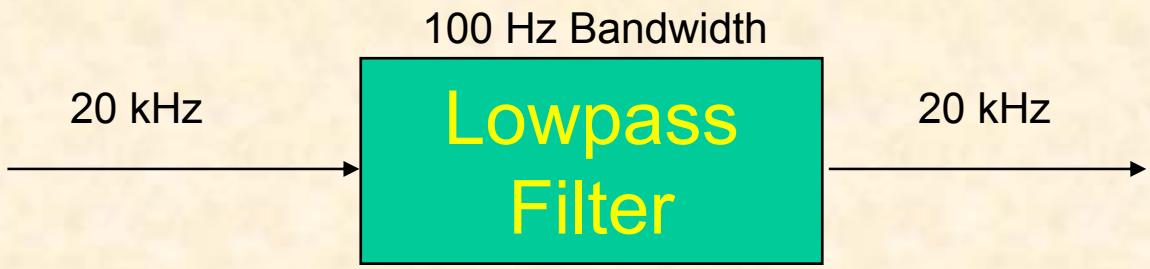
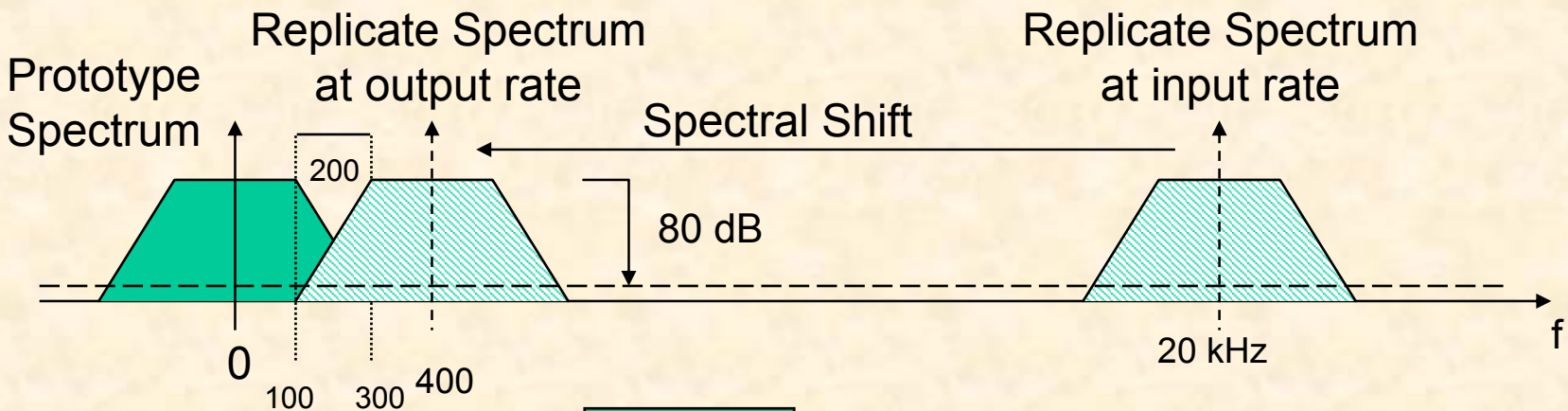
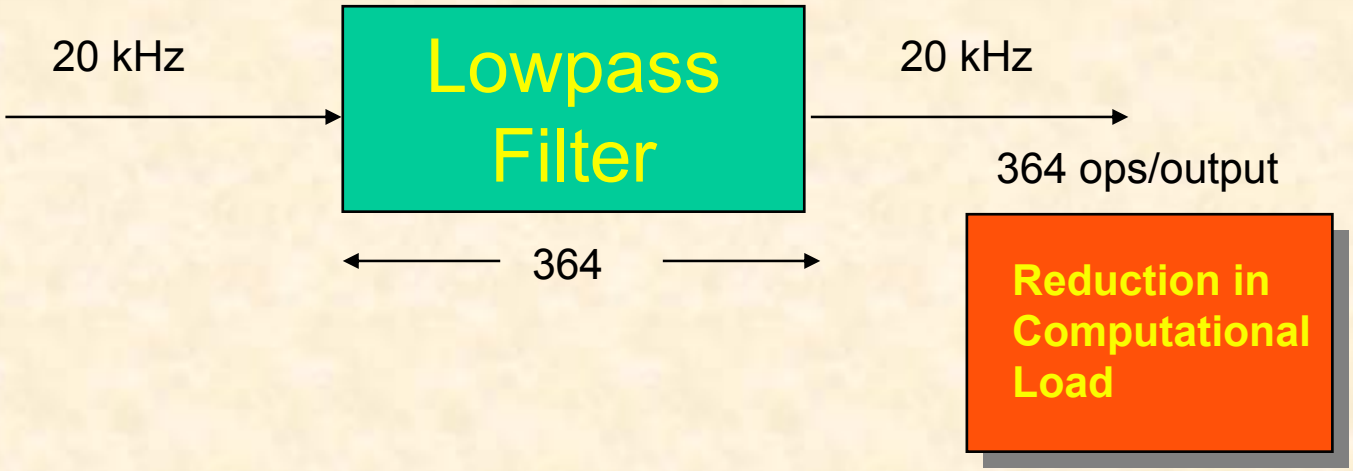
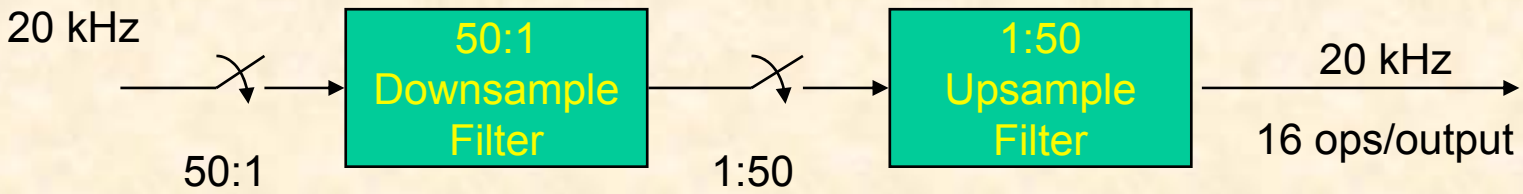
Single Rate Filtering With Polyphase Filters

