High-Gain Biquad Antenna with Planar Reflector: Analysis and Applications for the 866.5 MHz ISM Band

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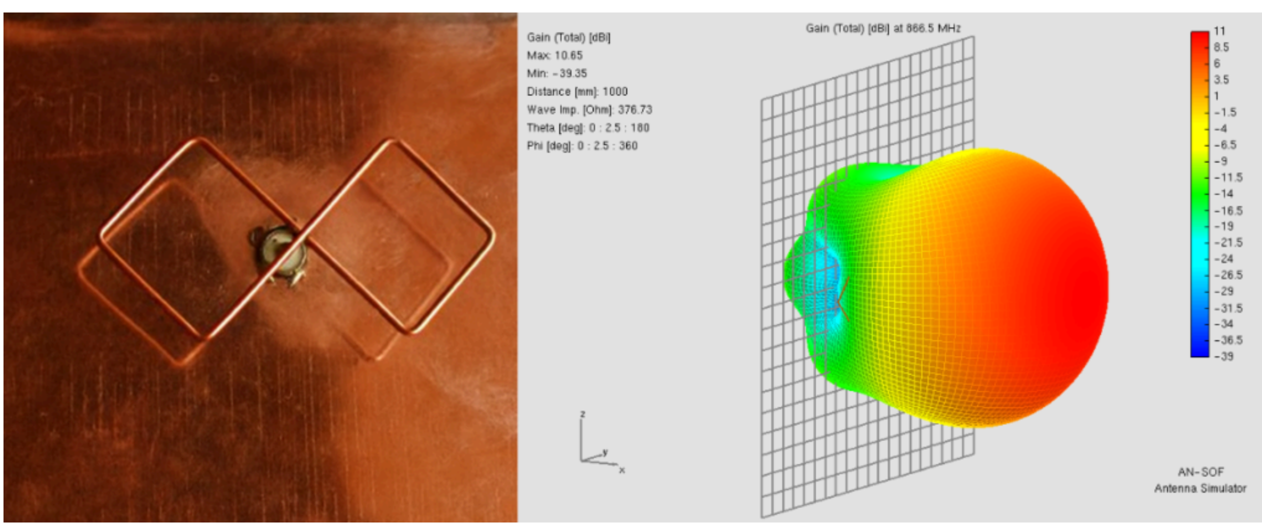
Discover the design and performance characteristics of a high-gain Biquad antenna with a planar reflector for the 866.5 MHz ISM band. This AN-SOF analysis details the antenna's 10.5 dBi gain, 10% impedance bandwidth, and exceptional beam symmetry, providing a professional-grade directional solution for LoRaWAN, UHF RFID, and long-range telemetry applications.



Introduction to the Biquad Radiator

The Biquad antenna, often referred to as a *Harchenko antenna*, is a high-gain directional radiator consisting of two loop elements configured in a "figure-eight" shape (**Fig. 1**). Traditionally favored in the microwave and UHF communities for its simplicity and robustness, the Biquad provides a significant performance boost over standard dipoles. When placed in front of a metallic reflector, the antenna transitions from an omnidirectional radiator to a highly directional system, making it an ideal candidate for point-to-point communication, telemetry, and long-range sensing in the 866.5 MHz Industrial, Scientific, and Medical (ISM) band.

