Explanation of Plate XX.

(A.)—Reproduction (reduced one-fifth) of Foucault-pendulum photograph (geogyrogram) taken 1916, March 4, from 2 h. 37 m. 54 s. a.m. to 4 h. 37 m. 55 s. a.m., (Sydney standard time). The exposures (in pairs) were made every five minutes, and the change of azimuth in the intervals is clearly seen. The twentieth pair of exposures was missed, owing to an accidental interruption.

Sh. indicates the edge of the occulting shutter or screen during the five-minute intervals.

C. is the zero-point of the oscillations.

(B.)—Cardan Suspension (see text-figure 4).

(N.B.—Text figures not strictly to scale.)

WIRELESS TIME SIGNALS—SOME SUGGESTED IMPROVEMENTS.

By W. E. and F. B. Cooke.

[*Read before the Royal Society of N. S. Wales, December 6, 1916.*]

Anticipating a re-determination of Australian longitudes by means of trans-Pacific radio signals, some experimental work has been recently undertaken at the Sydney Observatory, with a view of eliminating certain sources of error.

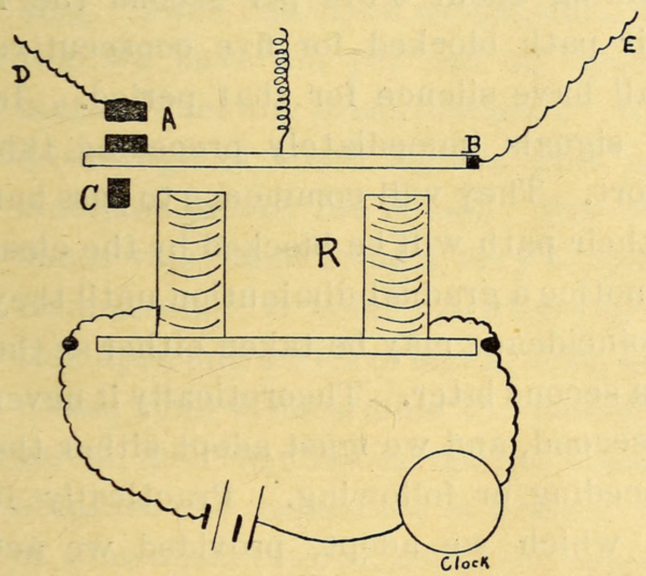
Prior to the war great and rapid progress was made with the new methods, culminating in the determination of the difference of longitude between Paris and Washington by means of radio signals across the Atlantic. In the course of this work every possible precaution to ensure great accuracy was taken. The results were undoubtedly good, but one gathers from the remarks of M. Baillaud (Director of the Paris Observatory) and others that there are still some outstanding difficulties which will have to be met and overcome.

With those of a purely astronomical character we are not here concerned. The object of this present paper is to indicate a method whereby two clocks or chronometers separated by some 5,000 miles or so may be compared with an error not exceeding one-hundredth of a second, and with entire elimination of personal equation.

In order that our remarks may be followed it will be advisable to briefly indicate the general features of the whole operation, and the special difficulties to be attacked.

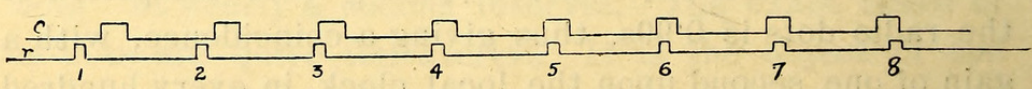
Three, or perhaps four, stations are concerned. Let us call the two astronomical stations (or those which contain the clocks to be compared) A and B. A third station C (the transmitting or signalling station) contains some piece of apparatus which radiates a series of "dots" regularly spaced at intervals of *nearly*, but not quite, one second apart. This station should preferably be about midway between A and B, but if this is impracticable, we shall probably have two stations C_1 and C_2 close to A and B respectively, and each acting alternately as a transmitting station. For definiteness we shall suppose a single station C. For example, if A and B were the Sydney and Lick Observatories, C might be at Honolulu: or with A and B at Sydney and Honolulu C might be at Nauru (near the equator).

