Measurement Challenges for cdma2000

Although specifications are not yet final, wireless engineers can prepare for the measurement requirements of this 3G technology

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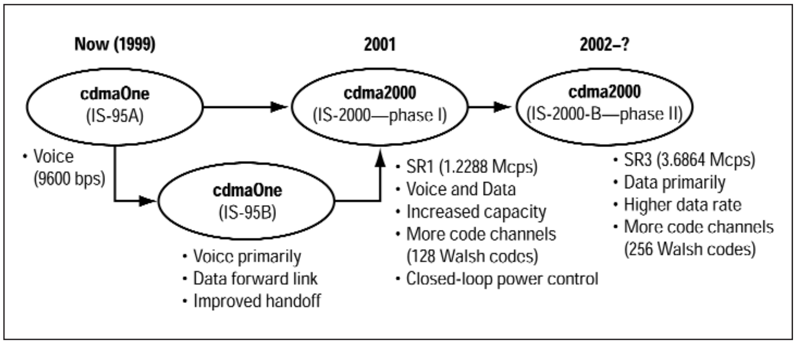
Cdma2000 is the 3GPP2 standard for 3G wireless technology derived from cdmaOne. Although the standard has not yet been defined, R&D component and system engineers need to test their cdma2000 designs now. Established cdmaOne measurements can be used as a reference for this testing and, in some cases, instruments with cdmaOne measurement capability can be used. However, measurements such as code-domain power pose particular challenges due to the specifics of cdma2000 technology. This article offers a brief discussion of cdma2000 technology concepts that will help one understand the challenges associated with making a code-domain power measurement.

cdma2000 is one of the proposals for the IMT-2000 requirements for a 3G global wireless communications system. The 3GPP2 is implementing this wideband CDMA system as a derivative of the IS-95-B CDMA system, also known as cdmaOne. The 3GPP2 organizational partners are ARIB, TTC, TIA, and TTA (see glossary for meanings of acronyms).

The main advantages cdma2000 offers over other IMT-2000 proposals are its backward compatibility with the cdmaOne system and its smooth migration from 2G to 3G. Figure 1 shows the expected evolution from cdmaOne to cdma2000 systems.

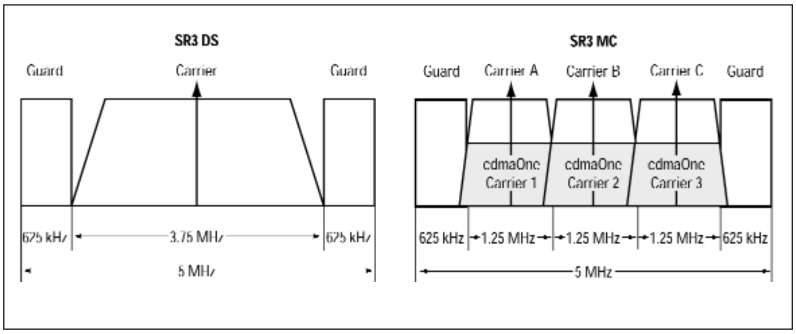


▲ **Figure 1. Evolution from cdmaOne to cdma2000**

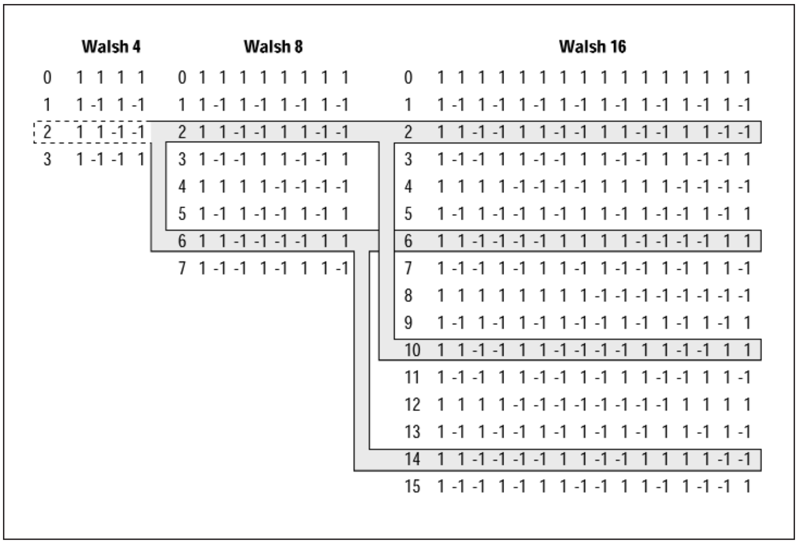
Spreading rate

Spreading Rate (SR) defines the final spread chip rate in terms of 1.2288 Mcps. The two main spreading rates are SR1 and SR3.

