Analog Transmission of Analog Data:

AM and FM

Required reading: -

CSE 3213, Fall 2010
Instructor: N. Vlajic

Modulation of Analog Data

Why Analog-to-Analog Modulation?

– two principal reasons for combining an an analog signal with a carrier at freq. f_c:

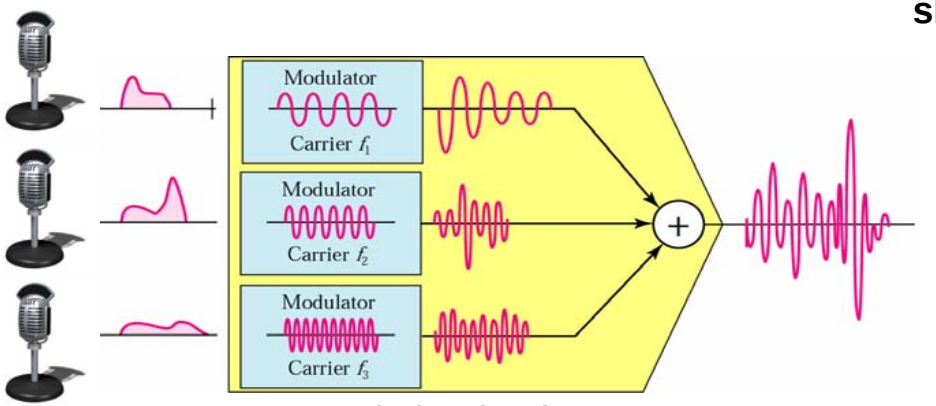
(1) higher freq. may be needed for effective transmission

- **in wireless domain, it is virtually impossible to transmit baseband signals – the required antennas would be many kilometres in diameter**

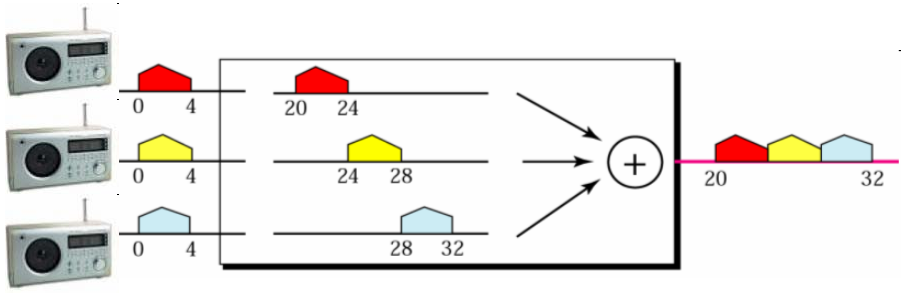
(2) modulation permits FDM (freq. division multiplexing) more on this later …

- **example: radio**

  analog signals produced by radio stations are low-pass, all in the same range - to be able to listen to different stations, the low-pass signals need to be shifted, each to a different range

