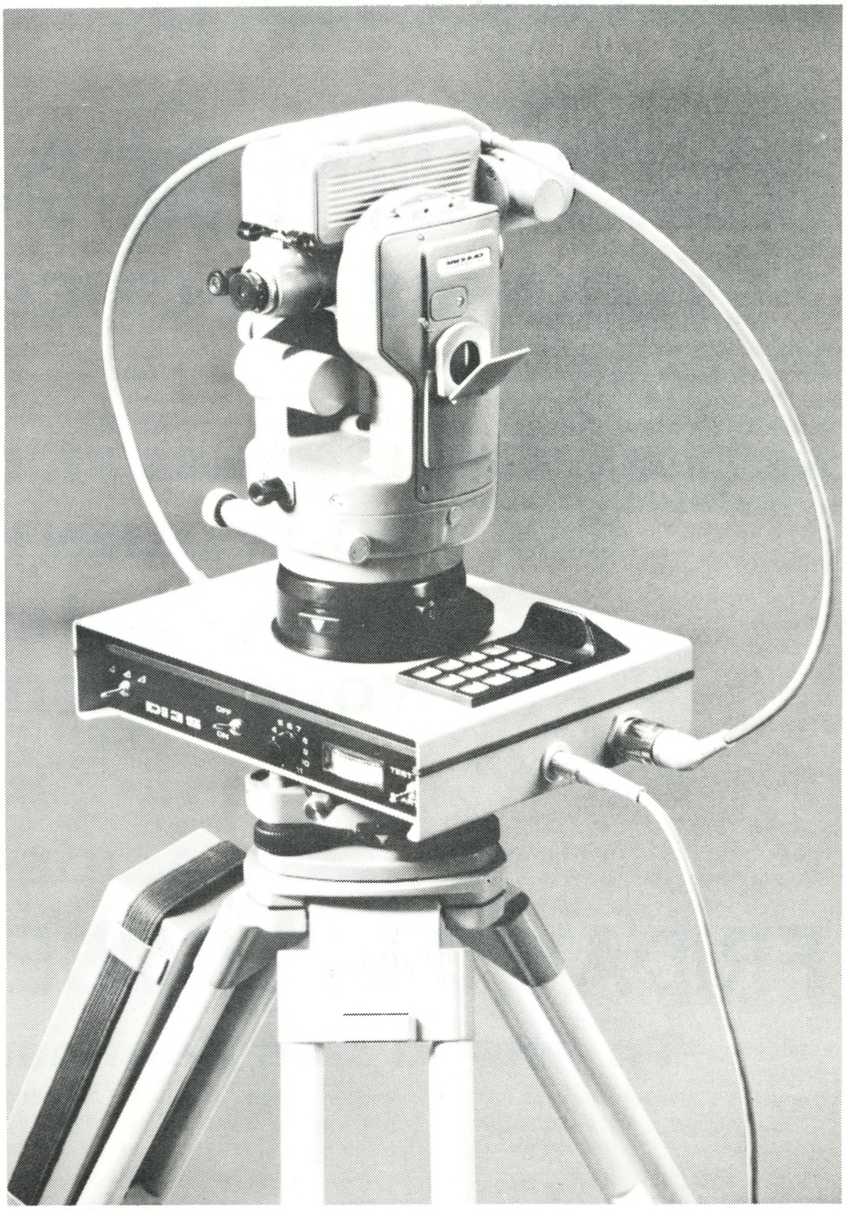
TECHNICAL REPORT

THE WILD D13S DISTOMAT

BY T. P. JONES, O.L.S.



The above instrument is an electro-optical distance measuring device and a computerised control unit. It is a product of Wild Heerbrugg of Heerbrugg, Switzerland and the Société d'Etudes Récherches et Constructions Electroniques (SERCEL) of Nantes, France. It is distributed in this country by Wild-Leitz Canada Ltd., and Norman Wade Co. Ltd.

The hollow axis of the control unit fits in any Wild tribrach; the top of it takes a Wild T1, T16 or T2 theodolite. The distancer, with counterweight, fastens to the telescope of the theodolite. The telescopes of the T1 and T16 will transit with this attachment.

