

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 7, July 2017

## Design of Quadrifilar Helical Antenna for Satellite Communication Applications

V.Saidulu

Associate Professor, Dept. of Electronics and Communication Engineering, Gandipet, Hyderabad, India

**ABSTRACT:** The quadrifilar helix antenna was simulated and the most suitable antenna model with optimum performance for the user segment of mobile satellite communications is presented. The simulation results agreed well with specifications with regard to gain and VSWR but agreed poorly with regard to beam width. In this paper the varying the helix radius, varying number of turns of helix varying spacing between the turns and the thickness of the dielectric observed that the helix radius (HR) is varied from 12.7 mm to 15.7 mm in steps of 1 mm. It is observed that the VSWR decreases and gain increases with helix radius. Hence HR = 15.7 mm is taken as the optimum value. The spacing between the turns (S) is varied from 62.5 mm to 64.5 mm in steps of 1 mm. It is observed that the VSWR increases with spacing but the desired radiation pattern and gain are obtained only for S = 64.5 mm. Hence the optimum value of spacing is taken as 64.5 mm. The number of turns (N) is varied from 1.1 to 1.3 in steps of 0.1. It is observed that the VSWR increases with number of turns. The desirable pattern and gain are observed when N = 1.1. Hence the optimum value of number of turns is taken as 1.1. The thickness of dielectric (t) is varied from 0.5 mm to 0.9 mm in steps of 0.2. It is observed from the VSWR plot that resonant frequency reduces below the operating frequency as the dielectric thickness increases. The desirable radiation pattern and gain are observed at thickness (t) = 0.9 mm. Hence the optimum value of dielectric thickness is taken as 0.9 mm. After examining the optimization plots, the optimized parameters such as Helix radius (HR) = 15.7mm, Spacing between turns (S) = 64.5mm, Number of turns (N) = 1.1, Thickness of the dielectric (th) = 0.9mm, Ground plane radius (GPR) = 22mm and strip width (SW) = 1.08mm are selected based on desired gain and VSWR.

**KEYWORDS:** Quadrifilar helix, Gain, Axial ratio, Beamwidth, VSWR and Return-loss..

### I. INTRODUCTION

A quadrifilar helix is formed by triple 90° rotations of a helix about its axis, to generate three additional ones. Thus, each helix will be azimuthally separated from the next by 90°, and the antenna has four terminals at each end. The multiplicity of the turns and terminals at both ends add to the parameters of the helix and make this antenna unique, which can produce an incredible array of radiation patterns, shaped beams, forward and backward waves, and geometrical configurations. The four helical conductors can be excited in phase quadrature at the feed point located in the centre of the top radials thus operating in the backfire mode. By reversing the phasing of the excitation, the antenna can also be fed at the bottom while still covering the top hemisphere with a circularly polarized beam. The radials at the opposite end of the antenna are usually open circuited for radiating elements with a resonant length which is an odd multiple of a quarter wavelength, and short circuited for even multiples of a quarter wavelengths. This is done to produce a current maximum at the feed and so ensure that the input impedance is small enough to obtain a good match between the antenna and the feed network. The structure of a quadrifilar is shown in Fig.1.

### II. CHARACTERISTICS OF QFH ANTENNA

The QFH has terminals at both ends, which can be fed at either end. The remaining terminals at the other end can be shorted together or left open. Since in a helix antenna the direction of wire rotation dictates the sense of circular polarization, the input feed has two possibilities. The terminals can be fed clockwise in phase quadrature like 0°, 90°, 180°, and 270°, or they can be fed counter clockwise. Additionally, in the clockwise feed, the terminals can be fed with a reverse phase progression like 0°, -90°, -180°, and -270°. If the phase progression coincides with the sense of circular polarization, the antenna radiates a forward wave. Otherwise, a backward wave is launched to match the sense of circular polarization to feed the phase progression. Thus, a quadrifilar helix antenna can function in both modes simultaneously, a

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 7, July 2017

significant advantage. Also, since the total phase progression at the feed terminals is  $2\pi$ , the radiated field is automatically circularly polarized. This means the antenna radius can be decreased further, without affecting its axial ratio. This property also enables the selection of very diverse configurations, from very thin and tall designs, to very short and broad ones, which can meet very broad application requirements. The axial mode of a quadrifilar helix can radiate both high gain and shaped conical beams are shown in Fig 1.

