Multiplexing

Radhika Sukapuram

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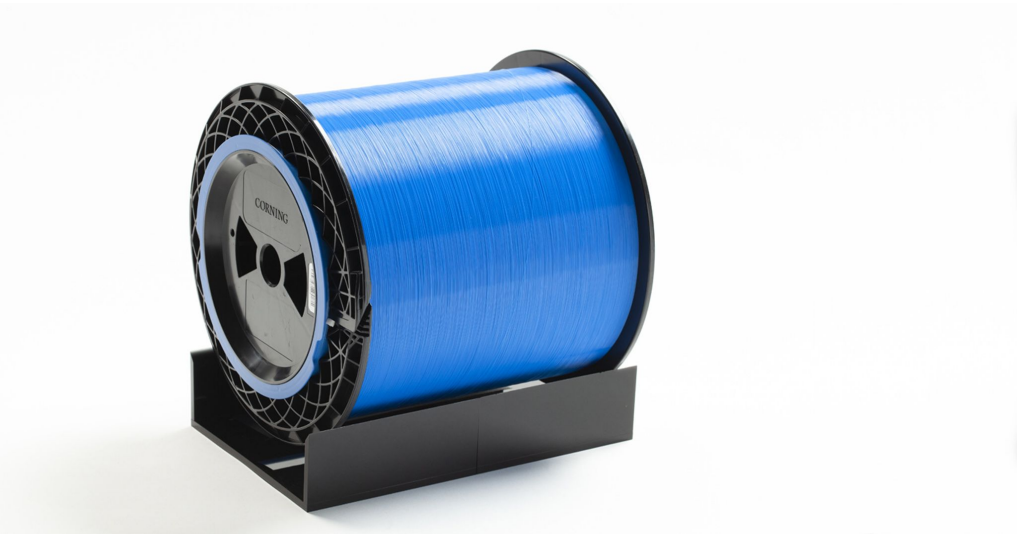
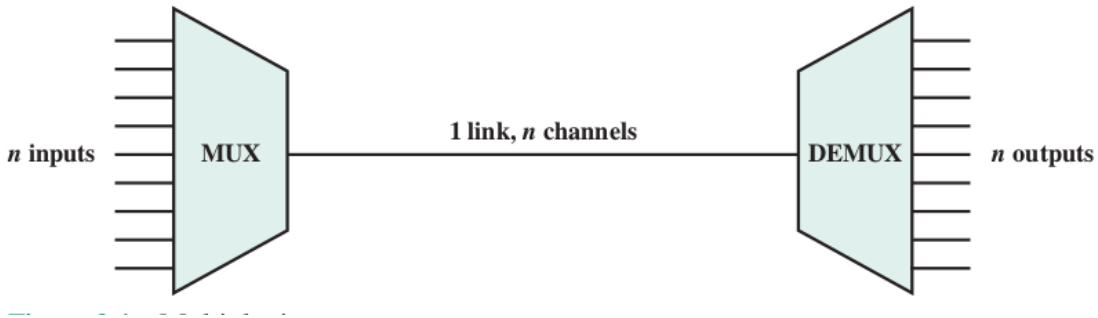
Multiplexing

- For efficiency, the capacity of a data link is shared between multiple communicating stations. This is called **multiplexing**
- Common application: long-haul communications (20 to 50km or longer) - high capacity fiber, coaxial or microwave links
- Can carry large numbers of voice and data transmissions simultaneously using multiplexing



Multiplexer



- Increase in data rate $\rightarrow$ low cost per kbps of transmission facility, transmitting and receiving equipment [given application, given distance]
- Most communicating devices require modest data support. For many terminal and personal computer applications that do not involve Web access or intensive graphics, a data rate of between 9600 bps and 64 kbps is generally adequate
- Similar statements apply to voice communications

Types of multiplexing techniques

- frequency-division multiplexing (FDM) : used in _____
- time-division multiplexing

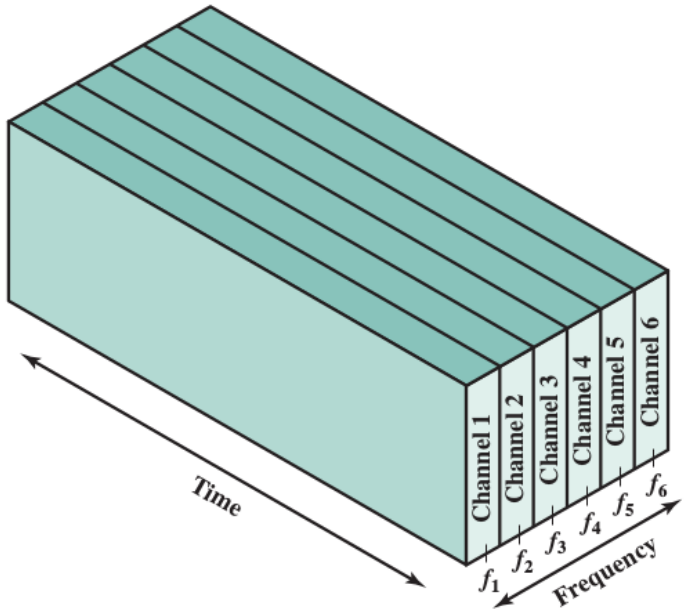
Question

Frequency-division multiplexing (FDM) is possible when useful bandwidth of the transmission medium _____ the required bandwidth of signals to be transmitted

