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Circularly Polarized Antenna System for the Quality Evaluation Application of Apple Fruit

Angeline M. Flashy and G.P. Ramesh

Abstract--- *This paper presents the Omnidirectional Circularly Polarized Antenna for the quality assessment applications of Apple samples. The Compact rectangular 2x2 antenna array is designed with a Band pass filter for the triple-band microwave sensing at 2.4/3.5/5.8 GHz. The Micro strip Antenna senses the spectrum of the signal produced from the apple sample for quality evaluation. The antenna comprises back-to-back micro strip patches fed by a 50 ohm impedance matching. A frequency ratio for the antenna design is achieved greater than 3 dB, which can be tuned for triple frequencies. An analysis of omnidirectional circular polarization mechanism, Gain, Directivity, Efficiency and Radiated Power Vs Frequency, Radiation Intensity Vs Magnitude of micro strip patch antenna as well the triple-band operation is achieved with numerical and experimental data. The proposed Omnidirectional Circularly Polarized antenna provides 15 dB for triple frequency bands.*

Keywords--- *Omnidirectional, Circular Polarization Mechanism, Gain, Directivity, Efficiency, Radiated Power, Radiation Intensity, Triple Band.*

I. INTRODUCTION

A linear polarization axial ratio derives the antenna is linearly polarized. It equals to one when perfect linear polarization is observed and becomes infinite for a Circularly Polarized (CP) antennas [1, 2]. The Circularly Polarized antennas gained much attention due to their improved immunity to multipath distortion and polarization mismatch losses including those caused by Faraday rotation. These properties are desirable for communications, WLAN and RFID systems.

However the number of compact Circularly Polarised antennas with omnidirectional radiation patterns is still very small [3-5]. In satellite communication, the radiated beam from the antenna is to be directed towards the sky, the orientation of the Circularly Polarised antenna cannot be determined for many applications in prior, making omnidirectional antennas desirable. Moreover, many modern systems require multi band operation with relatively low frequency ratios, which introduces additional complexity to the design. The first approach to provide omnidirectional CP (for single frequency) involved an array of radiating elements, located around a common centre [6,7].

The reported work introducing omnidirectional Circularly Polarised Antenna behavior using planar structures is analysed. The first one employs epsilon negative material and its zeroth order resonance to replace a mushroom in by a completely planar structure [8,9]. The Circularly Polarised Antenna exhibits good omnidirectional axial ratio (AR) with the use of several combined elements as antenna array and the zeroth order resonance makes it difficult to access and modify the antenna for dual band operation. The Circularly Polarised Antenna is analysed around 6 dB

Angeline M. Flashy, Research Scholar, St.Peter's Institute of Higher Education and Research, Chennai, India. E-mail: angelineflashy@gmail.com
G.P. Ramesh, Professor, St.Peter's Institute of Higher Education and Research, Chennai, India. E-mail: rameshgp@yahoo.com

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variation in the CP radiation pattern and the gain value is not determined as to the desired value. Many techniques have been proposed to implement dual frequency patch antennas for unidirectional CP, including stacked patches, dual-negative materials, slots cut in the patch or complex annual-ring structures. From the above-mentioned Circularly Polarised Antenna patch structures, the slot loaded with Circularly Polarised rectangular patch was chosen for our design due to its simplicity and relative compactness (compared to the stacked patch). Slots can be used to perturb the current distribution[10], shifting the higher modes down in frequency and modifying their radiation pattern to be broadside. As typical CP patch antennas employ two orthogonal modes, a total of four slots would be required using this technique.

Fruit nutrition is the important part of human diet; therefore it is necessary to evaluate and determine its quality. The analysis and grading of fruit quality is also a critical task in the commercial market. With the existing growing need for low production costs with high efficiency, the agricultural industry has to overcome number of challenges, including maintenance of high-quality standards and assurance of food safety while avoiding liability issues. Grading food products for different markets has become crucial to meet the challenges. Microstrip patch sensors have become useful and widely used in agricultures, industrials, food products, telemedicine fields. It has been more useful for apple fruit quality assessment. In agricultural industry there is a need to effectively grow a plant and increases its yield is very important task.

Apple fruit is taken as sample for quality assessment using Compact rectangular 2x2 antenna array[15]. It is designed with inverted C Shape for the triple band microwave sensing at 2.4/3.5/5.8 GHz, the LPF and HPF are cascaded to develop a Band pass filter (BPF), for passing frequencies 2.4/3.5/5.8 GHz and analyzed. The proposed antenna parameters are fabricated and analysed using Vector Network Analyser results in cost effectiveness.

II. GRADING OF APPLE FRUIT

A better electrical characterization of the dielectric properties of fruits is required for this purpose. Different Apple samples were graded such as Fresh Apple, Apple Scab, Apple blotch and Apple rot, Wax Coated Apple at different positions was investigated from 2.2 GHz to 7 GHz using MATLAB is shown in Table 1.

Table 1: Grading of Apple Samples

S.No.	Samples	Description
1.	Fresh Apple	A fresh, high-quality apple should have a pleasant aroma.
2.	Apple scab	Gray or brown corky spots are present on the surface of apple
3.	Apple blotch	The surface of fruit having fungal disease
4.	Apple rot	spore-bearing structures appear in concentric circles on the diseased apple surface
5.	Wax Coated Apple	Apples are coated with wax to look more appealing

III. ANTENNA DESIGN AND GEOMETRY

The Compact antenna can be designed by introducing inverted C-shape slot on the rectangular patch antenna with corresponding length and width. The Geometry layout of proposed antenna is shown in Fig. 1. Based on this designing parameter the antenna can satisfy the IOT Applications.

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3.1. Dimensions and Geometry of Single and 2x2 Rectangular Antenna Array

The Single rectangular antenna and 2x2 antenna array is designed with FR-4 substrate of dielectric constant 4.4. The dimensions for the proposed single antenna and antenna array are given in Table 2.