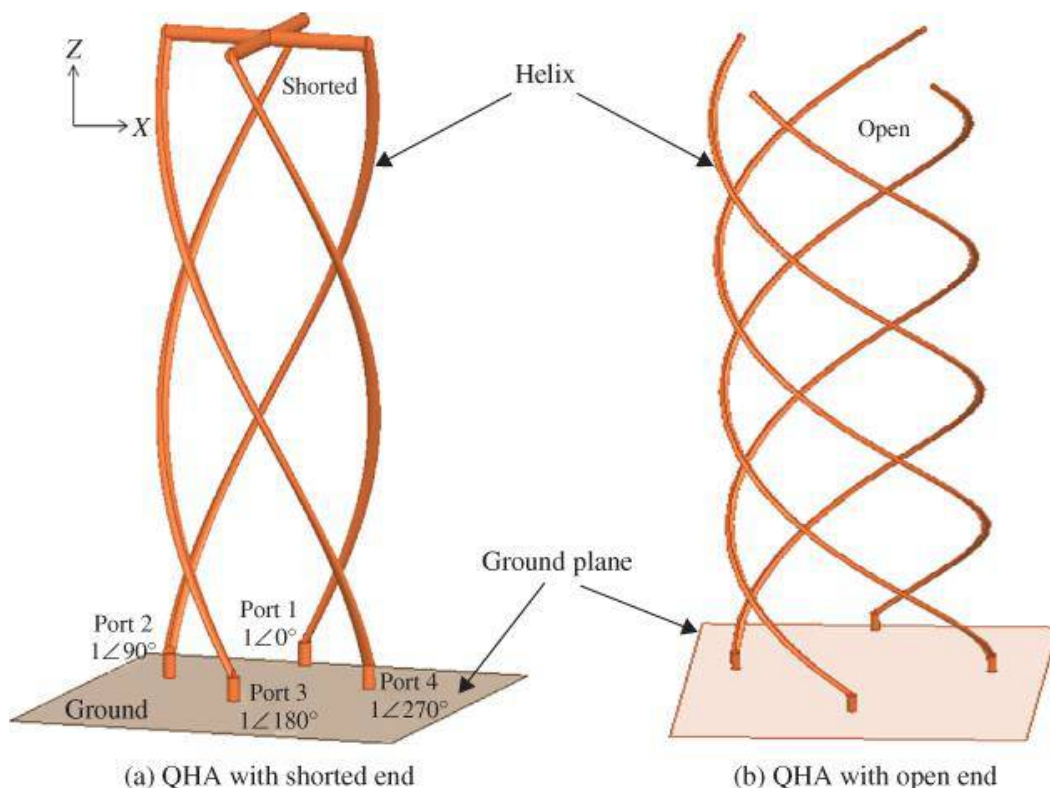


Fig.1 The structure QFH antenna

## III. RELATED WORK

The some of the research works presented on QFH antenna :XiaozhongShui and Haibo Tang in their paper “S-band Printed Quadrifilar Helical Antenna for Communication Devices” presented the design of a QFH with good heart-shaped radiation pattern from 3.05GHz to 3.45GHz, 3dB power-width of more than  $160^\circ$ , gain greater than -2dB in the azimuth range, the axial ratio lower than 5dB, and the VSWR lower than 1.4 [1-5]. This printed quadrifilar helical antenna was said to have good electromechanical characteristics and low cost. The length of each helical arm is a quarter wavelength multiplying an integer ( $M\lambda/4$ , M is an integer ). When the  $D/\lambda = 0.25 \sim 0.46$ , the helical antenna has maximum radiation in one direction of the axis. When  $D/\lambda > 0.46$ , a conical pattern results (D is the diameter of the helix). SarelJacobus Marais in his paper “The Quadrifilar Helix Antenna and its Application to Wide Angle Phase-Steered Arrays” designed a multi-turn QHA with shaped-conical patterns as a ground station antenna for the ZA-002 South African Small Satellite programme. The center frequency of operation is 403MHz [5-13]. Using the data presented by Kilgus, the antenna was designed and simulated in FEKO. The final values of the geometrical parameters are given in Table 1

