band usually more than 20 %. In recent years, the commercial operations of Ultra Wideband (UWB) technology attracted researchers to contribute in its evolution by proposing various microwave components for RF front-end design [1, 2]. A number of research works have been reported which address various issues ranging from antenna designing to calculating channel capacity. Since the power levels used by UWB system is as low as 0.5 mW, which is close to the noise floor when compared to the narrow-band systems, therefore, the antennas employed for these applications should be very efficient. Usually printed antennas are preferred due to their limited footstep and easy installation.

The UWB antennas cover a wide bandwidth which makes them susceptible to interference from other narrow-band systems like in 5.8 GHz ISM band, HyperLan and WiFi. To protect the system from such interference, a notch can be introduced in the radiation or receiving characteristics of UWB antennas which eliminate the requirement of any additional high quality band-pass filter structures. Several techniques have been proposed to introduce a notch in the desired band, such as a tuning fork shaped antenna [3], printed monopole antenna with slots [4], antenna with inverted L shaped slot in the ground plane [5], antenna with parasitic elements on the patch [6], etc. One of the basic techniques is the use of inverted U shaped slot in the patch antenna to create the notch [7, 8]. This technique of inverted U shaped slot has been adopted to introduce the band rejection characteristics in this work.

In general, it is rare to achieve the desired characteristics with mere theoretical calculations; the optimization process is thus required which involves various variables whose inter-dependencies are not well established. Sequential search techniques for optimizing these parameters consume time and valuable resources. The research works discussed in [3-10] have used sequential search techniques to optimize their respective designs. Hence a random search in the

*Corresponding Author: M. Farhan Shafique, Center for Advance Studies in Telecommunications, COMSATS Institute of Information Technology, Park Road, Chak Shahzad, Islamabad, Pakistan. farhan.shafique@comsats.edu.pk

solution space is highly beneficial in terms of temporal cost as well as convergence to the optimal/ near optimal solution. This reduces significant amount of time and resources as compared to techniques used otherwise.

Recently, Genetic Algorithm (GA) has gained a lot of popularity in electromagnetic research community, especially in antenna designing, optimization and MEMS technology [9-15]. GA is a stochastic search technique inspired by the theory of evolution [16]. The algorithm evolves towards an optimum solution by randomly searching a population of candidate solutions, and then applying genetic operators of mutation, cross-over and replication on the best individuals to create the next generation. With scoring based on a pre-defined fitness function, the algorithm advances in a step wise iterative manner until a desired termination condition is reached. The fitness function is defined on the basis of desired antenna attributes like bandwidth, VSWR, gain, antenna dimensions or a multitude of these parameters.

The scientific contribution of this paper is that it provides prime solution for optimizing antennas which saves time and resources. Optimizing band rejection characteristics of an antenna using GA will help scientists and researchers to achieve a global optimum solution efficiently for any desired radiation characteristics.

In this work, a staircase UWB antenna with inverted U shaped slot for 5.8 GHz band suppression is proposed. The bandwidth, notch band, and return loss were selected as the core components of the fitness function for establishing dependencies and optimizing the selected parameters. The remainder of paper is organized as follows: In section II, the selected antenna designed is discussed. A parametric analysis of this design and its optimization using GA is purposed. Section III, compares the simulated and measured results. Finally in section IV, paper is concluded.

II. MATERIALS AND METHODS

1. Antenna design

The purposed antenna consists of a rectangular patch with stair case on the feeding edge. The patch has an inverted U shaped slot which creates the notch at the desired frequency. The ground plane of the antenna has a slot beneath the feeding line which helps in better impedance matching. The proposed layout is shown in Fig 1. The design is symmetric along Y axis from center which helps in reducing the complexity of the optimization process.

