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PRELIMINARY RESULTS OF MARECS-A MEASUREMENTS IN CENTRAL MARYLAND AND PLANS FOR 1988 MSS EXPERIMENT IN AUSTRALIA

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Abstract--Past and future efforts are described, using L Band (1.5 GHz) satellite signals for MSS propagation measurements. Preliminary results from the December 1987 campaign in Central Maryland with the Atlantic Ocean MARECS satellite are given. The fade level statistics from this 22 degree elevation source are consistent with helicopter measurements made along the same roads and presented in a companion paper. The day to day repeatability of the fade probabilities is shown to usually be better than about 20 percent. An experiment plan is presented for measurements using ETS-V's southern beam. These measurements will be made in Australia in collaboration with AUSSAT during the July/August 1988 time-frame.

1.0 Introduction

In early December of 1987, the Electrical Engineering Research Laboratory of The University of Texas and the Applied Research Laboratory of Johns Hopkins University jointly performed a further test of LMSS propagation, part of a series of systematic experiments, starting with balloon measurements in 1983, and then also using remotely piloted vehicles and helicopters as source platforms until June 1987. References describing these experiments can be found in a companion paper in this issue of the NAPEX proceedings. The new aspect of the last measurement was that a satellite signal was received. The opportunity to do this arose, because the Atlantic Ocean satellite operated by INMARSAT (MARECS-A) was being used by the European Space Agency (ESA) for land mobile propagation measurements in Europe. Through the cooperation of ESA, we were informed of the experiment schedule, allowing us to make low elevation angle measurements in Central Maryland along the same roads where a number of helicopter measurements were performed previously.

Another opportunity for satellite beacon measurements of LMSS propagation effects arises with the launch of ETS-V by Japan. This satellite's southern beam illuminates all of the Australian continent. AUSSAT, Australia's National Satellite System, has entered into an agreement with Japan, allowing them to use the satellite transponder for LMSS measurements in Australia. We have been invited by AUSSAT to come to Australia at the end of July 1988 with our receiving van and perform propagation measurements there. AUSSAT is contributing payment for the shipping and travel expenses of this trip and supplies the uplink, NASA is contributing the receiving van and the experimenters and supports the analysis and Japan contributes the use of the satellite. All parties will have access to the results of these measurements. This experiment will allow us to obtain satellite data at higher elevation angles than was possible before. Previous measurements have shown that the behavior of the communication link most strongly depends on scatterers and obstacles in the close vicinity of the vehicle. It is therefore possible to apply the results obtained at any location to any other one, as long as similarity exists in the general close environment. The results obtained in Australia can be applied to the US (or Japan), as long as similar percentages of shadowing by roadside trees or scattering by roadside objects are assumed.

2.0 The MARECS-A Experiment

The elevation angle to the satellite along the East Coast of the US was about 22 degrees, lower than angles measured with the helicopter, but within the range of operational angles for a real system covering the US. The satellite transmitted a carrier at a frequency of 1541.35 MHz with right hand circular polarization and an EIRP of 28 dBW. This resulted in a signal-to-noise ratio of better than 25 dB in a bandwidth of 100 Hz, using an azimuthally omni-directional crossed drooping dipole antenna mounted on the roof of the vehicle.

The fade distributions for the three roads along which measurements were made (Rt. 295, Rt. 108 and Rt. 32) are given in Figures 1 through 4. In order to demonstrate the repeatability of the measurements, data were collected on two consecutive days along the same roads. The results of each day are shown, for each particular direction of driving and, on Rt. 295, each lane selected. The abscissa shows the percentage of the distance driven, for which the fade exceeded the value along the ordinate. Negative values along the ordinate represent signal enhancements due to constructive interference.

At the 10 percent level, along Rt. 295, the attenuation ranged from 12 to 19 dB, depending upon the driving geometry. The satellite was to the east. Therefore the best performance was obtained when the van drove south in the right lane. The worst performance was found for driving north, in the shadow cast by the trees immediately to the right. Surprisingly, driving north in the left hand lane seemed to produce fades about 1 dB higher than those obtained when driving in the right hand lane. Along the two lane roads, the corresponding spread was narrower, about 1 dB for each road.

