Design Study Of Normal Mode Helical Antenna With Dual-Frequency And Circular Polarization Used In Mobile Communication

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Abstract

In this paper, a compact and low profile internal normal mode helical antenna with dual-frequencies and circular polarization has been proposed. The proposed antenna shows a wider operating bandwidth and it easy to cover the GSM band(890-960 MHz) for wireless communication dual mode operation of a mobile handset phone.

This paper is contained four different designs for normal mode helical antenna , each design operates at dual- frequency band and circular polarization . The analysis of normal mode helical antenna is achieved at GSM band, and the MATLAB program is used for the design simulation.

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الخلاصة :

في هذا البحث أفترض هوائي الحلزوني ذو الطور العمودي الداخلي المدمج وذو منظر جانبي قليل يعمل ضمن حزمة ثنائية التردد وذات استقطاب دائري. يعمل هذا الهوائي بحزمة عريضة لكي يغطي حزمة (GSM) (890-960 MHz) لغرض الاتصالات اللاسلكية ويعمل بحزمتي تردد التلفون النقال.

يحتوي هذا البحث أربعة تصاميم مختلفة لهوائي الحلزوني ذو الطور العمودي ، كل تصميم يعمل بحزمة ثنائية التردد وذات استقطاب دائري . و تم تحليل الهوائي الحلزوني ذو الطور العمودي في حزمة GSM ، وأستخدم برنامج الماتلاب لمحاكاة التصميم.

1. Introduction

Radiation of normal mode helical antenna with higher gain than single loop providing an omni-directional antenna with compact size and reasonable efficiency, but rather narrow bandwidth. It is commonly used for hand-portable mobile application where it is more desirable to reduce the length of the antenna below that of a quarter-wave monopole[1]. They have also been widely used in cellular phones for mobile communications[2].

The helical antenna is in common use nowadays in space communications , telephone, television and data communication. The normal mode helical antenna is especially attractive for mobile communi- cation and portable equipment[1].

Non-uniform helix provides a unique approach for widening the bandwidth of a helical antenna with improved gain and pattern characterstics[1]. This is similar to a spiral that is not flattened. Start with a piece of wire that is 2 or 3 times longer than a whip and wind it into a coil. The number of turns on the coil will depend on wire size, coil diameter, and turn spacing. The big problem with this antenna is the mechanical construction[3].Although there are many antennas capable of radiating circular-polarized waves, helical antennas are considered to be the most desirable antenna for this purpose because of their theoretically simple structure. However, helical antennas in axial mode are not suitable for use in wireless communication because the geometrical size of the axial mode helical antenna is much greater than the operating wave length [3].

Wheeler reported that a helical antenna operating in normal mode could generate a circularly polarize wave omni-directionally while still remaining small in size. However, normal-mode helical antennas (NMHAs) have yet to be adopted in practical networking technologies. Wheeler showed that when the diameter of the helical antenna is smaller than one wavelength, the antenna can be approximated by a combination of a small dipole antenna and a small circular loop antenna, as shown in **Figure. (1)** [4].The antenna structure shown in **Figure. (2)** can radiate a cross-polarized wave in the y-z plane. Therefore, helical antennas with diameter smaller than one wavelength can radiate a circular-polarized wave, and is called a normal-mode helical antenna.[5,6]

For a normal-mode helix whose dimensions are small compared with wavelength, the current distribution along the helix is approximately sinusoidal. The terminal impedance is very sensitive to changes in frequency, and the bandwidth is narrow. Nevertheless, a normal helix has been used effectively to reduce the length of thin-wire-type (whip) antennas for personal radio and mobile communications systems in the HF and VHF bands. Also, balanced-fed dipole antennas can be constructed by using short-axial-length normal-mode helices when a reduced dipole length is desired. When a short normal-mode helix is used in conjunction with a ground plane, the polarization is predominantly vertical and the radiation pattern is similar to that of a monopole. Typical feeding arrangements for a helical monopole are shown in **Figure (2).** In the series-fed arrangement, the helix is connected directly to the coaxial input, and an impedance transformer or matching network may be required. In the shunt-fed arrangement, the helix provides a self-matching network by tapping a small portion of the helix. A feed arrangement that employs a bifilar helix to increase the input impedance is described in Hansen, and another design that utilizes a short helical monopole and top-loading wire to produce a self-resonant antenna over the (2-30)MHz frequency range without the need of a matching device is described in [7]. Given the large size of even a quarter wave whip at VHF frequencies for hand held operation, It is common to reduce the physical size of the radiating element by using a helical antenna radiating in normal mode as described in [8]. Very small normal- mode helical antenna has been developed by [9] for sensor antennas of the tire pressure monitoring system. The design simulation of dual- band (900/1800)MHz at low temperature co-fire ceramic (LTCC) ship antenna for mobile communication application given by [10]. Increasing the bandwidth of the normal mode helical antennas using two flat wire strips is presented by[11]

This paper is divided into main four parts: the first part is proposed the design of normal mode helical antenna has two different turn spacing along the helix with constant diameter(two different value of pitch angles), the second part is proposed the design of normal mode helical antenna has two different diameter with constant turn spacing, the third part is proposed the design of normal mode helical antenna and monopole antenna. And the fourth part is proposed the design of two normal mode helical antenna has two different diameters.

