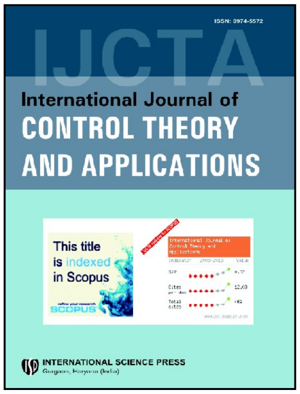

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Gap-coupled Circular Microstrip Patch with Single Ground for Triband Application

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***Abstract*:** The Proposed patch antenna is designed to operate over more than one frequency. Circular patch is designed on the FR4 substrate with a single ground plane at the bottom. The proposed antenna resonates at 2.4GHz, 2.8GHz and 3.6GHz which is suitable for Bluetooth, Wireless CCTV camera and WLAN (Wireless Local Area Network) applications. The dimension of the proposed patch antenna is 110×110×1.6mm.

Keywords: Gap coupling; Triband; Direct feed, Single ground, Bluetooth, Wireless CCTV camera & WLAN.

1. INTRODUCTION

In the past decade, many multiband antennas are designed for wireless applications. Multiband microstrip patch antennas are capable of operating more than one frequency in lieu of utilizing single antenna for each application. Achieving better gain and bandwidth in multiband antennas are remained challenging for authentic time applications. Placing a single antennas or array antenna for performing single application are overcomed by multiband antennas, which will be used for multiple application.

Multiband antenna is designed to operate in more than one frequency by introducing slots and varying the geometry of the design structure in terms of patch dimension, thickness of the substrate and ground plane. A multiband antenna should be designed in such a way which will not compromise in its gain and bandwidth. Modifications can be done not only in the patch section but additionally in the ground and substrate sections also. Single ground, defective ground and partial ground are few of the ground pattern which are introduced at the bottom of the design in a planar structure. The substrate which is between patch and ground plane will avails in enhancing the bandwidth and performance. On incrementing the thickness of the substrate the bandwidth can be enhanced, thickness of the substrate is directly proportional to the bandwidth [10].

The new multiband patch antenna design for multiple wireless application is proposed in this paper. In this approach, the concept of partial coupling or gap coupling is introduced in the patch structure of the antenna design. The proposed design is simulted using CST MWS V.14.

In this paper, step by step geometrical modification are made over the design and each modified design is simulated using CST MWS V.14 and results are observed. First, brief step by step description of the proposed design is presented in this paper and move on to fabricated design with results observed using network analyser.

Table 1
Dimensions of the Fabricated Patch Antenna

Quantity	*Value*	*Units*
Dielectric constant substrate	4.4	-
Material of the substrate	FR4	-
L (length)	110	mm
W (width)	110	mm
H (height)	1.6	mm
Resonant frequency	2.43 / 2.83 / 3.6	GHz

2. PROPOSED METHODOLOGY

Though there are many geometric shapes for designing patch, in this paper, circular shape patch is choosed to design multiband antenna. Circular patch is designed on the FR4 substrate with a single ground plane at the bottom. Slots and elongated strips are introduced to obtain multiband[4]. Slots are also introduced to prevent undesired bands[2]. The proposed antenna resonates at 2.4GHZ, 2.8GHz and 3.6GHz which is suitable for Bluetooth, Wireless CCTV camera and WLAN (Wireless Local Area Network) applications. The dimension of the proposed patch antenna is 110×110×1.6mm.

(A) Circular Patch and Field Configuration

Initially, circular patch microstrip antenna with radius 34mm, is considered. Thickness of the FR4 substrate is choosen as 1.6mm. Dielectric constant and relative permitivity is considered lying in xy plane over an astronomically immense ground plane.

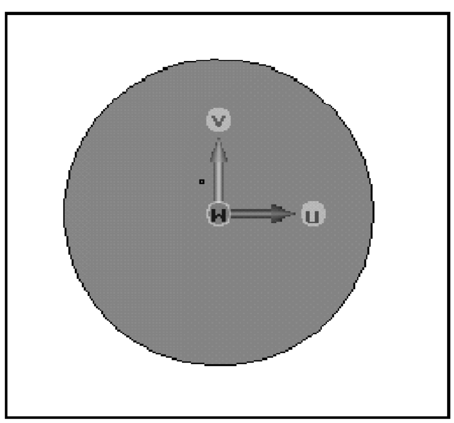


Figure 1: Circular patch

Fig. 1. shows the circular patch of radius 34mm radius which is the top layer of antenna laid on the FR4 substrate. The mode fortified by the circular patch antenna can be found by treating the patch, ground plane and the material between the two as a circular cavity. The radius of the patch is the only degree of liberation to control the modes of the antenna [2], [5].

(B) Patch Modification

The single layer circular patch geometry discussed above is modified by inserting slots. Based on the surface current distrubution, slots are decided. Initially V shaped slot is introduced at one side of the circular patch. The angle choosen for the V cut is 45^0 [2].

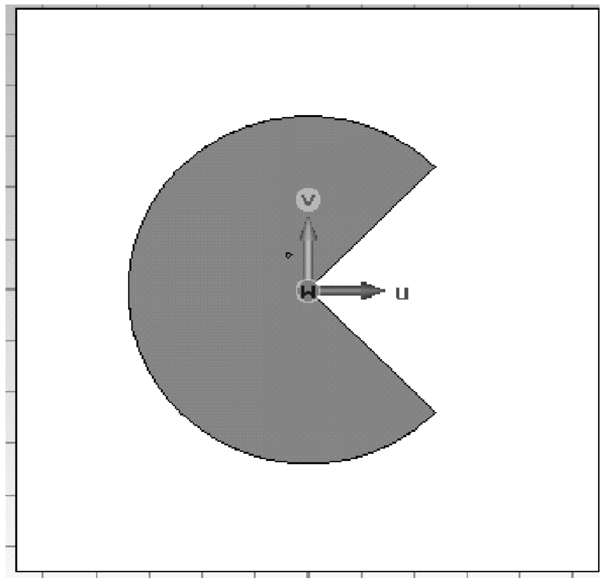


Figure 2: Circular patch with V-slot

In additament to already subsisting modes in circular patch antenna few supplemental modes get exhilarated in the present design. In fact it is observed that slot does not introduce any resonant mode but reduces the undesired resonant modes[2],[4]. The distribution on the surface of the patch can withal varied by varing the angle between V cut. The position of the aliment additionally matters for perfect current distributions over the patch to obtain desired resonant frequencies[8].

