HIGHLIGHTING

W-CDMA

W-CDMA measurement challenges

The move to third generation mobile communications systems, such as the W-CDMA system currently under development, will place new demands on component manufacturers, test equipment and measurement techniques. The history of recent mobile standards is examined, and the IS-95 system is compared to W-CDMA. Measurement challenges involved in the generation and measurement of the W-CDMA signal are presented.

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Wireless access history

As we move towards third-generation wireless communications, it is useful to review the existing systems to understand the market forces driving the development of the next generation (see Table 1).

	First generation	Second generation	Third generation
Goals	Dial tone	Digital voice, SMS, data, capacity	Higher bandwidth, multimedia
RF access technology	FDMA	TDMA CDMA	TDMA CDMA W-CDMA
Standards implemented	AMPS TACS NMT	GSM NADC PDC CDMA	under development

Table 1 Past, present, and future of mobile communications

Initially, analog cellular systems such as Advanced Mobile Phone System (AMPS), Nordic Mobile Telephone (NMT), and Total Access Communications System (TACS) were designed to provide a mobile dial tone. As the systems were deployed, features such as roaming and limited data transmission were added.

It became apparent that demand would exceed the available bandwidth allocated to mobile phones. Also, better voice quality, data transmission, and enhanced roaming were required.

Digital wireless communications in the form of the current Time Division Multiple Access (TDMA) standards IS-136, Global System Mobile (GSM), and Pacific Digital Cellular (PDC) were developed. Each of these standards employ digital speech encoding, data compression, and TDMA techniques to achieve enhanced transmission quality, data capability, short message service, and increased capacity.

Code Division Multiple Access (CDMA), as implemented in IS-95, has increased the capacity of wireless networks due to its code division multiplexing and the frequency reuse scheme this technology allows.

Comparing stages of development of the various generations of RF access, the analog phone systems (first generation) are the most widely used method available today, and they continue deployment in many countries around the world.

Second generation systems such as CDMA IS-95, and the GSM system are growing tremendously around the world. GSM has approximately 65 million subscribers in 109 countries around the world (as of February 1998), and CDMA IS-95 networks have seen extremely rapid growth since initial deployment in 1995, with current users estimated at 8 million in 32 countries.

Second-generation TDMA and CDMA systems have clearly been commercial successes, and both of these technologies have established a path that will allow evolutionary steps to third-generation capability.

Third-generation developments

The International Telecommunications Union (ITU) is an international organization within which governments and the private sector coordinate global telecom networks and services.

It developed the goals for the third-generation system referred to as International Mobile Telecommunications-2000, or IMT-2000. This system incorporates the goals of the Future Public Land Mobile Telecommunications System (FPLMTS) and the next generation mobile satellite access systems, Global Mobile Personal Communications by Satellite (GMPCS). IMT-2000 describes a mobile communications system with anytime, anywhere capability, able to access the public network through a combination of RF technology, ranging from pico cells used for in-building access to direct satellite communications where no land-based network is available.

In 1992, the World Administrative Radio Congress (WARC) allocated spectrum for IMT-2000 deployment, designating 1885 to 2025 and 2110 to 2200 MHz for terrestrial access, with 1980 to 2010 and 2170 to 2200 MHz reserved for satellite transmissions.

In January 1998, the European Telecommunications Standards Institute (ETSI) voted and approved the RF access method for implementation of IMT-2000. Within the European Union, W-CDMA was selected for the frequency division duplex (FDD) transmission bands.

At the end of the ETSI selection process, NTT DoCoMo, a major Japanese provider of mobile communications services, announced that they fully supported the decision of ETSI.

W-CDMA systems are now in development, with field trials scheduled in Japan in the Fall of 1998.

The decision made by ETSI concerns the RF access method only, and final definition of the fully interoperable system lies in the future. Many manufacturers have begun to develop components to be used in initial implementations. Based on the success of the IS-95 system, and the recent decision of ETSI, it's clear that code division multiple access methods will be a significant part of the future of mobile communications.

CDMA review

To understand the challenges faced by designers developing components for W-CDMA systems, a review of CDMA concepts may be helpful.

The block diagram shown in Fig. 1 is a generic implementation, with chip rates and data rates representative of a typical W-CDMA system. Though the chip rates may vary, up to 16.38 Mchips/s, the concepts are the same.

