ELECTROMAGNETIC ENERGY

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We would like, in this trip of ours among the energies, to give emphasis to a particular form of energy that, beginning from the 18th century, up to our days, it has changed without any doubt the evolution of our society, electromagnetic energy.

The origin of this knowledge makes him go up again to a Scottish physicist James Clark Maxwell (1831 - 1879) that it analytically foretold the existence of it also founding on the studies of Faraday (1791 - 1867). It was then the German physicist Heinrich Hertz (1857 - 1894) that with his experiments of interference it tried the existence of it beyond every reasonable doubt.
And it is important to know that these experiments were conducted in the portion of the electromagnetic spectrum related to the radio waves: this fact, thanks to the undisputed genius of Gugliemo Marconi, said beginning to the development of the radio communications.
Returning to the experiments of Hertz, they were put in evidence some properties of the radio waves as the reflection, refraction and polarization analogous to those revealed by light.
Concluded an amazing fact: the light is nothing more than an electromagnetic wave.

1 CHARACTERISTICS OF ELECTROMAGNETIC WAVES

An electromagnetic wave is constituted by an electric field (E) and a magnetic field (H) perpendicular among them and that they perpendicularly oscillate in phase to the direction of propagation.
A wave of this type is said wave polarized plain, and the plan of polarization is the plan in which the electric field oscillates.
In energetic terms, the electromagnetic wave is a flow of energy that, in the vacuum, is propagated at the speed of light. In a homogeneous dielectric the propagation happens in straight line.

1.1 Speed

The speed of the electromagnetic waves is different in dependence of the dielectric in which is propagated. In the vacuum speed has been measured in 299.792.458 meter/sec.
This value is normally rounded off to 300.000 Km/sec and it is indicated with the letter "c".
In a dielectric material not conductor the speed of the electromagnetic waves is smaller of that of the vacuum, and it can be calculated with the relationship:

$$c_m = \frac{c}{n}$$

Where “n" represents the index of refraction of the dielectric. This value is normally greater than 1.
Of it that the speed of propagation of the radio waves in a different dielectric from the vacuum is smaller than 300.000 Km/sec.

1.2 Wavelength

The wavelength represents the distance among two points correspondents between a cycle and the following one. For instance the distance among two maximum points of two succesive crests.

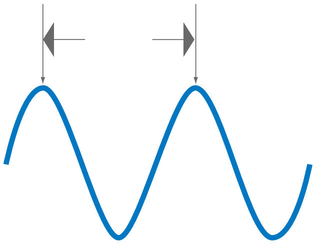

Fig.1.1

The wavelength is measured in meters.
In the case of the radio waves, such length starts from few millimeters (microwaves) to different Kms (very long waves).
The wavelength is indicated with the letter “λ” (lambda).

1.3 Frequency

The frequency of the electromagnetic waves is understood as the number of lengths of wave that pass in the unity of time. The frequency is indicated with the letter "f" and it is measured in Hertz (Hz). Frequency and wavelength are in relationship according to the formula:

$$\lambda = \frac{c}{f}$$

1.4 Amplitude

For amplitude of an electromagnetic wave we intends the maximum value that is reached by the electric field.

1.5 Intensity

The intensity of an electromagnetic wave is the energy that transits through a unitary area in the unity of time, and it is express in Watt/m^2.
In synthesis, it is the energy that crosses an area 1 meter per 1 meter wide, every second. In this optics, the electric field and magnetic field are related as is shown in the formula:

$$P_d = E \longleftrightarrow H$$

P_d = Power density [W/m^2]
E = Electric field vector [V/m]
H = Magnetic field vector [A/m]

2 ELECTROMAGNETIC SPECTRUM

The electromagnetic waves extend in a vast interval of frequencies and correspondents wave lenghts. These last ones vary from about ten Km, up to dimensions comparable to the atomic greatness (around 10^{-13}m).

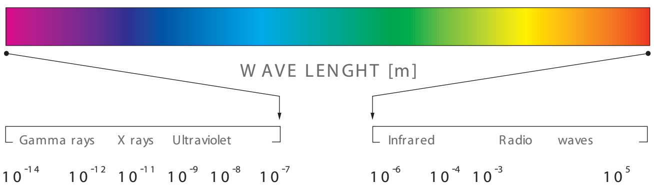

Fig.2.1

In base to the wavelength (frequency) the electromagnetic spectrum is separated according to the following classification.

• Radio waves

From frequencies lower than some KHz up to the microwaves (300 GHz). The radio waves are mainly used in the systems of communication, but also for medical therapies, diagnosis and systems of radar location.