Table 2: Dimensions of the Rectangular Antenna

Parameters		Dimensions (mm)
Rectangular Patch	Length (L_1)	8.9
	Width (W_1)	13
Inverted C-Shaped Patch	Length (L_2)	6
	Width (W_2)	10
Slot	Length (L_3)	1.4
	Width (W_3)	1
Feed Line	Length (L_f)	1.8
	Width (W_f)	1

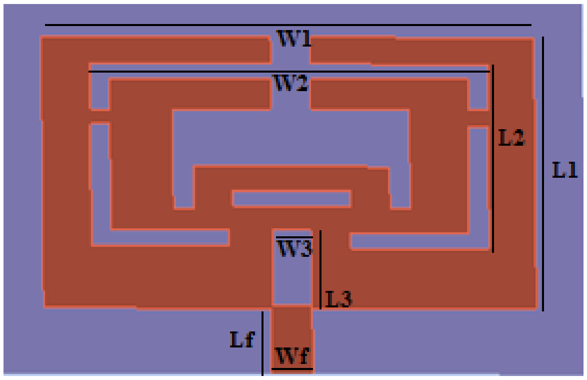

Fig. 1: Geometry for the Antenna

3.2. Prototype Design of Single Antenna

The Layout of the antenna structure is designed based on the Microstrip line feed is shown in Fig.2.

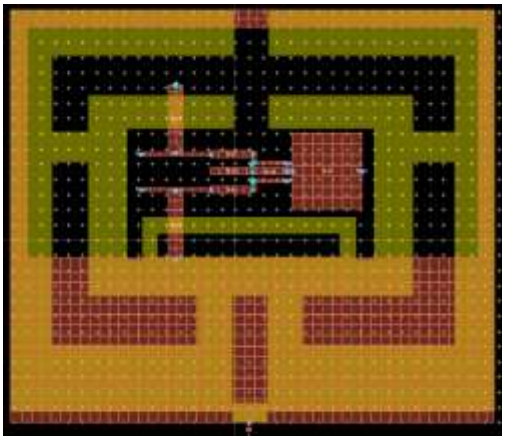

Fig. 2: Layout Design of Single Antenna

The purpose of the Microstrip line feed in the patch is to match the impedance between the patch and the feed line without the need of any additional matching element. This is done by properly controlling the position of the feed. The main advantage of this feed method is that it is simple for modelling and impedance matching. The

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bandwidth range of this feeding technique is between 2-5% The Layout design and fabrication model of the Single band antenna and is shown in Fig.3.

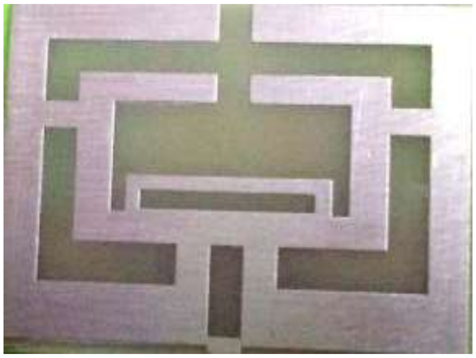

Fig. 3: Fabricated Single Antenna

Probably microstrip antenna is the type of patch antenna. The antenna patches has constitutive elements in the array are also possible. The Circularly Polarised patch antenna is analysed as narrowband with wide-beam, it is fabricated by etching an antenna element in metal trace bonded to the insulating dielectric substrate, such as the PCB Boards with a continuous metal element which bonded with the opposite side of the substrate, which forms a ground plane. Familiar microstrip antenna shapes are square, rectangular, circular and elliptical, but any continuous way is possible.

In Circularly Polarised patch antennas, the dielectric substrate is not used, instead it is made up of a metal patch which is bounded above a ground plane using the dielectric spacer the resulting structure, which is less toughened with broader bandwidth.

3.3. Return loss (S11) of Rectangular Microstrip Patch Antenna

The simulation and measurement plot of return loss S_{11} of single antenna is -19.551 dB resonates at 3.5 GHz and -20.241 dB resonates at 5.8 GHz is shown in Fig.4.

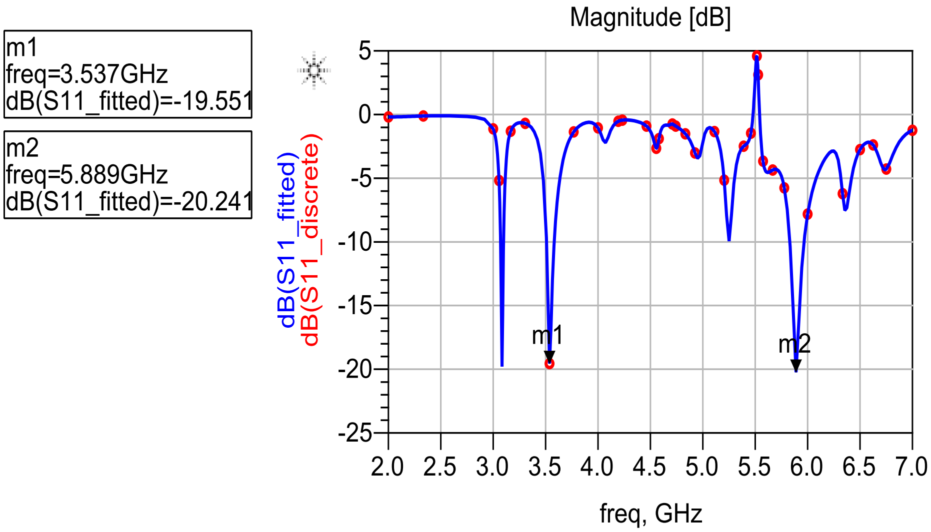

Fig. 4: Return Loss of Rectangular Microstrip Patch Antenna

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3.4. Gain, Directivity and Efficiency Vs Frequency of Rectangular Microstrip Patch Antenna

The simulation and measurement plot of Gain single antenna is 4 dB resonates at 3.5 GHz and 6.5 dB resonates at 5.8 GHz is shown in Fig.5.