(A) is more than

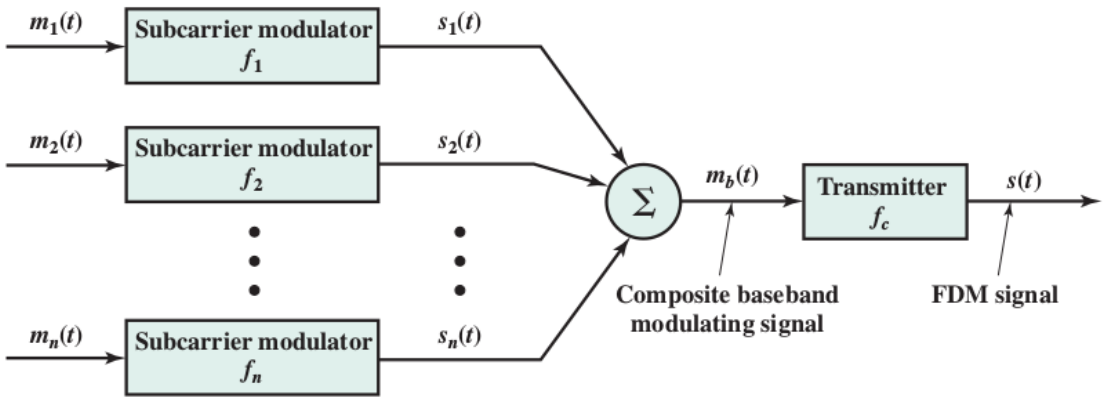
(B) is less than

Frequency-division multiplexing (FDM)



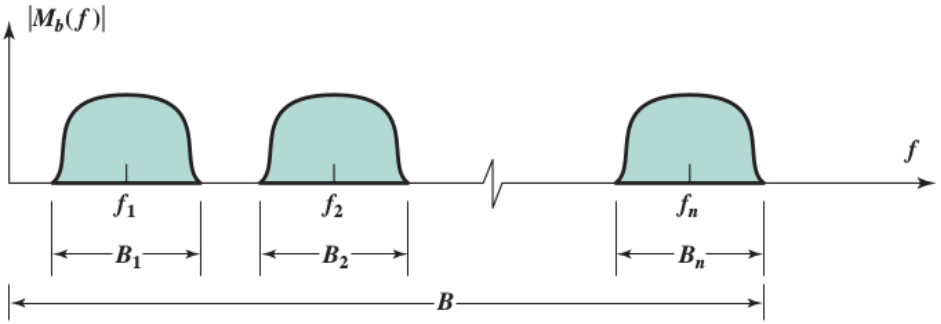
- Each signal is modulated onto a different carrier frequency
- the carrier frequencies are sufficiently separated (by guard bands) that the bandwidths of the signals do not significantly overlap
- See the picture: Each modulated signal requires a certain bandwidth centered on its carrier frequency, referred to as a channel.
- The composite signal transmitted across the medium is analog

Frequency-division multiplexing (FDM)



- $m_i(t)$ may be analog or digital
- Each f_i is a sub-carrier
- **Baseband**: the band of frequencies of the signal delivered by the source and potentially used as a modulating signal
- $m_b(t)$: Baseband signal, by summing up the analog, modulated signals $s_i(t)$

Spectrum : composite baseband modulating signal



- The spectrum of $m_i(t)$ is shifted to be centered on f_i
- f_i must be chosen so that the bandwidths of the various signals do not significantly overlap — otherwise it will be impossible to recover the original signals
- The composite signal may then be shifted as a whole to another carrier frequency by an additional modulation step
- This second modulation step need not use the same modulation technique as the first
- Total bandwidth of the signal is B , where $B > \Sigma_{i=1}^{n} B_i$

