Validation of Blended Rolled Edge Reflector Characteristics for Compact Test Ranges

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***Abstract*—This paper presents a recent advance in designing and validating blended rolled edge (BRE) reflectors for compact antenna test range (CATR) applications. BRE reflectors offer the potential of very smooth near-field patterns in the quiet zone (QZ) due to their improved diffraction characteristics. In house equivalent currents based physical optics (PO) simulation code results were compared and validated against Altair Feko Method of Moment (MoM) simulations for various BRE reflectors. Reflector comparisons have been shown for different modelling scenarios, *e.g.* imported CAD files versus surface created using Lua macros coding, which is a built-in macros language in Altair Feko. All results are in a very good agreement, including cross polar magnitude and phase.**

***Index Terms*—reflector antennas, compact antenna test range, blended edse reflectors. measurements.**

I. INTRODUCTION

Blended rolled edge reflectors were introduced a couple decades ago [1, 2]. They are known for offering better diffraction characteristics in the front of reflectors, which allow them producing a smoother quasi-plane wave in the so-called quiet zone of compact antenna test ranges (CATR) [3]. CATRs are widely used in antenna measurements since the early ‘70s [4]. During those years workers have been searching for methods to improve their performance. Less rippled and smoother field distribution (magnitude and phase) in a quiet zone (QZ) offers not only better representation of a quasi-planar wave, but usually increases the size of such zones. In order to achieve these improvements, several methods had been proposed. All of them are based on the idea of decreasing diffraction from the edges of reflector antennas. One of the most well-known methods introduces so-called serrated edges to the reflector [5, 6]. This seeks to avoid coherent superposition of diffracted waves illuminated by reflector edges. The configuration also offers rather nice diffraction pattern on the anechoic chamber walls. However, it usually produces rather rippled field amplitude and phase in the quiet zone. In order to reduce ripples within the QZ, the blended rolled edge (BRE) reflector concept was resurrected. Due to much higher computational power and dramatically improved commercial computational electromagnetic (CEM) software, it has become possible to solve such complex geometries with a very high accuracy without spending extended time in simulations. Moreover, full optimisation of these structures has become possible in very reasonable run-times requiring only comparatively moderate computational resources.

In general, commercial CEM software packages are based on so called full-wave solvers where a method of moments (MoM), a finite element method (FEM), a finite difference time domain method (FDTD) are all among the most popular. On the other hand, faster solutions which use methods, known as “high frequency methods” are available, *e.g.*, geometrical or physical optics (GO and PO). However, those approximate methods work only when some restrictions are satisfied. One of them is very simple: the electrical size of the structure should be much larger than the operational wavelength.

In-house developed CATR simulation and optimisation code which uses the current elements method, or PO in more general terms, showed a great ability to predict characteristics of CATR reflectors, including serrated [6, 7] and BRE reflectors. Moreover, it was successfully embedded into a genetic optimiser, which enables CATRs of various dimensions to be produced, for various microwave and mm-wave frequency ranges and for specific applications [6, 8]. Nevertheless, with every new design there is a concern that the method used is not precise enough to predict realistic characteristics of CATR. In order to eliminate those concerns and validate results, developed and optimised models of BRE reflectors have been replicated in a commercial CEM software package Altair Feko [9]. Also, two methods were used to avoid any doubts in terms of possible discrepancies between models created in different software.

Hence, in this paper a validation of results for optimised CATR BRE reflectors are presented. In the first section, models created in Altair Feko are demonstrated and explained along with the results and comparisons between various scenarios of 3-D design of those models. In the second section those models are compared with models, originated from in-house Matlab [10] optimisation and analysis. The paper is concluded by the Conclusions section.