The creation of a W-CDMA signal is based on the concept of signal spreading. In this example, we start with a 384 kbps data rate. At a rate of 384 kbps, the data would normally occupy 384 kHz of spectrum. The data is then spread using a code running at a much faster rate. In this example, the code rate spreads the signal over a 4.096 MHz spectrum.

The receiver sees this spread signal together with noise, interference, and users from the same and adjacent cells. The receiver's correlator then reapplies the code, thus recovering the original data signal.

CDMA systems combine multiple traffic channels on a single radio frequency. Each traffic channel is

Operational concept	IS-95	W-CDMA
Channel orthogonality	Walsh codes	layered orthogonal codes
Chip rate	1.2288 Mchips/s	up to 16.384 Mchips/s
Data rate, single user	8 kBit/s or 13 kBit/s	up to 2 MBit/s
Filtering	IS-95 defined finite impulse response	root cosine, alpha = 0.22
Pilot channel	Walsh code 0	pilot symbol assigned to each code channel

Table 2 W-CDMA compared to IS-95

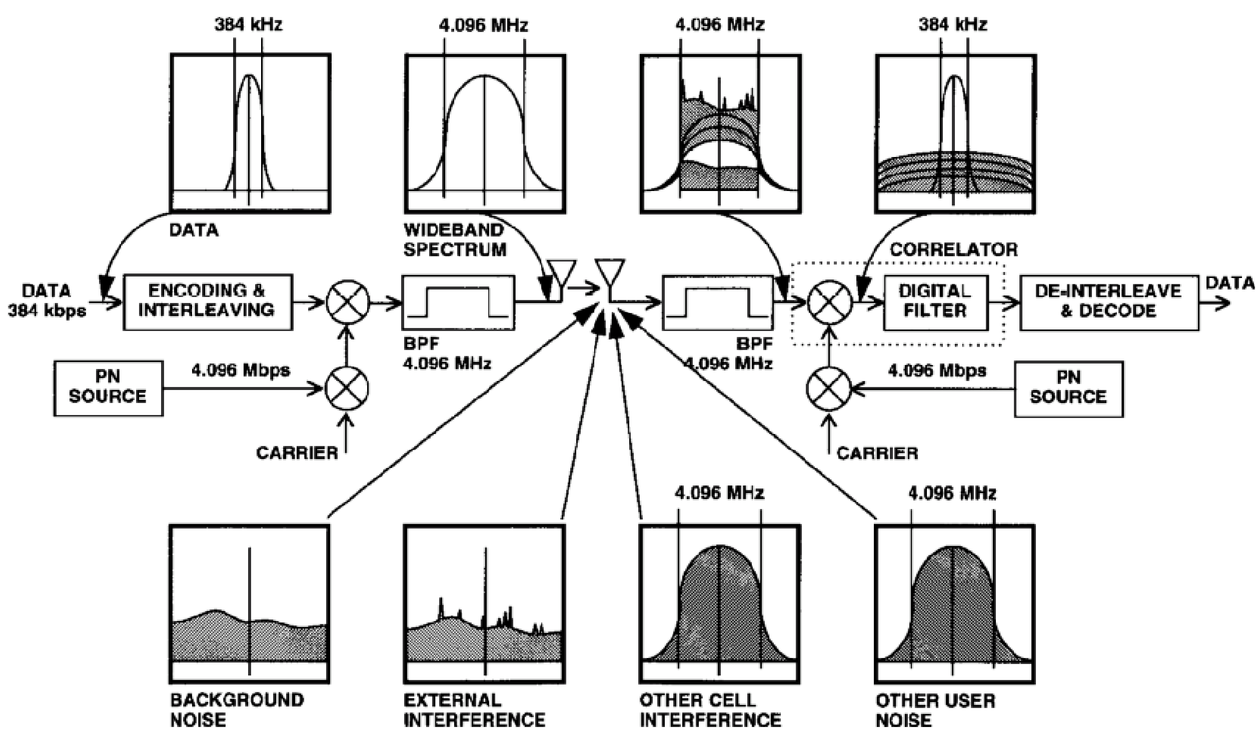

Fig. 1 Block diagram of generic CDMA system

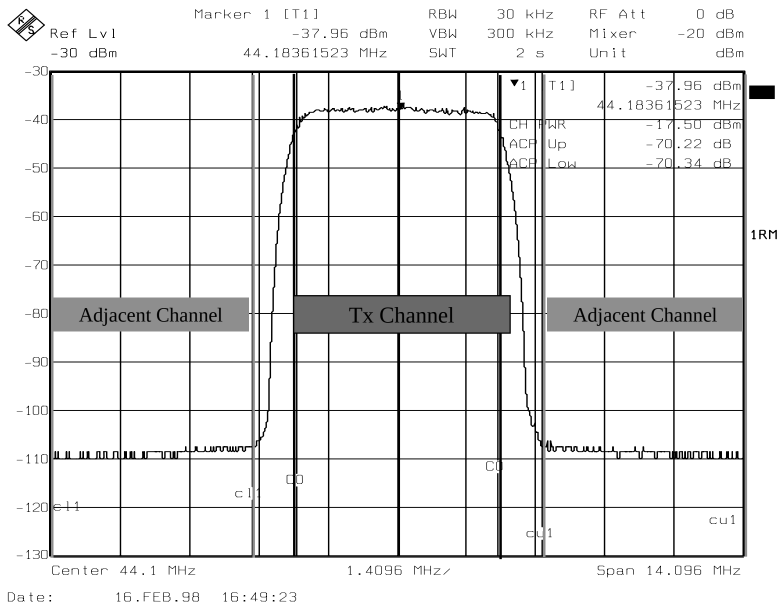

Fig. 2 W-CDMA adjacent channel power measurement

exclusive-or'd with a unique orthogonal code. In the case of IS-95, one of the 64 Walsh codes is used. Signal-spreading is achieved with the use of a pseudo-random long code. Each of these traffic channels is then additively summed in the modulation process. Application of the correct orthogonal code by the users phone allows data to be recovered.

Many of the current CDMA operational parameters are changed in the implementation of a W-CDMA system (see Table 2). For example, channel orthogonality is maintained using layered orthogonal codes of up to 256 bits in length instead of Walsh codes. Data rates may be as high as 2 Mbits/s for fixed access, and chip rates may be as high as 16.384 Mchip/s. Where IS-95 dedicates Walsh code 0 as the system pilot, synchronization signals are embedded in each traffic channel of the W-CDMA system. And so, W-CDMA is a new air interface, providing higher capacity, broadband access for wireless customers. Operating frequencies have changed, bandwidths are higher, and the challenges are greater. What does this mean for component (amplifier and mixer) testing?

The primary measure of distortion in amplifiers has come to be Adjacent Channel Power Ratio (ACPR). ACPR is equally important to W-CDMA system performance. The definition of the measurement has changed, and this has placed new requirements on signal generators for correct stimulus, as well as new dynamic range requirements on the spectrum analyzer used for the measurement.

