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The 40 and 50 GHz propagation experiments at the Rutherford Appleton Laboratory, UK, using the ITALSAT beacons

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ABSTRACT

This paper describes the current experimental programme and future plans for the reception of transmissions from the 18.7, 39.6 and 49.5 GHz beacons from the ITALSAT satellite by the Radio Communications Research Unit at Rutherford Appleton Laboratory, UK.

1. INTRODUCTION

The Radio Communications Research Unit at Rutherford Appleton Laboratory, which has had considerable experience in developing experimental millimetric equipment for propagation studies (1), has initiated the development of a single-channel receiver and a triple channel receiver to measure propagation effects at 49.5 GHz and 39.6 GHz respectively The initial location of the receivers will be at Chilbolton, Hampshire, UK.

2. CHARACTERISTICS OF THE ITALSAT 39.6 and 49.5 GHz BEACON

ITALSAT is situated in a geostationary orbit at 13° East longitude and is maintained in a $\pm 0.15^{\circ}$ orbit box. The satellite was launched in January 1991 with a scheduled five year operational lifetime. The 39.6 GHz beacon is modulated to produce side bands $\pm$ 505 MHz from the carrier with an EIRP of 24.8 dBW. The polarization of this beacon is right-hand circular. The two side bands can be used to measure amplitude and phase distortions produced by the medium and to assess the quality of its coherence bandwidth up to ~ 1 GHz.

The 49.5 GHz beacon on ITALSAT has very similar characteristics to that of the 20 GHz beacon on Olympus. The similarities between the design of this beacon and the 20 GHz transmission from Olympus were considered desirable, in that experimental systems and analysis techniques, developed for the Olympus project, could then be directly applied to these higher wavebands. The signal, which is switched between vertical and horizontal polarization at a rate of 933 Hz, has a specified EIRP of 26.8 dBW, after five years' operation. The coverage area of both 39.6 and 49.5 GHz beacons (3 dB footprint) includes most of Europe.

More details of this beacon and the other two on ITALSAT can be obtained through the ITALSAT Propagation Experiment Users guide (2).

3. SINGLE CHANNEL RECEIVER DESIGN

The 49.5 GHz system consists of a single polarization receiver for reception of one polarization and a 51 GHz radiometer. The construction of these systems can be seen in Figures 1 and 2. The receiving dish comprises a small 60 cm cassegrain dish, which feeds the signal through a polarization switch to allow selection of either vertical or horizontal polarization. The down conversion to 70 MHz is accomplished through a single balanced mixer with a noise figure of 6 dB. The local oscillator (LO) consists of a VHF crystal source which phase locks to an X- band generator, and is then multiplied to 49.42GHz by a times- four multiplier. The IF signal is amplified and filtered, before final detection by a conventional phase-locked loop (PLL) beacon receiver. This PLL system had been originally developed for the single channel beacon receiver operating in conjunction with the B1 beacon (20 GHz) of the Olympus satellite experiment. The received signal level achieved was 34 dB above the noise level in clear sky conditions and quite adequate for observing significant propagation effects.

The 51 GHz radiometer (Figure 2), follows the conventional design of a Dicke switched radiometer, where the input to the radiometer signal is switched at 1 KHz between the sky temperature, to be measured, and a reference load controlled by a Peltier junction device. The design is very similar to radiometers at 78 GHz and 95 GHz which had been developed for earlier studies (3). As the necessity for having a stable, low phase noise, local oscillator is not as high as in the receiver, a Gunn oscillator with fundamental frequency near 51 GHz has been used. The frequency drift is reduced to acceptable variations through controlling the temperature of this oscillator, again with a Peltier junction controlled heat-sink. The signal is detected after amplification through a 400 MHz bandwidth IF by a phase sensitive detector, sychronized to the input switching signal. The output from the system produces a measure of the medium temperature to an accuracy of $<1^{o}$K over a range of 0 to 300^{o}K.

3.1 Mechanical construction

The mechanical layout is based on a fabricated box section aluminium alloy chassis with the antenna mounting plate fixed at right angles to one end. This construction provides a rigid and stable platform for the waveguide components. The top plate carries the LO section, the RF and IF sections. The control circuits, protection circuits and power supplies are mounted on the lower plate. The system is temperature controlled to 20^{o}C and enclosed in a RAE type case. The RF head unit is mounted on an outside broadcast tripod fitted with an elevation over azimuth steerable mount. The gross weight of the receiver system is approximately 20 kg.

4. EXPERIMENTAL RESULTS

Experimental results from an engineering trial were reported in more detail in the ICAP'93 paper (4). However the cumulative distributions derived over a 4 month period (Figure 3) in 1992 have also been included again and compared with the CCIR predictions (4) for 50 GHz at 30^{o} elevation angle. Caution should be exercised in drawing any conclusion from these data as the period of observation was very limited and coincided with a particularly low rainfall period in the UK.

The final version of this 49.5 GHz system has been operational since July 1993 and analysis of propagation measurements is in progress.

