Milstar MDR Nulling Antennas

Space Technology
Northrop Grumman Corporation

Milstar MDR Nulling Antennas: Ensuring Secure Tactical Military Communications

The medium data rate (MDR) payload of Milstar II satellites (see box below) — delivering data to field terminals at T1 rates of 1.544 megabits per second, or more than 25 times the speed of a 56 kilobit-per-second computer modem — will make possible secure, real-time transmission of voice, image and data among tactical users. Northrop Grumman-developed adaptive nulling antennas on each MDR payload protect Milstar MDR communications against electronic jamming by enemy forces. Each "nuller" is a fully autonomous antenna system that continuously maximizes user signals while minimizing jammer signals.

Milstar I and II

The first two Milstar satellites, now operating on orbit, are referred to as Milstar I. They employ a low data rate (LDR) payload that transmits secure, jam-proof data at a maximum of 2400 bits per second.

Flights 3 through 6 collectively are called Milstar II. Milstar II satellites will carry both LDR and medium data rate (MDR) payloads. Northrop Grumman is the LDR payload integrator and builds the antenna and digital subsystems. Northrop Grumman also provides the MDR antennas and digital processing subsystem to Boeing Satellite Systems, the MDR payload integrating contractor. Lockheed Martin is the Milstar prime contractor.

Connectivity among Milstar satellites is established via space-to-space crosslinks in the 60 GHz band. Crosslinking will allow user communication networks to extend around the globe without retransmission through intermediate ground stations. The full constellation of six Milstar satellites is scheduled to be in orbit by 2001.

Extending the Range and Ensuring the Protection of Military Tactical Communications

Desert Storm demonstrated the fast pace of today's battlefield, where highly mobile military units rapidly move beyond the range of ground-based line-of-sight communications. The trend is accelerating: the U.S. Army says its first digitized division in 2000 will control an area 600 times larger than the conventional division of 1984.

The MDR payloads are a key “range extender” of the enhanced digital communications that 21st century U.S. military forces will employ.

Yet, the very feature that makes satellites so desirable for military communications — line-of-sight access over a large area — makes satellite uplinks vulnerable to enemy jamming. Jammers may be 100 or even 1000 times more powerful than the ground terminals of friendly forces.

The MDR adaptive nulling antenna instantly detects enemy jamming and counters it within a fraction of a second by placing a “null” in the jammer’s direction. (In antenna terminology, a null is a direction from which an antenna collects very little energy.) This adaptive action minimizes the strength of jammer signals received at the satellite, while maximizing the strength of desired communications signals. The null effectively “screens out” jammers, and all this happens automatically with no interruption to communications.

Nulling is required at MDR data rates to ensure the integrity of the communications data. (Milstar’s low-data-rate (LDR) payload, with much lower data rates, relies entirely on frequency-hopping, spread-spectrum techniques, and error correction to protect messages.)

The MDR Antenna Suite

The MDR payload’s antenna suite is designed to meet the diverse needs of Milstar users. The Army, for example, deploys large numbers of troops in a relatively small theater of operations, where the bulk of communications is in theater. Therefore, the Army needs to cover a small geographic area with one or two payload antennas. The Navy, by contrast, operates ships on every ocean and has shore stations around the world. The Navy needs as many antennas as possible covering the portion of Earth visible from the satellite.

Close-in jamming (where jammer and friendly terminals are both located within a single antenna beam) is a serious threat to the Army, which tends to operate near the front, close to enemy jammers. The Navy often operates from bases and carriers some distance from the front, where the jammers are often out of beam.

Two nulling antennas onboard each MDR payload are capable of negating the effects of both in-beam and out-of-beam jammers. In addition, the MDR payload carries six smaller antennas that produce spot beams without nulling. These are called Distributed User Coverage Antennas (DUCAs). Generally speaking, the nulling antennas are best matched to theater-type requirements, while DUCAs better match those of dispersed global users such as the Navy.

Adaptive Nulling: How The Nulling Antenna Works

Milstar satellites and ground terminals employ a spread-spectrum approach in which the signal hops in pseudo-random fashion from frequency to frequency within an assigned bandwidth. User terminals communicate with the satellite using a secure frequency hopping pattern shared by the terminal and the satellite.

In the absence of jammers, user signals received by the nulling antenna fall within an expected distribution of frequencies. When a jammer terminal begins operating within the satellite's spot beam coverage area, its radiated power does not follow the satellite's frequency-hopping pattern. As a result, anomalies appear in the nuller's power distribution curve, revealing the presence of jamming signals.

The antenna takes immediate steps to eliminate these unwanted signals. It calculates appropriate signal-weighting factors for the power received at each antenna feed to determine the position of the jammer and produces a null in that direction.

The MDR nulling antenna consists of four major components:

- Multibeam reflector and feeds. The MDR nuller produces 13 essentially non-overlapping narrow spot beams. Its design is based on a 40-inch offset-Cassegrain reflector, which illuminates a 13-element feed array. Each antenna is gimbaled and can be independently steered to any position on the visible Earth.
- Beamformer. A millimeter-wave beamformer provides sum and sample signals to a radio frequency combiner, which establishes the received radiation pattern. The pattern, of course, includes nulls that block out jammer signals.
- Correlator. The correlator constantly monitors each of the 13 EHF feed inputs, determines whether a jammer is present, and then computes baseband error weightings.
- Digital processor. Error signals produced by the correlator are passed to the processor. The processor updates the beamformer weights to drive the errors toward zero. As error weightings coming from the correlator are progressively reduced, the beamformer shapes a null in the antenna pattern in the direction of the jammer.

Northrop Grumman also developed the algorithm for the nulling antenna processor. The Northrop Grumman-patented algorithm determines the weight updates from the correlator error signals. The algorithm's performance, along with the speed of the processor, is essential to the nulling antenna's ability to counter jammers.

Nulling: Key to MDR Performance

The complex signal-processing algorithms required for adaptive nulling have existed for some time. Only in recent years, however, have advances in microelectronics enabled engineers to design a fully autonomous nulling antenna system light enough and compact enough to fly aboard a spacecraft.

Northrop Grumman delivered the first flight nulling antenna to MDR payload integrating contractor, Boeing Satellite Systems, in October 1996.

The MDR nulling antennas do far more than simply receive RF signals. Each antenna is a complete feedback control system designed to continuously maximize desired signals while processing out jamming signals. With nulling antennas in operation, the Milstar MDR payload can push data rates to 1.544 megabits per second. Or, by switching to lower data rates, it can receive signals from small, low-power ground terminals. Or it can operate at some intermediate combination of data rate and terminal power — all without sacrificing anti-jam performance.

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