See-through Microstrip Antennas and Their Optimization

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Abstract

Patch antennas made from meshed conductors are analyzed in this paper. Although meshed antennas have gained an increased interest in recent publications, we found some important antenna parameters not captured. This paper is intended to present a more complete study on the effect of the mesh geometry. We found that although there is a compromise between the antenna efficiency and see-through percentage, one is able to optimize the antenna by carefully designing the mesh. A refined mesh with thin grid width increases both radiation and the see-through properties.

1. Introduction

See-through antennas are favored in many applications where the antennas are required to be conformal and optically transparent. A typical example is to install see-through antennas on the window of buildings or cars to improve the appearance or hide the antennas.

There are studies reported on optically transparent antennas. One possibility is to use transparent conductors to design patch antennas [1, 2]. Although extremely appealing, transparent conductors are mainly under research in laboratories and not yet largely available in practice. An alternative method is to use meshed conductors [3, 4]. The design philosophy in using meshed conductors to achieve transparent antennas is straightforward as optical signals can transmit through the openings of the mesh, while the conductor is still a valid radiator at microwave frequencies. Also, this alternative see-through choice is cheap and can be easily achieved by printed circuit technology.

Although meshed patch antennas have been studied by several researchers [5-7], we found some important antennas parameters, such as bandwidth and input impedance, have not yet been captured in those studies. Most importantly, there has not yet been a discussion in how to optimize meshed patch antennas. It is the purpose of this paper to deliver a more complete study in antennas parameters as functions of transparency and to provide an insight in designing see-through antennas with optimal radiation and transparency.

The geometry of the meshed patch antenna is as shown in Figure 1. The antenna is probe-fed, and the location of the probe is a distance d from the edge of the patch. The length and width of the patch are L and W respectively, and the grid width (or line width of the mesh) is represented by t. The transparency of the patch is defined by the percentage of see-through area of the patch (or 100% minus the percentage of the metal area) such as

$$P_{tran} = \frac{A_{patch} - A_{metal}}{A_{patch}} 100\% = 100\% - metal\% .$$

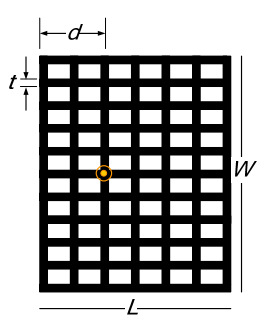

Figure 1. Geometry of a Meshed Patch

In the following study, the patch antennas with W = 49.4 mm and L = 41.3 mm are built with a meshed patch over a solid ground plane, and the dielectric constant of the substrate between the patch and the ground plane is 2.2. The thickness of the substrate is 1.588 mm. It should be noted that we only study the radiation from the fundamental mode in this paper, and the simulations are carried out with Ansoft's HFSS.

2. Antenna properties and transparency

To compare meshed antennas with different transparencies, we fix the dimension (L and W) of the patch while varying the transparency. One important mesh parameter that has to be fixed in this stage is t, which has not yet been studied in literature. We also compare the properties of meshed patches with the solid patch of the same dimension.

We examined the resonant frequency, gain, bandwidth, efficiency, and input impedance of the meshed patch antenna for various transparency represented with percentage, and the results are plotted in Figure 2 through Figure 6. The percentage bandwidth is calculated by setting VSWR<2. The input impedance is studied by examining the location of the probe, the distance d in Figure 1. In order to find the location of the feeding probe, we started with an initial guess by using the inset values for a solid patch [8]. We then move the probe until we have S11 value at the input port of the antenna below -20 dB. MATLAB is used to call HFSS in this iterative process to locate the probe position.

As Clasen et. el. reported on the antenna gain and resonant frequency [6], we found that as the transparency of the patch is increased, we have reduced resonant frequency, gain, bandwidth and antenna efficiency. The location of the probe d is found to be increased as the transparency increased. This implies higher input impedance [8] for higher transparency, and increases the challenge for impedance matching. When the transparency is reduced, all these antenna parameters approach an upper bound, which is the same radiation parameter due to a solid patch antenna of the same dimension.

