19940115-3

N94-16036

A REVIEW OF OPEX ACTIVITIES AND MEASUREMENT RESULTS

B. Arbesser-Rastburg

ESA-ESTEC, Noordwijk, The Netherlands

Abstract
A summary is given of the measurements carried out in the framework of OPEX (OLYMPUS Propagation Experimenters Group). In particular, the progress since mid 1990 is presented. In this period two OPEX meetings were held, OPEX XIV (October 1990) and OPEX XV (April 1991) and the First OPEX Workshop was held at ESTEC on 23-24 April 1991.

1. Introduction

The OLYMPUS Propagation Experimenters were well prepared when ESA's large communications satellite OLYMPUS was launched in summer of 1989. All important aspects of the measurement programme had been jointly defined and as far as possible standardized. Handbooks had been produced to define the requirements for the measurement hardware and the data processing software. However, only a handful of measurement sites were actually ready to operate - delays in funding and/or hardware delivery had delayed the start-up of the majority of stations. This was not considered a dramatic drawback since the satellite was designed for an operational lifetime of at least five years and a measurement over three years was generally considered sufficient.
In the time since the launch several new stations became operational and an even larger number were just about to be completed when a major anomaly in the spacecraft's attitude control caused a disruption of all OLYMPUS experiments on 29 May 1991 at 03:21 UTC.

2. Rain Attenuation Measurements

Several intensive rainstorms with one-minute rainfall rates exceeding 30 mm/h were observed during the first 1.5 years of operation. British Telecom Research Labs operated their 20/30 GHz beacon receivers with a 6.1 meter steerable antenna which gave a good dynamic range. Figure 1 shows an example of a time series recorded during a storm on 15 August 1990 [1].
An interesting aspect of multi-frequency beacon measurements is the instantaneous frequency scaling which is required for open-loop up-link power control systems. Although the long-term average of rain-attenuation scaling is fairly constant, the instantaneous ratio is not. Figure 2 shows a scatterplot of instantaneous 30 GHz versus 20 GHz copolar attenuation values measured at Darmstadt, Germany on 26 August 1990 [2]. Each point represents a 30-second average value - the averaging was used to remove scintillations. The pronounced hysteresis effect visible on the plot (increasing slope lower than decreasing slope, counterclockwise progression) comes from the fact that the drop-size distribution changes during the event.
At the combined experiment of the Dutch PTT and Delft University, the site diversity performance of 2 stations situated 10 km apart was investigated [3]. For high availability services at Ka-band (e.g. HDTV feeder links) site- diversity may be the only fade restoration method that produces enough margin. Several events of the summer of 1990 were analyzed. In most cases of convective storm the diversity performance was adequate (Figure 3). However, there was also an event with extreme high rainrates observed where both sites were affected at the same time (Figure 4). This means that the site distance was insufficient to produce the required time-lag between the rain attenuations occurring on the links.

3. Cloud attenuation and scintillation measurements

For very small Ka-band terminals which are designed for low availability systems with hardly any propagation margin not only rain but also clouds can constitute a problem. Rain occurs in most places for less than 5 percent of the time but clouds occur for more than 50 percent of the time in temperate climate regions. It is therefore necessary to investigate the occurrence of clouds and the related fade in the same way as has been done with rain in the past. Several experimenters have embarked on such investigations, but results have not been analyzed yet.
A theoretical assessment of the propagation phenomena relevant to low-availability systems has been completed in spring of 1990 [4].
Tropospheric scintillations which are rapid signal fluctuations caused by air turbulence also affect the link budget and can be problematic for dynamic fade restoration techniques. In previous experiments using Ku-band beacons, it had been established that scintillations are more intensive at low elevation angles (longer path) and at higher temperatures (more turbulence). At the University of Louvain-la-Neuve (Belgium) one of the two receiving stations is equipped with a special 30 Hz acquisition mode for measuring the scintillations at 12 and 30 GHz [5]. Figure 5 shows the measured spectral density of the 30 GHz beacon signal. The well known "-8/3" law of propagation through turbulent layers is also plotted; it shows that the measured spectrum is in good agreement with theory.

