A Survey on Design of Multiband Monopole Antenna for Wireless Applications

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***Abstract*—** The antennas are very essential device for communication as it is used as a transmitter device and receiving device. Today Communication devices such as mobile phones become very thin and smarter, support several applications and require higher bandwidth where the microstrip antennas are the better choice compare to conventional antennas. To perform this operation the microstrip antennas should provide wide bandwidth at the compact size. The aim of the survey is to design and simulation of rectangular Microstrip Patch Antenna for various feeding techniques using a 3D electromagnetic field simulator HFSS14.0 and measures the antenna parameters such as VSWR, radiation pattern and return loss.

Index Terms-*Multiband antenna, wideband antenna, monopole antenna, micro strip*

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I. INTRODUCTION

The rapid evolution has come forward as an advancement in hand held mobile devices and also the appearances of the devices must be attractive with small in dimension. An antenna can be described as a device, which transforms the electromagnetic waves in an antenna to radiating in an unbounded medium. Previously, mobile systems were designed to operate for 2G systems, which are Digital Cellular System, Personal Communications service and Global System for Mobile Communications networks. Presently, many mobile communication systems use several frequency bands such as GSM 900/1800/1900 bands(890-960 MHz and 1710-1990MHz); Universal Mobile Telecommunication Systems (UMTS) and UMTS 3G expansion bands (1900-2200MHz and 2500-2700MHz); and Wi-Fi (Wireless Fidelity)/Wireless Local Area Networks (WLAN) bands(2400-2500 MHz and 5100-5800 MHz) [6,9]. Typically, a single antenna cannot operate at all of these frequency bands, as a result multiband and wideband antennas are essential to provide multifunctional operations for mobile communication. Recent trend in multiband antenna designs used in mobile devices can be categorized into three types: slot - type antennas, monopoles antennas and planar inverted-F antennas (PIFA). Multiple resonant modes are achieved through different slots of various geometric cuts onto the radiator and ground plane [7]. The antenna in upcoming must be able to have not only multiband operation, but also wide bandwidths, simple structures, compact sizes, and the ability to easily integrate with RF circuits. To achieve these requirements monopole antenna is proposed [1]. The monopole antenna with low profile, light weight, low cost, easy to fabricate, provide

better efficiency and wide bandwidth [1,2]. In these presented monopole antennas, a large solid ground plane having the shape of a square, rectangle, circle, ellipse or a distinguished ground structure named defected ground structure (DFG) is usually adopted [8]. Along with this a microstrip patch antenna is proposed. It is a well-known printed resonant structure consisting of a conducting patch, a substrate and a ground plane. The shape of the microstrip patch can be continuous shape such as square, rectangular, circular, ring and elliptical, where rectangular patch is most commonly used because of conformable to planar and nonplanar surfaces [6]. The antenna has been built on FR4-type dielectric substrate and the analysis was carried out using the 3-D full-wave electromagnetic (EM) simulator HFSS (High Frequency Structure Simulator) by Ansoft.

II. SUMMARY OF THE CONTRIBUTED PAPERS

A. Antenna Designs, Simulations and measurements

1) Multiband and Wideband Monopole Antenna for GSM900 and other Wireless Applications [1]

In this paper, the antenna has three distinct frequency bands, centered at 0.94, 2.7, 4.75 GHz. The structure of the antenna has a microstrip feed which consists of a rectangular radiator, a 50- Ω microstrip feed line, and a ground plane. The antenna has an overall area of 30 x 40 mm^2 and a thickness of 1.57 mm with FR-4 substrate as shown in Fig. 1.