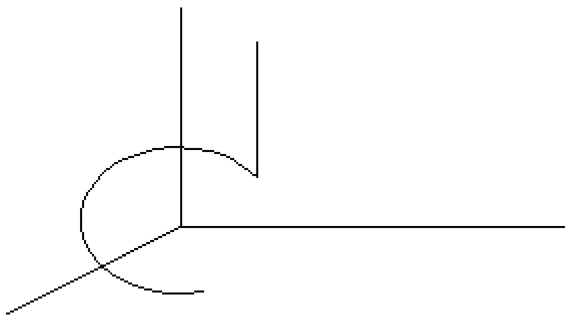

Fig. (1) one turn of a helix

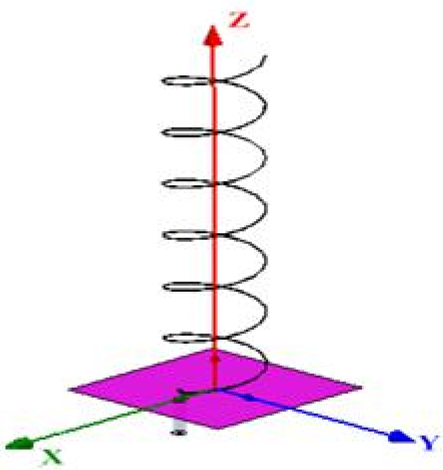

Fig. (2) Helical Antenna[6]

2. Geometry Description of Helical Antenna

Helical antennas are generally formed by winding a wire conductor into a right-hand or left-hand coil and have a much shorter linear dimension than the straight monopole antennas as shown in **Figure(3).** The design of a helix for radiating condition is controlled by three parameters, the diameter ,the pitch angle (α), and number of turns .The relation between these parameters for the normal mode as shown in **Figure(4)** is obtained as follows [2,5,8,12]:

s =spacing between turns= $C \tan \alpha$ …………………………(1)

where

s is the space between turns

C=Circumference of helix= Dπ

D = diameter of helix

α =pitch angle

h =axial length= Ns

d = diameter of helix conductor

L = length of one turn = $\sqrt{C^2 + s^2}$ ....(2)

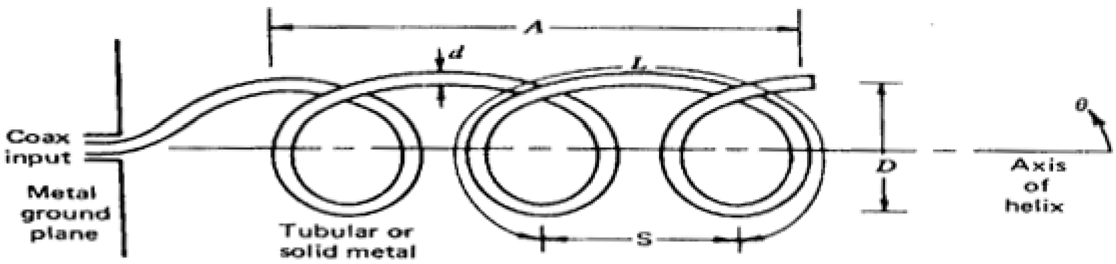

Fig. (3)Geometry and dimensions of helical antenna

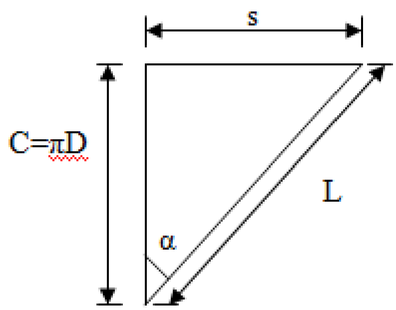

Fig. (4) one uncoiled turn of a helix

When the dimensions of helix are small compared with wavelength, the maximum radiation is in a direction normal to the helix axis. Kraus has shown that the radiation from a short –axial –length ,helix can be calculated by assuming that the helix is composed of a small loops of diameter D and short dipoles of length **l** as shown in **Figure(1).** The far field of a short dipole has only an E_q component and the far field of a small loops has only an E_f component [1]

$$E_D = jwm\mathrm{I}s\frac{e^{-jbr}}{4pr}\sin q\,\hat{q} \qquad \text{..............................(3)}$$

$$E_L = hB^2\frac{p}{4}D^2\mathrm{I}\frac{e^{-jbr}}{4pr}\sin q\,\hat{f} \qquad \text{..............................(4)}$$

