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Design and Construction of QFH Antenna for Receiving Earth Observation Images

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A B S T R A C T

To ensure optimal reception of circularly polarized signals, it's essential to design and tune a Quadrifilar Helix (QFH) antenna. QFH antennas offer excellent performance in satellite communication and radio astronomy applications, making them valuable tools for capturing signals from space. Calculate precise dimensions for the helical elements and ground plane based on the desired frequency of operation. Construct the antenna with attention to detail and alignment, ensuring the helical elements are wound accurately and mounted correctly on the ground plane. Utilize specialized equipment like network analysers and spectrum analysers to test the antenna's performance. Measure parameters such as return loss and radiation patterns, and fine-tune the antenna's dimensions or configuration based on the test results. Iteratively adjust until optimal performance is achieved, ensuring the antenna meets the specific requirements of its intended application.

Keywords: Quadrifilar Helix antenna (QFH), Helical elements, Satellite communication, Radio Astronomy.

1. Main text

The unique Quadrifilar Helix (QFH) antenna is designed to receive circularly polarized signals, which makes it perfect for receiving satellite-transmitted Earth observation photographs. To provide omnidirectional coverage and circular polarization, it is made up of four helical wires twisted in a certain form. In order to take pictures of moving satellites, this design minimizes interference and maximizes signal reception from various angles. By ensuring effective signal transfer, its impedance matching improves the antenna's ability to receive Earth observation data with high fidelity and dependability.

1.1 Introduction

For Earth observation, antenna design is essential to obtaining vital information and photos for tracking and analyzing the dynamic processes of our globe. Antennas are the essential connection between satellites in orbit and ground-based stations, enabling the transmission and reception of important data for a variety of applications, including tracking weather patterns, environmental changes, and natural disasters. Advances in design, materials, and deployment techniques brought about by the development of antenna technology have made data collection more dependable and efficient for a wide range of Earth observation applications.

Recent developments in antenna design have made it possible to create small, light antennas that can function in harsh conditions including deep sea sites, polar areas, and space. These antennas minimize size, weight, and power consumption while achieving great performance thanks to the use of cutting-edge materials including metamaterials and composites. Furthermore, Earth observation systems are now more agile and flexible thanks to the integration of beamforming, phased array, and adaptive antenna technologies, which allow for quick scanning, accurate imaging, and flexible data gathering methods.

The increasing scope and complexity of Earth observation missions is driving up need for creative antenna solutions. It is anticipated that future advancements in antenna technology will concentrate on increasing data transmission speeds, better spectrum and spatial resolution, and tackling new issues including sustainability and electromagnetic interference. Facilitating interdisciplinary cooperation among antenna engineers, remote sensing experts, and environmental scientists will be essential to propel these developments and provide fresh perspectives on Earth's workings and phenomena.

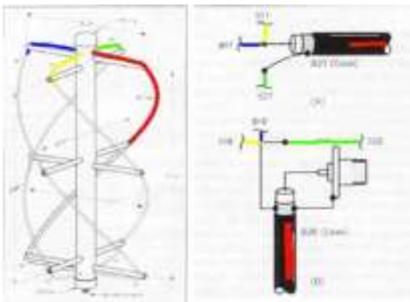

Fig1:QFH antenna[5]

1.2 QFH ANTENNA'S FOUNDATIONS:

A specialized antenna used in radio astronomy and satellite communication, the Quadrifilar Helix (QFH) antenna is made to receive circularly polarized transmissions. Here are the essential functions of it:

1. Helical Structure: The QFH antenna is made up of two or more helical conductors that have been coiled into a helix."Quadrifilar" refers to the arrangement of four conductors in a helical pattern.

2. Circular Polarization: QFH antennas are made to be able to send and receive signals that are polarized in a circle. When a wave propagates with circular polarization, the electric field vector rotates in a circular pattern.For satellite communication, circular polarization is useful since it keeps the signal strong even when the satellite rotates.

3. Helical Phase Shift: The QFH antenna's helical structure causes a phase shift in the signals that are received by each of the four conductors.The production of circular polarization depends on this phase transition. It makes sure that the horizontal and vertical components of the combined signal are 90 degrees out of phase with each other, resulting in circular polarization.

4. Radiation Pattern: The radiation pattern of the QFH antenna is comparatively narrow in the elevation plane and omnidirectional in the azimuth plane.Since it covers a large portion of the sky, it may receive signals from satellites at different angles.

