PART II CDMA BASICS

6.3 CDMA CHANNEL CONCEPT

As mentioned in previous chapters, cellular telephone networks use various control and traffic channels to carry out the operations necessary to allow for the setup of a subscriber radio link for the transmission of either data or a voice conversation and the subsequent system support for the subscriber's mobility. The cdmaOne and cdma2000 cellular systems are based on the use of code division multiple access (CDMA) technology to provide additional user capacity over a limited amount of radio frequency spectrum. This feat is accomplished by using a spread spectrum encoding technique that provides for numerous radio channels that all occupy the same frequency spectrum. To enable these distinct but same frequency channels, orthogonal Walsh spreading codes are used for channel encoding. Several of these encoded channels are used specifically within the CDMA system to provide precise system timing, control, and overhead information while other channels are used to carry user traffic.

This text will not attempt to derive the values or properties of these **Walsh codes** but only describe the basic structure of the 64-bit codes and their usage in IS-95 CDMA systems. To that end, each Walsh code consists of a binary combination of sixty-four 0s and 1s, and all the codes except one (the all-0s Walsh code—W_0^{64}) have an equal number of 0s and 1s. Suffice to say that the sixty-four Walsh codes used in the IS-95 CDMA systems have the unique quality of being orthogonal to one another. As stated earlier, this principle is exploited to create sixty-four distinct communications channels that can all exist in the same frequency spectrum. Also, as mentioned before, all other Walsh encoded signals will appear as broadband noise to the CDMA receiver except for the unique signal that was created with the same Walsh code as the one the receiver uses for demodulation. Figure 6–10 shows the basic principle behind the use of an 8-bit Walsh orthogonal spreading code to create a distinct signal. Note how the use of the spreading code increases the number of bits sent in the same time interval as the original digital signal and hence increases the overall signal bandwidth.

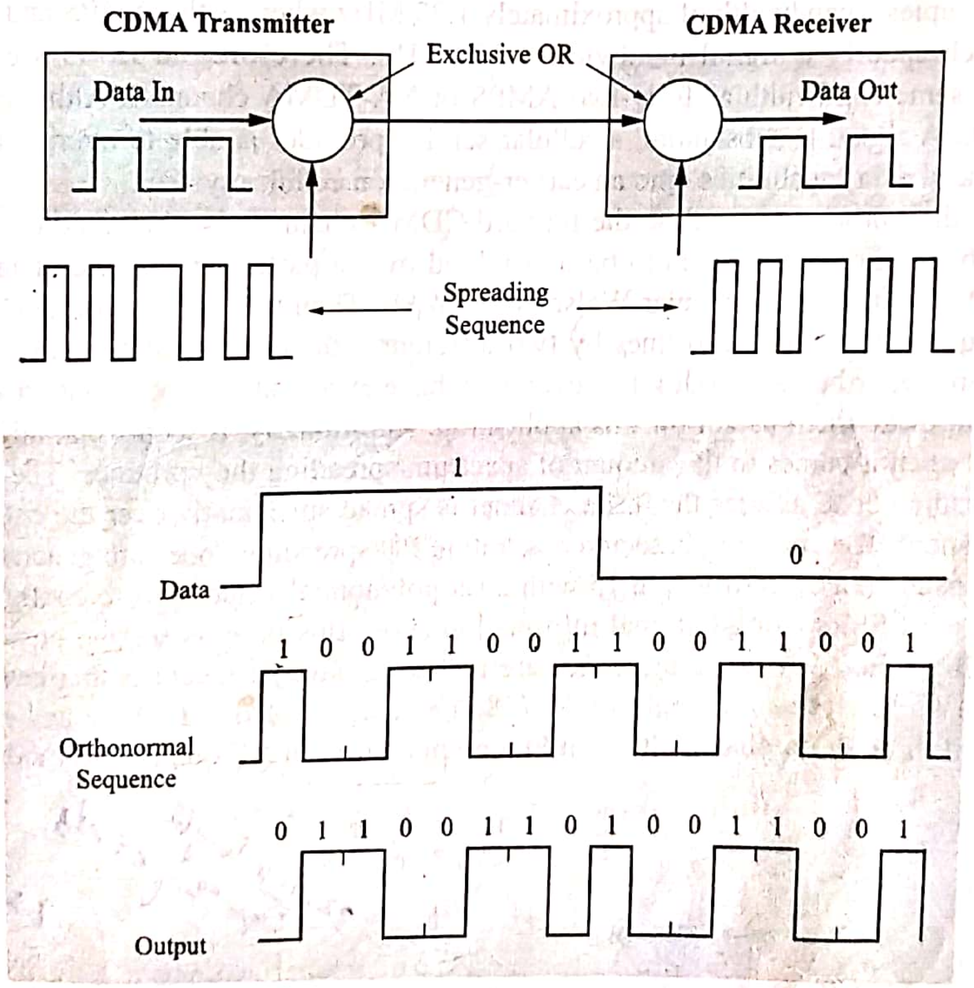


Figure 6–10 The basic spectrum spreading operation.

