

A HIGH POWER DIRECTIONAL HELICAL ANTENNA
MODELLING FOR COMMUNICATION AND SIGNAL
DISRUPTION OPERATING AT 10 MHz

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Abstract

This paper presents the design and analysis of a high-power directional helical antenna optimized for operation in the 9.6–15 MHz range. After reviewing existing antenna configurations, the authors concluded that the helical design offers the best combination of high directivity and radiation efficiency, suitable for systems powered by class E generators used in communications, signal jamming, UAVs, radio devices, etc. The proposed antenna with a length of 1 meter, a diameter of 35 cm, and 20 turns of 3 mm diameter copper wire was designed using mathematical calculations and iterative modelling. Using ANSYS HFSS modelling, the electromagnetic characteristics of the antenna – impedance, gain, and beam pattern – were analyzed, resulting in a calculated beam angle of 70°. Realistic materials and boundary conditions with a driver power of 200–300 W were used. Combining theoretical analysis with modelling tools, the study validates the proposed design and highlights the effectiveness and versatility of the spiral configuration for modern high-performance electromagnetic systems, including UAV applications, radio devices, etc.

Key words: directional antenna, class E generator, signal interference, spiral antenna, communication, UAV

Introduction. The development of antennas operating in the frequency range of 9.6–15 MHz is of increasing interest due to their utility in a variety of

high-power applications. This frequency range is particularly relevant in systems powered by Class E generators, which are known for their high efficiency in generating and directing electromagnetic radiation. Such systems have proven their value in many use cases, including communications, jamming, and advanced power transmission technologies. This paper focuses on the design, theoretical analysis, and modelling of a high-power 10 MHz helical antenna, highlighting its relevance in these areas [1–3].

High-frequency antennas operating in this range must achieve a balance between compactness, efficiency, and beam directionality. The proposed antenna is designed to support a primary resonant frequency of 10 MHz, with dimensions limited to 1 meter in length and 35 cm in diameter. These physical limitations are significant in contexts where space constraints are critical, such as in portable or mobile systems. Furthermore, the choice of a helical configuration provides a beam angle of approximately 70 degrees, providing favourable radiation directivity. The antenna design includes 20 equally spaced turns of 3 mm diameter copper wire without insulation, which improves both structural simplicity and conductivity [4].

The helical configuration supports axial mode radiation, where the coil circumference ($C = 2 \times \pi \times r$) is approximately equal to the wavelength λ divided by the number of turns. Thus, the helical geometry provides efficient radiation over the desired frequency range.

After establishing a theoretical design, a computational model was developed in ANSYS HFSS to analyze and optimize the antenna performance. The simulation process began with defining the antenna geometry, including its helical structure and material properties. Copper was chosen for its excellent conductivity and low resistive losses. The model incorporated a lumped port excitation to simulate a class E master oscillator and applied a finite conductivity boundary condition to simulate realistic operation. Key simulation metrics included the antenna impedance, radiation pattern, and gain. A parametric sweep was used to fine-tune the design, ensuring the antenna resonates at 10 MHz. The simulation results confirmed the calculated beam angle, confirming the effectiveness of the design to achieve the desired beam pattern of close to 70 degrees.

This paper provides a comprehensive framework for the design of high-power helical antennas, combining theoretical principles and practical implementation. Using advanced simulation tools, the proposed methodology ensures that the antenna meets stringent performance requirements, paving the way for its application in communication, fault communication, and power transmission technologies [5–7].

Analysis of modern foreign and domestic research and publications.

Existing research on signal disruption devices typically focuses on simulating the communications signals of a target system in order to confuse or overload its receivers. Such devices, often called jammers, operate by transmitting signals that

mimic the traffic of a real transmitter, effectively introducing noise into the communication channel. This method exploits the receiver's reliance on interpreting specific protocols or frequency patterns. Although this approach has been widely studied and applied, it has a notable drawback: the effectiveness of the disruption is highly dependent on the accurate identification and reproduction of the operating frequency and protocol of the target system [8,9]. This can be a serious problem in adversarial scenarios, where the opposing system may use frequency hopping, encryption, or other countermeasures to conceal its communications. Consequently, the success of such devices is not guaranteed, especially in dynamic or unknown environments.

