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Quadrifilar Helix Antenna for GPS Applications

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Abstract *–In GPS applications, the antenna requires omnidirectional pattern over approximately the entire upper hemisphere where the satellites may be visible. The fractional QHA(RQHA) is a compact size antenna which is suitable for GPS application which mobile handset.In this paper, we will present a FQHA design with square cross section.*

Keywords: helix, k-β diagram, back-fire mode, GPS, axial ratio, beamwidth, QHA,

1 Introduction

Quadrifilar helical antenna is one of the most commonly used antenna for satellite communications. The QHA produces a cardioid-shaped radiation pattern with excellent circular polarization over wide angular range. Furthermore, fractional-turn QHA is a compact size antenna which is suitable in mobile handset for global positioning system(GPS) applications. The effect of dielectric core on traveling-wave QHA will be presented. Furthermore, resonant QHA with dielectric core will also be given. Dielectric loading is also applied to reduce antenna size. Moreover, square dielectric core is used to obtain broader bandwidth than cylindrical dielectric core.

2 Traveling-Wave Quadrifilar Helical Antenna (QHA)

A quadrifilar helical antenna can support both traveling-wave type and resonant type of operation. The element length decides the type of operation. This section discusses the traveling-wave type of operation.

2.1 *QHA and Unifilar Helix Antenna*

Operation of a QHA is similar in some respects to an unifilar helix antenna. The determinantal equation of N-filar tape helix, excited in the exp(-j ϕ) mode, becomes identical to the sheath helix as the number, N, becomes infinite [2]. In this way, we can estimate the properties of traveling-wave type QHA by the theory of unifilar helix.

Periodic structure approach can be applied to analyze the helix of infinite extent.

Fig.1 shows a three-dimensional helix structure which may be either left or right handed. Parameters to describe a helix structure include helix diameter(D), helix radius(a) circumference(C), spacing between turns(S), pitch angle(α), length of turn(L), and number of turns(N).

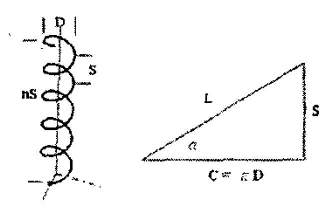


Fig1. Helix structure.

2.2 *k-β Diagram of Helix structure*

Periodic structure approach can be applied to analyze the helix of infinite extent by the mode diagram shown in Fig2.

Three modes of operation are marked as modes a, b c, representing the normal, scanning(back-fire), and axial modes, respectively.

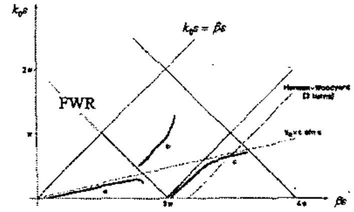


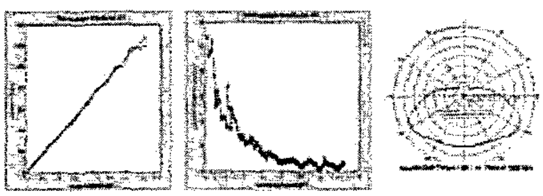
Fig2. k-β diagram of helix structure [2].

In curve a, the cylindrical harmonic of m=0 dominates. The axial mode is dominated by the right-handed cylindrical harmonic of m=-1, also referred to as the m=-1 super-mode.

2.3 Estimation QHA Using *k-β* Diagram

Fig.3 shows the current distribution of a traveling-wave QHA and its radiation pattern associated with the back-fire mode(b mode) in the k-β diagram.

Fig.3(a) shows the phase progression of current which propagates at the speed of light in free space. Fig.3.(b) shows the current amplitude which indicates a leaky-current. Fig3(c) shows the back-fire radiation pattern. The b mode is a leaky-wave and back-fire radiation pattern. As the frequency increases, the beam scans from back-fire to broadside. Fig.4. shows that for the same QHA, the beam bends towards the broadside direction with increasing operation frequency.



(a). phase (b). amplitude (c) pattern

Fig3. current distribution of traveling-wave QHA.

(a) 1.3GHz (b).1.5GHz (c). 1.7GHz

Fig4. Radiation pattern of QHA

2.4 Traveling-Wave QHA with Dielectric Core

Fig.5 shows the structure of a traveling-wave QHA. The pitch angle is 49°, the circumference is 94.2mm, and the number of turn is 5. The operation frequency is 1.5GHz. Four tape helices are fed with equal-amplitude signal with relative phases of 0, 90, 180, and 270 deg., respectively.

The dielectric core has the effect of slowing the current along the helical conductor. On the *k-β* diagram, the slower current velocity means that the slope of the uncoupled mode curve is decreased with associated decrease in bandwidth for a helix with the same pitch angle. An infinitely long QHA exhibits the same behavior.

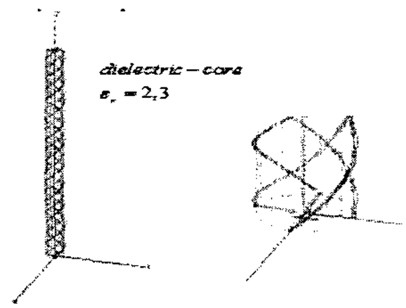
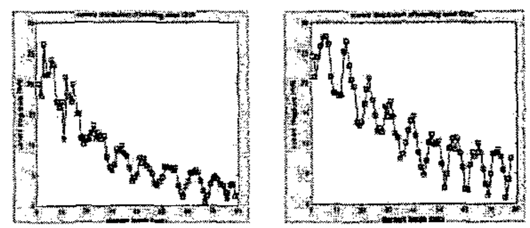


Fig5.QHA with dielectric core.