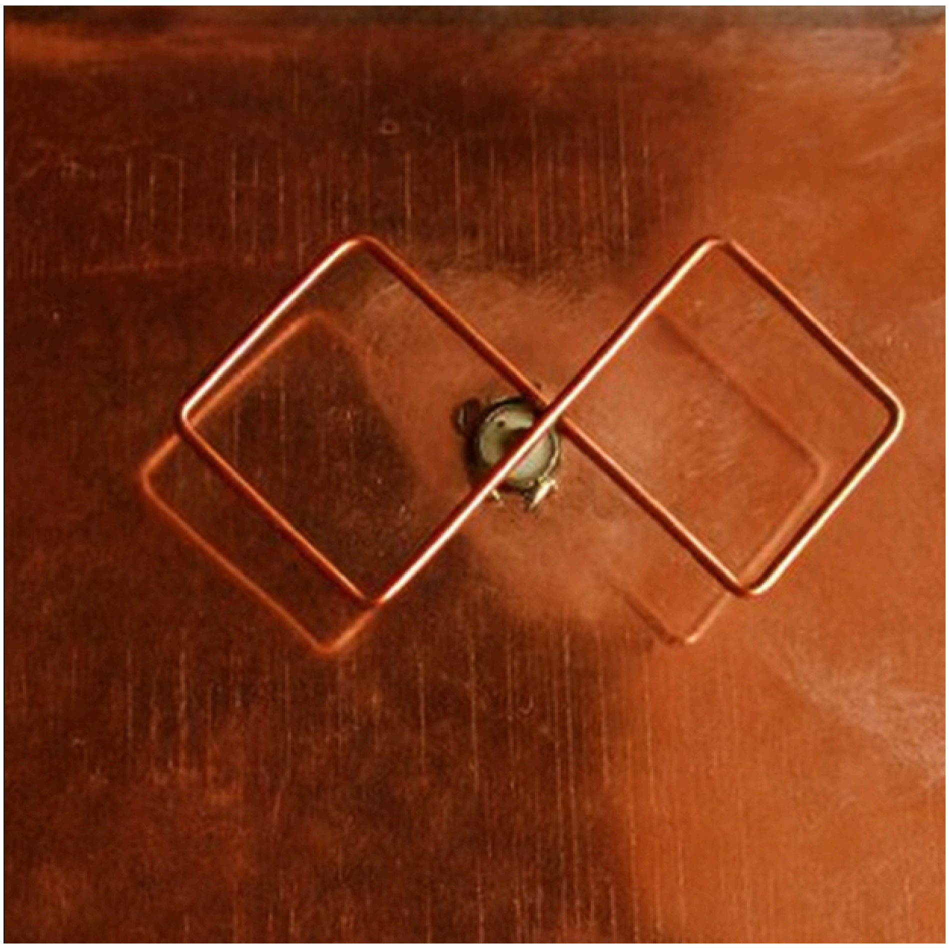


Fig. 1: Biquad or Harchenko antenna with a reflector.

Design Specifications and Geometric Configuration

For operation at a center frequency of $866.5\ \mathrm{MHz}$ ($\lambda \approx 346\ \mathrm{mm}$), the antenna must be precisely dimensioned to ensure resonance and optimal coupling with the reflector. The model presented here is constructed from $3\ \mathrm{mm}$ diameter conductive wire, providing structural rigidity and a stable surface area for current distribution (**Fig. 2**).

The Radiating Element:

- **Quad Side**: $S = 89.1\ \mathrm{mm}$ (approximately 0.258λ).
- **Quad Diagonal:** $D = 126\ \mathrm{mm}$.
- **Total Length:** $L = 2D = 252\ \mathrm{mm}$. The geometry consists of two interconnected square loops. The choice of 89.1 mm for each side ensures that the total perimeter of each loop is approximately **one wavelength**, the fundamental condition for the Biquad's resonant mode.

The Reflector System:

The backplane reflector is a square PEC (Perfect Electric Conductor) surface, measuring $380\ \mathrm{mm} \times 380\ \mathrm{mm}$ ($W = 380\ \mathrm{mm}$ in **Fig. 2**), which represents approximately $1.1\lambda \times 1.1\lambda$. The reflector is positioned at a distance of $h = 42\ \mathrm{mm}$ ($\approx 0.12\lambda$) from the biquad radiator. This spacing is a critical design variable; at 0.12λ, the reflected wave reinforces the forward radiation through constructive interference while maintaining a manageable input impedance close to the 50-Ohm standard.