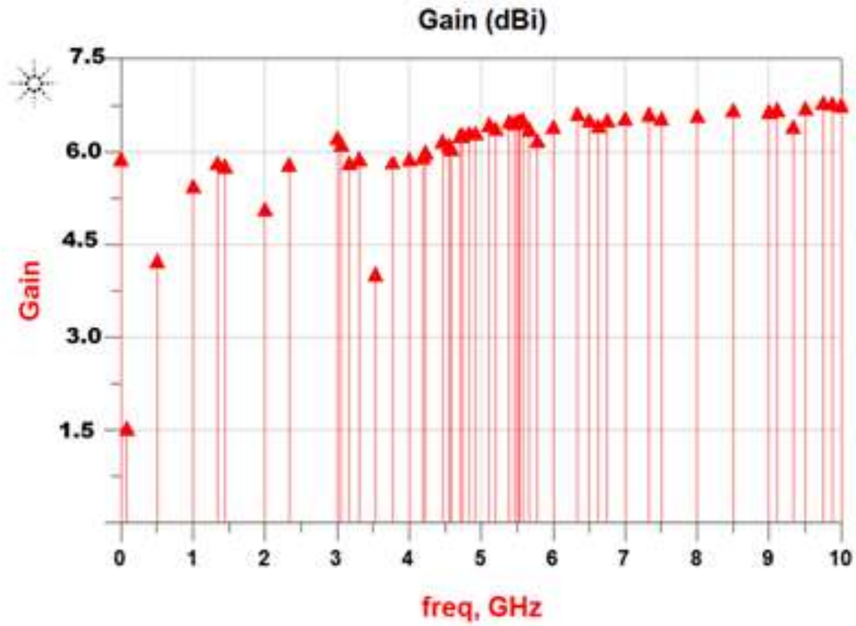

Fig. 5: Gain Vs Frequency of Rectangular Microstrip Patch Antenna

The radiation intensity corresponding to the isotropically radiated power is equal to the power from the generator, to the antenna is divided by 4π. The directivity of the antenna is 6dB resonates at 3.5 GHz and 9 dB resonates at 5.8 GHz is shown The Directivity Vs Frequency plot is shown in Fig.6 and the Efficiency of the antenna is 100%. The Efficiency Vs Frequency plot is shown in Fig.7.

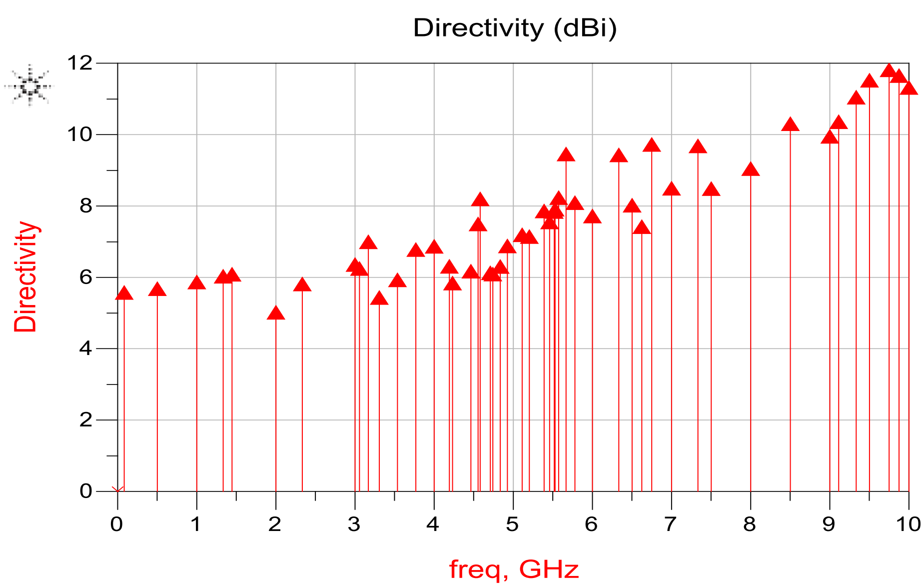

Fig. 6: Directivity Vs Frequency of Rectangular Microstrip Patch Antenna

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Fig. 7: Efficiency Vs Frequency of Rectangular Microstrip Patch Antenna

3.5. Radiated Power Vs Frequency of Rectangular Microstrip Patch Antenna

The total power radiated by the antenna, in Watts versus frequency plot, the power radiated from the antenna is 0.0009 dB resonates at 3.5 GHz and 0.0004 dB resonates at 5.8 GHz is shown is represented and shown in Fig.8.

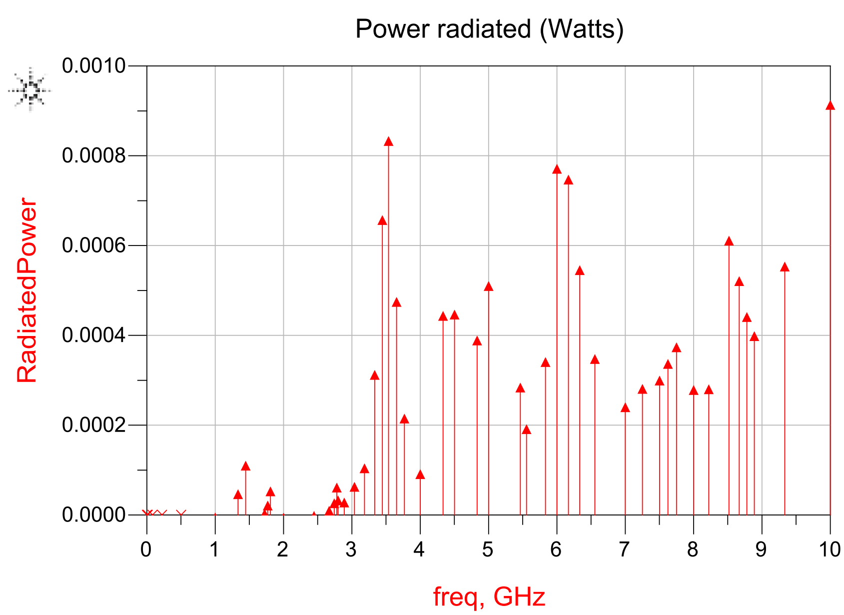

Fig. 8: Radiated Power Vs Frequency of Microstrip Patch Antenna

3.6. Voltage Standing Wave Ratio of Rectangular Microstrip Patch Antenna

When a transmission line is not matched to its load, some of the energy is absorbed by the load and some is reflected back down the line towards the source. The VSWR of the antenna is less than 1. The VSWR versus frequency plot is represented and shown in Fig.9.