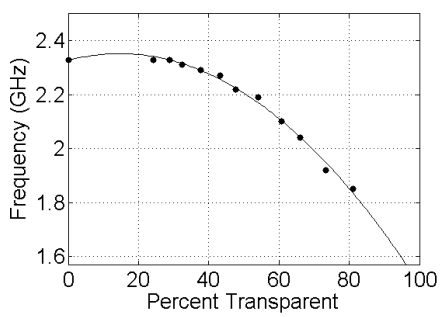

Figure 2. Mesh transparency and the resonant frequency

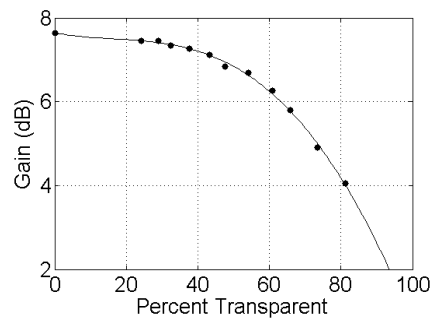

Figure 3. Effect of the transparency on the gain

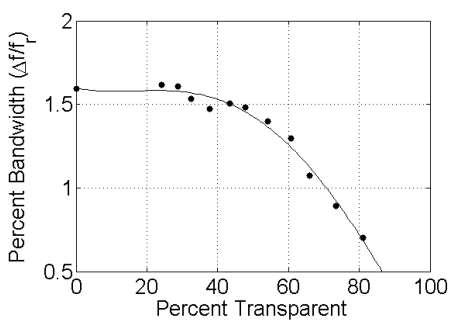

Figure 4. Effect of the transparency on the bandwidth

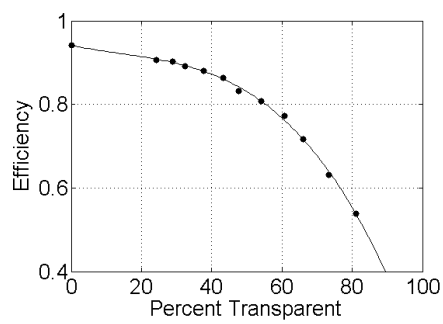

Figure 5. Effect of the transparency on antenna efficiency

All these results suggest a compromise in patch transparency and antenna properties and limited possibility of using meshed patch antennas as see-through antennas. However, when examining the grid width, we found very exiting results that will allow us to optimize the antenna design.

3. Effect of the grid width

In an experiment to verify simulation against measurement, we fabricated two meshed patch antennas with two different electroformed meshes. The measurements indicate although the two meshes have different transparency, their radiation properties (resonant frequencies and bandwidth) are very close. The result is different from the previous studies, and motivated us to exam the effect of the grid width on the antenna properties.

In the following study, the transparency of the patch is fixed at 60%, and the width of the grid is varied from 0.66 mm to 2.27 mm. The dimension of the patch is kept the same as the study in Figure 2 through Figure 6. Plotted in Figure 7 to Figure 11 are antenna properties for varied grid width. It is found that antenna gain, efficiency, resonant frequency and bandwidth increase as the grid line becomes thinner. From the location of the probe, it is seen that the input impedance of the antenna decreases as the mesh is made finer. Therefore, for a meshed patch antenna with a fixed transparency, refining the meshes to have thinner grid width improves antenna parameters. This result is very important because it suggests the possibility of optimizing antenna properties and transparency at the same time.

