Hexagonal Nonradiating Edge-Coupled Patch Configuration for Bandwidth Enhancement of Patch Antenna

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***Abstract*— For increasing the impedance bandwidth of patch antenna two novel configurations are described for the ISM band applications. A hexagonal patch structure is used in both of the configurations. First structure uses six additional patches which are gap-coupled to the each nonradiating edge of the original hexagonal patch whereas in the second configuration fractals are used in each of the hexagonal of first order. HFSS is used for the simulation. The simulation result shows that with a regular hexagonal patch which gives 6% of impedance bandwidth, a slight improvement in bandwidth with respect to square patch can be achieved. Further with the two novel configurations up to 15.5% of the impedance is achieved. The result shows that the fractal configuration is suitable for the circularly polarized radiation. The simulated gain over the operating band is found to be more than 9-dB.**

***Keywords*— Hexagonal patch, Edge gap-coupled, Parasitic patch, Return loss, Impedance bandwidth, Fractal.**

I. INTRODUCTION

Patch antennas are accepted universally as one the most versatile style of antenna structure. Because of their low profile, low volume and low cost advantages microstrip antennas are used in a wide range of applications. The inherent less space occupation advantage of the patch antenna makes them to be used in the military and space applications. However narrow bandwidth is the main drawback of the patch antenna which limits their application in wide band areas.

All the issues related to patch antennas are described in [1] and various techniques to overcome those issues are also explained. Parasitic patch design is explained to enhance bandwidth. With the probe feed mechanism stacked patch antenna design for the circular polarization application is described in [2] and improvement in the bandwidth is achieved with this design. Other designs are also used to enhance the bandwidth of the patch antennas like E-shaped slot antenna fed by CPW for the broadband applications and proximity coupling mechanism [3], [4].

With the parasitic elements bandwidth improvement for the patch antenna is attempted in [5] in which a method called bandwidth doubling is described and 5% of impedance bandwidth is achieved.

In the [6] by two additional resonators bandwidth is improved of a rectangular patch antenna. In this paper resonators are gap coupled to the nonradiating edges of the rectangular patch. In the [7] two novel configurations are proposed for the bandwidth enhancement, namely, REGCOMA and FEGCOMA.

In the [8] single layer and double layer substrate structures are proposed with the gap-coupled antennas for bandwidth enhancement and up to 10% of bandwidth is achieved.

The key idea behind the Edge-Coupled patch is to introduce additional resonant patches. Out of these, only one of the elements is fed. Other patches will be coupled through proximity affect. This has significantly affected the patch antenna field. In [9] fractals are used to design compact antennas.

In the previous paper [10] different edge coupled structures are described. With four additional patch structure 7 % of impedance bandwidth is achieved. Further it is enhanced by introducing the fractals in the four patch structure and up to 9 % improvement in bandwidth is achieved.

In this paper initially a simple hexagonal patch is used and with that 6% impedance bandwidth is achieved. Then two novel configurations are proposed, namely, hexagonal edges gap-coupled microstrip antenna (HEGCOMA) and Fractal hexagonal edges gap-coupled microstrip antenna (FHEGCOMA) which exhibit broader bandwidth. The feeding mechanism used in all of the antennas is probe feed.

II. ANTENNA GEOMETRY

The basic shape of patch is hexagonal. With the application of generator method iteratively fractal geometries are generated from an original hexagonal patch. The proposed antenna is depicted in Fig 1.

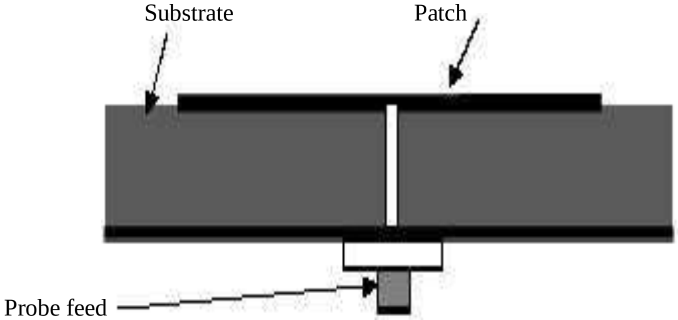

Fig 1. Antenna side view.