The day-to-day repeatability of the measurements is demonstrated in Fig. 5. The repeat error is defined as the percentage difference of the measured probability for each particular fade depth. The differences are less than about +-20 percent for Rt. 295. For instance, going south on Rt. 295 in the left lane resulted in a 1.72% probability of the fades exceeding 20 dB on the first day and a 2.15% probability on the second one, which results in a [(1.72-2.15)/2.15*100=] 20% repeat error. The error is larger for Rts. 108N and 32W, for which at fades above about 18 dB the error exceeds 50% and appears to be systematic.

The variability of the fade distribution function has been plotted in Fig. 6 for Rt. 295, in Fig. 7 for Rt. 108, in Fig. 8 for Rt. 32 and in Fig. 9 for the three roads combined. In these figures the axes have been reversed from the previous ones. The fade depth is plotted on the ordinate and the percentage of distance that a fade level exceeded the ordinate value is plotted on the abscissa. There are three curves in each plot. They were derived by first calculating the fade distribution function for consecutive 90 second intervals and then by finding the 90th, 50th and 10th percentile fade level of these distributions at the 1, 2, 5, 10 and 20 percent 90 second distribution value. From Fig. 9, for instance, one can see that there was a 90% chance that 10% of the distance the fades within a 90 second period exceeded 6 dB, a 50% chance that 10% of the distance the fades within a 90 second period exceeded 15 dB and a 10% chance that 10% of the distance fades within a 90 second period exceeded 20 dB.

It is expected that a typical voice call over the satellite link will last about 90 seconds. The overall fade distributions of Figs. 1 to 4 give information about the fade margin required for many callers in one particular area. The fade statistics are not stationary however, and within one general area one can, in a 90 second interval, encounter situations with much or little shadowing by roadside trees. Therefore information about the variability of the fade distributions is needed, if one wants to estimate the success of a particular call.

3.0 The ETS-V Experiment

3.1 Objectives

This experiment is to evaluate the fading probabilities of land mobile satellite communication systems at elevation angles between 42 and 57 degrees. The experiment will be performed at a frequency between 1540.5 to 1548 MHz, where the ETS-V satellite can transmit 27.2 dBW (EIRP) in its southern beam, illuminating all of Australia. The results will be fade distributions and their statistical variation as well as fade and no-fade duration data for a variety of environments, ranging from urban to rural to desert, with flat, rolling and mountainous terrain. Fades in LMSS channels are either due to (1) multipath reflections from roadside scatterers or (2) shadowing/scattering from roadside trees or (3) a combination of both. Using a satellite as a signal source will allow one to make systematic measurements of these effects by varying the driving direction along selected roads. Using a satellite source will also enable one to obtain a large amount of data in a relatively short time.

The data acquired will allow us to determine fade distribution statistics for shadowing and multipath geometries, for a variety of road types and lanes of road driven, in different environments and over a range of elevation angles from about 40 to 60 degrees. Fig. 10 indicates the vegetation zones of Australia along with the angle of elevation. We also will assess the variability of fade distributions as a function of location and elevation angle and express the results in functional form. We also will derive fade duration statistics from the measurements. Measurements will be performed at selected spots along the general route shown in Fig. 11, where we can vary the driving direction with respect to the satellite.

3.2 Logistics

The van with its receivers, data acquisition hardware and power generator has been consigned to a shipper in Houston on June 9th, 1988. It will sail to Sydney June 20th and is scheduled to arrive July 13th. It will be taken through customs in Sydney by AUSSAT upon arrival. At the conclusion of the measurements, the van will be shipped back to Houston.

3.3 Schedule in Australia

During the three weeks of the campaign, 15 days of measurements have been planned, with approximately 4 hours of data acquisition per measurement day. In order to be able to use both the video camera for recording the environment, as well as the sky brightness detector for assessing the shadowing percentages, all measurements will be performed during daylight hours. This schedule will result in about 1,500 MBytes of data recorded over a total distance of about 3000 km. The table below is a preliminary schedule for the experiment:

Table I
Campaign Schedule for ETS-V MSS Measurements

Measurement Day	Location	Elevation (deg)	Environment
1	Sydney	51	urban, sub-urban
2	Sydney	51	urban, sub-urban
3	Sydney to Canberra	51..48	rural, mountains
4	Canberra to Albury	48..46	mountains
5	Albury to Melbourne	46..42	hilly
6	Melbourne to Cobram	42..46	hilly, flat
7	Cobram to Dubbo	46..51	rolling
8	Dubbo to Armidale	51..53	mountains
9	Armidale to Brisbane	53..57	mountains
10	Brisbane	57	urban, sub-urban
11	Brisbane environs	57	rural, sub-urban
12	Brisbane to Grafton	57..55	flat, rural
13	Grafton to Port Mac	55..53	flat, rural
14	Port Mac to Sydney	53..51	flat, rural
15	Sydney	51	urban, sub-urban

Depending on road, traffic, weather or driver conditions, this schedule may be subject to real-time adaptive optimization.

