# DESIGNING MONOPOLE ANTENNA WITH ELECTOMAGNETIC BAND GAP (EBG)

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***Abstract*— This paper provides a study on designing Monopole Antenna with and without Electromagnetic Band Gap (EBG) technique. The antennas were designed and simulated using the Computer Simulation Technology (CST) microwave studio. The substrate of the antenna was fabricated using a substrate of FR4 with dielectric constant and height of 4.30 and 1.6 mm respectively. The conventional monopole antenna is added with 3X3 array matrices squares which is size is 3 mm x 3 mm stands with electromagnetic band gap (EBG) structures. The results show that the monopole antenna with EBG structures has better performance. The constructions of electromagnetic band gap (EBG) structures contribute better basic parameter of the monopole antenna such as return loss, bandwidth and size reducing. The minimum specification of return loss from simulated result is -10dB cutoff.**

***Keyword*— Monopole Antenna, Conventional Antenna, electromagnetic band gap (EBG**).

## I. INTRODUCTION

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The method of electromagnetic band gap (EBG) was found in late 1980's and became one of the most advancing sectors in the electromagnetic arena. This method allows manipulating the propagation of electromagnetic waves to next stage that cannot be achieved before. Besides, it promises the other way to overcome the limitation of current technology of electromagnetic and it is estimated that many new structures will be evolved based on this electromagnetic band gap concept [1, 2].

Monopole antenna has been discovered by Oliver Lodge on 1898 [3]. It was the apparently the first in the history of radio engineering. This antenna was used for a long time in all transceiver. However, recently this antenna is no longer acting outside of the body of receiving and transmitting [4]. A monopole antenna is actually a radio antenna which is one half of a dipole antenna and it is combined with right angle ground plane with considerable length in place of its another half. In other word, a dipole antenna has two halves, but the monopole antenna used one of the halves as electrically conductive surfaces known as ground plane. The ground plane act like the other halve of a dipole antenna as shown in figure 1 below [3, 4].

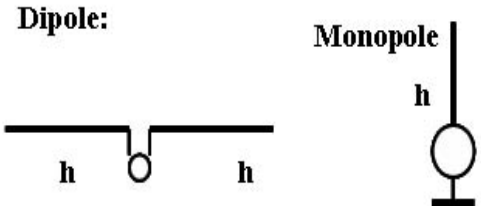


Figure 1.1: A dipole and a monopole

In other hand, the monopole antenna is the antenna that radiated element where the ground of the transmitter is connected with an electrical ground.

Electromagnetic band gap (EBG) unique structures have a property to avoid propagation of electromagnetic waves for more specific frequencies and direction which is stand of shape, size, symmetry and the material used in construction [2, 5]. The advantages by applying electromagnetic band gap (EBG) is it can be used to alter the electromagnetic interaction between an antenna and the platform. It also offers a mechanism to improve antenna performance and reduce antenna size. [5]

The features of electromagnetic band gap structure are to restrict unwanted substrate modes and acting as an artificial magnetic ground plane. The EBG structures are also used to improve the antenna performance as radiation patterns and to minimize the side and back lobe levels [6].

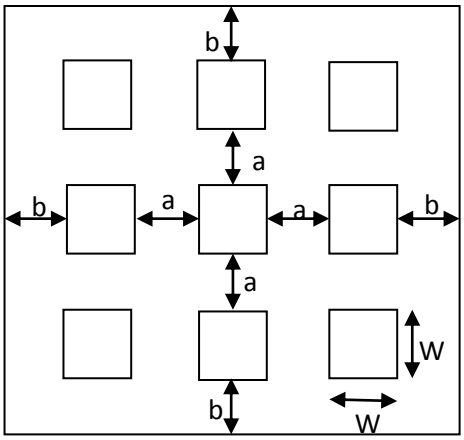


Figure 2 :EBG structures design

The monopole is pretty suitable for WLAN antenna design because it has a low profile; it can be etched on a single substrate and can provide the feature of broadband or multiband operation [9].

## II. DESIGN METHODOLOGY

### A) Flow chart

Figure 3 shows the flow chart on how monopole antenna was conducted.

