*Discussion on Paper No. 6643**

Measurement of distance by radio waves and its application to survey problems

Part 1: Introduction and the Tellurometer

by

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and

Part 2: Hydrodist and Aerodist

by

Commander R. Bill, *D.S.O.*, F.R.I.C.S., R.N.(Rtd)

Mr P. G. Mott (Technical Director, Hunting Surveys Ltd) congratulated the Authors on an excellent and lucid account of the workings of the Tellurometer and its many applications. There could be little doubt that the introduction of electronic means of distance measurement had produced quite a revolution in land surveying operations and had reduced in very large measure the time and effort required in the extension of coordinate control, as well as increasing the accuracy of many such operations.

78. Dr Sandover had mentioned some of the work done by Government departments using Tellurometer equipment, but Mr Mott believed that the commercial survey organizations had been no less active in exploiting the use of this new and valuable survey tool. Speaking for one company in particular, he believed that it had been one of the first to use the Tellurometer, and since that date, five or six years ago, it had been carrying out almost continuous Tellurometer operations in one part of the world or another, using both the MRA.1 and MRA.2 equipments.

79. One of the most striking examples of the value of the Tellurometer, combined with airborne transport by helicopter, had been the survey of the oil concession boundary in Southern Iran in 1959, in which an international team, comprising six British surveyors and some Dutch helicopters with French pilots, working under the overall direction of a Swiss, had completed, in five months, work over 1750 miles of major traverse control in the wildest and most mountainous country of the Middle East. The work had included landings by helicopter at heights up to 10 000 and 12 000 ft, with temperature changes of 80°F occurring during a single day's operations. Despite the many difficulties and the far-from-ideal conditions for Tellurometer operation, the accuracy of the measurements had subsequently been shown to be no worse than 1 part in 60 000 over the whole survey. Without the use of the Tellurometer and helicopter transport, such a task would almost certainly have taken up to five years to complete by conventional techniques.

80. On one occasion during this survey, a gust of wind had blown the Tellurometer over and had damaged the aerial and reflectors. Having no tools available at the time, the surveyor concerned had used a rock to beat back the reflectors into shape and had continued with the measurements, which proved entirely satisfactory. While not suggesting this as a standard procedure in operating the Tellurometer in

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* *Proc. Instn civ. Engrs*, vol. 24, January 1963, pp. 11–28.

such circumstances, it nevertheless demonstrated how remarkably robust the equipment was! Another proof of this was that the same Tellurometer in an emergency had been left out in the snow for five days without protection and was subsequently picked up and used again without any serious defects at all.

81. As with all electronic equipment, the Tellurometer contained a considerable amount of circuitry which was subject to wear and tear and the effects of climate and usage. Electronic failures of this kind were often difficult to locate and could not be repaired in the field. For this reason his company had made it a standard policy always to include an electronics engineer as part of the survey team. This engineer quickly acquired the necessary survey knowledge to serve as an efficient member of the observing team and was on the spot all the time to maintain the equipment. If this procedure was followed, the chances of any major breakdown were virtually eliminated, and delays from faults which might develop in the equipment were reduced to an absolute minimum.

82. The practice of employing an electronics engineer as a member of the survey team had paid handsomely in using the MRA.1 and MRA.2 equipments. With the MRA.3 equipment, which it was understood would be transistorized and so arranged that any one of the printed circuits could be replaced without expert knowledge, the requirement of an electronics engineer in the team might in future be less important; but it meant that even with the MRA.3, it would be necessary to carry a large amount of spare circuitry, at considerable cost, unless an expert was present.

83. Another recent survey carried out with MRA.1 and MRA.2 equipments had been in the delta area of Nigeria. Here the requirement had been for traverses along the twisting banks of tidal creeks with mangrove swamps on both banks. The length of the traverse legs had often been down to a mile or even less, and almost all the measurements had been taken over water with the Tellurometer supported on scaffolding standing in the muddy bottom of the creek. The climate was wet and humid. In order to keep the instrument serviceable, each day it had been necessary to cook the power pack in the kitchen oven before the party set out. Despite the very unusual and difficult conditions of this survey, the Tellurometers had given, on the whole, excellent service, and even under these adverse circumstances the closing error in one loop 250 km in length had been 1 in 64 000. It was easy to imagine what the difficulties of the survey would have been had the Tellurometer not been invented.