Proposed solution. The authors, on the other hand, propose a new system that uses a high-power directional antenna capable of generating intense electromagnetic fields. Rather than relying on protocol mimicry, this approach induces high currents in the antenna and circuits of the target receiver, effectively disabling it by overloading its electronic components. By avoiding the need to interpret or mimic the target's communication, this system provides a failure at the fundamental hardware level, rendering the receiver inoperable regardless of its operating frequency or protocols. This method offers a reliable and versatile alternative, especially in scenarios that require confidence in signal disruption under diverse and unpredictable conditions [10].

Purpose. The main objective of the article is to develop and analyze a directional antenna optimized for operation in the frequency range of 9.6–15 MHz. In particular, the study is aimed at determining the appropriate radiation angle for a helical antenna configuration to achieve the optimal balance between directivity and efficiency. Central to this goal is the calculation of the critical dimensions of the antenna, including its length, diameter, and turn spacing, which directly affect its performance characteristics. The proposed antenna is designed to operate in conjunction with a high-frequency class E generator, known for its ability to generate strong electromagnetic fields with minimal power losses.

Preliminary dimensioning. The design of a spiral antenna for 10 MHz involves detailed mathematical calculations to ensure that it achieves optimal performance for the intended applications at a power of 200–300 W. One of the most important parameters in the design of the antenna is the wavelength λ of the operating frequency. The wavelength is calculated using the formula:

$$(1) \quad \lambda = \frac{f}{c},$$

where $c = 3 \times 10^8$ m/s is the speed of light in a vacuum, and $f = 10 \times 10^6$ Hz is the operating frequency. Substituting these values, $\lambda = 30$ m. This wavelength is the basis for determining the basic dimensions and operating parameters of an antenna, including its beamwidth, directional pattern, and resonant properties. The beamwidth (θ) is a measure of the angular spread of the main lobe of the

antenna's directional pattern and is a key parameter for directional antennas. The beamwidth for a helical antenna is calculated by the formula [11]:

$$(2) \quad \theta \approx \frac{52}{N \times \frac{C}{\lambda}},$$

where N is the total number of turns, C is the circumference of the spiral, and λ is the wavelength. For this design, where $d = 0.35$ m: $C = \pi \times 0.35 \approx 1.1$ m. Substituting $N = 20$, $C = 1.1$ m, and $\lambda = 30$ m into the beamwidth formula: $\theta \approx 52/(20 \times (1.1/30)) = 52/(20 \times 0.0367) = 52/0.734 \approx 70.85^\circ$.

This result indicates that the designed antenna has a beamwidth of approximately 70.85° , providing the desired radiation directivity for effective operation in the target frequency range. The inclination angle α of the helical antenna, which determines the distance between the turns, is another important design parameter.

The radius r is calculated as $r = d/2$, where $d = 0.35$ m, $r = 0.35/2 = 0.175$ m. Substituting these values into the angle formula: $\alpha = \arctan(0.05/(2\pi \times 0.175)) = \arctan(0.05/1.1) \approx \arctan(0.0455) \approx 2.61^\circ$.

This small angle of inclination provides a tightly wound helical configuration, which contributes to the desired radiation in the axial mode. The gain G of a helical antenna in the axial mode can be approximately determined by [12]:

$$(3) \quad G \approx \frac{15 \times N \times C^2}{\lambda^3}.$$

Substituting $N = 20$, $C = 1.1$ m, and $\lambda = 30$ m:

$G \approx (15 \times 20 \times (1.1)^2)/(30)^3 = (15 \times 20 \times 1.21)/27000 \approx 363/27000 \approx 0.0134$, or approximately 1.34%. Although this gain value seems low, it is typical for antennas operating in the HF range and can be improved by optimizing the material and geometry using iterative modelling.