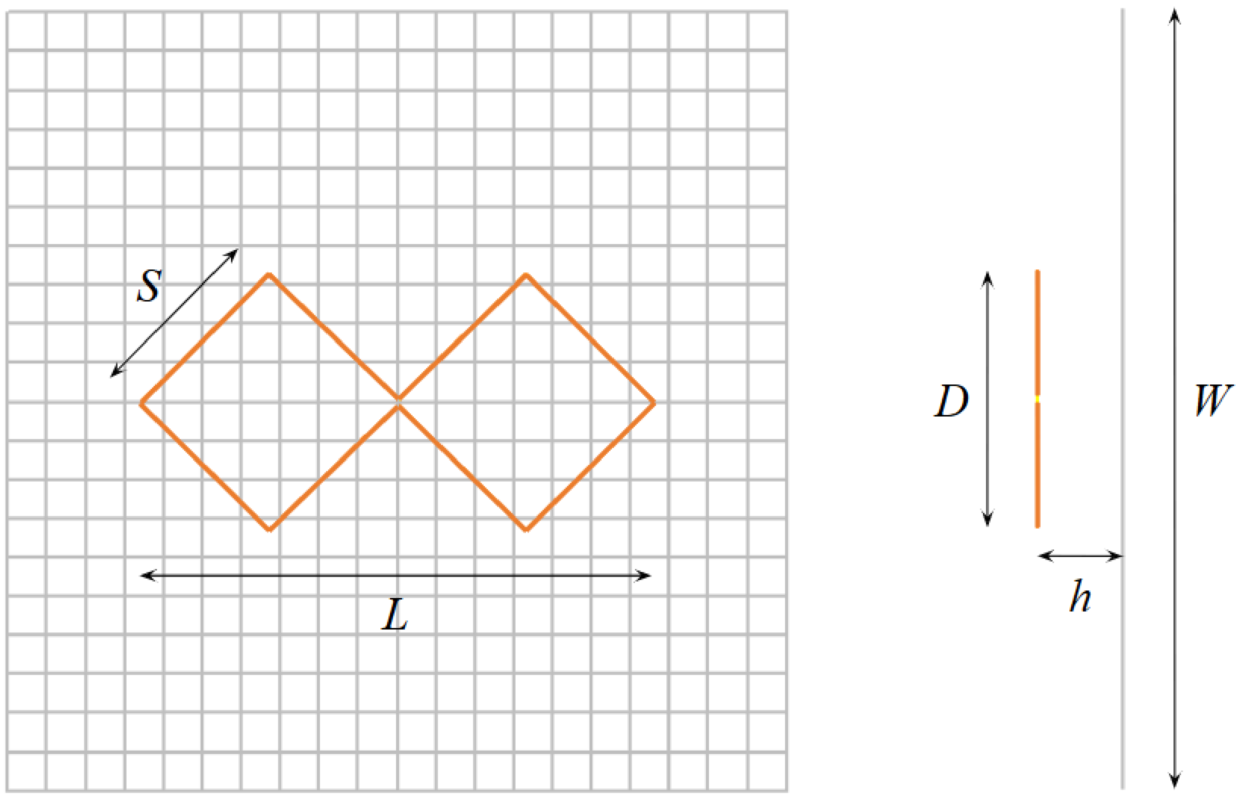


Fig. 2: Relevant geometric parameters of the biquad antenna with a reflector.

Download Model

The reflector in AN-SOF is modeled as a **solid surface** composed of 20 x 20 facets. The antenna is fed by connecting a short vertical wire with a 1V voltage source at the center of the biquad, which is the point where the two square loops meet.

Numerical Analysis and Impedance Characterization

The antenna performance was evaluated using a frequency sweep from $816.5\ \mathrm{MHz}$ to $916.5\ \mathrm{MHz}$. The simulation captures the transition of the antenna through its resonant state, revealing a highly stable impedance profile (**Fig. 3**).