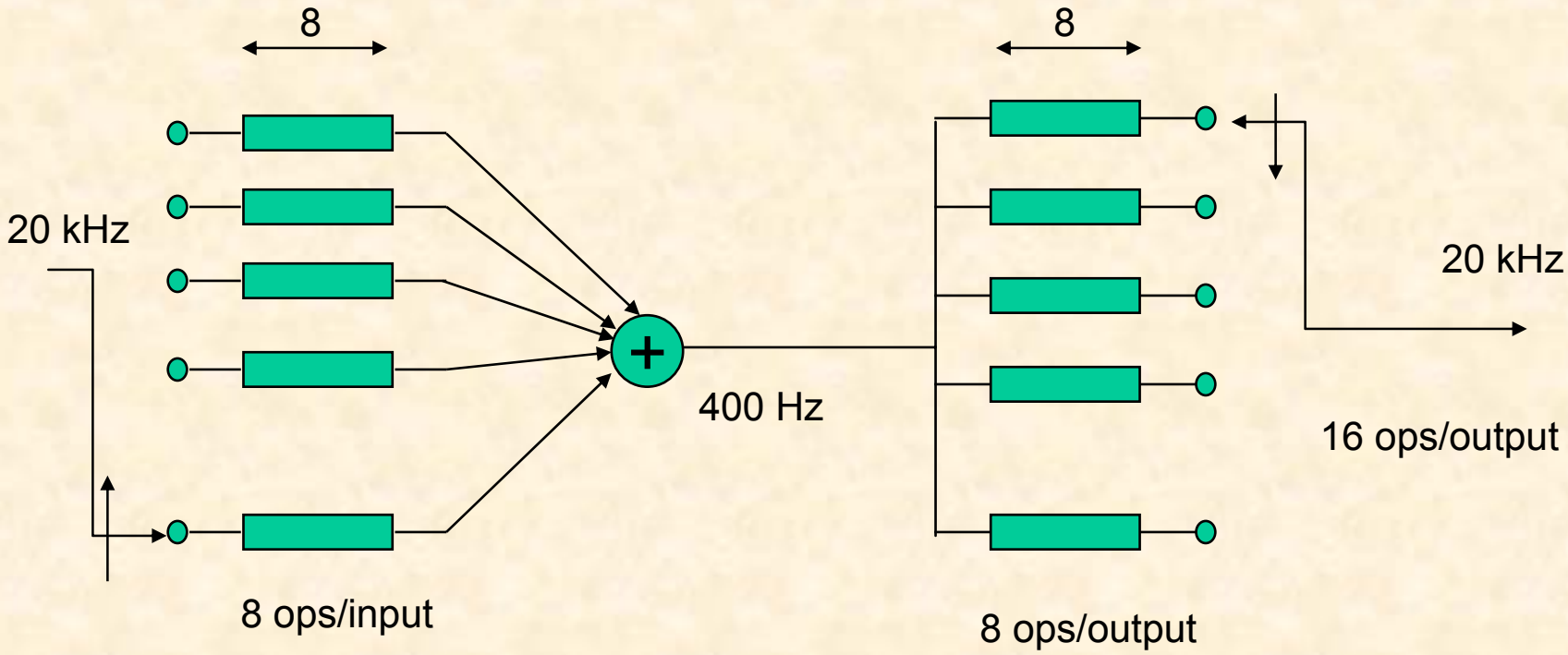




M = 50

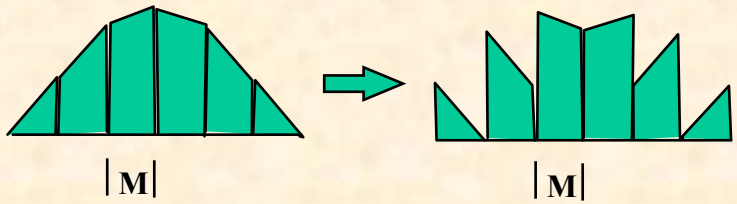

20 kHz
Lowpass Filter
20 kHz
364 ops/output
364
Reduction in Computational Load


20 kHz
50:1
50:1 Downsample Filter
1:50
1:50 Upsample Filter
20 kHz
16 ops/output



Note direction of Commutators
If you get these wrong then you get the "Sydney Opera House Effect"

