Enhanced Performance of Microstrip-fed Wide Slot Antenna using Periodic Gaps in Dielectric Substrate

S SINGH* AND R K SARIN[#]
*Dept of Applied Physics
[#]Dept of Electronics and Communication Engg
Dr B R Ambedkar National Institute of Technology
G T Road Bye Pass, Jalandhar-144011
INDIA

Abstract: - The effects of a two-dimensional periodic dielectric substrate on the performance of a microstrip-fed wide slot antenna are investigated. The microstrip-feed and wide slot is placed on opposite sides of the periodic dielectric substrate. Method of Moment calculations using volume integral equations is employed to determine the effects of the substrate. It is proposed that by introducing a periodic dielectric substrate, a broadband response can be obtained from inherently narrowband antennas.

Key-Words: - method of moment, periodic dielectric, microstrip, slot antenna

1 Introduction

In recent years, the current trend in communication systems has been to develop low cost, minimal weight, low profile antennas that are capable of maintaining high performance over a large spectrum of frequencies. This technological trend has focused much effort into the design of planar antennas. With a simple geometry, these antennas offer many advantages not commonly exhibited in other antenna configurations. For example, they are extremely low profile, lightweight, simple and inexpensive to fabricate using modern day printed circuit board technology, compatible with microwave and millimeter-wave integrated circuits (MMIC), and have the ability to conform to planar and non-planar surfaces. Among them slot antennas have played an important role for a variety of applications. The main advantages of radiating slots are less interaction via surface waves, better isolation and negligible radiation from feed network.

For over two decades, several methods were proposed to increase the bandwidth. Many of these techniques involve adjusting the placement and/or type of element used to feed (or excite) the antenna. The simplest and most direct approach is to increase the thickness of the substrate. As the layer thickness increases, the surface waves become highly excited[1]. Surface wave effects can be eliminated by using cavities or stacked substrate techniques [2]. However, this has the fundamental drawback of increasing the weight, thickness, and complexity of the microstrip antenna, thus negating many of the advantages of using it.

Recently, the concepts of electromagnetic band gap (EBG) material structure have been proposed by several researchers [3-4] paving the way for improved performance of microstrip antennas and microwave circuits when etched on high dielectric constant substrate materials by suppressing the surface waves. Uniplanar compact electromagnetic bandgap (UC-EBG) substrate has been proven to be an effective measure to reduce surface wave excitation in printed antenna geometries [5]. The EBG substrate needs complex design procedure in which normally periodic air columns are micro-machined in the substrate material [6].

In the present endeavour, authors propose a microstrip fed wide slot antenna using a simplified periodic dielectric substrate structure. The effect of the periodic gaps in the dielectric substrate on the impedance characteristics is discussed. The simulation results are generated using codes developed using the method of moment using volume integral equation as reported in [7].

2 Analysis and Geometrical Layout

The method of moment (MOM) with volume integral equation (VIE) is used since it is computationally demanding to model combined metal and dielectric structures of inhomogeneous materials. For the purpose of analysis all the current distributions and basis functions were considered in solving the integral equations. The details of MOM VIE approach is not presented here for brevity. The solution obtained in terms of vector and scalar-potential Green's functions was implemented in the codes used for the investigations

The proposed antenna has periodic square gaps in the dielectric substrate of 55 mm x 55 mm. The simplicity of this periodic dielectric structure is clearly evident from its configurations as shown in figure 1. It consists of square gaps of 5 mm and the periodicity of the gap is 3.75 mm, making it more useful in realization using milling machine. The substrate material selected for this study is Roger's RT/duroid 6006, ε_r = 6.15, tanδ = 0.0027 with thickness of 1.27 mm. The slot of 26.85 mm x 26.85 mm is considered to be etched in the ground plane and is fed by a 50-Ω microstrip line of width 1.8 mm, which is placed on the opposite side of the substrate.

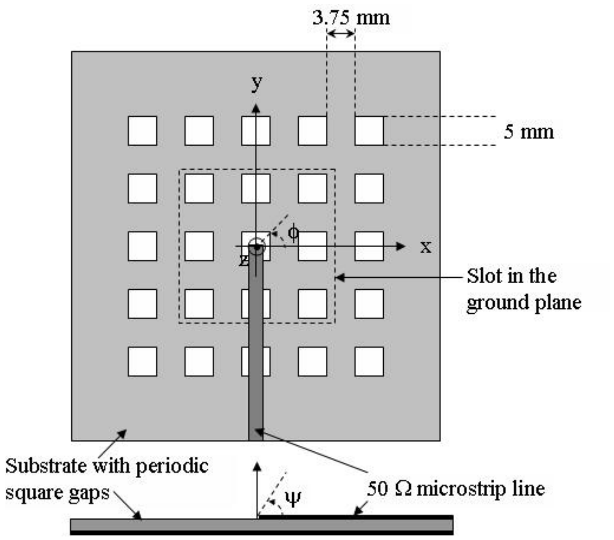

Fig. 1: Configurations of the wide slot antenna with periodic dielectric substrate

