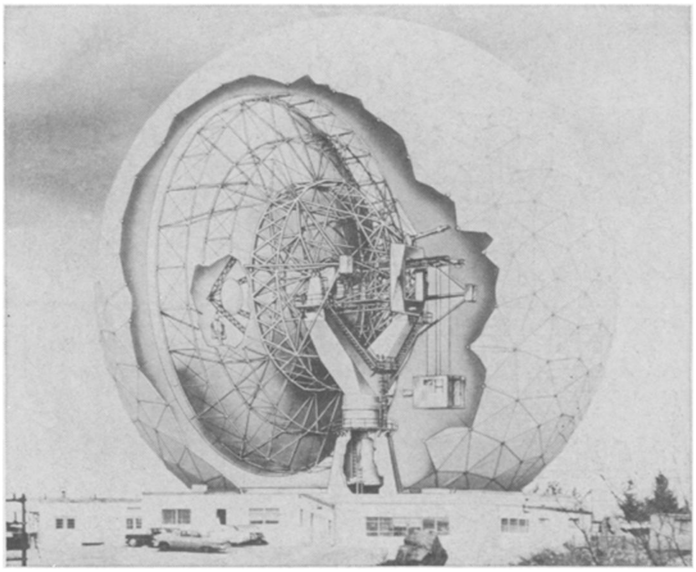
Astronomy for accuracy

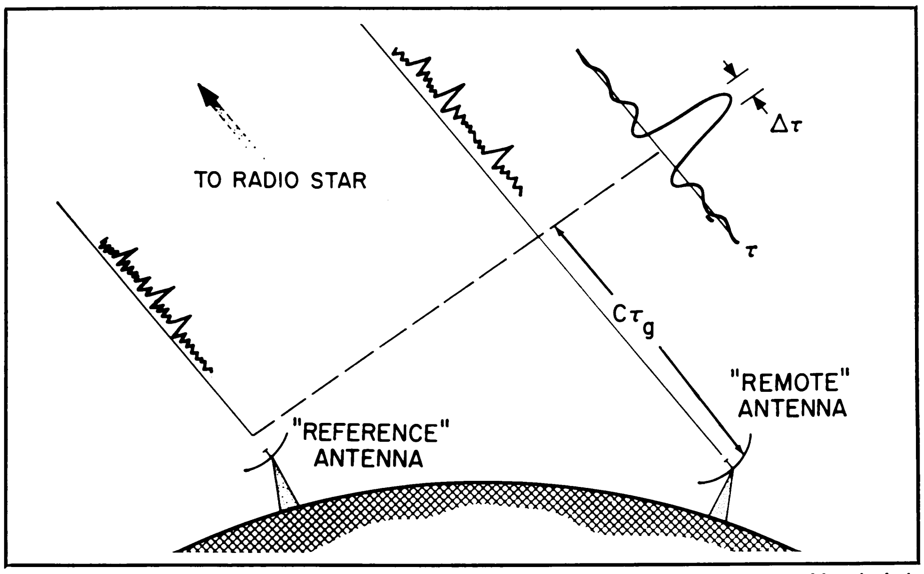
Geodesy and navigation benefit from advances in radio astronomy

by Dietrick E. Thomsen



Lincoln Lab.

Interferometry pinpoints Haystack within meters.



Lincoln Lab.

Small sources yield high accuracy in the long-baseline delay interferometer.

Astronomy is possibly the oldest example of a pure science with technological spin-off. The practical arts of geodesy and navigation have from their beginnings depended on astronomical data and observations for their functioning.

The newest technique in astronomy is a form of radio observation called very long-baseline interferometry (SN: 3/28, p. 318). A development of the last three years, it answers the need for detailed observations of small celestial radio sources. The smallness of the sources and the high accuracy of the technique make long-baseline interferometry a prime candidate for application to ever more accurate geodesic measurements and possibly also to navigation.

This is not the astronomers' prime goal. They are concentrating on the many new astronomical problems uncovered by the technique. But they are not ignoring geodesic applications. "It's a rather sophisticated subject," says Dr. S. H. Knowles of the Naval Research Laboratory. "Things are in a preliminary stage."

Long-baseline interferometry combines signals received from a single source at two or more widely separated telescopes. For astronomical purposes this gives extremely good resolution of fine details of the structure of the source. But if two antennas on earth are pointed at the same celestial source, a given wave crest will arrive at one before it comes to the other. With an accurate knowledge of the time lag and of the position of the radio source, an observer can compute with a high degree of accuracy the distance between the two antennas.

