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TERRESTRIAL MODE QUADRIFILAR HELIX ANTENNA

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Abstract—In this paper we present a modification to the QHA whereby a gap is introduced at the current minima points at the centre of the helical sections of the QHA. The linear and rotational movement between the two halves of the QHA against each other is optimised to get current distribution, so that when tilted 90°, it generates omnidirectional radiation pattern required for land communications in addition to hemispherical radiation pattern for space mode which is obtainable in conventional configuration. This makes it possible to use the single antenna for both terrestrial and satellite communications. The simulated results are validated by experimental measurements.

1. INTRODUCTION

The use of Quadrifilar Helix Antenna in space communications is a very suitable choice because of its many excellent characteristics such as front to back ratio, gain and axial ratio. Being a wire structure it is attractive because it adds very less weight to the total payload. The various performance characteristics of $\lambda/4$, $\lambda/2$, $3\lambda/4$ and λ volutes for 1/4, 1/2, 3/4 and 1 turn has been given in detail in [1] and [2] gives the effect of fractional turn angle on impedance and radiation parameters of $1/2\lambda$ QHA. In view of many new emerging applications such as confining criminals within specified boundaries, timely help of heart patients, real life spy games, DAB, GPS for personnel, commercial and public usage [3–6], it increasingly necessitates the use of dual mode antennas. Many of the dual mode

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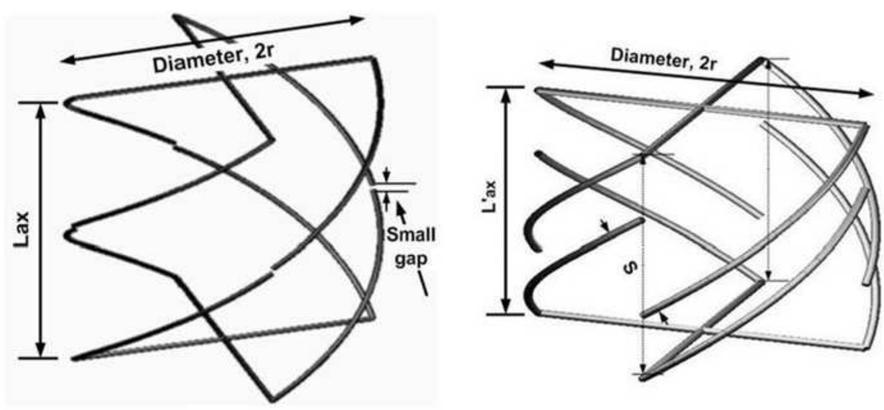
antennas structures incorporate two separate antennas for satellite and terrestrial communications [6]. Although these have an advantage of operating independently but mutual coupling between the antennas tends to deteriorate the performance of these antennas strongly because of their location in near field of each other. The relative position of the two antennas have to be very precise in order to get suitable characteristics such as VSWR and radiation pattern [7]. On the other hand a greater distance between the two antennas will increase the size of the combined structure beyond useable limit. In this paper we present a modification to the conventional QHA where the QHA along the axial direction is divided into two halves at the centre of the helical sections. Since the current at the centre is minimum when the QHA is operating in space mode, it does not significantly effect its performance characteristics. The two halves of the QHA now have two degrees of freedom, a rotational movement around axial direction and a linear movement along the axial direction. Varying these two parameters the reactance introduced at the centre of the helical sections is changed which gives suitable phase to the current such that it produces an omnidirectional radiation pattern when the structure is tilted by 90°.



(a) (b)

Figure 1. QHA in space and land communications mode. (a) QHA with small gap at the centre of helical sections which gives hemispherical radiation pattern. (b) The two halves rotated and axially moved at position which gives omnidirectional radiation pattern.

2. PRINCIPLE OF OPERATION

When a 1/2 turn, $1/2\lambda$ QHA antenna is operating in space mode the current distribution on the bifilar is such that it has current maxima at the centre of radial sections and current minima at the centre of helical sections [8]. Therefore in this region where a current null exists, a gap can be inserted (Figure 1(a)) without significantly changing the current distribution on the structure, and therefore the hemispherical radiation pattern that is generated by the antenna is not much degraded. If the top and bottom halves of the QHA are configured to overlap as shown in Figure 1(b), a distributed reactance is introduced around the centre section of the antenna which can be changed by varying the axial length and the angle between the two halves of the split wire structure. These two geometrical parameters, the overlap length ($\Delta L_{ax} = L_{ax} - \acute{L}_{ax}$) and the wire separation (S) can be used to optimize the pattern performance at a given frequency so that it generates an omnidirectional radiation pattern. One option for practical implementation is to mount the center of the lower half of the antenna on a threaded bar with the pitch angle chosen to provide the required relationship between the rotation angle and the linear translation that is necessary to generate monopole radiation pattern. The relationship between the axial length L_{ax}, the length of the helix L_{hel}, radius r and turn angle θ_t is given by