II. BRE REFLECTORS RESULTS

A. *Theory of BRE and 3-D modelling*

Blended rolled edge reflectors have been thoroughly investigated and mathematically formulated in previous works [1, 2, 11]. The authors advise readers to follow these links in order to understand the mathematical expressions defining such complex surfaces. Despite slight variations in the design strategies, the main idea can be briefly explained as follows:

1. The main reflector surface is a classical paraboloid.
2. Various central cut-out boundaries of the paraboloid, such as a rectangle, circle or diamond projection, are unmodified.
3. On the border of those cutouts the parabola (for the sake of simplicity, imagine a 2-D cut) is slowly blended into an ellipse. Here, it is important to explain, that the word “blended” is the most appropriate. A complex curve created is really a “blend” of ellipse and parabola. It avoids a discontinuity in the first derivative at the edge between two curved and, consequently, eliminates additional diffraction from a created rim.
4. The blended part slowly converges into a pure ellipse at the back of the reflector. By varying ellipse parameters, blending coefficients, etc., as well as defining cut-outs one can get different designs with a large variability of characteristics.

To illustrate a complexity of the surface a BRE reflector which is cut horizontally along the plane y = 638mm is shown in Fig. 1.

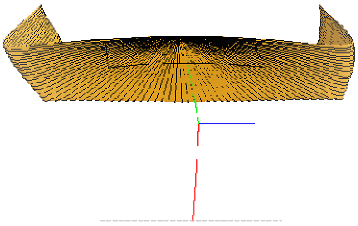


Fig. 1. BRE Reflector geometry.

To create such complex surface, one needs to use either a professional computer added design (CAD) software or write some kind of code/macros. The former yields a file in one of the interchangeable standards which are recognizable to a commercial CEM package. The latter creates a reflector in the CEM graphic user interface (GUI), which makes it more functional as it can be parametrized, for instance. Also, there is another option, which was used for validating Matlab results. Matlab has a feature of making an STL file, which is generally unreadable for CEM packages. So, it has to be converted using again one of CAD packages. After that the first route is repeated. This is the method which was used in this paper.

Both methods have been applied for validation and showed very good convergence as will be seen later in the paper.

B. *Results of CEM modelling*

Using the first method the geometry of the antenna has been created in Altair FEKO. A Gaussian source with -3.6 dB taper at 20 degrees has been utilized as a feed. Overall dimensions of the antenna are approximately 1085 by 1085mm. The geometry of the antenna is demonstrated in Fig.2.

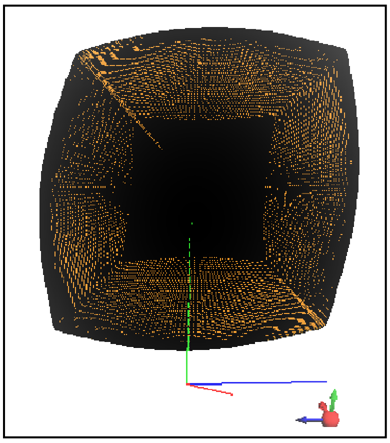


Fig. 2. CAD based model preapred for simulations.

The antenna has been analyzed using MoM/MLFMM method and a coarse mesh. Previous investigation, presented, *e.g.*, in [8, 11], had shown that the coarse mesh does not spoil results of simulation, however, they decrease required memory and, obviously, simulation time. Despite rather significant size even at 6 GHz, simulation time is usually less than 10 minutes, depending on how many near-field requests used. Near-field distribution, magnitude and phase, in the middle of the quiet zone (2784mm from the vertex of the parabola) is illustrated in Fig. 3. It is clearly seen that the BRE reflector performance is very good, demonstrating rather smooth behaviour in both amplitude and phase. It was a result of the preliminary genetic optimisation as well as an intrinsic characteristic of BRE reflectors, explained herein above.

The second method, which is usually more elaborate if one need to write the code, however, more flexible if you need to explore with the geometry independently, involves a creation of complex curves “lofted” and united together. Such procedure is seen in Fig. 1, where one can observe a set of “ribs” forming a surface of the reflector. Results of simulation for this reflector are shown in Fig. 4. Again, amplitude and phase are shown for the centre of the quiet zone. Visual comparison of those two results proves that both models yield very similar results, which are in an excellent agreement. Also, it proves that both models must have the same geometry. It is shown in Fig. 5, where yellow colored surface is a geometry created internally in Feko and amber one on the left and blue one on the right are the models imported as a CAD drawing.

