Omnipresent physics in technologies and other scientific fields

from the physics knowledge in secondary/high schools

by

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Book funded by the American Physical Society (APS), through the Public Outreach and Informing the Public grant. It is specifically written for Upper 6 students in sciences with majors in Physics for the Anglophone education system. A French version has also been written for the students in Terminales scientifiques in the Francophone education system.

Chapter 4: Physics in telecommunications technology

IV.1. Introduction

Physics has contributed to the development of the hardware of telecommunication technology starting from the microphone, loudspeaker, radio electric telecommunications, satellites telecommunications, optical fiber telecommunications, computers, phones and the Internet. There is no example of telecommunication technology that is not an application of physics or to be humble that does not involve the application of some physics somewhere in its functioning.

Let us recall that the telecommunication technology has been associated with software programming to form the Information and Telecommunication Technology (ICT) or telematics. One of the main role of the physics in telecommunications is the fabrication of the hardware devices made of appropriate materials whose properties are determined by physicists.

This chapter focuses on some physics laws used in modern telecommunications technologies. Since this book is limited to physics taught in secondary/high schools, a large number of applications involving higher level physics taught in universities will not be explained. We will concentrate on some applications which can be understood by a student who has covered his secondary/high school physics classes. Specifically, information will be given on how physics acts at the following stages: emission and reception, conversion and transmission of messages. Indeed, these are the stages contained in any telecommunication device (classical telephone, cell phone, smartphones, computers).

IV.2. Emission and reception of messages

When you speak into a microphone (of telephone set-up and computer), the up-and-down sounds of your voice are converted into a corresponding up-and-down pattern of electrical signals. The physics law used to convert voice into electrical signal can use the Faraday's law of induction. The membrane or diaphragm of the microphone is attached on an electrical wire which because of the pressure due to the sound wave moves inside a region where a magnetic field exists (Figure 4.1). Because of the motion of the electric wire, the flux changes and there is a birth of an induced electric voltage or a current which propagates in the electrical lines either to a loudspeaker, to an antenna or to a telecommunication diode or laser diode (for optical fiber communication).

