DUAL BAND MONOPOLE ANTENNA DESIGN

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***Abstract*: The WLAN and Bluetooth applications become popular in mobile devices, integrating GSM and ISM bands operation in one compact antenna, can reduce the size of mobile devices. Recently, lot many investigations are carried out in designing a dual band antennas with operating frequencies in GSM band and in ISM band for mobile devices. Printed monopoles are under this investigation. In this paper, dual-band printed monopoles are presented to operate at GSM band i.e. 900 MHz and ISM band i.e. 2.4 GHz. We intend to observe the antenna characteristics on the network analyzer and verify the theoretical results with the practical ones.**

Keywords: GSM-Global System for Mobile Communications, ISM-Industrial, Scientific and Medical Bands, WLAN- Wireless Local Area Network.

I. INTRODUCTION

A known challenge in design the embedded antenna for handheld devices is the balance between the antenna sizes constrain under a certain environment requirement and its performance. On one hand, users have come to expect smaller and to fit industrial design requirement. On the other hand users have come to expect devices with an antenna to achieve minimum performance over multi-frequency bands. As a result, antenna design engineers are struggling on customized design of the antenna for handheld devices case-by-case to meet all of above mentioned requirements by fine-tuning repeatedly.

Wireless communications have gained a wider and wider popularity in the later years. Presently, the trend is that of providing a wireless link to every kind of electronic device. In this framework, Personal Digital Assistants (PDAs), notebooks, cellular phones are becoming constitutive elements of new generation networks. In particular, there is a specific need for greater capacities and transmission speeds, which, together with a growing demand from users for more complicated services, imply the design of higher performance systems [1]. The first cellular telephones were big, heavy, and clumsy but worked well using large, coax-fed, half-wavelength antennas. As cellular-phone handsets became smaller, so did the antennas. As the continuing cellular- infrastructure build up eases demand on the communications-link margin more cell towers mean a better signal service providers are willing to surrender 2 or 3 dB of communications-link margin to offer distinctively designed, highly compact phones that rely solely on internal antennas. Multi-band operation is a necessary feature for nearly every cellular phone. The design of an effective single-band internal antenna is not trivial, and designing a multi-band internal antenna is even more demanding. Many of the fundamental design issues conflict with each other.

In this context, multi-band and wide-band antennas are required exhibiting low VSWRs and low sensitivity to other electronic devices and systems installed in the operational environment. In particular, it is important mentioning that the strongest limitation in antenna design for mobile wireless systems is the radiating element size. Indeed, the antenna must be small, light and conformal to the structure of the mobile terminal. Many antennas with multi-band and wide-band characteristics have been designed for wireless applications, but the resulting size of the final layout often comes out to be too bulky to be integrated in any part of a mobile terminal [2]. Monopole antennas are widely used in mobile communication systems, and dual-band monopole antennas have attracted considerable attention because of the increasing demand for dual or multiband wireless communication systems [3].

The design of dual band antennas with operating frequencies around 900 MHz GSM band and 2.4 GHz ISM band for mobile devices are presented in this the paper. As the WLAN and Bluetooth applications become popular in mobile devices, integrating GSM and ISM bands operation in one compact antenna can reduce the size of mobile devices. In this paper, dual-band printed monopoles are presented to operate at GSM 900 MHz and 2.4 GHz ISM band (IEEE 802.11b Standard) and observe the antenna characteristics on the network analyser.

II. DESIGN CONCEPT OF DUAL BAND MONOPOLE ANTENNA

The principle of the dual frequency operation is to make the antenna a combination of two monopoles connected in parallel at the feed point, each operating at a specified frequency mode. The design of dual band monopole antenna starts with designing of the radiating element. Since dual band, the radiating element for both frequencies is required. The length of radiating element can be designed using the quarter-wavelength equation for monopole antenna i.e. $\lambda/4$. Here, air substrate is used i.e. the gap between feed and substrate is air. When an air substrate is used, the lengths of two monopoles are approximately one quarter of a free-space wavelength at their corresponding frequencies. Due to the presence of different lengths of the two monopoles, the first resonant frequency of the proposed antenna is expected to be controlled mainly by the length of the longer monopole, and the second resonant frequency is greatly dependent on the length of the shorter monopole; that is, dual frequency operation can be achieved [4].

