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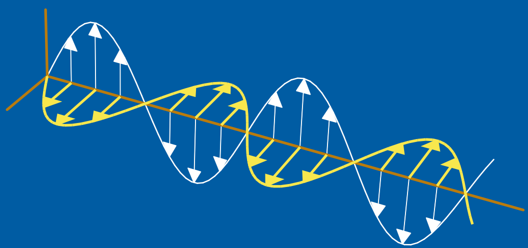

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Abstract

In order to reduce the monostatic signature of the junction between a radome and the metallic structure to which it is attached, a tapered resistive sheet can be used. In this paper, we describe an easy method to realize this tapering using geometric variations on a subwavelength scale, with a significant reduction of the number of processing steps as a result.

1 Introduction

Aircrafts need antennas to communicate or to scan the surroundings using radar. These antennas need to be shielded from wear and tear by a radome. To minimize the radar cross section of the aircraft, the radome can be made to be frequency selective by employing periodic structures within the radome wall. Ideally, this makes the radome completely transparent for frequencies in the pass band, and behave like a metal surface for other frequencies. The design of such surfaces is well documented in many journal papers and text books, and we refer to [5, 6] and references therein for more detailed information.

Even if the radome itself is well designed in the respect that it has high transparency in the pass band and high reflectance elsewhere, there is usually quite a lot of scattering generated by the interface between the radome and the hull of the aircraft, due to the different surface properties. This is particularly troublesome in the pass band. Since frequency selective radomes are usually based on a resonant periodic structure, the reflection coefficient from the radome surface can be located just about anywhere in the Smith chart. The hull of the aircraft on the other hand, is usually made of metal and has a well defined reflection coefficient of -1 for a very large range of frequencies.

In order to match these different reflection coefficients to each other, it is necessary to introduce a matching region between the radome and the hull. One solution to this is to introduce a tapered resistive sheet, as is described in [1, 3, 4, 7, 8]. The tapered sheet starts off as a metal surface close to the hull, and transforms gradually to free space properties as the matching region extends over the radome. The typical design requires the tapering to occur over one or several wavelengths; the smoother the tapering, the broader the bandwidth.

2 Implementation by conductivity and thickness

A straightforward realization of the tapered resistive sheet is given by the following strategy. The equivalent resistance for a thin sheet with conductivity σ and thickness d is $R = 1/(\sigma d)$. When backed by free space, such a sheet has the reflection coefficient [9]

$$\Gamma = \frac{-\eta}{2R+\eta} = \frac{-\eta}{2/(\sigma d)+\eta} = \frac{-\eta\sigma d/2}{1+\eta\sigma d/2}$$

where $\eta = 377\,\Omega$ is the wave impedance of free space. From this formula, it is seen that the reflection coefficient Γ can be controlled by two parameters, the conduc-

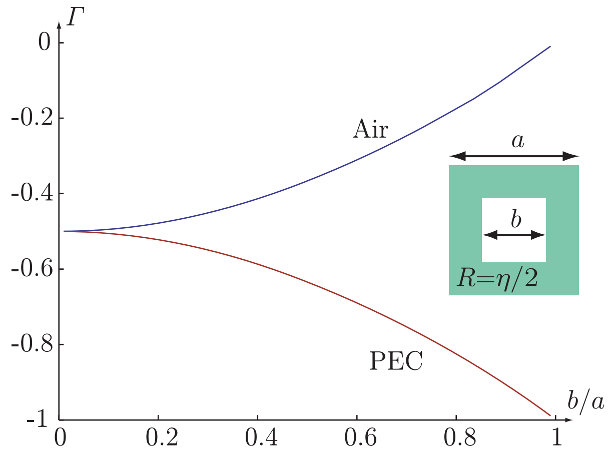

Figure 1: Reflection coefficient of the periodic air and PEC patches in a resistive sheet, respectively.

tivity σ and the thickness of the layer d. In order to create a good matching layer, at least 5–10, preferably more, different regions must be realized with a linear taper in the reflection coefficient $\varGamma$, as described in [1].

