MICROSTRIP PATCH ANTENNA POWER BALANCE BY A MIXED TIME FREQUENCY METHOD

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I. INTRODUCTION:

Recently, several papers have been published, presenting simple approximate expressions, or more rigorous methods for the space wave efficiency of rectangular microstrip patch antennas. Alexopoulos [1] first showed the influence of surface waves on the radiation dipole efficiency.

To find the local electromagnetic solutions, the moment method is generally used to solve frequency domain integral equations. Space wave radiation and surface wave losses are calculated using Alexopoulos's method, which requires laborious mathematical developments in the complex space.

In this paper, an original new method is presented to determine the power balance of an arbitrary shape microstrip antenna. The finite difference time domain method is used to solve Maxwell's equations. The solutions of the electromagnetic fields are then Fourier transformed. The near field Poynting vector flux is calculated through a closed area surrounding the antenna (**Fig. 1**). The radiated power in the free space, and the surface wave power losses are also calculated. The summation of these two terms is then compared to the power delivered by the generator to the antenna. Here, the antenna is supposed to be lossless.

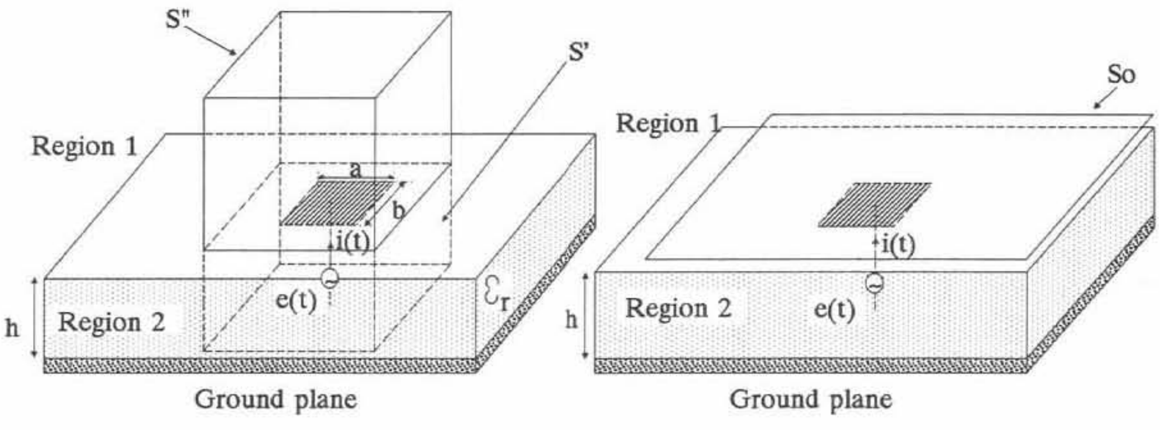


FIG. 1:DEFINITIONS OF SURFACES S',S" AND So

A comparison is made between the results obtained in this way and by Alexopoulos's method, associated with the Finite Difference Time Domain Method for the determination of surface currents. The radiation pattern is obtained by means of the equivalence principle near the antenna (**Fig. 1**).

II. THE MIXED TIME FREQUENCY METHOD:

II.1 The solution of Maxwell's equations by the Finite Difference Time Domain Method:

To express the local fields in the time domain, we use the finite difference method:

* The discretization of Maxwell's equations requires third order Taylor's developments in the time domain, and in the three space directions.

* The limited computation space is divided into parallelepipeds, called elementary cells. The position of the field components inside each cell enables one to center all the space derivatives.

* A relation between space increments and the time domain increment Δt gives the stability criterion [3]. The computation moments of E and H fields are $\Delta t/2$ shifted, in order to center the time domain derivatives.

* In the case of open structures (such as a microstrip antenna), a tridimensional meshing must be achieved, not only of the structure, but also of the surrounding volume. "Absorbing sheets" are placed on the boundaries of the computation space to avoid undesirable reflections.

Therefore, the open space is simulated by a finite one.

The microstrip antenna is gaussian fed. The electromagnetic fields in each point of the computation space, as well as the electric current i(t) on the feed wire are given by the finite difference time domain method. The surface currents induced on the patch and on a Huygen's surface are deduced.

II.2 Radiated power and surface wave power losses:

A closed surface S against the ground plane surrounds the radiative structure. We select a parallelepipedic surface for S, and devide it into two parts (see **Fig. 1**):

- a surface S' in region **1** representing the dielectric material
- a surface S" in region **2** representing the free space.