5. Impedance Matching: Effective power transfer between the antenna and the receiving/transmitting equipment depends on impedance matching. To obtain the required impedance, usually in the range of 50 ohms, matching networks might be employed.

Fig2: Quadifilar Helix Antenna [6]

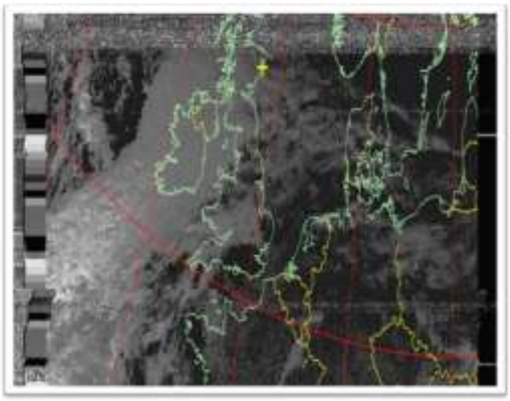

Fig 3: Image from QFH Antenna[7]

2. SPECIFICATIONS OF QFH ANTENNA (137 GHz):

Designing a QFH antenna for 137 GHz requires careful consideration of its dimensions and construction due to the high frequency involved. Here's how you can determine the specifications:

1. Frequency:

- Target frequency: 137 GHz

2. Wavelength Calculation:

- The wavelength ($\lambda\lambda$) at 137 GHz can be calculated using the formula: λ=c/λ where cc is the speed of light (3×1083×108 m/s) and ff is the frequency.
- λ≈2.19 mmλ≈2.19 mm

3. Size:

- The size of the antenna should be a fraction of the wavelength for efficient operation. A common fraction for QFH antennas is around 1/4 or 1/2 of the wavelength.

4. Helix Parameters:

- The pitch of the helix (PP) is typically around λ/4 to λ/2.
- P=λ/4=2.19/4
- P≈0.5475 mm
- The diameter of the helix (DD) can be calculated. A commonly used value is around $\lambda/2\pi$. D=$\lambda/2\pi$=2.19/2π
- D≈0.3489 mm

5. Number of Turns:

- The number of turns in the helix can vary. More turns can provide better performance but may also increase complexity.
- Typically, 2 to 4 turns are used for QFH antennas.

6. Ground Plane:

- The ground plane diameter should be approximately half of the wavelength (λ).
- Ground plane diameter≈λ/2
- Ground plane diameter≈22.19/2
- Ground plane diameter≈1.095 mm

7. Feed Line:

- Use a microstrip feed or other suitable method for feeding the antenna.
- The feed line length will depend on the design and setup but should be kept short to minimize losses.

8. Material and Construction:

- Use high-quality conductive material, such as copper wire, for the helix and ground plane.
- Maintain accurate dimensions and spacing during construction for optimal performance.

9. Testing and Tuning:

- After construction, test the antenna using appropriate equipment to ensure it meets performance expectations.
- Fine-tune the antenna, if necessary, by adjusting the dimensions or number of turns.
- the design and setup but should be kept short to minimize losses.

3. CONSTRUCTIONS OF QFH ANTENNA (137 GHz):

Because of the high frequency involved, building a Quadrifilar Helix (QFH) antenna for 137 GHz needs accuracy and close attention to detail. Determining the antenna's dimensions and geometry is the initial stage, as these are essential for best performance. These measurements are typically computed using the physical characteristics of the materials to be utilized and the intended operating frequency.

The antenna elements are then built. To create the quadrifilar structure, four helical wires must be meticulously wound in a particular geometry. Exact spacing and winding of the wires are necessary to guarantee correct polarization characteristics and matching of impedance. Furthermore, in order to keep the antenna stable and in shape, it could need a supporting structure, particularly at higher frequencies when mechanical integrity is more important.

The QFH antenna must be placed and properly oriented when it is created. To reduce signal blockage, the antenna should be positioned vertically and elevated above any surrounding impediments. To maximize the antenna's performance, fine-tuning may be required. This may involve adjusting the wire spacing, winding pitch, and overall shape. In order to guarantee that the antenna satisfies the necessary requirements and is capable of efficiently receiving signals at 137 GHz for Earth observation applications, stringent testing and validation procedures are also necessary.

