TIA IS-95 CDMA System

Qualcomm proposed the CDMA radio system for digital cellular phone applications. It was optimized under existing U.S. mobile cellular system constraints of the advanced mobile phone system (AMPS). The CDMA system uses the same frequency in all cells and all sectors. The system design has been standardized by the TIA as IS-95 and many equipment vendors sell CDMA equipment that meet the standard. The IS-95 CDMA system operates in the same frequency band as the AMPS using frequency division duplex (FDD) with 25 MHz in each direction.* The uplink (mobile to base station) and downlink (base station to mobile) bands use frequencies from 869 to 894 MHz and from 824 to 849 MHz, respectively. The mobile station supports CDMA operations on the AMPS channel numbers 1013 through 1023, 1 through 311, 356 through 644, 689 through 694, and 739 through 777, inclusive. The CDMA channels are defi ned in terms of an RF frequency and a code sequence. Sixty-four Walsh codes (see Appendix D) are used to identify the forward channels, whereas unique long PN code offsets are used for the identifi cation of the reverse channels. The modulation and coding features of the IS-95 CDMA system are listed in Table 11.9. Modulation and coding details for the forward and reverse channels differ. Pilot signals are transmitted by each cell to assist the mobile radio to acquire and track the cell site downlink signals. The strong coding helps these radios to operate effectively at an E_b/N_0 ratio of a 5 to 7 dB range. The CDMA system (IS-95) uses power control and voice activation to minimize mutual interference. Voice activation is provided by using a variable rate vocoder (see Chapter 8) which for Rate set 1 codec operates at a maximum rate of 8 kbps to a minimum rate of 1 kbps, depending on the level of voice activity. With the decreased data rate, the power control circuit reduces the transmitter power to achieve the same bit error rate. A precise power control, along with voice activation circuit, is critical to avoid excessive transmitter signal power that is responsible for contributing the overall interference in the system. The Rate set 2 coding algorithms at 13 kbps are also supported. A bit-interleaver with 20 msec span is used with error-control coding to overcome multipath fading and shadowing (see Chapter 3). The time span used is the same as the time frame of voice compression algorithm. A Rake receiver used in the CDMA radio takes advantage of a multipath delay greater than 1 _s, which is common in cellular/personal communication service networks in urban and suburban environments.

Downlink (Forward) (BS to MS)

The downlink channels include one pilot channel, one synchronization (synch) channel, and 62 other channels including up to 7 paging channels. (If multiple carriers are implemented, paging channels and synch channels do not need to be duplicated). The information on each channel is modulated by the appropriate Walsh code and then modulated by a quadrature pair of PN sequences at a fixed

