Characterization of Ka-band Mesh Surfaces for CubeSat Reflector Antennas: From Simple Wire Grid Model to Complex Knits

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***Abstract*—This work analyzes mesh surfaces at Ka-band for its potential use in CubeSat reflector antennas. The simple wire grid model is used as the starting point, since it has already been analyzed in closed form by Astrakhan. However, this analytical solution, by itself, cannot accurately characterize complex mesh surfaces or the nature of joint between the wires. Thus, full wave simulations must be used to study mesh surfaces in depth. A full wave simulation of the wire grid model is first carried out and the results are validated with the Astrakhan formulation. The excellent agreement between the two encouraged us to characterize and parametrically evaluate realistic mesh structures with complex knit patterns.**

I. INTRODUCTION

Mesh reflectors have been used for a variety of space applications due to its compactness, ease of deployment and high gain, as described in a recent review paper [1]. These features also make it a suitable candidate for CubeSat technology, which has the potential to be a cost effective means for remote sensing applications and deep space explorations. Ka-band has been considered for both scientific and communication applications [2]. At such high frequencies, an accurate characterization of the transmission loss due to the mesh surface is critical. The analysis of simple strip-aperture models and complex mesh surfaces was done in [3] and [4] respectively using strip-wire equivalence and MoM. This was extended in [5] which combined MoM with PO to analyze curved mesh reflectors. However, full wave simulations of wire grid model and its validation with Astrakhan formulation [3], [6], [7] have not been reported in the literature to the best of our knowledge. This paper analyzes the simple wire grid model in detail to study the dependencies of the mesh performance on various parameters such as wire diameter, size of mesh openings, angle of incidence, polarization and nature of contact. This is followed by simulating a representative complex knit pattern that is typically utilized to construct mesh reflectors, as shown in Fig. 1.

II. SIMPLE WIRE GRID MODEL

Periodic boundary conditions along with Floquet port excitations make it possible to perform a full wave simulation of the wire grid model in HFSS. The periodic cell is shown in Fig. 2. A common parameter to describe mesh surfaces is the number of Openings per Inch (OPI). The results for the full wave simulations are compared with the Astrakhan formulations for the following cases: 1. Different OPI with same wire diameter and angle of incidence (Fig. 3). 2. Different wire diameters with same OPI and angle of incidence (Table I). For each of these cases, the gain loss for the surface is compared, which is defined as:

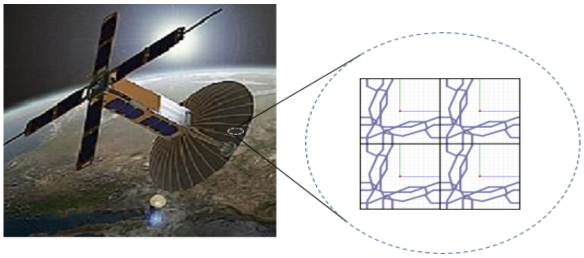


Fig. 1. A representative complex knit pattern [4] for mesh reflectors for future CubeSat applications [8].

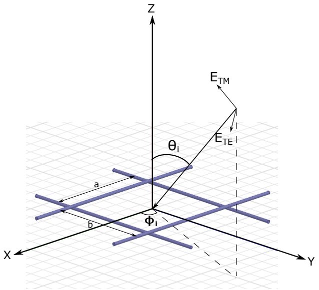


Fig. 2. A periodic cell simulated in HFSS. The quantities a and b are measured from the center of one wire to the other. E_{TE} , E_{TM} denote the direction of electric field vector for TE and TM polarization respectively for a plane wave incident at an angle θ_i and ϕ_i.

$$\Delta G = 10\log_{10}(1-|T|^2) \tag{1}$$

where T denotes the transmission coefficient. With NASA focusing on the frequency of 35.75 GHz for the deployment of future CubeSats for remote sensing applications, the same frequency is chosen for all simulations to follow. The wires are assumed to be PEC and the OPI is defined based on the distance between the centers of the two wires. In these simulations, the wires are made to intersect each other at the

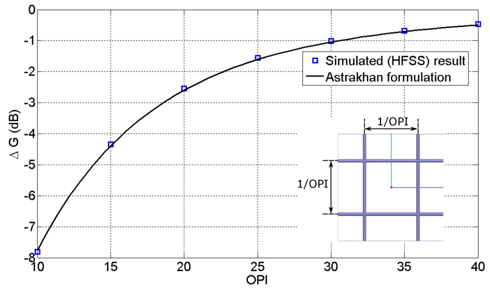


Fig. 3. Comparison between HFSS and Astrakhan formulation for a wire diameter of 0.0008” for various OPI and normal incidence ($\theta_i = \phi_i = 0°$) at 35.75 GHz.

