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Enhancement of bandwidth for Design of wideband Microstrip Antenna for 4G Applications

Salil Naik[1], Denzyl Fernandes[1], Saahil Dessai[1], Rajat Gawas[1], Shreeyank Jambhale[2], Dr.Shailendra Aswale[3]

[1] Students from Electronics and Telecommunication Engineering Department, Shree Rayeshwar Institute of Engineering and Information Technology
[2] Assistant professor, Electronics and Telecommunication Engineering Department, Shree Rayeshwar Institute of Engineering and Information Technology
[3] Principal, Shree Rayeshwar Institute of Engineering and Information Technology

Abstract— Technological developments in telecommunications, particularly wireless technologies, are evolving very rapidly. Compact mobile devices require low profile antennas to reduce the overall size of the device. The basic geometry of a Micro Strip Patch Antenna (MSPA) consists of a metallic patch printed on a grounded substrate. The MSPA offers the advantages of low profile, lightweight, low cost, robust, ease of fabrication, and compatibility with IC technology, but the basic geometry suffers from narrow bandwidth. In order to enhance the bandwidth of the antenna, one of the methods is adding parasitic elements. The 4G/LTE applications use frequency bands 850 MHz, 900 MHz, 1800 MHz, and 2300 MHz; therefore, an alternative to support all these bands in one antenna is to design a wideband antenna. The antenna design uses FR4 substrate with dielectric constant of 4.6, Partial Ground plane, feed line, patch, and parasitic element. This paper reviews the design of wideband MSPA, which is used for mobile communication, especially for 4G/LTE applications.

Keywords— MicroStrip patch Antennas (MSPA), wideband antenna, FR4 substrate, parasitic element, omnidirectional and Directional radiation pattern

I. INTRODUCTION

An antenna is a metallic device that converts Radio Frequency (RF) into Alternating Current (AC) or vice versa [1].MSPA is a crucial building in wireless communication and Global Positioning System (GPS). It was first demonstrated in 1866 by Heinrich Hertz and its practical application by Guglielmo Marconi. However, due to its small size, patch antennas face disadvantages in terms of bandwidth, gain, and power handling. The complexity of MSPA has increased due to the inherent correlation of the dielectric materials used, aperture coupling. For wireless communication such as WLAN and Bluetooth, the operating frequency is in the range of 2.4-2.47 GHz. Hence the antenna needs to have a slightly more-full bandwidth to enable it to capture more signals [2]. The fast development in wireless telecommunications technology demands the use of multiple frequencies in one device, for example, in 4G applications. The development of 4G technology in India is expected to improve the technology that already exists. However, one of the obstacles faced is the lack of regular communication on a first frequency band that can be used for the application of this technology. Also, the main reasons for slow 4G speed in India are coverage issues. Due to

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congested networks, the speed of 4G is slow in metro cities. The application of 4G technology in India is still using a frequency allocated to GSM and 3G frequency band that uses a frequency band of 850MHz, 900MHz, 1800MHz, and 2300MHz. It requires an antenna that has a working frequency in the desired range. With these characteristics, the implementation of the antenna, in the field of mobile communications, especially for the application of 4G / LTE on the Global System for Mobile communication (GSM) and 3G networks. The requirements for high mobility wireless communication are antennas with broader bandwidth, smaller size, and lighter than a conventional antenna size. MSPA is one of the most suitable candidates for this purpose because they are low profile, lightweight, low cost and easy to fabricate.

However, the underlying geometry of MSPA suffers from 3 main disadvantages: 1) narrow bandwidth, 2) small gain [3]. To enhance the bandwidth of the antenna, one of the methods is adding parasitic elements [4]. The gain of the antenna can be increased using antenna arrays, and size can be reduced using multi-layer stacked structures. There are also several research and designs that discuss wideband MSPA working at a particular frequency. However, the authors have not found any research and design that presented for 4G applications that work at a frequency from 800MHz up to 2400MHz [5-7]. This paper discusses wideband MSPA design that can operate in the frequency range, which includes 850 MHz, 900MHz, 1800MHz, and 2300MHz for 4G applications.

The paper is ordered as follows: Section II outlines the literature review where basic characteristics, design formulas, ground dimensions, feeding techniques, and applications of MSPA are discussed briefly. Section III presents the proposed approached, where the methodology used in the model is discussed. Section IV concludes the paper.