Question

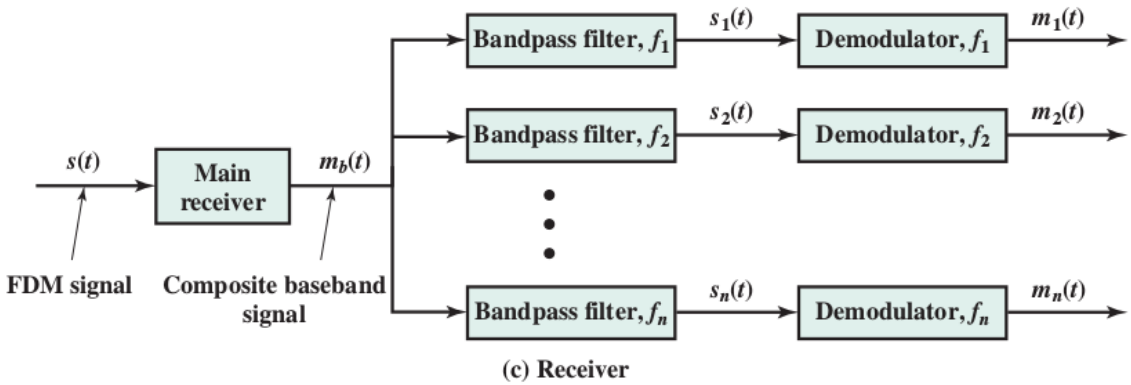
The output of an FDM transmitter is

(A) an analog signal

(B) a digital signal

(C) neither

FDM receiver

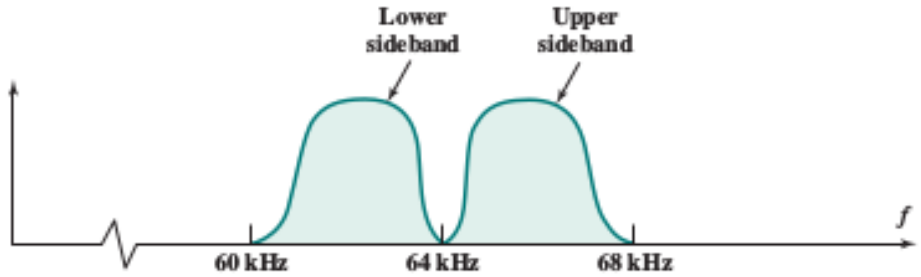


(c) Receiver

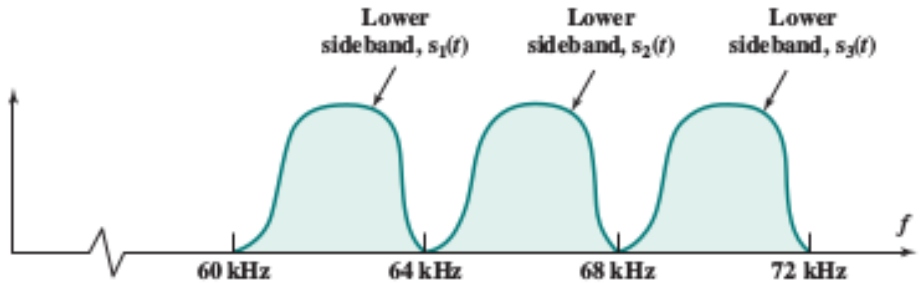
- Each bandpass filter is centered on f_i and has a bandwidth B_i

FDM of three voiceband signals

(a) Spectrum of voice signal



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



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

Figure 8.4 FDM of Three Voiceband Signals

Two problems that FDM must cope with

- Cross-talk — can be avoided by using guard bands (0-300 Hz and 3400-4000Hz)
- - the spectra of signals produced by modems for voiceband transmission also fit well in this bandwidth
- Intermodulation noise — the nonlinear effects of amplifiers on a signal in one channel could produce frequency components in other channels

North American and International FDM Carrier Standards

Number of Voice Channels	Bandwidth	Spectrum	AT&T	ITU-T
12	48 kHz	60–108 kHz	Group	Group
60	240 kHz	312–552 kHz	Supergroup	Supergroup
300	1.232 MHz	812–2044 kHz		Mastergroup
600	2.52 MHz	564–3084 kHz	Mastergroup	
900	3.872 MHz	8.516–12.388 MHz		Supermaster group
$N \times 600$			Mastergroup multiplex	
3,600	16.984 MHz	0.564–17.548 MHz	Jumbogroup	
10,800	57.442 MHz	3.124–60.566 MHz	Jumbogroup multiplex	

- 12 voice channels; 12*4 = 48 kHz; subcarriers from 64 to 108 kHZ in increments of 4kHz
- 5 group signals; 5*48=240 kHz; subcarriers from 420 to 612 kHz in increments of 48 kHz
- 10 supergroup signals (12*5*10=600 voice channels; 10*240 2.52 MHz;

Example

- The original voice or data signal may be modulated many times
- Original voice signal $\rightarrow$ encoded using QPSK to form an analog voice signal
- $\rightarrow$ modulate a 76-kHz carrier to form a component of a group signal
- $\rightarrow$ This group signal could then be used to modulate a 516-kHz carrier to form a component of a supergroup signal.