It should be pointed out right away that the forward channels in a CDMA system are encoded differently than the reverse channels. The different encoding schemes will be explained in more detail in the following sections about the forward and reverse CDMA logical channels.

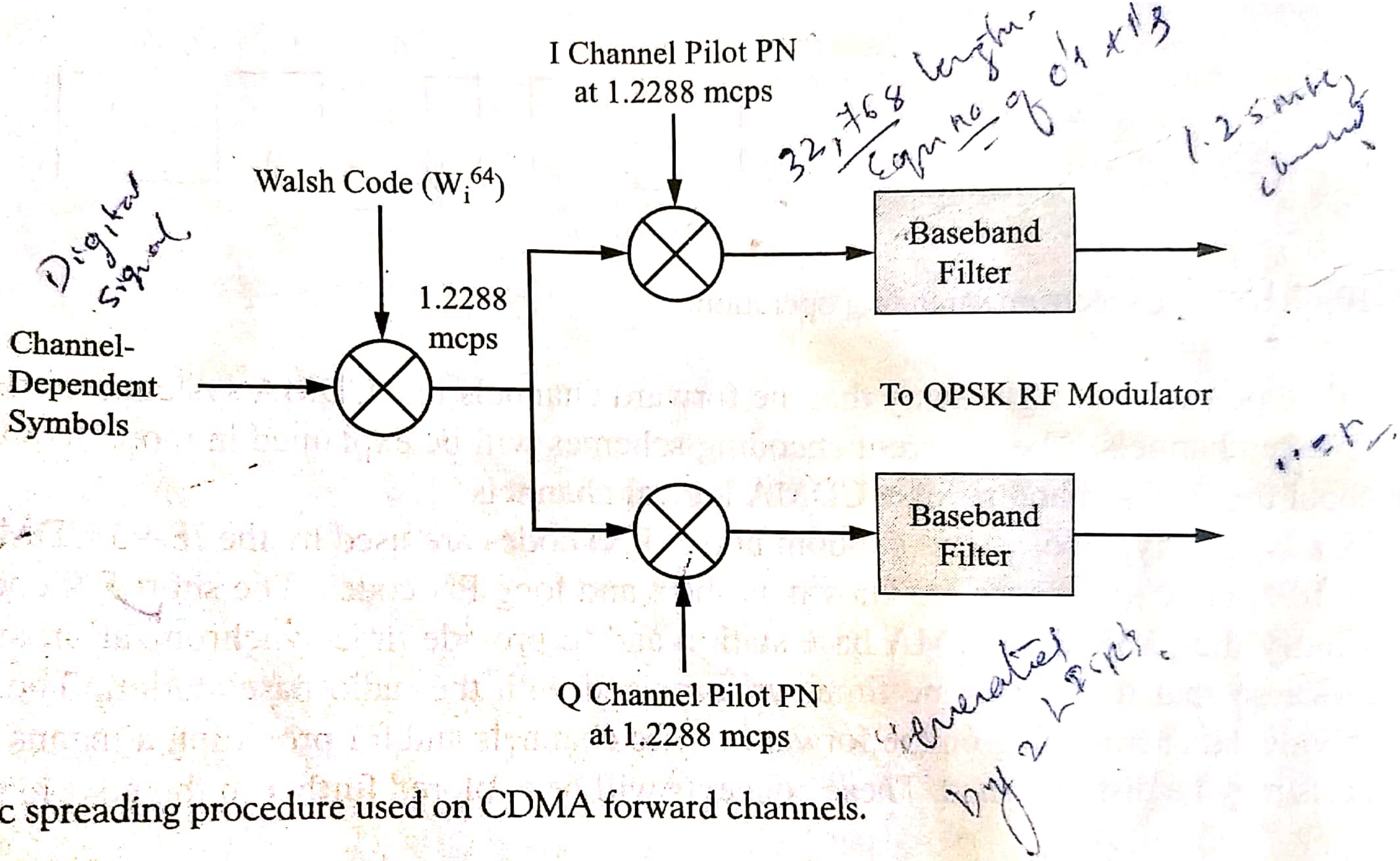
Additionally, two types of pseudorandom noise (PN) codes are used by the IS-95 CDMA system. These two types of PN code sequences are known as short and long PN codes. The short PN code is time shifted both to identify the particular CDMA base station and to provide time synchronization signals to the subscriber device so that it can become time synchronized with the radio base station. The long PN code is used to provide data scrambling on the forward traffic channels and for providing a means by which reverse link channels may be distinguished. These concepts will be explored further in the next few sections.