$$L_{ax} = \sqrt{\left(L_{hel}^2 - \left(\frac{r\theta_t\pi}{180}\right)^2\right)} \quad (1)$$

The separation distance S between the overlapping volutes, when the two halves move in the axial direction and rotate around axial axis is given by

$$S = \Delta L_{ax} \tan\theta - \Delta\theta_t r \quad (2)$$

where θ is the pitch angle of the volute and $\Delta\theta_t$ is the fractional turn angle between the two sections of the QHA. At any axial position, if the relative rotation angle is chosen so that the two overlapped parts of the half turn volute physically touch each other, this continuous equivalent QHA will have a turn angle θ_t that is less than 180°.

3. SIMULATED AND MEASURED RESULTS

The half wavelength QHA structure was analysed using the Numerical Electromagnetic Code [9] with values of 1.2 mm, 22 mm and 92 mm for the wire diameter, the antenna radius r and the length of the helical section L_{hel} respectively. The two bifilars of the QHA are fed at the centre of the lower radial sections using $\lambda/4$ balun [10] and a commercial 90° hybrid is used to feed the bifilars with signals which are 90° out of phase in order to get circularly polarized wave for satellite mode. The phase difference is such that it generates left hand circularly polarized copolar component. The computer model

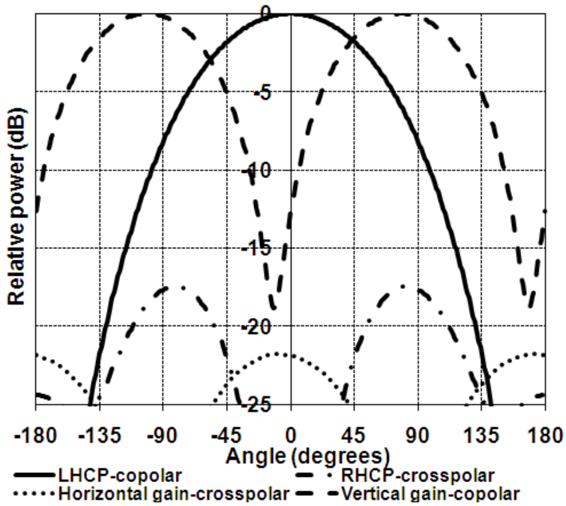


Figure 2. Predicted radiation patterns in elevation plane of the QHA in space mode (Figure 1(a)) and in terrestrial mode (Figure 1(b)).

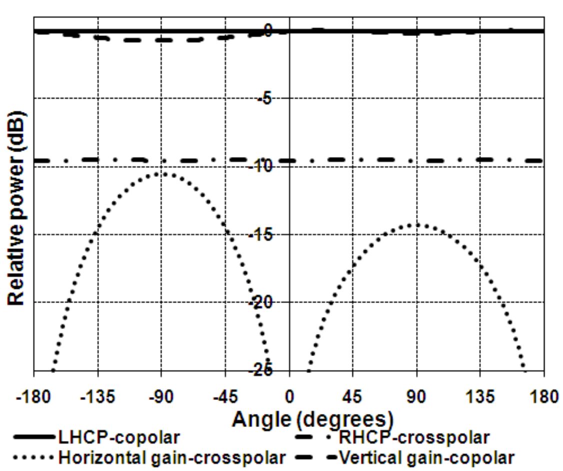


Figure 3. Predicted radiation patterns in azimuth plane of the QHA in space mode (Figure 1(a)) and in terrestrial mode (Figure 1(b)).

