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The Lower Ionosphere

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There are two well-defined regions in the lower part of the ionosphere. One of these (the D region) extends from 35–65 km, the other (the C region) lies between 2–30 km. They have been detected by the use of a very short pulse of the order of 3 microseconds and a receiving set with a small time lag. The ground and reflected pulses are separated by using a rapid sweep on a cathode-ray oscilloscope. Similar results have been obtained by Watson-Watt, Mitra and their co-workers.

FOR many years, it has been observed that there is a close connection between weather phenomena and radio wave propagation.[1–6] The changes in signal strength depend upon the location of the sending and receiving stations. For instance, the broadcast station KDKA, 150 km north of Morgantown, W. Va., sends out a signal which is steadier and of lower amplitude at night whenever a region of high barometric pressure is establishing itself over the signal path. When a low pressure area is approaching from the northwest, the night signals fade severely and increase their maximum amplitude to many times the day level. Wide fluctuations in day to day signal strength have also been measured.[4]

It was thought that the reasons for these fluctuations in intensity could be determined by exploring the ionosphere by the method of Breit and Tuve.[7] A transmitter was designed which sends out sixty pulses per second, each pulse lasting for 3 microseconds or less (Fig. 1). The operation of this pulse generator is as follows: the condenser C_p is charged on the positive alternation of the 60-cycle power line by the transformer X_p acting through the diode valve D_p; on the negative alternation, the grid of the mercury vapor triode T_p, operating 180° out of phase with the condenser charging potential, causes the condenser C_p to discharge through T_p and R_p. The current through R_p produces a potential drop which opposes the grid bias of the radiofrequency amplifier $T_{\mathrm{R.F.}}$ and, therefore, causes the emission of a pulse of radiofrequency power from the transmitter.

The transmitter circuit is a pentode crystal-controlled oscillator driving the pulse modulated 200-watt pentode power amplifier which supplies energy to a horizontal quarter wave Marconi antenna suspended 70 feet above the ground.

The receiving equipment is located 200 meters from the transmitter. The strong ground wave prevents the use of any type of antenna except a loop universally mounted so that it is rotatable about both the horizontal and vertical axes. A good commercial receiver gives satisfactory results for reflections from regions 10 km or more above the ground but for lower elevations, a special receiver was designed to eliminate long time constants and spurious damped oscillations in the various circuits. This receiver consists of three stages of screen grid tuned radiofrequency amplification and a screen grid detector. The complete circuit is shown in Fig. 2. Each stage is battery operated and completely shielded in a galvanized steel box which contains the amplifier and all the necessary batteries. The detector may be modified for use as a fourth radiofrequency amplifier for making oscilloscopic observations of the radiofrequency wave.

The pattern produced by the incoming ground and sky waves is viewed on the five-inch screen of a cathode-ray oscilloscope. The middle part of a 2000 volt (peak) swing produced by a 60-cycle a.c. sine wave sweeps the spot rapidly across the screen. Synchronization of the sweep circuit is obtained automatically by the use of the 60-cycle line voltage. Linearity is assured by the use of only one-twentieth of the total voltage swing for the base line on the cathode-ray tube screen. The scale is calibrated with a device which generates a high harmonic of the 60-cycle

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[1] C. T. R. Wilson, Proc. Phys. Soc. **37**, 32D (1925).
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[4] R. C. Colwell, Proc. I.R.E. **21**, 721 (1933).
[5] R. C. Colwell and A. W. Friend, Nature **137**, 782 (1936).
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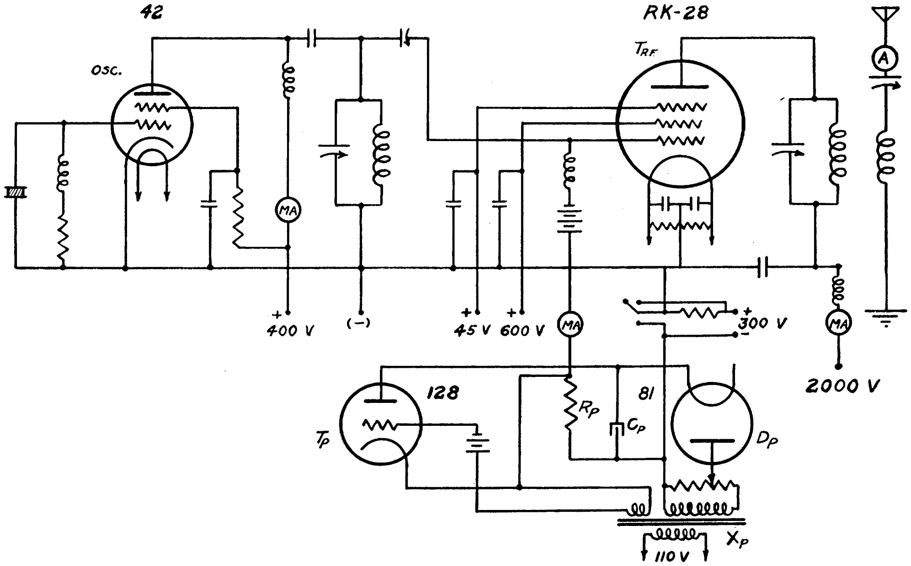