This solves the basic problem of both geodesy and navigation: knowing where you are.

So far geodesic work is more or less secondary to astronomical purposes. "The work we've been doing on a test of general relativity is automatically an exercise in geodesy as well," says Dr. Bernard Burke of Massachusetts Institute of Technology. Early data that he and his associates have taken allowed them to compute the distance between the 140-foot radio telescope at Green Bank, W. Va. and the Haystack radio telescope at Tyngsboro, Mass., to an accuracy of four meters.

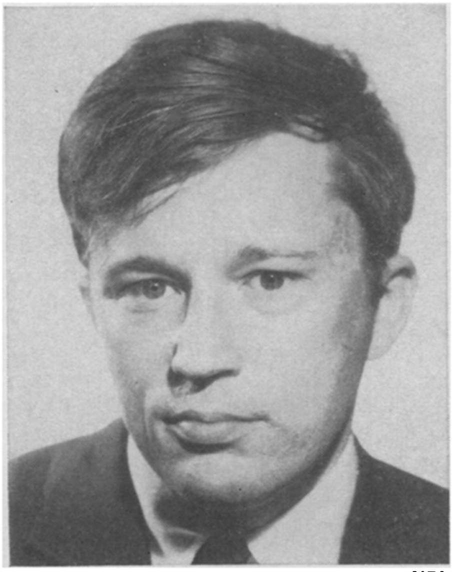
This, says Dr. Burke, is just a first step; "it's not the ultimate."

In principle, says Dr. Knowles, one could measure the distance between two points on earth to an accuracy of one centimeter. But, he adds, there are considerable problems and practical difficulties in the way.

The first problem is that the positions of the radio sources are not very well known. If the source positions were known accurately, observation of three different ones would locate the observing station. Each observation would locate the station on a plane determined by the direction to the star. Three planes intersect in a point, and that point would be the location of the station. But with poorly known source positions, says Dr. Burke, there is a whole assemblage of planes determined by the probable errors in the source positions, and this makes calculation of the station location difficult.

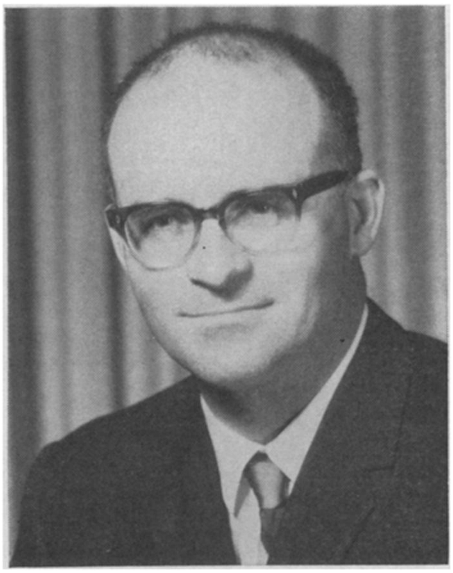
Much of current radio astronomy observation is intended to determine more accurate positions for prominent sources, so there is a good deal of hope that over the years this difficulty will be lessened.

Accuracy to within a few meters, says Dr. Burke, is easy to obtain, and a tolerance of 30 centimeters should not be too difficult. At this point calculations must take account of the slow-



