AIRBORNE DEMONSTRATION OF MILSTAR AND GBS RECEIVE CAPABILITY USING A SINGLE ANTENNA (U)

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(U) ABSTRACT

(U) The military community currently uses the Milstar satellite system for low data rate (i.e. 75 to 2400 bps) two-way communications using the 44 and 20 GHz frequency bands. Development and installation of the Global Broadcast Service (GBS) is currently underway providing high data rate (i.e. up to 23.5 Mbps) broadcast service using the 30/20 GHz frequency bands. Interest has been expressed by the Department of Defense (DoD) in demonstrating an airborne capability that will allow non-simultaneous reception of GBS and Milstar using a single antenna. The Milstar reflector antenna would continue to be used for transmiting to Milstar. Milstar would also be used to demonstrate a GBS reachback channel. A demonstration of this capability that includes a recently developed 20 GHz antenna and radome integrated with a Milstar terminal and GBS receive suite has been completed.

1. (U) INTRODUCTION

(U) The military community currently uses the Milstar satellite system for low data rate (i.e. 75 to 2400 bps) two-way communications. Milstar systems are deployed in ground, shipboard, and airborne applications and use the 44 and 20 GHz frequency bands, respectively, for uplink and downlink communications. Development and installation of the Global Broadcast Service (GBS) is currently underway and will provide high data rate (i.e. up to 23.5 Mbps) broadcast service to ground and shipboard users. The GBS uplink/downlink frequency bands are 30/20 GHz, respectively. Interest has been expressed by the DoD in demonstrating an airborne capability that will allow non-simultaneous reception of the Right Hand Circular Polarized (RHCP) signals of Milstar and the Left Hand Circular Polarized (LHCP) signals of GBS on a single antenna. Transmission to the Milstar satellite will remain via the Milstar reflector antenna for this phase of the effort. The objectives include the following:

- (U) Using a single antenna
  - (U) Receive GBS
    - (U) Unclassified video
    - (U) Unclassified data
    - (U) Classified data
  - (U) Receive Milstar (not sumultaneous)
- (U) Transmit to Milstar using the Milstar reflector antenna
- (U) Demonstrate a GBS reachback channel via Milstar

(U) A demonstration of this capability on an airborne platform that includes a recently developed 20 GHz antenna and radome integrated with a Milstar terminal and GBS receive suite has been completed.

2. (U) Milstar

(U) The Milstar system consists of a constellation of satellites and ground, shipboard, and airborne terminals. The terminal equipment includes a transmit/receive parabolic reflector antenna, radome, Antenna Position Control Unit (APCU), Low Noise Amplifier (LNA)/Downconverter which downconverts the 20 GHz received signal to a 7.4 GHz Intermediate Frequency (IF), Receiver Synthesizer Unit (RSU) to generate the signals used by the terminal, 44 GHz High Power Amplifier (HPA) and associated High Voltage Power Supply (HVPS), Modem, and Terminal Access Controller (TAC) and Baseband Processor (BBP) for terminal control and input/output device control.

3. (U) GBS

(U) The GBS system consists of payloads on each of three satellites (UFO-8, UFO-9, and UFO-10). Each GBS payload has four transponders with downlink frequencies at 20.295, 20.415, 20.475, and 20.595 GHz, respectively. The downlink transponders are used with two narrow 500 nmi steerable beams and one wide 2000 nmi steerable beam. For these demonstrations, UFO-9 located at 22.5°E over the Atlantic Ocean and the Primary Injection Point (PIP) located at the Norfolk Naval Base (Norfolk, VA) were primarily used. The GBS system is specified for operation at data rates up to 23.5 Mbps for each carrier using Quadrature Phase Shift Key (QPSK) modulation, Forward Error Correction (FEC) inner coding, and Reed Solomon outer coding. Rates transmitted by the PIP in Norfolk typically include 10 Msps at FEC rate _ and 17.625 Msps at FEC rate 2/3 (Note 1). The data stream typically includes a combination of MPEG encoded video/audio channels (at 2.2 or 3.0 Mbps each) and classified and unclassified data channels (at 6.0 Mbps each). The PIP is capable of various combinations of video and data channels with a combined data rate up to 23.5 Mbps for each carrier. The GBS 20 GHz receive chain includes an antenna and controller, Low Noise Block (LNB) converter to downconvert the 20 GHz band to L-band, Integrated Receiver Decoder (IRD) to demodulate the L-band to video, Personnel Computer (PC) to recover the classified and unclassified data, and FASTLANE decryption device.