All we expect from C is a series of regularly spaced "dots" at nearly a second interval. The exact times of the dots are quite immaterial. It is the object of the observers at A and B to receive this series of arbitrary signals and compare them with the beats of their respective clocks, and this is accomplished by the well known method of coincidences. Our problem now resolves itself into this—to determine the exact seconds at which the *C* signals coincide with the beats of our *A* (or *B*) clock. The principal difficulty seems to be this—that a very short sharp "dot" cannot be radiated and received over long distances, and that if the dot is of an appreciable length different observers take different parts of it to form their coincidences with their clock beats. The personal element also arises from the fact that the sound of the radio signal generally differs greatly from the sound of the clock beat, however it is introduced. We propose to avoid both these difficulties and eliminate the personal element by means of the following simple mechanical device.



The clock circuit, as usual, passes from the clock contacts through a battery to the relay *R*, and for all practical purposes *R* is the clock. The armature of the relay is pivoted at *B* and normally rests against the stop at *A*. When the seconds-impulse comes from the clock the contact *A* is broken and the armature rests against the stop *C*. Let us now interpose the contact *A* in the path of the incoming signals. That is, let *D A B E* be in series with the aerial. THAT IS ALL. Let us follow the sequence, supposing that the period of the radio dots is 0·99s, thus giving a coincidence, with a gain of one second upon the local clock, in every hundred seconds.

With relay open, as shown in the above diagram, the radio-dots come through uninterruptedly, but with relay closed, the radio circuit is broken and we hear nothing. For brevity, let us call the clock circuit *c* and the radio circuit *r*, and note that it is essential that the duration of the periodic closing of *c* shall be greater than the duration of the *r* signal. *E.g.* if the *r* signal occupies 0·1s, then the *c* must close every second for 0·15s or any period longer than this. There need practically be no limitation to the length of the *r* signal, provided that the *c* impulse is a trifle longer. There will thus occasionally occur a condition when *r* tries to come through but finds *c* closed and consequently no path available, and we shall then cease to hear the *r* signals for a time. Taking the above figures, this overlap will be 0·05s, and with *r* gaining about 0·01s per second the *r* signals will find their path blocked for five consecutive seconds, and we shall have silence for that period. In addition, the few *r* signals immediately preceding this silence will be cut short. They will commence to pass but almost immediately their path will be blocked by the closing of *c* and we shall notice a gradual diminution until they finally cease. The coincidence may be taken either as the last audible signal or a second later. Theoretically it never occurs at any exact second, and we must adopt either the one immediately preceding or following. Practically it makes no difference which we adopt, provided we act systematically; and then even the third place of decimals will in the long run be just about correct. To those accustomed to chronographs the following diagram may help to make the matter clear. The whole sequence is purposely exaggerated.



These two irregular lines show the records as they would appear if one could transfer them to a chronograph.

At 1 and 2 the signals come through without interruption. At 3 the signal starts but is broken when *c* closes. At 4 the same thing happens, but the making and breaking of *r* is almost simultaneous, and we hear a very short sharp dot. At 5, 6, and 7 *r* cannot get through and we hear nothing. Real coincidence occurs between 4 and 5, and we may make a rule to take either, provided we adopt the same rule at both *A* and *B*. It may perhaps be as well to point out that the shortening of the *r* signals in this way is quite different from the (unsuccessful) attempt to *send* short sharp dots by shortening the duration of key-closing at the transmitter. In our case the signal may normally be of any duration, and we do not interfere with it until it actually begins to sing. *Then* our clock automatically cuts it out. In practice we have not yet had an opportunity of testing the method over any great distance. We have, however, taken advantage of some signals sent by the Riefler clock at Adelaide (about 700 miles). The determination of coincidence was found to be a very simple matter and quite free from strain. It is far more easy to concentrate the attention upon one series of signal dots, and ascertain when they cease, than to determine the moment of coincidence of two series, and requires no special training. We occasionally obtained the assistance of friends who had no experience of time observations, and their determinations of the exact moments of coincidence always agreed with our own.

Incidentally a few side issues may be worth glancing at.

(1) It is obvious that *one* transmitting station, where possible midway between *A* and *B*, is preferable to two. We may then feel pretty certain that the arbitrary signals reach *A* and *B* practically simultaneously.

