2.3 Wireless Transmission

Wireless Transmission

- For mobile users, wireless transmission is vital.
- Some people believe that the future holds only two kinds of communication: fiber and wireless.
- All fixed (i.e., nonmobile) computers, telephones, faxes, and so on will use fiber, and all mobile ones will use wireless.
- Wireless has advantages for even fixed devices in some circumstances.

2.3.1 The Electromagnetic Spectrum

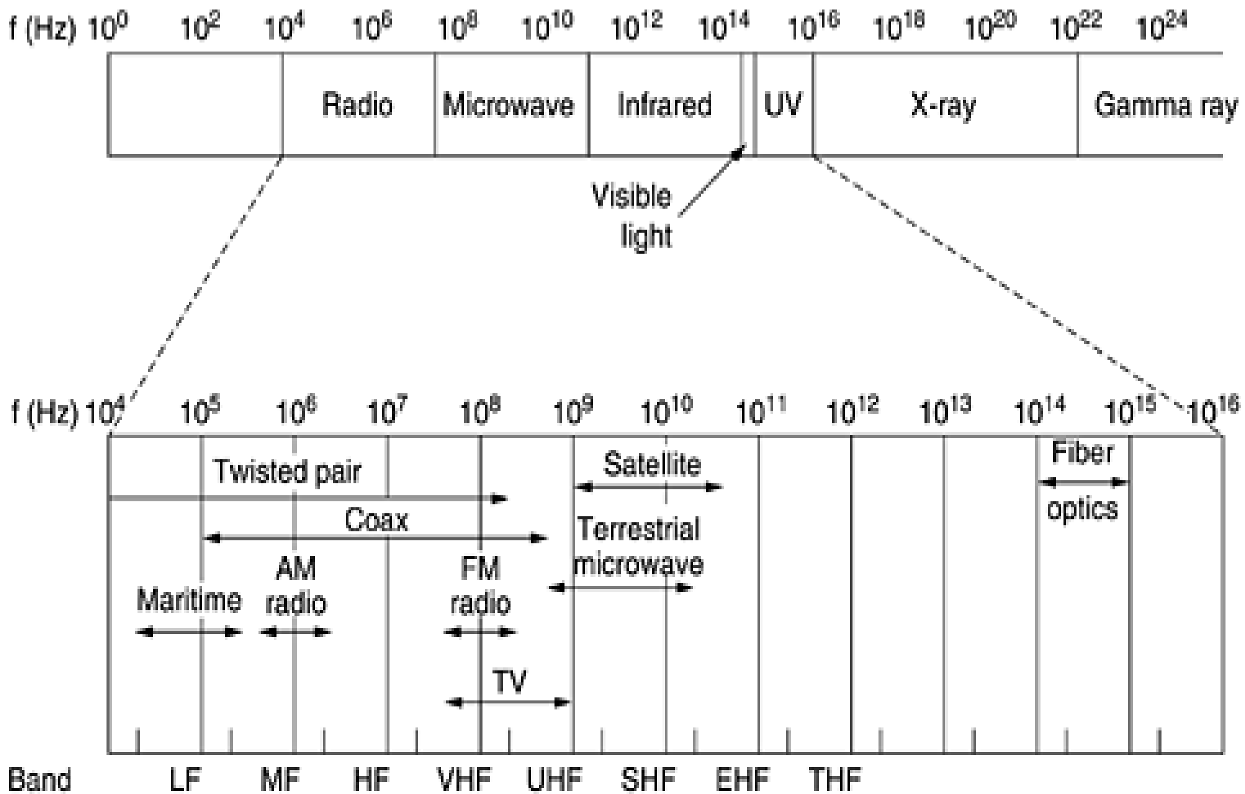
- When electrons move, they create electromagnetic waves that can propagate through space (even in a vacuum).
- The number of oscillations per second of a wave is called its frequency, f, and is measured in Hz.
- The distance between two consecutive maxima (or minima) is called the wavelength, which is universally designated by the Greek letter λ (lambda).
- When an antenna of the appropriate size is attached to an electrical circuit, the electromagnetic waves can be broadcast efficiently and received by a receiver some distance away.
- All wireless communication is based on this principle.