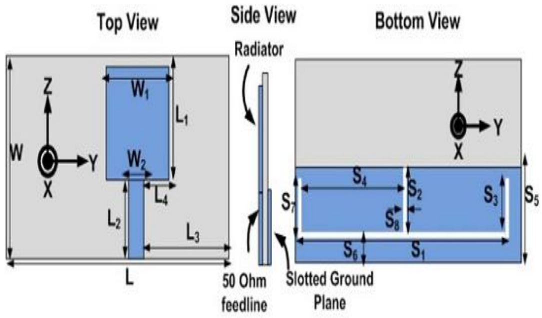

Fig.1. Layout of an antenna

The design procedure includes 3 steps, can be explained below and it is shown in Fig. 2: a) A monopole antenna with microstrip feed as is first designed to operate in a single band at approximately 3.7 GHz and optimized in terms of minimizing the reflection coefficient. b) An inverted T-shaped slot is cut on the ground plane to perturb the current path and so to create dual band operation. Adding the inverted T-shaped slot shifts the 3.6-GHz frequency band to about 4.25 GHz and creates a low-frequency band at around 1 GHz without increasing of the antenna size and S_{11} increases from -17 dB to slightly less than -11 dB. C) Two vertical slots are cut at both ends of the horizontal slot of the inverted T-shaped slot to form an E-shape. Cutting these two vertical slots lowers the low-frequency band from 1 to 0.94 GHz without requiring increasing of the antenna size and creates two more frequency bands at around 2.7 and 4.75GHz, with significantly better matching.

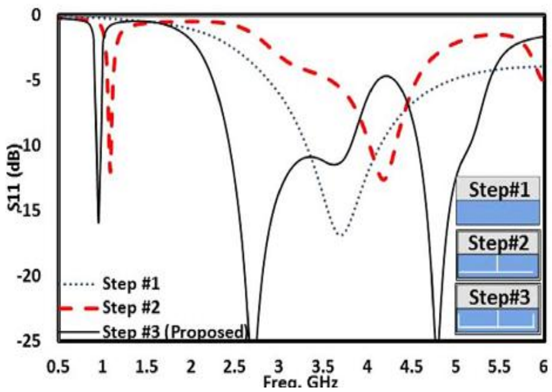

Fig 2. Steps of designed antenna with Return loss

Thus three frequency bands: one narrow band at 0.94GHz and two wide bands 2.8 and 5 GHz with impedance bandwidths (S_{11} < -10 db) of 5.29% (912 -972 MHz), 54% (2.390-3.943 GHz), and 44% (4.689-5.324 GHz). The measured efficiencies are about 0.94-, 3.25-, and 5-GHz bands, with the peak gains of -3.67, 1.24, and 4.94 dBi. The low profile of the antenna shows probable for compact and slim wireless devices to candidates.

2) High Gain Broadband Monopole Antenna for Wireless Communications [2]

In this paper, a wideband monopole antenna with high gain has been proposed for broadband wireless applications. The structure of the antenna has a microstrip feed which consists of a rectangular radiator; a 50- Ω microstrip feed line, and a ground plane. The antenna has an overall area of 50 x 35 mm^2 and a thickness of 1.6 mm with FR-4 substrate with dielectric constant of 4.4 and loss tangent of 0.02 as shown in Fig.3. Partial ground plane has been used to widen the bandwidth. No of slits were introduced at the radiating edge to transform as a multiple monopole radiators. To increase gain, the parasitic element technique is presented. Variation of the designed parameters gives different return loss characteristics: a) ground variation- provides larger impedance bandwidth with reasonable return loss, ground length 11mm.b) Variation of slit – when the length of the slit was increased there was no significant effect on the bandwidth but the return loss has changed of < -20 db at two frequencies, one for lower bands of LTE and other for UMTS band. c) Variation of thickness of the slit- the center frequency varied and remarkable change in return loss is shown in Fig.4.

