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The GBS dataset: measurements of satellite site diversity at 20.7 GHz in the UK

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The GBS (Global Broadcast Service) dataset is a series of radio attenuation measurements made at three sites in the UK: Chilbolton and Sparsholt, both in southern UK, and Dundee in Scotland. The aim of the experiment was to make long term measurements of the signal strength received from a 20.7 GHz beacon on the US Department of Defense satellite UFO-9 at multiple sites, in order to determine whether the use of site diversity as a fade mitigation technique would be effective. The dataset spans a period of 3 years, from August 2003 to August 2006 with signal attenuation sampled once per second.

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Key words: site diversity, radio propagation, fade mitigation techniques

Dataset

The GBS (Global Broadcast Service) dataset comes as 3 separate data streams:

- Identifier: doi:10.5285/639A3714-BC74-46A6-9026-64931F355E07
  Creator: Science and Technology Facilities Council (STFC), Chilbolton Facility for Atmospheric and Radio Research, [Callaghan, S. A., J. Waight, C. J. Walden, J. Agnew and S. Ventouras].
  Title: GBS 20.7 GHz slant path radio propagation measurements, Chilbolton site
  publisher: NERC British Atmospheric Data Centre
  Publication year: 2009
  Resource type: Metadata document
  Version: 1.0
- Identifier: doi:10.5285/db8d8981-1a51-4d6e-81c0-cced9b921390
  Creator: Science and Technology Facilities Council (STFC), Chilbolton Facility for Atmospheric and Radio Research, [Callaghan, S. A., J. Waight, C. J. Walden, J. Agnew and S. Ventouras].
  title: GBS 20.7 GHz slant path radio propagation measurements, Dundee site
  Publisher: NERC British Atmospheric Data Centre
  Publication year: 2009
  Resource type: Metadata document
  Version: 1.0
- Identifier: doi:10.5285/E8F43A51-0198-4323-A926-FE69225D57DD
  Creator: Science and Technology Facilities Council (STFC), Chilbolton Facility for Atmospheric and Radio Research, [Callaghan, S. A., J. Waight, C. J. Walden, J. Agnew and S. Ventouras].
  Title: GBS 20.7 GHz slant path radio propagation measurements, Sparsholt site
  Publisher: NERC British Atmospheric Data Centre
  Publication year: 2009
  Resource type: Metadata document
  Version: 1.0

Introduction

Radio signals at frequencies above 10 GHz suffer significant attenuation from rain, clouds and atmospheric gases. In spite of this there is significant pressure on the radio spectrum to open these (so far) unused higher frequencies to commercial exploitation. To do this, methods of compensating for atmospheric and rain fading must be developed (Castanet *et al.*, 2003; Panagopoulos *et al.*, 2004). One fade mitigation technique (FMT) proposed is the use of site diversity, where multiple satellite receive stations are set up sufficiently far apart so that the rain experienced at each site is de-correlated. In a properly configured site diversity system the sites experience fading at different times, and switching between the sites can improve the total communications system availability considerably.

The primary use of the GBS dataset is to provide the raw data for the development and testing of radio propagation models. However, it can also act as a proxy for rain rate measurements as there is an empirical relationship between the rainfall-induced attenuation and the part-averaged rainfall intensity (Goldshtein *et al.*, 2009).

1. Experimental set-up

The Radio Communications Research Unit (now the Chilbolton Group), part of STFC–Rutherford Appleton Laboratory, installed the Chilbolton GBS receiver in August 2003, the Sparsholt receiver in October 2003 (beginning the site diversity measurements) and the Dundee receiver was installed in February 2004. All three receivers were recording the signal strength received from the 20.7 GHz Global Broadcast Service (GBS) beacon carried on the US Department of Defense (DoD) satellite UFO-9 at approximately 23°W until contact with the satellite was lost in August 2006.

