UTILIZATION OF THE MATRIX PENCIL TECHNIQUE FOR DETERMINING MODAL PROPAGATION CHARACTERISTICS OF PRINTED CIRCUITS

Tapan K. Sarkar, R. S. Adve and Z. A. Maricevic
Department of Electrical and Computer Engineering
Syracuse University

Magdelena Salazar Palma
Polytechnic University of Madrid
SPAIN

Abstract:

First the surface current distributions on finite microstrip structures of arbitrary shape are solved for by the method of moments utilizing a conventional delta gap excitation. The Matrix Pencil Techniques is then used to decompose the currents along the feed and terminating lines into forward and backward travelling waves, yielding scattering parameters of device. This approach has been utilized to predict the input parameters of leaky wave antennas and for predicting scattering parameters of printed circuits. Experimental verification has been carried out to validate the theory.

1. Introduction

All the radiation effects are taken into account in a dynamic analysis of the microstrip. This method uses the theory of wave propagation in layered (stratified) media, first introduced by Sommerfeld. His approach was extended to microstrip structures by Mosig and Gardiol [1], and Mosig and Sarkar [2].

In this paper, we use the dynamic approach. We solve the Sommerfeld-type integral equation by the method of moments (MoM) [3]. In order to treat arbitrarily shaped microstrip patches, we consider triangular basis functions, first introduced by Rao et.al [4]. We solve for the current distribution on the structure, and find forward and backward traveling waves on the feed lines by use of the Matrix Pencil method [5,6]. The Matrix Pencil method decomposes the current along the microstrip into a sum of complex exponentials which correspond to the modes propagating along the microstrip line.

We also compare our results for scattering parameters over a wide frequency range for some two-port microstrip devices with experimental measurements.

2. Menzel's leaky-wave antenna [7-10]

Menzel presented a new traveling-wave antenna in microstrip, fed in its first higher order mode and operated near the cutoff frequency of that mode. He assumed the existence of the first higher order mode on the microstrip with a real propagating constant. However, in 1976, Ermert [10] showed that such a mode could not exist in the given frequency range. The main significance of his antenna was a high gain for its short physical length - only 2.23 λ_o. He obtained favorable agreement between his and experimental results; however, he

TU 3B

0-7803-3246-6/96/$5.00 © IEEE

failed to explain why this "traveling-wave" antenna radiated so well with its short length, and why propagation constant of the first higher mode is real.

Oliner [8,9] shows that the first higher order mode has complex propagation wavenumber (leaky mode) and that this "traveling-wave" antenna is actually a leaky-wave antenna, therefore resolving the contradiction between [7] and [10]. We analyze the Menzel's antenna by our numerical method and compare it with Oliner's theoretical and Menzel's experimental results.

The geometry of Menzel's antenna is shown in Figure 1. It is a 100 mm long, 15 mm wide section of open-ended microstrip line, on h=0.794, ε_r=2.32 dielectric substrate, fed unsymmetrically with a 50Ω, 2.3 mm wide line. We triangularize the structure and solve for the current distribution on it. We consider 10 sections across, 60 sections along the antenna, and two sections across, 50 sections along the feed line. Figure 2 shows the comparison between our results (solid line for ε_r=2.42, circles for ε_r=2.32) and experimental results from Menzel's paper (dashed line) at an operating frequency of 6.7 GHz. Our results, obtained for ε_r=2.42, coincides with the experimental one, supposedly measured for substrate of ε_r=2.32. The value for ε_r of 2.42 is only 4.3% away from prescribed ε_r=2.32, therefore within the 5% tolerance range for the dielectric constant.