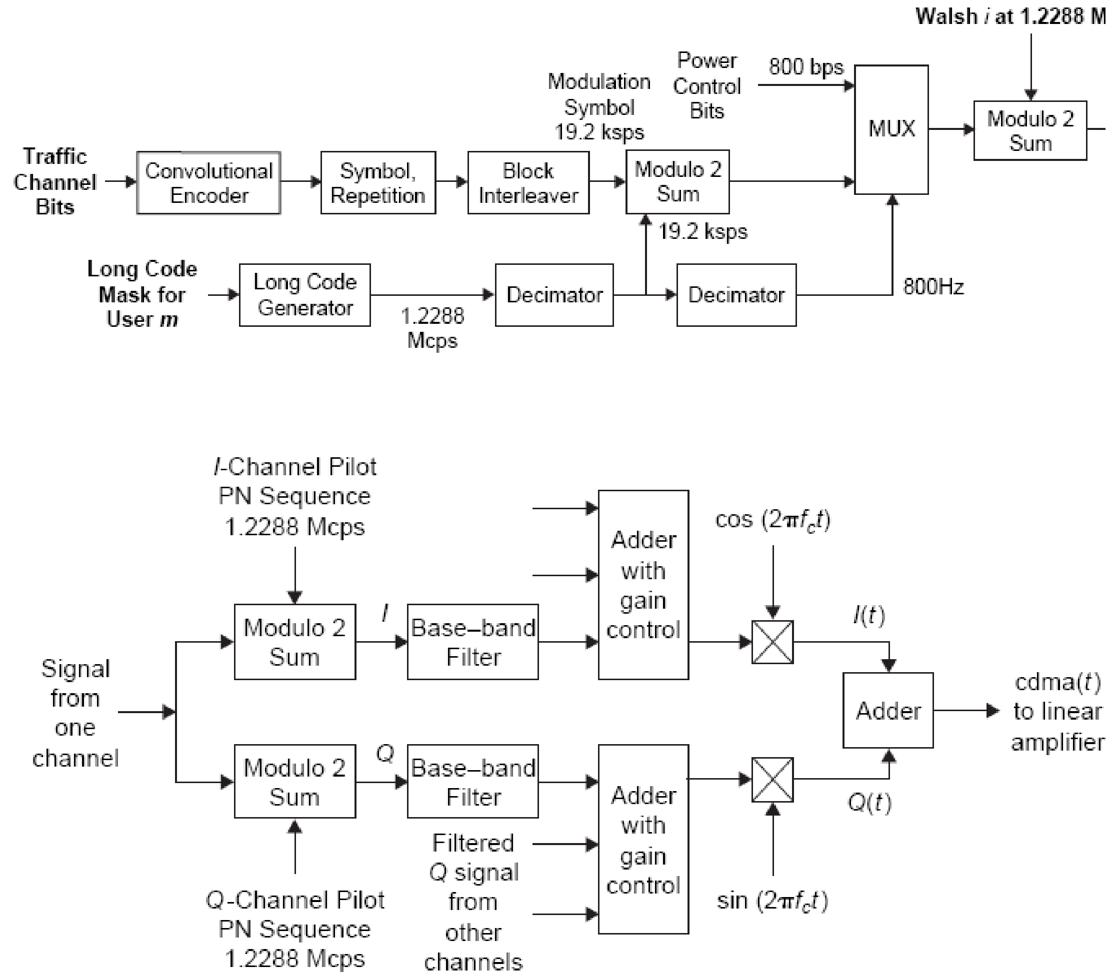

Figure 11.16 Forward traffic channel.

chip rate of 1.2288 Mcps (see Figure 11.15). The pilot channel is always assigned to code channel number zero. If the synch channel is present, it is given the code channel number 32. Whenever paging channels are present, they are assigned the code channel numbers 1 through 7 (inclusive) in sequence. The remaining code channels are used by forward traffi c channels (see Figure 11.16). The synch channel operates at a fi xed data rate of 1200 bps and is convolutionally encoded to 2400 bps, repeated to 4800 bps, and interleaved. The forward traffi c channels are grouped into sets. Rate set 1 has four rates: 9600, 4800, 2400, and 1200 bps. Rate set 2 contains four rates: 14,400, 7200, 3600, and 1800 bps. All radio systems support Rate set 1 on the forward traffi c channels. Rate set 2 is optionally supported on the forward traffi c channels. When a radio system supports a rate set, all four rates of the set are supported. Speech is encoded using a variable rate vocoder (see Chapter 8) to generate forward traffi c channel data depending on voice activity. Since frame duration is fi xed at 20 ms, the number of bits per frame varies according to the traffi c rate. Half rate convolutional encoding is used, which doubles the traffi c rate to give rates from 2400 to 19,200 bits per second. Interleaving is performed over 20 ms. A long PN code of 2^{42} _ 1 (_ 4.4 _ 10^{12}) is generated using the user's electronic serial number (ESN) embedded in the mobile station long code mask (with voice privacy, the mobile station long code mask does not use the ESN). The scrambled data is multiplexed with power control information which steals bits from the scrambled data. The multiplexed signal on the traffi c channel remains at 19,200 bps and is modulated at 1.2288 Mcps by the Walsh code, W_i, assigned to the *i*th user traffic c channel. The signal is spread at 1.2288 Mcps by quadrature pseudo-random binary sequence signals, and the resulting quadrature signals are then weighted. The power level of the traffi c channel depends on its data transmission rate. The paging channel data is processed in a similar manner to the traffi c channel data. However, there is no variation in the power level on a per frame basis. The paging channels provide the mobile stations with system information and instructions, in addition to acknowledging messages following access requests on the mobile stations' access channels. The 42-bit mask is used to generate the long code. The paging channels operate at a data rate of 9600 or 4800 bps. All 64 channels are combined to give single *I* and *Q* channels. The signals are applied to quadrature modulators and resulting signals are summed to form a QPSK signal, which is linearly amplifi ed. The pilot CDMA signal transmitted by a base station provides a reference for all mobile stations. It is used in the demodulation process. The pilot signal level for all base stations is much higher (about 4 to 6 dB) than the traffi c channel. The pilot signals are quadrature pseudo-random binary sequence signals with a period of32,768 chips. Since the chip rate is 1.2288 Mcps, the pilot pseudo-random binary sequence corresponds to a period of 26.66 ms, which is equivalent to 75 pilot channel code repetitions every 2 seconds. The pilot signals from all base stations use the same pseudo-random binary sequence, but each base station is identifi ed by a unique time offset of its pseudo-random binary sequence (short code). These offsets are in increments of 64 chips providing 512 unique offset codes. These large numbers of offsets ensure that unique base station identifi cation can be obtained, even in a dense microcellular environment. A mobile station processes the pilot channel to fi nd the strongest multipath signal components. The processed pilot signal provides an accurate estimation of time delay, phase, and magnitude of the multipath components. These components are tracked in the presence of fast fading, and coherent reception with combining is used. The chip rate on the pilot channel and on all frequency carriers is locked to precise system time by using the global positioning system (GPS). Once the mobile station identifi es the strongest pilot offset by processing the multipath components from the pilot channel correlator, it examines the signal on its synch channel which is locked to the pseudo-random binary sequence signal on the pilot channel. Since the synch channel is time aligned with its base station's pilot channel, the mobile station fi nds the information pertinent to this particular base station. The synch channel message contains time-of-day and long code synchronization to ensure that long code generators at the base station and mobile station are aligned and identical. The mobile station nowattempts to access the paging channel and listens for system information. The mobile station enters the idle state when it has completed acquisition and synchronization. It listens to the assigned paging channel and is able to receive and initiate calls.