The specifications of the simulated antennas are:
Substrate – Rogers RT/duriod5880(tm)
Substrate thickness – 3.2mm
Relative permittivity – 2.2
Loss tangent – 0.019
Feeding mechanism – Probe feed
Basic patch shape – Hexagonal
Dimension of patch – 18 mm each side.
Probe radius and height – 1.9 mm and 3.2 mm
Coax radius and height – 3.2 mm and -5mm

III. Proposed Structures and Simulation Results

Dependence of the bandwidth with the antenna height and resonance frequency for the microstrip patch antenna is given by the equation 1.

$$BW \propto \frac{f_r^2 h}{\sqrt{\varepsilon_r}} \qquad (1)$$

Where BW is the bandwidth, fr is the resonance frequency, h is the height of the substrate and ε_r is the dielectric constant of the substrate. From the equation it can be seen that BW can be enhanced by increasing the height of the antenna or by decreasing the dielectric constant of the substrate.

However some limitation can be there on the antenna height. In most of the applications low volume antennas are preferred hence BW enhancement by increasing antenna height may not satisfy the size specifications of the antenna. Performance can be degraded with increased antenna height. While enhancing the bandwidth by decreasing the dielectric of the substrate may cause some practical issues like increment in antenna cost.

For improving the bandwidth of low profile antennas edge coupled hexagonal patch configuration is proposed in this paper, which does not increase the antenna cost and volume significantly. Here three antennas are proposed: simple hexagonal, HEGCOMA and FHEGCOMA.

A. Simple Hexagonal Structure

This structure is formed with a simple hexagonal patch as shown in Fig 2.

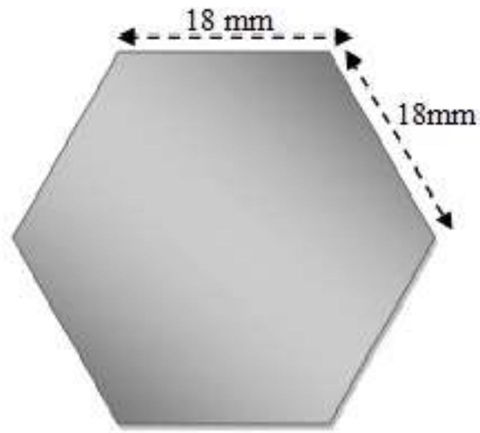

Fig 2. Simple hexagonal patch

The feed is located at the point (86mm, 86mm, 3.2mm) with the center of patch at (81mm, 81mm, 3.2mm). With this configuration an impedance bandwidth which is defined as the range of frequencies for which return loss is less than -10 dB, of 220 MHz is achieved. In terms of the % which is calculated by equation (2) 6% of impedance bandwidth is found which is more than 2% with respect to the square patch structure [8], [10].

$$BW = \frac{f_H - f_L}{f_H} \times 100 \qquad (2)$$

The simulated return loss curve showing 6% impedance bandwidth with -25 dB return loss at the resonating frequency (3.1 GHz) is shown in Fig 3.

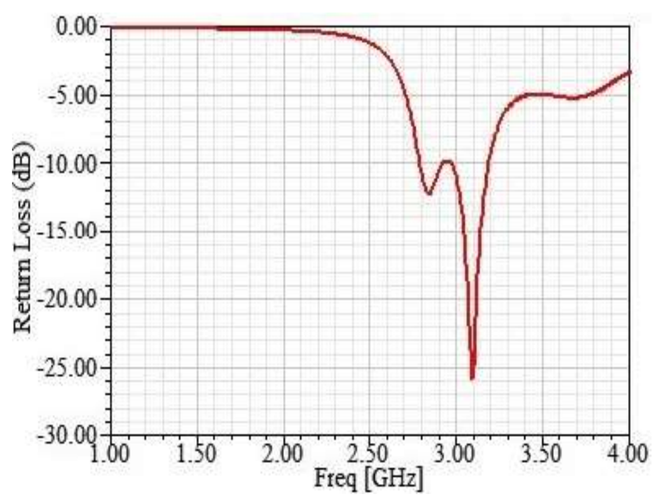

Fig 3. Simulated return loss

The simulated gain for this antenna at the resonating frequency is found to be more than 7 dB. Simulated gain curve is shown in Fig 4.