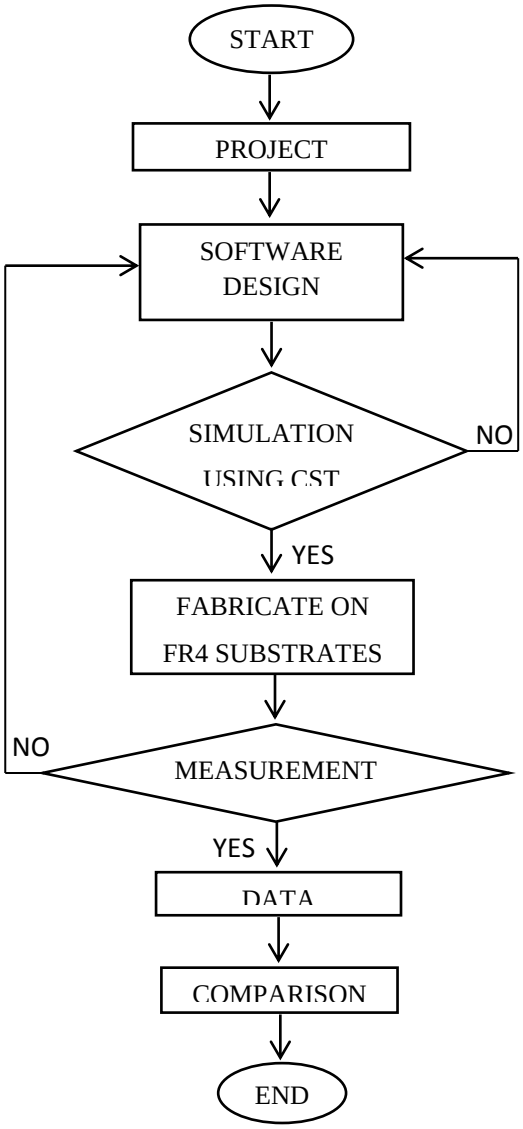


Figure 3: The design flow chart.

### B) Calculation

i) Dimension of patch width

$$W = \frac{c}{2f\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

ii) Effective dielectric constant, $\varepsilon_r$ = 4.3

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1+12\frac{h}{w}\right]^{\frac{1}{2}}$$

iii) Length extension,

iv) Patch length

$$L = \frac{c}{2f\sqrt{\varepsilon_{reff}}} - 2\Delta L$$

v) Ground substrate

$$Ls = L + 6h, Ws = W + 6h$$

Table 1: The FR4 substrate properties.

| Properties | Values |
|---|---|
| Permittivity, | 4.3 |
| Permeability, | 1.0 |
| Substrate Height, *h* | 1.60 mm |
| Thickness of Copper, *t* | 0.035 mm |