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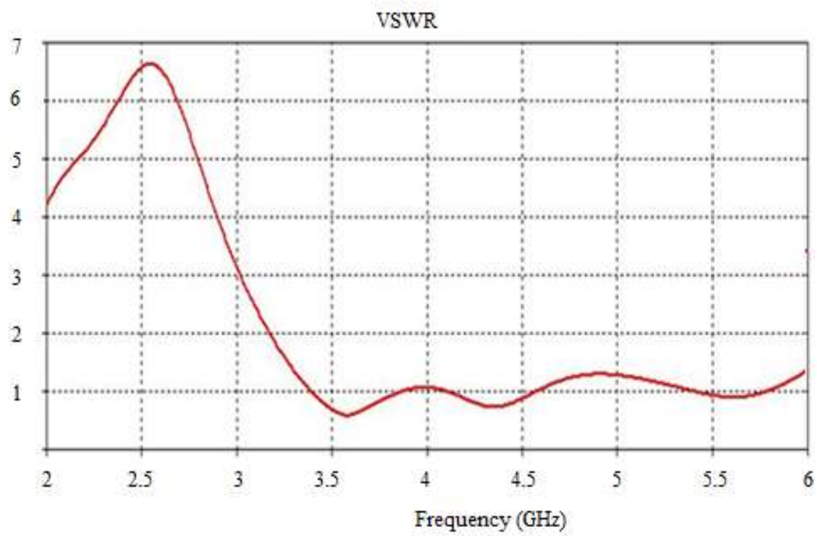

Fig. 9: VSWR Vs Frequency of Microstrip Patch Antenna

3.7. Linear and Circular Polarization of Rectangular Patch antenna

A linear polarization axial ratio (AR $_{lp}$) can be derives that the antenna is linearly polarized. The left hand and right hand circular polarized field components are shown in Fig.10 & Fig.11. The circular polarization axial ratio (AR $_{cp}$) can be calculated using the axial ratio, when the antenna is circular polarized. If its amplitude equals one, the fields are perfectly circularly polarized. It becomes infinite when the fields are linearly polarized. Hence the Rectangular Patch antenna is circularly polarized as 10.8dB.

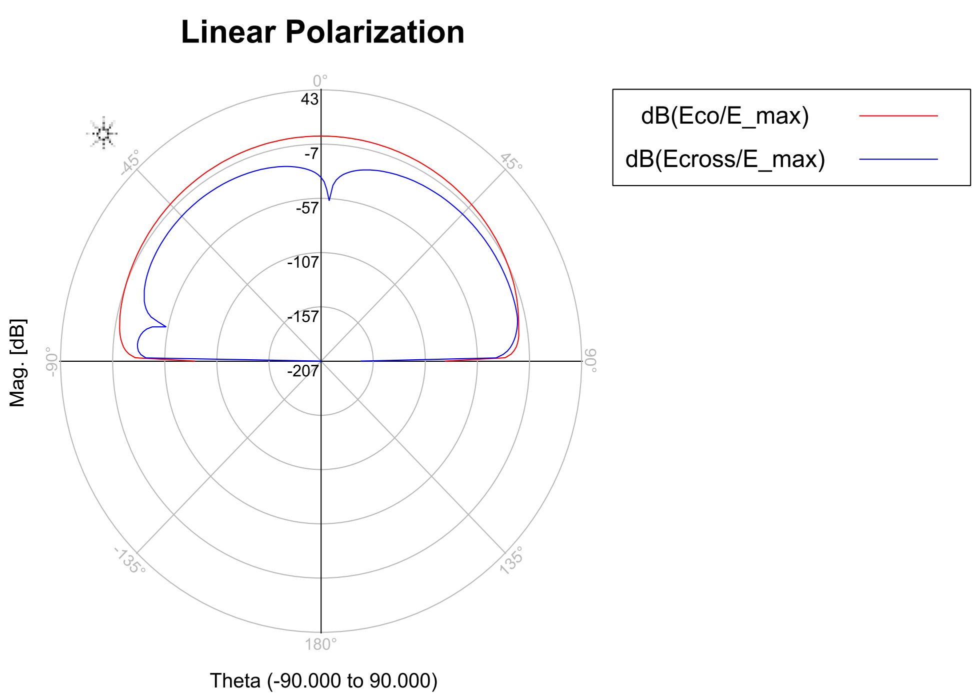

Fig. 10: Linear Polarization of Rectangular Patch Antenna

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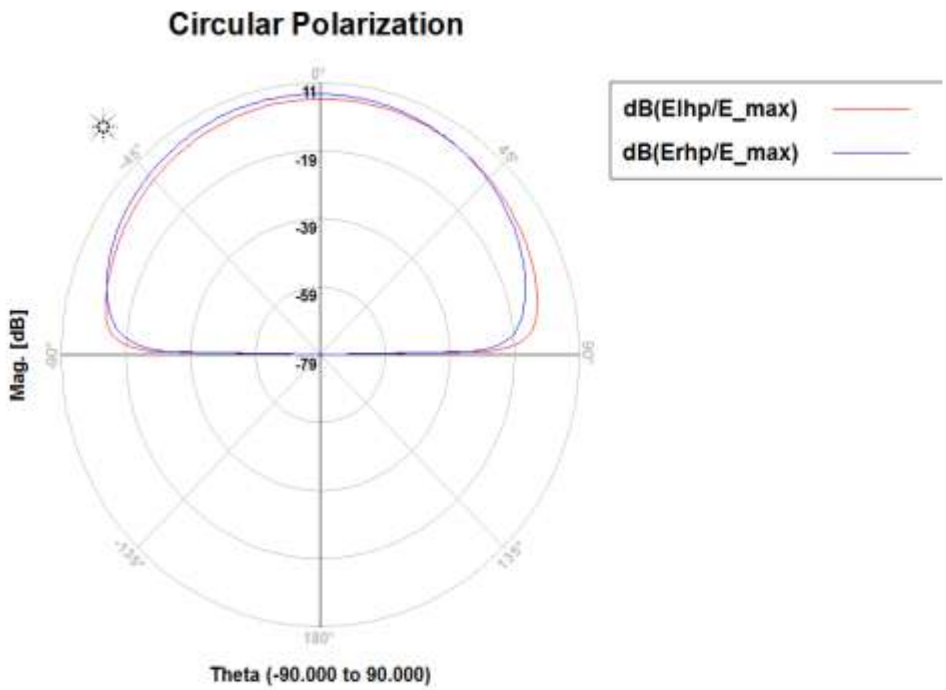

Fig. 11: Circular Polarization of Rectangular Patch Antenna

IV. SIMULATION AND MEASUREMENT RESULTS

4.1. Prototype Design of Single Antenna

The Layout of the Dual antenna array is designed based on the Microstrip line feed is shown in Fig.12 and Fig.13.

