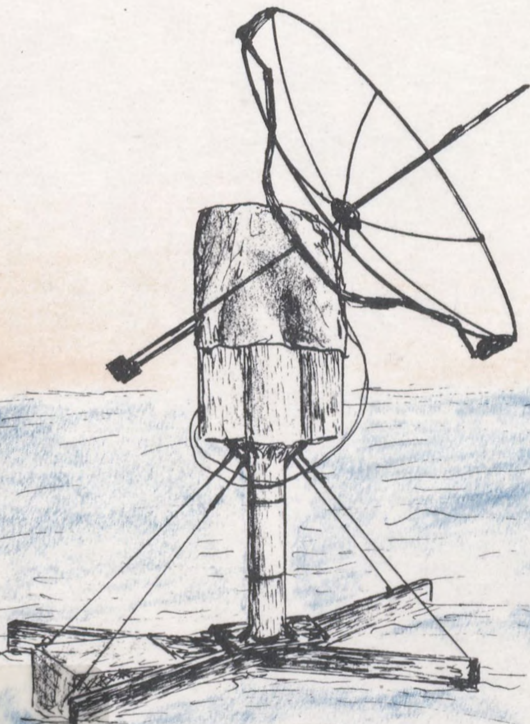
REPORT # HA-43

Centre for Radio Science

DIAGNOSIS OF THE CAUSES OF MULTIPATH FADING ON TERRESTRIAL MICROWAVE COMMUNICATIONS SYSTEMS.



A.R.Webster and T.S.Merritt

Final Report

D.S.S. Contract No.

24ST.36001-5-3549

August, 1986.

THE UNIVERSITY OF WESTERN ONTARIO
LONDON CANADA N6A 3K7

DOC-CR-RC-86-006

Diagnosis of the Causes of Multipath Fading on Terrestrial Microwave Communications Systems

A Final Report under
Department of Supply and Services
Contract # 24ST.36001-5-3549.

Submitted to
Communications Research Centre,
Department of Communications,
Ottawa, Canada.

by

Centre for Radio Science,
University of Western Ontario,
London, Canada.

Principal Investigator: A.R.Webster.

Research Associate: T.S.Merritt August, 1986.

DEPARTMENT OF COMMUNICATIONS

COMMUNICATIONS RESEARCH CENTRE

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ORIGINAL DOCUMENT REVIEW AND PUBLICATION RECORD

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1. INTRODUCTION.

In a previous contract (24ST.36001-4-0856), a prototype 12-element wide-aperture array, together with associated transmitting and receiving equipment, was developed and deployed in the field on a 30 km. path from the Ontario Hydro tower at Uniondale to the Centre for Radio Science. Operating in a CW mode at 16.65 GHz, the system was designed to resolve the received signal into its separate components under multipath propagation conditions.

As a result of the encouraging results which emerged from that work, it was proposed under this contract that further developments be undertaken with a view to improving the performance and, longer term, investigating the problems associated with specific communications links in collaboration with the industry.

The specific objectives were to:

(a) expand the 12-element array to 16-elements;

(b) improve the waveguide feed arrangement;

(c) install a small computer to control the acquisition of data from the array and monitor the operation of the system;

(d) cooperate with CRC in planning and carrying out a study of anomalous propagation.

In addition to the planned modifications to the system outlined above, a major fire (April,1985) in the laboratory at the Centre for Radio Science (CRS) destroyed virtually the whole of the receiving system so that, as a consequence, it had to be entirely re-built; minor modifications to the receiver to improve performance were incorporated.

All of the hardware modifications are now complete and the full system is operating on the Uniondale-CRS path at the time of writing (early August,1986). A delay in the obtaining of additional mixers resulted in the need to operate initially on 12-elements only; data from these 12-elements were recorded on a continuous basis from early July. The system operates with a minimum of attention and is now in a form where it may be re-deployed reasonably quickly as desired.

2. THE SYSTEM.

The principle of the system is illustrated in fig.1 and remains unchanged from that described in the above-mentioned report. In essence, the complex amplitude across a wide (vertical) aperture is sampled rapidly and the resultant data stored for further processing with the object of resolving multipath into individual components. Aside from the straightforward rebuilding mentioned above, the main changes and improvements made are described below.

