Radiation Performance Evaluation of Microstrip Antenna Covered With a Dielectric Layer

Hussain A. Hammas*

Received on: 7/10/2008
Accepted on: 5/3/2009

Abstract

In this paper, a comprehensive investigation of a microstrip antenna performance covered with a dielectric layer has been presented. An aperture coupled antenna has been designed as a case study. Antenna parameters have been evaluated with and without the presence of a dielectric layer with different thickness values. Theoretical performance evaluation of this antenna for different cases, corresponding to the different dielectric thicknesses, has been assessed using the method of moment (MoM) based EM simulator IE3D, v.10.06. A large number of dielectric thickness variations have been modeled, in an attempt to provide accurate antenna parameters response through this range. Simulation results show that the antenna resonant frequency is reduced as the dielectric layer thickness is increased. To maintain the resonant frequency, the antenna dimensions must be scaled down as a result of the existence of this layer. In addition, results also show that, as the dielectric layer thickness is increased, the resulting antenna gain decreases.

Keywords: Microstrip aperture coupled antenna, radiation performance, superstrate layer.

تقييم أداء إشعاع الهوائي الشريطي بوجود طبقة فوقية عازلة

الخلاصة

في هذا البحث تم تقديم دراسة شاملة للهوائي الشريطي بوجود طبقة عازلة فوقية, صممت فتحة الهوائي كنموذج لغرض الدراسة.مواصفات الهوائي قيست بوجود وعدم وجود الطبقة العازلة وباستخدام طبقات مختلفة السمك. تم تقيم عمل الهوائي نظريا طبقا لاختلاف طبقة العازل من ناحية السمك وباستخدام الحقيبة البرمجية IE3D التي تجري المحاكاة على وفق طريقة أيجاد العزوم (MoM) .عدد كبير من العوازل ذات السمك المختلف تم تصميمها كمحاولة لإثبات الاستجابة الدقيقة لمعالم الهوائي ضمن هذا المدى.أظهرت نتائج المحاكاة أن التردد الرنيني للهوائي يقل مع زيادة سمك طبقة العازل ولإبقاء قيمة هذا التردد ثابتة يجب تخفيض أبعاد الهوائي بنسبة معينة كنتيجة لوجود هذه الطبقة العازلة .بالإضافة إلى ذلك أظهرت النتائج أن زيادة سمك طبقة العازل أدت إلى تقليل ربح الهوائي .

1-Introduction

In spite of the limitations that accompany the performance of the microstrip antennas, such as the narrow bandwidth and the lower gain it possess, they are still attractive for antenna designers. Microstrip antennas have been used in airborne and spacecraft systems [1] due to their excellent advantages. Such advantages include small size, light weight, low production cost, conformal nature, and good aerodynamic characteristics.

Superstrate dielectric layers are often used to protect microstrip antennas from environmental hazards, or may be naturally formed during flight or severe weather conditions such as ice layers or dusty layers.

Most of the research studies of the effect of dielectric superstrate on the

*Electrical and Electronic Engineering Department, University of Technology / Baghdad

https://doi.org/10.30684/etj.27.7.5
2412-0758/University of Technology-Iraq, Baghdad, Iraq

microstrip antenna performance are not comprehensive. In [1-4], studies were restricted on the effect of the dielectric superstrate layer on the resonant frequency, half-power bandwidth and the quality factor of a microstrip patch antenna. In [5], the effect of the superstrate dielectric layer on the radiation pattern of a rectangular microstrip patch antenna has been presented.

However, there is no comprehensive study devoted to investigate the effect of the superstrate dielectric layer on the different performance aspects of microstrip antennas.

In this paper the effect of the superstrate dielectric layer on the microstrip antenna performance has been investigated more comprehensively. As a case study, the performance of the aperture coupled microstrip antenna has been evaluated when it is covered with a dielectric layer.