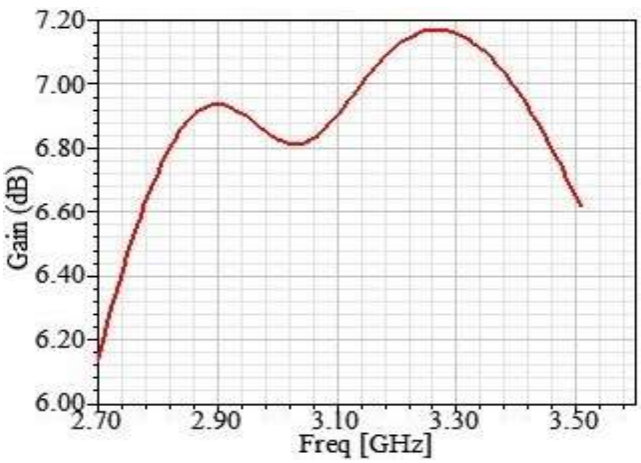

Fig 4. Simulated Gain

B. Hexagonal Edges Gap-Coupled Microstrip Antenna (HEGCOMA):

With the simple hexagonal configuration which is given in section *A* bandwidth improvement is not significant hence HEGCOMA configuration is proposed. In this structure six additional hexagonal patches are gap-coupled with the original hexagonal patch as shown in Fig 5.

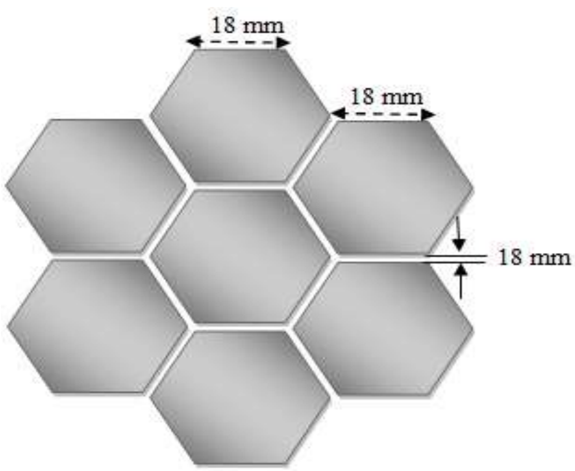

Fig 5. Hexagonal edge-gap coupled patch structure.

The gap between each of the patch is kept at 1mm.Only middle patch is excited with the probe feeding mechanism. Other patches are excited through proximity effect. The feed location for this structure is kept as (86mm, 88mm, 3.2mm) with the center of the middle patch at (81mm, 81mm, 3.2mm). With this configuration 15% of the impedance bandwidth is achieved which is a significant improvement as compared to the section A results. The simulated return loss curve with -17.5 dB return loss is shown in Fig 6.

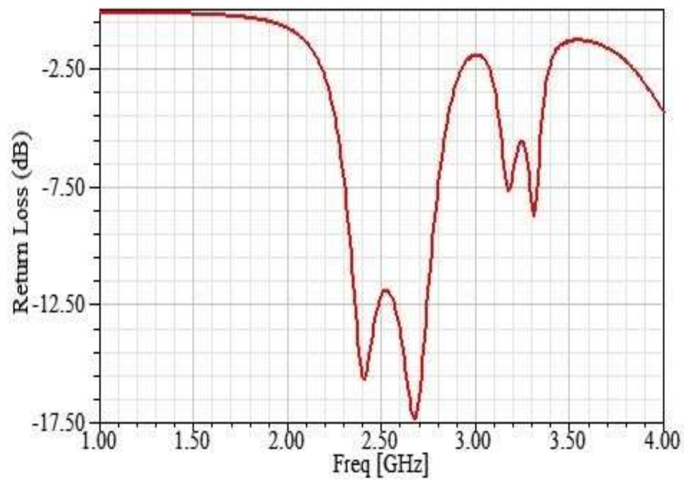

Fig 6. Simulated return loss

The antenna resonates at 2.7 GHz which is close to the ISM band (2.4 GHz) and the simulated gain at the resonating frequency is found to be 9 dB. Gain curve for this antenna is shown in Fig 7.