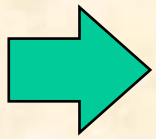
Filter Impulse Response



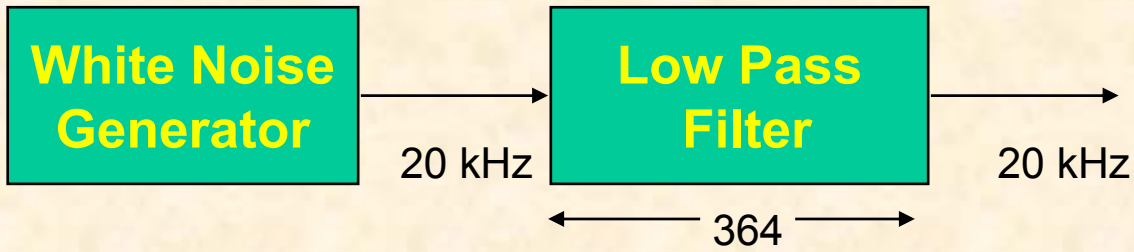
Task: Generate Narrowband White Noise

Filter Specifications

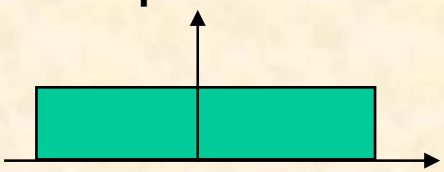
Sample rate = 20 kHz
Passband = 0-100 Hz
Stopband = 300-5000
Attenuation = 80 dB