In summary, for an IS-95 CDMA cellular system, a single radio base station may consist of up to sixty-four separate channel elements (CEs) that all use the same carrier frequency or portion of the radio frequency spectrum. Each of the base station's modulated signals effectively becomes a separate channel when the digital signal to be transmitted is encoded with a distinct Walsh code. Several of the Walsh codes are reserved for use with particular forward channels that serve various logical system functions as will be presented next. At this time, only the basic IS-95 CDMA system will be discussed. Later, the modifications and improvements incorporated into IS-95B and then into cdma2000 will be discussed. Chapter 8 will present more detail about the actual hardware used to implement a CDMA system.

Forward Logical Channels

The IS-95 CDMA forward channels exist between the CDMA base station and the subscriber devices. The first CDMA systems used the same frequency spectrum as the AMPS and NA-TDMA systems. However, the IS-95 signal occupies a bandwidth of approximately 1.25 MHz whereas the AMPS and NA-TDMA system standards each specify a signal bandwidth of 30 kHz. Therefore, an IS-95 signal will occupy approximately the same bandwidth as forty-two AMPS or NA-TDMA channels. Although the bandwidth required for a CDMA signal is substantial, a cellular service provider is able to overlay an IS-95 CDMA system with enhanced data capabilities onto an earlier-generation cellular system.

The basic spreading procedure used on the forward CDMA channels is illustrated by Figure 6–11. As shown in Figure 6–11, the digital signal to be transmitted over a particular forward channel is spread by first Exclusive-OR'ing it with a particular Walsh code (W_i^{64}). Then the signal is further scrambled in the in-phase (I) and quadrature phase (Q) lines by two different short PN spreading codes. These short PN spreading codes are not orthogonal codes; however, they have excellent cross-correlation and auto-correlation properties that make them useful for this application. Additionally, it seems that all Walsh codes are not created equal when it comes to the amount of spectrum spreading they produce. Therefore, the use of the short PN spreading code assures that each channel is spread sufficiently over the entire bandwidth of the 1.25-MHz channel. The short in-phase and quadrature PN spreading codes are generated by two linear feedback shift registers (LFSRs) of length 15 with a set polynomial value used to configure the feedback paths of each of the LFSRs (for additional information about this process see the present CDMA standards). The resulting short PN spreading codes are repeating binary sequences that have approximately equal numbers of 0s and 1s and a length of 32,768. The outputs of the in-phase and quadrature phase signals are passed through baseband filters and then applied to an RF quadrature modulator integrated



ure 6–11 Basic spreading procedure used on CDMA forward channels.

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circuit (IC) that upconverts the final output signal to the UHF frequency bands. This channel element signal is linearly combined with other forward channel element signals, amplified, and the composite passband signal is transmitted over the air interface.

The short PN spreading codes provide the CDMA system with the ability to differentiate between different base stations (or cells) transmitting on the same frequency. The same short PN code sequence is used by all CDMA base stations; however, for each base station the PN sequence is offset from the sequences used by other area base stations. The offset is in 64-bit increments, hence there are 512 possible offsets. In a scheme analogous to the frequency reuse plans described for other access techniques in Chapter 4, the same offset may be reused at a great enough distance away from its first use. Figure 6–12 shows but one example of this reuse method. The use of this offset scheme requires that the base stations used in a CDMA system must all be time synchronized on the downlink radio channels. This precise timing synchronization is achieved through the use of the Global Positioning System (GPS) to achieve a system time that has the required accuracy.

