TROPOSPHERIC PROPAGATION CHARACTERISTICS AT KU–BAND FOR SATELLITE TO GROUND AND LOS PATH IN SURABAYA, INDONESIA

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Summary
Some measurement results are presented for a one year period on an INTELSAT down link at Ku band with elevation of 14° for concurrent measurements of beacon attenuation sky noise and point rainfall rate. Also some results are presented of the measurements of the LOS link fading characteristics at the same place. The projection of the down link trajectory on earth has nearly the same direction as the LOS path trajectory. The measuring results are compared with the theoretical values according the CCIR recommended procedures for tropical regions especially Surabaya, Indonesia.

1. Introduction

The demand for communications services in Indonesia is such that the capacity available in C–band (6/4 GHz) for LOS and satellite becomes exhausted. To meet the demand Ku–band (14/11 GHz) capabilities are necessary for LOS as well as for the satellite services but the potential propagation impairements are much more significant than at C–band on many of the links.

This is particularly true in tropical high rainfall rate areas as Indonesia for the attenuation due to rain on satellite and LOS paths. And further for LOS paths the deep fading due to multipath caused by water reflections will detoriate communications in a serious way.

The experiments described in this paper were set up to acquire just this information necessary for link design and exists of a measurement set–up for satellite downlink measurements and LOS measurements on an over–water path. The projected link trajectories are given in Fig. 1. The experiment is a cooperative effort between INTELSAT, the Eindhoven University of Technology and the Institut Teknologi Surabaya and is co–sponsored by NUFFIC (Netherlands Universities Foundation for International Cooperation) [2].

2. Description of the measurement set–up

2.1. Satellite down link propagation measurements at Ku–band

The principal objectives of the experiment are:

- To acquire long–term path attenuation data, and rain rate data
- To characterise the effective medium temperature through a direct comparison of radiometric and beacon data
- To establish a relationship between the rainfall rate data and the path attenuation data to permit the existing CCIR model to be tested and, if necessary, modifications to be suggested to improve the accuracy.

The results from March 1990 – February 1991 are presented.

The earth station is situated in Indonesia on the island of Java in the town Surabaya at the university campus of the "Institut Teknologi Surabaya".

Relevant data is given in Table 1.

The equipment set–up was as follows. Fig. 2 gives an overview of the measurement system.

- An 11 GHz beacon receiver (switchable between the two INTELSAT beacon frequencies 11.198 and 11.452 GHz)
- An 11 GHz radiometer directed along the same look–angle as the beacon antenna
- A tipping bucket rain gauge
- A data acquisition system
- A data processing and analysis set–up.

Table 1: Data of measuring site	
Coordinates site	$7^{0}15'S$ $112^{0}44'E$
Satellite position Intelsat V F–8	180E
Frequency	11.198 GHz, RHCP
Antenna elevation	$14^{0}07'15''$
Antenna height	15 m MSL
Location of rain gauge	Tipping bucket within 10 m from antennas
Antenna diam.	3.6 m effective
Radiom. antenna	1.8 m