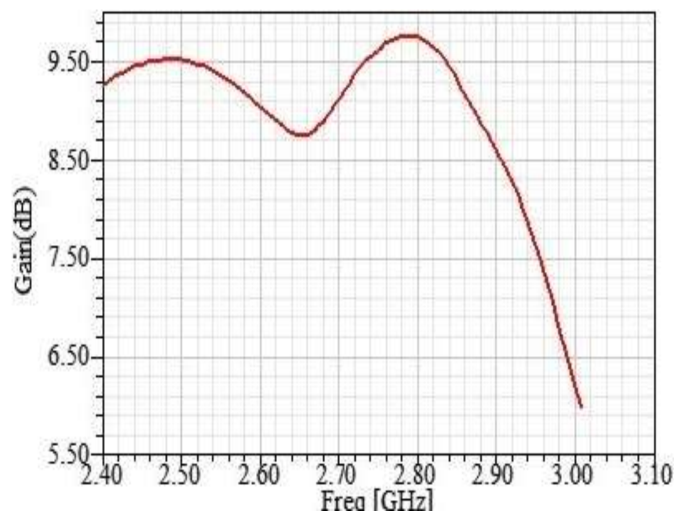

Fig 7. Simulated Gain.

C. Fractal Hexagonal Edges Gap-Coupled Microstrip Antenna (FHEGCOMA):

With the HEGCOMA configuration although a significant improvement in the bandwidth is achieved but that structure has two limitations, it does not resonate exactly at ISM band (2.4 GHz) and it is not suitable for the circularly polarized applications. To overcome these two limitations a new configuration namely Fractal Hexagonal Edges Gap-Coupled Microstrip Antenna (FHEGCOMA) is proposed. The structure is shown in Fig 8.

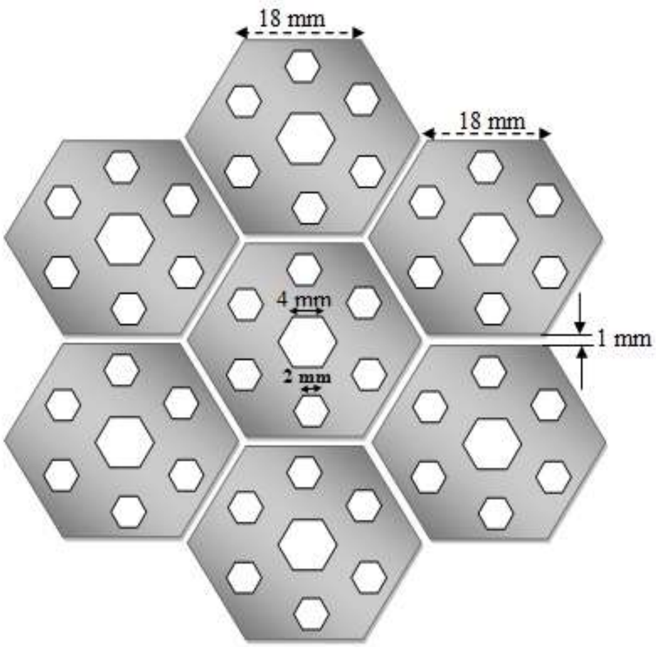

Fig 8. Fractal hexagonal edge-gap coupled patch structure

In this structure slots are introduced in the edge-coupled structure. Dimension of the middle slot is kept as the 4 mm while adjacent slots to that are of 2mm as shown in Fig 8. The gap between the patches is 1mm. Feed is located at the point (86mm, 89mm, 3,2mm) with the center of the middle patch at (81mm, 81mm, 3.2mm).

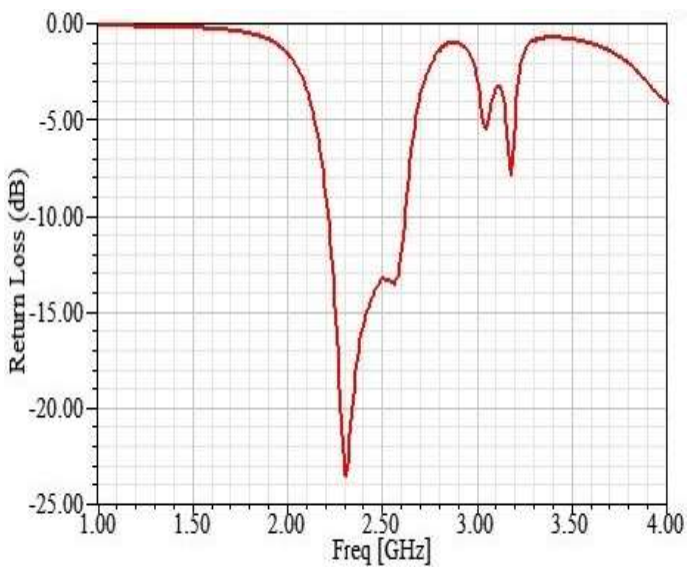

Fig 9. Simulated return loss

This structure resonates exactly at 2.4 GHz and the gain at this resonating frequency is found to be more than 9.5 dB. The simulated gain curve is shown in the Fig 10.

