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A PARAMETRIC INVESTIGATION OF THE ACOUSTICAL PERFORMANCE OF SIMPLE NOISE BARRIER TOP EDGE DEVICES.

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A detailed study has been undertaken, using computer modeling, of the effect of changing the size of various parameters on the relative insertion loss afforded by a T profile top edge. It was found that the relative insertion loss afforded by a given T top configuration is a function of the location of the source, the barrier and the receiver and also the height of the barrier. The relative insertion loss varies systematically with changes in these parameters and this systematic variation could be incorporated into a prediction method. The relative insertion loss afforded by a reflective T-top is negligible, however, significant attenuation can be obtained with an absorptive top and this increases with increasing top width. A given T-top appears to perform better when located on a reflective barrier, however, this may be due to the T-top acting to nullify any benefit arising from adding absorption to the face of a simple barrier.

1. Introduction

Modifications to the top edges of noise barriers have been shown to be capable of increasing noise attenuation over that of a simple barrier of the same height [1]. Whilst early work was concerned primarily with simple devices such as the T profile and multiple edged treatments[2, 3], more recent work has concentrated on more complex devices such as the use of Quadratic Residue Diffusors[4]. However, the experience of the authors on the EU funded Holiwood project, one aspect of which was the development of a "sustainable" top edge device to be manufactured from thermally treated timber, is that manufacturing difficulties with this material militate against the development of any device that is not simple to make. As part of the Holiwood project, therefore, a study has been carried out of the performance of a number of simple top edge devices. A detailed study was undertaken using computer modelling of the effect of changing the size of various parameters of the T profile top edge.

2. Parameters affecting top edge performance

Hothersall, Crombie and Chandler-Wilde[2], building on a body of earlier work, employed the Boundary Element Method (BEM) to conduct a detailed investigation into the performance of T-profile barriers which contributed greatly to the understanding of how these devices perform. However, although their work included an investigation of the effect of a number of parameters on the performance achieved with a T-top, the results presented were not in a form that could be easily incorporated into barrier prediction techniques. Whilst their work confirms the general consensus which is that an absorbent T-top is effective, there is no agreement amongst research findings as to the additional attenuation that it can provide. There are a number of reasons for this lack of agreement.

First, In order that the relative performance of different top edge configurations can be compared easily and also to provide information that can be used easily by highway engineers, it is usual to express the effect of the top edge relative to that of a simple barrier of the same height. The top edge performance is usually expressed in terms of a single figure value, the relative insertion loss, obtained by combining the frequency dependant characteristics with a standard traffic noise spectrum. It has been shown that the choice of spectrum can affect the single figure value obtained [5].

Secondly, the top edge device modifies the diffracting properties of a simple barrier and, as in the case of a simple barrier, its performance will be a function of frequency and the source-barrier-receiver geometry. Thus the source-barrier-receiver geometry might be expected to affect the attenuation provided. In early work on top edge performance, the additional effect of the top edge was expressed either as values at specific locations or as an average value relating to a number of specific receiver locations. The latter approach contains within it an implicit assumption that the top edge performance can be expressed as a constant numerical correction that can be applied to the predicted performance of a simple barrier irrespective of the relative positions of the source, barrier and receiver or of the height of the simple barrier. As noted by Morgan from examination of the literature, there is no consensus as to the distance that the source should be from the barrier or what height of barrier should be employed in far field measurements or simulations of barriers with top edge treatments [6]. More recently a near field measurement technique has been presented in the form of a European Standard in which the positions of source and receiver relative to the top of the barrier are tightly specified [7].

Thirdly, although the effect of applying absorbent treatment to the T-top has been investigated, the nature of this treatment has been varied. For example, when carrying out computer simulations, many investigators have modelled the absorption of a perfect absorber whilst others have employed more realistic treatments. Similar approaches have been used to model the absorptive properties of the face of the simple barrier.

