Computational Accuracy and Speed of Some Knife-Edge Diffraction Models

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***Abstract*—In this paper we compare the computational accuracy and speed of some knife-edge diffraction models. The Bullington, Epstein-Peterson, Deygout, and Giovaneli models were implemented in MATLAB and compared to the rigorous Vogler method. It is found that all these methods, except the Bullington method, are of similar accuracy. The computational efficiency, on the other hand, is quite different for these four methods. These results provide important guidance for the applications of these knife-edge models in practical simulations of radio propagation.**

I. INTRODUCTION

Radio-wave propagation in various environments can encounter a variety of obstacles which can block the line-of-sight paths between antennas or protrude into the first Fresnel zone defined by the transmit and receive antennas. In such cases, diffraction over the tops of the obstacles in the signal path has to be considered. However, accurate determination of the diffraction losses is very challenging for realistic propagation environments such as mountainous regions. A common approximation is to use knife edges to replace the mountain peaks and ridges. Although rigorous methods for solving such knife-edge models exist, such as the Vogler method [1], the computational complexity of these methods is usually high.

In practice, other simplified models are used, such as the Bullington [2], Epstein-Peterson [3], Deygout [4], and Giovaneli [5] models, which can be described as geometrical techniques, and can provide estimations of diffraction losses in various situations. In [1], the accuracy of these models are compared with the Vogler method and discrepancies are explained in terms of transition zones and shadow boundary. It is also mentioned in [1] (presentation slides) that the computation speeds of the geometrical methods are much faster than the Vogler method (microseconds vs. seconds).

In this paper we study both accuracy and speed of these methods for various test geometries. First, these knife-edge methods are implemented in MATLAB. The implementation is general and can take any knife edge definitions as input. Second, quantitative characteristics of the accuracy of these methods, such as the mean error and standard deviation, are provided. Finally, the computation speed for each of these methods is compared. Although the speed difference among these methods is small for a single run, the accumulative difference for many runs (which is very often in practice) may be significant.

II. MODEL COMPARISON

Four knife-edge diffraction models are implemented in computer programs (MATLAB) which can be used to calculate the diffraction loss for any terrain geometry input. The diffraction models implemented include those methods by Bullington, Epstein-Peterson, Deygout, and Giovaneli. The test cases used in this analysis are obtained from Table I in [6], which also provide computed results using the Vogler method (also in [1]) for each case. The test cases include situations with two, three, four, and six knife-edges, as well as varying dimensions of knife-edge height and separation distances.

The absolute error in dB of each of the methods from the Vogler results is shown in Fig. 1. Across all cases, the Bullington method has a mean error of 18.32 dB and standard deviation of 18.07 dB; the Epstein-Peterson method a mean error of 4.21 dB and standard deviation of 4.99 dB; the Deygout method a mean error of 6.70 dB and standard deviation of 5.40 dB; the Giovaneli method a mean error of 4.22 dB and standard deviation of 5.40 dB.

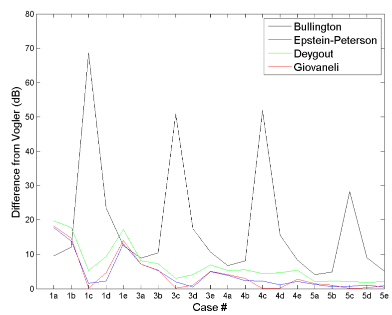

Fig. 1. Difference of diffraction loss models from Vogler.

From Fig 1. it is clear that there is no single best method which is accurate in all cases. However, it does show a good agreement between the diffraction models (except for Bullington) and the Vogler method for cases 1c, 3c, 4c, and 5c. Fig 2. shows the absolute difference for the models compared to the Vogler method (excluding the Bullington method) for these cases which are particular geometries from [6] including peak heights and separation distances much larger than the wavelength at the 1.5 GHz frequency used in calculations. For these cases, the Giovaneli method shows very good agreement with the results of the Vogler method for any number of peaks, with a mean error of 0.11 dB.

For cases 1d, 3d, 4d, 5d, and all cases with two peaks, the agreement between the knife-edge models and Vogler's method is still good. These *d*-cases are geometries which have peak height and separation distances comparable to the wavelength, but have height to distance ratios equal to those of 1c, 3c, 4c, and 5c. Fig 3. shows the absolute difference in diffraction loss for each model (except Bullington method) for each case compared to the Vogler method. In these cases, the Giovaneli model shows good agreement with Vogler's method for cases of two and three peaks. However, for cases with four and six peaks, the Epstein-Peterson model achieves better results.

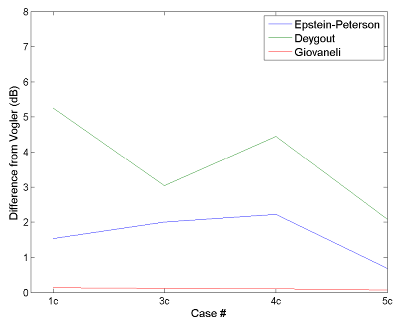

Fig 2. Absolute difference for *c*-cases.

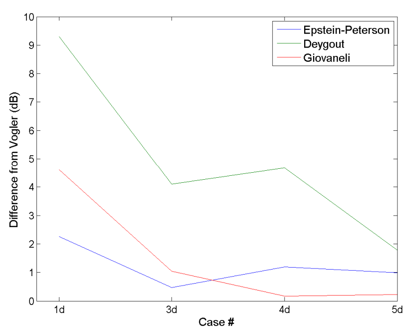

Fig. 3. Absolute difference for *d*-cases.

For cases 5a-5e, which contain only two peaks, the Epstein-Peterson method achieves the best results, except for cases 5c and 5d in which the Giovaneli method better agrees with the Vogler results as determined previously (see Fig 4).

In all other cases, the Epstein-Peterson method achieves a result closer to those using the Vogler method than the other models. However, for cases 1a, 1b, and 1e, where there are six peaks present, the Epstein-Peterson, Deygout, and Giovaneli models tend to over-estimate the diffraction losses compared to the Vogler method, while the Bullington method under-estimate the loss. This might appear as though the Bullington method achieves a better result in these cases, though all methods differ from the Vogler results by 10 dB or more.

For the computation speed, we ran each of these methods 250,000 times on the same geometries which are randomly generated (the random variables including the number of edges (2 to 6), the separation distances, and the heights of the edges). It is found that the Bullington method is the fastest (~12s). The Epstein method takes more than five times (~69s) longer, the Deygout about eight times (~93s) longer, and the Giovaneli 12 times (~146s) longer, compared with the Bullington method.

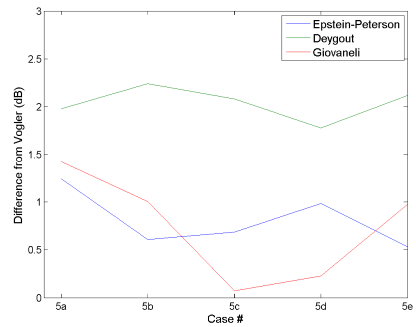

Fig 4. Absolute differences for cases 5a-5e.

III. Conclusion

The Giovaneli model has shown to at least achieve the best results for cases when the peak heights and separation distances are large compared to wavelength. In other cases, a selection can be made based on the number of peaks in the model and the relative height to distance ratios of the peaks. Furthermore, in some cases, all of the diffraction models cannot achieve a results comparable to the results obtained from the rigorous Vogler method. Also, the computation speed is quite different for these four knife-edge models and should be considered when the there are many diffraction calculations and when real time applications are needed.

Acknowledgement

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