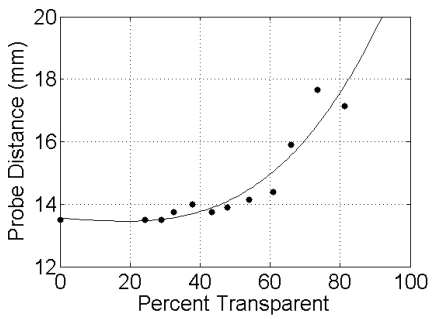

Figure 6. Effect of the transparency on the probe location

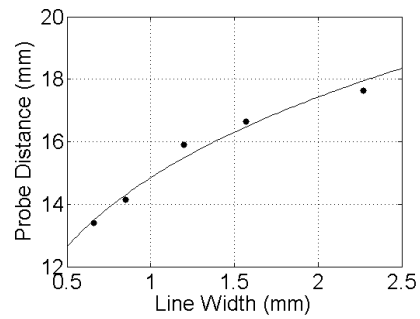

Figure 7. Effect of the grid width on the probe location

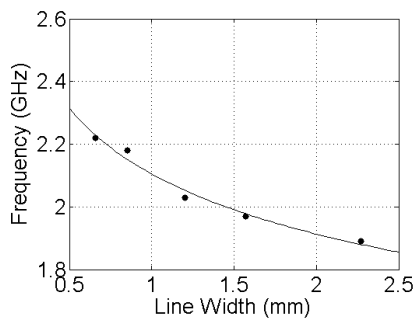

Figure 8. Effect of the grid width on the resonant frequency

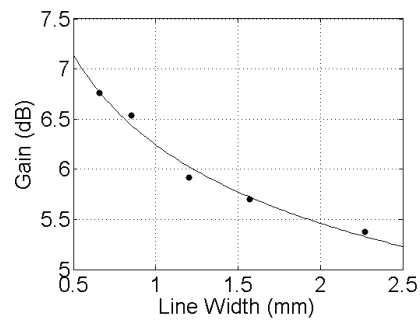

Figure 9. Effect of the grid width on the gain

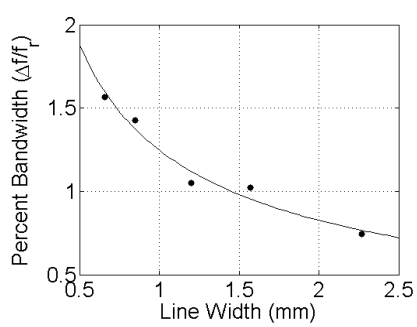

Figure 10. Effect of the grid width on the bandwidth

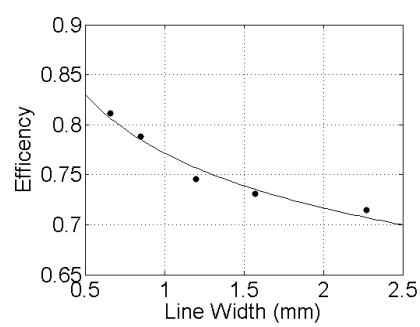

Figure 11. Effect of the grid width on antenna efficiency

4. Discussion

The study has examined the radiation properties of see-through antennas made from meshed conductors. When the grid width of the mesh is fixed, we found higher percentage of the metal results in better antenna properties. This means in order to have an effective radiator, see-through percentage of the patch has to be reduced. When the transparency (or the metal percentage) of the mesh is fixed, we found that antenna properties are improved by reducing the width of the individual grid. This discovery is promising because it suggests an optimization of both antenna properties and transparency by carefully designing the mesh geometry. For example, a solid patch antenna with the same dimension gives 7.7 dB gain (Figure 3), and a meshed patch with 60% transparency has a gain of 6.3 dB. From Figure 8, we can find this 6.3 dB gain is for a mesh with grid width of 1mm. If we keep the transparency at 60% and refine the mesh such as it has the grid width of 0.5 mm (this can be done by increasing the number of the grids while reducing the width), then the gain can be increased to about 7.1 dB.

Although the effect of the grid width is presented by having 60% transparency as an example, we found the same effect for other transparency. Optimizing antenna properties by refining the grids for higher transparency is especially favored due to the increased interest in effective see-through antennas.

In conclusion, we examined the effect of the mesh geometry on the see-through antenna properties and found an appropriate method to design optimal antennas. It is clear that one can increase the transparency and antenna radiation by designing the grid, and one can easily use an optimization method such as the genetic algorithm (GA) to achieve the optimal mesh geometry to satisfy requirements for both see-through and radiation properties.

5. References

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