# MVerb: A Modified Waveguide Mesh Reverb Plugin

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**Abstract.** MVerb is a plugin that is based on a modified five-by-five 2D waveguide mesh developed in Csound within the Cabbage framework. MVerb is highly flexible and can generate compelling and unique reverberation effects ranging from traditional spaces to infinite morphing spaces or the simulation of metallic plates or cymbals. The plugin incorporates a 10-band parametric EQ for timbrel control and delay randomization to create more unusual effects.

**Keywords:** Reverberation, Effects Plugin, Physical Modeling, Waveguide, Scattering Junction, Csound, Cabbage.

## 1 Introduction

Artificial reverberation can provide a compelling sense of acoustic space that factors significantly in the creation and production of digital audio. Digital reverberation models have changed dramatically both in quality and complexity as computational capabilities have evolved. These models include tapped recirculating delays comprised of comb and allpass filters coupled with multitap delay lines [1], physical models based on the projection of source vectors [2], impulse response convolution models [3], temporal smearing via asynchronous granular synthesis models [4], feedback delay networks [5] [6], closed waveguide mesh networks [3], and a wide variety of hybrid models.

Of these models, waveguide meshes provide interesting creative possibilities for great diversity of reverberation effects. The model for a classical waveguide mesh consists of a network of 4-port scattering junctions connected with waveguides that exhibit diverse delay times that can simulate different echo times and prominent resonances within an acoustic space [7]. With a sufficient number of waveguides, this physical model can emulate a wide variety of room colors and sizes as well as large plate reverberators and any number of other metallic (or non-metallic) percussion instruments. Waveguide mesh boundaries reflect the signal back into the mesh, inverting the signal with some signal loss and often filtering the reflection to emulate the absorptive qualities of a given physical space. Since it is a closed waveguide network, infinite reverbs will result unless a reflection coefficient of less than 1.0 is utilized. MVerb is based on a modified waveguide mesh that capitalizes on some of the unique possibilities of this physical model.

## 2 MVerb Waveguide Mesh Design

The classical 2D waveguide mesh consists of a network of 4-port scattering junctions configured with intermediary waveguides (see figure 1).

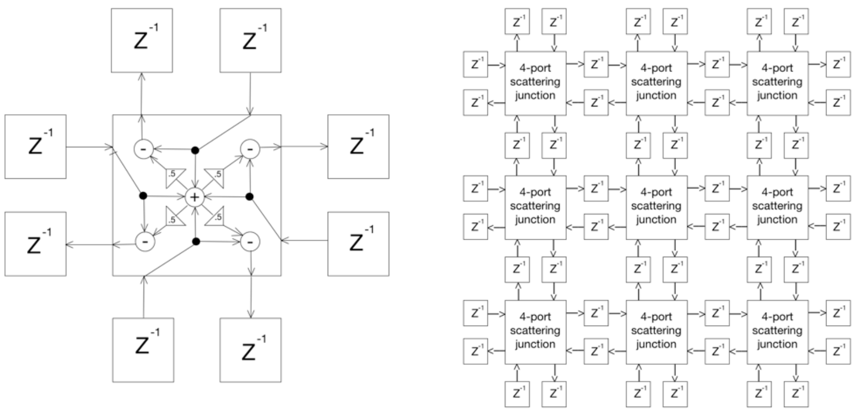


**Fig. 1.** 4-Port Scattering Junction and 2D Waveguide Mesh

While MVerb is fundamentally based on this model, it includes minor modifications that were incorporated to facilitate both slightly more efficient coding using Csound [8] within the Cabbage framework [9] and greater control and flexibility. MVerb consists of a 5 x 5 mesh with parametric EQ embedded within each scattering junction. A traditional 5 x 5 waveguide mesh includes a waveguide between every horizontal and vertical adjacency as well as each boundary, resulting in 120 delays organized in discrete pairs. Within Csound, the classical 2D waveguide mesh could be coded using UDOs to define each scattering junction and each connecting waveguide. However, the audio signal routing code connecting the scattering junctions and delay lines is extensive. In an effort to simplify this signal routing, the MVerb mesh model incorporates the waveguides within the scattering junction UDOs. Specifically, each scattering junction includes only the outgoing delays (half of each waveguide) with each of the 4 delays assigned a single delay time. While this still requires the use of 100 delays (25 scattering junctions with 4 outputs each), this modification provides greater efficiency and ease in structuring the waveguide mesh while retaining a rich set of prominent resonant frequencies.

