

The History of Tellurometer

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SUMMARY

This paper covers the development of the Tellurometer family of electronic distance-measuring instruments from the original specification, through the prototype and the subsequent models and systems up to the last instruments produced. The joint authors can claim almost 60 years of combined experience within the development of these instruments and will illustrate the different lines of application.

A timeline focus on the classic Tellurometers designed around the needs of Geodetic Survey shows how the models from MRA1 through to MRA7 were replaced as improved electronic technology became available with very little significant improvement in the accuracy or range of the products but with large leaps in the readout presentation and ease of use.

The Hydrographic models followed a similar technology path but prime development work was focussed on the problems arising from multipath effects generated from the proximity of large “ flat” reflecting water surfaces and the battle to find antennae that could resolve the issue.

The “commercial” instruments were generally the result of a request for a “cheap” instrument that could be used by the small firm and individual surveyors who wanted to use the products but could not afford the capital outlay that was standard in the governmental and military users’ domain.

The paper traces the product from the excitement of discovering new methods for surveying through the period of intense competition to the eventual replacement of the product by GPS systems and also highlights a few applications where the Tellurometer still offers a solution to a measurement need that cannot be replaced by alternative means.

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1. INTRODUCTION

Tellurometer logo

Before the Tellurometer or the Geodimeter were invented, surveyors had for decades or even centuries used bars, rods, chains and steel tapes for measuring distances, and compasses and angle measuring devices for determining directions. Triangulation was used for extending from base lines. In the 20th century radar was added to these devices for both distances and directions, and these led to Shoran and Hiran, both of which were used for long-range surveying but were not sufficiently accurate for normal land surveying. The Tellurometer introduced trilateration for extending control at an acceptable accuracy. This new form of instrumentation also established a new industry in Microwave instrumentation, later followed by infra-red measurement equipment. In Tellumat, the company which is the modern version of Tellurometer Pty. Ltd., this has developed into a centre of excellence in microwave technology, that currently develops digital radios (for the cell phone industry), microwave communications and transponder products.

After the Tellurometer, the next revolution in surveying technology was the use of satellite receivers. Firstly the Transit System Satellites and others like it and secondly GPS Satellites and others now joining the skies with them. Next came the laser scanners. Here we deal only with the Tellurometers.

2. ORIGINAL SPECIFICATION FOR THE TELLUROMETER

In 1954 Colonel H. A. Baumann, Director of the South African Department of Trigonometrical Survey, was familiar with the performance of Radar and of the Shoran and Hiran systems but was looking for a system with an accuracy of better than 1 in 100,000 at distances of up to 30 miles and none of the existing systems could provide this. His required system needed to be easily man-portable, work on line of sight and have a resolution of a few inches. This requirement was brought to the attention of Frank Hewitt in the Council for Scientific and Industrial Research (CSIR) in Johannesburg. The CSIR had plenty of other projects on hand and it was well into 1955 before there was an opportunity to give this project to anyone to look at. The person chosen was Trevor Wadley.

3. THE PROTOTYPE (WADLEY WITH PROTOTYPE)

In a remarkably short time Wadley, as he was often known, had drawn up a design, put together the necessary components and was making distance measurements. It is on record that the first “routine” measurement was made in the field between two beacons some 50km

apart to the North of Johannesburg on 14th June, 1955. The result was expressed in English Feet! Two slightly different equipments were involved; one was called the Master and one was the Remote.

4. ELECTRONIC PRINCIPLES OF THE TELLUROMETER

(MRA1 Block diagram)

(Diagram showing a comparison of two different frequencies)

The principles were apparently simple but, in practice, were actually complex. In the first Tellurometer model, commonly known as the MRA1, two slightly different equipments are involved. One instrument is called the “Master” and the other the “Remote”.

An instrument is sited at each end of the line to be measured and a radio link established between the instruments. The radio link is continuously maintained during the measurement process and the “housekeeping” tasks of alignment and operation using speech communications and signal strength measurement are performed on this “Carrier Wave”.

The Tellurometer is basically a time measuring device and this is achieved by measuring the phase of a frequency which has been modulated onto the carrier. On the early instruments this process gave a readout in nanoseconds which then had to be translated into distances by multiplying by the speed of radio waves, corrected by the refractive index of air.