• Infrared

This part of the electromagnetic spectrum is tied up to the heat. Everybody that an own temperature contained electromagnetic energy in the range of wavelengths that start from 10^{-12} ms to 10^{-14} ms.

• Visible light

Visible light represents a very narrow portion of wavelengths. They start from 380 nm to 780 nm. These wavelengths respectively correspond to the violet and the red colours.

• Ultraviolet

The ultraviolet one is above the visible spectrum and such waves are the result of atoms and molecules submitted to electric discharges.
Our sun produces enormous quantities of ultraviolet rays. This fact is very important in the study of the propagation of the radio waves. In fact the ultraviolet rays interacting with the present atoms in the low part of the atmosphere, ionize them resulting in a particular called layer "ionosphere". This layer has the particularity reflects a certain portion of the spectrum relating to the radio waves, making possible connections up to thousand of km.
The ultraviolet rays also have applications in the medical field, especially in the sterilizations.

• X rays

Discovered in 1895 by the German Roentgen, they are mainly used in medical applications.
This wavelength is so strong to be interacted with the constituent molecules of the human body

• Gamma rays

In this part of the electromagnetic spectrum the energy associated to the photons is so strong to be destroyed the molecules that they meet.
We are speaking of nuclear energy. It must be specified however that such waves also exist in nature, for instance in the cosmic radiation floor.

3 RADIO WAVES

As previously says, this portion of the electromagnetic wave, is almost exclusively devoted to "wireless communications".
The portion of spectrum starts from 3 KHz up to 300GHz.
Such portion is divided in frequency ranges and for each of them a different use is assigned according to international regulation.

RADIO WAVES		
FREQUENCY	WAVE LENGHT	DENOMINATION
3 KHz ÷ 30 KHz	100 Km ÷ 10 Km	Very Low Frequency (VLF)
30 KHz ÷ 300 KHz	10 Km ÷ 1 Km	Low Frequency (LF)
300 KHz ÷ 3 MHz	1 Km ÷ 100 m	Medium Frequency (MF)
3 MHz ÷ 30 MHz	100 m ÷ 10 m	High Frequency (HF)
30 MHz ÷ 300 MHz	10 m ÷ 1 m	Very High Frequency (VHF)
300 MHz ÷ 3 GHz	1 m ÷ 10 cm	Ultra High Frequency (UHF)
3 GHz ÷ 30 GHz	10 m ÷ 1 cm	Super High Frequency (SHF)
30 GHz ÷ 300 GHz	1 cm ÷ 1 mm	Extra High Frequency (EHF)

Fig.3.1

This subdivision in ranges is tied up to the fact that every one of them has different characteristics of propagation.
The first experiments with radio waves go up again to the epoch of Hertz but, as already mentioned, the first use for communications was served as Guglielmo Marconi.

3.1 Transmission of the information

An electromagnetic wave doesn't transport any information itself.
If it is wanted to send a message it is necessary to turn this message into an equivalent electric signal, then to superimpose it to the electromagnetic wave.
This process calls "Modulation" and, in more detail, it consists of varying one of the three fundamental characteristics of an electromagnetic wave:

- Amplitude, resulting in Amplitude modulation (AM).
- Frequency, resulting in the Frequency modulation (FM).
- Phase, resulting in the Phase modulation (PM).

Today we use digital forms of modulation very complex, with the purpose to exploit to the best the spectrum of the radio waves, non endless resource.

3.2 Propagation of the Radio waves

The electromagnetic waves and therefore also those radios, are propagated in straight line.
This is true in the vacuum, but not in a mechanism of terrestrial propagation where the interaction of the radio waves with the higher layers of the atmosphere, makes possible phenomenons of reflections.
On the base of this elementary concept three mechanisms of propagation of the radio waves can be classified:

• Direct wave

In a portion of space in which the transmitting antenna and that receiver are free from obstacles, the propagation it happens in straight line.

• Reflected wawe

This type of wave can be of two types.
Earth wave:
It is reflected by the terrestrial surface.
Sky wave:
It is reflected by the ionosphere.

• Superface wave

This way of propagation exploits the phenomenon of diffraction, for which when a terrestrial wave meets an obstacle of dimensions comparable to wavelength, it has the tendency to follow the profile of the object.