(2) In Australia the spark and crystal system still holds sway, and we understand that it is also in use in England and France. Through the courtesy of Mr. Ormiston, an American operator, we have been introduced to the arc system, and have been so fortunate as to obtain one of

the latest forms of oscillating Audion receivers. In our opinion this combination is greatly superior, for several reasons. In the spark system no current passes until the key is closed, and then some little time must elapse before radiations actually commence. In the arc system the current is flowing through the aerial continuously, and the action of pressing the key simply shorts a few turns of wire in the inductance and thus alters the wave length. It is quite probable, though we have not yet had the opportunity of testing the question, that very short sharp dots can be sent by this method, if required.

Then again, the tuning of the arc can be made far sharper than the spark, and the Audion is very much more sensitive than the crystal. *E.g.*, with our little aerial at the Observatory we have no difficulty in hearing Tuckerton (New Jersey) at a distance of about 10,000 miles. It would be a simple matter to choose some wave length sufficiently distinct to be free from interference, and to tune sharply, so that we should hear nothing except the time signals and the atmospherics.

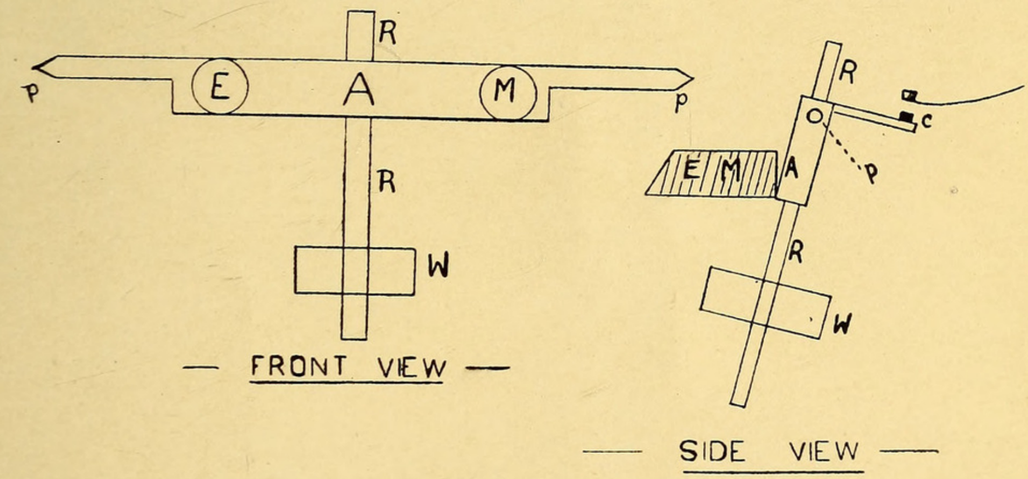
Finally the receiving observer makes his own "tune." That is, he can control the oscillation of his Audion so as to bring the signals to any musical pitch he desires, and by raising this sufficiently he can cause such a difference between the sound of the dots and the lower growl of the atmospherics, as to very considerably reduce the annoyance from the latter.

(3) The main principle can easily be used for the comparison of local clocks or chronometers, in particular for comparing mean and sidereal times. In this case the mean time clock takes the place of *c*, and the sidereal of *r*, and the latter instead of being in series with the aerial, is placed in series with a battery and high-pitch buzzer. With this arrangement not only can coincidences be obtained

with the greatest ease and certainty, but the slightest want of beat (irregularity of seconds) can be immediately and obtrusively detected.

(4) Alternatively, the radio signals can be made to *lose*, instead of gain, about one second in one hundred, and this appears to us to be rather better. In this case coincidence occurs at the *first* perceptible tick after the silence, instead of the last heard. It seemed to us to be easier to describe the gaining arrangement, but our own personal feeling is in favour of the losing ticks.

(5) It is an essential point that the duration of the closing of c should be slightly longer than the length of the *r* ticks: and to ensure the practicability of always obtaining this adjustment it is advisable to have some form of slow-acting relay. There are several on the market, but amongst those which we have seen, nothing appears to be quite suitable, so the following form was adopted.



In the above, *E M* are the electro magnets; *A* the armature, pivoted at *p p*; *R* a light rod passing through the armature and carrying a weight *W*; c the contact between the armature and a light spring.

Normally the clock circuit is closed, and broken momentarily every second. Therefore as a rule the armature rests against the magnets, but when the current is broken it acts as a pendulum, swinging away and forming contact at c for a period that is determined by the position of the weight *W*. This arrangement has been in use for another purpose at the Sydney Observatory for several months and works very satisfactorily.