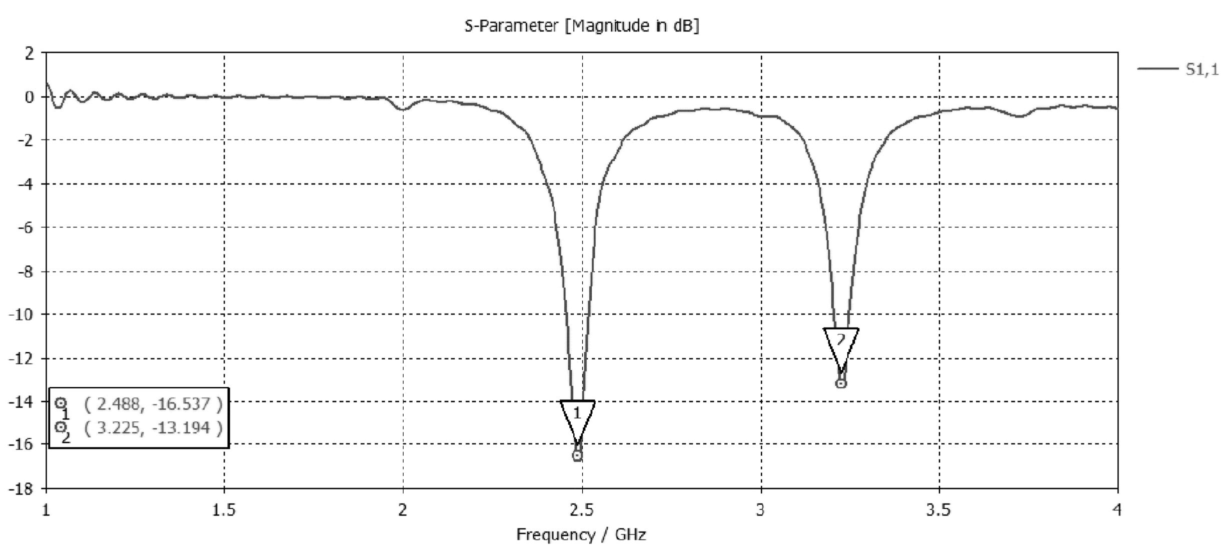


Figure 3: Return loss of modified circular patch with V-slot

It is observed that the the V-slot circular patch resonates below -10 dB with frequency 2.4GHz and 3.2GHz which prevarications in C-band with better gain but in order to obtain multiband in lieu of dual band, modifications are done over the patch and results are observed.

(C) Introducing parasitic patch to the central driven patch

The outer parasitic patch is gap coupled with the central main patch. Only the central main patch is driven by the victual line. This can additionally be kenned as directly coupled to the driven patch. When the outer patch is parasitic to the alimented patch along the radiating edges, a maximum bandwidth can be obtained on comparing a single structure patch.

The rudimentary principle underlying the operation of these antenna is capacitive coupling between the driven patch and the parasitic patches. The loading effect engendered by the parasitic patches amends the impedance bandwidth [4].

Parasitic patch in the circular geometry is designed by introducing outer parasitic patch with the proximately placed adjacent driven patch. The air gap between the outer patch and the driven patch is 1.59mm [4], [6].

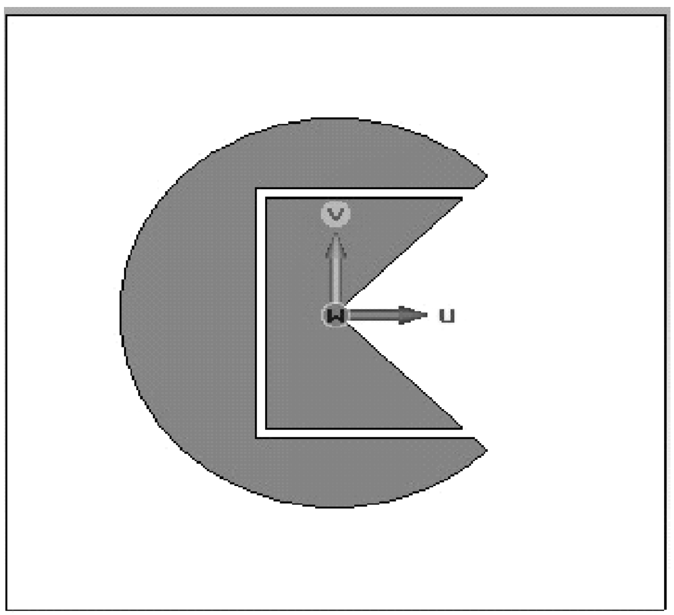


Figure 4: Gap coupled Parasitic patch

The length of the slots introduces adscititious resonant modes near the fundamental patch to yield parasitic patch multiband. The geometry of the patch is varied and results are observed. The performance of the modified patch is better comparing the anterior patch designd. The corresponding patch resonates at desired frequency bands slaking the C-band applications. The fact can be visualized through the presence of adscititious dips in S_{11} (return loss) results.

Triple band replication is observe after introducing parasitic patch which is gap coupled and resonated. For the proposed patch design it is observed that S-parameters is obtained as -19.97, -24.501 and -16.554 at the frequencies of 2.4, 2.8 and 3.5 GHz respectively.

