The Surface Waves' Impact on the Coupling Effect in Microstrip Antennas

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Abstract – **This study explores the mutual coupling between microstrip antennas provoked by the surface wave. The analysis of the microwave structure is made with a simulator based on the method of moments. Calculations of the mutual coupling are in good agreement with other measurements and calculations.**

Keywords - **Mutual coupling, surface wave, patch antennas.**

I. INTRODUCTION

Microstrip antenna arrays are commonly used antennas in modern communication systems for telemetry and control, as well in radar and navigation technology. This type of antennas is characterized by compact design, low cost and simple manufacturing technology. The two primary advantages of microstrip antennas are the possibility of a synthesis of desired radiation pattern and phase scanning up to ±60 degrees. Their main disadvantage is a narrow frequency band. It is caused by two factors:

- The basic constructive element (the microstrip patch) has resonant features and a narrow frequency band;
- The mutual coupling between the basic elements is higher than in usual antenna arrays leading to a higher shift in input impedance and a radiation pattern with the same frequency shift.

The process of determining the mutual coupling between radiating elements is difficult because of the influence of a variety factors such as reflected and surface waves exited in the impedance structure – the dielectric above the metal plane.

II. SHORT REVIEW OF EXAMINATIONS

The arrangement for determining of the mutual coupling is shown in Fig.1. In other antenna arrays (waveguide, dipole, etc.) the mutual coupling is determined by the method of inducted e.m.f. , which calculates the primary and secondary radiation of the single elements. In this case, only the amplitude and phase of space wave is considered (Fig.3). In the planar antenna arrays two other factors need to be considered as well the reflected and the surface wave. The process is complicated by the fact that in the same distance d, the dispersion characteristics of these three waves are different and their sum in the second element is a function of a complex law.

In a number of studies ([1], [2], [3] among others), the presence of these three components has been examined jointly, without a quantitative division. In [1], on the basis of an experiment it is proven, that mutual coupling in the H-plane is smaller than in E-plane and that increasing of d/λ (d – distance between radiating elements) reduces the mutual coupling. [2] and [3] provide a theoretical model and, using primarily computer simulations, examine the parameters S_{11} and S_{12} between two microstrip resonators in different distances and substrate parameters.

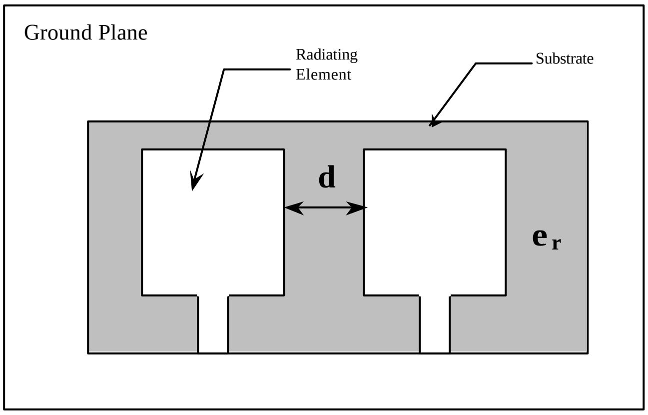

Fig. 1. Geometry of the two rectangular resonators for determining of mutual coupling

III. RESULTS

The purpose of this paper is to explore the factors that have an impact on the presence of a surface wave and evaluate it influence in parameter S_{12} (coupling between neighboring radiating elements).

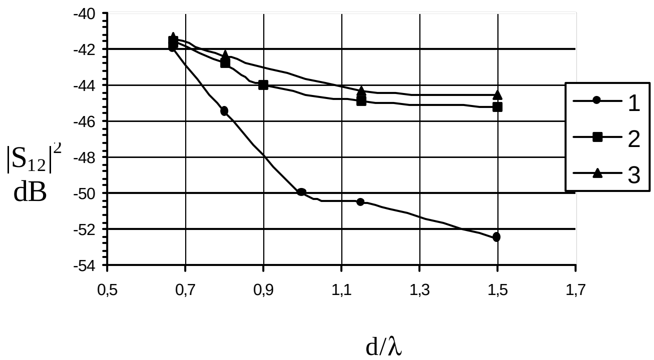

Fig. 2. Calculated coupling between elements at 11 GHz. Legend: 1-$\varepsilon_r = 1$, 2-$\varepsilon_r = 2.8$, 3-$\varepsilon_r = 5$

