International Journal of Electronic Engineering and Computer Science
Vol. 6, No. 1, 2021, pp. 1-6
http://www.aiscience.org/journal/ijeecs

Towards a Simplified UWB Prototype Antenna for Wireless Communications Uses

Moataz Elsherbini*, Islam Mohammed Ibrahim, Akrm Mohamed Abaza, Islam Ahmed Mohammed

Department of Electrical Engineering, The Egyptian Academy of Engineering and Advanced Technology (EAEAT), Cairo, Egypt

Abstract

Ultra-wideband (UWB) antennas used for wireless communication purposes regarding the materials just as a mathematical analysis are presented. These antennas are considered are listed as wideband micro-strip antennas. The micro-strip antenna consists of a rectangular patch of metal foil and a ground plane. The design and analysis of rectangular micro-strip patch antenna on FR-4 (Flame Retardant and type 4) epoxy substrate material thickness of the substrate is 1.6 mm is presented in this paper. The proposed antenna design operates between 4 GHz to 10 GHz. This range of frequencies is suitable for wireless communication (WLAN) applications. Miscellaneous simulation software tools are used for High-Frequency Structure Simulator (HFSS) and CST. The results from CST studio and HFSS software programs have compared concerning the S11 parameter and radiation pattern. The simulations of different two applied simulation tools give an acceptable judgement with the experimental results and get accepted in UWB applications. In this paper our antenna model results has been compared using two different simulation tools and also with practical results, HFSS and CST microwave studio has been made by simulating the micro-strip patch antenna. Actually, we need to best choice the most suitable simulation tool in our design because complex antenna structures cannot be simulated without Appling this tool, known as electromagnetic solvers. Results have been compared in point of less time.

Keywords

UWB, HFSS, CST, Patch, VSWR

Received: January 28, 2021 / Accepted: March 26, 2021 / Published online: April 16, 2021

1. Introduction

Antennas are considered an important part of electronic devices in wireless communication. UWB technology opens a new door for wireless communication systems [1-2]. Antennas are used to transmit more data to a short distance using low power. The concept of the micro-strip antenna was first introduced in the 1950s [3]. However, this idea needed to stand by almost 20 years to be acknowledged after the development of the printed circuit board (PCB) technology in the 1970s [4-5].

Micro-strip antennas are seen as the foremost common sorts of radio wires due to their prominent focal points of a lightweight, moo taken a toll, moo profile, planar setup, ease of conformal, predominant movability, reasonable for clusters, basic for make, and simple to be consistent with microwave monolithic integrated circuits [6-8]. They have been by and large operated for civilian and military applications such as tv, broadcast radio, portable frameworks, (GPS), (RFID), (MIMO) frameworks, vehicle collision evasion framework, partisan communications, reconnaissance frameworks, course establishing, radar frameworks, farther detecting, organic imaging, rocket direction, and so on It contains comprises a transmitting fix on one side of a dielectric substrate and a ground plane on the inverse side [9-11]. Micro-strip patch antenna patches are in a diversity of shapes, such as rectangular, square, triangular

* Corresponding author
E-mail address: m.moustafa@eaeat-academy.edu.eg (M. Elsherbini)

and circulator, etc. as shown in Figure 1. The antenna design consists of substrate thickness of 1.6 mm. the dielectric constant of the substrate is 4.4 and the antenna is fabricated on FR-4 material [12]. In this paper, select the value of the substrate (FR-4) constraints relative dielectric constant (ε_r) to be 4.4 and the substrate thickness (h) to be 1.6 mm. We cannot solve the complex antenna problems systematically and need computational electromagnetic (CEM) field applications to survey our results. CEM models the interaction of electric and magnetic fields with physical objects and their environment to find the numerical approximation of Maxwell's equations. Hence, its utilization in the antenna field is inevitable. It uses EM solutions which are software tool with high specifications that solve the subset of Maxwell's equation directly. Software that is compared here is HFSS and CST that were the most widely used software for antenna design and simulations. HFSS stands for high-frequency structure simulator and based on the finite element method (FEM). CST stands for computer simulation technology and has a number of solvers in it both frequency and time domain.