These calculations are the basis for the physical design of a helical antenna. They demonstrate how parameters such as beamwidth, tilt angle, and gain are interrelated and affect the antenna dimensions and operating wavelength. The mathematical analysis is complemented by computational simulation in ANSYS HFSS to verify and refine the design, ensuring that it meets the performance requirements for coupling to a high-frequency Class E generator [13–15].

ANSYS HFSS antenna modelling. The process of computer mathematical modelling involves conducting a numerical experiment with a computational model (Fig. 1).

Such a powerful tool enables researchers and engineers to create digital representations of antenna systems and analyze their electromagnetic behaviour under controlled conditions. By combining electromagnetic field theory, mathematical formulations, and numerical algorithms, it becomes possible to study radiation

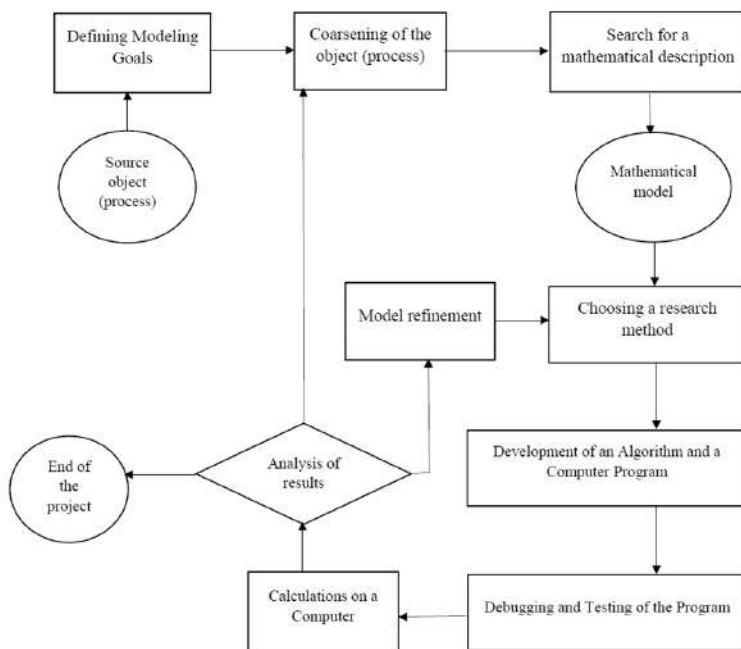


Fig. 1. Mathematical computer modelling process

patterns, impedance characteristics, and mutual coupling effects without the cost or constraints of full-scale physical prototyping.

The helical antenna design was modelled and simulated in ANSYS HFSS to verify its performance and refine its parameters (Fig. 2). A polygonal helix was used to approximate a round wire, using 20 segments per turn to closely mimic the physical geometry. The model excludes any base plates or additional structures, reflecting the simplicity of the design and focusing solely on the electromagnetic behaviour of the wire. In addition, the copper wire was considered uninsulated, allowing for a realistic modelling of its electromagnetic properties.

The electric field distribution E was calculated in the simulation domain, revealing a cone-shaped electromagnetic beam, typical of a directional helical antenna. This beam shape, which meets the design expectations, maintained the calculated radiation beamwidth of approximately 70 degrees. The simulation results confirmed the uniformity and directivity of the radiation pattern, which is in good agreement with the theoretical calculations. By integrating these results, the ANSYS HFSS model provided a detailed visualization of the radiation behaviour of the antenna, ensuring its suitability for high-frequency applications in the range of 9.6–15 MHz.

Figure 3 depicts the total electric field strength values in the form of polar coordinates.

