

GCT535: Sound Technology for Multimedia

# Delay-based Effects



Graduate School of  
Culture Technology

**Juhan Nam**

# Goal

- Understanding the perception of time delay in comb filters
- The implementation details of delay-based audio effects
  - Delay (Echo)
  - Chorus
  - Flanger effects

# Introduction

- Types of delay-based audio effect
  - Delay
  - Chorus
  - Flanger
  - Reverberation (this will be covered in the topic of spatial audio)



# Introduction

- Video demos
  - <https://www.youtube.com/watch?v=zmN7fK3fKUE&list=PL081D4BE59AE08F99&index=1>
- Delay
  - <https://www.youtube.com/watch?v=oCJLvtTkDKA>
  - <https://www.youtube.com/watch?v=8r3LzV4BnyM>
- Chorus
  - <https://www.youtube.com/watch?v=z9LiPuVRyU8>
- Flanger
  - <https://www.youtube.com/watch?v=Obnibgewtsw>

# Introduction

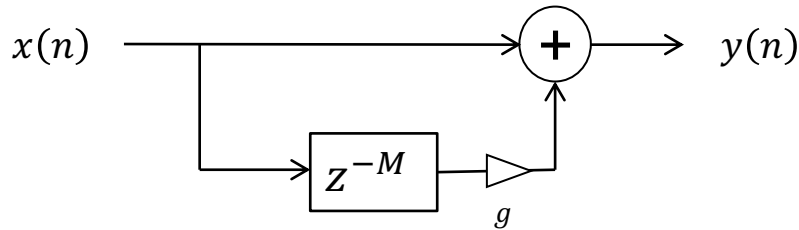
- Delay-based effects originated from tape recording
  - Les Paul: innovator in sound production
    - Well-known for “Gibson Les Paul” electric guitar and also developed unique guitar play techniques
    - Doubling/ensemble effects: make rich vocals
    - Delay or Flanging effects



Les Paul

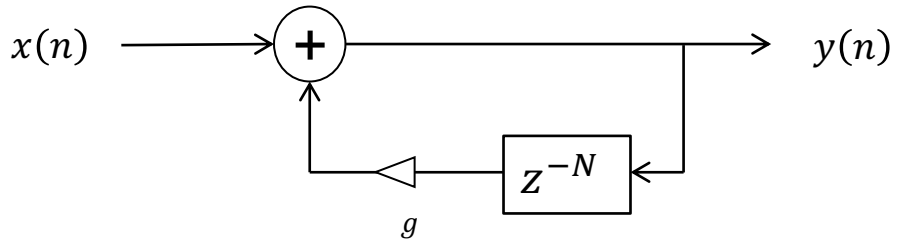
# Comb Filter

- Implemented by circular buffer: move read and write pointers instead of shift all samples in the delayline



