NAVY/MARINE CORPS DEMONSTRATIONS OF THE DARPA MICROSATS

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Abstract

Demonstrations of the DARPA Microsats with an emphasis on Navy and Marine Corps applications were conducted by personnel at the United States Naval Academy. These satellite communications demonstrations used the analog FM mode of the Microsats. Radios used were military transceivers, transmitters composed of laboratory signal generators with broadband power amplifiers, a modified amateur radio UHF transmitter, and commercially-available scanner receivers. Voice demonstrations included equipment checks with DARPA personnel, a tactical exercise at a Marine Corps base, and communications with a U.S. Navy destroyer. Position and status report data beacons were relayed through the Microsats from training vessels to Annapolis. Satellite-to-satellite communications using the Microsats and a U.S. Navy FLTSAT were successfully conducted.

Introduction

The DARPA Microsats were launched on the second Pegasus mission during July 1991 into 245 nm by 192 nm initial orbits[1]. These seven small spacecraft included both analog FM transponders and digital store-and-forward capability for operation in the military UHF spectrum of 225-400 MHz. The uplink and downlink frequencies were offset by 41 MHz during voice operations.

Personnel at the United States Naval Academy took part in the demonstrations of the Microsats with an emphasis on Navy and Marine Corps applications. Naval Academy facilities such as the Satellite Earth Station Facility, the 12-meter parabolic dish antenna, and training vessels were used. Note that frequencies described in this paper are approximate, not exact.

Equipment

The Microsat transponders were designed to be compatible with existing military UHF transceivers[2]. Units such as the AN/PSC-3A and AN/LST-5 could have been used, but such radios were not widely available. DARPA did loan equipment to the Academy for specific demonstrations; no other source for military equipment was found.

For day-to-day monitoring of the Microsat downlinks, commercially-available scanner receivers were used. Many of these frequency-synthesized receivers have the military UHF frequencies locked out by the microprocessor, but two units marketed by Ace Communications did not. The AR3000 is a multi-mode tabletop scanner that is tunable in 1 kHz increments, a feature that was used for tracking the severe Doppler shift of the Microsat downlinks. The AR1000XC is a handheld battery-powered scanner that was used for portable operations. Narrow-band FM mode (12.5 kHz IF filter) was used with the Microsats. The military radios have 25 kHz IF filters, so those units were not affected by the ±7 kHz Doppler shift caused by the velocity of the low orbit.

When operating from a fixed location or vessel, Academy personnel used laboratory signal generators and broadband power amplifiers configured as FM transmitters. A voice or data signal was used to frequency modulate a 260 MHz carrier in the signal generator, then the output was magnified to approximately 5 watts RF by the power amplifier. For voice operations, a microphone signal was preamplified by a cassette recorder before being routed into the signal generator. For data operations, the audio output of the data device was connected directly into the modulation input of the signal generator. Figure 1 is a photograph of a signal generator and AR3000 receiver being used for Microsat operations.

A battery-powered portable transmitter for use with the Microsats was adapted from an amateur radio kit. The Hamtronics TA451 UHF FM exciter is designed for the amateur band at 440 MHz, but crystals for 260 MHz were installed on the circuit board and tunable circuits were redesigned for military UHF operation. The transmitter was powered by several consumer-grade AA alkaline batteries and provided 2 watts RF power, sufficient for the low-altitude Microsats.

A variety of antennas were used with the Microsats. The downlink signals were strong enough that simple whip and discone antennas were usually sufficient. A circularly-polarized crossed dipole antenna was installed at the Naval Academy for day-to-day use; the circular polarization prevented signal fading during a satellite pass. A portable crossed-dipole manufactured by Dorn-Margolin for military use was borrowed from DARPA along with the AN/PSC-3A transceiver. An antenna similar to the Dorn-Margolin model was fabricated at the Naval Academy using metal mini-blind slats.

The only data device used in Naval Academy demonstrations was the Kantronics All Mode (KAM) terminal node controller (TNC) that is sold to the amateur radio market. The KAM can operate on both HF and VHF/UHF frequencies. A system of KAMs already installed on Naval Academy training vessels for HF communications was easily adapted for use with military UHF frequencies.

Two satellite tracking programs used by amateur satellite trackers were used for the Microsat demonstrations. OrbiTrack for the Apple Macintosh by BEK Developers was used to predict future passes in great detail. InstanTrak for MS-DOS machines was used in the Naval Academy satellite facility during Microsat passes to calculate Doppler shift and satellite elevation. NORAD satellite elements were distributed by T. Kelso of the Air Force Institute of Technology via the Internet on a weekly basis, so the satellites were accurately tracked until reentry.

