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Unclassified the Naval Postgraduate School GBS testbed

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THE NAVAL POSTGRADUATE SCHOOL GBS TESTBED

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A downlink testbed for the Global Broadcast System (GBS) has been installed at the Naval Postgraduate School in the NPS Systems Technology Laboratory (STL). The purpose of the testbed is to conduct research on the link characteristics of GBS broadcasts that can be received in Monterey. Currently, the GBS Conus transmission is a Ku-band signal from the uplink testbed at the Pentagon via the medium power SBS-6 satellite located at 79 degrees West. Beginning in 1998, UFO-8 high power GBS broadcasts at Ka- band will be analyzed. In addition, the testbed receives and analyzes commercial Direct TV and Dish Net Ku- band broadcasts. The testbed has been instrumented to monitor carrier power levels and background noise levels for each of the active transponders. Statistical analysis of this data is planned to develop distributions of C/No and Eb/No for the different transmissions. Values are compared with computed link budgets. Correlation with local meteorological measurements is planned.. Bit error rate testing is included to evaluate receiver/decoder losses and to validate effects of variable data rate.

INTRODUCTION

A Joint Program Office (JPO) was established to manage the acquisition of a GBS for the DoD in May of 1996. This followed a number of successful trials and demonstrations of commercial direct broadcast satellite (DBS) technology over the preceding two years that demonstrated its military utility[1]. The JPO has overall program responsibility for the terminal, space and broadcast management segments of the GBS. The program is being carried out in three phases:

Phase I (FY96-98) Establishment of a GBS testbed based on continuation of the leasing of Ku band medium power satellite transponders. Development of operational concepts and a broadcast management architecture.

Phase II (FY97-07) Development of a limited interim capability by placing Ka band GBS packages on UHF Follow-on (UFO) satellites 8, 9 and 10.

Phase III (FY97-20) Provision of a comprehensive worldwide GBS service based on the ongoing Space Architect's studies and lessons learned from Phases I and II.

In the summer of 1996, the Naval Postgraduate School (NPS) initiated planning to create a downlink testbed in support of the GBS program and the Navy's research program in High Data Rate Ship/Aircraft SATCOM. The objectives of the NPS project are several fold. First, we are anxious to involve student-officers in the emerging GBS technology and services for instructional and research purposes. This has the added benefit of having officers returning to their Services who have intimate knowledge of the GBS. Secondly, we want to have a facility where different technologies can be compared for their technical performance and for their suitability to military needs. Thirdly, we want to collect data that can be used to help improve methods of estimating the impairment of satellite communications at Ka band due to atmospheric and weather effects.

TESTBED DESIGN

With the aforementioned objectives in mind, we designed a facility with the following components:

1. A receive suite for the GBS Conus uplink testbed video and data transmissions.
2. Receive system for the DSS transmissions of the Direct TV DBS broadcast.
3. Receive system for the DVB transmissions of the Dish Net Echostar broadcast.
4. Instrumentation for automatic monitoring of receive carrier powers of the various transponders
5. Instrumentation for automatic monitoring of background noise power.
6. Instrumentation for automatic monitoring of bit error rates (BER) of data signals.

Commercial off-the-shelf (COTS) equipment components were identified and purchased for all items except the cryptographic device (KG-194a) which is needed to decrypt the GBS data stream. A block diagram of the testbed configuration is shown in Fig. 1.