II. LITERATURE REVIEW

A. Basic Characteristics

Various features that are common to the underlying geometry of the MSPAs, irrespective of the shapes of the patch.

1) There is an infinite number of resonant modes in MSPA; the resonant frequency of each mode is governed by the size and shape of the patch, the relative dielectric constant of the substrate, and the thickness of the substrate. For example, if the patch is a rectangular shape with dimensions a and b, the resonant frequencies are given by

$$fmn=(kmn\times c)/2\pi\sqrt{\varepsilon r} \quad (1)$$

Where,

$$kmn = [(m\pi/a)2 + (n\pi/b)2]1/2 \quad (2)$$

2) Because of fringing fields at the edge of the patch, the patch behaves as if it has a slightly larger dimension.

3) Each resonant mode has its characteristic radiation patterns. The customarily used modes are (1, 0) or (0, 1) modes. Both radiate strongest in the broadside direction. The patterns are broad, with half-power beam widths of the order of 100. The gains are typically 5dB. Polarization is linear. With appropriate design, circular polarization can be achieved by utilizing two modes.

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4) For coaxial-fed antennas, the input impedance is dependent on the feed position. For the basic MSPA geometry, the impedance bandwidth is limited to about 5%.

5) For the coaxial feed case, by choosing the feed location properly, the resonant resistance can be matched to the feed line resistance, while the use of thin substrates minimizes the feed inductance at resonance, resulting in a voltage standing wave ratio (VSWR) very near unity as the frequency deviates from resonance, the value S increases.

6) For linear polarization, impedance bandwidth is the range of frequencies for which S is less than or equal to two, corresponding to about 10 dB return loss.

7) The loss in the cavity comprises radiation, copper, dielectric, and surface wave losses. For thin substrates, a surface wave can be neglected.

8) For antennas, thick substrates having low relative dielectric constants are preferred because they can provide higher bandwidth, higher efficiency, and freely bounded electromagnetic fields for radiation into free space; however, the patch size increases which is to be tolerated.

9) Thin substrates having high dielectric constants are preferred for microwave circuits (other than antennas). The reason being that microwave circuits require closely bound EM fields to suppress unwanted coupling and radiations. Thus they also reduce the size of the circuit, but their losses are much higher, efficiency is low and small bandwidth [8].

B. Design Formulas:

Design formulas to calculate dimensions of rectangular MSPA. The width of the rectangular MSPA is as follows [9]:

$$W= c/2\ fr[2/(\varepsilon r+1)]\ 1/2 \quad (3)$$

Effective dielectric constant is given as:

$$\varepsilon reff= (\varepsilon r+1)/2 + (\varepsilon r-1)/2[1+ (12h/W)]\ 1/2 \quad (4)$$

The length extension is given as:

$$\Delta L=0.412h \times [((\varepsilon r+0.3)(W/h+0.264))/((\varepsilon r-0.3)(W/h+0.8))] \quad (5)$$

The actual length is given by:

$$L=c/(2fr\sqrt{\varepsilon reff}) - 2\Delta L \quad (6)$$

Ground dimensions:
For practical contemplation, it is essential to have a finite ground plane if the size of the ground plane is found to be greater than the patch dimensions by approximately six times the substrate thickness all around the periphery.

$$Lg = 6h+L \quad (7)$$

$$Wg = 6h + W \quad (8)$$

Feeding techniques:
1) Coaxial Feed: In this arrangement, the inner conductor of a coaxial connector extends through the substrate. It is attached to the radiating patch, and the outer conductor is attached to the ground plane. The location of the feed pin provides the best impedance match. The pros of this method are easy to fabricate. The cons are that it suffers from small bandwidth and false radiation.

2) Edge Feed: In this arrangement, a conducting strip is connected directly to the edge of the MSPA. It has the advantage of being photo etch processed along with the patch itself, thus having low manufacturing cost.

3) Aperture Coupled: In this arrangement, a ground plane is merged between two layers of the substrate material that separates the radiating patch layer. Accompany between the feed line and the patch is made using a slot or an aperture in the ground plane. Aperture coupled elements in the past have shown bandwidths up to 10-15% with a single layer and up to 30-45% with a stacked patch arrangement.

4) Proximity Coupled: In this arrangement, the whole antenna consists of a grounded substrate where an MSPA feed line is pinpointed. On top of this material is another dielectric layer with an MSPA etched on its top surface. The proximity-coupling method provides 13% bandwidth, which is the largest of all four feeding methods.