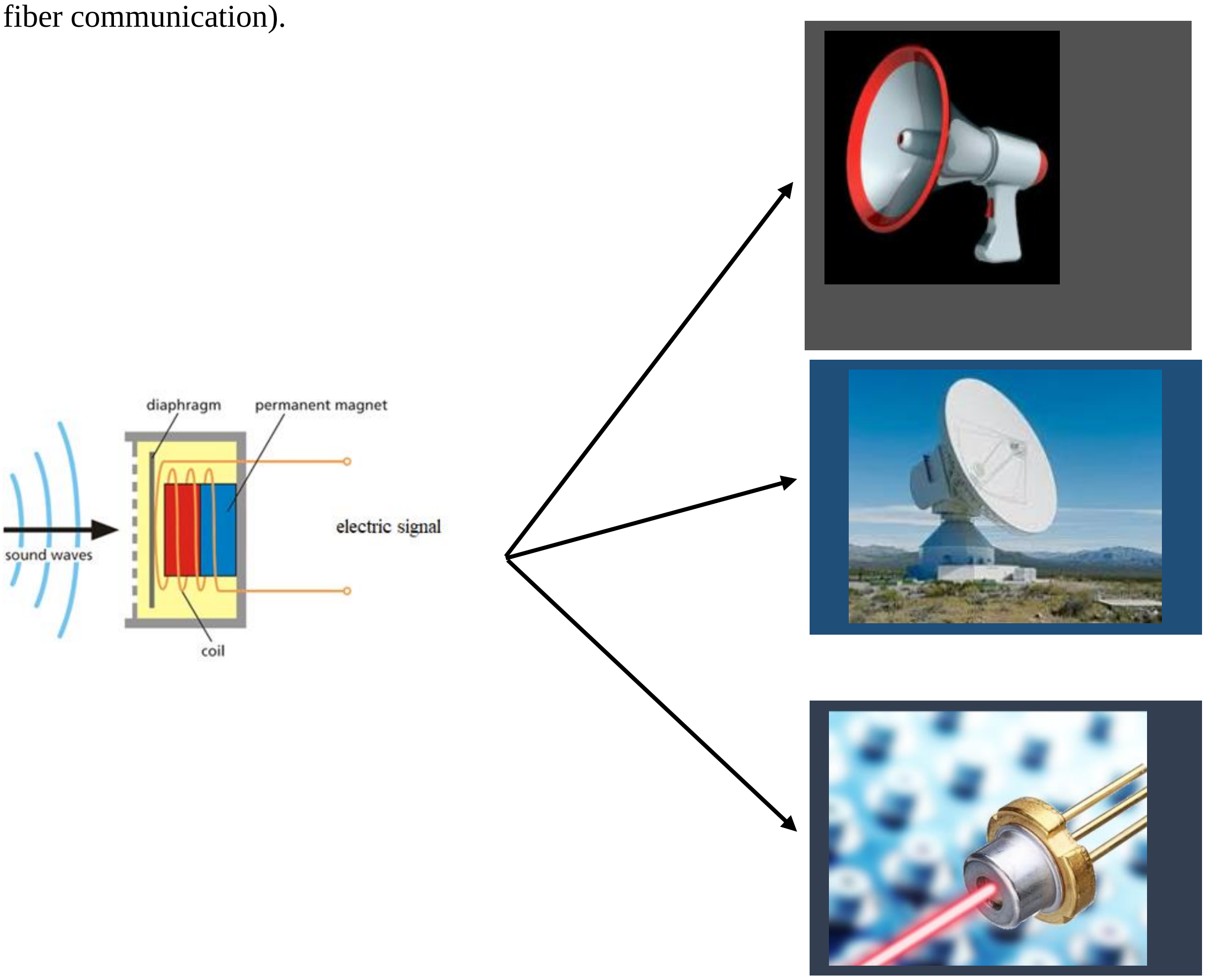

Figure 4.1 : A signal from a microphone going either to a loudspeaker, or to an antenna, or to a telecommunication diode for optical fiber.

The electrical signal generated is treated by an electronic set-up (modulation and demodulation, amplification, digitalization, filter, conversion into light, conversion by an antenna, etc.). It can then propagate through several media (electrical line, air or optical fiber).

When the electrical signal propagates to the loudspeaker, the loudspeaker reproduces the voices at it is explained below. This is the case for radio electrical transmission in telephone lines; but also for short distance communication.

When the electrical signal travels to an antenna connected to the microphone, the antenna radiates electromagnetic waves which propagates in the air and will be received by other antennas connected to the receivers.

If the receiver is a loudspeaker, the reverse process takes place. The structure is similar to that of the microphone. The electric current now flows in the electrical line inside a magnetic field. A Laplace force takes place and set the microphone membrane into vibration. The membrane vibration is then transferred into the air which vibrates, producing sound.

When the electric signal goes to the telecommunication laser diode, the diode converts the electricity into light signal which propagates in the optical fibers or in the free air.

One should note that the microphone can have large size or very small size as the one in our cellphones. In the cellphone, the microphone is connected to an internal antenna which radiates the message to large antennas dispersed in the country side.

Note that the Faraday's principle is just one of the physical principles used in microphones and loudspeakers. Other mechanisms are based on piezoelectric effect and electrostatic effect. In the case of the piezoelectric effect, the pressure due to the sound creates a pressure on the piezoelectric material which has the property of converting the mechanical pressure signal into electrical signals. For the electrostatic conversion, it is based on the fact that the capacitance of a plate capacitor depends on the gap between the two plates. If a capacitor, polarized by a fixed voltage, has a plate which can move, modifying the gap, then an electrical charge or current will be created because of the variation of the gap. This current can then be manipulated as in the case of the Faraday's law conversion.

IV.3. Conversion of electrical messages

IV.3.1. Conversion into electromagnetic waves by antennas and the reverse

A radio wave transmitter is a telecommunication equipment which radiates electromagnetic waves into air space through a radio antenna.

Consider Figure 4.2 in which the worm tube is assumed to be a radio antenna.

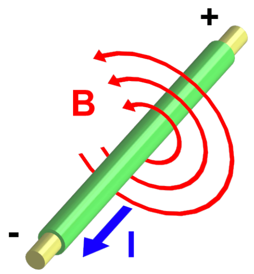

Figure 4.2: An electric cable (antenna) generating a magnetic field in its environment

Any electric current (variable or direct) generates a magnetic field as it is seen in textbooks at secondary/high schools. For straight electrical line in which a current I flows, the magnetic field intensity at a distance d of the line is

$$B = \frac{\mu_0 I}{d} \tag{4.1}$$

According to Maxwell equations, if the current I is variable, a variable electrical field is also generated so that electromagnetic wave takes place and propagates in the space. At the end of the propagation, the electromagnetic wave hits the receiving antenna. Because of the electrical field, electrons in the antenna are set into motion. The variable magnetic field also generates an electrical current since the magnetic flux is variable (Faraday's law). The generated electrical current can thus enter in a telecommunication device such as loudspeaker, telephone set, computer, etc.).

IV.3.2. Conversion into optical signals and the reverse

As it was indicated above, when the electrical message is emitted, it can be transformed into an optical signal propagates in an optical fiber. The conversion mechanism is through the light emitting diode or laser diode (LED) which converts an electrical signal into light or optical signal (Figure 4.3).