The length of the radiating element for 900 MHz is l_1 = 83 mm and the length for 2.4 GHz is l_2 = 31 mm. The width of the radiating element can be calculated using try-and-error method. The selection of width also decides the bandwidth required at both the frequencies. The impedance bandwidths for the two operating frequencies can be enhanced by increasing the width of the two monopoles [4]. Thus width is one of the important parameter in selecting proper bandwidth that can be used for communication. The material used for radiating element is a copper metal. The thickness of the copper metal for the fabrication of antenna is 0.5 mm. Our aim is to achieve a return loss S_{11} < -10 dB. To achieve this we need to design the ground plane of antenna in order to meet our requirements.

Substrate materials play an important role in antenna design, production and finished product performance. A simple method that can be employed to modify the different properties of the antenna is by changing the substrate; as height and dielectric constant of the substrate influence the antenna properties [5]. Substrate choice largely affects radiation efficiency/patterns, antenna dimensions, and instantaneous bandwidth. Typically, since patch antennas are intended to launch EM waves directly into the space above the radiating surface, substrate dielectric constants are kept as low as possible [6]. By selecting a proper length of the ground plane, it is found that the first two resonant modes of the proposed antenna can be excited with good impedance matching. The length of the ground plane is varied and the effect on the impedance matching is investigated. The dimension of ground plane of the antenna is 40 mm x 80 mm [3]. The length of ground plane decides the maximum return loss and width of ground plane decides the shift in frequency notch. The ground plane material used is similar to the radiating element i.e. copper metal. The dielectric used is air, because air has a dielectric constant 1. The tangent loss when air is used as a dielectric is minimized. The feed point of the antenna is calculated so as to obtain a characteristic impedance of 50 Ω. The width of the feed point is 2.5 mm and length is equal to length of ground plane i.e. 40 mm [7]. The material used for the fabrication of all the parameters of dual band monopole antenna is a copper metal. Therefore, this antenna can also be called as metal antenna.

The gap kept between the ground plane and feed point i.e. dielectric material is 0.6 mm when an SMA connector is used. The frequency ratio by calculation comes out to be 2.66. The frequency ratio also decides the size of ground plane. From many experimental studies, it is also found that larger the frequency ratio, larger is the size of ground plane.

Proposed structure of Dual Band Monopole Antenna

The proposed design according to the calculations is given in Fig.1. As we can see that there are two monopoles for both the resonating modes. The connection between ground plane and feed is also shown in Fig 1.

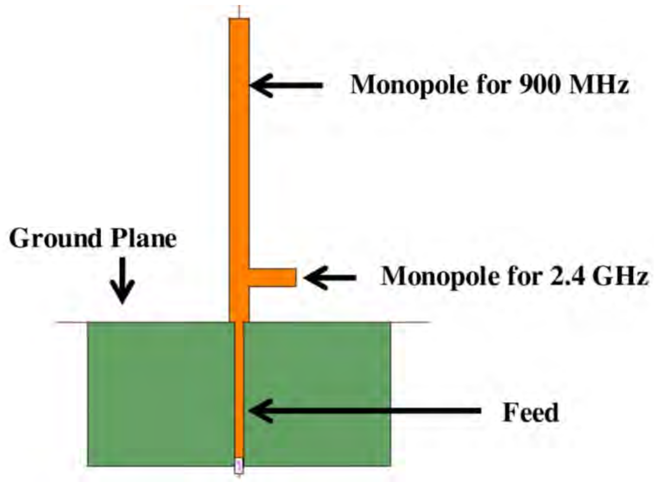

Fig. 1: Proposed design with all the parameters of dual band monopole antenna

The two monopoles are placed in parallel to the feed for impedance matching. The longer monopole of l_1 = 83 mm is the radiating element for GSM band i.e. 900 MHz and the shorter monopole of l_2 = 31 mm is the radiating element for ISM band i.e. 2.4 GHz. The gap of 0.6 mm is maintained between the ground plane and the feed. The metal thickness of all the elements is about 0.5 mm.