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

FIR Comb Filter

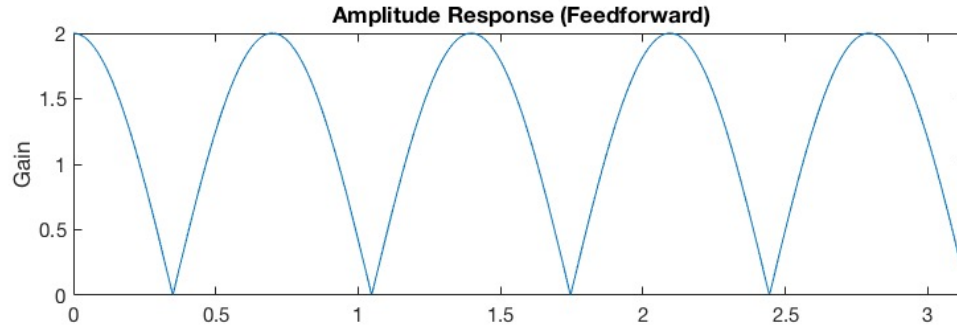


$$y(n) = x(n) + g \cdot y(n - N)$$

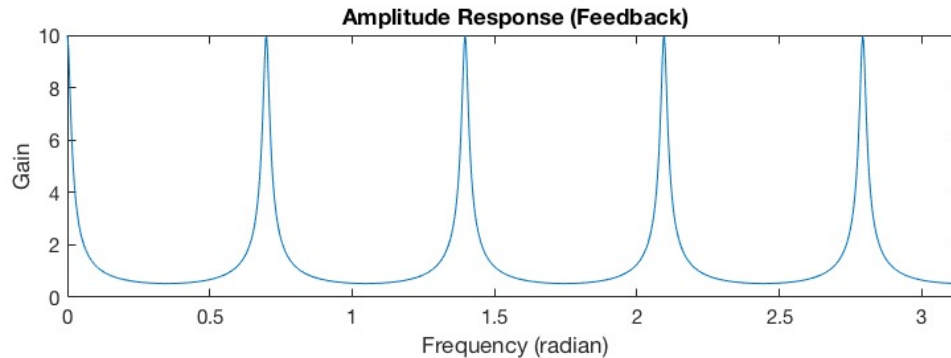
IIR Comb Filters

# Comb Filter: Frequency Response

- "Combs" become shaper in the feedback type



$$y(n) = x(n) + x(n - 8)$$



$$y(n) = x(n) + 0.9 \cdot y(n - 8)$$

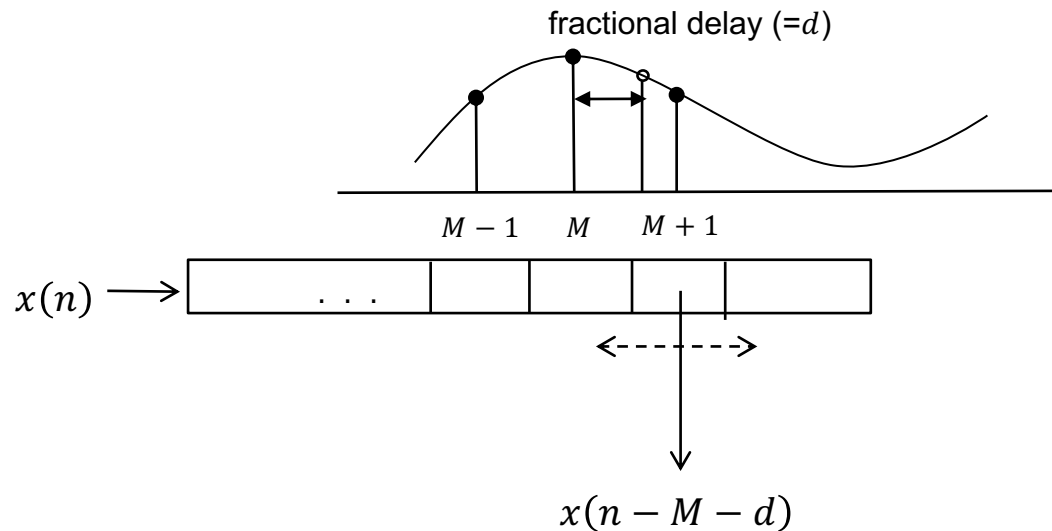
# Perception of Time Delay

- The 30 Hz transition
  - Given a repeated click sound (e.g. impulse train):
    - If the rate is less than 30Hz, they are perceived as discrete events.
    - As the rate is above 30 Hz, they are perceived as a tone
  - Demo: <https://auditoryneuroscience.com/pitch/range-period-pitch>
- Feedback comb filter:  $y(n) = x(n) + a \cdot y(n - N)$ 
  - If  $N < \frac{F_s}{30}$  ( $F_s$ : sampling rate): change tone of the input sound
    - If  $N$  is large under this condition, it can generate a pitched tone as it models sound propagation and reflection on a string (e.g. Karplus-Strong model)
  - If  $N > \frac{F_s}{30}$  ( $F_s$ : sampling rate): repeat discrete events with gain loss