The purpose of the Microstrip line feed in the patch is to match the impedance between the patch and the feed line without the need of any additional matching element. This is done by properly controlling the position of the feed. The bandwidth range of this feeding technique is between 2-5% .

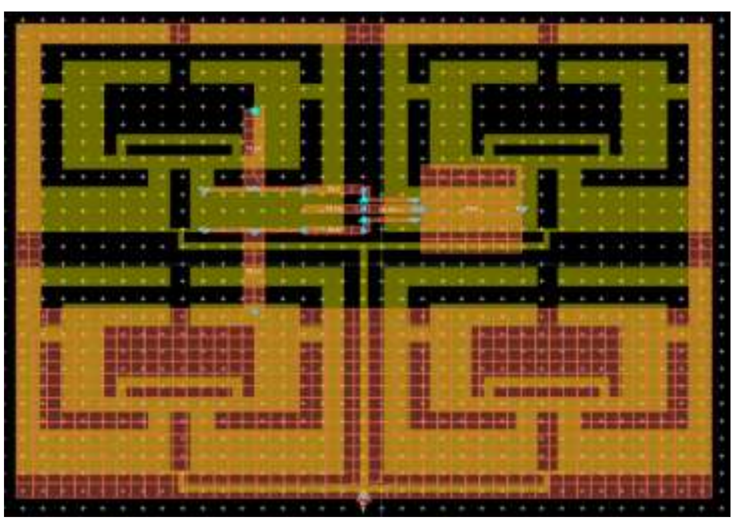

Fig. 12: Layout Design of Antenna Array

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The antenna patches has constitutive elements in the array are also possible. such as the PCB Boards with a continuous metal element which bonded with the opposite side of the substrate, which forms a ground plane.

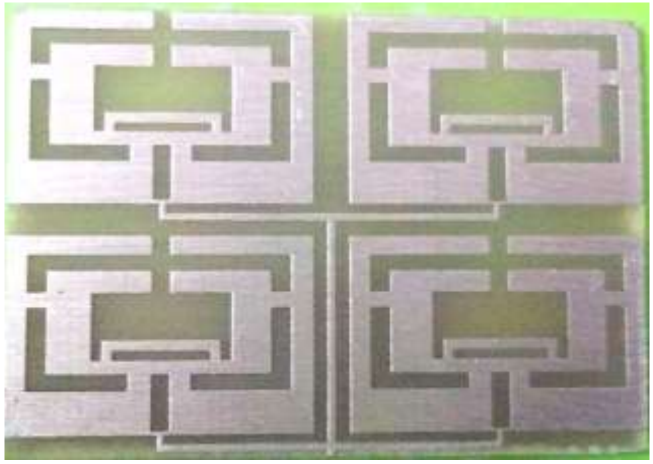

Fig. 13: Fabricated Antenna Array

Some patch antenna array do not use a dielectric substrate and instead made up of a metal patch bounded above a ground plane using the dielectric spacer to obtain broader bandwidth.

4.2. Return loss (S11) of Rectangular Microstrip Patch Antenna Array

The simulated and Measured plot of S_{11} of the antenna array is -11.850 dB at 2.4 GHz, -12.186 dB at 3.39 GHz and -20.050 at 5.8 GHz as shown in Fig.14.

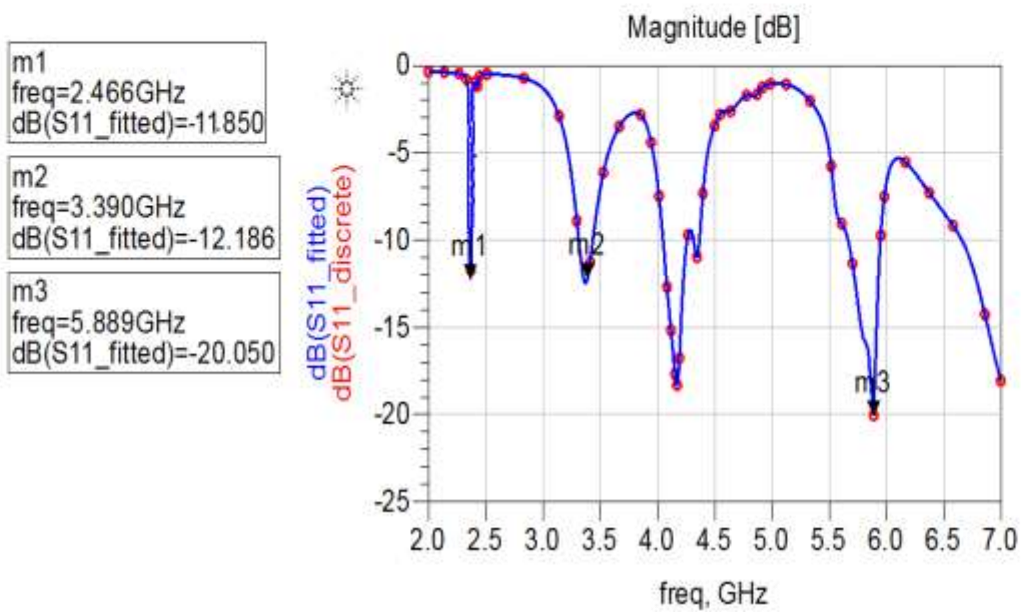

Fig. 14: Simulated Return Loss S11 of Antenna Array

The narrow bandwidth required by IoT applications are obtained. The Current flow distribution of antenna array is obtained as desired bandwidth.

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4.3. Gain, Directivity and Efficiency Vs Frequency of Rectangular Microstrip Patch Antenna Array

The simulation and measurement plot of Gain of rectangular microstrip patch antenna array is 5 dB resonates at 2.4 dB, 7 dB resonates at 3.5 GHz and 9 dB resonates at 5.8 GHz is shown in Fig.15..