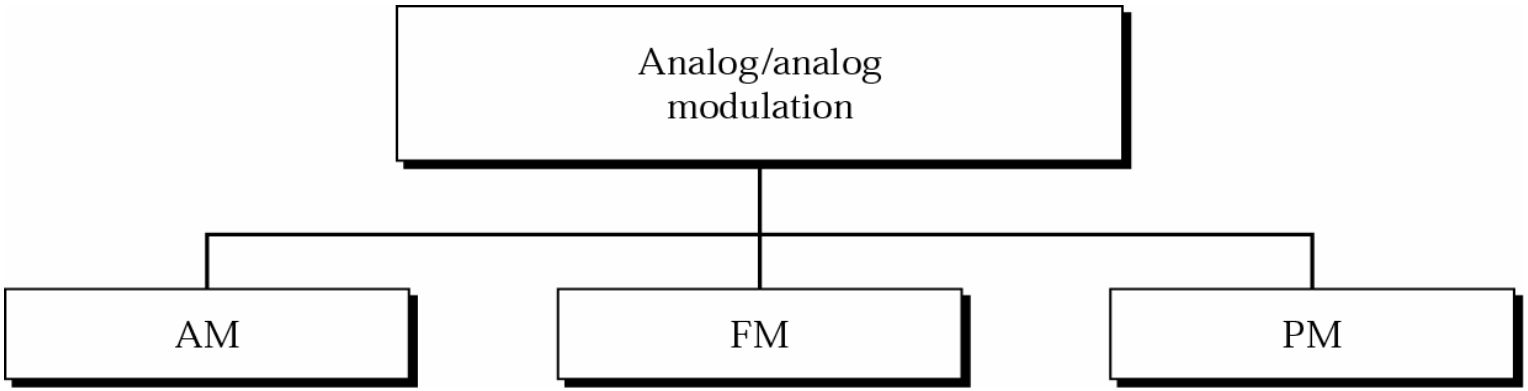


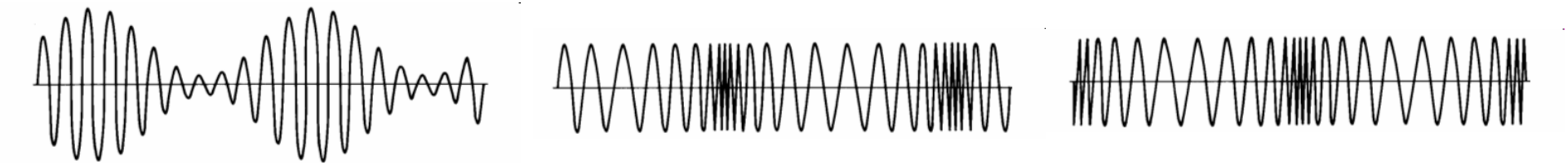
FDM in time-domain



FDM in frequency-domain

Types of Analog-to-Analog Modulation





Amplitude Modulation

Amplitude Modulation – **amplitude of the carrier signal varies with the changing amplitude of input/modulating signal; frequency and phase remain unchanged**

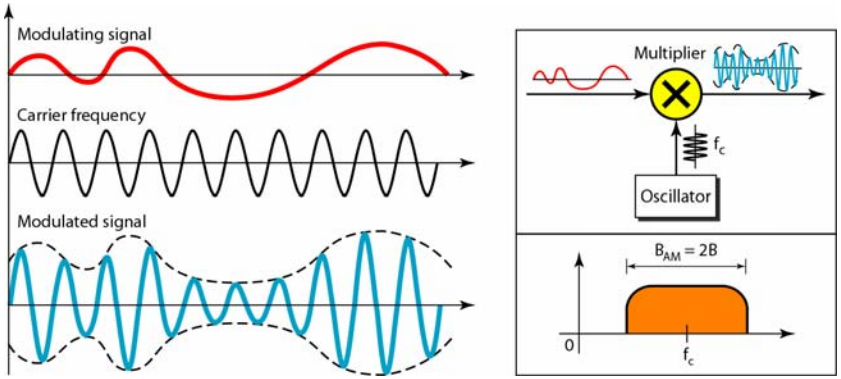
$$s(t) = [A_c + x(t)] \cdot \cos(2\pi f_c t) = A_c \cdot [1 + k_a x(t)] \cdot \cos(2\pi f_c t)$$

- **A_c – carrier amplitude**
- **k_a – amplitude sensitivity of the modulator, must be:**

