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Measurements on the Satellite-Mobile Channel at L & S Bands

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ABSTRACT

An experiment is described in which measurements are made on the satellite-mobile channel at L and S bands. A light aircraft carrying a c.w. beacon is flown at elevation angles of 40, 60 & 80 degrees to a mobile receiver. The signal strength at the mobile is recorded in open, urban, suburban & tree shadowed environments. This data is then analyzed to produce statistics for the channel with respect to frequency, elevation angle and environment. Results are presented together with a brief discussion, suggested interpretation and conclusion.

INTRODUCTION

Over the last decade in both Europe and the USA, interest in the development of a Land Mobile Satellite Service (LMSS) and in providing CD quality radio broadcasts from satellites, has given rise to a requirement for information on the satellite mobile channel at low microwave frequencies. In Europe, the use of satellites in Highly Elliptical Orbits (HEO's) has been proposed for these systems [1,2], as in these regions due to the low elevation angle of geostationary satellites, large margins are required to compensate for signal fluctuations caused by natural or man-made obstacles. It is assumed that a HEO satellite system will require much lower propagation margins, thus making a practical system possible. WARC'92 has allocated frequencies at about 1.5GHz (L-band) and 2.5GHz (S-band) for these services. The University of Bradford (UoB), the United Kingdom Radiocommunications Agency (UK-RA) and the European Space Agency (ESA), have for the last three years been collaborating on an comprehensive narrowband channel characterisation, involving measurement campaigns at 1.556GHz and 2.619GHz, in different physical environments using beacons at a range of elevation angles to the mobile.

EXPERIMENTAL DETAILS

A light aircraft fitted with a suitable c.w. beacon simulates the signal from the satellite. Since the propagation statistics are both elevation and environment dependent, the aircraft is flown over selected terrains at elevation angles to a ground mobile of 40, 60 and 80 degrees. The mobile receiver records the varying signal strength at the vehicles antenna in time synchronism with a vehicle speed signal and position/altitude information. The terrains were as follows:

Open rural
No obstructions to a line of sight path at any elevation angle, open flat countryside for a several hundred metres on each side of the

road.

Urban

The city of Bradford, UK. Many buildings close to the roadside of several stories. Short section of urban freeway.

Suburban

Buildings of one or two storeys, set back between 10 and 20 metres from the side of the road.

Tree shadowed

Mature deciduous trees of varying density and distance from the road. The statistics given are for a typical mix or "composite" cover.

EQUIPMENT

A c.w. transmitter was located in a Rallye 235E light aircraft. At L-band this unit consisted of a synthesiser operating at 1.556GHz and amplification to 0dBW. At S-band a 1.309GHz synthesiser was used together with a frequency doubler and again, amplification to 0dBW. An antenna having a gain of 2.8dB and a beamwidth of ±45° of boresight was mounted under the tail of the aircraft pointing directly down.

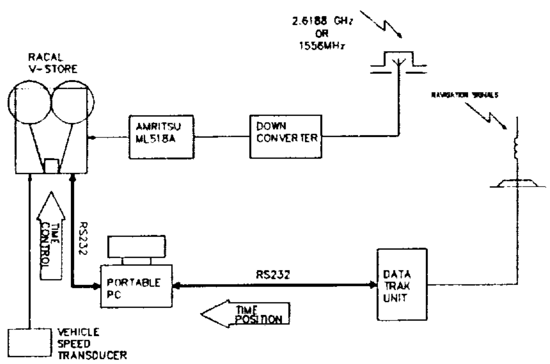

Figure 1- Mobile receiver system

The mobile receiver system was as shown in figure 1, it was identical for both frequencies except for the frequency downconverter unit which was appropriately configured to provide an intermediate frequency suitable for input into the commercial signal strength measurement receiver (Anritsu ML518A). The output from the receiver was a unipolar voltage related to the received signal power, which was recorded on an FM tape recorder. The antenna on the mobile was identical to that on the aircraft but pointing vertically upwards. A unit was fitted to the mobile's transmission so that the vehicle speed could be recorded along with the signal envelope. Both the aircraft and the mobile were fitted with "DATATRAK" locator units, giving an output of position every 1.6s accurate to ±35m.