- **Input Impedance:** At the target frequency of $866.5\ \mathrm{MHz}$, the calculated input impedance is $48 + j5\,\Omega$. This results in a Voltage Standing Wave Ratio (VSWR) of 1.1, indicating an nearly perfect match to a standard 50-Ohm feedline.
- **Impedance Dynamics:** Throughout the sweep, the input resistance varies between 35 and 70 Ohms, while the reactance ranges from -35 to $+45$ Ohms (series resonance at $866.5\ \mathrm{MHz}$). This smooth variation, typical of a **series resonance**, demonstrates the "wideband" nature of the biquad compared to **narrow-band patches** that operate around a parallel resonance.
- **Operating Bandwidth:** For a VSWR threshold of ≤ 2, the antenna exhibits an operational bandwidth of $85\ \mathrm{MHz}$ (approximately 10%). This bandwidth is sufficient to cover the entire European LoRaWAN and RFID spectrum without requiring additional tuning.

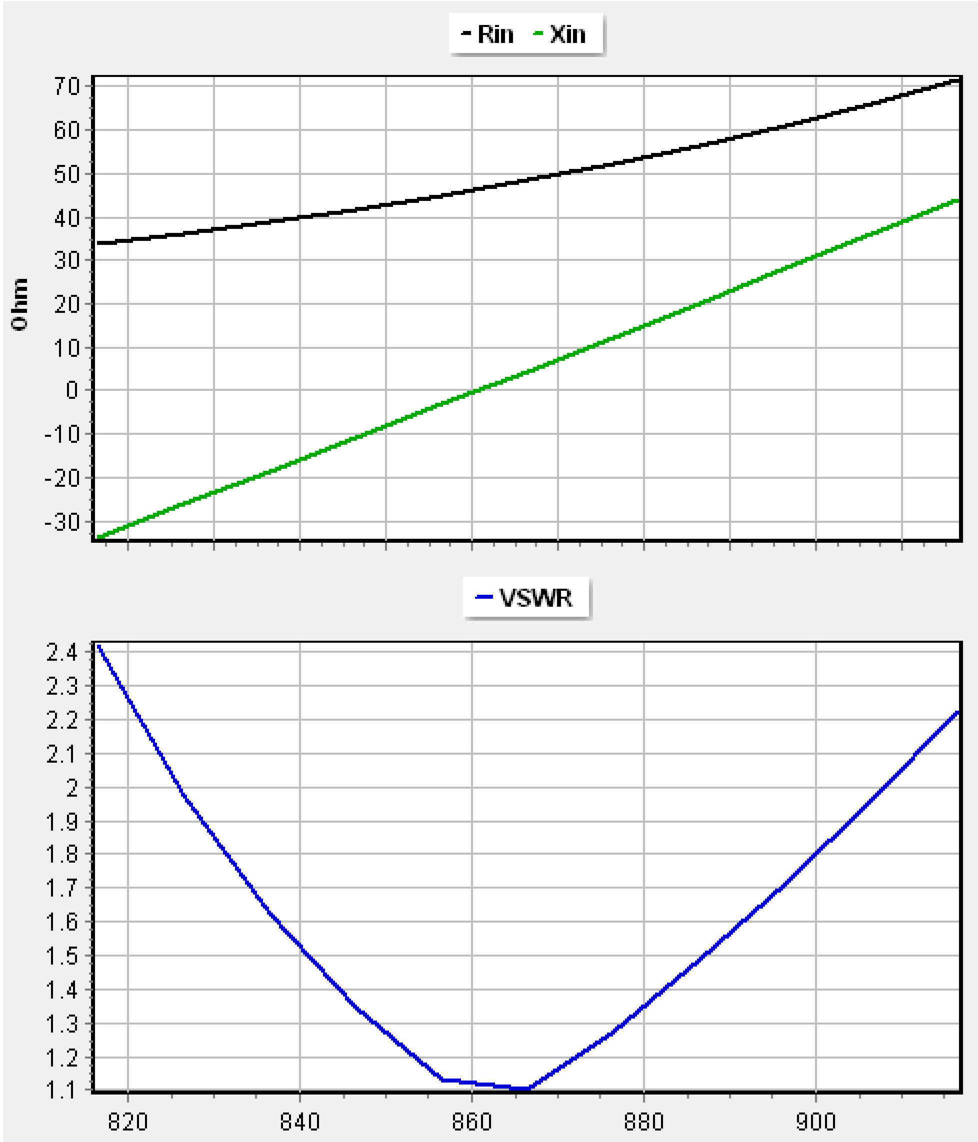


Fig. 3: Input impedance (top) and VSWR (bottom) of the biquad antenna with reflector, as modeled in AN-SOF, shown as a function of frequency (in MHz).

Radiation Pattern and Far-Field Performance

One of the most striking features of the Biquad with a reflector is the high degree of symmetry in its radiation characteristics. The simulation reports a gain that remains remarkably constant across the band, averaging $10.5\ \mathrm{dBi}$.

Pattern Symmetry and Beamwidth:

The main lobe is well-defined and points perpendicularly away from the reflector (**Fig. 4**). A key advantage of this design is its **rotational symmetry**; the half-power beamwidths (HPBW) in both the vertical and horizontal planes are identical at 55°. This symmetry is particularly beneficial for applications where the orientation of the receiving antenna might fluctuate, as it ensures a consistent signal link budget.

Sidelobe and Backlobe Suppression:

The design eliminates secondary forward-pointing lobes, focusing all energy into a single aperture. Due to the optimized reflector size, the Front-to-Back (F/B) and Front-to-Rear (F/R) ratios are maintained at approximately $20\ \mathrm{dB}$. While some back radiation exists due to edge diffraction at the $380\ \mathrm{mm}$ plate, the isolation is more than sufficient for mounting the antenna on walls or masts without significant interference from rearward objects.