III. SIMULATION AND MEASURED RESULTS OF DUAL BAND MONOPOLE ANTENNA

The prototypes of the proposed dual band monopole antenna were constructed. Because many design parameters of the proposed antenna affect the dual-frequency performance, IE3D simulation software has been applied to guide this design and thus reduces try-and-error design cycle. Thus, by simulating various prototypes optimum design of dual band monopole antenna is selected. The S_{11} graph of simulated design is shown in Fig. 2. The S_{11} graph gives us the relationship between return loss and frequency.

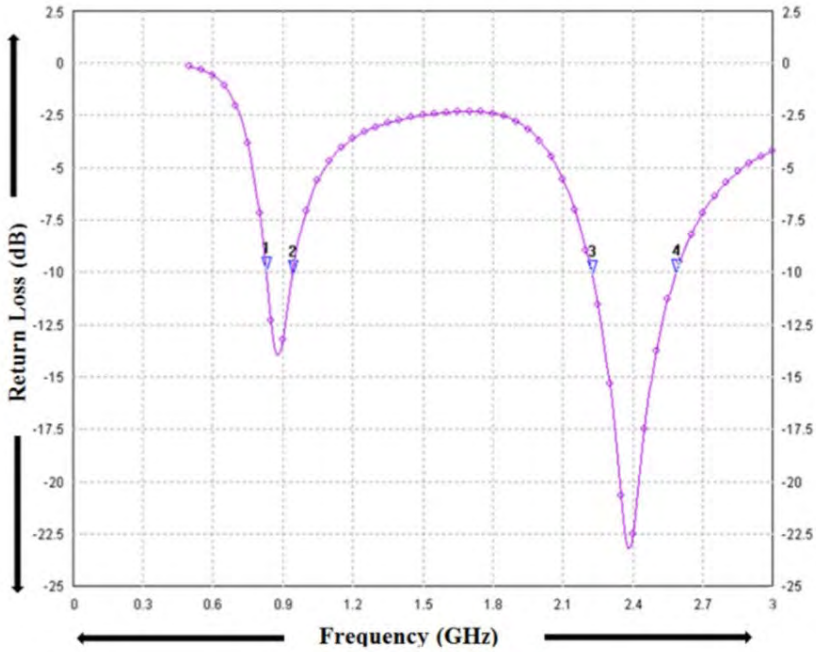

Fig. 2: Simulation results for return loss v/s frequency of dual band monopole antenna.

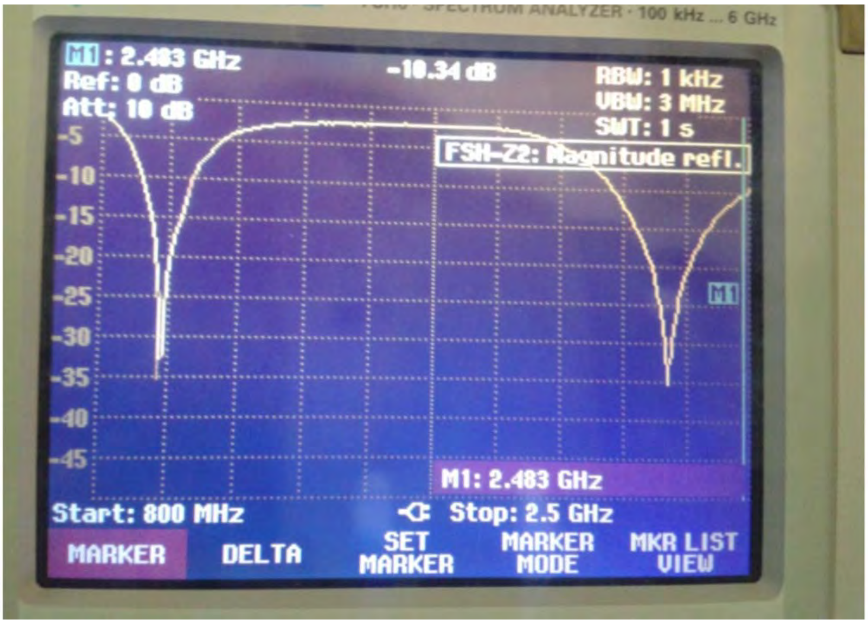

Fig.3: Measured results for return loss v/s frequency of dual band monopole antenna.

