



GPS Quadrifilar Antenna Designs for Portable Devices

Greg O'Neill

August 2005

Low cost, high performance Global Positioning System (GPS) antennas are in demand for portable devices. The effects of partial dielectric loading and physical volume (height and diameter) are very important factors in antenna design. Parameter tradeoffs have a direct bearing on antenna pattern and therefore the overall usability of the system. This presentation covers several aspects of small Quadrifilar Helical Antennas (QHA) relative to portable GPS applications.

GPS Quadrifilar Antenna Designs for Portable Devices

Table of Contents

1	Introduction and Background	3
1.1	Customer Base Wants Small Antennas	3
1.2	QHA Factors for Good GPS Operation	3
2	QHA Characteristics.....	3
2.1	General.....	3
2.2	Axial Height and Filar Length	3
2.3	Diameter.....	4
2.4	Pitch Angle	4
2.5	Driving Point Impedance	4
2.6	Dielectric Loading.....	4
3	Case Studies for Small GPS Quadrifilar Helical Antennas	4
3.1	Case Study 1. QHA Diameter of 13 mm and Pitch Angle of 60 Degrees.....	4
3.2	Case Study 2. QHA Diameter of 15 and Pitch Angle of 30 Degrees.....	5
3.3	Case Study 3. Dielectric Loaded QHA Diameter of 12 mm and Pitch Angle of 30 Degrees.....	5
4	Measured Results for 60 Degree QHA	9
4.1	Measured Gain vs. Frequency for Diameter = 12 mm and Pitch Angle = 60 Degrees .	9
4.2	Measured Efficiency for Diameter = 12 mm and Pitch Angle = 60 Degrees	9
4.3	Measured Radiation Pattern for Diameter = 13 mm and Pitch Angle = 60 Degrees...	10
5	Measured Results for 30 Degree QHA for Diameter = 12 mm and Pitch Angle = 30 Degrees.....	11
5.1	Measured Gain vs. Frequency for Diameter = 12 mm and Pitch Angle = 30 Degrees	11
5.2	Measured Efficiency for Diameter = 12 mm and Pitch Angle = 30 Degrees	11
5.3	Measured Radiation Pattern for Diameter = 12 mm and Pitch Angle = 30 Degrees...	12
6	Summary Discussion	13

Introduction and Background

1.1 Customer Base Wants Small Antennas

SkyCross customers generally want smaller antennas, and this trend continues for GPS applications. SkyCross has responded with quite small Quadrifilar Helical Antennas. This paper presents three simulated case studies and their respective measured antenna results.

1.2 QHA Factors for Good GPS Operation

The ideal antenna radiation pattern for a GPS handheld device covers the upper hemisphere equally in all azimuth directions looking for right hand circular polarized signals from the GPS space vehicles. Also important, the total polarization lower hemisphere pattern should be diminished to reduce the antenna noise temperature. For reference, consider an antenna that has a spherical radiation pattern with 0 dBirhcp as a goal for gain. Considering some loss occurs in the antenna structure and the matching, a more reasonable gain might be -0.5 dBirhcp or less. The upper hemisphere ideal gain would be +3 dBirhcp or a little less considering the antenna loss factors.

GPS receivers work best when they receive signals at low elevation angles separated by azimuth. A properly sized QHA can provide this near ideal upper hemisphere right hand circular radiation pattern. The pitch angle, diameter, and filar length can be arranged for near ideal upper hemisphere right hand circular polarization.

The goal is to develop good performance for small practical antennas capable of being manufactured in high volume at low cost.

2 QHA Characteristics

2.1 General

The QHA, more so than many other antennas, wants to utilize a resonant structure. One bifilar opposing pair of filars is balanced against a quadrature related second opposing pair of filars to cause the circularly polarized pattern to be realized. The first resonance occurs when a filar total length is near a quarter wavelength. Our goal is to use the smallest practical antenna for our purpose. If more coverage of the upper hemisphere is desired then longer multiples of quarter-wavelength antennas can be considered.