SR1 — A Spreading Rate 1 signal has a chip rate of 1.2288 Mcps and occupies the same bandwidth as cdmaOne. The SR1 system doubles the system capacity. Therefore, it can be considered an improved cdmaOne system. The main differences from cdmaOne are fast power control and QPSK (Quadrature Phase Shift Keying) modulation rather than dual BPSK



▲ **Figure 2. Bandwidth limits for SR3DS and SR3 MC.**



▲ **Figure 3. Hadamard generation of Walsh codes. Effects of using variable-length Walsh codes for spreading. Using a Walsh 4 code (in dashed box) precludes using codes in shaded area.**

(Binary Phase Shift Keying) in the forward link; and Pilot signal to allow coherent demodulation, and HPSK (Hybrid Phase Shift Keying) spreading in the reverse link.

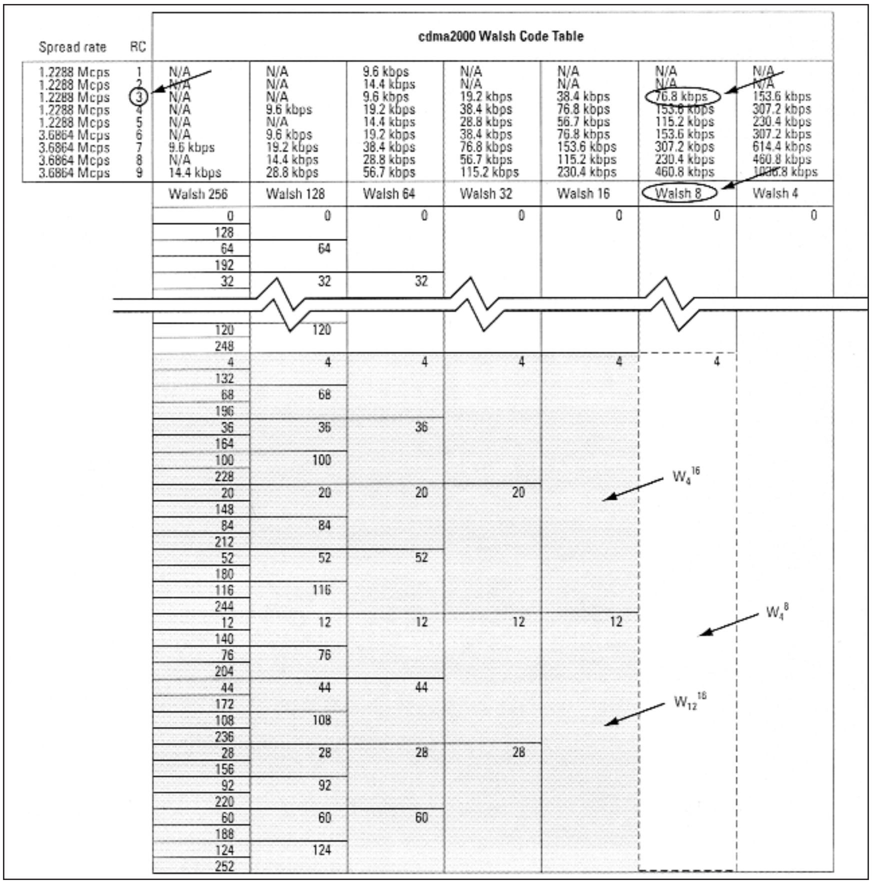
SR3 — A Spreading Rate 3 signal has a rate of 3.6864 Mcps (3×1.2288 Mcps) and occupies three times the bandwidth of cdmaOne. The SR3 system incorporates all of the new coding implemented in an SR1 system and supports higher data rates. It has two air interface options — direct spread (DS) using a single 3.75 MHz wide carrier, requiring a clear spectrum (green field) to operate; and multi-carrier (MC) using three 1.25 MHz wide carriers. MC is designed to allow SR3 signals to be directly overlaid on top of existing cdmaOne systems. To achieve an overlay system, the SR3 MC mode breaks up the data into three carriers, each of which is spread at 1.2288 Mcps (Figure 2).