- In vacuum, all electromagnetic waves travel at the same speed, no matter what their frequency. This speed, usually called the speed of light, c, is approximately 3 x 10^8 m/sec, or about 1 foot (30 cm) per nanosecond.
- In copper or fiber the speed slows to about 2/3 of this value and becomes slightly frequency dependent. The speed of light is the ultimate speed limit. No object or signal can ever move faster than it.
- The fundamental relation between f, λ, and c (in vacuum) is

$$\lambda f = c$$

- Since c is a constant, if we know f, we can find λ, and vice versa.
- For example, 100-MHz waves are about 3 meters long, 1000-MHz waves are 0.3-meters long, and 0.1-meter waves have a frequency of 3000 MHz.

- **Figure: The electromagnetic spectrum and its uses for communication.**



- The radio, microwave, infrared, and visible light portions of the spectrum can all be used for transmitting information by modulating the amplitude, frequency, or phase of the waves.
- Ultraviolet light, X-rays, and gamma rays would be even better, due to their higher frequencies, but they are hard to produce and modulate, do not propagate well through buildings, and are dangerous to living things.
- The bands listed at the bottom of figure are the official ITU (International Telecommunication Union) names and are based on the wavelengths, so the LF band goes from 1 km to 10 km (approximately 30 kHz to 300 kHz).
- The terms LF, MF, and HF refer to low, medium, and high frequency, respectively.
- The higher bands were later named the Very, Ultra, Super, Extremely, and Tremendously High Frequency bands.
- Beyond that there are no names, but Incredibly, Astonishingly, and Prodigiously high frequency (IHF, AHF, and PHF) are used.

- The amount of information that an electromagnetic wave can carry is related to its bandwidth.
- It should now be obvious why networking people like fiber optics so much.
- If we solve $\lambda f = c$ for f and differentiate with respect to λ, and consider the absolute value

$$\Delta f = \frac{c \Delta \lambda}{\lambda^2}$$

- Thus, given the width of a wavelength band, Δλ, we can compute the corresponding frequency band, Δf, and from that the data rate the band can produce.

- The wider the band, the higher the data rate.
- As an example, consider the 1.30-micron band. Here we have $\lambda=1.3 \times 10^{-6}$ and $\Delta\lambda = 0.17 \times 10^{-6}$, so Δf is about 30 THz. At, say, 8 bits/Hz, we get 240 Tbps. (1 Tb=$10^{24)}$
- Most transmissions use a narrow frequency band (i.e., $\Delta f/f \ll 1$) to get the best reception (many watts/Hz).
- However, in some cases, a wide band is used.

2.3.2 Radio Transmission

- Radio waves are easy to generate, can travel long distances, and can penetrate buildings easily, so they are widely used for communication, both indoors and outdoors.
- Radio waves also are omnidirectional, meaning that they travel in all directions from the source, so the transmitter and receiver do not have to be carefully aligned physically.
- The properties of radio waves are frequency dependent. At low frequencies, radio waves pass through obstacles well, but the power falls off sharply with distance from the source, roughly as $1/r^2$ in air.
- At high frequencies, radio waves tend to travel in straight lines and bounce off obstacles. They are also absorbed by rain.
- At all frequencies, radio waves are subject to interference from motors and other electrical equipment.

2.3.3 Microwave Transmission

- Above 100 MHz, the waves travel in nearly straight lines and can therefore be narrowly focused.
- Concentrating all the energy into a small beam by means of a parabolic antenna (like the familiar satellite TV dish) gives a much higher signal-to-noise ratio, but the transmitting and receiving antennas must be accurately aligned with each other.
- Unlike radio waves at lower frequencies, microwaves do not pass through buildings well.
- Microwave communication is so widely used for long-distance telephone communication, mobile phones, television distribution, and other uses.
- Microwave is also relatively inexpensive.

2.3.4 Infrared and Millimeter Waves

- Unguided infrared and millimeter waves are widely used for short-range communication.
- The remote controls used on televisions, VCRs, and stereos all use infrared communication.
- They are relatively directional, cheap, and easy to build but have a major drawback: they do not pass through solid objects.
- On the other hand, the fact that infrared waves do not pass through solid walls well is also a plus. It means that an infrared system in one room of a building will not interfere with a similar system in adjacent rooms or buildings.
- Security of infrared systems is better than that of radio systems precisely for this reason.
- Therefore, no government license is needed to operate an infrared system, in contrast to radio systems.
- Infrared communication has a limited use on the desktop, for example, connecting notebook computers and printers, but it is not a major player in the communication game.