4. Depolarization Measurements

Depolarization by oblate raindrops and by ice-needles may cause severe interference problems with frequency re-use systems. Most experimenters in the OPEX group are therefore undertaking measurements of the crosspolar beacon levels. A special working group has been set up to study the proper bias removal procedures [6].
In several stations specialized switching receivers make use of a special feature of the OLYMPUS 20 GHz beacon: The transmitted polarization plane alternates between two orthogonal orientations at a rate of 933 Hz. Since this switching rate is much higher than the de-correlation time, the received signals (2 co- and 2 crosspolar levels) allow for a quasi-simultaneous retrieval of the full transmission matrix.
Event analysis was performed and reported by the DBP-Telekom group [7] and by the Technical University of Eindhoven [8]. Some limited statistics (Figure 6) were presented by Telecom Denmark at the OPEX 14 meeting [9].
An important conclusion from these measurements is the observation that the XPD prediction of the CCIR [10] heavily under-estimates the ice-depolarization at low attenuation values.

5. Radiometric Measurements

All major stations in the OPEX program are equipped with one or more radiometers. Measuring the sky noise temperature at one frequency within the water vapour absorption line (22 GHz) and another one well outside this line (e.g. 30 GHz) allows to retrieve the vapour and liquid water content of atmosphere along the beacon reception path. [11] This information is used for calculating the clear air ("0 dB") reference level for the beacon measurements and to investigate cloud attenuation. Special cloud studies with a scanning radiometer are undertaken by the Fondazione Ugo Bordoni in Rome, whose staff is also in charge of the network of 20 GHz receivers in Italy (25 sites).
Another specialized application of ground based radiometry is the simultaneous measurement of the 19 GHz sky-noise temperature at two orthogonal polarizations, as reported by DLR [12]. An example for the observed differential sky noise temperature (T_h-T_v) is given in Figure 7.
The OPEX working group on radiometry (which is also in charge of auxiliary measurements) has very active participation in the field of comparing and improving retrieval algorithms. A handbook will be published summarizing all major findings.

6. Radar Measurements

Several sites are equipped with specific meteorological radars operating at S-,C- or X-band. These radars are used to establish the drop size distribution of a rain-cell, the horizontal and vertical structure of the precipitation event, the existence and extent of a melting layer. Radars with doppler processing are also capable of measuring the air turbulence.
In order to better coordinate their measurements and analyses, the experimenters have formed a Radar Working Group within OPEX. Of particular interest are the backscatter (at radar frequency) and forward-scatter (at beacon-frequency) programmes used for raindrops and ice/water mixtures. An anisotropic melting layer model is also being studied and developed. It is envisaged that all the achievements of this working group will be published in a handbook. Since the processing of radar data is known to be time-consuming, analyzed results of joint radar and beacon measurements have not been available until now but are expected to be presented at the OPEX 16 meeting in Aveiro, in October 1991.

7. The Standardized DAPPER Software

The Data Preprocessing and Analysis Software was completed and distributed by ESA to all signatories of the OPEX agreement. The general distribution was preceded by a half-year beta-testing phase in which some experimenters had volunteered to participate. Currently, a conversion of the UNIX-based software to HP-UX is underway which will make the software available to experimenters using HP-9000 workstations rather than 386- or 486 based PCs.

