Nigerian Journal of Engineering Science Research (NIJESR), Vol. 2, Issue 2, pp.38-46
Copyright@ Department of Mechanical Engineering, Gen. Abdusalami Abubakar College of Engineering, Igbinedion University, Okada, Edo State, Nigeria.
ISSN: 2636-7114
Journal homepage: www.nijesr.iuokada.edu.ng

Study of Wideband Rectangular Dra

Abdullahi SB Mohammed[1*], Babangida Jauro Mohammed [2], Akinlabi, A.A.

[1]*Department of Electrical and Electronics Engineering, Kebbi State University of Science and Technology Aliero, Nigeria*
[2]*Department of Electrical and Electronics Engineering, Alooma Polytechnic Gaidan, Nigeria*
[3]*Department of Electrical and Electronics Engineering, Kebbi* State Polytechnic, Dakingari, *Nigeria.*

* **Abdullahi SB Mohammed, abdulsbauchi@gmail.com, *+2348037106906***

Manuscript History
Received: 23/09/2019
Revised: 25/12/2019
Accepted: 30/12/2019
Published: 15/01/2020

Abstract: The increasing demand for the broadband antenna as high data rates for wireless communication technology. The antenna also plays an essential role in the wideband system. There are, however, some difficulties in designing wideband antenna compared to the narrowband antenna, especially Dielectric Resonator Antenna, rather than a patch antenna. The radiation properties, frequency ranges, and low power consumption are also necessary parameters for antenna design. A few strategies to increase the antenna bandwidth are the aim of this research work. The main challenge is by using Duroid RT6010 as the dielectric material. The performance such as the antenna's return loss and radiation pattern are thoroughly investigated and implemented. The simulated return losses are lower than -10 dB (Voltage Standing Wave Ratio < 2), measurably around -16.29 dB, at 119 MHz with bandwidths of 227 MHz. The measured return loss is -21.68 dB with 223 MHz are found enough for proper impedance matches. However, it is pointed out that the bandwidth difference is 1.1 MHz constitutes about 5.59 % between the simulated and measured bandwidth. This amount of mismatch as a result of manufacturing sensitivity and the effect of the coaxial feed. Excellent correlation was observed between the measured and simulated results.

Key words: Dielectric Resonator Antenna, Dielectric material, Resonant frequency, Wideband antenna.

INTRODUCTION

Due to its small size and high efficiency, the radiating element of the Dielectric Resonator Antenna (DRA) has recently been of considerable interest. The rigorous analysis of DRA elements, however, has been largely restricted to rotationally symmetric shapes (Junker *et al.*, 1994; Junker *et al.*, 1996). Wireless LAN (WLAN) has attracted significant attention as a technology that enables short-range wireless communications between wide varieties of devices such as mobile phones, and notebooks. The dielectric resonator antenna (DRA) is a resonant antenna, fabricated from low-loss dielectric material the resonant frequency of which is predominantly a function of size, shape, and material permittivity. DRAs offer the advantages of small size, lightweight, low profile, low cost, and high radiation efficiency, making them attractive candidates for WLAN applications (Mongia *et al.*, 1994; Petosa *et al.*, 1998). DRAs frequently are available in rectangular, cylindrical, and hemispherical geometries. Rectangular DRAs offer more design flexibility since two of the three of its dimensions can be varied independently for a fixed resonant frequency and known dielectric constant of the material (Mongia *et al.*, 1997). Nowadays, the communication field places much importance on the wireless application. The whole wireless system becomes small and compact as well as the size of the antenna. A Dielectric Resonator Antenna (DRA) is a type of antenna which has a high-frequency. From the International Telecommunication Union (ITU), which is an international civil organization that established to standardized worldwide telecommunications, have stated that the high frequency range from 3 GHz to 30 GHz is a category by Super High Frequency (SHF). In this range, it can operate in many applications. For example, it can be used in microwave devices, wireless LAN, most modern radars, communications satellites, and amateur radio. Normally, the standard of the DRA antenna has a narrow bandwidth. Enhancement of the performance to cover the demanding bandwidth is necessary. Hence it is reasonable to have a wideband antenna than narrowband antenna.

