Monopole with Defect Ground Structured (DGS) antenna for BCWC application.

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***Abstract*—This paper presents the comparison between monopole antenna with Defected Ground Structured (DGS) and conventional monopole antenna. The printed monopole antenna proposed to operate at 2.45GHz Industrial, Scientific and Medical (ISM) band with the application for body-centric wireless communications (BCWC) [1]. The antenna was designed and simulated using the Computer Simulation Technology (CST) microwave studio. The substrate of the antenna was fabricated using RT5807 with dielectric constant and height of 2.33 and 0.504 mm respectively. The monopole antenna is added with a DGS by using double H-shape DGS at the ground plane to contributes the performances of monopole antenna. The result shows that the monopole antenna with DGS gives better performance in term of return loss, antenna size, gain and directivity.**

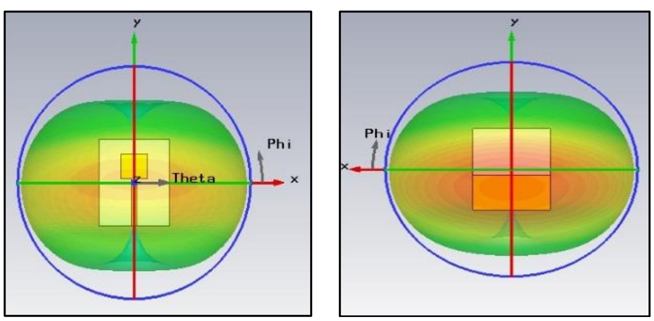
***Keyword*—Conventional Antenna, Defect Ground Structure (DGS), body-centric wireless communications (BCWC).**

I. INTRODUCTION

Monopole antenna is one of the types which are extensively being incorporated in various applications. The greater demands on antenna design of modern wireless systems give opportunity to the researchers to do some research on body-centric wireless communication due to the increasing of application in the personal communication systems. With compact and small antenna that will make a suitable antenna to be used. In various researches, the printed monopole antenna has received more attention due to their characteristic such as omnidirectional radiation patterns, high radiation efficiency and compact size [2]. Besides that, it can maintain a strong ray diffracted around the body due to its normal polarization to the human body surface. This characteristic proves that, monopole antenna is a suitable candidate to be used in BCWC [1].

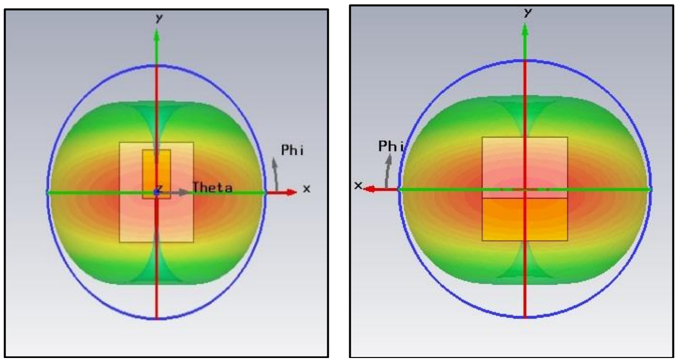
The improvement development of Electromagnetic Bandgap (EBG) has attract the researches on the interest of antenna performance improvements such as size reduction [3], gain enhancement [4] and radiation efficiency improvement [5]. A notable class of EBG structure named Defected Ground (DGS) that shows it has a controllable finite transmission zero characteristics [6]. From the research U-shaped DGS is offer to enhance the impedance bandwidth of the antenna [7]and a circular DGS will reduces the cross-polarized radiation of a monopole antenna by 8dB [8]. To this end, double H-shaped DGS is proposed because of their characteristic to suppress higher order harmonics of a monopole antenna by more than 20dB [9]. Different with the conventional monopole antenna, with etching this H-shape DGS underneath the simple monopole antenna feedline, impedance bandwidth broadening can be obtained.

