Very-Low-Frequency Radio Waves and the Ionosphere

In the early days of radio, very low frequencies (3 to 30 kilocycles per second) were used for communication over long distances, but these frequencies were seldom utilized after the middle 1920's, for Marconi had pointed out the advantages of much higher frequencies. About 1950, however, interest was renewed because, among other things, it was recognized that low frequencies have remarkably high phase stability and are relatively immune to ionospheric disturbances. Because of the great advances made in theoretical problems in this field, a symposium on the ionospheric propagation of very-low-frequency radio waves was held at the Central Radio Propagation Laboratory of the National Bureau of Standards, Boulder, Colorado, 12–14 August. Approximately 300 scientists and engineers from six countries attended the symposium.

The present state of our knowledge of the physical processes involved in the ionization of the lower, or D region, of the ionosphere, which is responsible for guiding very-low-frequency waves around the earth, was surveyed by G. C. Reid (National Bureau of Standards). In discussing current ideas on the distribution of the resulting electrons as a function of height R. W. Knecht (NBS) showed that there is surprising agreement among observations made at various times and places. Papers dealing with various new methods of determining electron density relative to height profiles ranged from the use of continuous wave vertical incidence very-low-frequency signals (E. E. Gossard, Naval Electronics Laboratory) and the reception of signals on a rocket passing through the ionosphere (L. H. Rorden, Stanford Research Institute) to the measurement of changes in attenuation of cosmic noise under disturbed conditions (C. G. Little, NBS).

After discussions on the theory of propagation in the earth-ionosphere waveguide, J. R. Johler (NBS) and L. A. Berry (NBS) concluded that (i) for a fixed frequency and isotropic, sharply-bounded ionosphere of fixed height, as many as three different effective ionospheric conductivities yield the same attenuation rate; and (ii) that propagation around 10 kilocycles per second is comparatively insensitive to either the actual electron density or the presence of the earth's magnetic field. Other speakers, however, indicated that in general the electron density and magnetic field were important (J. R. Wait, L. C. Walters, NBS; and J. Galejs, Sylvania). Furthermore, it was shown that the actual height distribution of electron density was also of considerable significance.

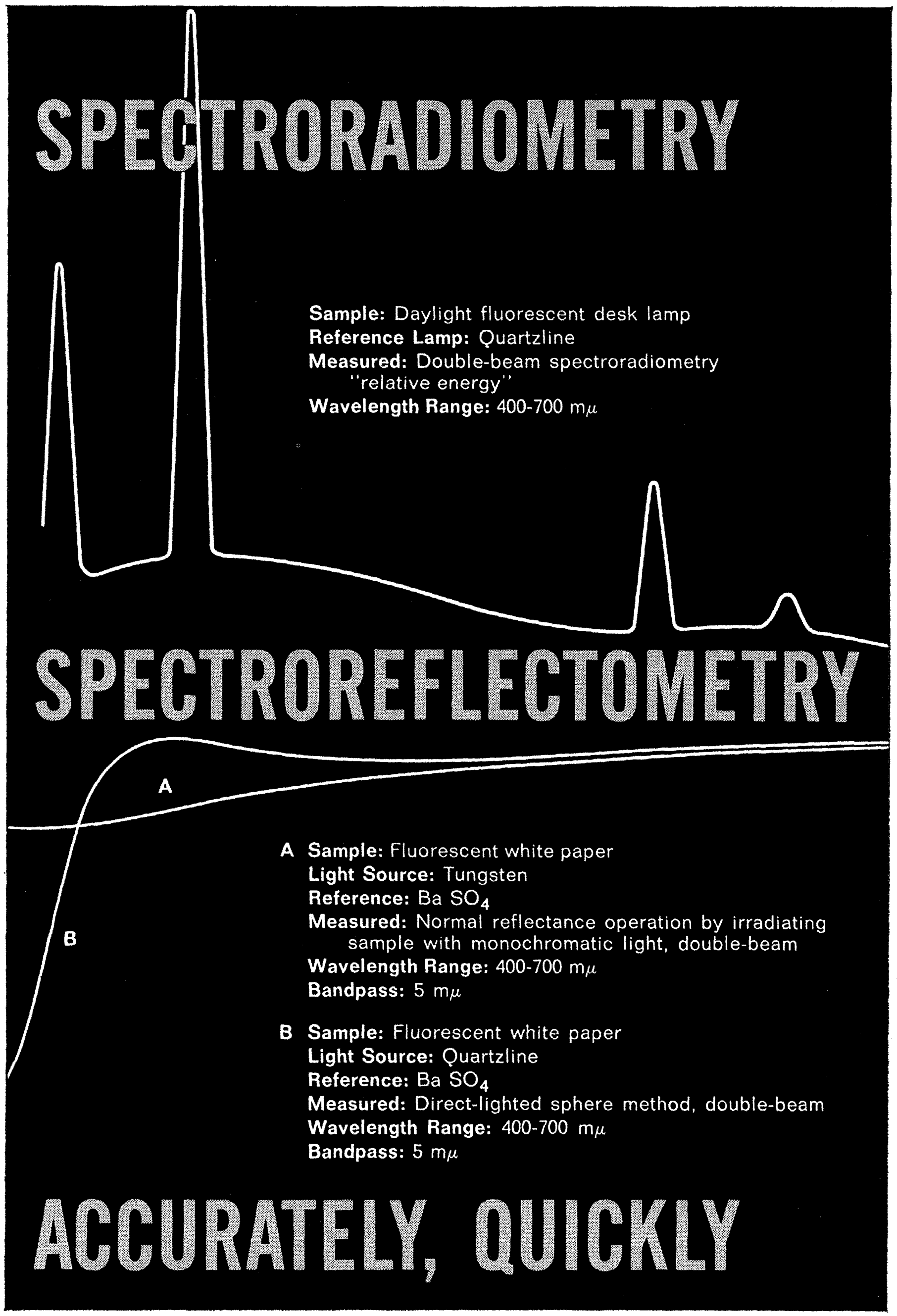
The variations with distance of the field strength and size of the diurnal phase variation were discussed by A. D. Watt (DECO Electronics, Inc.) and B. Burgess (Royal Aircraft Establishment, England). Both speakers stressed the importance of the excitation factor in explaining experimental observations, for this factor determines the relative amplitude and phase with which a given mode is excited in the earth-ionosphere wave-guide. Watt also showed that many observations of field strength relative to distance confirmed that very-low-frequency propagation across a magnetic meridian was nonreciprocal. By using these concepts, he demonstrated considerable agreement between the predictions of mode theory and the experimental observations.