The ratio of the major to the minor axis of the polarization ellipse of the electric field intensity is called axial ratio, the axial ratio for helical antenna in normal mode is given by [5,12]

$$AR = \frac{|E_q|}{|E_f|} = \frac{4wms}{\sqrt{\left(m/e\right)}\,w\sqrt{mw(2p/l)}\,pD^2} = \frac{2sl}{p^2D^2} \qquad \text{..............................(5)}$$

Axial ratio is unity for circular polarization

$$\frac{2sl}{p^2D^2} = 1 \qquad \text{..............................(6)}$$

The relationship between pitch length (space between turns) and diameter for perfect circular polarization is given

$$\frac{s}{l} = \frac{1}{2}\left(\frac{pD}{l}\right)^2 \qquad \text{. ....(7)}$$

Then the circumference for circular polarization is given

$$C = pD = \sqrt{2sl} \qquad \text{..............................(8)}$$

The radiation resistance of a short resonant helix above a perfect ground is approximately given by [1]

$$R_r = \left(\frac{25.3h}{l}\right)^2 \quad \text{..............................(9)}$$

where h is the axial length or height above the ground plane.
The helix diameter is controlled by the relation

$$pD = k\,l \quad \text{..............................(10)}$$

Where k is less than (0.5). The total length of the helix is given by

$$NL = NpD \ \sec a \quad \text{..............................(11)}$$

Where N is the number of turns

3. Design of Normal Mode Helical Antenna;

The normal mode helical antenna (NMHA) was selected because this antenna fits well with the research requirements (Omnidirectional radiation pattern, small physical size, dual frequency, and circular polarization)**.**

This paper is divided into main four parts: The first part is the proposed design of normal mode helical antenna has two different turn spacing along the helix with constant diameter such that two resonant frequencies of the antenna can be adjusted to meet the desired dual-frequency operation for cellular mobile communications. The parameters of this design is tabled in the **Table(1).** The second part is the proposed design of normal mode helical antenna has two different diameter with constant turn spacing, The parameters of this design is tabled in the **Table(2).** The third part is the proposed design of normal mode helical antenna and monopole antenna. The parameters of this design is tabled in The **Table(3).** And the fourth part is the proposed design of two normal mode helical antenna has two different diameters. The parameters of this design is tabled in the **Table(4)** .

Table(1) Helical antenna is designed using two pitch angle at GSM band.

Number of turns (N)=20

Wavelength

$l_1 = 33.707 \ \ cm$ corresponding to 890 MHz and $l_2 = 31.25 \ \ cm$ corresponding to 960 MHz

$l_o = 32.42 \ \ cm$ corresponding to 925 MHz (Center frequency of the band)

Let $k = \frac{p}{20}$

Choosing the diameter $= D = \frac{32.42}{20} = 1.6215 \, \text{cm}$

Radius $= 0.81075 \ \ cm$ and Circumference$= p * 1.6215 = 5.09409 \ \ cm$

$s_1 = 0.385 \ \ cm$ and $s_2 = 0.415196 \ \ cm$

$a_1 = 4.310887^o$ and $a_1 = 4.65196^o$

h =axial length =8 cm

Table(2) Helical antenna is designed using two different diameters at GSM band.

Number of turns=N=20

Wavelength

$l_1 = 33.707 \ \ cm$ corresponding to 890 MHz and $l_2 = 31.25 \ \ cm$ corresponding to 960 MHz

$l_o = 32.42 \ \ cm$ corresponding to 925 MHz (Center frequency of the band)

Choosing the space between turns =s=0.4 cm

$C_1 = 5.193 \ \ cm$ and $C_2 = 5.0927 \ \ cm$

$a_1 = 4.4046^o$ and $a_2 = 4.0434^o$

$D_1 = 1.16852 \ \ cm$ and $D_2 = 1.621 \ \ cm$

h =axial length =8cm

Number of turns (N)=20

Wavelength

$l_1 = 33.707 \; cm$ corresponding to 890 MHz and $l_2 = 31.25 \; cm$ corresponding to 960 MHz

$l_o = 32.42 \; cm$ corresponding to 925 MHz (Center frequency of the band)

Let $k = \frac{p}{20}$

Choosing the diameter $= D = \dfrac{33.707}{20} = 1.685\,\text{cm}$

Radius $= 0.8425 \; cm$

Circumference$= p * 1.685 = 5.2946 \; cm$

$s = 0.41584 \; cm$ and $a = 4.49^o$

h =axial length =8.3 cm

Length of monopole$= \dfrac{l_2}{4} = 7.8125 \; cm$

Table(4) Two helical antenna are designed uses different radii at GSM band.

