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A PATCH ANTENNA WITH A TOP DIELECTRIC LAYER

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1. Introduction

A conducting patch sandwiched by two dielectric layers (top and bottom dielectric layers) has already been analyzed and its radiation characteristics have been revealed [1]. It was found that the top dielectric layer contributes to controlling the radiation characteristics. Note that the top and the bottom dielectric layers in [1] have the same relative permittivity.

This paper is a sequel to the investigation of the patch antenna in [1]. In this paper the top and bottom dielectric layers have different relative permittivity, unlike those in [1]. Analysis is performed using the finite-difference time domain (FDTD) method, where Yee's rectangular mesh is used with Liao's second order absorbing boundary condition [2]. The assumptions used in the FDTD analysis are as follows: the bottom (substrate) and top dielectric layers are lossless, the ground plane is of infinite extent, and the patch is infinitesimally thin. The effects of the top dielectric layer on the gain are discussed, as well as the effects on the input impedance and radiation pattern.

2. Configuration

Fig. 1 shows a patch sandwiched by two dielectric layers. The bottom layer has thickness B_{btm} and relative permittivity ε_r and the top dielectric layer has thickness B_{top} and relative permittivity $\varepsilon_{r,top}$. The patch is square with side length s_{ptch} and located at height B_{btm} above a conducting plane (a ground plane (GP)) of infinite extent. The patch is excited using a vertical strip of width w, whose starting point s_{FD} is the feed point. Note that the dielectric layers are square with side length L.

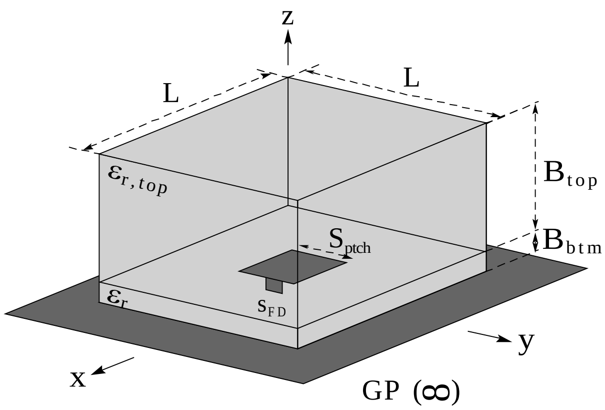

Fig. 1. A patch antenna sandwiched by two dielectric layers.

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To simplify the discussion, the following parameters are fixed: ε_r = 2.07, s_{ptch} = 0.28λ_{8G}, B_{btm} = 0.04λ_{8G}, and w = 0.04λ_{8G}, where λ_{8G} is the free-space wavelength at a test frequency of 8 GHz. The relative permittivity $\varepsilon_{r,top}$, thickness B_{top}, and side length L are varied subject to the objectives of the analysis.

3. Antenna characteristics

We start with determining the side length L. This is performed under the condition that the patch does not have the top dielectric layer (B_{top} = 0). Fig. 2 shows the input impedance $Z_{in} = R_{in} + jX_{in}$ at 8 GHz as a function of the side length L. The analysis shows that the input impedance converges for L > 0.6λ_{8G}. Based on this result, the antenna characteristics for parameters (ε_r, L) = (2.07, 0.8λ_{8G}) are discussed, with the remaining configuration parameters defined in section 2.

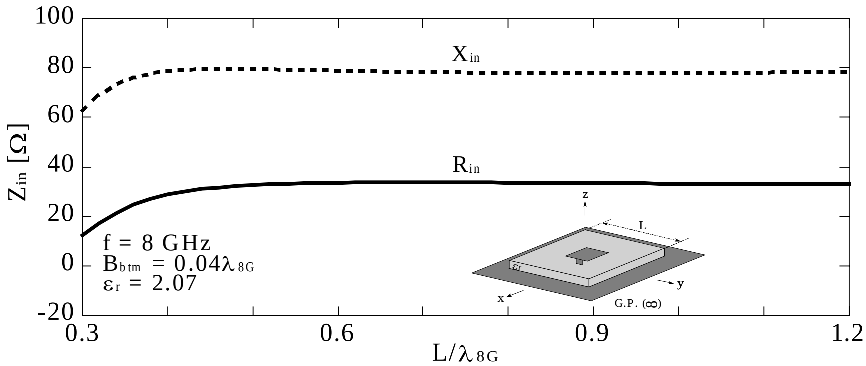

Fig. 2. Input impedance as a function of the side length L.

As described in [3], the top dielectric layer of thickness B_{top} is regarded as a waveguide structure for the wave generated by the patch. When the wave reaches the upper surface of the top dielectric at height $z = B_{btm} + B_{top}$, it is desired that the wave completely radiates into free-space. If this radiation from the dielectric surface is not complete, part of the wave is reflected back in the –z direction. The reflected wave illuminates the patch and disturbs the current distribution over the patch, changing the antenna characteristics.