2.2 Axial Height and Filar Length

The filar element length includes the helical length as well as the radius length to a common feed point at the center of the cylindrical structure. The free space wavelength of the GPS L1 frequency of 1575 MHz is about 190 mm, whereas a quarter wavelength is about 48 mm. The axial height is the sum of the helical length plus the radius of the cylindrical structure. The axial height for a QHA using a 60 degree pitch angle is less than 40 mm; for 30 degrees, the axial height is less than 20 mm.

The axial height for a QHA utilizing some dielectric loading will be even smaller. Use of a thin-walled internal sleeve and an external radome tends to reduce the overall axial length another percentage depending on the exact geometries. The overall dielectric has more than 50 % air, but the dielectric loading from the thin walls is an important consideration when making high

volume low cost antennas. The thin-walled internal sleeve can be made of high temperature molded plastic. The internal sleeve is very light, allowing the overall weight of the antenna to remain low. Since accurate dimensions are required, good simulation correlation to real antennas can reduce “cut and try” design time. The dimensions and materials need to be stable.

2.3 Diameter

The diameter plays a role in the bandwidth of the antenna. Generally, those styling products desire narrow diameters while those needing performance prefer wider diameters.

2.4 Pitch Angle

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. The number of turns, per se, is not a primary indicator of QHA performance.

2.5 Driving Point Impedance

The QHA is basically a resonant structure. To some degree, the structure might be fore-shortened away from resonance if the feed structure completes the resonant relations. The QHA, in the form typically used, tends to be a narrow band or high “Q” device. The series equivalent lumped element resistance tends to decrease toward zero for very narrow diameter structures.

The “art” of matching the QHA to the typical 50 Ohm receiver is distinctly not covered in this paper. It is a very fascinating aspect of product development and is therefore appropriate to acknowledge as an important aspect for a complete product description.

2.6 Dielectric Loading

The SkyCross approach considers dielectric loading as a means to give support to the antenna structure. Dielectric loading causes the axial height of the structure to be shorter. Four factors contribute to dielectric loading:

- I. The filars are typically wound on a dielectric film.
- II. The film is wound on an internal sleeve made from a high temperature material to tolerate assembly processes.
- III. The antenna structure is housed inside an external radome structure. This is typically a plastic material.
- IV. A fourth layer may also be used in production.

3 Case Studies for Small GPS Quadrifilar Helical Antennas

3.1 Case Study 1. QHA Diameter of 13 mm and Pitch Angle of 60 Degrees

The first antenna is a small quarter wavelength QHA having a structure diameter of 13 mm. The pitch angle is 60 degrees and results in an axial height of about 40 mm. This antenna is shown as it would be in free space without dielectric loading. The diameter is about 16 mm when enclosed in a radome. Normally a radome would be placed over the antenna for practical protection. The pitch angle of 60 degrees is an excellent compromise for wide beamwidth in the upper hemisphere.

