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What Is CDMA and How Is It Tested?

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Caller ID, voice mail and short messaging service—features normally not found in cellular systems—are provided in the new code division multiple access (CDMA)-based handsets that Sprint Spectrum is placing into service in 15 to 20 markets. A consortium consisting of three Bell companies and Air Touch Communications have placed orders for similar sets.¹ And Motorola expects to sell more than 4,000 CDMA base stations by the end of this year.

These reports make it clear that, although it is a new technology for cellular and personal communications services (PCS), CDMA's commercial acceptance is rapidly increasing. In fact, some industry analysts believe that more than half of the U.S. PCS providers will chose CDMA.

CDMA is a proven technology due to its long use by the military. The primary potential for CDMA's near-term commercial application lies in cellular and, especially, in PCS applications. It also is chosen for cordless systems such as wireless private automatic branch exchange and wireless local area networks.

CDMA uses a wideband spread-spectrum technology. It is implemented in the United States in conformance with a protocol developed by Qualcomm and is standardized as the IS-95 specification by the Electronic Industry and Telecommunications Industry Associations.

With CDMA, multiple conversations are spread over a wide segment of the spectrum so that many users simultaneously share a 1.25-MHz-wide channel. Each signal is assigned a different spreading code to differentiate one call from another.

CDMA mobiles operating in the 800-MHz range must also receive and transmit the presently predominant advanced mobile phone system (AMPS) signals. All three types of cellular systems, AMPS, time division multiple access (TDMA) and CDMA, operating in this range use the same frequency spectrum and maintain the same base-station/mobile frequency spacing, but use the spectrum in different ways, as shown in Figure 1.

Applications and Advantages of CDMA



When a narrowband signal (such as encoded speech) is spread over a wide spectrum, the resultant modulated signal will contain redundant information. This redundancy makes it inconsequential if individual bits of the spread signal are lost or corrupted which, in turn, means that near-perfect signal recovery is possible, even with very low S/N ratios.

This has two advantages for cellular applications. First, a CDMA system can readily operate in the presence of disturbing signals, such as other AMPS transmitters operating in the same cell on the same frequency. Secondly, since they tolerate very low S/N, CDMA systems operate satisfactorily at very low power levels. According to Qualcomm, CDMA systems require only 1/25 to 1/1,000 of the power required by AMPS or TDMA—a very important consideration for any mobile application.

Other advantages of CDMA for cellular applications include increased system capacity (three times more than TDMA and 10 times more than AMPS), higher tolerance to multipath fading and better hand-off (within cell sectors or between cells) capabilities. System expansions can also be handled more readily since all cells operate over identical frequencies without interfering with each other, as opposed to implementations that depend on frequency reuse.

Whenever there are so many advantages, there usually are some disadvantages, and in this case it is complexity. While the digital nature of CDMA makes it possible to place many functions on a few ICs, such as the Qualcomm chip set, testing and performance evaluation is not easy without special instrumentation and, as always, a thorough understanding of all signal characteristics. We will consider only a few of the operating principles and test issues involved.

Signal Processing, Spreading and Coding

The IS-95-compliant CDMA systems employ variable-rate speech coders that generate 9,600-bit per second (b/s) bitstreams while users are talking, but drop the rate to 1,200 b/s during speech pauses. This can lower the effective transmit duty cycle of the mobile and provides time slots for inserting information redundancy at the base station during quiet periods. In both cases, less transmit power is required, resulting in a system-capacity increase approaching a *1/voice-activity-percentage* factor.

The 9,600-b/s bitstream is processed through convolutional encoding and interleaving circuitry, resulting in a 19.2-kb/s data stream. This, in turn, is logically multiplied (using eXclusive OR gates) by a long pseudorandom noise (PN) sequence code.

Signal spreading is accomplished by XORing this data with one of 64 64-bit-long Walsh codes, producing a 1.2288-Mb/s (19.2k x 64) data stream. The signal is split, XORed with an “I” PN short code and a “Q” PN short code and then fed to an IQ modulator to generate a quaternary phase-shift keyed (QPSK) signal (Figure 2).

The long code serves as a master clock and synchronizes all CDMA radios. It is generated by a 42-bit linear feedback shift register, producing a sequence that repeats itself only every 41 days. By applying specific bit masking and time shifts, up to 4.4 trillion unique long codes can be generated, which are used to distinguish and provide privacy for individual calls.