4. (U) LUNEBERG LENS ANTENNA AND RADOME

(U) The 20 GHz receive antenna and radome used for the demonstration were developed by Datron/Transco Systems Incorporated (DTSI) under contract from Air Force Research Laboratory (AFRL/IFGC), Rome NY. The prototype low-profile antenna is shown in Figure 1 and consists of four lens hemispheres mounted on a ground plane. The lens are phase combined to produce a beam. The beam is varied in elevation by movement of the feed assembly and in azimuth by movement of the ground plane. Descriptive characteristics for the antenna and radome are summarized in Table 1 and Table 2, respectively. An Antenna Control Unit (ACU) interfaces with the airborne pointing commands to point the antenna.

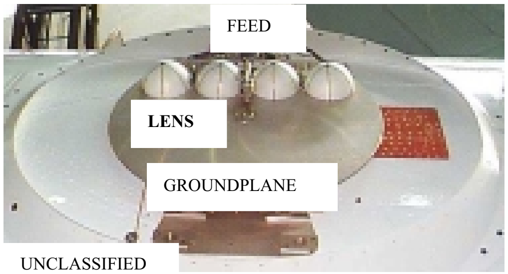

Figure 1. (U) Luneberg Lens Antenna

Type	Luneberg 4-Lens Array
Frequency	19.2 – 21.2 GHz
G/T	9.3 dB/°K (minimum)
Polarization	LHCP or RHCP, selectable
Beamwidth (nominal)	2° (AZ), 5° (EL)
Azimuth Range	360° continuous
Elevation Range	10° to 90° continuous
AZ Rate, Acceleration	> 15°/second, $20°/sec^2$
EL Rate, Acceleration	> 10°/second, $20°/sec^2$
Drive	Mechanical
Diameter	30 inches
Height	6 inches
Weight	≈ 55 pounds
Access Hole Diameter	1 inch (2 each)
LNA Noise Figure	< 1.5 dB
UNCLASSIFIED	

Table 1. (U) Characteristics for Luneberg Lens

Receive	
Frequency	19.2 – 21.2 GHz
Insertion Loss	< 1.5 dB
Polarization	LHCP or RHCP
Transmit (future applications)	
Frequency	44.5 – 45.5 GHz
Insertion Loss	< 2.5 dB
Polarization	RHCP
Size	49'(W), 58"(L), 8.3" (H)
Including adapter ring	59"(W), 63"(L), 8.7" (H)
Weight	< 50 pounds
Material	ElectroVu 581 Quartz Solid laminate
Thickness	0.180" (nominal)
UNCLASSIFIED	

Table 2. (U) Characteristics for Radome for Lens

5. (U) AIRBORNE INSTALLATION

(U) The MILSATCOM test aircraft at AFRL/IFGD, Wright Paterson Air Force Base (WPAFB) was used for the demonstration. The equipment normally onboard the test aircraft includes a Milstar terminal. For the demonstration, the Luneberg lens antenna and radome were installed on the top of the test aircraft aft of the Milstar reflector antenna and radome as shown in Figure 2. The GBS equipment was installed inside the test aircraft (Figure 3). The GBS equipment and Milstar receive equipment were integrated with the Luneberg lens antenna. The Milstar transmit functionality was retained with the Milstar reflector antenna. The Luneberg Lens antenna and Milstar antenna are pointed to the respective satellites by means of open loop commands derived from the onboard Inertial Navigation System (INS). The installation of the Luneberg lens antenna and radome was performed by personnel at Edwards Air Force Base (AFB). The integration of the antenna with the GBS and Milstar equipment, and development of the pointing software, was performed by AFRL/IFGD. The block diagram for the integrated Milstar and GBS equipment and antennas is shown in Figure 5.

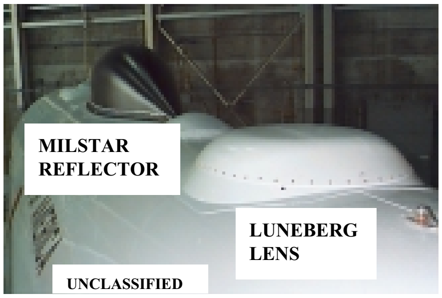

Figure 2. (U) Radomes Installed on Test Aircraft

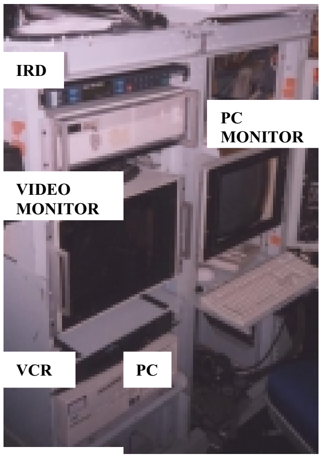

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Figure 3. (U) GBS Equipment Mounted in Aircraft

