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Comparison of the Microwave Performance of Transparent Wire Monopole Antennas Based on Silver Films

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In this paper, transparent printed lines used in microwave radiating structures are studied. Two transparent wire monopole antennas and an opaque reference counterpart are presented, compared, and discussed. The first transparent antenna was fabricated from a transparent conductive AgGL coating (silver grid layer: a silver/titanium bilayer deposited on a glass substrate and meshed by a standard photolithographic wet etching process). It exhibits optical transparency T of $59.2 \pm 0.1\%$ in the visible-light spectrum and sheet resistance $R_\square$ of $0.017 \pm 0.001\ \Omega/\square$. The second transparent antenna was fabricated from a usual transparent conducting multilayer of indium tin oxide/silver/indium tin oxide, also deposited on a glass substrate. It exhibits optical transparency T of $71.3 \pm 0.1\%$ and sheet resistance $R_\square$ of $5.05 \pm 0.05\ \Omega/\square$. Both transparent wire monopole antennas have been characterized for microwave performance and compared with an opaque reference counterpart made from a continuous silver/titanium bilayer deposited on the same glass substrate ($T = 0\%$, $R_\square = 0.0025 \pm 0.0002\ \Omega/\square$). Microwave measurements show similar performance for the transparent AgGL antenna and opaque reference counterpart. At 2.05 GHz, their maximum measured gains are both 4.4 ± 0.3 dBi. Conversely, the transparent indium tin oxide/silver/indium tin oxide antenna presents significant ohmic loss due to its sheet resistance value and consequently a low measured gain value (-2.1 ± 0.3 dBi maximum). This study demonstrates the relevance of the AgGL coating in the fabrication of transparent wire monopole antennas.

Key words: Printed transparent antennas, wire monopole antennas, S-band, meshed metal films, transparent conducting thin films

INTRODUCTION

Previous studies on transparent antennas and see-through antennas were published in the early 1990s.[1,2] However, the number of developments remains fairly low. This situation arises due to the sheet resistance values ($R_\square$) achieved by available transparent conductive materials, which level off at a few ohms/square and lead to negative antenna gains due to ohmic loss; For example, in Refs. 3,4, sheet resistances are equal to $4.5\ \Omega/\square$ and $8\ \Omega/\square$, respectively, and both maximum gains reach values close to -2 dBi.

More recently, research has focused on reduction of the ohmic resistance of such transparent antennas to improve their microwave performance. On the one hand, such reduction can be achieved by improving the conductance of the antenna structure; For example, in Ref. 5, Song et al. propose printing highly conductive narrow strips on the slot edges of transparent antennas, and in Ref. 6, Peter et al. improved the connection performance of transparent polymer antennas by applying a silver

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