

# On the Transmission of Waves

By SIR OLIVER LODGE

**T**HERE seems to be a good deal of misunderstanding as to how electric waves are propagated from an aerial, not only as regards the distance traveled, and the way in which they get round the curvatures of the earth, but as to their actual mode of propagation, and the process which is going on in the Ether, so that they are able to advance with the velocity of light. For electric waves are not only electric, they are electromagnetic: that is to say, they have an electric component which is detected at a receiving station by an elongated or linear conductor; and they have a magnetic component which is detected by a closed loop or coil of wire. These are the two kinds of aërials in common use, the elevated wire and the closed loop. One responds to the electric, the other to the magnetic oscillation; and it is pretty well known that these two oscillations are at right angles to each other, and that it is most efficient to have the electric one vertical and the magnetic one horizontal. It may also be known that they have equal energies, and necessarily have equal amplitude, so that the weakening of one equally weakens the other. The whole progress of the wave depends on the co-existence of these two forms of energy, the electric and the magnetic; and if one stops, they both stop. If one is reversed, the other must be reversed if the propagation is to continue in the same direction. If one is reversed without the other, the wave goes backwards. And if at any place the one exists alone the wave stops, and at that place you have either an electric phenomenon or a magnetic phenomenon, but not both.

The consequence of all this is that the electric and magnetic disturbance must be co-existent in position; one cannot lag behind the other in a true wave. Whenever one is at a maximum, the other must be at a maximum; which is expressed by saying that they must be in the same phase, as a condition of the progress of the wave.

Yet it is often taught that one is a quarter period behind the other, like the piston and slide valve of an engine; so that when one is at the extremity of its swing, the other is in mid course; and that the energy oscillates from one form to the other, being alternately kinetic and static. For magnetism is due to current or kinetic energy, while electrification is due to static or potential energy; and in ordinary cases they do not co-exist. You may have an electric current, or you may have a charged body. Wherever you have both, you have oscillations and the generation of waves.

But the curious thing is that at the generator the energy really does oscillate from the static to the kinetic form, and back again. Consider an ordinary aerial, with a capacity area above and below, and a coil in the middle between them. At one instant the upper area is charged positively, the lower area negatively, and there is no current in the coil. At the next instant, separated from the first by a quarter period, the current in the coil is a maximum, and neither area is charged at all. In half a period from the start the current has stopped again, having piled up its momentum in the two areas in the form of a reverse charge, the lower being now positive, and the upper negative. This sets up an elastic strain which recoils back again, generating an inverse current in the coil; which current reaches a maximum, and then expends its energy in recharging the areas in the origi-

nal way. And so on periodically, the process just recorded being a complete period, and occupying of course a very minute fraction of a second, even with the biggest areas.

Hence at the emitting station the electric and magnetic disturbances are not in phase. One lags a quarter period behind the other, just like the slide valve and piston of an engine. A little way off in the Ether the conditions have become different. At a distance of about a quarter wave length the electric and magnetic disturbances have caught each other up, and got into phase. Within that quarter wave-length they are not in phase; and accordingly the energy in that space oscillates to and fro, alternately traveling outwards and traveling backwards, from and to the source,—a pulsation in the Ether,—and no true wave is broken off or emitted within the first quarter wave length. But at a certain distance, which was calculated by the great discoverer, Heinrich Hertz, in the light of Clerk Maxwell's theory, some of the energy is flicked off at every oscillation. At that distance the two ethereal disturbances have got into phase. They are coincident with each other, and when that happens the only way in which they can co-exist is to fly along with the velocity of light; which accordingly they continue to do, until their energy is somehow absorbed or dissipated by conductors. Hertz gave diagrams of the whole process, according to Maxwell's principles, before the year 1890, and thoroughly understood it.