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 7, July 2017

TABLE 1: GEOMETRICAL PARAMETERS OF THE GROUND STATION ANTENNA

Parameters	Description	Value
R	Volute radius	34mm =0.046 $\lambda$
L	Axial length	983.2mm =1.32 $\lambda$
P	Pitch distance	491.6mm =0.66 $\lambda$
K	Ratio r/p	0.0692
N	Number of turns	2
GPR	Ground plane radius	372.2mm =0.5 $\lambda$

**Inference:** Identifying the affecting parameters that lead to a desired pattern shape is the challenging aspect of the development. A limited number of experimental results, applicable to a few cases, can be found in the literature; however, a combination of starting points from these results was utilized to develop the antenna which is presented in this paper. After the literature survey, it was understood that it is possible to develop a very high performance QFHA with excellent impedance matching if the antenna parameters such as radius, pitch angle and height, which will control the phase velocity and current distribution over the antenna structure, are carefully designed. Heather Fraser in his paper "Parametrisation and Design of Quadrifilar Helices for use in S-band Satellite Communications" discusses Multiturn Quadrifilar Helix Antenna (QHA) with focus on its application as a ground station antenna for S-band communications with a Low Earth Orbit Satellite. The QHA was simulated and the most suitable results were found for the antennas with low to mid-range of number of turns, radii less than  $0.22\lambda$  and pitch less than  $0.6\lambda$ . A QHA with 3 turns, pitch of  $0.6\lambda$ , and radius of  $0.034\lambda$  was suitable for satellite communications. Simulations showed it to have a gain of 6.16dB at  $52^\circ$  and -2.25dB at  $0^\circ$ .

TABLE II: SIMULATION RESULTS FOR N=3 AND PITCH=0.6 $\lambda$

Radius ( $\lambda$ )	Center gain (dB)	Edge gain (dB)	VSWR
0.031	-1.85	6.18	1.54
0.032	-2.0	6.18	1.36
0.033	-2.1	6.17	1.21
0.034	-2.25	6.16	1.07
0.035	-2.4	6.11	1.10
0.036	-2.51	6.10	1.23
0.037	-2.61	6.08	1.37
0.038	-2.67	6.06	1.52
0.039	-2.74	6.05	1.69

In 1974, Charles C. Kilgus described the effects of changing these parameters. His paper describes QHAs with 1-5 turns, pitches of 0 to 1 and radii of  $0.01\lambda$  to  $0.14\lambda$ . He noted that there was a region of shaped conical beams between Pitch =  $0.3\lambda$  and  $0.9\lambda$  and Radius =  $0.01\lambda$  and  $0.14\lambda$ . The antennas are described in terms of the parameter k which is the ratio of radius, r, to pitch, p. He noted that an antenna for the purpose of satellite communications occurs when  $k = 0.083$  and  $p = 0.6$  with  $N=3$ ,  $k = 0.083$  and  $p = 0.609$  when  $N = 5$ . Jamal S. Izadian in his paper "QFHA Antennas for Satellite radio and mobile phone applications" designed a QFH antenna with 1.5 turns, 4" length and a diameter of 0.750". To obtain this diameter, however, various diameters were simulated. The measured results indicated that the centre dip is too deep. Other designs were tested to bring the dip up, involving changing the diameter of the antenna

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 7, July 2017

tube. The measured results for the QFHA with a diameter of 0.750" on a 16" × 16" finite ground plane are shown in Fig. 5. .