Number of turns (N)=20
Wavelength

$l_1 = 33.707 \quad cm$ corresponding to 890 MHz and $l_2 = 31.25 \quad cm$ corresponding to 960 MHz

$l_o = 32.42 \quad cm$ corresponding to 925 MHz (Center frequency of the band)

Let $k = \frac{p}{20}$

Choosing the diameter $= D_1 = \dfrac{33.707}{20} = 1.685$ cm

Radius $= 0.8425 \quad cm$ and Circumference= $p * 1.685 = 5.2946 \quad cm$

$s = 0.41584 \quad cm$ and $a = 4.49^o$

Choosing the diameter $= D_2 = \dfrac{31.25}{20} = 1.5625$ cm

Radius $= 0.78125 \quad cm$ and Circumference= $p * 1.5625 = 4.9087 \quad cm$

h_1= axial length= Ns=8.3 cm

$s = 0.3855314 \quad cm$ and $a = 4.498^o$

h_2 =axial length =7.71 cm

4. Results and discussion

In this section, the analysis of normal mode helical antenna with dual frequency and circular polarization is achieved at GSM band. The MATLAB program is used for the design simulation.

Figure(5) shows the radiation pattern of normal mode helical antenna(E-plane). **Figure(6)** shows the relation between frequency and axial length at ($l_o = 32.42 \quad cm$ corresponding to 925 MHz (Center frequency of the band) and $D = \frac{l_o}{20}$, $s = 0.0123 l_o$) . and it is noticed that the axial ratio is equal to 1 at center frequency of band , the axial ratio at lower frequency ($f_1 = 890 \quad MHz$) is equal to 1.04 , and the axial ratio at higher frequency ($f_2 = 960 \quad MHz$) is equal to 0.965. **Figure(7)** shows the relation between Diameter and axial length at ($f_o = 925 \quad MHz$ and $s = 0.0128 l_o$) .it noticed that at diameter is equal to 1.62 cm the axial ratio is equal to one. **Figure(8)** shows the relation between spacing between turns and axial length at $D = \frac{l_o}{20} = 1.62 \ cm$ and the axial ratio is equal to one at $s = 0.4 \ cm$ corresponding to $s = \frac{0.4}{l_o} = 0.0123 l_o$. **Figure(9)** shows the relation between spacing between of turns and radiation resistance at center frequency (925MHz) and the number of turns is equal to 20 and the space between turns is equal to 0.4 cm, it is noticed that the radiation resistance is equal to 40 ohm . **Figure(10)** shows the relation between number of turns and radiation resistance with different values of space (s=0.2, s=0.3 ,s=0.4, s=0.5). **Figure.(11)** shows the relation between radiation resistance and frequency at center frequency (925MHz) and the number of turns is equal to 20 and the space between turns is equal to 0.4 cm , it is noticed that the radiation resistance is equal to 40 ohm . the points in **Figure(12)** indicate the obtained relationship between spacing between turns and Diameter for this antenna when axial ratio equal to one . this result confirms that the design criterion given by equation (7) is useful for constructing a normal mode helical antenna with good axial ratio.

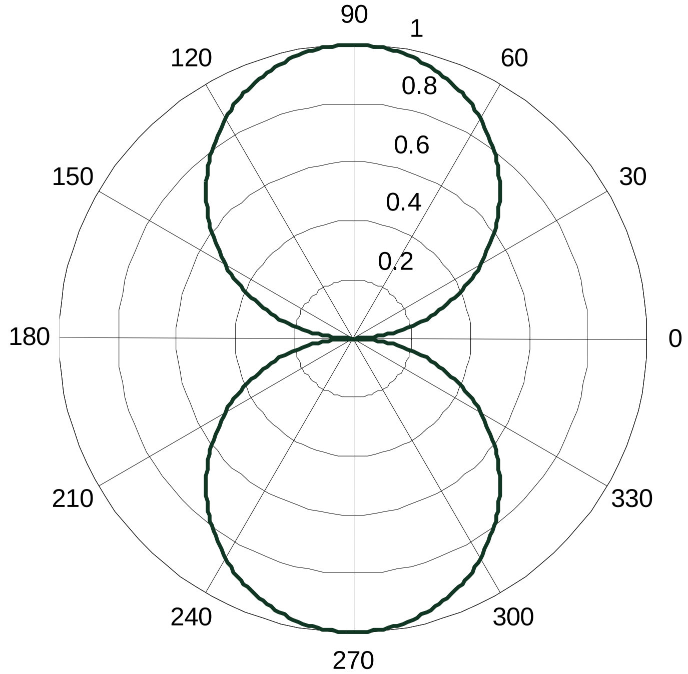

Fig. (5)shows the electric field of normal mode helical antenna(E-plane)