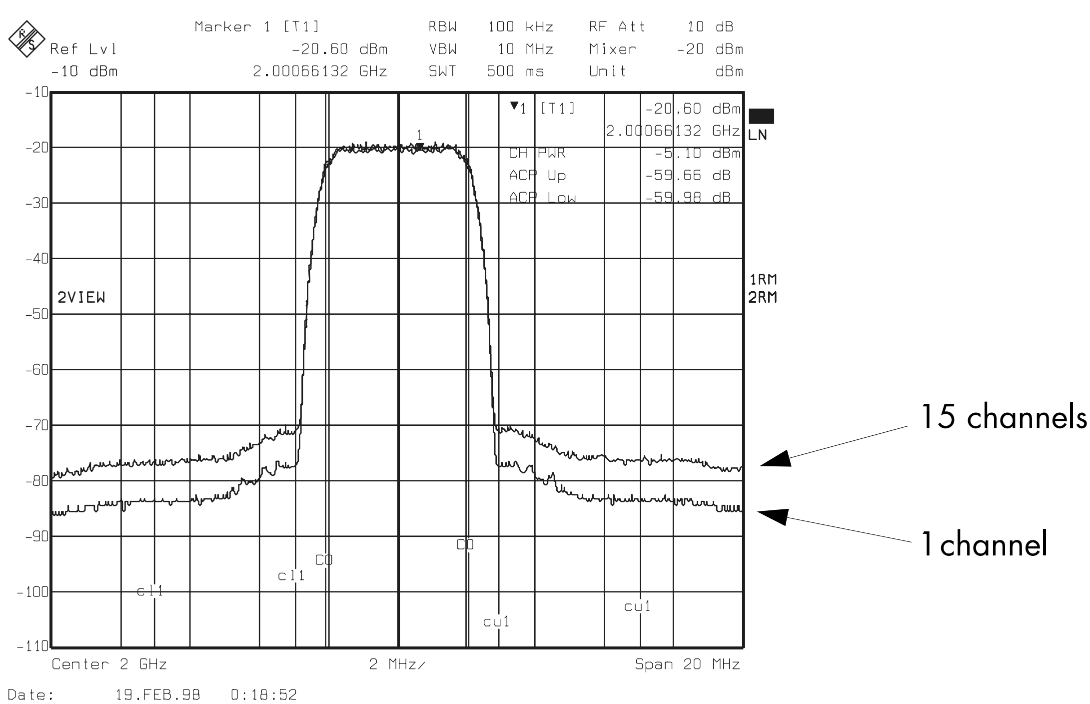

Fig. 3 W-CDMA adjacent channel power, 1 vs. 15 channels

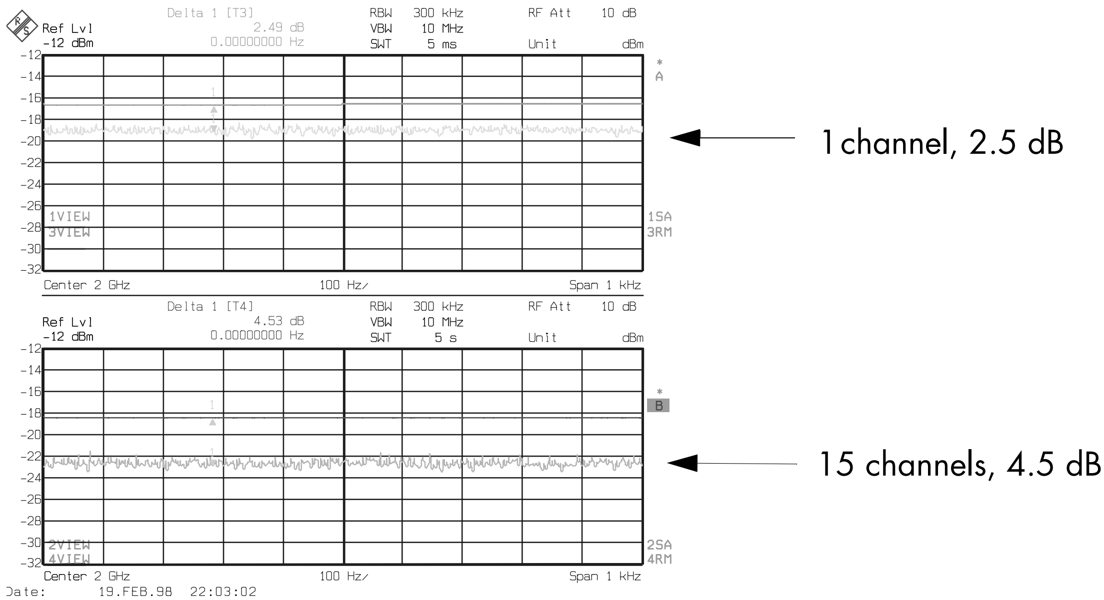

Fig. 4 RMS vs. average detection methods on W-CDMA signals (single channel vs. 15 channels)

W-CDMA ACPR measurement definition

IS-95 measurements are intended to predict performance in an operating network. In the cellular band, it's possible for a CDMA signal to be located adjacent to an existing analog phone channel occupying 30 kHz bandwidth.

Adjacent channel power ratio was defined as the ratio of channel power in the operating bandwidth (1.23 MHz) to an adjacent channel, measured in a 30 kHz bandwidth.

For W-CDMA, no existing analog channel will be present. For this reason, the adjacent channel and the main channel bandwidths are the same. In the example in Fig. 2, the channel and adjacent channel bandwidths are 4.096 MHz, and the channel spacing is 5 MHz.