ANALYSIS

In the laboratory, the aircraft altimeter recordings and navigational information from the aircraft and the mobile is used to determine areas in the signal strength recordings at which the required elevation angles occur. These portions of the tape are digitised (both signal strength and vehicle speed), and a statistical analysis is performed. The amplitude of the recorded signal is processed, generating a probability density function (pdf) from which a Cumulative Density Function (CDF) is produced (first order statistics). For the same data, the duration of fades occurring at various levels below the reference is determined, producing information on level crossing rates, average duration and distribution of fades (second order statistics). However, before the first and second order statistics are calculated a 20 wavelength sliding window is applied to the data (due to experimental conditions), and a 0dB reference for the data of 1.1dB below the 99% level of the CDF is chosen. For in depth documentation of the experimental system, errors, referencing and analysis, [3] should be consulted.

RESULTS

Only the CDF's for the four environments at both L and S-bands will be presented here in figures 2-5. An anticipated level of error for the curves is ±0.7dB with an error in the determination of elevation angle at a maximum of 2 degrees. Consideration of the curves leads to the following comments.

Open rural (figure 2)

In an open environment, received signal statistics show a general independence from elevation angle and frequency, indeed, the statistics say more about the characterisation experiment than the channel. It is thought that the small differences in the curves are due to residual multipath generated by the varying traffic density on each run.

Urban (figure 3)

The general form of the curves is as might be expected, in that they show that larger margins are required for a given availability at S-band than for L-band. The CDF for an angle of 80 degrees however, shows that for availabilities in excess of 80% - 90% larger margins are required at S-band, than might have been anticipated. It is thought that this is largely due to terrain culture close to the vehicle. During the measurements it was noticed that more significant signal perturbation occurred when passing under overhead road signs or utility poles at S-band than at L-band. Certainly for S-band, the first order statistics in urban areas do not present a favourable margin for any system, it is almost certain that in a practical system some form of repeater would be needed. The margin required at L-band is significantly smaller and it may be that this alone would justify the choice of a frequency of $\approx$1.5GHz as opposed to $\approx$2.6GHz for these systems.

Suburban (figure 4)

In the suburban areas results which are different in nature occur at L and S band, in that at S band the curves are similar for all elevation angles, indeed, the CDF's show agreement within the limits of experimental error up to 90% availability. The L band curves show a difference for each elevation angle. At present no explanation is offered for this behaviour.

Tree shadowed (figure 5)

If it is borne in mind that the L-band measurements were made with full dense foliage and the S-band with no foliage, the statistics show a significant worsening from L to S band. Outside of urban areas, tree shadowed routes pose a significant problem to these systems. Much difficulty was experienced in producing a set of curves which may be said to form representative statistics.

Open rural area data as "calibration"

It would be reasonable to expect that a back to back test on an ideal transmit/receive experimental system would result the generation of a "brick wall" CDF, ie. a change from no values occurring, to all values occurring, at point which was related to the signal level (ie. a dynamic range of fades of 0dB). In the case of the open rural area the actual dynamic range of the measurement was $\approx$2.6dB (1% of CDF to 99% of CDF) for most cases. It is therefore suggested that as a "first approximation" the S-band, 80 degree curve on figure 2 be used to calibrate all others. That is, for any given curve, in any given environment, at any given % of the cdf, the fade level to be considered is the fade level obtained from the relevant graph minus the equivalent fade level (for that given % of the CDF) from the 80 degree open rural area CDF. Table 1 of margins v availabilities has been developed using this idea and is therefore suggested as a guide for systems planning purposes. It should be noted however that these "margins v availability" apply strictly to the curves presented here and are not intended to be applied to cover all propagation effects.

CONCLUSIONS

In general, at both L and S bands, for a given environment, an increase in satellite to mobile elevation angle from 40 to 80 degrees is accompanied by an improvement in primary statistics. For a given elevation angle, as the environment in which the mobile finds itself changes from urban to suburban to open, so here too the improvements in received signal statistics mentioned above are also seen.

The results indicate that, for Northern Europe, propagation problems associated with geostationary satellites could be significantly reduced by using a satellites in a suitable high elevation orbit. The maximum benefit would be obtained by using L-band frequencies for the mobile links, with a satellite elevation angle from the mobile as near 90° as possible.