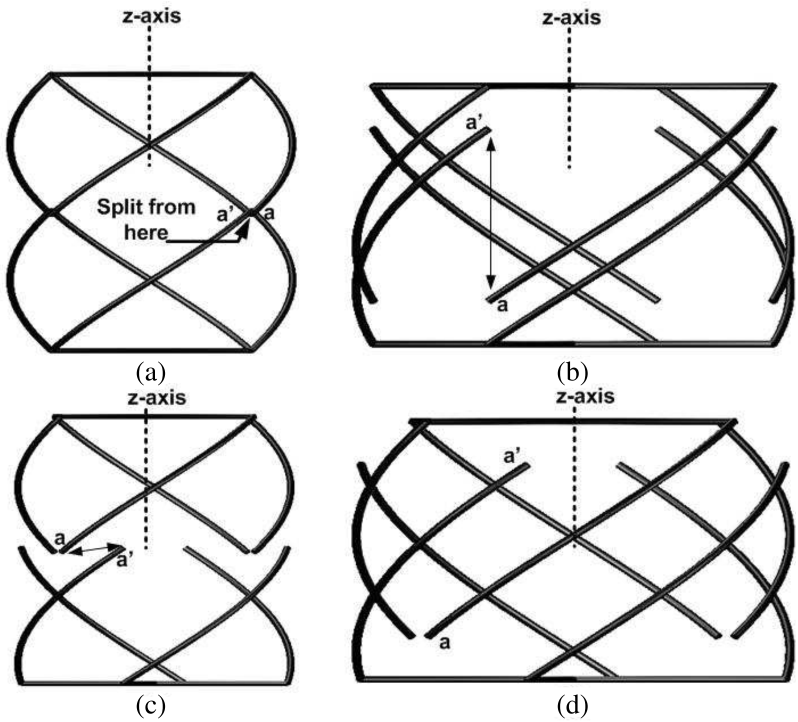


Figure 4. 2D models of split QHA. (a) Split only. (b) Translated only. (Top halve translated by 24 mm along $-z$-axis). (c) Rotated only. (Top halve rotated by 30° around z-axis). (d) Top halve translated by 24 mm along $-z$-axis and rotated by 30° around z-axis.

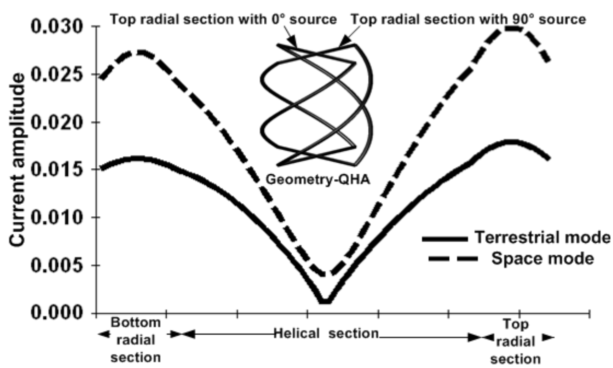


Figure 5. Current amplitude distribution for terrstrial and space mode.

gives an input impedance of 36 Ohms and a bandwidth of 50 MHz for VSWR ≤ 2 (referenced to 50 Ohms) from 1175–1225 MHz (4.1%). The predicted gain of the antenna is 5.5 dB and a 3 dB beamwidth of 118°. The predicted radiation pattern of the QHA is shown in Figure 2. The RHCP crosspolar component is more than 15 dB lower than the boresight value of LHCP copolar component. It is also evident from the results that introducing a gap at the centre of the helical sections (current minima points) does not effect its impedance and radiation pattern characteristics [2]. Figure 3 depicts the LHCP copolar and RHCP cross polar components in the azimuth plane which shows that the pattern is omnidirectional in this plane. Now if the upper halve of the QHA is moved linearly against the lower halve, the axial length of the structure reduces from L_{ax} to $\acute{L}_{ax}$ and the two bifilars overlap with a length of ΔL_{ax} where

