# MULTIMEDIA SELF-TRAINING PACKAGE FOR BASIC MICROWAVES LEARNING

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## ABSTRACT

*The purpose of this article is to present an original pedagogical product for teaching microwaves. It contains 9 lessons and is composed of 2 media :*
*- a handbook*
*- interactive educational software*
*It is a multimedia self-training product recommended for technicians and engineers working in conventional electronics and wishing to acquire advanced knowledge in microwaves in connection with their working structure. It can also be used in self access at the university by undergraduate students. In this last case, the authors will state in the conclusion, their observations following an experiment in computer aided learning (C.A.L.) carried out at the university of Lille.*

## WHY SUCH A PACKAGE ?

From the experience of microwave teachers [1] it has been noted that students of different classes always encountered the same problems such as :

* associating a mental image with abstract concepts
* giving a physical meaning to a mathematical expression
* understanding dynamic phenomena from static representation
* understanding rapidly the contents of the courses due to lack of specific vocabulary on the subject.

The package was made possible thanks to a French national project on the following subject: "Multimedia self-training in fields of high technological content and contributing to the expansion of firms".

The authors then saw the use of the computer through its interactive environment and the use of animated images, as a valid means of eliminating particularly important obstacles in the teaching of the basics of microwaves.

## DESCRIPTION OF THE PACKAGE

The package contains 9 lessons that can be divided into 3 topics :
- a review of electromagnetics

- plane wave in free space ; plane wave in a metallic bounded medium ; theory of transmission lines
- The Smith chart and its practical application.

This self-training package is composed of a handbook and a piece of educational software.

**1) The handbook**

The authors think that the hanbook is essential. It contains all the theoretical information that would be boring on the screen. The advantage of the handbook is that it can be read without the help of the computer. However, a link exists between the two media of the package thanks to an acronym "computer" showing the learner how to refer to the software if necessary. Every lesson is set out in a conventional manner. Yet, whenever it is necessary to draw the learner's attention to an important concept or key sentence, this is done by means of small boxes on the right hand side of the page. Thus, the student can immediately grasp the essential points.

**2) The educational software**

The originality of the software lies in a different, yet complementary and pragmatic approach to the handbook by means of simulation, animation and interactive exercises where students' answers are carried out with a high degree of accuracy.
Access to the software is very ergonomic. Forward and backward screening allows the student to go to any screen page in the educational software, as and when required.
The software is self-contained in order to avoid continual reference to the handbook. However, a link does exist with the hanbook thanks to a special book-sign which appears on the right side of every screen page. When this function is "on", the page of the handbook concerning the subject being studied appears.

The computer equipment needed for operating this software is an AT personal computer with a hard disk, an EGA videocard and a mouse.

## USE OF THE COMPUTER FOR BETTER UNDERSTANDING OF BASIC MICROWAVES

In the following paragraph by means of a chronological summary of the introductory course to microwaves, the authors will highlight some key points for which the computer can provide a greater level of understanding and a consolidation of knowledge acquired.

**1) Review of Electromagnetism [2]**

As soon as the student begins to study electromagnetics, he has difficulty understanding the physical meaning of basic concepts such as field vectors, the line integral or flux of a vector. It becomes essential to put animation and simulation at his disposal allowing him to "experiment" with these ideas and to form a mental image more easily.

For example, one only has to trace all the field vectors from a source, at all points of a path, to introduce the necessity of a line integral in order to calculate, for example, the common potential function in the electrostatic case.
The study of flux and divergence is undertaken very slowly. First, the use of an animated corkscrew on the screen allows one to orientate successfully on a surface. Then, a number of interactive exercises related to the study of simple field vectors are treated in a numerical way, without any mathematical formalism. It is only after this very concrete approach that the case of more complicated field vectors is tackled. After these exercises the understanding of Gauss's theorem and Ampere's theorem is immediate, since all the underlying elementary concepts are well established and understood [3].

### 2) Plane wave in free space [4]

#### *a) Dynamic phenomenon*

After the electrostatic and magnetostatic fields, time-varying phenomena are tackled, this leads naturally to wave propagation. Only very few students succeed in making a mental image of the double periodicity of the wave, in time and in space. This periodicity is easily demonstrated on a computer screen using animation, where at a given abcissa, a window shows the temporal variation of the field during the propagation of a linearly polarized wave.

#### *b) Abstract concept of wave polarization*

The circular or elliptic polarization of waves is often not well understood by the students. This may be shown by the displacement of two linearly polarized plane waves which are normal. It is then easy to observe the tip of the resultant field vector, describing a circle or an ellipse in a plane perpendicular to the propagation axis.

