Velocity of Radio Waves in Air

The results of Colwell and Friend[1] on the determination of the velocity of radio waves in air were between 50 and 80 percent the velocity of light. The uncertainty of the path over the long distances which were used seems to be the only possible source of error. All earlier measurements[2] were the determination of the velocity of propagation along wires. The authors therefore attempted to check the results of Colwell and Friend with ultra-short waves over distances of a few meters. The method used was the determination of the wave-length of a known radiofrequency source by interference measurements in air. The velocity is then obtained from the product of the frequency and the wave-length. The apparatus consisted of a transmitter of frequency 113.749 mc/sec. located on a straight line between a receiver and a plane reflector, the plane of which was perpendicular to the line of the receiver, transmitter and reflector. The receiver detected waves directly from the transmitter and also indirectly after being reflected from the movable reflector. By moving the reflector along the line of the apparatus, the length of path of the indirect wave could be varied. The distance between positions of the reflector which give maximum responses in the receiver is equal to half a wave-length. The distance between positions of the reflector which give minimum responses in the receiver is also half a wave-length. A typical set of measurements is shown below.

Figure 1 is shown simply to point out the accuracy that might be expected in these measurements. Actually the positions of maxima and minima were obtained more accurately by taking more readings about these points.

The frequency was known to be accurate to 0.03 percent. It was obtained from a crystal-controlled oscillator of frequency 28.437 mc/sec. which was doubled twice. To insure operation of the crystal frequency it was checked by the heterodyne method with a General Radio Type 684-A oscillator which has a calibration accurate to within one percent. The final output of the transmitter was monitored by means of a cathode-ray oscilloscope to insure an output exactly four times the crystal frequency and not some stray oscillation originating in the circuits after the crystal. This was accomplished by applying the crystal frequency to one set of deflecting plates and the output frequency to the other set of deflecting plates. A Lissajous figure characteristic of a frequency ratio of 1 : 4 was then a definite assurance of the proper frequency output. The inaccuracy in the wave-length measurements was due almost in full to the movement of the cumbersome reflector as it was impossible in the present apparatus to keep the plane of the reflector perpendicular to the axis of the antennas of the transmitter and receiver as the reflector was moved. A thermocouple ammeter was used in the transmitter antenna to monitor the power output which was about two watts. This was done to be sure the movement of the reflector did not introduce a variable mutual impedance in the transmitter antenna and hence vary the output of the transmitter as the reflector was moved. If the closest position of the reflector to the transmitter was greater than two wave-lengths the output remained constant.

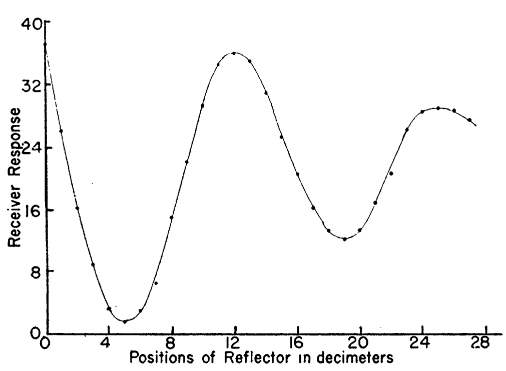

FIG. 1.

The results of these measurements for the velocity of radio waves in air were $(2.98\pm0.07)\times10^{10}$ cm/sec.

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[1] R. C. Colwell, A. W. Friend, N. I. Hall and L. R. Hill, Phys. Rev. **50**, 4, 381 (1936); R. C. Colwell and A. W. Friend, Phys. Rev. **51**, 11, 990 (1937).
[2] M. J. Mercier, J. Physique **5**, **6**, 168 (1924); MacLean, Phil. Mag. **48**, 115 (1899).

Droplet Fission of Uranium and Thorium Nuclei

The Fifth Washington Conference on Theoretical Physics, sponsored jointly by George Washington University and the Carnegie Institution of Washington, began January 26, 1939, with a discussion by Professor Bohr and Professor Fermi of the remarkable chemical identification by Hahn and Strassmann in Berlin of radioactive barium in uranium which had been bombarded by neutrons. Professors Bohr and Rosenfeld had brought from Copenhagen the interpretation by Frisch and Meitner that the nuclear "surface-tension" fails to hold together the "droplet" of mass 239, with a resulting division of the nucleus into two roughly equal parts. Frisch and Meitner had also suggested the experimental test of this hypothesis by a search for the expected recoil-particles of energies well above 100,000,000 electron-volts which should result from such a process. The whole matter was quite unexpected news to all present.

We immediately undertook to look for these extremely energetic particles, and at the conclusion of the Conference on January 28 were privileged to demonstrate them to Professors Bohr and Fermi. It was subsequently learned that the particles had been observed independently by Fowler and Dodson at Johns Hopkins the same day, by Dunning and co-workers at Columbia on January 25, and by Frisch in Copenhagen two weeks earlier.

