Digital Signal Processing for Music

Part 20: Reverb

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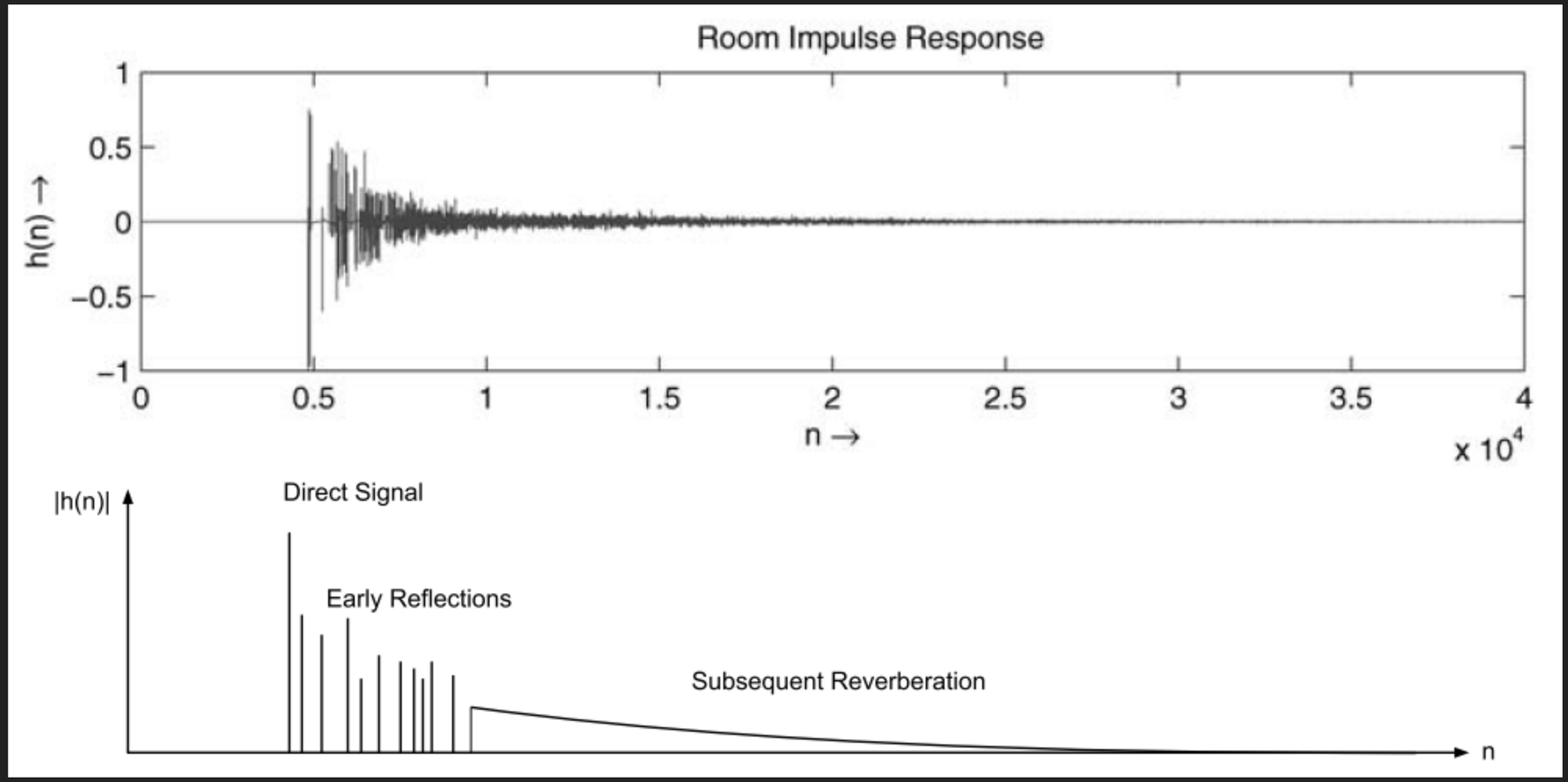
Intro

- **Idea:**
  - Artifically generate the impression of envelopment and reverberation
  - Possibly allow to modify specific characteristics of the "modeled" room
- **Approaches**
  - (Digital) parametric reverberation (predecessors: spring, plate, room, ...)
  - Fast convolution