Arising from the above discussion, a number of decisions were made with respect to the conduct of this study. First, the standard traffic noise spectrum employed was that defined in EN 1793-3 [8]. Secondly, an initial investigation was undertaken to investigate the effect of source location and barrier height on the performance of T-tops in order to establish a suitable configuration for a more detailed study of the performance of different T-top configurations. Tops with widths of 0.6m and 1.6m were employed for this part of the study as these values encompass a range of practical sizes. The second part of the work involved a parametric study of the performance of T tops, with and without absorptive treatment.

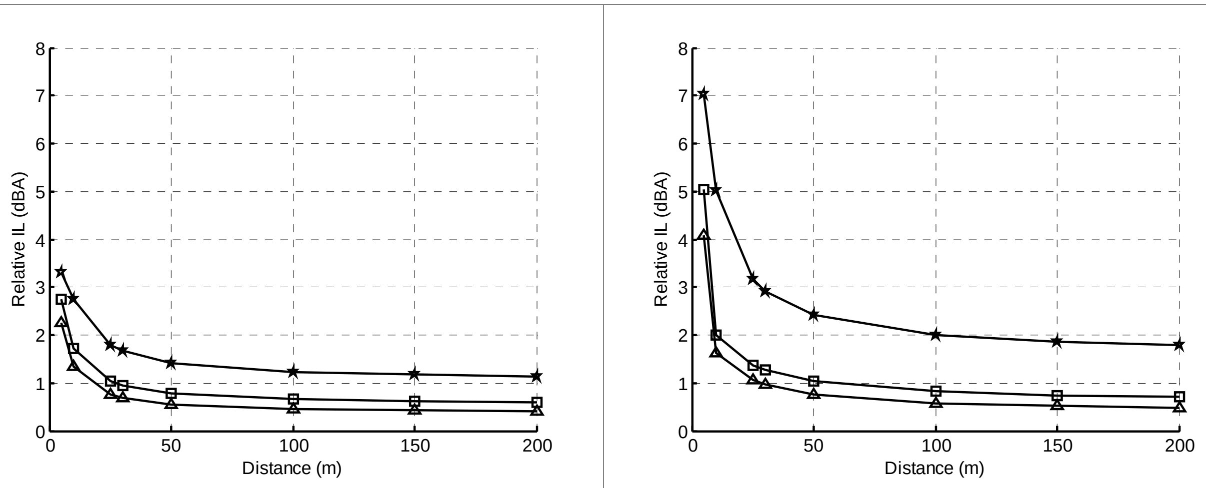
3. The BEM models

The 2D models of the barriers were meshed using Patran and then evaluated using SYSNOISE (BEM Indirect Frequency option) which is well suited to exterior radiation problems. For computational efficiency and to avoid the effects of interference, both source and receiver were located in the ground plane which was assumed to be a plane of symmetry.

Each model was evaluated at one third octave band frequencies from 100 Hz to 3,150 Hz which encompasses the most important frequencies in traffic noise. The sound pressure level on the opposite side of the barrier to the source was calculated out to a distance of 200m from the barrier. The sound pressure level was then weighted using the traffic noise weighting spectrum from BS EN 1793-3 which has its peak level at and around the 1 KHz frequency. Finally the components of the weighted spectrum were summed and subtracted from the free field level at each point to obtain the relative A weighted traffic noise insertion loss.

4. The effect of source location and barrier height

Figure 1 shows the variation in the relative insertion loss for 0.6m and 1.6m wide T-tops on a 3m high barrier as a function of the distance of receiver location for sources at 5m, 10m and 15m from the barrier. The barrier height was chosen as being typical of that employed in practice and the distances were chosen as covering the range of distances that a barrier might be positioned relative to traffic streams. For a given source location it can be seen that the relative insertion loss afforded by both T-tops decreases systematically with increasing distance of the receiver from the barrier. The additional attenuation afforded by the 1.6m top is always greater than that afforded by the 0.6m top. At any given receiver location the additional attenuation for both tops increases as the source barrier distance decreases.