FIG. 1. Circuit diagram of transmitter.

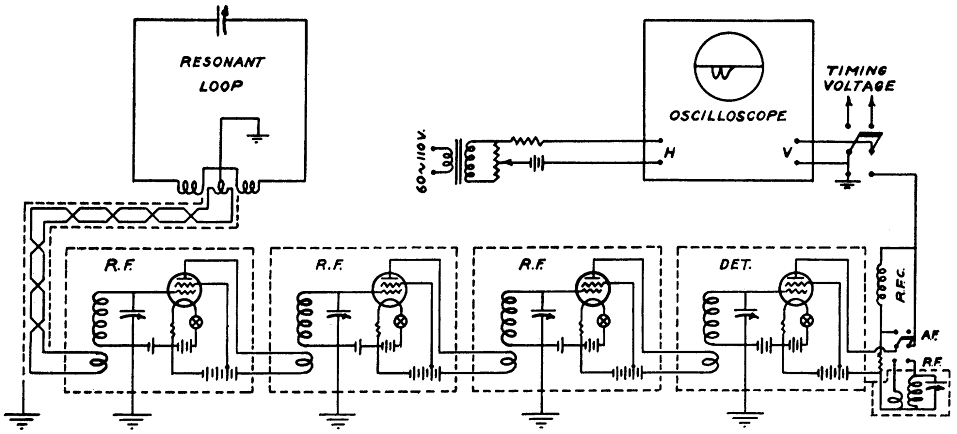

FIG. 2. Circuit diagram of receiver.

current. This harmonic sweeping vertically is used to measure the time intervals on the scale.

In operation, all radiofrequency circuits are tuned for maximum signal output. This exact condition eliminates beat phenomena produced by shock excitation. In Fig. 3, apparent peaks are shown which come from the receiver and not from the ionosphere. These do not appear when the receiver is properly tuned.

When the loop antenna, which is rotatable about the vertical and horizontal axes, is turned so as to pick up a strong direct (ground) signal, the ground and sky wave impulses merge on the screen; but when the loop is properly oriented so as to weaken the reception of the ground wave and increase that of the sky wave or *vice versa*, either wave may be made to appear on the screen without the other.

In measuring the height of the lowest reflecting layer, the loop is adjusted so as to pick up a small signal from both the ground and sky waves (Fig. 4). When this adjustment is obtained the horizontal and vertical angles of the loop are recorded, along with the virtual height of the reflecting region. When the loop antenna is turned for maximum pickup of the combined

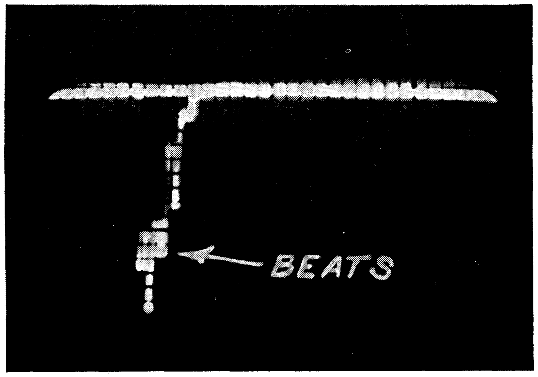

FIG. 3. Oscilloscope pattern which shows apparent peaks coming from the receiver when it is not properly tuned.