DRA was first proposed in the early 1980's (Long *et al.,* 1983). After then various investigate offer significant enhancements to parameters such as bandwidth, gain, polarization, or power coupling. Over the last decades, various bandwidth enhancement techniques have been developed for DRAs. An overview of these techniques has also been reported, where these techniques were classified into three broad categories: Lowering the inherent Q-factor of the resonator; using external matching networks; and combine multiple dielectric resonators. Since many devices such as Bluetooth equipment, household appliances, and medical devices also use the 2.4GHz ISM band, resulting from interference within this band, which undoubtedly will provide cleaner spectrum and higher data rate for innovative wireless network applications. As a result, the HiSWAN, IEEE 802.11a, and HIPERLAN/2 standards were approved in separate parts of this band in April 1999, September 1999 and February 2000, respectively (Yeh *et al.,* 2003). Rectangular Dielectric Resonator Antennas (RDRAs) offers many appealing features such as high radiation efficiency, small size and simple structure that candidate it for several applications such as WLAN (Durlabhji, 2016). The aim of this work is to design a wide-band bandwidth of the antenna. The antenna is simulated in Computer Simulation Technology, CST. The simulation result is then compared with the performance antenna by using different parameters such as the size of rectangular and space of air gap between antenna and single plate. This comparison allows the investigation of that parameter Lan *et al.,* (2003).

Overview on Dielectric Resonator Antenna (DRA)

Dielectric resonators appeared in the 1970s in work that led to miniaturization of active and passive microwave components, such as oscillators and filters (Lai *et al.,* 2013). In a shielded environment, the resonators built with dielectric resonators can reach an unloaded Q factor of 20 000 at frequencies of 20 GHz. One of the attractive features of a DRA is that it can assume any one of several simple shapes, the most common being ones with circular or rectangular cross-sections, as shown in Fig. 1.

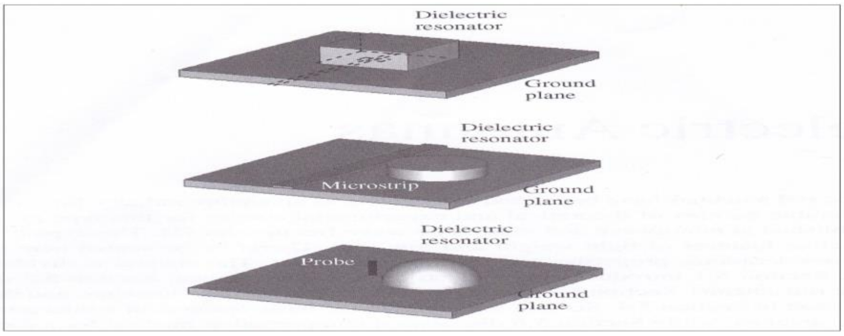


Fig1. Typical dielectric resonator antennas and feeding mechanism (Aperture feed, (b) Microstrip feed and (c) Probe feed) (Kao-Cheng, 2008)

Over the past years, DRA has been considered as an alternative to the traditional antennas. The DRA is a better choice than the conventional low-gain elements such as dipoles, monopoles and microstrip patches (Huang and Edwards, 2008).

MATERIALS AND METHODS

In this research work, the various parameters of dimensions of the antenna are varied to study about the effect of each parameter on the bandwidth of the antenna. Hence the optimum bandwidth of the antenna can be design. In order to accomplish the objective of this study, a flow chart is drawn in Fig. 2 to illustrate the procedure and the methodology taken to design the DRA in this study.