ACKNOWLEDGEMENTS

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REFERENCES

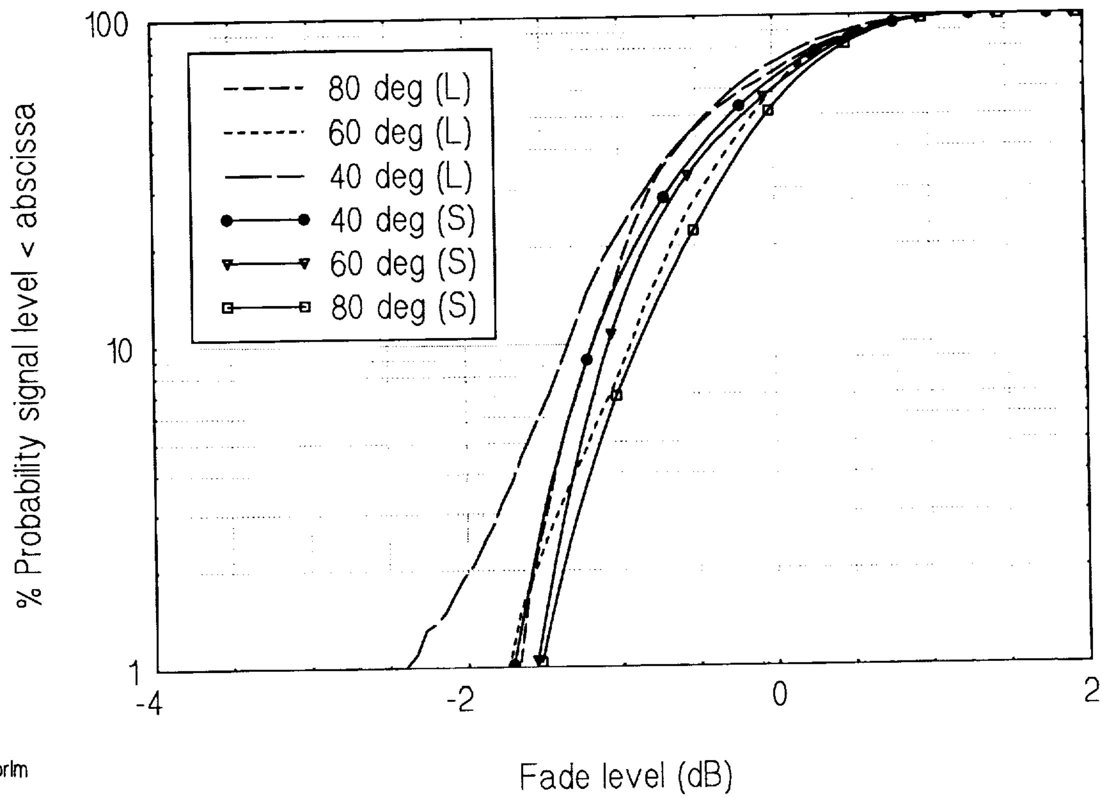
[1] P. Dondl, "LOOPUS opens a new dimension in satellite communications" *Int. Jnl. Sat. Comms*, Vol 2, 1984

[2] D. Robson et al, "ARCHIMEDES for BSS(S)", *Report on ESA contract No.8642/89/F/RD(SC)*, November 1990

[3] H. Smith et al, "Characterisation of the Land Mobile Satellite (LMS) Channel L & S Bands: Narrowband measurements" *Report on European Space Agency AOP's 104433/114473*, February 1993

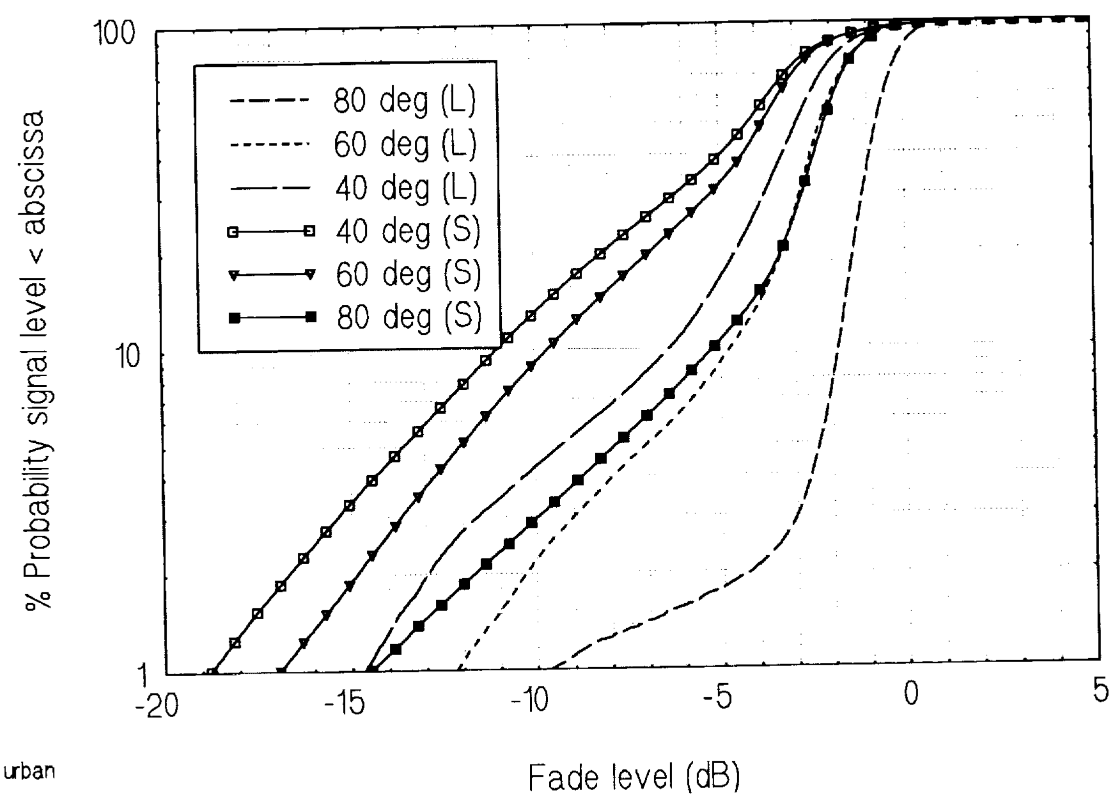
Table 1 - Suggested Margins v Availability