Furthermore, Oliner shows that the current along the Menzel's antenna at frequency of 6.7 GHz can be described by a single complex mode, with its normalized real (β/k_o) and imaginary part (α/k_o) of the propagation wavenumber given in Table 1, alongside Menzel's and our results. Menzel assumed a real propagation constant, therefore his α/k_o=0. We obtain our values for propagation wavenumber by decomposing current along one edge of the antenna into complex exponentials by our Matrix Pencil method. Menzel's, Oliner's and our value for β/k_o are within 2.5% from each other, while our value for α/k_o is of the same order as Oliner's. The relatively large value of α/k_o (= 0.05) explains why Menzel's antenna radiates so well despite its short length (0.23 λ_o), approximately 65% of the incoming power is actually radiated. Leaky-wave antennas are typically designed to radiate at least 90% of power, Menzel's antenna would do so if its length is increased from 100 mm (2.23 λ_o) to 217 mm (4.85 λ_o). The main beam-width then reduces from 26° to more practical 14°.

Another useful property of this antenna is that the position of its main beam can be swept by a change of the operating frequency, as demonstrated in Figure 3. Oliner's results for the normalized far field pattern of a 217 mm long version of Menzel's antenna is shown for frequencies of 6.7 GHz (ooo), 7.5 GHz (xxx) and 8.5 GHz (+++) in comparison with results obtained by our method (solid line). Oliner uses ε_r of 2.32, but we consider ε_r=2.42. The agreement between Oliner's and our results is excellent for frequencies of 7.5 GHz and 8.0 GHz, and very good for f=6.7 GHz. If we consider ε_r=2.32, then the far field pattern for all three frequencies rotates for approximately 8° counterclockwise, with no other changes.

3. Gap-coupled ring resonator with a notch

In case of a ring resonator, two degenerate modes occur at the resonance frequency. If the ring resonator is excited by symmetrical coupling lines, only one mode will be excited. Due to the orthogonality of degenerate modes, there will be no coupling between the two. However, if the ring is coupled asymmetrically, or if a discontinuity is introduced in the ring, e.g., a notch, as illustrated in Figure 4, both modes are excited. This ring is made on a h=0.508, ε_r=2.33 dielectric substrate, fed with 50Ω, w=1.51 mm wide lines. As seen in Figures 5 to 8, our method clearly locates all cases of split resonance that are captured in measurements.

4. Conclusion

Use of the triangular basis functions in conjunction with the method of moments allowed for characterization of complex, arbitrarily shaped microstrip patches, over a broad range of frequencies. The Matrix Pencil method was utilized for decomposition of current along the microstrip lines into various modes, in addition tot he numerical match-terminating condition, to solve for scattering parameters of the device under test. Comparison with experiment shows an overall very good agreement with theory.

References

[1] J. R. Mosig; F. E. Gardiol. General integral equation formulation for microstrip antennas and scatterers. *IEE, Proc. H. Microwave, Opt., Antennas*, 132:175-182, December 1985.

[2] J. R. Mosig; T. K. Sarkar. Comparison of quasistatic and exact electromagnetic fields for a horizontal electric dipole above a lossy dielectric backed by an imperfect ground plane. *IEEE Transactions on Microwave Theory andTechniques*, 34(4):179-187, April 1986.

[3] T. K. Sarkar, P. Midya; Z. A. Maricevic, M. Kahrizi; S. M. Rao, A. R. Djordjevic. Analysis of arbitrarily shaped microstrip patch antennas using the sommerfeld formulation. *International Journal of Microwave and Millimeter-Wave Computer-Aided Engineering*, 2(3):168-177, 1992.

[4] S. M. Rao; D. Wilton; A. Glisson. Electromagnetic scattering by surfaces of arbitrary shape. *IEEE Transaction on Antennas and Propagation*, 30:409-418, 1982.

[5] Y. Hua; T. K. Sarkar. Generalized pencil-of-functions method for extracting the poles of an electromagnetic system from its transient response. *IEEE Transactions on Antennas and Propagation*, 37(2):229-234, February 1989.

[6] Y. Hua; T. K. Sarkar. Matrix pencil method for estimating parameters of exponentially damped/undamped sinusoids in noise. *IEEE Transactions on Acoustics, Speech and Signal Processing*, 38(5):814-824, May 1990.