Artificial Reverberation: Room Impulse Response



Room Impulse Response: Properties

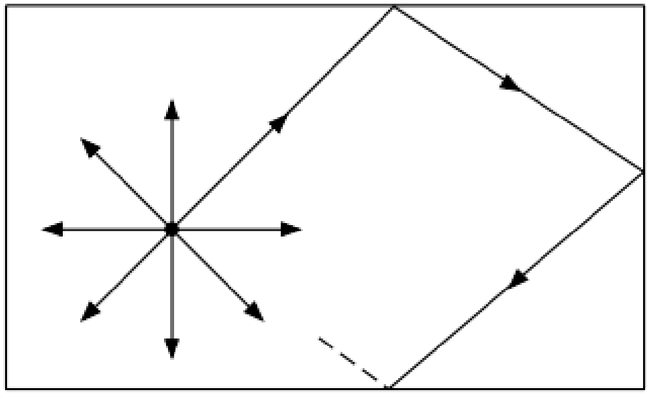
Room impulse response is sum of (filtered and delayed) reflections

- **Properties**
  - Level decrease is approximately linear
  - Density of reflections increases
- **Description**
  - Reverberation time: time in seconds for a level decrease of 60 dB
  - Depends mainly on
    - Room *volume*
    - Surface *area*
    - Surface *absorption*
  - Sabine:

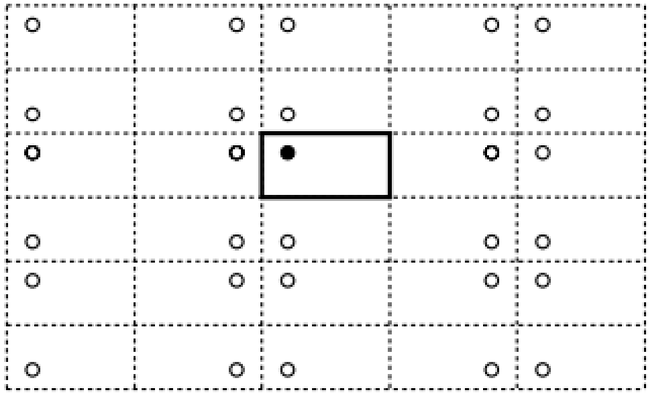
$$T_{\mathrm{RT}} = 0.163\mathrm{m}^{-1}\frac{V}{\sum \alpha_n \cdot S_n}$$