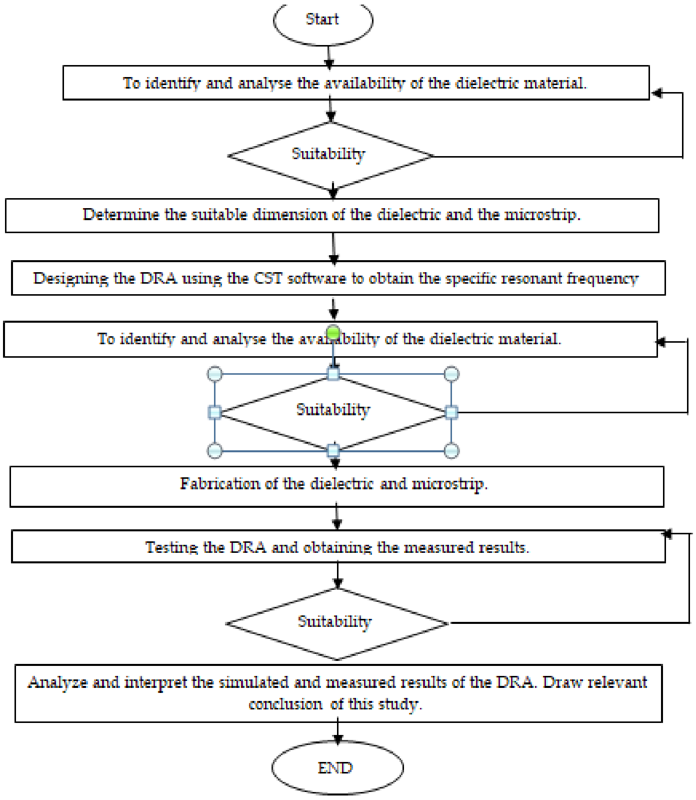


Fig.2 Methodology Flow Chart

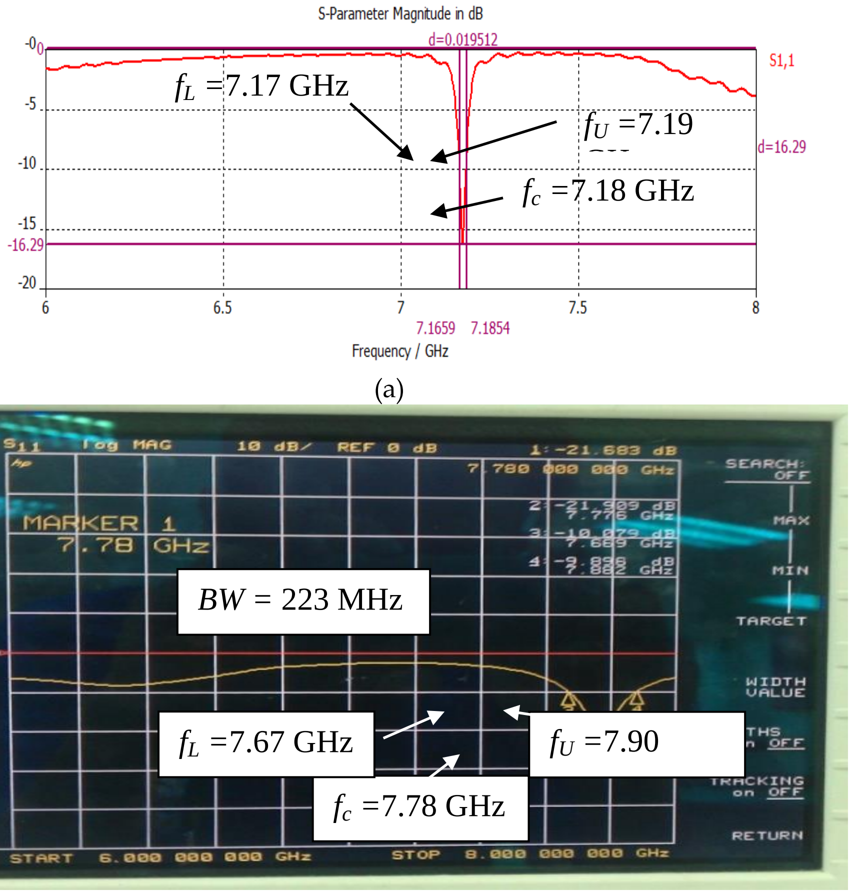
RESULTS AND DISCUSSION

A few techniques result to get a wide bandwidth antenna. Among comparison that has been made are in comparing the different effect of bandwidth with different permittivity dielectric material that is used. The other is compare the effect on bandwidth through increase the air gap between DRA and microstrip. In this study, 2 types of different dielectric material are used in order to differentiate the effect by using both materials on the enhancement of the bandwidth. Summary of the technique that is used in enhancement the bandwidth as shown in Table 1.