C. **Applications:**

1) GPS: MSPA having high permittivity sintered substrate material for GPS. These antennas are circularly polarized and very compact.
2) Radar: It is used for detecting moving targets such as people and vehicles. It utilizes a low profile, lightweight antenna system. The fabrication technology is based on photolithography that enables the bulk production of MSPA with better performance at a lower cost and at a lesser time frame.
3) Mobile and Satellite Communication System: Mobile communication requires a small, low profile, low-cost antenna. MSPA meets all the necessities, and several MSPA has designed for use in a mobile communication system. In satellite communication, circularly polarized radiation patterns are mandatory and can be perceived by utilizing square or circular MSPA with one or two feed points moreover.
4) Radio Frequency Identification (RFID): It is used in areas like mobile communication, logistics, manufacturing, transportation, and health care. RFID system generally uses frequencies between 29 Hz and 5.8GHz depending on its application.
5) Medical Application: It is found that in the treatment of malignant tumours, the microwave energy is said to be the best way of prompting hyperthermia. The radiator, which is to be used for this purpose, should be lightweight, comfortable in handling, and to be rugged.
6) Reduced Size MSPA for Bluetooth Application: In this, the MSPA operates in the 2400 to 2484MHz ISM band. Although an aired substrate is introduced, MSPA occupies a small volume of 33.3mmx6.6mmx0.8 mm [10].

D. **Reviews of wideband MSPA**

There are many surveys/reviews of MSPA, as mentioned [11-20]. However, the below paper highlights recent MSPA design approaches.

The finite difference time domain method helps to find the frequency dependence of relevant parameters of an MSPA. Information on the resonance mode can be found by plotting the spatial distribution of the current density [11].

The aperture-coupled configuration also exhibits shallow cross-polarization levels, making it well suited to circularly polarized antenna designs. The aperture-coupled MSPA can generally be impedance matched with an aperture that is well below resonant size. A quarter wavelength section of the transmission line in place between each aperture to create the 90degree phase difference required for circular polarization [12].

The paper presents a number of designs for small size wideband MSPA. The addition of the sorting wall between the conducting patch and the ground plane can be accomplished by increasing the dielectric constant of the microwave substrate material [13].

The slot matching concept is introduced in the design of a compact patch antenna — four frequency bands in the range from 2 to 5 GHz. Return loss is achieved less than -9.54db, and vice VSWR is less than or equal to 2 [14].

This paper focuses on two techniques to improve the bandwidth and gain of MSPA. Improvement of the bandwidth can be made by shorting pins, manipulation of substrate parameters, and the use of slots in the patch could be used; shorting pins are also able to reduce the dimension of the patch antenna. Gain can be enhanced by using resonators or parasites [15].

In this MSPA is used because they are low profile, conformal to the planar and non-planar surface, simple and low price to manufacture using modern printed circuit technology. The antenna is its inherently narrow impedance bandwidth. Software used is a soft designer V-2.2.0; it is used to calculate and plot return loss, VSWR, radiation pattern, smith chart, and various other parameters [16].
This paper introduces the design and simulation of wideband operating frequency E-shape MSPA for wireless applications. Several applications like remote sensing, biomedical, mobile radio, and satellite communication use E-shape MSPA. It is simulated using HFSS (High-frequency structure simulator) version 11 software. Coaxial feed or probe feed is used in this experiment [17].

A wideband circularly polarized, single-feed, stacked square slotted MSPA has been presented for RFID reader applications. For proper impedance matching and impedance bandwidth, a Microstrip stub was added at the radiating edge of the lower square slotted MSPA. It was found that the impedance matching and axial ratio of the antenna can be tuned by adjusting the radius and location of the slot on the lower square slotted MSPA [18].

