earth will produce an error in the form of an apparent diurnal variation in the speed of rotation of the earth (since the fringes are stabilized relative to a direction that now has a diurnal motion). Again, from many observations spread out over the day, some of these errors can be deduced. The magnitude of day-to-day changes in the direction of the pole is likely to be enough to enter into these considerations. The best solution obtainable from all the data would include a determination of this effect.

The system discussed here is, of course, elaborate. Nevertheless, it may be worthwhile setting it up, not only for the more precise measurements of the motion of the earth around its center of mass, but also for the determination of distortions of the surface and other geophysical effects, and possibly also for the determination of proper motion in radio sources. Very precise measurements are often used not only to determine the magnitude of known or expected effects, but also to search for new ones.

Note added in proof. The technique of independent radio interferometry has been successfully demonstrated by at least two groups, a combined Canadian group (*3*) and a group from the National Radioastronomy Observatory and Cornell University (*4*). The results indicate that there are a large number of radio sources with structures smaller than 0.01 second of arc.

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Implications for Geophysics of the Precise Measurement of the Earth's Rotation

Abstract. *A radio interferometer could yield an error on the order of 10^{-9} second at the semidiurnal frequency. With errors of this magnitude, yearly changes in the rate at which the earth's rotation is slowing down could be determined. The proposed interferometer could also yield significant improvements in the determination of the Love number* k *and its variation with frequency, and in the changes in angular momentum of the atmosphere for periods greater than 1 week.*

The determination of the length of day depends both on the precision of astronomic observations and on the time standard by which the length is fixed. Precision of the time standard depends on two things: the precision in the clock rate and the precision with which it can be read. As a consequence of the development of hydrogen maser oscillators and accompanying electronics the precision in time standard can now approach one part in 10^{14}. The limit in determination of the length of day for periods shorter than about a year lies in "reading" the rate of rotation; that is, in astronomical observation determining the right-ascension transits of predetermined stars across the meridian (*1*). Gold (*2*) outlines a scheme reducing the error in fixing the variable rate of rotation, m_3(t).

The probable error $\mathcal{E}$ of a time sight from one night's observation is about 5 msec, as calculated with conventional astronomy (*3*). Gold suggests that with a two-point interferometer variation in the rate of rotation may be determined to a precision corresponding to an angular displacement of 10^{-7} radians, for an observation of a radio source lying near the equatorial plane. The precision of a single determination would thus be about 1 msec or even less, if a fraction of a fringe width can be recognized.

The mean square error of observation of N sources is $\mathcal{E}^2/N$. Values of the rotation rate can then be obtained at intervals of M days where N radio sources have been observed in the M days. For maximum geophysical information, M should be ¼ or less, since this sampling rate permits the determination of fluctuations in the time whose period exceeds ½ day. In principle, such high-frequency terms could also be obtained from nighttime optical astronomical observations, but this would require the combination of observations from the different observatories as well as a marked improvement in precision. There would remain errors associated with the differing instrumental techniques of the various observatories. In the case of the radio interferometer, a single installation is sufficient, although care must be exercised to remove properly the day-night fluctuation due to ionospheric conditions.

The spectral density of the error in the rate of rotation is

$$(2\pi f)^2 (2N/N)\Gamma\mathcal{E}^2 = (2\pi f)^2(M/N)\ 0.2 \text{ second for } \mathcal{E} \approx 1 \text{ msec} \quad (1)$$

where f is the frequency under consideration and Γ is the length of day. The error spectrum of the suggested radio interferometric measurements would be at least a factor of 25 less than that of modern optical techniques. At the semidiurnal frequency, the error spectrum is 1×10^{-9} second for four radio sources observed during a 6-hour period.

The spectrum of variations of the rate of rotation is composed of two parts. There are spectral lines centered at annual, semiannual, monthly, fortnightly, diurnal, and semidiurnal periods, and there is a continuum. The lines are in part due to the tidal alteration of the moment of inertia, and the continuum is presumed to be the result of motions within the atmosphere, oceans, and core.

With conventional astronomical techniques it is possible to determine the annual and semiannual variations and the continuum for periods between several years and several months. It is barely possible to determine the tidal effects for the monthly and fortnightly periods. For a variety of reasons the higher period fluctuations are of great interest to geophysicists. The long-term slowing down of the earth's rotation due to the tidal friction interaction with the sun and moon depends on the amplitude and phase of the semidiurnal tides. In the past, this rate has been determined by combining astronomical observations over several centuries or observations of eclipses over longer periods. A precise determination of the semidiurnal fluctuation in the length of day will permit a fresh determination of the amplitude and phase of semidiurnal tides and thus will permit examination of whether or not the long-term retardation is constant or fluctuating. This is important in considerations of the origin of the earth and moon, since discussions of the dynamical history of the earth and moon depend on the identification of frictional processes, whether they lie within the solid earth or in the oceans (*4*).

