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AN INSERTION LOSS ANALYSIS OF PARTIALLY INCLINED BARRIER

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ABSTRACT
To increase an insertion loss of the barrier, the top of the barrier is designed in various shapes such as "Y", "T", multiple edges, cylinder, etc., whereas one of the widely used way is to incline the upper part toward the noise source. So far, insertion loss of the barrier having complicated top shapes may have been predicted in an approximate way where the barrier is replaced by a simple screen type having increased height, as long as the dimension of the complicated top part is much smaller than the height. In this paper, more rigorous prediction method is developed for partially inclined noise barrier where the length of the inclined portion may be comparable to the total height. In addition to the diffraction at the top, the diffraction at the corner point in the middle portion is also considered, which is an extension of Kouyoumjian and Pathak's method. A 1/10 scaled-down model test is performed in anechoic room, where effect of the finite length of the barrier is also studied. The comparison of theoretical and experimental values in narrow band spectrum shows that the theoretical result generally represents the average value of experimental insertion loss, while there are many oscillations in experimental result.

1 - INTRODUCTION
Barriers are commonly used as an effective measure against traffic and other industrial noise. To obtain better performance, the height of the barrier must be increased for generating larger shadow regions. However, in most situations, the height of the barrier is limited due to construction cost and more importantly, visibility of the residents. Alternatively, to have a high insertion loss without increasing the height, the top part of the barrier has been designed in various shapes such as "T", "Y", "O", arrow profile [1] and even more complicated designs like a interference type.
Theoretical analyses of the barrier, based on diffraction theories, have been done only for simple configurations such as a semi-infinite wedge [2, 3] and simple screen type barrier. For a thick barrier Pierce [3] proposed a formula for double diffraction by applying single wedge diffractions consecutively and Kawai [4] extended Pierce's idea to many-sided barriers or pillar. In this study we investigate the insertion loss of a partially inclined barrier by considering multiple diffractions.

2 - THEORETICAL ANALYSIS
We consider a barrier whose upper part is inclined toward the source with angle θ as shown in Fig. 1. The edge angles at the point 1, 2, and 3 are defined as $\nu_1\pi$, $\nu_2\pi$ and $\nu_3\pi$. The waves propagating from the source point S reach the receiver point R by diffraction at the top and corner points. The total sound field ϕ may be expressed as summation of individually diffracted waves over all possible paths

$$\phi = \phi_2 + \phi_{12} + \phi_{23} + \phi_{123} \tag{1}$$

where subscript numbers denote the points at which the waves are diffracted. For instance, ϕ_2 represents singly diffracted wave at point 2 and ϕ_{12} means doubly diffracted wave at point 1 and 2. The waves may

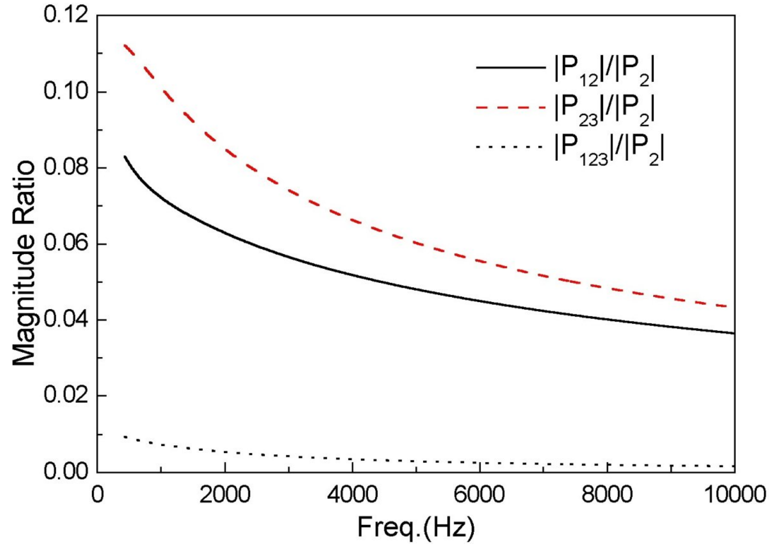

Figure 1: A partially inclined barrier.

be diffracted at the same points more than once. However, such terms are negligible compared to the terms diffracted by the same point only once.