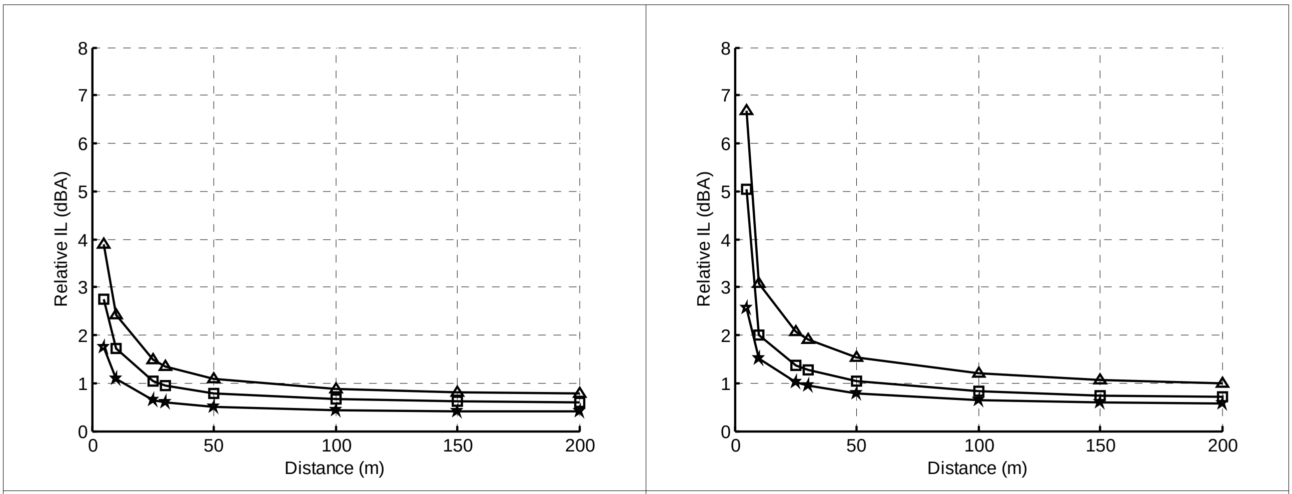
0.6m Wide T-Top

1.6m Wide T-Top

Figure 1 Effect of source position with distance for 2 T-top widths. (─★─5m Source Position, ─□─10m Source Position and ─△─ 15m Source Position).

Figure 2 shows the variation in the relative insertion loss for 0.6m and 1.6m wide T tops for a source distance of 10m as a function of the distance of receiver location for barrier heights of 2m, 3m and 4m. The barrier heights were chosen as covering the range commonly employed in practice and the source barrier distance was the median of the range employed above. For a given barrier height, it can be seen that the relative insertion loss afforded by both T-tops decreases systematically with increasing distance of the receiver from the barrier. The additional attenuation afforded by the 1.6m top is always greater than that afforded by the 0.6m top. At any given receiver location the additional attenuation for both tops increases as the barrier height increases.

The above observations are what might be expected from an effect that is due to diffraction at the barrier top. The condition for maximum path difference in all configurations examined is that for the minimum source barrier distance, maximum barrier height and largest T-top. The systematic decrease in top edge performance with increasing distance of the receiver from the barrier has been observed by Yamamoto et al [9] . The systematic variation of the additional attenuation with source barrier distance and barrier height suggests that data obtained for the median source barrier distance and the median barrier height considered above, can be used to estimate the performance for different geometrical configurations. Thus, for the remainder of this study a source barrier distance of 10m and a barrier height of 3m were employed.



0.6m Wide T-Top

1.6m Wide T-Top

Figure 2 Effect of barrier height with distance for 2 T-top widths. (—★—2m Barrier, —□—3m Barrier and—△—4m Barrier.)