Radio configuration

Radio Configuration (RC) defines the physical channel configuration based upon a specific channel data rate. Each RC specifies a set of data rates based on either 9.6 or 14.4 kbps. There are two existing data rates supported for cdmaOne. Each RC also specifies the spreading rate (either SR1 or SR3) and the physical coding.

Currently, there are nine radio configurations defined in the cdma2000 system for the forward link, and six configurations for the reverse link. For example, RC1 is the backward-compatible mode of cdmaOne for 9600 bps voice traffic. It includes 9.6, 4.8, 2.4, and 1.2 kbps data rates and operates at SR1. It does not use any of the new cdma2000 coding improvements. RC3 is a cdma2000-specific configuration based on 9.6 kbps that supports 4.8, 2.7, and 1.5 kbps for voice, while also supporting data at 19.2, 38.4, 76.8, and 153.6 kbps. It operates at SR1.

Each base station or mobile station can transmit several channels using different radio configurations at the same spreading rate. Refer to [2] for detailed information on the different RCs.



▲ **Figure 4. Subset of the cdma2000 Walsh Code Table.**

Code-domain power

Although cdma2000 measurement specifications have not yet been defined, designs may need to be tested now. Established cdmaOne measurements can be used as a reference for this testing [1].

The main indicator of modulation quality for cdmaOne base station systems and components is code-domain power. By using this measurement, one can verify that each Walsh channel is operating at its proper level, and quantify the inactive traffic noise level [3].

In cdma2000, the measurement is com-

RC	Walsh Code Length					
	128 bits (Walsh 128)	64 bits (Walsh 64)	32 bits (Walsh 32)	16 bits (Walsh 16)	8 bits (Walsh 8)	4 bits (Walsh 4)
1	N/A	9.6 kbps	N/A	N/A	N/A	N/A
2	N/A	14.4 kbps	N/A	N/A	N/A	N/A
3	N/A	9.6 kbps	19.2 kbps	38.4 kbps	76.8 kbps	153.6 kbps
4	9.6 kbps	19.2 kbps	38.4 kbps	76.8 kbps	153.6 kbps	307.2 kbps
5	N/A	14.4 kbps	28.8 kbps	56.7 kbps	115.2 kbps	230.4 kbps

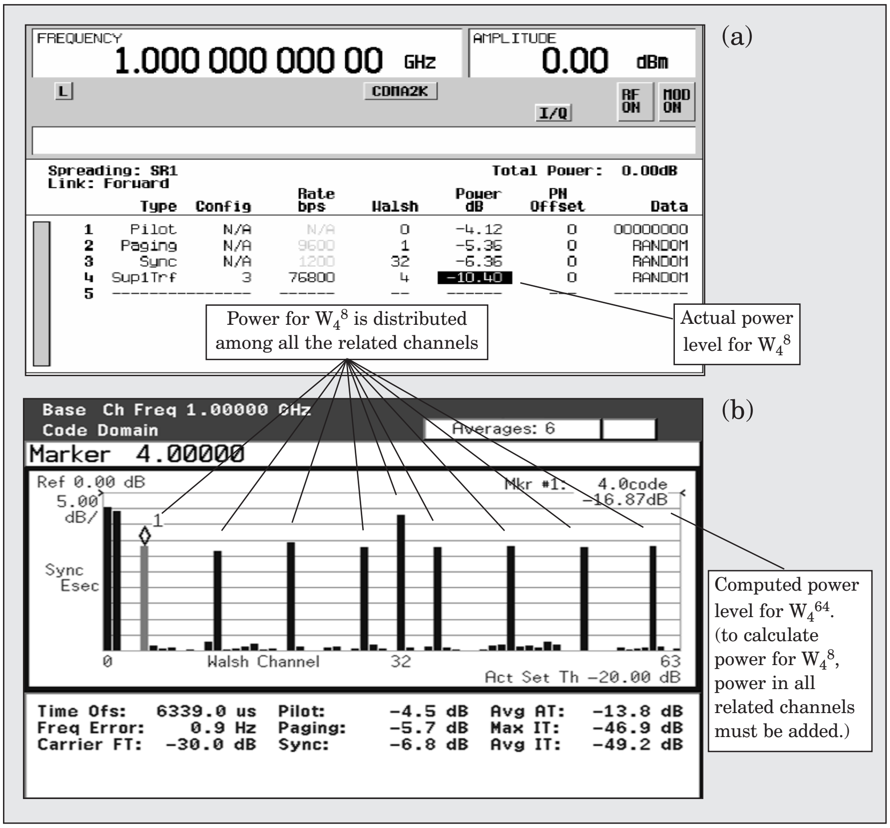
▲ **Table 1. Walsh code length for different RCs at SRI.**