5. THE 39.6 GHz RECEIVING SYSTEM

The 39.6 GHz receiving system is currently in its development phase. The overall design is shown in block diagram form, in Figure 4 is a slightly more complex version of the single channel 49.5 GHz receiver. The RF section consists of an initial down conversion to frequencies in the 1.4 to 2.5 GHz band. A three way multiplexer splits the carrier and two side bands into separate channels, before a second down conversion to 70 MHz. The radiometer which operates near 41 GHz is a conventional Dicke switched system. Calibration of the system is important to monitor any changes in the relative amplitudes and phases between the carrier and side bands. The scheme shown uses the same basic local oscillator for both the second down conversion and calibration signal.

The final stage, a triple channel phase locked loop receiver, is a modification of a single channel design, produced by Ferranti International, which had been used extensively on the Olympus experiment [5].

6. EXPERIMENTAL ARRANGEMENTS

The initial testing of the 49.5 GHz and 39.6 GHz has been performed at Chilbolton. Currently the 49.5 GHz has been operational for nearly 12 months and trials of the prototype 39.6 GHz system started in late April 1994. However it is intended to move both these two receivers together with an 18.7 GHz receiver to Sparsholt, a site 8 km from Chilbolton. The 18.7 GHz receiver will monitor the Ku band beacon on the ITALSAT satellite, intended initially for only Italian coverage. Although the EIRP is 12 to 14 dB lower than at beam centre, the fade margin of about 17 dB is adequate to compare fades at millimetric wavelengths with those at the lower frequencies, which were extensively researched through the Olympus project [5]. A 12.5 GHz receiver monitoring the EUTELSAT F4 satellite at 16^{o}E, a 30 GHz radiometer, a rapid response rain gauge and a distrometer complete the instrumentation at Sparsholt. The multiparameter radars (6) situated at Chilbolton will also be used as a diagnostic instrument to monitor selected events. The experimental measurements at Sparholt will continue for at least two years assuming a start of operations in late 1994 and the continued transmissions from of ITALSAT.

7. ACKNOWLEDGEMENT

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8. REFERENCES

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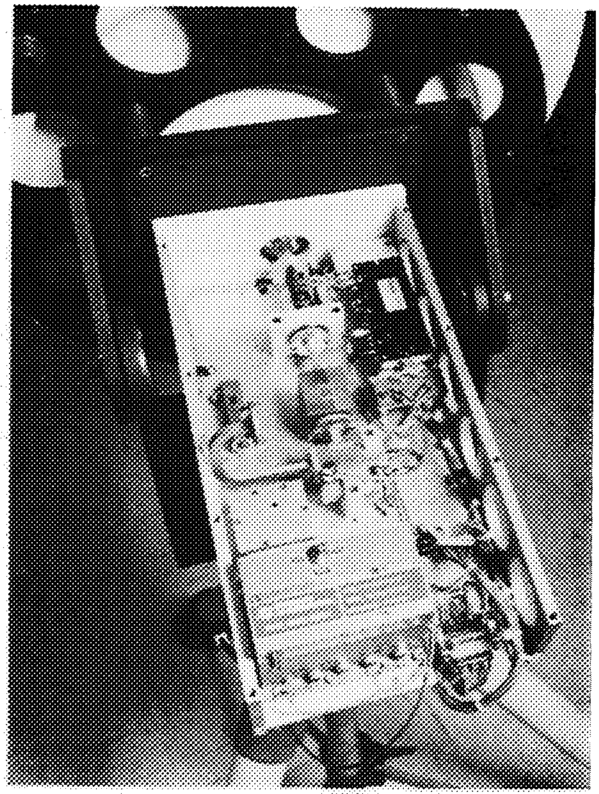

Figure 1
ITALSAT RECEIVER
at 49.5 GHz

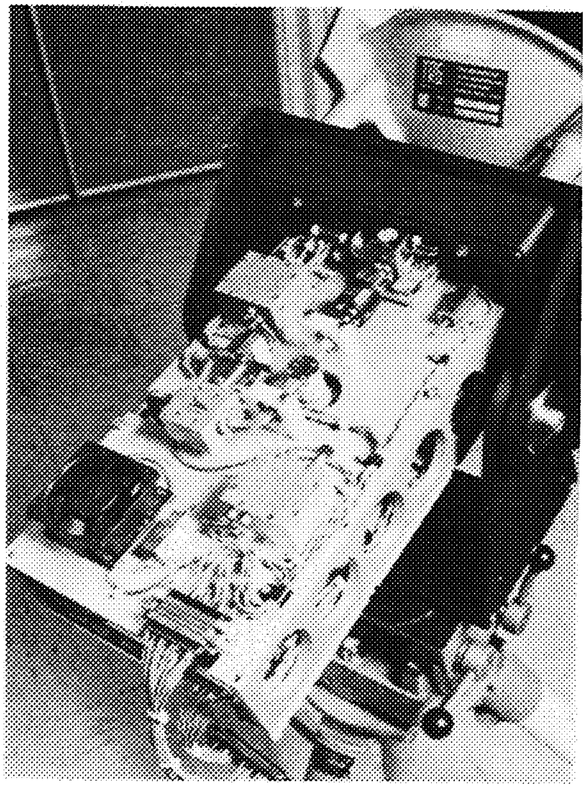

Figure 2
ITALSAT Radiometer
at 51.0 GHz.