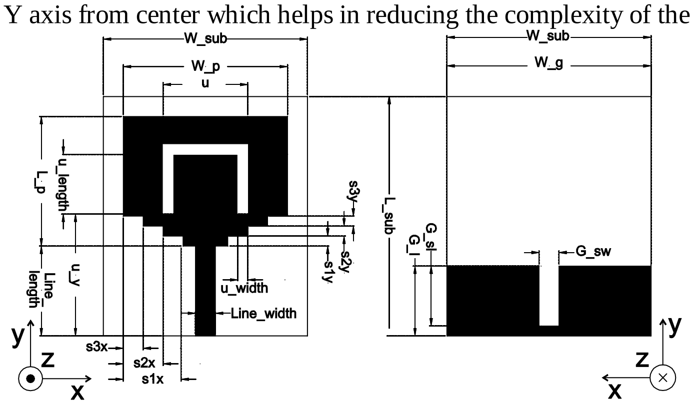


Figure 1. Layout of the proposed notch antenna

2. Design Analysis

Various antenna parameters from fig 1 were analyzed to define the variable set for optimization. It was observed that the inverted U shaped slot affects the notch position and attenuation at the rejection band. This effect of changing slot length is shown in fig 2. The length of slot, represented by *u* in fig 1 affects the notch position, thus, it can be used to fine-tune the notch to the desired frequency. Larger slot length brings the notch to lower frequencies and vice versa.

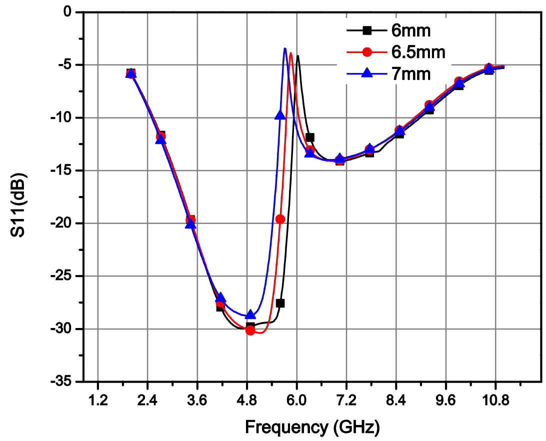


Figure 2. Effects of changing length of inverted U shaped slot on x-axis

The position of the slot with reference to the feeding line, referred to as *u_y*, directly affects attenuation and the quality factor of the notch. It controls the stop band characteristics as shown in fig 3.

Apart from the parameters related to the slot, the impedance matching is very important to achieve the desired in-band rejection and out-of-band transmission. In this regard, the slot in the ground plane was adjusted, which improved the impedance matching.

The parametric analysis including various tests concluded that overall 12 parameters required optimization to achieve the desired response. These parameters are listed in table I with their initial values, their optimization range and their optimized values. The initial simulated results without optimization shows the reduced band performance along with band notch characteristics at 5.3 GHz instead of 5.8 GHz as shown in fig 4.

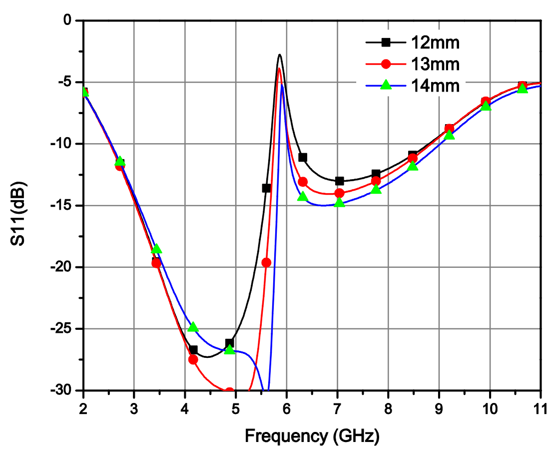


Figure 3. Effects of changing the position of slot with reference to feed line

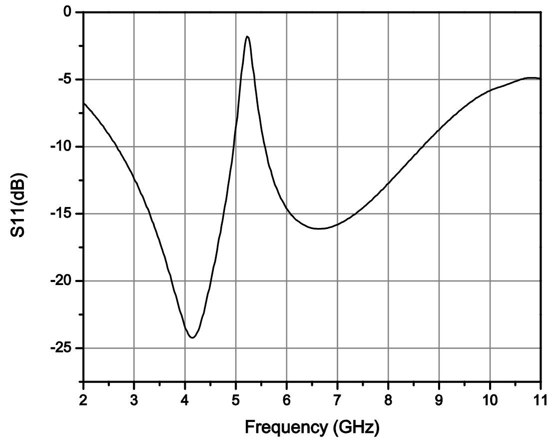


Figure 4. Initial simulated results without optimization

3. Design Optimization

GA was implemented in MATLAB, whereas the antenna was simulated in the commercially available finite element method based electromagnetic solver (Ansys HFSS™). An interface was created between these too tools by using Visual Basic (VB) script. The GA with population size of 15 was chosen and it evolved over 10 generations. The flowchart of GA used is depicted in fig 5. GA starts by selecting an initial population. With the help of fitness function; the fitness of each chromosome was evaluated and on basis of this evaluation next population was selected by crossover or mutation. This new generation was evaluated again on the basis of fitness function. GA again selects population on basis of this evaluation and process continues until stopping criterion set for GA is met.