2. A Case Study; the Aperture-Coupled Microstrip Antenna

The aperture coupled antenna design comprises of two substrates with the ground plane between them, the line on the bottom and the patch on the top. The feed line couples through an aperture with the patch. In this way it is possible to optimize the substrate dielectric constants at the same time shield the patch from spurious feed radiation. This produces antenna design with many degrees of freedom, as there are many variables that can be tuned to optimize the design. The aperture can be of any shape, but it is shown as a rectangular.

Figure (1) shows the structure of the aperture coupled microstrip antenna to be used in this work as a case study of the effect of the superstrate dielectric layer covering its top on its overall performance. An aperture-coupled patch antenna is well suited for the use in active arrays, because its fabrication is simple due to its planar nature. Additionally, it is compatible with microstrip circuitry and monolithic integrated circuits [6].

3. Antenna Design and modeling Process

The aim of this work is to investigate the effect of the microstrip antenna performance in the existence of a superstrate dielectric layer, and not to present a new design idea of the aperture-coupled microstrip antenna. Based on this fact, this work makes use of an existing design of the aperture-coupled microstrip antenna reported in [7]. For the sake of comparison, the substrates parameters and the antenna dimension are chosen to be the same as in the original work, to get an antenna resonating at a frequency of 2.2 GHz.

However, there are many considerations that might be taken into account in this antenna design.

The antenna substrate dielectric constant primarily affects the bandwidth and radiation efficiency of the antenna, with lower permittivity giving wider impedance bandwidth and reduced surface wave excitation. In the other hand substrate thickness affects bandwidth and coupling level; a thicker substrate results in wider bandwidth, but less coupling for a given aperture size.

The length of the patch radiator determines the resonant frequency of the antenna. The width of the patch affects the resonant resistance of the antenna, with a wider patch giving a lower resistance. The patch length can be calculated [7]:

$$L = 0.49 \frac{l}{\sqrt{e}} \qquad (1)$$

Where e , is the substrate dielectric constant and l is the wavelength at resonance.

Thinner microstrip substrates result in less spurious radiation from feed lines, but higher loss. A compromise of 0.01λ to 0.02λ is usually good.

The coupling level is primarily determined by the length of the coupling slot, as well as the back radiation level. The slot should therefore be made no larger than is required for impedance matching.

The width of the slot also affects the coupling level, but to a much less degree than the slot width. The ratio of slot length to width is typically 1/10.

Besides controlling the characteristic impedance of the feed line, the width of the feed line affects the coupling to the slot. To a certain degree, thinner feed lines couple more strongly to the slot.

For maximum coupling, the feed line should be positioned at right angles to the center of the slot. Skewing the feed line from the slot will reduce the coupling, as will positioning the feed line towards the edge of the slot.

Antenna modeling and performance evaluation have been performed using the IE3D software EM simulator from Zeland Software Inc. This software performs electromagnetic simulation using the method of moments (MoM). Table 1 summarizes the dimensions of the different parts of the resulting antenna structure. The final patch and slot dimensions are 40×30 and 1.53×11.5 mm respectively.

4- Discussion of the Simulation Results

In modeling process, the superstrate dielectric layer has been assumed to vary from zero thickness (no dielectric superstrate layer exists) up to a maximum thickness of 15 mm, in steps of 5mm each. At each value of the dielectric superstrate thickness, the antenna has been modeled and its performance has been evaluated.

Figure (2) shows the variation of the antenna resonant frequency versus the superstrate dielectric layer thickness. It is clear that as the superstrate thickness is increased as the resonant frequency decreases. This is equivalent to increasing the dimensions of the conducting patch.