Filter Length = $\frac{20000}{200} \bullet \frac{80}{22}$ = 364

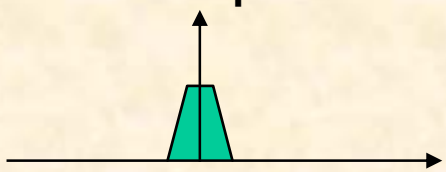


Input Noise



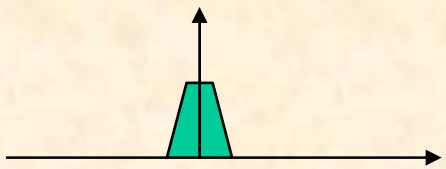
Fs = 20 kHz

Filter Response



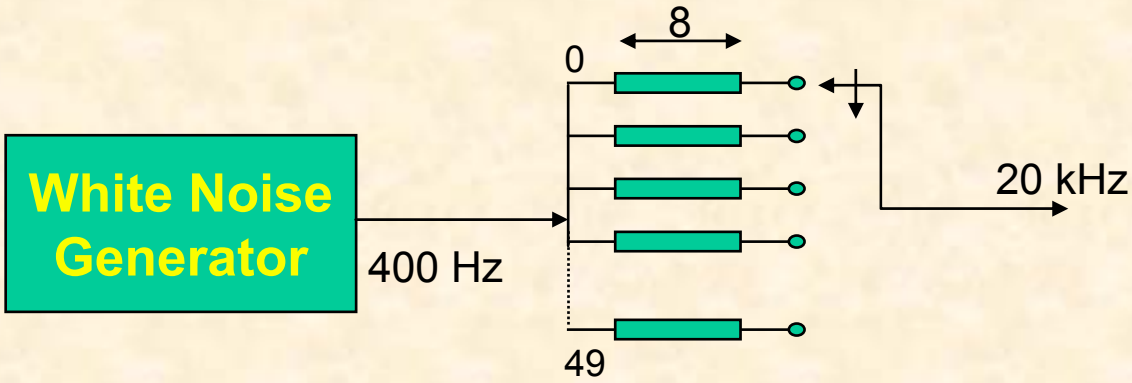
Fs = 20 kHz

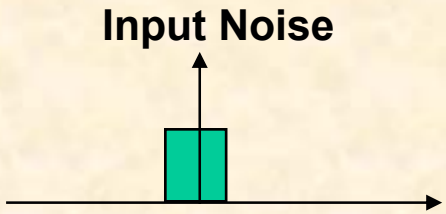
Filtered Noise



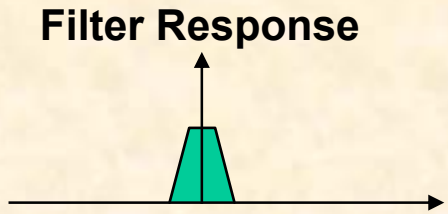
Fs = 20 kHz

Resample 50:1 to 400 Hz

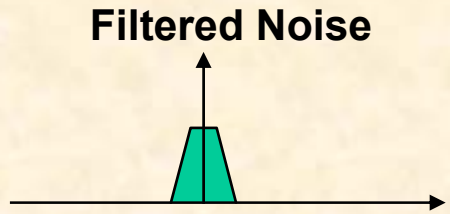




Fs = 0.4 kHz

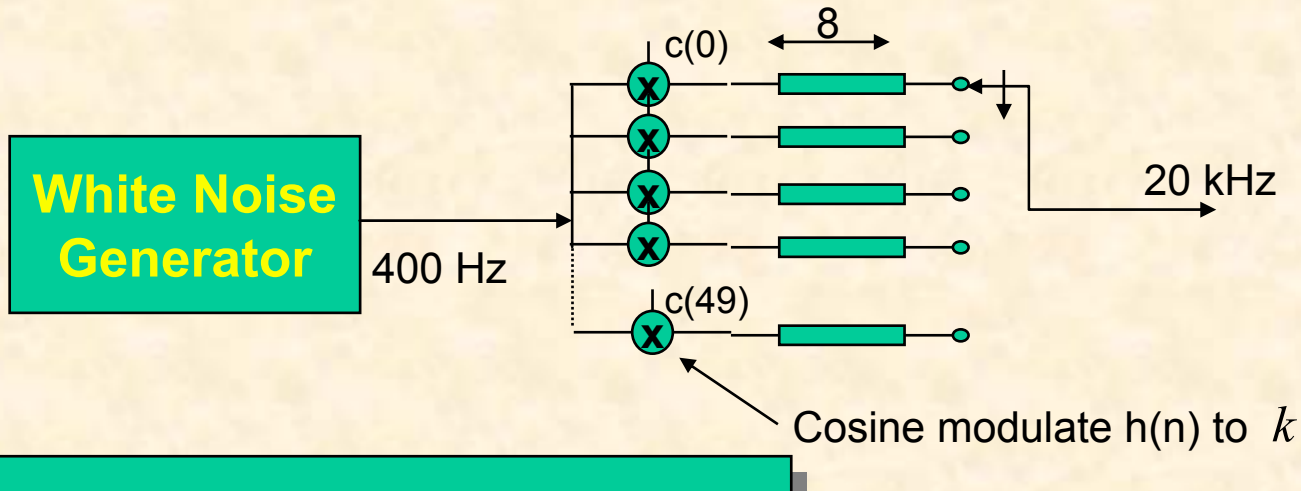


Fs = 20 kHz

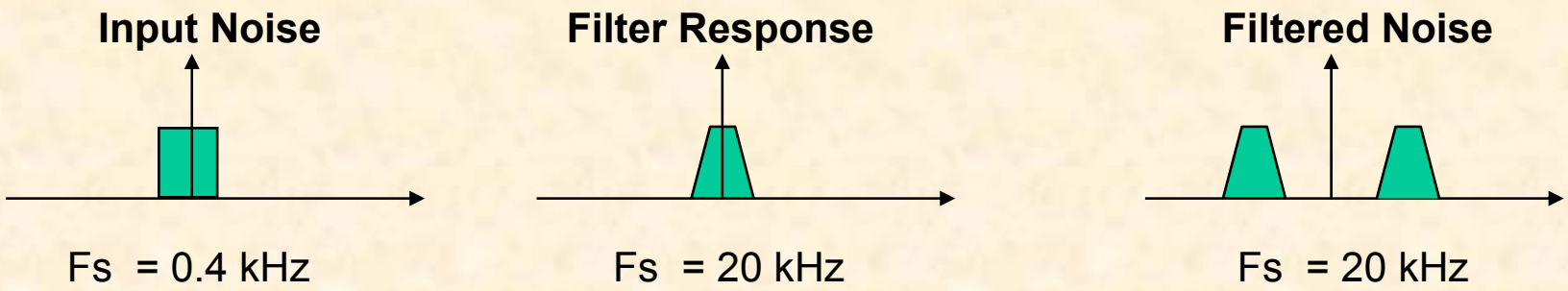


Fs = 20 kHz

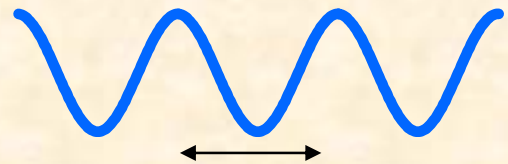
Task: Generate Narrowband White Noise and Heterodyne Spectrum