Room Simulation

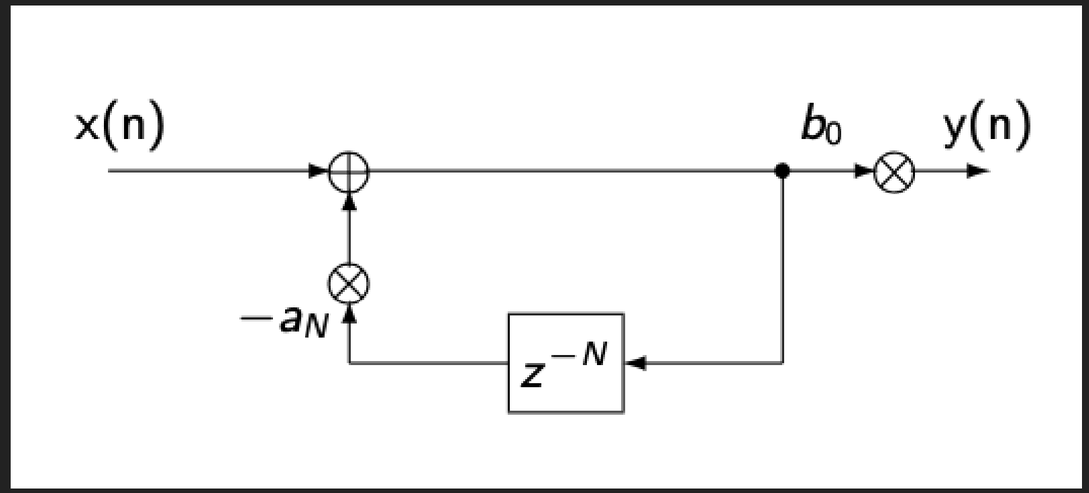
a) Ray Tracing



b) Virtual Image Sources



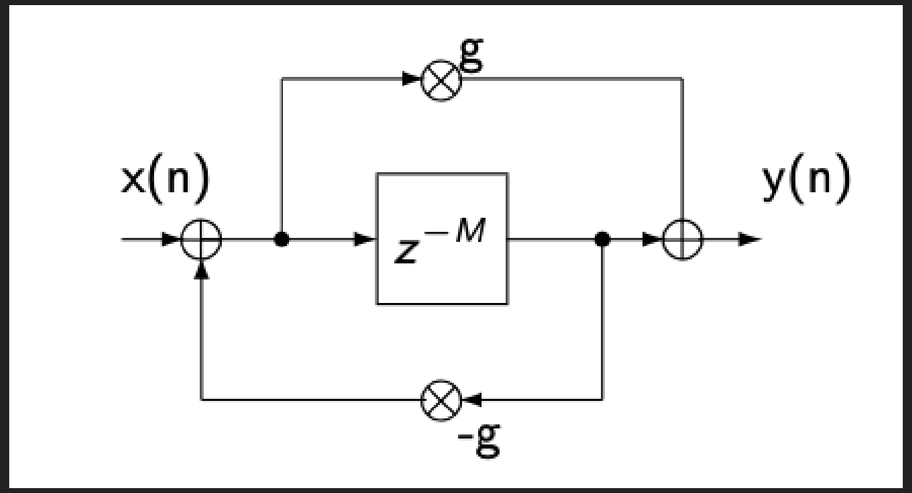
Traditionally Used Filters: Comb Filter



$$y(n) = b_0 \cdot x(n) - a_N \cdot y(n - N)$$

$$H(z) = \frac{b_0}{1 - a_N \cdot z^{-N}}$$

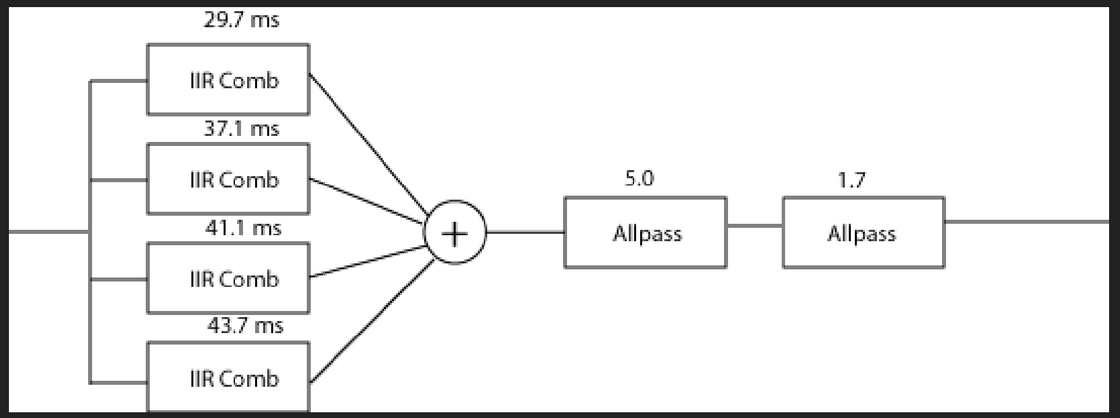
Traditionally Used Filters: All Pass Filter



$$y(n) = g \cdot x(n) + x(n - M) - g \cdot y(n - M)$$

$$H(z) = \frac{z^{-M} + g}{1 + g \cdot z^{-M}}$$

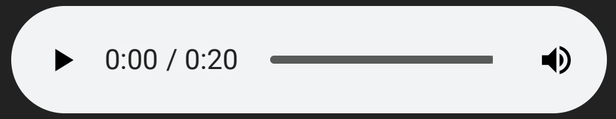
Reverberation: Schroeder

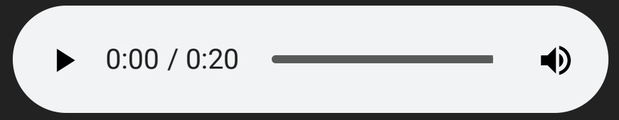


Questions:

- How to change the reverberation time?
- How to change the density?