84. It was interesting to note that in this survey the best conditions over water were obtained when the surface of the water was slightly ruffled by wind. When there was a very large amount of wind, causing a choppy surface, the cathode-ray tube was almost unreadable, and when the water was absolutely smooth, there was a tendency to get a lot of reflexions and the readings were not so reliable.

85. Apart from the great advantage of the Tellurometer in controlling remote and inaccessible areas, the equipment had also proved a great asset for large-scale surveys of major cities and for providing control for photogrammetric mapping in connexion with new building developments, motorways, and so on. In the survey of a town, for instance, it was usually possible to find an elevated location for the master station at the top of a tower or high building and from this to supply control over a radius of two or three miles by measuring distances and angles to a remote unit which was moved from control-point to control-point within visible range of the master station. Compared with the older method of taped traverses round busy city streets, it could be understood what a tremendous advantage was gained by using the Tellurometer in this way. The MRA.3 equipment, with its higher frequency and narrower beam, would almost certainly give greater accuracy at the shorter distances and would therefore be of particular value in the provision of this type of large-scale control.

86. One of the claims for the Tellurometer as compared with the Geodimeter was that the Tellurometer could be used in daylight and even in conditions of mist when

the master station could not see the slave station. It must not be forgotten, however, that the fixing of a point required the measurement of an angle as well as of distance except, of course, in the case of a trilateration, and even then both vertical and horizontal angles should be measured if possible. For this reason one still depended on the inter-visibility between master and remote instruments in the vast majority of measurements made.

87. In § 34 of the Paper reference was made to the possibility of the Geodimeter replacing the Tellurometer in the future, since the velocity of light waves was less affected by meteorological effects than was the velocity of radio waves. Mr Mott believed that the Tellurometer would hold its own for a very long time to come, and when it was replaced, it would be probably by the development of another instrument, a type of measuring beam known as a 'laser' or 'maser',* which was a very concentrated beam of light at a frequency of, he believed, over 9000 Mc/s, and in its most concentrated form was even capable of boring a hole through anyone who got in its way!

Mr A. L. Allan (Lecturer in Land Surveying, South-West Essex Technical College) joined with Mr Mott in congratulating the Authors on writing such an interesting Paper.

89. There was a tremendous amount of literature on the Tellurometer. It was very difficult to assimilate it all and therefore correspondingly valuable to have the information so concisely given as in the present Paper.

90. The impression might have been created that because this instrument was tremendously accurate, to something like 1 part in 200 000, engineers might not have a use for it in general work. He thought that the instrument had a place in engineering surveys, as Mr Mott had pointed out, and also in township surveys. For example, considerable attention to the refractive index correction was necessary to give an accuracy of 1 part in 200 000, but if no individual refractive index determination was made at all and the standard refractive index accepted, it was still easily possible to get accuracies of 1 part in 10 000: an error of 1°F produced an error of 1 part in 200 000 in the length, so that it was possible to go 20°F from standard before considering temperatures. The whole problem was not, of course, quite so simple as that.

91. The computations involved might appear to be rather difficult but much could be done with tables and nomograms; it was merely necessary to lay a ruler on a nomogram to obtain the value of the refractive index. Mr Mott had mentioned trilateration, which was a very important method. The co-ordination of a trilateration could be done easily by direct formulae. It was not necessary first to solve the triangulation for angles; it was possible to compute the co-ordinates directly on a calculating machine from the measured distances. It would be interesting to hear from Commander Bill how the Navy did it. The Navy used rapid graphical methods which engineers could copy with advantage.

92. Recently, there had been another development on the side of computation, produced by Professor Jerie from Holland. It was an analogue computer, in appearance, rather like a Meccano set. One could scale off the distances of one's trilateration and obtain provisional co-ordinates, and each time the process was repeated, an extra decimal of a metre obtained. It was a very quick method and, incidentally, it gave a least squares adjustment of the lengths; it was 'Least Squares without tears!'

93. One method which had been used in Finland was of interest to engineers. The Finns took the type of tower wagon used by electricity undertakings and used it with the Tellurometer. Traversing in that way should have a future.

94. In connexion with Tellurometer work, the Directorate of Overseas Surveys

* Light/Microwave Amplification by Stimulated Emission of Radiation.

took truly reciprocal vertical angle observations by having theodolites at each end of a survey line. Since refraction effects were almost eliminated, they had reduced the height error by a factor of 3. It was possible that for preliminary surveys this method might be substituted for levelling; one could get accuracies of 0·1 m over quite long distances.