c(n) = cos 2π*nk/M, k = 0..M-1* ⟵ **A Scalar!**



Example



50 samples

White Noise Generator

400 Hz

c(0) = 1.0

8

c(1) = cos 2πk/50 = 0.9921

c(2) = cos 4πk/50 = 0.9686

c(49) = cos 98πk/50 = 0.9921

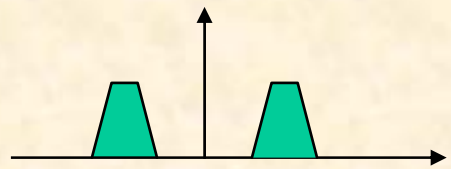
20 kHz

k indicates shift frequency

$$c(n) = \cos 2\pi nk/M,\ n = 0..M-1$$

$$f_c = k\frac{f_s}{M} = 1 \bullet \frac{20000}{50} = 400$$

Filtered Noise

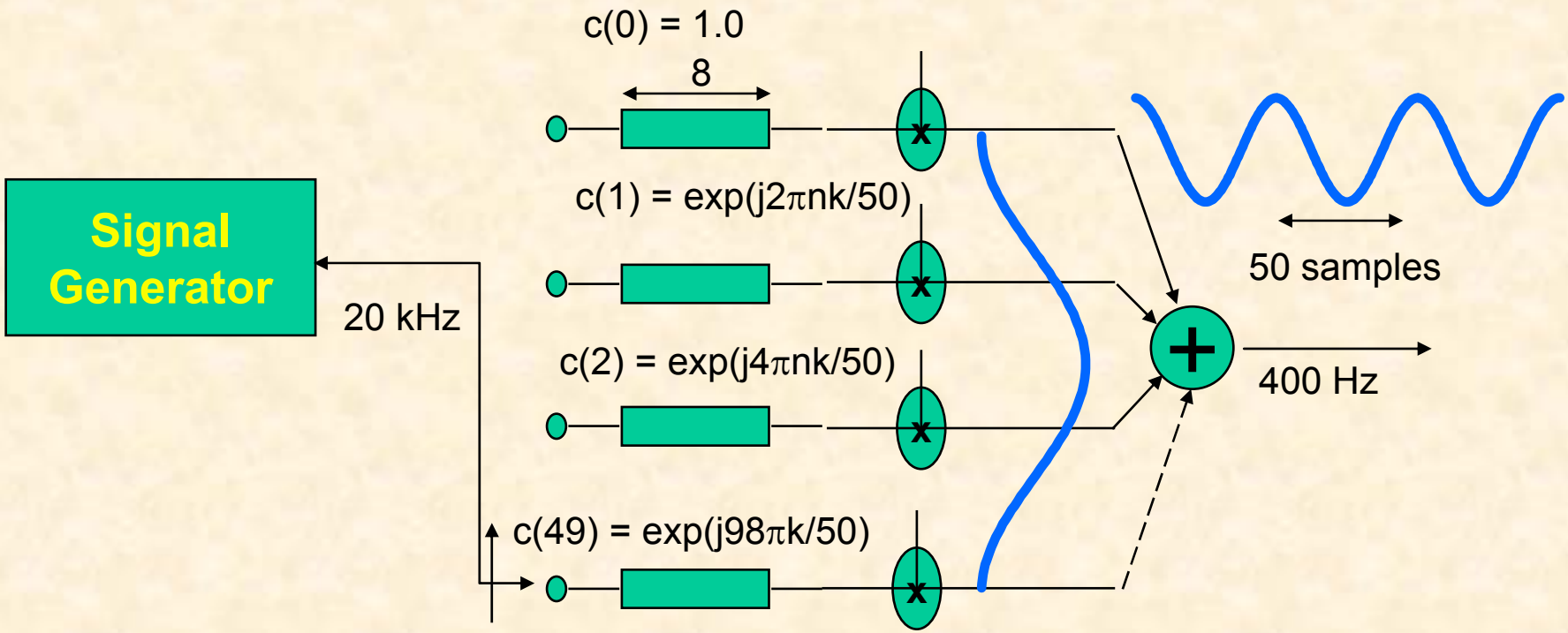


Centre Freq = 400 Hz

Comments

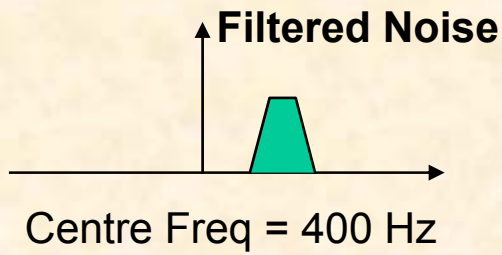
- Frequency shift is achieved with no additional computational load.
- Scalar weighting function for frequency shift can be combined with subfilter weights so no additional computation is required.
- Method can be used with downsampling filter to extract any given frequency band of the input signal with no additional computation.