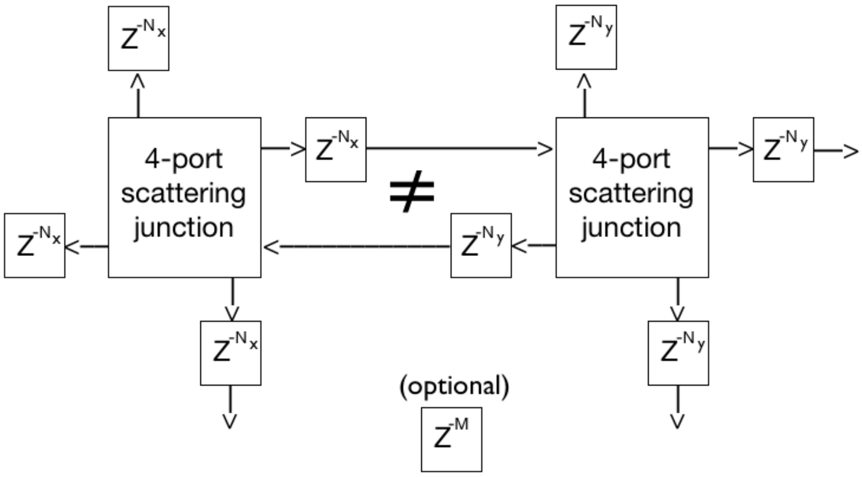


**Fig. 2.** MVerb Mesh Design

In this model, the waveguides between adjacent scattering junctions will consist of unequal delay values. Each unequal delay value will consequently have a unique resonant frequency. In addition, the MVerb mesh model also allows for variable delay lines.

The MVerb mesh modifications facilitate coding efficiencies through the incorporation of several primary UDOs. The *EQ* UDO creates a 10-band parametric equalizer that is embedded within each scattering junction. The *meshEQ* UDO defines a scattering junction and its associated output delay lines with identical delay times as follows:

```
opcode  meshEQ,aaaa,aaaaak
aUin,aRin,aDin,aLin,adel,kFB xin
afactor=(aUin+aRin+aDin+aLin)*-.5     ;calculate raw value
```

```
aUout   vdelay  aUin+afactor,adel,1000 ;calculate outputs
aRout   vdelay  aRin+afactor,adel,1000
aDout   vdelay  aDin+afactor,adel,1000
aLout   vdelay  aLin+afactor,adel,1000
aUout   EQ   aUout  ;apply EQ UDO to each output
aRout   EQ   aRout
aDout   EQ   aDout
aLout   EQ   aLout
xout    aUout,aRout,aDout,aLout
endop
```

After initializing the necessary delay lines, the code simply builds the mesh one scattering junction at a time. The naming conventions for this 5 x 5 model assign each scattering junction a letter (A through Y) with scattering junction inputs and outputs designated as up (U), right (R), down (D), or left (L). Thus, the audio signal *aGD* is the downward output from scattering junction G. The following code represents the top two rows of five scattering junctions using the *meshEQ* UDO:

```
aAU,aAR,aAD,aAL   meshEQ       aAU,aBL,aFU,aAL,adel1,kFB
aBU,aBR,aBD,aBL   meshEQ       aBU,aCL,aGU,aAR,adel2,kFB
aCU,aCR,aCD,aCL   meshEQ       aCU,aDL,aHU,aBR,adel3,kFB
aDU,aDR,aDD,aDL   meshEQ       aDU,aEL,aIU,aCR,adel4,kFB
aEU,aER,aED,aEL   meshEQ       aEU,aER,aJU,aDR,adel5,kFB
aFU,aFR,aFD,aFL   meshEQ       aAD,aGL,aKU,aFL,adel6,kFB
aGU,aGR,aGD,aGL   meshEQ       aBD,aHL,aLU,aFR,adel7,kFB
aHU,aHR,aHD,aHL   meshEQ       aCD,aIL,aMU,aGR,adel8,kFB
aIU,aIR,aID,aIL   meshEQ       aDD,aJL,aNU,aHR,adel9,kFB
aJU,aJR,aJD,aJL   meshEQ       aED,aJR,aOU,aIR,adel10,kFB
```