3.2 Case Study 2. QHA Diameter of 15 and Pitch Angle of 30 Degrees

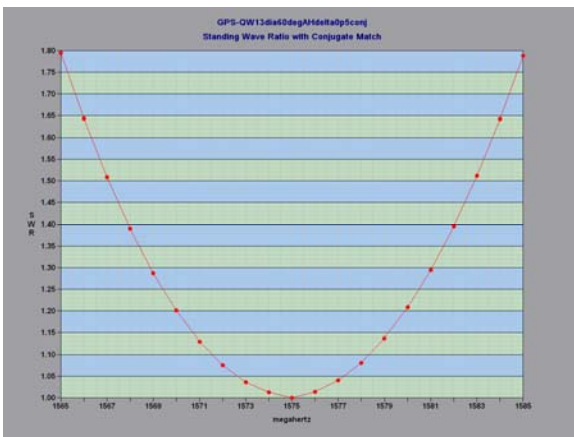
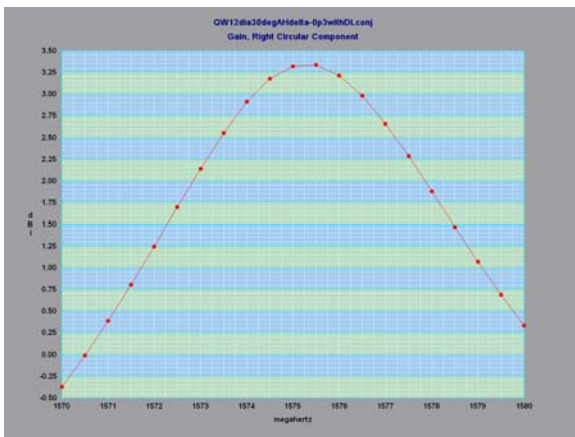
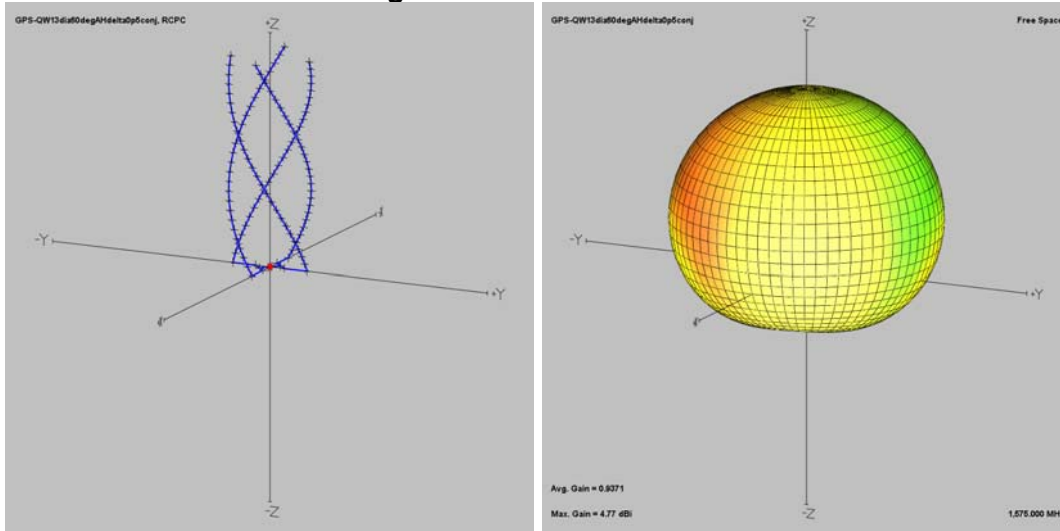
This second antenna is half the axial height, volume, and weight of the first 60 degree antenna example. As one would suspect, the “Q” is much higher, so the bandwidth is much narrower. Experience shows that the beamwidth, while narrower, may be adequate for GPS applications. The efficiency for practical implementations of this 30 degree pitch angle QHA tends to be one decibel or 20% less than that of the 60 degree versions. The diameter including the radome is about 15 mm, and the axial height is 21 mm.

3.3 Case Study 3. Dielectric Loaded QHA Diameter of 12 mm and Pitch Angle of 30 Degrees

This third antenna is a practical implementation of the Case Study 2 antenna. This example shows the effects of dielectric loading. The antenna is mounted on an internal cylindrical sleeve of about 0.75 mm wall thickness. A radome of about 15 mm outside diameter and a wall thickness of about 1 mm surround the antenna with a small air gap. The diameter of the antenna structure is 12 mm, and the axial height is 17.5 mm.

Dielectric loading of the quadrifilar helical structure reduced both the diameter and the axial height for equivalent performance. The dielectric loading introduces some loss and a reduction in the efficiency. The dielectric loading reduced the diameter by 25 percent and the axial height by 21 percent.

Case Study 1: Diameter 13 mm. Axial Height 40 mm. Pitch angle is 60 degrees. Simulation for no dielectric loading.