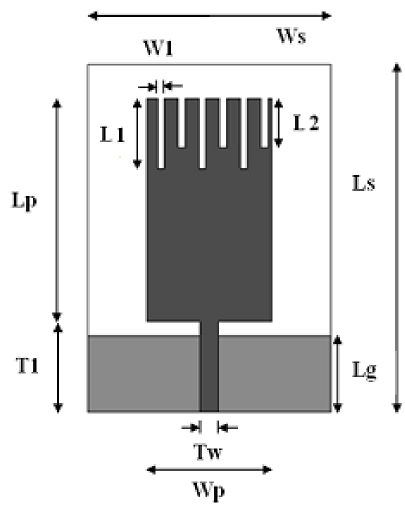

Fig.3. Layout of an antenna

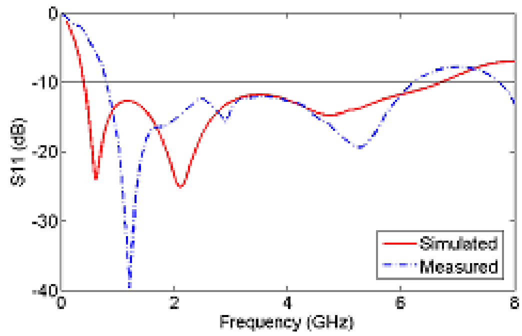

Fig.4. Return Loss of antenna

The antenna has impedance bandwidth of 6.3 GHz (0.4-6.7 GHz). The range of frequency operation from 0.4 to 6.69 GHz and high gain upto 13 dB is the remarkable feature of the proposed antenna. It is applicable in GSM, GPS, DCS, PCS, UMTS, Bluetooth, WLAN, Wi-Fi, WiMAX, HIPERLAN and LTE applications.

3) Multiband and compact WCDMA/WLAN Antenna for mobile Equipment [3]

In this paper, a compact, multiband, planar and low-profile WCDMA/WLAN antenna is presented. WCDMA is a 3G mobile system that offers higher data bandwidth, improved voice quality, simplified system planning over 2G systems etc. The WLAN functionality has been added over WCDMA to enable the mobile equipment to access existing WLAN networks for the ultimate wireless connectivity. The WCDMA/WLAN antenna is a combination of a planar monopole, a T-shaped element, and a parasitic element, which results in two distinct operation bands as well as enhanced radiation due to the parasitic element. The antenna has been built on FR4-type dielectric substrate, and the radiating patch is loaded by another FR4 layer on top completely covered by an 18 x 21 x 1 mm^3 dimensions, referred as FR4 superstrate. The structure of the antenna has a microstrip feed which consists of a rectangular radiator; a 50- Ω microstrip feed line, and a ground plane. The antenna has an overall area of 58 x 65 mm^2 and a thickness of 1 mm with FR-4 substrate with dielectric constant of 4.4 and loss tangent of 0.02 is shown in Fig.5. The radiating patch consists of two parts: a) a main patch with 10 x 18 mm^2 is a planar monopole, and two side patches on the left and the right of the main patch with dimension 4 x 2 mm^2 is responsible for the low-band response. The two side patches and an 8 x 4 mm^2 PCB ground below the feeding microstrip line form the T-shaped element is responsible for the high-band response.