2.1 The Array.

In order to improve both the resolution of the system and the unambiguous range in AOA, the number of elements was increased to 16 from the previous 12. The element spacing was reduced to 41λ (from the previous 51λ), which has the effect of increasing the range in AOA by about 20%. At the same time the aperture width is increased from 612λ to 660λ, resulting in about 8% improvement in nominal resolution. These dimensions, it should be noted, are constrained partly by physical considerations (in this case tower height) and have some degree of flexibility in other deployments.

In the previous version of the system, great pains were taken to ensure that the electrical lengths from Local Oscillator to each mixer were similar on the grounds that in the waveguide used, a 1°C change in temperature results in a 1°

change in phase per 100λ ; this could have serious effects on the phase measurements, especially if the waveguide were subject to heating from direct sunlight. Regretably the arrangement used, consisting of alternate runs of waveguide and coaxial cable, proved troublesome partly due to the many connectors and partly to the lack of pressurization of the waveguide. In view of this, and with an eye on future needs, the L.O. feed to the mixers was redesigned as shown in fig.2 in which the elements are arranged in four 4-element sub-arrays and the waveguide is pressurized (dry air or nitrogen can be used). Some compromise is accepted here in terms of phase of the L.O. signal, but the effect is predictable and consistent across the array. Temperature changes are minimized by mounting the waveguide inside lightweight U-channel, thus providing shielding from the sun; this also provides a mechanically strong base for each of the 4-element sub-arrays.

The switch which selects the appropriate element in the array was also modified so that each sub-array is self-contained with its own sub-switch; the 4-element switch is shown in fig.3 and the essence of the array switching in fig.4.

2.2 The Receiver.

The principle of the receiver is unchanged from that reported previously. In re-building the main receiver, some improvements were made in the light of experience gained in the operation of the prototype. For example, the AGC circuit was redesigned to give a somewhat wider dynamic range (approx. 60dB) and the Analog-to Digital converter modified to allow for this. The basic receiving system is shown in fig.5.

The A/D converter forms part of the newly developed data acquisition and control system based on a Zenith Z-161 microcomputer. In this, the computer orchestrates the entire operation starting with the selection of the appropriate horn antenna. Following that, the amplitude is read (from the A/D board) together with several (choice of 8 or 16) phase values from a digital phase-meter. All of these values are stored and the computer moves on to the next horn. A complete sweep of the array is accomplished in 48 ms. and can be repeated at rates approaching 20 s^{-1}, although in practice "housekeeping" requirements limit this repetition rate; one sweep/s. is used routinely. In the inter-sweep interval, an average phase value for each element is computed and on the minute, accumulated data (one minute's worth) written to 9-track magnetic tape (a newly acquired Kennedy 9600). Much software has been developed in bringing this new part of the system on-stream.

