A Comparative Analysis of Multiple Knife-Edge Diffraction Methods

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Diffraction Analysis Effort

- The rigorous diffraction loss computation algorithm for many diffraction edges is very time consuming even with state-of-the–art computers.
- A faster diffraction loss computation algorithm for many diffraction edges is needed for the short-range mobile-to-mobile propagation model.
- The rigorous diffraction algorithm of L.E. Vogler has been verified to be extremely accurate when compared to measured data, but the run times for many edges are too excessive.
- Need to find an alternative algorithm by comparing the accuracy of four faster diffraction algorithms to the L.E. Vogler algorithm for many diffraction loss scenarios with multiple edges.

Diffraction Analysis Effort

- Rigorous Vogler method with run times on the order of seconds on a PC, whereas alternative methods run in microseconds.
- PC based mobile-to-mobile propagation model under development will need to make diffraction computations for many radials for interference and area predictions.
- If ray path from one edge to next is in transition zone and aligns too closely with incident shadow boundary, an error results in computation.
- In most cases this error is detectable, predictable and can be corrected.

Four Alternative Diffraction Algorithms

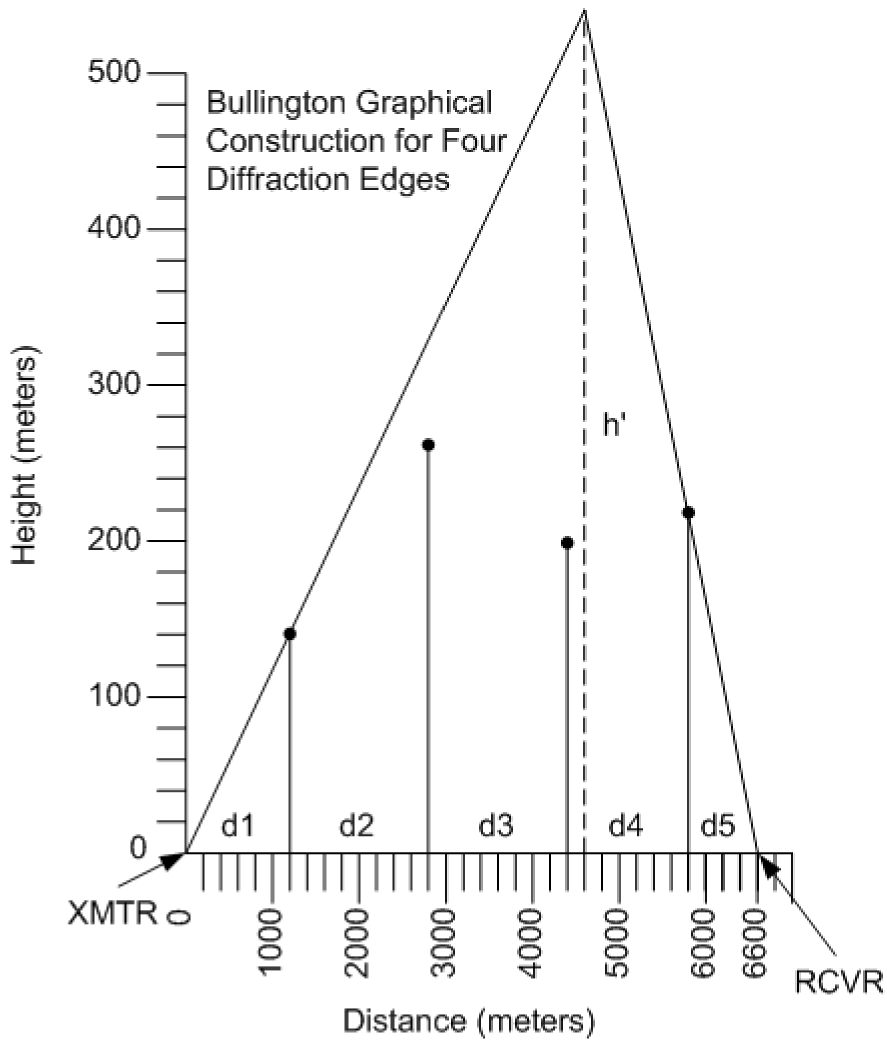
- The Bullington Algorithm- simplest method to implement, but least accurate.
- The Epstein/Peterson Algorithm-slightly more complex than Bullington algorithm, but with improved accuracy.
- The Deygout Algorithm-more complex than previous two algorithms, but with improved accuracy.
- The Giovaneli Algorithm-most complex to implement when compared to previous three algorithms, but with improved accuracy.
- The Bullington algorithm has been determined to be the least accurate diffraction loss computation for many multiple edges.

Diffraction Analysis Approach

- All four of the alternative diffraction algorithms are graphical techniques, and they are usually computed manually.
- Mathematical algorithms for each of the four alternative diffraction algorithms were developed, so that they could be implemented in computer code and incorporated into the short-range mobile-to-mobile model.
- The diffraction algorithm that is selected must apply to all of the possible diffraction edge geometries that can occur.
- Fifty different scenarios were tested against the four alternative algorithms for an initial attempt at simulation of many different scenarios.
- These scenarios included many variations of: varying distances between edges, different heights, and different ratios of heights-to-distances between edges over the range of frequencies.
- It was necessary to resurrect the Vogler diffraction algorithm, which is a complex computation of multiple summations and multiple integrals.

The Vogler Method

- The knife-edges are assumed to be perfectly conducting screens placed normal to the direction of propagation extending to infinity in both directions and vertically downwards.
- Vogler derived the multiple knife-edge solution using Fresnel-Kirchoff Theory.
- The expression for the multiple knife-edge attenuation function is in the form of a multiple integral, which is developed into a series which can be numerically evaluated.
- The terms of this series involve repeated integrals of the complementary error function.
- In the application of Fresnel-Kirchoff theory to multiple knife-edge diffraction, the elements of the wavefront are formed in the aperture above each knife-edge and the assumption is made that the field at any particular element arises solely from the total field over the preceding aperture.
- The solution is a successive summation of integrals.



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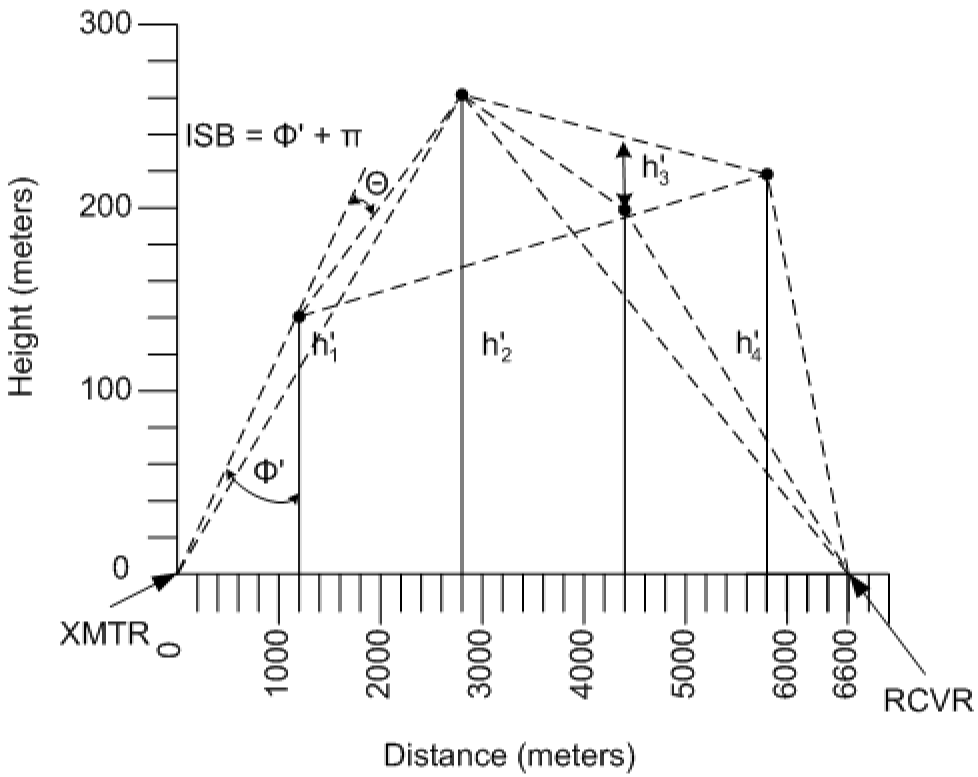
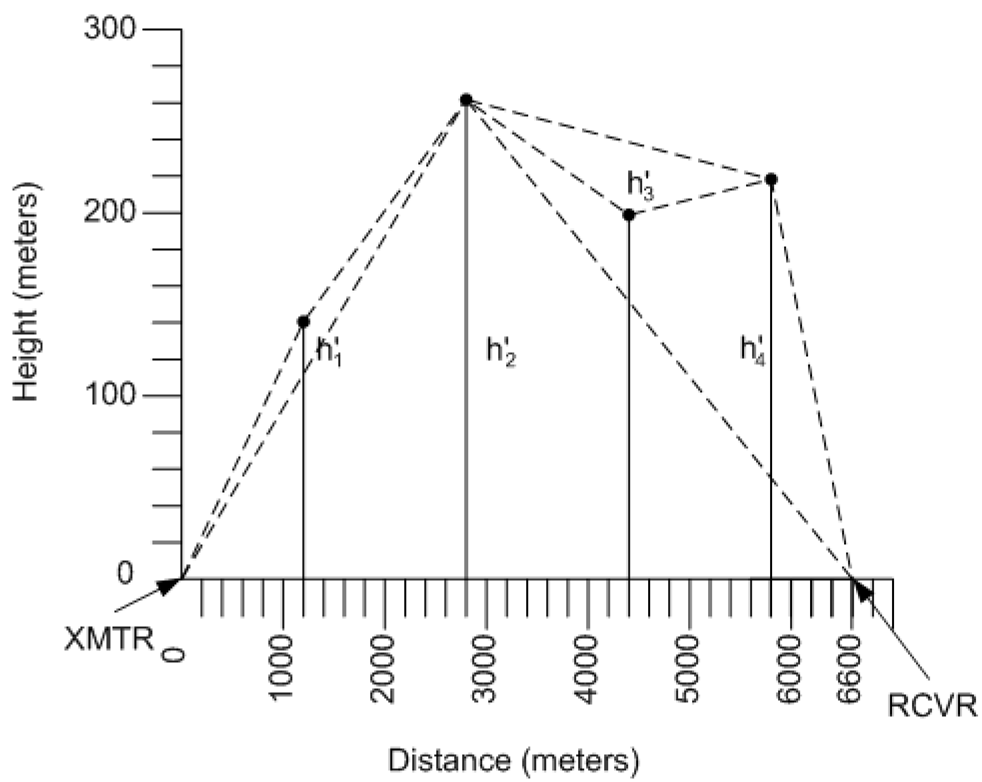
Epstein-Peterson Graphical Construction for Four Diffraction Edges