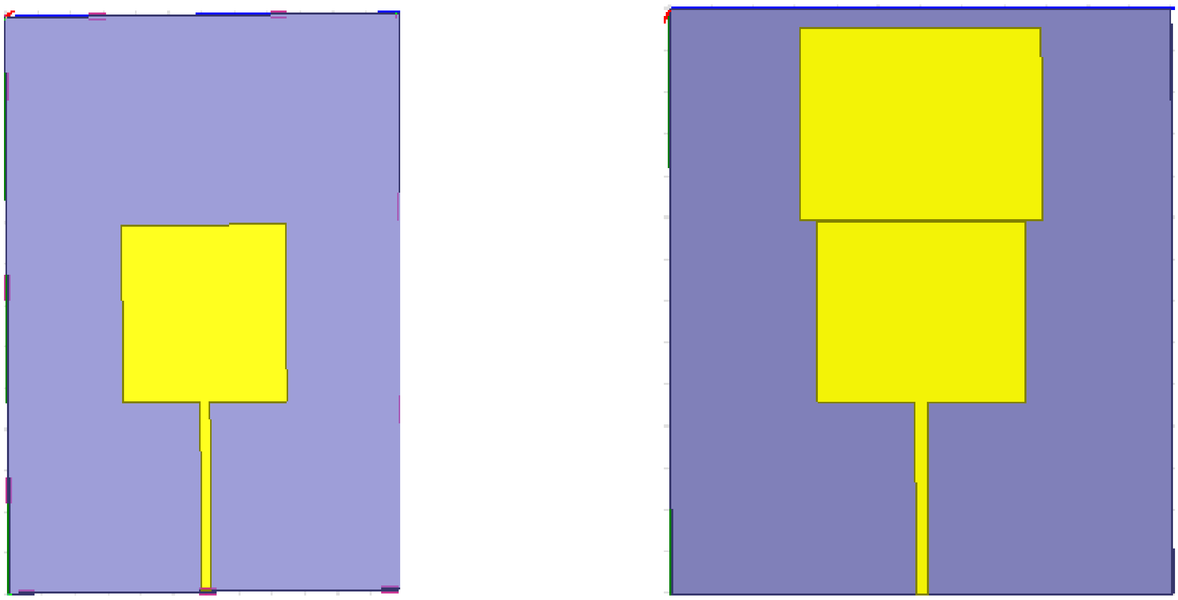
A double g textile CPW monopole antenna design for dual-band WLAN applications is proposed. This novel "double G" antenna is usable in wearable Wi-Fi (2.4GHz-2.484GHz) and (5.15GHz-5.87GHz) and 4G LTE (2.5GHz-2.69GHz) systems. The double G antenna exhibits monopole behavior with an omnidirectional H-plane cut. At 2.5GHz, return loss is about -15db with 1GHz bandwidth. At a higher resonance frequency of 5.5GHz, return loss is lower than -20db with a 1.5GHz bandwidth. It is desirable to make a textile antenna conformable and as non-obstructive as possible since it is meant to be attached to or integrated with user's clothes. The antenna bends along with the clothes while still maintaining its functionality when the user moves. However, the antenna performance is degraded due to changes in antenna shape. CST Microwave Studio software is used. The final antenna dimensions are 60mm*30mm (length*width). The double G antenna is flexible, low cost, compact size, and easy to integrate into garment [19].

This paper proposes the design of MSPA to minimize the polarization mismatch. It consists of a circular radiating patch and multiple parasitic elements. The number, length, and angular positions of the parasitic elements are adjusted to vary the antenna polarization. Multipath effects can reduce polarization [20].