2. Proposed Antenna Design

The proposed antenna is a rectangular micro strip patch antenna fabricated on an FR4 substrate as mention before. The design is applied based on reference [13, 14]. The patch, feed line, and ground are made of copper material. FR4 material has dielectric constant (ε_r) 4.4 and tan δ= 0.02. The substrate thickness is 1.6 mm, and the copper components thickness is 0.035 mm. the ground was not designed to cover the whole substrate but to be of length 34 mm and width 36mm. The design of the proposed antenna is presented in Figure 2 with design specifications discussed later in table 1.

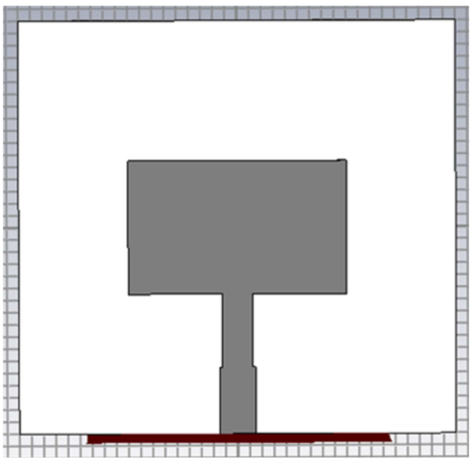

Figure 1. Elevation view for MS patch.

The dimension of the patch L and W can be calculated from these equations [15] at f = 4.3 GHz, εr 4.4, and h = 1.6 mm.

where ε_{reff}: effective dielectric constant, λ_g: guided wavelength, W_g: ground plane width, L_g: ground plane length, L_{eff}: effective length, ε_r: dielectric constant of the substrate, W: width of the patch L: Length of the patch, h: substrate thickness or height, f: resonant frequency, C: free space speed of light, η: the efficiency, ΔL : the length extension.

1. The width of antenna is determined by:

$$W = \left(\frac{c}{2f_r}\right)\left(\frac{\varepsilon_r + 1}{2}\right)^{-0.5} \quad (1)$$

At speed of light, εr =**2**.2

2. effective dielectric constant due to fringing effect

$$\varepsilon_{eff} = \frac{1}{\sqrt{\left(\frac{\varepsilon_r + 1}{2}\right) + \left(\frac{\varepsilon_r - 1}{2}\right)\left(1 + \frac{12h}{W}\right)}} \quad (2)$$

3. Now the extension in length due to fringing effect is calculated by:

$$\Delta L = 0.412h\left(\frac{\varepsilon_{eff} + 0.3}{\varepsilon_{eff} - 0.258}\right)\left(\frac{\left(\frac{W}{h}\right) + 0.264}{\left(\frac{W}{h}\right) + 0.8}\right) \quad (3)$$

4. The overall length including fringing effect is:

$$L = \left(\frac{c}{2f_r\sqrt{\varepsilon_{eff}}}\right) - 2\Delta L \quad (4)$$

5. Finally the ground length and width are calculated by:

$$L_g = L + 6h \quad (5)$$

$$W_g = W + 6h \quad (6)$$

While the ground plane dimensions can be chosen from these equations.

Finally, the antenna gain and directivity determined from CST or HFSS radiation pattern results.

3. CST Studio Simulation

Using CST software [16], the patch antenna has been designed as shown in Figure 2 with parameters shown in table 1. Port size was selected according to the standard port size calculator as shown in Figure 3.

Table 1. Antenna dimensions.