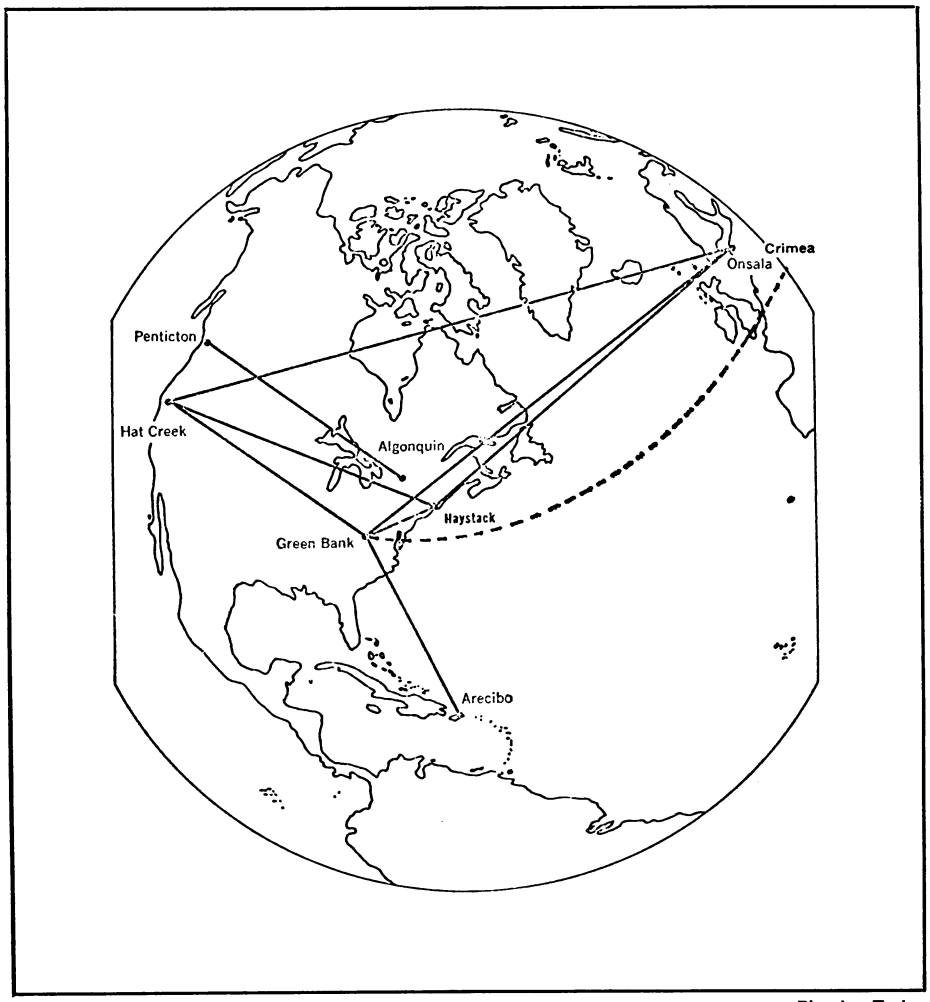
NRL

Knowles: ". . . a preliminary stage."



MIT

Burke: "It's not the ultimate."



Physics Today

Worldwide radio telescope network: More will be needed for accurate geodesy.

ing of the radio waves imposed by the atmosphere and the differences in this slowing that may arise between the two stations. But, he says, it should be possible to do enough experiments on the atmosphere to determine this effect with the required precision.

Beyond 10 centimeters, things become difficult. Here not only the atmosphere, but even solid-earth tides become important. Earth tides are the response of the earth's surface to the gravitational pull of the moon (SN: 2/14, p. 170). The solid surface rises and falls a few centimeters as the moon passes over.

"You could probably make measurements correct to one centimeter," says Dr. Burke. "Beyond one centimeter no one knows."

With precision like this, distances between continents could be accurately measured and long-distance surveying baselines established. Furthermore there is a possibility of testing directly the theory of continental drift. This would be done by making measurements over 5 or 10 years to see if two continents moved a few centimeters farther apart in that time.

A possibility for a practical opening to geophysics and navigation are the small water clouds that Drs. Burke, Knowles and other MIT and NRL astronomers have been studying (SN: 5/2, p. 436). These are small celestial sources that emit a sharp single frequency that is strong enough to be picked up by a six-foot antenna. An antenna of this size could be carried around on land or sea and open up a great flexibility for both geodesy and navigation.

An important necessity for accuracy is that the sources should be very small; they must look essentially like points. At a baseline of 1,000 kilometers, they do, says Dr. Burke. He and his colleagues are now extending the baseline to 3,000 kilometers. If the sources still look like points at this baseline, navigational use may be practical.

In practice, a small antenna carried on a ship would correlate its observation with a shore station. Dr. Burke figures an accuracy of 100 meters would not be hard to obtain, and this would be sufficiently precise for most navigators.

Allowing for the pitch and yaw of the ship would insert some fancy computer work into the calculations, and at least one observer feels that the calculations would be so slow that the navigator would find out not where he was but where he had been a few moments before.

Navigation by radio stars could still be a practical resort in parts of the world like the Antarctic, where there are frequent long stretches of cloudy weather, and the usual navigation by visible stars cannot be done; one ship reported sailing for 100 days in Antarctic waters and never seeing the sky.

Development of these possibilities will take time and funds.

Most of the telescopes that have so far been used for long-baseline interferometry are in the Western Hemisphere. The extremes of the present network lie in British Columbia, California, Puerto Rico, Sweden and the Crimea. Astronomers intend to extend the network.

Says Dr. Knowles: "Astronomers being broke as usual, we have trouble scraping up the money." □