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NOVEL SINGLE LAYER PROXIMITY FED GAP COUPLED MICROSTRIP PATCH ARRAY FOR WLAN/WiMAX APPLICATIONS IN PORTABLE DEVICES

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ABSTRACT

This paper focuses on the development of a novel single layer dual band proximity fed gap coupled microstrip array antenna. A basic 2x1 microstrip patch array consisting of a pair of rectangular patches which are coupled with a centrally placed microstrip line in the same plane and an arrow headed dumbbell shaped slot in the ground plane is investigated. By using two additional parasitic patches gap coupled to the patch elements of the basic array, an enhancement in bandwidth and gain is achieved along with dual band operation. This proximity fed gap coupled 4x1 array provides resonances at two frequencies of 2.465 GHz and 3.608 GHz. The proposed array antenna is suitable for WLAN (2.414-2.507 GHz) and WiMAX (3.586-3.644 GHz) applications. This 4x1 array has a gain of 8.85 dBi and 6.57 dBi, with an impedance bandwidth of 4.64% and 1.78% respectively in the lower and upper bands. The simulated results are in good agreement with the experimental results.

Keywords: microstrip patch array, dual band, proximity feed, gap coupled.

1. INTRODUCTION

The development of miniaturized portable electronic devices like i-pods, laptops etc. having high speed data transfer is one of the fastest growing segments of wireless communication engineering. Antennas play an important role in these portable devices and there is a growing demand for miniaturization and for integrating more than one communication standards in these devices. WLAN and WiMAX technologies are extensively applied in portable devices for high speed data connectivity and enabling user mobility. This needs lead to the development of compact and multiband antennas for portable wireless terminal devices with broader bandwidth and higher gain. Microstrip antennas are suitable candidates in modern portable devices for wireless communication due to the advantages like light weight, low profile and ease of integration with microwave circuits [1]. However the conventional microstrip patch antennas exhibit the inherent drawbacks of narrow impedance bandwidth, low gain and single band operation [2].

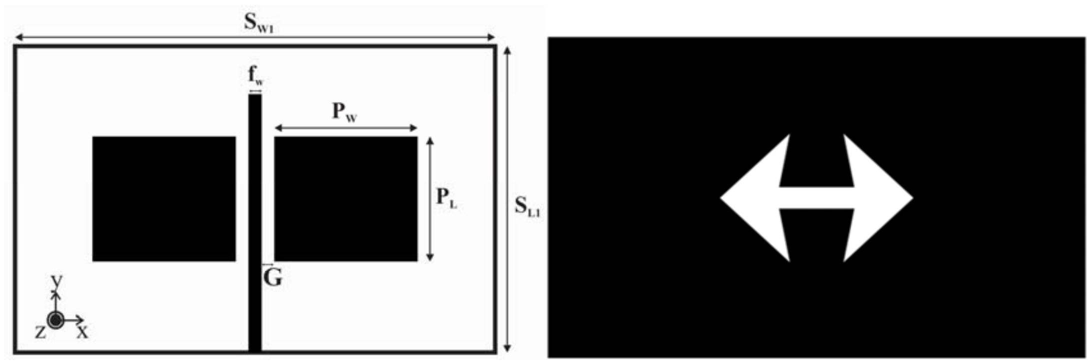
Some of the techniques reported towards development of microstrip patch antenna with wide impedance bandwidth are aperture coupling [3], stacking [4] and the use of gap coupled resonators [5]. Gain of the microstrip antenna can be improved by introducing variation in the material side as well as in the structural side. Some of the reported methods from structural side are array antenna configuration [6], using frequency selective surface [7] and gap coupled method [8]. For most of the portable devices it is desired to have dual band or multiband antennas. Many designs of dual band microstrip patch antennas have been demonstrated in recent years including fractal geometries in designing patches [9] and by incorporating slits in patch structures [10].

One of the commonly used methods to enhance bandwidth and gain of microstrip antenna simultaneously is by using the concept of gap coupled parasitic patches. In most of the reported gap coupled parasitic patch antennas, either probe feed or corporate feed is employed to excite the driven patch [11-12]. Many researchers have reported electromagnetically fed gap coupled patch antennas for wireless applications. An antenna consisting of a pair of square radiating patches coupled in close proximity to a microstrip line in the same side and a coupling arrow shaped slot in the ground plane is reported [13]. In another gap coupled configuration coupling strip is placed below the patch [14]. Other variations are reported in developing dual band antennas that cover WLAN/WiMAX applications [15-16].

