Genetic Hybrid Antenna Fills the Gap

AFRL combined in-house skills with lessons from genetics and evolution to create a simple, low-cost antenna that increases the accuracy and reliability of the Digital Ionospheric Sounding System network.

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Ionospheric measurements provide crucial information to the warfighter about the accuracy and reliability of sensor and communication systems. The ionosphere is the ionized portion of the earth's upper atmosphere that extends from approximately 60 to 1000 km altitude. The ionosphere influences all radio signals propagating through the region, and the resulting impact to civilian and military communication systems capabilities ranges from negligible to severe, depending on a signal's frequency.

Characterizing the ionosphere is important for maintaining situational awareness, mitigating adverse impacts to US military operations, and exploiting enemy susceptibilities. Combatant commanders, as well as operational and tactical units, use ionospheric analyses and predictions to diagnose and avoid errors and outages in communication, radar, and precision navigation systems.

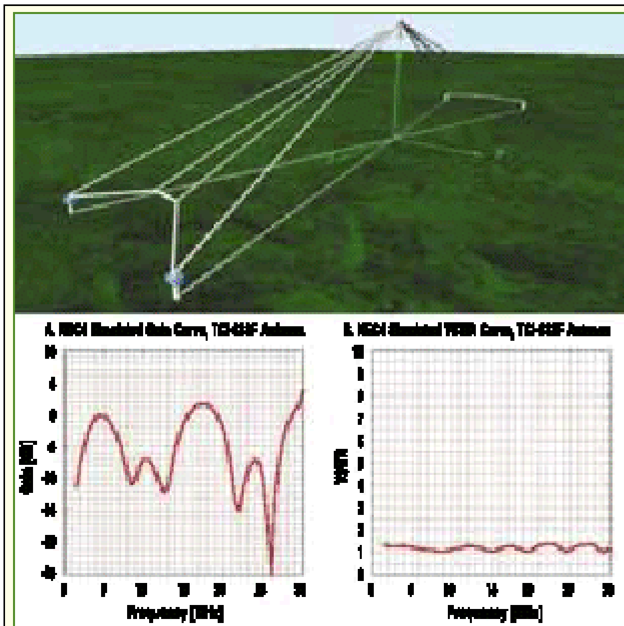
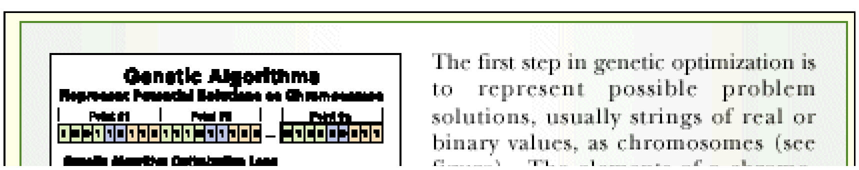


Figure 1. Existing TCI antenna design

The US Air Force Weather Agency (AFWA) and the AFRL Space Vehicles Directorate's Space Weather Center of Excellence operate the Digital Ionospheric Sounding System (DISS) network to observe and specify attributes of the global ionosphere. The DISS network has 18 fully automated digital ionosondes deployed worldwide that provide data for many products, including: (1) specification and forecasts of primary and secondary high-frequency (HF) radio propagation characteristics, (2) ionospheric electron density and total electron content, (3) ionospheric scintillation, (4) environmental conditions for spacecraft anomalies, and (5) sunspot number.

The DISS network includes Technology for Communications International (TCI) model 613F communications antennas (see Figure 1) that transmit radio signals of different frequencies across a specified sweep of 1- 30 MHz in a vertical direction. The ionosphere reflects,absorbs, or distorts the radio signals, and receiving antennas intercept the returning signals for processing. However, the current DISS transmitting antenna is designed for HF communications and not for ionospheric measurements. As simulated in Numerical Electromagnetics Code version 4 (NEC4), the antenna does not transmit a consistent gain for all desired frequencies in the vertical direction, and it exhibits a vertical gain of less than 0 dB over most of the HF band. A second measure of antenna performance, the voltage standing wave ratio (VSWR), which is a ratio of provided power to actual transmitted power, remains excellent across the entire frequency band. Because of the antenna's low vertical gain, interference from other sources (e.g., radio stations and radar) overwhelms the reflected DISS signals and leads to false echoes, missing echoes, and generally poor analysis results. The AFWA and AFRL sought a simple, low-cost antenna design modification to correct the problem.



Researchers in the AFRL Sensors Directorate's Antenna Technology Branch, located at Hanscom Air Force Base, Massachusetts, have experience in genetic antenna design and optimization.