plicated by the fact that the length of the Walsh codes varies to accommodate the different data rates and spreading rates of the different radio configurations. In general, as the data rate increases, the symbol period is shorter. For a specific SR, the final chip rate is constant. Therefore, fewer Walsh code chips are accommodated within the symbol period, and so the Walsh code length is shorter. Table 1 shows the different Walsh code lengths for the various RCs that operate at SR1.

One effect of using variable-length Walsh codes for spreading is that a shorter code excludes using all longer codes derived from it. Figure 3 illustrates this concept. If a high data rate channel using a four-bit Walsh code such as 1, 1, -1, -1 is transmitted, all lower data rate channels using longer Walsh codes that start with 1, 1, -1, -1 must be inactive, to avoid conflicts in the correlation process at the receiver.

Individual Walsh codes (or functions) are identified by W_n^N, where N is the length of the code and n is the row in the $N \times N$ Hadamard matrix. For example, W_2^4 represents code 2 of the 4×4 Hadamard matrix (4-bit Walsh code). Therefore, W_2^4 precludes using W_2^8 and W_6^8; W_2^{16}, W_6^{16}, W_{10}^{16}, W_{14}^{16}; W_2^{32}, W_6^{32}, W_{10}^{32}, W_{14}^{32}, W_{18}^{32}, W_{22}^{32}, W_{26}^{32}, W_{30}^{32}; (not shown in Figure 3), and so forth.

Figure 4 is a subset of a table that shows the relationship between Walsh codes of different lengths for the different RCs at different data rates. A complete version of this table is found in [1].



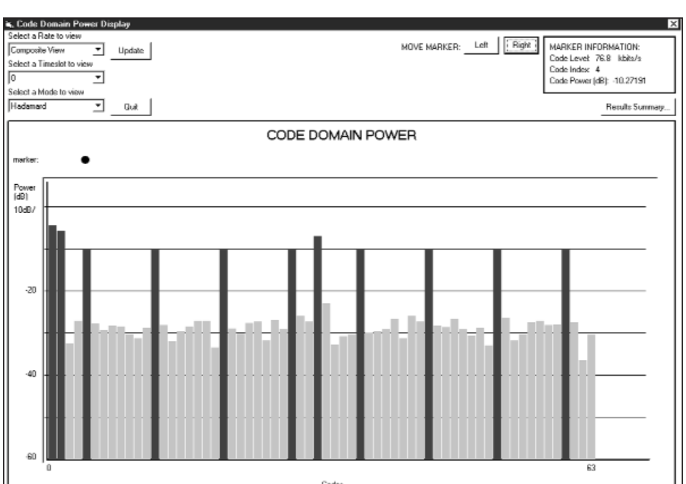
▲ **Figure 5. (a) Signal generation and (b) code-domain power for a cdma2000 signal with pilot, paging and sync channels and an RC3 (76.8 kbps) channel (W_4^8). The measurement is performed using an instrument with code-domain power capability for cdmaOne.**

As discussed earlier, the energy in a channel with a shorter code correlates into all channels with longer related codes. Therefore, a shorter code precludes using all longer codes derived from it (from right to left in the table). For example, RC3 at 76.8 kbps uses Walsh 8 codes. W_4^8 (in dashed box) precludes using all codes in shaded area such as W_4^{16}, W_{12}^{16}; W_4^{32}, W_{12}^{32}, W_{20}^{32}, W_{28}^{32}; W_4^{64}, W_{12}^{64}, W_{20}^{64}, W_{28}^{64}, W_{36}^{64}, W_{44}^{64}, W_{52}^{64} and W_{60}^{64}; and so forth.