Figure 4.3: A laser diode

The generated optical signal can thus propagate in the optical fiber and arrives at the other side where it is converted into electrical signal. This second conversion is through specialized photodiodes which can convert light into electricity as we explained in chapter 2 (Figure 4.4). Let us mention that the optical signal can also propagate through the free space and reach the receiver at a given point.

Figure 4.4: The symbol and image of a photodiode

When a photon of sufficient energy strikes the photodiode, a phenomenon similar to the photoelectric effect takes place, but inside the material. An electrical current is produced. This current can then be treated electronically before been displayed in diverse forms (audio, text, video).

IV.4. Transmission of messages

The transmission of messages takes place in electrical lines (radio electrical communications), in free space (electromagnetic waves), and in optical fibers (light signals).

The propagation in electrical lines follows laws that will not be presented here. But, some information have already been presented in secondary/high schools on longitudinal waves.

Inside optical fiber, the physics laws used here are those of reflection and refraction presented in Chapter 2. Indeed, optical fibers (Figure 4.5) use total internal reflection to transmit light. It has a solid core of dense glass surrounded by a less dense cladding. The light ray passing through the inner core is reflected back instead of being refracted (Figure 4.6).

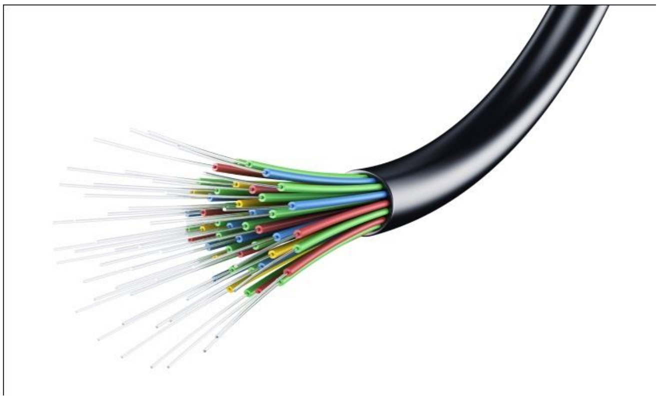

Figure 4.5: A bundle of optical fibers

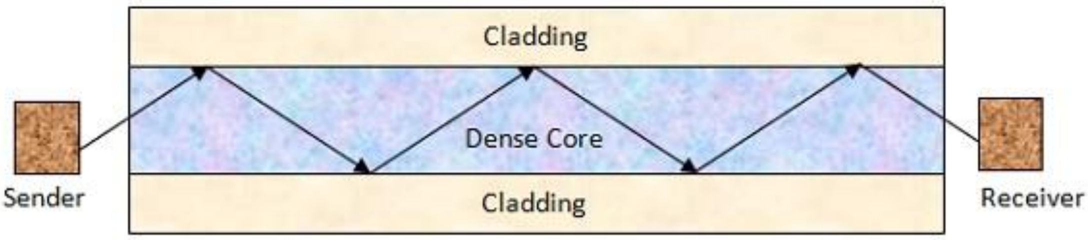

Figure 4.6: Reflection of light in an optical fiber

For free space propagation, they follow a three dimensional wave equation which will be explained during the university courses. The electromagnetic waves are emitted and received by special antenna such as the ones presented in Figures 4.7 et 4.8.

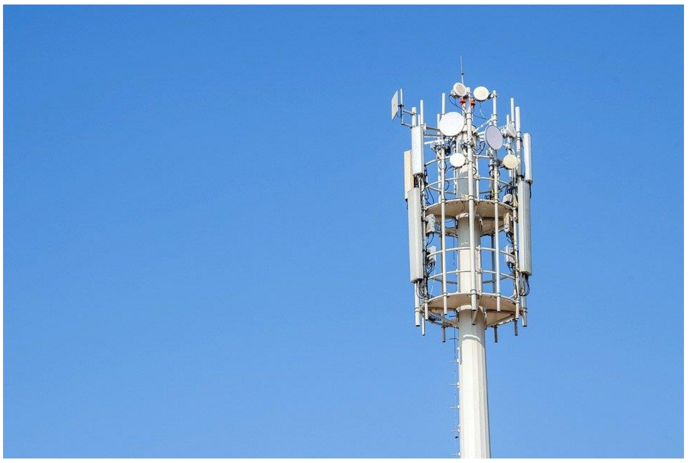

Figure 4.7: A telecommunication antenna

Figure 4.8 : A reception telecommunication antenna or parabola

IV.5. Conclusion

This chapter has dealt with some information on how physical laws are used for the emission and reception, conversion and transmission of messages in telecommunication network. This constitutes one important element of the Information and Telecommunication Technology. These are just some few applications which can be understood with the physics taught at secondary/high schools. At the university level, more will be learnt, either in physics courses or in specialized training on telecommunications (engineering).