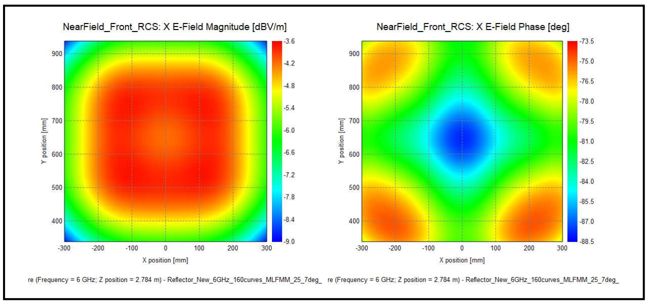


Fig. 3. Amplitude and phase in the middle of the quiet zone for the CAD based model.

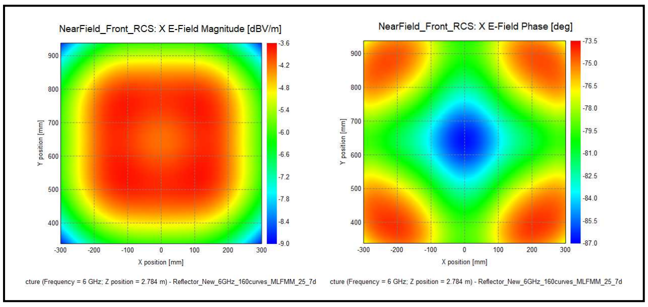


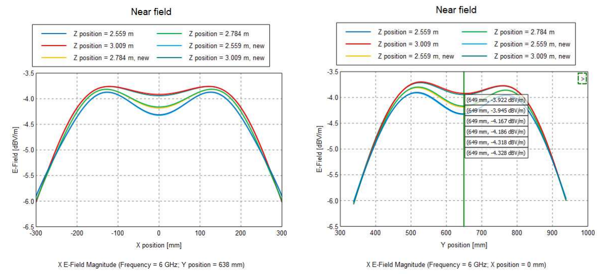
Fig. 4. Amplitude and phase in the middle of the quiet zone for the Feko built model.

Finally, in order to demonstrate good agreement between models, Fig. 6 shows two cuts in principal planes of the reflector (x = 0mm and y = 638mm) for three near-field measurements, namely: rear, middle and front of the quiet zone.

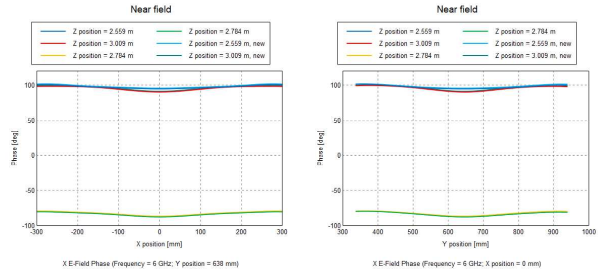
Fig. 5. Comparison of two geometries created by two approaches.

III. MATLAB MODEL AND VALIDATION

In this chapter a short discussion on the Matlab model and its validation is presented. Matlab analysis of BRE reflectors is based, as it was stated earlier, on the current method, which is actually a physical optics high frequency method. More detailed description of the methodology and implementation could be found in earlier papers by the authors, e.g., in [7]. Also, the original code was successfully incorporated into the genetic optimisation algorithm [6, 11]. At reasonably low frequencies and for modest electrically sized structures, the method is rather fast and consumes similar amount of memory and time during simulations. Obviously, it is for one frequency only as the method is a frequency domain technique.



a) Amplitude, X-cut b) Amplitude, Y-cut



c) Phase, X-cut d) Phase, Y-cut

Fig. 6. Amplitude and phase in the quiet zone for different cuts, distances and reflectors. Those, marked as “new” are results for the Feko built model.