3.4 Data Analysis

The data obtained in this experiment will be analyzed during the Sept. 1988 to Sept. 1989 time frame. Both these authors and AUSSAT will be involved in this phase, which will lead to a joint paper in a peer-review journal.

4.0 Acknowledgements

We very much would like to acknowledge the cooperation we received from Dr. Gert Brussaard of ESA in conducting the MARECS-A experiment. We also appreciate the initiative taken by Dr. Kim Dinh of AUSSAT, enabling us to significantly add to our data base. We also thank G. W. Torrence of EERL for continually improving the receiver van and for helping to carry out the experiment.

5.0 References

See: Goldhirsh and Vogel, Results of 1987 MSS Helicopter Propagation Experiment at UHF and L Band in Central Maryland, in this issue of the NAPEX proceedings.

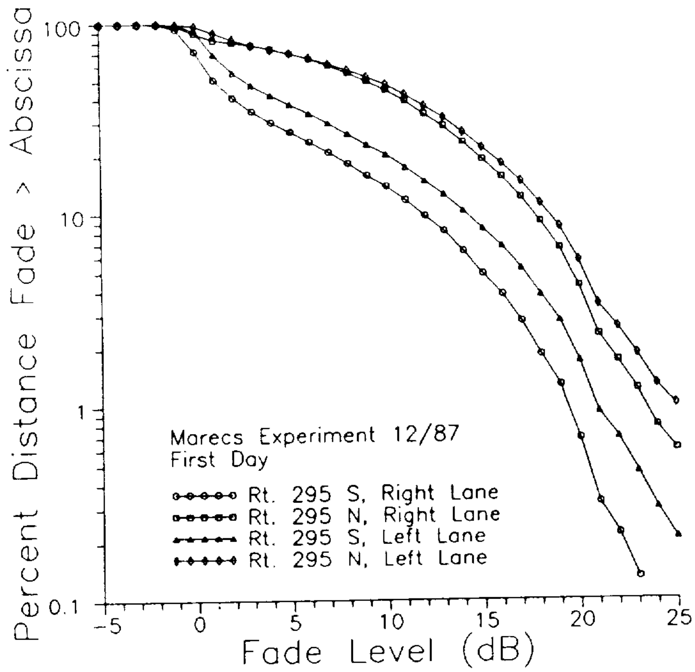

Figure 1 Cumulative fade distribution for Rt. 295 measured on the first day of the experiment.

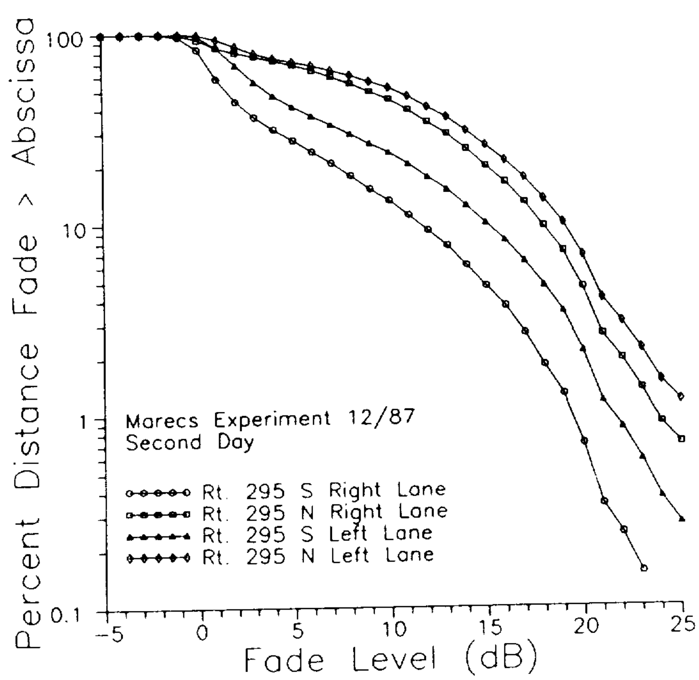

Figure 2 Cumulative fade distribution for Rt. 295 measured on the second day of the experiment.

