REPORT ON THE GEODETIC APPLICATION OF WIRELESS TELEGRAPHY

(Extract from the Report on Latitudes, Longitudes and Azimuths presented to the Section of Geodesy (International Geodetic and Geophysical Union) at Stockholm, August 1930, by H. L. P. JOLLY.)

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The history of wireless telegraphy has been largely that of a series of quick progressions, each following on a particular invention or discovery. The accidental discovery by amateurs in 1921 that short waves carried to enormous distances but might leave intermediate blank regions was a case in point. By 1923 the short wave system had found wide application in commercial circles and it now appears that it is rendering good service to geodesists in the field by reason of its reliability and the light weight of its equipment. The United States Coast and Geodetic Survey reports that a field receiving set with vertical antenna of 10 m. in height is now in use. The weight of the set is 35 lbs. (16 kg.) and that of the dry cell battery 10 lbs. (9 kg.). The particular wave-lengths used in the U. S. A. are from 19 to 75 m. and these have been received in the form of rhythmic signals in Canada and in the Argentine.

There are still anomalies to be met with in the use of the short waves. Reception may be difficult in some places at certain local times. In the case of long waves their automatic reception in polar regions is often rendered impossible by atmospherics.

The large question of the best method of receiving rhythmic time signals for precise work has not been settled. On examination of the records of the International Longitude Operation of 1926 it is found that less than half the 42 observatories which took part made use of the purely automatic methods of reception. This cannot have been entirely on grounds of economy and must be taken to indicate that considerable confidence is placed in methods involving the use of the ear. The advantages of automatic reception are obvious. It is extremely convenient and relieves the observer of a certain amount of fatigue. It also introduces an apparent gain in accuracy. Its disadvantages are not quite so obvious and are worth considering. In the first place both interference and low intensity are bad for automatic reception. A signal seen on paper does not possess the individuality that an audible musical dot or dash does. Amidst the confusion of atmospherics and other possible sources of interference the ear would pick out the desired signals by reason of their quality or "timbre". The case of failure of automatic reception and the consequent resort to methods of audition is quite frequent. Again, it must happen occasionally with every receiving set that the strength of the signals received is not as great as is desirable with the particular instrumental equipment.

It is in this border-line regions where automatic reception is only just possible that a danger point is reached and that unknown systematic errors may come in. Even when the reception is apparently easy systematic error is generally present and it does not seem likely that the artificial determination of time-lags quite overcomes the difficulty.

To give a concrete case :- The present writer, having occasion to make use of rhythmic time-signals for the purpose of gravity pendulum work, obtained the corrections to the time-signals from an observatory which habitually receives the rhythmic signals from several emitting stations.

The gravity pendulum makes a more exacting demand upon the time-keeper than even the determination of longitude does. In these circumstances it seemed worth while to obtain the additional check of another observatory on the time signals used. One result of this was to show that not only do observatories differ, as is well known, in their adopted absolute times but they may differ systematically in their estimates of short time intervals if the latter are defined by signals from two different emitting stations. In other words, the combination of a particular wireless signal emission with a particular automatic receiving set at a particular place leads to a systematic error in the recorded time of the signal.

To investigate the matter further, the daily recorded times of reception of signals from two sources by a certain two observatories were compared over a month. It was, of course, the finally adopted times which were compared. In the following table is shown the difference between the time interval of two hours as estimated by one observatory and that estimated by the other.

Day of Month	*At*	*Day of Month*	*At*	*Day of Month*	*At*
	s		s		s
1	+ 0.02	8	+ 0.02	19	+ 0.05
2	+ 0.03	11	+ 0.01	21	+ 0.01
4	+ 0.02	13	+ 0.00	22	+ 0.04
5	+ 0.03	14	+ 0.00	23	+ 0.02
6	+ 0.01	16	+ 0.04	25	+ 0.02
7	— 0.01	18	+ 0.04	26	+ 0.04
				27	+ 0.02

The clocks are of such high grade that their variations of rate over the two hours in each day have failed to mask the systematic effect, though such variations undoubtedly account for some of the fluctuations in the above figures.

The conclusion to be drawn is that, in rating clocks and chronometers in gravity pendulum work, it is important to use not only signal corrections from the same observatory at the two ends of the period over which the pendulums were swung, but also signals from the same source. Two or more observatories may, of course, collaborate provided they all observe the signals at both ends of the interval. The same remarks apply, though with less force, to the rating of clocks and chronometers in longitude determinations. The existence of this systematic error in the reception of wireless signals is probably already known to many people (1).

