International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-4, February 2020

Compact Hexagonal Ultra Wide Band Fractal Antenna for Wireless Body Area Networks

V. Dinesh, J. Vijayalakshmi, B. Vignesh, G. Vignesh, S. Selva saravanan

Abstract*: A Hexagonal Microstrip Ultra Wide Band Fractal Antenna for wireless body area network applications is proposed. The Hexagonal antenna is powered through co-planar waveguide (CPW) feed structure. The proposed antenna uses a hexagonal fractal structures to achieve its Ultra Wide Band characterization. The addition of fractal elements introduces multi-resonance at different frequencies and covers a large bandwidth of 3.8GHz–10.1GHz respectively. This antenna creates a Fractal geometry inside the patch with similar in shape but difference in sizes. Electromagnetic Band Gap structures are introduced in order to improve gain and directivity of the antenna. Electromagnetic Bandgap Structure (EBG) is mainly focused on overcoming the limitation of Microstrip Patch antenna parameters such as low gain, excitation of surface waves. Electromagnetic Band Gap structures are defined as artificial periodic structures that exhibit unique electromagnetic features, such as frequency band gap for surface waves and in-phase reflection coefficient for incident plane waves, which makes them desirable for low-profile antenna designs. The Electromagnetic Band Gap structure is placed behind the antenna to suppress the propagation of surface wave and to improve gain, directivity and to reduce the side lobes of the radiation pattern. The effect of surface currents in the ground plane reduces the antennas operating bandwidth which is reduced by introducing defective ground structure. The size of the antenna is 25×25×1.588 mm^3. The proposed antenna has an average gain of 3.8dB. The radiation pattern obtained is unidirectional.

Keywords: Ultra wide band, Fractal antenna, Electromagnetic bandgap structures, Hexagonal structure, Gain improvement, Bandwidth improvement.

I. INTRODUCTION

Wireless Body Area Networks (WBAN) are used to communicate between wireless devices located inside, on or around the human body.

Revised Manuscript Received on February 28, 2020.
***** Correspondence Author
V. Dinesh*, Assistant Professor, Department of Electronics and Communication Engineering, Kongu Engineering College, Erode, India. E-mail: dineshme04@gmail.com
J. Vijayalakshmi, Assistant Professor, Department of Electronics and Communication Engineering, Kongu Engineering College, Erode, India. E-mail:vijaya.jagadeesh09@gmail.com
B. Vignesh, Department of Electronics and Communication Engineering, Kongu Engineering College, Erode, India. E-mail: smartvicky1123@gmail.com
G. Vignesh, Department of Electronics and Communication Engineering, Kongu Engineering College, Erode, India.
S. Selva saravanan, Department of Electronics and Communication Engineering, Kongu Engineering College, Erode, India

In this case of medical applications, these devices are connected to sensors that monitor vital body parameters and movements. The WBAN have been considered not only for the medical and healthcare applications but also for sports and entertainment. These systems require extremely low power, low weight and small size. In addition, human body

Effect needs to be considered since the body may be located near Radio frequency sources. Besides, the human body has a high dielectric constant with a high loss tangent and low conductivity at the microwave frequency band. Therefore, the Gain and radiation efficiency of the antenna can be deteriorated when the antenna is operating on or in the human body. To overcome this, we make the antenna highly directional. For making antenna directional, Electromagnetic Band Gap (EBG) structures are introduced behind the antenna. In addition, the gain is also improved when we introduce mushroom type electromagnetic band gap structures behind In order to attain sufficient bandwidth and to achieve Ultra Wide Band characteristics we introduced hexagonal fractal structures at the edges of the patch.

II. RELATED WORKS

Coplanar waveguide-fed hexagonal antenna design for Ultra Wide Band applications [1]. The size of the antenna is 25×25×1.588 mm3 and the impedance bandwidth is improved by adding fractal elements at the edges. The effect of surface currents in the ground plane reduces the antennas operating bandwidth which is reduced by introducing defective ground structure. Electromagnetic Bandgap Structure (EBG) is mainly focused on overcoming the limitation of Microstrip Patch antenna such as low gain, excitation of surface waves etc. The Microstrip Patch Antenna consists of dielectric substrate with ground plane at one end and patch at other end [2] whereas in EBG concept, additional EBG substrate with EBG cells are inserted in between ground and dielectric substrate. An ultra-wideband antenna with a defected ground structure with the radiating element is a circular patch on which a fractal based geometry is inscribed in the form of slots and excited by a tapered feed-line for impedance matching [3]. The antenna has an impedance bandwidth of 8.2GHz (117% at center frequency of 7GHz).To improve the impedance bandwidth and gain, a Swastika Shape Electromagnetic band gap (EBG) structure is used. The unit cell of the EBG has a compact size of 3mm×3mm and is obtained by introducing discontinuities in the outer ring of the Cross-Hair type EBG. Compact ultra-wideband circular monopole antenna with an acceptable band-rejection characteristic [4]. The rejection band is created by means of an electromagnetic band-gap (EBG) structure.