This conventional monopole was simulated by two conventional monopole with different substrate. Firstly by using FR-4 as substrate with dielectric constant and height of 4.34 and 1.6mm respectively. Then by using Rogers group RT5807 as substrate with dielectric constant and height of 2.33 and 0.504mm respectively. It was found that the simulated gain, directivity, return loss and radiation pattern characteristics agreed well with the conventional RT5807 monopole antenna. One of the factors that RT5807 are choose due to the radiation pattern characteristic and the other reason is any further increase in the substrate thickness decreases the efficiency of the monopole antenna and increases cross-polar level [10].



(a) (b)

Figure 1: Fairfield of the proposed conventional monopole antenna with substrate FR-4.
(a) Front view. (b) Back view.



(a) (b)

Figure 2: Farfield of the proposed conventional monopole antenna with substrate RT5807.
(a) Front view. (b) Back view.

II. METHODOLOGY

A. *Flow Chart*

Figure 3 below shows the flow chart design a comparison of monopole antenna with DGS and conventional antenna.

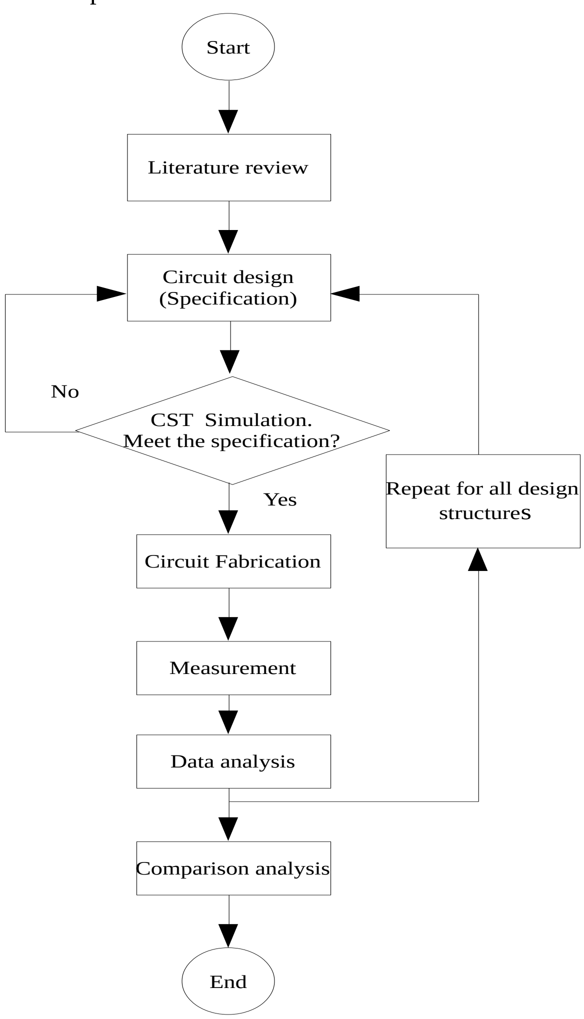


Figure 3: Design methodology flowchart.

B. *Defect Ground Structure (DGS)* design.

The structure proposed is shown in Figure 4. It was constructed by using double H-shape DGS. In this design structure, RT5807 substrate with the H-shape DGS was used to improve the features of monopole antenna. The conventional monopole antenna and monopole antenna with DGS was test by placed the 50.5078 ohm and 50.809 ohm lines above the substrate. This line need to match with 50 ohm to make sure that signal can be transmitted and received. The properties of RT5807 substrate are shown in Table 1.