Downsampling Example

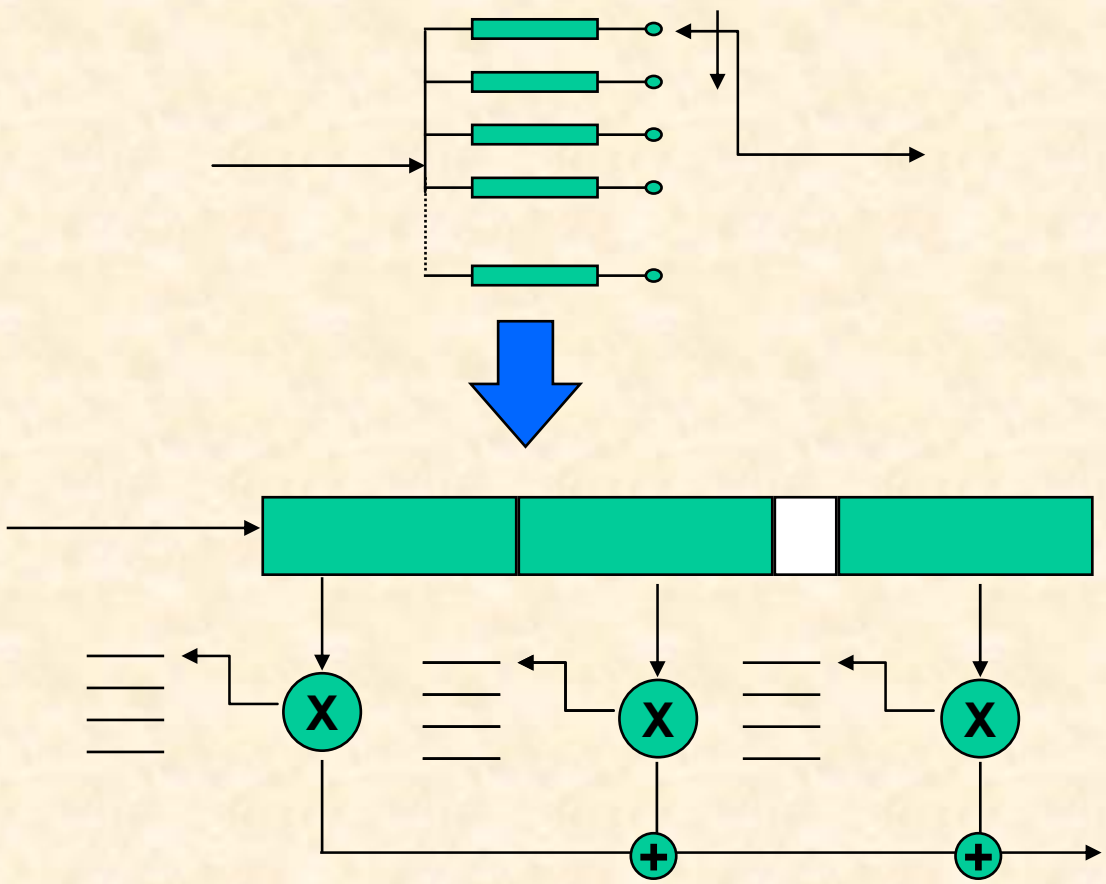


$$c(n) = \exp(j2\pi nk/M),\ n = 0..M-1$$

$$f_c = k\frac{f_s}{M} = 1 \bullet \frac{20000}{50} = 400$$



Efficient Upsampler Implementation



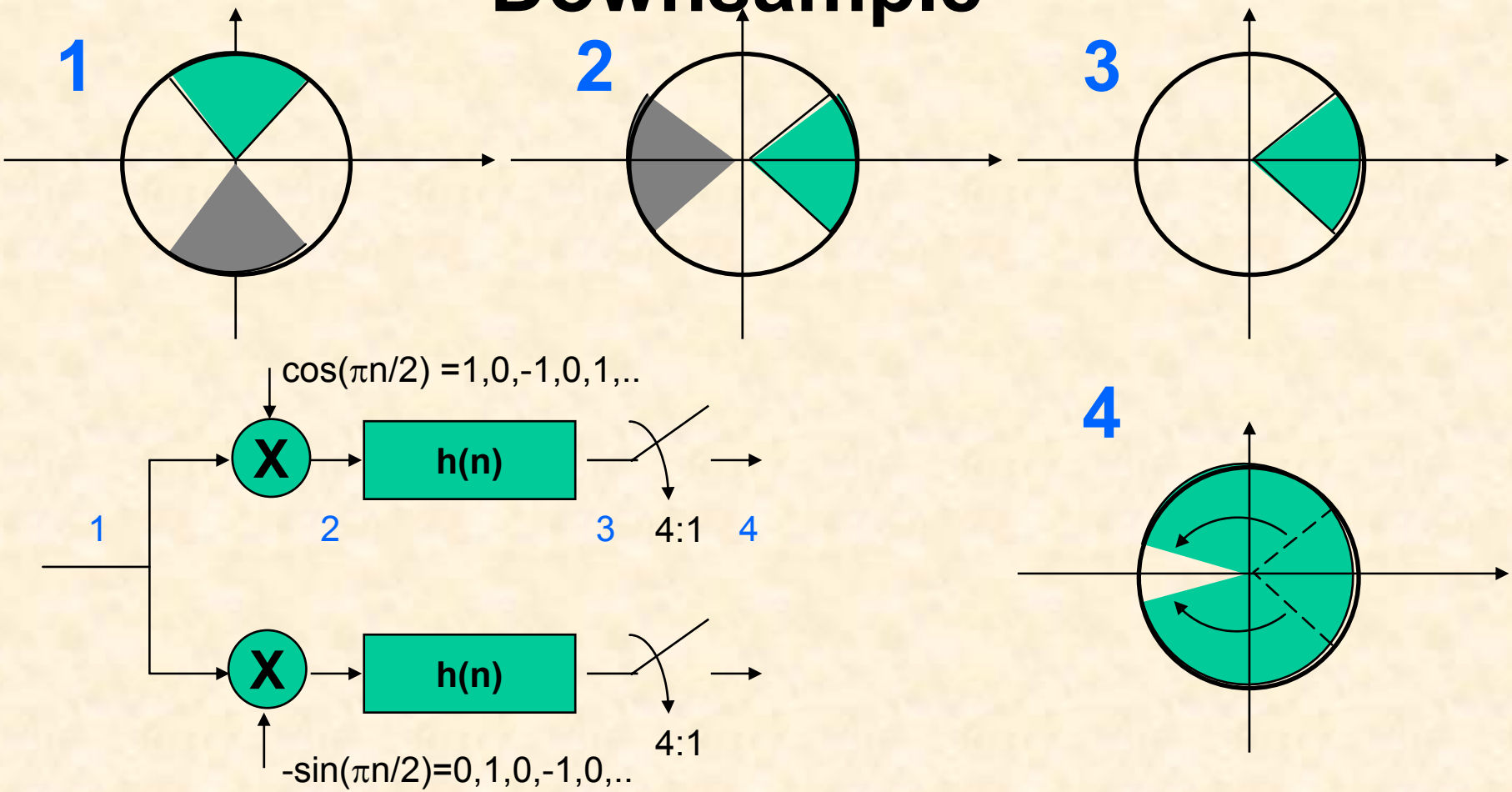
Commutate Filter Outputs

Commutate Filter Coefficients

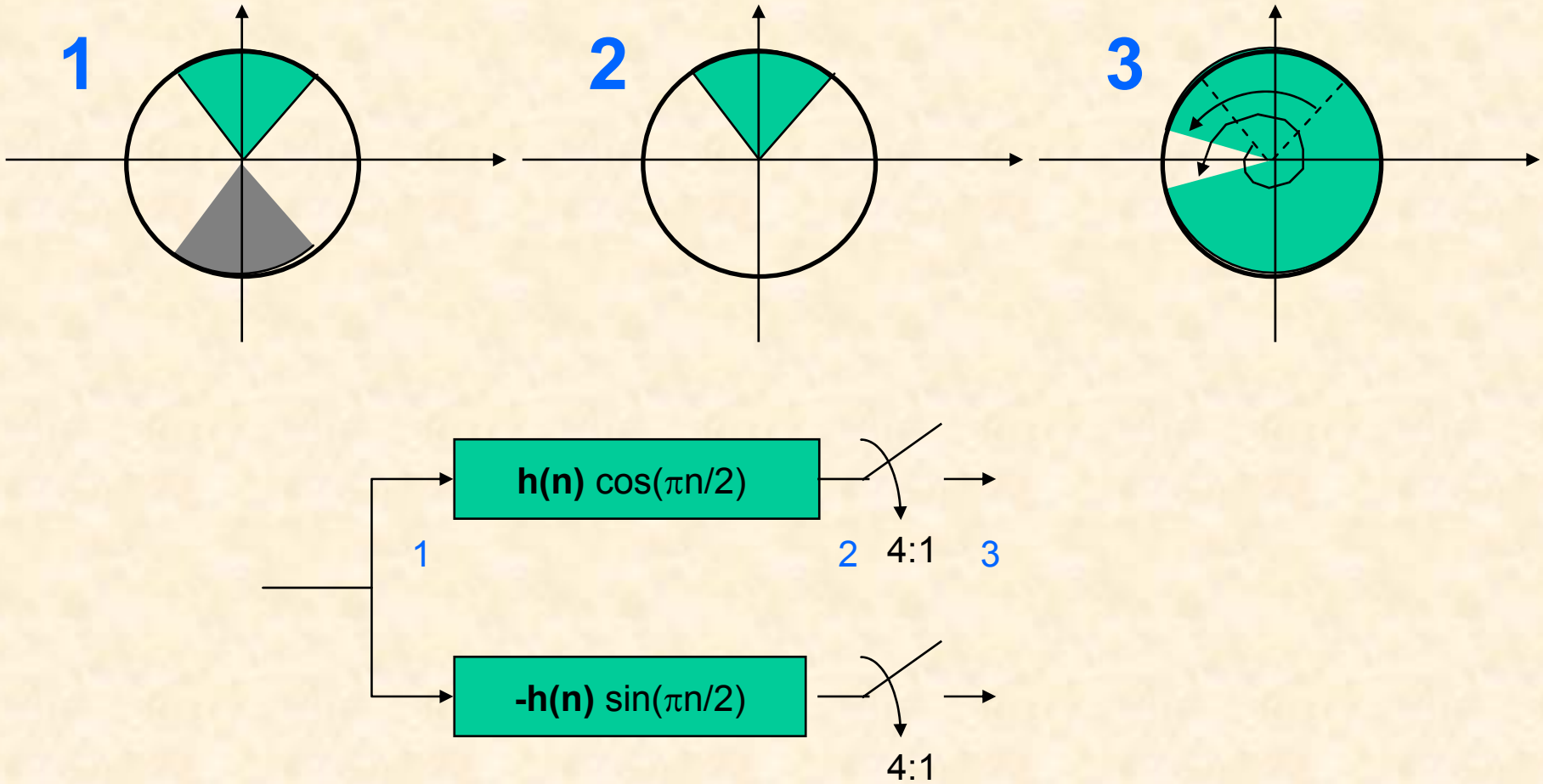
Task: Extract Frequency Band and Downsample

- There are a number of ways of performing this task.
- Some methods are more efficient than others.
- Once again it may be advantageous to sample before filtering.
- Certain frequency shifts (90 degrees, 180 degrees) are much more efficient to implement than others because they involve multiplication by just 1, -1, or 0.
- Filters that exploit these fast techniques to extract frequency bands are called quadrature mirror filters.