The problem is that this may call for many different orders of magnitude of either thickness d or conductivity σ, requiring many processing steps in the manufacture. As an example, the continuous tapering realized in Figure 3 ranges from $R = 0.19\,\Omega$ to $R = 11\,\mathrm{k}\Omega$, a difference in 5 orders of magnitude. This increases the complexity of the manufacturing, and increases the cost.

3 Implementation by geometry

Instead of changing the obvious parameters σ and d to change the effective resistance of the sheet, we propose to use heterogeneities in the sheet in order to realize a sufficiently variable reflection coefficient of the sheet. This drastically reduces the number of processing steps needed.

We consider a resistive tapering that only requires a single resistive sheet of given thickness and conductivity. The resistance per square of the resistive sheet is reduced by adding isolated metal patches in it, and is increased by making holes in it. The patches and holes can be of arbitrary shape, e.g., squares and rectangles. A symmetric patch/hole gives an isotropic resistivity whereas an asymmetric patch/hole can be used to realize an anisotropic resistivity.

The reflection coefficient of a periodic structure utilizing square patches and holes in a resistive sheet with intrinsic resistance per square $R = 1/(\sigma d) = \eta/2$ is shown in Figure 1. It is seen that this geometry offers every reflection coefficient between 0 and -1 and hence it is simple to design any desired tapering, *e.g.*, a linear resistive tapering, see Figure 2.

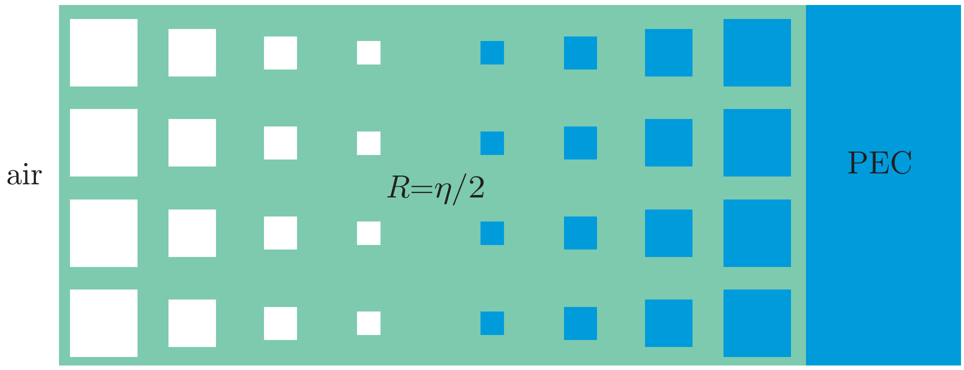

Figure 2: Illustration of a resistive tapering from air to PEC.

4 Results

To evaluate the proposed realization of a tapered resistive sheet, the following test was performed. A frequency selective pass band radome with three dielectric layers and two metal surfaces with a periodic square slot structure was implemented in FDTD, using the PB-FDTD program described in [2]. The radome structure is infinite in the x-direction, and finite in the y-direction, z being the normal direction to the radome. The geometry is depicted in Figure 3. At each end of the radome in the y-direction, an infinite metallic ground plane was attached. The tapered resistive sheet, extending 1 dm from the metal surrounding onto the radome structure (about three wavelengths on the center frequency 10 GHz), was realized both as a continuous tapered sheet (down to the precision of the FDTD discretization) by varying the conductivity as described in Section 2, and as a geometric tapering with fixed conductivity as described in Section 3. Since the radome structure supports a surface wave for the TM polarization at an angle of incidence of about 60 degrees, some bulk losses (loss tangent 0.14 at 10 GHz) were introduced in the core dielectric layer below the tapered resistive sheet as well. This additional loading absorbs the surface wave, which reduces the signature of the radome for TM polarization and improves on the design in [1].

The results of the full wave simulations are shown in Figure 4. The discrete geometric tapering is compared with simulated results for a continuous tapering (varying the conductivity σ and keeping the thickness d constant), and it is seen that the results are very similar. In Figure 5, the backscattered field is plotted as a function of frequency, to demonstrate the broad band properties of the realization.