It has been also found that, as the superstrate layer thickness increases the antenna gain decreases as shown in Fig (3). This can be attributed to the additional increase in the dielectric loss caused by the increased thickness of the superstrate layer. The effects of the dielectric superstrate layer on other antenna parameters such radiation efficiency, antenna efficiency; half-power beamwidth. HPBW, and antenna directivity, *D* have been demonstrated in Table 2, where these parameters have evaluated for four values of the superstrate layer thickness of 0, 5, 10, and 15 mm respectively. As it is clear, all of these parameters affected as the dielectric superstrate layer is increased. Both radiation efficiency and antenna efficiency become lower as the thickness is increased due the accumulative dielectric loss added. The half-power beamwidth becomes narrower causing the directivity to be increased. Figs 4-7 show the simulated E-field of the antenna with different values of the superstrate thickness from zero to 15 mm respectively.

5-Conclusion

A comprehensive performance evaluation of a microstrip antenna has been presented in the existence of a dielectric superstrate layer on its upper surface. As a case study, the aperture-coupled microstrip antenna has been proposed. Simulation results have shown that all antenna parameters have been affected by this layer. The primary effect is on the antenna resonant frequency. The antenna resonant frequency has been reduced as the layer thickness has been increased; this may make the antenna resonates beyond the design frequency. This situation could take place when the layer naturally formed during severe weather conditions such as ice layers or dusty layers. Other antenna parameters have found to be slightly affected.

References:

[1]. I. J. Bahl and P. Bhartia, “Design of microstrip antennas covered with a dielectric layer,” IEEE Trans. Antennas Propagat., vol. AP-30, pp. 314-318, Mar. 1982.

[2]. J. S. Row and K. L. Wong, “Resonances in a superstrate-loaded rectangular microstrip structure,” IEEE Trans. Microwave Theory Tech., vol. 41, pp. 1349-1355, Aug. 1993.

[3]. V. Losada, R. R. Boix, and M. Horno “Resonant modes of circular microstrip

patches in multilayered substrates," IEEE Trans. Microwave Theory Tech., vol. 47, pp. 488-498, Apr. 1999.
[4]. F. Bouttout, et.al, "Resonant frequency and bandwidth of a superstrate-loaded rectangular patch on a uniaxial anisotropic substrate," Commun. Numer. Meth. Engng., vol. 16, pp. 459-473, July 2000.
[5]. T. Fortaki, et.al, "Evaluation of the radiation of rectangular microstrip antenna covered with a dielectric layer," 4th International Conference IEEE-SETIT, Tunisia, 2007.
[6]. T. Brauner, R. Vogt, and W. Bachtold, "A differential active patch antenna element for array applications," IEEE Microwave and Wireless Components Letters., vol. 13, pp. 161-163, Aug. 2003.
[7]. D. M. Pozar, "A review of aperture coupled microstrip antennas: history, operation, development, and applications," http://www.ecs.umass.edu/ece/pozar/aperture.pdf.

Table 1, Summary of the dimensions and material specifications of the modeled aperture-coupled microstrip antenna.

Layer	Material	Dielectric Constant	Thickness, mm
Free Space	Air	1	Open Boundary
Antenna Patch	Copper		
Antenna Substrate	Duriod	2.54	1.6
Ground Plane	Copper		
Feed Substrate	Duriod	2.54	1.6
Feed Line	Copper		
Free space	Air	1	10.00

Table 2. Variation of some antenna parameters with dielectric superstrate layer thickness at resonance.

Antenna Parameters / Superstrate Thickness, mm	Rad. Eff. (%)	Ant. Eff. (%)	HPBW (deg.)	*D* (dBi)
0.0	92.41	92.34	109.94	6.901
5.0	78.46	72.33	102.45	7.249
10.0	71.56	66.08	91.11	7.637
15.0	69.86	60.13	90.19	7.876

