Virtual Education Lab: Eliminating flat plate frequencies through optimization.

The final solution to improving reflection phase gratings involves modifying the integer-related well depths associated with number theory sequences, which result in the diffusor transitioning into a reflecting flat panel at integer multiples, n, of the prime, N, times the design frequency f_0, (nNf_0). The integer-related relative well depths for a simple QRD based on a prime 7 are 1,4,2,2,4,1. If you know the depth of the well related to sequence number 1, you know them all. This results in a breakdown in the diffusor's ability to scatter incident sound uniformly at certain "flat plate" frequencies, because at these frequencies, all of the wells scatter in phase and the incident sound is specularly reflected.

For this QRD example, based on a prime 7 and a design frequency of 500 Hz, the diffusor will transition into a reflector at the flat plate frequencies of 3500 Hz, 7,000 Hz, 10, 500 Hz, etc. This is illustrated in a 40-year-old "overhead projector transparency" in Figure 1. The scattered energy is constant at integer multiples of f_0, the scattering is uniform up to $(N-1)f_{0,}$ and at integer multiples of Nf_0, the surface scatters incident sound in a specular direction.

Figure . Flat plate frequencies at $Nf_{0,}$ $2Nf_{0,}$ $3Nf_0$.

To design an improved well-depth sequence, we created a wave-based Boundary Element Method software called the Shape Optimizer. The flow chart for the Shape Optimizer is shown in Figure 2. It describes an iterative search for a non-integer-related well-depth sequence that provides an optimal diffusion coefficient.

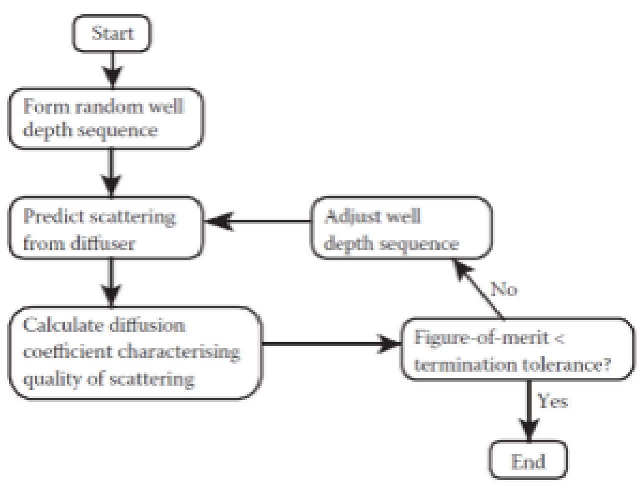

Figure . Shape Optimizer flow chart.

To do this iteratively requires the following:

1. A validated BEM prediction model.

2. A diffusion coefficient to measure the quality of scattering, based on ISO 17497-2.

3. A robust optimization algorithm, like the downhill simplex, to iteratively change the well depth sequences.

This optimization process produces an asymmetric, non-integer related, well depth sequence diffusor with optimal scattering properties. An example is shown in Figure 3. Thus, we simultaneously solve two problems:

1. We eliminate the flat plate frequency problem and
2. Produce an asymmetric diffusor that can be modulated according to an optimal binary sequence minimizing grating lobes.

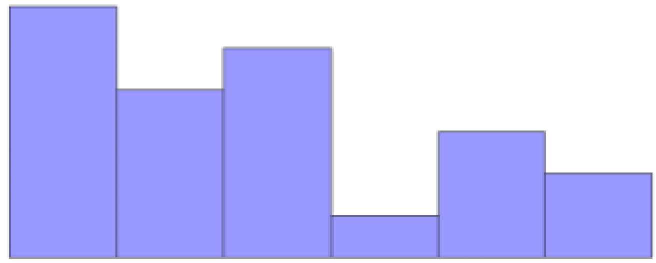

Figure . Optimized asymmetric diffusor with non-integer related well depths.

This concludes a description of how it is possible to remove three important limitations of a number theoretic diffusor. In the next post, we will review this evolution and present the improvement in the diffusion coefficient that has been possible.

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