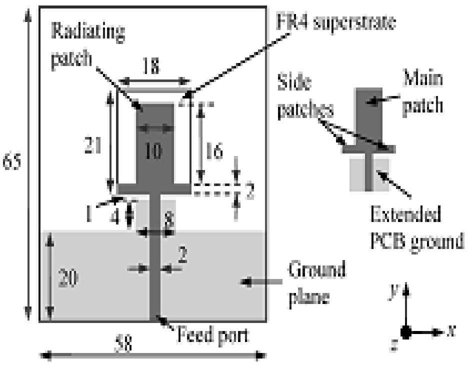

Fig.5. Layout of an antenna

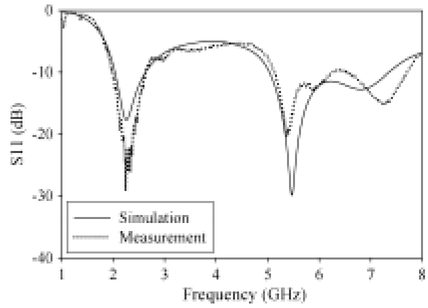

Fig.6 (a) Return loss for the antenna with no parasitic elements

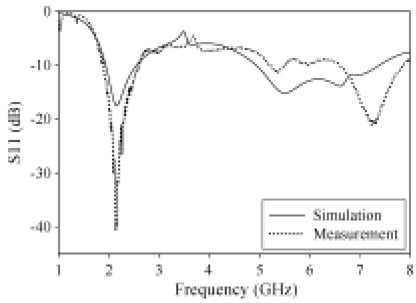

Fig.6 (b) Return loss for the antenna with parasitic elements

The FR4 superstrate is referred to as the antenna with the parasitic element, which shift the S_{11} response to a lower frequency without increasing the size of the radiating patch. The S_{11} has -10dB and bandwidth is about 640 MHz from about 1.99 to 2.63 GHz when there is no parasitic element, and the bandwidth is about 690 MHz from about 1.90 to 2.59 GHz with parasitic element. The antenna with the parasitic element can be preferred over the antenna with no parasitic element because a good impedance matching is desired at 1.9 GHz, also does not cause any degradation in the antenna gain at 2.1 GHz is shown in Fig.6 (a) and (b).The return loss is slightly greater than 10 dB for the 5150-5350 MHz WLAN (a, n) band and is in the range of 9.0-9.4 dB for the 5725-5825-MHz WLAN (a, n) band. The proposed antenna can operates in 1920-2170 MHz WCDMA, 2400-2497 MHz WLAN, 5150-5350 MHz WLAN, and 5725-5825 MHz WLAN bands.

4) Dielectric –Loaded compact WLAN/WCDMA Antenna with Shorted Loop and Monopole [4]

In this paper, the antenna has a planar loop element with a shorting pin and a planar monopole element that are covered by a FR-4 type dielectric substrate. However 2.1 GHz WCDMA functionality has been added over the 2.45/5 GHz WLAN band. The loop element is shorted to RF ground through a 1.2mm diameter shorting pin for multiband operation. The dimension of the antenna is 58 x 62 x 1 mm^3.The structure of the antenna has a microstrip feed which consists of a rectangular radiator, a 50- Ω microstrip feed line, and a ground plane is shown in Fig.7.

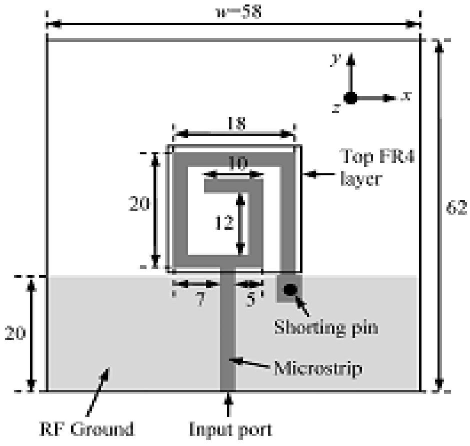

Fig.7 Antenna design

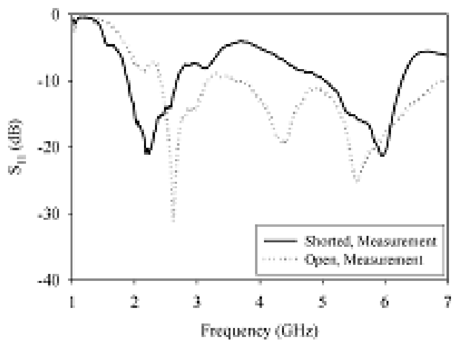

Fig.8.Simulated return loss

The high band is generated by the monopole, whereas the low band is generated by the coupling of the loop and the monopole. The coupling effect provides: a) the first loop resonance is around 2 GHz with S_{11} more than -9 dB. b) The monopole has a resonance at around 2.1 GHz with S_{11} of about -10 dB. Both S_{11} does not meet the -10 dB specification with a usable bandwidth. When the loop and the monopole element exist together, a coupling occurs between them during these two weak resonances, and as a result, a stronger resonance with good bandwidth is formed.

When the connection to the shorting pin is cut by scratching some copper from the PCB, the loop element is no longer RF-grounded through the shorting pin and, in fact it behaves like a monopole due to the open end. The case "open" corresponds to the antenna when the connection of the loop element to the RF ground is cut, the low band is shifted to about 2.7 GHz, and the high band spans from about 3.5 to 7 GHz. When the loop element is short-circuited to the RF ground through the shorting pin, the case is "shorted", and then the S_{11} response in Fig.8 shows two distinct resonances around 2.1 and 5.9 GHz. The peak antenna directivity is about 2.2 and 4.4 dBi for resonance at 2.1 and 5.9 GHz. Efficiency is about 90% at low band and 80% at high band and gain are about 2 and 2.7 dBi.