That is why an ordinary alternating dyna-

tion, but that the waves are better qualified to overcome obstacles, and to travel to a great distance without so much loss. That is a digression. What I want to say, further, is that the above process of wave-transmission, which has been described and worked out for electromagnetic waves, is essentially true of all waves. The kinetic and static energies are not oscillating from one form to the other, but are coincident and traveling together. Professor Howe has recently pointed out that it is true even of sound waves. At the place of greatest compression or rarefaction we might have thought that the particles would be stationary. So they are in an oscillating column, like that in an organ pipe. So they are in any source of sound. But not so a little distance away: not so in a sound wave, as distinct from the alternating pulse which generates a sound-wave. When we study the phenomenon in a true wave we find that the particles in a condensation, or greatest compression, have likewise their greatest speed. They are traveling full-speed forward, while in a rarefaction they are traveling full-speed backward. The static and the kinetic energies agree in position, just like the electric and magnetic. It is at the intermediate parts of the wave that we find them both momentarily zero. The particles are stationary at the places where the air is of average density, not in a compression or rarefaction. Hence the theory is very general, and those models which have been constructed to illustrate the propagation of

waves, and to show the lag of one form of energy on the other, are erroneous. They only apply to the oscillator, not to the waves. So-called stationary waves, the result of reflexion, are essentially akin to an oscillator. True waves must advance. The fact that the true wave only starts a quarter wave length away from the oscillator is very instructive. It applies even in the case of

light, although in that case the oscillator is of ultramicroscopic dimensions; and the frequency hundreds of millions of millions per second; so that the following-out of the process in detail might seem impossible. But it was not impossible to the great mathematician, Sir George Stokes, who in his work on Fluorescence arrived at the conclusion that the quarter wave lag or difference of phase at the start must be compensated or neutralized so that it became obliterated in the true wave.

It is in many respects the same even with waves on the surface of water. The particles of water are moving forward on the crests, and are moving backward in the hollows. They are moving only up and down at the position of mean level. If you watch sea waves traveling along in deep water, you will not at first notice the motion for-

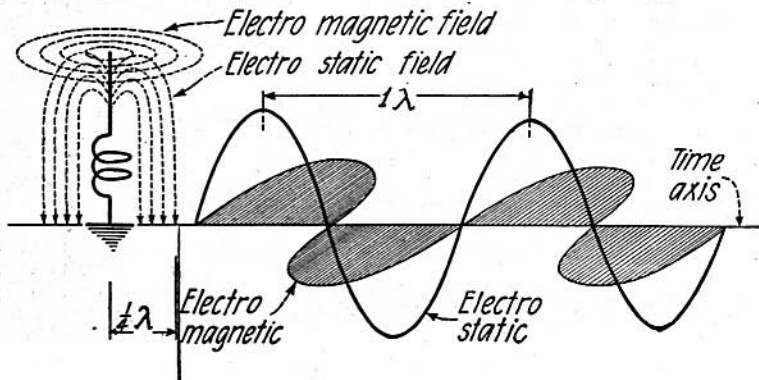
(Continued on page 1536)

**W**E are pleased to present to our readers, this most interesting article on the transmission of waves written by one of the foremost English authorities on radio.

Sir Oliver Lodge, well-known in scientific circles, is one of the pioneers of radio and has set forth some of its principles. In the present article, he explains in a clear and concise manner, how the electro-magnetic waves are propagated through the ether, a thing which is not generally well understood by the amateur.—Editor.

mo of commercial frequency emits no appreciable waves. The place whence waves would start is a quarter wave length away. And if the oscillations are a hundred a second, the wave length is 3000 kilometers, or say 2000 miles, so that the quarter wave length is 500 miles. And the waves from an alternator of 100 a second in New York would not begin till about the distance of Pittsburgh; that is to say, practically they would not begin at all, though theoretically it is true that every alternator must emit waves of infinitesimal strength. But the waves only become strong and important when the frequency of oscillation is very great; and the higher the frequency, that is to say, the shorter the wave length, the greater is the proportion of energy emitted in radiation. The advantage of long wave length is not that more energy is emitted, for a given horsepower of the sending sta-

Illustrating the Formation of the Electrostatic and Electromagnetic Field Around an Aerial. Note That the Two Components are at Right Angle.



# The Telmacophone in Every Home

The Telmacophone in your home provides entertainment and instruction for every member of the family. No one has to take turns or miss any part of the program. No need to change headphones from one person to the other. You are always assured a loud, clear tone. Everybody can hear everything, clearly and distinctly.