### 3) Plane wave in a metallic bounded medium [5]

The case of plane wave propagating in metallic bounded medium is introduced. The purpose is to progressively lead the learner to detect, without calculation, the possibility for a T.E.M. wave to propagate or not in a closed structure ; this is deduced from concrete criteria stemming from the Laplace equation. This part of the course calls for the use of specific vocabulary used commonly by those working in the field of microwaves. Ideas such as "transverse cross section of a guide", "open" or "closed" guide, "homogenous" or "inhomogenous" guide, "disjointed" conductors and so on, are encountered through a series of short interactive exercises. So, with this knowledge, the student can practice, on final tests which consist of interactive exercises, taking into account a lot of structures of propagation that one can find in microwaves [6] ; an example is given figure 1.

### 4) Transmission line [7][8]

#### *a) An introduction to the distributed elements circuits*

The public we are aiming our package at, has a certain degree of knowledge of low frequency electronics. It is therefore of interest to demonstrate how to go from low frequency conventional electric circuit with discrete elements for which the dimensions of the circuits do not play any role, to the distributed elements circuits modeling the propagation of a high frequency T.E.M. wave. To this purpose, we have designed three animations at different frequencies, (figure 2). The first one shows a T.E.M. transmission line, 30 meters long, on which a 1 Mhz signal propagates. The students' attention is focused using a magnifier : only an elementary slice 30 cm long can be seen. The student then notes, that through the magnifier, he can only see one thousandth of the wavelength and that the field amplitude at a given time t is constant over the whole length of the slice. In the second animation, the signal frequency is multiplied by 100. The E and H fields amplitudes observed under the magnifier are no longer constant. In the third animation, the frequency is 1 Ghz and through the glass, the student notes that the field varies largely since the length of the elementary slice is the same as that of the wavelength. At this stage, the student immediately understands that, if he wants to use an electric circuit schematic of the low frequency type with constant lumped elements, he will have to consider elementary slices for which the field amplitudes remain practically unchanged, that is to say elementary slices which are much shorter than the wavelength. Thus, the cascading of elementary slices demonstrates to the student, in a natural way that it is possible to translate the propagation phenomenon.

*b) The shift from electric et magnetic field notations to those of voltage and current*

The problem is now to shift from field notations to those of voltage and current. Let us return to our elementary slice of waveguide made of two separate conductors carrying a T.E.M. mode, the electric field defined between the two conductors is constant all along the slice, as has previously been shown. The line integral of the electric field between the two conductors generates a voltage and the student is then asked to identify the circuit element (capacitor, inductor, resistance) that represents the structure.
Let us now define an elementary surface dS obtained by the product dz*L where dz represents the length of the slice and L the distance between the two conductors ; the magnetic field H, the amplitude of which is constant over dz is time-variable. The student immediately notes that the magnetic field normal to dS generates a time varying flux through dS, thus creating a self-inductive E.M.F (figure 3). The student can thus replace the elementary guide slice by an equivalent lumped electric circuit of the LC type and thus build his distributed elements schematic.

**5) Terminated transmission line : simulations of various stationary wave regimes**

First of all, to illustrate the idea of varying value impedance, the student is asked to go and "click" at different points on a charged transmission line. By doing so, he reveals the impedance representation in the corresponding plane along with its numerical value. Further in the course the student has the possibility to choose a load and obtain the corresponding standing wave mode representation on the line. The following exercise is proposed: we define a vector, the length of which represents the incident voltage on the load, and the student has to define the reflected one, thus he gives a numerical value to the load. The displacement on the line, from the load towards the generator results in a rotation of the two vectors in opposite directions. The vectorial sum is made at different points along the line and resultant vector amplitude is tabulated thus establishing the standing wave regime specific to this loaded line.

### 6) The Smith chart and its application

In the chapter on the Smith chart and its practical application, our aim is the following : the student must be able to redraw quickly and easily on the Smith chart any displacement or modification made on the line. Then, in the software, any displacement on the line and on the Smith chart is made synchronous. An analytic demonstration is given in the handbook explaining how the Smith Chart is built. In the software, numerous interactive exercises allow the student to become familiar with the Smith chart (figure 4). More complicated problems are proposed in synthesis exercises. For example, the determination of the impedance at a distance from the load or the impedance matching with a quarter-wave transformer or a simple stub are performed. In this type of exercise the student must choose the right solution to the problem in a series of multiple choice questions. For every wrong choice, a comment is always prompted to allow the student to understand and rectify his mistake.

