Electrical properties of triaxially woven fabrics for reflector antennas

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Introduction.

The new light-weight reflector antenna technology being used by several spacecraft companies requires accurate electromagnetic modelling of the reflector surface properties. In particular, the new tri-axially woven carbon fibre skins are of interest.

In a recent study for ESA a new computer program has been developed in a co-operation between TICRA and Politecnico di Torino. The name of the program is MESTIS(1), METallic STrIps Simulator, and by means of this it is possible to model one or more layers of strip grids and each layer can consist of up to three strip grids making arbitrary angles with each other. In this way it is possible to model the new triangular weave materials.

In the following sections the electrical properties of the triangular weave will be illustrated as a function of some simple geometrical parameters of the material. The performance for a reflector antenna with a typical, triangular weave surface is calculated and the consequences are identified.

Mechanical and electrical modelling of the triangular weave material

The geometrical structure of the triangular weave is illustrated in Figure 1. Three sets of parallel carbon fibre grids are tilted 120° with respect to each other. One notices that each set of wires passes alternately above and below the wires of the other sets.

The material in Figure 1 can easily be bent over a dual curved surface with only a minor deformation of the mesh pattern. Once the wires are glued together a very light-weight but yet form-stable reflector shell is obtained.

To arrive at the electrical model it is assumed that all the wires are lying in the same plane and that they are in electrical contact at all intersection points. It is further assumed that the wires in each set can be approximated by conducting strips of the width w and the spacing s. With these assumptions the triax model shown in Figure 1 can be considered as three co-planar strip grids completely described by the two parameters, s/λ and w/λ, where λ is the wavelength.

The reflection and transmission properties of the structure in Figure 1 can be analysed by MESTIS. It is possible to take into account the finite conductivity of the strip grid material and also dielectric layers on both sides of the strip grid can be considered. In order to make the present investigation simple it is assumed in the following that the strip material is a perfect conductor and no dielectrics are present. The structure in Figure 2 can therefore be completely described by the two parameters, s/λ and w/λ, where λ is the wavelength.

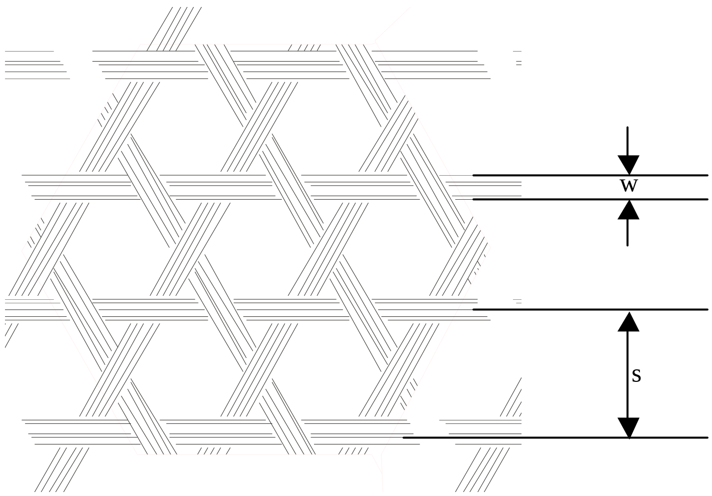

Figure1 The triangular mesh with the interleaved sets of carbon fibres

Reflection properties of the triangular weave

The reflection properties of a planar sample of a general reflector material may be characterised by the reflection matrix

$$\begin{Bmatrix} R_{\theta\theta} & R_{\phi\theta} \\ R_{\theta\phi} & R_{\phi\phi} \end{Bmatrix}$$

where the coefficients $R_{\theta\theta}$ and $R_{\phi\phi}$ represent the coupling from the incident to the reflected θ- and ϕ-components, respectively. These components are also referred to as R_{TMTM} and R_{TETE}, respectively. The off-diagonal elements in the reflection matrix represent the depolarisation effects of the material.

Typical values for the triangular grid in Figure 1 can be $s/\lambda = 1/20$ and $w/s = 1/10$. The MESTIS software has been used to calculate the four reflection coefficients for these values and for the incidence angles $0° \le \theta \le 60°$ and $0° \le \phi \le 360°$. The results for $R_{\theta\theta}$ and $R_{\phi\phi}$ are presented by the plots in Figure 2. The results for the off-diagonal elements are not shown because they are very small, more than 80 dB down.

Two important characteristics are readily identified from Figure 2. The triangular grid in Figure 1 is very regular with symmetry planes every 30º in ϕ.

This will limit the possible variation in ϕ and the results in Figure 2 show that in practice the reflection coefficients are constant in ϕ. This is a very useful conclusion since it means that it is only necessary to investigate the variation with θ.

