THE MEASUREMENT OF SHORT ELECTRICAL WAVES AND THEIR TRANSMISSION THROUGH WATER CELLS.[1]

By A. D. Cole.

IN 1892 Ellinger[2] measured the refractive index of water for electrical waves about 60 cm. long, by using a huge prism of water. In 1895 the author[3] attempted to make a similar measurement with waves of only 5 cm. length, and found that the absorption was so great that scarcely any effect could be observed beyond the prism. A flat cell, containing a layer of water 1.1 cm. thick, allowed only 2 or 3% of the electrical energy to pass through it. The prism method seemed so unpromising as a means of determining the refractive index that it was forsaken and the measurement made by another method.

This summer an attempt was made to determine the absorbing power of water more definitely. As it had been shown to have great absorption for 5 cm. waves, but feeble for 60 cm. waves, measurements were made with waves of several different lengths. Thus far three different lengths have been tried, namely five, eight and sixteen centimeters. Both longer and shorter ones will also be used.

This general plan has been followed: the energy radiating from a modified Righi exciter is received and measured, first when nothing but air intervenes, secondly with a thin cell of water interposed, and finally with a thicker cell of the same sort. It would seem that the difference of the last two, as compared with the total given in the first reading, would give a measure of the absorbing power of a water-layer having a thickness equal to the difference in the thickness of the two cells. We would expect the losses by reflection to be about the same for each.

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[1] Read before Section B, Am. Assoc. Adv. Sci., at Boston, August, 1898.

[2] Ellinger, Wied. Ann., Vol. 46, p. 513, 1892.

[3] Cole, Wied. Ann., Vol. 57, p. 290, 1896.

For producing and measuring the electrical oscillations, apparatus was employed very similar to that used in the 1895 experiments.

Fig. 1 shows the exciter used.

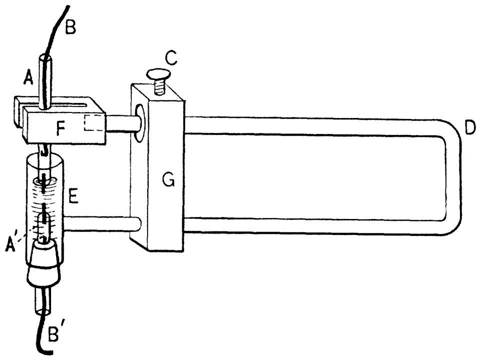

Fig. 1.

A and *A′* are glass tubes about 5 cm. long and .6 cm. in diameter. Their inner ends are drawn out and serve to support two small cylinders of metal which are cemented into them. These cylinders, immersed in oil and separated by a very short spark-gap, form the oscillating system, and their dimensions determine approximately the wave-length of the radiation. The discharge from an induction coil is brought to them by means of the wires *B*, *B′*, whose ends are bent into loops just large enough so that friction will hold them in the glass tubes about 3 mm. distant from the little cylinders. Thus there are three spark-gaps as in Righi's exciter. The length of the oil gap, which must be very short and exactly adjusted, is controlled by the screw *C*, which presses with variable force upon the ⊐-shaped spring frame *D*, whose lower limb supports the oil vessel *E* and the tube *B′* while its upper limb holds the tube *B* by means of the wooden clamp *F*. Metal was avoided in making the apparatus ; the frame *D* and oil vessel *E* are made of glass, and *G* of hard fiber. This oscillator was mounted in the focal line of a cylindrical parabolic mirror.

The receiving instrument was the same as that used in the earlier research, and has been described already[1] in this journal.

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[1] PHYS. REV., Vol. IV., p. 54 ; also Wied. Ann., 57, p. 298, 1896.

It is essentially a Righi resonator with a minute thermo-junction of fine iron and German-silver wires in place of the spark-gap. It was enclosed in a tight cardboard box to protect it from heat radiation and mounted in the focal line of a small parabolic mirror. This mirror did not have a continuous metallic surface, but was made of cardboard covered with strips of tinfoil having the same length as the combined length of the two strips in the resonator.

For each wave-length a different exciter was used, and each exciter had its own receiver, with period corresponding to its own.