The operation frequency band is 3.1–10.6 GHz with a rejection band of 0.7 GHz around 5.5 GHz. Hexagonal antenna is powered through co-planar waveguide (CPW) feed structure [5].

The stepping fed configuration is used to improve the antenna electrical characteristics at the centre and higher frequencies in the FCC designed UWB frequency range from 3.1 to 10.6 GHz. This antenna uses a fractal technique to analyse its UWB characterization. Electromagnetic band-gap structures (EBG) are embedded underneath the bottom layer of the substrate in order to support slow-wave propagation [6], in which smaller effective wavelength compared to those in free space and dielectric is achieved. Electromagnetic bandgap structure (EBGs) with mushroom-like EBG [8], by introducing Double reverse split rings (RSR) into the square patch, the size of EBG cell is reduced by 30%, and the bandgap achieves bandwidth about 65%. A fractal microstrip antenna is implemented using the EBGs as a ground plane. By introducing Fractal-like geometry is implemented on a microstrip fed planar hexagonal monopole antenna [9] wideband characteristics of antenna is achieved.

III. PROPOSED WORK

The antenna is designed using FR4 Substrate for Medical applications. Antenna is made to resonate at Ultra wideband frequency from 3.1 to 10.6 GHZ. The antenna dimensions are 25mm x 25mm. The design procedure begins with monopole antenna with substrate, ground plane and a feed line. Then fractal structures are introduced in order to improve bandwidth. Mushroom type EBG structures are introduced to improve gain and directivity of the antenna. Initially a hexagonal patch structure is developed with a side length of 8mm. The ground plane is placed on top of the substrate separated by feed line. Coplanar waveguide feed structure is used because both ground plane and feed line are on top of the substrate. The feedline of length 8.85mm are placed between feed and the patch with good impedance matching as shown in Figure 1. The hexagonal patch resonates at center frequency of 5GHz with bandwidth of around 5.5GHz (2 - 7GHz). The fractional bandwidth of the hexagonal patch antenna is greater than 500 MHz and it satisfy the FCC standard of Ultra Wide Band antenna. The gain of the monopole antenna obtained is -3dB**.** The radiation pattern obtained is bidirectional.

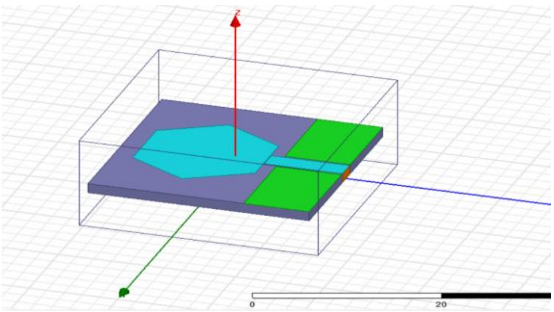

Fig 1. Hexagonal monopole antenna

To introduce multiband operation and increasing the bandwidth of the antenna, Fractal elements are incorporated in the antenna geometry. In additional to the monopole antenna six hexagonal fractal elements with the optimum radius of 1 mm are attached at the corners as shown in Figure 2. Addition of fractal elements introduces new resonant frequencies in addition to the resonant frequency of the monopole antenna. Due to addition of fractal elements, the resonant frequencies will shift towards low frequency band due to the presence of surface current on the outer surface of the patch at high frequencies. Addition of fractal elements results in increased bandwidth of antenna with two resonant frequencies at 4.8GHz and 8GHz with the impedance bandwidth of around 6.5 GHz.