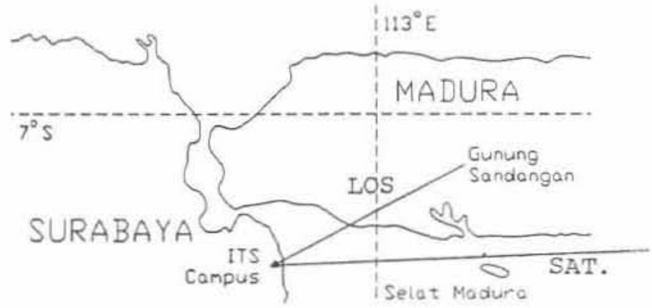

Fig. 1. Earth projected links

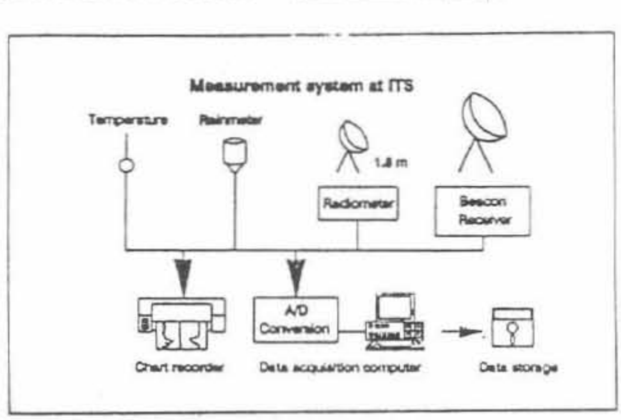

Fig. 2. Overview of the measurement system for the satellite down path

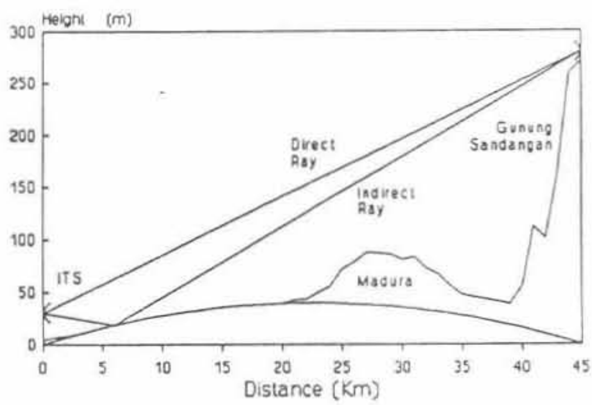

Fig. 3. Path profile of the LOS link from Madura to Surabaya over 46 km distance

2.2. LOS propagation measurement set–up at Ku–band

The principal objectives of the experiment are

- To separate multipath fading from rain attenuation
- To acquire long–term path rain attenuation data, and rain rate data
- To acquire long–term multipath fading data
- To determine optimum diversity operation on this over–water LOS link.

The LOS link is set–up from the "Gunung Sandangan" on the island of Madura to the university campus of ITS in Surabaya on the island of Java, with a path length of 46 km and the signal passes the Straits of Madura. The path profile is given in Fig. 3. In Surabaya the median k–factor has been determined on the basis of balloon measurements, to be 1.54 [2] . It is a function of time and causes the k–factor fading in a two ray propagation model. A block diagram of the measuring system is given in Fig. 4. In Table 2 relevant data is presented for the LOS measurements.

Table 2. Data of LOS measuring system	
Frequency	11.335 GHz
Antennas	1.2 m offset paraboloids
Diversity ant.	horn aperture 19.5x14.5 cm
Antenna height	30 m, 280 m, MSL
Dynamic range	80 dB, 0.02 dB resolution
Receivers	3xPLL, IF at 10 MHz
A/D conversion	12 bit samples
Data storage	every 10 sec., diskette
Polarisation	vertical
Software switched diversity	

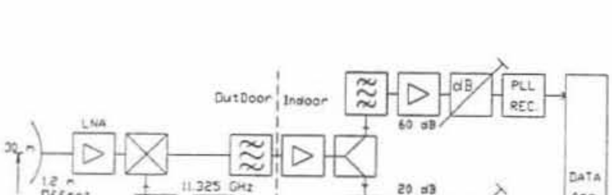

Fig. 4. Block diagram of the LOS measuring system in Surabaya

3. Measuring results

3.1. Ku–band satellite down link measurements

Long–term path excess attenuation data

Cumulative excess attenuation

The cumulative attenuation statistic is compiled for the period of March 1990 – Febr. 1991 between 5% and 0.02% of the analyzed period and is presented in Fig. 5. The level of reliability i.e. the highest attenuation value that can reliably be measured, is indicated to be 25 dB excess attenuation with respect to clear sky level.

Also given is the predicted excess attenuation according CCIR Report 564–4 using climate P rain statistics (p = 0.01 %, R = 145 mm/h) and the predicted excess attenuation using the measured rainfall (p = 0.01%, R = 110 mm/h). There appears to be a serious underestimation by the 1990 version of Rep. 564. As a comparison also the predicted excess attenuation according CCIR Report 564–3 is displayed. Here, the match is much better.

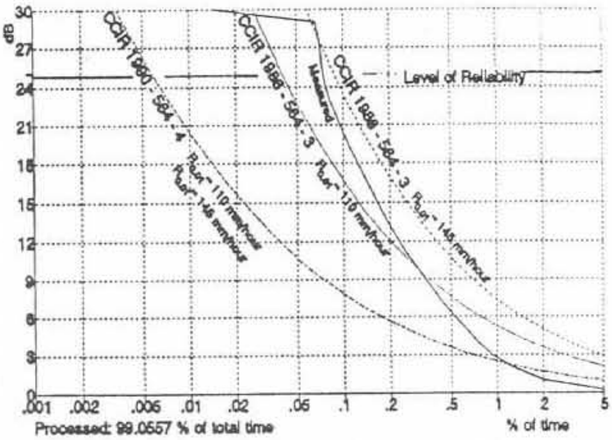

Fig. 5. Excess attenuation statistic March 1991 – Febr. 1991. Predicted attenuation according CCIR 564–3 and 564–4.

Further it is shown that the predicted (CCIR 564–4) excess attenuation cumulative distribution curves are the same for $R_{0.01}$ = 145 mm/h and R = 110 mm/h and in fact they are nearly the same for rain intensities between 90 and 150 mm/hour. This is due to the compensating effect of the path integration factor [3] [7].

Event duration Diurnal excess attenuation statistics and Antenna noise temperatures are measured as well [4].