Due to the additional patches and the asymmetry generated by the slots this structure provides higher bandwidth with sharp return loss of -24 dB and the circular polarization. 15.5% of the impedance bandwidth is achieved with this structure. Return loss curve for this antenna is shown in Fig 9.

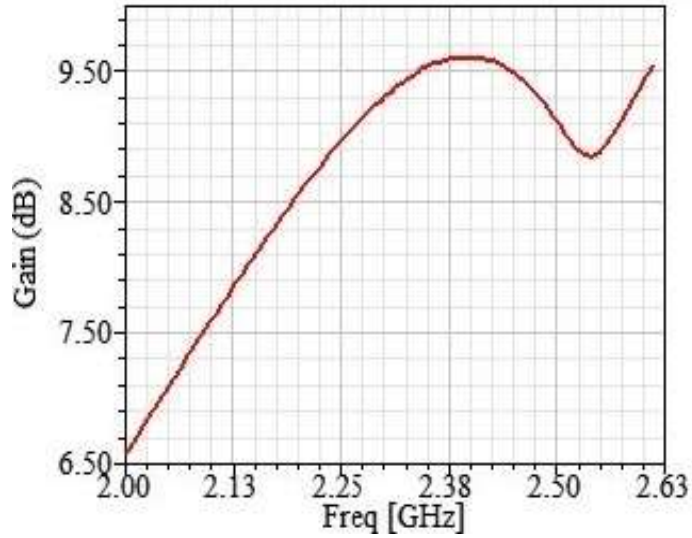

Fig 10. Simulated Gain.

With this structure circular polarization is also observed with the 3 dB axial ratio bandwidth of 4%. The Smith chart showing circular polarization is shown in Fig 11.

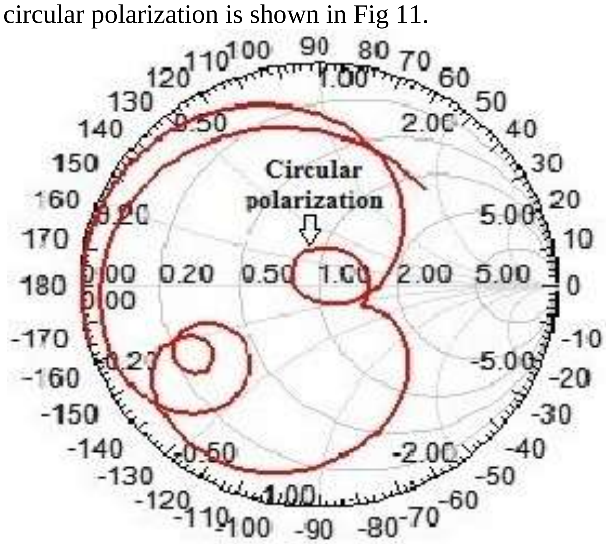

Fig 11. Smith Chart showing circular polarization

The axial ratio curve to show the 3 dB bandwidth for the FHEGCOMA is shown in the Fig 12. The axial ratio curve also resonates at ISM band(2.5 GHz).

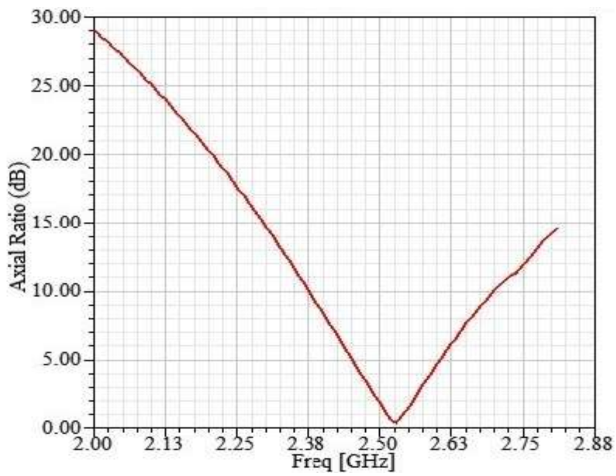

Fig 12. Simulated Axial ratio

This proposed structure FHEGCOMA overcomes the limitations of the previous structure HEGCOMA as it resonates at sharp 2.4 GHz and is suitable for the circularly polarized applications.