4. TESTING AND TUNING OF AN QFH ANTENNA:

Testing and tuning a QFH antenna involve measuring its performance and adjusting its dimensions or configuration as needed to optimize its characteristics. Here's how you can perform testing and tuning:

1.Testing Setup:

- Test Equipment:
  - Network Analyzer: For measuring return loss and impedance matching.
  - Signal Generator: For feeding signals to the antenna.
  - Spectrum Analyzer: For analyzing radiation patterns and gain.
  - Antenna Rotator (optional): For measuring radiation patterns in different directions.
- Test Environment:
  - Perform tests in an open area free from obstructions to minimize reflections and interference.
  - Ideally, use a controlled RF testing environment such as an anechoic chamber for accurate measurements.

2. Initial Testing:

1. Return Loss Measurement:
   - Connect the QFH antenna to the network analyzer via the coaxial feed line.
   - Measure the return loss to ensure proper impedance matching. Adjust the antenna dimensions if necessary for a low return loss.
2. Radiation Pattern Measurement:
   - Use the signal generator to feed the antenna with a test signal.
   - Use the spectrum analyzer to measure the radiation pattern of the antenna in both azimuth and elevation planes.
   - Rotate the antenna or move the measurement equipment to capture radiation patterns from different angles.

3. Tuning:

1. Adjustment of Helix Dimensions:
   - If the radiation pattern is not satisfactory or the return loss is high, consider adjusting the dimensions of the helical elements.
   - Experiment with different pitches, diameters, or number of turns to optimize performance.
2. Fine-tuning the Ground Plane:
   - Modify the dimensions or shape of the ground plane to improve radiation characteristics.
   - Ensure that the helical elements are centered on the ground plane for optimal performance.

4. Repeat Testing:

- After making adjustments, repeat the testing process to evaluate the effects of the changes.
- Continue iterating through adjustments and testing until the desired performance is achieved.

5. Validation:

- Validate the antenna's performance by testing it in real-world scenarios, such as receiving signals from satellites or other source in the intended application environment.

5. INTERNAL WORKING OF A QFH ANTENNA:

The design and polarization properties of a QFH antenna are the main areas where its internal operation varies from those of a regular antenna. To achieve circular polarization, a QFH antenna is made up of four helical wires twisted in a particular form. The antenna's ability to effectively receive circularly polarized signals—which are frequently utilized by Earth observation satellites—is guaranteed by this design.
On the other hand, a standard antenna might be less complex in design and might not be designed with circular polarization in mind. If it receives signals that are circularly polarized, its efficiency may be decreased due to its possible linear or other polarization orientation.

In addition, the QFH antenna's special design offers omnidirectional coverage, which enables it to receive satellite signals at all angles. No matter where the satellite is in relation to the antenna, this omnidirectional feature makes sure that the antenna can efficiently receive signals. All things considered, the QFH antenna's unique construction and capacity for circular polarization make it more appropriate for obtaining Earth observation photos than a standard antenna.

6. Future scope:

Miniaturization: As long as antenna miniaturization techniques are developed further, it will be possible to create lightweight, compact antennas that can be installed on small satellite platforms, which will increase the range of uses for these antennas in Earth observation.

Multi-Band Antennas: In order to improve spectral diversity and allow for more thorough data collecting, future research will concentrate on creating multi-band antennas that can operate over multiple frequency bands.

Adaptive Antenna Systems: Beamforming and phased array technologies combined with adaptive antenna systems will allow for dynamic antenna pattern control, enhancing signal quality and spatial resolution for remote sensing applications.

Artificial Intelligence Integration: By combining machine learning and artificial intelligence algorithms with antenna systems, data processing, analysis, and interpretation may be done automatically. This will speed up the creation of insights and the process of making decisions.

Sustainable Design: To reduce the environmental impact of antenna systems used in remote sensing applications, special attention will be given to the development of environmentally friendly antenna materials and manufacturing techniques.

Interdisciplinary Collaboration: To address complex social and environmental concerns, interdisciplinary research and innovation will be fostered by collaboration between antenna engineers, remote sensing specialists, and domain experts from fields including ecology, agriculture, and climate science.

Quantum sensing: With previously unheard-of levels of sensitivity, accuracy, and resolution for identifying and tracking Earth's surface and atmosphere, emerging quantum sensing technologies have the potential to completely transform distant sensing applications.
Global Collaboration: Researcher and organization capacity growth, knowledge sharing, and data interchange are all made possible by international collaboration and partnerships, which are essential to the advancement of antenna technology for remote sensing.

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