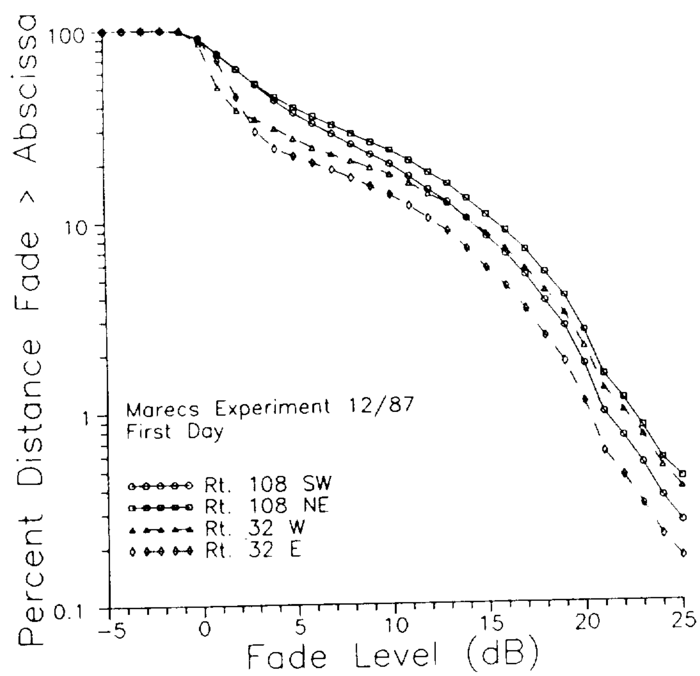

Figure 3 Cumulative fade distribution for Rts. 108 and 32 measured on the first day of the experiment.

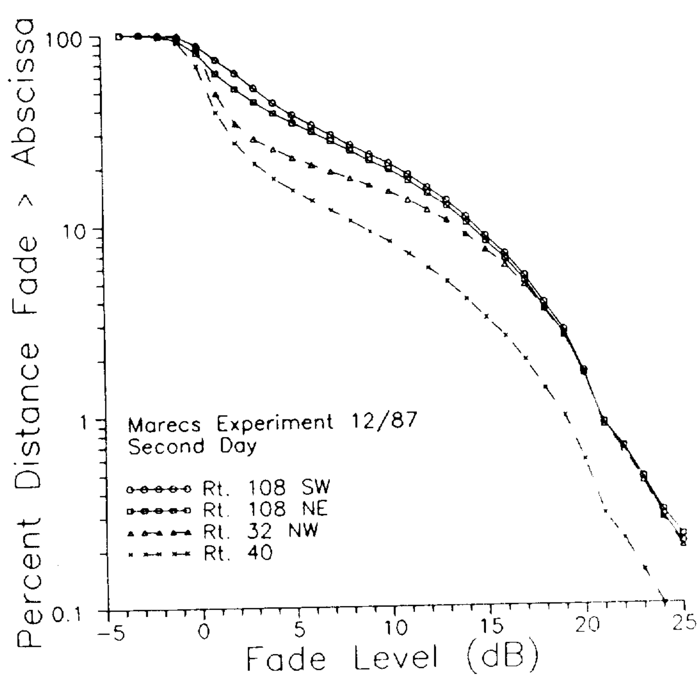

Figure 4 Cumulative fade distribution for Rts. 108, 32 and 40 measured on the second day of the experiment.