C) Conventional Monopole Antenna

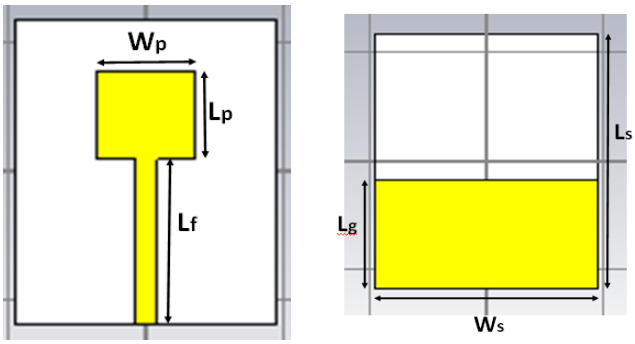


Figure 4 : front and back view of conventional monopole antenna

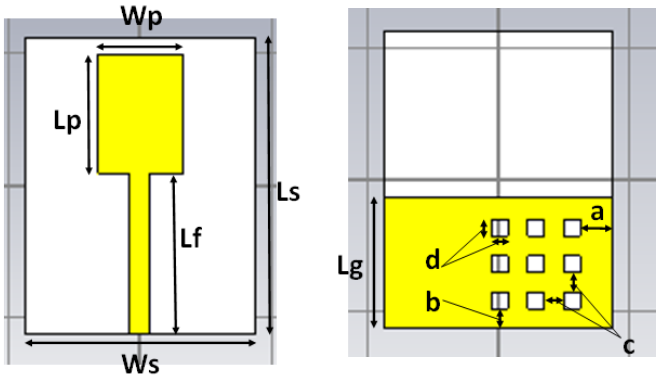


Figure 5 : front and back view of monopole antenna with EBG structures

Table 2: The comparison between values of parameters designed

| Parameters | Conventional monopole antenna. (mm) | Monopole antenna with EBG structures. (mm) |
|---|---|---|
| Wp | 14.0 | 13.0 |
| Lp | 13.7 | 18.0 |
| Ws | 47.0 | 45.0 |
| Ls | 38.0 | 35.0 |
| Wf | 3.0 | 3.0 |
| Lf | 25.5 | 24.3 |
| Lg | 38.0 | 35.0 |

## III. RESULT AND SIMULATION

*a) Simulation*

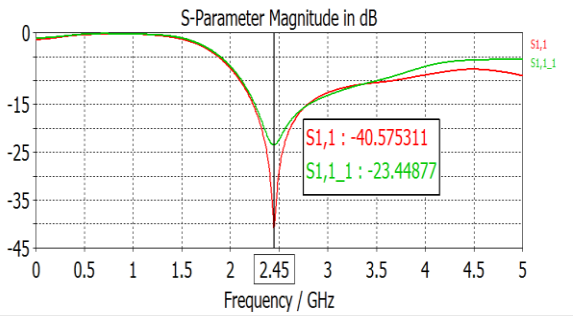


Figure 6: The comparison between return loss of both antennas

The result shows that the return loss of conventional monopole antenna and monopole antenna with EBG structures. According to the simulation designed, the value of return loss of conventional monopole antenna is -23.45 dB. Meanwhile the value of monopole antenna with EBG structures is -40.57 dB. Both simulation results can be accepted because their return loss value is below -10 dB.

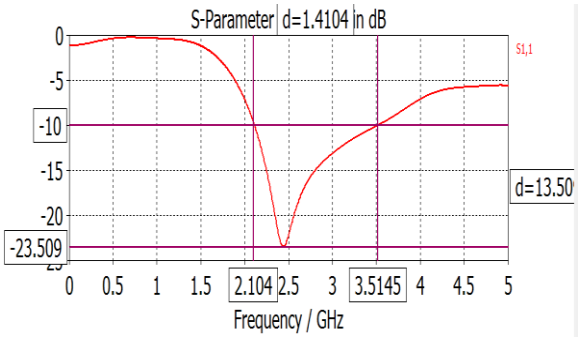


Figure 7: The value of bandwidth of conventional monopole antenna

The simulation shows that the bandwidth of conventional has a range of frequencies between 2.104 GHz and 3.5145 GHz. This range contributes the bandwidth of 1.4104 GHz. The bandwidth was measured at a -10 dB. This value of bandwidth is compared to the monopole antenna with EBG structures.

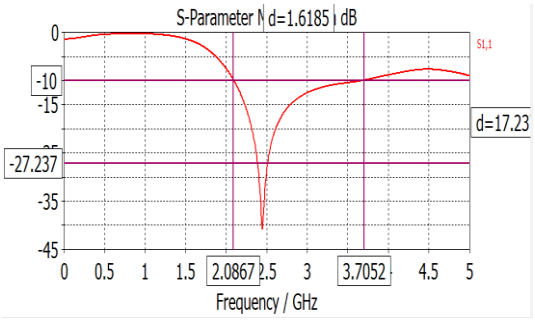


Figure 8: The value of bandwidth of monopole antenna with EBG structures.

As shown in the figure 4.5 above, through simulation, the value of the bandwidth of monopole antenna with EBG structures which is 1.6185 GHz is greater than the value of bandwidth of conventional monopole antenna which is 1.4104 GHz. The value of bandwidth also taken from the -10 dB line. It was proven that EBG structures can improve the bandwidth of antenna. The simulation shows that the bandwidth is increased about 14.75%.