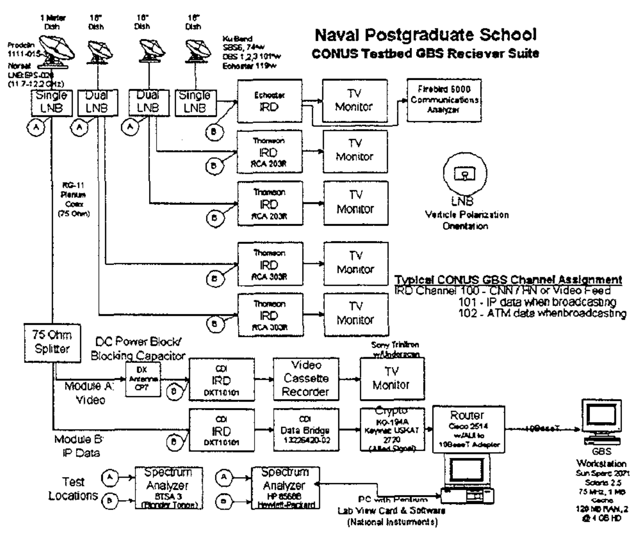

Fig. 1 Initial configuration of GBS testbed

The antennas were mounted on the roof of Root Hall, above the NPS secure Systems Technology Laboratory (STL). A location was selected that provided clear views of the three satellites. The Conus GBS transmissions are received via the Ku-band SBS-6 satellite located at 79 degrees West. From Monterey, which is located at 36° 42' N and 121° 45.6' W, the 1 meter parabolic dish receive antenna is inclined at a 25 degree elevation angle. SBS-6 has an EIRP of 45-46 dBW at Monterey and uses linear polarization. The low noise block (LNB), mounted at the antenna, amplifies and down converts the 11.2-11.7 GHz Ku-band signal from the satellite to a .95-1.45 GHz L-band signal for transmission on the cable from the antenna to the remainder of the receive suite located in the STL. RG-11 low loss cable was selected for the 200' cable run to minimize cable attenuation.

The DSS transmissions are received via the Hughes DBS satellites located at 101 degrees West. From Monterey, the .46 m (18") parabolic dishes are inclined at 31 degree elevation angles. The 53 dBW EIRP circularly polarized Ku-band signals are amplified and down converted to L-band by the LNBs for transmission over the cable. Dual LNBs on the DSS antennas result in the availability of four DSS signals for distribution and analysis in the testbed.

The Dish Net DVB transmission is received via the Echostar II satellite located at 119 degrees West by a .48 m (19") dish inclined at 48 degrees elevation angle. The circularly polarized Ku-band signal is amplified and down converted to L-band for transmission over the cable for distribution and analysis in the testbed. Fig. 2 shows a photograph of the antennas and rooftop mounting platform.

The L-band signal from the GBS LNB is split and sent to two separate integrated receiver decoders (IRDs). The parallel data port output from one IRD is converted to a serial data stream by the Data Bridge and decrypted. The IP data is routed via a 10 base T LAN to a SPARC 20 Workstation equipped with GBS software for the data. (ATM data is also available on a periodic basis via the same IRD data port). The second IRD decodes the video data which at the present time is CNN/HNN news. It also contains a program guide describing what is available on the data channels. At the present time, the video and data channels are multiplexed together at the uplink testbed into a single 23.6 Mbps DSS signal and utilize 27 MHz of a 45 MHz bandwidth SBS-6 transponder.

The signals from the Direct TV and Dish Net systems are routed to their respective IRDs for decoding. Video and

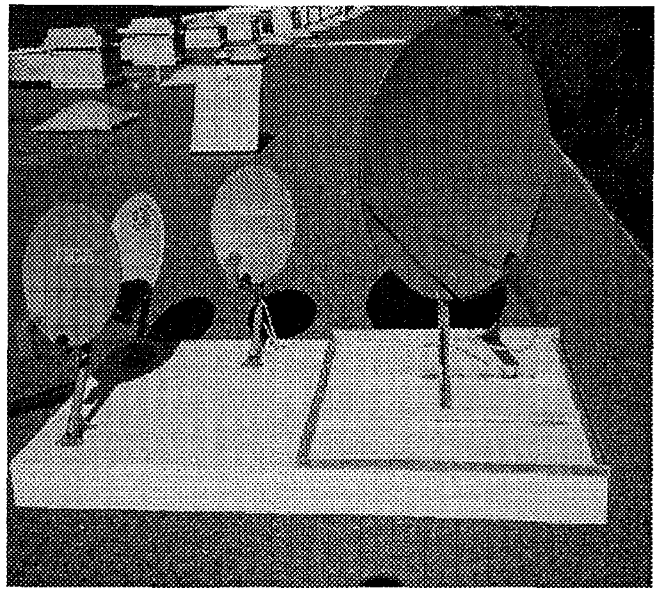

Fig. 2 Rooftop antennas and mounting

data signals are available for the COTS commercial DBS systems. Direct TV is on the verge of launching a version of its Direct PC service via their DSS data port and Dish Net currently utilizes their data port for testing and development.