Reverberation: Schroeder

- **Problems**
  - sound coloring (→ prime numbers)
  - Periodicity
- **Audio**
  - Original: 

  - Wet: 

Reverberation: Moorer

- Similar to Schroeder's model
- More comb filters
- Low pass in feedback paths
- Simple FIR model for early reflections
- Original: 0:00 / 0:20
- Wet: 0:00 / 0:20

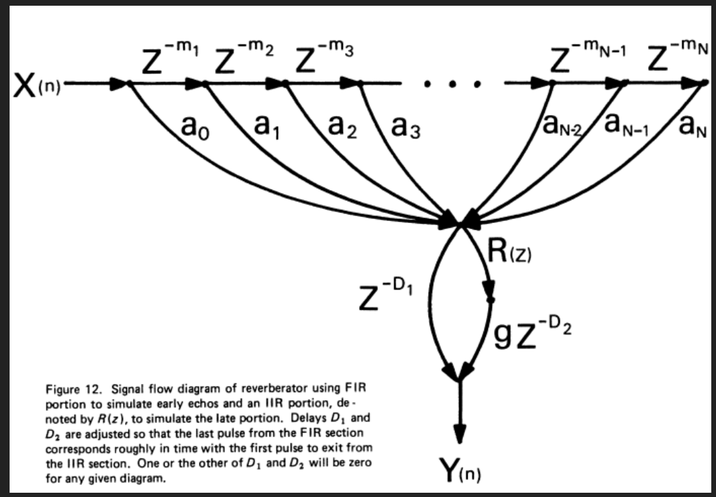
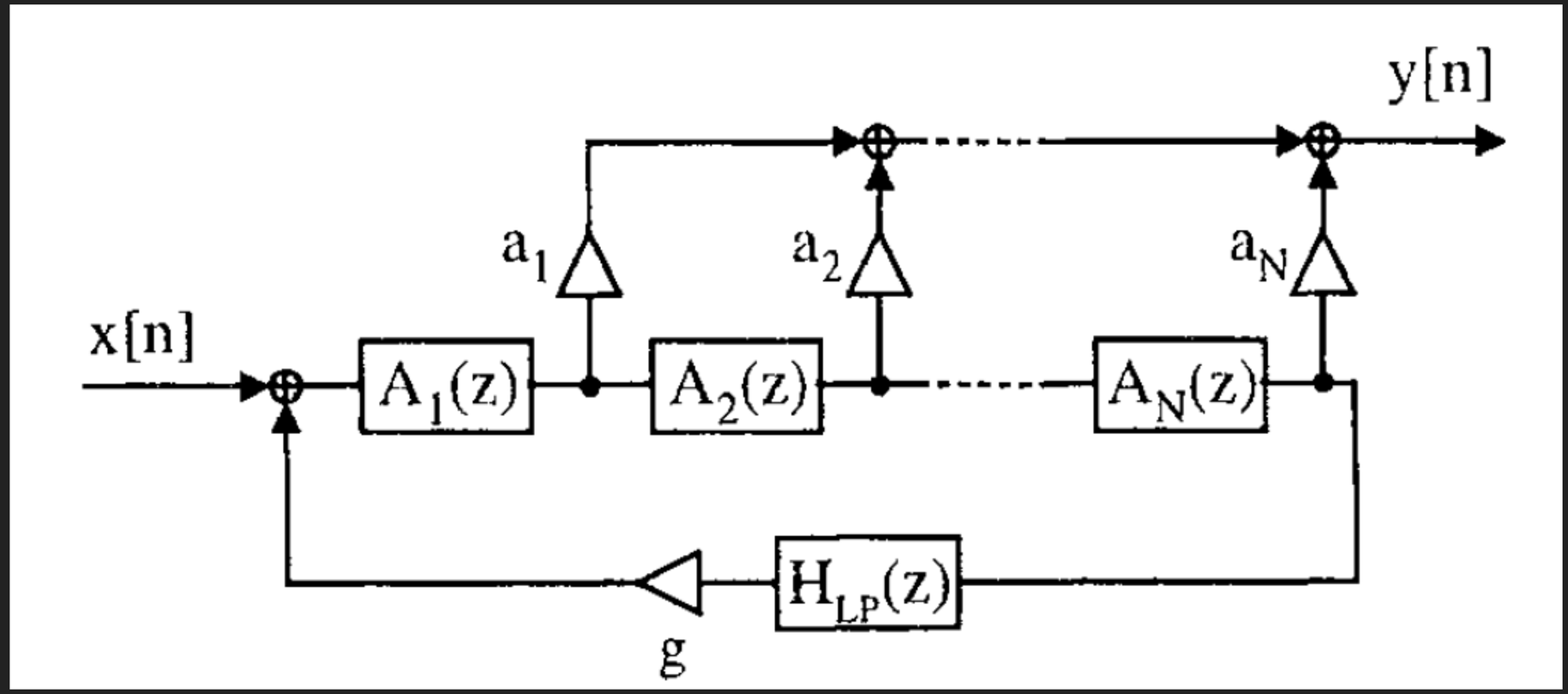
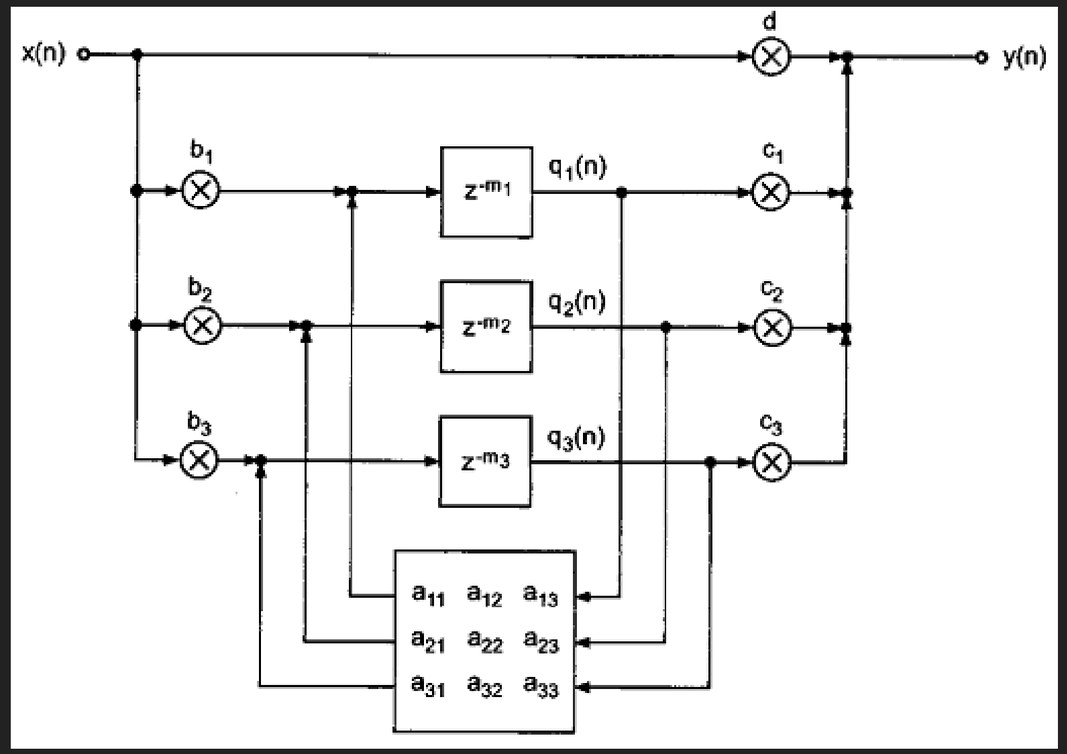