The UFO-9 satellite was in a slightly inclined (approximately ±3.5 degrees) geosynchronous orbit requiring a tracking system on the ground receiver to ensure that the receiver pointed correctly. Ephemeris information was not available as UFO-9 was a military satellite. Unfortunately, the cost of implementing a tracking system on the receivers was prohibitive, so wider beamwidth antennas were used capture the complete movement of the satellite without the need for tracking. This resulted in a reduction in receiver gain of 6 dB, but the dynamic range of the receivers was wide enough to record a full range of measurement. The relative movement of the satellite and lack of tracking introduced a sinusoidal diurnal variation into the recorded data which was removed during preprocessing. The GBS receivers had a dynamic range of approximately 13 dB, sufficient to measure attenuation at 20.7 GHz down to time percentages of 0.02% (approximately 2 h in a year). Table 1 gives the technical specifications for the GBS receivers.

Table 1. Technical specifications for the receivers used in the GBS site diversity experiment.

Receiver type	Single down-conversion, superheterodyne
Antenna type	Flann CW820-FA, 150 mm diameter high performance horn lens antenna
External antenna polariser transition	Left hand circular to linear (in WG20/WR42)
Antenna gain	29 dBi
Beamwidth	11
Local oscillator (two-stage)	10.315 GHz PLO (internal XTAL)→X2 multiplier→20.63 GHz
I.F. Frequency	70.0 MHz
LNA mixer/preamplifier noise figure, F	2.4 dB
I.F. bandpass filter bandwidth (3 dB)	3% (2.1 MHz max.)
Overall R.F. to I.F. gain at mixer output	>47 dB
Overall noise figure (pre-beacon I.F. tracking receiver), F	3.5 dB max.
I.F. amplifier gain	56 dB
Intermediate frequency (I.F.)	70.0 MHz
Front-end I.F. processing by satellite beacon receiver, type:	Matra Marconi Space SBR100 or Novella Satcoms B150 with preset 70 MHz channel input, 50 Ω impedance
Input frequency range for tracking (search range)	70 ± 200 KHz (B150)
Input signal range	−60 dBm to −20 dBm (saturation level)
Phase locked loop bandwidth	300 Hz
Threshold for reacquisition of lock (300 Hz PLL B/W)	<35 dBHz
Output range (for specified input range)	−10 V d.c. to +10 V d.c.
Slope	2.0 dB/V d.c.
Datalogger details	Microlink 3040 A/D converter, 12 bit resolution
Satellite beacon receiver d.c. output sampling rate	One sample *per* second, continuous

Figure 1. The GBS receiver in operation at Sparsholt.

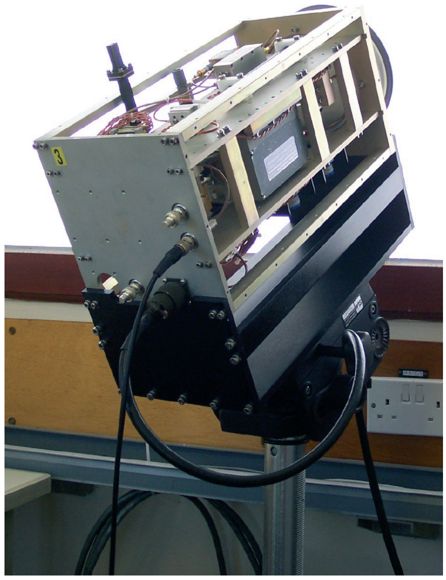

Figure 2. The GBS receiver in operation at Chilbolton (opened to show the components inside).

Both receivers were designed and custom-built in-house by members of the RCRU (Figures 1 and 2), and were situated in specially designed cabins, looking along the path to the satellite through radomes of woven PTFE acquired from Gore Associates. More information on the GBS project can be found in (Callaghan *et al.*, 2005) and details of the results of the experiment can be found in (Callaghan *et al.*, 2008).

