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ACCURATE ORIGINAL SYNTHESIS MODEL FOR MICROSTRIP ANTENNAS WITH AUTOMATIC CHOICE OF THE SHAPE VERSUS PHYSICAL AND GEOMETRICAL CRITERIA

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Topic : microstrip antennas

Abstract

We present an accurate and original synthesis model applied to multilayer probe-fed microstrip antennas. We have developed an original modified Wolff cavity model to obtain, with a low computing time, the optimal size and the shape of the antenna, versus the physical and geometrical parameters, necessary to a good approach. Unpublished results for elliptical and annular ring antennas are presented. We show and discuss numerical and experimental results for different synthesis.

1 Introduction

These last years, a great number of models have aimed at determining the electrical characteristics of printed antennas of various shapes with a good agreement with experiments and other rigorous investigations. However, at our knowledge, a synthesis model for multilayer probe-fed microstrip antennas with or without an air-gap taking into account the shape of the element has not been yet published.

We show, figures 1 and 2, the different studied structures. An air-gap enables to obtain exactly the resonant impressed frequency [1,2], the dielectric cover can offer protection against environmental hazards (ice, snow for example) [3 - 5], the ring microstrip antenna can be proposed for dual band operation [6 - 8], and the eccentricity of the elliptical antenna allows us to obtain a wider frequency band and the desired resonant frequency [9 - 11].

For all these reasons, we propose an original synthesis. The analytical model introduced in the synthesis, takes into account all of this parameters and the advantages and drawback of each shape and proposed the best structure possible for each case. Electrical criterias like bandwidth, quality of polarisation, circular polarisation or efficiency versus the shape of the element are associated concurrently with geometrical and physical parameters.

2 Symbolic approach

Our theoretical study is achieved from a modified Wolff model [11]. The boundary conditions are taken into account using dynamic permittivity including physical and geometrical parameters and fringing field effects. The calculation of the dynamic edge capacitance is required. It consists in considering the

radiating element as an open microstrip line for which a variational expression of the characteristic impedance allows us to take into account the multilayer lossy structure. The input impedance is determined using one or two equivalent electrical circuits.

The closed-form expressions for the resonant frequency and the input impedance allow us to work in synthesis. For example, the dielectric substrate being given and a set of physical criteria being known, it is easy to compute the dimensions of the patch and the optimal position of the feed to obtain a real part of the impedance equal to 50 Ω , for the impressed resonant frequency.

For example, a microstrip antenna destined to be integrated in an array structure with a small distance between radiating source, should be as small as possible to limitate the coupling effects. Other criterias, like the desired bandwidth, or the resonant frequencies of the superior modes must be taken into account too.

Table 1 gives the performance of modeling. The synthesis was carried out using Quick Basic on 486 DX2 computer. The different calculations were obtained in few seconds.






Characteristic					
Accuracy	+	++	-	+	++
Calculation time	++	++	+	+	-

Table 1 : Performances of the modeling
++ : excellent + : good - : medium

Table 2 gives a fast view of the advantages that we can expect of each shape, i.e. a large bandwidth at SWR = 1.5, easy circular polarisation.






Shape					
Bandwidth	-	+	-	+	+
Circular Polarisation	-	+	-	-	+
Use of Superior modes	+	+	-	-	++
Metallic relative surface required	1.85	1.85	1.35	1,46	1
Total relative surface required	1.4	1.4	1.01	1.1	1

Table 2 : Advantages of each shape

3 Results

We present figure 3, the theoretical variations of the characteristic size of the radiating element versus the impressed resonant frequency, for different well-known shapes. For each shape, we indicate the given dimension, for example, disc : diameter $2a$, ellipse : the major axis $2a$ (eccentricity $e = 0.745$). The ratio for the ellipse (a/b) is equal to 1.5 and for the annular ring $r_2/r_1 = 2$. The annular ring take less space than the others shapes. We have a very good agreement with experiments.

The figure 4 shows the case of an annular ring with a dielectric cover for the first two resonant modes TM_{11} and TM_{21} . We give the theoretical ratio (r_2/r_1) versus the desired frequency for $r_1 = 5$ mm and 10 mm. We can notice that the ratio r_2/r_1 decreases strongly for a small variations of the resonant frequency. Moreover we can choose, according to our specifications, the ratio that we want at a given frequency.

