Helical Antenna Design and Measurement for Cellular Phone Operation

Chia-Min Lo, Kuo-liang Wu, Jwo-Shiun Sun, and Guan-Yu Chen
Department of Electronic Engineering
National Taipei University of Technology
1, Sec. 3, Chung-hsiao E. Rd., Taipei, 10608,
Taiwan, R.O.C.
t5418512@ntut.edu.tw

Abstract: - A high performance helical wire monopole antenna fabricated using two kinds of helical wire as radiator is presented. A prototype of the proposed helical monopole antenna with a small area size of 30 mm x 5 mm x 5 mm is implemented, and the antenna shows a wide operating bandwidth for low band and high band bandwidth, making it easy to cover the GSM, EDGE, CDMA, CDMA 2000, W-CDMA and UMTS band for wireless communication and 2.5G/3G dual mode operation of a mobile handset phone.

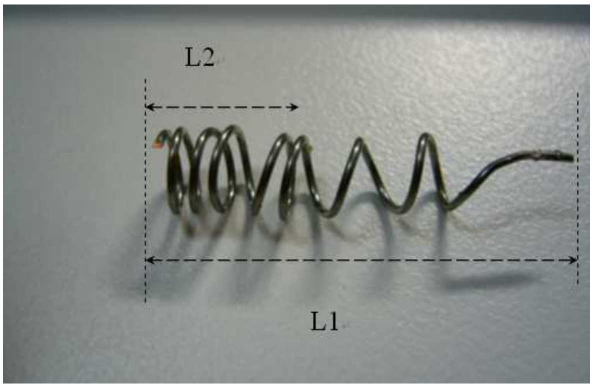
Key-Words: Monopole antenna, wireless communication, 3G.

1 Introduction

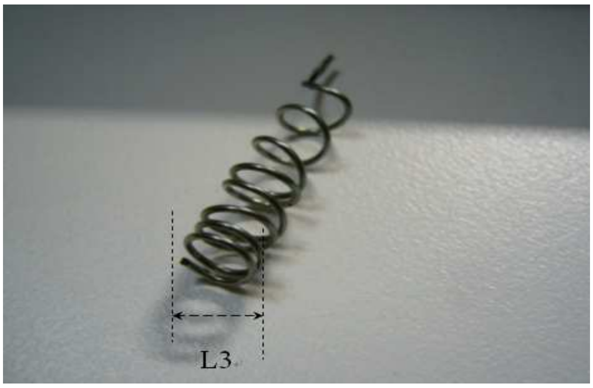
Mobile antenna that can be easily integrated on the RF circuit board and module of a wireless device for wireless consumer electronics operations has been reported recently. Some antenna structures [1, 2] to satisfy specific bandwidth specifications for modern wireless cellular communication systems such as GSM (824-894 MHz), EGSM (880-960 MHz), DCS (1710-1880 MHz), PCS (1850-1990 MHz), CDMA Cellular (824-894 MHz) and CDMA PCS (1750-1990 MHz) have been implemented and developed. Mobile communications have progressed very speedily and many mobile terminals are required small dimensions and compact size then to meet the miniaturization requirement and are very capable quality for satisfying concerns of antenna design. In this paper, helical monopole antenna analysis [3, 4] and design in practical PDA handset size for experiment is implemented. Frequency characteristics and antenna input impedance optimized with various design parameters are analyzed and measured. Designed internal monopole antenna on the handset is simulated and measured. And the internal monopole antenna attached on the handset is tested for far-field antenna anechoic chamber. And a result of the external monopole antenna bandwidth is referenced -6dB return loss and bandwidth cover 793-992 MHz and 1750-2260 MHz, respectively. So the internal helical wire antenna has a wider antenna bandwidth in comparison with traditional external monopole antenna. The proposed antenna, therefore, has advantages to meet wider bandwidth requirements, easy fabrication, matching tuning, and radiation pattern control by wire and metal patch radiator.)

