Multiplexing Examples

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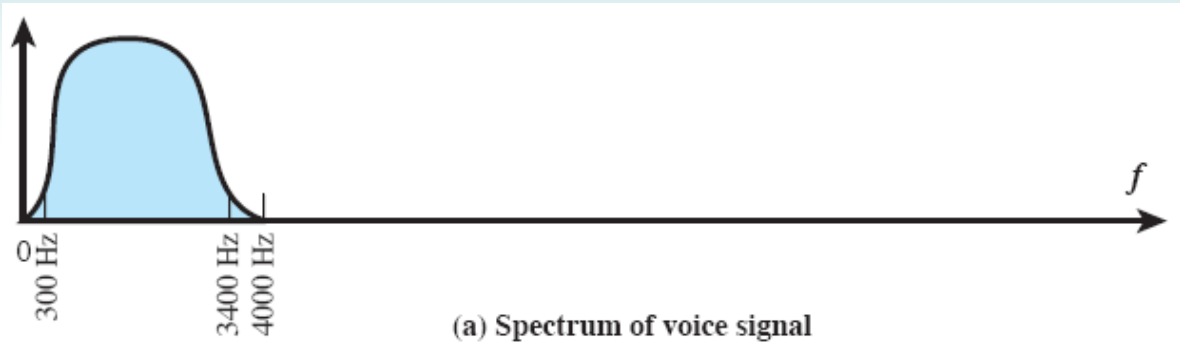
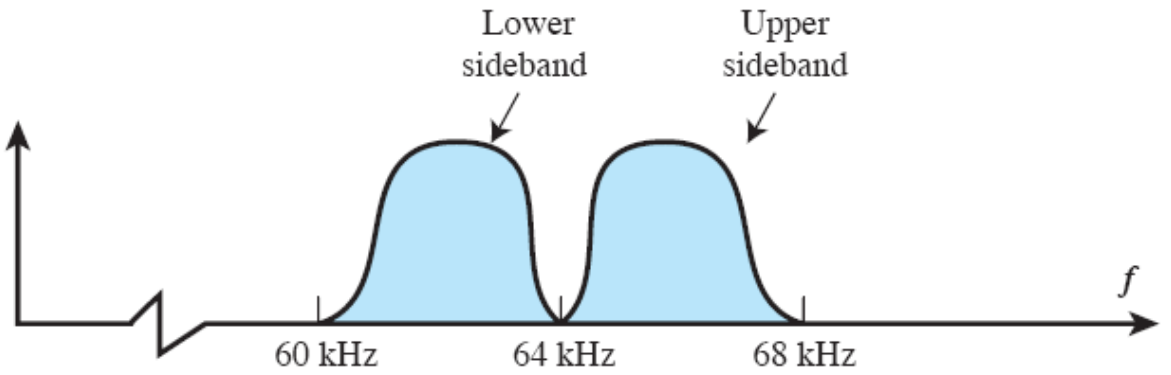
Analog Voice Signal