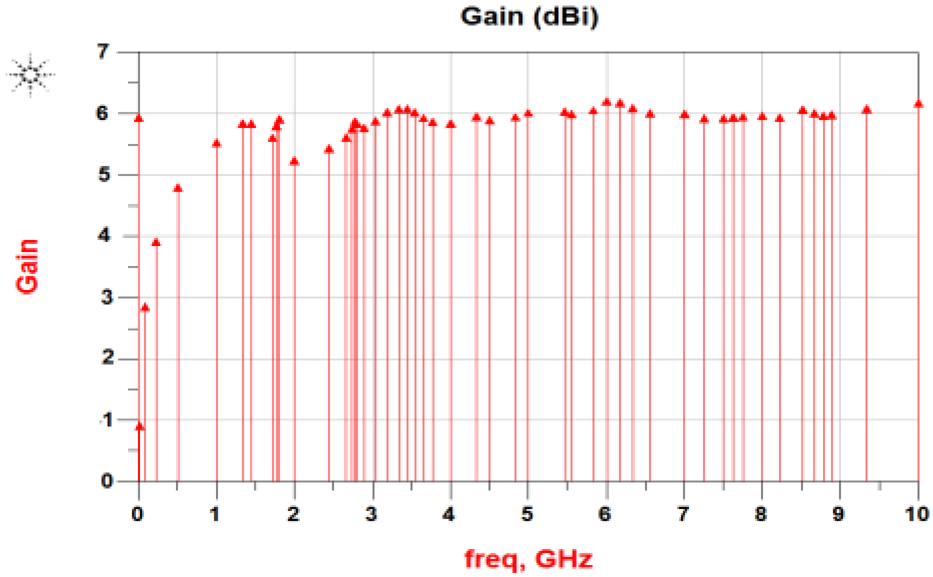

Fig. 15: Gain Vs Frequency of Rectangular Microstrip Patch Antenna Array

The radiation intensity corresponding to the isotropically radiated power is equal to the power from the generator, to the antenna divided by 4π. The Directivity of the array antenna is 6 dB resonates at 2.4 dB, 5.9 dB resonates at 3.5 GHz and 8.2 dB resonates at 5.8 GHz and the Efficiency of the antenna array is 100%. The Directivity Vs Frequency plot is shown in Fig.16 and The Efficiency Vs Frequency plot is shown in Fig.17.

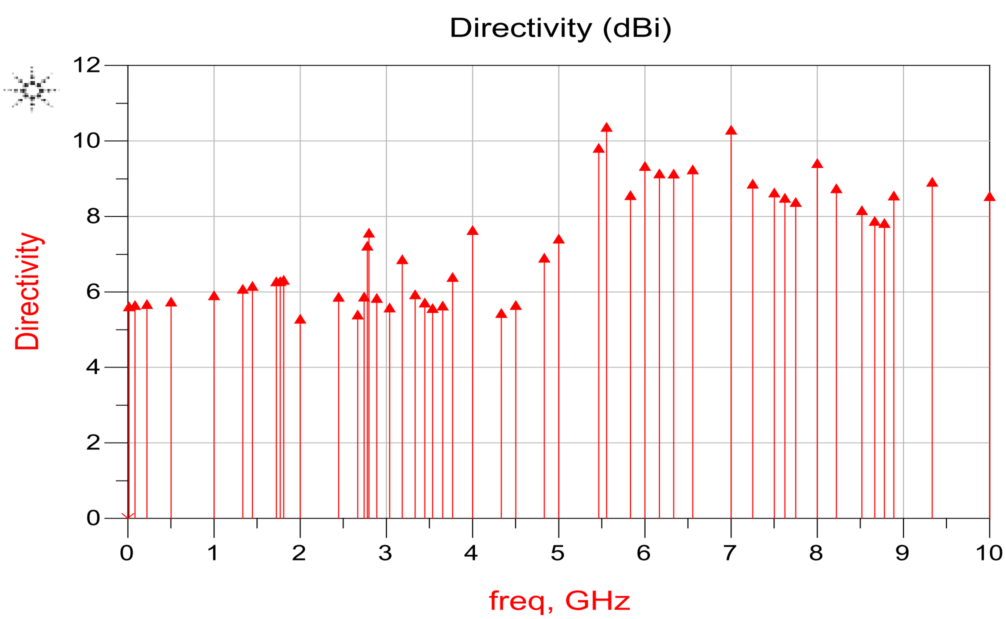

Fig. 16: Directivity Vs Frequency of Rectangular Microstrip Patch Antenna Array

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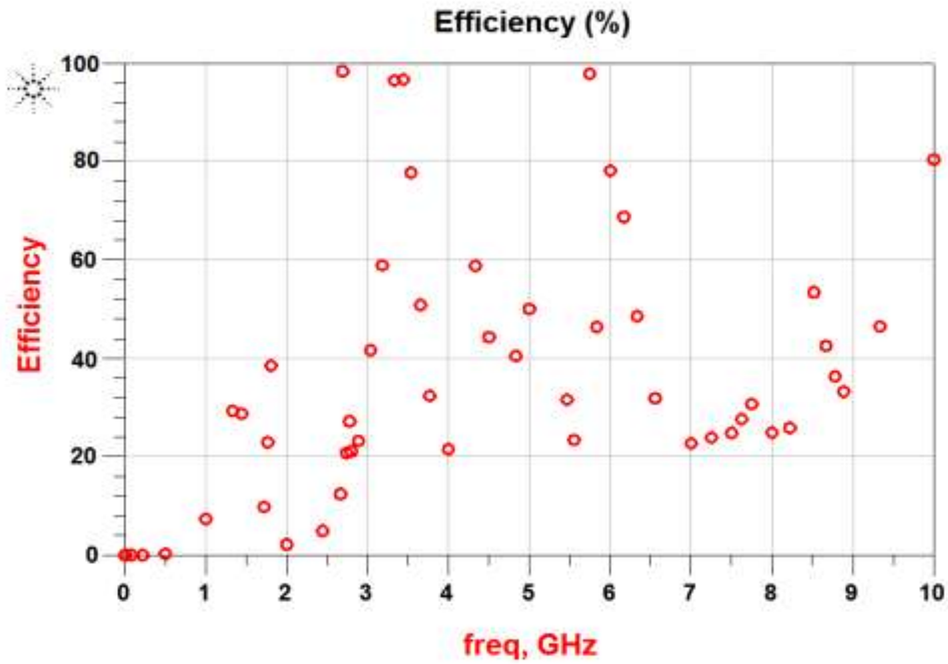