It is expected that the illuminations for B_{top} = B and B_{top} = B + ΔB will be similar, if the wave for B_{top} = B + ΔB experiences a phase change of 2mπ rad, passing through length 2ΔB, where m is an integer. Note that the wave for B_{top} = B + ΔB passes through a section of length ΔB twice, first as an incident wave and then as a reflected wave. The phase change 2mπ rad corresponds to ΔB = m(λ_g/2), where λ_g is the guided wavelength in the top dielectric. This repetitive illumination means that the input impedance should change with a period of approximately λ_g/2 with respect to B_{top}.

We choose three top dielectric layers of $\varepsilon_{r,top}$ = 1.44, 2.07, and 2.60 and continue our discussion. Fig. 3 show the input impedance $Z_{in} = R_{in} + jX_{in}$ at 8 GHz as a function of the thickness B_{top}. Note that B_{top} (shown on the top horizontal axis) is normalized to the guided wavelength in the dielectric, λ_g, where $\lambda_g = \lambda_{8G} / \varepsilon_{r,top}^{1/2}$, assuming that the guided wavelength for a finite dielectric layer is close to the guided wavelength for a plane wave traveling in an unbounded space filled with a dielectric of relative permittivity $\varepsilon_{r,top}$. It is found that maxima of the input resistance R_{in} appear with a period slightly larger than $\lambda_g/2$ with respect to B_{top}. This period holds true for maxima of the input reactance X_{in} as well.

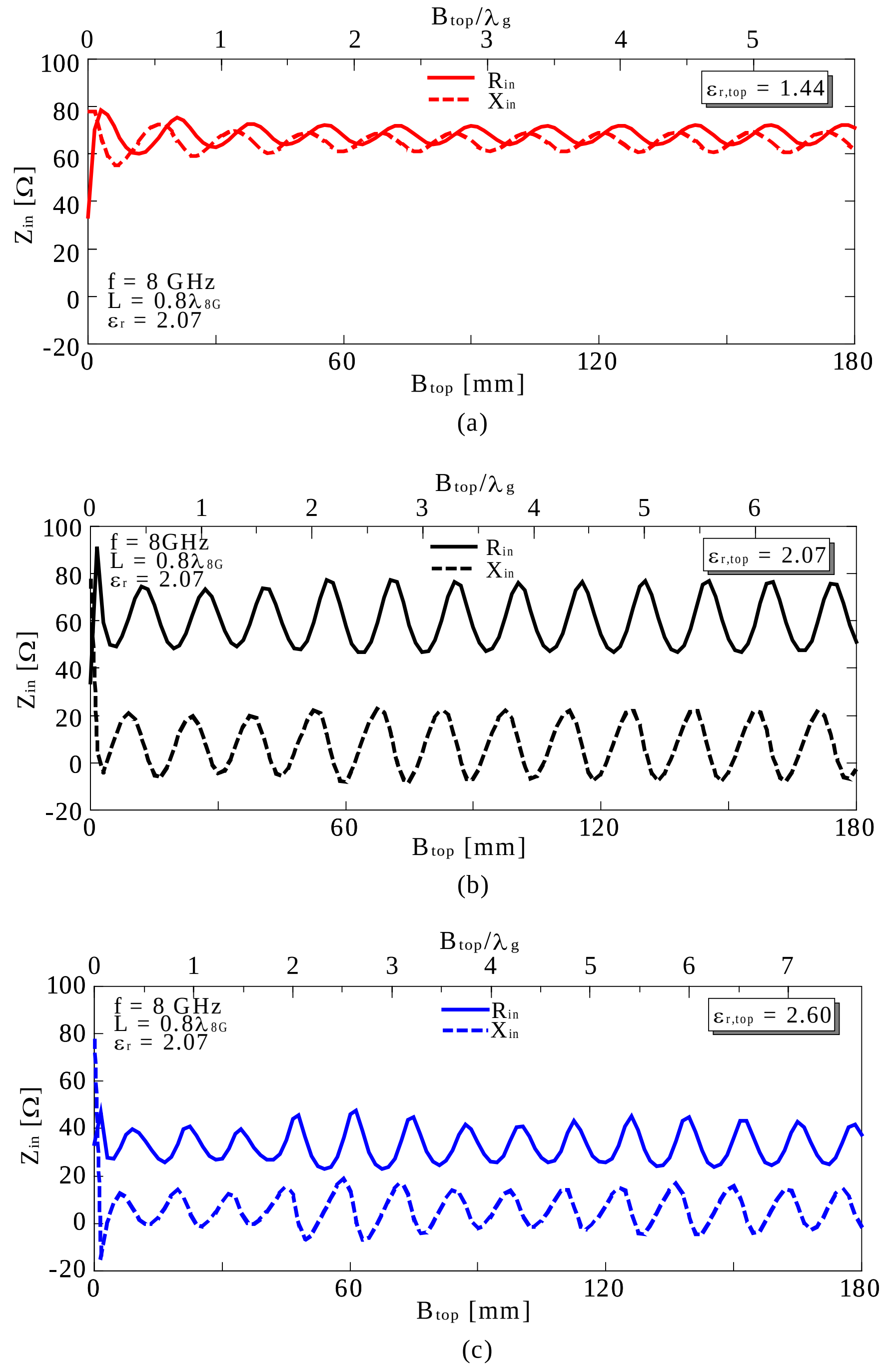

Fig. 3. Input impedance as a function of the top dielectric layer thickness B_{top}.