The tone is produced by original Baldwin Type C. Unit and reflected into the outer horn. There is no metallic effect. Finished in black and gold to harmonize with any surroundings.

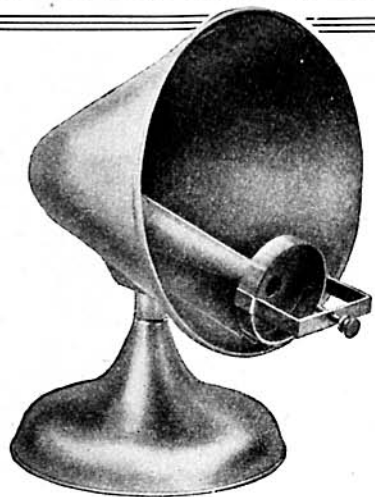
Correctly designed—fairly priced—unreservedly guaranteed. The ORIGINAL \$20.00 loud speaker and still the BEST. With original Baldwin Type C. Unit. Price complete \$20

If your dealer hasn't the Telmacophone in stock, send us his name and order direct from this ad enclosing \$20.00. Prompt shipment. Write for new free catalog.

RADIO DIVISION

TELEPHONE MAINTENANCE CO.

20 S. Wells St. Dept. B Chicago, Illinois



Return Money

Will return money, if dissatisfied, any time within 15 days of shipment. Adjustable for every make of a Phone, receiver, large or small. Adjustable for tone. Center horn slides in and out for adjustment and tuning in.

Jobbers—Dealers—Get our discounts.

WILLIAMS SPECIALTY CO.

465 Dean St.  
BROOKLYN, N. Y.



Galena Crystal, Mounted ..... 35c  
Galena Crystal, Unmounted ..... 25c

IMMEDIATE DELIVERY

Manufacturers, Jobbers, Dealers,  
Write for quantity prices

GALENA CRYSTAL MFG. CO.  
2894 Fulton Street Brooklyn, N. Y.

LIST PRICE  
**\$10.00**

This Loud-R-Tone 3-in-1 horn is a Parlor and Auditorium entertainer. By sliding out center, horn can be used for transmitting music and lectures over the Telephone 2,000 to 3,000 miles.

The center horn is removable, so that it can be taken out and used for tuning; an extra pair of phones is unnecessary.

The entire horn is made of spun brass. It has no solder seams, thereby giving a beautiful, clear mellow tone.

Dealers 40% off. Sample—\$6.00

## LOUD-R-TONE 3-IN-1

Our moulded variometer and other moulded products will mean satisfied customers and more sales to you Mr. Jobber & Dealer, why not write to us for full particulars?

The RIDgewood RADio Shop  
1603 Myrtle Ave., Ridgewood, L. I.

Amateurs we rewind and repair fones; send them to us

cannot be used for receiving and special applications certified to by responsible citizens must be filed before licenses are issued. Certain exceptions are made in cases of well-known foreign scientists, but their apparatus will probably be limited in range of reception and restricted to those of British make.

## On the Transmission of Waves

(Continued from page 1446)

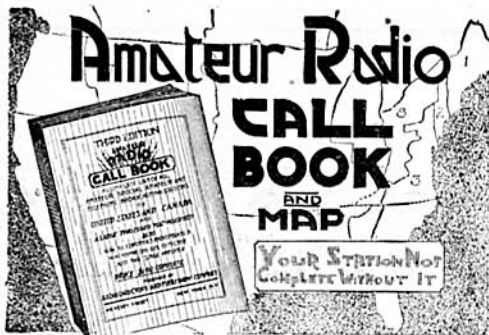
ward of the particles at the top of the crest, since straws and ripples on the surface go backward relative to the wave as it advances. But that only means that the water particles which are moving forward are not moving at anything like the speed of the wave itself. The wave is going much faster than the particles, and hence overtakes them, and slides under them. The speed of the water particles varies with the amplitude or magnitude of the disturbance. The speed of the wave does not depend on that at all, but only on the wave length, that is, on the distance from crest to crest; whether the wave is a mere inequality of the surface, or whether it rises twenty or thirty feet. The velocity of the wave—the speed with which the crest itself advances—depends not at all on the height or intensity of the wave; but it does, in the case of a water wave, depend on wave length, i.e., on the distance separating successive crests. In fact in deep water the velocity of wave-progress varies with the square root of wave length, for big waves. For ripples the law is different.

