CHAPTER XV.

THE ÆTHER AND THE ATMOSPHERE.

472. It is now time to consider more carefully what happens to the æther wave after it leaves the aerial.

Certain general facts have been stated in the earlier chapters. These are :—

The whole universe including the earth is surrounded and permeated by a medium termed æther.

The æther can be set in vibration by electron movements, by reason of the electric fields associated with the electrons.

All movements of the æther travel at the same rate, viz. 3×10^8 metres per second.

Different rates of electron movement produce æther waves of different length, viz., "X" Rays, light, Hertzian or wireless waves, &c.

The energy conveyed by the different æther waves can be converted into heat energy if suitable receivers are used.

When a condenser is charged and discharged a state of varying strain is produced between its plates, and "lines of electric strain" spread out from it.

When a current is varied through an inductance, "lines of magnetic strain" in the æther are produced.

When an aerial circuit is set in oscillation, the energy imparted to it is transferred rapidly backwards and forwards between the capacity and inductance of the aerial, and a wave due to alternate electric and magnetic strains—termed an electro-magnetic wave—is propagated.

Any substance, or medium which acts as an insulator or dielectric, passes a wireless wave readily ; *i.e.*, the electric and magnetic forces pass freely through it without losing any of their energy.

Any substance possessing conductive properties absorbs energy from the wave, because movements of electrons take place in it, and the energy of the wave is converted into heat energy ; thus a sheet of soft iron is almost a complete barrier to a passage of an electro-magnetic wave.

473. **The Form of a Wave.**—The original open oscillator of Hertz did not employ the surface of the earth to form one plate of the circuit, but the oscillator was of the "linear" or "dumb-bell" type, as shown in Fig. 305.

This forms an open oscillator with a certain capacity between the two plates (as indicated by the dotted lines) and a certain amount of inductance in the connections to the plates.

When this circuit is set in oscillation, then at the moment when the condenser is fully charged and the current is zero,

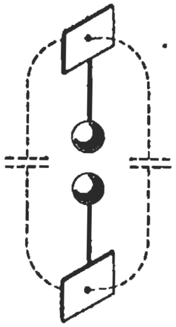

FIG. 305.

we may imagine lines of electric strain to be connecting each positive ion on the upper plate to its "opposite number"—a negative ion on the lower plate, as in Fig. 306 (*a*).

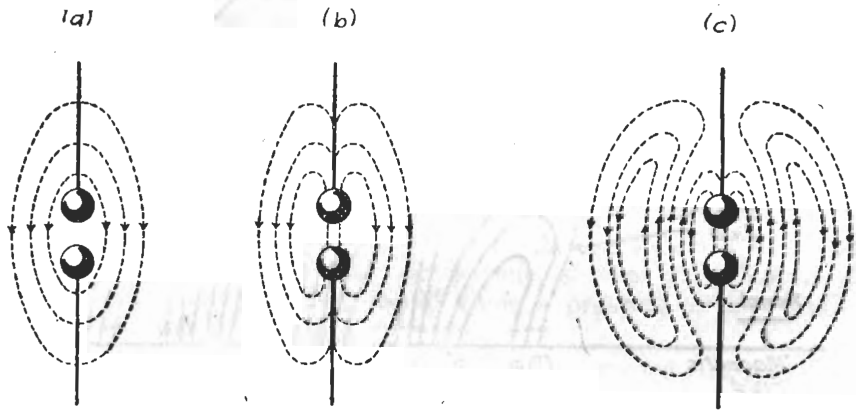

FIG. 306.

As the open oscillator discharges, current will flow downwards across the gap.

The ends of the electric lines of force slide together along the wires (as in Fig. 306 (*b*)) and finally unite as in (*c*). The current now goes on flowing and the charges in the condenser are reversed, and new lines of force are produced with reversed polarity, the first electric disturbance having been snapped off in the form of closed loops.

The first disturbance is forced outwards by the birth of the new electric field, for the directions of the lines in the inner surface of the first and the outer surface of the second are the same.

As the current oscillates in the circuit, we see that a series of closed loops of **electric strain** are flashed off into space, each repelling its predecessors to make room for the latest born; each set of loop representing lines of force in opposite directions to the set of loops next in front and in rear.