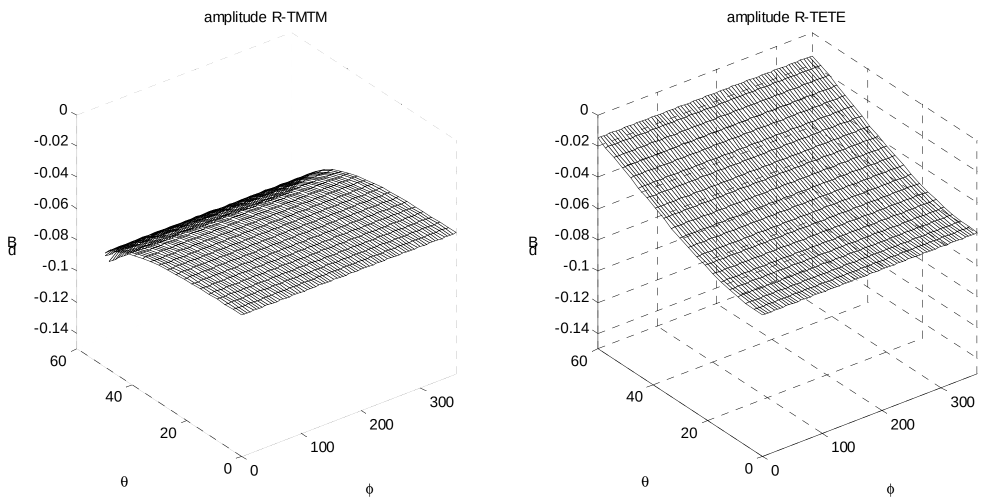

Figure 2 *The reflection coefficients $R_{\theta\theta}$ (left) and $R_{\phi\phi}$ (right) versus the angle of incidence (θ,ϕ)*

The other observation from Figure 2 is that $R_{\theta\theta}$ decreases with increasing θ whereas $R_{\phi\phi}$ increases. This can have an effect in circular polarisation for offset reflector antennas, as will be demonstrated in the next section.

Application example

In this section we will illustrate the influence of the triax material for a single offset reflector antenna. The diameter is $D = 50\lambda$ and the focal length is $f = D$. The feed is located at the focus and it is a simple Gaussian beam operating in circular polarisation. The antenna is illustrated in Figure 3.

Figure 4 shows the radiation pattern in the plane of asymmetry both for a solid reflector and for a reflector constructed as a triangular weave with the typical parameters, $s/\lambda = 1/20$ and $w/s = 1/10$. For the solid reflector the co-polar component exhibits the typical beam squint in circular polarisation and the cross-polar lobes are very low, about 60 dB below the co-polar beam peak.

For the triax weave the co-polar component in Figure 4 is indistinguishable from the solid reflector (although there is a transmission loss of 0.06 dB). However, the difference between $R_{\theta\theta}$ and $R_{\phi\phi}$ generates a cross-polar component with the same shape as the co-polar beam and the maximum cross-polar lobe is now only about 45 dB below the co-polar peak. This result shows that with a slightly larger s/λ the cross-polar performance could soon become critical.

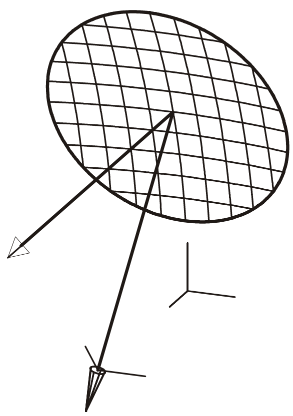

Figure 3 Offset reflector antenna

Conclusions

This paper demonstrates that the reflection coefficients for the triax mesh are almost independent of the azimuthal variation of the angle of incidence but they do depend on the angle from normal incidence. It is demonstrated by an example how this can affect the cross polarisation performance for an offset reflector system operating in circular polarisation.

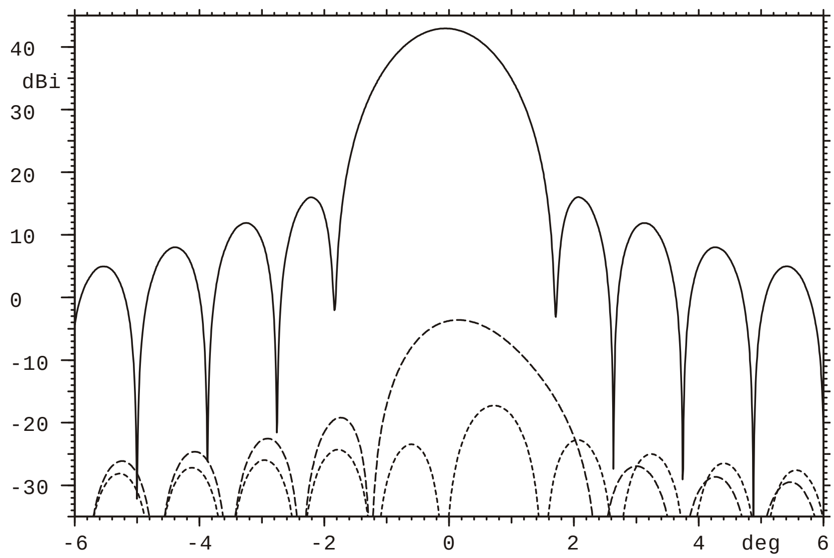

Figure 4 The radiation pattern in the plane of asymmetry for the antenna in Figure 3. The full line curve shows the co-polarisation for both the solid reflector and the triangular weave. The curves with short and long dashes are the cross polarisation for the solid reflector and the triangular weave, respectively.

References.

[1] R. Orta, R. Tascone, and D.Trinchero, "USER MANUAL, Metallic Strip Simulator", Dipartimento di Elettronica and IRITI-CNR, Politecnico di Torino, October 2001.