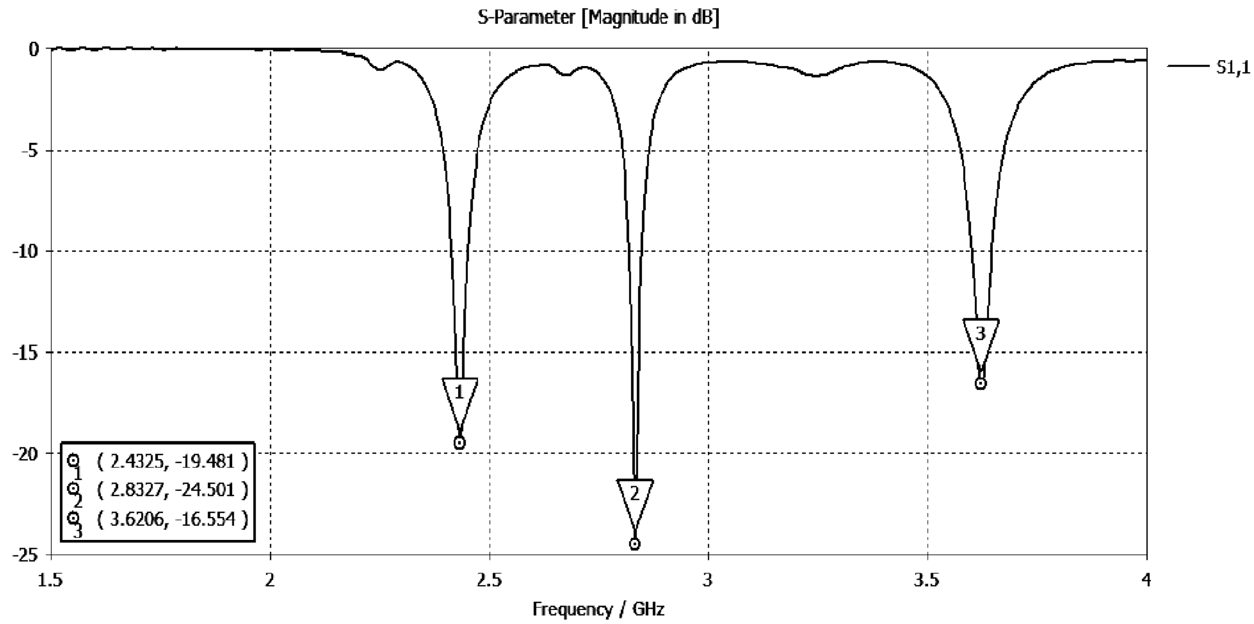


Figure 5: Return loss of the gap coupled patch

Table 2
Observed results of patch having substrate height (1.6mm)

Parameters	*Size of the patch 110×110×1.6mm*		
Resonating frequency (GHz)	2.4325	2.8327	3.6206
Return loss (dB)	-19.97	-24.501	-16.554
Gain (dB)	3.428	-1.220	1.384
Bandwidth (MHz)	37	29	45
VSWR	1.2	1.15	1.36

(D) Position of Coax Feed

In this type of aliment, a coaxial probe is utilized to connect to patch antenna by drilling an aperture through the dielectric substrate at a location which provides the best impedance match for the coaxial line.

The puissance from the coax is victualed to the patch with direct contact. Coax victualing is in contrast to the indirect victualing technique like proximity and aperture.

The outer conductor of the coaxial line is annexed to the bottom of the ground plane and the center conductor is brought through the substrate and soldered to the patch.

The diameter of the outer conductor and inner conductor is calculated using CST MWS so that it matches 50Ω. The diameter of the inner conductor is 1mm and outer conductor is 2.30205mm. The position of the coax aliment over the patch is decided by tribulation and error method on observing better results.

(E) FR4 Substrate Modification

FR4 material which is fire retardant and available at ease of cost is used as a substrate. In general, the different areas considered are rudimental material properties, circuit fabrication, reliability and culminate-use performance needs. It is needed to amended electrical performance of the proposed design for sundry frequency bands of interest. The proposed antenna is a single layer design that uses FR4 as substrate.

1. Observation of patch with substrate height 2.4mm

The bandwidth can be enhanced by incrementing the height of the substrate. Other than 1.6mm substrate thickness, the height of the substrate is varied as 2.4mm and 3.2mm and simulation results are observed.

Table 3
Observed results of patch having substrate height (2.4mm)

Parameters	*Size of the patch 110×110×2.4mm*		
Resonating frequency (GHz)	2.39	2.80	3.57
Return loss (dB)	-17	-14	-21
Gain (dB)	4.373	-0.344	2.101
Bandwidth (MHz)	44	29	64
VSWR	1.3	1.4	1.19