Similarly we must imagine the wires to be surrounded by rings or ripples of **magnetic strain,** whose intensity will vary with the current strength and whose direction will alternate as does the current.

Further, these lines of force are horizontal, being in a plane at right angles to the current-carrying wire, and consequently at right angles to the electric lines of force.

This type of oscillation, causing symmetrical loops to travel outwards, is called a "free-wave" system, and is that which results from using a "Hertzian" or dumb-bell oscillator excited in the middle, and is very similar to the waves emitted by aircraft.

474. The case of an earthed aerial wire excited at its lower end presents a different form of electrical disturbance, as shown in Fig. 307.

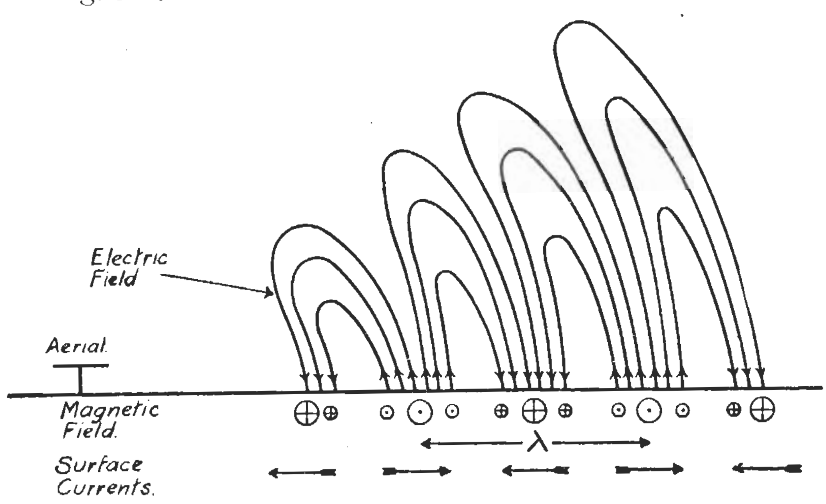

FIG. 307.

The effect is the same as if only half of the Hertzian oscillator had been regarded, at any rate when the waves have travelled some little distance from the aerial.

If the aerial consists of a capacity area at the top with the feeder symmetrically placed, the distribution of the electric and magnetic fields is somewhat as shown in Fig. 307.

The full lines represent the electric field spreading out in the form of annular loops of ever increasing height but constant width.

These loops are accompanied by horizontal bands of magnetic flux spreading out from the aerial with the electric loops.

The maximum magnetic flux density occurs when the electric field is the greatest.

In the surface of the earth there will be circular bands of currents flowing alternately radially inwards and outwards.

The wave length, λ, will be the distance from one point of maximum electric or magnetic field to the next maximum in the same direction.

Near the aerial the electric and magnetic fields are not in phase with one another.

They are in fact very nearly 90° out of phase since they depend upon the aerial voltage and current respectively.

It is only small components of the two fields which are in phase with one another and which are, as it were, shed from the aerial in the form of electro-magnetic waves.

It is obvious that they must be in phase, as otherwise the energy in the wave at any moment would be zero.

475. **Part played by the Atmosphere.**—As the æther wave has to travel through the atmosphere, the latter plays a very important part in determining how the wave behaves.

At the surface of the earth dry air is a **perfect dielectric ;** *i.e.*, æther waves pass through it without any appreciable loss of energy.

The total depth of the shell of air that envelopes the earth is not more than about 100 miles. Its depth is therefore small when we remember that the earth's diameter is 8,000 miles, and that we can easily transmit signals for distances of 2,000 miles.

Now, the higher we rise above the earth's surface the less heavy does the layer of air become, so that at a height of 35 miles the barometer would show a pressure of only 1 mm. of mercury.

Air at this pressure suddenly becomes **a good conductor.**

So good a conductor does it become that a layer of air at this pressure, only half an inch in thickness, will not allow a wireless wave to pass.

It is just at this height of about 35 miles that we get air becoming a good conductor due to the critical pressure arrived at. Below this pressure—*i.e.*, higher still from the earth—it again becomes an insulator.