Table 1. Summary of the technique that are used in enhancement the bandwidth

Type of Dielectric Material	Technique Applied
Calcium Copper Titanate	Using high dielectric material By added air gap between DRA and microstrip
RT/duroid 6010LM	Using low dielectric material with vertically Stacked rectangular DRA By adding air gap between DRA and microstrip By adding air gap between each layer of RT/duroid 6010LM

The fabricated wideband rectangular DRA is measured using a Network Analysers. Fig. 3 (a) and (b) show the experimental and simulated for return loss of the design. The simulation value of resonant frequency f_c is 7.18 GHz while the experimental result show frequency 7.78 GHz. However, the bandwidth, BW is 19 MHz from simulation and 20.1 MHz from measurement. From the results above, value of resonant frequency is not same for simulation and experimental. That also goes same for bandwidth because of the permittivity of dielectric material is higher than predicted due to loss in sintering process. Fractional bandwidth for simulation is 0.26 % and 2.87 % for measurement.

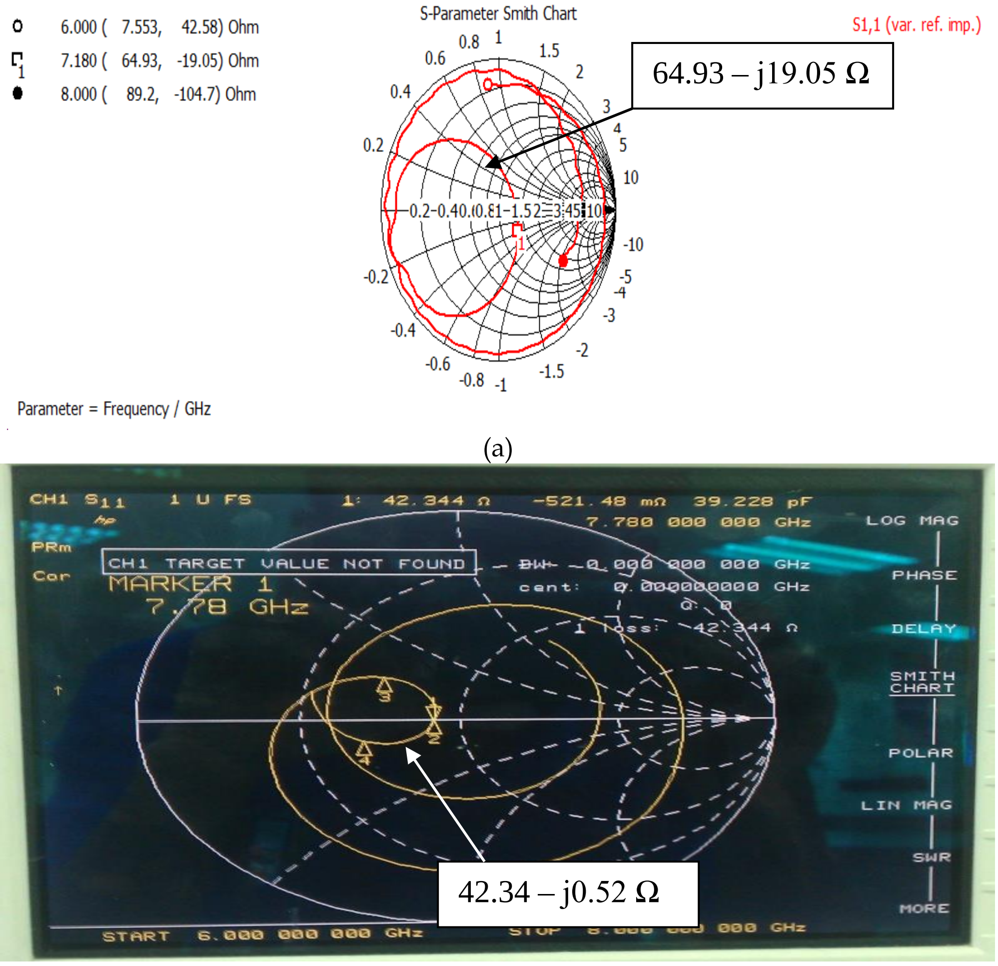


(a)

(b)

Fig.3 S_{11} Result Rectangular CCTO DRA (a) from simulation (b) from measurement

While from comparison both of S_{11} result in Fig. 3, value of return loss is slightly different between simulations and experimental. Where the return loss for the simulation is -16.29 dB and from measurement is -21.68 dB. Fig. 4 shows smith chart result from simulation and measurement. Smith chart are used to determined impedances matching of the antenna design.



(a)

(b)

Fig.4 Smith Chart Result (a) from simulation (b) from measurement

From Fig. 4, both loops are not almost close to the prime center of smith chart and revealed that at their minimum S_{11}, the resistance and reactance are not approaching 50 Ω respectively. From Fig. 4 (a) the simulation the input impedance is 64.93 – j19.05 Ω at frequency 7.18 GHz compare to experimental input impedance is 42.34-j0.52 Ω at frequency 7.78 GHz. Thus, the level of matching between the simulated and fabricated DRA show a difference because the permittivity of fabricated CCTO is not achieved as expected due to loss by sintering process. Fig. 5 shows simulation result on gain from the range of frequency 6.0 GHz to 8.00 GHz. As can be noted, at the resonant frequency of 7.18 GHz, the gain value is 4.47 dB.