Another parameter that should be considered is the value of line impedance. The line impedance is maintained although the size of the antenna was reduced. In figure 4.6 below shows that the line impedance of the monopole antenna is approximately equal to 50 Ohm

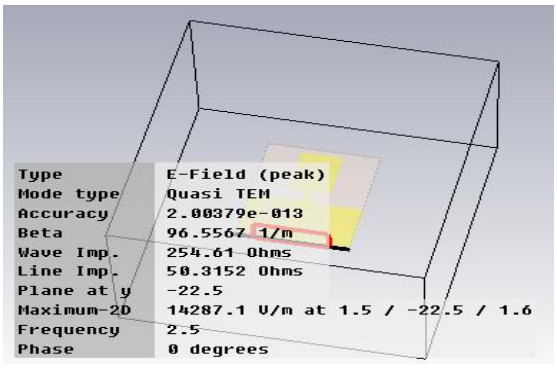


Figure 9: The line impedance of monopole antenna designed

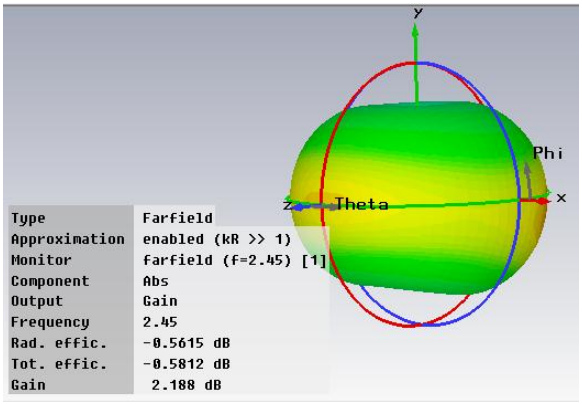


Figure 10: The gain 3D plot of conventional monopole antenna.

The Figure 10 above shows the 3D plot of radiation pattern of gain for antenna without EBG structures. the gain was measured and the value was 2.188 dB.

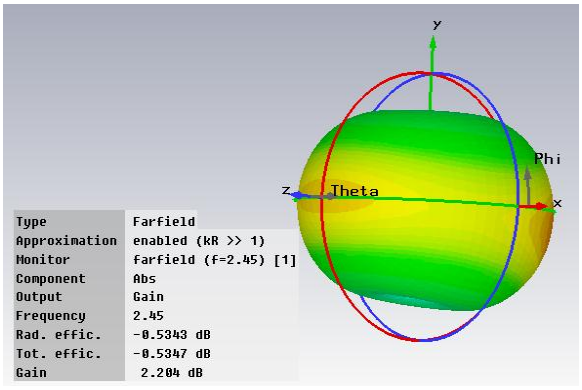


Figure 11: The gain 3D plot of monopole antenna with EBG structures.

However, when applying EBG structures to the antenna, the gain has increased to 2.204 dB. This shows that the method of EBG structures can increase the gain of antenna

Table 3: The comparison of some parameters between conventional monopole antenna and monopole antenna with EBG structures

| | Conventional Monopole Antenna | Monopole Antenna with EBG structures | Percentage Difference (%) |
|---|---|---|---|
| Size of antenna (mm) | 45.00 x 35.00 | 47.00 x 38.00 | 13.90 |
| Return Loss, $S_{11}$ (dB) | -23.45 | -40.57 | 73.00 |
| BW (GHz) | 1.4104 | 1.6185 | 14.89 |
| Gain (dB) | 2.118 | 2.204 | 4.06 |

Table 3 shows the different of some parameters between between monopole patch antenna with and without EBG structures which is size of antenna, return loss, bandwidth and gain in terms of percentages. The size of the antenna has been reduced by 13.9%. as known, when the value of frequency is higher, the size of antenna will be lower. But, EBG structures has shown that the size of the antenna can be reduced without increasing the value of frequency. The return loss has increased to -40.57 which is 73%. The bandwidth became larger and increased by 14.89%. Lastly, the gain shows improvement about 4.06%.