The upper shell of conducting air, then, is separated from the earth by a layer of non-conducting air whose thickness—about 35 miles—is less than one hundredth part of the earth's radius, and the conducting properties of the upper shell are such that it is 40 times a better conductor than is the surface of the sea, and over 600 times better than damp soil.

476. The reason of this conductivity is that the atmosphere is ionised by bombardment by flying electrons originating probably from the sun itself.

Large ions are formed consisting of small clusters of molecules surrounding the excess positive and negative charges.

During the night these free charges tend to re-unite. When they are produced in very large numbers, however, the recombination is incomplete.

The outer atmosphere thus remains to a greater or less degree permanently ionised.

In the middle atmosphere, where the ions are not produced in anything like such large numbers, the recombination is more complete, and for most of the night the middle atmosphere is not ionised.

The low levels of the atmosphere are probably never sufficiently ionised to produce any appreciable effect.

Besides sunlight there are other causes at work ionising the outer atmosphere; for example, "shooting stars" continually arriving in the atmosphere probably carry with them some free electrical charges which they give up.

This will also tend to keep the outer layers permanently ionised.

477. The path in which the æther wave is free to travel is a spherical shell, bounded on one side by the surface of the earth or sea, and on the other by the conducting layer of air.

The high frequency resistance of the former is about 6,600 ohms per cubic centimetre for earth, or 373 ohms per c.c. for sea, while that of the latter is not more than 10 ohms per c.c.

The reason why W/T waves travel round the earth at all is that the presence of ions in the upper atmosphere gives rise to an increase in the forward velocity of the waves, whilst at the same time a small proportion of their energy is frittered away in heat.

Thus as a wave spreads out its upper parts quickly reach the ionised layers and move more rapidly than the lower.

The wave accordingly becomes bent, the upper halves being reflected more and more towards the earth.

In just the same way, at sunset the sun's rays strike the atmosphere obliquely, and being refracted or bent from their straight path illuminate the surface of the earth for some time after the sun has actually disappeared.

478. Two very well known facts about W/T waves are that signals are normally weaker by day than by night, and that short waves suffer a much greater decrease than do long waves.

This is because the atmosphere becomes irregularly ionised. The conducting layer does not present a nice smooth surface for the wave to slide along, but becomes rough and jagged. Large patches of air in the middle atmosphere become ionised also.

The reflecting effect of the upper atmosphere varies with the wave length; the longer the wave the more sharply is it bent back.

Thus, for equal energy in the two waves, the energy of the long wave will be available at the earth's surface to a greater extent than that of the short wave. The short wave may dissipate all its energy in the middle atmosphere before it is bent back to the earth.

By night, however, the middle atmosphere, since it becomes de-ionised, does not affect either wave, but the strongly ionised outer layer bends both long and short waves sharply back. Neither of them, therefore, has a long path through the ionised medium during which its energy would be absorbed. Long and short waves thus have a more equal range by night than by day.

In this connection it should be remembered that a great increase of signals at night cannot be expected from the long waves used in continuous wave systems. Whereas a short spark wave may increase in range anything from 100 per cent. to 300 per cent., a long spark or continuous wave will be little, if any, stronger by night than by day, and may be more difficult to read owing to the greater prevalence of atmospheric disturbance at night.

Many other observed peculiarities can be similarly explained. It is observed that long waves are better than short ones in mountainous country by day, but that there is not much difference by night.

This is put down to both waves being reflected sharply from the outer layers at night, whereas by day only the long waves are bent back sharply enough to penetrate the valleys.

The not infrequent irregularity of long waves by night may perhaps be due to large masses of the middle atmosphere remaining ionised.

Such ionised clouds are quite possible, because during the day-time the atmosphere is in a state of continual motion, and parts may accumulate an excess of negative ions and other parts an excess of positive ions.

Recombination cannot then take place very quickly, and these clouds remain to bend the waves in various directions.

They will have a greater effect on long waves than short ones, which may account for the long waves being more irregular.

Some action of this kind might also explain the "freak" distances so often reported, the ionised clouds acting as large lenses or mirrors.

The maxima and minima of ionisation of the middle atmosphere occur at noon and 5 a.m. respectively, and these are the times at which the worst and best signalling ranges may be expected.