III. METHODOLOGY

3.1. Antenna Design

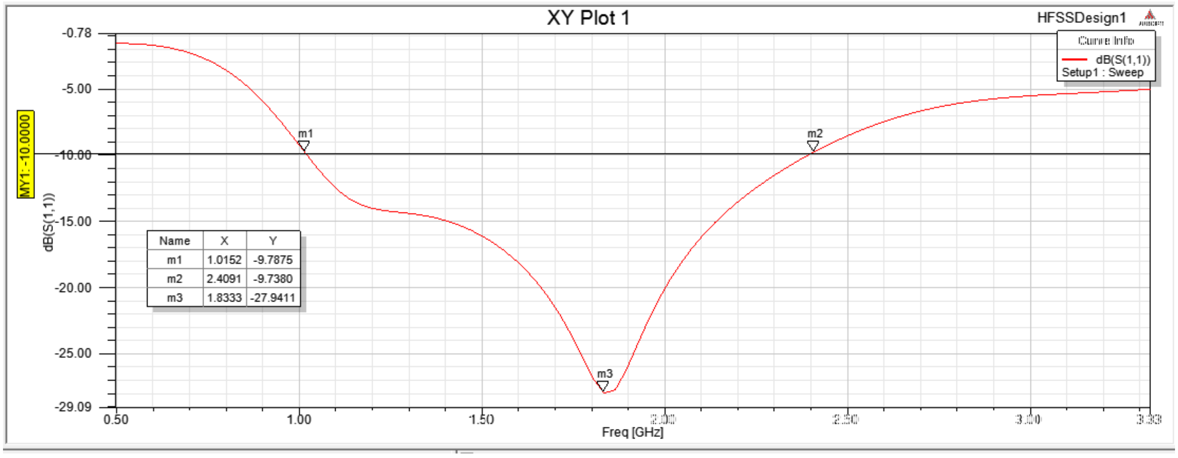
The proposed antenna is a rectangular Microstrip antenna. The antenna design uses a FR4 substrate with a dielectric constant of 4.6. The antenna design is performed using an Ansoft High Frequency Structure Simulator. In order to achieve the desired bandwidth from 800MHz to 2400MHz, one parasitic element is added in the design with a partial ground plane at the bottom of the substrate. Addition of parasitic element will provoke the bandwidth to be wider than the antenna with no parasitic element. The proposed antenna design will have a simple and manageable structure with a small size of approximately 140mm x 120 mm. It will consist of the patch and parasitic element at the top plane similarly ground plane at the bottom of the substrate.



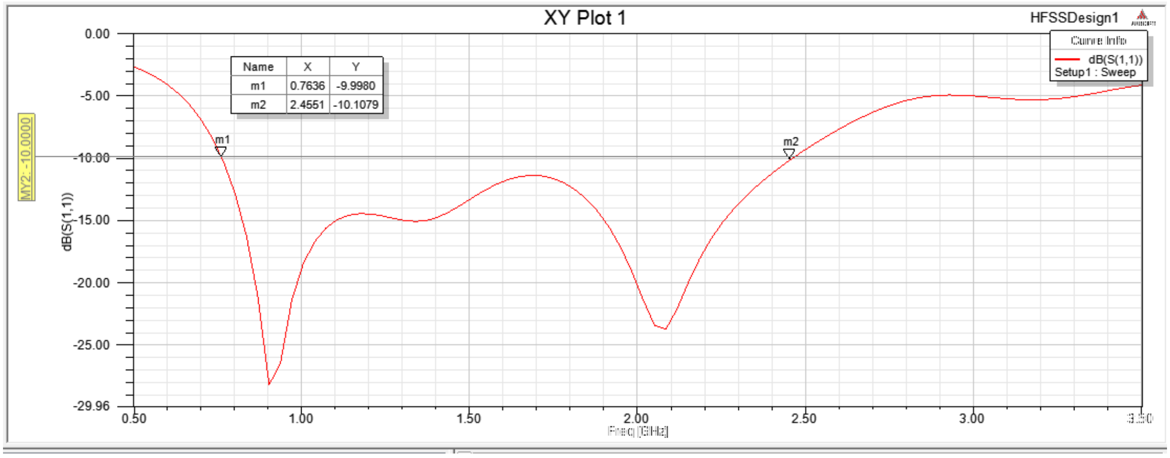
(a) (b)

Fig 1: Design evolution of (a) An Antenna without parasitic element, (b) An antenna with parasitic element

Fig 2 shows the return loss graph S11 of an antenna with no parasitic element and antenna with one parasitic element in the design. The bandwidth of the antenna is determined by the area bounded by the working frequency of reflection coefficient < -10dB. From Fig 2(a) it can be seen that this antenna has the working frequency of 1015MHz to 2409MHz. In other words, this antenna has a bandwidth of 1394MHz.Whereas in fig 2(b) antenna with one parasitic element has the working frequency of 764MHz to 2455MHz. This antenna excites the bandwidth of 1691 MHz which covers the frequency range of 4G LTE bands.