W-CDMA stimulus requirements

On the stimulus side, it is necessary to provide the device under test with signals that have similar amplitude distributions to system signals. Since the W-CDMA system relies on orthogonal codes that are not pseudo-random in nature, the additive summation of the combined traffic channels will not have a Gaussian distribution of amplitudes. It has been seen (References 1 and 2) that the cumulative distribution function (CDF) of the IS-97 CDMA base station signal is dependent upon the Walsh code values selected for transmission.

Since W-CDMA orthogonal codes are also non-random, selection of these codes will affect the CDF of the signal. Additionally, both the forward and reverse link of the W-CDMA channel can contain multiple coded channels. As a result, mobile phone amplifiers will now need to contend with CDFs more challenging than those found in the IS-95 reverse link. Based on the information above, a test was performed to determine the effects of two different W-CDMA signals on amplifier Adjacent Channel Power Ratio (ACPR). A single channel vs. 15 channel W-CDMA signal was used, and as can be seen in Fig. 3, a difference in ACPR of 8 dB resulted.

In the IS-97 CDMA system, there is general agreement on the effects of Walsh code selection on CDF. For W-CDMA systems, no standard signal is yet established. Therefore, it will be important that the signal generator be flexible enough to generate multiple code channels, with assignable orthogonal codes, in order to allow for a range of CDFs. This must be done with high signal fidelity.

The signal generator SMIQ with WCDMASIM software provides the ability to user define 15 traffic channels with assignable orthogonal codes, spreading codes, modulation maps and baseband filtering.

W-CDMA ACPR measurement, spectrum analyzer requirements

Measurement of ACPR requires that the signal first be accurately measured, and second that sufficient dynamic range is available for the measurement. These factors are controlled by the detection method used and the dynamic range of the spectrum analyzer.

Employing a spectrum analyzer with an RMS detector can help overcome many of the problems associated with-power measurements of digitally modulated signals (e g, averaging and test result stability). A more complete description of the RMS detection system is found in the January 1997 article in Microwaves and RF (Reference 3). An example of the errors caused by averaged sample detection is shown in Fig. 4. This display compares the power measured using RMS vs. averaging methods on a W-CDMA signal. For this single traffic channel, the error is approximately 2.5 dB.

However, when 15 traffic channels are used, the error increases to 4.5 dB. RMS detection provides the correct power measurement independent of the CDF of the signal.

Dynamic range considerations

W-CDMA places especially heavy demands on the dynamic range of the spectrum analyzer when making an ACPR measurement.

The reasons for this are the characteristics of the signal itself, and the broad range over which the signal must be measured. The peak power of the signal will depend on the number of coded channels transmitted. For example, the peak/average ratio could be 13 dB; e g, the peak power is 13 dB higher than the power measured using a power detector such as a thermal power meter. In order to not distort the signal, the spectrum analyzer must cope with these high peak amplitudes.

The requirements for adjacent channel power ratio measurement capability imposes a high demand on the mea uring device. The dominant factors that control dynamic range are third order intercept point and noise figure.

An example of the effects of these parameters is found in a related application note available from Tektronix (see Reference 4).

An example of an instrument that is capable of making the 70 dB ACPR measurement required for W-CDMA is the FSE series from Rohde and Schwarz. Its combination of high third order intercept, low input noise, and RMS detection provide the solution required for W-CDMA ACP measurements. An example of a 70 dB ACP measurement is seen in Fig. 2.

Summary

The advances in third-generation wireless systems, employing W-CDMA RF access methods, places new demands on test equipment for component design. W-CDMA traffic channels must be accurately and flexibly generated in order for the designer to test components under a wide variety of operating conditions.

Measurement of the W-CDMA signal requires RMS detection methods and very broad dynamic range.

The FSE Spectrum Analyzer and SMIQ Signal Generator provide flexible, high performance solutions to meet the needs of W-CDMA component design.

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[2] Bob Buxton, Steve Stanton and Josef Wolf, "ACP Measurements on Amplifiers Designed for Digital Cellular and PCS Systems", Rohde & Schwarz application note.

[3] Josef Wolf and Bob Buxton, "Measure Adjacent Channel Power With a Spectrum Analyzer", Microwaves & RF, January 1997, pp. 55-60.

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