

Broadband Quadrifilar Helical Antennas

#David C. Ni¹, Peter Chung², Ray Chen³, and C. W. Hsu³

¹Direxion Technology

9F, No. 177-1, Ho-Ping E. Rd., Taipei, Taiwan, R.O.C, davidcni@yahoo.com

²King Communication Materials

Hsin Chu, Taiwan, R.O.C.

³Department of Electrical Engineering, National Taiwan University of Science and Technology
Taipei, Taiwan, R.O.C.

1. Introduction

Quadrifilar Helical Antennas (QHA) have been used for the spacecraft-satellite communications because they can provide omni-directional radiation in a single hemisphere without requiring a ground plane [1]. Recently, QHA are also adopted in the applications of GPS handheld devices since the antenna radiation pattern can be tuned to cover the upper hemisphere equally in all azimuth directions and the lower hemisphere pattern can be diminished for reducing the interference of antenna noise.

Furthermore the handheld devices are increasingly hosting multi-band applications, which drive the antenna design efforts toward integrating several antennas into a single one. In this paper, we adopt QHA as the base structure for designing broadband antennas. Due to the space constraints of the handheld devices, we adopt techniques such as capacitive matching for bandwidth and performance optimization.

2. Approaches of QHA Optimization

The physical parameters for characterizing a helix structure include helix diameter(D), helix radius(a) circumference(C), spacing between turns(S), pitch angle(α), element length(L), and number of turns(n). The main parameters determine the properties of multifilar helical antenna are pitch angle(α), circumference(C/λ), number of turns(n), and element length(L). There are approaches developed in the past for optimizing these parameters in order to obtain the desirable performance. For examples, Evolutionary Optimization [2] and Genetic Algorithms [3] are among the approaches for design optimization. The pitch angle, when other factors are placed optimally, controls the beamwidth of the antenna. Higher pitch angles tend to yield wider beamwidth at lower gain. Lower pitch angles tend to yield narrower beamwidth at higher gain.

A QHA can support both traveling-wave type and resonant type of operation, determined by the element length. The QHA designed by the resonant type tends to be a narrow band or high Q factor device. The series equivalent lumped element resistance tends to decrease toward zero for very narrow diameter structures. Various manufacturers of GPS equipments use different sizes and constructions to cover two GPS frequencies at 1575.42MHz (L1) and 1227.6MHz (L2). Other works are intended to cover more frequencies of satellite systems. In this paper, we focus on the design by the traveling-wave type with low Q factor and extend the approach with capacitive matching for the target of antenna integration with the features of low cost, wide bandwidth, and wide beamwidth for wireless applications, particularly handheld devices. In addition, we have also designed a broadband module with LNAs and filters in conjunction with this antenna for the design target. This module provides typical 30 dB gain uniformly from tens of MHz to 3 GHz with noise figure around 1.5 dB.

3. Antenna Design

Figure 1 shows the QHA with different diameters and lengths. The relative dielectric constants of these QHA range from 5 to 100 and the pitch angle is 60 degrees for wider beamwidth and bandwidth. The diameters range from 5 mm to 6 mm and the lengths range from 10 mm to 60 mm. The antenna body is supported by a PCB, which includes matching circuit and a SMC cable for connecting to main PCB. The matching circuit includes conventional impedance matching circuit and an embedded capacitive load, which is extended into antenna body. This design is based on the techniques of capacitive top-loading and non-uniform substrate [4].

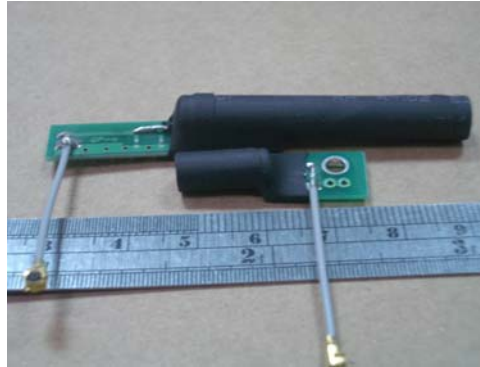


Figure 1: Two Quadrifilar Helical Antennas with different diameters and lengths. The supporting PCBs and SMC cables are also shown

4. Measurements

Two configurations are measured for performance comparison. First set is measured with the embedded capacitive load connected to the ground pad of supporting PCB and the second set is measured with the embedded capacitive load floating without connecting to the ground pad of PCB.