Fitness values were assigned to the individual chromosomes by using the fitness function given in (1). It consists of three variables. All the three variables were assigned values on the scale of 0 to 3; with 0 being the worst and 3 being the best value.

$$fitness = \alpha + \beta + \gamma \tag{1}$$

The first part of this fitness function represents the desired bandwidth, which can be calculated by the expression given in (2).

$$\alpha = \frac{\sum_{i=1}^{n} x_i}{n} \times SF \tag{2}$$

Here n is the total number of points on which frequency response of the antenna was determined, S.F. is a scaling factor. Its value used in the simulation was set empirically to 3. xi is the ith point where S11 (x) ≤ -10 dB. Second part of the fitness function consists of searching notch band existence and it is expressed as in (3)

$$\beta = \begin{cases} 3, & if\ spike\ exists \\ 0, & otherwise \end{cases} \tag{3}$$

Third step finds the chromosome with lowest value of return loss and it is mathematically expressed in (4).

$$\gamma = \begin{cases} 1 & if\ S_{11} > -15dB \\ 2 & if\ -15 > S_{11} > -25dB \\ 3 & if\ S_{11} < -25dB \end{cases} \tag{4}$$

Roulette wheel selection was used to elect parents for next generation, with crossover probability of 0.8. The roulette wheel assigns probability of selection on the basis of fitness values of every individual candidate solution in order to select individuals for the next generation.

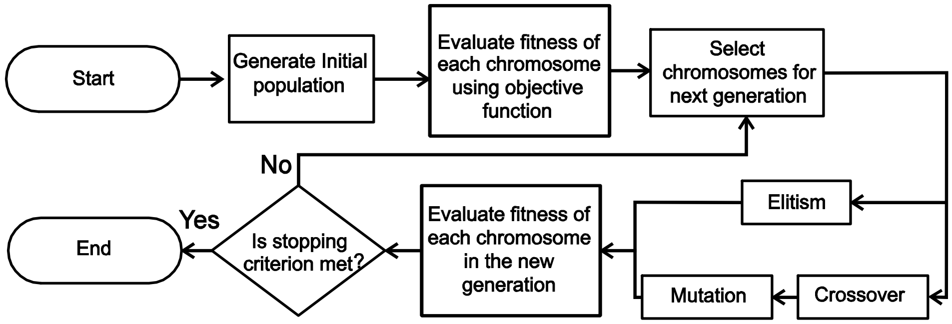


Figure 5. Genetic algorithm flowchart

Simulation was performed five times to remove any possibility of error. The optimum value of each variable is presented in table I. It is worth noting that the optimized value for s3_y is negative which shows that the third stair case is merged in second stair case (s2_y) and the optimized design consist of only two level stairs.

TABLE I. THE POPULATION VARIABLES BEFORE AND AFTER OPTIMIZATION

Inter-dependent variable	Initial Value (mm)	Optimization Range (mm) (initial value ± 1.28 mm)	Optimized Values (mm)
s1x	6	4.72 – 7.28	5.1200
s1y	1	-0.28 – 2.28	1.8800
s2x	4	2.72 – 5.28	4.0700
s2y	1	-0.28 – 2.28	1.8100
s3x	2	0.72 – 3.28	2.2200
s3y	1	-0.28 – 2.28	-0.1700
u_y	13	11.72 – 14.28	13.1800
u_width	1	-0.28 – 2.28	2.2200
U	6.5	5.22 – 7.78	7.5300
U_length	6	4.72 – 7.28	6.0100
ground_sw	2	0.72 – 3.28	1.9600
ground_sl	6	4.72 – 7.28	5.4700