95. Something should be done to solve the problem of batteries, which was the biggest single problem associated with the Tellurometer. If a liquid electrolyte was used, it was too easily spilled. Batteries with solid electrolyte and non-spill types had been tried. Now one of his students had hit on the happy idea of carrying a battery in a golf trolley, which was not such a silly idea as it might sound.

Mr W. A. C. Wright (Lecturer in Surveying, Enfield Technical College) mentioned that he was supported at the meeting by thirty or more of his boys. They did not know much about the Tellurometer and he did not know much about it either; he had come to the meeting to find out something about it and perhaps explain it to them when he returned.

97. From his point of view as a civil engineer, he would like to know something about the personnel aspect. How long did it take to train a man who was a graduate civil engineer or an Associate Member of the Institution to use one of these instruments if called on to do so? Also, what did they cost? There was no mention of cost in the Paper, and he would like to know the cost of the complete set, master and slave.

Mr J. Martin Orr (Engineer, Admiralty Navy Works Dept) was interested in the fact that allowances had to be made for temperature and atmospheric pressure with electromagnetic waves of such high frequency and asked what errors would be involved if such allowances were not made.

Mr Patrick Simperingham (Auckland Harbour Board) asked whether it was possible to set up a permanent or semi-permanent set of remote stations for general work in a harbour.

Mr C. C. Brown (Hunting Surveys Ltd) asked whether, since it was essential to set the theodolite up on the same tripod as the Tellurometer, any thought had been given to an attachment to enable the theodolite to be mounted on top of the Tellurometer, to avoid the inconvenience of having always to take the Tellurometer off the tripod before putting the theodolite up. That might sound lazy, but if a number of distances had to be measured, and vertical and horizontal angles taken, and there was a helicopter waiting for the process to be completed, it would help if the theodolite could be mounted on the top of the Tellurometer.

Major R. C. Gardiner-Hill (formerly Ordnance Survey) said that in Table 1 of the Paper a specimen was given of one of the Ordnance Survey's observations. He had not been responsible for this being supplied, but he was delighted to see that the ground swing was only about $1\frac{1}{2}$ mμsec. That was ideal, but they did not get it every time. Nothing could be done about ground swing; it was a function of the geometry of the line. The line was not necessarily an accurate line because there was very little ground swing or a bad line because there was a lot. He would not weary the meeting by referring to all the work which had been done on this subject recently, but it was true to say that if, when the ground swing was plotted, the curve looked something like a sine curve, there was nothing to worry about, but if it looked nothing like a sine curve, it might still be possible to do something about it. When measuring over water in particular, it seemed possible to set up a mathematical model of the situation which was fairly true to life and thereby compute a correction, but the answer might no longer be the same as the arithmetic mean of the fine readings. For practical purposes any of the forms given would, except to the geodisist, give a satisfactory answer. The one over water would probably give an answer which was slightly too short.

102. Dr Sandover had suggested that the Tellurometer might not find a great deal of use by the Ordnance Survey in this country because of the completeness of its mapping. They themselves had tended to take that view when they first acquired the instruments, but they were rapidly being disillusioned and were finding more and more uses for them. They hoped next year, for example, to complete another triangulation link between this country and France, across the Channel from the Isle of Wight area to Cherbourg, and to use the Tellurometer on this. As an experiment, to test the feasibility of this, they had measured last summer a line between Dunnose and Beachy Head. The maximum distance suggested in the Paper could in certain cases be considerably exceeded.

103. Even on the scale of 1 in 1250, used for town surveys, they had found increasing use for the instrument. Probably their problems there were very similar to civil engineering problems. On geodetic work they could place their trig points where they wanted them, but for these large-scale town plans that was not possible. It was necessary to locate a trig point within a very small specific area. The town might be in a valley surrounded by trees, as was Haslemere, which had caused a great deal of trouble. It was not possible to use conventional triangulation or to traverse easily through trees, but a combination of methods, making use of the Tellurometer, had proved very satisfactory.

104. Those familiar with the semi-graphic approach to computation, position lines and the like, might be interested to know that the Ordnance Survey used that also on that type of work with the Tellurometer. They measured a length with the Tellurometer giving a position line at right angles to the direction of measurement. This could be combined with the intersections and resections to give a satisfactory answer.