2 Antenna Design

In this paper, the helical wire monopole antenna has several advantages over conventional monopole-like antenna and planar antenna for mobile handsets. In this antenna design, the helical wire antenna must consider radiator, antenna input impedance and radiation polarization for specific absorption rate issue. In this design, we designed a new small internal monopole antenna for multi-band operation covering the GSM, DEGE, CDMA, CDMA 2000, W-CDMA and UMTS bands and application. We present an innovative monopole antenna (Fig.1) suitable for application as an internal antenna in a 2.5G and 3G mobile handset. The proposed dual path monopole antenna co-design is designed on a practical PCB size (100 mm x 60 mm), which serves as a support for the monopole, and has a radiator compact size of 30 mm x 5 mm x 5 mm. The proposed helical monopole is formed by two helical wire lines (L1 and L2). This long helical wire line radiator has a total length of about (L1=30 mm), which excited low band antenna bandwidth of the helical wire monopole antenna. The short helical with wire line radiator has a length of about (L2=10 mm), which excited high band antenna bandwidth of the monopole antenna. With the finite dimensions of the helical wire monopole antenna in this design, the total length of the effective radiator wire path of the antenna is close to one quarter wavelength at free space of the center frequency of low band and high band, the low band resonant frequency of the long wire radiator occurs at about 892 MHz center frequency and high band resonant frequency of the short wire radiator occurs at about 1960 MHz center frequency.



(a)



(b)

Fig.1 (a),(b) Wideband monopole antenna with helical structure (L1=30 mm, L2=10 mm, and L3=5 mm)

2.1 Pitch Angle Design

In [5], typically the metal-grounding plan should be at least $3\lambda/4$, and the geometrical configuration of a helical antenna consists of N turns, diameter L3 and spacing S between each turn, see Fig.2. The total length of the helical antenna is L1=N*S, the total length of wire is $Ln = N * L_0 = N\sqrt{S^2 + C^2}$, as $L_0 = \sqrt{S^2 + C^2}$ is the length of the wire and $C = \pi * \mathrm{L3}$. The helical antenna's pitch angle α is defined by

$$\alpha = \tan^{-1}\left(\frac{S}{\pi \mathrm{L3}}\right) = \tan^{-1}\left(\frac{S}{C}\right) \tag{1}$$

The helical antenna's pitch angle α should be in $0^{\circ} < \alpha < 90^{\circ}$, then a true helix is formed. When helical antenna's pitch angle α is 0°, the winding is flattened and the helix reduce to a loop antenna of N turns. And, if the helical antenna's pitch angle α is 90°, then the helix reduces to a linear wire. As the far zone electric field radiated by a short dipole of length S and constant current I_0 is E_θ, and it is be defined as

$$E_\theta = j\eta \frac{kI_0 S e^{-jkr}}{4\pi r} \sin\theta \tag{2}$$

In addition the electric field radiated by a loop is E_ϕ ,and it is defined as

$$E_\phi = \eta \frac{k^2 \left(L3/2\right)^2 I_0 S e^{-jkr}}{4r} \sin\theta \tag{3}$$

To defined the ratio of magnitudes of the E_θ and E_ϕ inhere as the axial ratio (AR) as

$$\mathrm{AR}=\frac{|E_\theta|}{|E_\theta|} = \frac{4S}{\pi k L3^2} = \frac{2\lambda S}{\left(\pi L3\right)^2} \tag{4}$$

By varying the L3 or S to fulfill AR values in $0 \le \mathrm{AR} \le \infty$, when $\mathrm{AR}=0$ is means $E_\theta = 0$, that helix is like a loop. If $\mathrm{AR}=\infty$ is means $E\phi = 0$,that helix is like a vertical dipole antenna. A special case as $\mathrm{AR}=1$ when

$$\frac{2\lambda_0 S}{\left(\pi L3\right)^2} = 1 \tag{5}$$

or

$$C = \pi L3 = \sqrt{2S\lambda_0} \tag{6}$$

We can get the $\tan\alpha$ as below

$$\tan\alpha = \frac{S}{\pi L3} = \frac{\pi L3}{2\lambda_0} \tag{7}$$

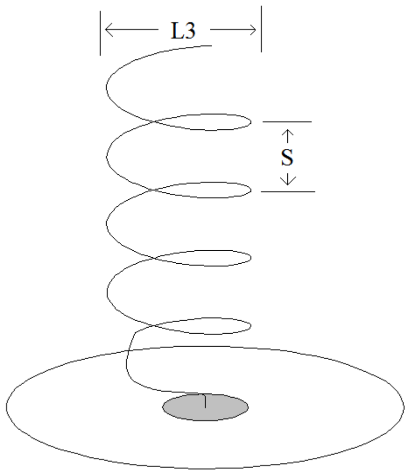


Fig.2 Helical antenna in normal mode

2.2 Feed Design

The nominal impedance of a helical antenna nearly 150 Ω, when using in the axial mode as a coaxial have characteristic impedance of about 50 Ω. It is be control the first 1/4 turn of the helix which is next to the feed, impedance from 150 Ω down to 50 Ω, with a dielectric slab of height in the form of a strip of width *w* by nearly touching metal-grounding in flattening [5-8], defined as [5]