6. (U) DEMONSTRATION FLIGHTS

(U) A series of flights over a six-month period included destinations in Bermuda, various locations in CONUS, and Puerto Rico. The scenario is shown in Figure 6. The flights demonstrated simultaneous reception of GBS unclassified video/audio (2.2 or 3.0 Mbps) and classified (6.0 Mbps) and unclassified data (6.0 Mbps) with the aircraft as the planned subscriber. The links typically were with the GBS narrow spot beam, but upon occasion were with the wide area beam. The video typically consisted of news rebroadcasts, taped programming, or live video feeds from the PIP at Norfolk. The data typically consisted of web pages (i.e. weather or map information) or a test file. The test file consists of 200 linked and uniquely identified pages of text with each page approximately 825 K in size. This allowed real-time monitoring of the received data. The flights also demonstrated Milstar operation with transmission at 44 GHz using the Milstar reflector antenna and reception at 20 GHz using the Luneberg Lens antenna. The Milstar system was also used as a reachback channel to Norfolk to request changes.

(U) The flight from Bermuda to WPAFB is a typical flight. The route, shown in Figure 4, included both racetrack and 20°, 25°, and 35° circular roll patterns. A video signal was transmitted from the PIP in Norfolk. The GBS downlink patterns for the narrow beam pointed at Bermuda and the wide beam pointed at Norfolk are shown, along with reference lines for 5°, 15°, and 25° elevation look angles. Expected GBS link performance is shown in Table 3. As can be seen, with all system parameters optimal, up to a 17.625 Msps transmission stream from the PIP is supportable on the narrow beam. This stream included the 3.0 Mbps video signal intended for the test aircraft. The video was received continuously with disruption only in high roll turns which exceeded the mechanical elevation limits of the Luneberg lens antenna.

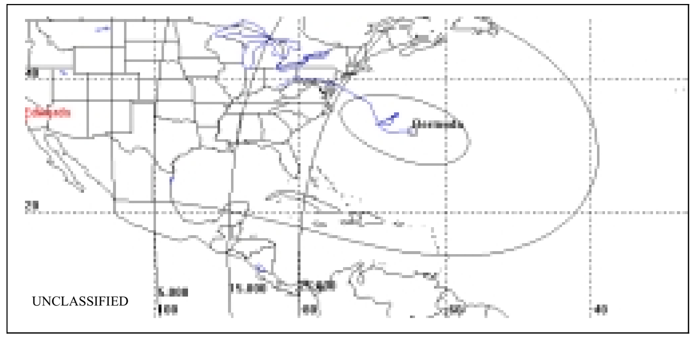

Figure 4. (U) Route and Beam Pattern for Bermuda Flight

Frequency	20.475 GHz (typical)
Satellite EIRP	53.2 dBW
Satellite Margin (Note 2)	3 dB
Slant Angle	15° nominal
Free Space Loss	-210.8 dB
Antenna Pointing Loss	-0.2 dB
Polarization Loss	-0.2 dB
Radome Loss	-1.5 dB
Atmospheric Loss	-0.5 dB
Weather Loss	0 dB
Receive Power at Terminal	-158 dBW
Temperature of Environment	275°K
Receiver Noise Figure	2 dB
Antenna gain	32.3 dB
Receive G/T	9.3 dB/K
Boltzman's Constant	228.6 dBW/K-Hz
Downlink Pr/No	79.9 dB-Hz
FEC Coding	2/3
Symbol Rate	17.625 Msps
Noise Bandwidth	72.5 dB-Hz
Pr/No	7.3 dB
Eb/No (incl implementation losses)	6.2 dB
Margin	2.1 dB
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Table 3. (U) Typical GBS Link Budget

(U) Data recording on the various flights was accomplished through a combination of methods. A strip chart recorder was connected to a spectrum analyzer which continuously monitored the GBS L-band receive signal. This provided a record of GBS signal strength for later correlation with aircraft maneuvers. Visual observation of the video signal provided a real-time assessment of relative quality of that signal and a VCR provided a permanent record. Both classified and unclassified GBS data files were saved in the PC with time identifiers. The test file software allowed continuous monitoring of incoming GBS data for comparison with aircraft dynamics. Bit Error Rate (BER) was displayed for the Milstar receive signal. Summary results for GBS from the various demonstration flights are shown in Table 4.