Fig. 4 shows the gain. It is found that, as the relative permittivity $\varepsilon_{r,top}$ decreases, the thickness B_{top} that gives the maximum gain increases. It is also found that, as the relative permittivity $\varepsilon_{r,top}$ decreases, the value of the maximum gain increases. The gain for $\varepsilon_{r,top}$ = 1.44 is enhanced to 16.1 dB at thickness B_{top} = 168 mm = 5.38λ_g. This gain is 9.3 dB greater than the value for B_{top} = 0 (G = 6.8 dB), with the radiation pattern variation shown in Fig. 5.

4. Conclusions

The effects of the top dielectric layer on the radiation characteristics of a patch antenna sandwiched between two dielectric layers have been investigated. The input impedance as a function of the top dielectric layer thickness shows oscillatory variations, with a period close to one-half of the guided-wavelength of a plane wave propagating in an unbounded dielectric material. It is also found that, as B_{top} increases, the gain increases and reaches a maximum value. The gain for $\varepsilon_{r,top}$ = 1.44 increases to 16.1 dB at thickness $B_{top} = 5.38\lambda_g$ from 6.8 dB at B_{top} = 0.

Acknowledgement

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References

[1] P. H. Huang, J. Yamauchi, and H. Nakano, “A patch antenna sandwiched by dielectric layers”, Proc. 2003 IEICE Communications Society Conference, p. B-1-167, Niigata, Japan, Sept. 2003.
[2] A. Taflove, *Computational electrodynamics*, Artech House, Norwood, MA, 1995.
[3] H. Nakano, M. Ikeda, and J. Yamauchi, “A spiral antenna sandwich by dielectric layers”, IEEE Transactions on Antennas and Propagation, Accepted for publication, 2003.

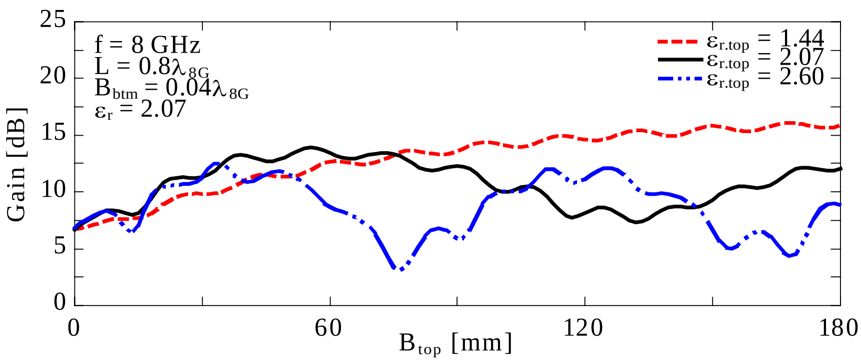

Fig. 4. Gain as a function of the top dielectric layer thickness B_{top}.

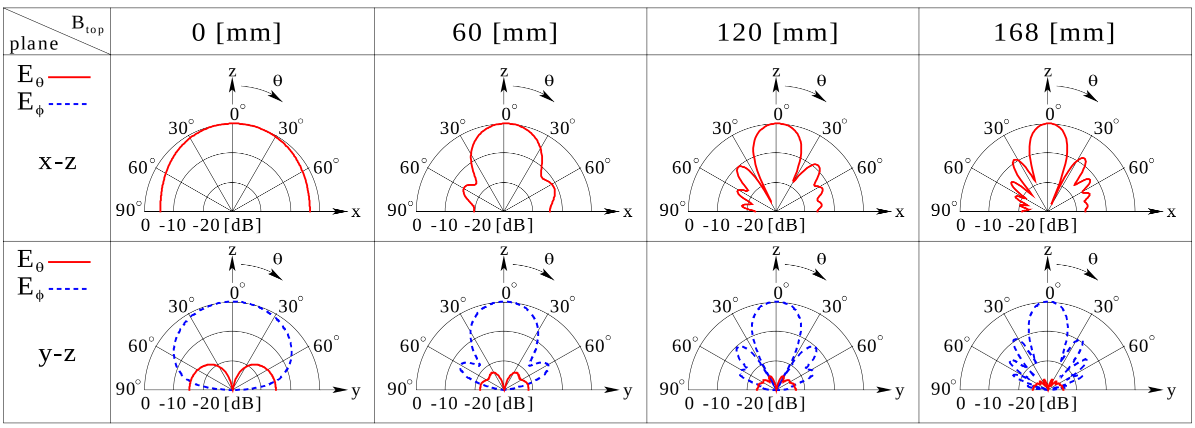

Fig. 5. Radiation pattern for $\varepsilon_{r,top}$ = 1.44 as a function of the top dielectric layer thickness B_{top}.