Sponsored by Dr. Arje Nachman of AFRL Air Force Office of Scientific Research for the past several years, they apply soft computing algorithms, such as genetic algorithms (GA) and neural networks, to antenna design and optimization. GA optimization is a robust, stochastic search method modeled on the principles and concepts of natural selection and evolution (see inset). GAs are well suited for solving complex problems of many parameters and are thus ideal for intricate antenna design where performance is measured by complex three-dimensional electromagnetic interactions among large numbers of radiating structures.1 In addition to thoroughly understanding genetic antenna optimization and chromosome parameter interrelationships, AFRL researchers have an in-house suite of antenna optimization code and numerous software tools specialized for electromagnetic-related GAs, including cyclic grey-code chromosome encoding, genetic boiling, chromosome diversity maintenance using multiple elitism, and direct interface to the NEC4 analysis software.

AFRL's researchers combined their talents and used GA optimization to design an improved DISS antenna. The team decided to add a number of wires to the TCI structure. They chose the number of new wires, the installation angle, the active wire heights and lengths, and the load resistors as the parameters represented in the chromosome for the GA to optimize. The cost function used to evaluate the solutions consisted of a weighted combination of the best vertically radiated power gain across the frequency sweep with a low, well-behaved VSWR.

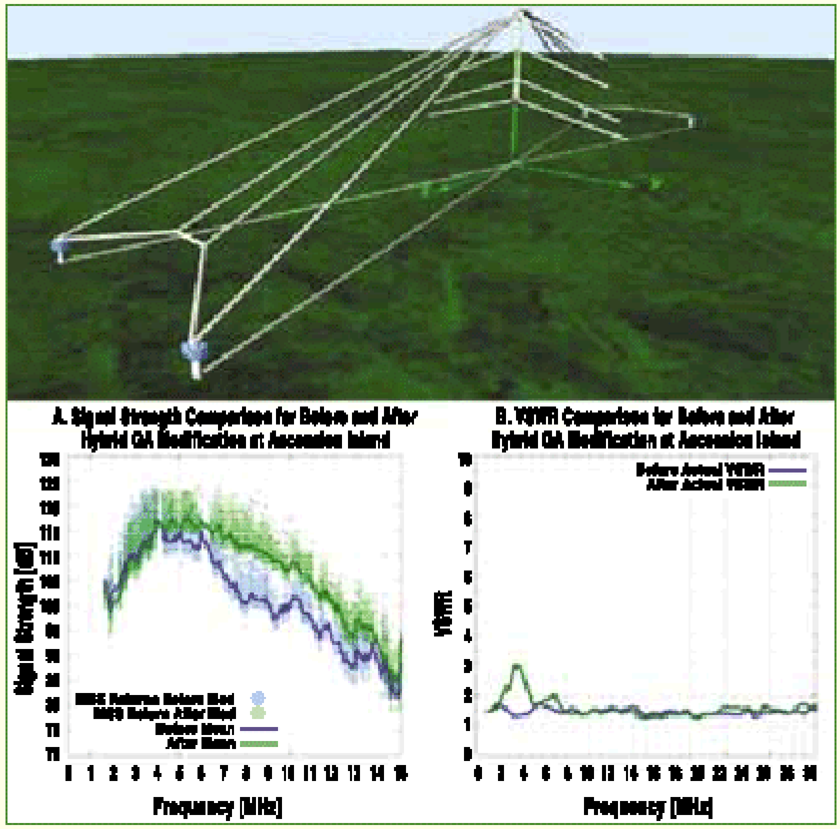


Figure 2. Actual antenna performance improvement as a result of the GA design

After several months of retuning antenna representations and testing construction techniques, the GAs provided the team with an antenna solution. The final design, consisting of eight wires suspended between the existing TCI antenna tower and four ground stakes, met the electrical requirements of positive gain across the DISS frequency band and the mechanical requirements of stability and ease of construction. In simulation, the antenna performed superbly,with gain improvement at all frequencies and a VSWR with only a minor single-frequency spike. The team installed the optimized modification to the DISS antenna on Ascension Island in the South Atlantic. In operation,the antenna's electrical performance is superb, with improvement at almost all measured frequencies and only a minor increase in VSWR (see Figure 2). As a result, DISS echoes bouncing off the ionosphere became much stronger due to the improved antenna performance. The error associated with measuring the critical frequency of the ionosphere, the primary DISS mission requirement, decreased from 16% to 1.6% and remained well inside the 5% error levels expected by the Department of Defense. The improved performance of the DISS antennas verifies the effectiveness of the GA optimization technique in a real-world application. AFRL's engineers are currently modifying the remaining antennas in the DISS network.2,3

Lt Richard Barton, Lt Col Terry O'Donnell, Dr.Terence Bullett, and Maj Jim Hunter, of the Air Force Research Laboratory's Space Vehicles Directorate, and Dr.Steven Best, of the Air Force Research Laboratory's Sensors Directorate, wrote this article. For more information, contact TECH CONNECT at (800) 203-6451 or place a request at http://www.afrl.af.mil/techconn/index.htm. Reference document VS-04-06.

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