TABLE I
COMPARISON BETWEEN HFSS AND ASTRAKHAN FORMULATIONS FOR VARIOUS DIAMETERS FOR NORMAL INCIDENCE ($\theta_i = \phi_i = 0°$) AND 40 OPI AT 35.75 GHZ.

Diameter	ΔG (dB)	
	HFSS	Astrakhan
0.0008”	-0.47	-0.49
0.0016”	-0.24	-0.25
0.002”	-0.17	-0.19
0.004”	-0.05	-0.05

junctions. Such a contact can be defined as a ‘hard contact’ and would physically imply soldering the junctions of the mesh. However, in practice, the mesh is composed of interwoven strands of wires that are held together by tension in the wires. Thus, the wires just touch each other at the junctions. This form of contact can be defined as ‘soft contact’. It is seen from Fig. 4 that the difference in the performance of the two joints is negligible. This implies that the performance of the mesh surface is not affected significantly as long as the wires have some form of contact.

III. COMPLEX MESH MODELING

Based on the excellent agreement between Astrakhan’s results and full wave simulations, it is now possible to look into characterizing the mesh structures that are used to build the surface of mesh reflectors. The diagram of a tricot knit mesh is shown in Fig. 5a. This structure was analyzed in [4] using strip-wire equivalence. Here, we perform a full wave simulation of the structure using wires of diameter 0.0008” at 35.75 GHz. Table II compares the performance of this complex mesh with two wire grid models: one that has the same wire diameter as the ones used to make complex mesh and the other that has an equivalent diameter, which is more representative of the complex mesh. The equivalent diameter can be estimated using strip-wire equivalence, as shown in Fig. 5b and Fig. 5c. A hard contact is assumed for all simulations. A reasonably good match is seen between the gain loss of the complex mesh and that of the equivalent wire grid model.

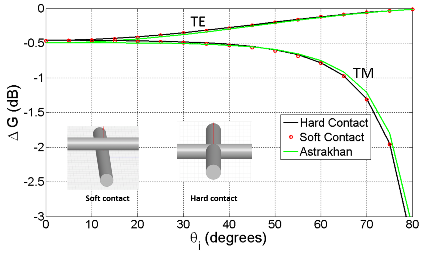
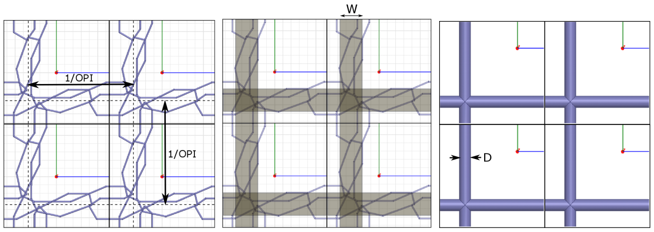


Fig. 4. Comparison of different forms of contact with the Astrakhan formulation for 40 OPI at 35.75 GHz. The plane of incidence is $\phi_i = 45°$.



(a) (b) (c)

Fig. 5. A representative complex tricot knit pattern utilized to construct mesh reflectors [4] (a) Mesh structure (b) Equivalent strip model with strip width W, scaled according to the OPI (c) Equivalent wire grid model of wire diameter D=W/2.

TABLE II
COMPARISON BETWEEN TRICOT KNIT MESH AND SIMPLE WIRE GRID MODELS FOR NORMAL INCIDENCE ($\theta_i = \phi_i = 0°$) AT 35.75 GHZ. THE PARAMETERS D, W AND OPI ARE AS DEFINED IN FIG. 5.

OPI	ΔG (dB)		
	Tricot Knit Mesh	Wire Grid Model	
		D=0.0008”	D=W/2
20	-0.56	-2.53	-0.42
30	-0.19	-1.01	-0.19
40	-0.09	-0.47	-0.10

IV. CONCLUSION

The results of the full wave simulation are successfully validated with Astrakhan’s formulation for the simple wire grid model. The capabilities of full wave simulators to analyze different joints and complex mesh structures were used to gain a deeper insight into the performance of these mesh surfaces when used to make reflectors.

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