Dr M. F. Kaplan (Director, Civil Engineering Research Council) observed that it was unquestionable that the Tellurometer had been a great success. He believed that at the present time it was earning something like £2m/a in foreign exchange for South Africa. Dr Sandover in Part 1 of the Paper referred to various other methods, using radio waves, for measuring distances, but it seemed that the Tellurometer was superior to them. As a layman, Dr Kaplan wished to ask the Authors exactly what had been the achievement of Dr Wadley in producing the Tellurometer.

Mr W. F. Johnston (Engineering Surveys Ltd) asked what was the accuracy of the MRA.3. An important factor was the training of the operator to use the instrument. How long would it take to become really proficient and able to use the instrument in general field conditions? Were there any comments which should be made on the limitations of the instrument, for example, over flat sand and scrub country?

Mr N. Reuben (Student) asked whether, in addition to measuring exact horizontal distances, the Tellurometer could be used to find the distance of an artificial satellite from the earth.

Mr J. J. C. Crocker (Director, Engineering Surveys, Ltd) suggested that the Authors should make some reference to the possible use of the Tellurometer in tunnelling work. There might be contractors present who had experience of using the instrument for measuring distances along tunnels. He could see the advantage of being able to get accurate distances from a fixed station when only a very short time was available to do this in, since the work had to be done virtually between shifts.

Mr M. H. Davis (Engineer, Rendel, Palmer & Tritton) said he had recently been engaged in a route survey in the delta area of Nigeria, where a Tellurometer had been used for the measurement of distances, and one thing which he had noticed had been that when preparing the line for measurement, it was necessary to clear the line to a greater extent than would probably have been necessary had normal tape methods been used, in order to get the signals through. The instrument had been indispensable in the survey, because it had been necessary to cross many swamp areas and creeks with distances of up to half a mile or more. On the question of site clearance, the ground was flat and the clearance had to be as much as 12 ft wide. The Tellurometer had been put on towers. He wondered whether in thick bush country anyone had experienced difficulty because of the clearance necessary for the radio wave.

Mr Allan, commenting on Dr Sandover's statement that the range of the Tellurometer was increased by elevating the dipoles, asked for some further explanation of this. Was it not true that the actual range electronically was reduced, but, because of the elevation, one could see further?

The following contribution was received in writing:

Mr M. Murray (Engineer, Aga Geodimeters, Brentford, Middlesex) wrote that the Author mentioned comparative accuracies of the latest Tellurometer with that of the Geodimeter at a length of approximately one mile, listing the maximum error as 2·19 in. and 2·10 in. respectively. While, however, the type of Geodimeter from which these accuracy figures were taken was not stated, it was obvious from the quoted limits, i.e. 2 p.p.m. $\pm$ 5 cms, that the instrument was a Model 3. Readers might like to note that the Model 3 was in production some time ago and had now been obsolete for about four years. It had been superseded by the Model 4 Geodimeter, having an average error of less than 10 mm $\pm$ 2 p.p.m. over the full range. By using specialized techniques in certain engineering problems, this error could be reduced to less than 2 mm $\pm$ 2 p.p.m. With the introduction of the mercury lamp to this equipment, the instrument could measure lines from 15 m to 25 km at night, but more important still, from 15 m to over 4 km in full daylight.

112. Mention was briefly made of a portable Geodimeter, but that its weight of 79 lb militated against its use. However, the total weight of Geodimeter equipment for the measurement of any line, i.e. instrument and reflector set up, complete with generator, was in the region of 116 lb, whereas the total weight of Tellurometer MRA.2 equipment for the measurement of a similar line would be approximately 150 lb (depending upon the weight of the batteries) made up by the need for both master and slave units.

113. It was unfortunate that such misleading information should have been presented in this technical Paper. Civil engineers were probably more interested in the highly-accurate measurement of short distances for which the Geodimeter was most suited.

Dr J. A. Sandover (joint-Author), in reply, wished to thank all those who had contributed to the discussion.

115. Concerning the trials of the MRA.3, he had no doubts but that the Ordnance Survey and the Directorate of Overseas Surveys would do sterling work testing this equipment and making their usual invaluable suggestions of possible modifications. At the Conference of Commonwealth Survey Officers in Cambridge, August 1963, a paper (No. 48) was presented by Mr A. S. Macdonald of the Directorate of Overseas Surveys on Field Trials of the MRA.3 Tellurometer in Bechuanaland. Mr Macdonald made a number of suggestions for possible improvements to the equipment.