Deygout Graphical Construction
for Four Diffraction Edges



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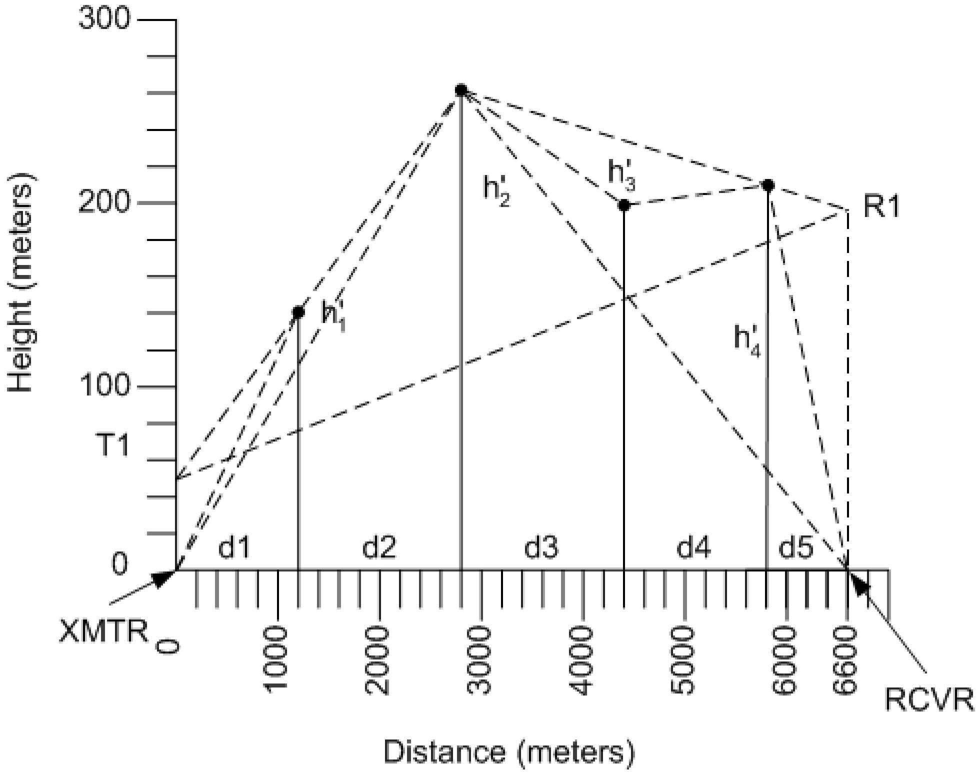
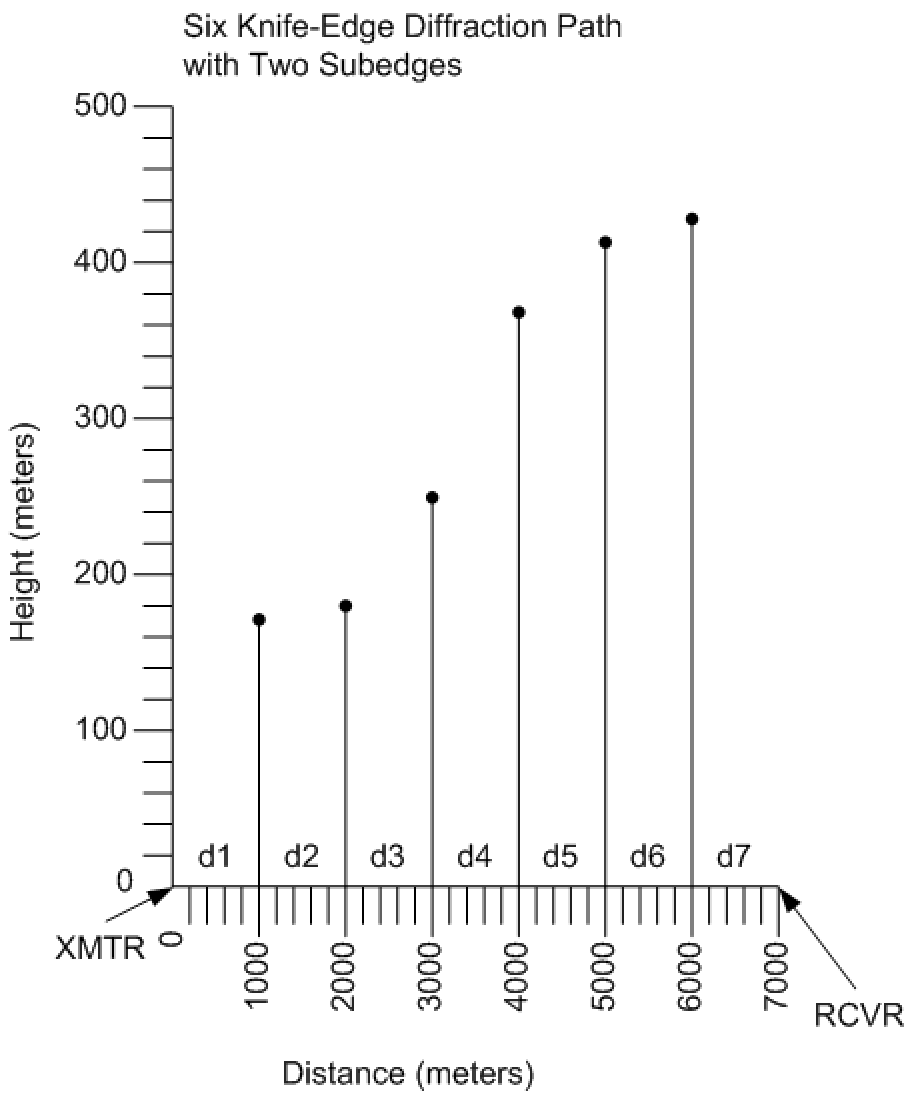
Giovaneli Graphical Construction for Four Diffraction Edges





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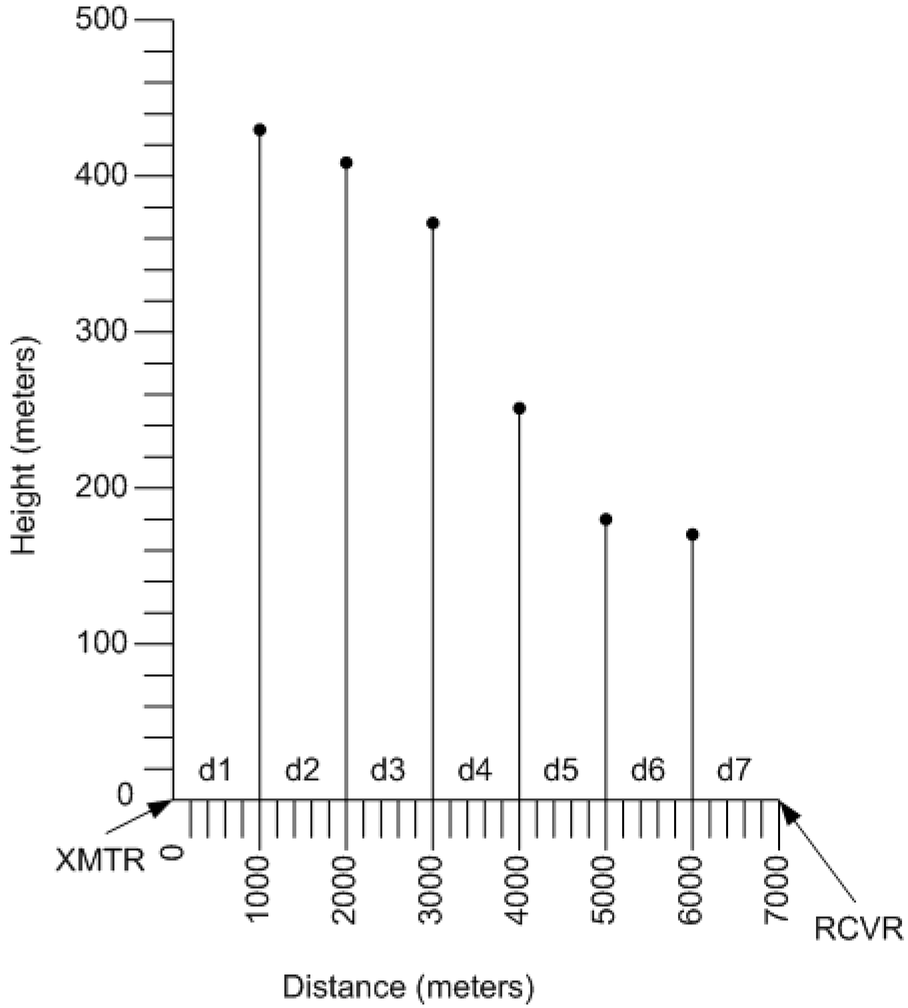
Six Knife-Edge Diffraction Path
with Two Subedges