In this paper a novel single layer proximity fed gap coupled microstrip array configuration is investigated. The basic array structure consists of two rectangular radiating patches, which are proximity coupled with a centrally placed microstrip line in the same plane. The feed arrangement used in this work is similar to the one reported in [13]. A tapered arrow headed dumbbell shaped slot in the ground plane is employed to enhance the coupling to the radiating patches. To further enhance bandwidth and gain, along with dual band operation parasitic patches having the same dimensions as that of driven patches are gap coupled to both radiating elements of the basic 2x1 array configuration, which results in the formation of 4x1 array antenna. The proposed dual band single layer proximity fed gap coupled 4x1 microstrip array antenna can be used in portable devices for WLAN / WiMAX application with enhanced bandwidth and improved gain.

2. GEOMETRY OF ANTENNAS

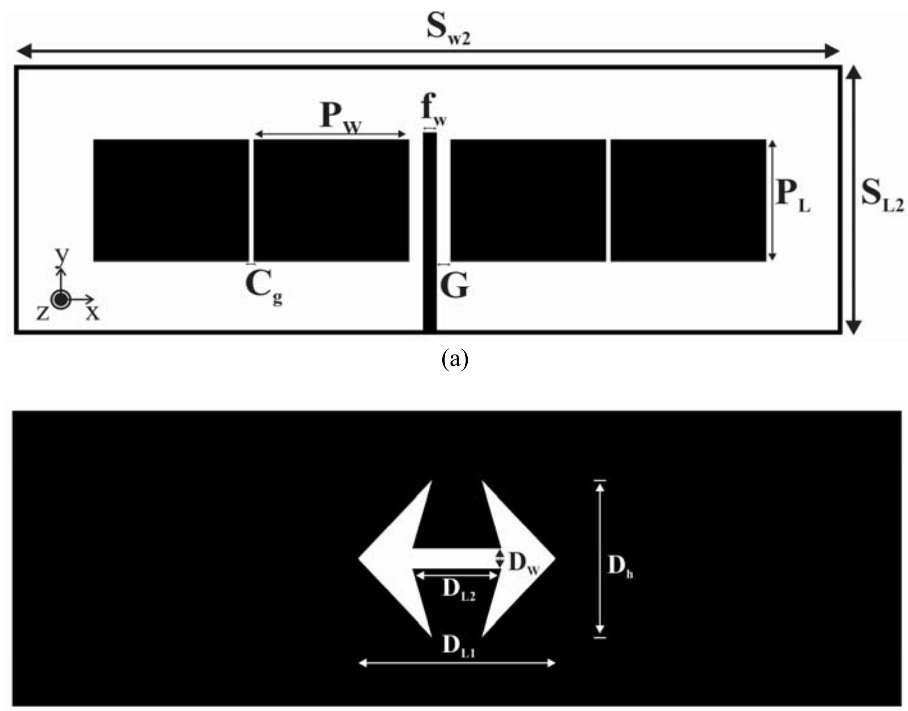
The proposed microstrip array antenna have been designed and fabricated on FR-4 substrate with thickness h = 1.6 mm and relative permittivity of 4.3. In conventional gap coupled configurations only one of the radiating elements are excited, by keeping the rest of the elements coupled to it. But in the proposed array configuration two radiating elements are excited simultaneously. The configurations of the proposed basic single layer proximity fed 2x1 microstrip patch array are shown in Figure-1. The radiating patches and the feed line are in the same plane and hence reduced height is achieved when compared with conventional proximity fed antennas. The proximity coupled feed method is used to excite the two radiating patches. The back side of the substrate has a metallic ground plane with a tapered arrow headed dumbbell shaped slot as seen in Figure-1(b). The evolution stages of the array antenna are described by the authors in [17].



(a) (b)

Figure-1. Geometry of the proposed proximity fed basic 2x1 microstrip array antenna (a) top view (b) bottom view.

The radiating patches are excited using a microstrip line placed centrally between the two patches in the same plane. The energy from the microstrip line is electromagnetically coupled to the radiating patches. In order to enhance more energy to the radiating patches a tapered arrow headed dumbbell shaped slot is etched in the ground plane. The basic 2x1 microstrip patch array configuration is a single band antenna with a centre frequency of 2.791 GHz with an impedance bandwidth of 2.1%. The configurations of the proposed single layer dual band proximity fed gap coupled 4x1 microstrip array antenna are shown in Figure-2.