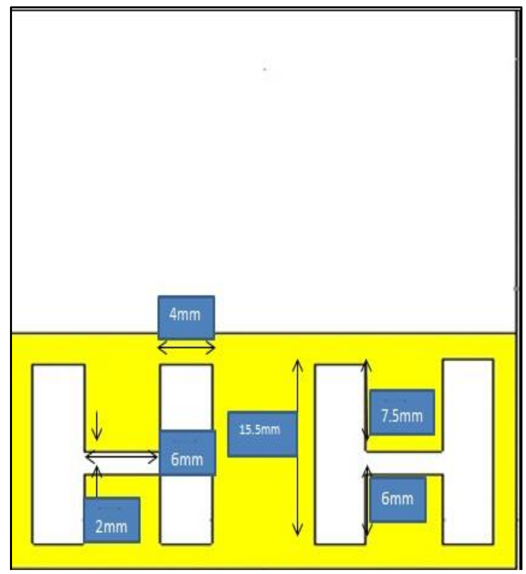


Figure 4: Dimensions of the double H-shaped DGS construction

TABLE I
RT5807 SUBSTRATE PROPERTIES

Properties	Values
Permittivity,	2.33
Permeability,	1
Substrate Height, *h*	0.504mm
Thickness of Copper, *t*	0.035mm

The simulation of double H-shaped structure in Figure 4 was perform by using Computer Simulation Technology (CST) Microwave Studio. From the simulation result, data in S parameter used as a reference in order to increase the value of S parameter to produce suitable matching on 50 ohm and give a smaller reflection coefficient. As a result double H-shaped DGS was choosen by its characteristic of increasing the value S parameter and reduce the reflection coefficient.

When the signal is transmitted to a transmission line, the signal will travel without interference if no discontinuities at the transmission line. Discontinuities will acts as an obstacle to the flow of the signal. This obstacle will give a result the signal bounce back towards the main source [11]. The expression for calculating the reflection coefficient is as follows:

$$\Gamma = \frac{VSWR - 1}{VSWR + 1}. \quad (1)$$

Where,

VSWR= Voltage Standing Wave Ratio.
Γ = reflection coefficient of the circuit.

C. Rectangular Monopole Antenna Design

The design procedures of conventional monopole antenna and monopole antenna with DGS consist of several important parameters which are the operation frequency, f_o, dielectric constant, of the substrate and height, h of dielectric substrate. The parts of both antennas are feed line, patch antenna, ground plane and type of substrate. Patch antenna, feed line and ground plane are made from copper, while the substrate is RT5870. The antenna was designed to operate at 2.45 GHz.

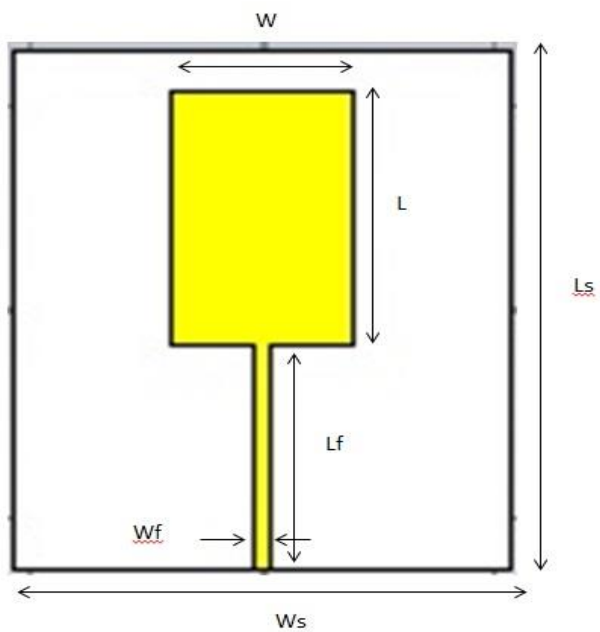


Figure 5: Dimension of conventional antenna.

After all the parameters were selected, the next step is to calculate the dimension of the antenna. The following formula is used to obtain the suitable parameter.

Step 1: calculation of width (W)

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

With c is the free space velocity of light, f_o is the frequency of operation, ε_r is the dielectric constant and h is the height of the dielectric substrate.