To validate our model of synthesis, we present, for an elliptical radiating element, figure 5 the experimental and theoretical variations of the real part of the input impedance versus frequency. The feed-point (XF) is located at 20 mm from the center. The agreement is excellent. These results are presented for the first time, indeed only the study of resonant frequency was published [10]

The algorithm gives for example the fed position for the desired real part of the input impedance of the ellipse (figure 6).

We show figure 7, for different thickness of air-gap, the variation of the eccentricity e versus the half minor axis b of the ellipse. The bandwidth increases with increase the thickness H_a , for example, for $H_a = 0$ mm we obtain a bandwidth(BW) equal to 1.6 % (SWR = 1.5) and for $H_a = 5$ mm $BW = 8.9\%$.

4 Conclusion

We have presented an original synthesis model for multilayer microstrip antennas of different shapes. We have shown that we can determine, when a set of desired parameters is known, the optimal shape and size of microstrip patch to choose.

The knowledge of the advantages and inconvenients of each shape are very important points for synthesis or CAD models. The comparison between theoretical and experimental results shows a very good agreement. Some entirely unpublished results as regards the annular ring and ellipse.

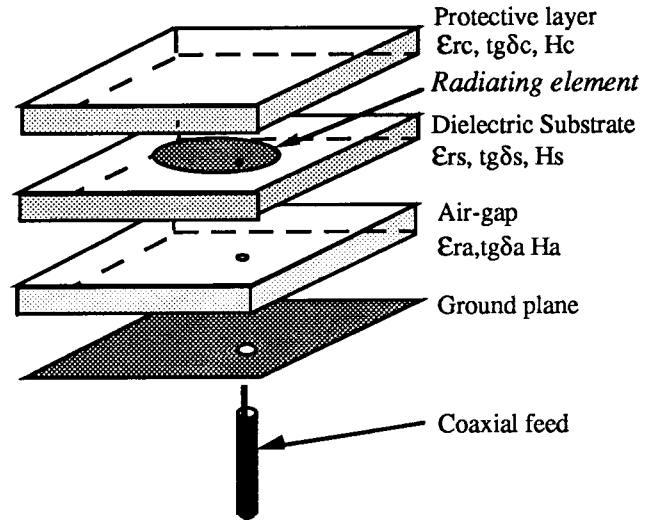


Figure 1: Multilayer microstrip antenna

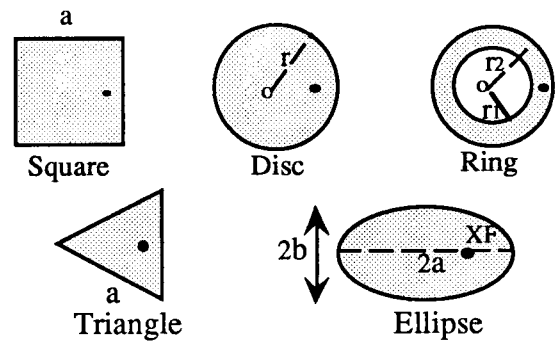


Figure 2 : Various shapes

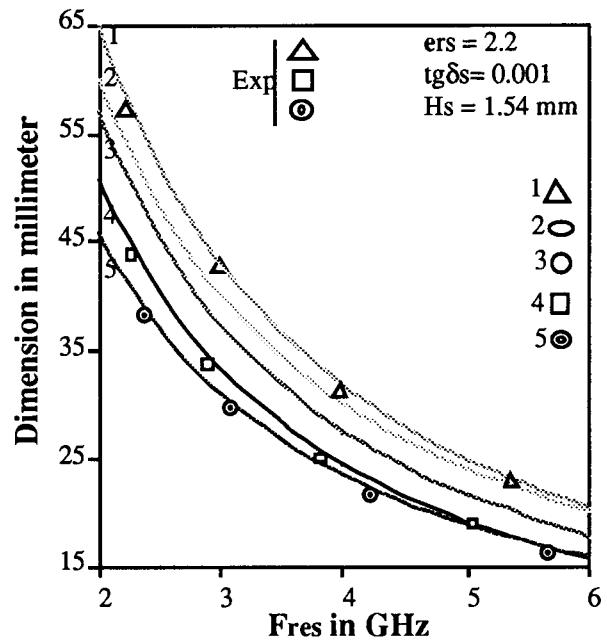


Figure 3 : Variations of the synthesis size of the radiating element versus resonant frequency