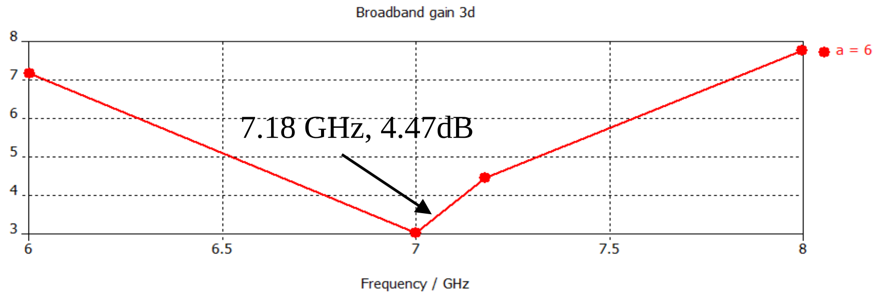
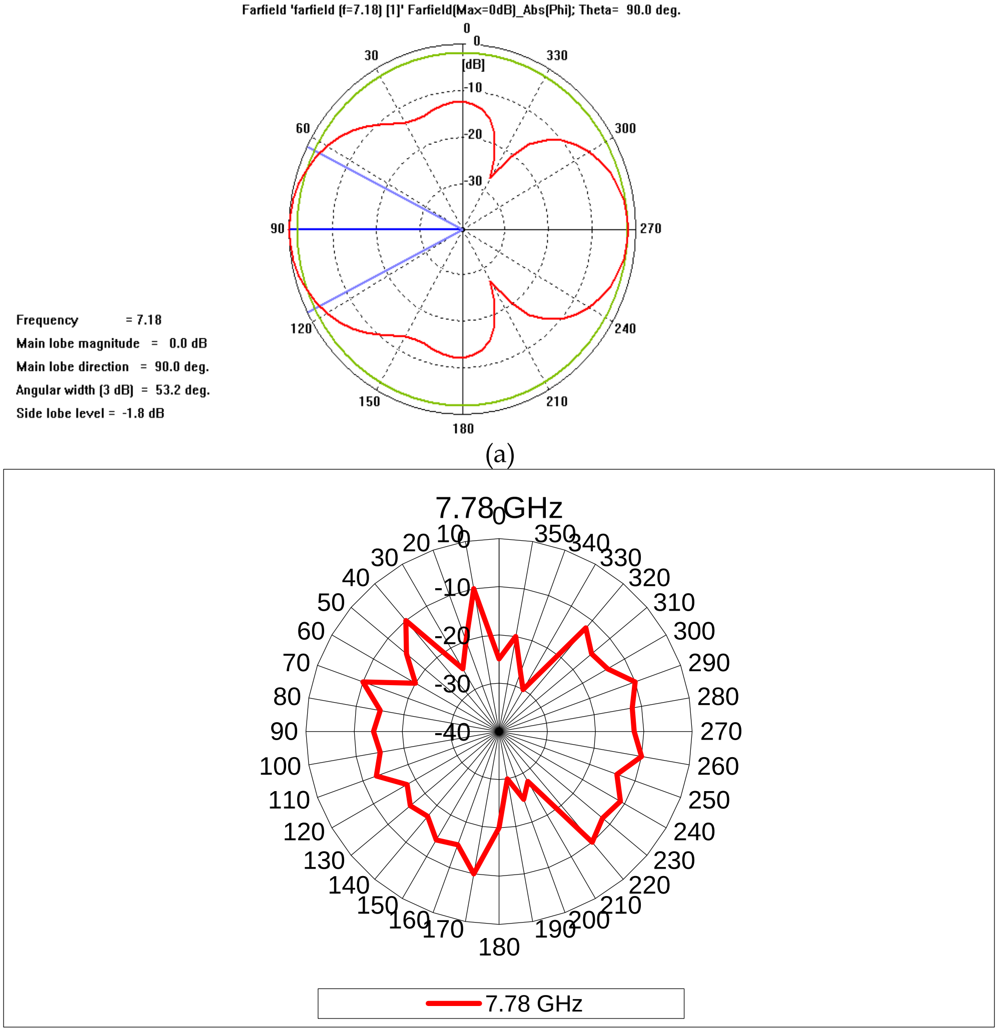