(a) $\varepsilon_r = 2$ (b) $\varepsilon_r = 3$

Fig.6 Current distribution of QHA with dielectric core.

Fig.6. shows the effect of dielectric core on traveling-wave QHA. The dielectric core increases the reflected wave from its open end. Fig.6.(a). shows the current distribution of QHA with dielectric core of $\varepsilon_r = 2$. The reflected wave becomes stronger when the dielectric constant is increased. The standing wave ratio will decrease when helix length is increased.

3 Quadrifilar Helical Antenna of Resonant Type

3.1 Fractional-Turn Quadrifilar Helical Antenna

In GPS applications, the antenna requires omnidirectional pattern over approximately the entire upper hemisphere where the satellites may be visible. The fractional QHA(RQHA) is a compact size antenna which is suitable for GPS applications embedded in mobile handsets.

Thought RQHA is a compact size antenna, mobile nandset for satellite communication applications demands smaller antenna. Using of dielectric loading for RQHA can reduce the antenna size. However, there is a disadvantage with dielectric loading, the antenna has a low gain or poor radiation efficincy.

In this paper, we present a new square resonant quadrifilar helical antenna(SRQHA). The simulation results show fairly good circular polarization, radiation pattern, return loss bandwidth, and wide beamwidth. The radiation efficiency is higher than cylindrical RQHA.

3.2 Resonant QHA with Dielectric Core

Fig.7 shows the current distribution of RQHA. The current indicates that a short QHA will support a resonant mode. This type of antennas has the properties of small size and narrow bandwidth comparing with traveling-wave QHA. However, using dielectric core for resonant QHA will have fairly good performances of radiation pattern, beamwidth, axial ratio, F/B ratio. However, the dielectric core will degrade the antenna efficiency.

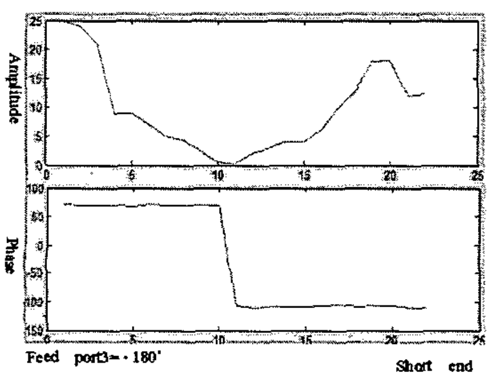


Fig7. Current distribution of RQHA

RQHA with dielectric core behaves like a dielectric resonator. In order to increase its radiation efficiency, we may increase the surface area of an RQHA. Hence, cylindrical core is replaced by rectangular core to extend its surface area with the same volume.

3.3 Square Resonant QHA with dielectric core

Fig7 shows a square resonant QHA(SRQHA) with dielectric core of $\varepsilon_r = 5$. The size of SRQHA is 14.4×14.4×35(mm), which has a size reduction of 45% compared to an air core which is 32×32×64(mm). The resonant frequency is 1.565GHz(GPS L1 frequency is 1.575GHz). The antenna input impedance is 4Ω.

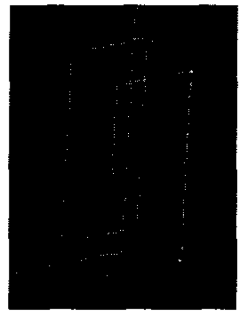
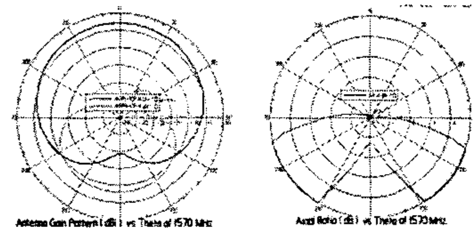


Fig8.structure of square resonant QHA with dielectric core.

Fig8. shows the radiation properties of the SRQHA. The 3dB beamwidth is 124°, front-to-back ratio is 13dB, axial ratio is 0.34dB at $\theta = 0°$, maximum value is 2.53dB.



(a) gain pattern (b) axial ratio

Fig8. Square resonant QHA with dielectric core

Fig9. shows the return loss performance of SRQHA which has a 10MHz bandwidth (−10dB return loss).

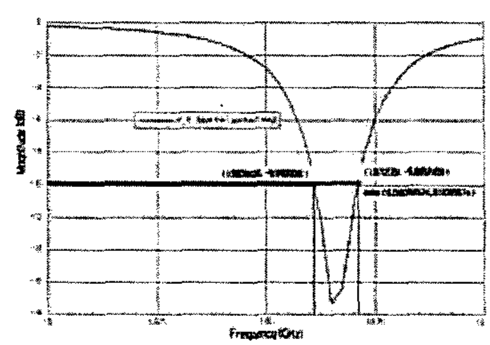


Fig9. Return loss of SRQHA

4 Conclusions

Traveling-wave QHA with dielectric core will degrade the performance of radiation pattern and axial ratio. Using dielectric core for resonant QHA maintains the same performance in pattern and axial ratio. However, the size of antenna is reduced by 45%.

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