## IV. DESIGN SPECIFICATIONS

The QFH is to be designed for the following specifications

Parameters	Specifications
Frequency of operation	2.6 GHz
Polarization	RHCP
VSWR	2.5dB (max)
Gain	2-3dB
Axial ratio	3dB (max)
Radiation pattern	Hemispherical coverage
Power handling	1W (Continuous wave)

## V.QFH CONFIGURATION

In this paper, we design printed QFH antenna. The reason behind opting printed antenna is its low cost of manufacturing, light weight; compactness and ease of fabrication. The helices are printed on a flexible dielectric film and rolled into a cylinder. Dielectric medium allows surface waves to propagate through it and extracts some part of the total power available for radiation, which degrades the electrical properties of the antenna. The cost of antenna design is also affected by dielectric material; hence the selection of substrate is crucial. High dielectrics can store more energy with small size, but they can't withstand intense electrostatic fields. Hence a trade-off must be made between antenna size and input power. We use PTFE (poly tetrafluoroethylene) and RT Duroid 5880 with relative permittivity 2.1 and 2.2 respectively as substrates in our design. The four ports of the antenna are fed by coaxial cables, which provide excitation with equal amplitude and required phase differences at each port.

## VI.DESIGN GUIDELINES FOR PRINTED QFH ANTENNA

Various literatures are searched and studied and the following guidelines are obtained:

According to *Modern antenna handbook* by Constantine A. Balanis the parameters for axial mode radiation are  $C = 0.56\lambda$ ,  $\alpha = 60^\circ$ ,  $L = 0.77\lambda$ . In a standard QFH the number of turns of the helix  $N=1$ .  $N$  can also be a fraction as in the fractional turn QFH.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 7, July 2017

## VII. SIMULATION RESULTS AND OBSERVATIONS

Simulation results are obtained in the form of radiation pattern, VSWR, axial ratio and return loss.