Therefore, in the code-domain power measurement, channels with higher data rates (shorter code lengths) occupy more code space. For example, W_4^8 occupies twice as much code space as W_4^{16}, and eight times more code space than W_4^{64}. The measurement must provide some way to identify the different layers (Walsh code lengths) and data rates of the code channels being measured.

One can use an instrument with cdmaOne capability to make code-domain power measurements on SR1 cdma2000 signals by taking into account some considerations. For an SR1 channel with a Walsh code length different from cdmaOne (that is, a channel with a Walsh code shorter than 64 bits), the detected power is spread onto all the Walsh 64 channels with a related Walsh code (a code that starts with the same sequence). Figure 5a shows the actual power levels for a cdma2000 signal with pilot, paging and sync channels and an RC3 channel with data rate of 76.8 kbps (W_4^8). Figure 5b shows the code-domain power measurement on that same signal. The power in W_4^8 is spread onto W_4^{64}, W_{12}^{64}, W_{20}^{64}, W_{28}^{64}, W_{36}^{64}, W_{44}^{64}, W_{52}^{64} and W_{60}^{64} (Figure 4 indicates what Walsh 64 codes are related to W_4^8). The total power of W_4^8 in the code-domain power measurement can be calculated by adding the indicated power levels (in linear units) of all related Walsh 64 channels.

Therefore, you can measure code-domain power on SR1 cdma2000 signals using a cdmaOne-capable instrument. However, when multiple code channels with different data rates are active, the measurement process can become tedious. In any case, an instrument with specific cdma2000 capability offers many advantages, such as fast identification of channels with different data rates and accurate power readings for all channels. Figure 6 shows an example of a cdma2000 SR1 code-domain power measurement (performed using an instrument with code-domain power capability for cdma2000). The signal measured is the same as in Figure 5a.



▲ **Figure 6. Code-domain power measurement of cdma2000 SRI signal (instrument has specific cdma2000 capability).**

Conclusion

R&D component and system engineers need to test their cdma2000 designs today, before the system specifications are final. Measurements such as code-domain power pose particular challenges due to the specifics of cdma2000 technology. As a 3G system, cdma2000 offers the capability of transmitting multiple channels at different data rates. This is accomplished by using Walsh codes of variable lengths. When measuring code-domain power, you must be able to identify the data rate and total power for each transmitted code channel. You can use a cdmaOne-capable instrument if the configuration of the signal is known and only a few channels are transmitted. However, when multiple code channels with different data rates are active, the measurement process can become tedious. An instrument with specific cdma2000 capability will offer many advantages, such as fast identification of channels with different data rates and accurate power readings for all channels. ■

References

1. "Performing cdma2000 Measurements Today," HP Application Note 1325, literature number 5968-5858E.

2. Ken Thompson, "Concepts of cdma2000," *Wireless Symposium*, 1999.

3. "Understanding CDMA Measurements for Base Stations and Their Components," HP Application Note 1311, literature number 5968-0953E.

Glossary

2G –	Second Generation
3G –	Third Generation
3GPP2 –	Third-Generation Partnership Project 2
ARIB –	Association of Radio Industries and Businesses (Japan)
CDMA –	Code Domain Multiple Access
IMT-2000 –	International Mobile Telecommunications-2000
IS-95-B –	Interim Standard for U.S. Code Division Multiple Access
TIA –	Telecommunications Industries Association
TTA –	Telecommunications Technology Association (Korea)
TTC –	Telecommunication Technology Committee (Japan)

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Marta Iglesias holds a BSEE from the Universitat Politecnica de Catalunya, in Spain. During her career she has performed technical support for RF and microwave spectrum analyzers. Currently she is a wireless applications engineer for the Microwave Instruments Division of Hewlett-Packard where she is responsible for understanding the test needs of the wireless communications industry.