Fig. 5 Gain

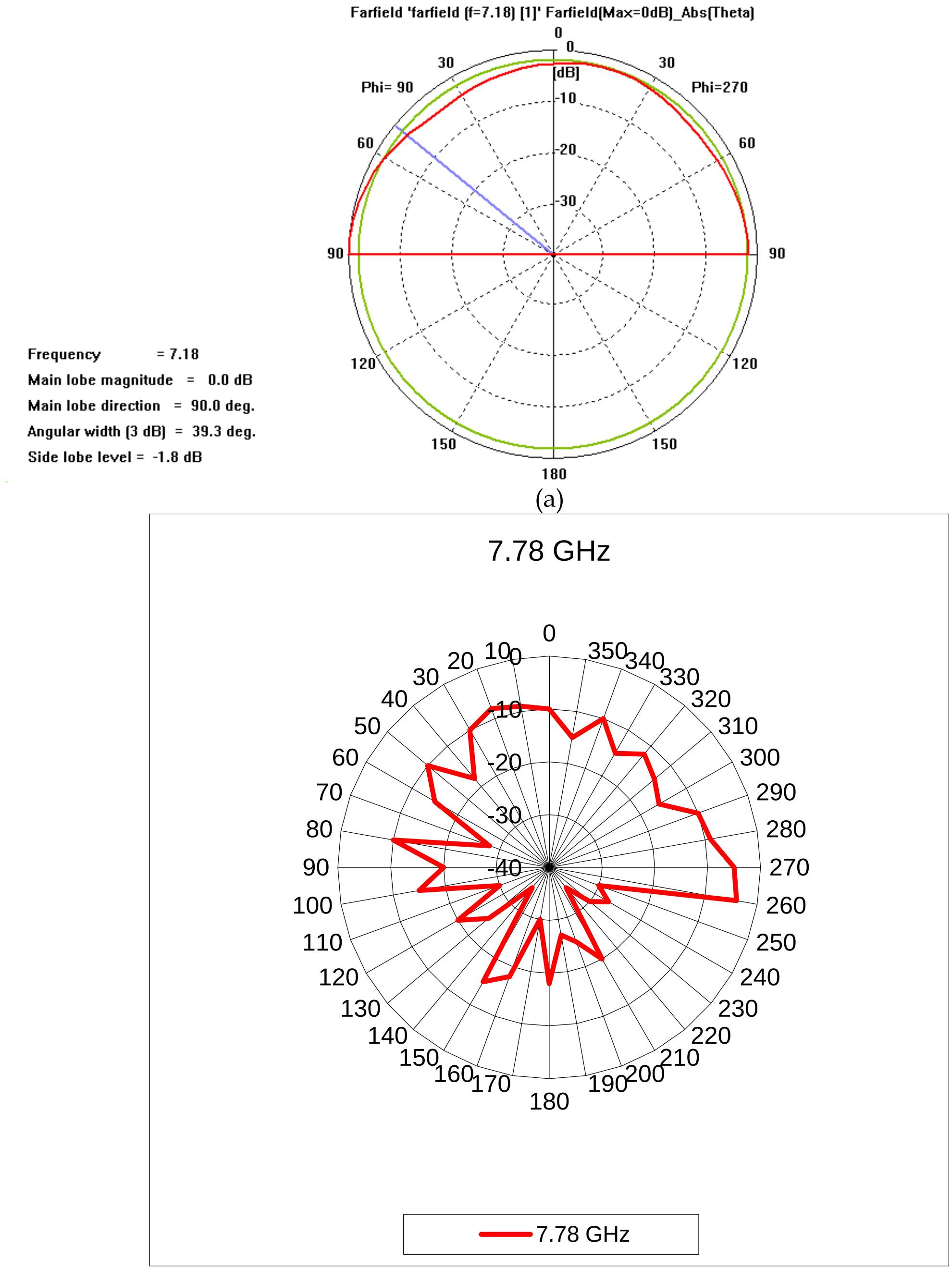
Fig. 6 and Fig. 7 shows simulated and measured E-plane and H-plane radiation pattern for rectangular CCTO DRA at their respective resonant frequency. The patterns are taken at their respective resonant frequencies for which the maximum power is the highest.



(a)

(b)

Fig.6 Radiation pattern for rectangular CCTO DRA E-Plane (a) from simulation (b) from measurement



(a)

(b)

Fig. 7 Radiation pattern for rectangular CCTO DRA H-Plane (a) from simulation (b) from measurement

From Fig. 6 (a), the pattern shows that the signal not inclined to radiate equally in whole direction since there have dip at -30° and -150° which reveals that at there is weak signal. From Figure 6 (a), the antenna can be categorized as directional antenna because the main lobe magnitude is 0.0 dB, main lobe direction 90.0°, angular width is 53.0°, and side lobe level is -1.8 dB, Measured E-plane show a difference compared with simulated pattern, however both pattern is almost same which indicates that this DRA is a type of directional antenna. From Fig. 7 (a), main lobe magnitude is 0.0 dB, main lobe direction 90.0°, angular width is 39.3°, and side lobe level is -1.8 dB.

Both measured and simulated are matched except at below part of ground plane because of the signal from surrounding objects.