Step 2: The effective dielectric coefficient is given as

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} \quad (3)$$

Step 3: Calculation of Effective Length

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{reff}}} \quad (4)$$

Step 4: The length Extension is given as

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \quad (5)$$

Step 5: Calculation of actual Length of patch

$$L = L_{eff} - 2\Delta L \quad (6)$$

Step 6: The substrate dimensions is given as

$$Ls = 6h + L \quad (7)$$

$$Ws = 6h + W \quad (8)$$

The design of a single rectangular patch antenna was done. Macros application from CST microwave studio is used to determine the width of the antenna. It function is to match the patch antenna by utilizing feedline where 50 ohm is desired. This is the best feeding techniques and it is also easy to control the input impedance of the antenna. The input impedance level of the patch can be controlled by adjusting the width of the inset.The following formula was used to calculate the distance of quarter-wavelength

Step 7: Calculation the distance of quarter-wavelength.

$$\lambda_o = \frac{c}{f} \quad (9)$$

$$\lambda_g = \frac{\lambda_o}{\sqrt{\varepsilon_{reff}}} \quad (10)$$

$$Quarter-wavelength = \frac{\lambda_g}{4} \quad (11)$$

The major differences between microstrip patch antenna with monopole antenna is at the ground section. From the Figure 6 partially ground is needed in order to get the radiation pattern as an omnidirectional pattern. For an omnidirectional pattern the monopole which radiates equal power in all directions and has a "spherical" radiation pattern [12] that will radiate in front and at the back of monopole.

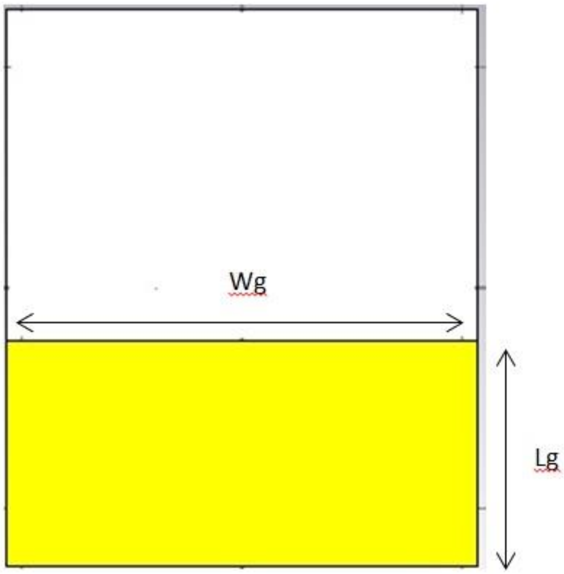


Figure 6: Dimension of conventional antenna.

Table 2 presents the antenna dimensions are at the optimized value after adjusting the size of parameters to meet the requirement of antennas specification.

TABLE II
CALCULATED DIMENSION OF CONVENTIONAL MONOPOLE ANTENNA AND MONOPOLE ANTENNA WITH DGS.

Description	Conventional antenna(mm)	Antenna with DGS(mm)
Patch Width, *W*	16.0	17.1
Patch Length, *L*	24.6	24.8
Substrate Width, W_s	430	39.5
Substrate Length, L_s	50.5	48.5
Feeder Width, W_f	1.50	1.10
Feeder Length, L_f	22.0	22.0
Ground, *Lg*	20.5	20.5
Ground, *Wg*	43.0	43.0

III. RESULT AND DISCUSSION

In this research, antenna performance was investigated through simulation and measurement process. The simulation results are obtained from the CST-MW whereas the measurement results are obtained from Vector Network Analyzer (VNA) measurement. These results are shown in part *A* and *B*.

The simulations of the conventional antenna have been used by 2 different material which is FR-4 and RT5870.The substrate of the FR-4 with dielectric constant and height is 4.34 and 1.6mm respectively. For RT5870 substrate dielectric constant and height is 2.33 and 0.504mm respectively. By comparing the result of these two substrates it shows that RT5870 give a better performance in bandwidth, gain, directivity and the radiation pattern. This founding also proven that a technically substrate FR-4 have more loss compare to R5T870.