Symbol	Size (mm)
Wsub	35
Lsub	33
Lsub_a	16
Lsub_b	10.9
Wpatch	17
Lpatch	10.8
Wmlin_a	6.9
Lmin_a	8.9
Wmlin_b	6.2
Lmlin_b	9.9
Lgnd	10.8

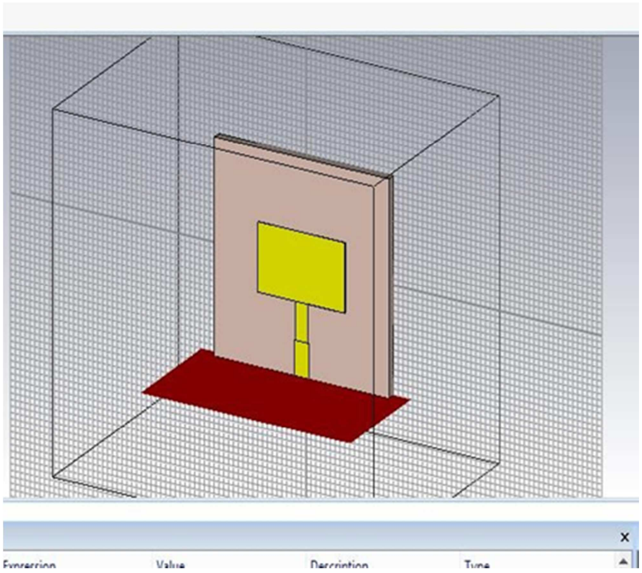

Figure 2. Simulation of proposed design using CST.

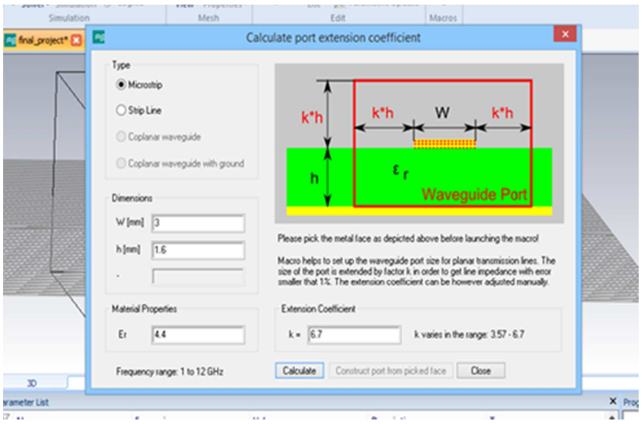

Figure 3. Calculation of standard port dimensions.

Simulation is done at 4.6 GHZ and with substrate length 34mm this resulted in the following:

a) S11 parameter:

S-parameters (or scattering parameters) are utilized to describe how energy can propagate through an electric network.

Scattering Parameters measures the relationship amplitude and phase versus frequencies, also, voltages and currents for different ports in the network. S-Parameters are used to show what happens to the signal in that network. It shows the efficiency of the antenna and its matching along with the specified frequency band.

Where,

$$VSWR = (1 + |S_{11}|) / (1 - |S_{11}|)$$

The plot of the gain (dB) relative to the frequency of operation shows the efficiency of the antenna and its matching along with the specified frequency band. In this simulation, the band ranged from 1 to 12GHz.

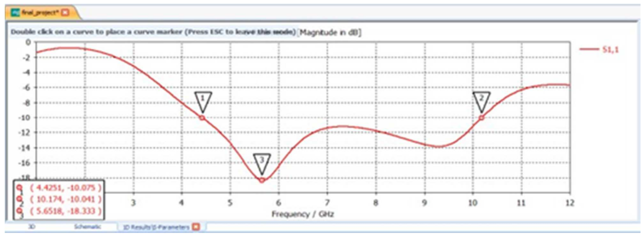

Figure 4. S11 parameter detection.

We notice that the operation band of the antenna is approximately from 4.425GHz to 10.17GHz as shown in Figure 4. Matching in the antenna design takes place at marker 3 at a frequency of approximately 5.6518GHz.

In this result, there is a mismatch in the antenna where the loss value did not exceed -18dB wherein antennas' design the matching peak is preferred to be near -30dB.

b) Far-field result:

This simulation result shows the representation of wave transmission/reception at far distances, which is a very important parameter in the design of the antenna. the radiation efficiency which is the efficiency of the radiation in no loss case is - 0.6562dB as shown in Figure 7, while the total efficiency in case of loss existence is -1.021dB.