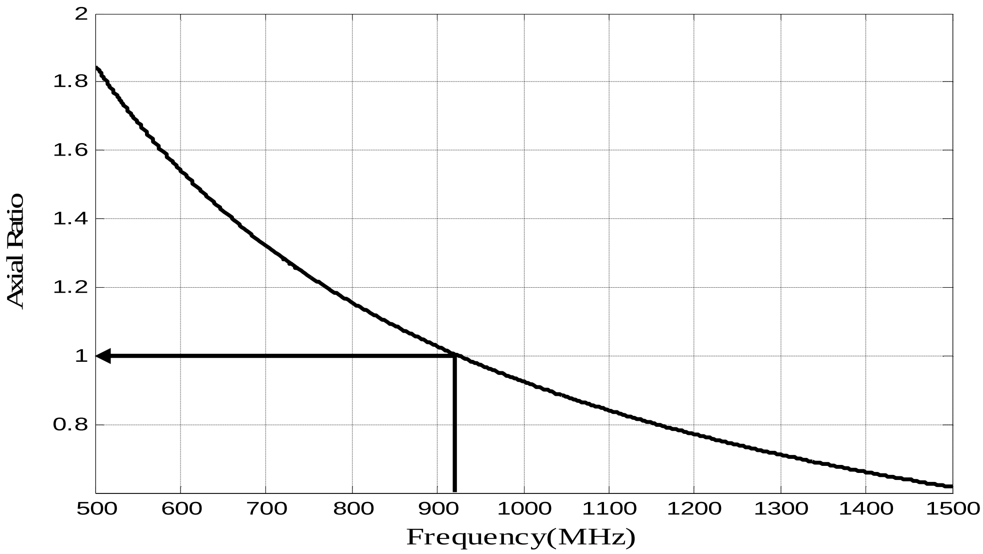

Fig. (6) Relation between frequency and axial length

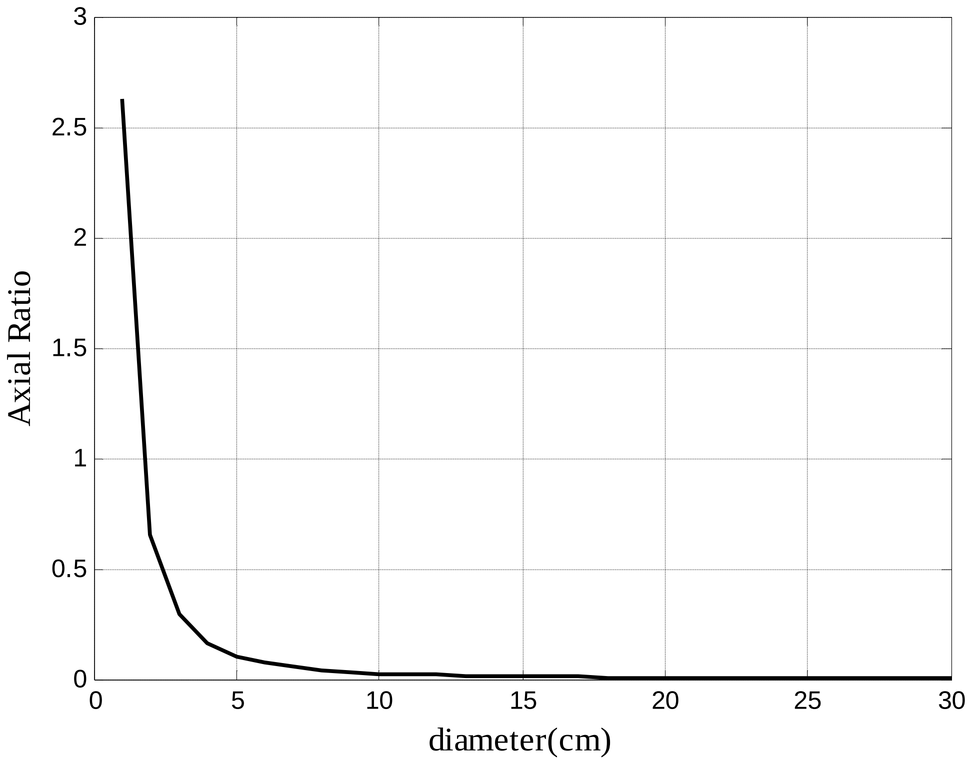

Fig. (7) Relation between Diameter and axial length