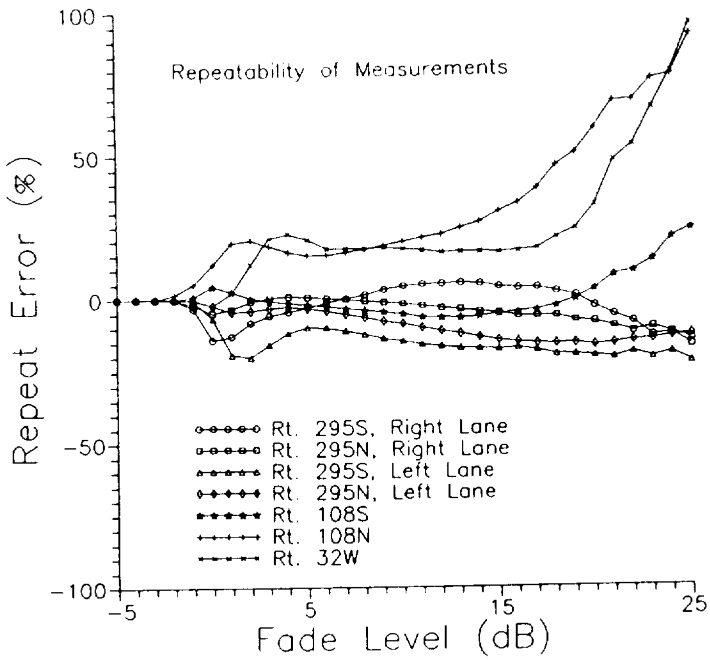

Figure 5 Repeatability of the distribution curves expressed as the % change at each fade level.

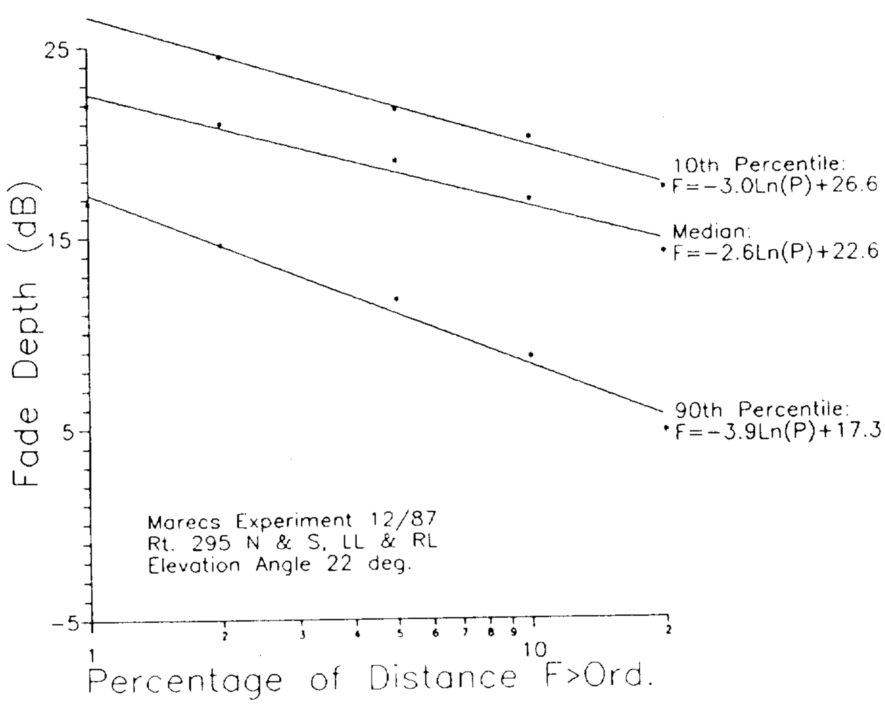

Figure 6 Measured 10th, 50th and 90th percentiles of the fade cumulative distributions taken over 90 seconds duration for Rt. 295.