Ordinarily the resonator was placed about 60 cm. away from the exciter. Between them a large tin-foil screen was mounted, having in it an opening 11 by 13 cm. The energy passing through this gave deflections of about 40 scale divisions in an Elliott galvanometer of five ohms resistance, which was joined to the thermo-element of the resonator. The sensitiveness of this instrument was such that one scale division of deflection was produced by 2×10^{-9} ampères of current when the scale was one meter distant. The deflections are not as large as may easily be obtained in a coherer, but the thermo-receiver was very much more regular in its action and strictly quantitative in character. I found the coherer much more capricious and irregular, and gave up the idea of using it after having given it a good trial. An illustration of the quantitative character of the results given by the thermo-resonator is given in the reference last cited. A 5 cm. exciter and its receiver were both deprived of their mirrors and set up 25 cm. apart. A series of deflections were noted, the distance between them doubled and another series taken. The mean deflection at 25 cm. was almost exactly four times that at 50 cm.

Professor Drude, of Leipsic, published an account of a similar study of the absorption of electrical waves of short period by water while these experiments were in progress (in Wied. Ann. for July). He used the coherer as his measuring instrument.

The details of the measurements with the thermo-resonator were as follows: a reading of the galvanometer was made when the exciter was thrown into action, with nothing interposed between it and the opening in the screen, then another with a water cell placed over the opening, then another like the first and so on alternately until about a dozen readings of each kind were obtained. From the mean of each of these series was deducted the small deflection (usually less than one scale division), which was obtained when a screen of sheet metal was interposed. This was simply due to the magnetic influence of the induction coil and its connection wires upon the galvanometer. One series of readings is given to illustrate the regularity and steadiness of the action—a steadiness which I have never been able to obtain with a coherer, even when the galvanometer was enclosed in a box of heavy sheet copper with joints soldered water tight. It should be noted that a sheet of metal interposed is sufficient to screen the thermo-receiver, which shows that the effects produced when the screen is removed are due to energy coming *directly* from the exciter.

	Nothing interposed.	Cell of water, 1 mm. thick.	
Deflection	30.8	6.3	
	29.6	6.0	
	30.3	5.9	
	29.5	6.0	
	28.8	5.6	
	27.7	5.6	
	27.6	5.3	
	27.1	5.6	
	26.5	5.1	
	26.8	5.3	
	26.9	5.4	
	26.1		
Mean	28.1	5.6	
Less	1.4	1.4	magnetic influence.
	26.7	4.2	

$$\frac{4.2}{26.7} = 15.7\%$$

Each series shows some falling off from beginning to end, as the spark-gap slowly widened. It is quite regular, but makes it necessary to take readings alternately with and without the cell.

Two cells were used; one having sides of two pieces of window glass about 2.5 mm. thick and placed 1.05 mm. apart, the other having the same two pieces of glass separated by 3.65 mm. The results of 29 series of readings made with these two cells and wave-lengths of 5, 8 and 16 cm. are here tabulated.

Wave-length used.	**Glass Vessel, Empty.**	**Vessel with water 3.65 mm. thick.**	**Vessel with water 1.05 mm. thick.**
5 cm.	66.5 %	32.5 %	13.3 %
		35.5	17.6
		33.3	15.7
		37.4	16.0
		35.6	15.7
		35.2	
		Mean 34.9	15.7
8 cm.	71.7	27.1	22.4
	69.1	24.6	20.7
	69.8	26.7	19.5
	69.5		
	Mean 70.0	26.0	20.9
16 cm.	69.0	12.0	15.8
	64.9	10.4	14.9
		14.7	
	Mean 67.0	12.4	15.4

We see from this table the curious result that the thicker cell of water seems more transparent to both the 5 and 8 cm. waves than the thinner. This is, perhaps, due to interference between the direct and reflected portions of the radiation. If so, it can be eliminated by varying the thickness of the water layer, which we propose to try.

The existence of considerable reflection from the glass surfaces is indicated by this, that about 30% of the radiation is cut off by the two plates of the empty cell, and about this same amount whether the plates are thin or thick, so that the loss is not by absorption in the glass. It can be shown also, by filling the cell with an oil, that it allows more energy to pass than when empty. It is easily understood how a material of about the same refractive index as glass would reduce reflection at two of the four surfaces.

Evidently the data for calculating the absorbing power of water for electrical radiation have not yet been obtained. Further experiments are needed to enable one to make due allowance for reflection and interference losses. It is proposed to resume the study as soon as possible.

In conclusion, attention is directed to the apparatus used in these experiments as suitable for any sort of quantitative demonstration of electrical oscillations by lecture. The deflections can readily be made visible to an audience, and yet are strictly proportional to the energy received. The phenomena of reflection, refraction, interference, polarization, etc., of electrical oscillations, can be rapidly and accurately shown.

The experimental work described above was done at the Ryerson Laboratory, University of Chicago.

GRANVILLE, O., August 15, 1898.