*b) Measurement*

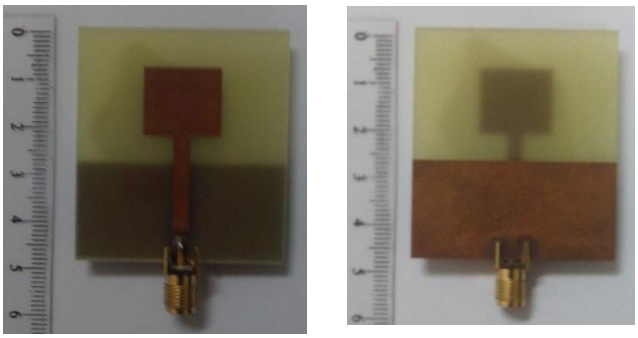

Figure 12: Fabrication of conventional monopole antenna

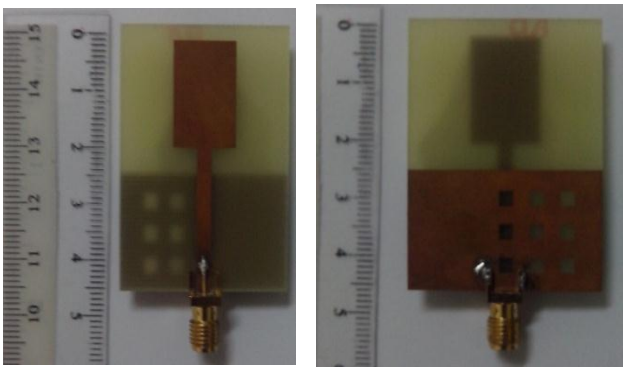

Figure 13: Fabrication of monopole antenna with EBG structure.

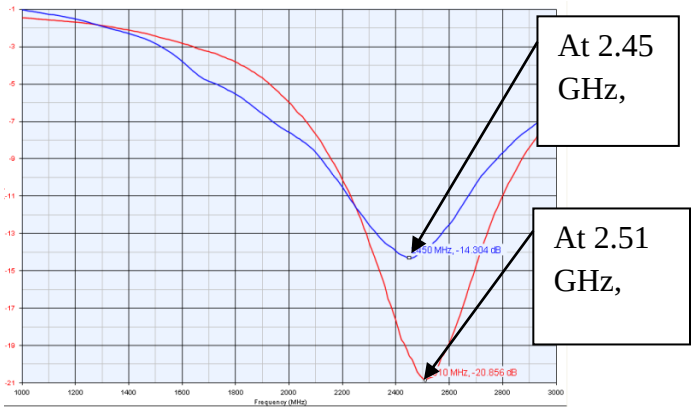


Figure 14: Measurement result of Return Loss ($S_{11}$) for conventional monopole antenna and monopole antenna with EBG structures

Figure shows the return loss result of conventional monopole antenna and monopole antenna with EBG structures. The blue line shows the conventional monopole antenna and the red line is monopole antenna with EBG structures. The return loss of conventional result gave -14.304 dB at frequency of 2.45 GHz. This result is different compared to simulation result which is -23.45 dB. However, the return loss measurement result for monopole antenna with EBG structures was -20.86 dB and this result is also shows a different to simulation result, which is -40.57 dB. All measurement was done by using Vector Network Analysis (VNA).

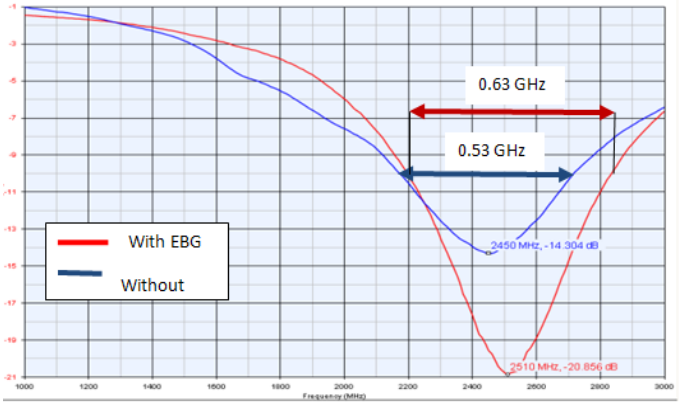


Figure 15: Measurement result of Return Loss ($S_{11}$) for conventional monopole antenna and monopole antenna with EBG structures

