

LTE and GPS based Deca Band Printed Antenna for Cellular Mobile Handset Communication Applications

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ABSTRACT

This paper presents novel mobile phone antenna for radiations simultaneously in ten frequency bands for applications of LTE (Long-Term Evolution), GPS (Global Positioning System), GSM (Global System for Mobile Communications), PCS (Public and Commercial Services), DCS (Distributed Control System), UMTS (Universal Mobile Telecommunications System) and WiMAX (Worldwide Interoperability for Microwave Access). The antenna demonstrates novel characteristics for resolving the challenge of simultaneous radiation capabilities for the GSM and GPS applications with frequencies of 850/900 and 1575 MHz respectively, along with resonances at frequency band of 700 MHz for LTE applications, 1800 and 1900 MHz for PCS and DCS applications, 2100 MHz for UMTS applications, 2400 and 2500 MHz for LTE applications and 3300 MHz for WiMAX applications with $S_{11} = -6$ dB matching criteria (VSWR 3:1). The antenna architecture comprises top and bottom copper layers embedded with monopole radiating element, branch line, slots and various stub lines. The desired operating bands are achieved in a compact area with overall dimensions of 0.8x60x120 mm for the height, width and length respectively of the antenna providing suitable platform for mobile handset applications. Omni-directional radiation pattern characteristics are achieved throughout the range of frequencies by designing the proposed antenna in monopole configuration. Proposed antenna is fabricated and results for the surface currents, s-parameters and 3D (Three-Dimensional) gain plots are illustrated for the proof of concept.

Key Words: Mobile Handset, Printed Antenna, Multiple Frequency Antenna, Long-Term Evolution.

1. INTRODUCTION

LTE provides the essential and far reaching vital solutions for wireless communication systems and mobile handheld applications. It provides high speed internet along with broader bandwidth and high throughput. During its initial stages in Europe, LTE has been assigned 1.8 and 2.6 GHz Bands. Currently due to the increase in the necessity of additional bandwidth the 790-865 MHz band has been added to the LTE

Operating system. With these improved system performance characteristics, LTE is also implemented in mobile handheld devices for wireless communications.

LTE based systems for wireless communications and data transfer through electromagnetic waves can be implemented by designing antenna elements supporting resonances for the LTE frequency bands. Microstrip line

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with rectangular tuning stub for excitation can be designed for TRI band coverage of LTE bands of 758-865, 1510, 1940 and 2488-2740 MHz [1]. Multi band with Dual Polarization is proposed [2], in which antenna system is a combination of six printed dipoles with vertical and horizontal polarization characteristics. A compact structure is formed by nesting the HP (Hewlett-Packard) elements between two cones of the VP element. WCDMA (Wideband Code-Division Multiple Access), CDMA800 and GSM900 are achieved with a vertical polarization segment, whereas with the combination of vertical and horizontal polarization elements the system can be operated for LTE bands. Dual bands of WLAN (Wireless Local Area Network) 802.11a/b/g operated at 2.4-2.4835/5.15-5.875 GHz and TD-LTE operated at 1.880-2.655 GHz are achieved by designing microstrip fed antenna and incorporating a rectangular slot, symmetrical inverted L-shaped metallic segments, a defected ground plane layer and fork shaped strip is illustrated in [3]. C-shaped metallic ground plane and loop parasitic shorted metallic strips are used to achieve LTE/WWAN multiband operation in mobile phone is presented in [4].

Combination of the two metallic segments generates multiple resonant modes in the 750-940 MHz resonant band with 0.25 wavelength frequency modes at 750-940 MHz band to cover the GSM and LTE frequency bands. For meeting the requirement of multipurpose wireless communication systems with operating bands of GSM at 800 and 900 MHz and LTE bands of 2300 and 2500 MHz, single antenna system with multiband characteristics is developed in [5], configured with monopole metallic element and coupled ground plane feeding line. Expedited development of mobile communication technologies has increased the demand on the design of wireless communication systems, where antennas for indoor wireless system are required to operate at multiple bands simultaneously. In this conjecture antenna is designed in