5) *Design of Triple-Frequency Microstrip-Fed Monopole Antenna Using Defected Ground Structure [5]*

In this paper, a triple-frequency microstrip-fed planar monopole antenna for multiband operation is proposed. The radiating element was modified by loading it with protrudent strips and feeding it with a cross-shaped stripline with the ground was cut out by shaped slots forms a DGS. These slots were introduced to increase the excitation of resonant modes and improve the impedance matching for the proposed antenna. It provide good triple-broad impedance bandwidths and radiation characteristic suitable for two multiband wireless communications such as WLAN 2.4/2.5/5.8 GHz and the WiMAX 3.5/5.5 GHz. The structure of the antenna has a microstrip feed which consists of a rectangular radiator; a 50- Ω microstrip feed line, and a ground plane. The antenna has an overall area of 20 x 30 mm^2 and a thickness of 1.6 mm with FR-4 substrate with dielectric constant of 4.4 and loss tangent of 0.02 is shown in Fig.9. The optimal geometrical parameters are listed in table 1.

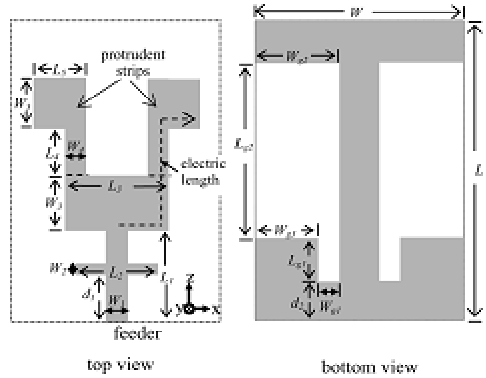

Fig. 9 Antenna Design

Parameter	L	W	L_1	W_1	L_2	W_2	L_3	W_3	L_4	W_4
Unit(mm)	30	20	9	2	8	1	10	6	5	2
Parameter	L_5	W_5	L_{g1}	W_{g1}	L_{g2}	W_{g2}	W_{g3}	d_1	d_2	
Unit(mm)	5	5	4	2	18	8	6	5	4	

Table 1 Optimal Geometrical Parameters of the Proposed Triple-Frequency Monopole Antenna

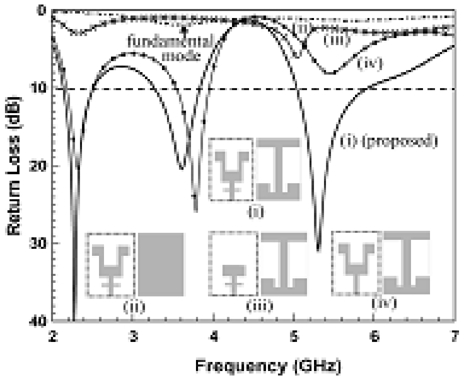

Fig.10. Simulated Return loss

In current distribution of the proposed antenna operates at the three bands, influences of the related geometrical dimensions on the impedance matching condition of the three resonant modes. The effect of the DGS to the matching condition at the highest operating band is obtained. The lowest resonant mode is shifted toward the higher frequency band, which gets affected slightly. Three resonant modes at frequencies of 2.31, 3.42 and 5.44 GHz were obtained. The measured impedance bandwidths are about 380 MHz (2.14-2.52 GHz), 920 MHz (2.82-3.74 GHz), and 870 MHz (5.15-6.02 GHz). The average efficiencies for the three bands are about 50, 58, and 74.5 %. For directivity the measured average values are5.5, 4.8, 4.5 dBi and gains are about 2.2-2.6, 2.1-2.6, and 2.5-3.4 dBi.

III. COMPARISON TABLE FOR SURVEY PAPERS

Paper	Size (mm^3)	Substrate	Frequency (GHz)	Gain (dBi)
1	30x40x1.57	FR4-substrate	0.94 to 4.75	-3.67 to 4.94
2	50x35x1.6	FR4-substrate	0.8 to 5.2	5.2 to 13.27
3	58x65x1	FR4-substrate	1.90 to 2.59	2.1
4	58 x 62 x1	FR4-substrate	2.1 and 5.9	2 and 2.7
5	20x30x1.57	FR4-substrate	2.31,3.42 and 5.44	2.2-2.6 2.1-2.6, 2.5-3.4

IV. PROPOSED ANTENNA

The structure of the proposed monopole antenna with a microstrip insert feed is shown in Fig.11 which consists of a rectangular radiator; a 50- microstrip feed line, and a ground plane. The antenna is designed on an FR-4 substrate with an overall area of 30x40 mm^2 and a thickness of 1.57 mm. Along with E-shaped slot cut on the ground plane a insert feed method is implemented. The antenna has four distinct frequency bands, centered at 2.6, 4.9, 6.5 and 7.9GHz.A monopole antenna with microstrip insert feed as shown in fig.11 is designed to operate in multiple frequency bands with significantly better matching.