8. Implications of the OLYMPUS Failure.

On 29 May 1991 at 03:21 UTC the spacecraft went into the "Emergency Sun Acquisition"-mode which is the pre-programmed position for coping with any sort of potentially dangerous malfunctions. Attempts to repoint the spacecraft back to the nominal position failed and left the spacecraft in a spinning condition with depleted batteries. The cause for the problem is under investigation by a special inquiry board.
With the sun getting into a more favourable angle towards the solar panel new attempts were made to command the satellite. The recovery of the spacecraft has begun by successfully executing telecommands on 19 June. However, at this point it is still unclear whether the spacecraft operation can be completely re-established.
If the recovery is successful, the remaining lifetime of the satellite will be reduced since some of the fuel needed for station keeping will have been spent in the recovery procedures. But any period of more than one year continuous operation can be considered worthwhile to continue the interrupted experiments and to start those measurements that were just about to begin when the failure occurred.
If, on the other hand, the nominal operation of the propagation beacons under nominal attitude control conditions cannot be restored, the OPEX group will have to turn to alternate beacon sources in order to achieve the goal of establishing better propagation prediction tools for satellite services using frequencies above 10 GHz. After all, the cost of the ground equipment exceeds US$ 20 million and a decision to discontinue this research activity would mean that this investment is lost.
Unfortunately, there is no exact replacement of the OLYMPUS beacon payload in orbit, which means that experimenters will have to convert their stations to receive beacon signals from other spacecraft. Of course, the possibility of re-flying the OLYMPUS beacon payload that was built for flight model 2 exists but even if the technical, contractual and financial questions can be solved, a time frame of at least 2 years is expected for getting this payload into orbit.
In order to co-ordinate the conversion activities and establish the new mode of co-operation in the OPEX group, a special OPEX meeting has been set up for 3 July 1991 at ESTEC.

9. Conclusion

The OPEX group has been very active during the last year and the First OPEX Workshop gave ample evidence of this point. First results have been obtained and links have been established to other propagation experimenters groups such as the INTERKOSMOS experimenters in Eastern Europe. Now, many groups are using the break in the measurements to analyze the data collected so far. Everyone of course hopes that OLYMPUS can be fully restored to the good performance displayed so far. However, even if this cannot be accomplished, the co-operative spirit of the group will continue to ensure scientific results at the highest level to the benefit of the sponsors and, through the submission to the CCIR, the whole satellite communications industry.

References

1. J. Harris, "BTRL OLYMPUS Experiment - Status & Results", Proc. OPEX XIV Meeting, Felixtowe, 15-17 Oct 1990.

2. F. Rücker, G. Ortgies & F. Dintelmann, "Aspects of Attenuation Frequency Scaling" Proc. OPEX Workshop ESTEC, 23-24 April 1991, Paper Nr 3.3

3. G.J.C. Verhoef, "Event Analysis of the Site-Diversity Experiment in the Netherlands" Proc. OPEX Workshop ESTEC, 23-24 April 1991, Paper Nr 2.1

4. E. Salonen,S. Karhu S & S.Uppala, "Study of Propagation Phenomena for Low Availabilities" ESA-ESTEC Final Report Contract # 8025/88/NL/PR, 1990.

5. D. Vanhoenacker, J. Matagne, H. Vasseur & A. Vander Vorst, "First Analysis of the Effects of Atmospheric Fluctuations on the 12.5, 20 and 30 GHz OLYMPUS Beacons." Proc. OPEX Workshop ESTEC, 23-24 April 1991, Paper Nr 4.2

6. F. Dintelmann "A note on X-polar bias removal", Private communication, February 1991.

7. F. Rücker, F. Dintelmann & G. Ortgies, " Analysis of 20 GHz Crosspolar Events" Proc. OPEX Workshop ESTEC, 23-24 April 1991, Paper Nr 2.3

8. R.A. Hogers, M. Herben, G. Brussaard (EUT): "Depolarization Analysis of the 12.5 and 30 GHz OLYMPUS Beacon Signals" Proc. OPEX Workshop ESTEC, 23-24 April 1991, Paper Nr 2.4

9. J R Larsen, "Separation of XPD data due to rain and ice depolarisation", Proc. OPEX XIV, Felixtowe October 1990, pp 83-85.

10. CCIR SG5, "Propagation Data & Prediction Methods Required for Earth Space Telecommunication Systems", Report 564-3 (MOD F), XVIIth General Assembly Düsseldorf 1990.