Transponder Beam	Narrow Spot
Transmitted Symbol Rates	10 and 17.625 Msps
FEC Coding Rates	_ and 2/3, respectively
Video Products	news, tape, live
Video Rates	2.2 or 3.0 Mbps
Video Quality	Generally high quality. Some visual imperfections noted at close viewing distance. Video continuously received (within limits of aircraft dynamics and ground atmospheric conditions)
E_b/N_o	≈ 8.5 dB (Note 3)
Data Products	Web pages, test software
Data Rates	6.0 Mbps (Classified and unclassified)
Performance	Files continuously received (within limits of aircraft dynamics and ground atmospheric conditions)
Aircraft Roll	20° typical
With Elevation Blockage	to 35°
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Table 4. (U) Summary of Results for GBS Video and Data

7. (U) SUMMARY AND CONTINUING ACTIVITIES

(U) Activities to date include characterization of reception of unclassified video and both classified and unclassified data from GBS and non-simultaneous data from Milstar satellites using a single antenna. Milstar links were established using a combination of the Luneberg Lens antenna for reception and Milstar reflector antenna for transmission. A reachback channel was established to the PIP via Milstar. Results indicate satisfaction of all performance objectives. Additional details are found in the test procedure and report for the demonstration.

(U) Recommended continuing activities include the following: further definition and characterization of airborne performance including performance with the wide area beam; evaluation of coverage over CONUS with the UFO-8 and UFO-9 beams; development of an antenna capable of receiving the 20 GHz GBS and Milstar signals as well as transmitting to the Milstar satellite at 44 GHz as part of the definition of advanced wideband terminals; development of closed loop antenna pointing and tracking algorithms for both GBS and Milstar; architecture studies defining methods of providing GBS video and data to users; and evaluation of operational GBS/Milstar concepts.

(U) NOTES

1. (U) For purposes of this paper, we define Megabits per second (Mbps) as the pre-encoded user rate, and Megasymbols per second (Msps) as the post-encoded QPSK modulated rates transmitted over the air.
2. (U) "Satellite Margin" refers to the difference between specified minimum EIRP and the actual EIRP.
3. (U) E_b/N_o was estimated using a technique suggested by D. Roth (Raytheon) in which the Signal Plus Noise (S+N) and Noise (N) levels are measured with a spectrum analyzer.

(U) ACKNOWLEDGEMENTS

(U) The activities reported here are the result of the contributions from ESC/MCV (Capt. E. Kinsley, Lt. J. Herrick, and Lt. J. Cox), GBS JPO (Cmd. D. Chappel and CAPT Delpino), AFRL/IFGD (H. Demers, the crew from the MILSATCOM test aircraft, and the team from the MILSATCOM lab), ESC/DIT (C. Bowers), AFRL/IFGC (W. Cook), AFRL/SNHA (J. Turtle), NCTAMSLANT (R. Messenger and the personnel at the Satellite Broadcast Manager at Norfolk Naval Base), ARINC (T. Thorp), Raytheon (D. Barrett and the GBS design team), the integration team at Edwards AFB, Datron, and Mitre (S. MacConduibh, D. Dunbrack,, J. Werth, M. Wunder, G. Goddard, and the personnel from the Milstar terminal lab and Broadcast lab).

(U) This technical data was produced for the U.S. Government under contract No. F19628-99-C-0001, and is subject to the Rights in Technical Data-Noncommercial Items Clause at DFARS 252.227-7013 (NOV 95).