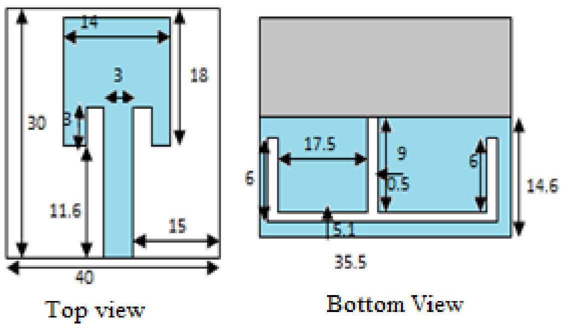

Fig. 11 Layout of Proposed Antenna Design

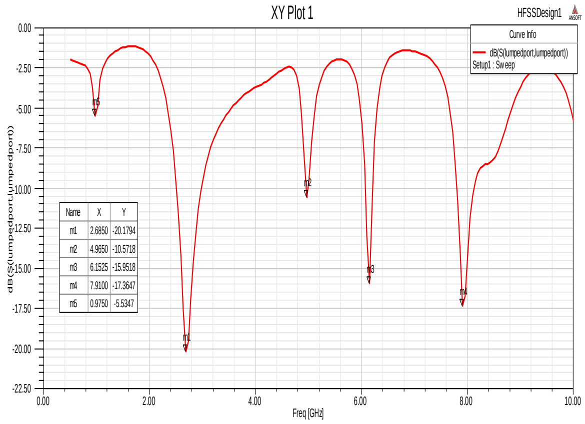

Fig.12 Simulated return loss for proposed design

The design procedure includes 4 steps, can be explained below and it is shown in Fig. 12: a) A monopole antenna with microstrip feed as is first designed to operate in a single band at approximately 3.7 GHz and optimized in terms of minimizing the reflection coefficient. b) An inverted T-shaped slot is cut on the ground plane to perturb the current path and so to create dual band operation. Adding the inverted T-shaped slot shifts the 3.6-GHz frequency band to about 4.25 GHz and creates a low-frequency band at around 1 GHz without increasing of the antenna size and S_{11} increases from -17 dB to slightly less than -11 dB. C) Two vertical slots are cut at both ends of the horizontal slot of the inverted T-shaped slot to form an E-shape. Cutting these two vertical slots lowers the low-frequency band from 1 to 0.94 GHz without requiring increasing of the antenna size and creates two more frequency bands at around 2.7 and 4.75GHz, with significantly better matching. d) Along with E-shaped slot cut on the ground plane an insert feed method is implemented. The antenna has four distinct frequency bands, centered at 2.6, 4.9, 6.5 and 7.9GHz. The S_{11} increases from -20 dB to slightly less than -11 dB are shown in fig.12. The simulated result shows the antenna has better efficiency and gain.The proposed design is suitable for WiFi/WLAN/Hiper LAN/IEEE 802.11 2.4GHz (2412–2484MHz), 4.9/5.0GHz (4915–5825MHz), Bluetooth (2400–2484MHz), LTE, UWB applications.

V.CONCLUSION

This paper presents a survey of the different structures used to realize multiple frequency or wideband operation in either a single-element patch antenna or a multi- element scheme. However, a closer study reveals that some of these examples create problems in the design or manufacturing stage, along with an increase in size or degradation in any of the other characteristics. By introducing slots in the patch, the multiple -frequency operation can be achieved in a single-element patch antenna. The designed antenna structure includes insert feeding method for the feeding purpose. This antenna structure provides a good amount of gain and the directivity , along with this antenna structure works in multiple frequency bands as shown in the return loss curve and provides a good bandwidth. Analyzing this type of structures we can further provide increment in the gain of the antenna. The designed antenna structure provides a good amount of gain and bandwidth to that of conventional antenna designs.

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