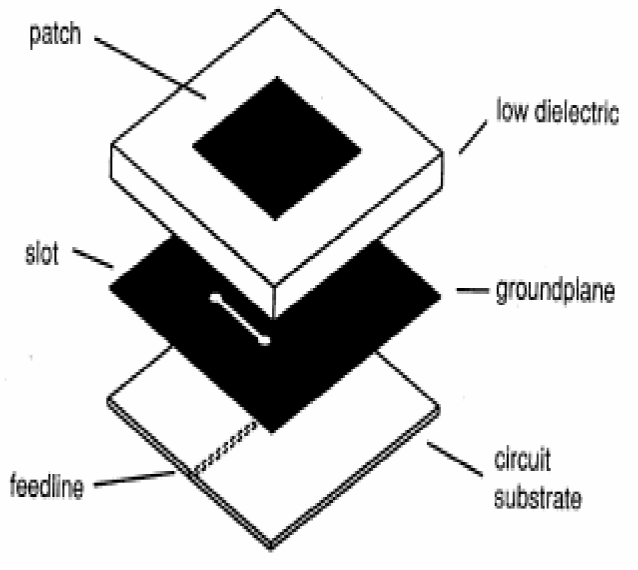

Fig.1. The layout of the modeled aperture-coupled microstrip antenna.

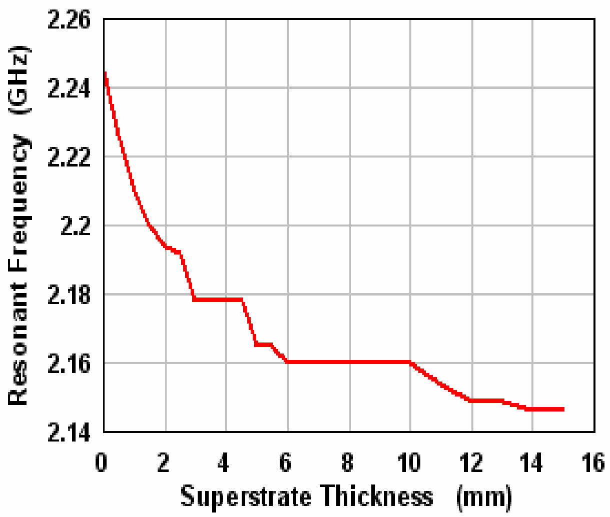

Fig.2. The variation of antenna resonant frequency with the superstrate thickness.

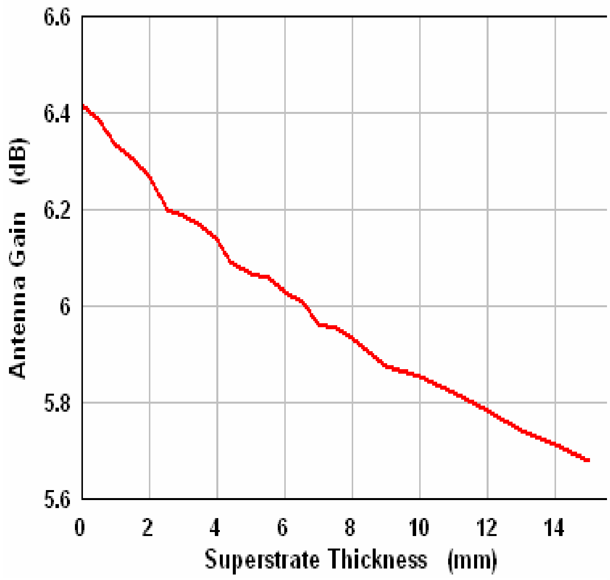

Fig.3. The variation of antenna gain with the superstrate thickness.