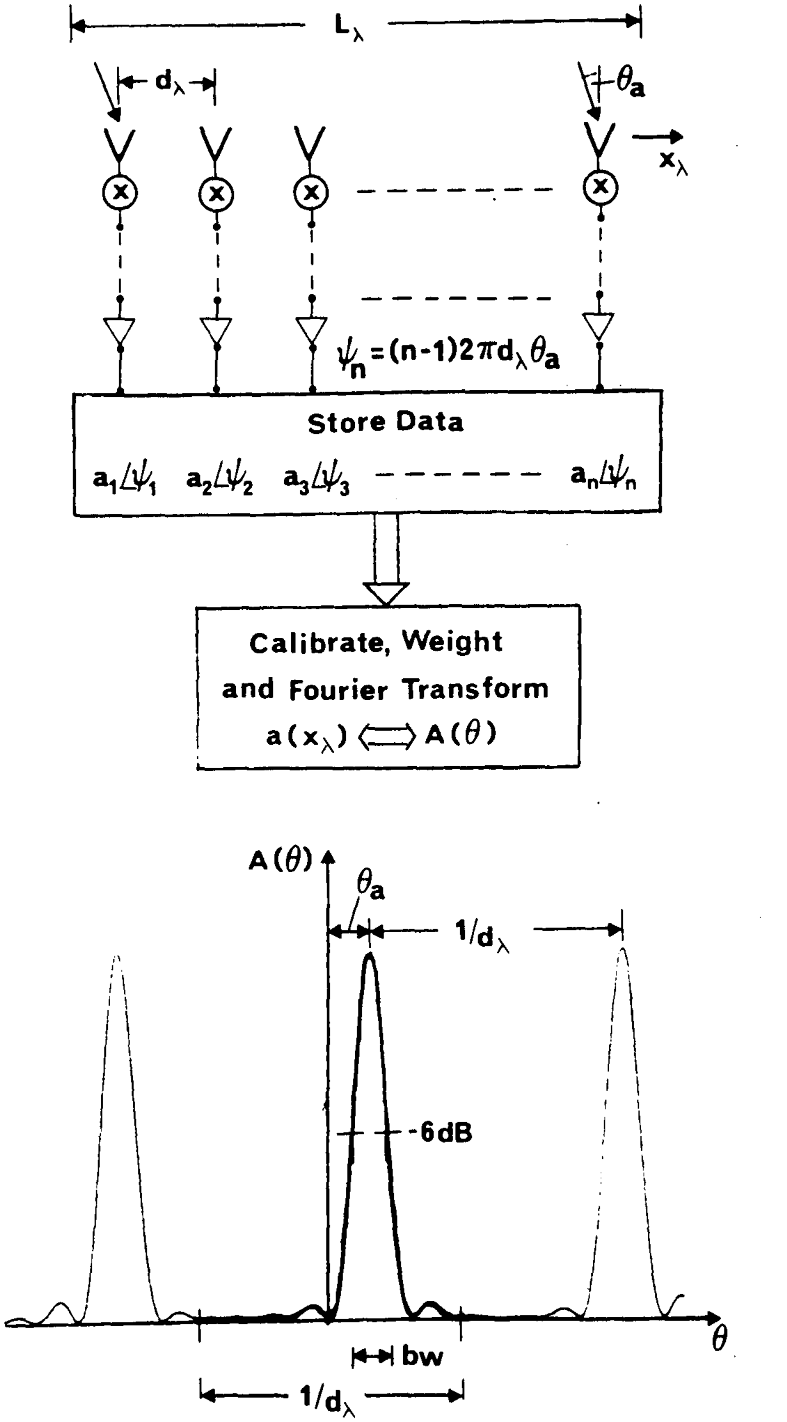
3. Discussion.

As mentioned previously, the system is now fully operational on the Uniondale-CRS path and data are being accumulated on a continuous basis; the path profile for the link is shown in fig.6. Several extensive periods of multipath have already been observed; typical derived results are shown in figs. 7 and 8. The plan, under a continuation of this contract, is to accumulate an extensive data base from which statistical information on the basic parameters of multipath propagation may be extracted. It is envisaged that observations will continue until late October, 1986.

In the meantime, some consideration will be given to possible ways in which collaboration with the industry might be strengthened with a view to providing useful interchanges of ideas regarding the effects of multipath propagation on the operation of modern microwave communications systems.

A start in this context was made during this contract period on two fronts. Discussions with Bell Canada in 1985 were initiated in which the operation of this system on a local digital radio link was envisaged. These talks were making good progress, to the point where a suitable link had been identified. Unfortunately for reasons unconnected with the cooperative work, Bell Canada felt compelled to withdraw from the proposal, at least for the time being. In early 1986, discussions were held between personnel from the Communications Research Laboratory (McMaster University), Northern Telecom, CNCP Telecommunications, the CRC and the CRS. Basically an initiative of the CRL, the thrust is to engage in cooperative research into the behaviour of digital radio systems under multipath conditions and, as such, involves input from industry, government laboratories and universities. As part of the continuing program, it is envisaged that this initiative will be pursued along with further measurements of basic atmospheric properties.

Acknowledgements. The cooperation of Ontario Hydro in allowing the mounting of the transmitter on the tower at Uniondale is greatly appreciated, as is the help of Mr. J. Kokkat in some of the software development.



Beam-width (bw): $\left\{ \begin{array}{ll} \text{Unweighted} & \sim 1.2/L_\lambda \\ \text{Dolph-Tcheb.(30 dB)} & \sim 1.5/L_\lambda \end{array} \right\}$ rad.

Fig. 1 The principle of angle-of-arrival measurement using a wide aperture array.