[6] with single port design for two different frequency bands of 800-960 and 1700-2700 MHz on printed circuit board technology for LTE applications, with return loss value of -14 dB for both resonances. Slot meander patch technique is used to construct various antennas [7], to achieve multiple resonant frequencies for LTE TDD applications and by inculcating unequal meander line dimensions compared to equal meander lines, the antenna efficiency is increased. Channel capacity and data transmission rates are increased in the future and emerging wireless communication systems by incorporating MIMO (Multiple Input Multiple Output) technology [8]. For LTE and WiFi applications MIMO antenna system is developed in [9], with printed modified rectangular monopole radiators constructed with wideband strip lines. For radiation in six different frequency bands, tri-resonant mode antenna is designed in [10], having dual metallic stubs of L and U shaped stubs, with one stub used as parasitic radiation element and the other one consists of a metallic feeder embedded as a transmission line.

For multiband radiations covering LTE and GSM applications, various designs are proposed for compact handheld mobile devices. Three arrays are used for beam steering for 5G (Fifth Generation) mobile wireless communication by switching between the arrays [11]. MEMS (Microelectromechanical Systems) based on a concept of tunable capacitor can be used for implementation of reconfigurable antenna with frequency selectivity for fourth generation LTE configured mobile terminal applications [12]. Printed antenna for radiation in seven bands can be designed using loop element based radiator for the mobile phone applications utilizing circuits based on matching chip capacitors [13]. Mobile phones are designed with metal frame radiator element for LTE frequency bands using matching circuits and band pass filter [14]. To design the mobile antenna for multiband characteristics for simultaneously making WiFi and LTE

applications operational, reconfigurable radiating element is also designed for selecting the frequency bands with slots embedded along with bandpass filter [15]. Metal rimmed architecture is used for radiations in LTE and GSM applications with three section configuration and inverted F radiating segments for proper radiation characteristics in the desired multibands [16].

Wireless communications for the LTE applications required wide bandwidth requirements that can be achieved by using metal bezel configuration along with monopole radiator for merging various eigen-modes [17]. Eight multibands can also be excited by using various branched lined parasitic ground segments along with T-shaped radiating elements in monopole antenna configuration for smart phone applications [18]. Next generation mobile phone systems require high speed data transfer along with enhanced channel capacity and mitigation of multipath fading, that can be achieved by implementing dual polarization capabilities using multiple loop radiator elements [19]. Mobile phone for broadband future services at 3.5 GHz is designed with dual asymmetrically mirror loop antennas with MIMO eight element array compact size characteristics [20].

Various mobile phone antennas for wireless communication applications design parameters comparison along with the proposed antenna design is summarized in Table 1.

In this paper, compact printed antenna is proposed to support simultaneous radiations in ten frequency bands for applications of GPS, GSM, LTE, UMTS, DCS, PCS and WiMAX suitable for mobile handheld applications. The lower frequency bands of LTE 700, GSM 850, and GSM 900 and upper frequency bands of DCS 1700, PCS 1800 UMTS 2100, LTE 2400, LTE 2500 and LTE 2700 are achieved and inculcated in antenna system. The antenna system consist of top and bottom radiating layers with multiple metallic line segments configured with optimized dimensions in accordance with the desired bands.

2. ANTENNA DESIGN

The multiband planar printed antenna is developed on printed circuit board for mobile handsets applications as shown in Fig. 1. The antenna consists of top and bottom copper layers separated by substrate middle layer. Substrate used for the proposed antenna is FR4, having dielectric constant of 4.4 and height of 0.8 mm. As seen from the Fig. 1, the top layer consists of radiating element that is fed from the bottom side from a feeding transmission line. Substrate middle layer size is of 120x60 mm with the bottom layer consisting of ground plane with size of 105x60 mm and several line segments and slots providing multiband resonant characteristics for the proposed antenna.