4.1 Embedded Capacitive Load Grounded

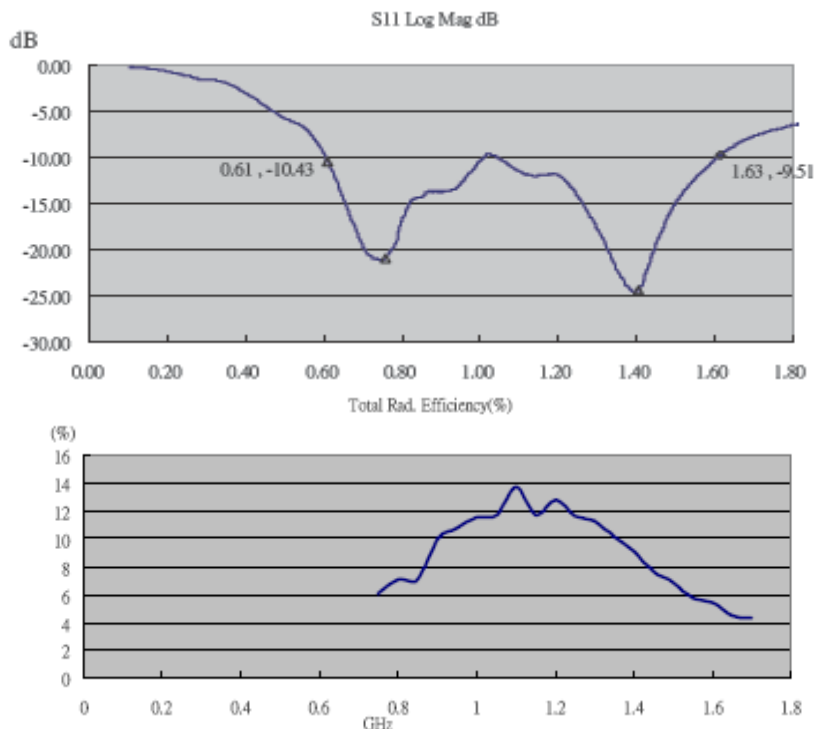


Figure 2 Return Loss and Total Radiation Efficiency of QHA with capacitive load grounded

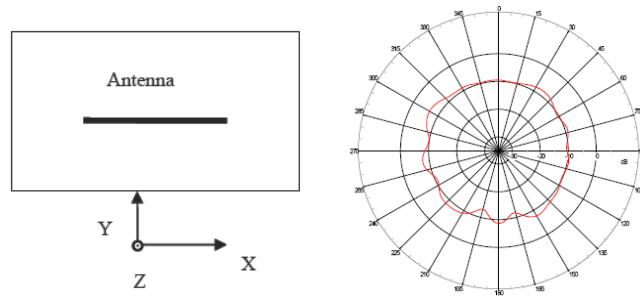


Figure 3 Far Field Power Distribution on Y-Z plane of QHA with capacitive load grounded

4.2 Embedded Capacitive Load Floating

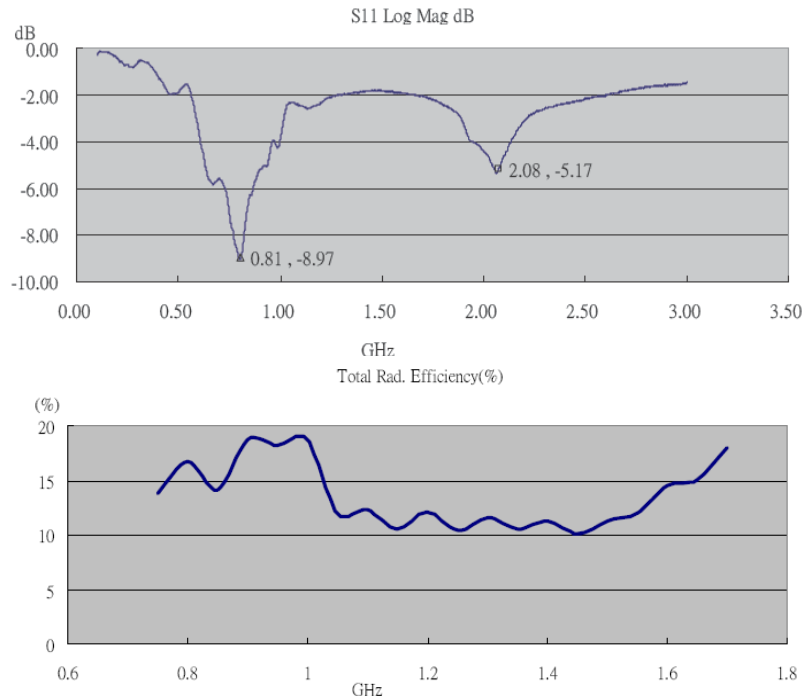


Figure 4 Return Loss and Total Radiation Efficiency of QHA with floating capacitive load

