Artificial Neural Network Model Analysis of Tunable Circular Microstrip Patch Antenna

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***Abstract*— In this paper, in order to evaluate the resonant frequency of tunable circular microstrip patch with a fast and accurate model, neural networks are introduced in the theoretical analysis. The obtained model is very suitable for the CAD of microstrip patch antennas. The output of the artificial neuronal network which is the resonant frequency is shown to be very close to the experimental results reported elsewhere. Finally, the influence of the air separation on the operating frequency of the circular disc is investigated.**

Key Words: circular patch antennas, air gap tuning effect, CAD model

I. INTRODUCTION

In recent years microstrip patch antennas have been used extensively in several civil and military applications. These applications include mobile communications, radars, satellites, sensors and also in new fields such as medicine and biology. This increasing use of microstrip patch antennas is due to their inherent advantages such as planar configuration, low weight, low profile and easy integration of passive and active devices [1]-[2]. They can also operate at multiple frequency bands and allow both linear and circular polarization. However, microstrip antennas have some disadvantages from which, we can list narrow bandwidth, low efficiency due to dielectric losses and conductor losses, spurious radiation from the feed network and the undesirable excitation of surface waves. These surface waves can affect significantly the radiation of the antenna and increase the coupling between radiating elements in array configurations. The radiating element of microstrip patch antenna can have different geometries; the most popular is rectangular, triangular and circular. The circular patch can offer best performances compared to the rectangular one specially when circular polarization is needed. In the present communication, the geometry selected for the patch is circular. This is shown in Fig. 1.

The resonant frequency value of a given antenna is determined by its physical and geometrical parameters, and hence it is obvious that if we want to change the resonant frequency, it is necessary to use another antenna.

With the aim of obtaining a tunable antenna, we can place a modifiable air layer above the ground plane, which leads to a two-layered configuration. To analyze this type of antennas, the cavity model which gives closed form solutions has been used [3]-[7]. This model can give satisfactory results for thin dielectric substrates. However, for thick substrates, the phenomenon of surface waves will be strong resulting in a deterioration of the quality of the results obtained by the magnetic wall cavity model. Another shortcoming of this model is its inability to analyze structures with several dielectric layers.

Recently, artificial neural networks have been extensively used in the antenna analysis and design since they can guarantee both accuracy and rapidity. In this work, artificial neural networks are used in the study of a circular microstrip antenna with air separation included above the ground plane. We not that the effect of the air gap on the antenna performances has not been studied previously using neural networks.

II. THEORY

The structure to be analyzed is schematized in Fig. 1. The circular disc is printed on a double layer substrate. The layer in contact with the ground plane is an air layer. To analyze this structure, we use the cavity model in conjunction with replacing the double layer by an equivalent single layer structure [7, 8]. The resonant frequency of the considered antenna operating at The TM_{nm} mode can be estimated via the following expression:

$$f_{r,nm} = \frac{\chi_{mn} \upsilon_0}{2\pi a_{ef} \sqrt{\varepsilon_{req}}} \tag{1}$$

In equation (1), χ_{nm} stands for the m^{th} zero of the Bessel function. The number n defines the order of this function. For the modes TM_{11}, TM_{21}, TM_{01}, and TM_{31}, the corresponding zeros are χ_{01}=3.832, χ_{11}=1.841, χ_{21}=3.054, and χ_{31}=4.021, respectively.

υ_0 in the above equation is the free space celerity. ε_{req} represents the relative permittivity of the equivalent single layer medium. This last can be derived using the moment method or the cavity model [4]

$$\varepsilon_{req} = \varepsilon_{r2}(d_1 + d_2)/(\varepsilon_{r2} d_1 + d_2) \tag{2}$$

d_1 and d_2 are the heights of the air layer and dielectric substrate, respectively. To take into account the influence of fringing fields at the edge of the circular disc, the radius a of the radiating patch should be changed by its effective value. In the open literature, numerous formulas have been proposed for the estimation of the effective value of the radius [9]-[11]. These formulas have been obtained using a fringing capacitance. In the present paper, we use the expression given in [10], which is very adequate for the case of tunable antenna

$$a_{ef} = \left\{ a^2 + \frac{2da}{\pi \varepsilon_{r2}} \left[\begin{array}{l} \ln\left(\frac{a}{2d}\right) + (1.41\varepsilon_{r2} + 1.77) \\ + \frac{d}{a}(0.268\varepsilon_{r2} + 1.65) \end{array} \right] \right\}^{\frac{1}{2}} \tag{3}$$

In equation (3) d is defined as $d=d_1+d_2$.

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