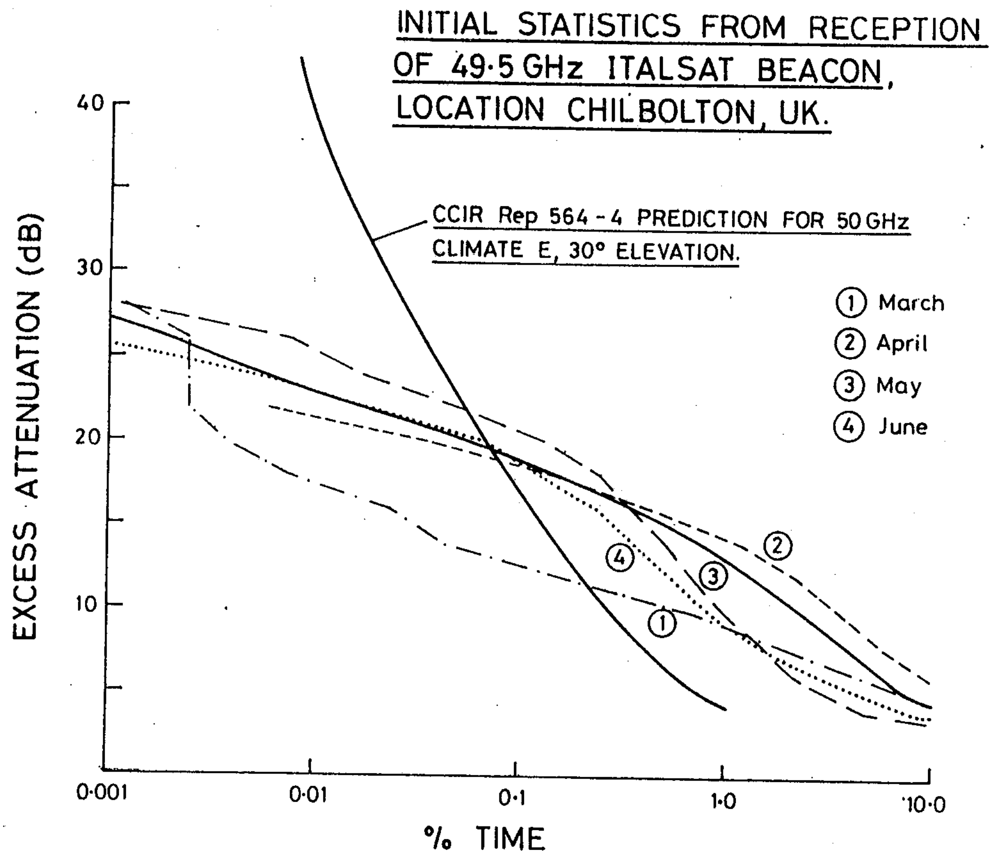

Figure 3

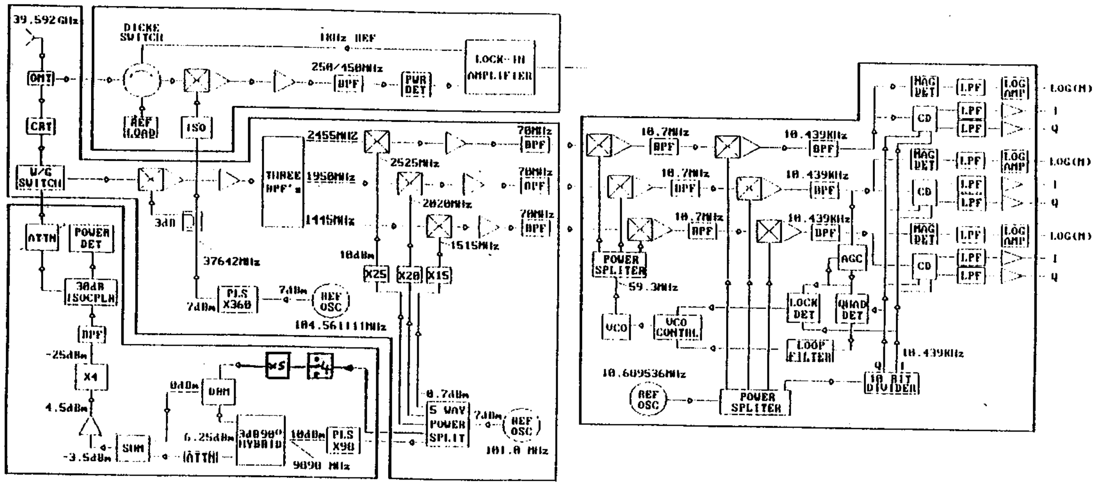

Figure 4
The Triple Channel 40 GHz
ITALSAT Receiver