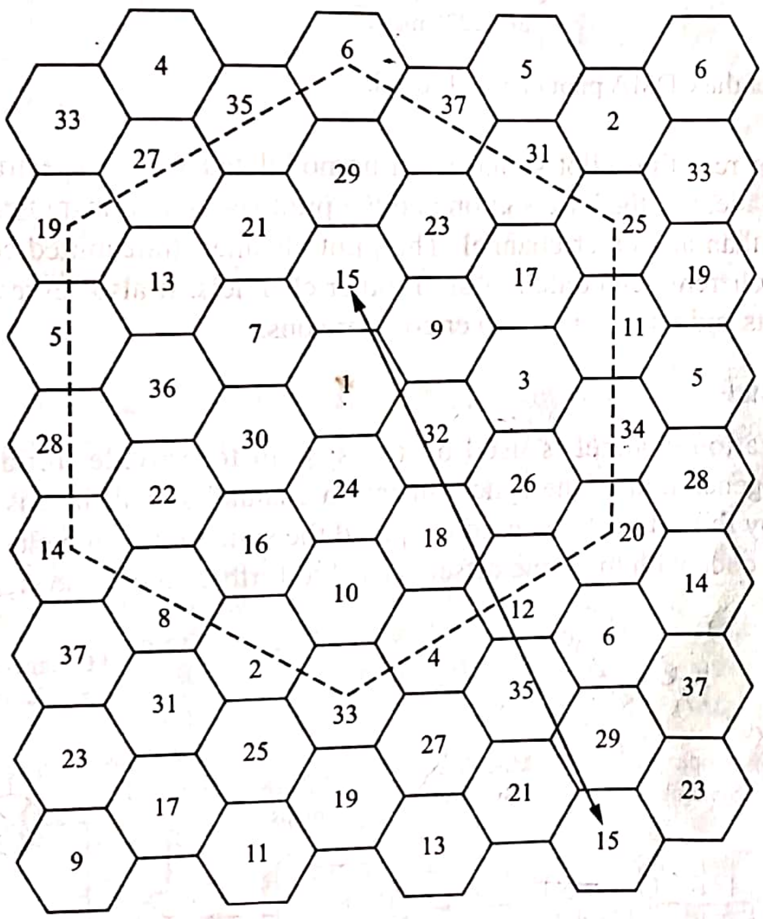


Figure 6–12 CDMA base station timing offset reuse pattern.

Figure 6–12 CDMA base station timing offset reuse pattern.

The initial IS-95 CDMA system implementation uses four different types of logical channels in the forward direction: the pilot channel, synchronization channel, paging channels, and traffic/power control channels. Each one of these types of forward channels will be discussed in more detail in the following sections.

Pilot Channel

The CDMA pilot channel is used to provide a reference signal for all the SDs within a cell. Figure 6–13 depicts the generation of the pilot channel signal. The all-0s Walsh code (W_0^{64}) is used for the initial signal spreading on a sequence of all 0s. This results in a sequence of all zeros that are further spread using the short PN spreading sequences resulting in a sequence of 0s and 1s. The I and Q signals drive a quadrature

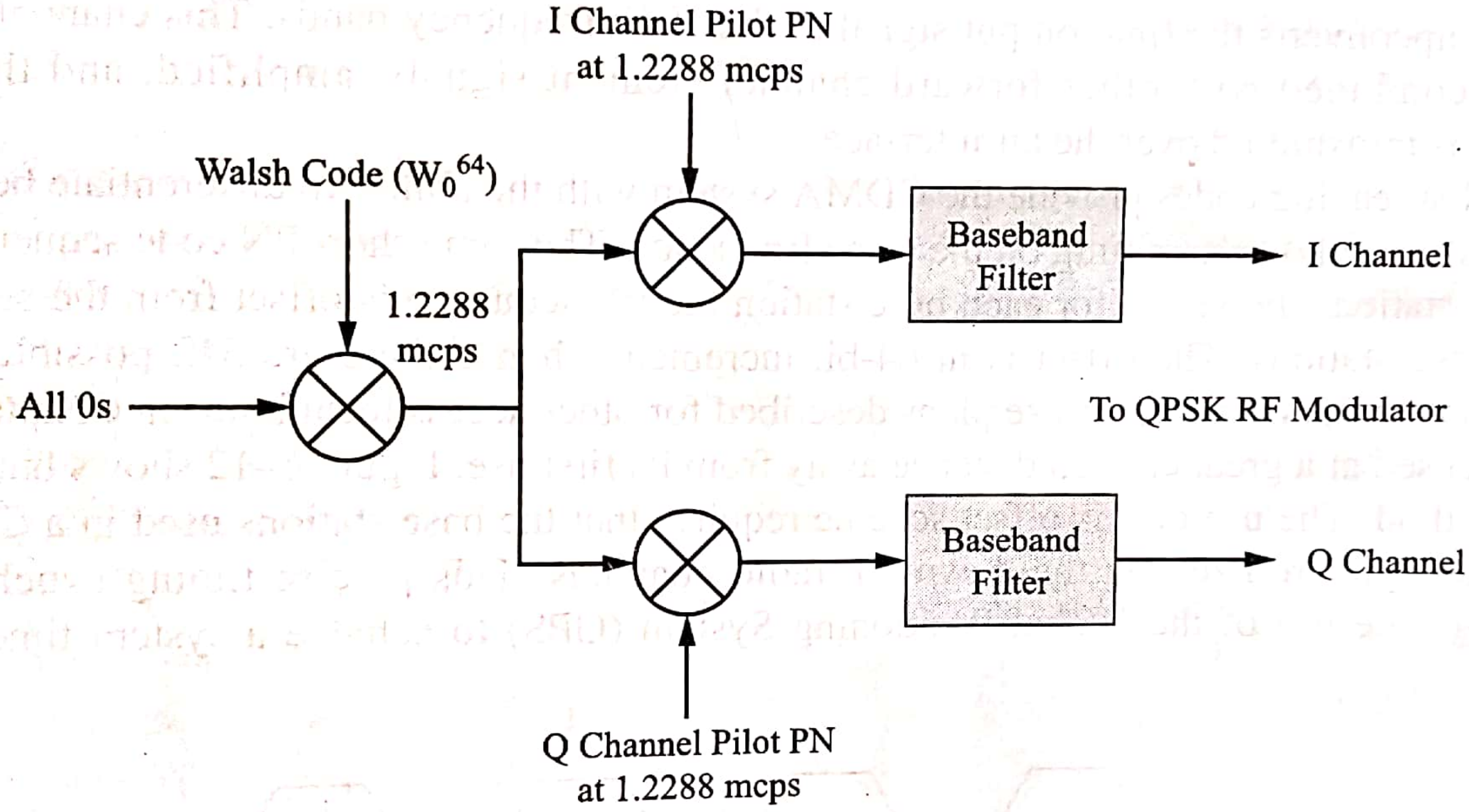


Figure 6–13 Generation of the CDMA pilot channel signal.