Fig. 17: Efficiency Vs Frequency of Rectangular Microstrip Patch Antenna Array

4.4. Radiated Power Vs Frequency of Rectangular Microstrip Patch Antenna Array

The total power radiated by the antenna, in Watts versus frequency plot, is represented and shown in Fig.18. The power radiated parameter of the array antenna is received as 0.00035W at 2.4 dB, 0.0008W at 3.5 GHz and 0.00034W resonates at 5.8 GHz

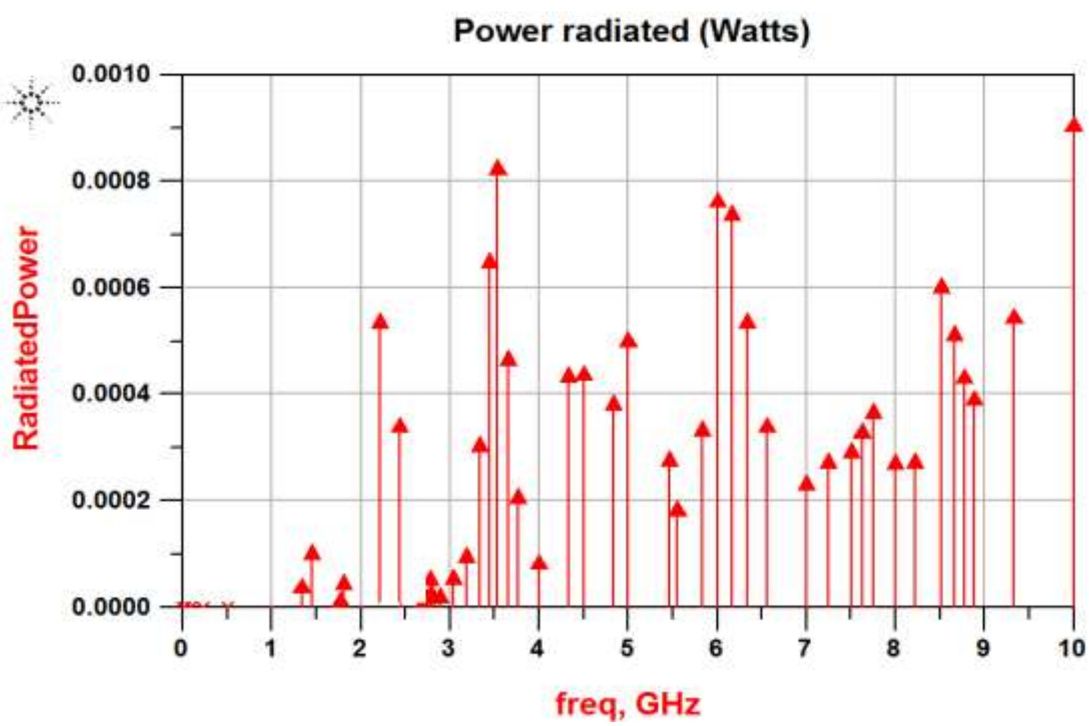

Fig. 18: Radiated Power Vs Frequency of Microstrip Patch Antenna Array

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4.5. Voltage Standing Wave Ratio Vs Frequency of Rectangular Microstrip Patch Antenna Array

When a transmission line is not matched to its load, some of the energy is absorbed by the load and some is reflected back down the line towards the source. The VSWR of the antenna array is obtained as lesser than 1. The VSWR versus frequency plot, is represented and shown in Fig.19.

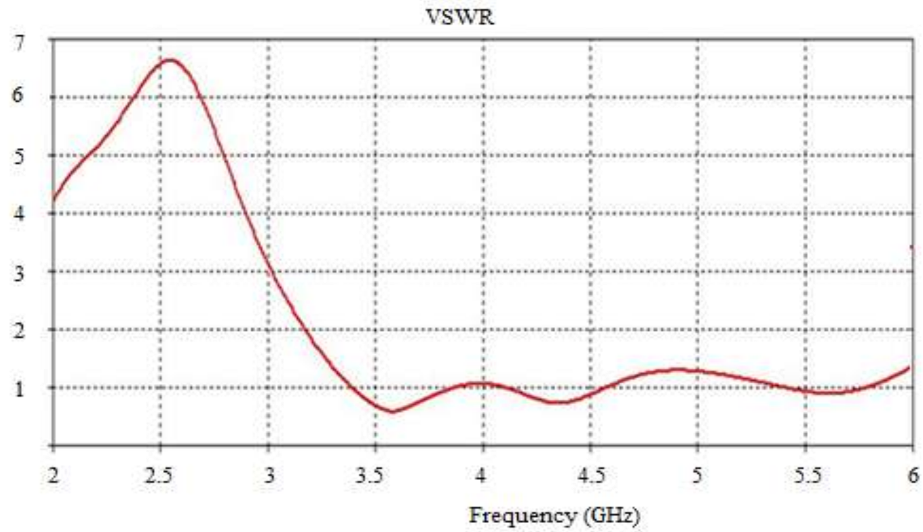

Fig. 19: VSWR Vs Frequency of Microstrip Patch Antenna Array

4.6. Linear and Circular Polarization of Rectangular Patch Antenna Array

A linear polarization axial ratio (AR $_{lp}$) can be derives the antenna is linearly polarized. The left hand and right hand circular polarized field components are shown in Fig.20 & Fig.21. Thus the antenna array is Circularly Polarised as 15dB in Omni directional radiation pattern.