116. Reference had been made to the use of lasers. A laser produced a highly concentrated beam of coherent light which could be used to transmit energy over considerable distances. It had been used in America in certain forms of opthalmic

surgery. If the light signal could be modulated it would be possible to use the laser as a basis of a distance measuring device. He had suggested such a use at the first Tellurometer Symposium in London in 1962, but the general attitude was that such a device was not possible in the near future. In fact, the Swedish army were using such a device which was portable and had an accuracy of ±5 m. Further, one industrial concern was now working on a similar but high-precision instrument, which they hoped to market within the next 18 months.

117. The question had been asked: 'What exactly had been the technical achievement of Dr Wadley in developing the Tellurometer?' The short answer was that it was like asking one's wife to shell peas while wearing boxing gloves. It was almost impossible but Dr Wadley had accomplished it. On the question of batteries, Mr Allan was known to have carried out considerable tests with the Tellurometer and was an authority on its use. It might be suggested that he asked the Chemical Engineering Department in his College to approach the Tellurometer Corporation on D.S.I.R. for funds for research in that direction. The manufacturers of the Tellurometer provided light-weight internal batteries for the MRA.3, but these required changing more frequently than the usual 60-A/h car battery. There was no doubt however, that as a demand developed, battery manufacturers would produce lighter batteries. In fact, the N.S.U. motor-car corporation used a relatively light-weight battery in their vehicles.

118. In reply to Mr Murray, Dr Sandover wished to state that all his figures were taken from literature supplied by Messrs AGA Ltd. However, the Author agreed that the Model 4 was capable of a higher degree of accuracy and was of considerable value in the measurement of shorter distances. Its daylight range, however, was only 800 m until the Mercury lamp was used in the model. However, it was thought that a mobile petrol generator was needed to provide the power for this lamp, the daylight range of which was 1500 m. There was the possibility that at these smaller distances, i.e. up to 1 mile, a development of the 'Mekometer' might prove to be a serious contender. Whatever the relative merits of the various instruments were, however, such competition was to the advantage of the user, since it spurred the manufacturers to greater efforts, and it was to be hoped that they might develop in the near future a simple device for the civil engineer for the accurate and speedy measurement of distances in the range 100–5000 ft.

Commander R. Bill (joint-Author), replying to Mr Allan, said that the Navy normally did plotting by drawing out a circular plot. The method used recently in Italy involved the use of printed range arcs on a transparency. The centres of these arcs were fixed on the two remote points and then positioned. That had been found to work extremely well. If it was desired to work on a very much bigger scale, for something like a dredging operation, the arcs could be computed, and the plotting could be done on, say, a metre to a centimetre scale if desired and the lines drawn in. One could go to sea with a board a foot wide and use an enormous scale with the stations 20 miles away.

120. The Authors had gone very deeply into the question of batteries. Commander Bill would like to hear of a good, cheap lightweight battery with a good reserve of power.

121. With regard to the training of personnel, the company ran training courses in London for operators. After taking the course, a man of reasonable intelligence should be able to operate the instrument and do ordinary, simple field maintenance. The course lasted five days, but the first had been only four days, the Monday being August bank holiday. In spite of this, those who took the course had done a very successful job.

122. The cost of a pair of instruments, which was the minimum equipment one could use, would be about £2500, with spares, etc.

123. On the subject of errors of refractive index, if one used the basic refractive

index, zero refractive index, one could get quite large errors, up to 30–40 cm, but if one used a mean refractive index for the approximate temperatures, humidity and barometer readings likely to be encountered, the errors were not likely to be more than 10–15 cm. For precise work, however, it was essential to find out what the refractive index was. Under reasonably static conditions it was quite safe for tertiary work or reconnaissance work to use a standard refractive index.

124. Permanent remote stations could easily be erected. The instrument could be put in a hut or a lighthouse with an extended aerial outside. If operating in a wide area, it was necessary to train the aerial and have someone to look after the set from time to time. It was fair to say that the remote instrument was semi-automatic, but not 100%; it had to be switched on, tuned and trained, but otherwise the operator did not have to do much to it. As for training to use the remote Hydrodist, the instrument was very simple, and in the recent Italian trials the Italian Navy were allowed to do all the work. It had taken one day to teach them and they had successfully carried out the rest of the work.