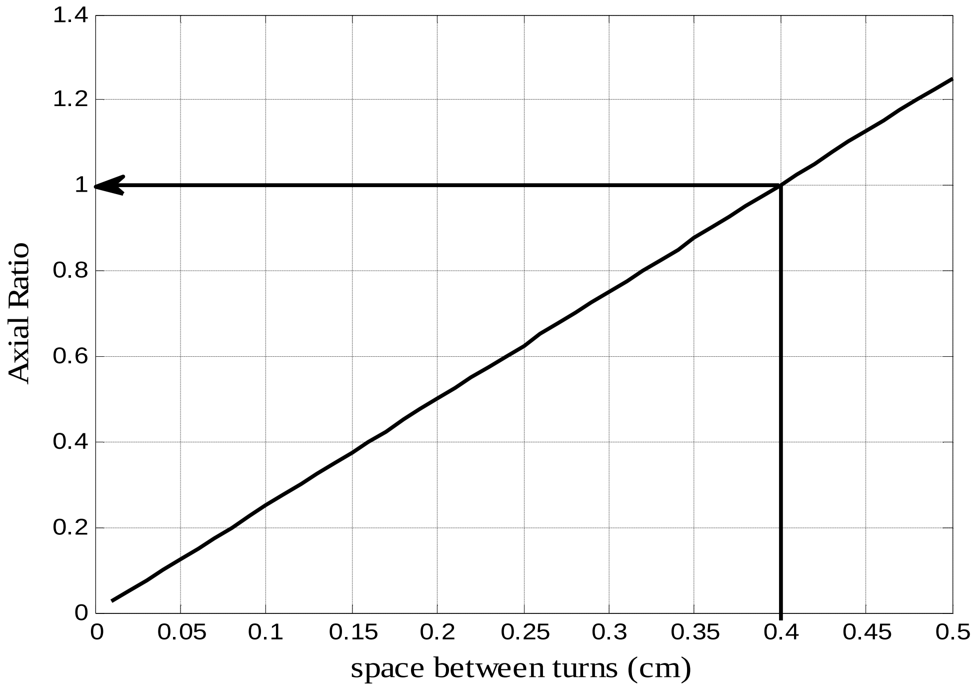

Fig. (8) Relation between spacing between turns and   axial length

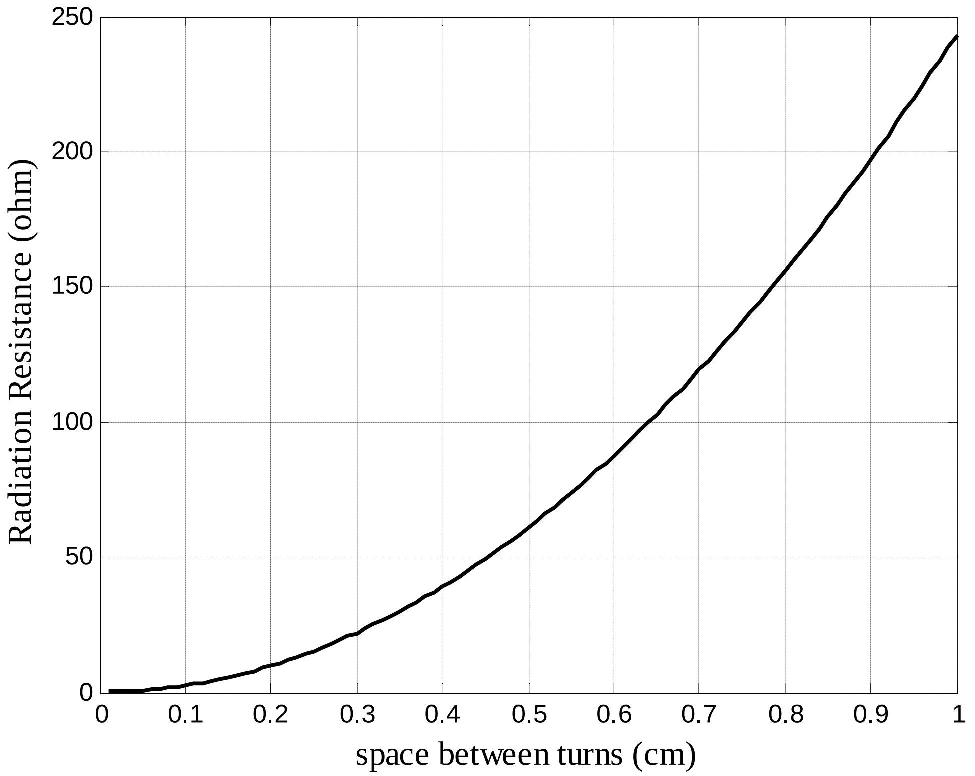

Fig. (9) Relation between