All these things are complications which we do not find in the Ether, nor even in the air. The speed of sound depends on the conveying material only, not on loudness, nor even on wave length or pitch. Sir Isaac Newton realized that, for he pointed out that a band heard at a distance could not possibly sound like music unless every note, loud or soft, high or low, had one and the same rate of travel. So it is also in the case of light and wireless waves. They all travel through the Ether at one identical pace, whether they be a hundred miles long, or the millionth of an inch short. Also whether they be bright like sunlight near the sun, or dim like a rushlight or a glow-worm. In this respect therefore Ether and Air waves differ from visible waves on the surface of the water. But all waves agree in this, that the potential and kinetic energies—that is, the displacements and the velocities,—are concurrent in phase, rising to a maximum and falling to a minimum together. This is a peculiar condition, destructive of equilibrium, and it can only be satisfied by the wave advancing through the medium at its own proper pace, a pace which in Wireless waves is determined by the mutual reaction of the electric and the magnetic components, in accordance with what is called Poynting's Theorem.

A receiver acts by obliterating some of the electric component, and thereby stops a position of the wave. This it does either directly, as by a linear aerial, or inductively, as by a loop aerial. The energy of such portion of the wave as effectively encounters the aerial is abstracted and utilised for the signal, some fraction of it degenerating into heat. The rest of the wave goes on.

So to sum up. The electric and magnetic components of a wireless or electromagnetic wave are at right angles to each other, and are equal in energy and coincident in phase, so that both reach a maximum, a minimum, or a zero, together. There is no lag of one behind the other, such as occurs naturally in all our emitting or receiving instruments. And the only way in which this curious unstable condition of things can be sustained, is for them both to advance forward with the velocity of light. And that is just what





## THE RADIO MAP

Of the United States, and Canada, size 2 x 3 feet, supplies an indispensable requisite of every radio station. The nine radio districts, broadcasting stations, standard time, areas, etc., etc. clearly indicated.

At Your Dealer or Send Direct

PRICE book and map complete (Do not send stamps) **\$1.00**

Dealers Write for Information

**RADIO DIRECTORY & PUBLISHING CO.**

45-C Vesey Street

New York, N. Y.

## THE BOOK for RADIO FANS

The New Edition of the **AMATEUR RADIO CALL BOOK** is the most complete directory of amateur stations published to date—listing Amateur, Special Amateur and Telephone Broadcasting Stations of the United States and Canada, also describes the Construction and Operation of a Honeycomb Coil Set, Detector and Two Stage Amplifier.

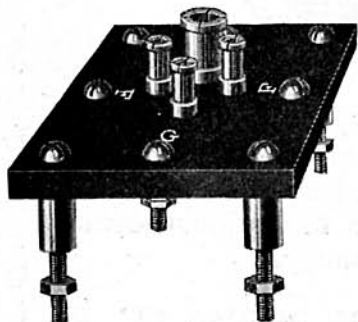
## Record Your DX Work

By pasting the map on heavy card board and using colored stick pins you can easily record your distant radio work.

## Ozburn-Abston Radio Co., Inc.

600-612 Monroe Ave., Memphis, Tenn.

RADIO PRODUCTS OF MERIT



Positive contact socket for the one and one-half volt Aeriotron WD-11 tube. No loose or oxidized spring contacts, consequently no tube noises. Cat. No. B-2. Price ..... \$1.25



MINIATURE JACKS for all uses

For standard tube prongs or for use with Miniature Plug. Cat. No. C-100. Price, 11c For Phone Tips. Cat. No. C-101. Price 11c For large prong of WD-11 tube or 50 watt tube. Cat. No. C-102. Price ..... 16c



An Adapter for the Aeriotron WD-11 tube. Fits any standard socket. No wiring changes necessary, merely insert Adapter and substitute dry cell for 6 volt storage battery. Cat. No. 0-1. Price.....\$1.40