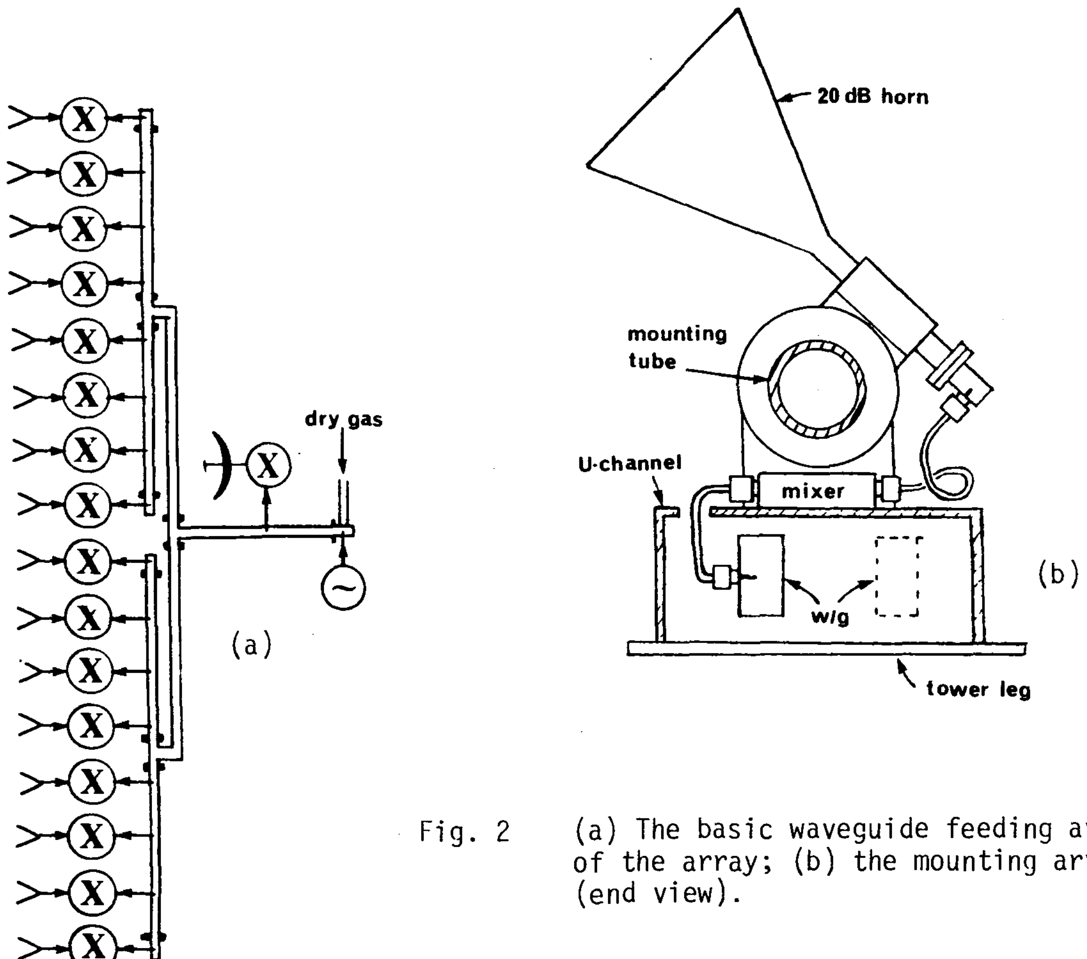


Fig. 2 (a) The basic waveguide feeding arrangement of the array; (b) the mounting arrangement (end view).