spacing between turns and radiation resistance

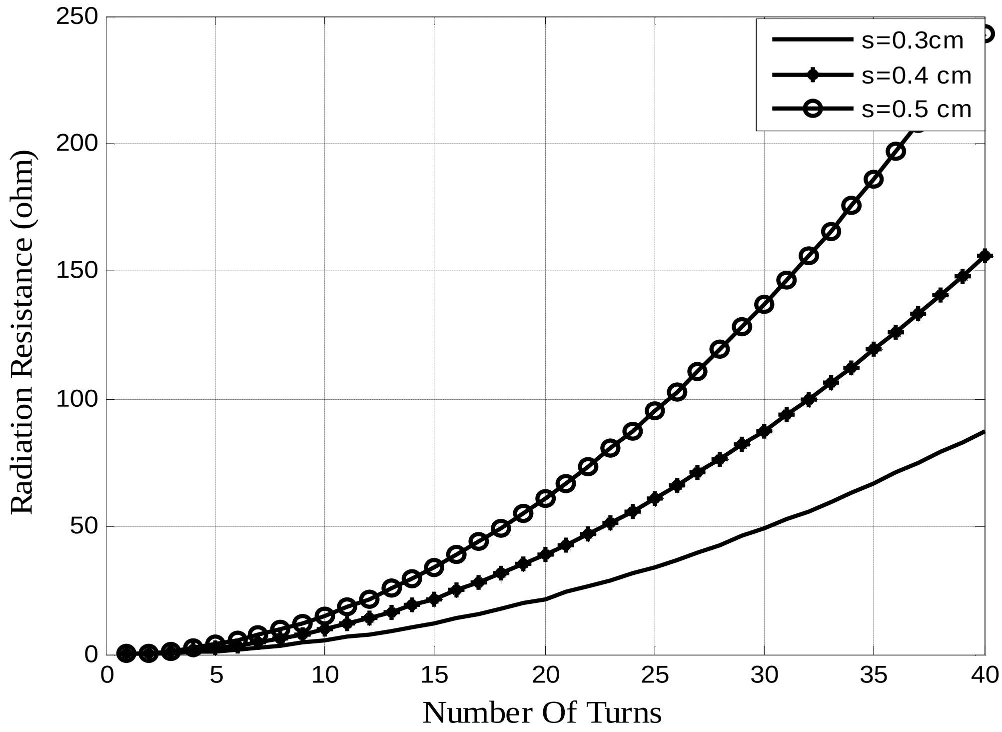

Fig. (10) Relation between number of turns and radiation resistance with different values of space

