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8.1.1 Introduction to Multiple Access

Frequency division multiple access (FDMA), *time division multiple access* (TDMA), and *code division multiple access* (CDMA) are the three major access techniques used to share the available bandwidth in a wireless communication system. These techniques can be grouped as *narrowband* and *wideband* systems, depending upon how the available bandwidth is allocated to the users. The duplexing technique of a multiple access system is usually described along with the particular multiple access scheme, as shown in the examples below.

Narrowband Systems — The term *narrowband* is used to relate the bandwidth of a single channel to the expected coherence bandwidth of the channel. In a narrowband multiple access system, the available radio spectrum is

divided into a large number of narrowband channels. The channels are usually operated using FDD. To minimize interference between forward and reverse links on each channel, the frequency split is made as great as possible within the frequency spectrum, while still allowing inexpensive duplexers and a common transceiver antenna to be used in each subscriber unit. In narrowband FDMA, a user is assigned a particular channel which is not shared by other users in the vicinity, and if FDD is used (that is, each channel has a forward and reverse link), then the system is called FDMA/FDD. Narrowband TDMA, on the other hand, allows users to share the same channel but allocates a unique time slot to each user in a cyclical fashion on the channel, thus separating a small number of users in time on a single channel. For narrowband TDMA, there generally are a large number of channels allocated using either FDD or TDD, and each channel is shared using TDMA. Such systems are called TDMA/FDD or TDMA/TDD access systems.

Wideband systems — In wideband systems, the transmission bandwidth of a single channel is much larger than the coherence bandwidth of the channel. Thus, multipath fading does not greatly affect the received signal within a wideband channel, and frequency selective fades occur in only a small fraction of the signal bandwidth. In wideband multiple access systems, the users are allowed to transmit in a large part of the spectrum. A large number of transmitters are also



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8.2 Frequency Division Multiple Access (FDMA)

Frequency division multiple access (FDMA) assigns individual channels to individual users. It can be seen from Figure 8.2 that each user is allocated a unique frequency band or channel. These channels are assigned on demand to users who request service. During the period of the call, no other user can share the same frequency band. In FDD systems, the users are assigned a channel as a pair of frequencies; one frequency is used for the forward channel, while the other frequency is used for the reverse channel. The features of FDMA are as follows:

- The FDMA channel carries only one phone circuit at a time.

Table 8.1 Multiple Access Techniques Used in Different Wireless Communication Systems

Cellular System	Multiple Access Technique
Advanced Mobile Phone System (AMPS)	FDMA/FDD
Global System for Mobile (GSM)	TDMA/FDD
U.S. Digital Cellular (USDC)	TDMA/FDD
Japanese Digital Cellular (JDC)	TDMA/FDD
CT2 (Cordless Telephone)	FDMA/TDD
Digital European Cordless Telephone (DECT)	FDMA/TDD
U.S. Narrowband Spread Spectrum (IS-95)	CDMA/FDD

- If an FDMA channel is not in use, then it sits idle and cannot be used by other users to increase or share capacity. It is essentially a wasted resource.
- After the assignment of a voice channel, the base station and the mobile transmit simultaneously and continuously.
- The bandwidths of FDMA channels are relatively narrow (30 kHz) as each channel supports only one circuit per carrier. That is, FDMA is usually



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Nonlinear Effects in FDMA — In a FDMA system, many channels share the same antenna at the base station. The power amplifiers or the power combiners, when operated at or near saturation for maximum power efficiency, are nonlinear. The nonlinearities cause signal spreading in the frequency domain and generate *intermodulation* (IM) frequencies. IM is undesired RF radiation which can interfere with other channels in the FDMA systems. Spreading of the spec-

trum results in adjacent-channel interference. Intermodulation is the generation of undesirable harmonics. Harmonics generated outside the mobile radio band cause interference to adjacent services, while those present inside the band cause interference to other users in the mobile system [Yac93].

Example 8.1

Find the intermodulation frequencies generated if a base station transmits two carrier frequencies at 1930 MHz and 1932 MHz that are amplified by a saturated clipping amplifier. If the mobile radio band is allocated from 1920 MHz to 1940 MHz, designate the IM frequencies that lie inside and outside the band.

Solution to Example 8.1

Intermodulation distortion products occur at frequencies $mf_1 + nf_2$ for all integer values of m and n , i.e., $-\infty < m, n < \infty$. Some of the possible intermodulation frequencies that are produced by a nonlinear device are

$$(2n + 1)f_1 - 2nf_2, (2n + 2)f_1 - (2n + 1)f_2, (2n + 1)f_1 - 2nf_2, (2n + 2)f_2 - (2n + 1)f_1, \text{ etc. for } n = 0, 1, 2, \dots$$

Table E8.1 lists several intermodulation product terms.

Table E 8.1: Intermodulation Products

$n = 0$	$n = 1$	$n = 2$	$n = 3$
1930	1926	1922	1918
1928	1924	1920	1916
1932	1936	1940	1944*
1934	1938	1942*	1946*

The frequencies in the table marked with an asterisk (*) are the frequencies