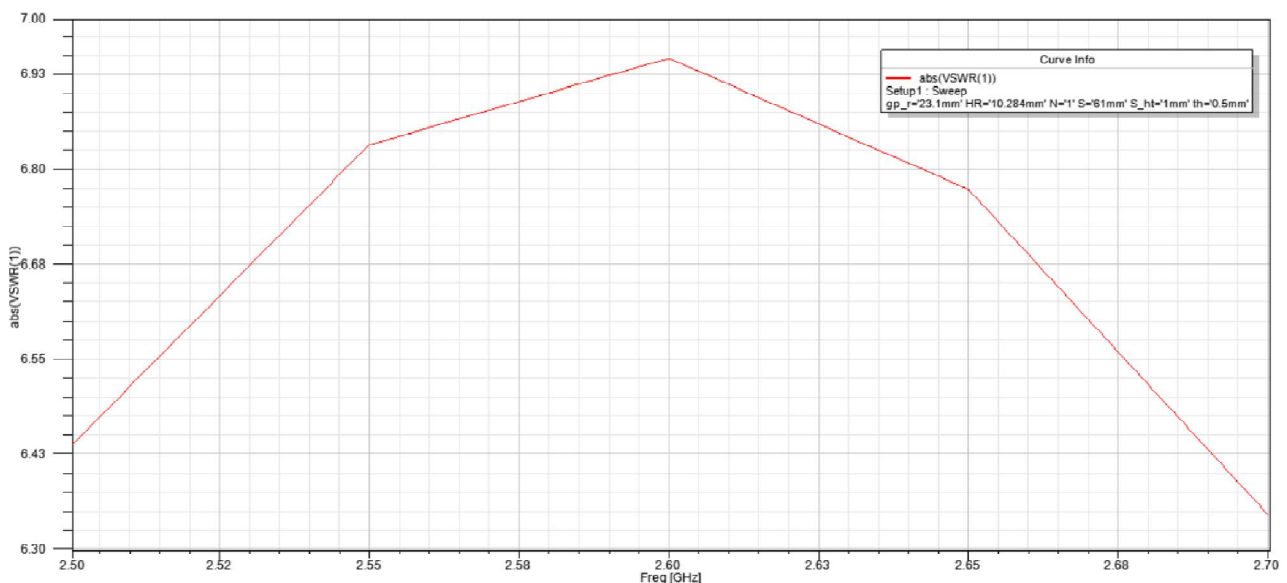


Fig 2 VSWR plot of the design

From the above plots, it can be observed that the gain is -0.5 dB along bore-sight with beamwidth of 68.50 and VSWR is 6.95 at 2.6 GHz.

### (A) Varying ground plane radius

The ground plane radius (GPR) is varied from 21 mm to 23 mm in steps of 1 mm. It is observed that VSWR increases with ground plane radius. The desired radiation pattern is obtained only for GPR = 22 mm. Hence it is taken as the optimum value.

### (B) Varying helix radius

The helix radius (HR) is varied from 12.7 mm to 15.7 mm in steps of 1 mm. It is observed that the VSWR decreases and gain increases with helix radius. Hence HR = 15.7 mm is taken as the optimum value.