3.2. LOS Ku–band measurements [4]

During the dry monsoon it was possible to characterize the bare multipath effects only. Measurements were performed with several antenna spacings. The signals are expected to have the most negative correlation with an antenna spacing of 1.6 m and positive correlation with a spacing of 2.8 m. Examples of measurement results compare favourable with theoretical simulated results.

During wet monsoon conditions a "mixed" propagation condition exists between multipath fading and rain attenuation. In general the switching diversity operation is active on the multipath fading and now it is possible to separate multipath fading from rain attenuation. One example is given in Fig. 6.

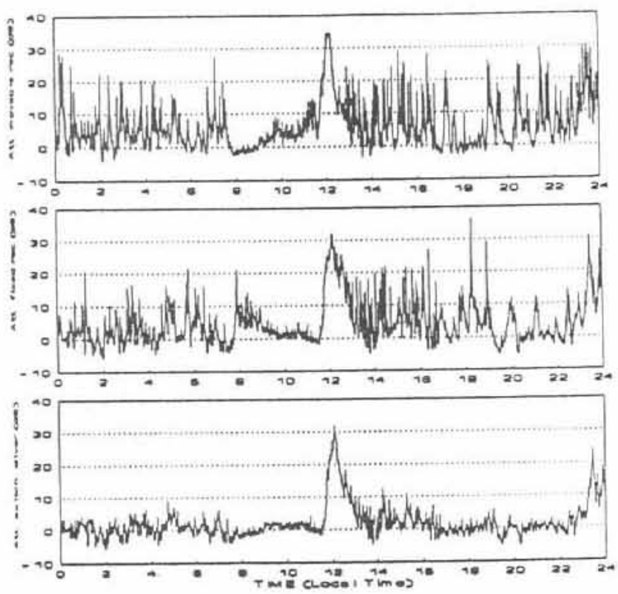

Fig. 6. Measurement results of 5 December 1991. The first two graphs show the attenuation signals of the movable and the fixed receiver, the third graph shows the "software–switched" diversity signal.

3.3. Point rainfall rate measurements and rain attenuation

The measured rainfall rate cumulative statistic for the one year of measured data is given in Fig. 7. More information can be found in [4]. An example of LOS rain attenuation (80 dB) is illustrated in Fig. 8.

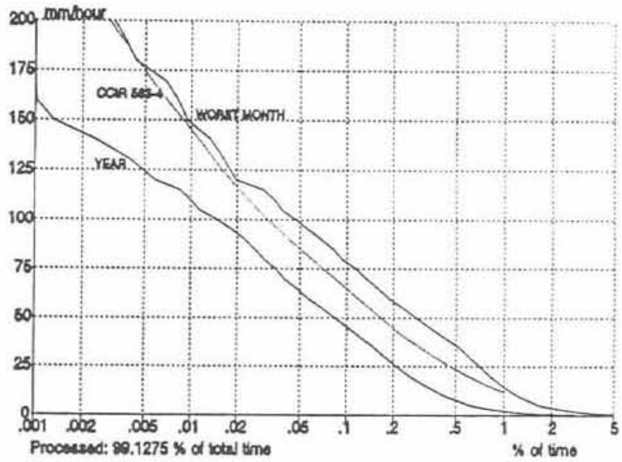

Fig. 7. Measured point rainfall rate cumulative distribution in Surabaya March 1990—Febr. 1991. CCIR 563—4 Predicted distribution. Worst month distribution.

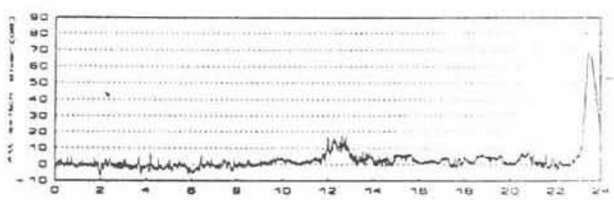

Fig. 8. Switched diversity results of 28 Jan. 1992. An event with rain attenuation of almost 80 dB is recorded.

5. Conclusions and Recommendations

- The measured rainfall statistic deviated not too much from the predicted one in Surabaya.
- The deduced satellite downpath attenuation in Ku—band did not agree well with the 1990 CCIR prediction model which underestimates the attenuation (el. is 14^o).
- The median medium temperature is found to be 285 K.
- A switched diversity measuring system can be used as a mean to separate the effects of multipath and rain fading especially for research purposes on LOS paths.
- Correlation analysis can be used for the calculation of optimum antenna spacing in a diversity arrangement for LOS operation.
- It is recommended to undertake more study in tropical regions to determine the path length reduction factor r for both LOS and satellite paths.

6. References

1 Reports of the CCIR [1990] annex to volume V, Propagation in non—ionized media.

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