A. Simulation Result

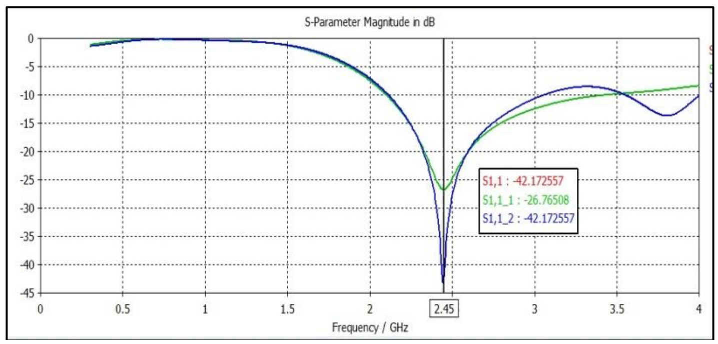


Figure 7: Simulation result of S_{11} parameter between conventional monopole antenna and monopole antenna with DGS.

In Figure 7, the simulation result of S_{11} parameter at the frequency 2.45GHz between conventional monopole antenna and monopole antenna with DGS are -26.766608 dB and -42.369254 dB respectively. It shows that the return loss value of monopole antenna with DGS is higher compare to the conventional monopole antenna. The conventional monopole antenna produce acceptable level of return loss, however monopole antenna with DGS performs better than conventional monopole antenna. The high value of return loss means that the amount of radiated signal by antenna is higher and very small reflection signal back to the source. Furthermore it also has the filtering characteristics which reject the unwanted signal and avoid the interference with another signal.

Figure 8 and Figure 9 show the gain for the conventional monopole antenna and monopole antenna with DGS. The gain of the monopole antenna with DGS is 2.654 dB which is higher than conventional antenna is 2.587 dB. From both figures, there are report that the monopole antenna with DGS produce higher gain compared conventional monopole antenna which is about 2.6 %.

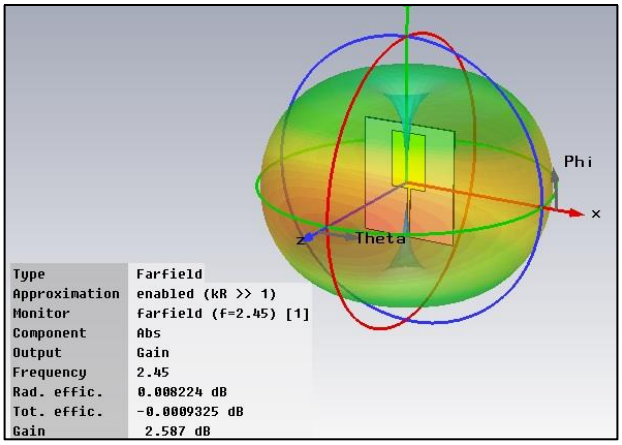


Figure 8: Gain of conventional monopole antenna

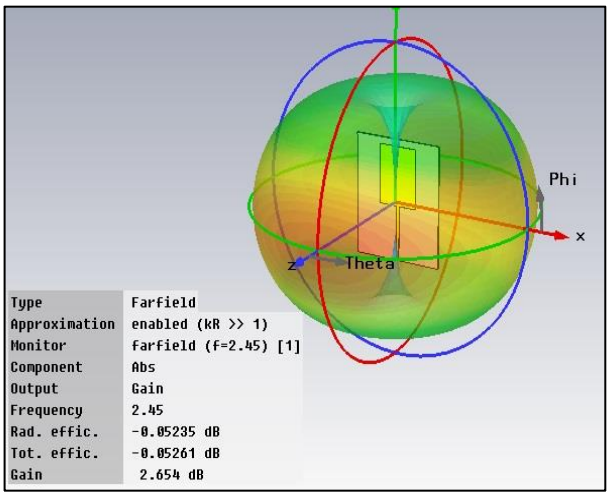


Figure 9: Gain of monopole antenna with DGS.