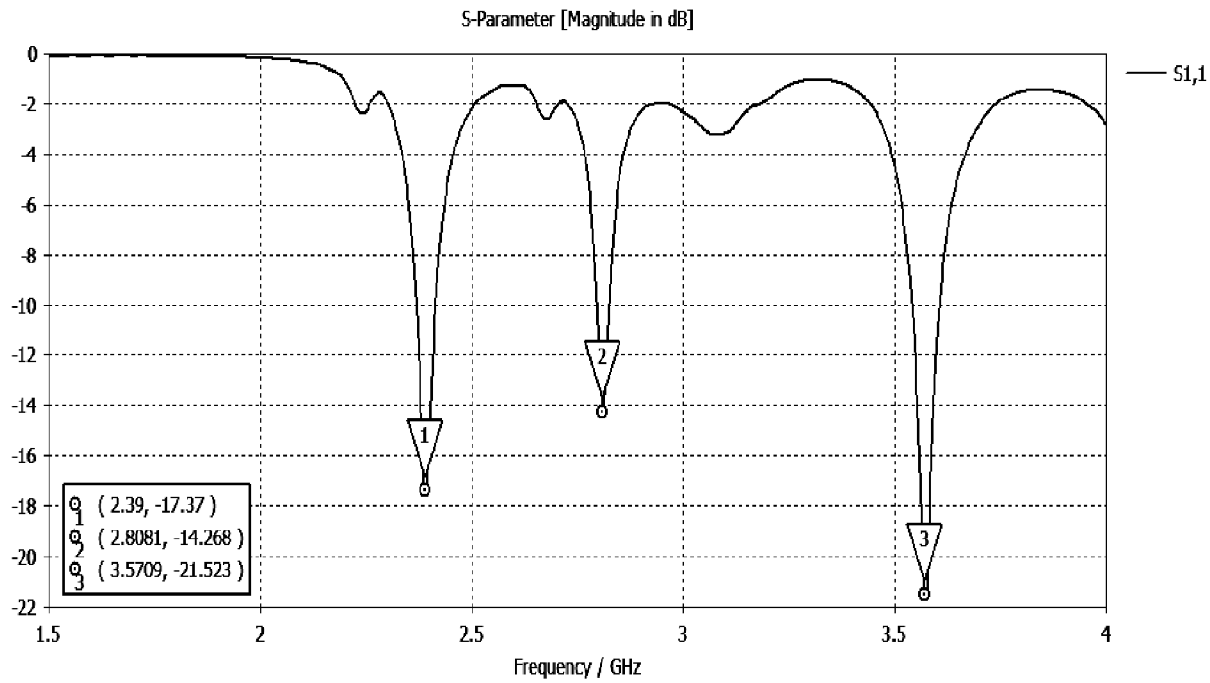


Figure 6: Return loss of the modified design with height 2.4mm

2. Observation of patch with substrate height 3.2mm

The height of the substrate is further varied to 3.2mm to enhance the bandwidth and gain. The simulation results are observed.

Table 4
Observed results of patch having substrate height (3.2mm)

Parameters	*Size of the patch 110×110×3.2mm*		
Resonating frequency (GHz)	2.39	2.8	3.57
Return loss (dB)	-19	-12	-18
Gain (dB)	4.96	0.624	3.96
Bandwidth (MHz)	54	34	78
VSWR	1.22	1.5	1.28

Comparing the 1.6mm and 2.4mm thickness, for the 3.5mm height, the patch antenna gives best bandwidth but at the cost of gain and return loss for 2.80GHz frequency. This is interpreted from the simulated results of the modified designs.

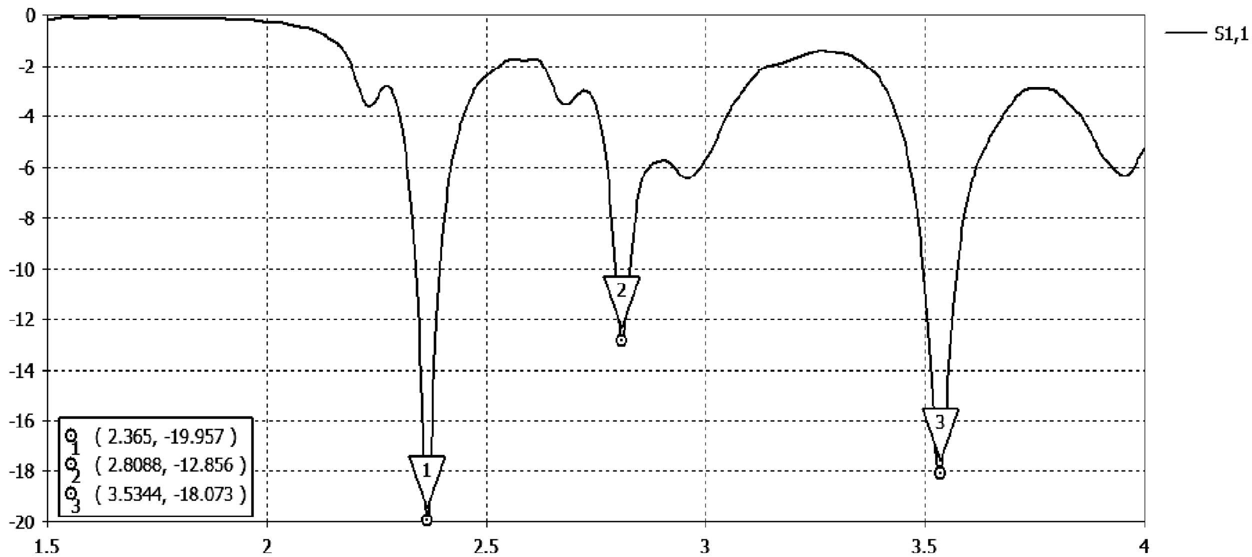


Figure 7: Return loss of the modified design with height 3.2mm

(F) Ground Plane Modification

Ground plane is introduced at the bottom of the substrate. Back scattering can be averted by the single ground plane. The gain can be achieved better by incrementing the ground surface[4],[6]. The antecedent results were observed for the ground dimension of 110×110mm. The size of the ground plane is incremented as 150×150mm to enhance gain and bandwidth and simulation results are observed for all the three thickness of substrate (1.6, 2.4 and 3.2mm).

1. Observation of patch with dimension 150×150×1.6mm

The simulation results are observed for the extended ground plane. The design is keep on modifying, as the motive is to achieve miniature antenna with better results.

Table 5
Observed results of patch having substrate height (3.2mm)

Parameters	*Size of the patch 150×150×1.6mm*		
Resonating frequency (GHz)	2.4325	2.8327	3.606
Return loss (dB)	-19	-24	-16
Gain (dB)	3.428	-1.22	1.425
Bandwidth (MHz)	36	29	36
VSWR	1.3	1.10	1.36

2. Observation of patch with dimension 150×150×2.4mm

The simulation results are observed for the thickness 2.4mm, as the motive is to achieve antenna with better results.