E and H fields on S and S" surfaces are Fourier transformed, and the Poynting vector outgoing flux through S' and S" is calculated. We obtain:
The radiated power:

$$P_{rad} = \frac{1}{2}\,\mathrm{Re}\left(\iint_{S''} (\vec{E}(M,\omega) \wedge \vec{H}^{*}(M,\omega)) \cdot \vec{n}\,dS \right)$$

The surface wave power loss:

$$P_{sur} = \frac{1}{2}\,\mathrm{Re}\left(\iint_{S'} (\vec{E}(M,\omega) \wedge \vec{H}^{*}(M,\omega)) \cdot \vec{n}\,dS \right)$$

$\vec{n}$ is the normal unit vector to S' and S".

This calculation is available for a well-confined surface wave mode like the TM_0 mode.

II.3 Radiation pattern:

A horizontal surface S_0 is set above the patch (**Fig. 1**). Its dimensions must be large enough for S_0 to be considered as a closed surface surrounding the radiative structure.

The radiated far fields $(\vec{E}(M,\omega),\vec{H}(M,\omega))$ are determined from the fictive currents on S_0,

$\vec{J_m}(M_0,\omega) = \vec{E}(M_0,\omega) \wedge \vec{n}$

thanks to the usual expressions of the far field created by a current distribution [4].

$\vec{E}(M_0,\omega)$ and $\vec{H}(M_0,\omega)$ are the Fourier transforms of the electromagnetic fields on S_0, given by the finite difference time domain method.

The far field radiated power is given by:

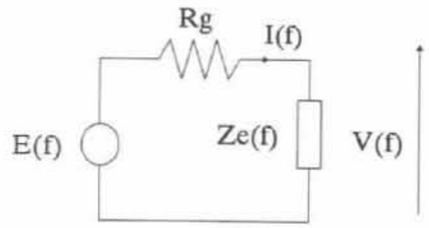
$$P_{rad}(M,\omega) = \frac{1}{2Z_0}\left|\vec{E}(M,\omega)\right|^2 \qquad Z_0 : \text{free space impedance}$$

III. RESULTS - COMPARISON WITH ALEXOPOULOS's METHOD:

III.1 Input impedance and reflection scattering parameter:

Fig. 1 shows the antenna characteristics. The excited mode is the fundamental mode TM_{10} (f_o=3.135 GHz).

This figure shows the electric diagram of the antenna.



The input impedance calculation **[5]** is given by the following relation:

$$Ze(f) = \frac{E(f)}{I(f)} - Rg$$

where E(f) and I(f) are the Fourier transforms of e(t) and i(t); Rg is the internal resistance of the generator.

We determine the scattering parameter S_{11},

$$S_{11}(f) = \frac{Ze(f) - Zc}{Ze(f) + Zc}$$

and the power delivered to the antenna P_{load},

$$P_{load}(f) = P_{gen}(f)(1-|S_{11}(f)|^2)$$

where $P_{gen}(f)$ is $P_{load}(f)$ maximum and is equal to $\frac{|E(f)|^2}{8Rg}$