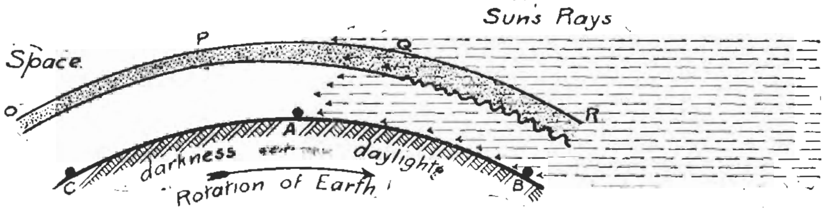

FIG. 308.

479. **Effect of Sunset and Sunrise.**—Intercommunication between two stations is always worst when one station is in darkness and the other in daylight.

These conditions are illustrated in Fig. 308, where station A is in twilight, station B in daylight, and station C in darkness. (It should be assumed that these three stations are at the corners of an equilateral triangle, *i.e.*, that the distances between them are equal.)

Over station A, at which sunrise is just taking place, the conducting shell is at least as sharply defined as during the night and is therefore capable of reflecting; while at B where the sun is high, the under surface of the shell is indefinite and no longer reflects well. Between P and Q the shell slants downwards towards the earth, forming what is sometimes termed "the shadow wall." It therefore strengthens forward radiation or condenses the received waves at A. Between O and P the shell is parallel to the earth's surface, as also between Q and R.

Signals are best when both stations are either in daylight or darkness simultaneously.

If the sun has risen at one station but not at the other, signals are usually much weaker than at any other time.

Also the best wave length for transmission is not constant but varies from time to time.

It would seem that the first-mentioned phenomenon must be related to the varying thickness of the dielectric lower layer of the atmosphere, which is smaller where the sun is shining, and greater on the dark side of the earth.

Thus the waves, generated at a station in daylight, where the height of the dielectric is small, in travelling westward pass into a deeper dielectric layer, *i.e.*, into a region where the conducting upper layer is further from the earth.

In the opposite direction the waves travel from a deep dielectric into a shallow one.

In the region of transition from the one to the other the curvature of the upper conducting layer—*i.e.*, of the upper surface of the dielectric—must be greater than when the conditions are uniform over the whole range.

This may cause a greater dissipation of energy on the way.

An alternative explanation is that the zone where the change from light to darkness is taking place may be the scene of very violent and irregular ionisation or recombination.

This zone may disperse the waves in all directions.

In the same connection it is not infrequently observed that **strong** signals can be sent or received when this twilight band is immediately behind a station.

The band therefore appears also to have some reflecting property.

Operators in Arctic regions have also reported that strong signals are always received when auroras are observed. Auroras in all probability consist of zones of excessive ionisation, and their presence coincidentally with strong signals tends to confirm the theory.

480. **The Part played by the Earth.**—We have seen previously that the bases of the electro-magnetic waves move outwards from the aerial over the surface of the earth, and also that circulating currents are set up in the ground.

The surface of the earth is not everywhere a good conductor of electricity. The sea and moist soil are better conductors than dry stone.

In some places the surface materials of the earth are in fact good insulators.

The attenuation—or weakening—of the electric wave is on this account very different over different parts of the surface of the earth—depending on the fact that there is a greater or less penetration into the insulating portions and a greater or less absorption of energy at the poorly conducting portions.

For example, a theoretical calculation (by Zenneck) shows that a station having a range of 1,000 miles over a perfectly conductive expanse, would have a range of—

920	miles	over	sea water,
700	,,	,,	fresh water or very wet soil,
560	,,	,,	wet soil,
270	,,	,,	damp soil,
150	,,	,,	dry soil,
55	,,	,,	very dry soil,

and these figures accord very well with practical experience.

Short waves suffer much more in passing over land (even flat land) than do long ones. This is due to the greater losses suffered by the high frequency currents.

The useful "layer" of earth becomes shallower and the consequent resistance greater.

An ordinary high frequency current will not be perceptible at a greater depth than 15 metres in damp soil. Damped wave trains will penetrate even less than this amount.

It is quite possible to receive signals on an insulated wire buried in the ground.