Table 2. Summary on the Design of Rectangular CCTO DRA

Parameter	Simulated	Measured	% (different)
Return loss	-16.29 dB	-22.38 dB	0.38%
Resonant Frequency	7.18 GHz	7.78 GHz	8.36%
Bandwidth	19 MHz	223 MHz	91.48%
Fractional Bandwidth	0.26 %	2.87%	90.94%
Gain	2.88 dB	Not available	Not available

Table 2 summarizes the result simulated and measured in terms of input impedance, s-parameter, pattern of radiation, gain and beam width. Therefore, the comparisons between all the findings have been specified. The return loss characteristics indicate the resonant frequency and impedance bandwidth are also closely matched, with the resonant frequency predicted within 5 % and usually much closer than that. In general, simulated field patterns are predicted with very close agreement to the experimental results. The results of this field pattern comparison, although in general was not equivalent but the pattern can be clearly seen.

CONCLUSION

In this paper, a compact rectangular DRA has been designed for 7.18 .4 GHz operation with a simple microstrip line feeding mechanism. This design makes use of different with permittivity dielectric material. From the simulation result, it clearly shows that by using high permittivity dielectric material, the bandwidth produced is 20 MHz. The high permittivity dielectric material used is Calcium Copper Titanate (CCTO) that has 57 permittivity. To increase the bandwidth, investigation by adding air gap between DRA and microstrip is done. The result shows 1.45% or 100MHz of bandwidth around the centre frequency is produced instead of 0.26% or 20MHz. the resulting antenna meets typical requirements for wireless applications at this band

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

ACKNOWLEDGEMENT

This work was supported by Tetfund (TETF/ES/UNIV/KEBBI/ASTD/2008.

REFERENCES

Durlabhji, M. G. (2016). Bandwidth Considerations in Miniaturized Rectangular Dielectric Resonator Antennas: Experimental Validation (Doctoral dissertation, Dhirubhai *Ambani Institute of Information and Communication Technology*).

Huang, K. C., and Edwards, D. J. (2008). Millimetre wave antennas for gigabit wireless communications: a practical guide to design and analysis in a system context. John Wiley & Sons.

Junker, G.P., Kishk, A. A., and GLISSON, A.W. (1996). Input Impedances of Aperture coupled dielectric resonator antenna. *IEEE Tran. on Antennas Pmpagat*, 44, pp.60&67.

Junker, G.P., Kishk, A.A., Glisson, A.W. and Kaifez, D. (1994). Effect of air gap on cylindrical dielectric resonator antenna operating in TM01 mode. Electronic Letters, Vol.30, No 2.

Mongia, R. K., Bhartia, P. July 1994.Dielectric resonator antennas - A review and general design relations for resonant frequency and bandwidth. *International Journal of Microwave Millimeter-Wave Engineering,* vol. 4, pp. 230-247.

Mongia, K., Ittipiboon, A. September 1997. Theoretical and experimental investigations on rectangular dielectric resonator antennas. *IEEE Transactions on Antennas and Propagation,* vol. 45, no. 9, pp.1348-1356.

Lan, K. Chaudhuri, S.K., Safavi-Naeini, S., June 2003. A compact wide-dual-band antenna for Bluetooth and wireless LAN applications. *IEEE Antennas and Propagation Society International Symposium*, vol. 2, pp. 926-929.

Long, S.A., McAllister, M.W., Shen L.C., May 1983.The resonant cylindrical dielectric cavity antenna. *IEEE Transaction on Antennas and Propagation*, vol. 31, no. 3, pp.406-412.

Lim, E. H., & Leung, K. W. (2012). *Compact multifunctional antennas for wireless systems* (Vol. 215). John Wiley & Sons.
Yeh, J. H., Chen, J. C., & Lee, C. C. (2003). WLAN standards. *IEEE Potentials*, *22*(4), pp.16-22..

O'Keefe, S.G., Kingsley, S.P., Saario, S. February 2002. FDTD simulation of radiation characteristics of half-volume HEM and TE-mode dielectric resonator antennas. *IEEE Transaction on Antennas and Propagations*, vol. 50, no. 2, pp. 175-179.

Petosa, A., Ittipiboon, A., Antar, Y. M. M. and Roscoe, D. June 1998.Recent advances in dielectric resonator antenna technology. *IEEE Antennas and Propagation Magazine*, Vol. 40, No. 3, pp.35‑48.