## CONCLUSION

We have designed a multimedia self-training introductory course package to microwaves. It is composed of a handbook and some interactive educational software which corresponds to about 20 hours of C.A.L.. At the present time, the English translation of the product is being undertaken.
We have presented some examples allowing the student to understand some basic concepts in microwaves. Undergraduate students of the university of Lille have tested this computer assisted learning tool and appreciated tackling this field in a manner different from the traditional approach, each at his own speed and with an attractive tool. Teaching staff also noted a greater curiosity on the part of the students, expressed by unusual questions they never asked for in a classical course, more motivation and a greater consolidation of their knowledge. This is due to the interactivity of the software and immediate correction of their errors.
This very positive experience has encouraged us to continue in this frame on a detailed study of waveguides such as rectangular metallic guide, coaxial line and microstrip.

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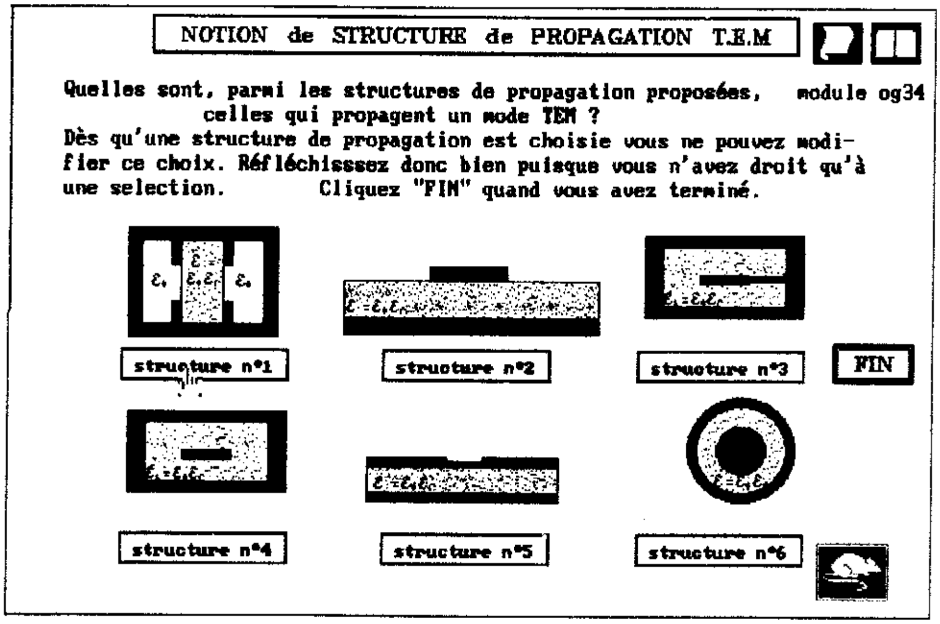


Figure 1 : Example of test : "Choose, among these structures of propagation, the ones that can propagate a TEM wave" .

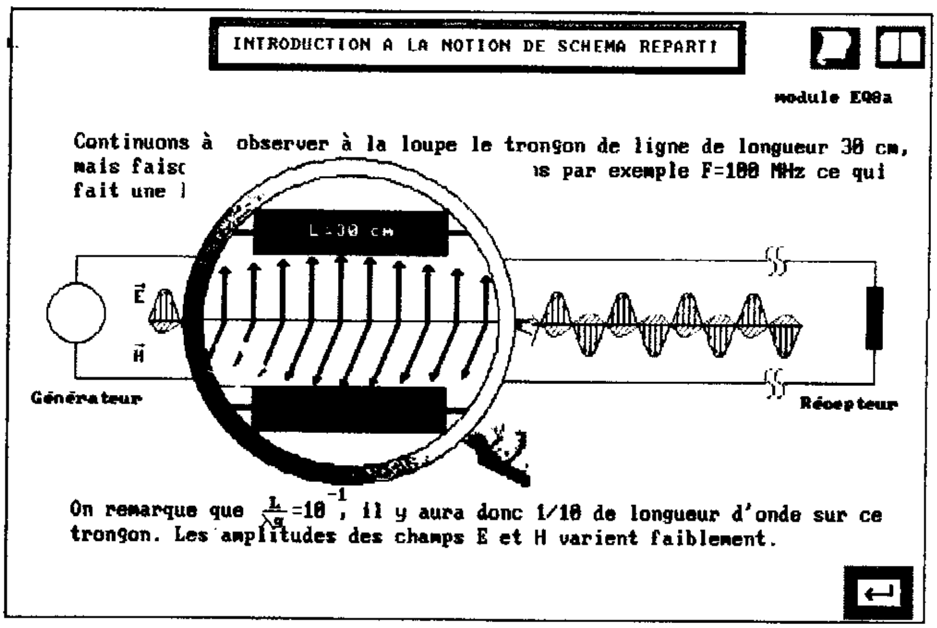


Figure 2 : Example of animation, showing the student, the evolution of a TEM wave on an elementary slice (L=30cm) of transmission line at frequency F=100Mhz.