Figure 12. Signal flow diagram of reverberator using FIR portion to simulate early echos and an IIR portion, denoted by $R(z)$, to simulate the late portion. Delays D_1 and D_2 are adjusted so that the last pulse from the FIR section corresponds roughly in time with the first pulse to exit from the IIR section. One or the other of D_1 and D_2 will be zero for any given diagram.

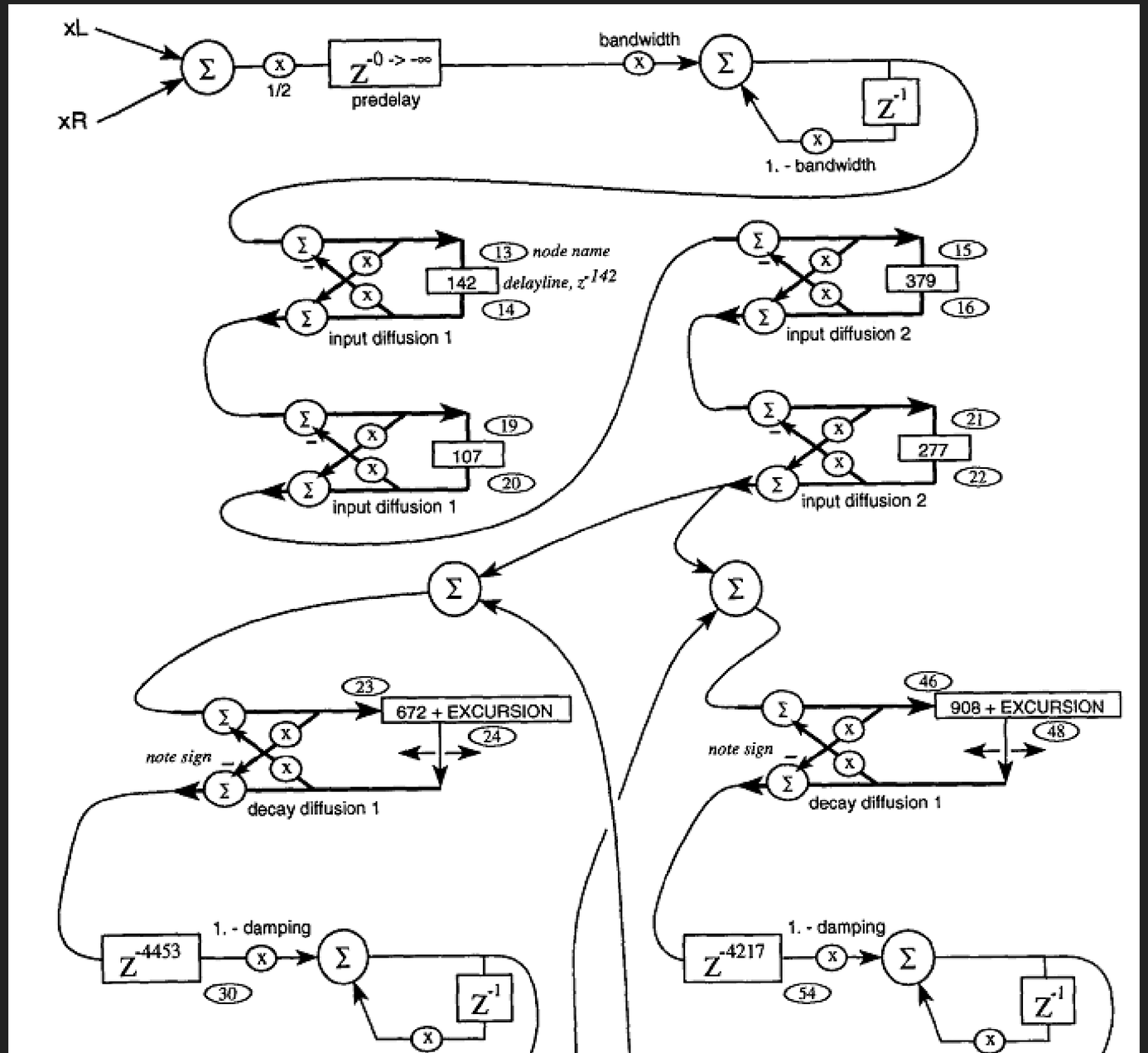
Other Reverberation Approaches: Gardner



Other Reverberation Approaches: Jot (Feedback Delay Network)