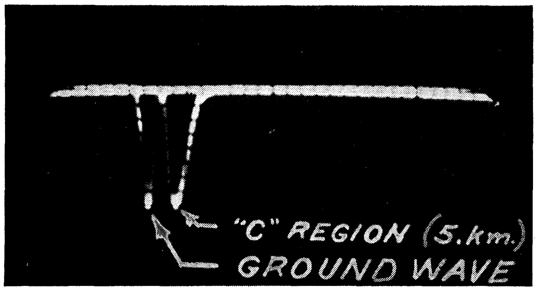

FIG. 4. Form of oscilloscope pattern when the receiving loop is adjusted to pick up a small signal from both the ground and sky waves.

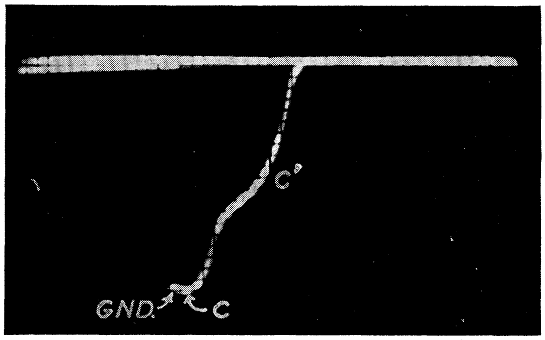

FIG. 5. Form of oscilloscope pattern when the loop antenna is turned for maximum pickup. $C=4.8$ km; $C'=26$ km (approximately).

signals, the received signal takes the form shown in Fig. 5. The ground wave in the photograph is marked "*GND*," the signal from the low side of the reflecting medium is marked *C* and that from the top of this particular region is marked *C'*. The "*GND*" and "*C*" signals were run together by overloading the amplifier.

It has been repeatedly observed that, at this short distance (200 meters), strong reflections from the *C* region (2–30 km) or the *D* region (35–65 km) coincide with weak reflections from the *E* and *F* regions. Neither the *E* or *F* reflections are shown in these photographs since they fall off the edge of the screen because their height is very great compared to that of the *C* region.

These measurements have been made on frequencies of 1614 kc, 2398 kc and 3492.5 kc. The heights and penetrations on these frequencies do not differ greatly. The highest frequency 3492.5 kc gives much more erratic performance than the other two. It shows wider deviations in the angles of polarization. The wave

TABLE I. *Fluctuations both in height and intensity of the C and C' layers.*

Date	Time	Height C	Strength C	Height C'	Strength C'	Height D	Strength D
3– 5–36	5:00 P.M.	5 km	strong	17 km	medium		
3– 9–36	6:30 P.M.	3–12 km	"	33 km	strong	60 km	medium
3–11–36	8:30 P.M.	11 km	"	35 km	"	none	
3–12–36	2:56 P.M.	8–12 km	"			50 km	strong
3–31–36	2:57 P.M.	7.5 km	"	18 km	weak		
4– 6–36	9:20 P.M.	10.5 km	"	18 km	very weak	none	
4–28–36	11:15 A.M.	2–4 km	very strong	12–14 km	strong		
5–10–36	12:03 P.M.	4.3 km	strong	12 km	fairly strong		
5–24–36	1:05 P.M.	5.1 km	very strong	12 km	medium		
5–30–36	11:40 A.M.	3.6 km	" "	10 km	strong		
6– 6–36	11:10 A.M.	3.7–4.6 km	" "	18 km	medium		
6– 6–36	11:29 P.M.	7.5 km	strong	20 km	strong		
6– 7–36	2:55 A.M.	8.6 km	"	22 km	medium		
6– 7–36	12:35 P.M.	4.3 km	very strong	16 km	strong		
6– 7–36	11:03 P.M.	8 km	strong	18 km	"		
6– 8–36	11:30 A.M.	4.3 km	"	14.5 km	"		
6–11–36	5:15 P.M.	0–2 km	extra strong	16 km	"		
6–29–36	12:30 P.M.	3.5 km	very strong	21 km	medium		
7– 5–36	3:34 P.M.	1.5 km	strong	23 km	"		

seems to be more penetrating and permits more frequent observations on the E region.

The readings given in Table I show the great fluctuation of the C and C' layers in both height and intensity. It is much more difficult to detect the D region in summer than in winter.

Similar observations have been made in England on frequencies from 6–12 megacycles and also in India.[8] Extreme care must be exercised so as not to interpret beats caused by circuit oscillations for multiple layers or reflections. The peaks caused by circuit oscillations are always fixed in position and intensity; the peaks caused by the sky wave vary rapidly in intensity and shift their position from minute to minute as the reflecting layer rises or falls. The sky wave from the C region may be described as fluctuating or scintillating. In the summer months it is so strong that it prevents observations on the D region.