We observe from the graph that the maximum return loss for GSM band i.e. around 900 MHz is -14 dB and maximum return loss for ISM band i.e. around 2.4 GHz is about -23 dB. If we cross the -10 dB line then we get for GSM band, lower cut-off frequency f_l = 828 MHz as indicated by 1 in Fig. 2 and higher cut-off frequency

f_h = 941 MHz as indicated by 2 in Fig. 2 and for ISM band we get the lower cut-off frequency f_l = 2.22 GHz as indicated by 3 and higher cut-off frequency f_h = 2.58 GHz as indicated by 4 in Fig. 2. The bandwidth for GSM band comes out to be 113 MHz and for ISM band it is 360 MHz. This simulated result for dual band monopole antenna is then compared with the measured results from the graph obtained in Fig. 3. The return loss v/s frequency of the fabricated antenna measured using network analyzer. From the graph obtained in the network analyzer we see that the maximum return loss for GSM band i.e. around 900 MHz is -33 dB and maximum return loss for ISM band i.e. around 2.4 GHz is about -35 dB. The -10 dB line gives the lower cut-off frequency f_l = 906 MHz and higher cut-off frequency f_h = 1.01 GHz for GSM band and we also get the lower frequency cut-off frequency f_l = 2.13 GHz higher frequency f_h = 2.48 GHz for ISM band. The bandwidth obtained for GSM band is 104 MHz and for ISM band it is about 350 MHz.

Comparison between the simulated results and the measured results is shown in Table I for GSM band i.e. 900 MHz and in Table II for ISM band i.e. 2.4 GHz.

TABLE I
Comparison of GSM band results

PARAMETERS	**SIMULATED**	**MEASURED**
LOWER CUT -OFF FREQUENCY	828 MHz	906 MHz
HIGHER CUT -OFF FREQUENCY	941 MHz	1.01 GHz
MAXIMUM RETURN LOSS	-14 dB	-33 dB
BANDWIDTH	113 MHz	104 MHz

TABLE II
Comparison of ISM band results

PARAMETERS	**SIMULATED**	**MEASURED**
LOWER CUT -OFF FREQUENCY	2.22 GHz	2.13 GHz
HIGHER CUT -OFF FREQUENCY	2.58 GHz	2.48 GHz
MAXIMUM RETURN LOSS	-23 dB	-35 dB
BANDWIDTH	360 MHz	350 MHz

Thus, from the above results we can see that there is a bandwidth difference of approximately 10 MHz between the simulated and the measured results. We can see that in the simulated results and the results obtained on the network analyzer are almost similar. The difference in the result obtained in the network analyzer could be due to variation in the thickness of the metal, errors induced due to impedance mismatch due to soldering, change in the width of the dielectric due to unevenness in the gap between the ground plane and the feed line, slight variations in the dimensions of the antenna due to fine filing of the edges and other practical errors.

Radiation Pattern Results of Dual Band Monopole Antenna

As for the radiation characteristics, the proposed antenna with the design parameters of l_1 = 83 mm and l_2 = 31 mm is studied. The measured radiation patterns at 900 MHz and 2.4 GHz are plotted.