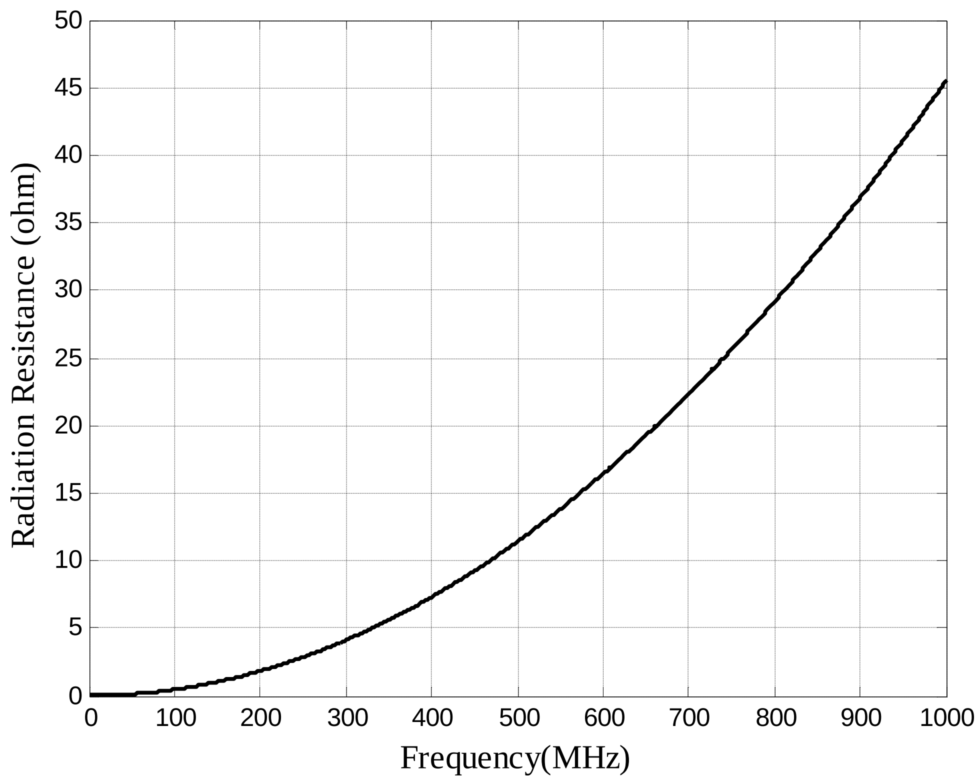

Fig. (11) Relation between radiation resistance and frequency

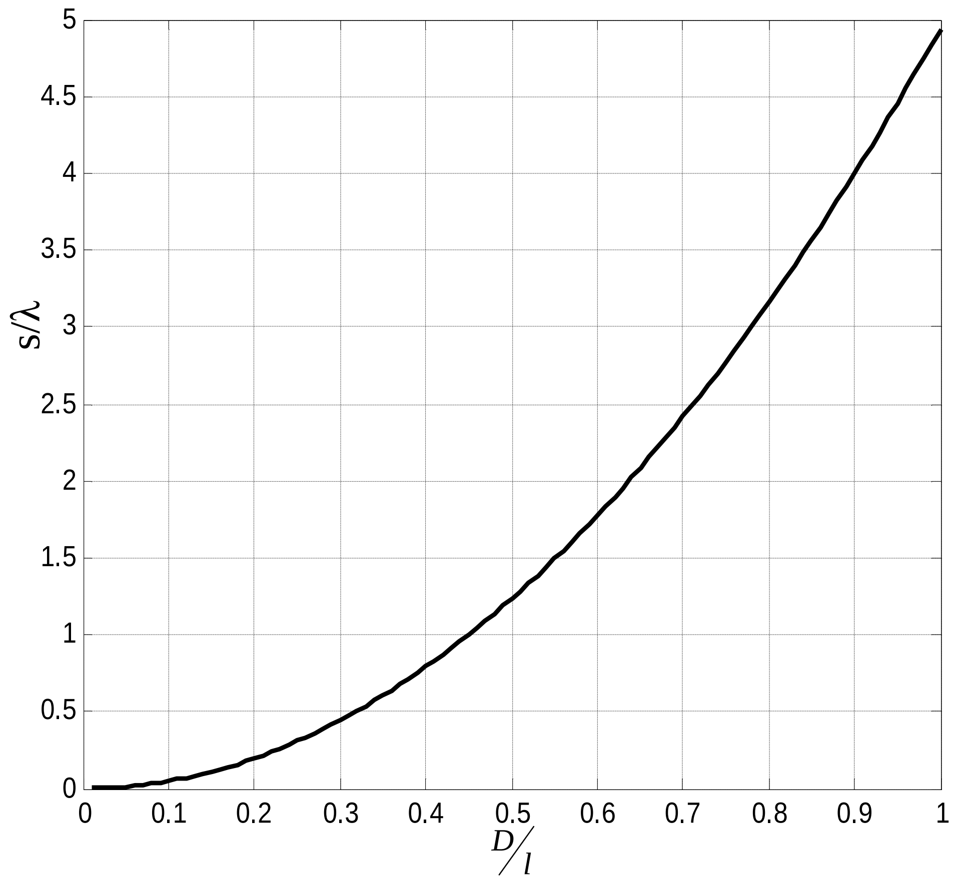

Fig. (12) Relation between spacing between turns and Diameter at axial ratio is equal to one

5. Conclusions

1- In this paper , dual frequency(890-960)MHz of circular polarized normal mode helical antenna is designed at GSM band on small size mobile handset. It has been presented with four configurations are designed and their antenna characteristics are investigated. The characteristics of the antenna are analyzed by changing the helix's pitch spacing , and diameter of helical antenna.

2- Circular polarization is achieved at center frequency (925 MHz) such that an axial ratio is equal to 1. An axial ratio is equal to 1.04 at lower frequency ($f_1 = 890 \ MHz$), and 0.965 at higher frequency ($f_2 = 960 \ MHz$).

3- In four different designs ,the height of antenna is not exceed 8 $cm = 0.25 l_o$ and the radius is not exceed $0.81075\ cm = 0.025 l_o$. These dimensions provides very small and low profile normal mode helical antennas (NMHA).

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