between the two systems will be preserved, and any interval, however long, can be expressed in terms of the atomic unit. A time system of this kind, in which interval is based on the atomic unit but epoch on astronomical measurements, has been provided by the National Physical Laboratory for the past two years. It has caused no difficulties and has already been used for measuring the variations in the period of rotation of the Earth[12].

These problems have been discussed with my colleagues, Drs. H. Barrell and L. Hartshorn and Mr. J. V. L. Parry, and the form in which my views are presented owes much to these discussions. This communication is published by permission of the Director, National Physical Laboratory.

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## Delayed Signals in Ionospheric Forward-scatter Communication

IT has been reported[1] that long-delay multipath effects were observed when pulsed transmissions on 37 Mc./s. from Gibraltar were received in the United Kingdom during very high frequency forward-scatter propagation measurements. Delayed signals at multiples of approximately 20 msec. up to 80 msec. and traces of later components with about 130 msec. delay were detected. It was suggested that these were caused by a combination of reflexions at the $F2$ region and ground back-scatter behind the transmitting aerial, but the possibility of round-the-world propagation was discounted. The earlier delayed echoes were most probably due to the mechanism suggested, but observations at the Radio Research Station have shown that the signal with the longest delay was more likely to be due to round-the-world propagation.

Soon after the start of transmissions in March 1956, a weak pulse of intermittent nature was seen having a delay of about 140 msec. relative to the direct pulse received by $E$-region scattering. In the autumn, when $F2$ ionization was increasing, the pulse was again detected and was strong enough for its characteristics to be observed (see Fig. 1). Little distortion of the delayed pulse was apparent, showing that ground back-scatter was not involved. Directional measurements indicated that this pulse was arriving from the direction of Gibraltar and close to the great-circle path. The echo was most persistent during 0900–1030 hr. U.T., and at this time the complete great circle path was close to the twilight zone. Repeated echoes at 140 msec. intervals were occasionally seen similar to those observed at lower frequencies[2,3]. All these characteristics indicate that round-the-world propagation was occurring.

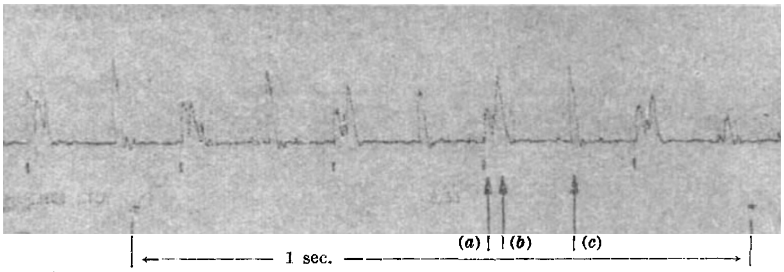


Fig. 1. High-speed record of pulses received at Slough. Time: 0916 U.T., October 18, 1956. (a) $E$-region forward scatter pulse; (b) $F2$-region and ground back-scatter pulse; (c) round-the-world echo.

Measurements of the time delay of the pulse were made and gave a value greater than that previously reported[2] for frequencies of 10–20 Mc./s.; this suggests that a longer effective transmission path is involved at 37 Mc./s. Possible mechanisms for this type of propagation and its effect on communication by $E$-region forward scatter are being studied and a full account of the work will be given later.

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## Ionospheric Studies by the Lunar Radar Technique

INVESTIGATION of the ionosphere by the lunar echo technique is now being carried out at the Defence Research Telecommunications Establishment near Ottawa.

The transmitter consists of a klystron power-amplifier capable of delivering to the antenna better than 10 kW., in continuous operation. The exciter, which drives the power amplifier, operates at 488 Mc./s. derived by multiplication from a 1 Mc./s. crystal standard, stable to about 1 part in $10^9$. The receiver is fed from a pre-amplifier which has a noise figure of 5 db. and a gain of 20 db. Local oscillator injection-frequencies are obtained from a crystal standard similar to that used at the transmitter. The receiver is a dual-conversion type with intermediate frequencies of 32 and 4 Mc./s. Synchronous detection is employed to give an audio output signal equal in frequency to the Doppler shift of the signal reflected from the Moon. An improved signal-to-noise ratio is obtained by following the Doppler shift with a narrow band-pass filter of variable centre frequency.

The transmitting antenna is a horn mounted at the focus of a 28-ft. paraboloid. The radio-frequency