Later instruments used frequencies which gave readouts directly in metres, already corrected for an average refractive index and arranged in a sequence which gave a series of differing “pattern lengths”. While the readout process was performed manually these pattern frequencies were in multiples of ten to avoid ambiguity and to ease computation. With digital readouts, of course, this is no longer necessary and the pattern lengths are chosen to suit the processing systems.

5. PRODUCTION OF THE TELLUROMETER MRA1

(MRA1)

The production was initiated by an order received for 6 instruments from a Mr. W. H. Miller, the Director of the Survey and Mapping Branch of the Department of Mines and Technical Surveys of Canada. He visited Cape Town to see the prototype and on the strength of that visit placed an order for the first six production receivers. The name Tellurometer was selected and the production facility of Tellurometer (PTY) Limited was set-up at Plumstead in Cape Town. There were initial difficulties because of ground swing. Measuring slope distance instead of horizontal distance gave comparison misunderstandings. These all were overcome, the Tellurometer proved itself and the Canadian instruments were delivered. M = Master. R =

Remote. A = Ancillary equipment. Tellus = Greek for Earth. Meter = measure. Hence Tellurometer MRA1.

6. TESTS AND TRIALS

(Wadley lecturing at Ridgeway Base)
(MRA1 on Jungfrau Glacier)
(Arthur Allen and MRA1 on Malindi – Isiolo traverse)
(Malindi – Isiolo traverse map)

In 1955, 1956 and 1957, news of the success spread rapidly throughout the world and test measurements were made in a wide variety of countries and climates. These tests and demonstrations were made in the UK, in Switzerland, in Canada, in Africa and in Australasia. During this period, the Canadians utilised the instruments very successfully in aircraft using a “line-crossing” technique. This also was used in Australia. New applications were being found everywhere. In Kenya, the UK Directorate of Colonial Surveys (DCS) had a 2½-year plan for a triangulation traverse from Malindi to Isiolo. Using the Tellurometer instruments this “2½-year” traverse was completed by trilateration in 28 days.

7. TELLUROMETER WORLD NETWORK FOR DISTRIBUTION

(Mr. Fixit (Monkey) servicing an MRA2)

The same three years (1955 to 1957) saw the development of a five-branched distribution network under the direction of the Cape Town headquarters, namely:

Tellurometer (PTY) Limited, Cape Town, South Africa.
Tellurometer (UK) Limited, Staines, England.
Tellurometer Canada Limited, Ottawa, Canada.
Tellurometer Inc., New York, USA.
E. L. Heymanson & Co. (Pty) Limited, Melbourne, Australia.

Through these five companies Tellurometer Instruments were supplied to many of the world’s National Survey Departments, Armies and Universities.

8. FURTHER DEVELOPMENTS

(Tellurometer Chronology)

1959 saw the development of the MRA2 and 1960 the MRB2 or Hydrodist, an instrument designed for hydrographic applications where one end of a measured line was fixed on land and the other end was on a ship and always moving. This was important for the Navies and harbour authorities of the world. Future developments can be streamed into three main

channels, namely “land survey”, “dynamic / hydrographic survey” and “infra-red distance measuring / engineering”.

9. TELLUROMETER LAND SURVEY DISTANCE MEASURING INSTRUMENTS

(Photograph of the MRA2)

(MRA2 in Canada)

The MRA2 incorporated both the Master function and the Remote function in one instrument and the power supply unit (PSU) was built into the main instrument housing. Since the accepted practice of measuring a line was to measure it from both ends, this dual function ability produced the benefits of having to carry only one instrument to each of the points of measurement instead of two (Master and Remote), no PSUs and only half the number of batteries. Power consumption was lower and so this also helped to reduce the battery load. The measuring result, instead of inches or millimicro-seconds, was now metres and centimetres.

(Wadley with MRA3)

The Tellurometer MRA3 was of modular construction and used transistorised circuitry (apart from the klystron for generating the carrier), had an improved accuracy of +/- 15mm + 3ppm because of the use of a 3cm (10GHz) wavelength, had an integral antenna protected by a radome and had the option of three different types of readout. A cathode ray tube as in the MRA1 and MRA2, or a digital readout, or a dial-readout. All of these gave results directly in metres. The more favoured readout in terms of numbers ordered was the “Dial Readout”.

(MRA101 in Greenland)

In 1964 the MRA101 was produced. This was directly compatible with the MRA3 but was much lighter in weight and also was solid state except for the Klystron that generated the signal output. The main part of the circuitry was contained on a single printed circuit board which made it much easier and cheaper to produce. This was primarily intended for civilian use.