Table 6
Observed results of patch having substrate height (150×150×2.4mm)

Parameters	*Size of the patch 150×150×2.4mm*		
Resonating frequency (GHz)	2.39	2.8	3.57
Return loss (dB)	-16	-15	-21
Gain (dB)	4.241	0.232	2.56
Bandwidth (MHz)	43	31	63
VSWR	1.35	1.42	1.19

The corresponding simulation results portrays better performance with enhanced gain for the frequencies 2.4GHz, 2.8GHz and 3.6GHz when compared to 1.6mm thickness. Bandwidth can be enhanced only when the thickness of the substrate increased even more. The S-parameters is below -10 dB resonating at desired bands at 2.3901 GHz, 2.81 GHz and 3.5688 GHz.

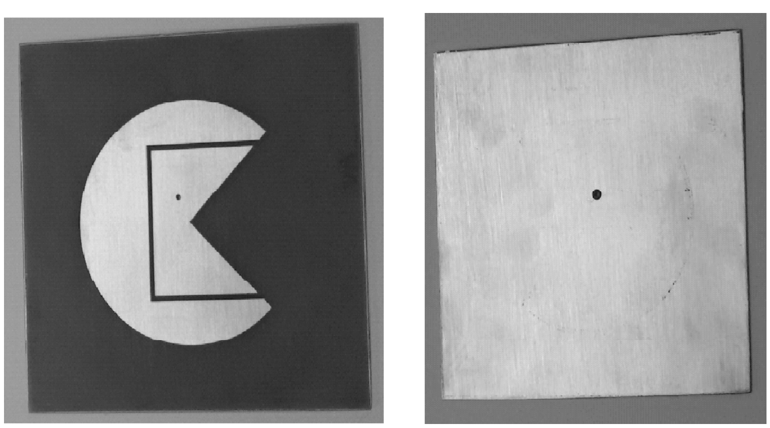
3. *Observation of patch with dimension 150×150×3.2mm*

With the extended ground plane of 150×150mm, the height of the substrate is varied to 3.2mm to enhance the bandwidth and gain. The corresponding simulation results portrays enhanced gain for all the three frequencies 2.4GHz, 2.8GHz and 3.6GHz with enhanced bandwidth which suits well for C-band applications.

Table 7
Observed results of patch having substrate height (150×150×3.2mm)

Parameters	*Size of the patch 150×150×3.2mm*		
Resonating frequency (GHz)	2.3676	2.81	3.530
Return loss (dB)	-18	-13	-17
Gain (dB)	4.75	1.7	3.97
Bandwidth (MHz)	51	36	75
VSWR	1.7	1.16	1.36

The circular patch with gap coupled parasitic patch is fabricated on FR4 substrate. The length, breath and height of the substrate is 110mm, 110mm and 1.6mm respectively.



(a) (b)

Figure 8: a)Top view of fabricated patch b) bottom view of fabricated patch

The small drilled hole over the patch represents the feed point, through which coax feed is given to radiate the patch.

3. RESULTS AND DISCUSSION

With all the tribulations and modifications applied over the circular patch antenna with parasitic structure having patch radius of 34mm was designed and fabricated. It is observed to resonate at three frequencies 2.4GHz, 2.8 GHz and 3.5GHz in the C-band when slots are embedded over the circular patch. It is designed on the glass epoxy FR4 substrate (er=4.4 , tan =0.002, sub thickness=1.6 mm). The proposed patch antenna is felicitous for wireless applications like Bluetooth, Wireless CCTV camera and WLAN.

(i) S- PARAMETER: (RETURN LOSS)

Return loss is the difference between forward and reflected power in dB[6]. The return loss is given by P_R/P_T. For maximum power transfer, the return loss should be as small as possible, the return loss should be as large a negative number as possible.

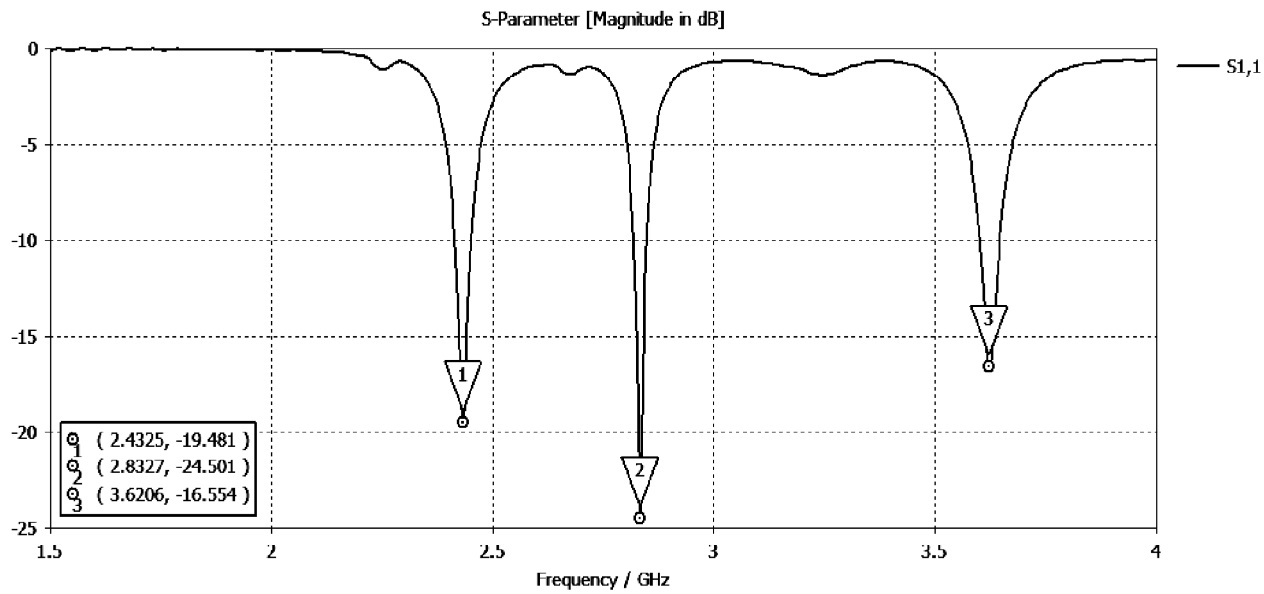


Figure 9: Return loss of the proposed patch

For the proposed patch design it is observed that S-parameters is obtained as -18.4489 dB, -36.4916 dB and -47.8562 dB at the frequencies of 2.4, 2.8 and 3.5 GHz respectively.