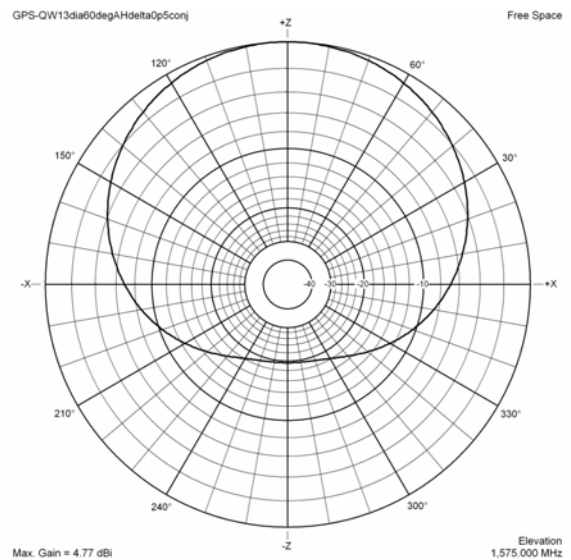
CASE STUDY 1

This antenna simulation performs well for a small quarter-wave QHA.

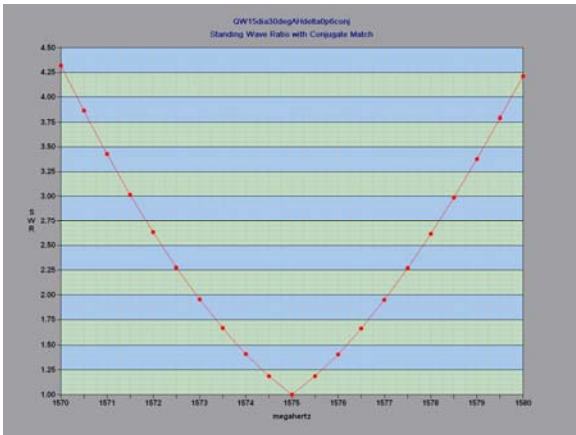
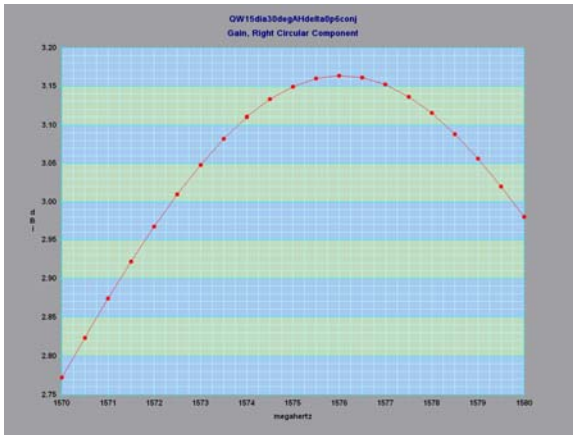
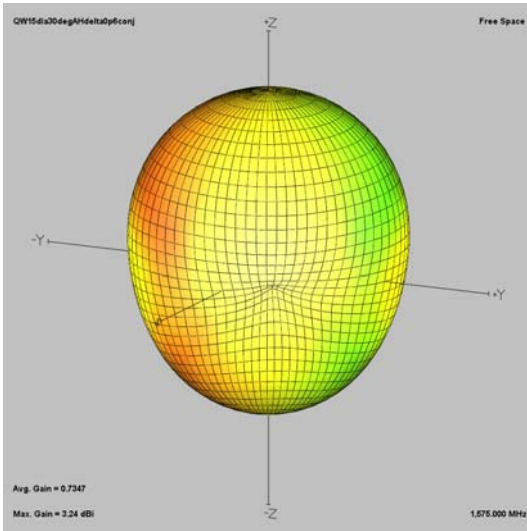
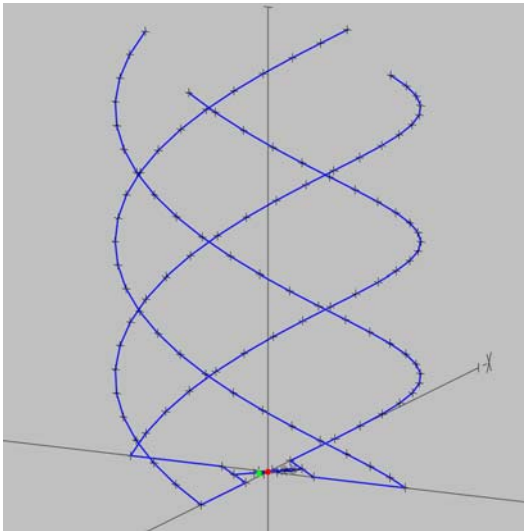
The structure dimensions:

- Diameter is 13 mm
- Axial Height is 39.6 mm
- Pitch Angle is 60 degrees

The antenna structure efficiency is over 90 percent. This does not include matching devices.