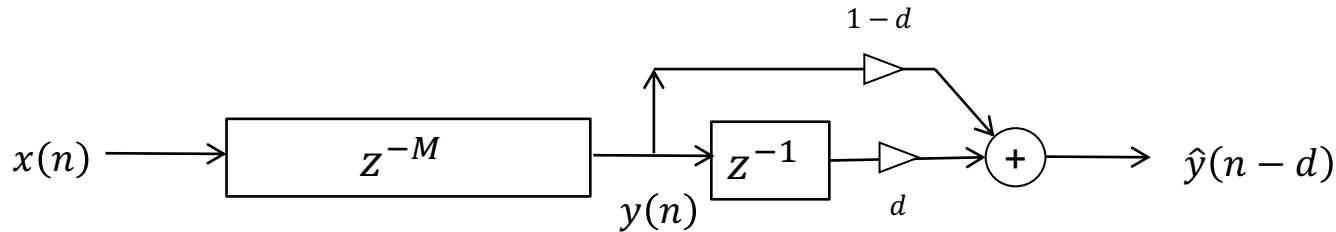
# Fractional Delay

- Necessary when the length of delay continuously changes
  - Chorus, flanger and other modulations



# Linear Interpolation

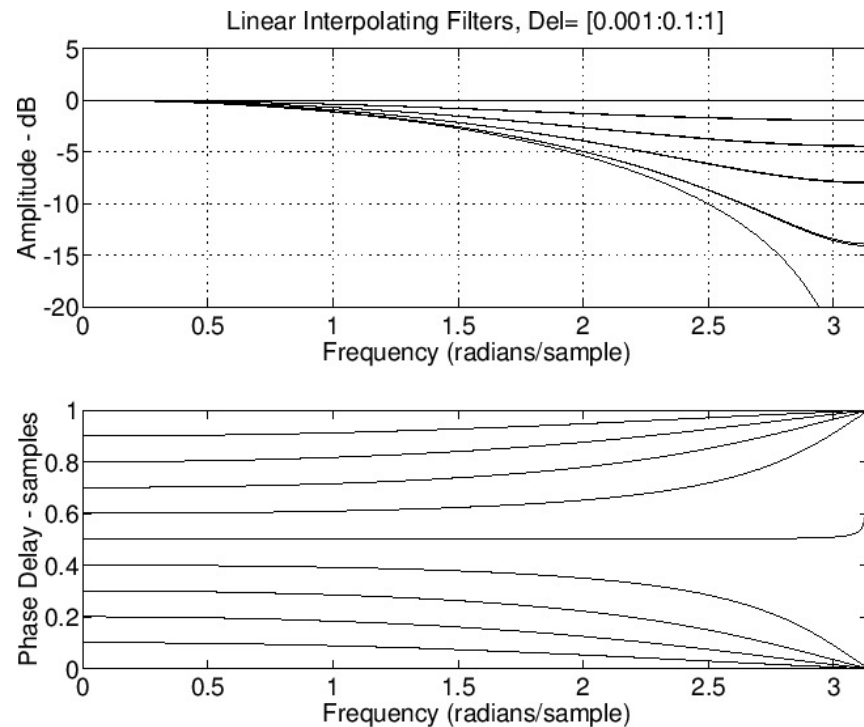
- The output is delayed approximately by  $d$ 
  - The phase delay in the low frequency range is close to the fractional delay  $d$
  - The output is attenuated in the high frequency range
  - Useful in “random access mode” (no recursion)