Application. The 10 MHz directional antenna is a versatile tool with signif-

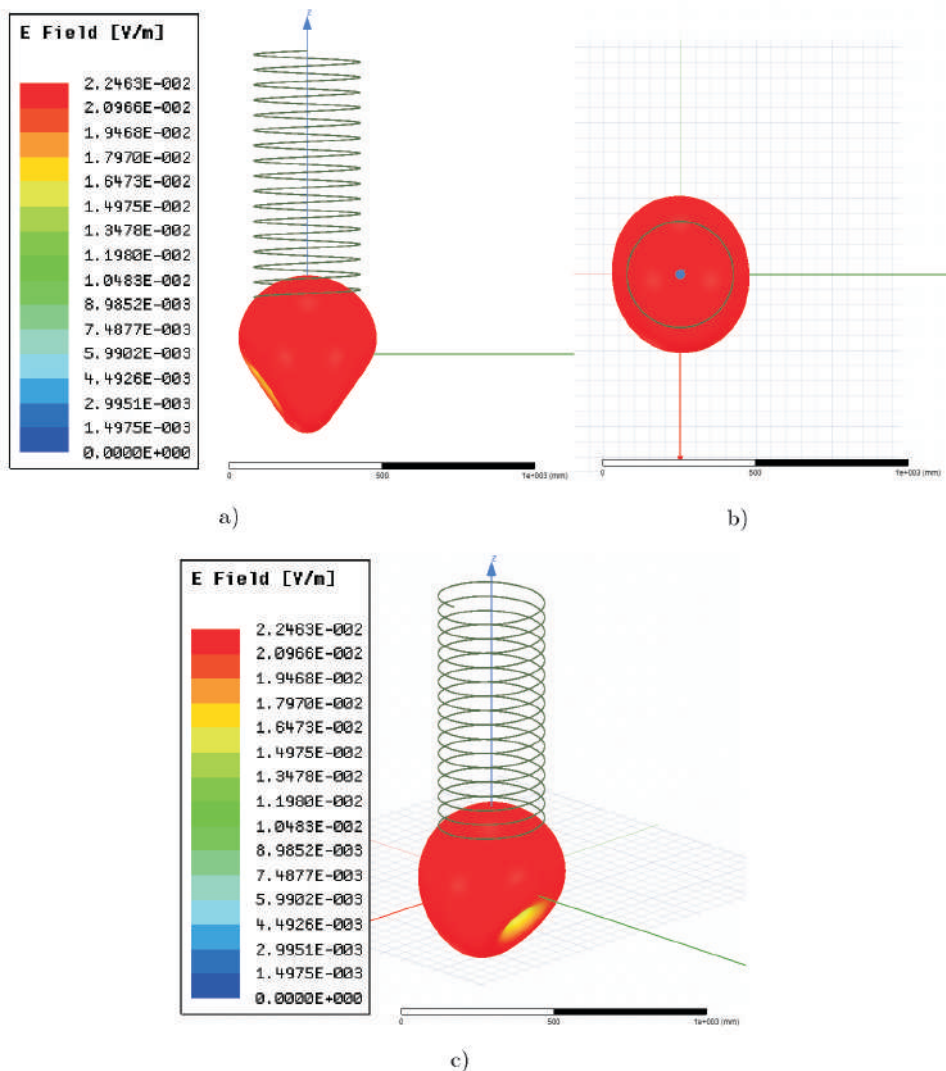
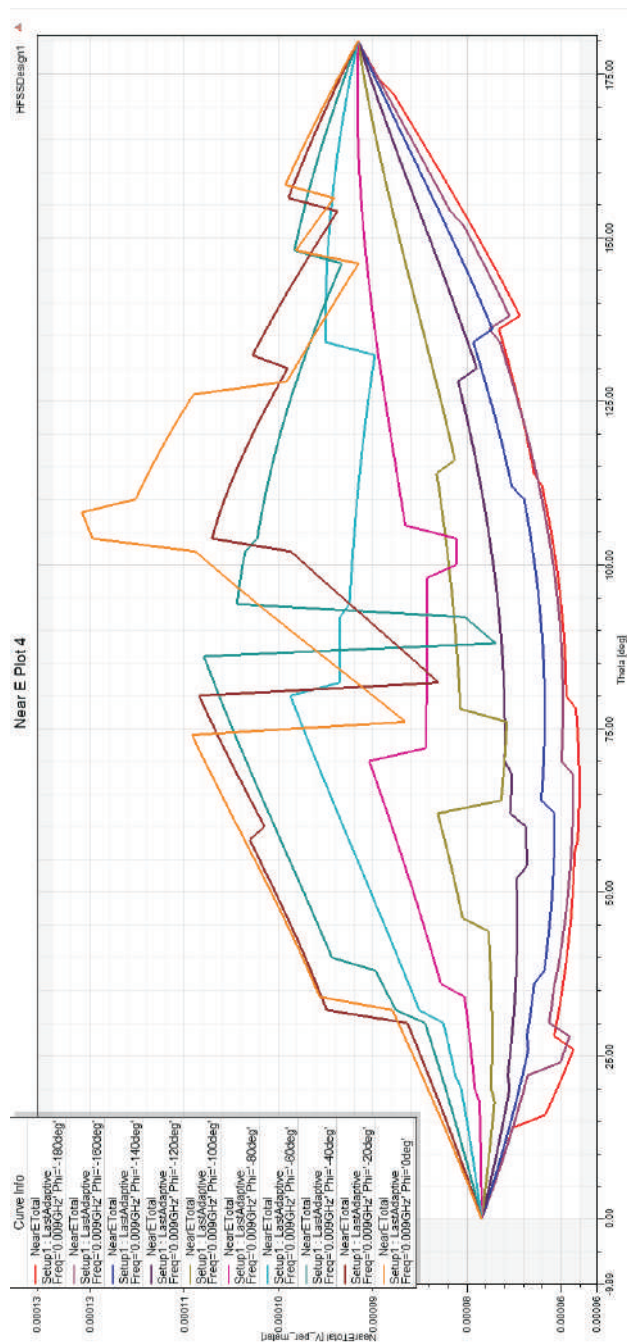


