MODELING BY FDTD OF PLANAR ANNULAR APPLICATORS USED FOR HEATING IN MEDICAL APPLICATIONS.

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INTRODUCTION.

A large number of devices have been designed and tested for medical applications (and more particularly hyperthermia). Among these devices, we are interested since more than a decade, in the study of external planar applicators. We present in this paper the last results (theoretical study and experimental verifications) concerning the specific planar applicators we have developed for heating in medical applications.

MATERIALS AND METHODS.

The studied structure is the annular planar microstrip-microslot applicator : it consists of an annular aperture opened in the ground plane of a microstrip line.

Several kinds of applicators have been realized :

- A "single" applicator (Figure 1) realized on a substrate of relative permittivity ε_r equal to 4,9 and of thickness equal to 1,58 mm. The aperture is of annular shape and its dimensions are the following : internal diameter 28 mm, external diameter 38 mm.
- A "twin" applicator (Figure 2) realized from two single applicators set side by side. This configuration allows us to test the efficiency of the association of several applicators : the final goal is the realization of a honeycomb network for the treatment of large areas. The two rings have the same dimensions : internal diameter 25 mm, external diameter 45 mm. They are from a distance H equal to 4 mm.

For both applicators, the feeding line has a length equal to 82 mm and a width of 2.5 mm. They have been designed in order to be used at the frequency equal to 915 MHz.

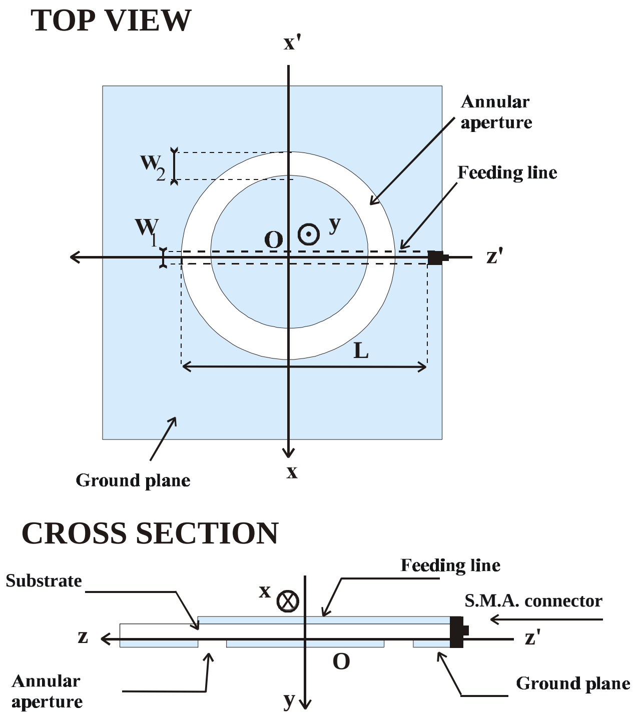
The main theoretical problem to characterize these applicators is the determination of the radiating pattern. So, in order to take into account the exact shape of tissues and also of the applicators, a three-dimensional model based on the Finite Difference Time Domain (F.D.T.D.) method has been developed. This model allows us to obtain the reflection coefficient (S_{11} parameter) and the power deposition inside lossy media. Then the determination of the temperature in the heated media is deduced from the resolution of the heat transfer equation using the model based a finite difference method.

Confirmation of the theoretical approach is given by experimental measurements, which have been carried out on phantom models of human tissues (saline solution at 6g/l or polyacrylamid gel). We have first measured the S_{11} parameter as a function of frequency in order to control the level of impedance matching of the applicator. An example of a comparison between theory and experiment is given in Figure 3. Then, we have determined the power deposition in saline solution with a simple system for mapping the electric field pattern created by the microwave applicator under test. Endly, the thermal performances have been characterized by using an automatic experimental system.

CONCLUSION

We have presented the study of a planar annular applicator to be used for microwave heating in medical applications. The comparison between theoretical results and experimental measurements obtained at the frequency F = 915 MHz shows the efficiency of the FTDT as a simulation method. The thermal results points out the interest of the "twin" applicator for which the therapeutic zone is three time greater than the one of the "single" applicator considering the composition of electromagnetic fields.

The next step of the study is concerning on one hand, the modification of the applicator in order to be used at a lower frequency (434 MHz) without increasing the dimensions and, on the other hand, the development of an array of several applicators in order to heat a larger area and a greater volume. We are also envisaging the possibility to introduce a phase difference for the current in the different feeding lines of the array of applicators.



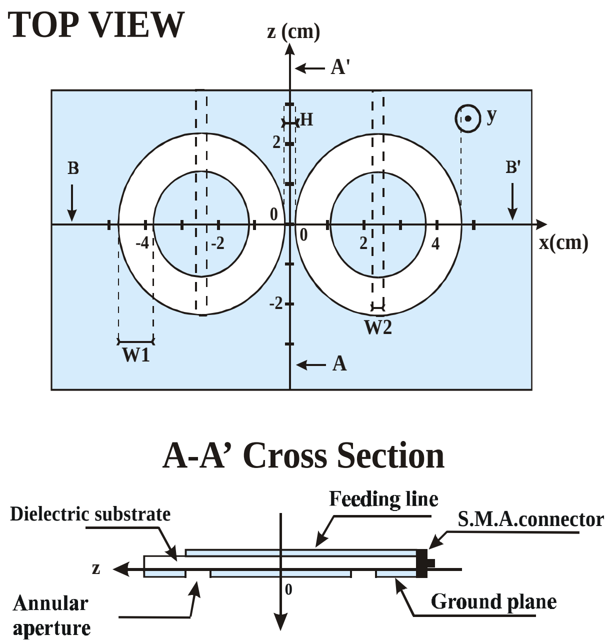


Figure 1: Top view and cross section of the "simple" applicator : W_1 =2,5 ; L = 82 mm ; W_2 = 10 mm

Figure 2: Top view and cross section of t "twin" applicator : W_1 = 2,5 mm ; W_2 = 10 m H = 4 mm

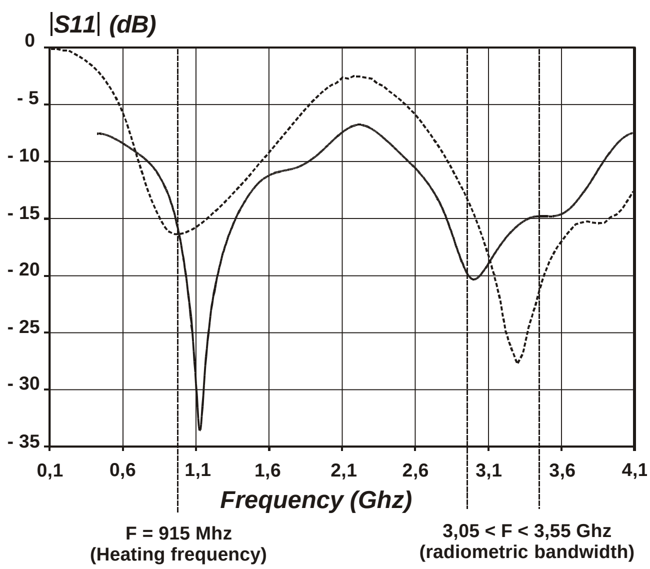


Figure 3: Theoretical (——)and experimental (------) variations of the reflection coefficient $|S_{11}|$ as a function of frequency for the "single" applicator.