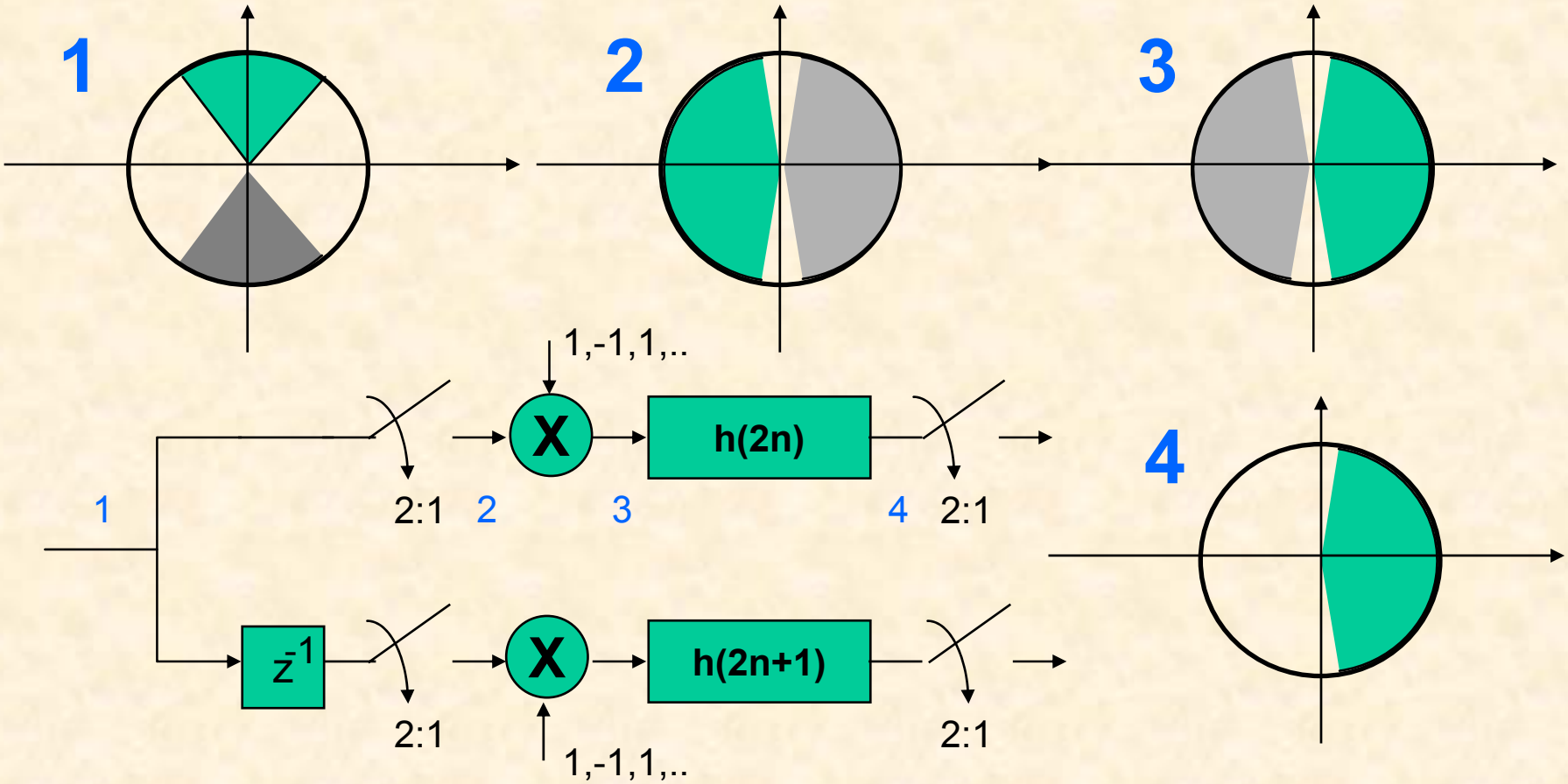
Heterodyne, Filter and Downsample



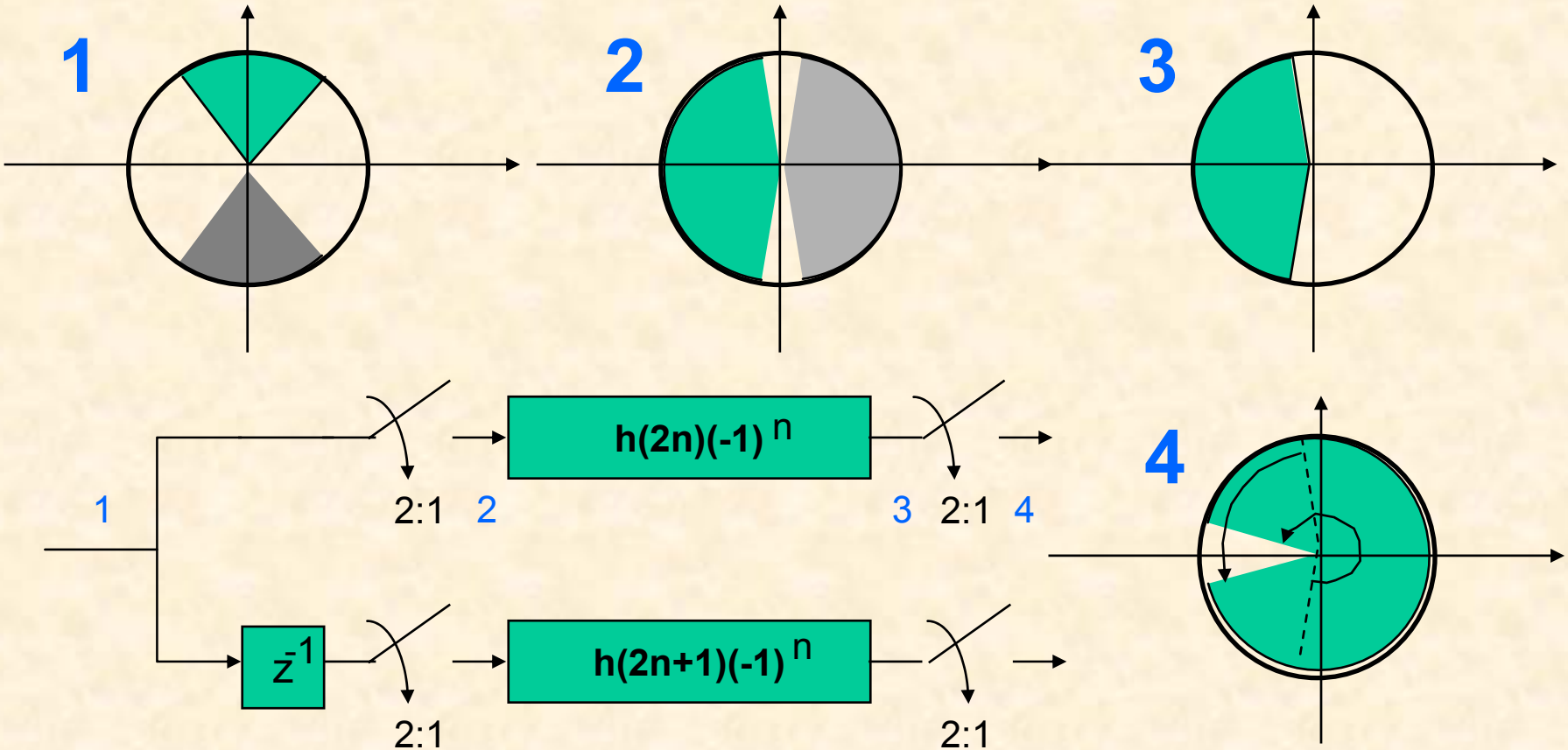
Band Centred Filter and Downsample



Downsample, Heterodyne, Filter, and Downsample



Downsample, Band Centre Filter, and Downsample



Final Form