TABLE 1. COMPARISON OF MULTI- BAND GSM, WIMAX, LTE AND GPS CELLULAR ANTENNA WITH THE LITERATURE

References	Frequency (MHz)	No. of Bands	Applications
Wang and Cai [13]	850/2100/2300	7	WWAN/LTE
Chen and Zhao [14]	700/2100	2	LTE
Soltanpour and Fakharian [15]	2100/2400	2	WiFi/LTE
Liu et. al. [16]	900/2100/2300	7	GSM/LTE/WLAN
Tang and Du [18]	700/850/2300/2500	8	LTE/GSM
Wong et. al. [20]	3500	1	MIMO
Proposed Work	700/850/2500/3300	10	GSM/GPS/LTE/WiMAX

The detailed dimensions of the LTE and GPS based radiator illustrating the various slots and stubs embedded in the top and bottom layers are presented in Fig. 2, where the top and bottom layer details are demonstrated in Fig. 2(a-b) respectively. Microstrip line directly feeding the monopole strip comprises of two segments, where each segment is designed with constant uniform width, and individual responses are optimizing in terms of radiation characteristics and antenna efficiency. Line segment of 1.5 and 56.5 mm width and length respectively is embedded in the top layer for radiation of LTE 700 MHz frequency band. The feed line is designed to match the overall response of multiband printed antenna. The details of the slots and lines embedded in the bottom layer is shown in Fig. 2(b), with the ground plane width optimized at 60 mm. Various line segments with optimal values of 18, 23 and 24.50 mm respectively are optimized for achieving the desired frequency bands for WiMAX, LTE and GPS applications.

The top Layer consists of the radiating element with length of 56.5 mm which is optimized to obtain the lower band 900 MHz. The bottom layer consists of multiple

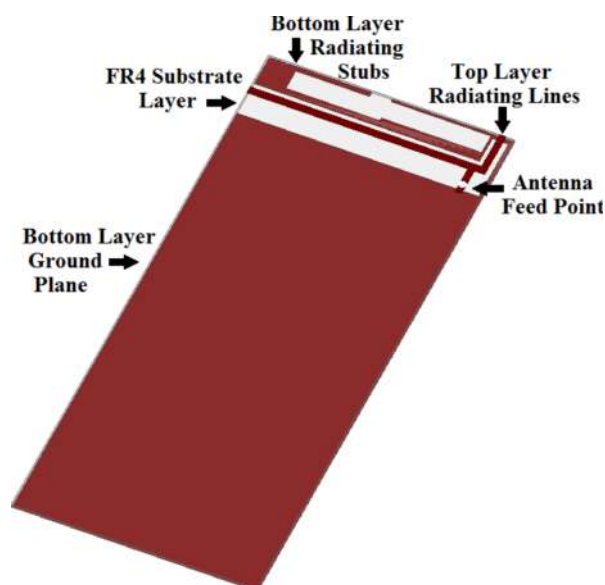


FIG. 1. PROPOSED GPS AND LTE BASED CELLULAR ANTENNA LABELED ARCHITECTURE

slots to inculcate the rest of the frequencies, while line segments are introduced at bottom layer for controlling desired response and high performance. Length of line segments 6, 4 and 5 are optimized at 7, 23 and 18 mm respectively. The feed of length 6 mm with width of 1.50 mm is designed on top layer. Parametric analysis is performed for optimized values of the LTE and GPS based cellular planar antenna. The complete detailed labeled dimensions of the proposed multiband printed antenna are demonstrated in Table 2.

3. SIMULATION AND ANALYSIS

The LTE and GPS based cellular planar antenna is optimized designed and analyzed in CST Microwave Studio. Discrete port of 50 ohms is connected to the feeding line for the excitation of the radiating structure.

The radiator element is optimized for GPS applications with its second band centered at 1575 MHz while the higher frequency band for LTE is optimized at 2500 MHz. The proposed radiator element is embedded with