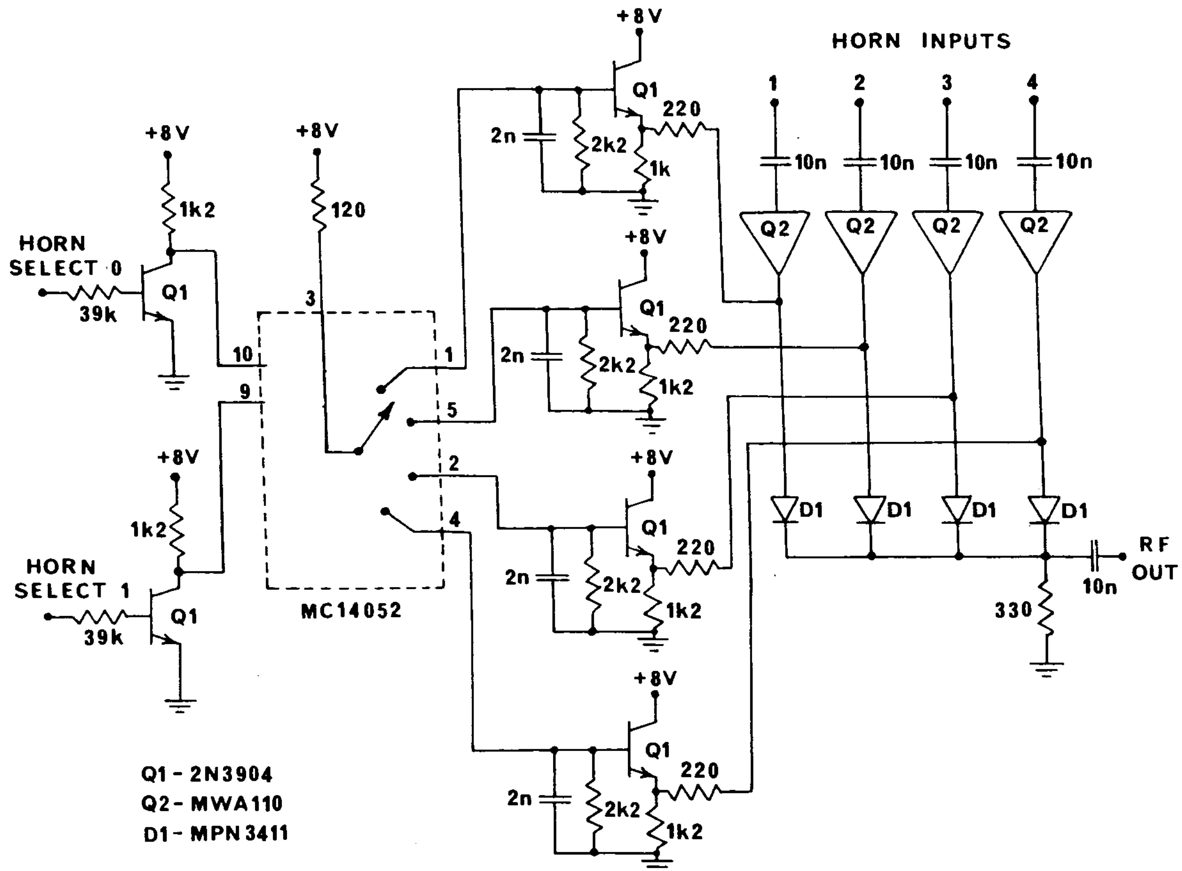


Fig. 3 The basic 4-element switch.

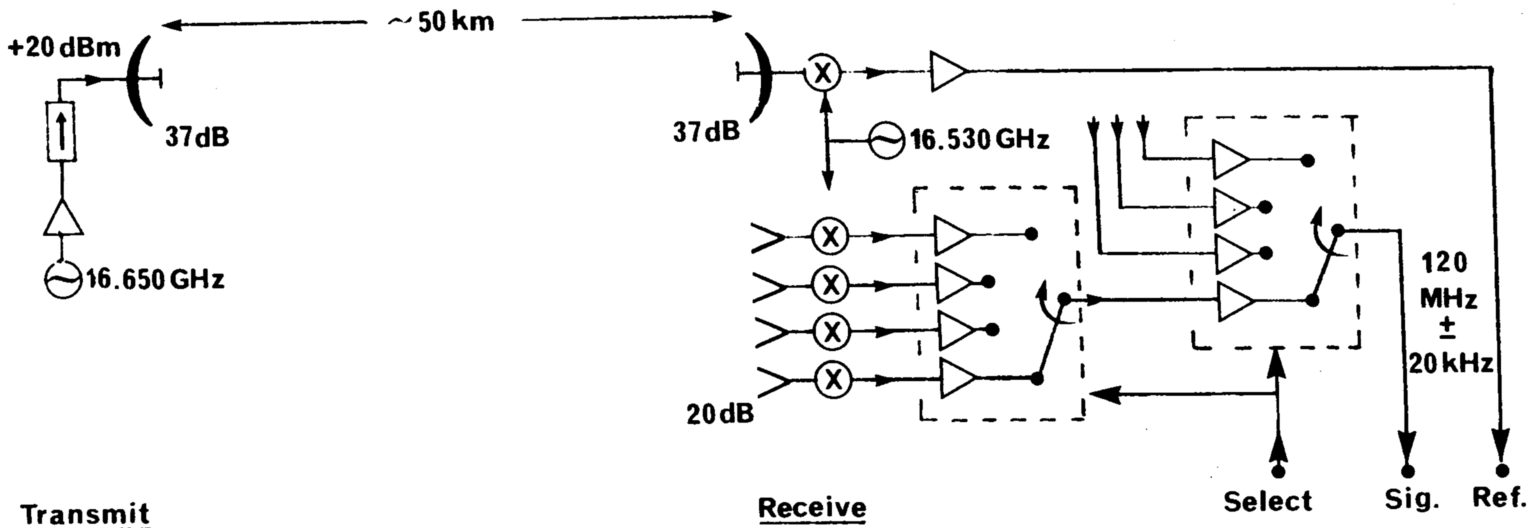


Fig. 4 The array switching arrangement; one of the 4-element subarrays is shown.