modulator. Therefore, the resulting pilot signal is an unmodulated spread spectrum signal. The short PN spreading code is used to identify the base station and the pilot signal is transmitted at a fixed output power usually 4–6 dB stronger than any other channel. The pilot channel, transmitted continuously, is used as a phase reference for the coherent demodulation of all other channels. It also serves as the reference for signal strength measurements and other signal power comparisons.

...ization Channel

...provide initial time synchronization

nal strength measurements and other signal power comparisons.

Synchronization Channel

The CDMA synchronization channel is used by the system to provide initial time synchronization. Figure 6–14 depicts the generation of the synchronization channel signal. In this case, Walsh code W_{32}^{64} (thirty-two 0s followed by thirty-two 1s) is used to spread the synchronization channel message. Again, the same short PN spreading code with the same offset is used to further spread the signal.

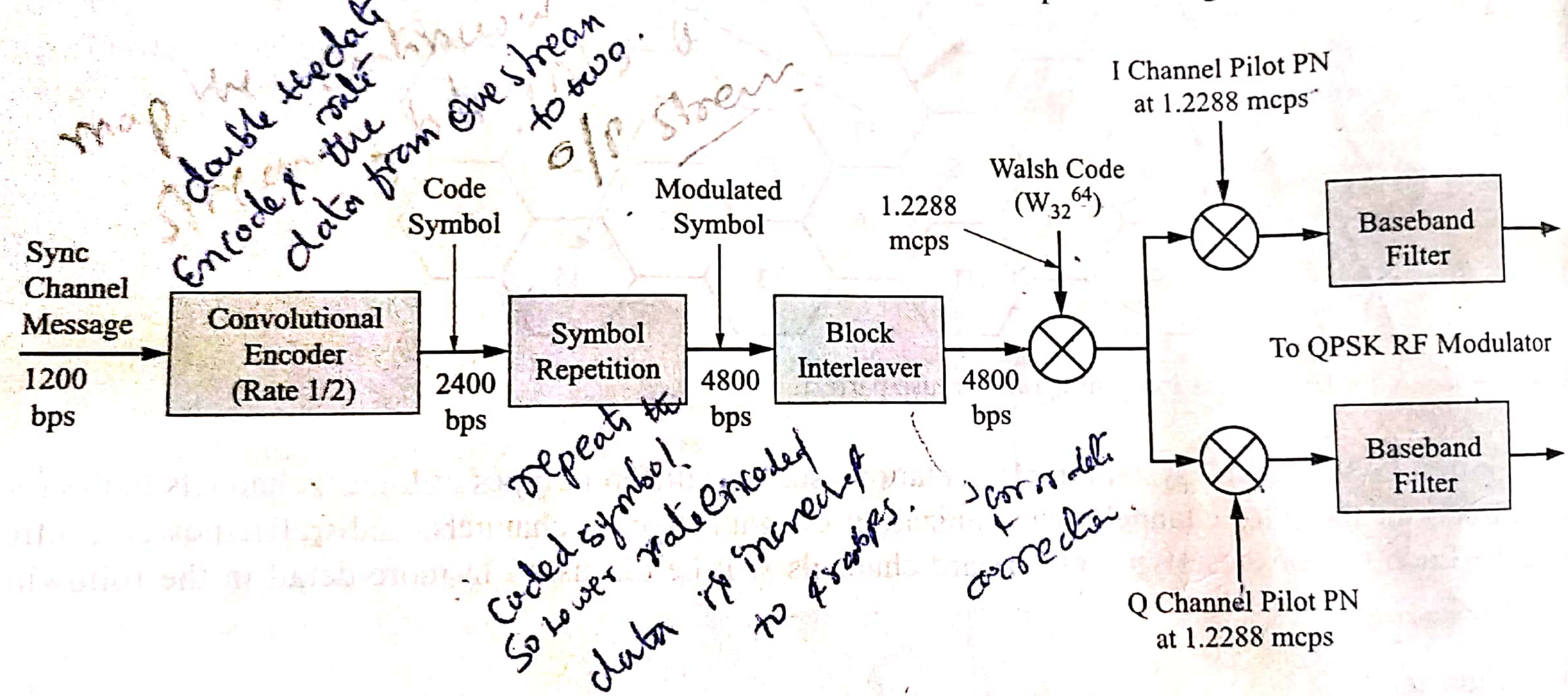
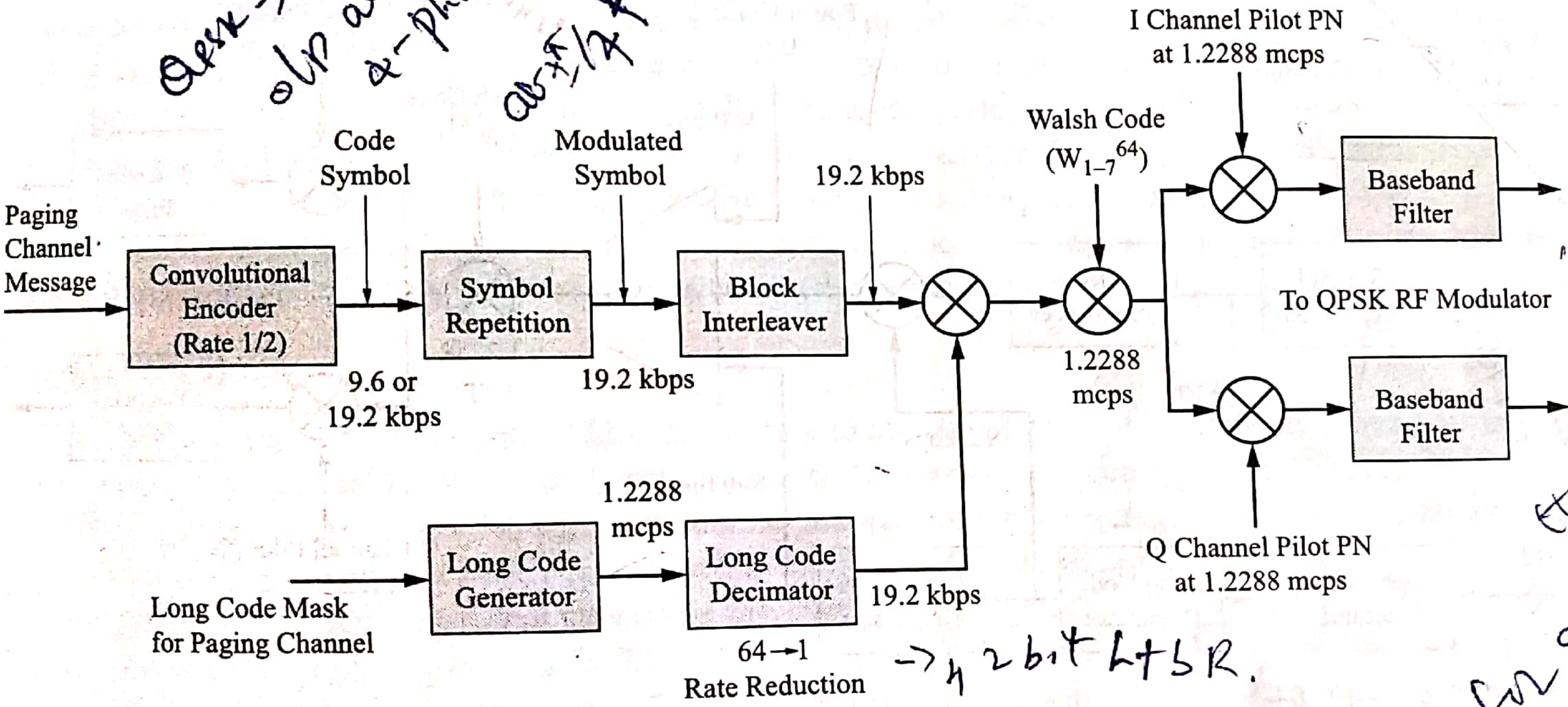


Figure 6–14 Generation of the CDMA synchronization channel signal.

As shown in Figure 6–15, the initial synchronization channel message has a data rate of 1200 bps. The sync messages undergo convolutional encoding, symbol repetition, and finally block interleaving (to be explained in Chapter 8). This process raises the final sync message data rate to 4.8 kbps. The information

QPSK → the binary I&Q o/p are mapped onto 4-phase of Quadr mod at π/4, 3π/4

F-C → 869 to 894
RV → 824 – 849 MHz



→ 42 bit LFSR.

RF mod r. data are raised to the cellular radio band for 935 to 960 MHz, 890 to 915

Figure 6–15 Generation of the CDMA paging channel signal.

contained in the sync message includes the system and network identification codes, identification of paging channel data rates, the offset value of the short PN spreading code, and the state of the long PN spreading code. Like the pilot channel, the synchronization channel has a fixed output power.

Paging Channels

Paging Channels

The CDMA paging channels serve the same purpose as the paging channels in a GSM cellular system. These channels are used to page the SDs when there is a mobile-terminated call and to send control messages to the SDs when call setup is taking place. Figure 6–15 depicts the generation of a paging channel message.