TABLE III

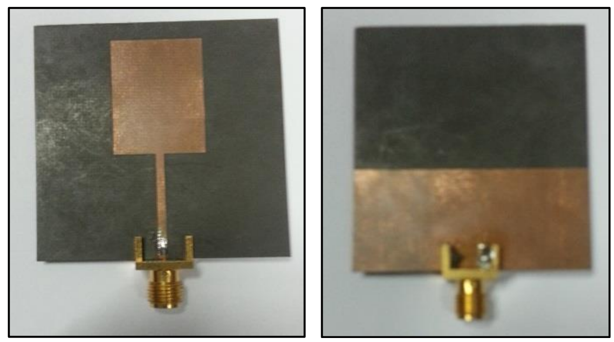
COMPARISON BETWEEN SIMULATED OF CONVENTIONAL MONOPOLE ANTENNA AND MONOPOLE ANTENNA WITH DGS.

	Conventional monopole Antenna	Monopole Antenna with DGS	Percentage Difference (%)
Return Loss, S_{11} (dB)	-26.766608	-43.36254	61.98
Size antenna (mm)	50.49601581x 42.96699189	48.5x 39.5	11.70
Gain (dB)	2.59	2.71	2.71
Directivity (dB)	2.58	2.65	5.79

Comparison between simulation performance of the conventional monopole antenna and monopole antenna with DGS is shown in Table III. The monopole antenna with DGS produce better performance compared to the conventional antenna in term of return loss, antenna size, directivity and gain. Table 3 stated that the return loss (S_{11}) is increase by 61.98% which is higher improvement and this result directly will give impact on reflection signal back to source. It is proven that the monopole antenna with DGS would effect of reducing antenna size. As a consequence of using DGS, antenna size is reduced by 11.70 %. The gain improved by 2.71 % and the directivity increase by 5.79 %.

B.Measurement Result

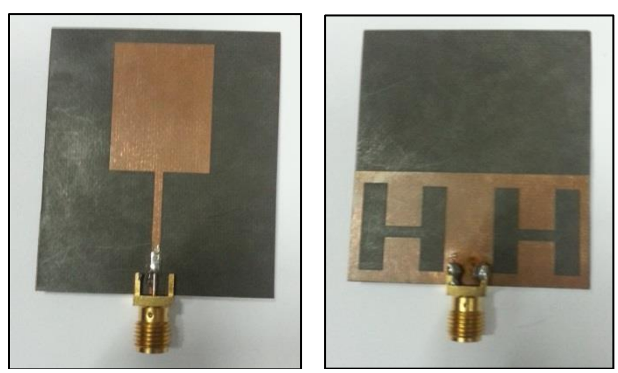
Figure 10 represents the conventional antenna that has been fabricated. As mentioned earlier, this project is fabricated on Rogers RT5870 substrate. Figure 10 a) shows the view of conventional monopole antenna at the front of the substrate while figure 10 b) shows the back view (ground plane).



a) b)

Figure 10: Conventional monopole antenna.
a) Front view b) back view

Figure 11 show the view of the monopole antenna with DGS. Figure 11 a) show the front view of the monopole antenna and b) shows the monopole antenna with H-shape DGS structure at the ground plane respectively.



a) b)

Figure 11: Monopole antenna with DGS.
a) Front view b) Back view

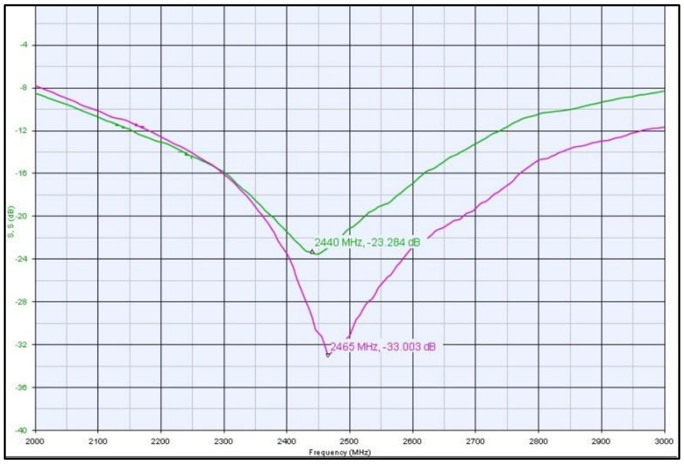


Figure12:Measurement result of S_{11} parameter between conventional monopole antenna and monopole antenna with DGS.