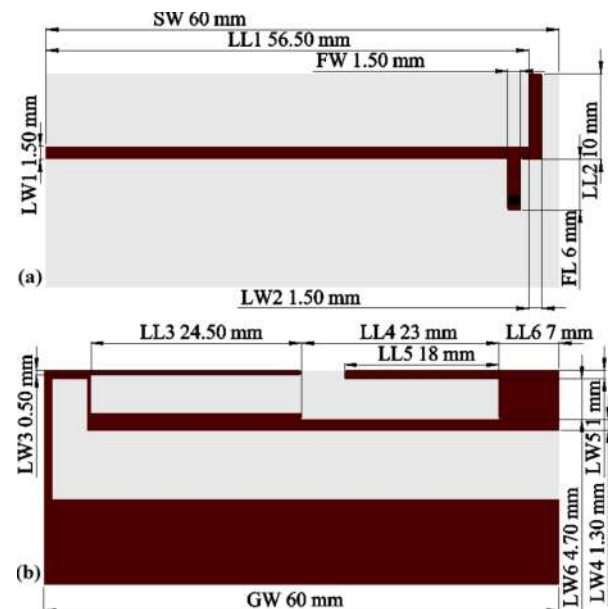


FIG. 2. DETAILED DIAGRAM OF THE GPS AND LTE CELLULAR PHONE ANTENNA ILLUSTRATING DIMENSIONS FOR (a) TOP, AND (b) BOTTOM LAYER

various slots and stubs for providing radiation characteristics for UMTS at 2100 MHz and WiMAX at 3300 MHz with impedance bandwidth of $S_{11} < -6$, demonstrating the complete frequency range from 500-3500 MHz in Fig. 3.

The frequency response of the GPS and LTE based cellular printed radiator is optimized for various line segment lengths and widths. GPS and DCS frequency bands are achieved with the impedance bandwidth of $S_{11} < -6$, at 1575 MHz for GPS applications and 1800 MHz for DCS applications by parametrizing the third embedded slot element and optimizing for various lengths as demonstrated in Fig. 4. As seen in Fig. 4 the selection of value of GPS band is accordance to the value of DCS band if a higher value is selected our 1575 MHz improves but the 1800 MHz decreases with the return loss less than -6 dB and same effect is incorporated at the 1900 MHz band. The dimensions of the fourth element embedded in the radiator element is parametrized as illustrated in Fig. 5 for achieving the frequency band at 1900 MHz for the PCS applications by selecting segment width of 1.30 mm and impedance bandwidth of $S_{11} < -6$.

Lower frequency bands of 700, 850 and 900 MHz are optimized by controlling the dimensions of the first line segment element as demonstrated in Fig. 6, parametrizing three varied lengths of 56.5, 50.5 and 44.5 mm, with the first frequency band of 700 MHz having bandwidth

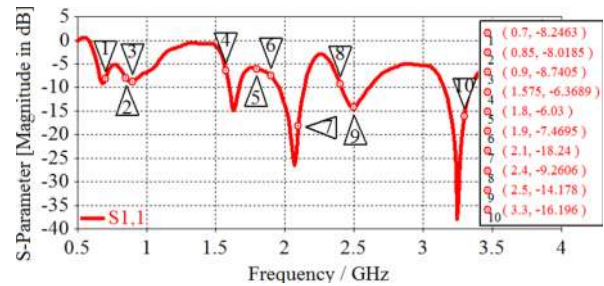


FIG. 3. S_{11} REPOSE OF LTE AND GPS BASED PROPOSED CELLULAR ANTENNA

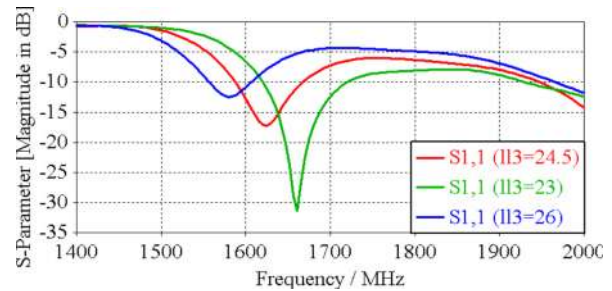


FIG. 4. OPTIMIZED S_{11} REPOSE OF LTE AND GPS BASED CELLULAR ANTENNA DUE TO LENGTH OF THIRD ELEMENT

TABLE 2. MULTI- BAND GSM, WIMAX, LTE AND GPS CELLULAR ANTENNA DETAILS

Label	Description	Dimensions (mm)
LW5	Fifth Line Width	01.11
LL5	Fifth Line Length	18.00
LW4	Fourth Line Width	01.30
LL4	Fourth Line Length	23.00
LL2	Second Line Length	10.00
LW2	Second Line Width	01.50
GW	Ground Width	60.00
SW	Substrate Width	60.00
LW3	Third Line Width	00.50
FL	Feed Line	06.00
FW	Feed Width	01.50
LW1	First Line Width	00.50
LL1	First Line Length	56.50
LW6	Sixth Line Width	04.70
LL6	Sixth Line Length	07.00
LL3	Third Line Length	24.50