Messrs. N. I. Hall and L. R. Hill collaborated with us in the development and construction of the apparatus.

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Must Neutron-Neutron Forces Exist in the H^3 Nucleus?*

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A wave function in the form of a series in the three interparticle distances with coefficients to be determined by the variational method is used to solve the H^3 problem for a Wigner neutron-proton interaction of the form $B\ e^{-2r/b}$. For interaction radii b of 1.0 and 2.0×10^{-13} cm the best energies obtained are -11.0 and $-9.5\ mc^2$, respectively, and the convergence of the energies obtained from successive improvements in the wave function is so rapid that the eigenvalues may be estimated to occur at -11.5 ± 0.3 and $-9.6\pm 0.1\cdot mc^2$. Both pure and mixed exchange operators must give a higher total energy. It is shown that the narrower interaction radius is too small to be compatible with the known mass defects of H^2 and He^4 and that, accordingly, the value of $11.5\ mc^2$ is a very safe upper limit for the binding energy. From this we can conclude the existence of direct like-particle forces in the nucleus. Possible modification of the experimental data is considered and a comparison is made with the results of the equivalent two-body method.

LIKE-PARTICLE FORCES

THE evidence for explicit like-particle forces in the nucleus falls under four categories. The most recent, direct and incontrovertible evidence is furnished by the anomalous scattering of high energy protons in hydrogen. The experiments of White[1] indicated a departure from the Coulomb law at small distances; the more precise measurements of Tuve, Heydenburg and Hafstad[2] remove certain difficulties that were present in the earlier experiments and offer accumulating evidence for a short range attractive interaction between two protons with antiparallel spins.[3] Probably second in order of reliability is the evidence derived from explicit computations of the binding energies of the hydrogen and helium isotopes. This will be discussed below in detail. Thirdly, there are certain well-known properties of heavier nuclei (e.g., the existence of pairs of stable isobars of even weight and charge, differing by two charge units, with intermediate odd-charged isobar unstable) which seem to require an attractive interaction between like-particles.[4, 5] Weizsäcker[6] has shown that such an interaction might be partially, if not wholly, explained by second-order effects in the binding of a second neutron (or proton) due to a distortion of the nuclear field by the introduction of the first. Since it is not known to what extent the interaction must be attributed to *explicit* attractive forces, this

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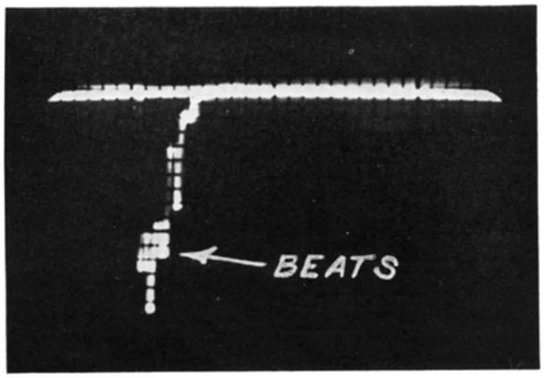

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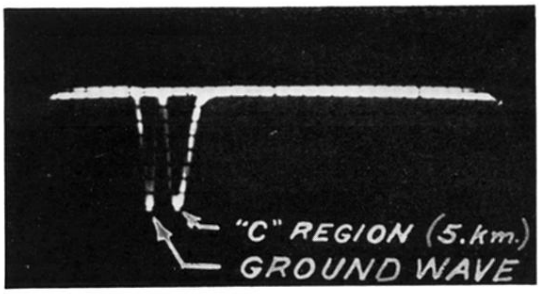

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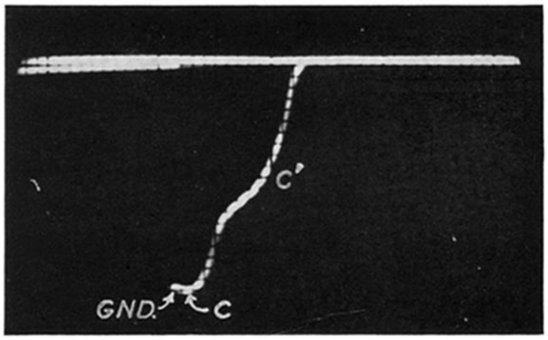

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