11. J.Lavergnat & C. Mallet, "Zero Level Retrieval by Means of a Multifrequency Radiometer" Proc. OPEX Workshop ESTEC, 23-24 April 1991, Paper Nr 1.3

12. A. Hornbostel, "DLR Status Report", Proc. OPEX XIV, Felixtowe 15-178 Oct 1990, pp 63-66.

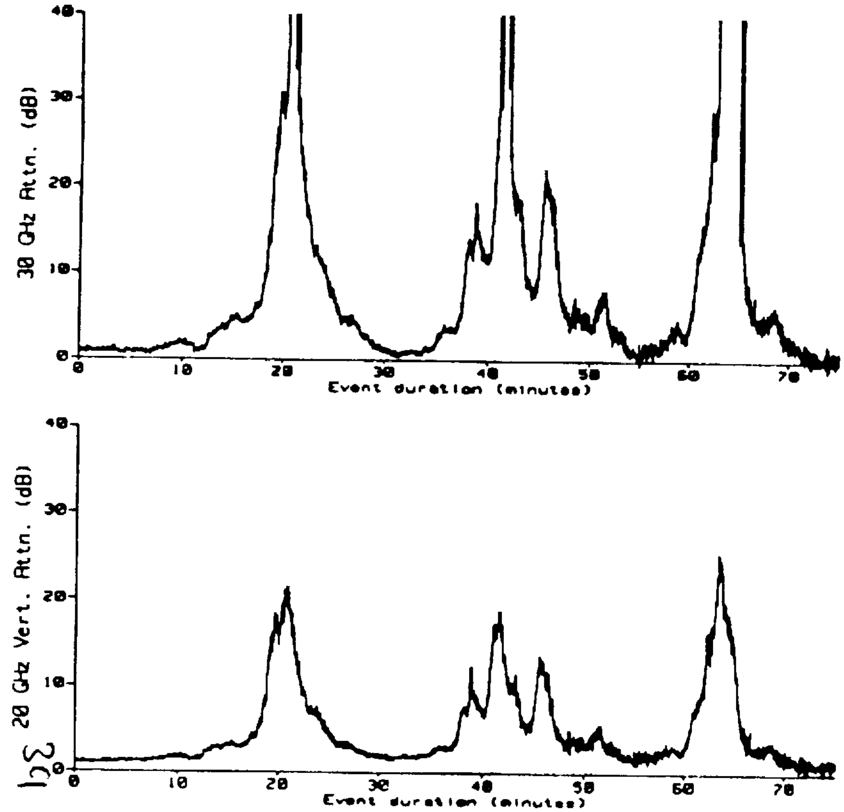

Figure 1: Co-polar attenuation of OLYMPUS 20 & 30 GHz beacons measured at BTRL Martlesham on 15 August 1990 from 16:50 UTC to 18:05 UTC. (Elevation: 27.5 deg)

