CHAPTER VII

The Transmission of Wireless Waves

THERE seems to be a good deal of misunderstanding as to how electric waves are propagated from an aerial, not only as regards the distance travelled and the way in which they get round the curvature of the earth, but as to their actual mode of propagation, and as to what process is going on in the ether which is able to advance with the velocity of light. For electric waves are not only electric, they are electro-magnetic. 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 aerials 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

https://doi.org/10.1017/CBO9781139381093.009 Published online by Cambridge University Press

energies; their energies are necessarily equal, so that any 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 too 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 disturbances must be coincident 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

https://doi.org/10.1017/CBO9781139381093.009 Published online by Cambridge University Press

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 original way. And so on periodically. The process just recorded is a complete period, and occupies, of course, a very minute fraction of a second, even with the biggest aerials.

https://doi.org/10.1017/CBO9781139381093.009 Published online by Cambridge University Press

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 travelling outwards and travelling 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 etherial 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, about the year 1890, and thoroughly understood it.

https://doi.org/10.1017/CBO9781139381093.009 Published online by Cambridge University Press

That is why an ordinary alternating dynamo 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 3,000 kilometres, or say 2,000 miles, so that the quarter wave-length is 500 miles. And the waves from an alternator of 100 a second in the south of England would not begin till about the distance of Aberdeen: 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 horse-power of the sending station, 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 process of wave-transmission, which has been described and worked out for electro-magnetic 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 travelling together. Prof. 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 travelling full-speed forward, while in a rarefaction they are travelling 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 at 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,

https://doi.org/10.1017/CBO9781139381093.009 Published online by Cambridge University Press

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 backwards in the hollows. They are moving only up and down at the position of mean level. If you watch sea-waves travelling along in deep water, you will not at first notice the motion forward 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 for-

https://doi.org/10.1017/CBO9781139381093.009 Published online by Cambridge University Press

ward 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 20 or 30 ft. 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.

SOUND AND LIGHT SIMPLER THAN WATER WAVES

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 portion 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 utilized 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 electro-magnetic 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 and 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 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.