Previously we have spoken of radio waves reflected from the ionosphere and of reflections that allow connections up to thousands of km.
It must be said that not all the radio waves are able to use this phenomenon. Only those frequencies between 3 and 30 MHz.
They are the short waves. Frequency lower than 3 MHz it propagates by means of earth wave, instead, frequency higher than 30 MHz it propagates by means of sky wave.
The ionosphere is composed from different layers set to different heights that introduce different characteristics of reflection:

• Layer D

It is found to an inclusive height between 50 and 90 Km.
Its level of ionization is maximum until midday and disappears sunset.

• Layer E

It is found to an inclusive height between the 100 and 150 Km.
Its level of ionization is maximum to midday it is at the minimum at midnight and it has an increase at sunrise.

• Layer E sporadic

It is found to an inclusive height between 100 and 120 Km.
As it points out name, it is formed only in a sporadic way with particular conditions of ionizations and meteorological.
It is creates and it fades away in a little amount of time and it allows reflections of radio waves whose frequency is higher than 30 MHz.

• Layer F1

It is found to an inclusive height between 150 and 250 Km.
During the night only a layer F exists .

• Layer F2

It is found to an inclusive height between 250 and 500 Km. Its level of ionization is maximum to midday, with a slow decrement up to the sunrise.

CONCLUSIONS

We conclude this brief trip among electro-magnetic waves with a normative picture on the exposures of the human body to the electromagnetic fields, in use in the different countries of the world.

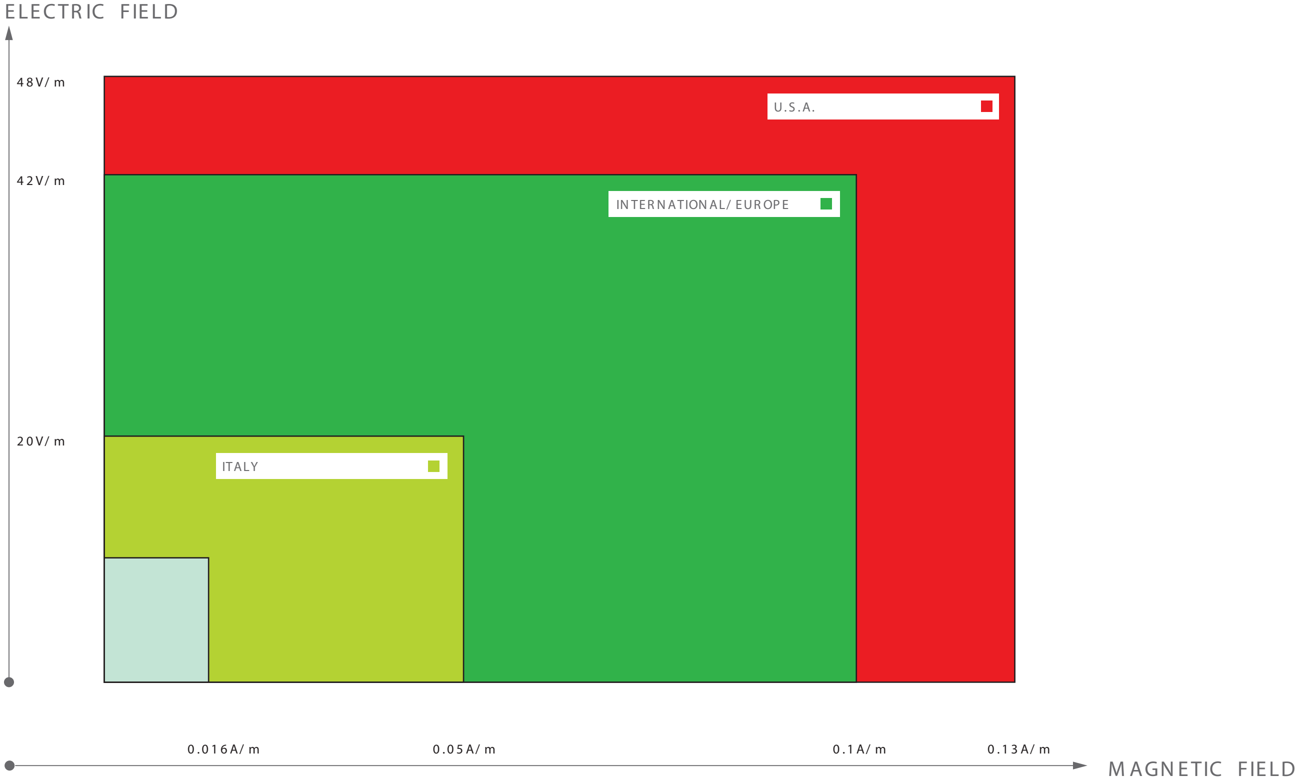

Fig.4