(ii) Bandwidth

The bandwidth can be calculated by finding the difference between the upper frequency and lower frequency[6].

$$\text{Bandwidth} = f_2 - f_1$$

where, f_1 and f_2 are the lower and upper frequencies.

It is interpreted that present patch design can optimized to obtain better bandwidth than the current values. The bandwidth of the respective resonating frequency are calculated and tabulated.

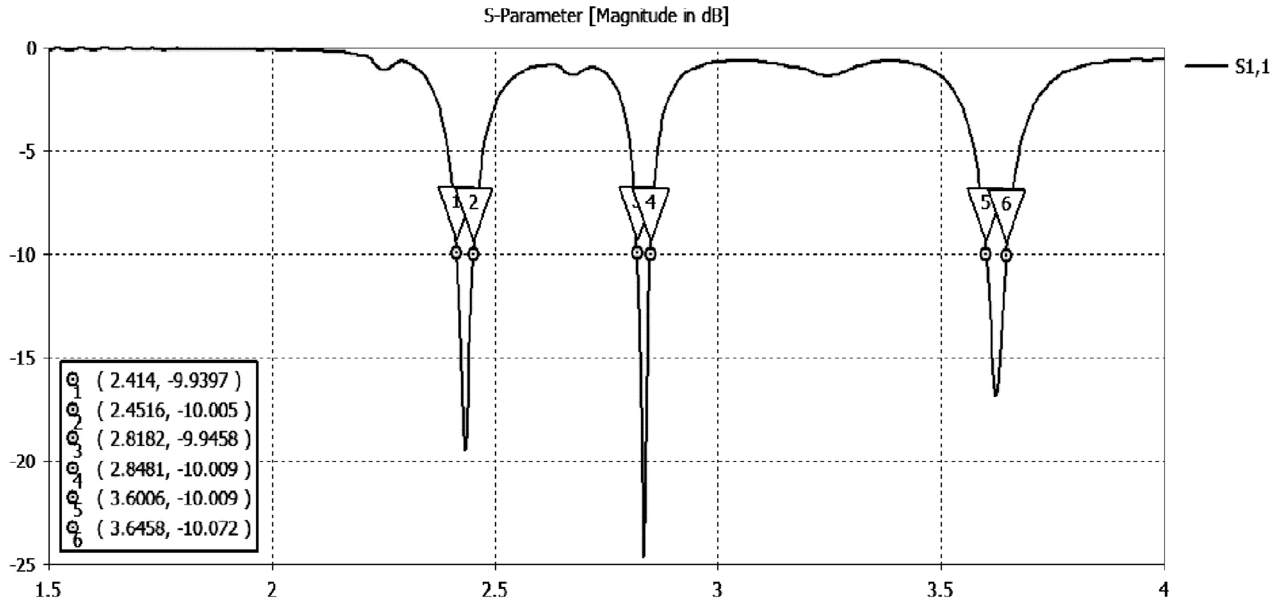


Figure 10: Bandwidth of the proposed patch

Table 8
Observed results of patch having substrate height (150×150×3.2mm)

Frequency (GHz)	*Band Width (MHz)*
2.4	37
2.8	29
3.6	45

(iii) Voltage Standing Wave Ratio (VSWR)

The most common case for measuring and examining VSWR is when installing and tuning transmitting antennas [6]. When a transmitter is connected to an antenna by a feed line, the impedance of the antenna and feed line must match exactly for maximum energy transfer from the feed line to the antenna to be possible.

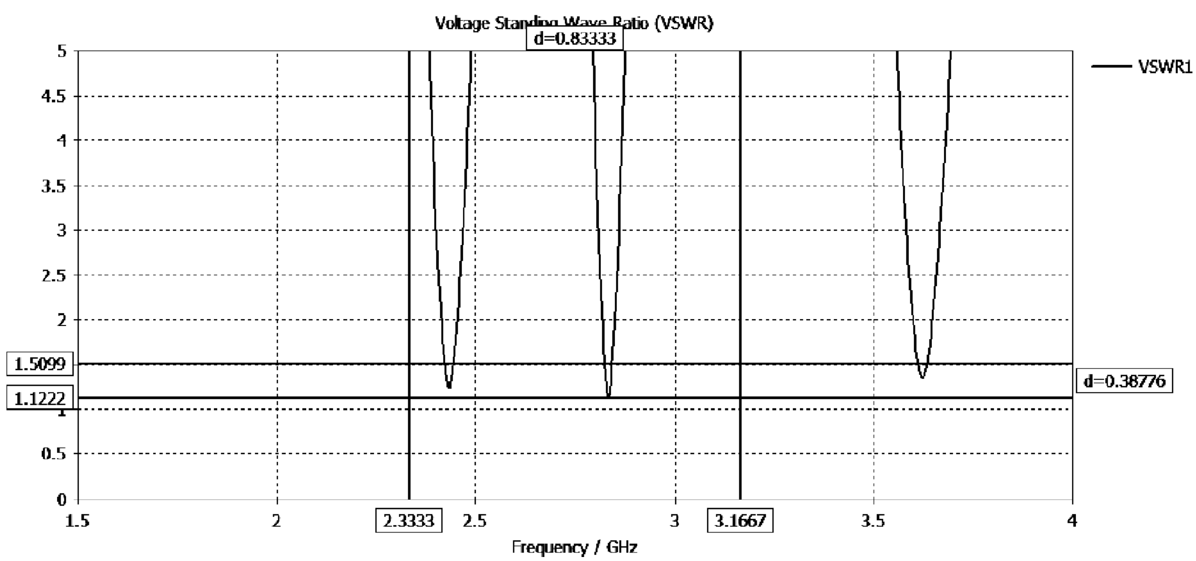


Figure 11: VSWR of the proposed patch

For a VSWR plot drawn for the proposed antenna, it is observed that the impedance matching attains desired level as 1.2231, 1.0924 and 1.0143 at frequencies 2.4, 3.4 and 5.2 GHz respectively.