Uplink (Reverse) (MS to BS)

The uplink channel is separated from the downlink channel by 45 MHz at cellular frequencies and 80 MHz at PCS frequencies (1.8 to 1.9 GHz). The uplink uses the same 32,768 chip code as is used on the downlink. The two types of uplink channels are the access channel and reverse traffi c channels (see Figure 11.17). The access channel enables the mobile station to communicate nontraffi c information, such as originating calls and responding to paging. The access rate is fi xed at 4800 bps. All mobile stations accessing a radio system share the same frequency assignment. Each access channel is identifi ed by a distinct access channel long code sequence having an access number, a paging channel number associated with the access channel, and other system data. Each mobile station uses a different PN code; therefore, the radio system can correctly decode the information from an individual mobile station. Data transmitted on the reverse traffi c channel is grouped into 20 ms frames. All data on the reverse traffi c channel is convolutionally encoded, symbol repeated, block interleaved, and modulated by Walsh symbols transmitted for each six-bit symbol block. The symbols are from the set of the 64 mutually orthogonal waveforms. The reverse traffi c channel for Rate set 1 may use either 9600, 4800, 2400, or 1200 bps data rates for transmission. The transmission varies proportionally with the data rate, being 100% at 9600 bps to 12.5% at 1200 bps. An optional second rate set is also supported in the PCS version of CDMA and new versions of cellular CDMA. The actual burst transmission rate is fi xed at 28.8 ksps. Since six code symbols are modulated as one of 64 modulation symbols for transmission, the modulation symbol transmission rate is fi xed at 4800 modulation symbols per

second. This results in a fi xed Walsh chip rate of 307.2 kcps. The rate of spreading PN sequence is fi xed at 1.2288 Mcps, so that each Walsh chip is spread by 4 PN chips. Table 11.10 provides the signal rates and their relationship for the various transmission rates on the reverse traffi c channel. Following orthogonal spreading, the reverse traffi c channel and access channel are spread in quadrature. Zero-offset *I* and *Q* PN sequences are used for spreading. These sequences are periodic (short code) with 32,768 PN chips in length and are based on characteristic polynomials $g_I(x)$ and $g_Q(x)$.