For singly diffracted wave ϕ_2, we use the formula by Kouyoumjian and Pathak [2], for which the error is within 0.5dB if the associated distances are less than $\lambda/4$, where λ is the wavelength. According to Kawai's expression [4], the singly diffraction term is given by

$$\phi_2 = \frac{\exp\left(ikL_{SR}\right)}{L_{SR}}\left[V_2\left(A, B, \theta_{R2}-\theta_{S2}\right)+V_2\left(A, B, \theta_{R2}+\theta_{S2}\right)\right] \tag{2}$$

where

$$L_{SR}=\sqrt{\left(r_{S2}+r_{R2}\right)^2+\left(z_S-z_R\right)^2}, \qquad A=r_{S2}r_{R2}/L_{SR}, \qquad B=1$$

in which r_{S2} and θ_{S2} are radial distance and angle from point 2 to S, etc., and k is the wave number. The function V_2 represents diffraction coefficient at the edge point 2 (see Kawai [4] for detailed expressions). For doubly diffracted waves where all edges are convex such as ϕ_{23} in Fig. 1, we may use Pierce or Kawai's expression. However, the partially inclined barrier has convex (at point 2 and 3) and concave edges (at point 1). If we closely reexamine Kouyoumjian and Pathak's theory, we find that their diffraction theory holds for arbitrary wedge angle. Hence, we can formulate the double diffraction terms by applying Kouyoumjian and Pathak's single diffraction theory consecutively for convex and concave edges. The doubly diffracted term ϕ_{12} is given by

$$\phi_{12}=2\frac{\exp\left(ikL_{S12R}\right)}{L_{S12R}}V_1\left(A_1, B_1, \nu_1\pi-\theta_{s1}\right)V_2\left(A_2, B_2, \theta_{R2}\right) \tag{3}$$

The triply diffracted term ϕ_{123} may be given in a similar manner.

As a numerical example, we consider a barrier where $\theta=45°$, $\nu_1=3/4$, $\nu_2=2$, $\nu_3=5/4$, inclined part is 0.2m, and height of vertical section is 0.4m. The source and receiver positions in (x,y) coordinates (the origin is at the cross point of the barrier and ground) are: S=(1 m, 0.05 m); R=(-1 m, 0.25 m). To see the contributions from high order diffraction terms, we compare the ratio of magnitudes, $|P_{12}/P_2|$, $|P_{23}/P_2|$ and $|P_{123}/P_2|$ in Fig. 2 (here, we did not take into account the reflection from the ground). Doubly diffracted term is 5% to 10% of singly diffracted term, while triply diffracted term is less than 1%.

3 - SCALE MODEL EXPERIMENT

A scale model of a barrier was constructed in an anechoic room, where room size is 4 m × 5 m × 4 m (length × width × height). The model was made of 9 mm thick plywood with polished surface and the ground was covered with the same plywood. The length of the inclined part is 0.2 m, while vertical part is 0.4 m long. The source is fixed at (1.0 m, 0.077 m). The inclined part is connected to vertical section by using a thin metal brace. The insertion loss of the barrier was measured for frequency range from 500

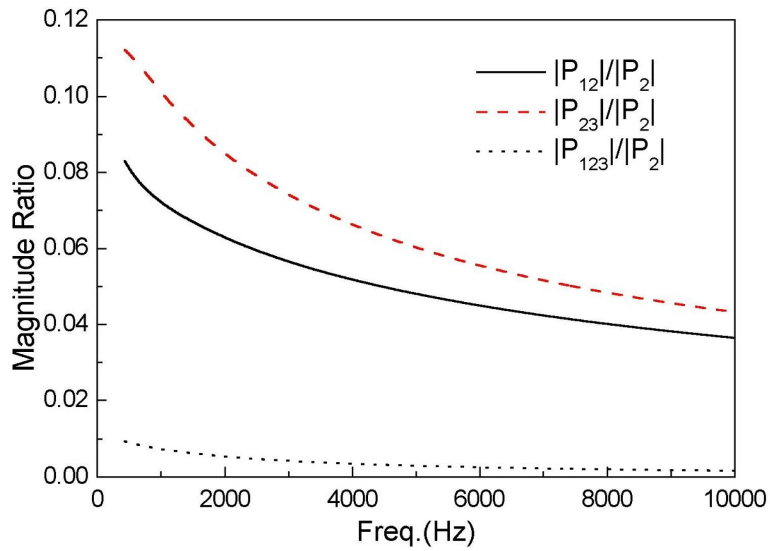

Figure 2: Magnitude ratios of doubly and triply diffracted waves to singly diffracted wave.

to 20 kHz. To increase the omni-directionality of the speakers, we attach circular pipes to the speakers. In Fig. 3, we compare the measured and computed insertion losses of the infinitely long barrier when $\theta = 45°$. The receiver position is R=(-1.0m, 0.9 m). The comparison shows reasonable agreements.