The measurement result of bandwidth of both antennas showed that the monopole antenna with EBG structures improved the conventional monopole antenna. It revealed that by applying EBG structures to the antenna can increase the bandwidth of the antenna. According to the measurement in figure above, the value of bandwidth of conventional monopole antenna was 0.53 GHz. But the simulation showed that the bandwidth of the antenna is 1.4104 GHz. The bandwidth has dropped approximately about 1 GHz.

Meanwhile, the measurement of the monopole antenna with EBG structures also showed the dropped of bandwidth when it is compared to simulation bandwidth. The measurement of bandwidth obtained was 0.63 GHz while the simulation bandwidth obtained was 1.6185 GHz. The value of bandwidth also dropped approximately about 1 GHz.

Table 4: The comparison of measurement results.

| | Conventional Monopole Antenna | Monopole Antenna with EBG structures | Percentage Difference (%) |
|---|---|---|---|
| Return Loss, $S_{11}$ (dB) | -14.304 | -20.856 | 45.9 |
| BW (GHz) | 0.530 | 0.630 | 18.9 |

Table presents comparisons of measurement between conventional monopole antenna and monopole antenna with EBG structures. The result was obviously different with simulation results.

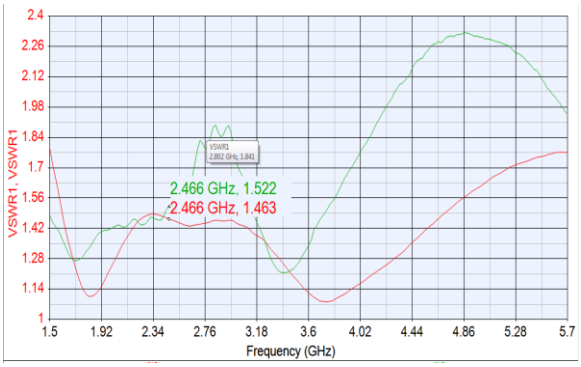


Figure 16: The value of VSWR obtained

Figure shows the value of VSWR of both antennas. The green line represents the conventional monopole antenna and its value at 2.45 GHz is approximately 1.52. The red line represents the monopole antenna with EBG structures and its value at 2.45 GHz is approximately 1.46. This revealed that the monopole antenna with EBG structures is more efficient. The perfect design is where the value of VSWR is equal to 1. When a signal is transmitted, the receiver received 100% of the signal. This can be said as perfect design. However in this project, the value of VSWR is 1.52 and 1.46 shows that the signal transmitted is not fully receive by the receiver. The more value of VSWR approaching to 1, the more efficient the antenna is.

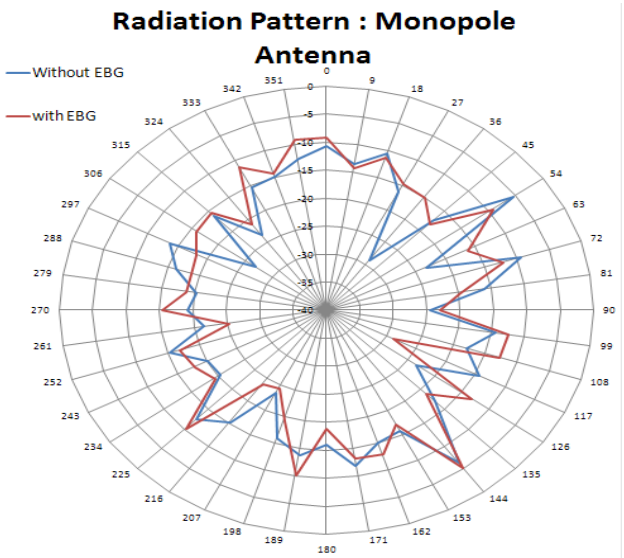


Figure 17: The comparison of radiation pattern of both antennas

Figure presents the radiation pattern of both antennas. The blue colour represents the conventional monopole antenna which is without EBG structures while the red line shows the monopole antenna with EBG structures. The result show that the monopole antenna with EBG structures is more efficient compared to the conventional monopole antenna.