$$h = \frac{w}{\frac{377}{\sqrt{\varepsilon_r} Z_0} - 2} \tag{8}$$

Where *w* is the width of strip conductor of the helix starting at the feed, ε_r is dielectric constant, and Z_0 is characteristic impedance of the input transmission line.

3 Results

Fig.3 shows the return loss data of the proposed antenna helical structure. We used PCB (100 mm x 60 mm) for practical PDA phone size. A 50 Ω semi-rigid RF cable is used to feed the monopole antenna, and is co-design and co-testing on the same PCB board. The feeding network is a wideband 50 Ω low loss RF cable as probe. The PCB material is metal conductor and dielectric substrate with the thickness 1 mm and relative permittivity 4.6. These two wider resonant frequencies of helical wire antenna, has a wider antenna impedance bandwidth, thereby making it possible that the resonant frequencies of the antenna be tuned to occur, respectively, at bandwidth (reference VSWR=3) about 793 - 992 MHz and 1750 - 2260 MHz. The dual wideband radiator in this helical monopole antenna structure, the operating impedance bandwidth for the further wireless communication bands can be obtained. Besides, it can also generate the good radiation patterns in the azimuth plane and good antenna performance has been obtained. Based on the measurement coordinates for H-plane, E1-plane and E2-plane. The measured peak gain data as shown in Table 1.

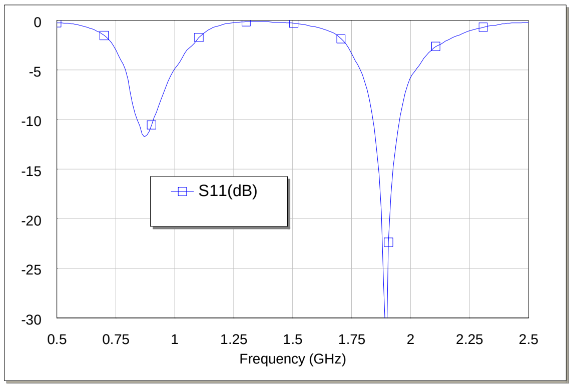


Fig.3 Measured data of Return Loss

Table 1 Measured antenna gain

Frequency (MHz)	800	850	900	950	1000	1050
Gain (dBi)	2.6	2.4	2.4	2.8	3.2	2.8
Frequency (MHz)	1700	1800	1900	2000	2100	2200
Gain (dBi)	3.1	2.2	3.4	3.4	3.2	3.2

4 Conclusion

In this paper, a compact and low profile internal helical monopole antenna for multi-bands has been proposed. This antenna was designed and measured. A good agreement between measurement and analysis has been obtained. The proposed antenna shows a wider operating bandwidth and it easy to cover the GSM, EDGE, CDMA, CDMA 2000, W-CDMA and UMTS band for wireless communication and 2.5G/3G dual mode operation of a mobile handset phone, co-design, co-integration and application.

Acknowledgement
The authors acknowledge the Antenna and EMC Department of HTC, Taiwan, for sport the wireless technique and measurement environment.

References:

[1] K.L Wong, Planar antennas for wireless communications, John Wiley & Sons, Inc, 2003
[2] J.F. Zurchur, F. Gardiol, Broadband patch antennas, Artech House, 1995
[3] J.D. Kraus, R.J. Marhefka, Antennas for all applications, McGraw-Hill, 2002
[4] R.C. Johnson, H. Jasik, Antenna engineering handbook, McGraw-Hill, Inc., 1961
[5] C.A. Balanis, Antenna Theory, John Wiley & Sons, Inc., 2005
[6] J.D. Kraus, Electromagnetics, McGraw-Hill Book Co., New York, 1965
[7] J.D. Kraus, Antennas, McGraw-Hill Book Co., New York, 1965
[8] J.D. Kraus, "A 50-Ohm Input Impendance for Helical Beam Antenna," , *IEEE Trans. Antennas Propagat.*, Vol. AP-25, No.6, p. 913, November 1977.