5. The effect of the width of the T top.

In this part of the work the effect of varying the width of the T- top was examined for reflective tops, for tops treated with perfect absorber and for tops with a more realistic absorption treatment. The latter was taken to be a porous material of thickness 5cm with a flow resistivity of 10,000 rayls/m. The acoustical impedance of this treatment as a function of frequency was calculated by employing the Delany-Bazely model [10] and in the remainder of this paper will be denoted by DB_{10000}. It has the typical characteristics of a porous absorber with its efficiency falling at low frequencies.

Figure 3 shows one third octave attenuation spectra corresponding to the additional attenuation afforded by T-tops with widths from 0.6m to 1.6m as a function of frequency for the three absorbent conditions. It can be seen that whilst the effect of the perfect absorber is to increase the additional attenuation at all frequencies compared with that due to the reflecting top, the effect is more complicated for the case of the more practical absorbent treatment. Whilst the attenuation at frequencies above 1kHz is comparable to that of the perfect absorber, the additional attenuation at lower frequencies tends to be negative. Similar results have been reported by Garai and Guidorzi [11] who carried out near field measurements on T-top devices using the method of EN1793-4. Their results show a similar trough in the attenuation characteristics at around 400-500Hz and a peak at around 1600Hz. However, it is not possible to make a direct comparison as data regarding the absorbent treatment and the width of the T-top are not given.

Figure 4 shows the variation of the relative insertion loss, calculated using the traffic noise spectrum of EN1793-3, as a function of top width for T-Tops with the three different absorbent conditions, all mounted on a barrier with a reflective face. It can be seen that in all cases the relative insertion loss increases systematically with increasing top width, however, the rate of increase diminishes with increasing width suggesting that the benefit to be obtained from attempting to gain in performance by this method would not be an economical option. The values obtained for the reflective top are low, typically less than 1dBA, which is consistent with data provided by Hothersall et al [2]. However, Ishizuka [5] et al report a relative insertion loss of 1.9 dBA for a 1m wide rigid T-top which may be due to the use of receiver positions close to the barrier. A significant amount of additional attenuation is afforded by the tops treated with absorption. At a top width of 1m, the attenuation for the perfect absorber is approximately 5.1 dBA and for the more realistic absorber it is approximately 3.4 dBA. Ishizuka et al report a relative insertion loss of 5.3 dBA for a 1m wide T-top treated with perfect absorber which is comparable with the value of 5.1 dBA from this study. Hothersall et al, for the configurations with their most absorbent top, reported an additional attenuation of approximately 3dBA with a 1m wide top which again compares favourably with the results of this study. A direct comparison of results is not possible as their values were for a mean insertion loss corresponding to a number of measurement positions and for an unspecified broad band source spectrum.

