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High-Gain and Reduced Side-Lobe Levels for a Patch Antenna Operating in the TM_{05}-Mode for Millimeter-Wave Applications at 60GHz in Indoor Environments

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Introduction

Efficient wireless communications require radiated characteristics that overcome attenuation effects. Patch Antennas offer advantages such as low cost, ease of construction and manufacturing and higher-directivity and higher-gain radiation patterns for higher-mode operating TM_{nm} see Fig. 1. Thus, the planar nature of these antennas supports various applications such as aerodynamic and automotive surfaces, integration with printed circuits, among other implementations.

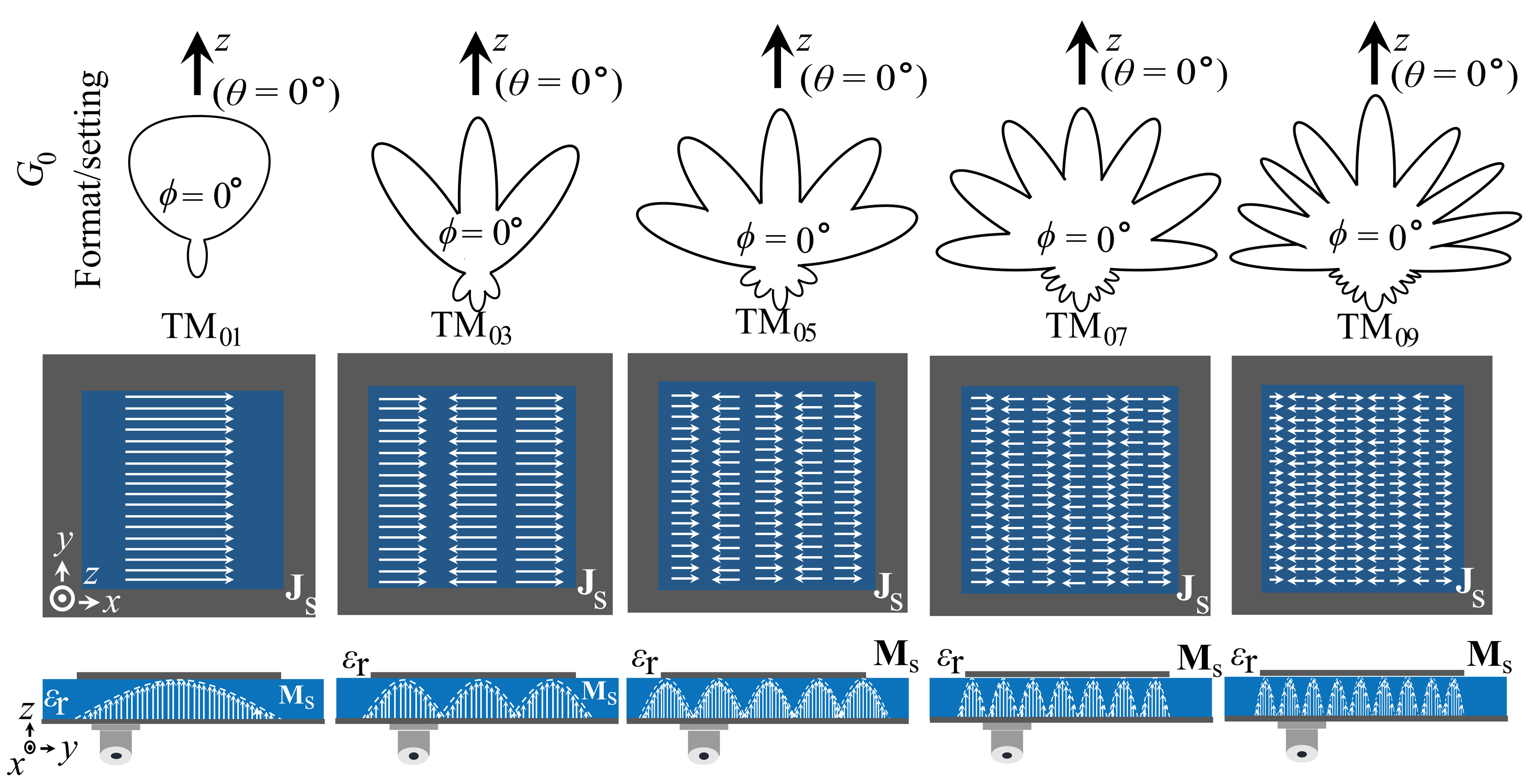

Figure 1: Formatting and setting for radiation pattern in gain G_0 and increasing sidelobes at top-view and distribution current density $\boldsymbol{J}_s$ on patch *xy*- and substrate *zy*-plane at bottom-view, TM_{0m} odd-mode.

Actuality, the migrating bands to new unlicensed spectrum (increasing device frequencies) is a challenging task, especially with the advent of the fifth generation 5G and the beyond-5G (B5G) that extended some applications to millimeter waves (*mmW*, 30—300GHz), currently in the implementation phase in Brazil. The use of mmW at 60GHz allows for the propagation of these waves at short-range ($\sim$ 20 meters) as at this frequency, a significant portion of the radiated energy is absorbed by oxygen molecules $O_{2(g)}$, allowing for increased network security and high data transmission rates such as connections between streams, video calls, high-resolution movies, games with low latency for applications *indoor* communications. This work is a generalization for the TM_{05} mode in mmW of [1], which performed the technique for reducing side lobes in the TM_{03} mode.

Objectives

To reduce side lobe levels (*SLL*) in the TM_{05}-mode, as we can see Fig. 2(b) through a set of combined slots laterally and centrally arranged on the patch resonator plane, it observes at Fig. 2(c).