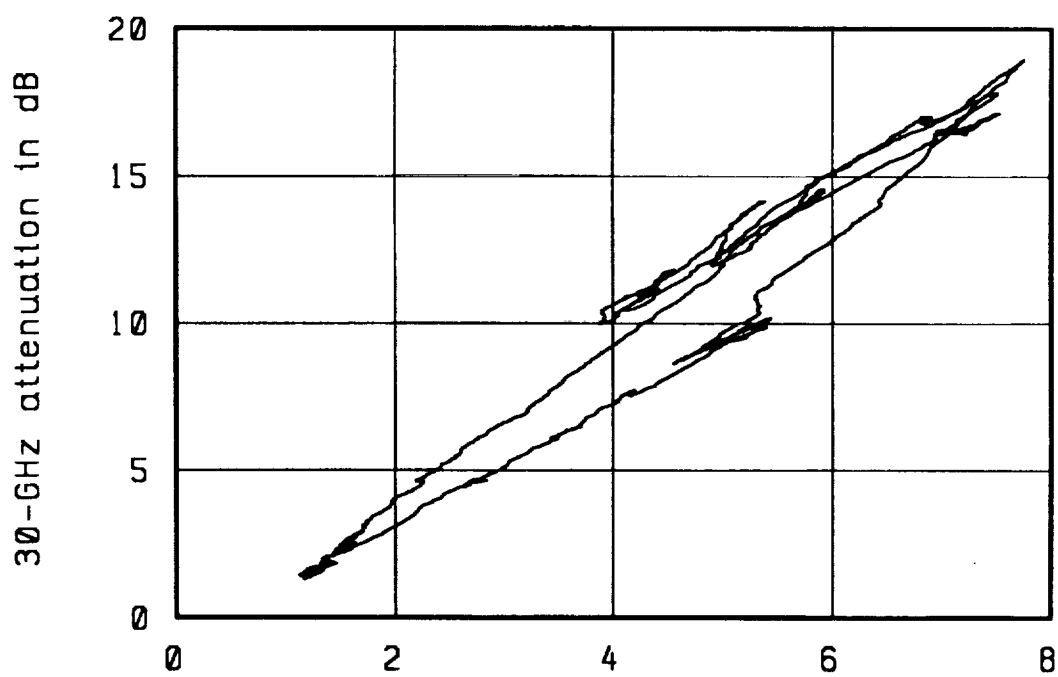

Figure 2: Scatterplot of instantaneous 30 GHz versus 20 GHz copolar attenuation measured at Darmstadt, Germany on 26 August 1990 from 14:00 to 15:00 UTC (data averaging: 30 seconds)

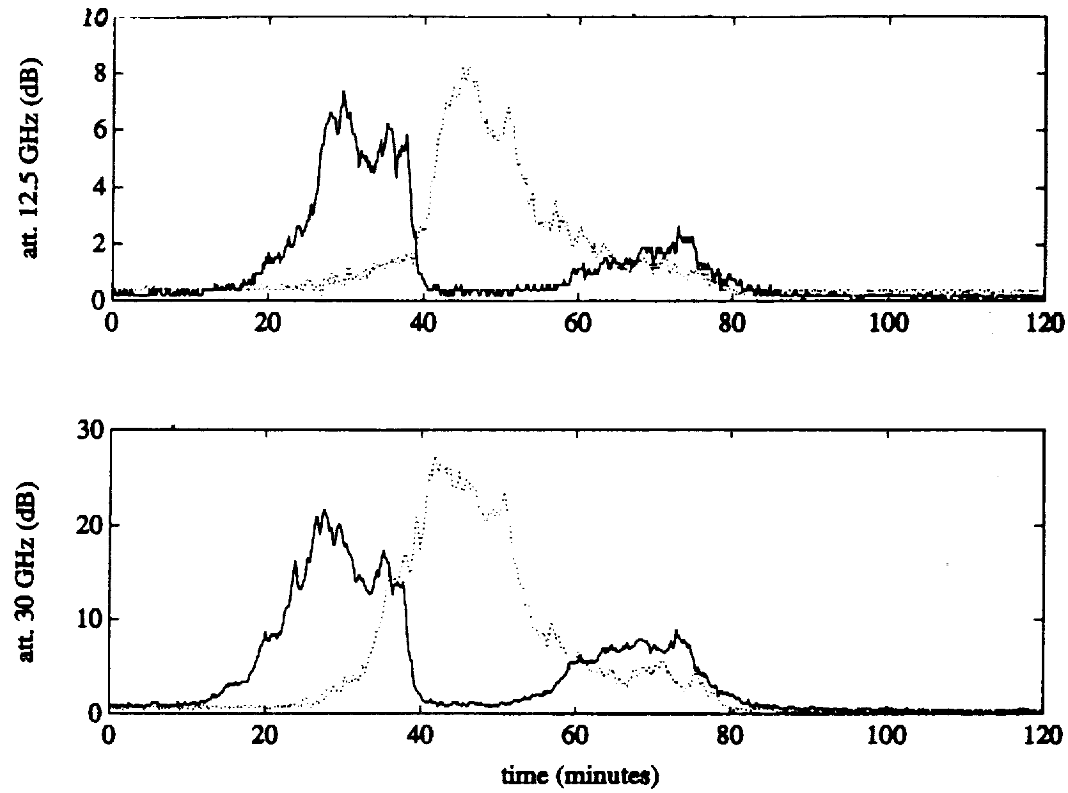

Figure 3: Site diversity observation in Delft (solid line) and Leidschendam (dotted line) on 27 June 1990 from 20:00 to 22:00 UTC. Here the 10 km site distance is sufficient.