(b)

Figure-2. Geometry of the proposed proximity fed gap coupled 4x1 array antenna (a) top view (b) bottom view.

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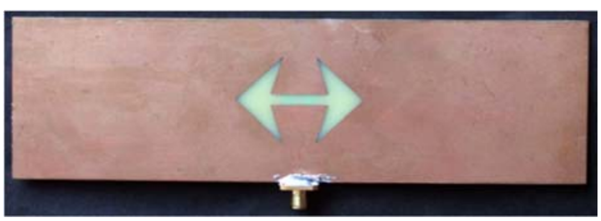
As seen in Figure-2 (a) two rectangular patches are placed on either sides of the microstrip feed line and these patches act as driven patches. Additional parasitic patches are gap coupled to the driven patches to enhance gain and bandwidth, along with dual band operation. The dimensions of parasitic patches and driven patches are same. The length and width of each radiating patches are designed for 2.45 GHz operation. The back side of the substrate has a metallic ground plane with a tapered arrow headed dumbbell shaped slot as shown in Figure-2 (b). The impedance matching of the array antenna can be improved by varying the length of the feed line. The optimized dimensions of the proposed single layer proximity fed gap coupled 4x1 microstrip patch array are given in Table-1 (units: mm).

The resonant properties of the proposed single layer proximity fed gap coupled 4x1 microstrip array configurations were predicted and optimized using electromagnetic field solver CST microwave studio. To verify our design methods prototype antenna has been fabricated and tested. The prototype of the proposed 4x1 array antenna is shown in the Figure-3.

(a)



(b)

Figure-3. Photographs of the fabricated proximity fed gap coupled 4x1 array antenna
(a) top view (b) bottom view.

Table-1. Dimensions of the proposed array antenna (units: mm).

G	3.5	S_{W2}	180	D_{L1}	40
f_w	3.02	S_{L2}	60	D_{L2}	18
C_G	1	P_W	33.5	D_h	32
P_L	27.6	D_W	4	S_{W1}	100

3. PARAMETRIC STUDY

A parametric analysis is conducted using CST microwave studio to optimize the parameters of the proximity fed gap coupled 4x1 array antenna and helps in understanding the effect of coupling gap C_g, on impedance band width and return loss.

Effect of coupling gap (C_g) between driven and parasitic patch

The gap between the driven and parasitic patches (C_g) was varied from 0.1 mm to 2 mm, keeping the other parameters at constant values.

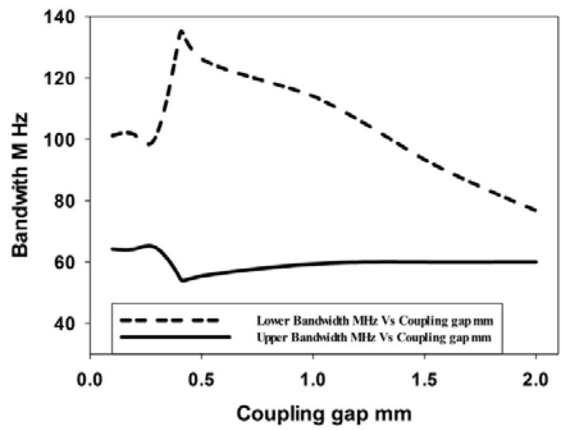


Figure-4. Variations of bandwidth with coupling gap.

Bandwidth variations of the dual band antenna for varying coupling gap are shown in Figure 4. It is observed that the significant variations were noted in the lower band. The lower bandwidth increases from 101 MHz to 133 MHz as the coupling gap varies from 0.1 mm to 0.4 mm and then it drops to 21 MHz as the coupling gap increase to 2.0 mm. The resonant frequency ratio (f_{r2}/f_{r1}) deviation that can be obtained from the study is from 1.423 to 1.465.