[7] W. Menzel. A new traveling-wave antenna in microstrip. *AËU Electronics and Communications Journal*, 33(4):137-140, April 1979.

[8] A. A. Oliner. Leakage from higher modes on microstrip line with application to antennas. *Radio Science*, 22(6):907-912, November 1987.

[9] A. A. Oliner; K. S. Lee. Scannable millimeter wave arrays; chapter ix: Microstrip line leaky-wave strip antennas. *Technical Report*, Polytechnic University Weber Research Institute, 1988.

[10] H. Ermert. Guided modes and radiation characteristics of covered microstrip lines. *AEU Electronics and Communications Journal*, 30(1):65-70, January 1976.

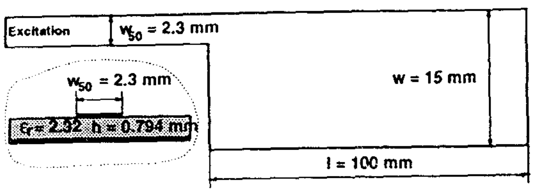

Figure 1: *Geometry of Menzel's antenna*

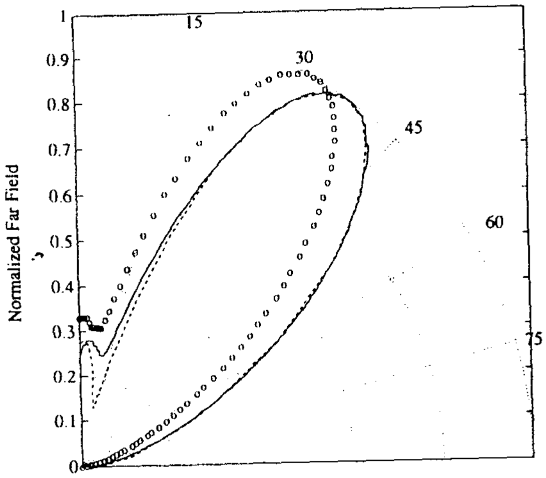

Figure 2: *Normalized far field pattern*

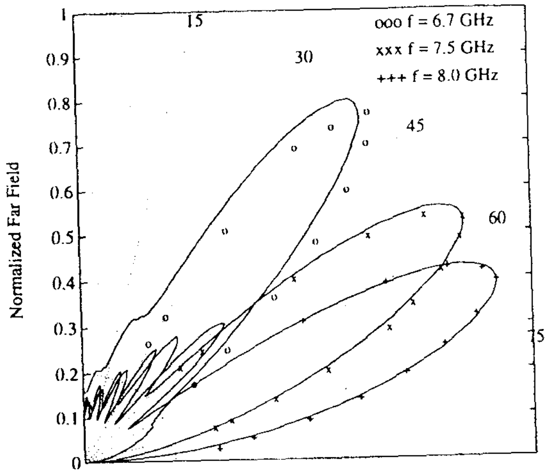

Figure 3: *Normalized far field pattern*

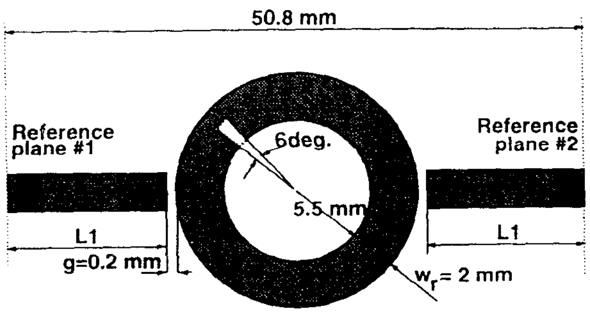

Figure 4: *Gap-coupled ring resonator*

	β/k_0	α/k_0
Menzel	0.645	0.00
Oliner	0.661	0.04
Our work	0.647	0.05

Table 1: *Normalized real* (β/k_0)