AREA	AVAIL (%)	MARGIN (dB) L-BAND, ELEVATION (deg) 40	L-BAND 60	L-BAND 80	S-BAND 40	S-BAND 60	S-BAND 80
URBAN	99	13.1	10.7	8.1	17.3	15.4	13.0
	95	8.2	5.9	1.3	12.5	11.0	6.7
	90	5.5	3.8	0.9	10.1	8.7	4.3
	85	4.5	3.1	0.9	8.7	7.4	3.2
	80	4.0	2.7	0.8	7.6	6.3	2.7
	70	3.4	2.4	0.7	5.8	4.8	2.4
SUBURBAN	99	7.2	4.4	2.2	12.5	10.8	9.2
	95	4.5	2.5	1.4	6.7	6.0	6.3
	90	3.5	1.9	1.1	5.1	4.5	5.2
	85	3.0	1.7	1.0	4.4	3.9	4.7
	80	2.7	1.6	0.9	3.9	3.5	4.2
	70	2.3	1.4	0.8	3.3	3.0	3.6
TREE SHADOWED	99	11.3	7.7	4.1	12.6	10.5	9.0
	95	7.9	4.9	2.0	6.3	5.7	5.2
	90	5.9	3.4	1.5	4.7	4.2	3.8
	85	4.8	2.8	1.4	4.0	3.6	3.2
	80	4.0	2.5	1.3	3.6	3.3	2.8
	70	3.3	2.2	1.2	3.1	2.8	2.5