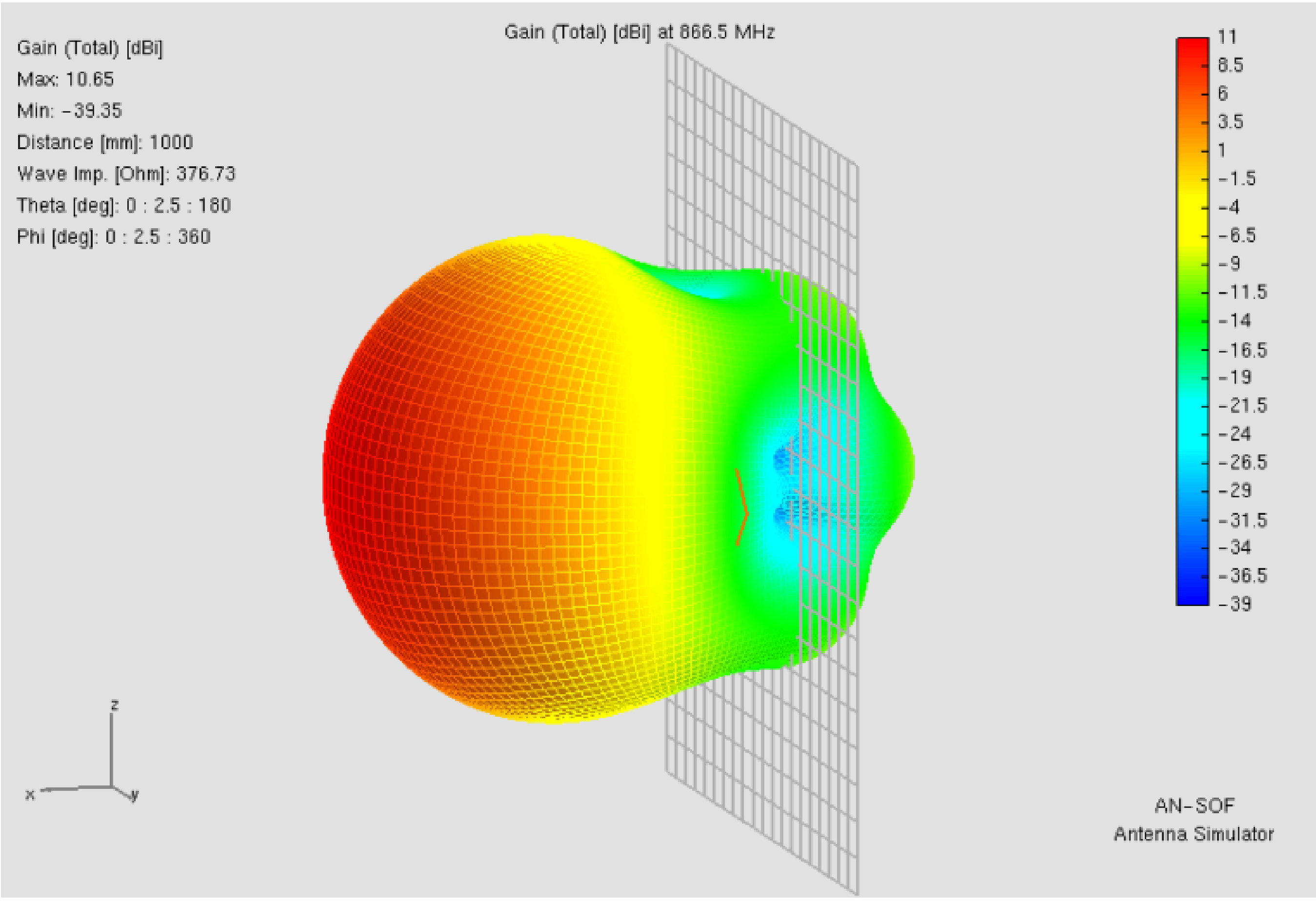


Fig. 4: *Gain pattern (in dBi) of the biquad antenna with a reflector, modeled in AN-SOF.*

Practical Applications at 866.5 MHz

The 866.5 MHz frequency is a critical window within the EU863-870 MHz band. The 10.5 dBi gain of this Biquad antenna makes it a powerful tool for several key industries:

1. **LoRaWAN and LPWAN Gateways:** In IoT (Internet of Things) deployments, gateways often need to reach sensors located several kilometers away. This antenna's 10.5 dBi gain can significantly extend the range of a LoRa gateway compared to a standard omnidirectional whip antenna, especially in sectorized coverage or point-to-point relay links.
2. **UHF RFID Systems:** The 865–868 MHz range is used for passive RFID tag reading. The rotational symmetry of the Biquad's beamwidth is ideal for "portal" style readers where tags pass through a specific area. The high gain ensures that even small, low-power tags can be energized and read from a distance.
3. **Industrial Telemetry:** For SCADA systems and remote industrial monitoring, the Biquad offers a robust, high-directivity solution that is less sensitive to nearby metallic structures than a Yagi-Uda antenna, thanks to its wide-aperture reflector.

Conclusion

The Biquad antenna with a planar reflector is a highly efficient aperture-style radiator that balances high gain with ease of matching. By achieving 10.5 dBi gain and a 10% bandwidth with a VSWR of 1.1, this design provides a "plug-and-play" solution for the 866.5 MHz band. Its symmetrical radiation pattern and high F/B ratio make it one of the most reliable directional antennas in the "Apertures and Reflectors" category of modern CEM study.

See Also:

- **Design and Analysis of a Parabolic Cylinder Reflector with a Back-Firing Primary Radiator**
- **Learning Antennas Through Simulation: 1.8 Ground Plane and Image Theory**

Technical Keywords: Biquad Antenna, Harchenko Radiator, Planar Reflector, 866.5 MHz, ISM Band, LoRaWAN, UHF RFID, Impedance Matching, Front-to-Back Ratio.

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