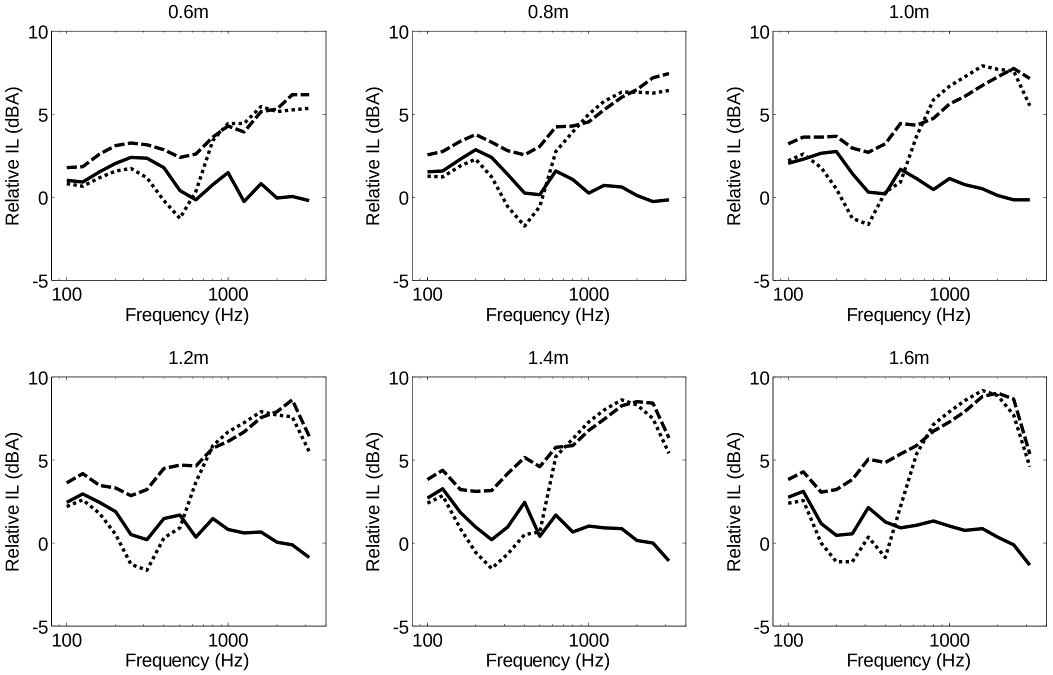


Figure 3 Spectral response of a reflecting T-top barrier with different T-top edge conditions (perfectly reflecting, perfectly absorbing and a realistic absorber). (—— Reflecting Top, ·········DB_{10000} absorber Top and ----- Perfect absorber Top).

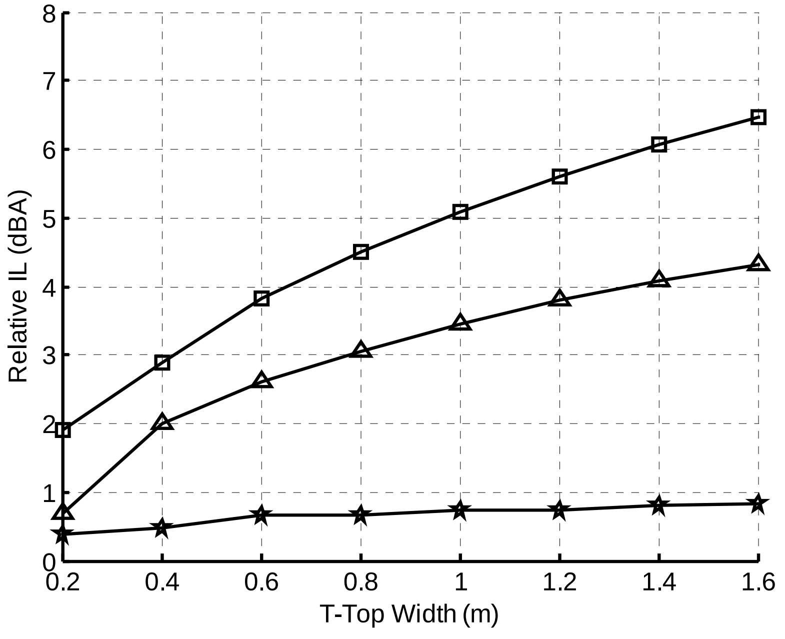


Figure 4 Relative insertion loss as a function of T-top width. (—★—Reflecting T-Top, —△— DB_{10000} absorbing T-Top and —□— Perfectly absorbing T- Top)