125. Commander Bill did not think it would be desirable to fit a theodolite on the top. There was no reason why a Tellurometer should not have a self-centring base similar to the Tavistock so that the Tellurometer could be lifted out and the theodolite could be slipped straight in. It was desirable to keep the equipment as simple as possible and not add too many frills to it, but if anybody wanted a Tellurometer to fit into the self-centring base of the Tavistock theodolite there was no reason why that should not be arranged. It would not be satisfactory to put the theodolite on top of the instrument; there would be too much vibration.

126. Dr Kaplan asked about Dr Wadley's contribution to surveying. There was no doubt that the Tellurometer had proved to be one of the biggest advances in surveying techniques since aerial photography came into being. That had been the previous break-through, and the Tellurometer was the next. Before that it was necessary to go back to dividing an accurate circle.

127. In reply to Mr Johnston the MRA.3 would be in production by about March 1963. The prototype had already been shown in this country at the Symposium in August 1962. The chief engineer of their firm was in Africa with the Director of Overseas Surveys and was, at the moment, doing field trials with the first production equipment; it was hoped to have the instrument in this country once those trials had proved satisfactory. It had a 3-cm wave and had a much narrower beam. The accuracy should be ± 1 cm and the same limitations and ambiguities and refractive index would apply. Reflexion should be very much less and it should be possible to use it for much shorter distances. The present trials had shown that it was possible to measure down to about 100 ft with an accuracy of ± 1 cm, but there was not enough information on that to make a definite statement. The cost would be a little greater.

128. Training had been mentioned more than once in the discussion. Any intelligent man could be trained to use the Tellurometer, whether the MRA.2 or the MRA.3, in a couple of days, so far as actual operation of the instrument was concerned. The training course which they ran at the moment was an introductory course and included a day's field training and a little maintenance. If instruction was given in a concentrated form, Commander Bill thought someone could be trained to act as remote in two or three hours. The finer details of a good or bad line were a matter of experience and he did not think that it would be possible to write a textbook on it.

129. On the question of terrain, when close to the ground on a flat line there was a tendency to lose signal strength, particularly when scrub and bushes were in the way. The instrument depended entirely on optical line of sight, or something very near it, and the more obstacles there were in the way the shorter the range. Sand absorbed the signal quite heavily and over a flat stretch of desert, although it might be possible to see the other station, the signal was usually weak, but by lifting the

instrument even 10 ft the performance would be improved considerably. With regard to the effect of trees, in Belgium, when measuring over the Ardennes from a tower, if there were very high trees, and particularly if the trees were wet, it was found that a lot of signal strength was lost and it was better to measure from a greater height if possible.

130. They had not tried to measure the distance of artificial satellites. Theoretically it was quite possible to do so and it was a subject which had been discussed but no work had been done on this so far. It would mean putting the remote instrument into the rocket or satellite. It would be quite an expensive method, but theoretically it should produce an answer.

131. As for tunnelling, the nearest approach they had made to measuring in tunnels had been to measure down a long corridor of 600–700 yd in the Ordnance Survey building. Quite a good result had been obtained. Usually the reflexions from the side of the tunnel with a 10-cm equipment would not allow a sufficiently accurate answer to be given for a tunnelling survey. The Ordnance Survey result had been 7–8 cm in 700–800 yd, and that was unlikely to be acceptable. The MRA.3 might give a very much better result, but that was not yet known.

132. The question had been raised of using separated aerials with a cable connexion between the dipole and the instrument. That cut down the range and there was a loss of signal strength in the cable. It was a battle between losing signal strength and gaining height and the answer was to raise the instrument if possible. With low scrub, separated aerials would be very useful, but with a 30-ft aerial the maximum range would be cut down about 50%.

133. Mr Davis referred to clearing the area in Nigeria. A tunnel of trees was as bad as a tunnel in the earth and there were bound to be reflexions from the trees, which would cut down the range more than anything else; but provided it was possible to get a reasonable swing, measurements could be made through quite a narrow gap without any trouble. Every time the signal hit a tree, however, the signal strength was slightly reduced, so that in the end there was not much signal left. There again the MRA.3 should be very much better, with a narrower beam and smaller reflexions, and they hoped that it would overcome some of the difficulties.

134. On the subject of the MRA.3 and 3-cm work, very little was known about this and very few trials had been done. He believed that the trials which were at present taking place in Africa were the first extensive ones to be carried out. The 3-cm wave was likely to have less penetration, so that the maximum range was likely to be cut down, and they did not know what effect snow and fog were going to have. He hoped that at the next Tellurometer Symposium in about three years' time he would be able to give a great deal more information about 3-cm Tellurometer work.