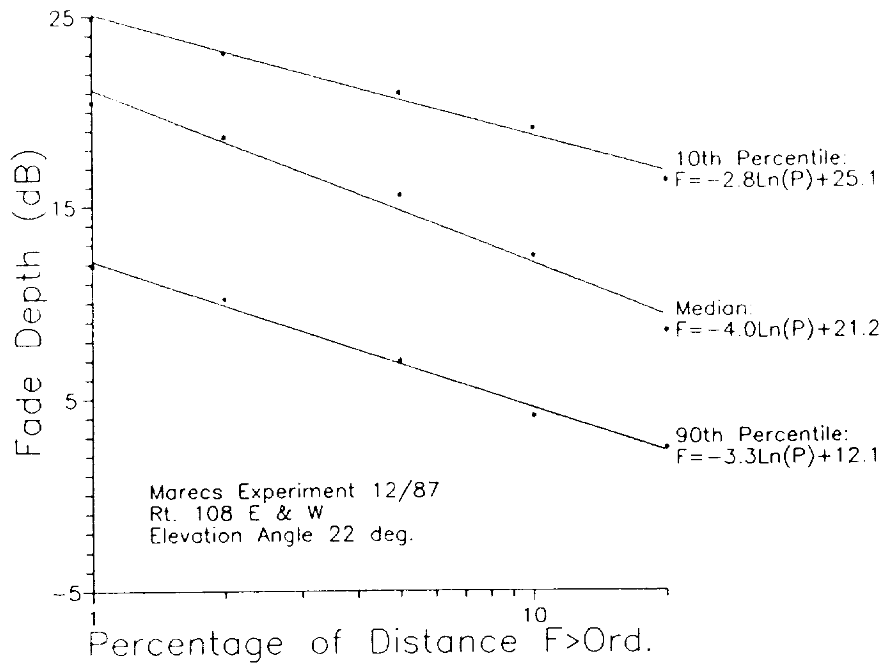

Figure 7 Measured 10^{th}, 50^{th} and 90^{th} percentiles of the fade cumulative distributions taken over 90 seconds duration for Rt. 108.

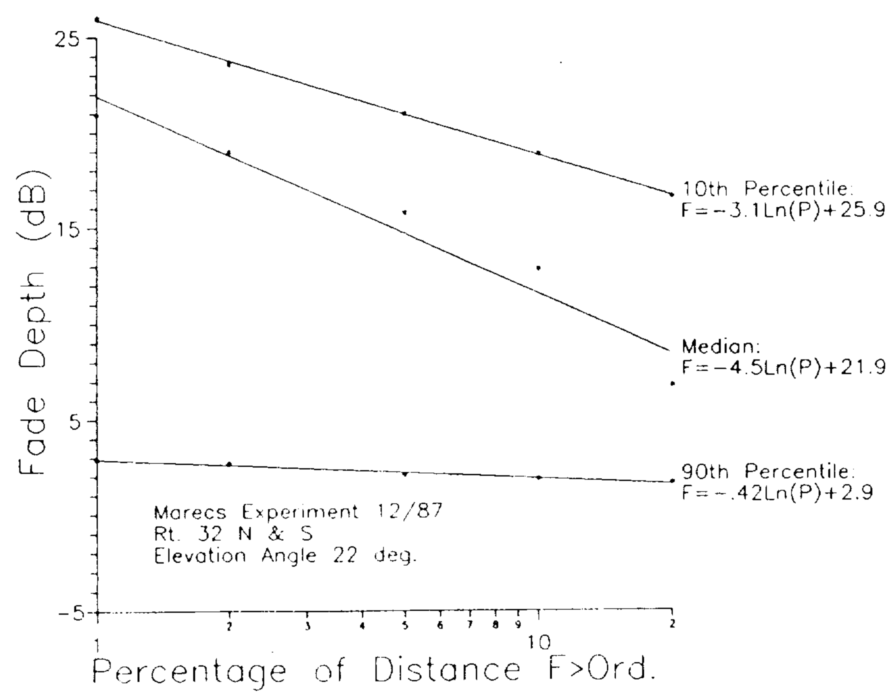

Figure 8 Measured 10^{th}, 50^{th} and 90^{th} percentiles of the fade cumulative distributions taken over 90 seconds duration for Rt. 32.

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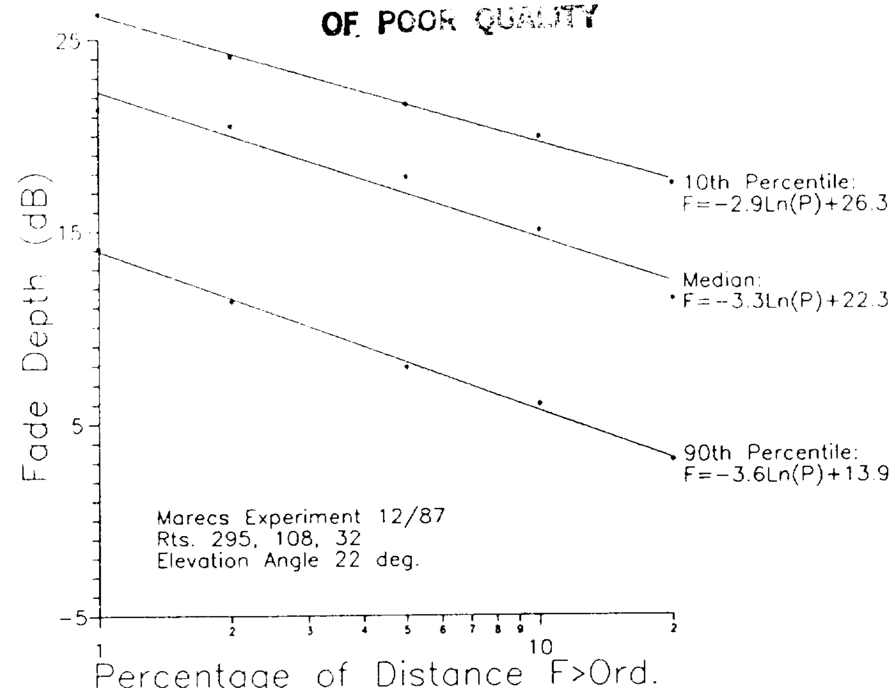

