Improvements in Insertion of Auxiliary Parity Segments in WIPL-D All-Quad Meshing Algorithm

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Abstract **— This paper provides a new technique that improves the all-quad meshing algorithm implemented in the WIPL-D software. The technique allows for the insertion of required auxiliary segments to achieve parity of a number of segments over all closed loops of all faces. The aim of the improvement is to reduce the total number of mesh elements in the final mesh. The efficiency of the proposed technique is compared to the traditional one mentioned earlier. A reduction in the number of mesh elements of about 15% has been achieved when applied to a log-periodic antenna WIPL-D model.**

Keywords **— All-quad mesh, fully connected mesh, parity of closed loops, WIPL-D.**

I. INTRODUCTION

In most cases, a CEM simulation starts with meshing of an appropriate CAD model. From the perspective of this paper, emphasis is placed on MoM SIE numerical engines that typically implement triangular or quadrilateral mesh elements. It is shown in [1] that the use of a quadrilateral mesh results in a more efficient analysis. According to [2], using higher order basis functions (HOBFs), rather than low-order ones, brings an additional effectiveness to the method since it reduces memory requirements and increases simulation speed even further [3].

A quadrilateral meshing algorithm, optimized for HOBFs and based on reducing the meshing of an arbitrary shaped surface to the meshing of a flat polygon, is presented in [4]. A problem occurring with the mesh described in [4] is how to minimize the number of auxiliary segments to be added to the polyline representation of the edges, in order to achieve parity of the total number of segments over the closed loops of the faces. The requirement to achieve a fully connected mesh implies that the addition of auxiliary segments on an edge cannot be performed independently from the meshing of its adjacent faces. A technique to eliminate redundant auxiliary parity segments is suggested in [4]. In this paper, an improvement to the meshing technique that enables further reduction of the number of auxiliary parity segments, and consequently, a reduction of the total number of mesh elements in the final mesh, is described.

The quadrilateral meshing algorithm implemented in WIPL-D is briefly described in Section II. Improvement to the technique of insertion of parity segments over closed loops is described in Section III. Finally, a comparison between the technique described in [4] and the new technique is provided in Section IV.

II. DESCRIPTION OF MESHING ALGORITHM

The specific all-quad meshing algorithm of interest is described in detail in [4]. Only the basics will be repeated here. The algorithm is composed of 5 steps:

1. Division of all faces into sub-faces. At the completion of this procedure, the angle between the normal vectors of any two points of a sub-face is smaller than or equal to the predefined surface angle tolerance.
2. Polyline representation of edges. The edges of sub-faces, created in Step 1 are divided into polylines according to the predefined mesh size and the edge angle tolerance. The lengths of all the segments within these polylines are less than or equal to the maximum mesh size. The outer angle between adjacent segments is less than or equal to the predefined edge angle tolerance.
3. Face projecting on a plane. All polyline nodes created in Step 2 are projected to a plane that uniquely corresponds to the face. In this way, a face is mapped into a flat polygon that lies in the plane. The plane itself contains a parametric center of the face and its normal vector is parallel to the normal vector of the face in its parametric center.
4. Quadrilateral meshing of flat polygons. The algorithm used for meshing flat polygons is described in [5]. This algorithm has been modified in order to take into account the shape of the face mapped to the polygon. In order to maintain face connectivity in the final mesh, insertion of additional points to the polygon edges is forbidden.
5. Projecting flat polygon meshes onto corresponding faces. Once the flat polygon is meshed, the final mesh is created by projecting the flat quads to the face.

III. INSERTION OF AUXILIARY SEGMENTS

After the second phase of the algorithm described in Section II is completed, all quasi-planar sub-faces are ready to be projected onto the polygons that lie in the corresponding planes. Meshing of these polygons and the projection of the mesh elements onto the original sub-faces will then result in the final mesh of the structure. Nevertheless, polygons whose number of segments over closed loops is an odd number cannot be divided into quads without leaving triangular gaps in the division. Therefore, auxiliary segments have to be added to the polyline representation of certain edges in order to achieve an even number of segments over the closed loops of all sub-faces.