### (C) Varying number of turns

The number of turns (N) is varied from 1.1 to 1.3 in steps of 0.1. It is observed that the VSWR increases with number of turns. The desirable pattern and gain are observed when N = 1.1. Hence the optimum value of number of turns is taken as 1.1.

### (D) Varying spacing between the turns

The spacing between the turns (S) is varied from 62.5 mm to 64.5 mm in steps of 1 mm. It is observed that the VSWR increases with spacing but the desired radiation pattern and gain are obtained only for S = 64.5 mm. Hence the optimum value of spacing is taken as 64.5 mm.

## International Journal of Innovative Research in Science, Engineering and Technology

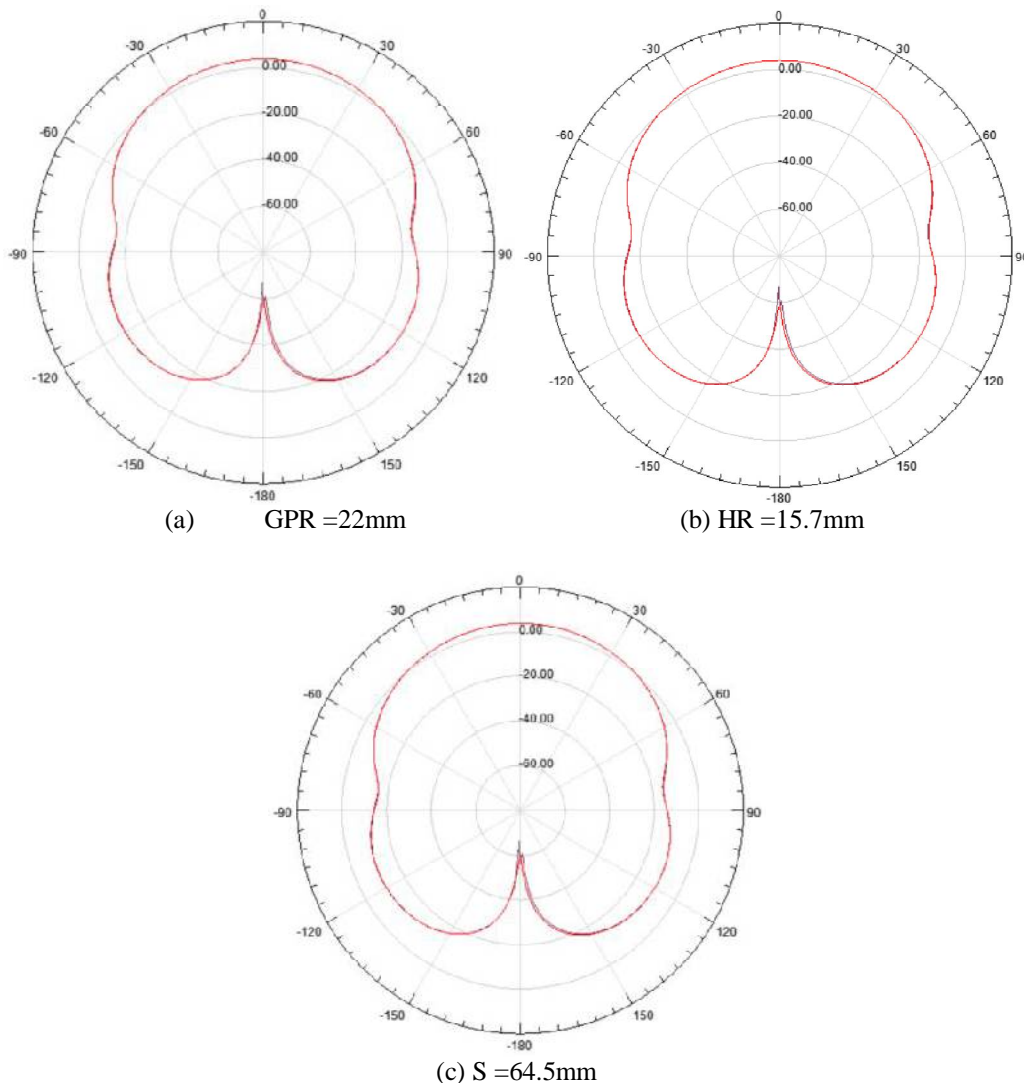
(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 7, July 2017