III. RESULTS AND DISCUSSION

1. Design Realization

Rogers 4533 substrate with thickness of 1.524 mm, relative permittivity of 3.3 and loss tangent of 0.0023 was used to realize the optimized design. The fabricated design with dimension of 20.5 × 24 mm^2 is shown in Fig 6. The antenna was tested on Agilent PNA-X N5242A network analyzer. The measured and simulated results are presented in Fig. 7. This figure shows good agreement between simulated and measured results. Antenna covers the frequency band of 2.2 – 8.5 GHz as predicted in simulations. The notch band is achieved at 5.8 GHz where the return loss has climbed up to -3.2 dB. The band from 5.7 to 6.2 GHz has been suppressed to avoid interference from any other wireless technology operating in the band. The radiation pattern characteristics in azimuth and elevation planes for 3, 5.8 and 8 GHz are shown in fig 8. Omni directional radiation characteristics can be observed at 3 and 8 GHz which assures the optimum communication at these frequencies. The maximum absolute gain observed is -2 dB at 3 GHz and 3 dB at 8 GHz in the azimuth plane. The gain pattern resembles to a UWB circular disk monopole antenna. The suppressed band clearly shows little radiation in the azimuth plane depicting no interference from other signals at 5.8 GHz.

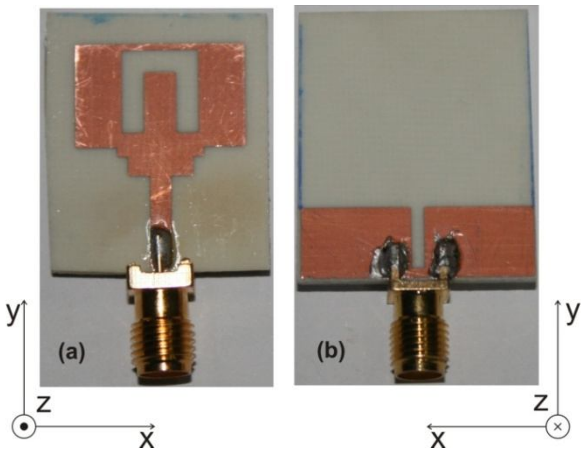


Figure 6. Fabricated design of purposed antenna

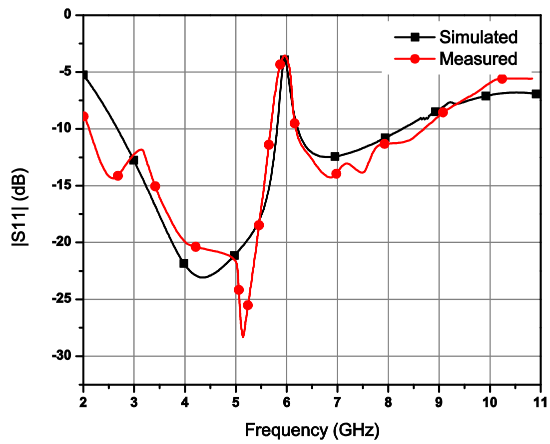
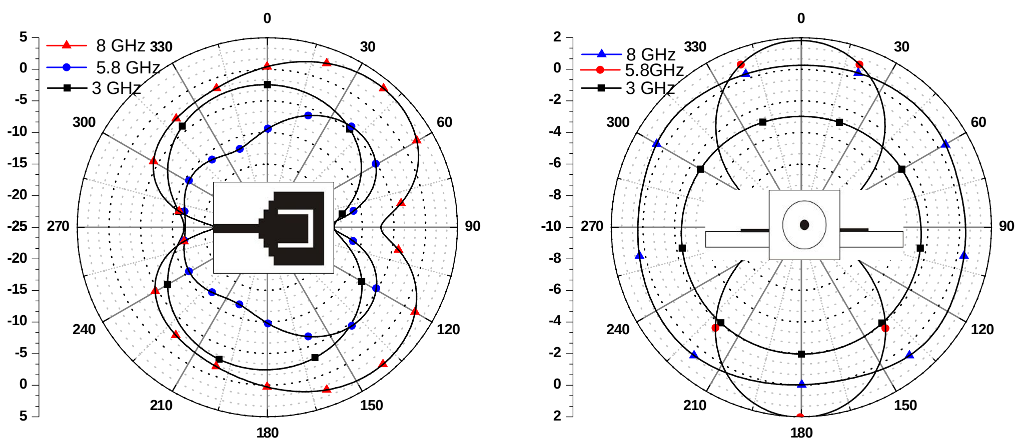


Figure 7. Comparison between measured and simulated results



XYplane XZ plane

Figure 8. Radiation characterisicts of the antenna for XY (azimuth) and XZ (elevation) plane at 3, 5.8 and 8 GHz

IV. Conclusion

The optimization process of an UWB antenna has been proposed with notch band characteristics to reject the narrow band communications at 5.8 GHz. A rectangular staircase with a slot in ground plane was used to achieve the desired specifications. GA has been applied on the initial design to optimize the radiation characteristics and significant improvement in the results has been achieved as compared to initial design. The antenna covers frequencies from 2.2 GHz to 8.5 GHz with rejection level of -4dB at 5.8 GHz.