$$\Delta L_{ax} = L_{ax} - \acute{L}_{ax} \tag{3}$$

If the upper half of the structure is not rotated around the axial direction, the radial spacing between the overlapping bifilars will be $\Delta L_{ax} \tan\theta$ where θ is the pitch angle of the volute. With a $\Delta\theta_t$ rotation of the upper half around the axial direction the spacing between the overlapping sections of the two nearby volutes is given by Equation (2). The linear movement of the upper halve of the quadrifilar along the axis and rotation around the axis introduces a variable reactance between the centres of the helical sections. The 2D models of split QHA, translated only, rotated only, both translated and rotated are shown in Figure 4. This variable reactance arises due to mutual coupling of the overlapped portions of the helical sections, which changes the relative phase of the current on the two bifilars and the relative phase of the current between the upper and lower radial sections. In addition to this the separation distance between the upper and lower radials also changes and becomes shorter and therefore the fields do not cancel in the lower hemisphere as was the case when the QHA was in normal configuration and operating in space mode. The current distribution is still such that it has maxima at the centre of the radial sections and minima at the ends of the bisected helical sections which in satellite mode were the mid points of the helical sections. This distribution of current magnitude is shown in Figure 5 where it can be seen that the two current distributions are identical except that in terrestrial mode, the current peaks are lower than the those of space mode beacuse of additional rectance. However the introduction of additional rectance changes relative phase of the currents on the two bifilars. In space mode the top and bottom crossed radial sections alongwith four helical sections being at relative phase of ±90° produces circularly polarized field, which in final effect cancel out radiations towards

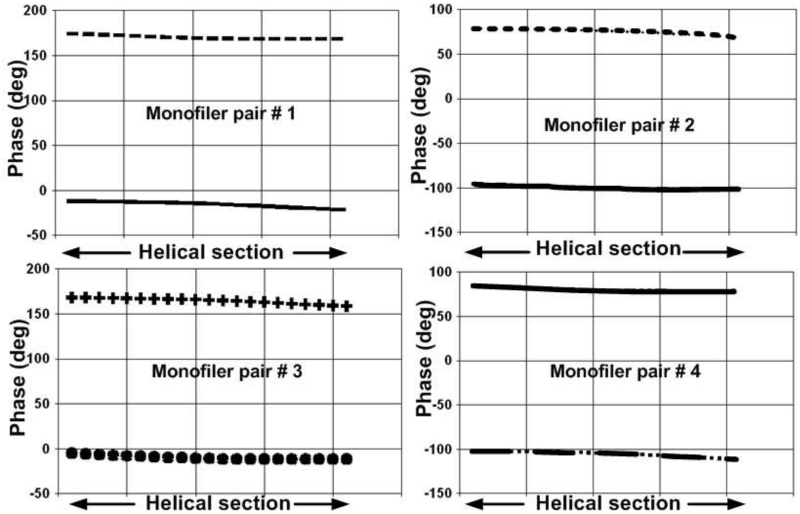


Figure 6. Pairs of monofilers with opposite phase for terrestrial mode.

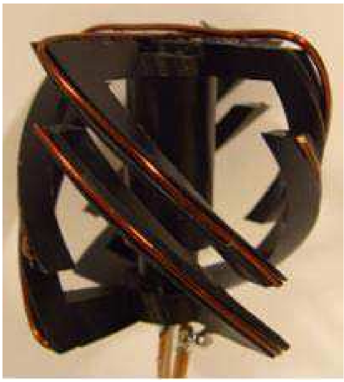


Figure 7. Photo of split QHA rotated (30° around z-axis) and translated (24 mm along $-z$-axis) alongwith feed mechanism.

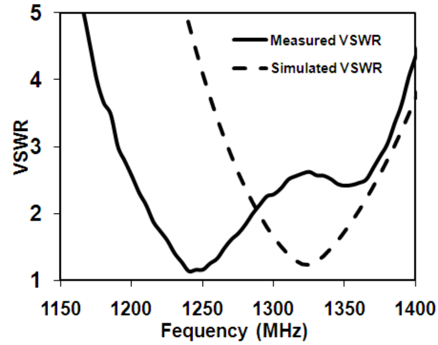


Figure 8. Simulated and measured VSWR of antennas.

ground producing hemispherical radiation pattern. In terrestrial mode eight overlapping helical sections [Figure 1(b)] forms a quasi-octofilar arrangment in which rectance due to gaps changes the phase of the current. The eight helical elements in terrestrial mode form four pairs in which current are 180° out of phase [Figure 6] largelly cancelling out their radiations. This results in toriod shaped pattern formed mainly by radiations from two crossed radial sections, when tilted 90°.