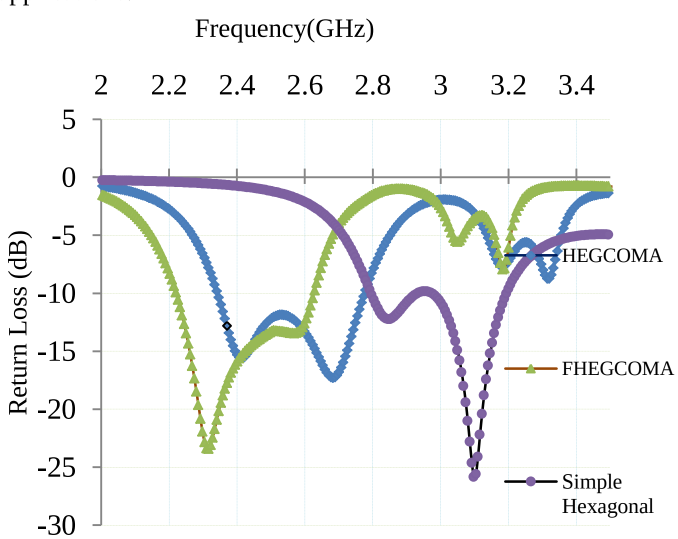

Fig. 13. Simulated Return loss comparison

IV. Discussions and Comparison

With the proposed hexagonal patch, edge coupled and fractal structures significant improvement in the impedance bandwidth is observed. Return loss characteristics of all the three antennas proposed in the paper are compared in the Fig 13.

Gain of all the three antennas is compared in Fig 14. It shows that at the resonating frequency FHEGCOMA gives the highest gain. Results of all the three antennas are are summarized in the table 1. C.P used in the FHEGCOMA indicates that the structure exhibits the circular polarization.

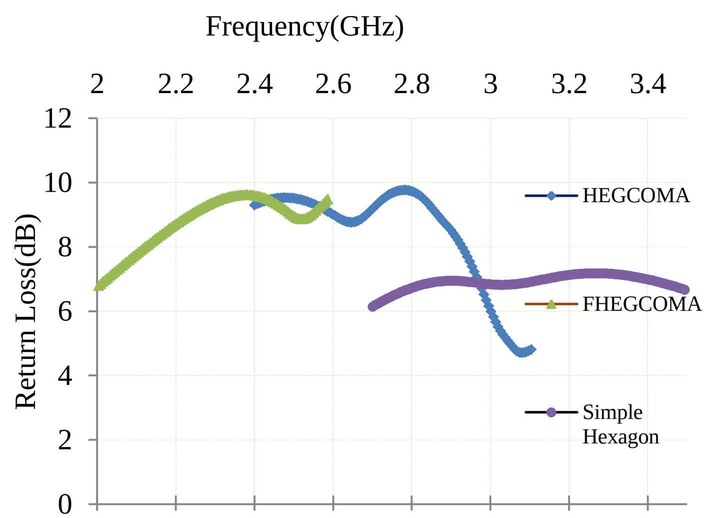

Fig. 14. Simulated gain comparison.

Proposed antennas in this paper are compared with the pervious relevant structures and the comparison shows that proposed structure exhibits higher bandwidth and is small in size. A typical comparison is given in table 2.

TABLE I
SUMMARIZED SIMULATION RESULTS

Structure	Resonating freq(GHz)	3 dB bandwidth	Impedance Bandwidth	Gain (dB).
Simple Hexagonal	3.1	-	6%	7
HEGCOMA	2.7	-	15%	9.5
FHEGCOMA	2.4	4% (C.P)	15.5%	9.5

TABLE III
COMPARISON OF DIFFERENT PARASITIC PATCH ANTENNAS

Antenna	**Patch size**	**Dielectric constant**	**Resonating frequency(GHz)**	**Impedance Bandwidth**
Proposed	18mm each side	2.2	2.4	15.5%
[6]	64mm×64mm	2.5	1.275	5%
[7]	27mm×39mm	2.5	3.27	6.9%
[8]	40mm×30mm	2.2	2.4	2.18%
[9]	36mm×36mm	2.2	2.41	9%

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