INSTRUMENTATION

The purpose of the instrumentation is to monitor system variables related to the technical performance of the satellite links. National Instrument's LabVIEW® software is utilized to read and record data from the instruments. Currently, an HP 8568B digital spectrum analyzer and a Fireberd 6000 communications analyzer are in use in the testbed. The LabVIEW software runs on a Pentium PC. Virtual instruments (VIs) are programmed for each instrument in use. The VIs read data into the PC from the instruments via a GPIB interface. They format and record the data in flat ASCII files for further analysis.

For example, received power levels across L-band are recorded automatically by the HP8568B VI at periodic intervals. The resulting time series data are analyzed, graphed and can be compared with link budget predictions. MATLAB® has been used to create the data shown in Fig. 3 and in Fig. 4. Fig. 3 shows a superposition of 144 samples of the spectrum received from the Dish Net DVB Echostar satellite taken at intervals of 10 minutes over a 24 hour period. Measurements commenced at 1730 hours on June 25 in clear sky conditions. Each of the 144 spectra consist of 1001 equally spaced points in the 950 to 1450 MHz band. The spectrum analyzer was set to a resolution bandwidth of 1 MHz. The ten RHC polarized Echostar transponder signals are evident in the figure. Blurring of the lines indicates a variability of the spectra over the period of observations. Fig. 4 shows the variation of total carrier power in transponders 1 and 10 over the 24 hour period. These power levels are corrected to the output of the LNB. The average carrier powers are -34.9 dBm for transponder 1 and -36.5 dBm for transponder 10. Link budget predicted carrier power for Echostar is -39.1 dBm. Notice the small but obvious reduction in carrier power around sunrise. This may be due to warming of the LNB or atmospheric effects. All three systems exhibit this phenomena[2].

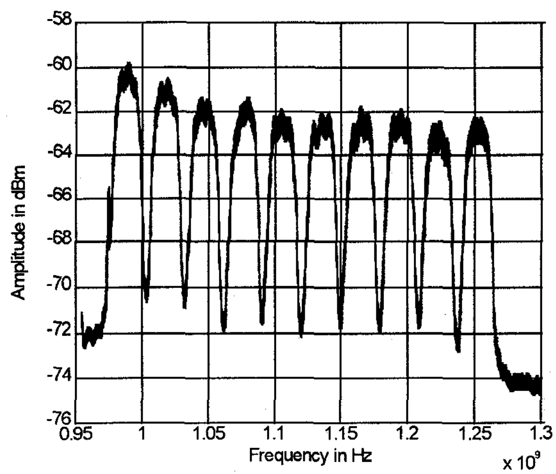

Fig. 3 Dish Net DVB spectra

We plan to use data such as this to develop a statistical model for C, and No. We hope to be able to correlate it with atmospheric and meteorological observations and predict availability. In particular, differential measurements between Ku and Ka-band rain and fog effects should be quite accurate by comparing the DBS or Echostar Ku-band transmissions with the UFO-8 Ka-band transmissions. In addition we plan to use the C and No data to compare different antennas, evaluate antenna tracking performance (the GBS antennas for the UFO

GBS are required to track the satellite), and to evaluate the impact of camouflage netting, foliage and other obstructions in the path of the transmissions.