Figure 12 presents the measurement result for the return loss is presented. The return loss, for conventional monopole antenna is -23.84 dB at frequency 2.44 GHz. It shows that the frequency shifted to the left from the original frequency (2.45 GHz). Meanwhile the return loss for monopole antenna with DGS has been shifted to the right about -33.003 dB at frequency 2.46 GHz. It may occured due to the error during fabrication process or has losses along the VNA cable.

The VSWR (Voltage Standing Wave Ratio) measurement describes the voltage standing wave pattern that is present in the transmission line due to the phase addition and subtraction of the incident and reflected waves. The ratio is defined by the maximum standing wave amplitude versus the minimum standing wave amplitude.

Figure13:Measurement result of Volatge Standing Wave Ratio (VSWR) between conventional monopole antenna and monopole antenna with DGS.

Figure 13 show that measurement of VSWR. The VSWR for a conventional monopole antenna (green line) whereas at the 2.45GHz the value is 1.251. Meanwhile for the monopole with DGS,VSWR (red line) that show 1.553. For a good antenna the value of VSWR must be equal to 1.

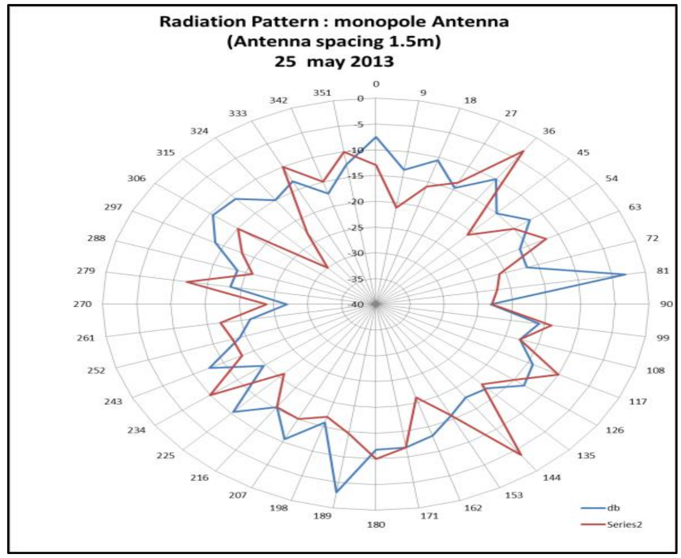


Figure13:Measurement result of radiation pattern between conventional monopole antenna and monopole antenna with DGS.

Radiation pattern of conventinal monopole antenna and monopole with DGS is presented. This comparison show that the blue line is monopole antenna with DGS have a good omnidirectional pattern compare to the conventional with the red line line. However this radition pattern show some of loss maybe due to some reflection of the signal with the item in the labrotary when it radiate.

IV. Conclusion

As a conclusion, a comparison of monopole antenna with DGS and conventional monopole antenna has been successfully designed, simulated and fabricated. The H-shape DGS structure is able to produce the improvements of the antenna features. By using this monopole antenna with DGS, the signal propagated become more sharper and it enhances the performance of the conventional antenna in term of antenna size, gain and return loss about 11.7%, 2.71%, 5.79% and 61.98%. This monopole antenna with DGS is suitable for body-centric wireless communications (BCWC), Wlan and Bluetooth application.

V. Future Recommendation

In the designing of the monopole antenna with DGS, there are several improvements to enhance the gain, return loss, bandwidth, directivity and antenna size of the monopole antenna can be taken into consideration for future research. It also can reduce the size of the substrate that will be minimizing size of the antenna. For future designing monopole antenna with DGS need to improve about 10% from performance of conventional monopole antenna to declare it as a good design. Furthermore the different substrate, structure, and type of patches may also affect the performance of antennas. The other method can be used in the future is by using metamaterial with a unique structured. This method has been given attention to the researcher to make an antenna with a better performance compare to the DGS method.

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