$$|k_a x(t)| < 1$$

to ensure that the function $[1+k_a x(t)]$ is always positive

- **otherwise the envelope will cross the time axis, and info. will be lost**

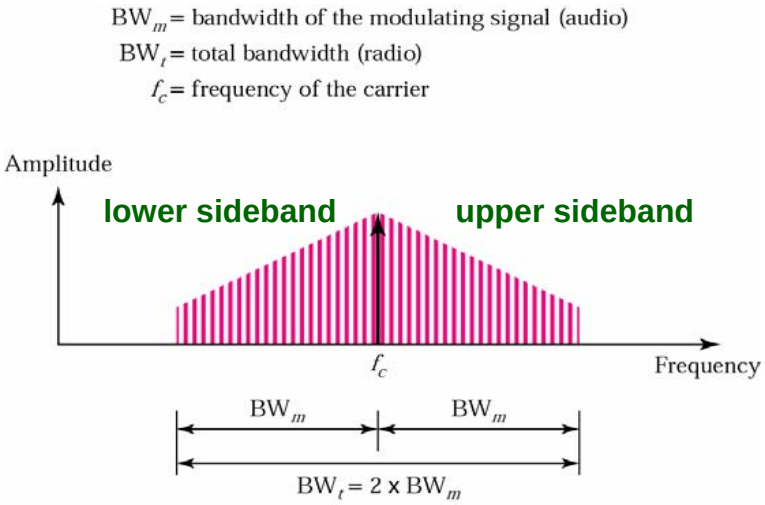


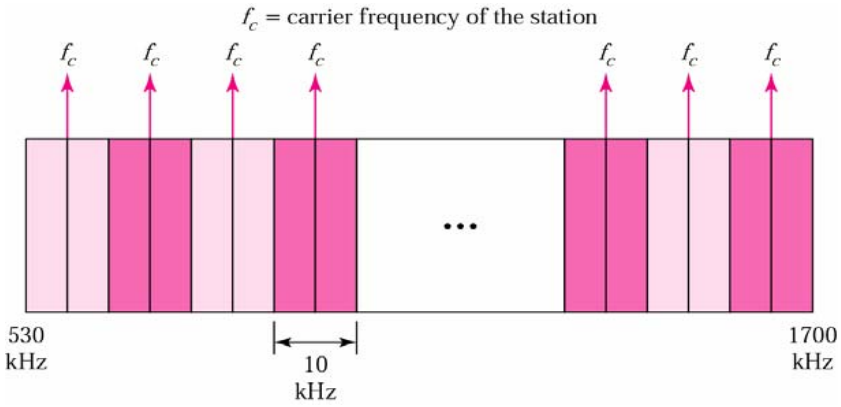
http://cnyack.homestead.com/files/modulation/modam.htm

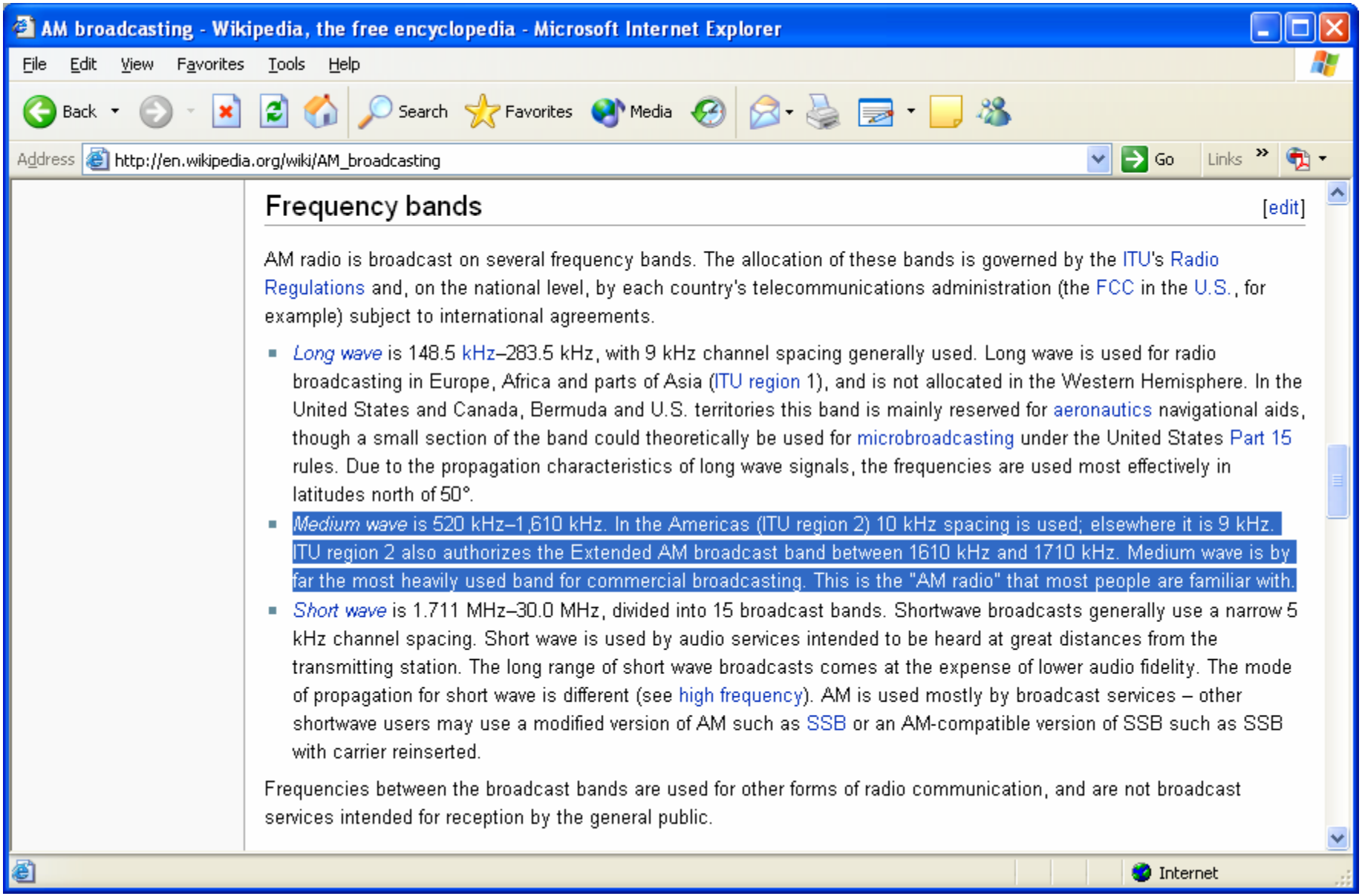
Amplitude Modulation (cont.)