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In the proposed technique, it is assumed that auxiliary segments have to be added to the polyline representation of all edges initially represented by a polyline with an odd number of segments. In the technique proposed in [4], the additional segments are not required on the edges that satisfy certain conditions. The basic idea of the new technique is that auxiliary segments can be added not only to the polylines that initially possess an odd number of segments, but to all polylines. The following principles are applied in the new technique:

1. Edges going out from one vertex or going out from two adjacent vertices, must have an all even or an all odd number of segments. The decision regarding the parity of the edges is based on the number of additional auxiliary segments that should be added to the analyzed group in its entirety, in order to achieve the mentioned condition. A minimal number of auxiliary segments is preferred.
2. If an auxiliary segment is already added to some edge from the analyzed group (as defined above), no change is allowed to the other edges, i.e., the initial requirement that the auxiliary segments should be added to odd edges but not even edges remains.

IV. Numerical Example

A comparison of the new technique and the one proposed in [4] is provided for the WIPL-D Pro CAD [6] model of a log-periodic antenna, shown in Fig. 1.

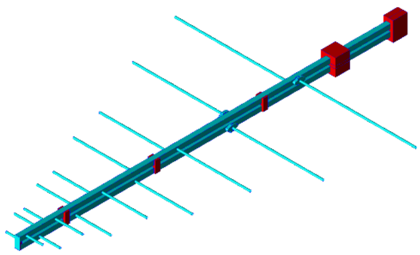


Fig. 1. WIPL-D Pro CAD model of a log-periodic antenna.

The antenna length is equal to 1.6 m. The longest dipole length is 1 m, and the shortest dipole length is 0.15 m. The antenna is simulated in the frequency range of 100 MHz to 1 GHz.

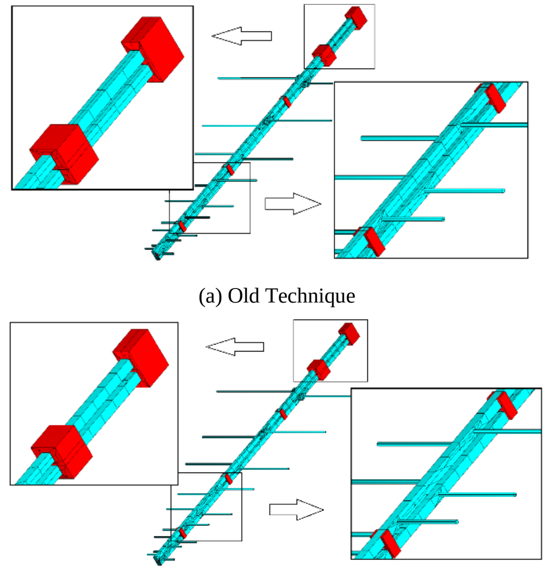
The number of mesh elements and number of unknown coefficients for the two techniques is provided in Table I. As can be seen, the new technique brings a reduction in both: number of mesh elements and number of unknown coefficients.

Table I. Number of Mesh Elements and Unknowns

Technique	**Number of Mesh Elements**	**Number of Unknown Coefficients**
Old technique	2056	7147
New technique	1764	6374

The mesh of the antenna obtained using the two techniques is shown in Fig. 2. The portions of the model where large differences in the meshes occurs are marked and magnified in the picture.

The meshes shown in Fig. 2 demonstrate that, in certain parts of the model, the number of mesh elements is reduced by a factor of 4 using the insertion of auxiliary parity segments technique proposed in this paper.



(a) Old Technique

(b) New Technique

Fig. 2. All-quad mesh of log-periodic antenna.

V. Conclusion

The new technique of insertion of auxiliary segments, required to achieve parity of the total number of segments on the closed loops of the faces, has been introduced. The basic idea of the proposed method is that it allows the addition of auxiliary segments to all edges, and not only to those whose initial polyline representation contains an odd number of segments as previously proposed. Moreover, using the new technique significantly reduces the total number of mesh elements in the final mesh.

In this paper, the focus was solely on the number of mesh elements. Nevertheless, it is important to note that the new technique provides much more flexibility than its predecessor. Auxiliary segments can be added to edges represented by even and odd number of segments. Applying different criteria than the number of additional segments, such as minimal length of a segment or a number of segments over the analyzed edges, should also be considered in order to obtain a better mesh quality factor and further reduce the number of mesh elements.

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