MVerb code also includes a master feedback coefficient, *kFB*, that is applied to each scattering junction as well as code to clear all delay lines. The plugin code contains ample gain and DC offset control to minimize potential signal problems prevalent in a closed waveguide mesh, thus providing convincing and controlled infinite reverberation when using a reflection coefficient of 1.0.

## 3 MVerb Features

Working within the Cabbage framework, MVerb incorporates a user interface (see figure 4) that includes numerous end-user controls that modify and shape the sonic result.

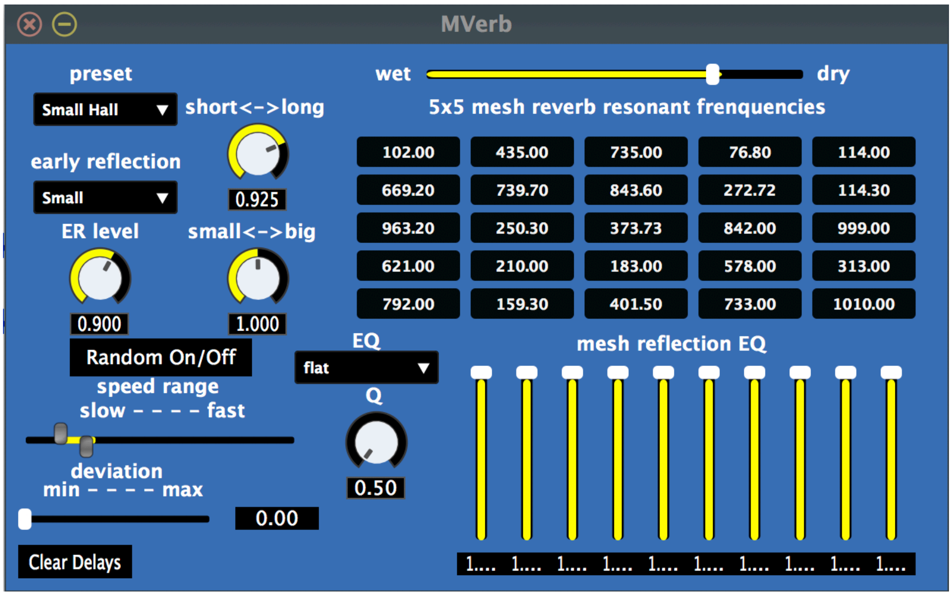


**Fig. 3.** MVerb User Interface

A variety of preset values can be selected to control an optional multitap delay line that adds early reflections to the incoming audio signal with independent output level control. Similarly, a number of preset delay times have been stored for the user to select. These presets include more traditional concert spaces, very colored or unusual reverbs, and effects with prominent resonances derived from sampled cymbals. MVerb also allows the user to define 25 prominent resonant frequencies, thus tuning each scattering junction output. The user interface also includes parametric equalizer controls, a master reflection coefficient, a button to clear all delays, and a master size control that applies a delay time multiplier to every scattering junction delay line. Finally, in an effort to create some more unusual and interesting effects, this plugin also includes an optional random deviation for each scattering junction delay value. This provides a possible means of creating the sense of a very slowly evolving and morphing room or, conversely, a rapidly changing and very noisy delay effect.

## 4 Conclusion

MVerb provides flexible and rich reverberation effect possibilities. While its current instantiation is a stereo effect, future plans include the development of MVerb plugins with various channel counts for inputs and outputs and better user preset capabilities. In addition, greater exploration of the sonic properties of meshes with a higher dimensionality (3D, 4D, . . . xD) and diverse configurations may prove to be a fertile area of discovery. In particular, non-planar mesh structures with more arbitrary or random scattering junction connectivity and reflection boundary placement may facilitate the development of more unusual effects.

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