The question of nonreciprocity received further emphasis. J. C. Hanselman (Naval Electronics Laboratory) presented the results of an excellent set of measurements using the Omega transmissions of 10.2 kilocycles per second. These showed very clearly that for the Hawaii-Canal Zone path, which is quite close and parallel to the geomagnetic equator, the attenuation rate in the east-to-west direction was twice that for propagation in the opposite direction. Lack of reciprocity was also demonstrated in a different way by B. Burgess (RAE, England). He gave evidence that on some paths the direction of arrival changed diurnally from the short great circle to that of the long great circle path. F. H. Reder (U.S. Signal Corps) showed differences in attenuation, in phase velocity, and in the size of the diurnal phase variation, when the direction of propagation was reversed. These variations agree, in sign at least with the theoretical predictions of J. R. Wait (NBS). These findings have removed any remaining doubts as to whether nonreciprocity can be expected, and confirm previous estimates of the magnitude of the effect.

W. E. Garner (Naval Research Laboratory) and C. J. Chilton (NBS) suggested that there may be a hitherto unrecognized dependence of propagation on latitude. This effect is manifested by the fact that for at least two paths the signals received south of the Canal Zone very-low-frequency transmitter are less at night than during the day. On the other hand, the reverse is true for paths that are north of the transmitter and for most other propagation paths in the northern hemisphere. Chilton suggested that his results might be explainable if the D-region near the geomagnetic equator was caused only by solar radiation without any significant contribution from cosmic rays. In discussion, it became apparent that further observations of this type are desirable and that observations of the electron density profile in the lower ionosphere should be made near the geomagnetic equator.

The phenomena of sunrise and sunset fading on long very-low-frequency paths has been known for many years. Observations on two long paths were discussed by D. D. Crombie (NBS); he concluded that the observed fading was due to the interference of a first- and second-order mode propagating in the nighttime portion of the path. This explanation requires that conversion of one mode into another takes place at the sunrise or sunset boundaries. Observations made with a microwave model of the earth-ionosphere wave-guide operating at 10,000 megacycles per second were presented by E. Bahar (University of Colorado) who showed quite convincingly that mode conversion of the correct type did occur in the model of a day-night boundary.

In noting the effects of nuclear explosions on the lower ionosphere and the resulting changes in propagation of radio waves, J. F. Kenney (Boeing) attempted to calculate contours of the rate of ionization caused by the β particles resulting from neutron decay. The contours illustrated the influence of the geomagnetic field in determining the spatial extent of the resulting ionospheric effects. B. Burgess (RAE, England)



gave evidence of long-lived effects presumably due to radioactive debris. The effects were to increase the attenuation on the long great circle path so that for 8 to 12 days the diurnal variation of phase was that to be expected for signals which were received only over the short great circle path.

One surprising feature of the symposium was that several authors utilized observations which were originally made in 1922 as a source of data on the variations of very-low-frequency field strength with respect to distance. Although this should be taken as a compliment to that work, it also points out the necessity for new high quality measurements in this area.

The symposium was sponsored by the Central Radio Propagation Laboratory of the National Bureau of Standards. It is expected that a selection of the presented papers will be published in the Jan.-Feb. 1964 issue of Section D (Radio Propagation) of the *NBS Journal of Research.*

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Radioiodine: Its Nature and Effects

Radioiodine-131 is considered one of the most significant fission product elements because of its abundance in early fallout and in the gaseous effluent of certain nuclear industries, its high inventory in irradiated reactor fuels, its chemical, physical, and physiological characteristics, and its widespread use in clinical and therapeutic medicine. All these factors were considered at a symposium held at the Hanford Laboratories, Richland, Washington (17–19 June). In addition to the 75 Hanford scientists about 150 visiting researchers from Belgium, Canada, France, India, Japan, United Arab Republic, the United Kingdom, and West Germany attended.

Historically, the thyroid gland, which concentrates a substantial portion of any administered dose of iodine, was considered a radioresistant structure. Following reports of increased incidence of thyroid tumors in children as a consequence of exposure to x-irradiation early in life, the Federal Radiation Council recommended that a thyroid radiation dose to the general population from I^{131} in excess of 0.5 rem per year should call for some con-