CHAPTER 2

MULTIPLE ACCESS

A limited amount of bandwidth is allocated for wireless services. A wireless system is required to accommodate as many users as possible by effectively sharing the limited bandwidth. Therefore, in the field of communications, the term *multiple access* could be defined as a means of allowing multiple users to simultaneously share the finite bandwidth with least possible degradation in the performance of the system. There are several techniques how multiple accessing can be achieved. The are four basic schemes [1], [5]:

1. Frequency Division Multiple Access (FDMA)
2. Time Division Multiple Access (TDMA)
3. Code Division Multiple Access (CDMA)
4. Space Division Multiple Access (SDMA)

2.1 Frequency Division Multiple Access (FDMA)

FDMA is one of the earliest multiple-access techniques for cellular systems when continuous transmission is required for analog services. In this technique the bandwidth is divided into a number of channels and distributed among users with a finite portion of bandwidth for permanent use as illustrated in figure 2.1. The vertical axis that represents the code is shown here just to make a clear comparison with CDMA (discussed later in this chapter). The channels are assigned only when demanded by the users. Therefore when a channel is not in use it becomes a wasted resource. FDMA channels have narrow bandwidth (30Khz) and therefore they are usually implemented in narrowband systems. Since the user has his portion of the bandwidth all the time, FDMA does not require synchronization or timing control, which makes it algorithmically simple. Even though no two users use the same frequency band at the same time, guard bands are introduced between frequency bands to minimize adjacent channel interference. Guard bands are unused frequency slots that separate neighboring channels. This leads to a waste of bandwidth. When continuous transmission is not required, bandwidth goes wasted since it is not being utilized for a portion of the time. In wireless communications, FDMA achieves simultaneous transmission and reception by using *Frequency division duplexing* (FDD). In order for both the transmitter and the receiver to operate at the same time, FDD requires duplexers. The requirement of duplexers in the FDMA system makes it expensive.

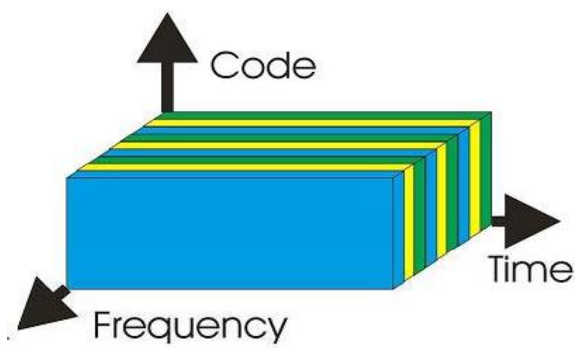

Figure 2.1 Channel usage by FDMA (courtesy: www.ant.uni-bremen.de/research/cdma/)

2.2 Time Division Multiple Access (TDMA)

In digital systems, continuous transmission is not required because users do not use the allotted bandwidth all the time. In such systems, TDMA is a complimentary access technique to FDMA. Global Systems for Mobile communications (GSM) uses the TDMA technique. In TDMA, the entire bandwidth is available to the user but only for a finite period of time. In most cases the available bandwidth is divided into fewer channels compared to FDMA and the users are allotted time slots during which they have the entire channel bandwidth at their disposal. This is illustrated in figure 2.2. TDMA requires careful time synchronization since users share the bandwidth in the frequency domain. Since the number of channels are less, inter channel interference is almost negligible, hence the guard time between the channels is considerably smaller. Guard time is a spacing in time between the TDMA bursts. In cellular communications, when a user moves from one cell to another there is a chance that user could experience a call loss if there are no free time slots available. TDMA uses different time slots for transmission and reception. This type of duplexing is referred to as *Time division duplexing* (TDD). TDD does not require duplexers.

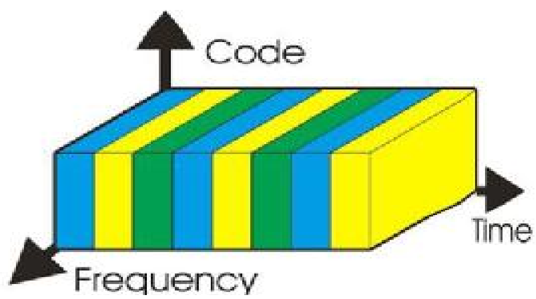

Figure 2.2 Channel usage by TDMA (courtesy: www.ant.uni-bremen.de/research/cdma/)