Demonstrations

Immediately after the satellites were launched and orbital elements became available in early August 1991, Naval Academy personnel began monitoring the downlink frequencies using the AR3000 scanner receivers. The signals were strong and initial voice tests were clear and legible. As soon as a voice transmitter composed of a signal generator and power amplifier was assembled, the Naval Academy joined the early Microsat nets that also included stations at Quantico, Virginia and Fort Gordon in Georgia.

The HF position reporting system being used by Naval Academy training vessels was adapted to Microsat operations in August 1991. The VHF audio output of the KAM TNCs was connected to a signal generator/power amplifier transmitter and routed to an external UHF antenna. Watch personnel on the vessels typed updated position and status reports on a computer terminal that was connected to the KAM. The KAM was set to beacon the position report every minute. When a Microsat in analog FM mode came into view, the satellite would receive and retransmit the beacon. An AR3000 receiver connected to a KAM received the reports in Annapolis; the reports were both stored in memory and printed on paper. On 16 August 1991, the Naval Academy received the beacon "NS-4>T1600/L395056/G0751807/C272/S11/F63/W100/LO99/MSD20/ALL OK/NS-4" from a training vessel near Philadelphia. The latitude and longitude place NS-4 in the shipping channel near the Philadelphia airport. An amateur radio operator in Massachusetts received the beacons using similar equipment. For example, the operator received the text "ACADMY-1>LOG>BEACON: US Naval Academy MICROSAT TEST Lat:38 59 Long 76 29" on 20 November 1991.

In mid-September 1991, personnel from the Naval Space Command organized a demonstration using AN/PSC-3 transceivers and Dorn-Margolin antennas. One station was set up on the roof of a building in Dahlgren, Virginia while the other station was set up on board one of the Naval Academy training vessels (see Figure 2). At the beginning of the first satellite pass, the vessel was under way in the Chesapeake Bay near Annapolis. The two stations exchanged voice communications without difficulty. The satellite downlink was monitored ashore at the Naval Academy and the signals from both stations were clear and understandable.

In mid-November 1991, a tactical satellite communications exercise utilizing the Microsats was conducted by midshipmen and faculty at the Quantico Marine Corps Base in Virginia. For nearly one hour, two groups of midshipmen were able to communicate with each other and with a station at the Naval Academy. Amateur radio operators and scanner enthusiasts in the eastern United States and Canada monitored the satellite transmissions. This exercise is detailed in an accompanying paper[3].

During December 1991, a demonstration was conducted with the USS Arleigh Burke, the first Aegis-class destroyer. The Burke was at the U.S. Navy base in Norfolk, Virginia. An officer on the Burke configured the existing WSC-3 UHF radio on the ship for satellite use. Although not all the settings were made correctly (the radio was probably left in AM mode when it should have been in FM mode), the following hour-long exercise provided communications that were understandable. For example, the officer on the Burke read a telephone number to the Naval Academy and the number was copied correctly. During the demonstration, one of the DARPA support contractors joined the net by transmitting from a vehicle in northern Virginia using an AN/PSC-3A and Dorn-Margolin antenna. An amateur radio operator in Massachusetts monitored the transmissions from all three stations by using a commercial scanner receiver and discone antenna.

One of the original goals of the Microsat program was to demonstrate satellite-to-satellite communications. This goal was achieved during a December 1991 test conducted by personnel at the Naval Academy and by DARPA contractors located in northern Virginia. The Microsat transponders had an uplink frequency 41 MHz below the downlink frequency; the U.S. Navy FLTSATCOM transponders also have 41 MHz offsets, but the uplink is above the downlink frequency. The Microsat transponders were tuned to a FLTSATCOM channel frequency so that the geostationary satellite could relay the Microsat transmissions over a much larger area (see Figure 3). During the demonstration, two stations in northern Virginia communicated through the Microsats while personnel at the Naval Academy monitored the FLTSATCOM downlink using a 12-meter parabolic dish antenna. The voice communications were clear and understandable in both the Microsat and FLTSAT downlinks.

The success of amateur radio operators monitoring the Microsats prompted an effort to organize a wide-area network of stations. Naval Academy personnel received permission to publicize the effort through the Military Affiliated Radio System (MARS) that usually passes messages for military personnel by HF radio nets. Bulletins regarding the demonstration were circulated through amateur radio networks as well. During some of these nets, stations all over the United States checked in; two ships at sea participated at various points. While the tests took place when the satellites were about to decay from orbit, clear and understandable contacts were made by participants with varying types of equipment.