When an antenna and feed line do not have matching impedances, some of the electrical energy cannot be transferred from the feed line to the antenna. Ideally, VSWR must lie in the range of 1-2 which is achieved.

(iv) Radiation Pattern

It is observed that the gain for the proposed patch is comparatively less at 2.8 GHz. Further modifications can be done over the patch to enhance gain and bandwidth. Bandwidth can be enhance by increasing the thickness of the patch. The thickness of the substrate is increased to 3.2mm and simulated.

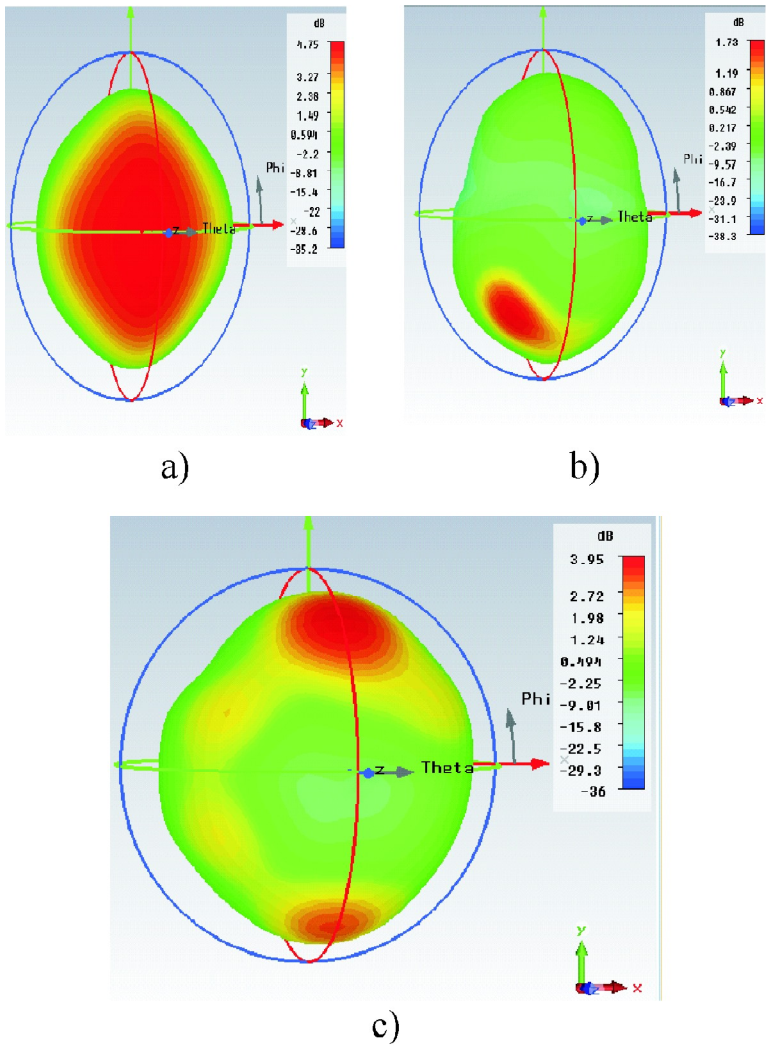


Figure 12: Radiation pattern of a) 2.4 b) 2.8 & c) 3.6 GHz

V. MEASUREMENT OF FABRICATED PATCH ANTENNA USING NETWORK ANALYSER

The measured S_{11} at all the three resonance frequencies are well within acceptable value. The measured values of the proposed antenna at the three frequencies 2.4, 2.8 and 3.5 dB are respectively.

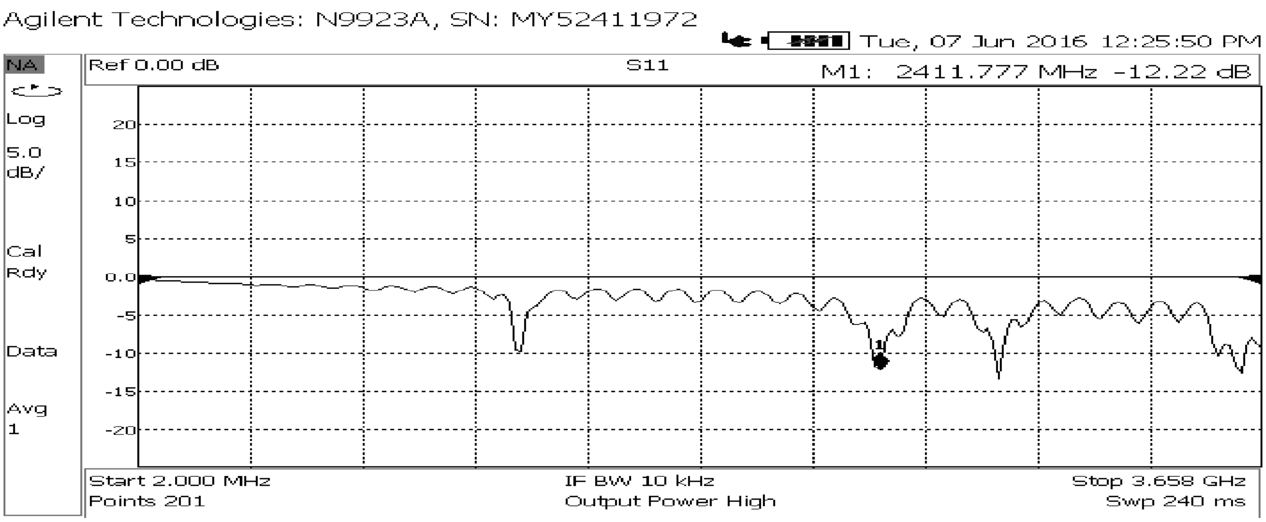


Figure 11: Measured result of the fabricated patch (2.4 GHz)