AM Bandwidth – **bandwidth of an AM signal = 2x bandwidth of modulating signal, and covers a range centered on carrier frequency**

- **BW_{total} = 2*$BW_{modulating\text{-}signal}$**
- **example: AM radio**
  - **the bandwidth of an audio signal (speech only) is 5 kHz ⇒ each AM radio station needs a min bandwidth of 10 kHz**
  - **AM stations are allowed carrier frequencies anywhere between 530 - 1700 kHz; each station's carrier frequency must be separated from those on either side by at least 10 kHz, to avoid interference**






AM broadcasting - Wikipedia, the free encyclopedia - Microsoft Internet Explorer
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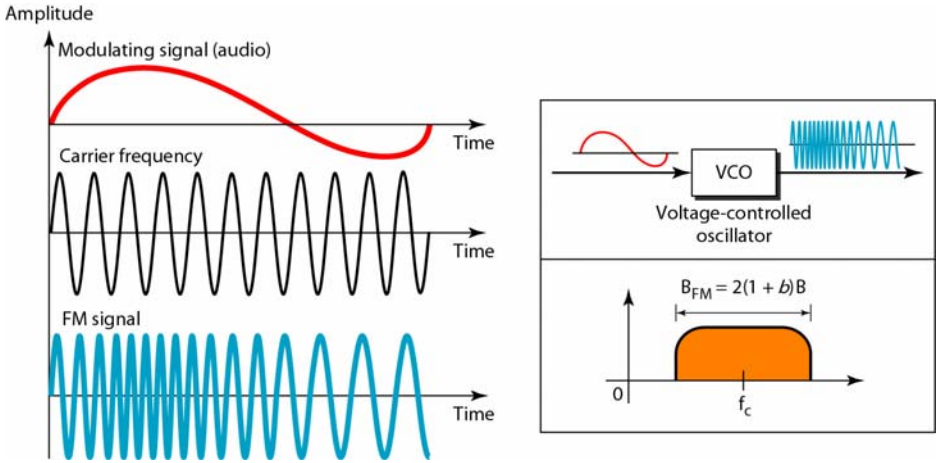
Frequency bands [edit]
AM radio is broadcast on several frequency bands. The allocation of these bands is governed by the ITU's Radio Regulations and, on the national level, by each country's telecommunications administration (the FCC in the U.S., for example) subject to international agreements.
Long wave is 148.5 kHz–283.5 kHz, with 9 kHz channel spacing generally used. Long wave is used for radio broadcasting in Europe, Africa and parts of Asia (ITU region 1), and is not allocated in the Western Hemisphere. In the United States and Canada, Bermuda and U.S. territories this band is mainly reserved for aeronautics navigational aids, though a small section of the band could theoretically be used for microbroadcasting under the United States Part 15 rules. Due to the propagation characteristics of long wave signals, the frequencies are used most effectively in latitudes north of 50°.
Medium wave is 520 kHz–1,610 kHz. In the Americas (ITU region 2) 10 kHz spacing is used; elsewhere it is 9 kHz. ITU region 2 also authorizes the Extended AM broadcast band between 1610 kHz and 1710 kHz. Medium wave is by far the most heavily used band for commercial broadcasting. This is the "AM radio" that most people are familiar with.
Short wave is 1.711 MHz–30.0 MHz, divided into 15 broadcast bands. Shortwave broadcasts generally use a narrow 5 kHz channel spacing. Short wave is used by audio services intended to be heard at great distances from the transmitting station. The long range of short wave broadcasts comes at the expense of lower audio fidelity. The mode of propagation for short wave is different (see high frequency). AM is used mostly by broadcast services – other shortwave users may use a modified version of AM such as SSB or an AM-compatible version of SSB such as SSB with carrier reinserted.
Frequencies between the broadcast bands are used for other forms of radio communication, and are not broadcast services intended for reception by the general public.
Internet