5 Discussion and conclusions

The proposed method drastically reduces the number of processing steps needed to realize a tapered resistive sheet, compared to solutions where the thickness or conductivity of the sheet is changed. The sheet can be processed in only two steps: first etching out the metal patches from a standard substrate, and then screen

(a) Different simulation cases (b) Edge geometry

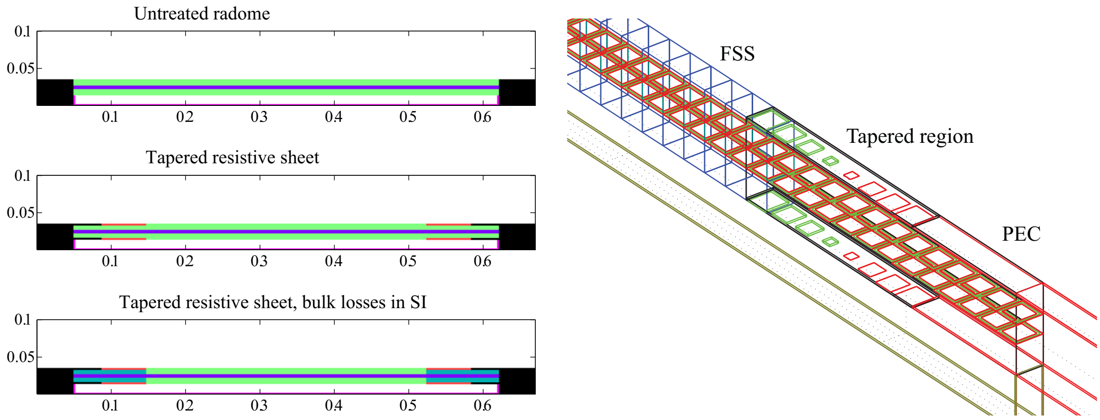

Figure 3: Geometry of the simulation cases. The frequency selective radome is mounted in a metal surrounding (black regions), and three different cases are simulated. The top case corresponds to no edge treatment, the middle to using only a tapered resistive sheet, and the bottom uses both a tapered resistive sheet and additional loading in the dielectric underneath the sheet. To the right is a blow-up of the edge region when the tapered resistive sheet is realized as described in Section 3.

printing the resistive sheet with corresponding holes. Since the precision of making patterns in metal or resistive sheets is very high, at least compared to wavelength in radar bands, the proposed method also significantly increases the precision of the design. In order to improve the design using tapered resistive sheets in [1] for TM polarization, we have also added small bulk losses in the dielectric below the tapered resistive sheet.

6 Acknowledgements

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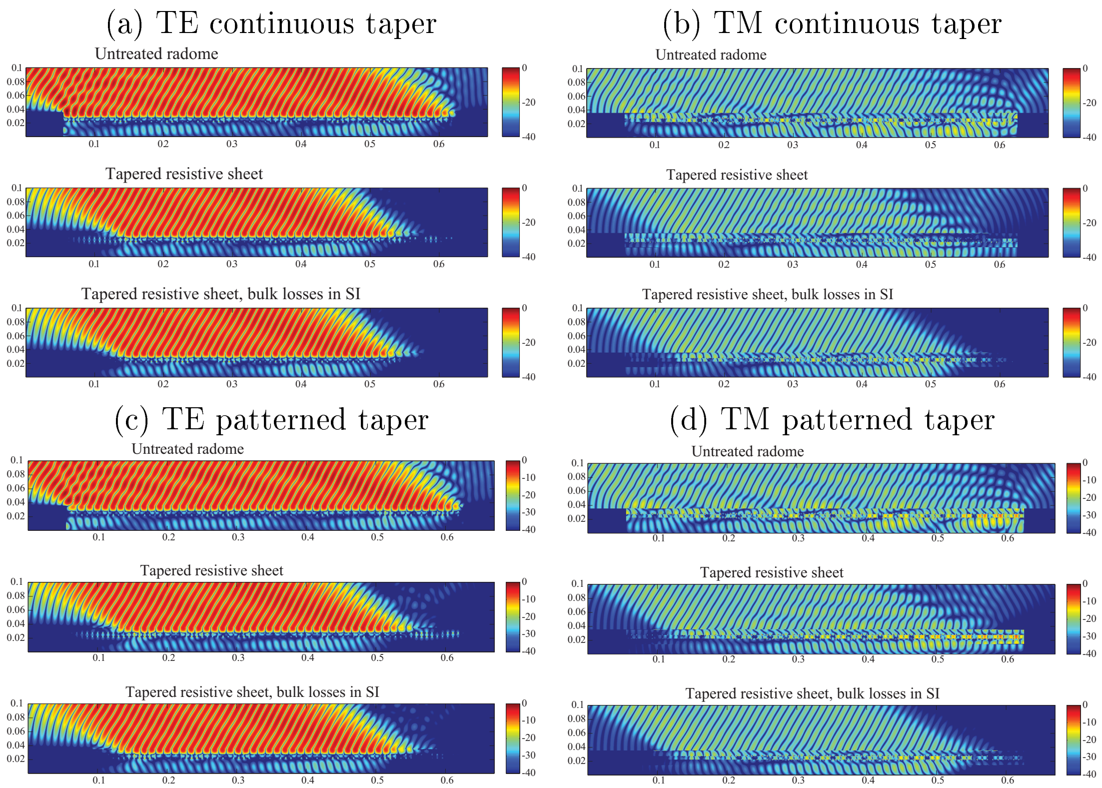