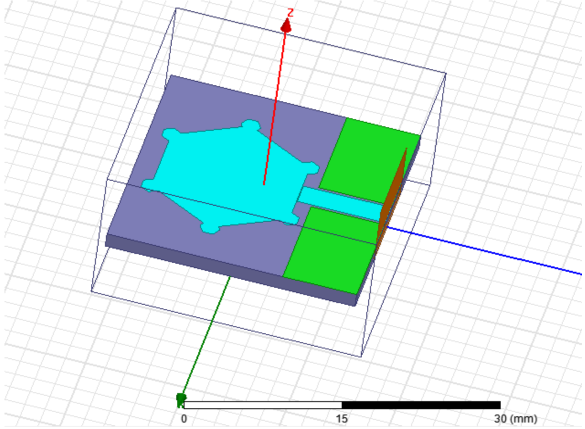

Fig 2. Antenna with first iteration fractal elements

Another twelve hexagonal fractal elements of radius 0.5 mm are attached to the first fractal elements to give multi-resonance as shown in Figure 3. The proposed UWB antenna consists of second iteration of fractal elements at the corners of the first hexagon fractal elements which increases the length of the antenna and shifts the frequency of resonance towards low frequency due to the presence of surface current on the outer surface of the patch at high frequencies and this results in a wider bandwidth of 7GHz (2-9GHz). The average gain obtained is around -4 dB. The two resonant frequencies are obtained at 5GHz and 7GHz. Bidirectional radiation pattern is obtained.

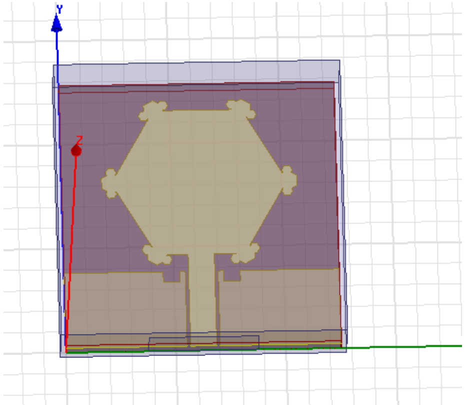

Fig 3. Antenna with second iteration fractal elements

EBG cell consist of patch, substrate made of FR4 and ground plane and vias connecting ground plane and patch. The side of the square patch is 3mm and radius of the vias is 0.3mm. Each cell of EBG is 3mm x 3mm as shown in Figure 4. The inductor is a result of the currents flowing through the vias, and the capacitor is due to the gap effect between the adjacent patches. The main advantage of EBG structure is their ability to suppress the surface wave current. By placing a EBG structure along with the patch improves gain of the antenna and suppress back lobe and makes antenna unidirectional.

To make antenna more directional with increased gain, we are introducing an array of EBG structures behind the antenna which consist of 6*6 unit cells (24 unit cells) as shown in Figure 5. Each unit cell has a resonant frequency at 8 GHz. By introducing EBG array behind the antenna, the EBG array reflects the radiation without any phase shift, Making antenna unidirectional with a improved gain of around 4 dB. The antenna resonates at 5GHz and 10GHz with a desired bandwidth of around 7GHz. The resonance shifts towards high frequency because of introducing EBG array.

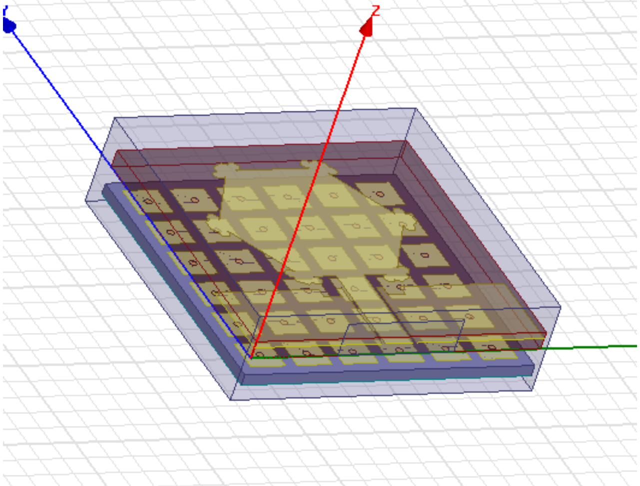

Fig 4. Second order fractal antenna with EBG Structure

C. Equations

The dimension of the hexagonal patch is calculated using the Equations 1 - 4.

$$W = \frac{c}{2f_0\sqrt{\varepsilon_r+1/_2}} \quad (1)$$

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{re}}} - 2\Delta L \quad (2)$$

$$\Delta L = \frac{h}{\sqrt{\varepsilon_r}} \quad (3)$$

$$\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+\frac{12h}{W}\right)^{-\frac{1}{2}} \quad (4)$$

where

ε_{re} is effective relative permittivity of substrate

ε_r is relative permittivity of substrate

f_r is a resonant frequency of antenna

h is height of the antenna

W is width of the patch

L is side length of hexagonal patch.