Frequency Modulation

Frequency Modulation – **frequency of carrier signal follows changes in voltage level (amplitude) of modulating signal**

$$s(t) = A_c \cos(2\pi f_c t + 2\pi k_f \int_0^t x(t)dt) = A_c \cos(\theta_i(t))$$

$$f_i(t) = \frac{1}{2\pi}\frac{d\theta_i(t)}{dt} = f_c + k_f x(t)$$



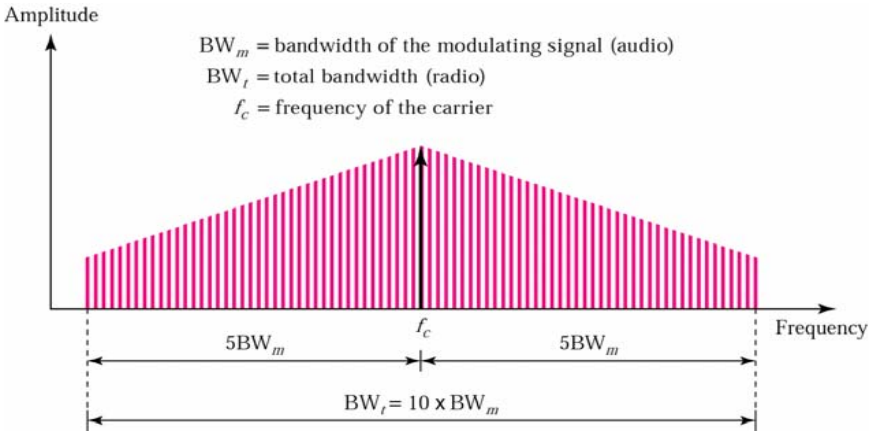
http://cnyack.homestead.com/files/modulation/modfm.htm

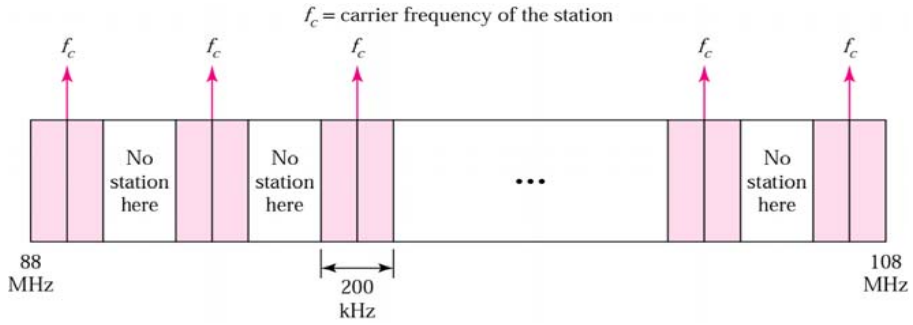
The actual frequency spectrum of a FM signal is "challenging" to find.
(The spectrum contains multiple sideband on each side of the carrier frequency.)

Frequency Modulation (cont.)

FM Bandwidth – **bandwidth of an FM signal = 10xbandwidth of modulating signal, and covers a range centered on carrier frequency**

- **BW_{total} = 10*$BW_{modulating\text{-}signal}$**
- **example: FM radio**
  - **the bandwidth of an audio signal (speech AND music) in is almost 15 kHz ⇒ each FM radio station needs a minimum bandwidth of 150 kHz**
  - **FM stations are allowed carrier frequencies anywhere between 88 and 108 MHz; stations must be separated by at least 200 kHz to keep their bandwidths from overlapping**





AM vs. FM

AM Disadvantages

(1) Most natural & man made radio noise is AM in nature, and AM receivers have no means of rejecting that noise.