## IV. CONCLUSION

In conclusion, a conventional and with EBG structures monopole patch antenna has been successfully designed, simulated by using Computer Simulation Technology (CST) and fabricated. The square of EBG structures which is 3x3 matrices is able to produce the better features. By using this antenna with EBG structures, the signal propagated become more efficient and it contributed the performance of the conventional antenna in term of

antenna size, gain, bandwidth and return loss about 13.9%, 4.06%, 18.9%and 45.9%. This monopole patch antenna it's suitable for wireless LAN communication application.

## V. ACKNOWLEDGEMENT

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## REFERENCE

[1] Ozgur Isik, Yuehe Ge, Karu P. Esselle (Centre of Electromagnetic and Antenna Engineering, Department of Electronics, ICS Division, Macquarie University Sydney, NSW 2109, Australia)

[2] Ainor Khaliah Binti Mohd Isa (Faculty of Electrical Engineering University Technology Malaysia)

[3] Hans Gregory Schantz (h.schantz@ieee.org)
Next-RF, Inc. 4811Cove Creek Drive Brownsboro, AL 35741

[4] M. Bank, M. Haridim
Holon Institute of Technology (HIT), Israel

[5] Review of Electromagnetic Bandgap Technology and Applications Peter de Maagt, Ramon Gonzalo, J (Yiannis) Vardaxoglou (*Electrical and Electronic Engineering Department, Universidad Publica de Navarra, Campus Arrosadia, E-31006, Pamplona, Navarra, Spain*

[6] Aijaz Ahmed, Yogesh (Dept. of ECE, ASET/ Amity University, India)

[7] Mohd. Isa, Ainor Khaliah (2007) *Electromagnetic band gap (EBG) for microstrip antenna design.* Masters thesis, Universiti Teknologi Malaysia, Faculty of Electrical Engineering

[8] Mahdy Rahman Chowdhury Mahdy, Md. Rashedul Alam Zuboraj, Abdullah Al Noman Ovi and Md. Abdul Matin. (Department of Electrical and Elecronic

[9] A Compact Tri-Band Monopole Antenna
With Single-Cell Metamaterial Loading Jiang Zhu, *Student Member, IEEE*, Marco A. Antoniades, *Member, IEEE*, and George V. Eleftheriades, *Fellow, IEEE* Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh)

[10] Investigation of loaded monopole antenna by Nikolaos – Hrissovalantis Vardalahos.

[11] Monopole Antennas
O. P. Gandhi, G. Lazzi, and C. M. Furse
Electrical & Computer Engineering Department
University of Utah
Salt Lake City, UT 84112-9206

[12] Indian Space Research Organisation Antenna Systems Group, "Proceedings of

International conference on Antenna Technologies", Allied Publishers, 2005, pp. 539.

[13] Alan Ames, "Patch Antenna and Circular Polarization", EE994 Antenna Project, 2009.

[14] Krishnananda, T. S. Rukmini, "EBG Antennas: Their Design and Performance Analysis for Wireless Applications", Kuvempu University, 2012, pp. 1-8.

[15] C.A. Balanis, ""Antenna Theory Analysis and Design", Third Edition, John Wiley and Sons, USA, 2005, pp.811-843

[16] Nakar, Punit Shantital, "Design of a compact Microstrip Patch Antenna for use in Wireless/Cellular Devices", *Electronic Theses, Treatises and Dissertations, Paper 2790,* 2004.

[17] Debatosh Guha, Yahia M.M. Antar," Microstrip and Printed Antennas: New Trends, Techniques and Applications", John Wiley & Sons, Feb 2, 2011, pp. 113