The experimental sites were:

- Sparsholt (51°04′N, 01°26′W), started October 2003.
- Chilbolton (51°08′N, 01°26′W), 7.8 km NNW of Sparsholt, started August 2003.
- Dundee (56.45811°N, 2.98053°W), started February 2004.

Chilbolton and Sparsholt are approximately 7.8 km apart and were chosen to investigate short range site diversity. Dundee is approximately 600 km north of Sparsholt and Chilbolton, allowing an investigation of long range diversity. Co-located with the Chilbolton and Sparsholt receivers were a range of supporting meteorological instruments, such as a drop counting rain gauge and instruments to measure wind speed and direction, as well as pressure and temperature. These meteorological measurements were augmented by the multi-parameter 3 GHz radar, CAMRa, also located at Chilbolton.

The signal strength in dB was recorded at the three receive sites at a sampling frequency of 1 Hz. Due to the diurnal variation of the satellite, this data was pre-processed to produce the archived attenuation time series, using the same methods as was used for the ITALSAT data (Ventouras *et al.*, 2006). This process is outlined below:

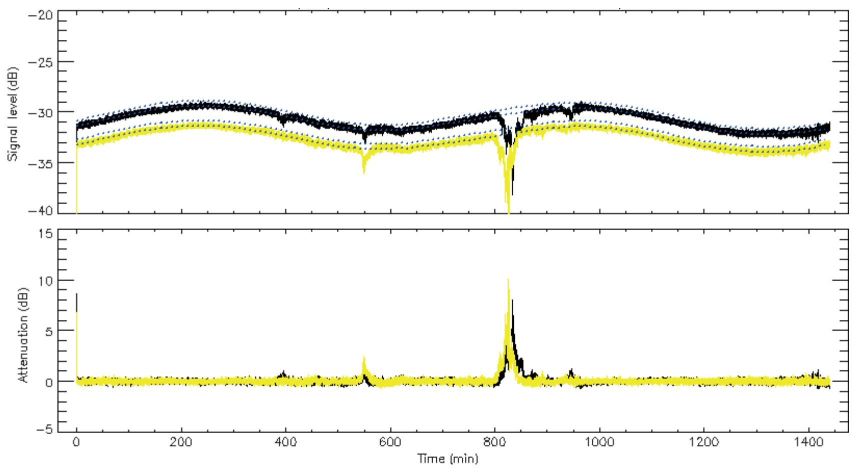

Figure 3. Signal levels and attenuation time series for 9 January 2004. Black: Sparsholt data, yellow: Chilbolton data.