The dimension of the EBG structures is calculated using the Equations 5-7.

$$L = \mu_0 h \quad (5)$$

$$C = \frac{\omega_1\varepsilon_{0(\varepsilon_r+1)}}{\pi}\cos^{-1}\left\{\frac{2\omega_1+pg}{pg}\right\} \quad (6)$$

$$f_{ci} = \frac{1}{2\pi\sqrt{L_iC_i}} \quad (7)$$

where

L is inductance of EBG cell

C is capacitance of EBG cell

μ_0 is permeability of free space

ε_0 is permittivity of free space

f_{ci} is resonant frequency of EBG array

g is gap between two unit cell

p is width of the vias

IV. RESULTS AND DISCUSSIONS

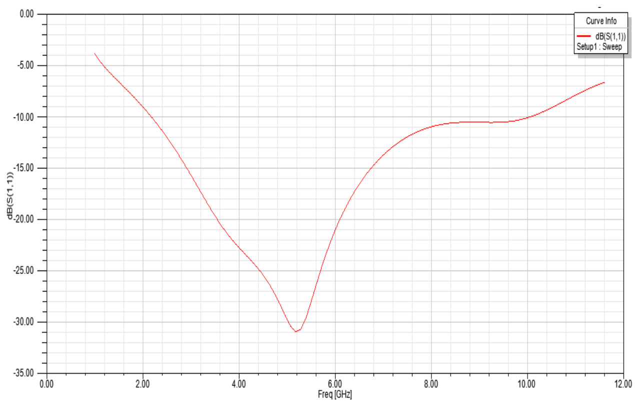

Figure 5. Return loss characteristics of Hexagonal Monopole Antenna

From this return loss curve, the resonant frequency of single hexagonal monopole antenna obtained is 5.2GHz with the impedance bandwidth of around 5GHz (2.4 – 7.4 GHz) as shown in Figure 6. The return loss of resonant frequency is -30dB which means only less than 1% of input power is reflected back to generator. Thus, 99% of input power is transmitted via antenna.

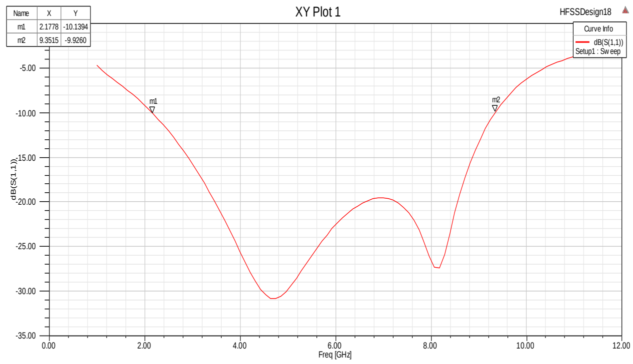

Figure 6. Return loss characteristics with First order Fractal elements

From this return loss curve, two resonant frequencies are obtained at 4.8GHz and 8GHz with the impedance bandwidth of 6.8GHz (2.2 - 9GHz) as shown in Figure 6. The return loss of resonant frequencies is around -27dB which means only less than 1% of input power is reflected back to generator. Thus, 99% of input power is transmitted via antenna.

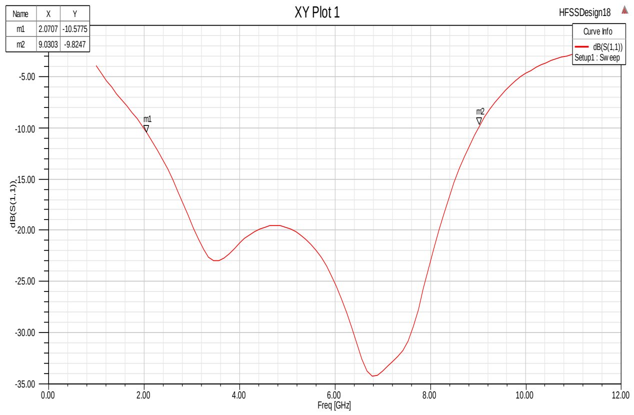

Figure 7. Return loss characteristics with Second order Fractal elements

From this return loss curve, two resonant frequencies are obtained at 3GHz and 6.8GHz with the impedance bandwidth of 7GHz (2 - 9GHz) as shown in Figure 7. The return loss of resonant frequencies is around -27dB which means only less than 1% of input power is reflected back to generator. Thus, 99% of input power is transmitted via antenna.