Figure 4: Results of the full wave simulation. A plane wave is obliquely incident from the right, and the scattered field is plotted in dB scale. In the top row, a continuous tapered resistive sheet has been used, realized by varying the conductivity as described in Section 2. In the bottom row, the tapering is realized by the procedure described in Section 3 and Figure 2. The frequency is chosen so that the periodic structure in the radome supports a surface wave for TM polarization, contributing to strong scattering if the edges are not properly treated. This scattering is visible in the simulation case where only a resistive sheet is used, and absent in the case when additional bulk losses at the edges are introduced. This corresponds to the narrow peaks around 16GHz for TM polarization in Figure 5.

(a) TE polarization (b) TM polarization

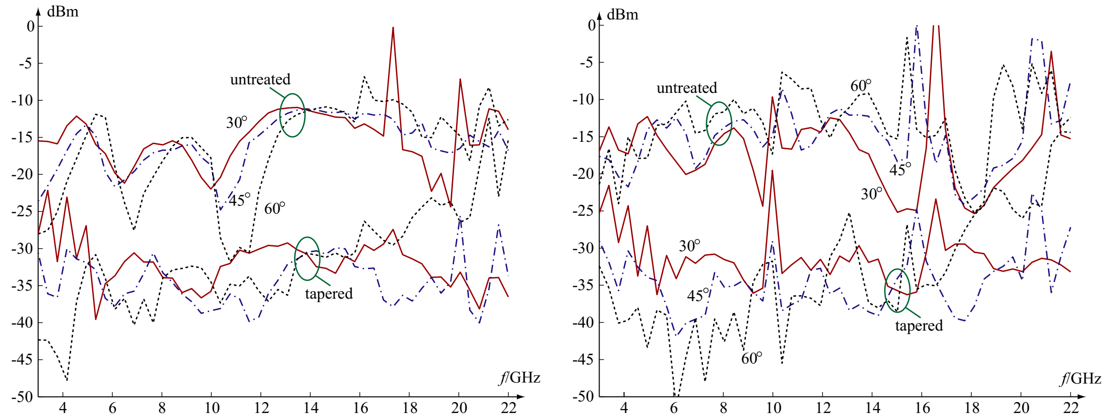

Figure 5: The monostatic RCS from the full wave simulation in Figure 4. The results are given for three angles of incidence: 30° (solid), 45° (dot-dashed), and 60° (dashed). The curves around −15 dBm are for the untreated radome edge, whereas the ones around −35 dBm are for the tapered resistive sheet and bulk losses in the radome at the edges. It is seen that the edge treatment significantly reduces the monostatic RCS.

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