GOLDEN-ANGLE FRACTAL ANTENNA ARRAY (GAFAA)

A Biomimetic, Aperiodic, Multi-Scale Antenna Architecture for Next-Generation Communications

Executive Overview

The Golden-Angle Fractal Antenna Array (GAFAA) is a biomimetic antenna architecture derived from phyllotaxis, the naturally occurring spiral packing principle observed in sunflowers, pinecones, and other biological systems. GAFAA replaces conventional periodic antenna layouts with an aperiodic, irrationally spaced spiral governed by the golden angle, eliminating grating lobes, reducing mutual coupling, and enabling broadband, scalable performance.

Design Motivation and Problem Statement

Modern wireless and space communication systems face severe constraints including interference, narrowband behavior, high power consumption, and limited scalability. Traditional phased arrays rely heavily on digital correction to compensate for geometric inefficiencies. GAFAA inverts this paradigm by embedding optimization directly into geometry.

Phyllotactic Geometry and Element Placement

Each radiating element is positioned using a square-root radial law and golden-angle angular progression. This ensures constant element density, eliminates periodicity, and produces a quasi-crystalline spatial spectrum that inherently suppresses coherent interference.

Electromagnetic Behavior and Performance

Golden-angle spacing minimizes mutual coupling, suppresses grating lobes, and enables ultra-wideband operation. Fractal scaling allows the same architecture to function from handheld devices to large satellite apertures.

Fractal Scaling and Fault Tolerance

GAFAA is self-similar across scales, allowing predictable performance scaling. Manufacturing defects, thermal drift, and partial element failure decorrelate rather than compound, resulting in graceful degradation.

Materials and Fabrication

GAFAA supports conventional PCB fabrication, advanced lithography, wafer-level manufacturing, and conformal flexible substrates. Low-loss dielectrics, high-conductivity metals, and radiation-tolerant materials enable terrestrial and spaceborne deployment.

Beamforming and Control

Because sidelobe suppression is achieved geometrically, beamforming algorithms require lower resolution and power. GAFAA supports electronic beam steering, adaptive nulling, and multi-beam operation with reduced DSP overhead.

Applications

GAFAA is suitable for 5G/6G base stations, LEO satellite constellations, inter-satellite links, UAV swarms, vehicular networks, IoT aggregation nodes, and deep-space communication systems.

Intellectual Property Positioning

The architecture is novel in its systematic application of golden-angle phyllotaxis, square-root radial scaling, and fractal aperiodic synthesis to antenna arrays, forming a defensible class of systems and methods.

Conclusion

GAFAA represents a geometry-native approach to electromagnetic systems, uniting mathematics, biology, and RF engineering. By adopting nature’s solution to interference and packing, GAFAA enables simpler, more resilient, and more scalable communication architectures for the future.

Prepared as an open technical disclosure and conceptual white paper.
This document is intended for research, engineering evaluation, and further development.