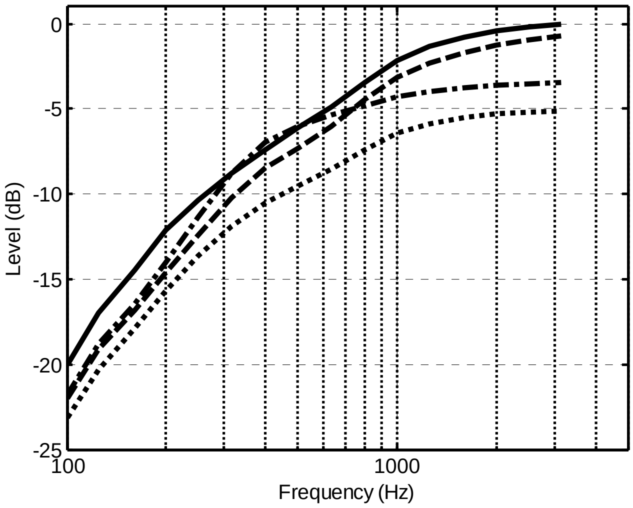


Figure 5 Cumulative plot for summation of one third octave levels with increasing frequency. —— Unmodified Standard Traffic Noise Spectrum, ----- Standard Traffic Noise Spectrum modified by 1m Reflecting T-Top, Standard Traffic Noise Spectrum modified by -·-·-·- 1m DB_{10000} absorbing T-Top and Standard Traffic Noise Spectrum modified by ·········· 1m Perfectly absorbing T-Top.

Figure 5 shows the cumulative addition of levels in the third octave bands for the standard traffic noise spectrum of EN1793-3; first without any absorption and then modified by the attenuation obtained with a 1m wide T-top for the three absorbent conditions examined. In the case of the reflective top it can be seen that the cumulative curve tends to lie just below that of the unmodified standard spectrum. In the case of the perfect absorber, the cumulative curve lies beneath that of the standard spectrum but the divergence increases as the frequency increases because of the dominant nature of the high frequency components of the A weighted traffic noise spectrum. In the case of the more practical absorber, the cumulative curve at low frequencies tends to lie above that of the reflective top but then falls below this curve at frequencies above 800Hz where the material absorbs efficiently. The curve suggests that employing a sound absorber with a better low frequency performance could be beneficial.

6. The effect of barrier face absorption on the performance of the top edge

In this part of the study a source barrier distance of 10m and a barrier height of 3m were employed and a T-top width of 1m. The relative insertion loss afforded was calculated for the case of a perfectly reflecting barrier face, a perfectly absorbent barrier face and a face covered with a 5cm thickness of porous material with a flow resistivity of 10,000 rayls/m. The additional attenuation was determined relative to that of the simple barrier for the three absorptive treatments employed for the T-top.

Figure 6 shows the relative insertion loss of the 1m wide T-top for all three treatments when mounted on barriers with the three different treatments. From examination of Figure 6, it can be seen that the results fall into three distinct bands, each corresponding to a particular T-top treatment. It would appear that the relative insertion loss afforded by the top edges, expressed in terms of the increase in attenuation relative to the attenuation of a simple barrier with the same absorptive treatment, decreases as the absorptive treatment of the barrier face becomes more efficient. This observation is similar to that reported by Garai et al [11] who found that the T-top performed better when located on a reflective barrier. However, as reported by Hothersall et al [12], the relative insertion loss afforded by a simple barrier increases slightly when the face on the source side is treated with absorption. Figure 7 shows the insertion loss of the simple barrier relative to that with a reflective face when treated with a perfect absorber and the DB_{10000} absorber. It can be seen that in the far field of the barrier this decrease in top edge attenuation is comparable to the increase obtained by treating the face of the reflective barrier with this absorption.