The reflector surface, created in Matlab as a set of points in STL format, is shown in Fig. 7. Comparisons between two methods are shown in Figs. 8-10 for various frequencies. It is demonstrated that for lower frequencies, when electrical size of the reflector getting smaller and it cannot be used in CATR, an agreement between two methods is still good, otherwise it is nearly perfect. Also, it is necessary to mention that two reflectors, designed by slightly different approach and in different software packages, have a 2mm difference in overall size. However, even at 0.5 GHz where the electrical size is around 1.6 of the wavelength, the agreement is still reasonably good as shown in Fig. 11. Unlike GO, the physical optics method is based on physical current distribution which makes possible to predict a performance of electrically rather small objects.

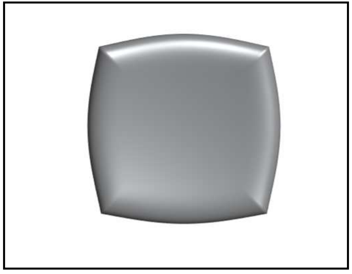
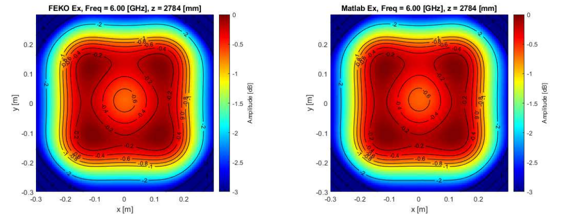


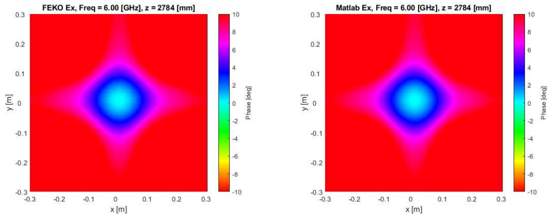
Fig. 7. Matlab generated geometry of the BRE reflector

IV. CONCLUSIONS

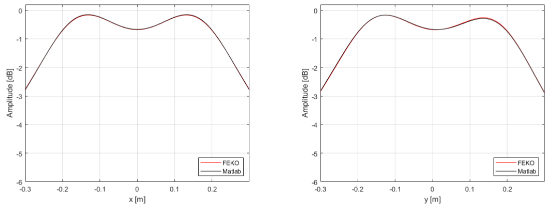
An excellent agreement between Matlab simulations based on PO and commercial CEM software based on MoM has been achieved and demonstrated. Complex 3-D surfaces have been created, analyzed and successfully validated. Very good performance of the generated BRE reflector is achieved in the quiet zone. It makes it a reasonable candidate for utilization in X- and Ku-band CATRs. Further optimization could be required for moving into higher bands.