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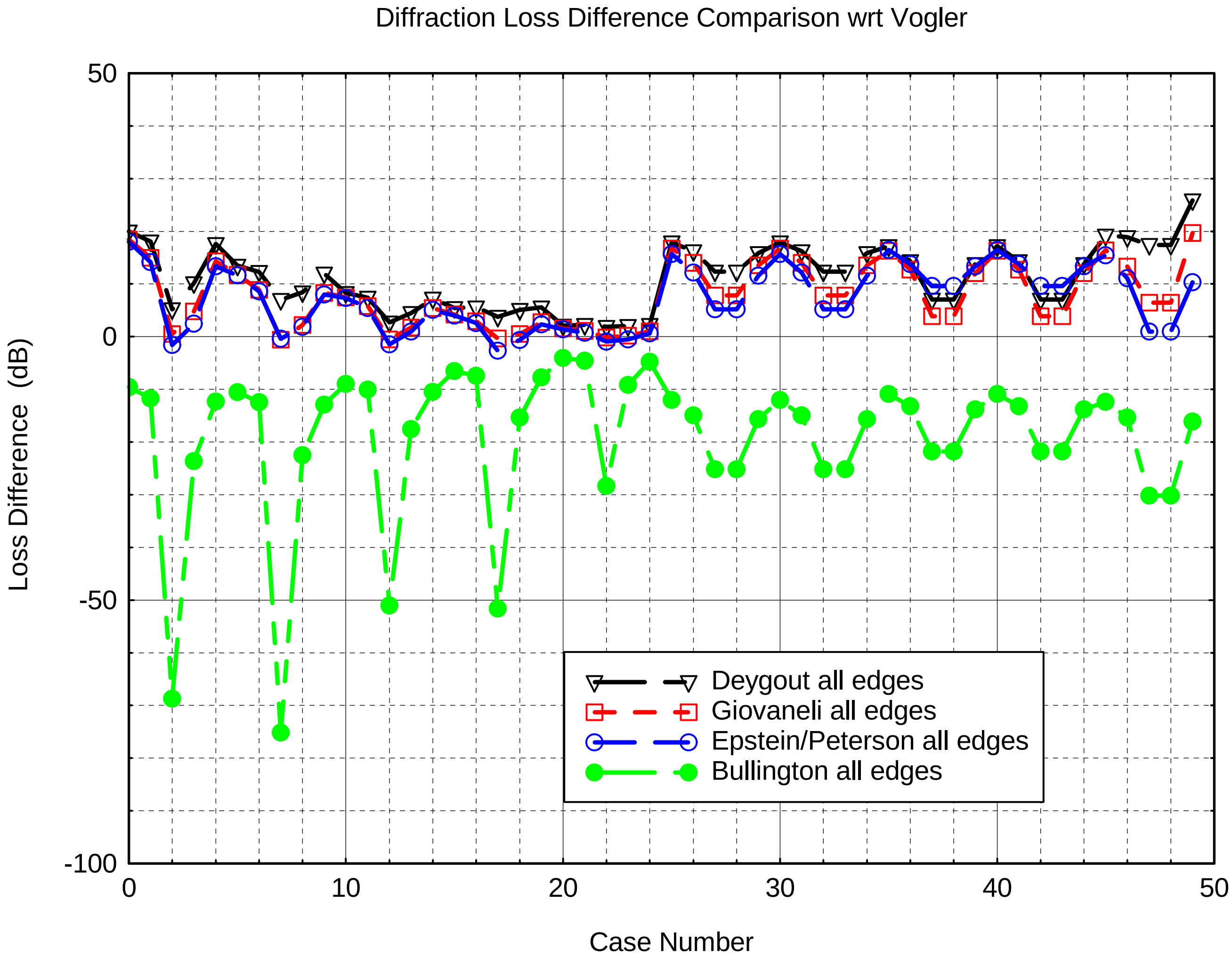

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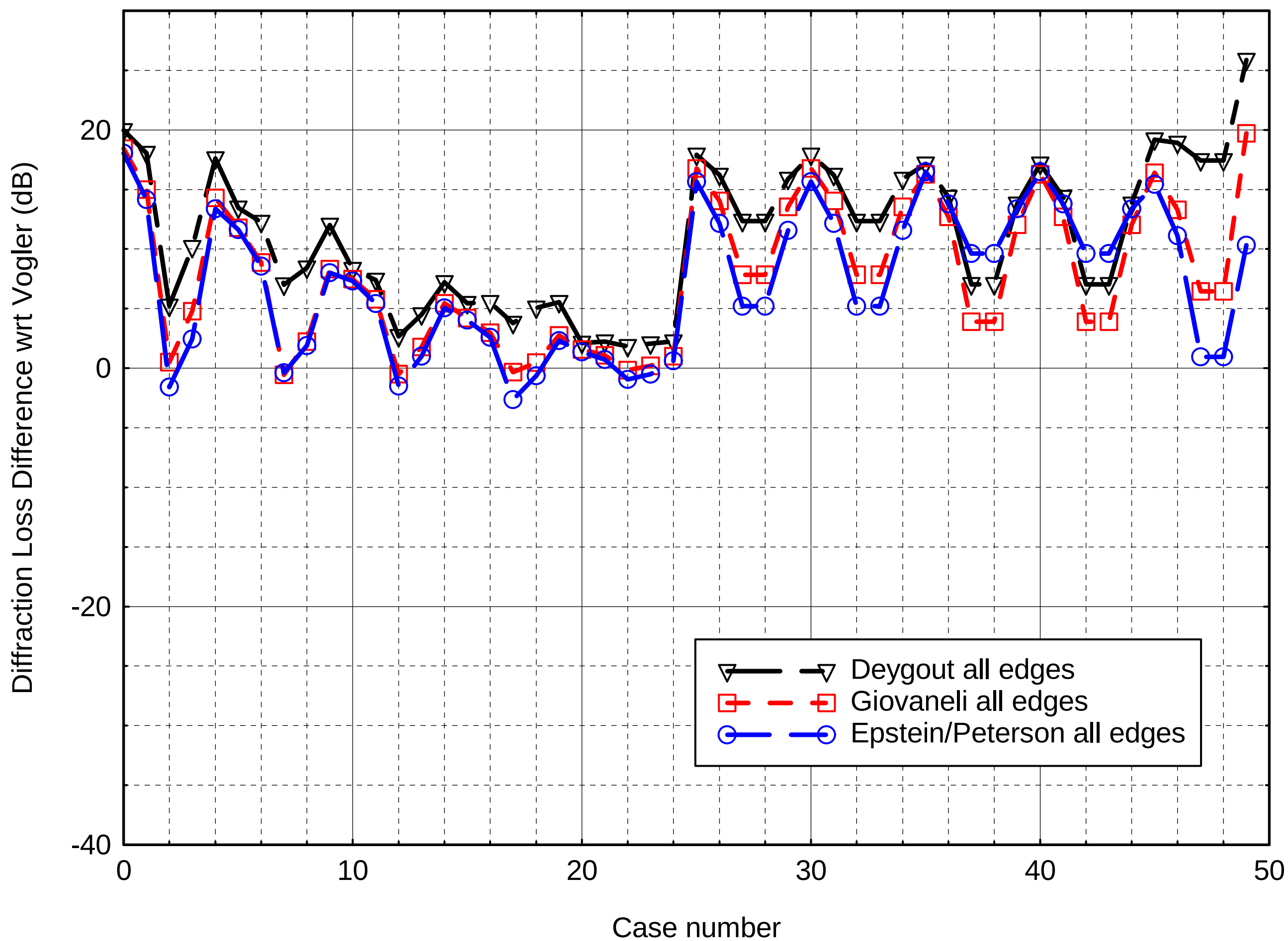
Diffraction Loss Difference Comparison wrt Vogler



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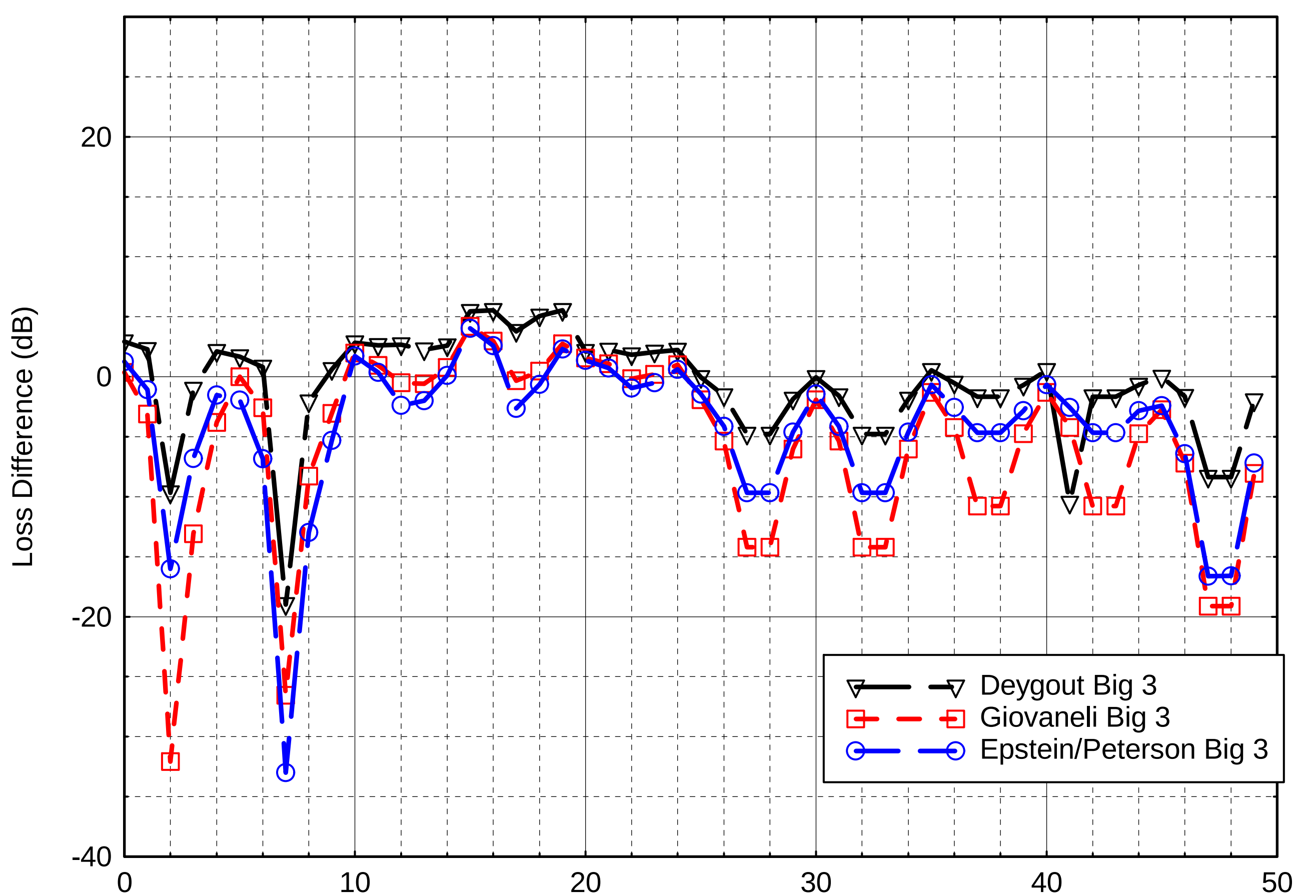