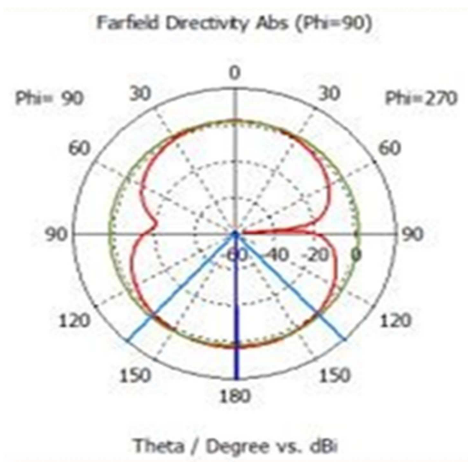

Figure 5. Far-field directivity at φ=90°.

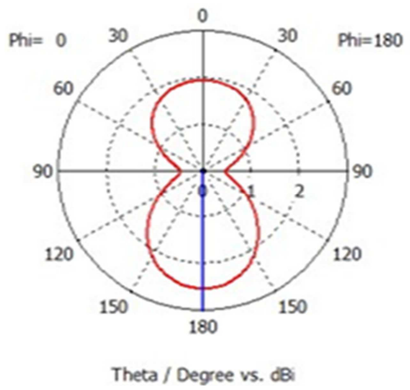

Figure 6. Far-field directivity at φ=0°.

In Figures 5, 6, the far field measurements, in the azimuthal and horizontal planes are represented. As appeared in Figure 10, at φ=90° and 0° the curve tends to move to the origin (0, 0) indicating the presence of a mismatch at these two angles. Directivity D is important antenna parameters that measure the qualification of radiation in one direction than other. It is the ratio between the radiation intensity of the antenna to the average power over all surrounding it, or it is the ratio between the real measured power to the power radiated by an ideal isotropic radiator (which emits uniformly in all directions) radiating the same total power. The directivity of an antenna is the maximal estimation of its directive gain. Directive gain is represented as D (θ, φ), Where:

$$D(\theta,\emptyset) = \frac{U(\theta,\emptyset)}{Prad/4\pi}$$

As shown from CST curves at f = 4.6GHz the total efficiency in case of loss existence is -1.021dB and Directivity is 2.523 dBi. It is an acceptable value for the gain in communications uses.

4. ANSYS HFSS Simulation

In this section, we make an analysis of the antenna using the HFSS simulator. Port size was selected according to the lumped port width of the feed line x thickness of the substrate as shown in Figure 7.

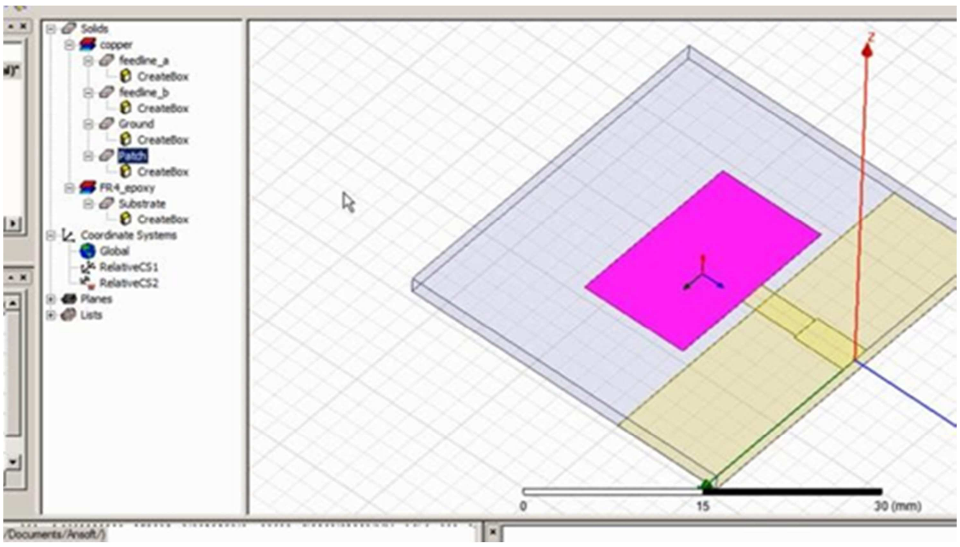

Figure 7. Antenna design at 4.6GHZ using HFSS Simulation.