The depth of penetration in salt water is about 5 metres—depending upon the amount of salt in the water.

As a general conclusion, one expects to get much the longest ranges over sea, and range falls off considerably if dry ground intervenes. For example, transmission from the Red Sea to the Persian Gulf, across Arabia, is difficult unless an ample reserve of power is available.

Great difficulty occurs in communication between two stations which have jungle or dense undergrowth intervening, especially if the jungle grows close up to the station.

A tremendous absorption of energy occurs; moreover, there seems to be a layer of air, level with the tree tops, at the same potential as the earth, and the wave travels along the surface of this, and does not influence a receiving aerial, unless the latter be a good deal higher than the trees.

481. **Screening.**—It is a well-known fact that if a ship is lying close to a very high piece of land, or in a land-locked harbour surrounded by high cliffs, her reception of signals is greatly diminished, while if she steams away clear of the land by a few miles, she picks up signals once more.

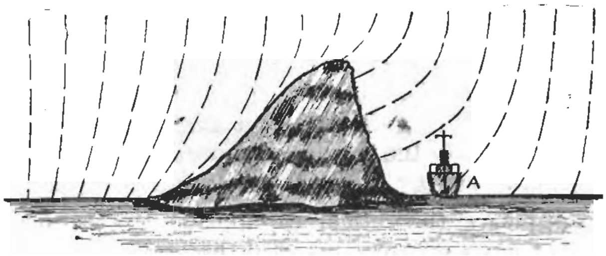

Fig. 309.

This occurs for two reasons :—

(a) The electric field of the æther wave is deflected by the land as illustrated in Fig. 309. This means that the lines of force acting on the aerial of the ship (A) are in a horizontal instead of a vertical direction, and thus are made very ineffective.

(b) A great deal of the available energy in the portion of the wave front with which the ship is concerned is wasted in the high ground.

This effect is very noticeable if the soil is very permeable, *i.e.*, if it contains a high percentage of iron ores.

A similar screening effect takes place if a ship is lying under a big crane, or a bridge like the Forth Bridge.

482. **Atmospherics or Strays.**—Since the beginning of the world, æther waves of the order of length used in wireless telegraphy have been and are continuously traversing its surface, but have only been noticed comparatively recently.

They are generally known in the Service as "atmospherics," and are also known as "strays" or "X's"; disturbances known as "statics" are a special variety.

Atmospherics have a very variable but generally long wave length.

Their damping is heavy, and their shocking effect is severe.

When they encounter an aerial they set it oscillating at its own natural frequency and are consequently very difficult to cut out; they may be reduced in strength by the use of some limiting or balancing device, and as they are non-musical they can be over-read by a skilful operator if they are not too severe.

As regards their origin, they may be divided into two classes:—

(*a*) Those produced by convective conditions in the atmosphere within, say, 100 miles of the station, which may be termed local atmospheric storms.

(*b*) Those originating at a distance.

It will have been gathered from what has gone before that the atmosphere is by no means at a uniform zero of potential, but that large patches of it accumulate excessive positive and negative charges.

These charges are continuously accumulating and uniting, frequently with such violence as to produce the convection current known as a flash of lightning.

Accurate records of atmospheric disturbances have been kept of late years, the result tabulated, and certain general conclusions deduced—

(*a*) Atmospherics heard in the dark hours are much more numerous and louder than those heard during daylight.

The changes from day to night conditions are more abrupt on and near the mainland, less so at sea.

(*b*) Heavy atmospheric storms occur at irregular intervals, generally accompanying periods of low barometer, high wind velocity, rapid change of temperature, and great rainfall; they are especially prevalent during rapid barometer fluctuation.

(*c*) The worst atmospherics occur when there is a thunderstorm in the neighbourhood.

(*d*) Certain seasons of the year are much the worst in various parts of the world, *e.g.*, September and October in the Mediterranean, the South-west and North-east monsoons in the East Indies, &c.

483. Statics are a special variety of atmospherics, and are due to electrical charges accumulated by the aerial like a lightning rod. For this reason it is always inadvisable to leave any aerial insulated from earth by a receiving condenser, as a statical charge is liable to accumulate and puncture the condenser.