The distancer measures a distance completely automatically to 2 000 metres in approximately ten seconds. Signal balancing and calibration are taken care of by the control unit. Its accuracy is claimed to be plus or minus 5mm plus 5ppm. Distances may be displayed in feet or metres at the discretion of the operator.

The control unit, besides monitoring the measuring cycle, computes horizontal distances, height differences and co-ordinate differences (latitudes and departures) from the keyed-in data. Angles may be keyed into the computer in the sexagesimal or centesimal systems.

What follows is a short description of the electronics in the E.D.M., and some remarks on such instruments in general.

When such a subject arises, the first thought that occurs is "To what extent should I, a land surveyor, qualify myself in the field of miniature circuitry and solid state electronics?"

I have used complicated optical instruments for years, and have never felt the lack of an ability to grind out a new objective lens for a first-order theodolite. In the unlikely event that I will ever need to replace such a lens, I will buy one from an expert lens maker, and probably have it installed and aligned by another expert under laboratory conditions. I can recognise malfunctions in my optical instruments, and can identify non-working parts which I can repair myself, or have repaired by others, as the circumstances dictate.

I think the same philosophy should govern our abilities with E.D.M. equipment. I do not believe that we should go to the extreme quoted by Bomford in "Geodesy" that 'geodesy is regarded as beginning when the waves leave the instrument and ceasing when they return.' But by the same token, we should not expect ourselves or newly qualified members of our Association to be on a par with graduate electronic engineers.

ELECTRO-MAGNETIC WAVES

The basis of the electronic distancer of the DI3S, as most others, is the speed of propagation of electro-magnetic waves. Light can be said to be a mixture of electro-magnetic waves of slightly different wave lengths.

The speed of these waves in vacuum is known to within very precise limits. In air, their speed is affected by barometric pressure, temperature and humidity. Some waves are affected more by one factor than another.

The availability of wavelengths for distance measurement is restricted somewhat to two bands or "windows"; those from 0.3 micrometre to approximately one micrometre (light waves and infra-red waves in the electro-optical instruments) and from about one to ten centimetres (so-called radio waves in the micro-wave instruments).

In these regions no strong absorption bands exist. Extremely short waves, such as gamma rays or x-rays, cannot be used because they are so readily absorbed by the atmosphere, and their range would be too short. Longer waves are too difficult to focus, and reflections, because of the divergence of the beam, cause problems.

The advantages of the micro-waves are their long range, and their ability to penetrate fog and haze. They are, however, more susceptible to temperature and humidity than the shorter light waves, and cannot give results to the same degree of accuracy over shorter distances.

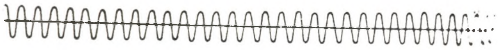
The light-waves are not so dependent upon temperature and humidity, have a very high accuracy over short distances and their transmitters consume little power. They do not penetrate fog and haze too well. This disadvantage is being overcome with the introduction of lasers; the Geodimeter 8, for example, could measure up to 40 miles.

The DI3S has a carrier wave in the infra-red range, having a wavelength of 885 nanometres. This is practically a light wave, of course, and as such is ridiculously short - about one hundred thousandth of a millimetre. By itself it cannot be used to measure anything.

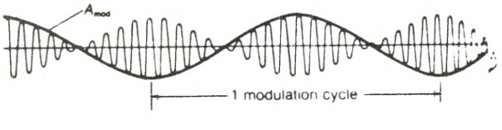
There is no definite position on this radiation that can be noted as it leaves the transmitter, and noted again as it is received at the detector. The radiation has to be marked with a signal, or modulated.

THE MODULATION WAVELENGTH

This can be done in several ways. By pulsing, or interrupting, the carrier wave, by modulating the frequency of the carrier wave, or by modulating the amplitude of the carrier wave. The last one is mainly used, gives the best results, and is used by the DI3S.



CARRIER WAVE



CARRIER WAVE - AMPLITUDE MODULATED

FIG 1

The carrier wave can be modulated indirectly or directly. It can first be generated and then modulated afterwards, just before it leaves the instrument, i.e. indirect, or the modulation frequency can be applied directly to the radiation, in this case the gallium arsenide diode generating the infra-red waves.