Simulation is done at 4.6 GHZ and with substrate length 34mm as shown in Figure 7 this resulted in the following:

S11 Parameter:

From Figure 8 we can determine S11 at -10dB and it is an acceptable value.

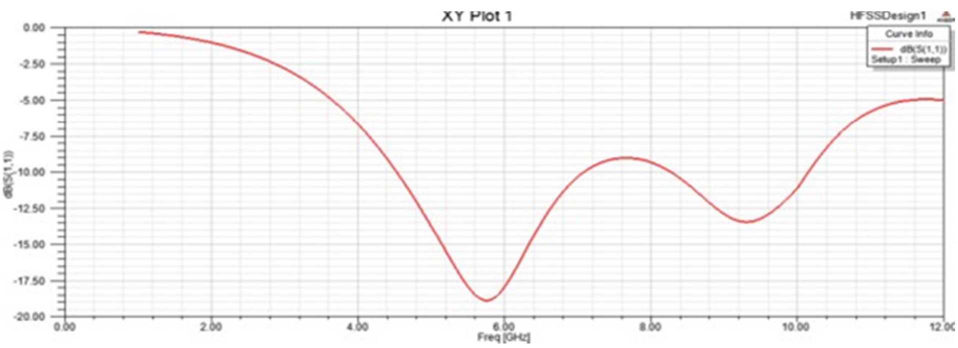

Figure 8. S11 Parameter Using HFSS.

Far-field result:

Far-field two dimensions polar form results are shown with the variation of φ and θ shown in Figure 9.

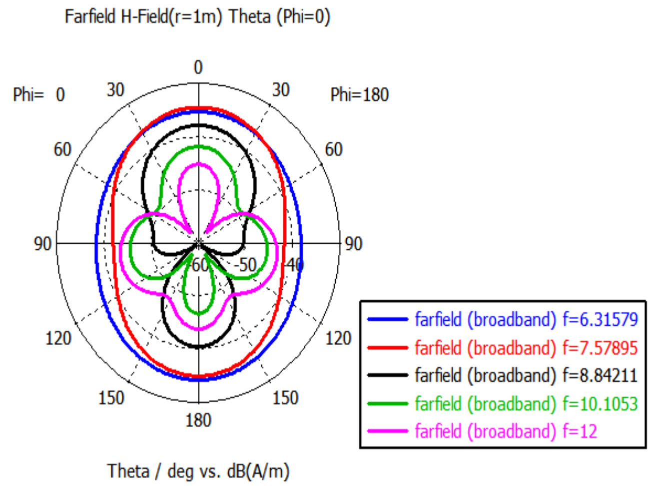

Figure 9. Far-field 2D result using HFSS.

It is clear from results that the radiation pattern takes behaviour of dipole antenna but at very high frequency ranges.

5. The Test Results of the Fabricated UWB Antenna

We implemented our design and fabricated it practically as shown in figure 10.

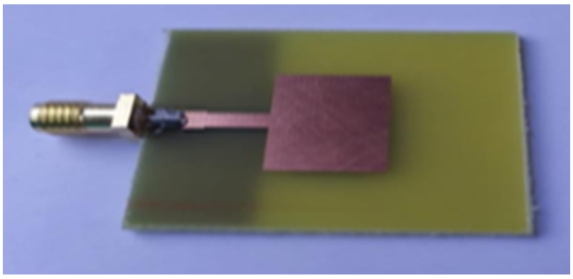

Figure 10. Fabricated Micro-strip Antenna.