Dattorro

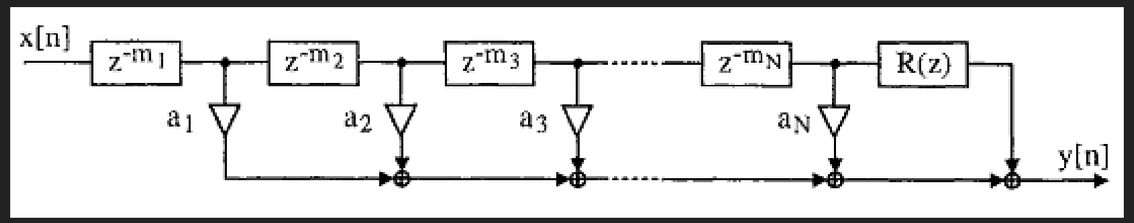

xL
xR
1/2
predelay
bandwidth
1. - bandwidth
node name
delayline, z^-142
142
input diffusion 1
379
input diffusion 2
107
input diffusion 1
277
input diffusion 2
672 + EXCURSION
note sign
decay diffusion 1
908 + EXCURSION
note sign
decay diffusion 1
1. - damping
1. - damping

Dattorro Examples

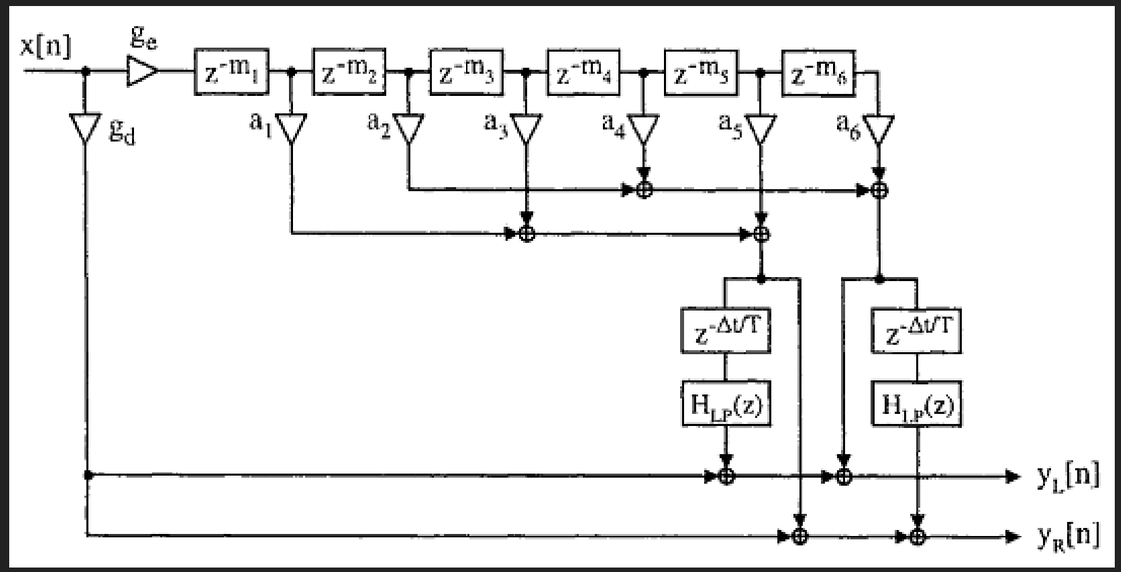
Intention: Plate Reverb Model (Dense, Bright, Fast Build-Up Time)

- Original: 0:00 / 0:20
- Wet (Plate): 0:00 / 0:21
- Wet (Medium Hall): 0:00 / 0:21
- Wet (Cathedral): 0:00 / 0:21

Early Reflections: Models



Early Reflections: Models



Quality Enhancements

- **Multi-Channel Processing**
  - Mono In → Mono Out
  - Mono In → Stereo Out
  - Stereo In → Stereo Out
- **Delay Modulation**
  - Increase "diffusity" and "liveliness

Common Parameters

- Wetness
- Reverberation Time
- Pre-Delay
- Low Pass Cutoff
- Low Pass Slope
- Bass Boost
- Ratio of Early Reflection / Late Reverberation
- Diffusion, Liveliness, etc

Summary

- **Advantages** over convolution reverbs
  - Fully parametrizable - not restricted to predefined IR library
  - Works well with already somewhat reverberated recordings
  - Lower workload (IIR vs. FIR)
- **Disadvantages** over convolution reverbs
  - Less realistic, no real-world IRs