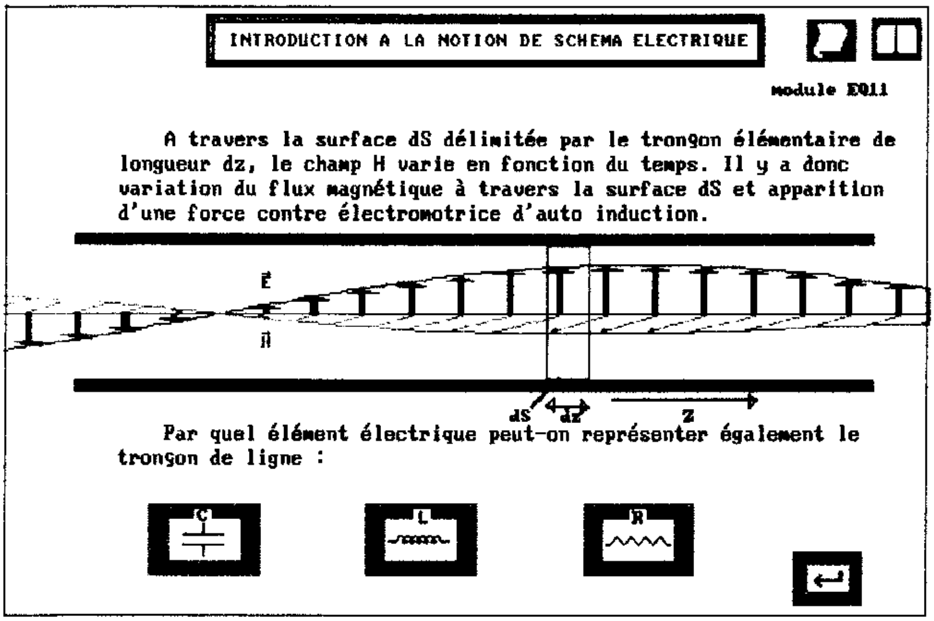


Figure 3 : Electrical equivalent circuit research of an elementary slice dz. Here, research of the inductance.

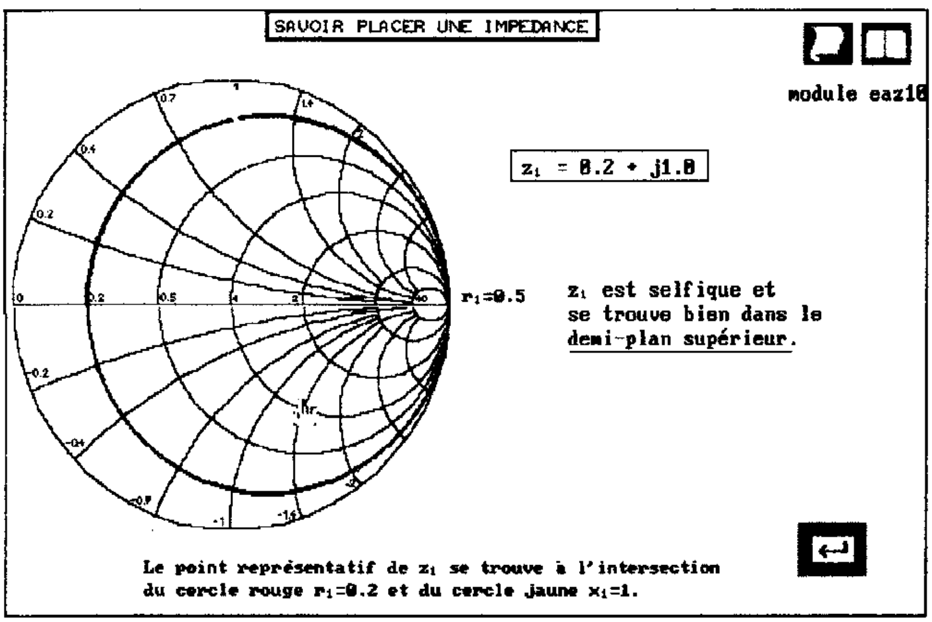


Figure 4 : Test on the Smith chart : the student must point out the representative point of the normalised impedance z1.