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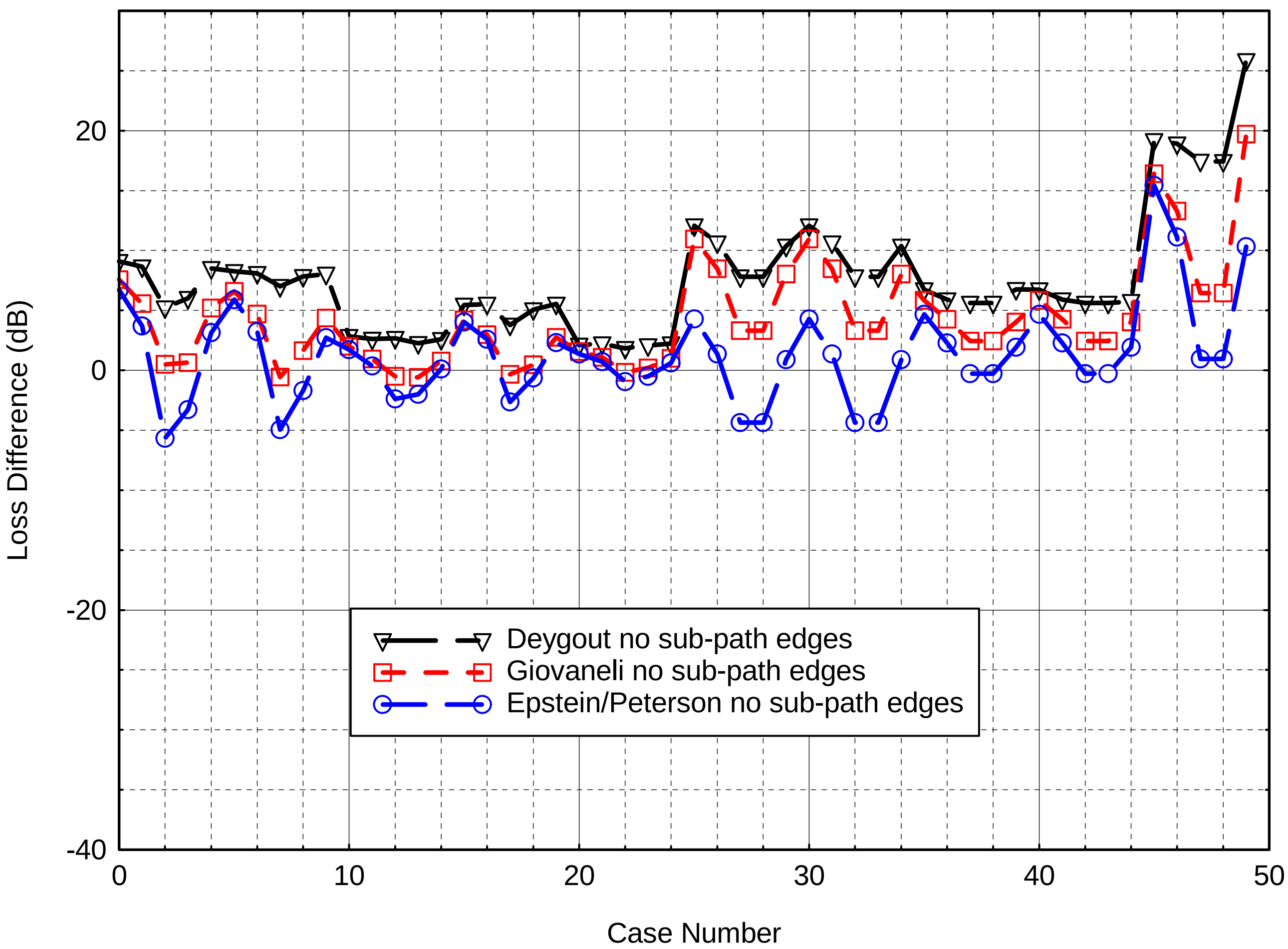

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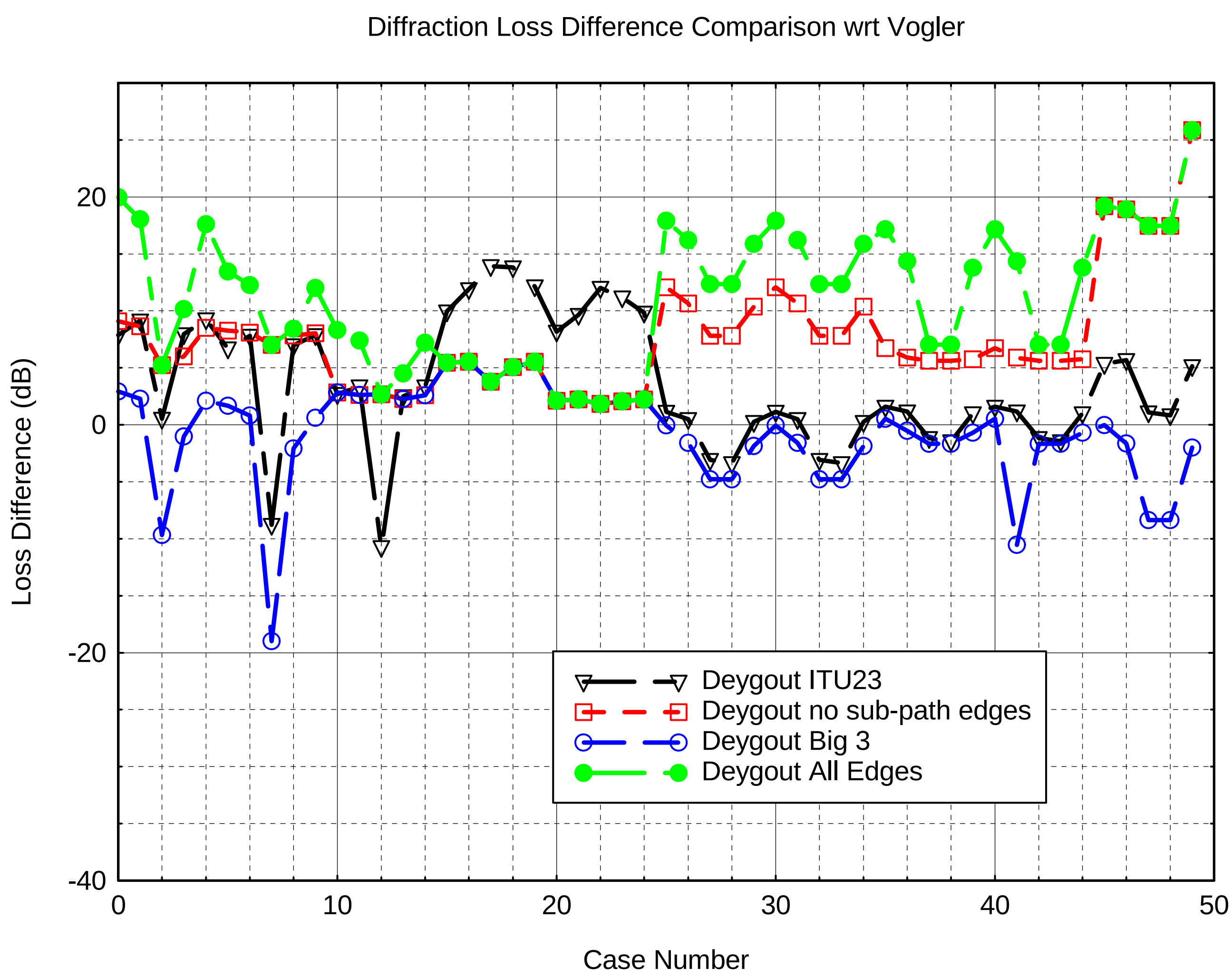

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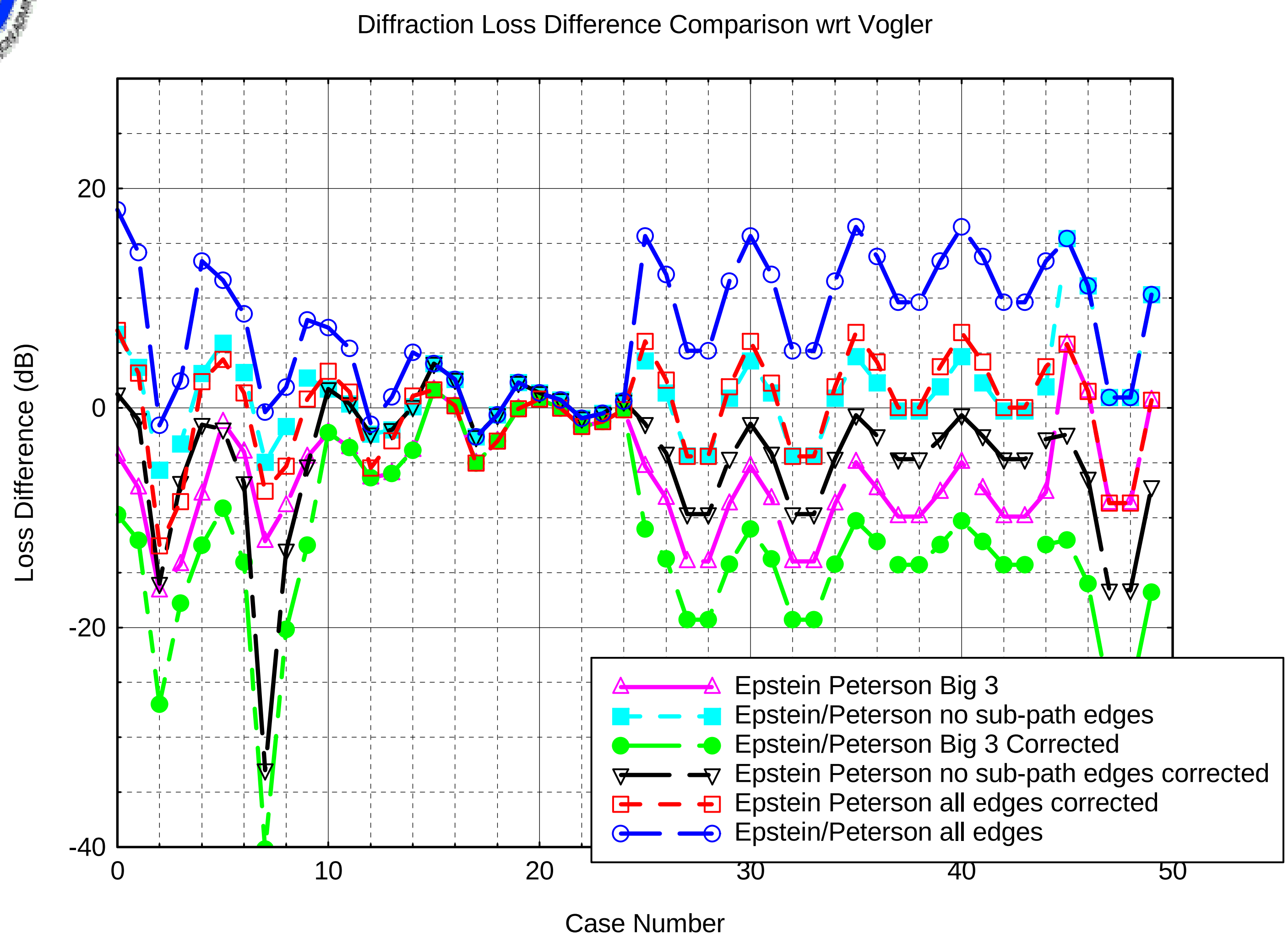