Automatic reception, then, is not the perfect solution of the problem that it appears to be. One source of small error resulting from differences of practice can easily be eliminated. Where there are slight inequalities of interval within one and the same set of rhythmic signals, or in the rate of movement of the tape or drum, the deduced time of the commencement of the first "dash" will depend on the selection of dots made on the chronograph for comparison with the time scale impressed on the same chronograph by the clock or chronometer.

It will be sufficient to specify certain dots and dashes for this purpose. They should have a somewhat irregular distribution in the series and should be sufficiently numerous to reduce the probable error of reading the mean signal, from inequalities and reading errors alone, to about $0^s.002$.

Amongst the automatic devices used to receive and convert into a chronographic record the incoming wireless signal two different tendencies are apparent. In the one group free use of relays of a mechanical type is made, so that the energy conveying or releasing the signal may change two or three times from the electrical to the mechanical and back again to the electrical.

(1) *Between the time of writing this report and the printing of it, the writer had the pleasure of conversing with* Mr. Einar ANDERSEN *of the Geodetic Institute, Copenhagen, and was given a copy of* Mr. ANDERSEN'S *paper* "Ueber die Korrektionen der Zeitsignale" (*Gerlands Beiträge zur Geophysik. Bd.* 23, *Heft* 4, 1929). *This paper is an intensive study of the differences between the corrections to the various European rhythmic time signals as determined by four different observatories. The period covered is six months during* 1928 *and the well-known seasonal differences between observatories are analysed. The systematic dependence of the difference between any two observatories on the particular signal received is also brought to light.* Mr. ANDERSEN *finds that, if he adjusts the corrections to time-signals accordingly, he obtains a much smoother rate for the clock throughout the period of* 16 *hours covered by the seven sets of signals in any one day.*

In this type great care has to be taken to eliminate *time-lags*.

In the other type, the whole of the amplification is done by the thermionic valve assemblage and the registration is done by a very sensitive galvanometer designed specially for the purpose. Of this type is the "Ondulateur" used by the Geodetic Institute at Copenhagen. All relays are suppressed and the "point d'angle" on the record is independent of the strength of the galvanometer current. The resistence of the coils is 1000 ohms and 1-2 milliamperes suffice.

In both types of apparatus the final recording is done by electromechanical means.

It does not seem impossible that an alternative should lie in the luminous effects produced in vacuum tubes of a certain kind by amplified currents coming from the wireless receiver.

If these could be photographed sufficiently quickly through a narrow slit on to a moving film, there would be no mechanical inertia in the system at all.

Semi-automatic devices appear to find increasing favour for the reception of time signals. In these the clock short-circuits the telephone head-piece or otherwise alters the tuning arrangements in the receiving circuits in such a way that one or more "dots" are just cut out at coincidence. By noting the gradual disappearance of the dots before coincidence and their gradual return to completeness after it a very accurate estimate of the several coincidences is obtained. Condensers placed across the clock contacts serve as shock absorbers and noise eliminators at the moment of contact. There is little room for systematic error in this method.

Coming down to still more personal methods of receiving rhythmic signals, there is the one in which hand-tapping on the chronograph key in coincidence with the audible incoming signals is resorted to. This method is by no means to be despised. The personal equation is only about one-tenth of its magnitude for non-rhythmic signals and it can be determined easily by means of an artificial set of rhythmic signals proceeding from the transmitter recording directly on the chronograph. The longitude of Buenos Ayres was recently determined by means of such hand-tapping of signals received from Washington. During the 6 nights on which observations were taken there was only an extreme range of apparent longitude equal to $0^{s}.1$ and this in spite of the use of the uncorrected signals from the transmitting station. The same method was used on the DE FILIPPI Expedition to the Karakoram and also in Italy in 1928, where no probable error in longitude as great as $0^{s}.02$ occurred. In this case the elimination of instrumental and personal errors was provided for by the observation on 12 nights of the known longitude Padua-Greenwich.

In all methods making use of a chronograph there is now a tendency to eliminate parallax by the use of a single pen to record all three events — clock beats, star transits and rhythmic signals. If the displacement of the pen caused by clock beats can be arranged to be in the opposite direction to those caused by the other two impulses such a simplification is ideal.

The equalisation of the currents from all three sources, where possible, is also to be desired.

The original coincidence method of receiving rhythmic signals is not so useful as any of those described above. For expeditions into difficult country where equipment has to be cut down to a minimum it will doubtless still find a use. It might be possible to design a transmitter for short waves in which the dots were taps instead of piping notes. The coincidence of these with the taps given by a chronometer would be much easier to observe than that of existing rhythmic signals.