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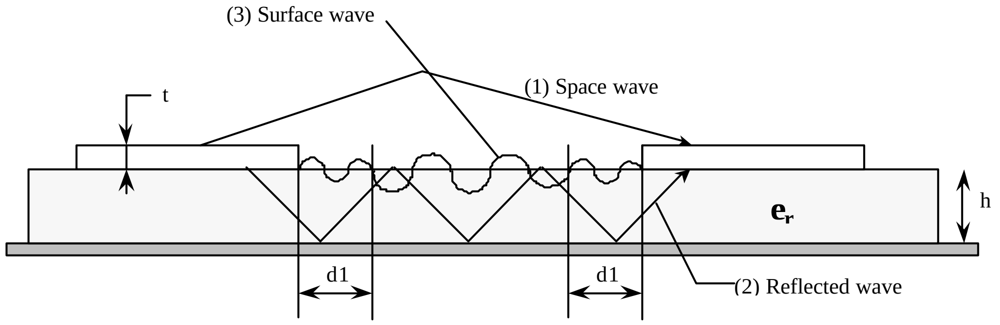

Fig. 3. Waves exited in microstrip structure

Analysis was performed with electromagnetic simulation software, based on the method of finite elements at frequency of 11 GHz. It computes electric fields at the nodes (vertices) of tetrahedra. To obtain values for the field at other points, it interpolates the field from the nodal values of the finite element mesh.

After that it automatically computes multiple adaptive solutions until a user-defined convergence criterion is met. Field solution calculated from first principles accurately predicts all high-frequency behavior, such as dispersion, mode conversion, and losses due to materials and radiation.

The final results are displayed in Fig.2. In order to explain the results the following specifications should be taken into account:

The reflected wave is predominant only in cases of high values of ε_r;

- In small values of tg(δ) of the dielectric, the reflected wave almost holds its magnitude along the direction of propagation, regardless of the variation of d/λ;

- There is not zone of excitation in reflected wave.

- For excitation of surface wave a distance $d_1 \approx (0.5\div0.7)\lambda$ is necessary (Fig.3). In this zone the surface wave has a small magnitude. The distance d_1 is dependant of ε_r and h (thickness of the dielectric);

- If the surface wave has significantly higher magnitude than a reflected wave, than its excitation depends a little from ε_r and h.

The results obtained support the following conclusions:

1. In the case of a presence of a dielectric substrate, the surface wave is important for determining of parameter S_{12} of mutual coupling.

2. In zone d_1/λ between the resonant elements the influence of surface wave is much smaller and may be not taken into account. $d_1=(0.5\div0.8)\lambda$.

3.The alternation of S_{12} is ε_r significant in cases when $\varepsilon_r \geq (2.2\text{-}2.4)$

4.The decrease of S_{12} from a distance is much slower in the presence of a surface wave;

5. In a distance recommended in literature between radiating elements (0.8λ) in antenna arrays, the influence of the surface waves is small. In case of bigger antenna arrays (when the size of entire array is higher than 0.8λ), the influence of the surface wave is significant, even predominant in not immediately neighboring elements.

IV. CONCLUSION

This paper examines and explains certain basic features of patch antenna arrays. The main conclusion of this study is that the influence of surface wave is not significant in close neighbouring resonant elements. However, it is significant in all other elements and therefore should be considered in the design of this type antenna arrays. Future research in this field will focus on analysis of the structure examined hitherto, including a larger number of elements, as well as the interaction between not neighbouring elements.

REFERENCES:

[1] R. P. Jedlicka, M. P. Toe and K.R. Carver, “Measured mutual coupling between microstrip antennas” *IEEE Trans. Antennas Propagat.*, vol. A-P 29, pp. 147-149, Jan.1981

[2] E. Penard and J. P. Daniel, “Mutual coupling between microstrip antennas”, *Electron. Lett.*, vol.18, no.14, pp. 605-607, July 8, 1982.

[3] D. Pozar, “Input impedance and mutual coupling of rectangular microstrip antennas”, *IEEE Trans. Antennas Propagat.*, vol. A-P 30, pp. 1191-1196, Nov. 1982