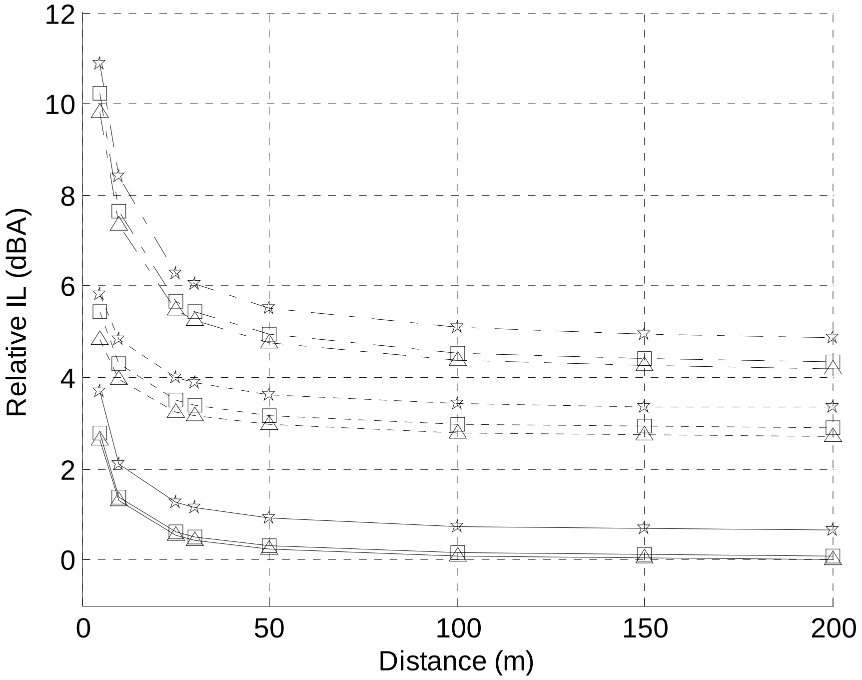


Figure 6 Variation of relative insertion loss with distance for a T-top incorporating different absorber conditions applied to top and barrier face. Upper band: top with perfect absorber with: * reflecting face; □ DB_{10000} absorbing face and Δ perfectly absorbing face. Middle band: top with DB_{10000} absorber with: * reflecting face; □ DB_{10000} absorbing face and Δ perfectly absorbing face. Lower band: reflecting top with: * reflecting face; □ DB_{10000} absorbing face and Δ perfectly absorbing face.

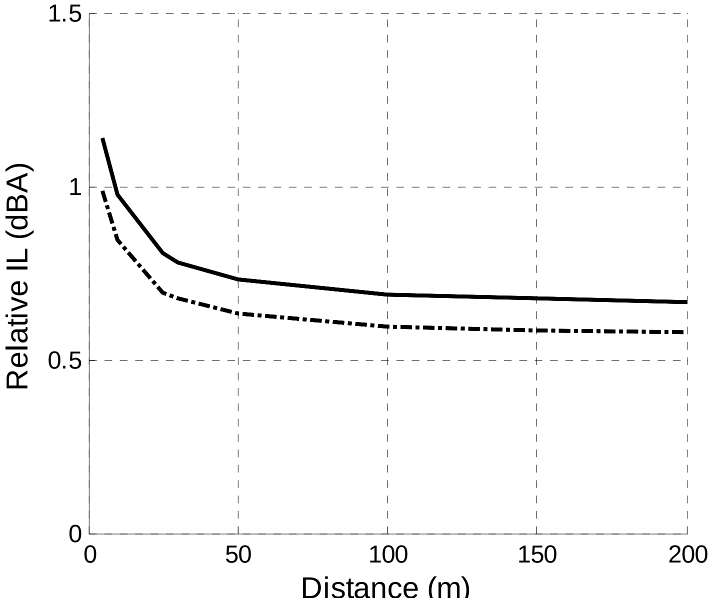


Figure 7 Variation of insertion loss relative to a simple barrier with reflective face with distance for a simple barrier incorporating different absorber conditions. -·-·- DB_{10000} absorbing face; — Perfectly absorbing face).

7. Conclusions

The following conclusions can be drawn from the above investigation. First, the additional attenuation afforded by a given T-top configuration is a function of the location of the source, the barrier and the receiver and also the height of the barrier. The additional attenuation varies systematically with changes in these parameters and this systematic variation could be incorporated into a prediction method. Secondly, although the additional attenuation afforded by a reflective T-top is negligible, significant attenuation can be obtained with an absorptive top. The amount of additional attenuation increases with increasing top width but the benefit to be obtained for widths in excess of 1.6m is not an economic proposition. Finally, a given T-top appears to perform better when located on a reflective barrier, however, this may be due to the T-top acting to nullify any benefit arising from adding absorption to the barrier face.

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