Materials and methods

A conventional patch antenna with Coplanar Waveguide (CPW) feed was constructed for 12GHz in Rogers substrate $\epsilon_r = 2.2$, height $h = 130\mu m$, $L_p = W_p = 6850\mu m$ and $d_{\text{feed}} = 1700\mu m$.

All simulations were realized at Ansys Electronic 2023, using Finite Elements Method (FEM). Three slots (Fig. 2(c) as shown) were inserted to cancel out the out-of-phase density surface current components $-\boldsymbol{J}_s$ (Fig. 2(d)) on edge of the slot and we can made parametric studies about slot length L_{slot} at the TM_{05} mode to reduce undesired sidelobes.

Results

The results show the behavior for fundamental TM_{01}-mode (Fig. 2 (a)) and TM_{05}-mode with high *SLL* in the *E*-plane at 60.1 GHz (fig. 2 (b)) with 9.1dBi gain for the model without radiating slots.

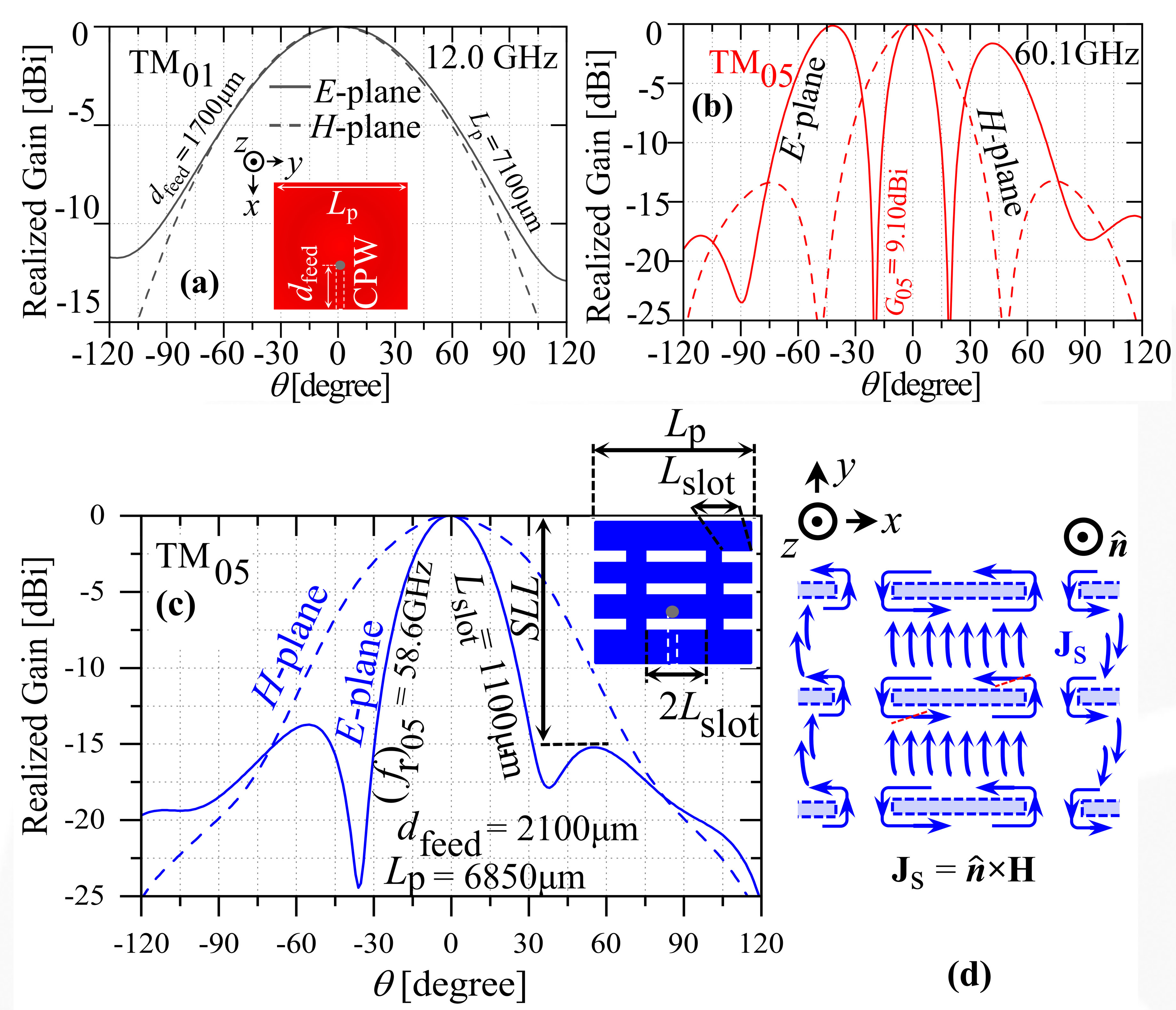

Figure 2: Radiation pattern relating to the normalized realized gain (a) TM_{01} without slots (b) TM_{05} without slots and (c) TM_{05} with slots.

The modifications in the resonator patch across the slots causes a frequency shift at resonance ($\Delta f_r \sim 1.5$ GHz) and a $\downarrow$15dB reduction for *SLL* (increasing the $G_0 \sim 12$dB).

Conclusion

This technique is promising and can be extended to other higher modes; the research aims to rearrange this element for array antenna structure in the objective of higher-gain and directivity.

References

X. Zhang, L. Zhu, and Q.-S. Wu, "Sidelobe-reduced and gain-enhan… antennas with adjustable beamwidth under TM_{03} mode operation," *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 4, pp. 1704–171…

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