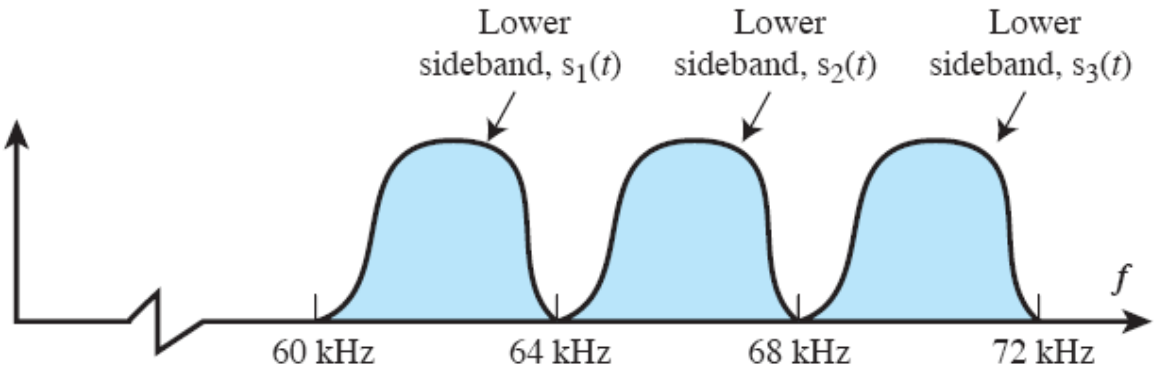
(a) Spectrum of voice signal

Analog Voice Signal with Amplitude Modulation on carrier Frequency of 64kHz



(b) Spectrum of voice signal modulated on 64 kHz frequency

Left sideband of 3 AM voice signals



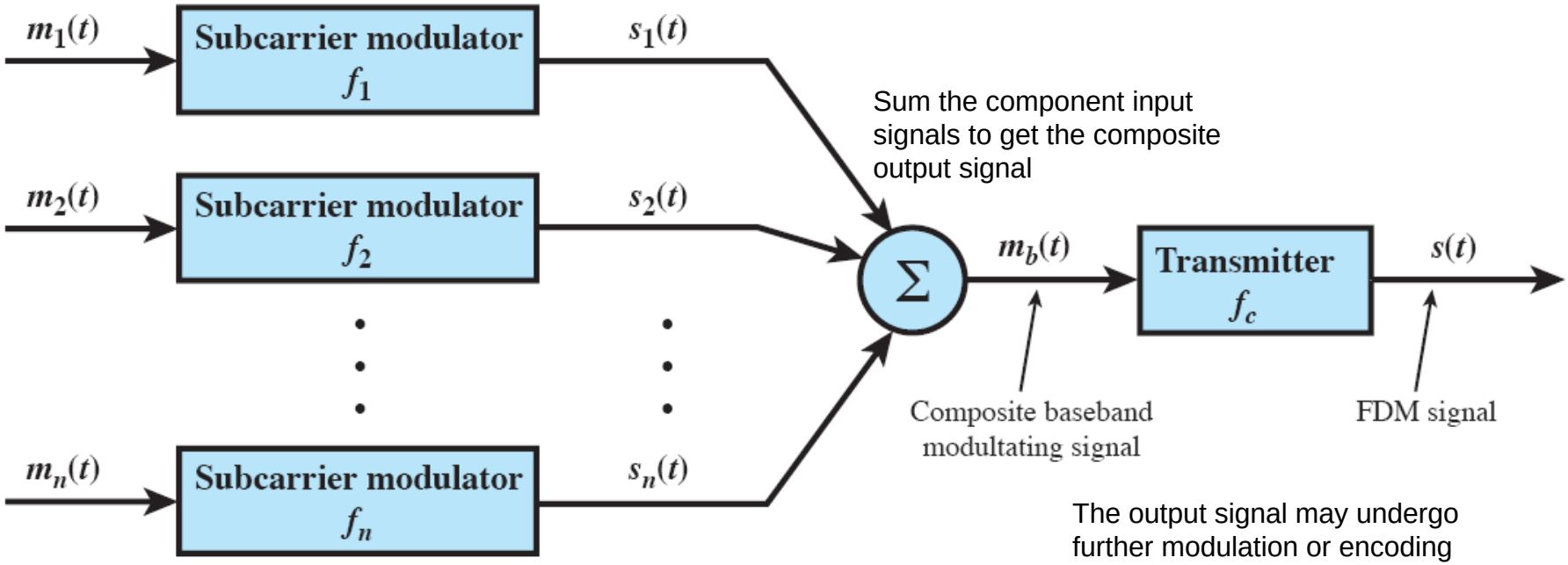
(c) Spectrum of composite signal using subcarriers at 64 kHz, 68 kHz, and 72 kHz

FDM for Voice Signals

- Analog voice ranges from 300Hz to 3400Hz – telephone systems transmit this in a 4kHZ bandwidth
- If this is modulated on a carrier frequency of 64kHz (using amplitude modulation), then resulting bandwidth is 8KHz
- To make efficient use of available bandwidth, only the lower sideband (left half of the modulated signal) is transmitted
  - This still allows for accurate reproduction of the original voice
- Take other voice signals (with carrier frequencies of 68kHz, 72kHz) and sum them together to get resulting signal to transmit