Case Study 2: Diameter 15 mm. Axial Height 21 mm. Pitch angle is 30 degrees. This model does not use any dielectric loading.



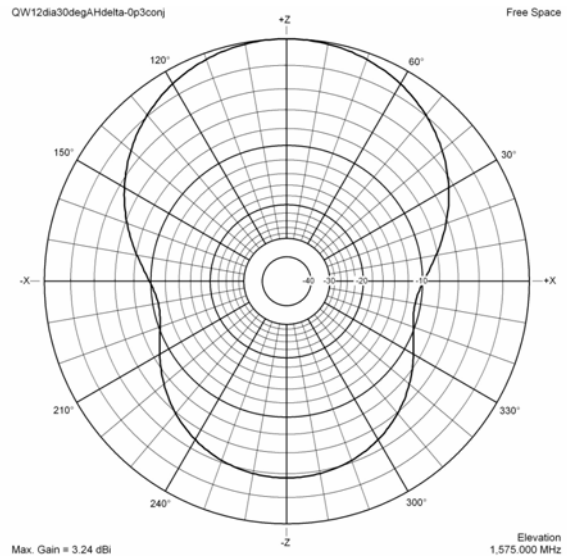
CASE STUDY 2

Antenna simulation similar gain, but a greater lower hemisphere.

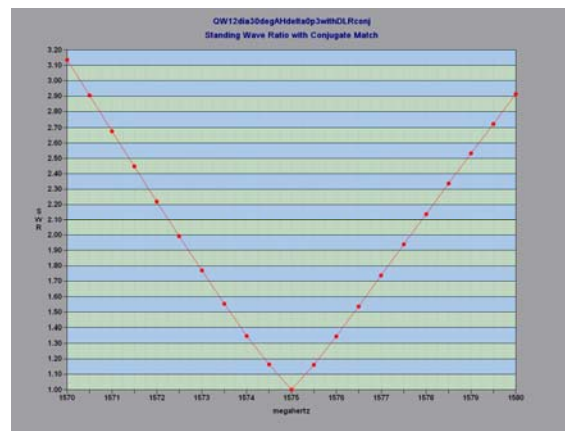
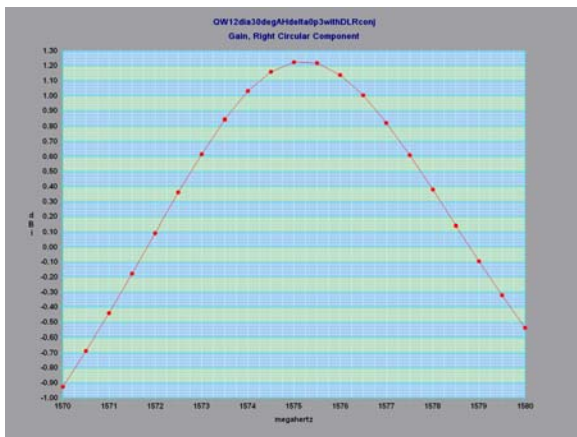
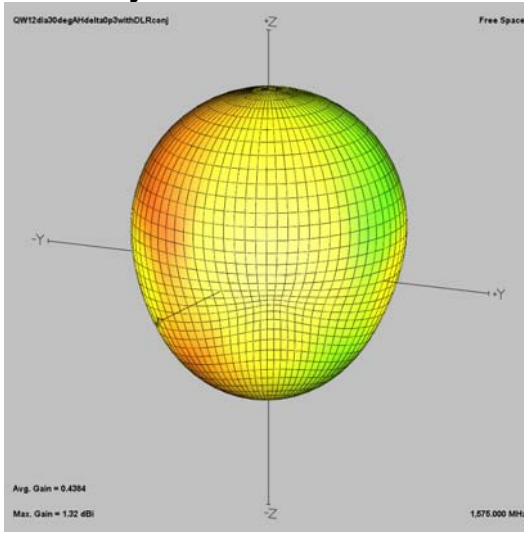
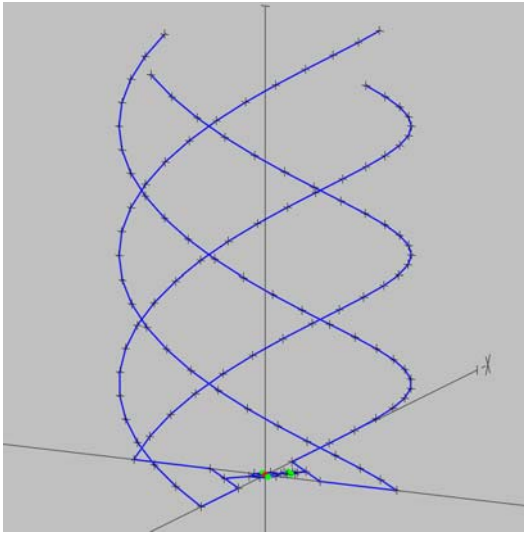
The structure dimensions:

- Diameter is 15 mm
- Axial Height is 21.2 mm
- Pitch Angle is 30 degrees

The antenna structure efficiency is over 70 percent. This model does not include matching devices.



Case Study 3: Diameter 12 mm. Axial Height 18mm. Pitch angle is 30 degrees. Simulation includes dielectric loaded internal sleeve cylinder and external radome.



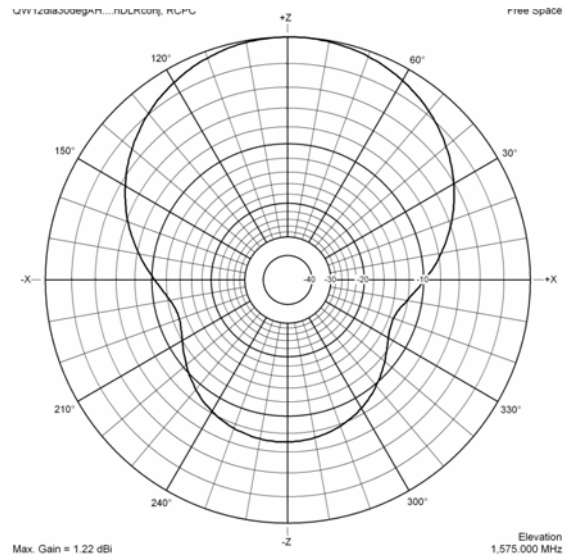
CASE STUDY 3

This dielectrically loaded antenna simulation indicates less gain. The efficiency is over 30 percent.

The structure dimensions:

- Diameter is 12 mm
- Axial Height is 17.9 mm
- Pitch Angle is 30 degrees

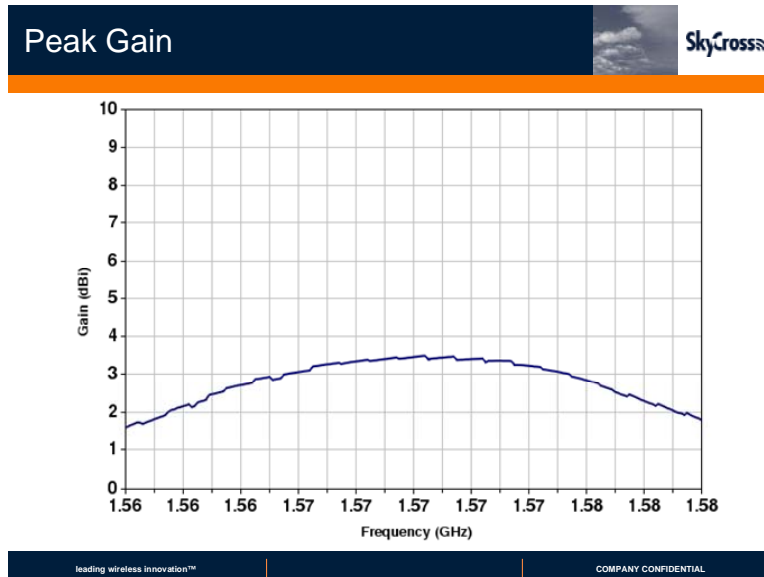
The antenna structure efficiency is over 30 percent. This does not include matching devices.