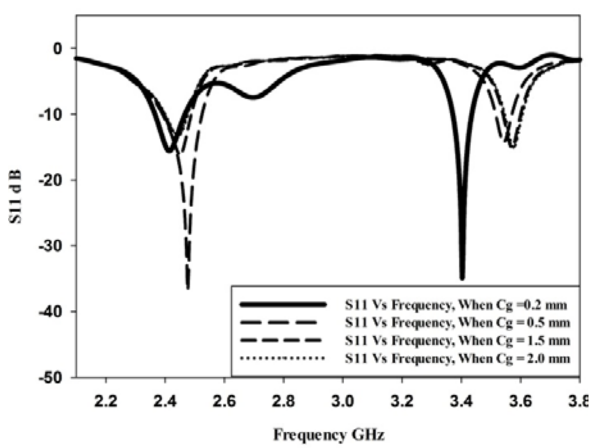


Figure-5. Variations of reflection coefficient with frequency for different values of coupling gap between driven patch and parasitic patch.

The effect of coupling gap between the driven patches and parasitic patches on return loss characteristics

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of the proposed proximity fed gap coupled 4x1 array antenna is illustrated in Figure. 5.

3.1 Surface current analysis

To understand the excitation mechanism more closely, surface current distribution obtained from CST simulation on both the resonant frequencies of the optimized proximity fed gap coupled 4x1 array antenna were studied. The Figure 6illustrates the current distribution on the array surface for the lower resonant frequency. From the analysis it is observed that at the initial stage large surface current was concentrated between the driven patches and microstrip line, and when the phase changes it can be observed that a large current is induced on both the parasitic elements and these two elements affects the coupling characteristics of the proposed 4x1 array antenna.

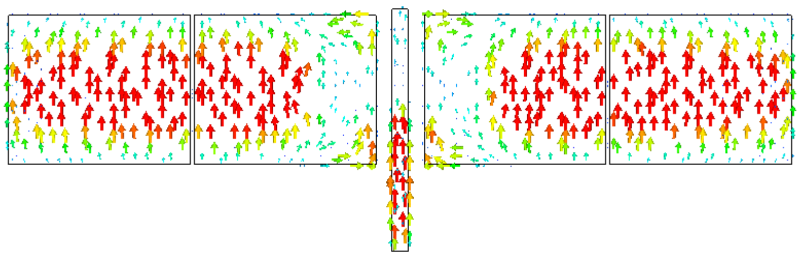

Figure-6. Simulated current distribution on the surface of proximity fed gap coupled 4x1 array antenna at lower resonant frequency.

The simulated current distribution on the array surface for the upper resonant frequency is illustrated in Figure-7. As seen in the Figure-7 surface current distribution is fully dominated across the feed line and driven patches region. Negligible amount of surface current flows along the parasitic patches. At higher resonant frequency only the driven patches are excited and their coupling suppression characteristics can be seen in the Figure-7.

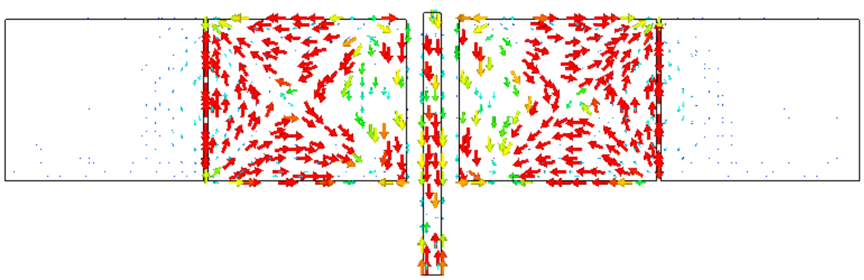

Figure-7. Simulated current distribution on the array surface of the proximity fed gap coupled 4x1 array antenna at upper resonant frequency.

4. RESULTS AND DISCUSSIONS

Figure-8 shows the measured and simulated return loss variations with frequency of the single layer proximity fed gap coupled 4x1 array antenna whose dimensions are given in Table-1. Measurements were carried out using Agilent network analyser E 5071C.

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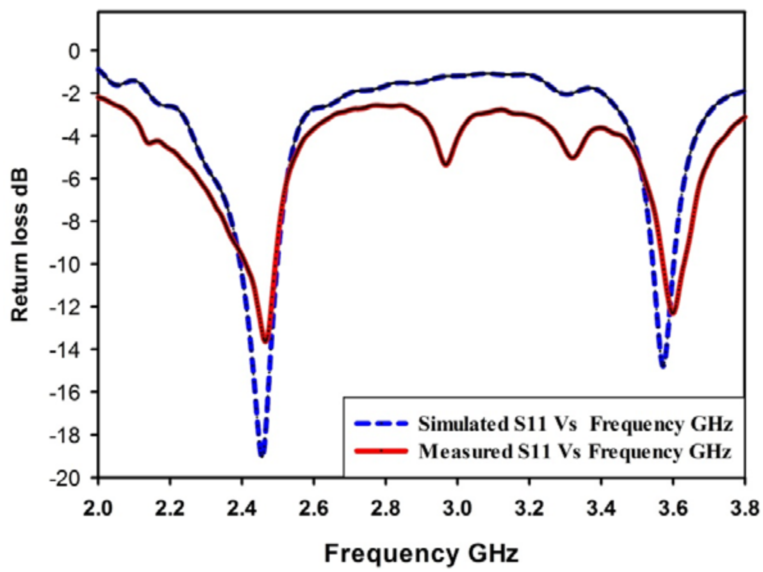