A spectral line, $m_3 = M_3 \cos 2\pi f (T + \varphi)$, of amplitude M_3, frequency f, and phase φ has a mean-square value of $\frac{1}{2} M_3^2$, which is spread over a frequency interval T^{-1}; T is the length of record. The spectral density is then

$$S(f) = \tfrac{1}{2} M_3^2 T = 2.5 \times 10^{-16} \quad (2)$$

for $12^{h}.42$ lunar tide for frequency interval T^{-1} centered at f. A year's observation of the length of day with a radio interferometer gives a spectral density at the semidiurnal period of 10^{-8} second, a value comfortably above the noise level. Radio star determination of the length of day would thus permit a study of the yearly variations in the retardation of the earth's rotation period.

The amplitude of the tide depends on the Love number k. In Eq. 2, k has been assigned the conventional value of 0.29 (*1*). It provides a measure of the deformability of the planet Earth, which depends not only on the elasticity of the mantle but also on motions within the earth's fluid part. At present, k is determined from observations of the Chandler wobble, having a period of 14 months. A precision determination of the spectral lines in the fluctuation of the length of day permits an investigation of the dynamic response of the core to tidal excitations at a variety of frequencies. This is of great current interest because it is possible that the driving force for the earth's magnetic field is dynamical in origin (*5*).

The precision investigation of the spectral lines is likely to yield significant data regarding the earth's interior and possibly frictional processes within the oceans. Investigation for the continuum at higher frequencies than has been possible in the past will be of greatest importance to meteorology. The error spectrum in the radio interferometer for a fortnightly period is about 10^{-12} second. Atmospheric variations can give rise to fluctuations exceeding this by substantial margins. Thus, it will be possible to determine the variations of angular momentum of the atmosphere for periods longer than 1 to 2 weeks. This determination, coupled with satellite determinations of the heat balance within the atmosphere, will make possible detailed investigations of major weather anomalies, their thermal sources, and their influence on the large-scale dynamics of the atmosphere.

The only system so far proposed which would be competitive with Gold's suggestion for precise determination of variations of length of day is that of Alley and his associates (*6*). In their system, an optical corner reflector would be placed on the moon and illuminated by a ground-based laser; the varying range would then be obtained. This determination of the earth's rotation rate with respect to the moon yields an expected accuracy of about one part in 10^8 for a 1-day interval. In order to obtain the earth's rotation, the moon's motion must be very accurately separated from it. The combination of observations of the kind suggested by Gold and those of an optical reflector on the moon would improve our information about the earth's rotation and the moon's motion. The combined information would then strengthen the basic dynamical data of the solar system.

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New Reflected-Light Microscope for Viewing Unstained Brain and Ganglion Cells

Abstract. *We have designed and constructed a new type of reflected-light microscope to form images including only light reflected near the plane of the object. This selectivity of image formation is based on a mechanical flying-spot technique. Objects difficult or impossible to see with earlier microscopes, such as unstained cells and cell processes in brains of living salamanders and in excised dorsal root ganglia of frogs, have been observed routinely with this microscope.*

A new type of light microscope makes possible observation of brain cells and brain-cell organelles in living vertebrates over extended periods. Conventional transmitted-light microscopy, including phase and interference microscopy, is unsuitable for such observation because of the thickness of the material to be examined. Because light reflected back into the microscope from many different layers of tissue degrades the quality of the image of the object, conventional reflected-light microscopy is usually unsatisfactory with low-contrast, translucent material such as unstained brain tissue.

The new microscope was designed to scan the optical field in order to eliminate much of the unwanted reflected light and to take advantage of the contrast-enhancing properties of an illuminated field of small diameter (*1*). A disc of copper foil, 20 μ thick and 85 mm in diameter, was perforated near its periphery with 26,400 electrolytically etched holes approximately 90 μ in diameter, with an average shortest distance between centers of 280 μ; the holes were arranged in Archimedean spirals. The disc was reinforced and placed between the light source and the objective (Fig. 1). The image of the light source was focused on one side of the disc; only light passing through the holes in the disc illuminated the object. An image of these holes was formed by the objective in the object plane. The pattern of holes in the disc was such that when the disc was rotated three times per second the entire optical field was scanned 120 times per second. Light reflected from the object also had to pass through holes in the disc to reach the eyepiece, but these were holes on the opposite side of the disc; the disc's two sides were made optically congruent by inverting prism systems.

Of the light reflected back into the microscope, only that reflected from the plane of the object formed an image in the plane of the rotating disc; only this portion of the reflected light could pass, without attenuation, through the holes in the disc and be seen through the ×15 orthoscopic eyepiece focused on the disc. Light reflected from above or below the plane of the object was largely intercepted by the opaque portions of the disc; thus the reflected-light image could not be degraded by scattered light reflecting into the microscope.

Undesirable reflections from optical surfaces within the microscope itself were eliminated by use of crossed polarizing filters, with a quarter-wave