For IS-95 CDMA there can be as many as seven paging channels in operation at any one time. Walsh codes W_1^{64} through W_7^{64} are used for this purpose. As seen in Figure 6–15, the paging channel undergoes an additional scrambling operation using the long PN spreading code sequence. The long PN code is generated by using a 42-bit linear feedback shift register that yields a repeating sequence of length 2^{42}. The paging channel message also goes through a convolutional encoding process, symbol repetition, and block interleaving before being scrambled by a slower version of the long PN code.

Traffic/Power Control Channels

The CDMA forward traffic channels carry the actual user information. This digitally encoded voice or data can be transmitted at several different data rates for IS-95 CDMA systems. Rate Set 1 (RS1) supports 9.6 kbps maximum and slower rates of 4.8, 2.4, and 1.2 kbps. Rate Set 2 (RS2) supports 14.4, 7.2, 3.6, and 1.8 kbps. Figure 6–16 and Figure 6–17 depict the generation of a forward traffic channel. As shown in Figure 6–17, for generation of Rate Set 2 traffic an additional operation is performed after the symbol repetition block. For a data rate of 14.4 kbps the output from the symbol repetition block will be 28.8 kbps. The "puncture" function block selects 4 bits out of every 6 offered and thus reduces the data rate to 19.2 kbps, which is what the block interleaver needs to see. More details about this operation will be presented in Chapter 8.

All of the CDMA system's unused Walsh codes may be used to generate forward traffic channels. The traffic channels are further scrambled with both the short PN sequence codes and the long PN sequence codes before transmission. As also shown in Figures 6–16 and 6–17, power control information is transmitted to the mobile stations within the cell over the traffic channels. This power control information is used to