Figure-8. Measured and simulated return loss variation versus frequency of the single layer proximity fed gap coupled 4x1 array antenna.

From the return loss plot it is observed that proposed 4x1 array antenna is a dual band antenna. The simulated -10 dB impedance bandwidth of the array antenna for the lower band is 108 MHz (2.389-2.497 GHz) with center resonant frequency at 2.456 GHz and for the upper band is 61 MHz (3.543-3.604GHz) with resonance at 3.571GHz. While the measured -10 dB impedance bandwidth at the lower band is 114.2 MHz (2.378-2.492 GHz) or 4.64 % with resonance at 2.465 GHz and for the upper band the impedance bandwidth is 63 MHz (3.573-3.636 GHz) or 1.78 % with resonance at 3.608 GHz. The measured and simulated results show some difference, this may be due to uncertainty in thickness and/or dielectric constant of substrate and soldering effects of the SMA connector.The operating bands of the single layer proximity fed gap coupled 4x1 microstrip patch array is suitable for WLAN (2.45 GHz) and WiMAX (3.5 GHz) applications in portable devices.

Figures 9 and 10 illustrates the normalized co-polar and cross polar radiation patterns of the proximity fed gap coupled 4x1 array antenna in the E plane (y-z plane) and H plane (x-z plane) are plotted at the frequency of 2.465 GHz and 3.608 GHz respectively. At the lower resonance frequency (2.465 GHz) the maximum power was received by the antenna at the bore sight direction while at the upper resonance frequency (3.608 GHz) the maximum power was received at an angle of 39˚ with respect to bore sight on either sides. At upper resonant frequency presence of back lobe is noted which was not observed during simulation stages. The patterns show a front lobe to back lobe ratio of 11 dB at the center frequency. The 3 dB beam-width in E plane at the two resonant frequencies (f = 2.465 and 3.608 GHz) are 31^0 and 45^0 respectively. Similarly the 3 dB beam-widths in H plane at the two resonant frequencies are 95^0 and 85^0 respectively. The upper band characteristics are suitable for non-line of sight applications including WiMAX.

