Jagged-edge noise barriers

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Abstract: Experimental investigations have shown that noise barrier performance can be improved by making the top edge randomly jagged. In the present theoretical approach the edge is modeled as a directive, crooked line source. Besides yielding predictions that agree favorably with measurements, the model is easy to apply. It is a promising and powerful tool for further research on jagged barriers.

INTRODUCTION

Interest in the theory of diffraction by a jagged edge has been stimulated by experimental data that show that edge irregularity can cause a substantial degradation of the diffracted signal(1, 2, 3). In many cases the jagged edge improves insertion loss by up to 5 dB. However, the experimental investigation showed that although the jagged edge changes the insertion loss by ±1 dB, as an average over all receiver locations, measurements made at single points show changes in the range -4 to 6 dB (3). Numerical investigations based on the Kirchhoff theory of diffraction led to the same observation. Two barriers having different edge profiles, but the same statistical description, differ greatly (±6 dB) in their shielding effect at a given receiver location(4). In the past the degradation of the diffracted signal has been qualitatively attributed to the incoherence of scattered contributions coming from a jagged edge as opposed to coherence of contributions coming from a straight edge. This explanation fails, however, to explain the aforementioned findings. In the following a method to predict the diffracted field behind a jagged edge barrier is presented.

THE DIRECTIVE LINE SOURCE MODEL

A method termed Directive Line Source Model (DLS model) is presented for predicting the field due to diffraction by straight- and jagged-edge barriers.

Diffraction from a straight-edge noise barrier, idealized as a thin rigid half plane, has a known exact solution for plane, cylindrical and spherical incident waves. We observed that in all three cases, provided the receiver is not close to the barrier edge and/or to the shadow boundary, the diffracted signal is equivalent to radiation from a coherent infinite line source, modified by the following directivity function: $D(\phi_s; \phi_r)$:

$$D(\phi_s; \phi_r) = \sec \frac{\phi_s - \phi_r}{2} + \sec \frac{\phi_s + \phi_r}{2}, \quad (1)$$

where $\phi_s$ and $\phi_r$ are the angles between the barrier surface and the plane containing the edge and the source or the receiver, respectively.

The mathematical formulation of this observation allows us to transform the diffraction problem into a radiation problem, which is in general simpler to solve. Consider for example a spherically spreading incident wave. The edge of the straight or jagged barrier is modeled as an infinite set of point sources continuously distributed along the edge. All point sources radiate the incident signal in phase. The radiation from each point source is directive according to Eq. (1). The diffracted signal at a receiver location is proportional to radiation from the directive line source, which is in turn obtained by integrating the contributions of the directive point sources along the edge of the barrier. However, the effective distance between the line source and the receiver in the radiation problem must equal the length of the shortest source-edge-receiver path in the diffraction problem.
RESULTS

The DLS model has been used to predict the diffracted field caused by a spherically spreading N wave diffracted by a jagged-edge barrier. The diffracted signals obtained by the DLS model are compared with experimental time waveforms measured in the shadow zone behind a variety of jagged-edge barriers and at various receiver locations. Typical comparisons are shown in Figs. (1) and (2) for a straight- and a jagged-edge barrier, respectively. The predictions are in reasonably good agreement with the experimental data.

Besides yielding predictions that agree favorably with measurements, use of the model presented here provides the following useful qualitative results:

1. Insertion loss varies significantly with receiver position.
2. The portion of the edge that intersects the shortest path between source and receiver plays an important role.
3. The shape of the diffracted signal remains roughly the same when the receiver moves away from the barrier, but changes appreciably when the receiver moves parallel to the edge.
4. The diffracted field behind a jagged-edge barrier approaches that behind a straight-edge barrier at great distances from the barrier.

Furthermore, because the model is easy to apply, it is a promising and powerful tool for further research on jagged-edge barriers. The ultimate goal is to be able to use the DLS model in the design process to specify the edge profile of a barrier that would increase the insertion loss (relative to a straight-edge barrier with the same average height) at a given set of receiver positions.

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REFERENCES