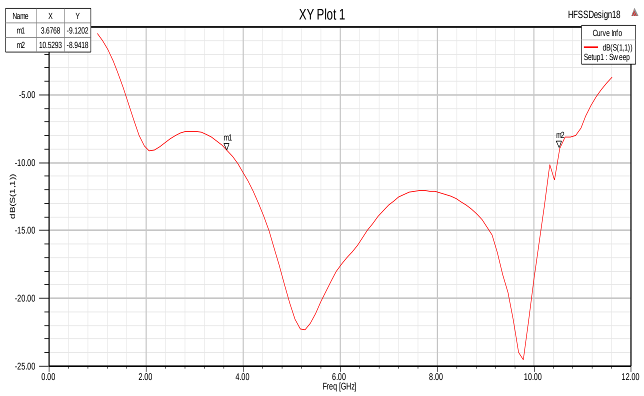

Figure 8. Return loss of Antenna with EBG behind the Patch

From this return loss curve, two resonant frequencies are obtained at 3GHz and 6.8GHz with the impedance bandwidth of 7GHz (2 - 9GHz) as shown in Figure 7. The return loss of resonant frequencies is around -27dB which means only less than 1% of input power is reflected back to generator. Thus, 99% of input power is transmitted via antenna.

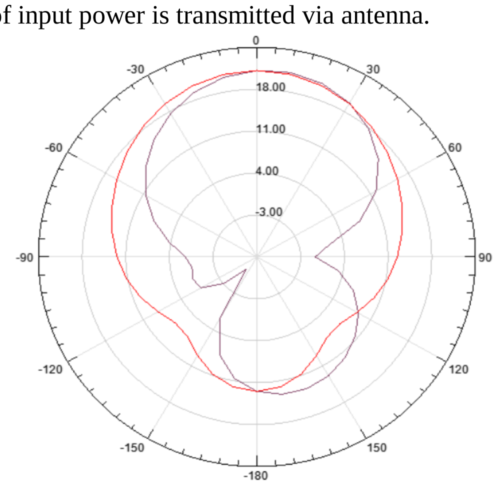

Figure 9. Radiation pattern of Antenna with EBG behind the Patch

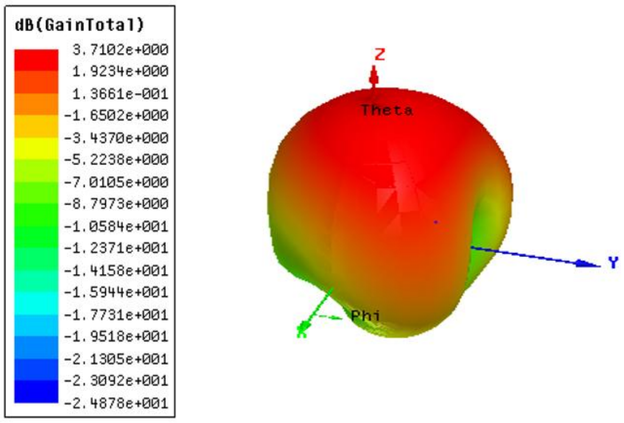

Figure 10. Gain plot of Second order Fractal antenna with EBG structure

From this gain plot, the average gain obtained for second order fractal antenna with EBG structure is 3.7dB.

Table 1. Comparison table

Design structure	Bandwidth	Gain	Radiation pattern
Hexagonal monopole antenna	5GHz	-3dB	Bidirectional
First order fractal antenna	6.8GHz	-3.5dB	Bidirectional
Second order fractal antenna	7GHz	-4dB	Bidirectional
Antenna with EBG structure behind the patch	7GHz	3.8dB	Unidirectional

V. CONCLUSION

A CPW-fed UWB hexagonal antenna with fractal elements is the design investigated in the proposed work. The miniaturized hexagonal fractal of size 25 × 25 × 1 mm3 is proposed to operate in UWB frequency range. The parametric study of fractal elements attached is examined from the current distributions at frequencies 3 GHz, 5GHz and 9.8 GHz respectively. The current distribution of the fractal radiator shows the response of the antenna from lower to a higher frequency. The proposed antenna has multi-resonance at 5GHz and 9.8 GHz with an improved gain of 4 dB using EBG structure with a Unidirectional radiation pattern. Hence the designed antenna is best suitable for body area networks.