Transmitter

Original analog signal
of each user

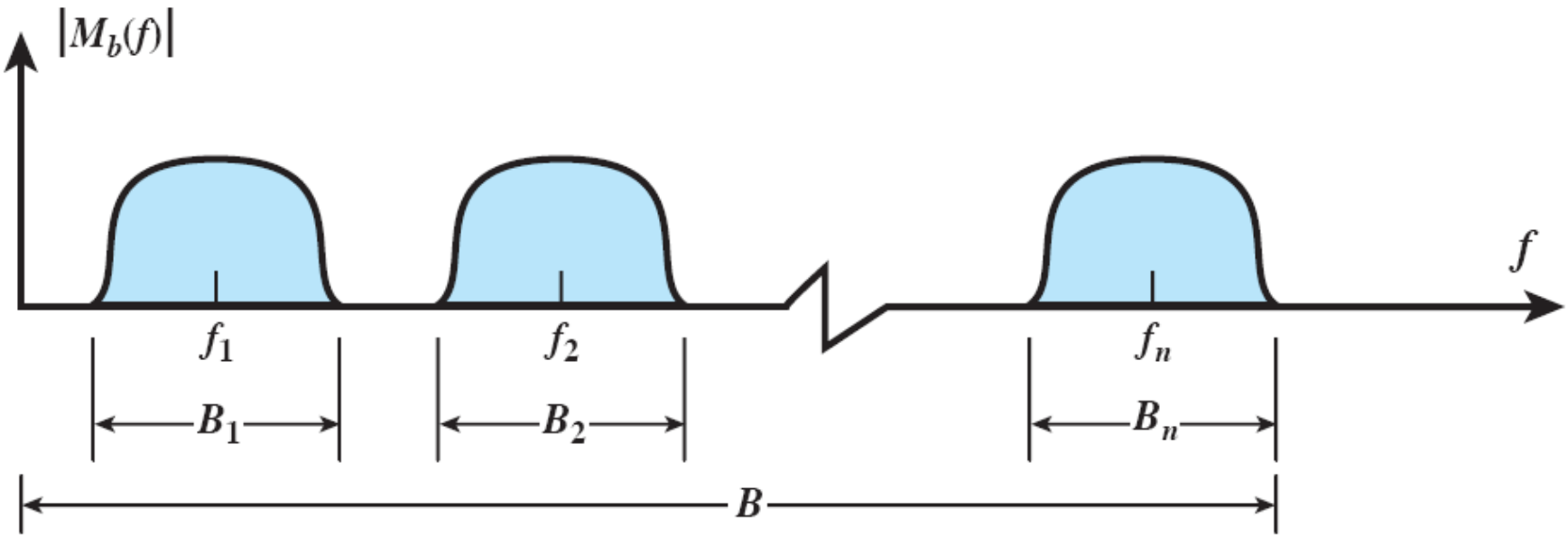


Sum the component input signals to get the composite output signal

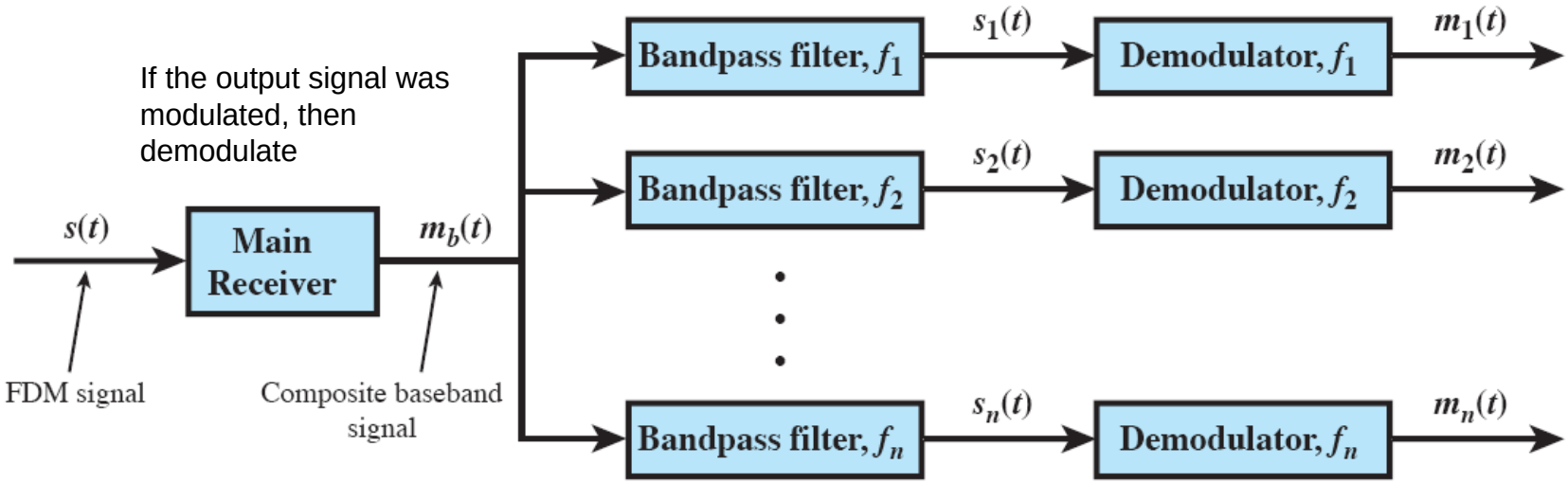
Modulate each signal onto a separate frequency (also remove components that are not necessary)