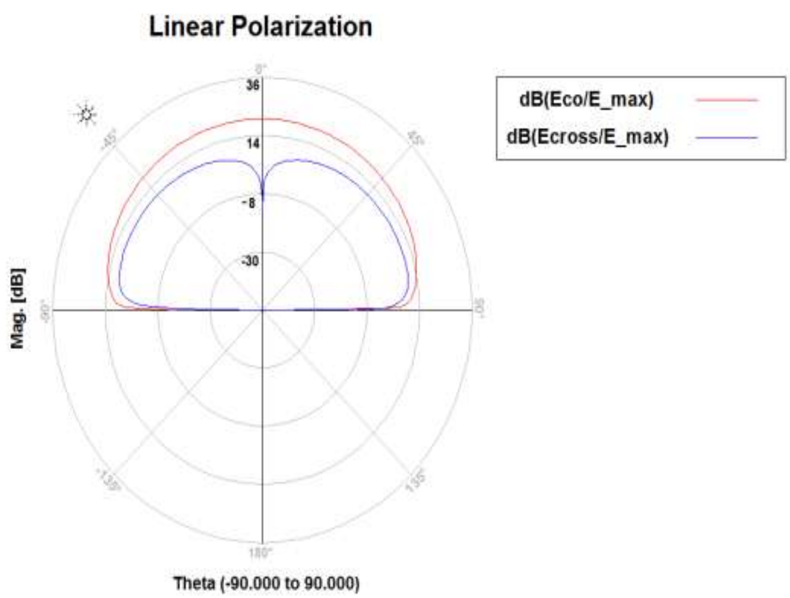

Fig. 20: Linear Polarization of Rectangular Patch Antenna Array

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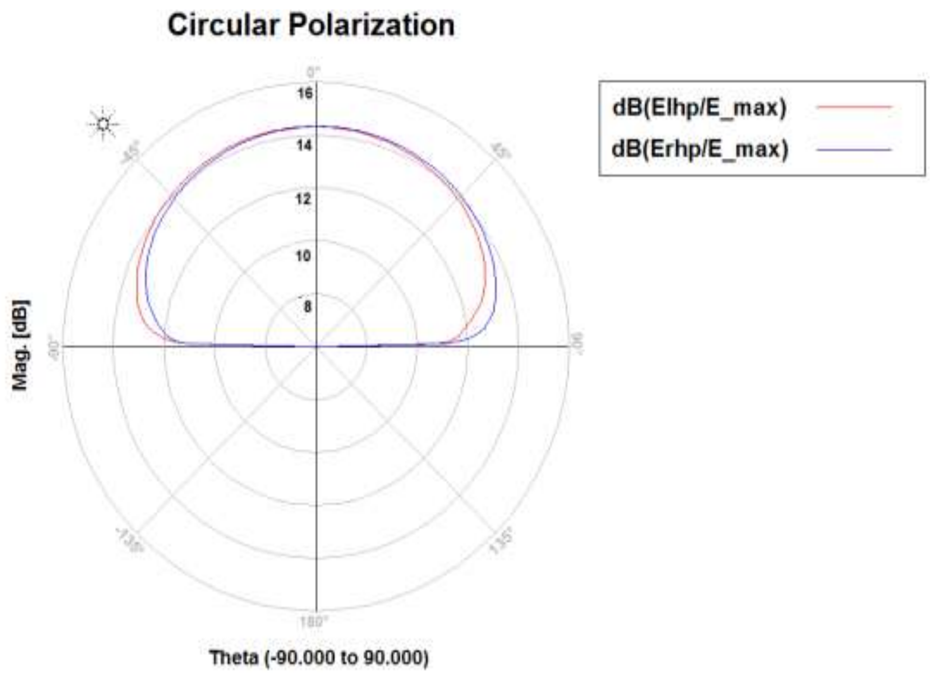

Fig. 21: Circular Polarization of Rectangular Patch Antenna Array

V. Conclusion

The Omnidirectional Circularly Polarized Antenna for the quality assessment applications of Apple samples is proposed. The Compact rectangular 2x2 antenna array is designed with a Band pass filter for the triple-band microwave sensing at 2.4/3.5/5.8 GHz is analysed. A back-to-back Microstrip patch antenna was shown to provide omnidirectional circular polarization over triple frequency bands. A novel circular polarization patch antenna is proposed in this paper. The result shows that the rectangular patch antenna array is greater than 3dB relative axial ratio bandwidth is up to 100% efficiency within 2-7 GHz frequency band. The structure of the radiation pattern of the antenna array is circularly Polarised antenna array and it has better quality based on the former research. The proposed antenna meets the needs of the current technologies such as antenna sensors, antenna miniaturization developments. Its excellent characteristics are worth us to study and explore.

References

[1] H. Abdelrahman, A. Z. Elsherbeni, F. Yang, "Transmitarray antenna design using cross slot elements with no dielectric substrate", *IEEE Antennas Wireless Propag. Lett.*, vol. 13, pp. 177-180, 2014.

[2] R. H. Phillion, M. Okoniewski, "Lenses for circular polarization using planar arrays of rotated passive elements", *IEEE Trans. Antennas Propag*., vol. 59, no. 4, pp. 1217-1227, Apr. 2011.

[3] S. Lin-Ping; H. Trigui, S. Dean, Y. Bing, "Low profile multibeam dual polarization antenna array with compensated mutual coupling," *IEEE Antennas and Propagation Society International Symposium (APSURSI),* pp. 1,2, 8-14 July 2012.

[4] Angeline M. Flashy and Ramesh, G.P."Design of Compact Reconfigurable Miniaturized Triple-band filtenna for IoT Applications", *Indian Journal of Forensic Medicine and Toxicology,* vol. 11, no. 2, pp. 39-45 2017.

[5] A. Balanis, "Antenna Theory" *Analysis and Design 3rd edition, John Wiley & Sons*, Inc., 2005.

[6] K.Y.You, J.salleh, Z.Abbas, L.L.You " A rectangular patch antenna technique for the determination of moisture content soil" *PIERS proceedings, Cambridge,* USA, pp 850-854, 5-8 July 2015.

DOI: 10.37200/IJPR/V24I5/PR201700
Received: 07 Feb 2020 | Revised: 01 Mar 2020 | Accepted: 18 Mar 2020

[7] N. Nguyen-Trong, A. Piotrowski, L. Hall, C. Fumeaux, "A frequency- and polarization-reconfigurable circular cavity antenna", *IEEE Antenna Wirel. Propag. Lett.*, vol. 16, pp. 999-1002, 2016.

[8] W. Lin, H. Wong, "Polarization reconfigurable aperture-fed patch antenna and array", *IEEE Access*, *vol.* 4, pp. 1510-1517, Apr. 2016.

[9] Angeline M. Flashy and Ramesh, G.P. “Multi Band Antenna System for Quality Evaluation Application of Apple Fruit”, *Recent Trends and Advances in Artificial Intelligence and Internet of Things, Springer,* vol. 172, pp. 199-206, 2019.

[10] T. Tantisopharak, H. Moon, P. Youryon, K. Bunya-athichart, "Non-destructive determination of the maturity of Durian fruit in the frequency domain using its natural frequency", *IEEE Trans. Antennas Propag.*, vol. 64, no. 5, pp. 1779-1787, May 2016.