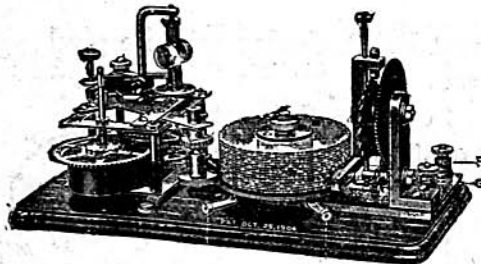
Miniature Plug made of polished bakelite and nickel metal parts. Used to replace binding posts where quick, positive action is desired. Cat. No. C-1. Price, 25c

## LEARN THE CODE AT HOME

"Just Listen—The Omnigraph will do the teaching"

with the

## OMNIGRAPH



THE OMNIGRAPH Automatic Transmitter will teach you both the Wireless and Morse Codes—right in your own home—quickly, easily and inexpensively. Connected with Buzzer, Buzzer and Phone or to Sounder, it will send you unlimited messages, at any speed, from 5 to 50 words a minute.

THE OMNIGRAPH is not an experiment. For more than 15 years, it has been sold all over the world with a money back guarantee. The OMNIGRAPH is used by several Depts. of the U.S. Govt. All applicants applying for a Radio license. The OMNIGRAPH has been successfully adopted by the leading Universities, Colleges and Radio Schools.

Send for FREE Catalog describing three models, \$14 to \$30. DO IT TODAY.

**The Omnigraph Mfg. Co., 20 Hudson St., New York City**

If you own a Radio Phone set and don't know the code—you are missing most of the fun

## MONEY for YOU

Add to your Salary—Make extra Pin Money. Start a lucrative business of your own. Spend an hour each day taking subscriptions for the "Radio News." We'll pay you well and you'll enjoy the work. Write for full particulars. Circulation Dept. RADIO NEWS, 53 Park Place, N. Y. C.

they do. The oscillator is stationary, true, but then the two disturbances there are not in phase. One is a quarter period behind the other, as one would expect: then the energy mainly pulsates, first out, then in, and is not all lost by radiation. The only part lost by radiation is that which has got a quarter wave length away, where the one disturbance has caught up the other, and where the energy—that which is used in Wireless Telegraphy,—is flicked off into space.

## SOMETHING NEW

(Extract from "Acroplane Boys in Record Flight")

Suddenly the bell of the wireless on board the auto began to ring.

"The boys are sending us a message," exclaimed Billy.

He and Lathrop raced back up the hill to the car, where the latter placed the detector over his ears and tapped out his ready signal.

After all—radio is simple.

## SWEDISH RADIO COMPASS CALL IS "SAM."

The good old American name S A M is the call of a new radio compass station at Hallo on The Skagerrak, in Sweden, which was opened for general service on November 1, according to information reaching the Hydrographic Office of the Navy. The new station, which is operated through Goteborg, S A B, will determine the true bearing of vessels calling within 150 miles on a 600 meter wave length. The charge for a bearing is placed at five kronor or about \$1.34.

## RADIO LETTER SERVICE

The Radio Corporation of America has announced a radio letter service to London and Germany at a rate slightly higher than postage. The rate is six cents per word and the messages, filed any day in the week up to Saturday with the designation for "radio letter", will be transmitted to London or Germany for delivery on the following Monday morning.

## SAVING BY RADIO COMMUNICATION

The Signal Corps of the Army in Washington continues to save money through the transmission of official messages by radio instead of by land wires. In September a total of 239,826 words were handled, with a saving for the month of \$2,668 over what the cost would have been at commercial rates.

## RADIO ADDS TO THE MAIL

TO THE NEW YORK HERALD: Your editorial article in regard to the Government's increased postal receipts touched upon a point I had been thinking about for some time. Aside from the fact that better times should account for a good postal business, I believe that radiophone broadcasting is no mean item in the account.

There are about 530 broadcasting stations in the United States, and others at Havana, Cuba, and San Juan, Porto Rico. About 30 are very powerful and they receive all the way from three to six thousand letters from radiophone listeners every day. At 5,000 letters each this would mean 150,000 letters for the 30. About 100 stations will receive say 1,000 letters daily; 50 stations 500 each, and 350 stations say 200 letters daily. This makes a total of 345,000. Now at a fair estimate probably 75 per