REFERENCES

1. *Kushwaha*, N. and Kumar, R., (2013). An UWB fractal antenna with defected ground structure and swastika shape electromagnetic band gap. Progress in Electromagnetics Research, 52, pp.383-403.
2. Dinesh, V. and Murugesan, G., (2016). Coplanar Waveguide Fed Hexagonal Shaped Slot Antenna for Breast Tumor Detection. JOURNAL OF ADVANCES IN CHEMISTRY, 12(22), pp.5392-5397.
3. Wahab, M. G., AS Abd El-Hameed, W. Swelam, and MH Abd ElAzeem., (2017). "Novel miniaturized UWB antenna based on EBG structure." In 2017 Progress in Electromagnetics Research Symposium-Spring (PIERS), pp. 1171-1175.
4. Yazdi, M. and Komjani, N.,(2011). Design of a band-notched UWB monopole antenna by means of an EBG structure. IEEE Antennas and Wireless Propagation Letters, 10, pp.170-173.

5. Singhal, Sarthak, Tushar Goel and Amit Kumar Singh, (2017). Hexagonal tree shaped ultra–wideband fractal antenna, International Journal of Electronics Letters, Vol. 5, No. 3, pp. 335–348.
6. Singhal, Sarthak, Ankit Pandey and Amit Kumar Singh., (2017), CPW-fed circular-shaped fractal antenna with three iterations for UWB applications, International Journal of Microwave and Wireless Technologies, Vol. 9, No. 2, pp. 373–379.
7. Aissaoui, Djelloul, Lamine M. Abdelghani, Noureddine Boukli-Hacen and Tayeb A. Denidni, (2016).,CPW-fed UWB hexagonal shaped antenna with additional fractal elements, Microwave and Optical Technology Letters Vol. 58, No. 10, pp. 2370–2374.
8. M. Mahdavi, Z. Atlasbaf and K. Forooraghi, a very compact CPW-fed ultra- wideband circular monopole antenna, Microw. Opt. Technol. Lett, Vol. 54, No. 7, pp. 1665–1668 (2012).
9. R. Zaker and A. Abdipour, Bandwidth enhancement and miniaturization of fork- shaped monopole antenna, IEEE Antennas Wireless Propag. Lett., Vol. 10, pp. 697–700 (2011).
10. Fallahi, Hojjatollah and Zahra Atlasbaf ., (2013). Study of a class of UWB CPW-fed monopole antenna with fractal elements, IEEE Antennas and Wireless Propagation Letters, Vol. 2013, No. 12, pp. 1484
11. Dinesh, V & Murugesan, G , A CPW-Fed Hexagonal Antenna With Fractal Elements For UWB Applications', Applied Mathematics & Information Sciences, vol.13, no.1, pp.73-79. (2019)
12. Dinesh, V & Murugesan, G, A miniaturized planar antenna with defective ground structure for UWB applications, IEICE Electronics Express, vol. 16, no. 14, pp. 1-6 (2019)

AUTHORS PROFILE

Dinesh. V, Assistant Professor, Department of ECE, Kongu Engineering College, Perundurai, Erode. received the Bachelor degree in Electronics and Communication Engineering from Anna University, Chennai in 2007 and Master of Engineering in Communication Systems from Anna University, Coimbatore in 2010 respectively.

Vijayalakshmi. J, Assistant Professor, Department of ECE, Kongu Engineering College, Perundurai, Erode. received the Bachelor degree in Electronics and Communication Engineering from Anna University, Chennai in 2005 and Master of Engineering in Communication Systems from Anna University, Coimbatore in 2009 respectively.

Vignesh. B, Final year student, BE Electronics and Communication Engineering, Perundurai, Erode.

Vignesh. G, Final year student, BE Electronics and Communication Engineering, Perundurai, Erode.

Selva saravanan. S, Final year student, BE Electronics and Communication Engineering, Perundurai, Erode.