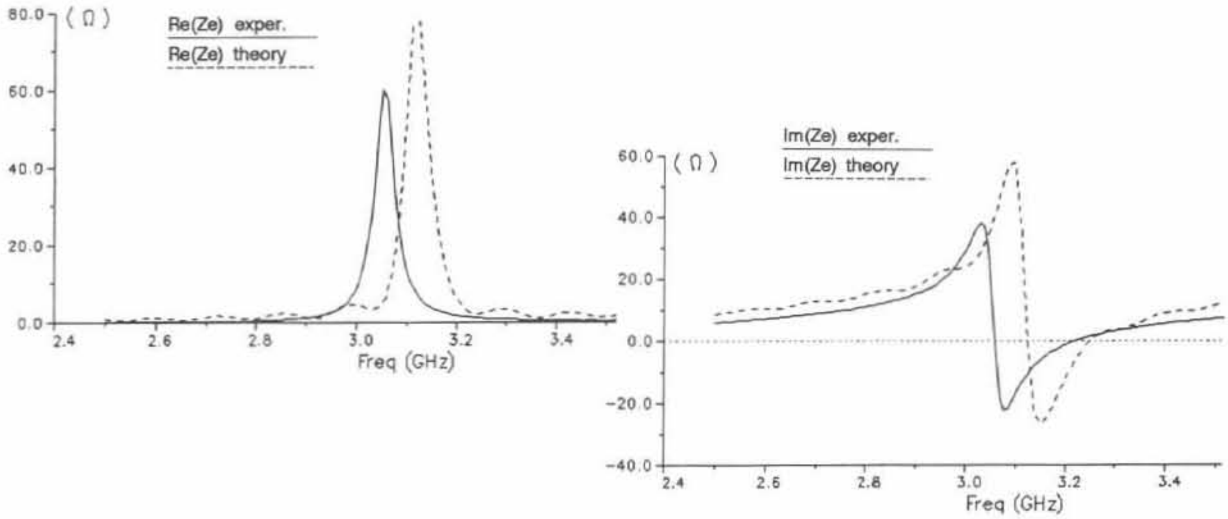
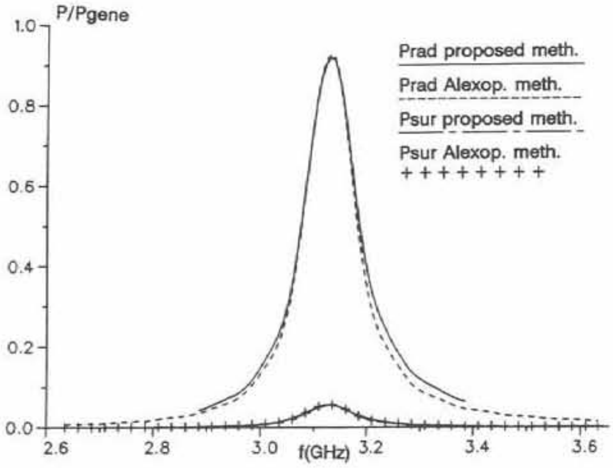
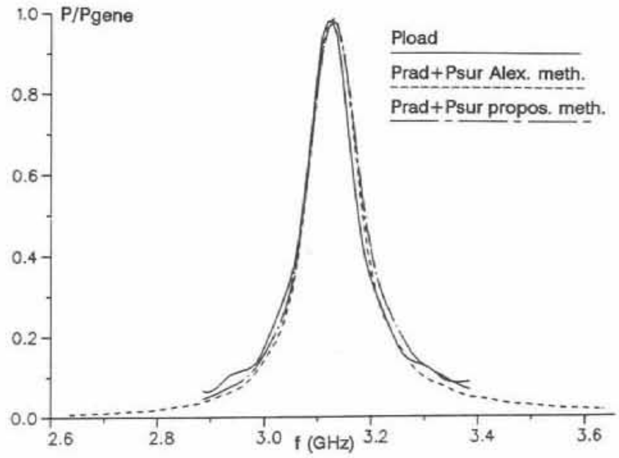


FIG. 2: Ze(f) - a=30mm b=15mm h=1.54mm ε_r=2.55

III.2 Power calculations:

Fig. 3 shows the radiated power and the surface wave power loss calculated using the proposed method, compared with the results of Alexopoulos's method. They seem to match perfectly. **Fig. 4** shows the comparison between $P_{rad}(f)+P_{sur}(f)$ calculated by both methods and $P_{load}(f)$. The whole power delivered to the antenna is radiated in free space waves (93%) or lost in surface waves (7%).





ALL THE POWERS ARE NORMALIZED TO Pgene(f)

FIG. 3
RADIATED POWER IN FREE SPACE
AND SURFACE WAVE LOST POWER

FIG. 4
COMPARISON TO THE POWER
DELIVERED BY THE GENERATOR

III.3 Radiation pattern:

Fig. 5 shows the H plane radiation pattern calculated by the two methods compared to the experimental results.

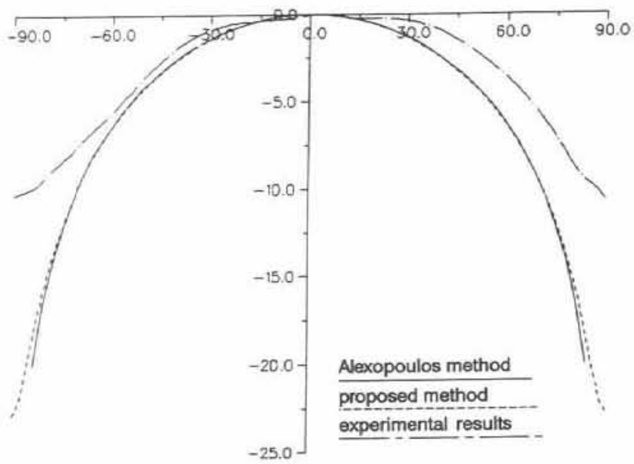


FIG. 5: RADIATION PATTERN
IN H PLANE

IV CONCLUSION:

The mixed time frequency domain method gives good results for radiated and surface wave power. This method may be used for all structures. The multilayered dielectric antenna can be taken into account, even though Alexopoulos's method requires more mathematical derivations. The radiation pattern obtained according to the equivalence principle is very similar to the one derived from Alexopoulos's method.

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