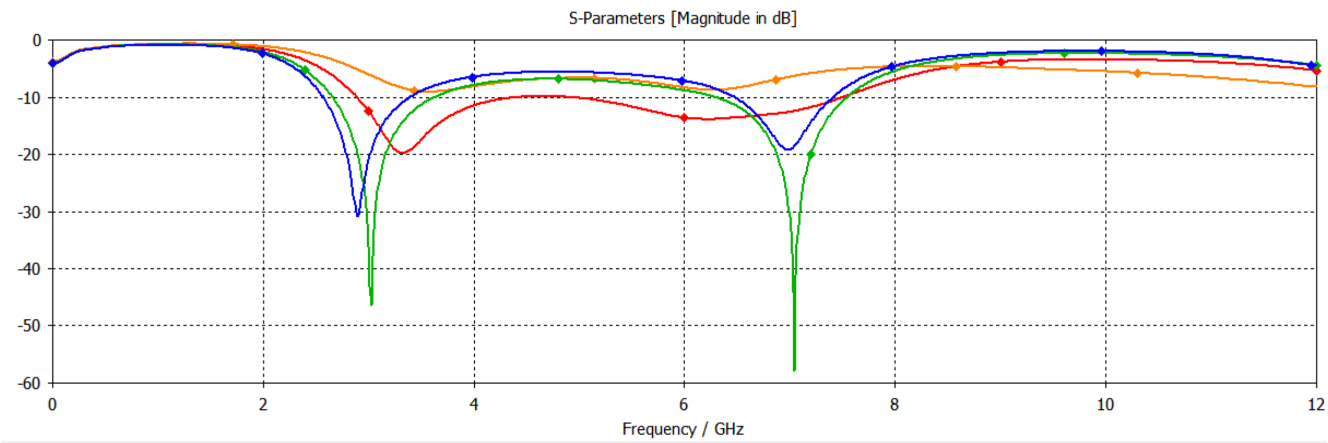

Figure 11. S11 diagram.

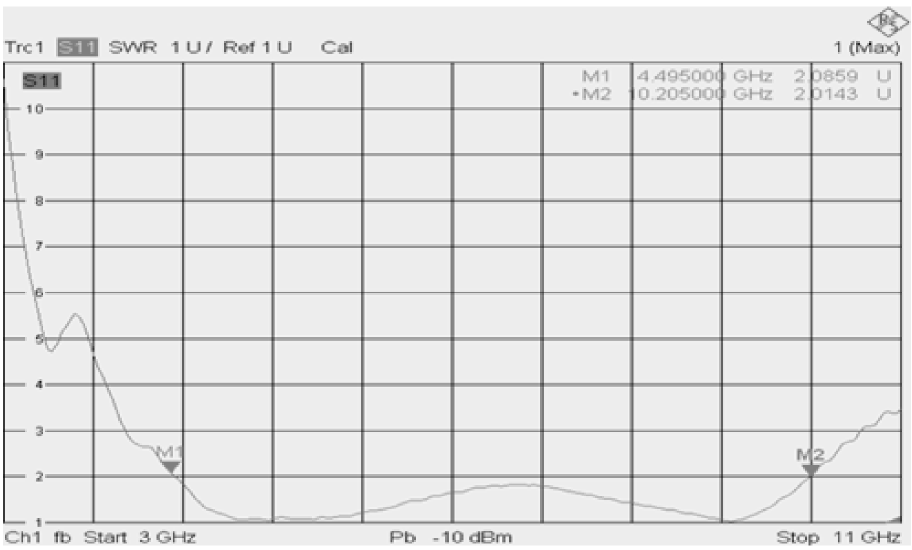

Figure 12. VSWR output from HFSS Simulation.

In the following section, the practical measurements for antenna parameters after fabrication is noticed in figures 11 and 12.