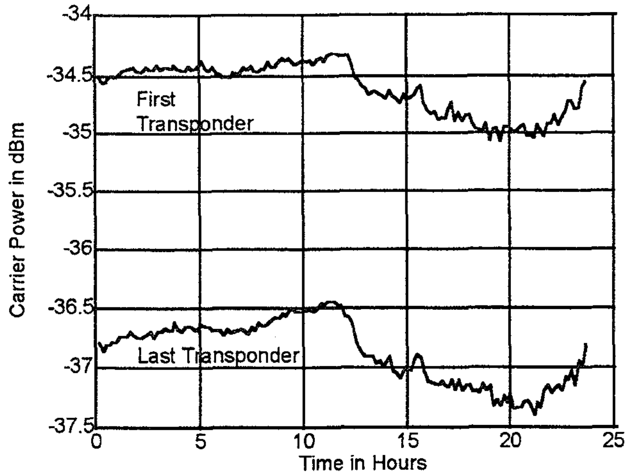

Fig. 4 Dish Net DVB carrier power variations

Data from the Fireberd communications analyzer is used to compare observed BERs with those predicted for the systems from the C/No measurements. The GBS uplink testbed is now transmitting a BERT channel via SBS-6 as part of the data stream. In addition, we are in the process of making arrangements with the commercial services to conduct BER testing on their transmissions. These data will be used to evaluate the implementation losses of different IRDs , and to validate the variation in BER with varying data rate. An L-band noise source is being integrated into the testbed so that No can be artificially increased. Ultimately, we plan to develop a technique to imbed a quality of service (QOS) mechanism within the GBS transmissions so that each receiver terminal can know its own level of availability and feedback that information by its back-channel to the broadcast management facility.

GBS PHASE II

Our goal is to have the NPS testbed completely operational and all instrumentation calibrated by the time the 20.1 GHz K-band downlink GBS transmissions begin from UFO-8 in early 1998. UFO-8's final orbital slot is at 179 degrees West. The GBS package supports two downlink spot beams with nominal diameters of 500 miles and one area coverage beam with a nominal diameter of 2000 miles The beams are steerable and their actual coverage depends on their pointing angles as is illustrated in Fig. 5. This Fig. shows the edge of coverage, that is 0 degree elevation angle, for UFO-8 and the coverage obtained by the three beams with Spot 1 and Area Coverage aimed at Korea and Spot 2 aimed at San Diego. This is the instantaneous access area for the time epoch when the satellite crosses the equator. The elevation angle from the NPS GBS testbed in Monterey to UFO-8 varies from 6.3 ° to 14.2° (UFO satellites are in six degree inclined orbits.) Analytical Graphics, Inc. Satellite Toolkit software installed on a Pentium PC in the testbed provides dynamic graphical display and computes instantaneous access areas, elevation angles and link budgets for all DBS/GBS satellite systems we are, or plan, to receive. When linked to the data being recorded in real time, we are able to accurately derive carrier power and noise power differentials, that is the difference between prediction and measurement, after accounting for all known systemic variables.

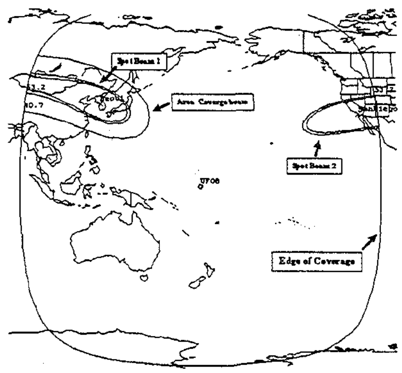

Fig. 5 UFO-8 instantaneous access area

SUMMARY

A GBS/DBS downlink testbed that has been installed in the Naval Postgraduate School's System Technology Laboratory is providing a unique learning opportunity for the student-officers in engineering and technology curricula. In addition, data being gathered will be used to validate link budget projections, evaluate alternative component technologies and improve rain signal impairment models at Ku and Ka-band.

REFERENCES

[1] 'Information dissemination via global broadcast service (GBS)", Blohm et. al., **MILCOM 96 Conf. Proc.**, pp 506-511.

[2] 'Instrumenting the NPS GBS testbed', John Watkins, Master's Thesis, Naval Postgraduate School, June 1997.

ACKNOWLEDGEMENT

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