(2) Also, weak signals have lower amplitude than strong ones, which requires the receiver to have circuits to compensate for the signal level differences.

AM Advantages

(1) AM signals can be reflected from the ionospheric layer back to earth, so that the signals can reach unintended places that are thousands of miles away.

FM Disadvantages

(1) At the high(er)-frequency FM signals pass unreflected through the ionosphere.

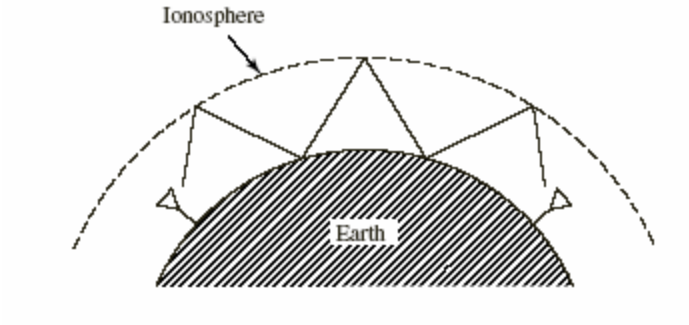
FM Advantages

(1) The effects of amplitude noise are minimized, since the recovered audio is dependent only on the frequency, and not the strength.

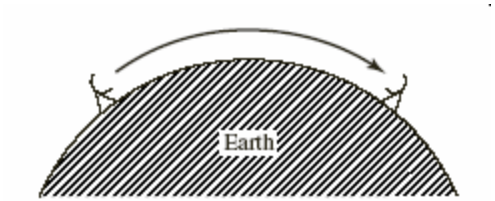
(2) The FM bandwidth can easily cover entire musical range of the human ear of about 20 kHz, and that is why FM radio sounds better than AM radio.

AM radio has wider coverage than FM radio;
FM radio has better sound quality than AM radio.

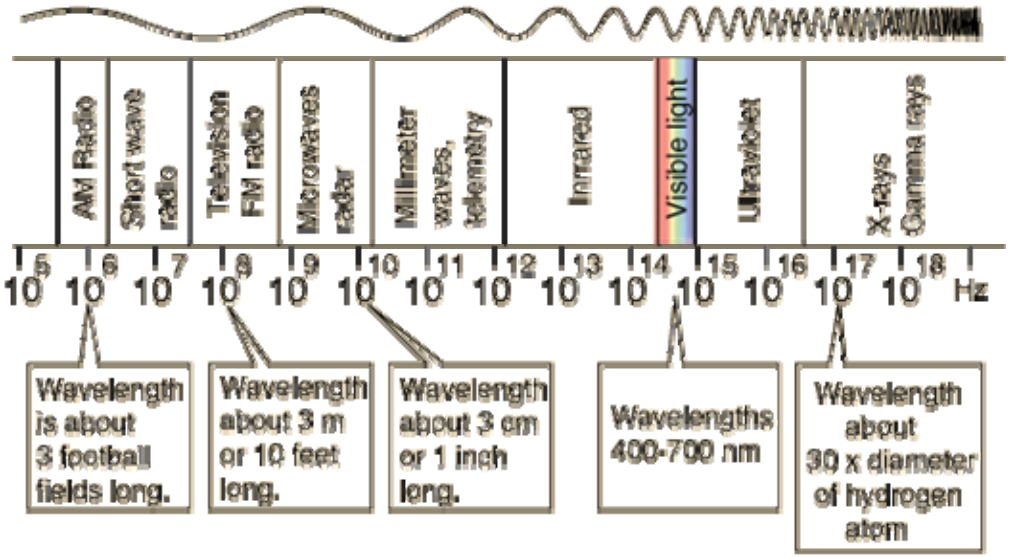
AM vs. FM (cont.)



sky-wave (AM signal) propagation



ground-wave (FM signal) propagation



"Radio waves are generally unaffected by obstacles smaller than their wavelength. So it is easy to visualise the 300 meter (1000 feet) waves of a 1 MHz AM radio station being unaffected by the hills and city buildings which play havoc with the 0.5 metre waves of UHF television. …"

http://www22.verizon.com/about/community/learningcenter/articles/printerfriendly1/0,1728,1131,00.html