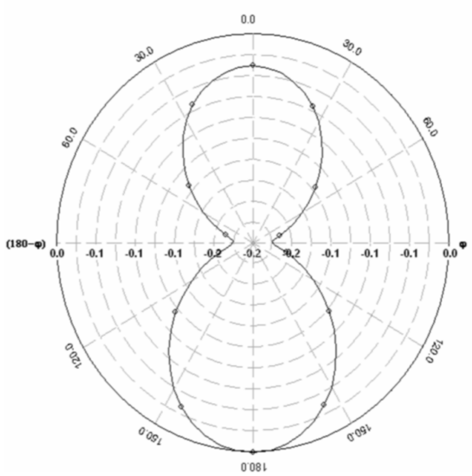

Fig. 4: E-plane radiation pattern at 900 MHz

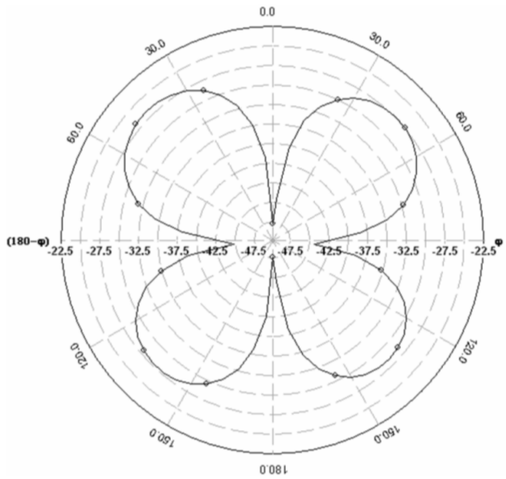

Fig. 5: H-plane radiation pattern at 900 MHz

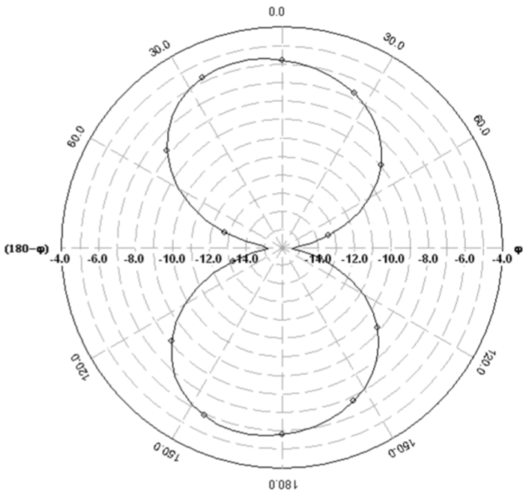

Fig. 6: E-plane radiation pattern at 2.4 GHz

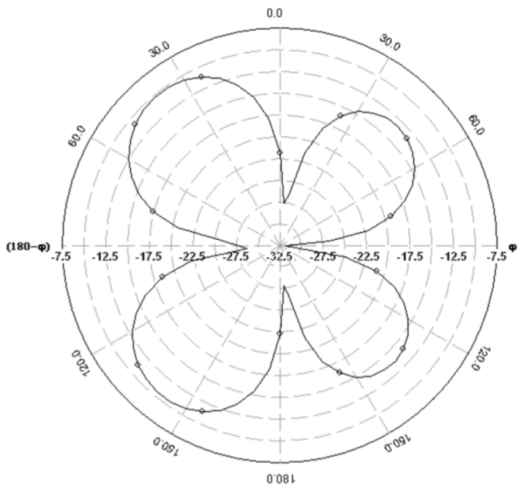

Fig. 7: H-plane radiation pattern at 2.4 GHz

The variations of the radiation patterns are negligible for frequencies across the entire impedance bandwidth. The results for radiation pattern of E-plane and H-plane at 900 MHz is shown in Fig. 4 and Fig. 5, respectively and the radiation pattern of E-plane and H-plane at 2.4 GHz is shown in Fig. 6 and Fig. 7, respectively. It is observed that both of the two operating frequencies are of the same polarization planes and have good omni-directional radiation patterns. The measured gain for the typical antenna is 1.40 – 1.64 dBi for GSM band i.e. at 900 MHz and 3.13 – 4.24 dBi for ISM band i.e. at 2.4 GHz, respectively.

The voltage standing wave ratio (VSWR) of the simulated dual band monopole antenna comes out to be 1.248 for GSM band i.e. at 900 MHz and 1.543 for ISM band i.e. 2.4 GHz. This shows that the impedance mismatch and reflections are minimized at both the frequency bands.

The efficiency is defined as the ratio of radiated power versus total available power from power source. Thus the efficiency value includes all impacts from mismatch loss, dielectric loss, conductor loss and matching component loss. The antenna efficiency of dual band monopole antenna at GSM band is 87% to 90% and at ISM band is approximately 89% to 91%.

IV. CONCLUSION

In this paper, the dual band monopole antenna is simulated and tested using network analyzer. The simulated antenna operates at two frequencies 900 MHz (GSM band) and 2.4 GHz (ISM band). At both the frequencies a sharp return loss of less than -10 dB for both the bands is achieved. The antenna also gives a good directivity, antenna gain of 1.40–1.64 dBi and 3.13–4.24 dBi for GSM band and ISM band, respectively. The efficiency of the antenna is from 87% to 90% for GSM band and from 89% to 91% for ISM band. The VSWR is obtained between 1 and 2 for both the bands. The use of air as a dielectric gives minimum tangent loss. The proposed antenna gives a satisfactory bandwidth for mobile applications. This has been verified with the practical results obtained on the network analyzer.

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