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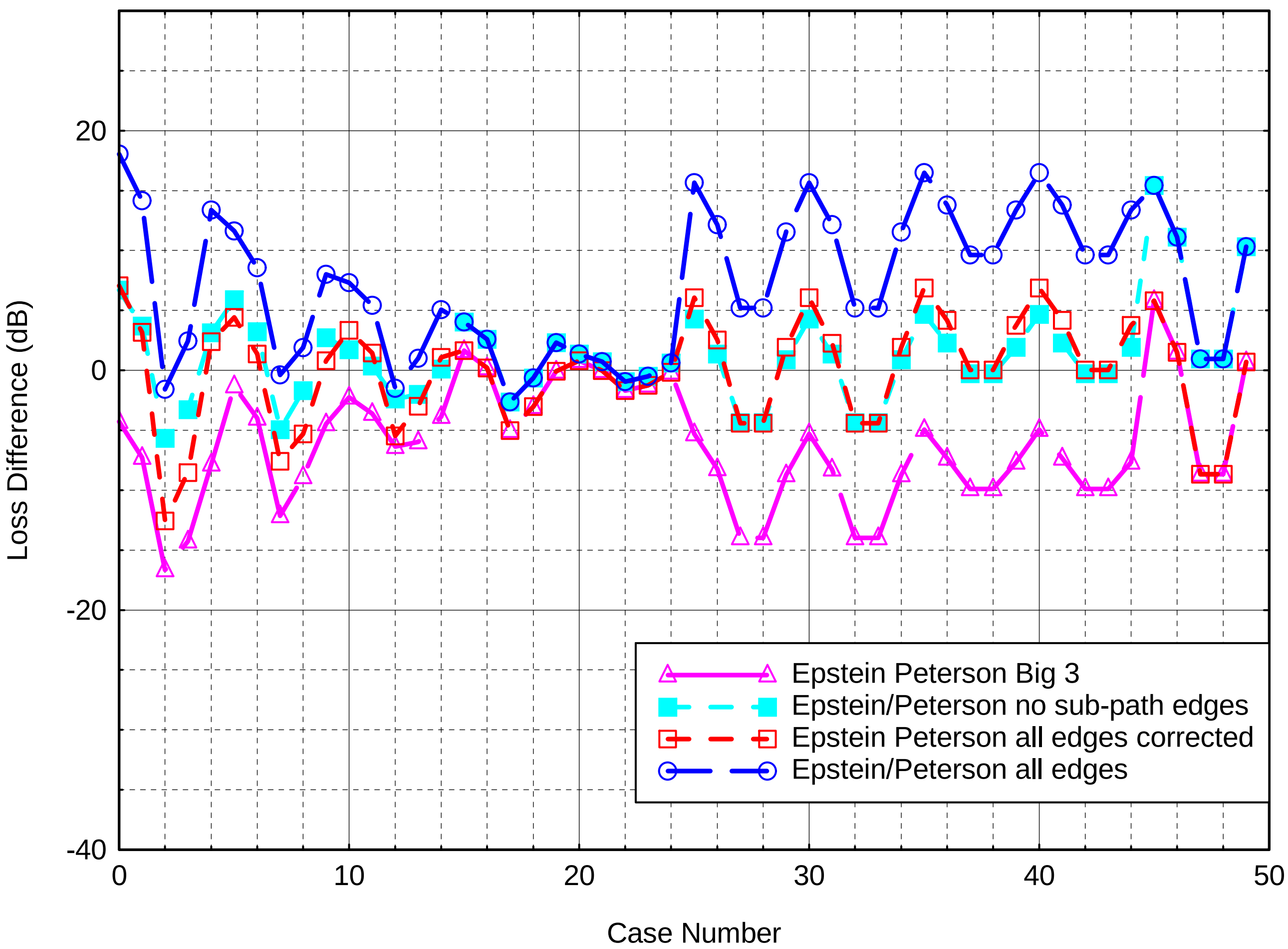

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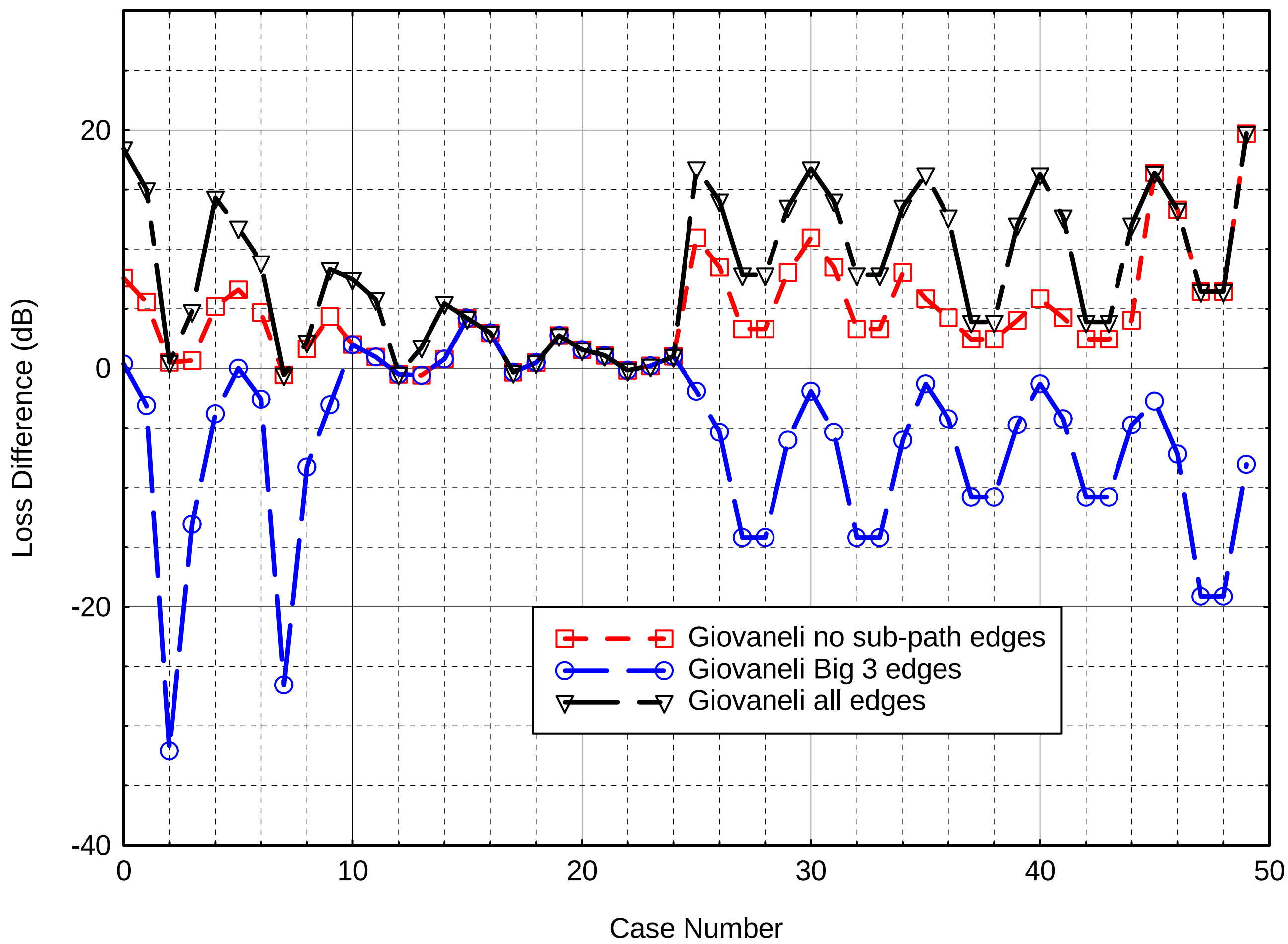
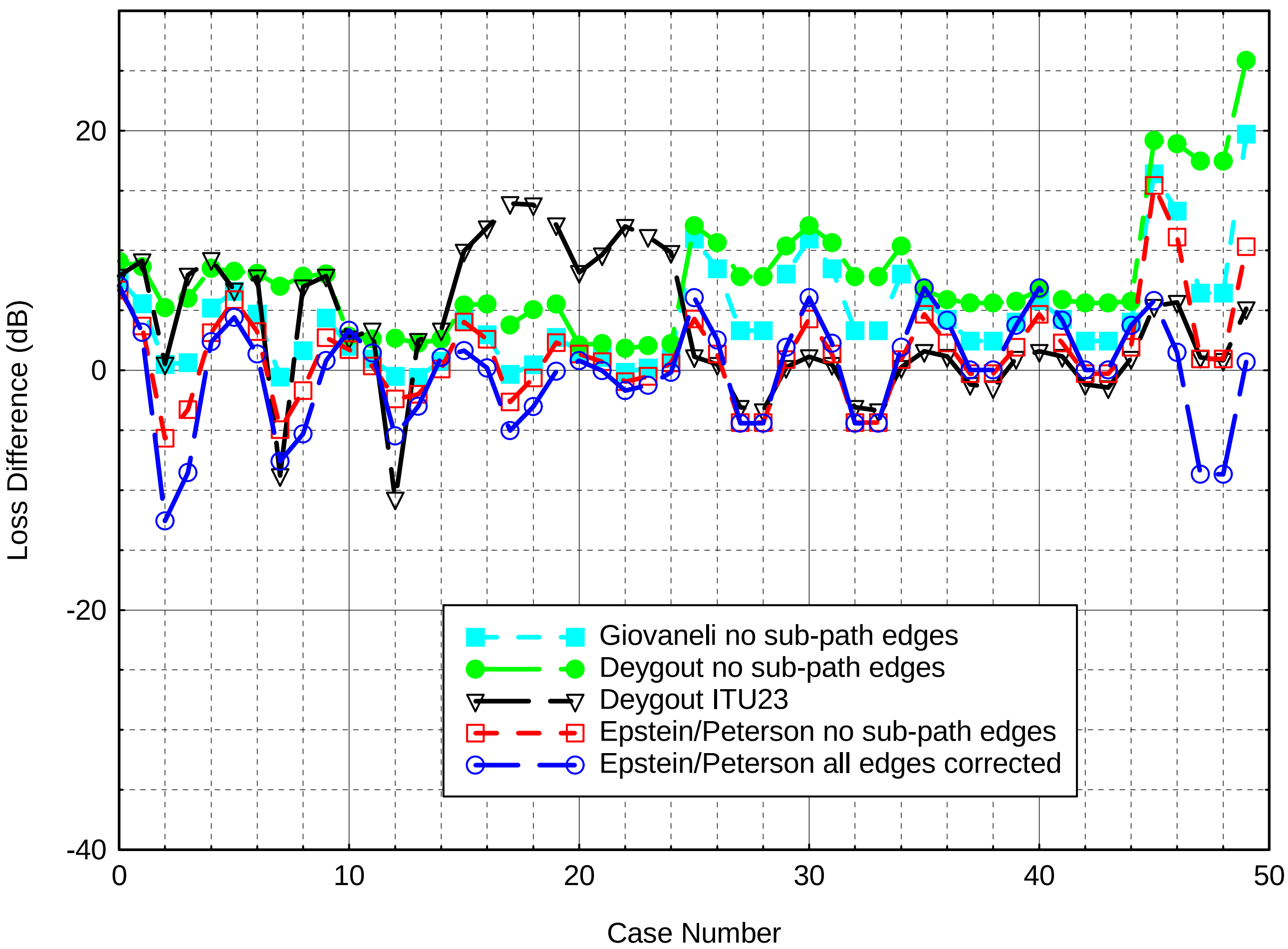
Diffraction Loss Difference wrt Vogler