The output signal may undergo further modulation or encoding before transmission

Transmitted Signal



Receiver

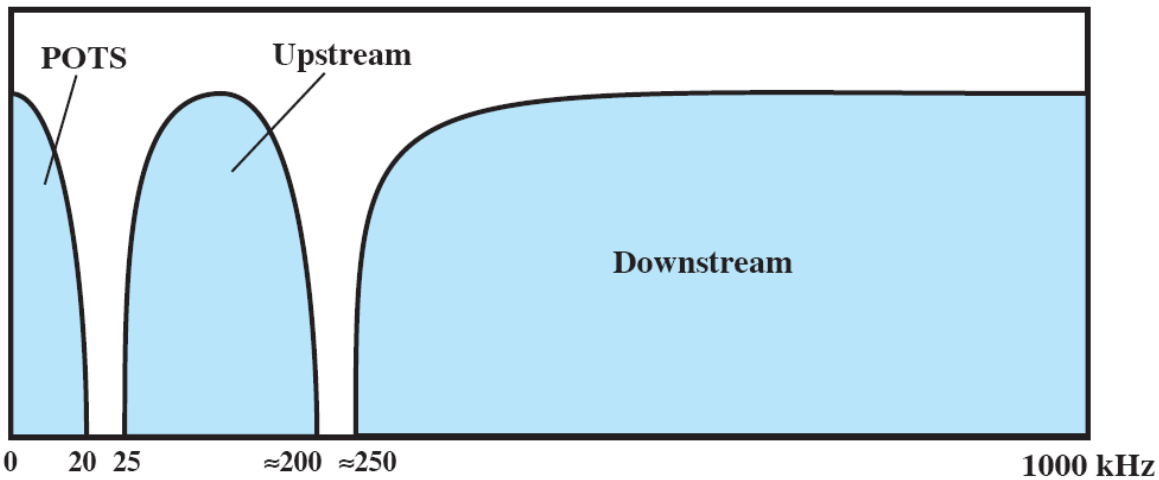


A bandpass filter only allows signal within a certain bandwidth to pass, thereby separating the output signal into individual user signals

Demodulate to return to original frequency of the input analog signal

ADSL

- Telephone lines (copper) are used to transmit 4kHz voice signals
- But the lines can actually transmit signals at wider spectrum, around 1MHz
- Asymmetric Digital Subscriber Line (ADSL) makes use of this unused spectrum to transmit data
  - 25kHz reserved for voice (Plain Old Telephone Service)
  - Separate data into upstream (you to exchange) and downstream (exchange to you)
  - Asymmetric: more down than up
    - Suits (or used to) many Internet applications



ADSL

- The upstream and downstream bands are split into small 4kHz sub-channels using Discrete Multitone (DMT)
  - DMT sends test signals over the line to determine signal-to-noise ratio for each sub-channel
  - Based on the SNR, DMT sends at different data rates in each sub-channel
    - Data rates from 0 to 60kb/s
    - Good SNR, send more bits
  - Data on each sub-channel is converted to analog signal using QAM; sum all the QAM signals to get transmitted signal
  - ADSL 1 allows 256 downstream sub-channels
    - Total of 15.36Mb/s download
    - However because of transmission impairments this data rate is never achieved
    - Data rates from 1Mb/s to 10Mb/s more likely, depending on line quality and distance (3 to 5km)