### (E) Varying thickness of dielectric

The thickness of dielectric (th) is varied from 0.5 mm to 0.9 mm in steps of 0.2. It is observed from the VSWR plot that resonant frequency reduces below the operating frequency as the dielectric thickness increases. The desirable radiation pattern and gain are observed at  $th = 0.9$  mm. Hence the optimum value of dielectric thickness is taken as 0.9 mm.





# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 7, July 2017

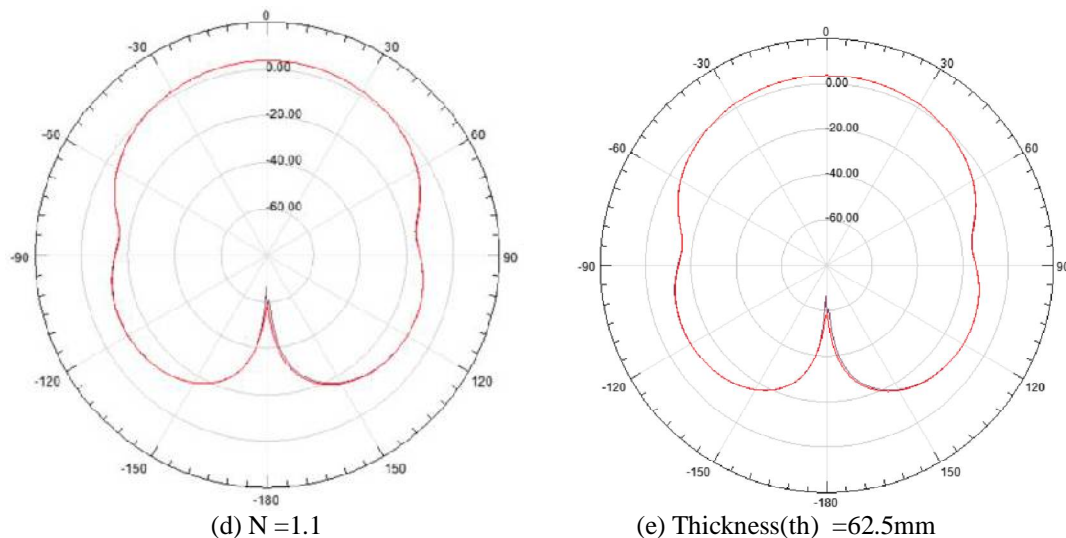


Fig.3 Optimum Radiation patterns with variations of (a) ground plane radius (GPR) (b) Helix radius (HR) (c) Spacing between the turns (S) (d) Number of turns (N) (e) Thickness of dielectric (th) of turns

## VIII. OPTIMIZED QFH PARAMETERS

After examining the optimization plots, the optimized parameters such as Helix radius (HR) =15.7mm, Spacing between turns (S) =64.5mm, Number of turns (N) =1.1, Thickness of the dielectric (th) =0.9mm, radius of the ground plane (RGP) =22mm and strip width (SW) =1.08mm are selected based on desired gain and VSWR.