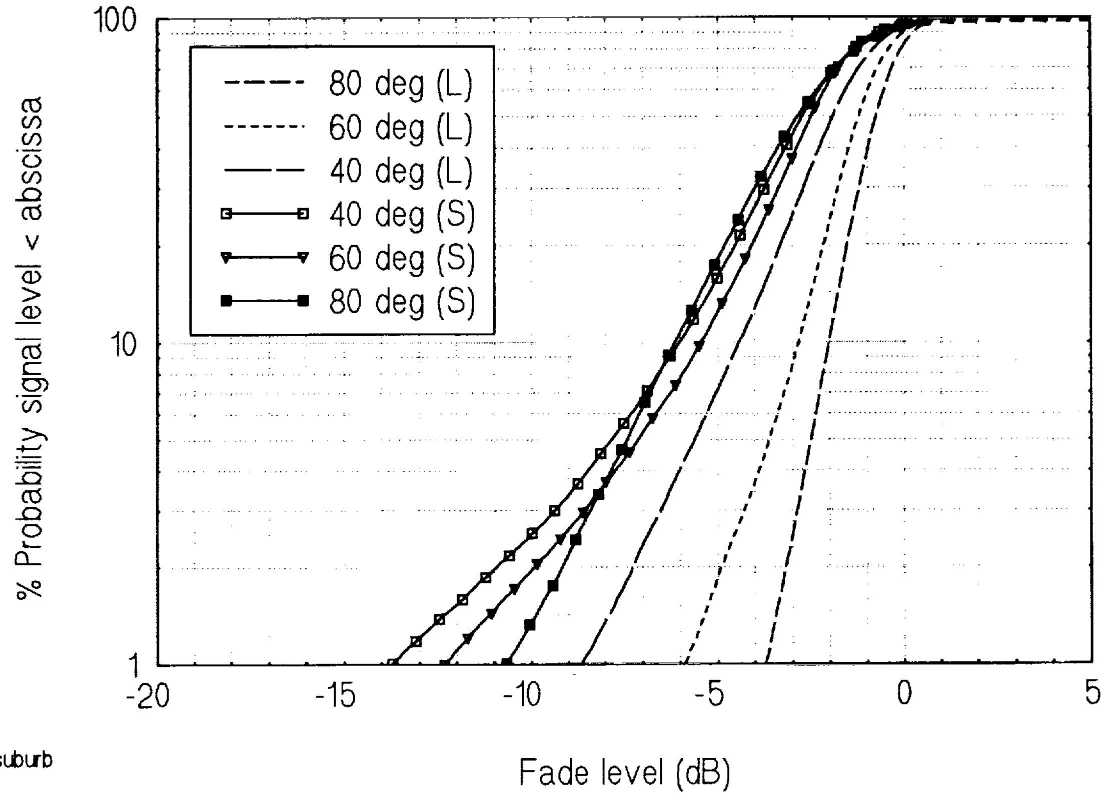
orlm

Figure 2 - Open rural area CDF's



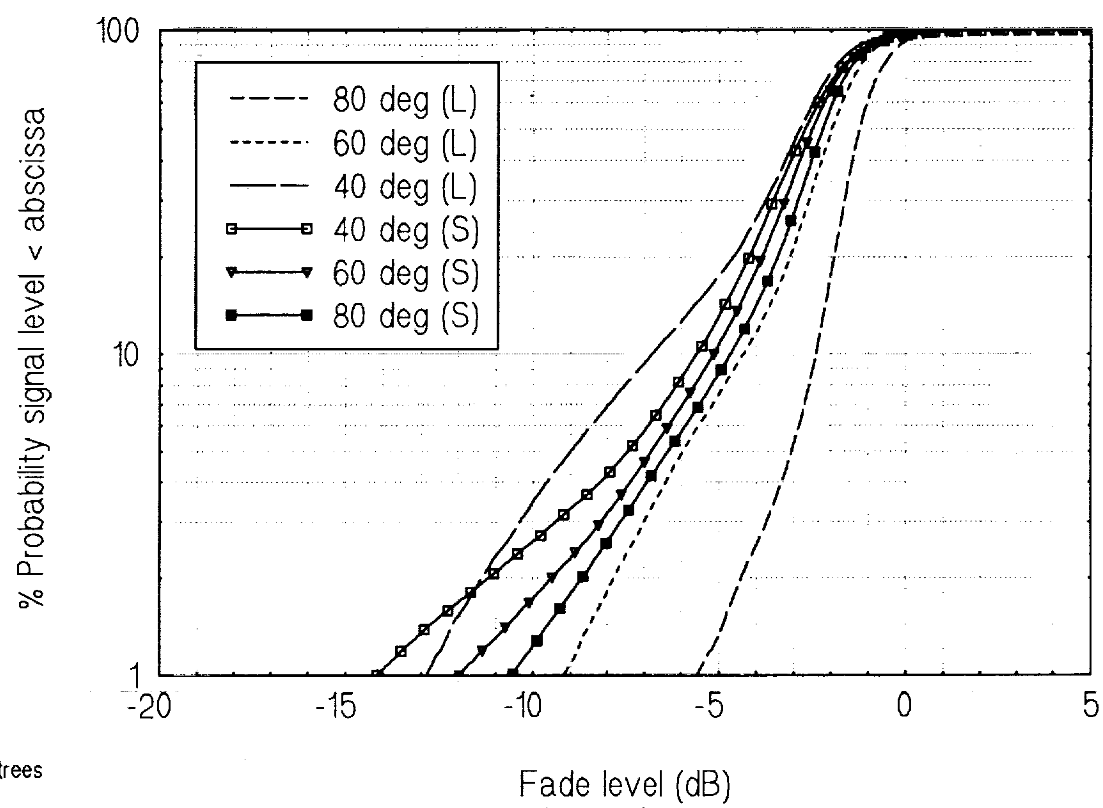
urban

Figure 3 - Urban area CDF's



suburb

Figure 4 - Suburban area CDF's



trees

Figure 5 - Tree shadowed area CDF's