CHAPTER 4:
MULTIRATE SIGNAL PROCESSING

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Multirate signal processing

- Multirate signal processing involves the manipulation of signals at different sampling rates within a single system.
- It plays a crucial role in modern digital signal processing (DSP) systems, where different parts of the system operate at different rates, depending on the application requirements.
- Multi-rate techniques are used in areas such as communication systems, audio and video compression, and filter banks.

Downsampling (Decimation)

The process of reducing the sampling rate of a signal. This involves discarding some samples from the signal, which reduces the data rate and can save computational resources.

✓ Aliasing Consideration: Before down-sampling, the signal must be low-pass filtered to avoid aliasing (high-frequency components folding into the lower frequencies). This filter is called an anti-aliasing filter.

✓ Down-sampling Factor: If the signal is down-sampled by a factor of M, only every M-th sample is kept.

Upsampling (Interpolation)

The process of increasing the sampling rate of a signal. This is done by inserting zeros between the original samples to create a higher-rate signal.

✓ Interpolation Filter: After upsampling, a low-pass filter (called an interpolation filter) is applied to smooth the discontinuities caused by the inserted zeros and to reconstruct the signal at the higher rate.

✓ Upsampling Factor: If the signal is upsampled by a factor of L, zeros are inserted between each original sample.

Sample Rate Conversion

Changing the sampling rate of a signal by a rational factor (non-integer). It involves both downsampling and upsampling steps.

✓ Upsample by L
✓ Apply a low-pass interpolation filter to smooth the upsampled signal
✓ Downsample by M
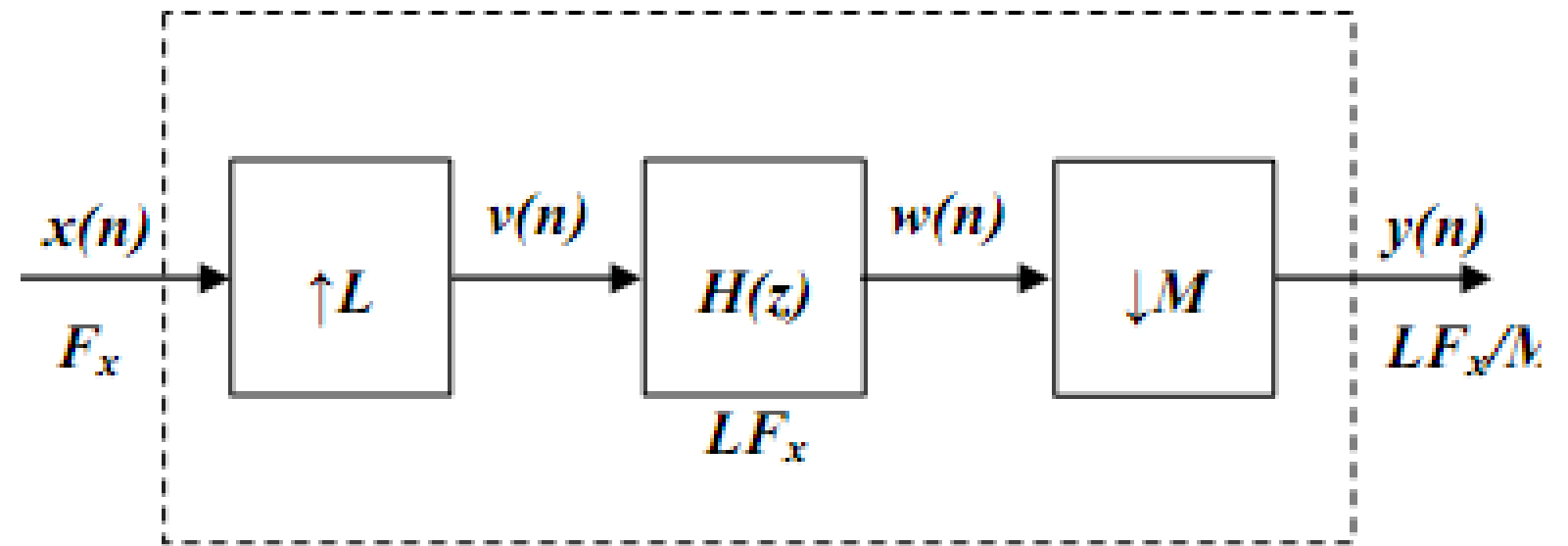
Polyphase Filters

- Polyphase structures are highly efficient implementations of multi-rate filters (for both up-sampling and down-sampling).
- They break down the filtering process into multiple phases, reducing computational complexity.
- This is particularly useful when designing multi-rate systems with large up-sampling or down-sampling factors.

Advantages of Multi-rate Signal Processing

- Efficiency: Multi-rate techniques allow efficient processing by reducing the number of operations in systems where signals are only required to be processed at specific rates.
- Flexibility: These techniques make it easier to design systems that can handle multiple signal formats or adjust to different bandwidths dynamically.
- Scalability: Multi-rate designs can scale across applications, from small embedded systems to complex communication networks.