Conclusions

Numerous Navy and Marine Corps demonstrations of low Earth orbit UHF communications were conducted at the Naval Academy. Military transceivers, commercially-available equipment, and experimental gear was used. These demonstrations indicate the ability of low Earth orbit satellites to provide additional communications paths for units on the ground or at sea.

References

1. R. Bonometti, E. Nicastri, T. Darone, R. Steele, and W. Montag, "Application of Small Satellites for Defense Space Communication Systems and Technology Development," Fifth Annual AIAA/USU Conference on Small Satellites, Logan, Utah, August 1991

2. "Technical Operations Guide for Users, DARPA Advanced Space Technology Program, Lightsat Communications Demonstration," Defense Advanced Research Projects Agency, Arlington, Virginia, February 1990

3. W. K. Daniel, G. Rivas, and R. E. Bruninga, "Marine Corps Tactical Satellite Communications," Sixth Annual AIAA/USU Conference on Small Satellites, Logan, Utah, September 1992

Acknowledgements

In addition to the individuals who monitored the Quantico demonstration (see list in accompanying paper), the authors wish to thank John Biro for monitoring the packet beacons as well as recording the exercise with the USS Arleigh Burke.

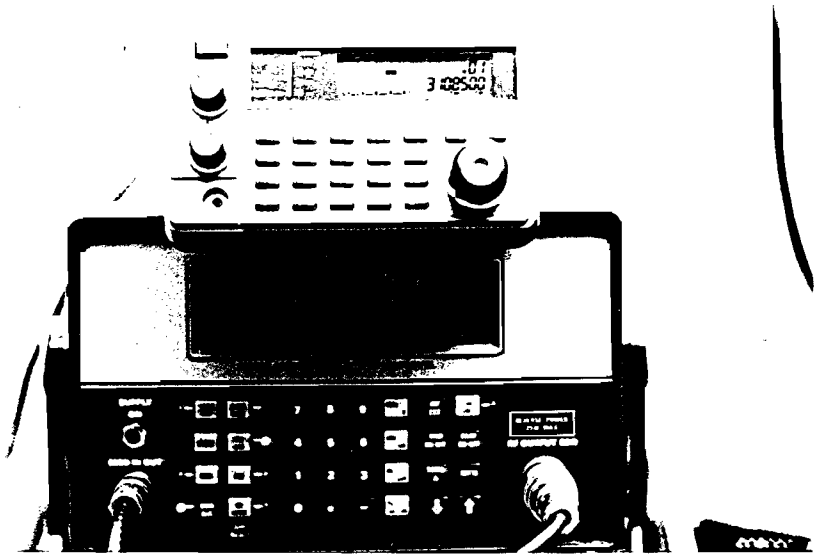

Figure 1. Signal Generator Transmitter and AR3000 Scanner Receiver

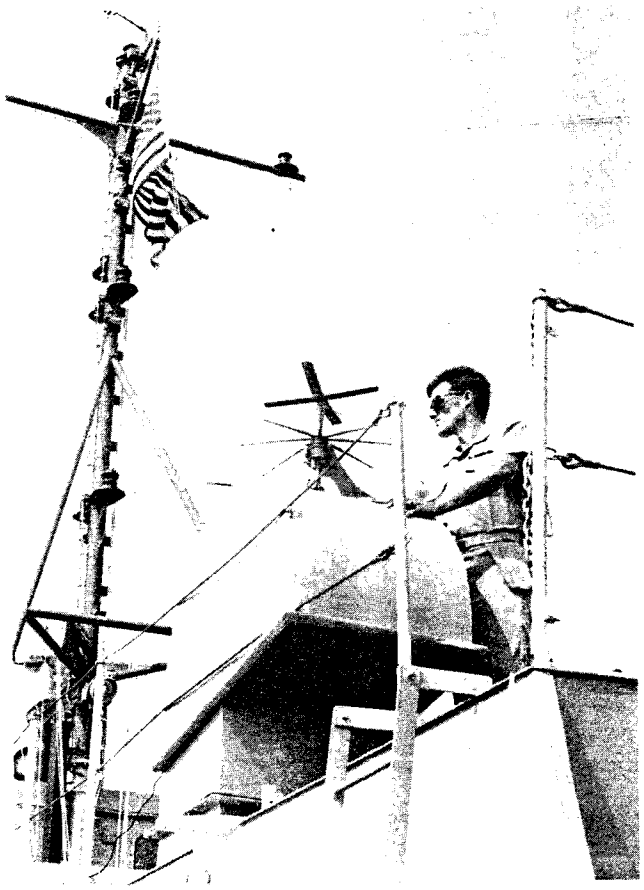

Figure 2. Microsat Antenna Being Installed on Training Vessel

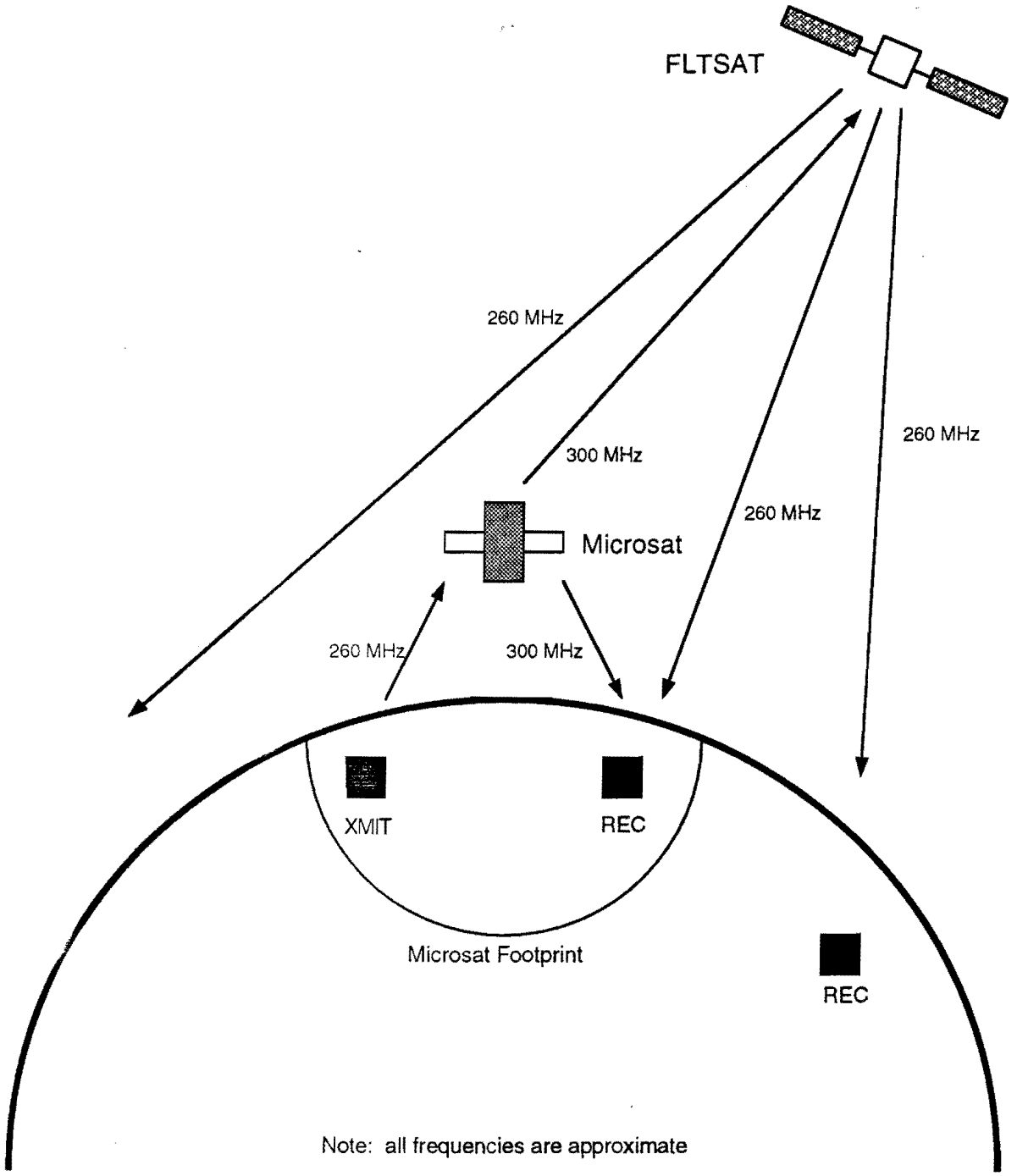

Figure 3. Microsat-to-FLTSAT Relay