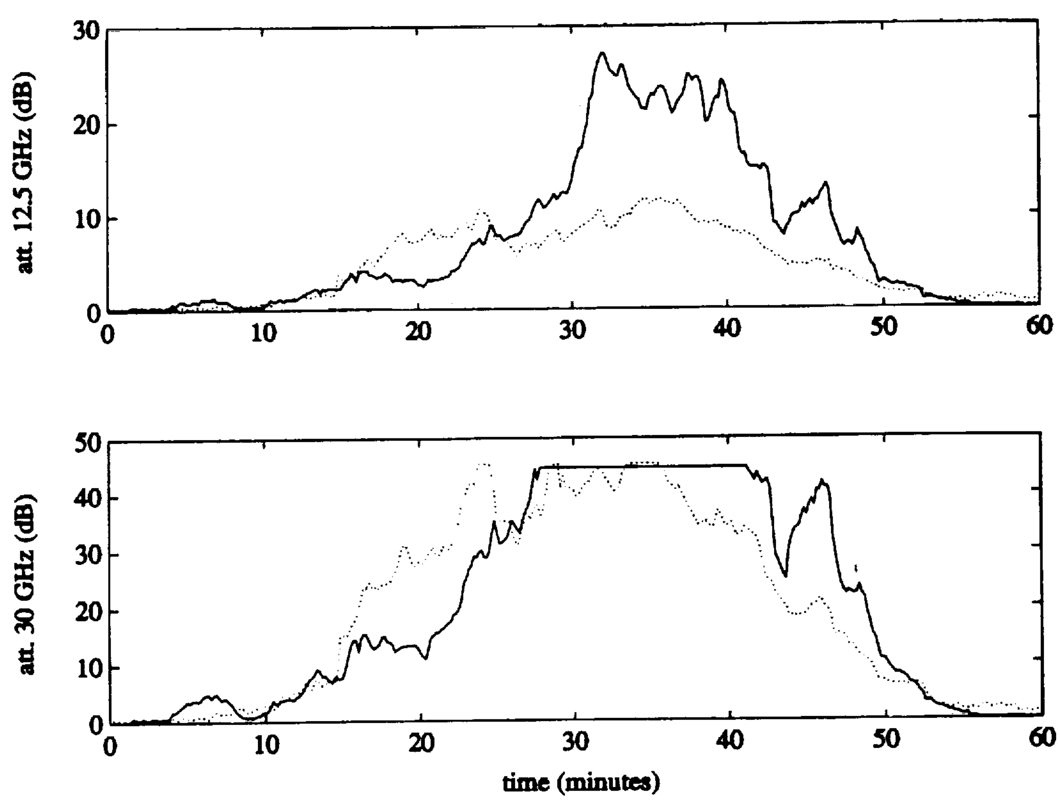

Figure 4: Site diversity observation in Delft (solid line) and Leidschendam (dotted line) on 30 June 1990 from 14:00 to 15:00 UTC. Here the 10 km site distance is in-sufficient.