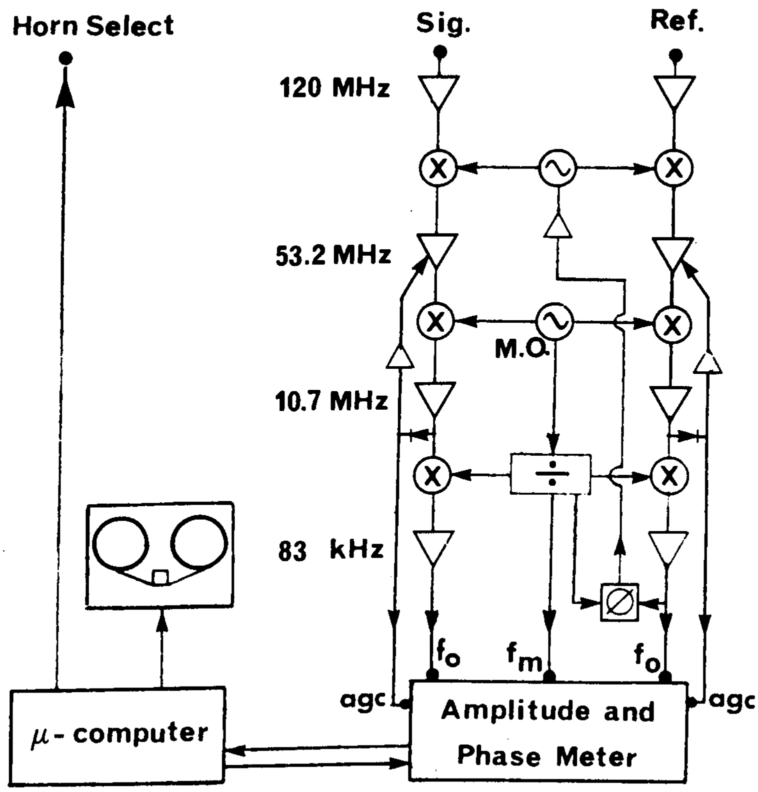


Fig. 5 The essence of the receiving system.

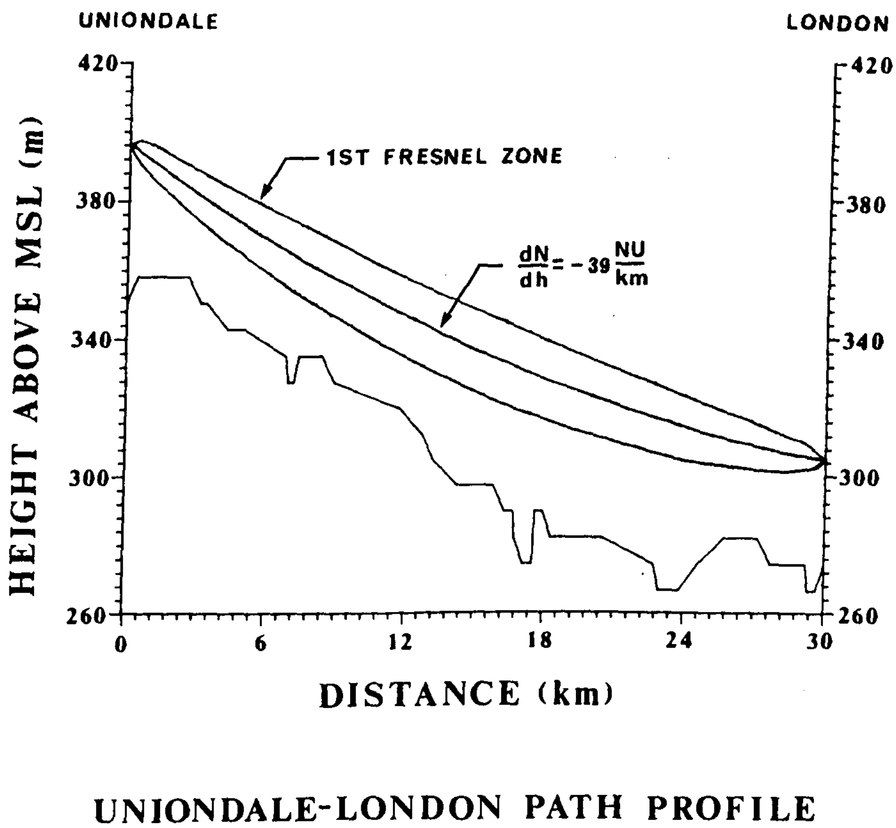


Fig. 6 The Uniondale-CRS path profile.