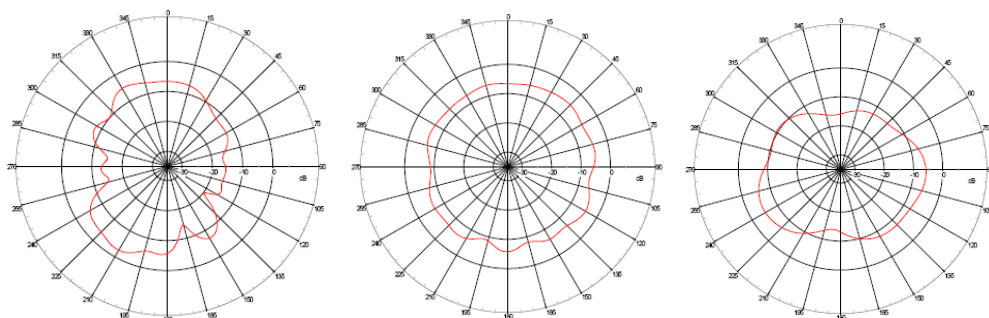


Figure 5 Far Field Power Distributions on X-Z, Y-Z, and X-Y planes of QHA with floating capacitive load

Figure 2 shows Return Loss and Total Radiation Efficiency of QHA with grounded capacitive load. The $S_{11} < -10$ dB region ranges from 0.61 GHz to 1.63 GHz. However, the total radiation efficiency peak at 1.1 GHz is about 14%. Figure 3 shows Far Field Power Distribution on Y-Z plane of QHA with grounded capacitive load. When we keep the embedded capacitive load floating, the Return Loss S_{11} degrades, but the Total Radiation Efficiency improves and rather flat with peak value moves to lower frequencies as shown in Figure 4. A 10% peak shift is observed in this case. The Far Field Power Distributions on X-Z, Y-Z, and X-Y planes are rather omnidirectional as shown in Figure 5. The phenomenon that the return loss degradation while total

radiation efficiency improvement is also observed for QHA with different physical parameters. Some samples show that the differences of the gain are as high as 10 dB.

5. Future Work

In this paper, we compare two configurations of capacitive load to QHA. We observed inconsistency of return loss, gain, and radiation efficiency from the perspective of data correlation. The floating-capacitive-loaded configuration shows degraded return loss, but demonstrates better gain and efficiency. This observation may indicate that we need to examine more in details about the energy distribution when assessing the Chu's limitation [5].

Currently we are improving the Return Loss, Gain, and Total Radiation Efficiency of QHA with floating capacitive load. The initial optimization on Return Loss shows that the bandwidth decreases for $S_{11} < -10$ dB region. We will continue to do optimization of non-uniform capacitive load and the related improvement of the optimization process.

Acknowledgments

We acknowledge of the support of RF measurements by Standard Labs of Bureau of Standards, Metrology and Inspection of Ministry of Economical Affairs of R.O.C.

References

- [1] C. C. Kilgus, "Resonant Quadrifilar Helix," IEEE Trans. Antennas and Propagation, Vol. 17, May 1969, pp. 349-351
- [2] J.D. Lohn, W.F. Kraus, D.S. Linden, J. Lohn, W. Kraus, D. Linden, "Evolutionary Optimization of a Quadrifilar Helical Antenna," Proc. of the IEEE AP-S International Symposium and USNC/URSI National Radio Science Meeting, vol 3, June 2002, pp. 814-817.
- [3] Y. Rahmat-Samii and E. Michielssen, eds. *Electromagnetic Optimization by Genetic Algorithms.*, Wiley, 1999
- [4] M. W. Nurnberger and J. L. Volakis "Extremely Broadband Slot Antenna with Shallow Reflecting Cavities", *Electromagnetics*, 20, 4, 2000, pp. 357-376
- [5] L. J. Chu, "Physical limitations of omni-directional antenna," *J. Appl. Phys*, vol. 19, pp. 1163-1175, Dec. 1948.