In the DI3S the opportunity has been taken to provide an eleven position "scale factor" switch to vary this variable power source (see block diagram). The atmospheric corrections, sea level correction, and even the projection scale factor, if it is not too big, can be applied automatically to the distance. Graphs for using the switch are provided by the Company.

The measuring frequencies, therefore, are transmitted to the amplifier which supplies the exciting voltage for the GaAs diode.

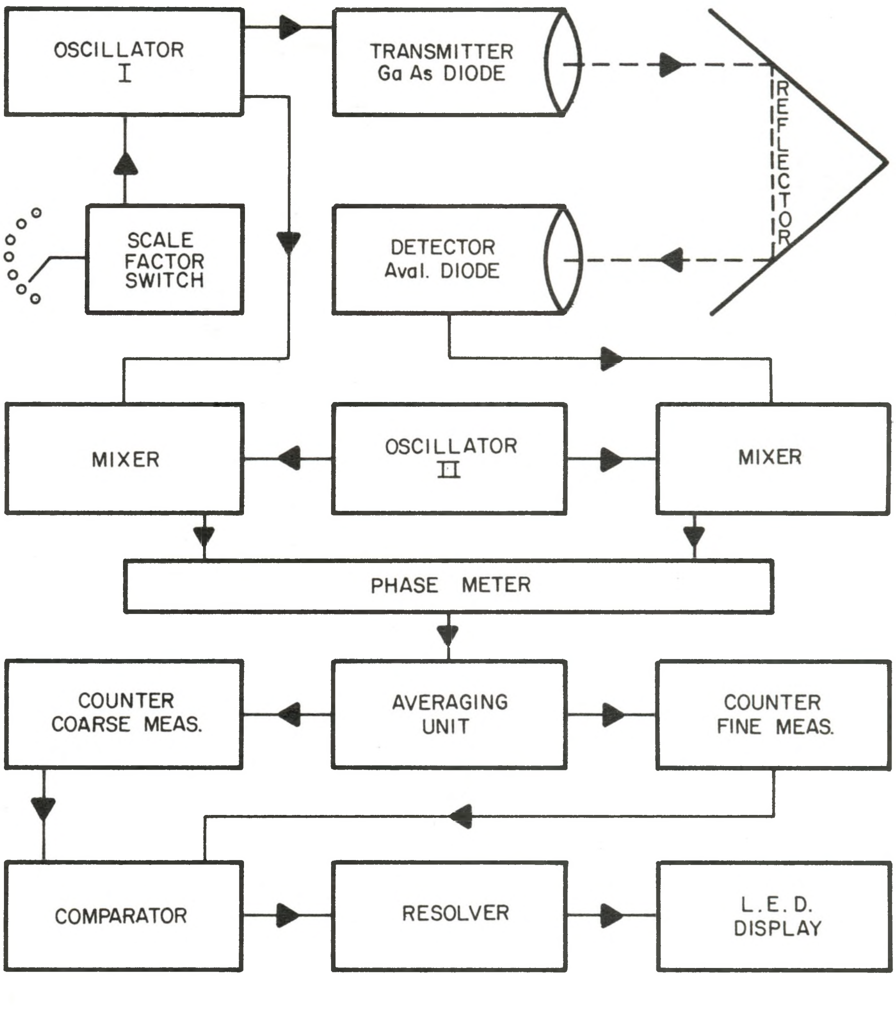
The radiation is bundled, or focused, by a 35 mm objective, reflected by a specially designed 'prism-target' combination at the far end of the line, and at the receiver, focused onto an avalanche detector by another 35 mm objective.

The modulation wave is of a much lower frequency, and consequently of a much greater length. It is the actual measuring frequency.

The wavelength chosen by the designer-manufacturer for any particular instrument depends to some extent upon what sort of work the instrument will be required to do, its accuracy, its range, and of course the state of the science of electronics at the time it is designed. The same economic principles apply for distance measuring instruments as hitherto applied for angle measuring instruments. Disregard of these principles will result in an inefficient and expensive hybrid.