2.3 Code Division Multiple Access

In CDMA, all the users occupy the same bandwidth, however they are all assigned separate codes, which differentiates them from each other as shown in figure 2.3a. Figure 2.3b shows typical Walsh codes used for this purpose. CDMA systems utilize a spread spectrum technique in which a spreading signal, which is uncorrelated to the signal and has a large bandwidth, is used to spread the narrow band message signal. Direct Sequence Spread Spectrum (DS-SS) is most commonly used for CDMA. In DS-SS, the message signal is multiplied by a Pseudo Random Noise Code (PN code), which has noise-like properties. Each user has his own codeword which is orthogonal to the codes of other users. In order to detect the user, the receiver is required to know the codeword used by the transmitter. Unlike TDMA, CDMA does not require time synchronization between the users. A CDMA system experiences a problem called *self-jamming* which arises when the spreading codes used for different users are not exactly orthogonal. While dispreading, this leads to a significant contribution from other users to the receiver decision statistic. If the power of the multiple users in a CDMA system is unequal, then the user with the strongest signal power will be demodulated at the receiver. The strength of the received signal raises the noise floor for the weaker signals at the demodulators. This reduces the probability that weaker signals will be received. This problem, known as the *near-far problem* can be taken care of by using *power control*. This ensures that all the signals within the coverage of the base station arrive with same power at the receiver.

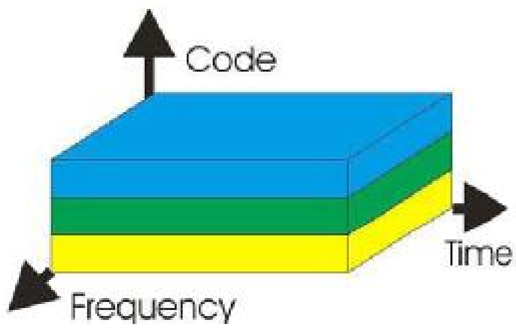

Figure 2.3a Channel usage by CDMA (courtesy: www.ant.uni-bremen.de/research/cdma/)

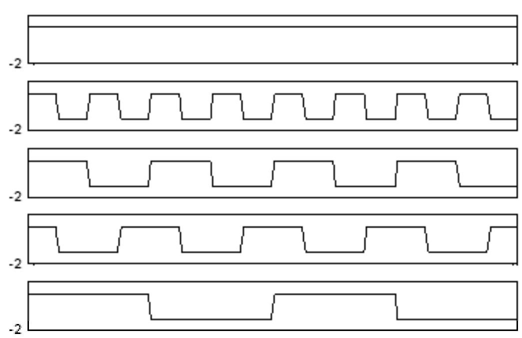

Figure 2.3b Walsh Codes

2.4 Space Division Multiple Access (SDMA)

SDMA utilizes the spatial separation of the users in order to optimize the use of the frequency spectrum. A primitive form of SDMA is when the same frequency is re-used in different cells in a cellular wireless network. However for limited co-channel interference it is required that the cells be sufficiently separated. This limits the number of cells a region can be divided into and hence limits the frequency re-use factor. A more advanced approach can further increase the capacity of the network. This technique would enable frequency re-use within the cell. It uses a *Smart Antenna* technique that employs antenna arrays backed by some intelligent signal processing to steer the antenna pattern in the direction of the desired user and places nulls in the direction of the interfering signals. Since these arrays can produce narrow spot beams, the frequency can be re-used within the cell as long as the spatial separation between the users is sufficient. Figure 2.4 shows three users served by SDMA using the same channel within the cell. In a practical cellular environment it is improbable to have just one transmitter fall within the receiver beam width. Therefore it becomes imperative to use other multiple access techniques in conjunction with SDMA. When different areas are covered by the antenna beam, frequency can be re-used, in which case TDMA or CDMA is employed, for different frequencies FDMA can be used.

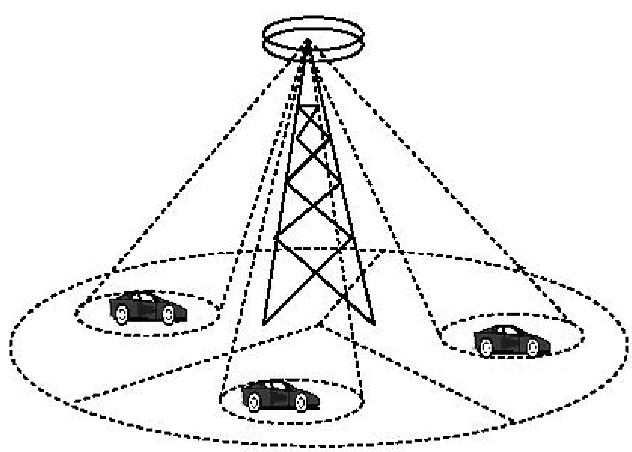

Figure 2.4 Intra-cell SDMA