REFERENCES

[1] Giuliano R., and Mazzenga F., 2006. Capacity Analysis for UWB Systems with Power Controlled Terminals under Power and Coexistence Constraints, IEEE Transactions on Wireless Communications, 5 (11): 3316-3328.

[2] Simitsakis P., Papananos Y. and Kytonaki E. S. 2010. Design of a Low Voltage-Low Power 3.1–10.6 GHz UWB RF Front-End in a CMOS 65 nm Technology, IEEE Transactions on Circuits and Systems II: Express Briefs, 57 (11): 833-837.

[3] Ryu K. S and Kishk A. A. 2009. UWB Antenna with Single or Dual Band-Notches for Lower WLAN Band and Upper WLAN Nand, IEEE Transactions On Antennas And Propagation, 57 (12): 3942-3950.

[4] Movahedinia R. and Azarmanesh M. N., 2010. Ultra-Wideband Band-Notched Printed Monopole Antenna, IET Microwave Antennas & Propagation, 4 (12): 2179–2186.

[5] Movahedinia R., Ojaroudi M and Madani S. S.,2011. Small Modified Monopole Antenna for Ultra-Wideband Application with Desired Frequency Band-Notch Function, IET Microwave Antennas & Propagation, 5 (11): 1380–1385.

[6] Abbosh A. M. and Bialkowski M. E., 2009. Design of UWB Planar Band-Notched Antenna Using Parasitic Elements, IEEE Transactions On Antennas And Propagation, 57(3): 796-799.

[7] Kerkhoff A. J. and Ling H.,2007. Design Of A Band-Notched Planar Monopole Antenna Using Genetic Algorithm Optimization, IEEE Transactions On Antennas And Propagation, 55 (3): 604-610.

[8] Kerkhoff A. and Hao L., 2004. A Parametric Study Of Band-Notched Uwb Planar Monopole Antennas, IEEE Antennas And Propagation Society International Symposium Digest, 2: 1768-1771.

[9] Johnson J. M. and Rahmat-samii Y. 1994. Genetic Algorithm Optimization And Its Application To Antenna Design, IEEE Antennas And Propagation Society International Symposium Digest. 326-329.

[10] Gudarzi A., Mohajeri F., Mahzoon M. and Bazrkar A. 2013. Design and Fabrication of an UWB Patch Antenna with CRLH TL, Journal of Basic and Applied Scientific Reseaerch, 3(4): 246-253.

[11] Sun S. Y., Lu Y. H. and La D. S. 2009. Application Of Genetic Algorithm In Broadband Microstrip Antenna Design,Proc. of 5th Asia Pacific Conf. on Environmental Electromagnetics, 192-195.

[12] Xie L., Jiao Y. C. and Zhao G., 2011. A Compact Band-Notched Uwb Slot Antenna Optimized By Genetic Algorithm, IEEE International Conf. on Microwave Technology & Computational Electromagnetics, 313-315

[13] Adelpour Z., Mohajeri F. and Sadeghi M., 2010. Dual-Frequency Microstrip Patch Antenna with Modified Koch Fractal Geometry Based on Genetic Algorithm, Loughborough Antennas & Propagation Conference, 401-404.

[14] Johnson J. M., 1997. Genetic Algorithms in Engineering Electromagnetics, IEEE Antenna and Propagation Magzine, 39 (4): 7-21.

[15] Sabouhi H. R. and Baghelani M., 2012. Design of a Shock Immune MEMS Acceleration Sensor and Optimization by Genetic Algorithm, Journal of Basic and Applied Scientific Research, 2 (10): 10480-10488

[16] Holland J. H, 1975, Adaptation in Natural and Artificial Systems, Ann Arbor, MI: Univ. Michigan