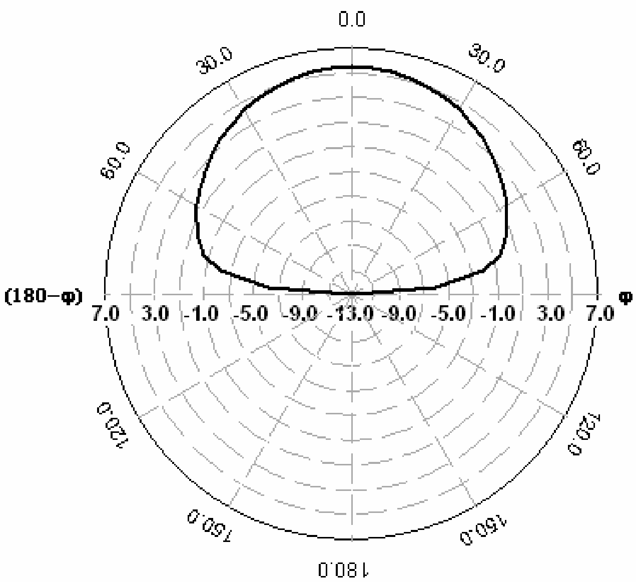

Fig.5 The simulated E-plane antenna radiation pattern with a superstrate thickness of 5 mm.

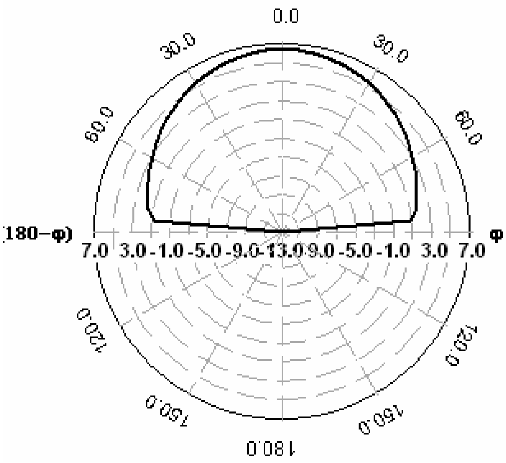

Fig.4 The simulated E-plane antenna radiation pattern with no superstrate.

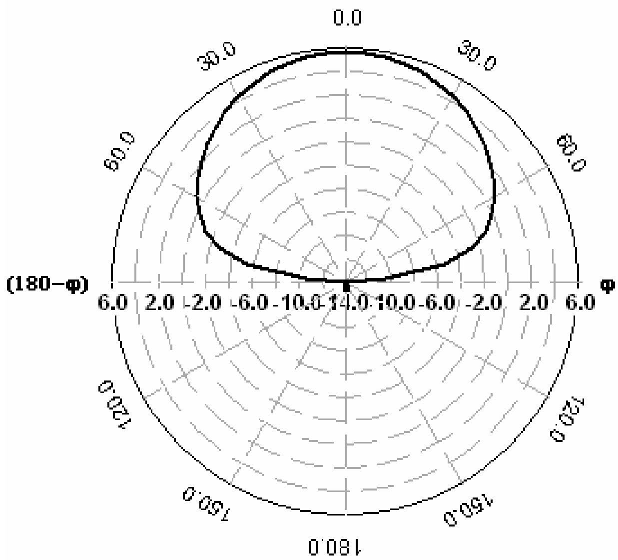

Fig.6 The simulated E-plane antenna radiation pattern with a superstrate thickness of 10 mm.

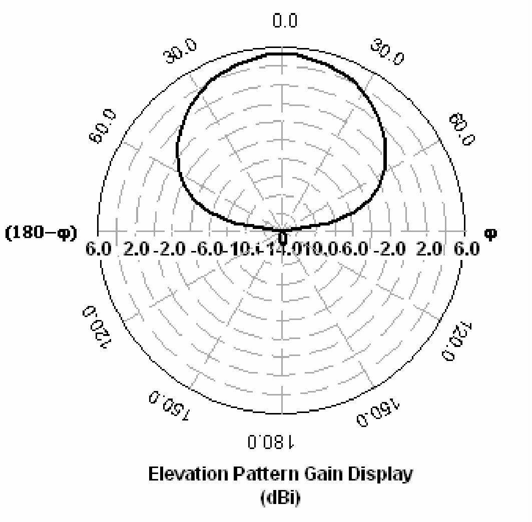

Fig.7 The simulated E-plane antenna radiation pattern with a superstrate thickness of 15 mm.