Figure 9 Measured 10th, 50th and 90th percentiles of the fade cumulative distributions taken over 90 seconds duration for the combined roads.

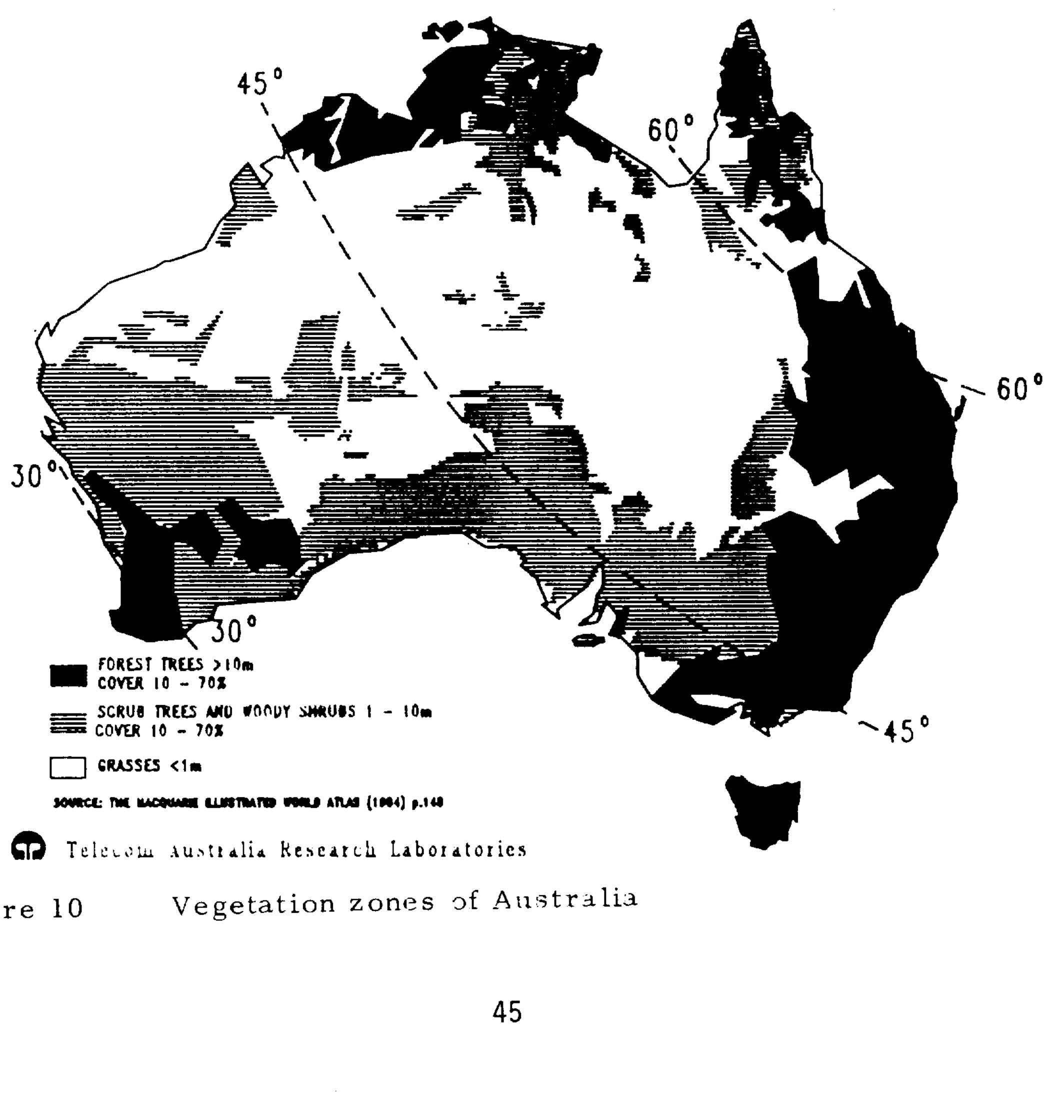