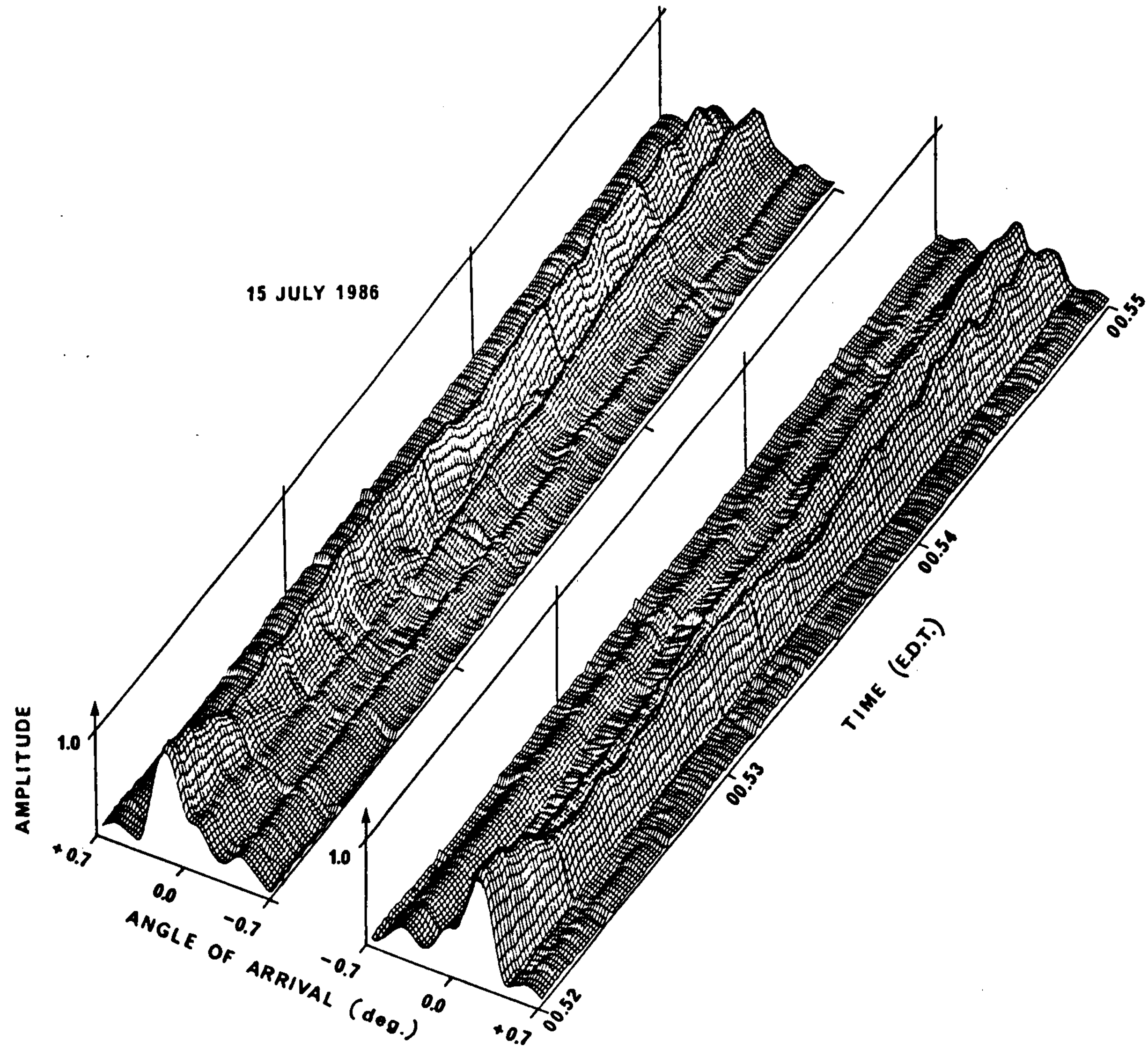


Fig. 7 A typical record of amplitude versus AOA as a function of time; the grid represent 0.022° in AOA and 1 second in time. Mirror-images are presented for clarity.