The approximate modulation frequencies of some instruments are listed below (one megaHertz indicates a frequency of one million cycles per second):-

Mekometer	500 MHz
Wild DI60	150 MHz
Tellurometer MRA-4	75 MHz
Geodimeter 8	30 MHz
Kern DM500	15 MHz
Reg Elta 14	15 MHz
Wild DI10	15 MHz
Wild DI3S	7.5 MHz



DI3S BLOCK DIAGRAM

Note the high frequency used by the Mekometer. This is an extremely accurate instrument (one fifth of a millimetre - 0.2 - plus or minus one part per million up to a maximum range of three kilometres) developed by the National Physical Laboratory in London, England and manufactured by Kern, of Aarau, Switzerland. It is used for laying out nuclear machines in power stations and things like that. The Surveys and Mapping Branch of our Federal Department of Energy, Mines and Resources use it for measuring their series of base lines across the country. A separate report will be found in this issue on the installation, measurement, use and location of a reference line in Metro Toronto by Ralph Smith, O.L.S.

For a detailed description of the Mekometer, please refer to the July, 1968 issue of our O.L.S. Quarterly.

The lengths of the modulation waves produced vary indirectly with the frequencies. According to the definition of propagation, this is the product of wavelength and frequency, which is 300 000 km/sec. approx. The wavelength used in the DI3S, therefore, if you haven't figured it out already, is 40 metres.

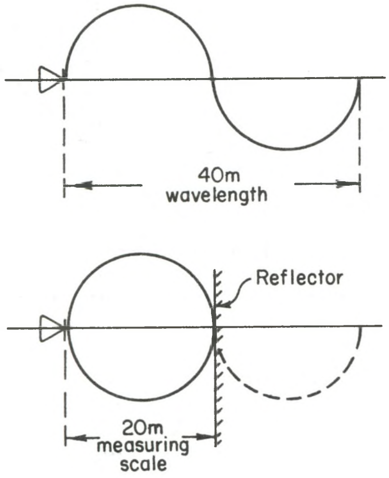


Fig. 2

Remembering that as the light travels the distance to be measured twice between the transmitter and the detector (both located in the same instrument) via the reflector at the end of the line, the "measuring scale" for the single distance is only one half of the modulation wavelength, in this case 20 metres.

Distance in most E.D.M.'s is determined by comparing the phase of the emitted light with that of the reflected light. Owing to the periodicity of the phase, if the fine measuring frequency alone were used, an unambiguous result would be obtainable only up to 20 metres with the DI3S.

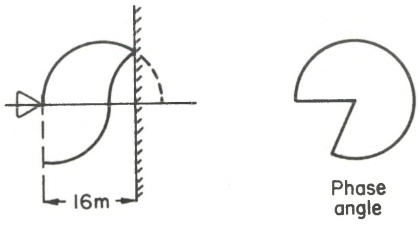


Fig. 3

Figure 3 shows the situation with the reflector set 16 metres in front of the instrument, and the corresponding phase angle. Figure 4 has the reflector at 36 metres in front of the instrument. The corresponding phase angle, of course, is identical with that in Figure 3. For longer lines, unambiguous determination of distance requires an additional measurement with another frequency. This second, or course, frequency today is usually chosen to be one hundredth of the fine frequency. In the case of the DI3S, this is 74.927 kHz, producing a wavelength of 4 000 metres, and a "measuring scale" of 2 000 metres.

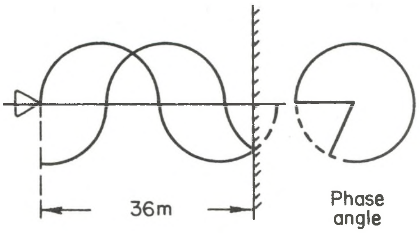


Fig. 4

The business of comparing the phase of the emitted, or reference, signal with that of the reflected, or measuring, signal has been attained in several ways in the past.

One is the direct reading of the phase angle on a circle of a cathode ray tube graduated in either units of seconds of the wave travelling time or in metric units of the wavelength. The pioneering Tellurometer models MRA-1 and MRA-2 are examples of this type of equipment.

SI PREFIXES

Multiplying Factor	Prefix	Symbol
1 000 000 000 000 000 000 = 10^{18}	exa	E
1 000 000 000 000 000 = 10^{15}	peta	P
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto	h
10 = 10^{1}	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	µ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

The compensation, or nulling, method, using a phase detector is another. The null balancing between the alternating current of the emitted and that of the reflected, measuring wave is observed on a galvanometer and the value of their mutual phase shift is read, usually on a three-digit counter. The Tellurometer MRA-3 and the Model 6 Geodimeter are examples.