$$\hat{y}(n-d) = (1-d) \cdot y(n) + d \cdot y(n-1)$$

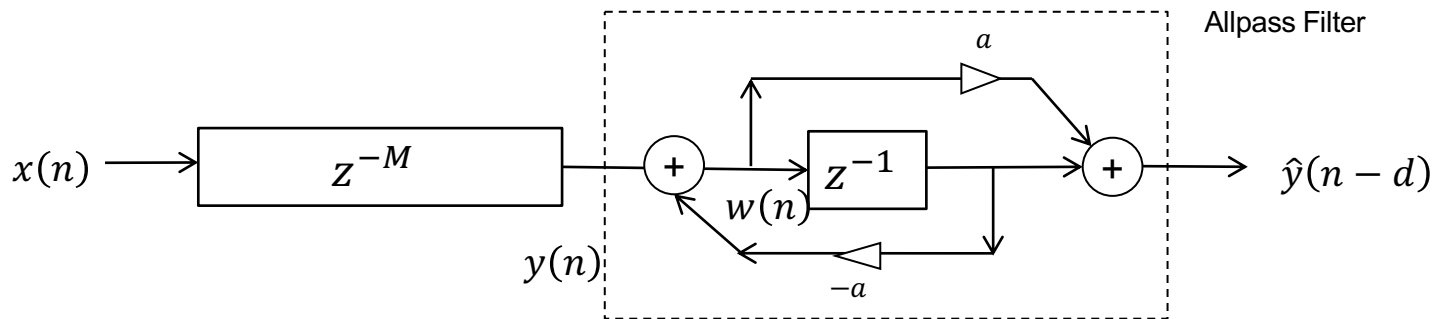
# Linear Interpolation

- Frequency Response



# First-Order Allpass Interpolation

- The output is delayed approximately by  $d$ 
  - The phase delay in the low frequency range is close to the fractional delay  $d$
  - The output is unity at all frequency range
  - Be careful in “random access mode”