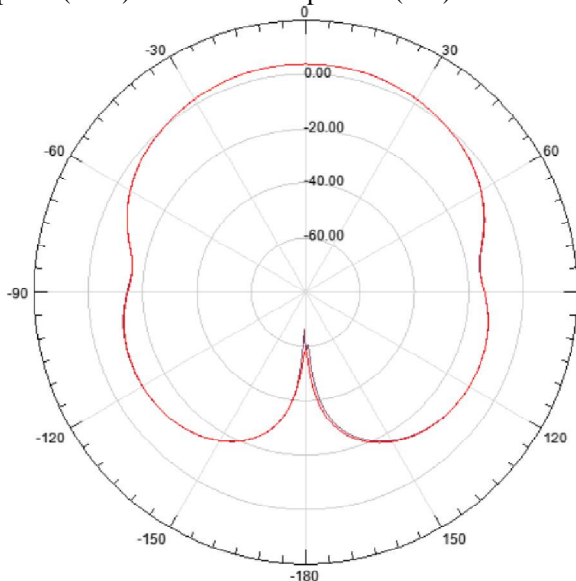


Fig 4 Radiation pattern of the optimum design

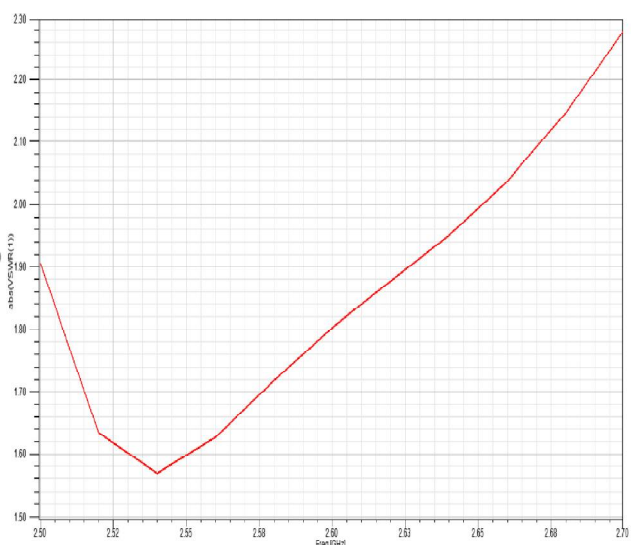


Fig 5 VSWR plot of the optimum design

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 7, July 2017

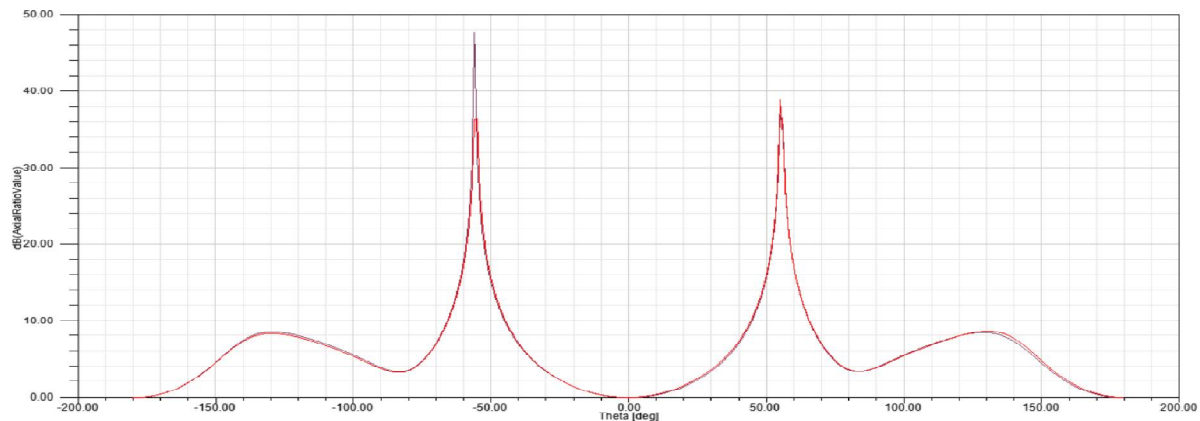


Fig 6 Axial ratio plot of the optimum design

## (A) Optimization of QFH

From the simulation results it can be observed that the gain is less and VSWR is beyond the acceptable value. To achieve optimum performance, design parameters have to be varied one by one. The parameters such as ground plane radius, helix radius, number of turns, specifying between of the turns and thickness of the dielectric substrate are varied and analyzed to obtain desired gain and VSWR.

## IX.CONCLUSION

The quadrifilar helix antenna was simulated and the most suitable antenna model with optimum performance for the user segment of mobile satellite communications is presented. The simulation results agreed well with specifications with regard to gain and VSWR but agreed poorly with regard to beam width. The QFH design presented in [10] has a beam width of 1600 with a gain of -2 dB at 00, whereas the simulated model presented in this project has a lesser beam width of 720 and a higher gain of 3.8 dB in comparison to the results in [10]. A receiving antenna with high gain is useful, as the antennas in satellites have a restriction on the transmitted power. As there is a trade-off between gain and beamwidth of an antenna, the beam width of our QFH model has been compromised to have more gain.

## REFERENCES

- [1] Matthew N. O. Sadiku. Elements of electromagnetics – Oxford series, 2013
- [2] John D Kraus, Ronald J Marhefka, Ahmad S Khan. Antennas and wavepropagation – Tata McGraw Hill, fourth edition, 2012
- [3] Constantine A. Balanis. Modern antenna handbook - John Wiley & Sons, Inc.,2008
- [4] Yi Huang, Kevin Boyle. Antennas from theory to practice - John Wiley & Sons Ltd, 2008
- [5] Lamont V. Blake, Maurice W. Long. Antennas: Fundamentals, design, measurement – SciTech Publishing, Inc., third edition, 2009
- [6] Robert K. Stilwell. Satellite applications of the bifilar helix antenna. Johns Hopkins APL Technical Digest, Volume 12, Number 1 (1991)
- [7] Jamal S. Izadian. QFH antennas for satellite radio and mobile phone applications
- [8] Heather Fraser. Parametrisation and design of quadrifilar helices for use in S-band satellite communications. A dissertation submitted to the faculty of the university of the Witwatersrand, Johannesburg, 2010
- [9] SarelJacobus Marais. The quadrifilar helix antenna and its application to wide angle phase-steered arrays. Thesis presented at the University of Stellenbosch, March 2007
- [10] XiaozhongShui. A S-band printed quadrifilar helical antenna for communication devices. Proceedings of the 2nd international conference on Computer Scienceand Electronics Engineering (ICCSEE 2013)
- [11] Anzar Khan. Analysis of five different dielectric substrates on microstrip patch antenna. International journal of computer applications (0975 – 8887) Volume 55 No.18, October 2012
- [12] Steven (Shichang) Gao, Qi Luo and Fuguo Zhu. Circularly polarized antennas – John Wiley Sons.
- [13] V.Saidulu, “Design and Development of Square Patch Antenna with 90° Hybrid Feed for Communication Applications”published paper in the proceeding of International Conference on Communication, Signal Processing Computing and Information Technologies (ICCSPCIT-2016), ISBN: 978-93-83038-45-9 at MRCET, Hyderabad, December 16-17, 2016.