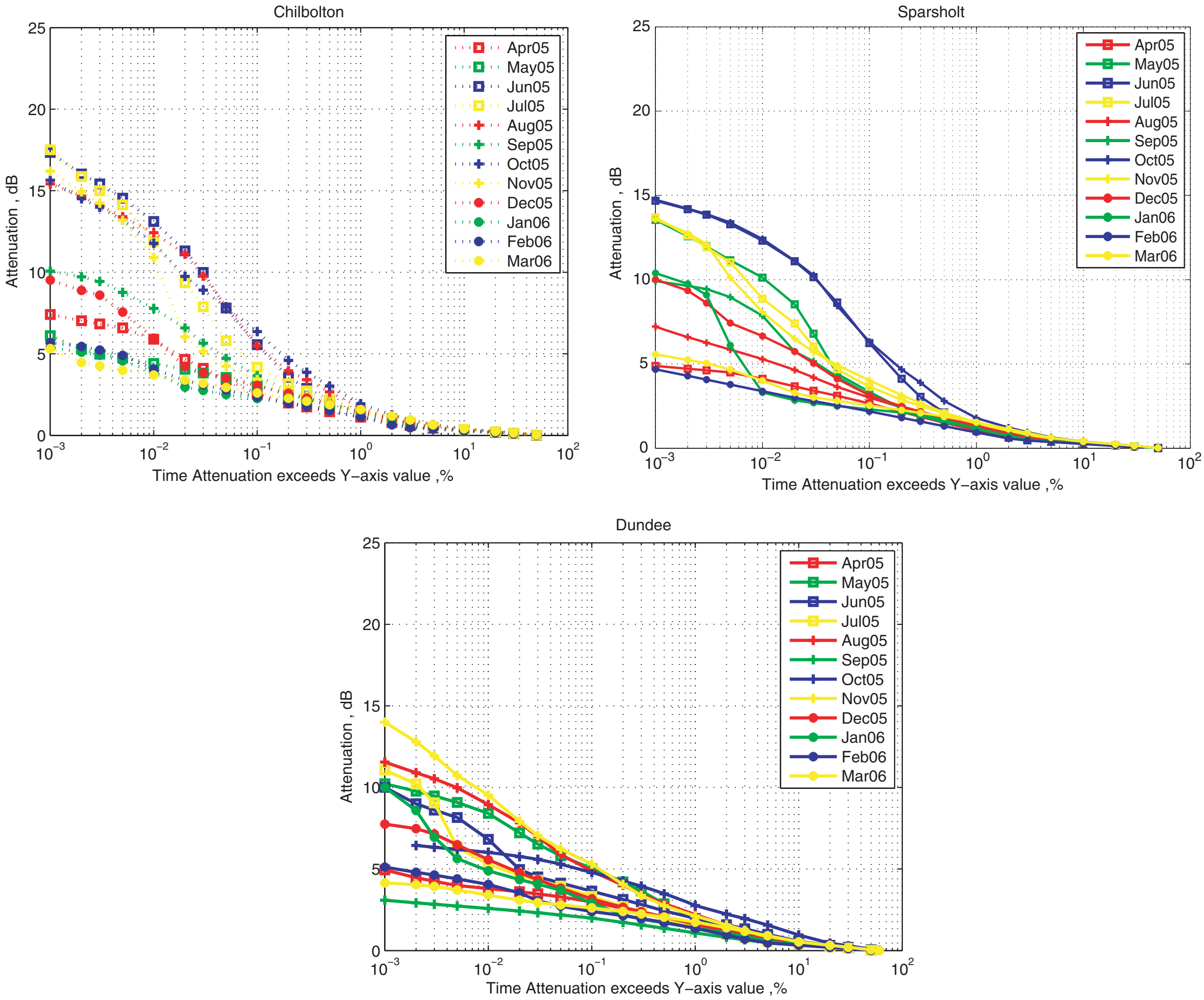

Figure 4. Monthly cumulative distributions of attenuation at the three receive sites, April 2005–March 2006. (a) Chilbolton (b) Sparsholt and (c) Dundee.

Figure 3 shows the signal levels and attenuation time series for the whole day of the 9th January 2004. The *x*-axis gives the time values as minutes after midnight. The upper plot shows the signal levels as recorded by the beacon receivers. The blue dotted lines indicate the variation that the signal would have if the day were completely free of attenuation. These lines are fitted during the data pre-processing to remove the daily sinusoidal variation of the satellite relative to the beacon receiver, as well as adjusting for any sudden change in beacon signal power or receiver sensitivity. (The upper of the dotted lines indicates the attenuation relative to vacuum, whereas the lower dotted line indicates the attenuation relative to clear sky, i.e. attenuation including the gaseous attenuation due to atmospheric water vapour and oxygen, but not due to clouds or rain.) The lower plot in Figure 3 shows the resulting processed attenuation time series for the day, which is the time series stored in the archived attenuation time series.

In general the data availability for this experiment was very good, with monthly availabilities generally greater than 95%. The Sparsholt and Chilbolton datasets are continuous between the start of data collection and the loss of the UFO-9 satellite. This is not the case with Dundee, where funding issued resulted in a 2 month gap when data was lost due to networking problems.

Figure 4 shows example monthly cumulative distributions of attenuations for the 3 sites.

Acknowledgements

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