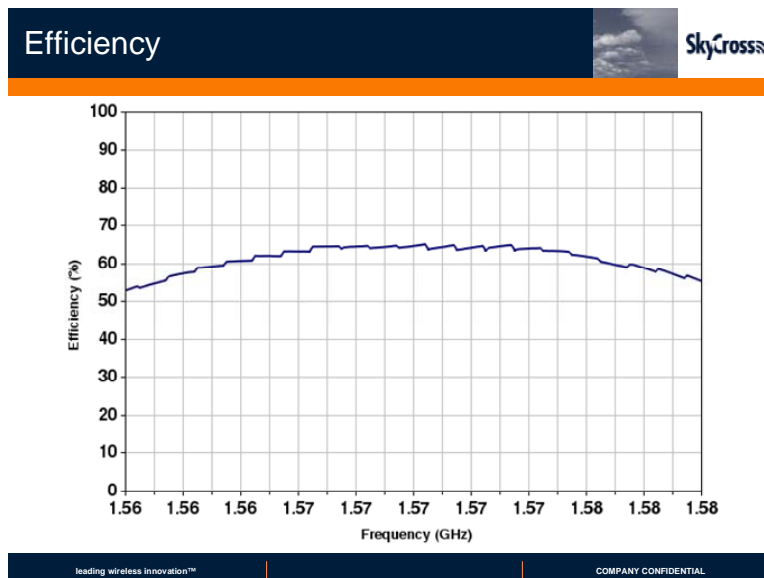
4 Measured Results for 60 Degree QHA

The SkyCross Quarter-Wave Quadrifilar Helical Antenna for GPS L1 applications is based around a helical structure diameter of 12 mm. The resulting packaged diameter is approximately 15 mm. The extra diameter allows a radome of about 1 mm thickness as well as some comfortable internal slope for the injected molded plastic tooling. The axial height can be as low as 40 mm for the antenna portion of the assembly.

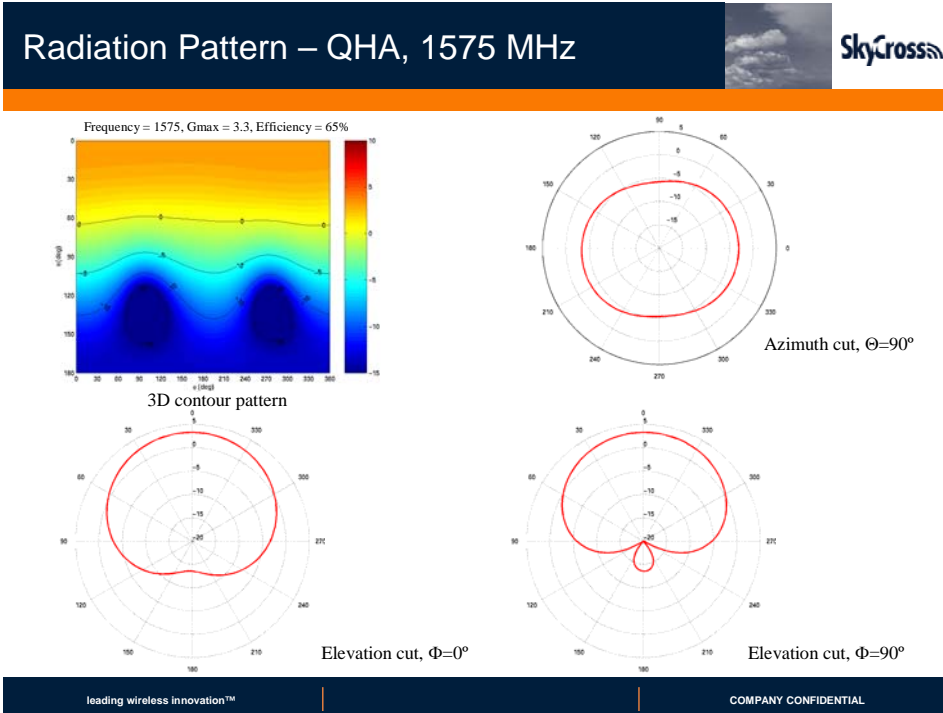
4.1 Measured Gain vs. Frequency for Diameter = 12 mm and Pitch Angle = 60 Degrees