○ : $2a$, △ : a , ○ : $2r$, □ : a , ⊙ : $2r_2$

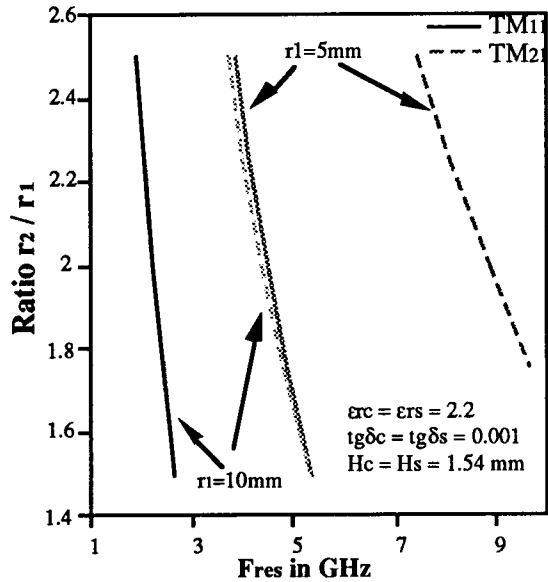


Figure 4 : Ratio r_2 / r_1 of annular ring with dielectric cover for TM_{11} and TM_{21} versus resonant frequency

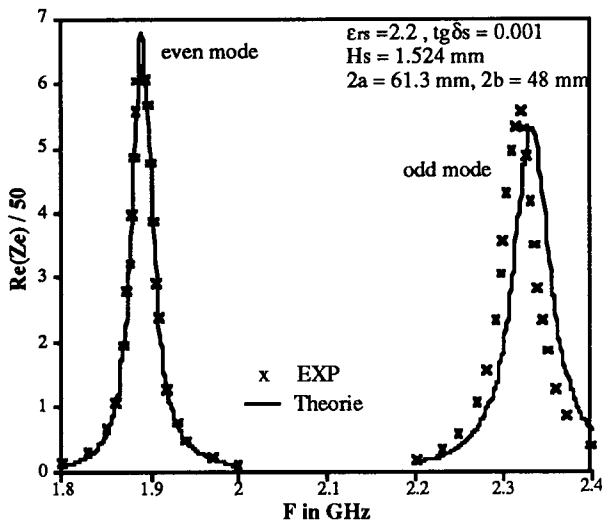


Figure 5 : Real part of the input impedance of ellipse versus frequency

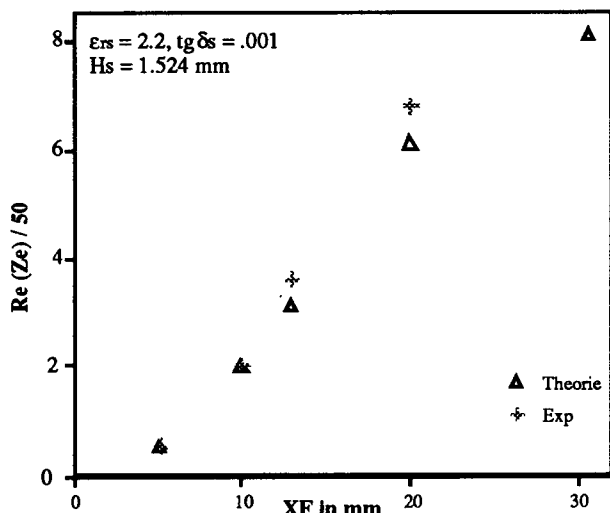


Figure 6 : Real part of input impedance versus the fed-position for the ellipse

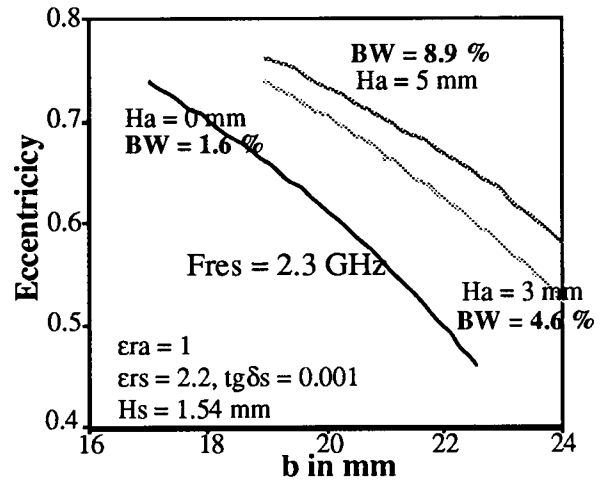


Figure 7 : Variations of eccentricity for different thickness of air-gap versus half minor axis b of the ellipse

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