Fig. 2. Electromagnetic beam shape: a) front view; b) top view; c) side view

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Electric field magnitude relative to the beam region

Region	Max value	Min value	Average value	Range
	10 (-2) V/m	10 (-2) V/m	10 (-2) V/m	10 (-2) V/m
Top	2.25	2.25	2.25	0.00
Bottom	2.25	2.25	2.25	0.00
Side	1.95	1.50	1.80	0.45



icant applications in many fields, including communications, technology development, and electromagnetic interference research. At this frequency, the antenna can serve as an effective transmitter for long-distance communications, such as in a maritime or military context, where low-frequency signals penetrate obstacles such as water or dense foliage more effectively than their higher-frequency counterparts.

In addition, its directional nature allows for focused signal transmission, increasing efficiency and reducing interference to unintended targets. The chosen frequency of around 10 MHz is particularly effective at generating electromagnetic waves that interfere with other radiation, making this device valuable in research related to electromagnetic compatibility (EMC) and interference mitigation. If such an antenna is designed to operate at high power levels, it can emit intense electromagnetic fields that can induce currents in nearby electronic circuits, potentially causing malfunction or damage to sensitive electronics at close range. This capability is of interest to industries such as defense and security, where controlled electromagnetic pulses (EMP) are being investigated to neutralize enemy electronic systems [16–18].

Conclusions. In this work, a compact 10 MHz directional helical antenna was designed, simulated, and analyzed to address the challenges of high power operation and focused radiation within a 1 meter device length. The design process included optimization of key antenna parameters such as helix diameter, pitch, and number of turns to achieve a balance between compactness, efficiency, and directivity. Special attention was paid to maintaining impedance matching with standard 50-ohm systems while maximizing gain and minimizing energy losses, even at power levels of 200–300 W. The simulation results confirmed the antenna’s ability to generate intense electromagnetic fields with a directional pattern. The focused beam characteristics make it highly effective for targeted communications applications, such as maritime and military operations, where low-frequency waves have an advantage due to their ability to penetrate obstacles such as water and dense vegetation.

Further research should be directed towards the interdisciplinary integration of electromagnetic, thermal, and mechanical analysis of the structure, taking into account the approaches [19, 20]. This will allow for the justification of complex modelling of thermal deformations of antenna elements and prediction of the impact of electromagnetic fields on the environment.

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