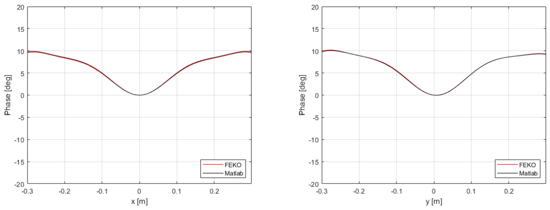
a) Amplitude



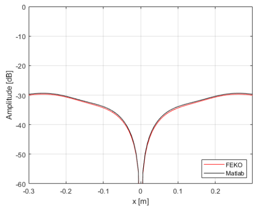
b) Phase



c) x and y cuts amplitude

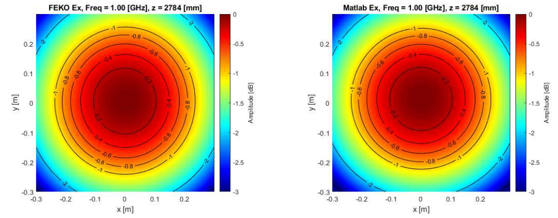


d) x and y cuts phase

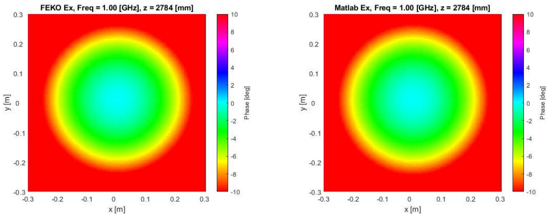


e) cross-polar x-cut

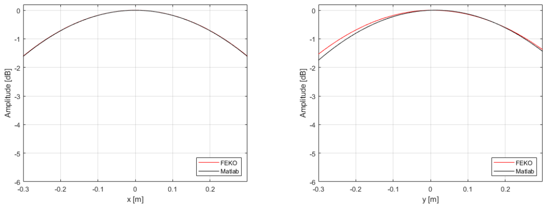
Fig. 8. Comparison between Matlab and Feko simulations at 6 GHz, size of the refelector is approximately 20λ.



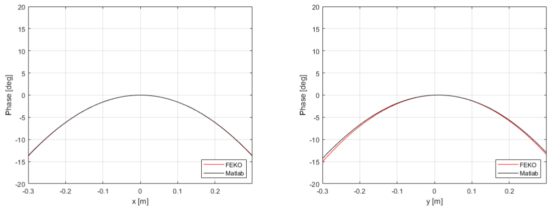
a) Amplitude



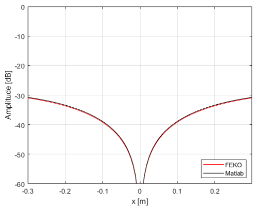
b) Phase



c) x and y cuts amplitude

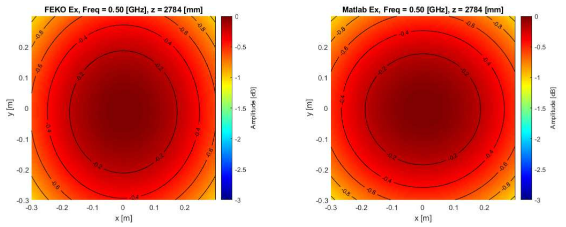


d) x and y cuts phase

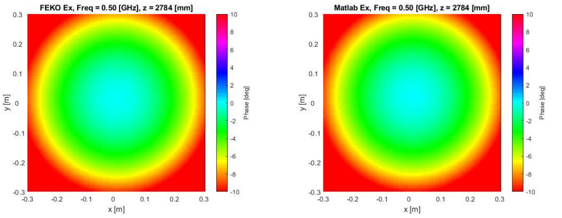


e) cross-polar x-cut

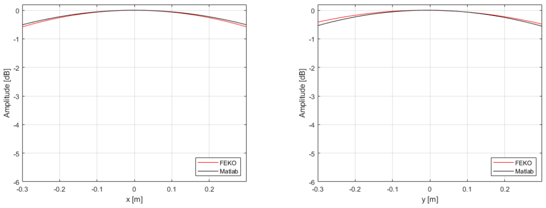
Fig. 9. Comparison between Matlab and Feko simulations at 1 GHz, size of the refelector is approximately 3λ.



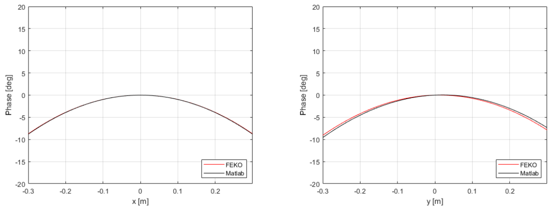
a) Amplitude



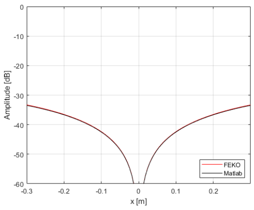
b) Phase



c) x and y cuts amplitude



d) x and y cuts phase



e) cross-polar x-cut

Fig. 10. Comparison between Matlab and Feko simulations at 0.5 GHz, size of the refelector is approximately 1.6λ.

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