Diffraction Loss Difference Comparison wrt Vogler



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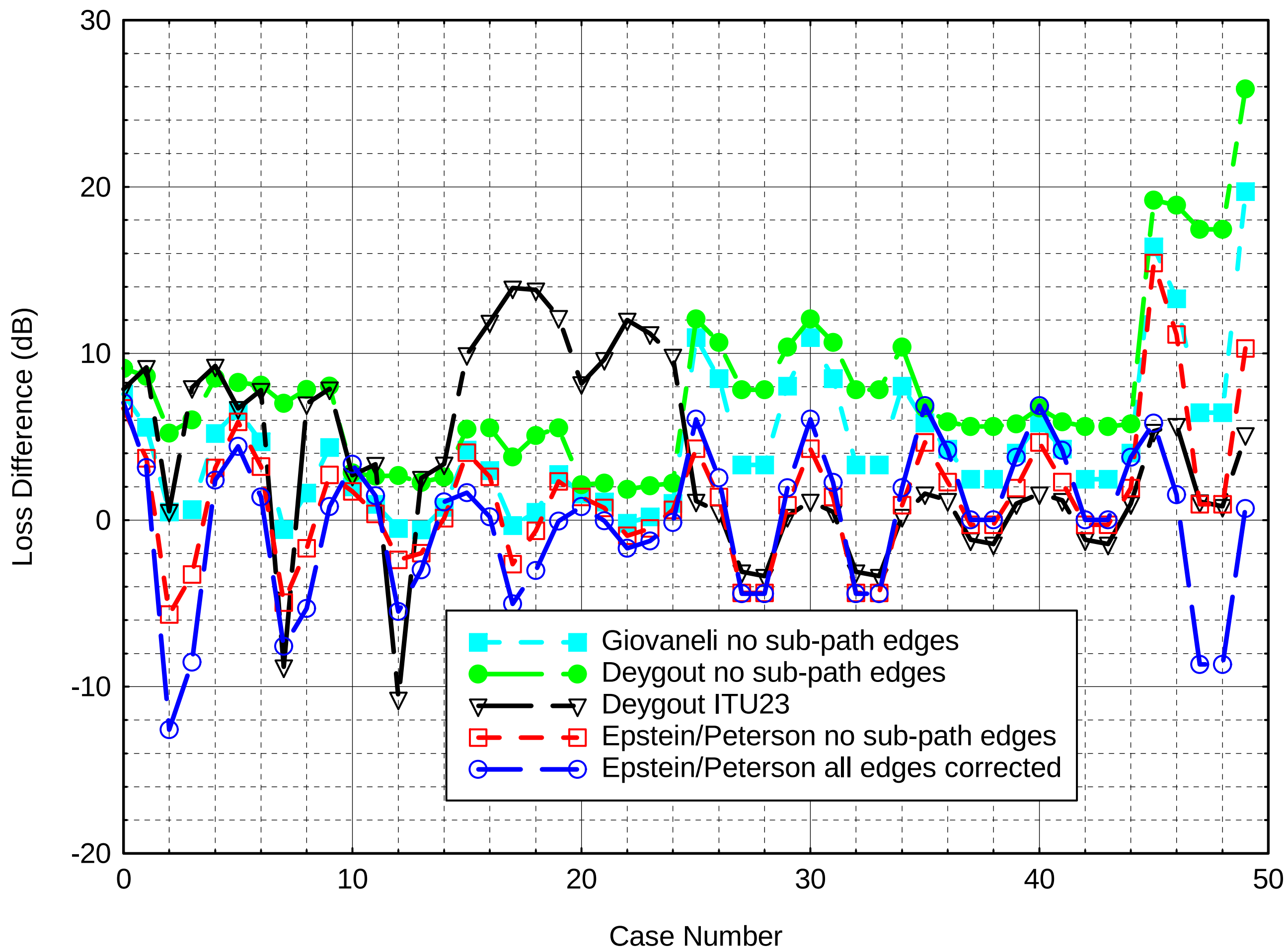
Diffraction Loss Difference Comparison wrt Vogler



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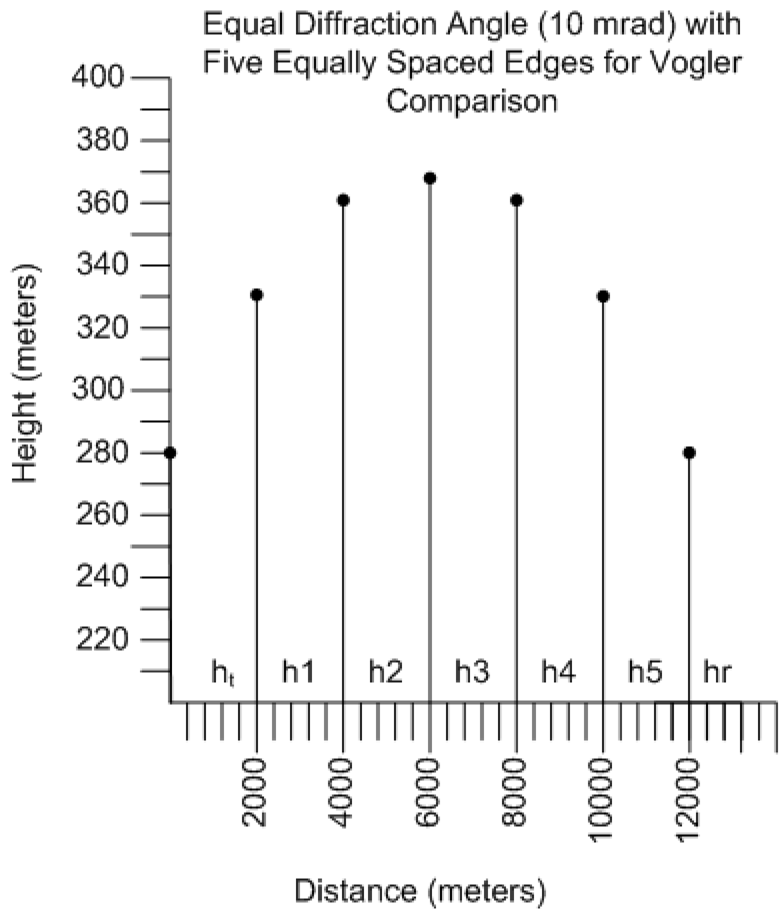