(Inside an MRA101)

(MRA301)

Two years later, in 1966, the MRA301 was produced specifically for a U.S. Army requirement. This American order was placed with three separate customers – Tellurometer, Electrotape and ?Keuffel & Esser?. Each supplied one third of the instruments.

The housing and microwave feed of this instrument was specified by the military but, in principle, had a lot in common with the MRA101. The main differences were the grade of materials used, the need for sealing and an extended range of temperature operation

(MRA4)

1967 brought the Tellurometer MRA4. This was built with military specification components and gave an improved accuracy of $\pm 3\text{mm} + 3\text{ppm}$ because an 8mm carrier wavelength (35 GHz) was used. It had a very narrow (2 degree) beamwidth and therefore used a tilting head mounting. It was very good but was bulky and heavy – difficult for carrying up onto the roof of a Church tower – and more difficult to direction-find. The higher carrier frequency also reduced the range performance due to the greater attenuation through the atmosphere.

(CA1000)

The CA1000 introduced in 1971 was a completely different instrument, especially when compared with the MRA4. The weight of the MRA4 was 18kg excluding battery and a large battery was needed. The CA1000 was the first instrument to use a solid state source (Gunn Diode) which considerably reduced the overall power consumption. The weight of the CA1000 was 1.6kg excluding battery and only 4kg with an attachable battery that would last several hours. It used three different antennae. A standard horn could be used up to 10km, an extended range horn could be used up to 30km, and a parabolic antenna extended the range to a specified 50km although I have measured over 70km using that. The specification for this instrument was developed in the USA and the measuring unit was the American foot. When sold to other parts of the world, different frequency crystals were used and the final result had to be multiplied by 0.3 to obtain a result in international metres.

(MRA5)

Introduced in 1973, the Tellurometer MRA5 was built to a British Army specification and the Quality Control was especially demanding. MOD inspectors visited throughout the design and qualification programmes and the whole company upgraded its quality system to the DEF Stan 05-21 requirements, a relatively new requirement at the time.

(Tellurometer MRA5 photograph)

The readout was digital and the antenna could be connected either to the front of the control unit, or on top of the control unit or, using a long cable, to an adaptor at the top of a mast up to 25m from the control unit.

(MRA6 / CMW6)

It was another ten years before the next model of land instrument was produced. In 1983 the Tellumat CMW6 came out for civilian use and also the Tellurometer MRA6 for military

applications. The only difference between the instruments was the name tag and the accessories supplied. The basic instrument was a rugged sealed equipment capable of operating in really harsh environments. The weight was about a third of that of the MRA5. This instrument had extraordinary range performance, well beyond its published specification, due mainly to very careful layout which minimised earth loops and isolated the RF circuitry from the noisy microprocessor components. I recently took four instruments which had been sent in for service, more than 20 years after delivery, out on a long range check and all four had more than 25dB fade margin at 69 kms, my reference MRA7 which I maintain for comparison purposes, worked during this test with only 3dBin hand.

(CMW20)

This unit operates at 35 GHz and performs to the same specification as the MRA4 which was designed 15 years earlier. With the more modern technology it was possible to make a much smaller unit that consumed far less power and this product was highly successful in the Far East markets such as China. The unusual shape and pointing arrangement result from the antenna which is an offset parabola that has the advantage of being able to be closed down to protect the microwave components during transportation. Its similarity to a lady's powder compact and its bright orange colour gave rise to many ribald comments in the field.

(MRA7)

In 1985 the last of the land microwave instruments was produced – and these still are operating and being manufactured today . The weight was down to 4kg. It is interesting to note that the accuracy and range are similar to those of the Tellurometer MRA3 introduced twenty three years previously and 46 years ago now!The major application for the modern variant of MRA7 is as a safety system with communications and data link capability for use in deep mines. The system is installed in parallel with the normal winding gear and reports on slack rope and other operational problems associated with hauling both men and ore out of the mines. We seldom see problems with the units mounted in the headgear but the items mounted on top of the ore skips and even those on the cages (human transportation) are frequently damaged beyond repair by falling rocks and polluted water.

10. TELLUROMETER HYDROGRAPHIC AND POSITION FIXING INSTRUMENTS

(MRB2 on board ship)

The MRB2 hydrodist arrived in 1960. It was a variant of the MRA2 but with remote switching capability. The readout had to be taken from the CRT by means of a rotated bezel and it is easy to imagine the difficulties faced by these operators during rough weather.