Walsh codes are used to differentiate up to 64 channels per modulated carrier. Walsh functions are orthogonal, meaning that codes of the same rate are transparent to each other, even when interfering. A prime requirement for CDMA



operation/configuration data.

The mobile uses a different coding scheme for the reverse link. It does not transmit a pilot signal, since each mobile would require a separate pilot channel. Consequently, the base station cannot employ synchronous demodulation of the mobile's transmission. Instead of QPSK, it uses offset QPSK modulation, which maintains a relatively constant power envelope and enables simpler implementation.

The Need for New Test Sets

Spreading a signal over a wide bandwidth by modulating it with Walsh codes and pseudorandom sequences gives the transmitted signal the appearance and properties of noise. Traditional transmitter-signal quality measurements, such as modulation depth or sideband analysis, are not applicable.

The process gain provided by CDMA signal spreading plus the extensive use of error-correcting codes makes the signal very tolerant to noise and interference. Losing individual bits is inconsequential, precluding the use of bit error rate testers for evaluating signal recoverability at the receiver.

A new set of tests, evaluation and instrumentation techniques had to be defined. The specifications IS-97 and IS-98 were generated to define minimum acceptable performance and test requirements for base stations and mobiles, respectively.

Special test equipment, emulating the functionality of a base station plus interference, has been developed to test compliance of mobiles with IS-98. The test-set list includes the Tektronix CMD80 and the Hewlett-Packard HP 8924C. NoiseCom has also developed noise sources, fading simulators and special test sets.

Required Test-Set Facilities

Testing the mobile's receiver requires not only a signal containing pilot, sync, paging and traffic channel data, but also controllable interference sources as provided by an Orthogonal Channel Noise Source (OCNS) and an Additive White Gaussian Noise (AWGN) generator. Figure 4 shows how the signal is affected by the various types of noise.

The OCNS simulates noise generated by other users in the same cell, while AWGN simulates all other noises, including those emanating from adjacent cells. To test how well the receiver can recover the originally transmitted information under specified noise conditions, frame error rate (FER) test facilities are provided.

Every 20 ms of digitized speech constitutes a CDMA frame. The error-correction circuitry in CDMA ensures that correct bits are substituted for corrupted ones most of the time. However, when the bit stream is corrupted so badly that adequate recovery is not possible, a frame error occurs. An FER of less than 3% is considered acceptable.

An FER provides a true measure of receiver performance. It is used not only for checking demodulation capabilities, but also for verifying receiver sensitivity and dynamic range.



orthogonal (100% uncorrelated) to the ideal signal. From these two results, r is calculated.

If r equals 1, there is no modulation error and all transmitted power correlates with the ideal signal; but if it is below 1, the erroneous portion of the signal will appear as noise. This is important since the ultimate capacity of any cell (number of calls that can be simultaneously handled) is limited by the total interference or noise level encountered.

Facilities must also be provided to conduct a vast number of other tests, such as exercising all call-processing protocols, simulating hand-offs and verifying power-control capabilities. While the application-specific test sets provide an ideal method for conducting a total system test, conventional test equipment still has a role in developing and troubleshooting functional submodules of CDMA systems.

Acknowledgments

Information for this article was derived from several references, particularly the Tektronix *Digital Wireless Seminar Notes* and the Hewlett-Packard tutorials *Concepts of CDMA* and *Introduction to CDMA Mobile Testing*.

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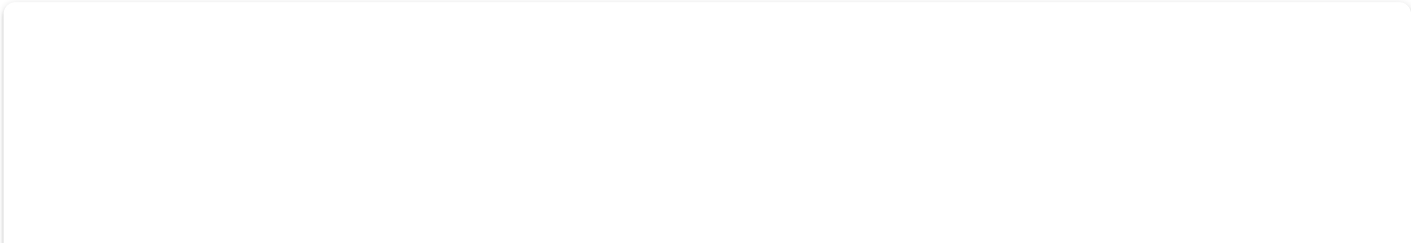


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