Robust and efficient modeling of such configuration requires a numerical discretization scheme permitting the analysis of radiation and scattering characteristics. For discretization of the cavity volume in a computational domain require tangential field continuity across element boundaries and suppress spurious modes. Tetrahedral elements are widely used in analyzing complex 3-D electromagnetic problems. Because of the tetrahedral shape, they offer higher flexibility, and are more suitable to automatic mesh generation of 3-D regions compared to other types of elements [8]. Based on an existing expansion of surface currents a suitable volume/surface meshing is done to the configuration. The feed is a voltage gap connector between the ground plane and the microstrip. The constant voltage *V* is given in the finite gap. The input impedance of the antenna is then given by the ratio of gap voltage to total current through the feeding edges

$$Z = \frac{V}{\sum l_n I_n}$$

where I_n are the solutions to MoM equations with the basis functions.

3 Result and Discussion

This section compares the simulated results of the antenna using periodic square gaps in the dielectric substrate with those of antenna without the gaps in the dielectric substrate. The effect of presence of the periodic gaps in the dielectric substrate on impedance bandwidth and VSWR is studied.

Figure 2 shows the relationship between return loss and frequency of the wide slot antenna with and without periodic square gaps in the dielectric substrate. It indicates that the antenna with the gaps in the substrate shows better return loss as compared to that of without gaps in the substrate. The return loss levels at resonance are -22.88 dB for the antenna with the gaps and -18.35 dB for the antenna without the gaps, which shows good impedance matching. Further it is observed that though there is a shift in the resonance frequency, the antenna with the gaps shows a substantial enhancement in the bandwidth as compared to that of without the gaps. At -10 dB, bandwidths of 1.725 GHz for the antenna with the gaps and 0.551 GHz for the antenna without the gaps are observed.

Figure 3 reveals that the VSWR of the antenna with the gaps is better than that of without gaps over a wide frequency range.

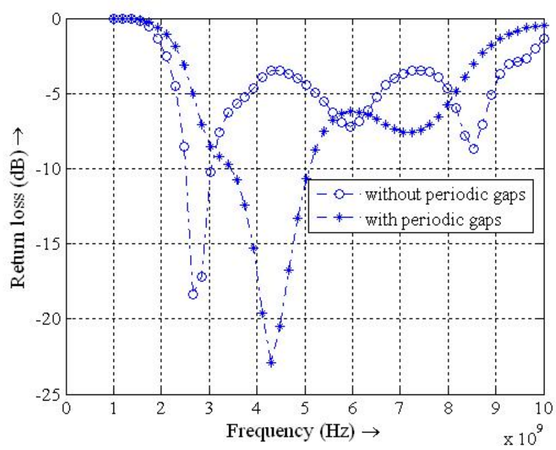

Fig. 2: Plot of return loss as a function of frequency

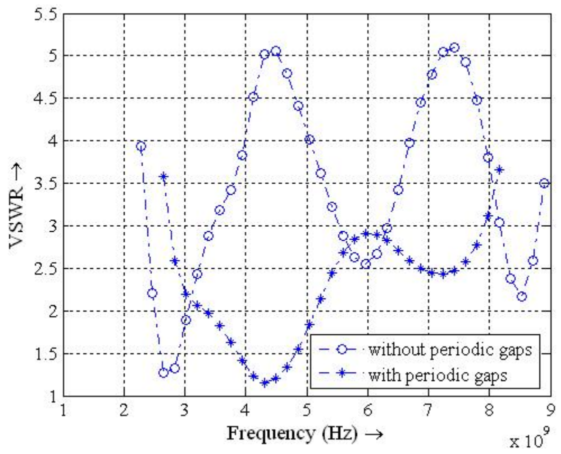

Fig. 3: Plot of VSWR as a function of frequency

4 Conclusions

From the above discussions, it can be concluded that the antenna with periodic square gaps in the dielectric substrate gives better bandwidth and VSWR as compared to that of without gaps. This meets the demand of low profile antenna that is capable of maintaining high performance over a large frequency range.

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