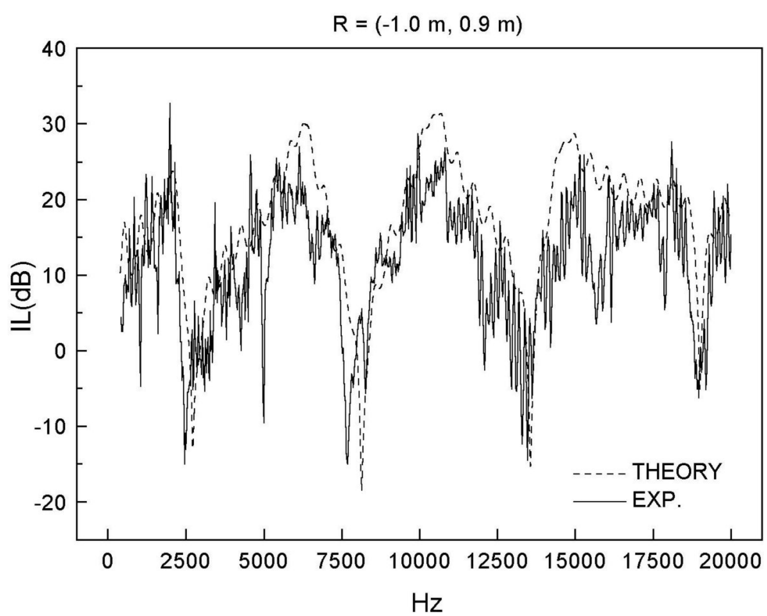

Figure 3: Insertion losses of infinitely long barrier when $\theta = 45°$.

In theoretical predictions in Figs. 2 and 3, we neglected the thickness of the barrier and assumed a knife edge. But, the barrier is of finite thickness (9 mm) and its edge is actually four-sided shape. In order to check the effect of the barrier thickness, we included diffraction at the additional points along the edge. In Fig. 4, we recalculated the insertion loss given in Fig. 3 by adding diffractions occurring due to the finite thickness. We find that small oscillations found in Theory 1 (neglecting thickness) becomes much smoother in new prediction (Theory 2). The small width along the edges is about 7 mm and the frequency satisfying the condition, $\lambda/4 \geq 7$ mm, is 12 kHz.

4 - CONCLUDING REMARKS

A partially inclined barrier has convex as well as concave edge shapes, and Kouyoumjian and Pathak's diffraction theory was employed to construct multiple diffraction coefficients. The assumptions of negligible barrier thickness and knife edge may have significant effects on the insertion loss for the present

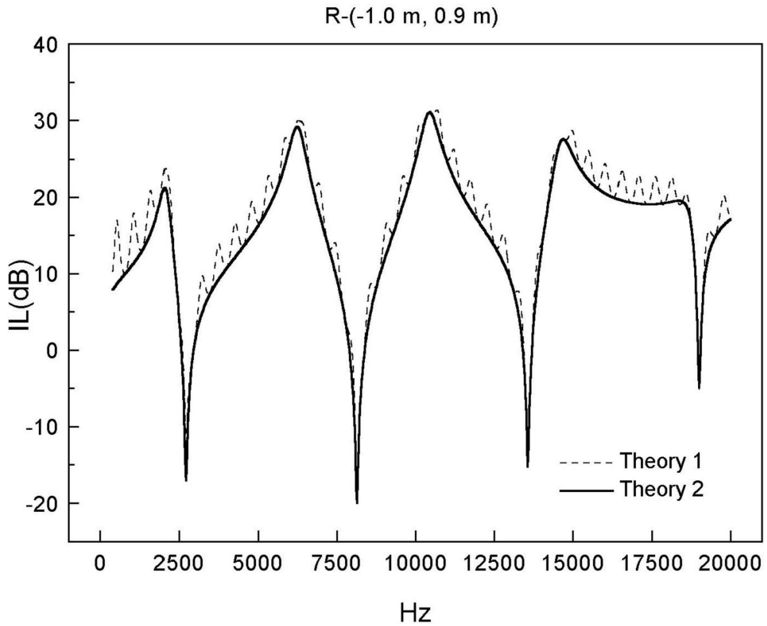

Figure 4: Insertion loss predictions: neglecting thickness (theory 1), and considering thickness and additional diffraction along edge points (theory 2).

barrier model, since the barrier thickness 9 mm is comparable to $\lambda/4$ for most frequency ranges. It was shown that additional diffraction at the edge points due to finite thickness causes smoothing effect by removing many small ripples in frequency domain. The theoretical formulation presented here may be applied to study performance of more general cases such as "T" and "Y" shaped barriers.

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REFERENCES

1. **D.C.Hothersall, D.H.Crombie, and S.N.Chandler-Wilde**, The performance of T-profile and associated noise barrier, *Applied Acoustics*, Vol. 32, pp. 269-287, 1991

2. **R.G.Kouyoumjian and P.H.Pathak**, A uniform geometrical theory of diffraction for an edge in a perfectly conducting surface, *Proceedings of IEEE*, Vol. 62, pp. 1448-1461, 1974

3. **A.D.Pierce**, Diffraction of sound around corners and over wide barriers, *Journal of the Acoustical Society of America*, Vol. 55, pp. 941-955, 1974

4. **T.Kawai**, Sound diffraction by a many-sided barrier or pillar, *Journal of Sound and vibration*, Vol. 79, pp. 229-242, 1981