optimized for $S_{11} < -6$ dB. For covering the GSM bands of 850 and 900 MHz, the second frequency band of the radiator is optimized for achieving impedance bandwidth of $S_{11} < -6$ dB. If the lower value is selected then it improves the return loss in 700 MHz but at the same time it disturbs the next two frequency bands of 850 and 900 MHz, degrading the return loss at less than -6 dB threshold for proper bandwidth.

Surface currents are demonstrated in Fig. 7, presenting the currents along various line segments are stubs at the top and bottom layers of the radiator. The bottom layer line segments L3 and L4 are responsible for the radiation in the lower band of 700 MHz, with maximum radiations along these line segments, as shown in the Fig. 7(a). The 900 MHz is radiated from the top layer plane radiating element L1 as shown in Fig. 7(b), while the GPS band (1575 MHz) is radiated from the bottom plane line segment L6 as shown in Fig. 7(c). The radiation for the higher frequencies of 1800, 2400 and 2500 MHz of the multiband printed antenna surface currents can be seen for frequencies in Fig. 7(d-f), with the radiations on the line segments of the bottom layer.

The 3D gain plot patterns of the multiband planar printed antenna is demonstrated in Fig. 8, showing radiation patterns of the multiband printed antenna in 3D at frequency bands of 850 MHz for GSM applications, 1575 MHz for GPS applications, 1900 MHz for PCS applications and 2100, 2500 and 2700 MHz for LTE applications. As

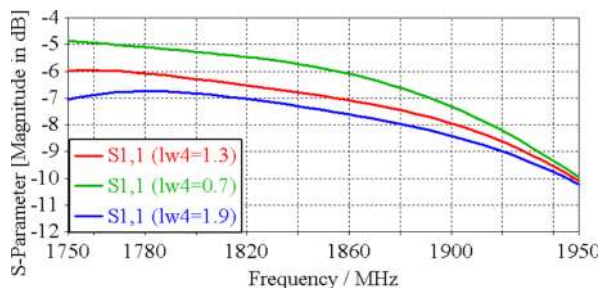


FIG. 5. OPTIMIZED S_{11} REPOSE OF LTE AND GPS BASED CELLULAR ANTENNA DUE TO WIDTH OF FOURTH ELEMENT

seen in Fig. 8(a), the radiation pattern at 850 MHz frequency is having omni-directional pattern. Similarly, Fig.8(b) shows the radiation pattern of GPS band frequency (1575 MHz), while Fig.8(c) shows the GSM 900 MHz radiation pattern. From Fig. 8(d-f), radiations in the DCS 1800, 2400 and 2700 MHz are demonstrated. The radiation patterns at the desired frequencies demonstrated a relatively omni-directional characteristic, which makes the proposed antenna suitable for mobile handset communication applications. The proposed multiband printed planar antenna demonstrates suitable gain values over the entire frequency band after optimization, as shown in Fig. 9. Gain vs. frequency plot demonstrates gain variation in the entire range of frequencies, with the higher frequencies of 2100, 2400 and 2700 MHz illustrating higher gain values up to 4.11 dB, whereas lower frequencies of 700, 850 and 900 MHz bands exhibiting gain values up to 2.6dB. The fabricated prototype of the proposed antenna is shown in Fig. 10.