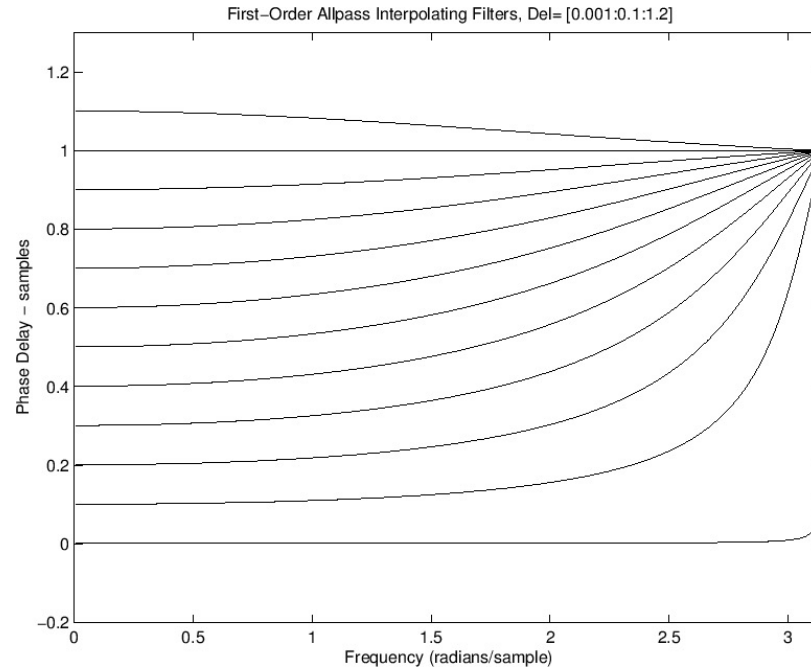


$$w(n) = y(n) - a \cdot w(n-1)$$
$$\hat{y}(n-d) = a \cdot w(n) + w(n-1)$$

$$d = \frac{1-a}{1+a}$$

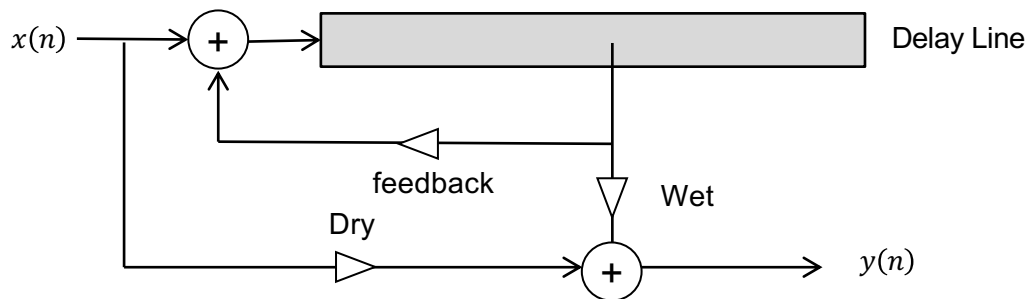
# First-Order Allpass Interpolation

- Frequency Response



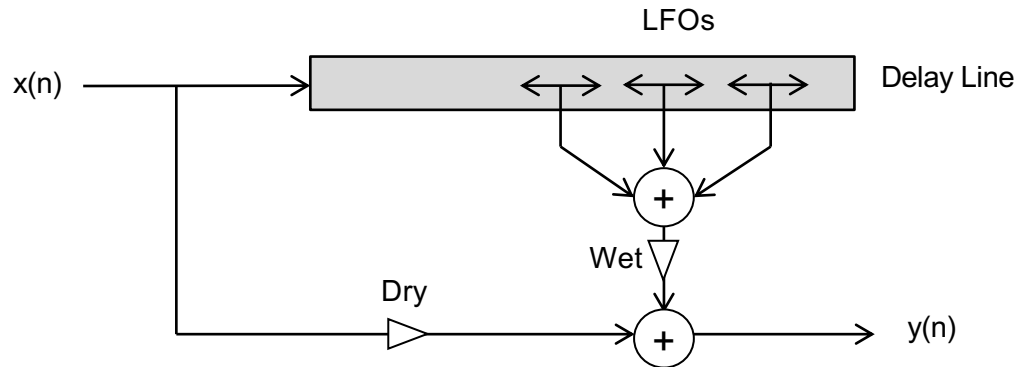
# Delay Effect

- Generate repetitive loop delay
  - Parameters
    - Feedback gain, delay length
  - Ping-pong delay: cross feedback between left and right channels in stereo
  - The delay length is often synchronized with music tempo



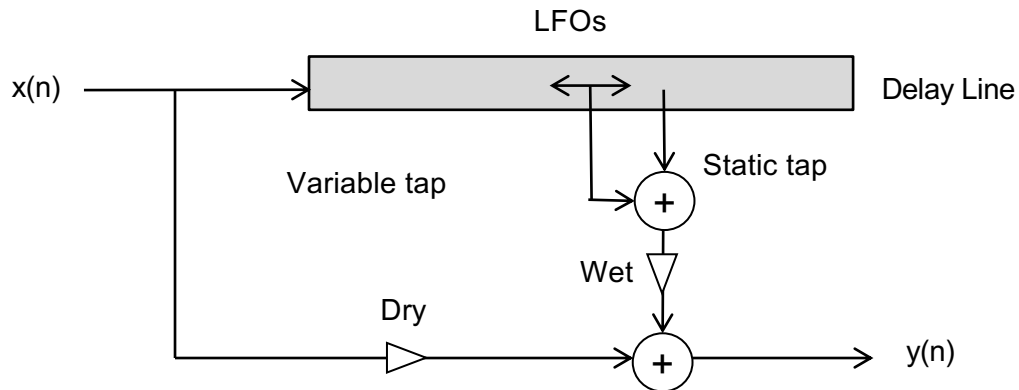
# Chorus Effect

- Gives the illusion of multiple voices playing in unison
  - By summing detuned copies of the input
  - Low frequency oscillators (LFOs) are used to modulate the position of output taps
    - This causes pitch-shift



# Flanger Effect

- Emulated by summing one static tap and variable tap in the delay line
  - “Rocket sound”
  - Feed-forward comb filter where harmonic notches vary over frequency.
  - LFO is often synchronized with music tempo





# Tape Delay Effect

- Model the warm and echo tone of tape delay effect
  - Roland space echo RE-201
    - Three play heads, bass/treble EQ and spring reverb
    - <http://www.roland.co.uk/blog/demystifying-magic-tape-echo/>
    - <https://www.youtube.com/watch?v=y3Whi-g-0A0>
  - Other models
    - <https://www.youtube.com/watch?v=b8DdHDRrBps>

# Loop Station

- Record and play musical tracks in a layer-by-layer manner with repetitions
  - 4 bar or 8-bar loop
- Examples
  - <https://www.youtube.com/watch?v=fOqR84PtctA>
  - <https://www.youtube.com/watch?v=O2iGwll-qig>
  - <https://www.youtube.com/watch?v=r46LmtitZ7A>