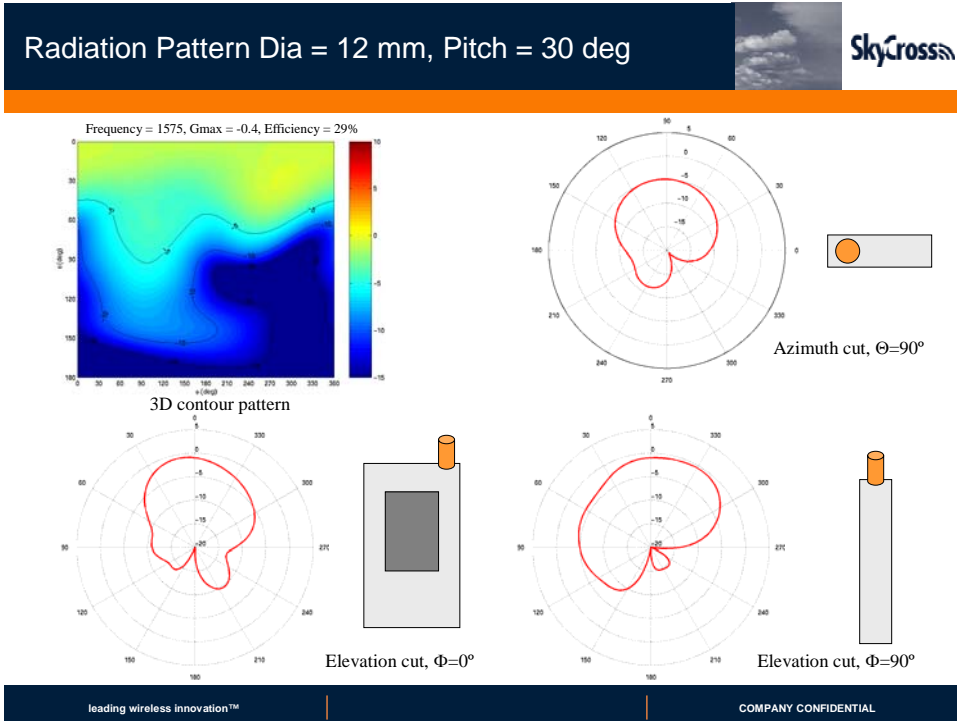
4.2 Measured Efficiency for Diameter = 12 mm and Pitch Angle = 60 Degrees



4.3 Measured Radiation Pattern for Diameter = 13 mm and Pitch Angle = 60 Degrees



5.3 Measured Radiation Pattern for Diameter = 12 mm and Pitch Angle = 30 Degrees



6 Summary Discussion

SkyCross compares the measured results of three simulated small quarter-wave GPS QHAs. Following is a short discussion about the antennas.

Case Study 1: Diameter 13 mm. Pitch Angle 60 degrees. Axial Height 40 mm. This antenna produces a near hemispheric right hand circular polarized antenna pattern. The radiation efficiency is greater than 60 percent even as a dielectric loaded model.

Case Study 2: Diameter 12 mm. Pitch Angle 30 degrees. Axial Height 21 mm. This antenna simulation is a means to show the effect of dielectric loading for the next case study. The gain is still good on this simulated version.

Case Study 3: Diameter 12 mm. Pitch Angle 30 degrees. Axial Height 18 mm. The dielectric loading of the internal sleeve and an external radome combine to provide a smaller antenna. The gain is reduced about 3 dB from the larger antenna with a 60 degree pitch angle. The measured radiation patterns were made with the antenna mounted on a small communications device.

The dielectric loading contributes to making the antenna smaller. There is some loss in efficiency, but the smaller size overall may be significant to some product designs.

The nature of current electronic products continues to drive toward acceptable performance while satisfying the desire for small forms.