(Illustration of the ABC System)

A year later saw the introduction, from the USA, of the AirBorne Control (ABC) Survey System. This was developed by the U. S. Geological Survey engineers. The system entailed setting-up an MRB2 (Hydrodist) Master unit and a theodolite at each of two known ground points and from these two sites observing distances and angles to a helicopter hovering vertically above an unknown point. The helicopter was equipped with a hover sight to achieve the correct vertical position, a height indicator to determine the height above the ground, and a high intensity rotating beacon to enable easy recognition from the two theodolite stations. The system was used for surveying in difficult terrain.

(Mike Mogg and Aerodist)

The next development in this arena was the MRC2 Aerodist. Two MRC2 Master equipments were mounted in the aircraft and a twin antenna dome was mounted underneath the fuselage. Two Remote equipments were set up on the ground, one at each of two separate points and the aircraft was flown at different heights between the points. There are various applications for the use of this system, but the principle feature is that the two ground points do not have to be intervisible. The use of an aircraft extends the length of line that can be measured. This operated at the lowest carrier frequency range of the Tellurometer family with a corresponding increase in the size of the microwave components.

(Hydrodist MRC12 photograph)

(MRB201 on Single Buoy Mooring)

(Tony Hamblin with MRB201 on oil tanker)

MRB201 was a highly successful instrument and had the first Digital Readout (DRO) system. The master and remote shared the same basic instrumental structure and were configured for the specific application by choice of a range of “Plug-in” modules. The remotes were frequently fitted with the DRO unit which enabled them to be used as a “Master “ in a static role so that the distance(s) between remotes could be determined to establish the measurement (position fixing) base line. A wide range of antenna configurations were designed to assist in the application of the equipment in many position fixing applications.

(Tellurometer MRB301 photograph)

There was a special plug-in unit for the MRB201 which enabled it to be connected directly to a computer so that the range could be downloaded at the speeds necessary for fixed wing applications. It was normally operated with an omni-directional antenna slung below the aircraft.

(CA1000D)

In 1975 a dynamic version of the CA1000 was introduced as the CA1000D. It was a low cost method of distance measuring for hydrographic applications.

(Tellurometer MRD1 photograph)

This was a full two or three range position fixing system with its own microprocessor based computer built in. The simultaneous measurement to three different remote stations made position fixing possible and the readout could be presented either as co-ordinates or as slope distances. The equipment was generally used together with depth sounding equipment and the results displayed in real time or stored in a computer. The remotes could be operated in a sleep mode for battery power conservation.

Two systems could operate in a multiplex mode in the same area, using the same remote instruments.

A wide range of antenna configurations were designed for various applications. The main difficulty when operating in confined harbour applications was the carrier reflections off the water and off many large metallic structures. Antenna diversity (changing height to avoid signal loss) slant and circular polarisation were all used to optimise the typical application but the knowledge of the nature of multipath signals and how to optimise each planned surveying operation were always the best formula for success.

Hydroflex is the same basic instrumentation as MRD1 but comes with slant polarised antenna and optional left/right indicators for applications such as dredging etc where a fixed course must be followed.

(Tellurometer MRD4 photograph)

11. TELLUROMETER INFRA-RED LAND APPLICATION INSTRUMENTS

(Tellurometer Chronology – again)

(Tellurometer Modlite photograph)

Development in this sector commenced in the early 1960s and the working prototype, the Modlite was produced in 1964.

(Tellurometer MA100 photograph)

(MA100 at Llyne Brianne Dam)

The MA100 was introduced in 1968. It had a resolution of 0.1mm, an accuracy of +/-1.5mm +2ppm and a range of 2km. It was possible to measure movements with an accuracy of 0.2mm even at the 2km range.