(a)



(b)

Fig 2: Return Loss simulation results of the antenna (a) Antenna with no parasitic element, (b)Antenna with one parasitic element

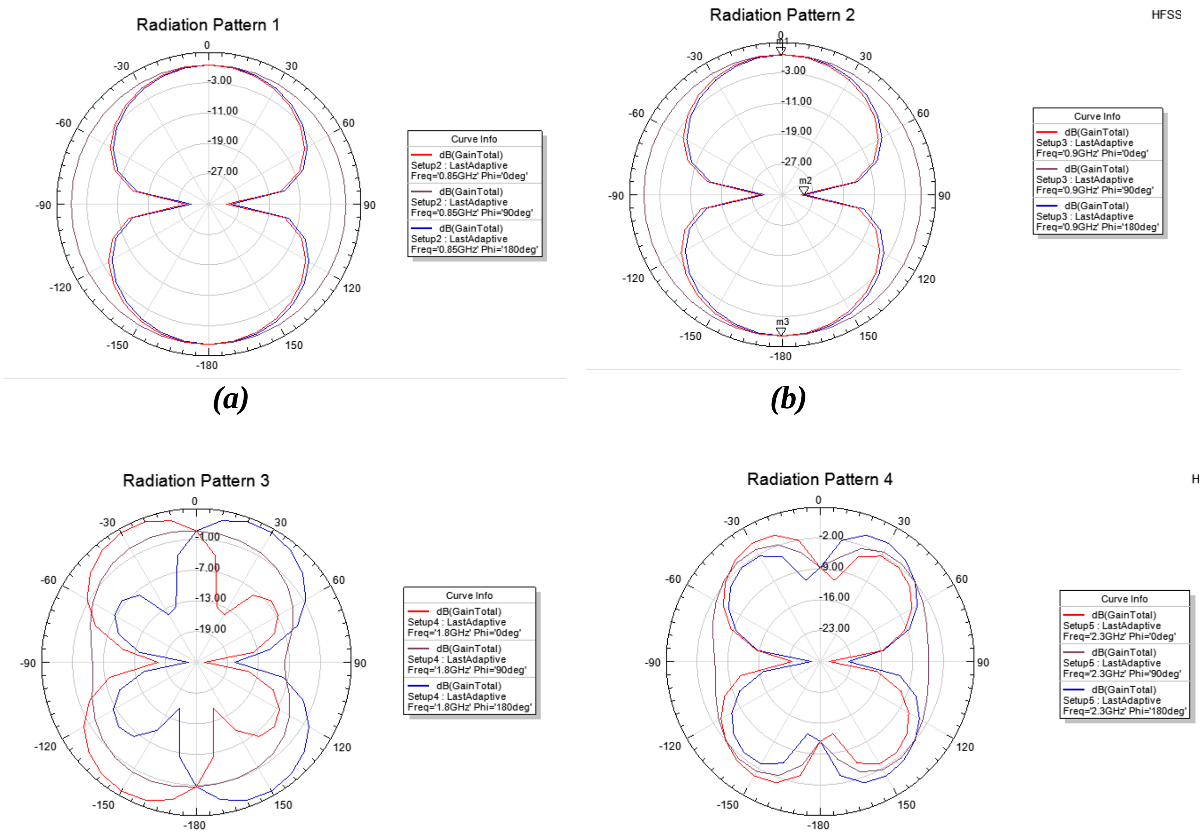
3.2 Design Calculations

The dimensions of the simulated antenna are as follows

Parameters	Dimensions (mm)
Patch Length (L)	43
Patch Width (W)	50
Feed length (Lf)	46
Feed width (Wf)	3
Ground length (Lg)	140
Ground width (Wg)	43
Parasite length (Lp)	46
Parasite width (Wp)	58
The gap between the patch and parasite	0.5
Substrate Thickness	1.6
Substrate length (Ls)	140
Substrate width (Ws)	120

3.3 Radiation pattern and gain of the simulated antenna

The radiation pattern for the proposed antenna was also simulated and shown in Fig.3.The simulation of radiation pattern for frequency 850MHz, 900MHz, 1800MHz and 2300MHz is proposed. Frequency 850MHz and 900MHz was closer to the Omnidirectional radiation pattern whereas frequency 1800MHz and 2300MHz approaching Directional radiation pattern.



(a) *(b)*

(c) *(d)*

Fig 3: Radiation of proposed antenna (a)850MHz (b)900MHz (c)1800MHz (d)2300MHz

IV. CONCLUSION

Enhancement of the bandwidth for the design of wideband Microstrip antenna for 4G application has been proposed. The Microstrip antenna with adding one parasitic element has an operating frequency from 764MHz up to 2455MHz and has a bandwidth of 1691MHz. At lower frequency antenna radiates in omnidirectional whereas at higher frequencies it radiates in a directional pattern. With this simulated results, the antenna can be used for various 4G applications.

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