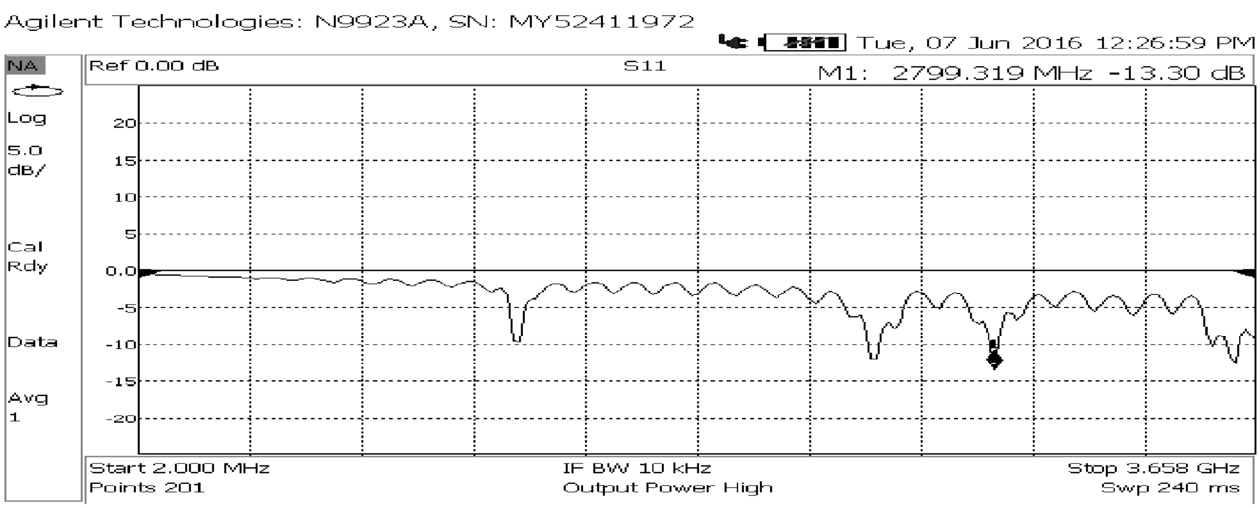


Figure 12: Measured result of the fabricated patch (2.8 GHz)

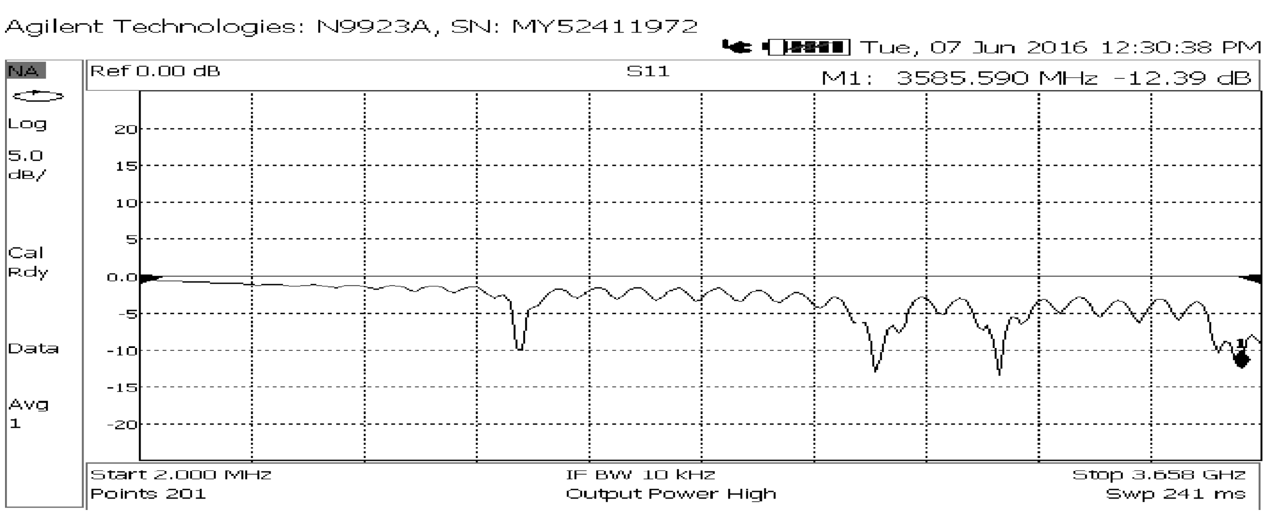


Figure 13: Measured result of the fabricated patch (3.5 GHz)

Table 9
Comparison of Simulated and Measured Results

Simulated results		*Measured results*	
Frequency (GHz)	*S11 (dB)*	*Frequency (GHz)*	*S11 (dB)*
2.43	-19.48	2.41	-12.22
2.83	-24.50	2.79	-13.30
3.62	-16.55	3.585	-12.39

4. CONCLUSION

The overall working of antennas was understood. The major parameters such as Return Loss curves, Radiation Patterns, Directivity, antennas and simulated. Finally, the desired level of optimization was obtained. A novel coax-fed multiband antenna with enhanced gain and bandwidth is presented. The position and gain that affect design and applications were studied and their implications understood. The proposed circular U & V slot patch antennas operated at the desired frequency (2.4GHz, 2.8GHz and 3.5GHz) and desired power levels. Several modification are done over the patch the bandwidth of the bands can be controlled easily, which makes the antenna suitable for most of the wireless communication applications like Bluetooth, Wireless CCTV camera and WLAN.

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