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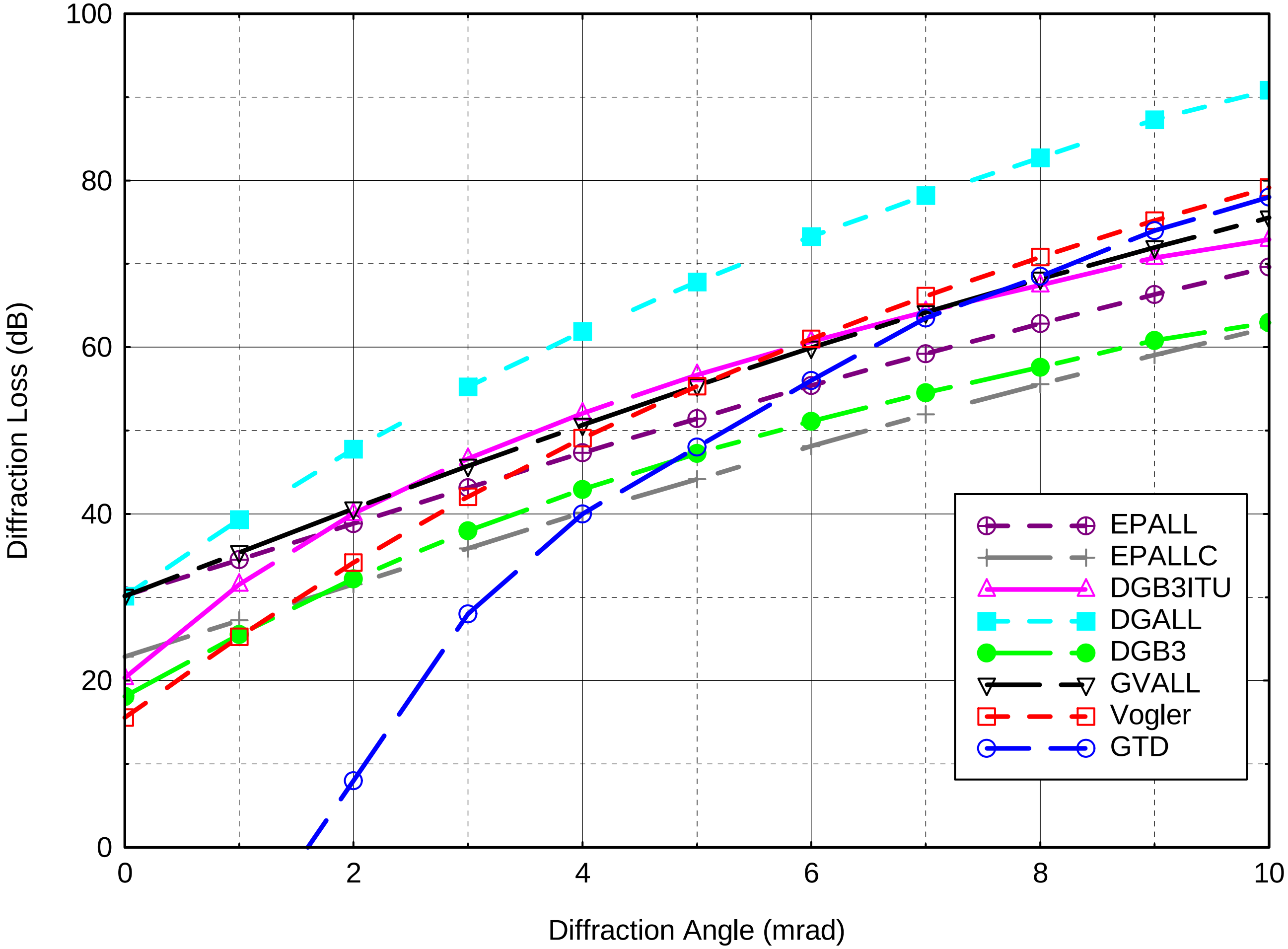
Comparison of Diffraction Algorithms With Vogler Algorithm for Five Equally Spaced Edges and Equal Diffraction Angles



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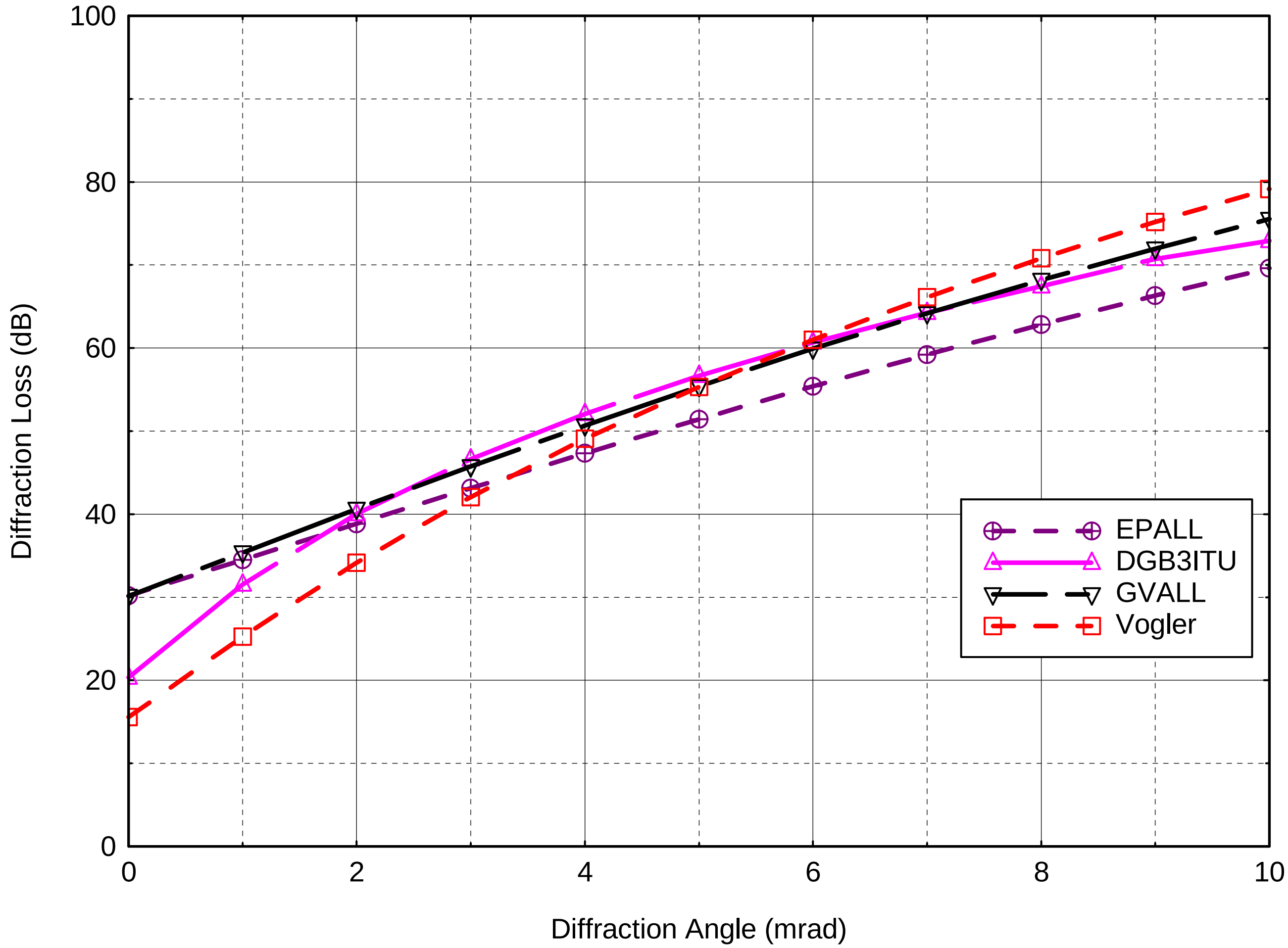

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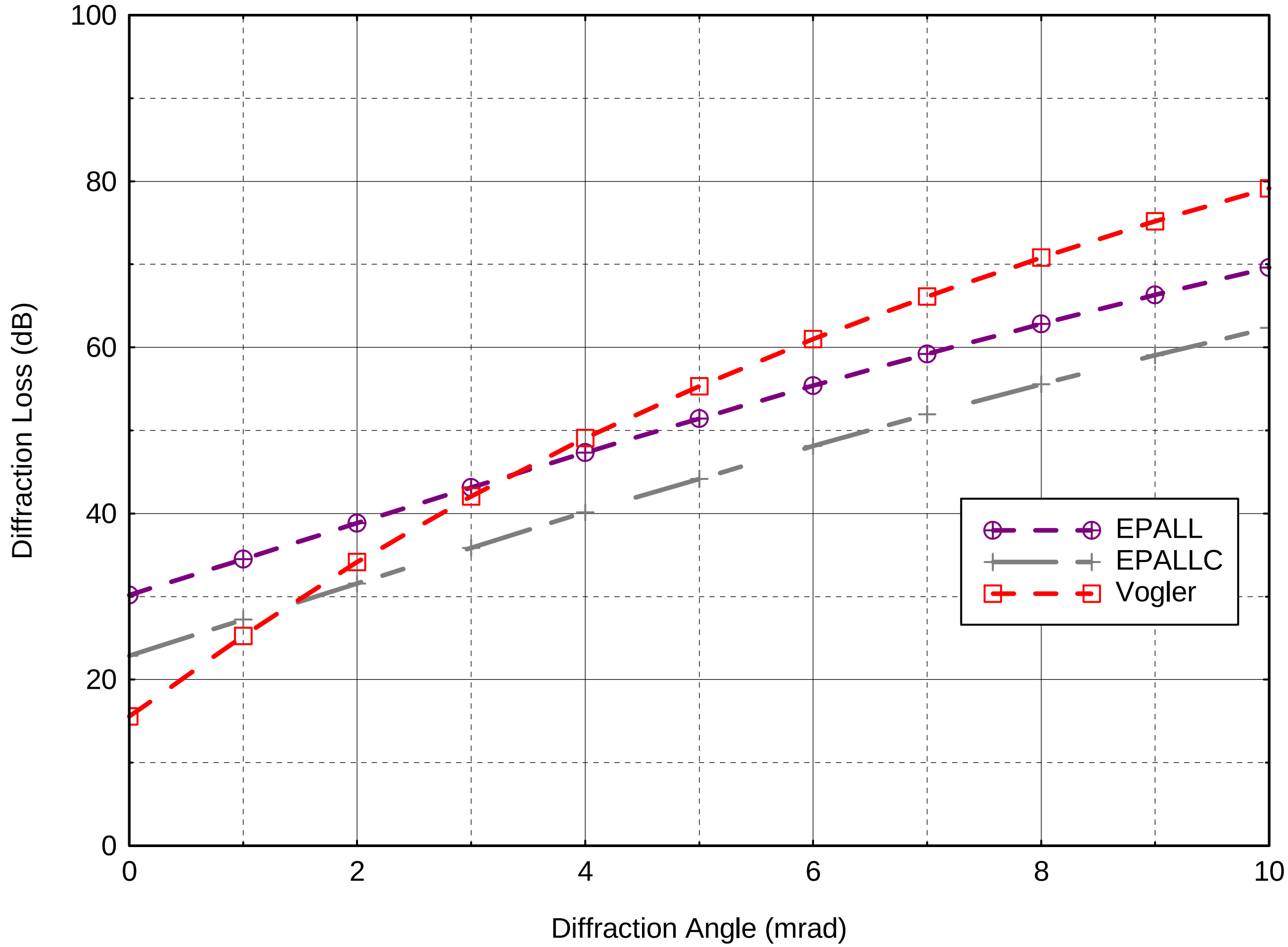