For observations of the high energy particles, an ionization-chamber, about five mm deep, was placed about three cm below the neutron-source and was so arranged that interchangeable copper disks about three cm in diameter could be placed on the collector, which was connected to a linear pulse-amplifier. The upper faces of these disks were then coated with the materials to be tested.

TABLE I.

NEUTRON-REACTION	MAXIMUM NEUTRON-ENERGY	URANIUM		THORIUM	
		NO Cd	WITH Cd	NO Cd	WITH Cd
	Mev				
Li+D	13.5	100	70	100	100
D+D	2.5	100	70	100	100
C+D	0.5	100	10	0	0

With the amplifier feeding a cathode-ray oscillograph the usual alpha-particle pulses were observed when a layer of uranium oxide was placed on the disk. On exposure to neutron-radiation from (Li+D) at 1000 kv two additional groups of pulses were observed. The first group corresponded to the "neutron-recoils" from the air in the chamber, as previously measured with the same amplifier gain and without the uranium. These neutron-recoils gave pulses about four times the size of the alpha-particle pulses. The second additional group was 20 to 40 times larger than the largest "recoil"-pulse, thus corresponding to energies of 75 to 150 Mev released in the chamber, or 150 to 300 Mev total energy for each individual process. With paraffin surrounding source and chamber the yield was roughly 30 counts per min. per μA of 1000-kv deuterons, which is a neutron-intensity corresponding to about 10,000 millicuries of radon-beryllium. The yield from thorium was of the same order of magnitude.

No effect was observed from bismuth, lead, thallium, mercury, gold, platinum, tungsten, tin or silver with as much as 1/1000 the intensity of that from uranium and thorium.

No effect was observed with either uranium or thorium produced by the gamma-rays from 3 μA of 1000-kv protons on lithium or on fluorine.

To determine roughly the energy-range of the neutrons involved in the fission-process, observations were made with the neutrons from several reactions, both with and without cadmium surrounding the ionization-chamber to filter out the thermal neutrons produced in the surrounding paraffin. Bearing in mind that the ratio of the counts with cadmium and without cadmium depends to a large extent on the amount of paraffin surrounding the source and chamber, the results of these tests may be deduced from Table I in which the relative number of "fissions" is given, with the total yield for uranium and thorium with high energy neutrons, being approximately equal, taken as 100 on an arbitrary scale.

From these comparisons it appears that the uranium fissions are produced by different processes for fast and slow neutrons, the fast-neutron process requiring more than 0.5 Mev but less than 2.5 Mev for effective operation. For thorium, on the other hand, only the fast-neutron process is effective, but somewhat surprisingly it also appears to require between 0.5 and 2.5 Mev.

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Heavily Ionizing Particles from Uranium

After reading in local papers of Hahn's discovery of the splitting of uranium into heavy elements, we wired Professor Gamow for further details. He answered that Tuve had observed the heavily ionizing particles in a differential linear amplifier chamber. We have confirmed this by using a thin ionization chamber, one of whose plates was covered with U, or U_3O_8. With a certain gain, the U natural alphas gave two-mm kicks on an oscilloscope, Po alphas passing parallel to the plates gave eight-mm pulses, and the Hahn-Tuve particles gave deflections of four cm. The energy released in a path length of less than 0.5 mm was about 10 Mev, so the particles must carry several charges, and therefore be "heavy." Check runs on Pb, Cu, Zn, W and Th showed no such bursts. After confirming the existence of these particles, we investigated the type of reaction responsible. A thin Cd covering around the chamber reduced the counting rate to less than five percent. This is unexpected in view of the fact that about half of the "transuranic" activity is due to resonance neutrons which could penetrate Cd. This result shows that Hahn's effect is due largely to thermal neutrons. By the use of a modulated beam of neutrons, we have looked for a time delay in the emission of heavy particles, after the neutron irradiation. The time delay is less than 3×10^{-3} sec. Our thanks are due Professor E. O. Lawrence for his interest in this experiment, and the Research Corporation for financial support.

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Intensely Ionizing Particles Produced by Neutron Bombardment of Uranium and Thorium

We have bombarded uranium nitrate and also thorium oxide with deuteron-deuteron neutrons in a three-millimeter brass ionization chamber and found particles producing an intense ionization. We attribute the results to extremely high energy particles of roughly half the mass of the bombarded nucleus, and believe that they confirm the recent work of Hahn and Strassmann[1] and of Frisch and Meitner[2] on uranium, and also establish a similar effect with thorium.

The substance was bombarded in the form of a layer (about 0.5 gram) stuck with collodion on a paper disk three centimeters in diameter and placed in contact with a mesh-covered opening into the ionization chamber. The gain of the oscilloscope was set so that the kicks resulting from the natural alpha-radiation were about one centimeter high. During neutron bombardment kicks of height greater than five centimeters (peak outside the field of vision) were observed. These were counted visually. Counts were made at various deuteron beam intensities with the chamber directly under the neutron source and also about a meter away, with paraffin and without paraffin