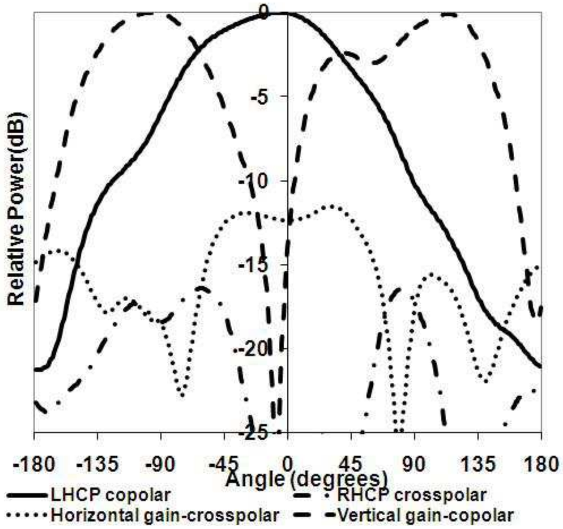


Figure 9. Measured radiation patterns in elevation plane of the QHA in space mode (Figure 1(a)) and in terrestrial mode (Figure 1(b)).

The optimised model that gives a monopole like radiation pattern has an axial length of 36 mm and a final turn angle of 150° [Figure 7]. The radial gap between the overlapped sections of the adjacent monofilars is 13.6 mm. The axial gap between the two upper radials is 5.3 mm and same gap is between the two lower radial sections. The final structure is predicted to be resonant at 1320 MHz in simulation [Figure 8]. The measured resonant frequency is 1240 MHz beacuase of slight change in the guided wavelength which occured due to the plastic supporting structure of the antenna wires. The measured and simulated bandwidths (for VSWR ≤ 2) are 5.5% and 5.9% respectively. The simulated gain in terrestrial omnidirectional mode is 2 dB with 3 dB beamwidth of 92°. The measured radiation patterns of the QHA operating in space and land communications mode are shown in Figure 9 and a good agreement between the predicted and measured results can be observed. In the case of hemispherical radiation pattern, the copolar component is slightly asymmetric which is most probably due to many scattering objects present nearby the antenna under test. The cross polar component is less than 15 dB when compared with the boresight peak value of copolar component. In case of terrestrial mode, the vertical field has fairly good measured dipole like radiation pattern. The cross polar component of the horizontal electric field is about 12 dB lower than the peaks at ±90°. In case of dipole, theoretically and in simulations, there is no cross polar component, assuming the radius of the dipole is negligibly small, however practical measurements show some cross polar component which is normally much lower than 12 dB.

4. CONCLUSIONS

It has been shown in this paper that by varying the overlap length of the two sections of the QHA and adjusting the gap between these, it is possible to operate the QHA in terrestrial mode. The operation in terrestrial mode requires translational and rotational movement of the upper half of the QHA against the lower half and a tilt of 90°. In conventional configuration the QHA operates in space mode with hemispherical radiation pattern. Thus it is possible to operate the single structure in dual mode operation.

REFERENCES

1. Kilgus, C. C., "Resonant quadrifilar helix," *IEEE Trans. Antennas Propag.*, Vol. 17, No. 3, 349–351, 1969.
2. Amin, M. and R. Cahill, "Effect of helix turn angle on the performance of half wavelength quadrifilar helix antenna," *IEEE Microw. and Wireless Components Lett.*, Vol. 16, No. 6, 385–386, 2006.
3. Evans, B., M. Werner, E. Lutz, M. Bousquet, G. E. Corazza, G. Maral, R. Rumeau, and E. Ferro, "Integration of satellite and terrestrial systems in future multimedia communications," *Special Issue, IEEE Wireless Communication*, Vol. 12, No. 5, 72–80, 2005.
4. News, "'Black box' could cut insurance costs," *IEE Review*, Vol. 50, No. 9, 21–21, 2004.
5. Graham-Rowe, D., "Gamers turn cities into a battleground," *New Scientist*, No. 2503, 26, 2005.
6. Petros, A., I. Zafar, and S. Licul, "Reviewing SDARS antenna requirements," *Microwaves* & *RF*, 51–62, 2003.
7. McCarrick, C. D., "A combination monopole/quadrifilar helix antenna for S-band terrestrial/satellite applications," *Microw. J.*, Vol. 44, No. 5, 330–334, 2001.
8. Amin, M. and R. Cahill, "Compact quadrifilar helix antenna," *Electron. Lett.*, Vol. 41, No. 12, 672–674, 2005.
9. NEC-Win Pro., version 1.6.2d, Nittany Scientific Inc., 2004.
10. Amin, M. and R. Cahill, "Mutual impedance between two dipole antennas fed by single source," *Microw. Opt. Technol. Lett.*, Vol. 42, No. 3, 187–189, 2004.