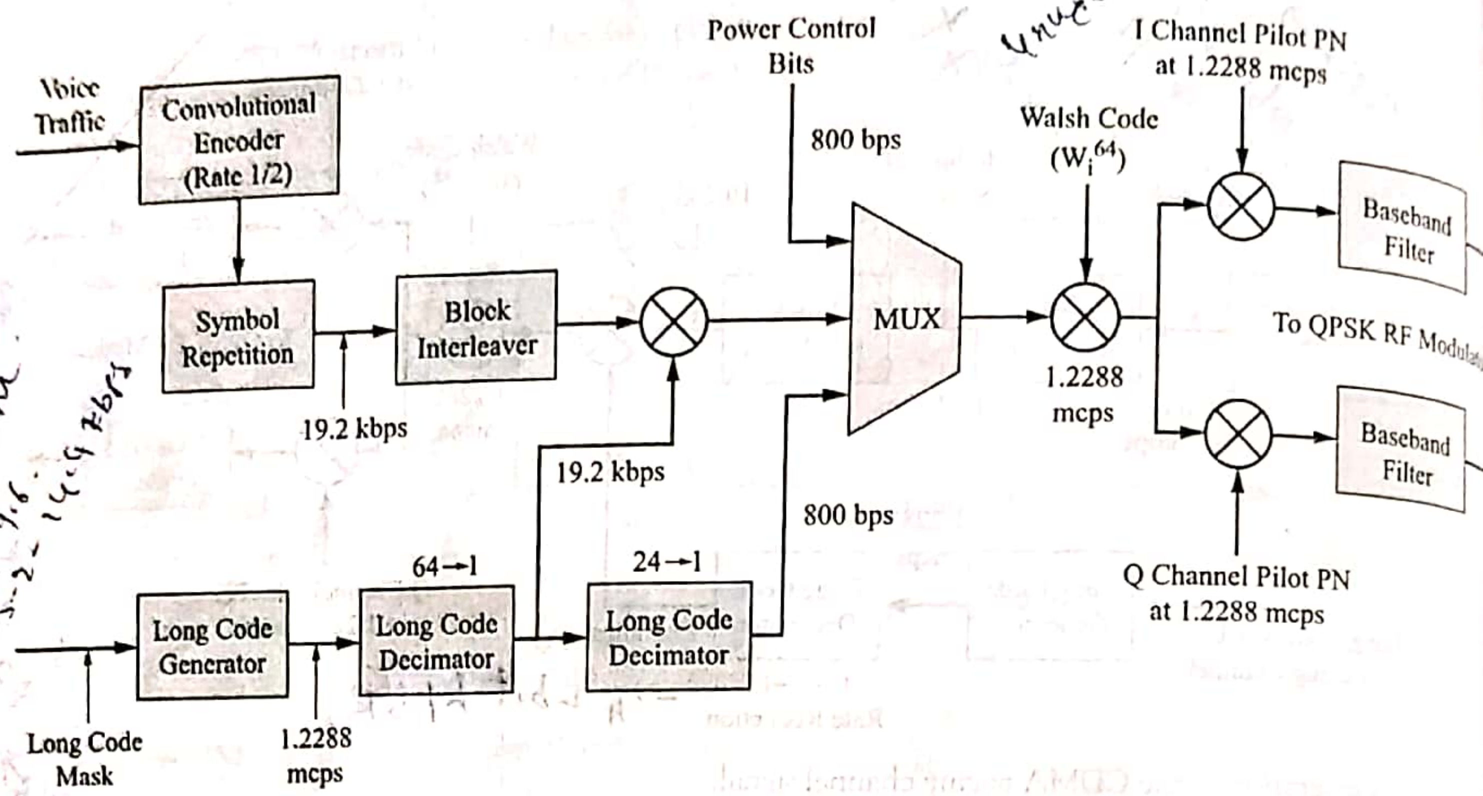


Figure 6–16 Generation of the CDMA forward traffic/power control channel for 9.6-kbps traffic.

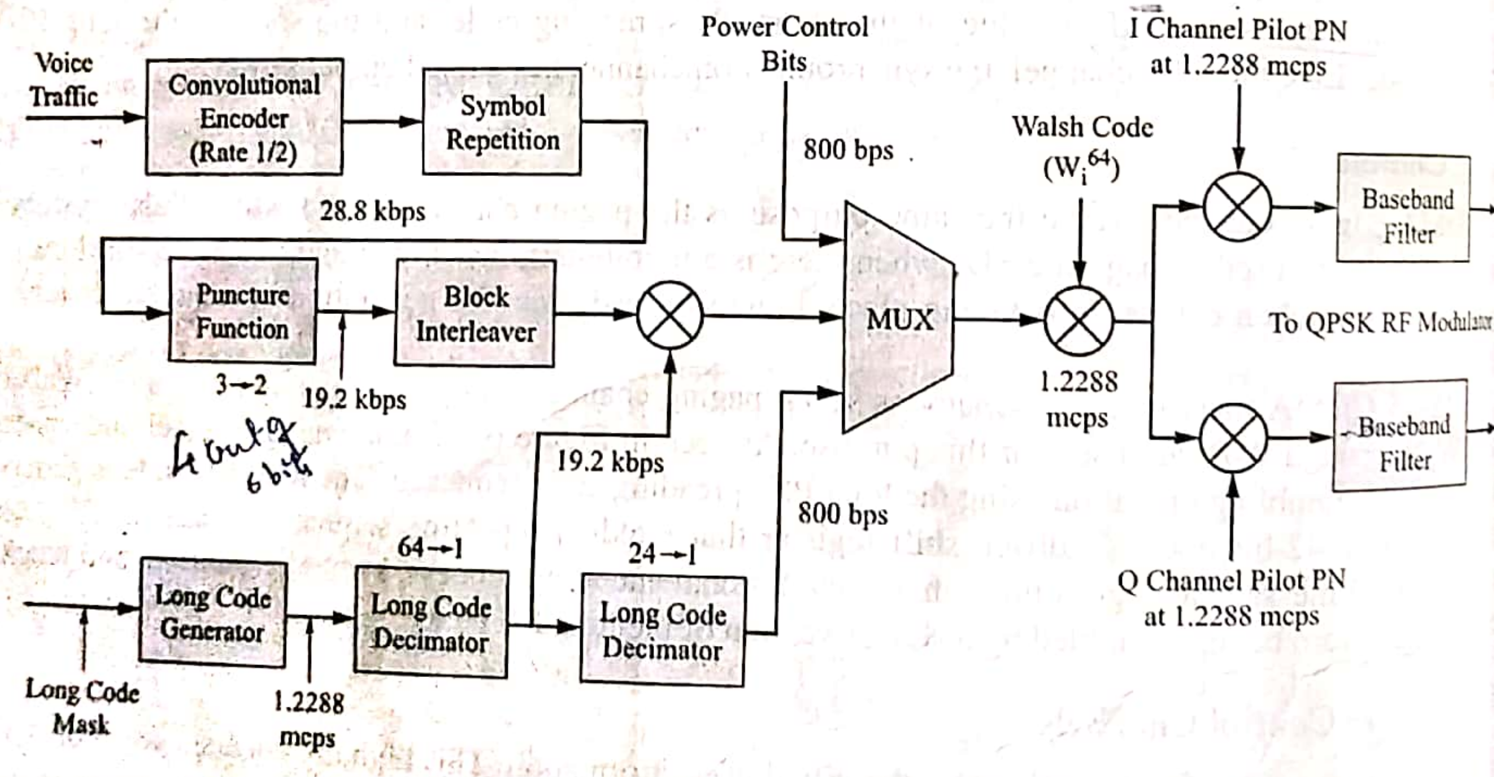


Figure 6–17 Generation of the CDMA forward traffic/power control channel for 14.4-kbps traffic.

set the output power of the mobile on the reverse link and is multiplexed with the scrambled voice bits at a rate of 800 bps or 1 bit every 1.25 msec.