Figure 10 Vegetation zones of Australia

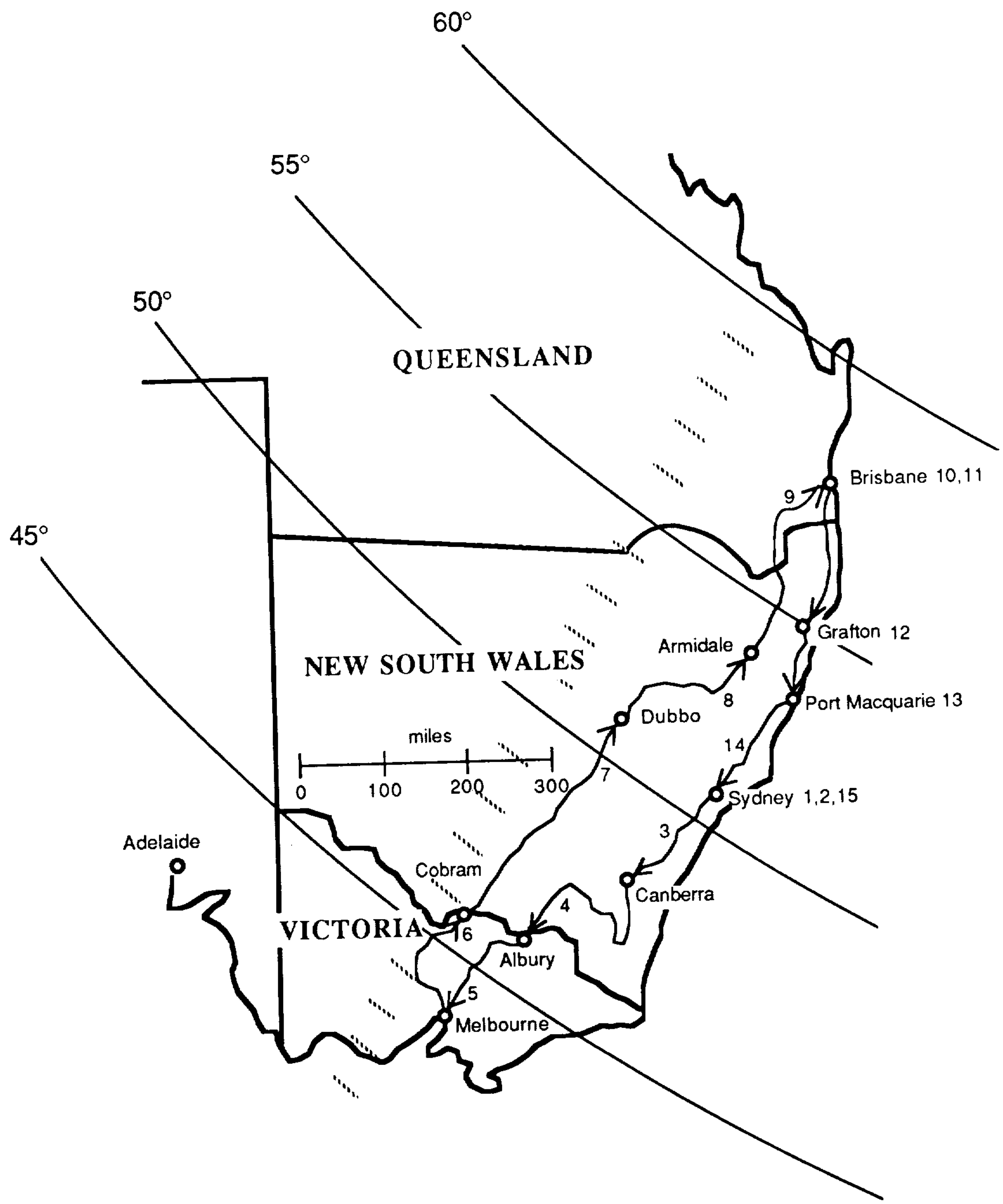

Figure 11 Preliminary itinerary for 15 days of measurements in southeastern Australia, covering a variety of vegetation zones and landscapes.