Phases of Electromagnetic Waves

Ccile Michaut, science journalist.

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Abstract

This is a Google translation by:
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of a document from the French website:
https://www.onera.fr/fr/actualites/maxwell-en-aurait-reve
It documents the electric and magnetic waves of a laser which are 90 degrees out of phase. This is quite contrary to the popular view that EM waves are in-phase.

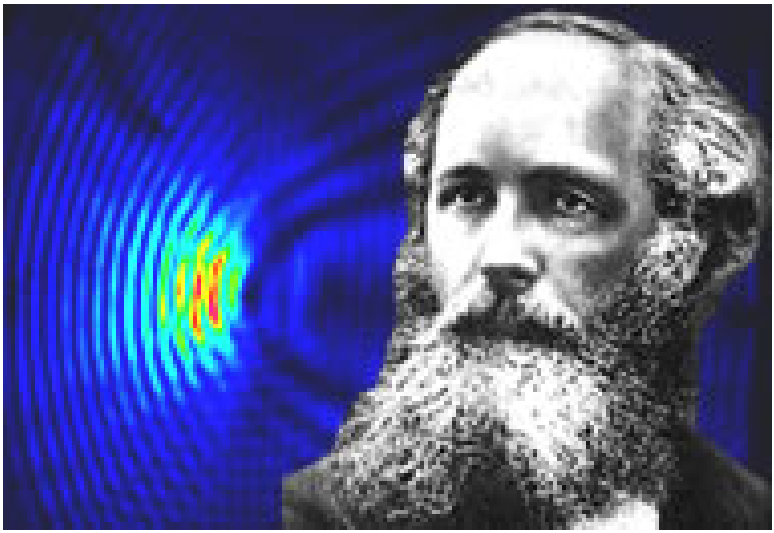

Figure 1: James Clerk Maxwell. James Clerk Maxwell. In particular, he demonstrated that electric and magnetic fields propagate in space in the form of a wave. In the background, electromagnetic field in a hyperbolic antenna.

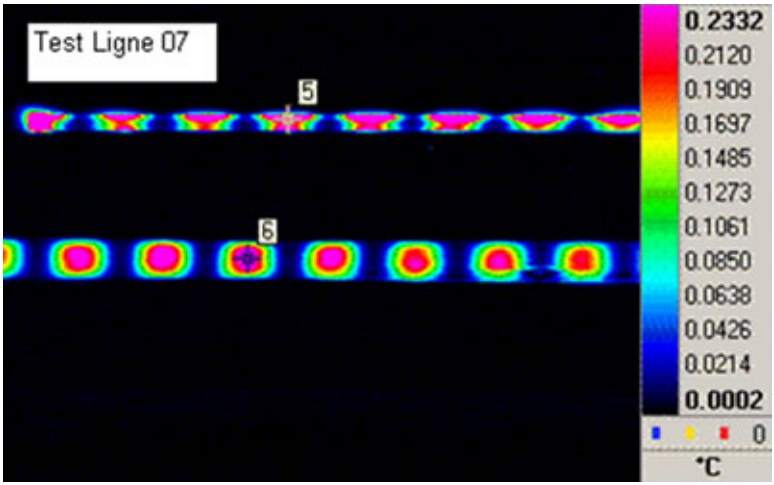

Figure 2: A first: the simultaneous visualization of the electric field profiles (proportional to the voltage, bottom) and magnetic field (proportional to the current, top), in phase opposition as predicted by the theory.

1

Have you ever seen a magnetic field? Or an electric field? No, they are invisible entities, which can be guessed only by the effects they exert on objects, for example the case of a magnet, in the case of the magnetic field. However, Onera researchers have succeeded in developing a system for visualizing electromagnetic fields (combining an electric field and a magnetic field). Previously, to achieve the same result, it was necessary to deploy a large number of sensors in many places of a room, to know the field point by point. A first: the simultaneous visualization of the electric field profiles (proportional to the voltage, bottom) and magnetic field (proportional to the current, top), in opposition of phase as the theory predicts. The experiment corresponding to the previous image where the films (one conductor, the other magnetic), whose warm-ups are recorded by an infrared camera, for a TEM wave [Transverse electrical magnetic]

2

The principle of Emir (Electromagnetic and Infrared) is simple: an electromagnetic wave interacts with the conductive objects and heats them: it is the Joule effect. This is for example what happens in a microwave oven. Here, a slightly conductive and very thin film is used. This film heats slightly, and one films the heating with an infrared camera (able to see differences of temperature).