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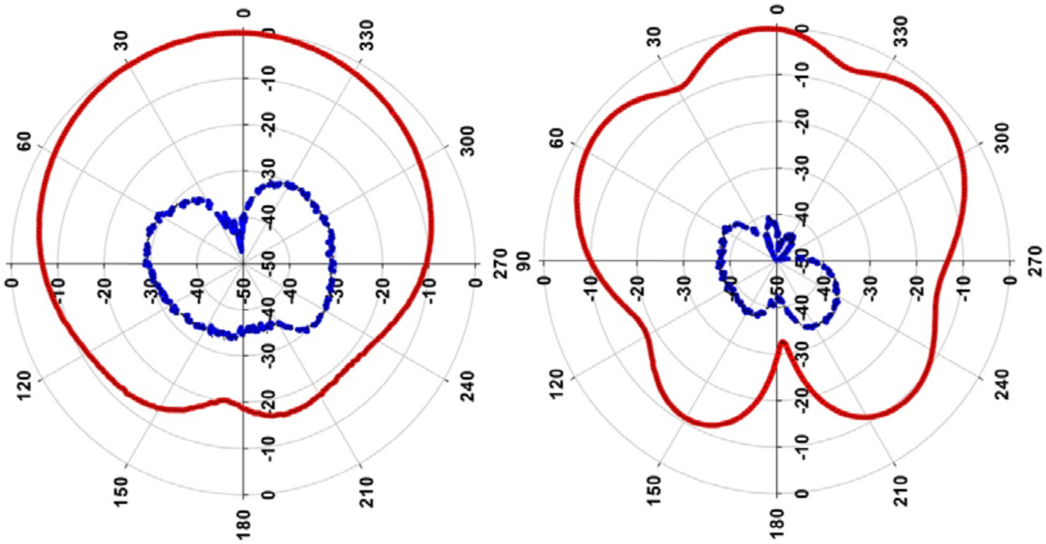
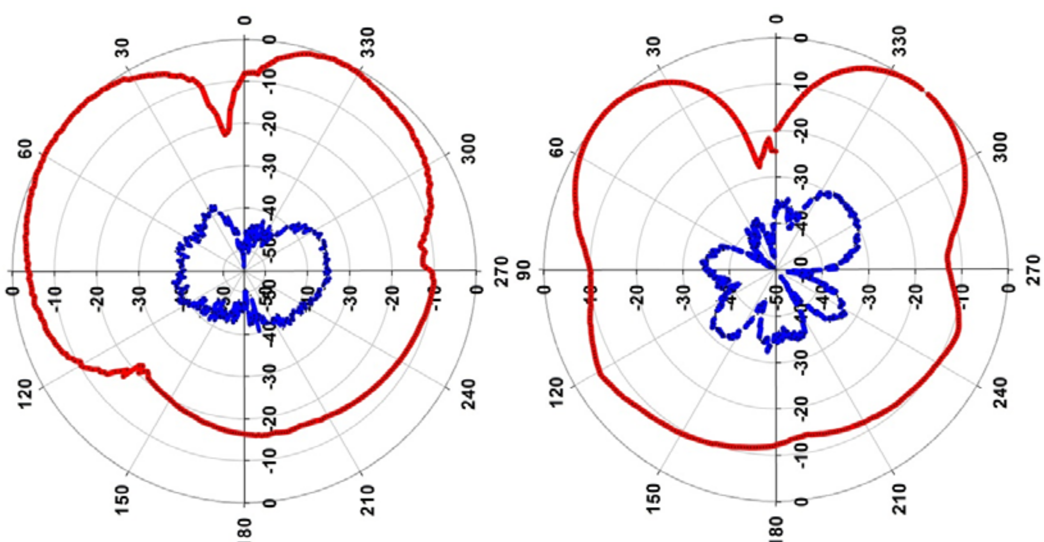


(a) y-z plane (b) x-z plane.

Figure-9. Normalized radiation patterns of the antenna at lower resonant frequency of 2.465 GHz. (a) E plane (b) H plane (co-polarized, _____ solid line and cross polarized, ………….dashed line).



(a) y-z plane (b) x-z plane.

Figure-10. Measured normalized radiation patterns of the antenna at upper resonant frequency of 3.608 GHz. (a) E plane (b) H plane (co-polarized, _____ solid line and cross polarized, …… dashed line).

A comparison between the developed proximity fed gap coupled 4x1 array and basic 2x1 array antennas are given in the Table-2. From the Table it is clear that the developed proximity fed gap coupled 4x1 microstrip array antenna operates in dual band with enhanced bandwidth and gain.

Table-2. Comparison between the proposed array configurations.

Measured parameters	Basic 2x1 array antenna	4x1array antenna	
Number of bands	Single band	Dual band	
Resonant center frequency GHz	2.792	2.465	3.608
Return loss dB	-28.204	-19.89	-15.84
Bandwidth MHz	56	114.2	63.0
Gain dBi	6.65	8.85	6.57

For the proximity fed gap coupled 4x1 array antenna the measured gain is 8.85 dBi at the lower resonant frequency and 6.57 dBi at the upper resonant frequency. It is also observed that in the case of 4x1 array antenna the bandwidth in the lower band is enhanced by 108 % and the gain is increased by 2.2 dBi when compared to basic 2x1 array antenna. The operating band of the proximity fed gap coupled 4x1 array antenna make it suitable of 2.45 GHz (WLAN) and upper band can be used for 3.5 GHz (WiMAX) applications.

5. CONCLUSIONS

A novel single layer proximity fed 2x1 microstrip patch array with a pair of radiating patches is presented as the basic antenna configuration. Additional parasitic patches are gap coupled to the driven patches of the basic configuration to enhance the bandwidth and gain. The proposed proximity fed gap coupled 4x1 array antenna shows dual band characteristics and is useful for WLAN and WiMAX applications. The radiation characteristic of the antenna makes it suitable for applications in portable wireless devices.

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