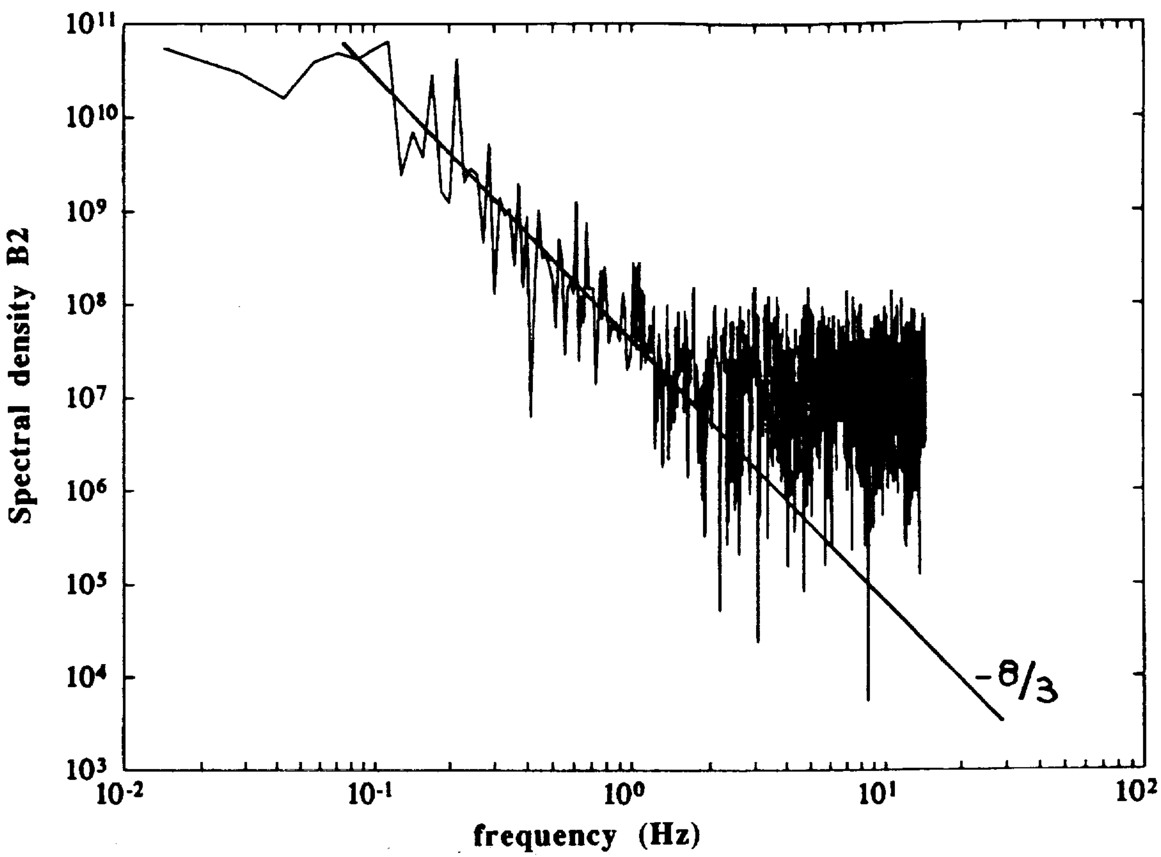

Figure 5: Spectral density of scintillations at 30 GHz measured at Louvain.