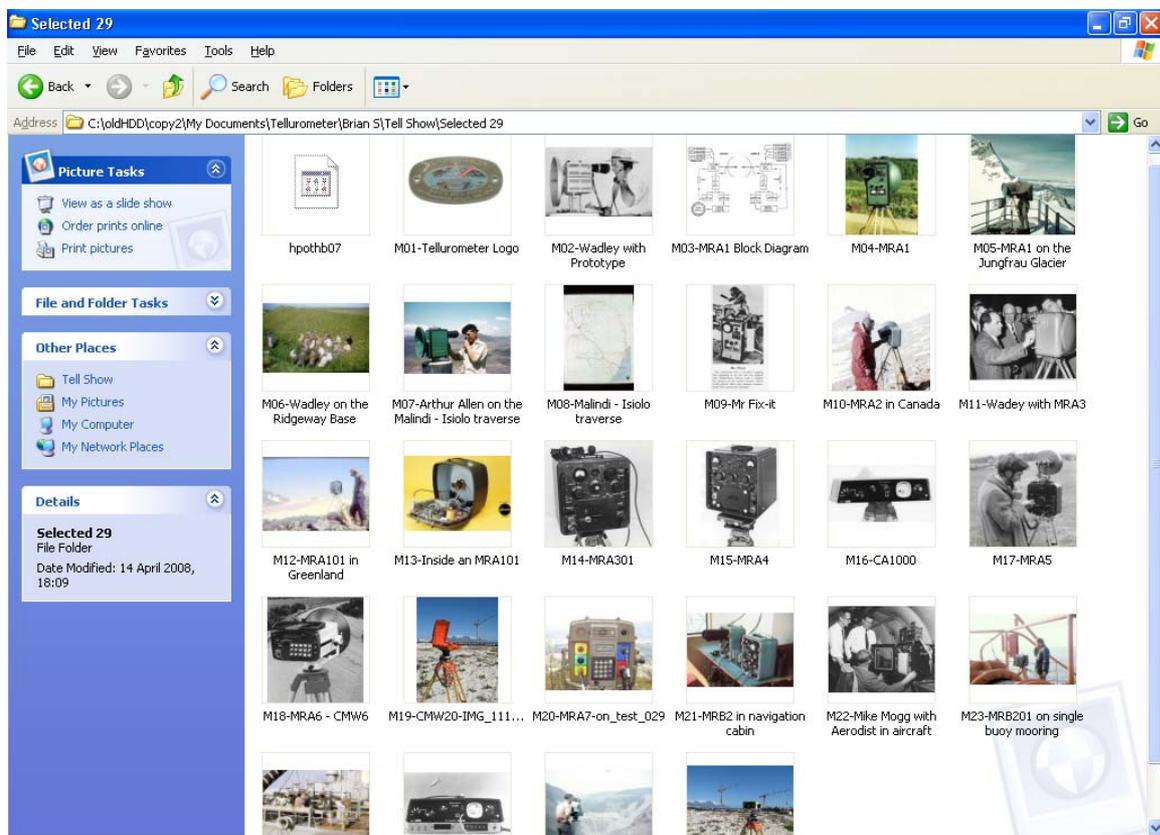
(CD6)

In 1973 the CD6 was born. It was a small, lightweight infra-red instrument operating over distances up to 2km with an accuracy of $\pm 5\text{mm} + 2\text{ppm}$. It could be used by itself mounted on a tripod or mounted on top of a theodolite.

(Tellurometer MA200 photograph)

In 1986, 18 years after the introduction of the MA100, the MA200 was produced. It can capture data at 50 measurements per second enabling it to measure structural vibrations up to 25Hz. Accuracy is better than $\pm 0.5\text{mm} + 0.5\text{ppm}$.

12. THUMBNAIL PICTURES



BIOGRAPHICAL NOTES

Alan Fredric Wright.

Early career was spent in education and training in mechanical engineering followed by research and experimental work on rocket motors and aero engines. Then trained in surveying and carried out field work in Antarctica for three years and wrote up results for 18 months, followed by three years as a site engineer for a construction company and then several years working for the Tellurometer company. In 1981 formed Global Surveys Limited, a company specialising in satellite surveying, particularly GPS. This led to undertaking many national and international surveying projects and to running training courses on gps and glonass equipment.

Brian Sturman,

Career spent in the electronics manufacturing industry, focussed on Quality Assurance in the development sector. Qualification of products, particularly the Tellurometer models from MRA3 through to MRA7, was a prime activity.

Other products managed ranged from PABX and POTS through Traffic Systems, Digital Radio's, Broadcast Transmitters, Defence, Radar and Space Class products.

Outdoor experience (field work) included the qualification of the Tellurometer instruments, mainly land and hydrographic instruments, under most operating conditions except for extreme cold (where our environmental chambers had to suffice).

Other field work included the laying of fibre optic networks in Malaysia, installation of Earth Stations for Satellite Communications and most recently the establishment of a Radio Telescope (15m dish) where a variety of new concepts were established prior to the building of a series of telescopes intended to form a square kilometre array.

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