Information Technology
Inside and Outside
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VI. Transmission and Storage Technology

16. Radio -Frequency and Satellite Systems

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16. Radio -Frequency and Satellite Systems

- Objectives:
  - the fundamental design parameters for a wireless system, including signal bandwidth, transmission distance, transmitter frequency and power, and limitations on antenna location;
  - limitations of ``line of sight'' in communications system design, including satellite systems;
  - basics of antenna design; and
  - the Global Positioning System as an example of a wireless information system.

16.2 Overview of Radio Communications System Design

- Basic parameters in the design of **RF (radio-frequency) systems**:
  - **Transmitter power**
  - **Transmitter frequency**, which determines the characteristics of signal``propagation" (how far the signal will travel, whether it goes in all directions or is beamed like a searchlight, the types of interference likely to occur)
  - **Receiver sensitivity**
  - **Desired bandwidth and/or bit rate**
  - **Limitations on antenna size, location, etc.**
  - **Desired transmission distance**
- The design of cell in a **cellular system**.
  - ***Desired transmission distance***: While more is usually better with respect to this parameter, other considerations will limit the distance, so it is important to consider the purpose to be served. For example, consider coverage of a small city for police radio; in this case, a radius of 10 miles would be more than adequate.

16.2 Overview of Radio Communications System Design(2)

- The design of cell in a **cellular system**.(2)
  - ***Transmitter frequency***: a Federal Communications Commission (FCC) frequency allocation in the 800 MHz region;
    - ✓ the FCC has assigned us a particular band of frequencies around 800 MHz.
  - ***Transmitter power***:
    - ✓ two quite different transmitters in this situation: **``base stations''** and the **mobile units**.
    - ✓ The transmitter power of hand-held units will be limited by two factors: (1) **available battery power & biological concerns** because the antenna will be quite close to the user's head. (2) **a function of frequency**, with more power being permitted at lower frequencies. At 800 MHz, 1 watt of transmitted power meets the biological limit, and also permits convenient battery size with reasonable life (on the order of 1 hour of transmission time).

16.2 Overview of Radio Communications System Design(3)

- The design of cell in a **cellular system**.(3)
  - ***Receiver sensitivity***: The receiver parameter corresponding to transmitter power is receiver sensitivity. This represents the amount of power at the receiver antenna needed to produce a usable signal (audible speech in this case). This quantity should be quoted on a ``per unit bandwidth'' basis, but often the bandwidth is assumed, as in an AM or FM radio receiver. A typical value would be about one picowatt (10^{-12}watt) for audio bandwidth (about 4 kHz). One picowatt is a very small value: 0.000000000001 watt; for comparison a standard electric light bulb consumes about 100 watts. For larger bandwidth systems (such as television), the required power would increase in proportion to the bandwidth. For example, a system with 40 kHz signal bandwidth would require about 10 picowatts at the receiver.

16.2 Overview of Radio Communications System Design(4)

- The design of cell in a **cellular system**.(4)
  - ***Limitations on antenna size and location***: For a given frequency, there is a direct correlation between antenna size and the amount of power received. Also, for a given amount of power there is an inverse correlation between frequency and antenna size (i.e., at higher frequencies antennas may be smaller). Practical considerations limit the antenna size for the hand-held unit. This is not so much a limitation on the base station. Antenna size is often measured with respect to the wavelength of the RF frequency in use. For this case (800 MHz) the wavelength is about 0.4 meters. A reasonably efficient antenna has a length of one quarter of the wavelength, so our hand-held antenna need only be about 10 cm, or 4 inches, long.

16.3 Satellite and Other Long-Distance Communications Systems

- **Television bandwidth** (approximately **5 MHz**), the **necessary radio frequency** would have to be **many times 5 MHz, perhaps 100 MHz**

16.4 The Global Positioning System

- **The major technologies that GPS**
  - satellite communications
  - powerful, miniature computers
  - high-performance microwave radio receivers
  - inexpensive graphics displays
  - large digital memories
  - geographic databases with fine detail
  - very high-accuracy time keeping

16.4.1 How Does GPS Work?

- The principle of operation of the GPS system, ***triangulation***, is very simple.
  - On the surface of the Earth, if you know your distance from a **given point**, you know that you are somewhere on **a circle with that point in the center**.
  - If at the same time you also know **your distance from a different point**, you know that you are on **another given circle**. Those **circles cross at (at most) two points**, so you have narrowed your position down to one of two points.
  - With a known distance from a third point, you can **identify your unique location**

16.4 The Global Positioning System(2)

16.4.1 How Does GPS Work?(2)

- The set of **24 GPS satellites** are in orbits arranged so that at any given time the satellites are distributed fairly evenly above the earth, so that four or more satellites are always in view. Use of more than the minimum number of satellites improves the accuracy of the position calculation. The satellites orbit at an altitude of approximately **11,000 miles**.
- **Each satellite transmits four types of information:**

1. **an identifying number (from 1 to 32 to provide for spares among the operational group of 24);**
2. **its location in astronomical terms;**
3. **time information; and**
4. **maintenance and ``health" information so that receivers can identify unreliable data.**

16.4 The Global Positioning System(3)

16.4.2 Components of the GPS System

Figure 16.1: A portable GPS of the type used by general aviation (private)pilots. This unit will display a detailed aviation map and shows the current location of the airplane on that map as well as a depiction of the route to be flown.

16.4 The Global Positioning System(4)

16.4.2 Components of the GPS System(2)

- **GPS is an excellent example of breakthrough invention, which generates many new products and capabilities.**
- **Following is a partial list:**

1. **aircraft navigation;**
2. **marine navigation: exact position information is now easily available to all boaters at a very low cost (a few hundred dollars);**
3. **hiking, hunting, and other outdoor activities;**
4. **driving: for route finding, emergencies;**
5. **surveying;**
6. **construction; and**
7. **farming (yes, literally each seed may be placed in a farmer's field guided by GPS)**