The S11 diagram result shown in Figure 11, The VSWR results are shown in Figure 12. From the analysis results from CST and HFSS, we can clear that HFSS is more accurate than CST at the same frequency because HFSS is based on Finite Element Method (FEM) which is more accurate for designing antennas while CST depends on Finite Integration in Technique (FIT) and is additionally famous among antenna designers due to ease in simulations. However, the results of both the simulators are not equivalent because of the different computational techniques involved. HFSS results are very acceptable compared with the experimental one. But we can notice that the Ansoft HFSS in frequency-domain perform the simulation with speed faster than the CST in time-domain.

6. Conclusion

The different results that are concluded from both the programs the CST STUDIO SUITE and the ANYSOFT HFSS happened because CST gives out an ideal result meanwhile the HFSS on the other hand gives out a practical result of the electromagnetic field even if they are still in the same radiation box of the AIR material, but seemingly the results in each program happen at the same exact frequency and close ranges of DB (Decibel) either in the magnitude of return loss or VSWR or even gain. Each antenna model has its strong and weak points which one should know to get the best result out of this software. It shows practically a similar result for the simulation of a Micro-strip patch antenna in terms of accuracy. However, HFSS is better in terms of time. The reason for this is its frequency-domain solver while CST used a time-domain transient solver. As the antenna operates on a single frequency at 4.6 GHz so it solves the result in a single frequency sweep. On the other hand, CST time-domain solver is suitable for wideband problems.

References

[1] A. F. Molisch (2009). Ultra-wideband communications: An overview. URSI Radio Science Bulletin.2009.31-42. 10.23919/URSIRSB.2009.7909730.

[2] Online: https://www.lifewire.com/ultra-wide-band-817953.

[3] M. Ojaroudi, O. A. Civi, “A Novel UWB Slot Antenna with a SelfComplementary Matching Network” IEEE, [LAPC Conf.] pp. 1-15, 2015.

[4] K. Fong Lee, K. F. Tong, “Microstrip patch antennas –Basic characteristics and some recent advances” Proceedings of IEEE, pp. 112, 2012.

[5] Pozar, D. M. (1992). Micro-strip antennas. Proceedings of the IEEE, 80 (1), 79–91.10.1109/5.119568.

[6] I. J. Bahl and P. Bhartia (1980). Micro-strip Antennas. Artech House.

[7] Carver, K., & Mink, J. (1981). Micro-strip antenna technology. IEEE Transactions on Antennas and Propagation, 29 (1), 2–24.10.1109/tap.1981.1142523.

[8] Singh, Indrasen & Tripathi, Dr. (2011). Micro strip Patch Antenna and its Applications: a Survey. International Journal of Computer Technology and Applications. 2. 1595-1599.

[9] Lee, Kai Fong; Luk, Kwai Man (2017). Micro-strip Patch Antennas. World Scientific. pp. 8–12. ISBN 978-9813208612.

[10] Bancroft, R. Micro-strip and Printed Antenna Design Noble Publishing 2004, chapter 2-3.

[11] Lim, Ka-Sing & Nagalingam, Manimaran & Tan, Chue-Poh. (2008). Design and construction of micro-strip UWB antenna with time domain analysis. Progress in Electromagnetics Research M. 3. 153-164. 10.2528/PIERM08051903.

[12] Ahamed, Md. Maruf & Bhowmik, Kishore & Suman, Abdulla. (2012). Analysis and Design of Rectangular Micro-strip Patch Antenna On Different Resonant Frequencies For Pervasive Wireless Communication. International Journal of Scientific & Technology Research. 1. 108-111.

[13] M. C. Ezuma, S. Subedi, “Design of a Compact UWB Antenna for Multi-band Wireless Applications” IEEE [ICON-2015 Conf.] pp. 1-15, 2015.

[14] Yilmaz, A. & Kuzuoglu, Mustafa. (2007). Calculation of optimized parameters of rectangular micro-strip patch antenna using particle swarm optimization. Microwave and Optical Technology Letters.

[15] Hossain, M. J., Faruque, M. R. I., & Islam, M. T. (2016). Design of a patch antenna for ultra wide band applications. Microwave and Optical Technology Letters, 58 (9), 2152–2156.