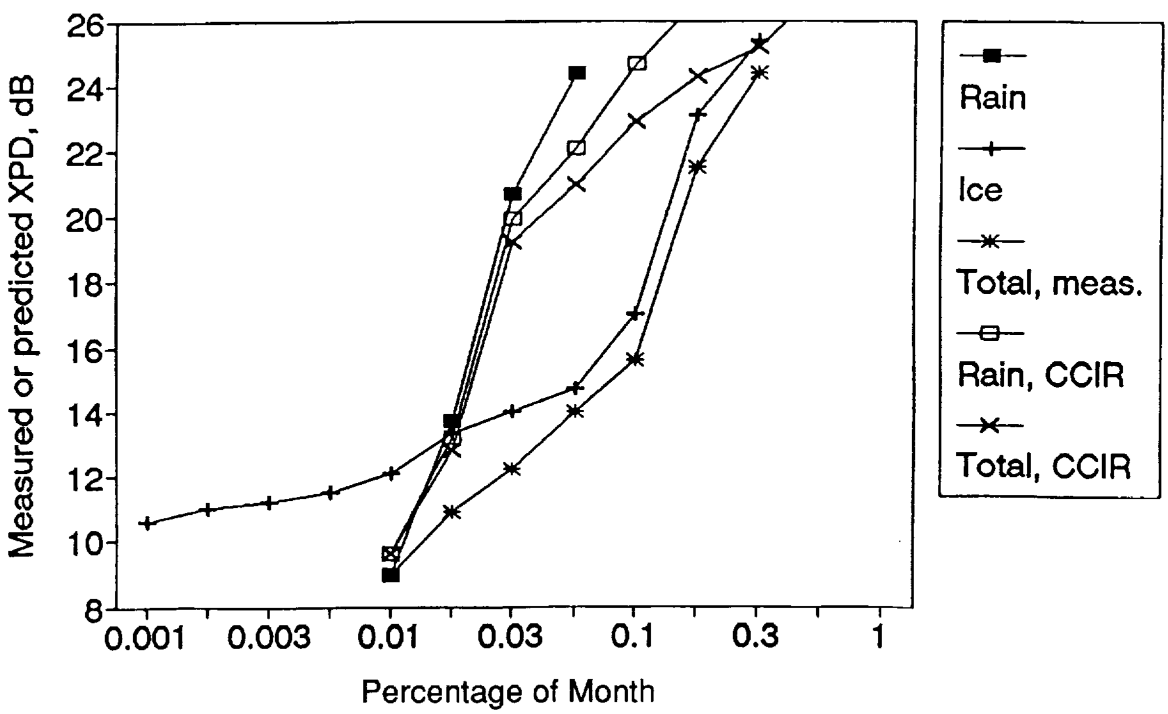

Figure 6: Cumulative statistics of 30 GHz XPD measured in Albertslund and compared with the CCIR predictions. (Preliminary analysis based on 11 days in June 1990)

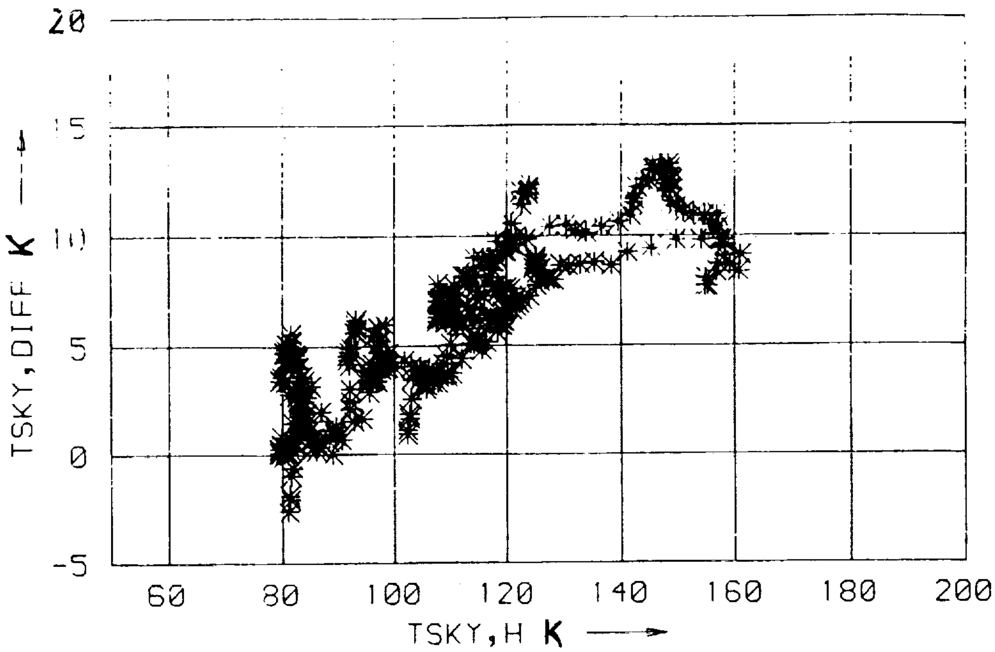

Figure 7: Differential 19 GHz sky noise temperature (T_h-T_v) versus T_h observed at DLR (Oberpfaffenhofen) on 5 Sept 1990 from 01:30 to 02:00 UTC.