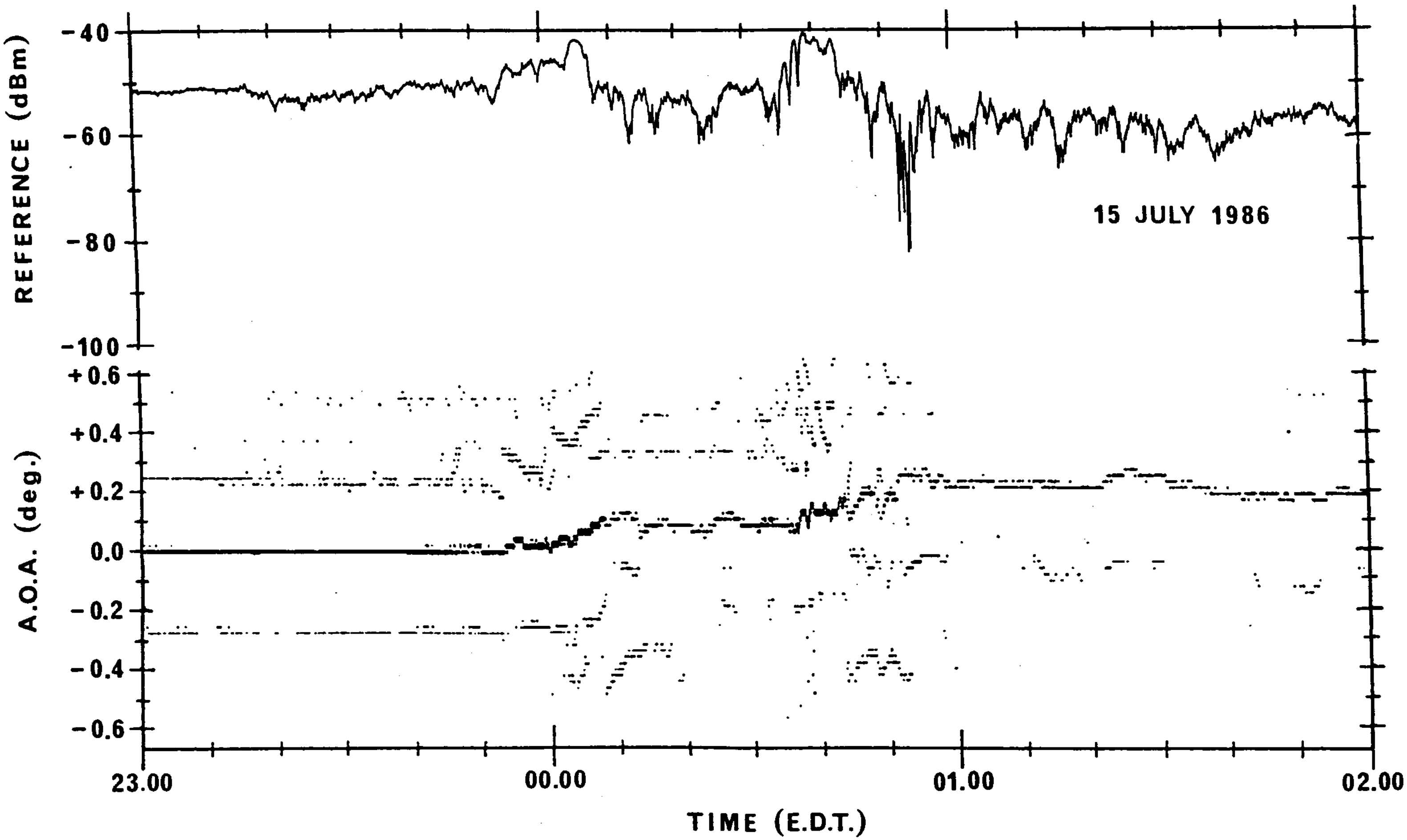


Fig. 8 A 3-hour record of the amplitude of the reference channel and the derived component AOA; the latter is obtained by scanning records such as in Fig. 7 and recording the positions of peaks. The line density is representative of the amplitude.