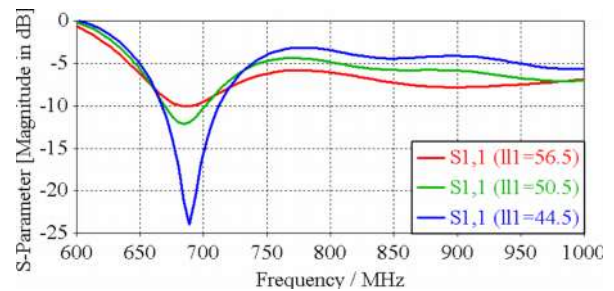


FIG. 6. OPTIMIZED S_{11} REPOSE OF LTE AND GPS BASED CELLULAR ANTENNA DUE TO LENGTH OF FIRST ELEMENT

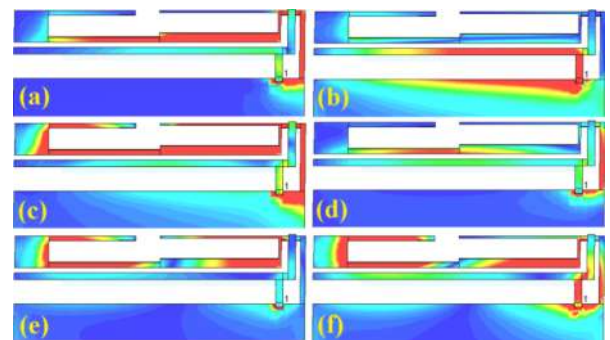


FIG. 7. SURFACE CURRENT PLOTS OF LTE AND GPS BASED CELLULAR ANTENNA AT FREQUENCY (a) 700, (b) 900, (c) 1575, (d) 1800, (e) 2100, (f) 3500 MHZ

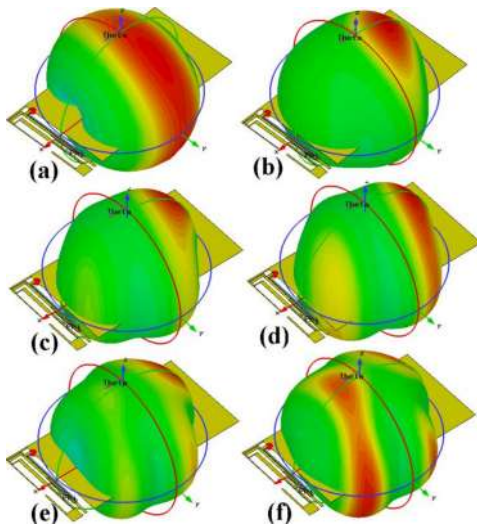


FIG. 8. THREE DIMENSIONAL GAIN PATTERNS OF LTE AND GPS BASED CELLULAR ANTENNA FOR THE FREQUENCIES OF (a) 850, (b) 1575, (c) 1900, (d) 2100, (e) 2500 AND (f) 3300 MHZ

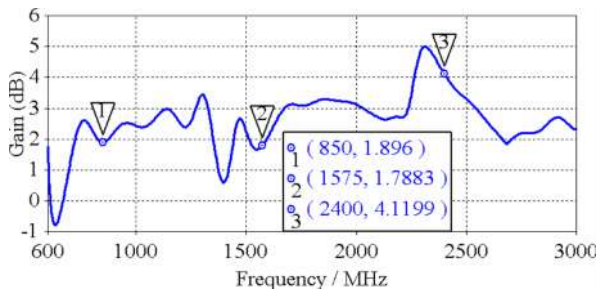


FIG. 9. GAIN VS FREQUENCY PLOT OF THE PROPOSED MULTIBAND PRINTED ANTENNA



FIG. 10. PROPOSED GPS AND LTE BASED CELLULAR ANTENNA FABRICATED TOP AND BOTTOM LAYER PROTOTYPE

4. CONCLUSION

In this paper, a printed antenna for mobile handset has been presented for LTE, WiMAX, GPS and GSM application covering ten radiation frequency bands. The cellular radiator antenna system comprises various slots and stubs that are embedded on the bottom and top layers of the printed circuit board, where the individual line segment dimensions are designed and simulated for achieving the desired frequency bands. Top layer upper line segment is resonated for lower band operations. Bottom layer slots and line segments impacts for resonance of the higher frequencies. The frequency bands of GPS 1575 MHz, WiMAX 3500, GSM 850 MHz and DCS 1800 MHz are achieved by optimizing the line segments incorporated in the metallic top and bottom layers. The proposed cellular radiator demonstrates -6dB return loss validating better radiation efficiency characteristics while maintaining higher gain values for the upper bands of LTE and GSM as well as providing better bandwidth characteristics for the GPS frequency band that will provide better performance characteristic for the mobile handheld applications.

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