The heating is proportional to the energy of the electromagnetic field: the stronger the field, the more the film heats up. "We tested several types of films because he had to be a driver, but not too much," says Franois Issac, research engineer at Onera Toulouse. A non-conductive film undergoes no heating because it does not interact at all with the electromagnetic field. A very good driver film does not heat up either, all the energy is reflected, only the "bad" drivers warm up a lot. The films tested are either a polymer from Dupont de Nemours, loaded with conductive carbon, or a polymer coated with a metal deposit, or conductive inks deposited on an insulating film.

The film is stretched over the area to be analyzed. It is filmed with the infrared camera, which offers a two-dimensional map. To obtain a three-dimensional cartography, it is necessary to reproduce the measurement on different planes. "We have developed a signal processing technique that eliminates parasitic phenomena, such as convection and conduction, which transfer heat from one area to another of the film, and disrupt the measurement," says Franois Issac .

3

Formation of the electric field at the output of an antenna Formation of the electric field at the output of an antenna in "patch network". Several measurement plans make it possible to establish a three-dimensional cartography.

Emir can measure electromagnetic fields from 10 to 30 volts per meter. However, the standards governing the maximum electromagnetic fields allowed near electrical appliances are of this order of magnitude. This technique could thus make it possible to verify that the apparatuses respect the norm. "We are trying to gain in sensitivity, to measure fields of 3 to 10 V / m, says Franois Issac. For this, we are working on the signal processing, to improve the signal-to-noise ratio, we are interested in the magnetic field in addition to the electric field, and we try to improve the quality of

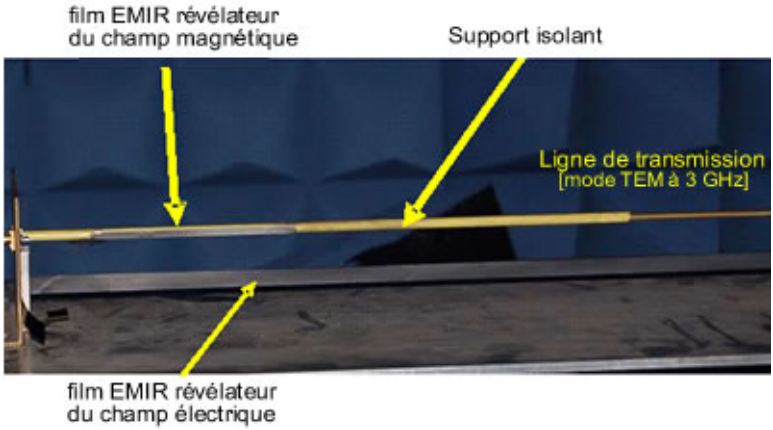

Figure 3: The experiment corresponding to the previous image in which films (one conductor, the other magnetic) whose heating has been recorded by an infrared camera, for a TEM wave [Transverse electrical magnetic].

the films, so that they produce more radiation infrared for a given field. ”

Visualization by EMIR of EMIR visualization of electric field ”leaks” from points in the cockpit canopy of a Rafale aircraft.

Currently, Emir is mainly used in ONERA research laboratories, to check that there is no leakage when the magnetic field remains confined, or to ensure that it does not enter there. where it does not, for example in an aircraft hold or a kerosene tank. This measure is relatively expensive, because of the price of ultrasensitive infrared cameras (about 50 000), but it is simple to implement. ”Emir’s technique is unique in the world, and the principle is very astute, enthuses Emmanuel Rosencher , scientific director of the physical branch at Onera. For the first time, we really visualize the electromagnetic field, which seems usually so mysterious. Until now, only the electric field was measured; we now come to see the magnetic field. The image where we observe the electric field and the magnetic field in phase quadrature (one is strong when the other is weak) is spectacular! ”.

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This article is dedicated to the memory of Patrick Levesque, researcher at Onera, who recently passed away. Patrick Lvesque had developed the Emir method as part of precursor work on infrared thermography.