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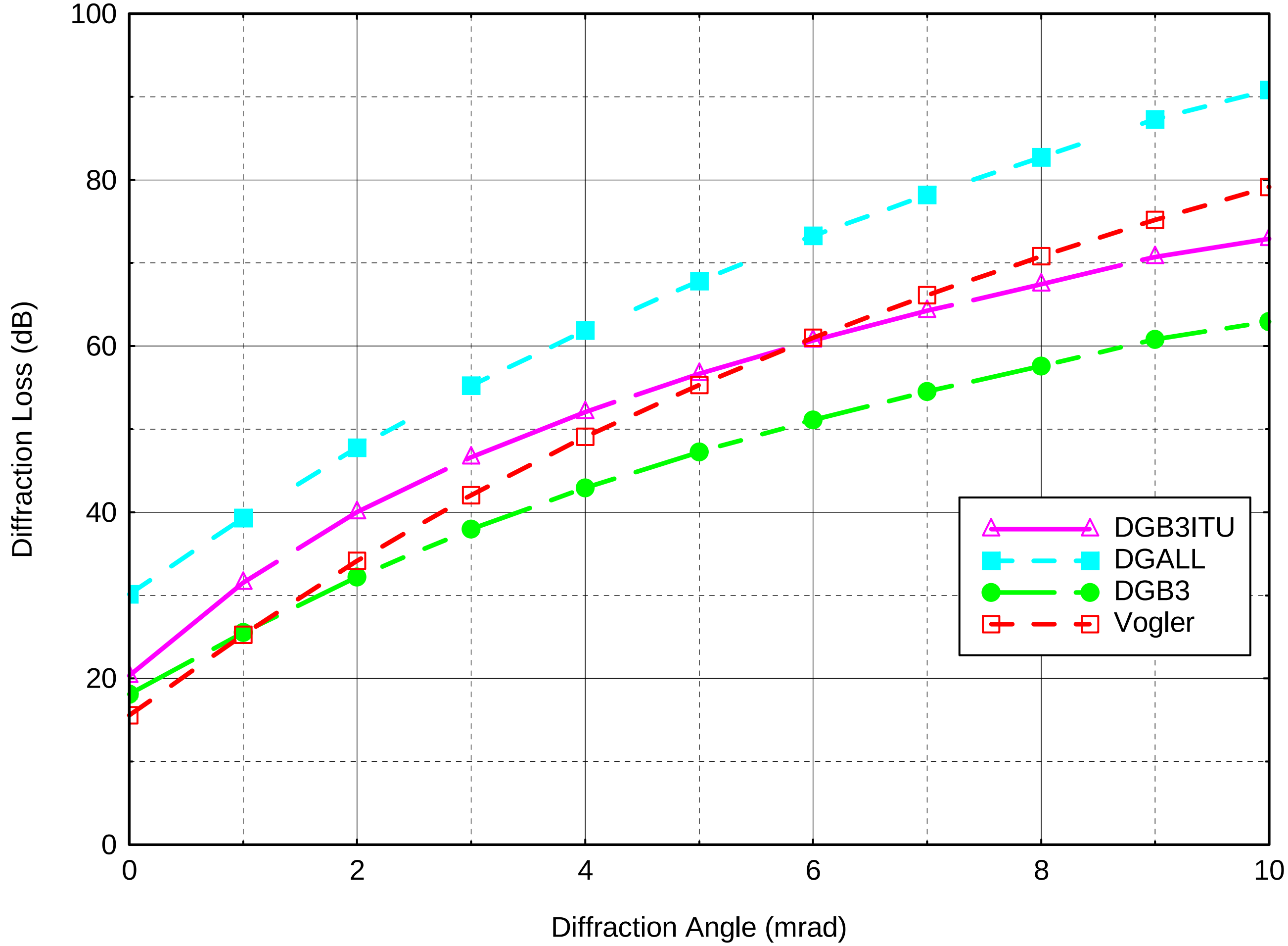

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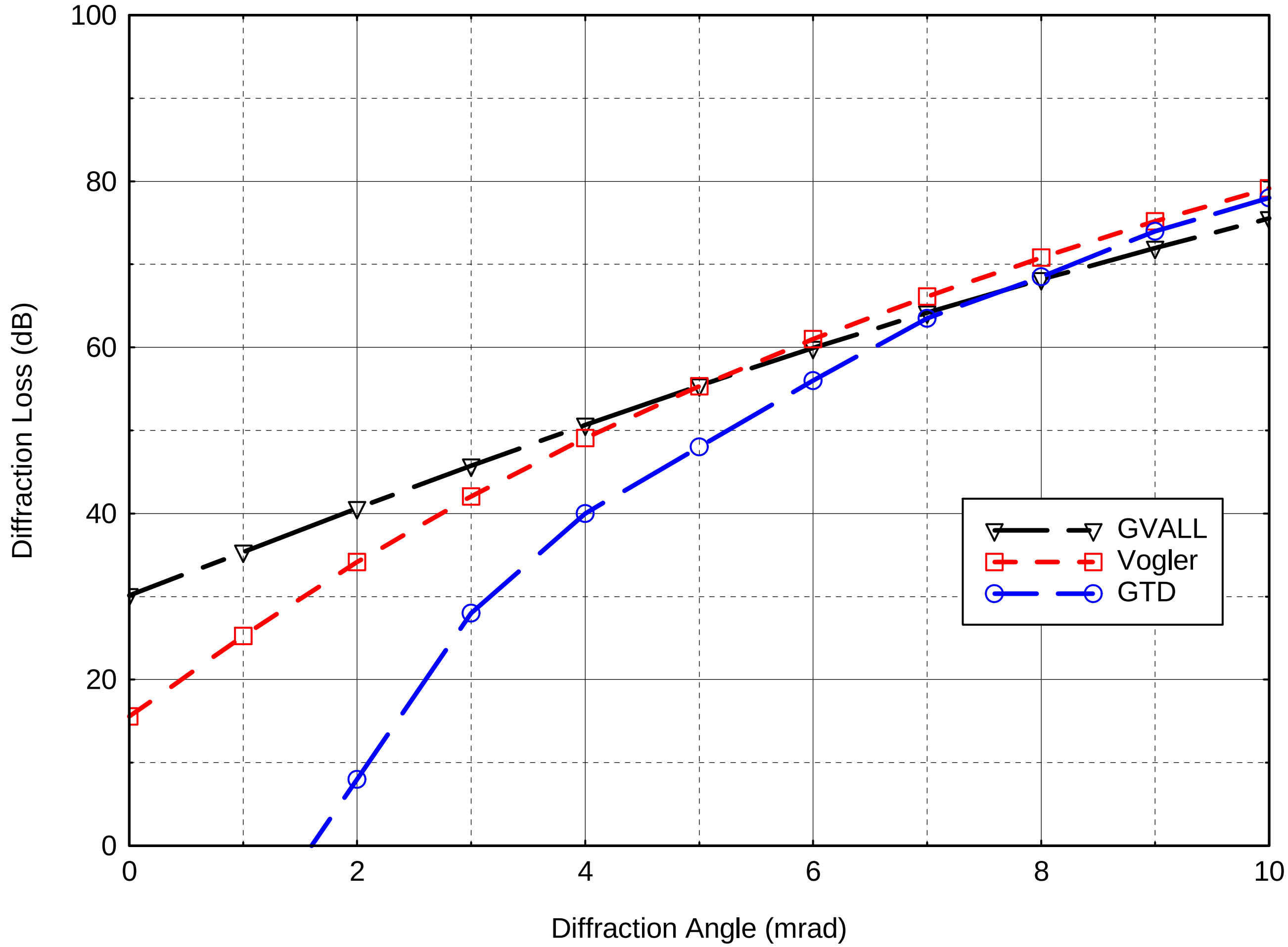

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Results

- It was found by comparative computations that removing the sub-path obstacles improves agreement between the Deygout method and the Vogler method, but degrades the Epstein/Peterson method's agreement with the Vogler method.
- Comparative computations show that the Deygout method achieves better agreement with the Vogler method when only the major three edges are included in the computation of diffraction loss.
- Further investigations of different geometric configurations representing additional diffraction scenarios will be run comparing the alternative methods with the Vogler method.

Results

- When a ray path from one edge to the next consecutive edge is in the transition region and near the incident or reflection shadow boundary, the alternative methods fail to compute the diffraction loss correctly.
- Computation of these ray-path angles and shadow boundaries confirm this.
- The procedure and order of computing edge diffraction loss is different for each of the alternative methods investigated.
- As a result, for the same diffraction scenario, one method may avoid alignment of the ray path with the incident shadow boundary, and another may align the ray path with the incident shadow boundary.
- The method that avoids this alignment will predict the diffraction loss with better accuracy, if the deviation of the ray path is large enough.
- An approach under study for selecting a diffraction method that achieves better accuracy is to use one method that has the largest deviation between the ray path and the incident shadow boundary.
- Another approach under study is to determine the magnitude of the error using the Fresnel Transition Function that provides a correction to the alternative method predictions.

Conclusions

- The diffraction losses for the four alternative algorithms were compared to the more rigorous Vogler algorithm for many scenarios.
- Preliminary results of this analysis show where the alternative multiple knife-edge methods investigated can be used in place of the vigorous Vogler diffraction method to reduce computation time while maintaining suitable accuracy.
- In addition, the analysis has demonstrated that any one of the three other alternative methods may be more suitable than the others for a particular knife-edge scenario.
- These scenarios included many variations of: varying distances between edges, different heights, and different height-to-distance between edge ratios over the range of desired frequencies.
- Which alternative diffraction method works best in a given scenario depends on how a method treats sub-path obstacles and the alignment of the deflection angles wit the shadow boundaries at the edges.