The industry is now coming around very quickly to automatic electronic measurement, in which the phase shift is measured digitally in what is called a phasemeter.

Assuming that the fine measurement series in the DI3S is in progress, then two signals are at the disposition of the internal electronics in the instrument. One has the phase-position of the reference signal at its departure, and the other one the phase-position of the measuring signal at its return.

Even though the frequency of these signals at 7 492 700 cycles per second its drastically lower than that of the frequency of the carrier wave, it is still a bit too fast to measure the phase difference without some modification. So the two signals are transposed into a lower frequency range. This is accomplished by mixing the two signals with the frequency of a VCXO (voltage controlled crystal oscillator) which is 1544.89 Hz higher than the measuring frequency, and then filtering out the measuring frequency.

The figures go like this:-
measuring frequency = 7 492 700 Hz
VCXOF = 7 494 244.89 Hz
low frequency = 1 544.89 Hz
and to be mentioned in a moment,
counting frequency = 15 448 900 Hz

While this transposition is going on, the difference in phase between the two signals is fully preserved.

The two low frequencies are now applied to the phasemeter. When the reference wave passes through zero voltage, a gate is opened and a counter begins to run, counting the impulses of the above counting frequency, until the gate is closed again by the zero passage of the incoming wave.

A more detailed description of this function, with diagram, will be found with the account of the Zeiss Elta 14 in the Spring '77 issue of the Quarterly.

You will see that the choice of these frequencies enables a phase cycle to be divided into ten thousand parts. Thus each pulse represents 2 mm as the fine measurement is being carried out.

A counter chain then adds up the value of one thousand phase measurements of this type, and at the same time averages them out. This averaging process reduces the scatter of individual measurements due to signal noise, or interference.

Five hundred coarse measurements follow the fine measuring procedure.

This resolution of the phase angle to such a fine degree is a fairly significant step forward in the development of these instruments. To my knowledge, the previous best phase resolution was to one thousand. With a "measuring scale" of ten metres, this yielded one centimetre for each unit of measurement.

With this advanced capability, SERCEL accepted the unit of 2 mm, and a "measuring scale" of 20 metres. Thus the DI3S enjoys not only a 'finer' measuring system, but with no change in the rest of the circuitry doubles the unambiguous measurement distance from the usual 1 000 metres to 2 000 metres.

The whole distance-measuring process, from pressing the start switch to reading the slope distance on the L.E.D. display, takes about ten seconds. The Company suggests that during this time the instrumentman, instead of standing around admiring the scenery, reads the horizontal and vertical circles of whatever theodolite is being used.

All data, whether read from the display or the theodolite or computed on the control unit, must be recorded by hand.

Today we hear a lot about recording the measured data. The main argument of the advocates of automatic recording is that it eliminates reading and booking errors that we surveyors are alleged to make all the time. However, it is interesting to note from the recent experiences of computer centres, which handle both handwritten notes and automatically recorded field data, that the former methods of reading and booking are surprisingly reliable. It has even been established that the level of errors in surveys undertaken with self-recording instruments is definitely higher than with the former methods.

Automatic recording is supposed to lighten the task of the instrumentman, because it is only necessary to point and then trigger the measuring/recording cycle. However, before pressing the trigger, the operator must set in an address code that has to be selected from a list containing up to fifty code numbers. These cover both station and target identification as well as being the key to control the subsequent computation in the computer centre.

If the automated system is to work efficiently, it is essential that the entry of code numbers, which may sometimes run up to twelve figures, is done very carefully. This requires far more concentration on the part of the observer than merely reading the instrument, and is certainly not easy under field conditions, especially in bad weather or in heavy traffic.

Automated systems, therefore, would seem to be more suitable for those surveys in which hundreds of detail points of more or less the same type can be picked up from only a few instrument stations, so that the feeding-in of coded information becomes routine.

Technical data for the foregoing was supplied by Messrs. Doug Peden, Wild-Leitz Canada Ltd., and Dave Butler, Kern Instruments of Canada, Ltd., and the diagrams by Roger Grant, Surveys and Mapping, City Hall, Ottawa. Their assistance is greatly appreciated.