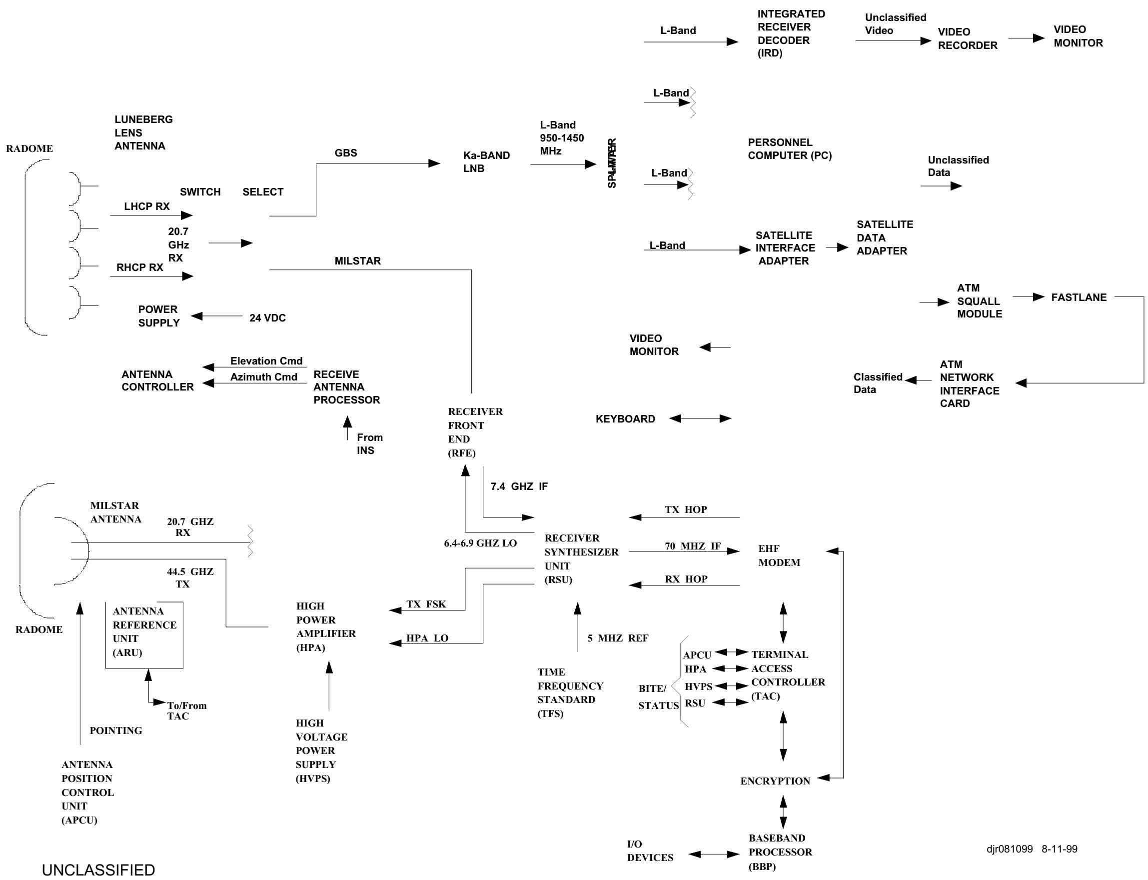

Figure 5. (U) Milstar and GBS Interconnection Block Diagram

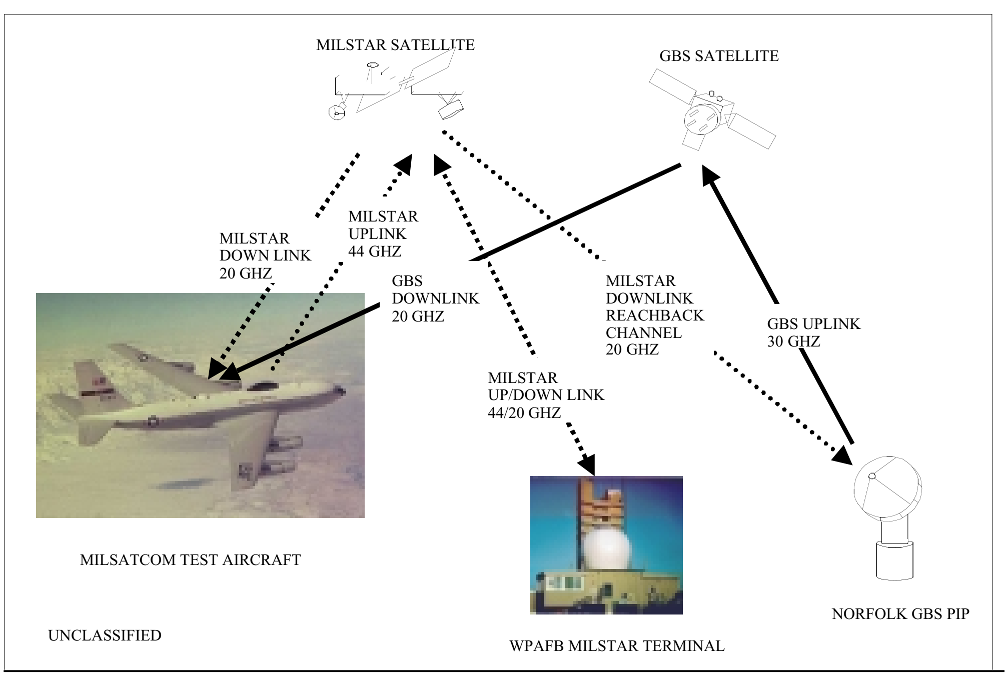

Figure 6. (U) Scenario for Demonstration Flights