



**Wireless Technology Seminar:**

**Third Generation (3G)  
Basics  
CDMA-2000 & 3GPP W-CDMA**

Rev 1.1 2000-02-05

 **Agilent Technologies**  
Innovating the HP Way

Welcome to the Wireless Technology Seminar Module on third generation (3G) wireless technologies, cdma2000 and 3GPP, W-CDMA. The aim of this module is to discuss the market drivers behind the third generation technologies, the implementation of the technology, and explain the test challenges associated with these technologies. The module will look at the similarities and differences between these systems and will review test requirements for both user terminals and base stations.

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*Notes:*

*Running time for this presentation is to be approximately 60 minutes. There are a total of 32 slides. The abstract provided to the audience for this module:*

*cdma2000 and 3GPP W-CDMA Basics*

*This presentation covers the basics of the cdma2000 and 3GPP W-CDMA 3G wireless technologies. Both technologies are primary proposals submitted in response to the ITU's (International Telecommunication Union) IMT-2000 initiative for establishment of global standards for high speed wireless data transmission up to 2 Mbps. Topics to be covered include the key characteristics of the technologies, their status in the world market, the relationship between them and some of the new test challenges they present.*



## Agenda

- Technology Drivers
- Technology Roadmap
- Acronym Definitions
- Technology Migration
- Technology Deployment
- Implementation Challenges





## What Is the Driving Force for 3G?

### W-CDMA

- Europe - Data
- Japan - Voice Capacity, Data

### CDMA-2000

- US - Voice Capacity, some Data
- Korea - Voice Capacity, Data



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The initial force behind the development of 3G systems originated in Japan where potential capacity of the current (PDC) system was seen to be a limit on future growth of mobile communications.

Europe leads the world in data delivery. The Wideband CDMA system proposed by NTT DoCoMo (originally a replacement for PDC) was recognized as a major improvement over GSM for data delivery. While W-CDMA will also offer voice services, data is seen as the path to the future.

Within the United States, there are today several different, incompatible, systems in use. One requirement for a new system was to offer a compatible path from today's systems whilst providing better capacity and improved data facilities than the systems currently in use. The cdma2000 system - heavily based on IS-95 - has achieved rapid acceptance in the IS-95 cdma community. There is no good upgrade path from the other US technologies to cdma2000.

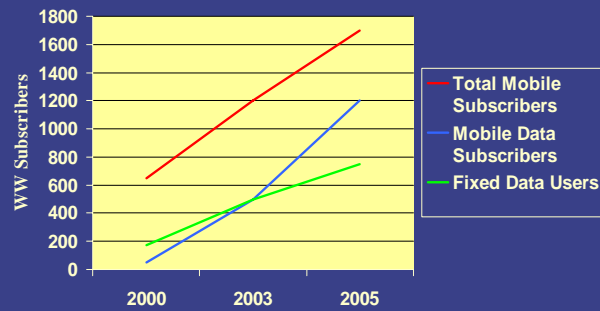
Although IS-95 began in the US, Korea has the highest concentration of IS-95 users in the world. They will continue in leading this technology with the rollout of cdma2000.

The 3GPP W-CDMA system is being designed to inter-work with GSM, although there is no direct relationship between the air interfaces as with IS-95 and cdma2000.



## Market Demand for Data Services

- Demand for wireless data services expected to grow significantly
- Driven by new services:
  - ✓ e-mail/messaging
  - ✓ m-commerce
  - ✓ location-based services
  - ✓ entertainment



Source: Arc Group, Oct. 2000

- Low availability of applications will limit the customer use of data services
- Network Operators are looking to promote data services to increase revenues



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Data services are seen as a key growth area for wireless mobile communications. The huge growth in the internet market is seen as key driver for the wireless market. The ARC Group predicts total mobile data users will be 1.2 billion worldwide by 2005. Wireless data revenues are predicted to exceed wireless voice revenues in the same year (Ovum). Fixed Internet will grow to about 750 million during same time.

Even if the market acceptance is slower than shown, wireless data is still a significant opportunity that is important to be investing in today to carve out future market positions. The market acceptance will depend on several factors such as pricing, smarter internet applications, new mobile applications, resolution of technical communications problems, handset availability and ease of use.

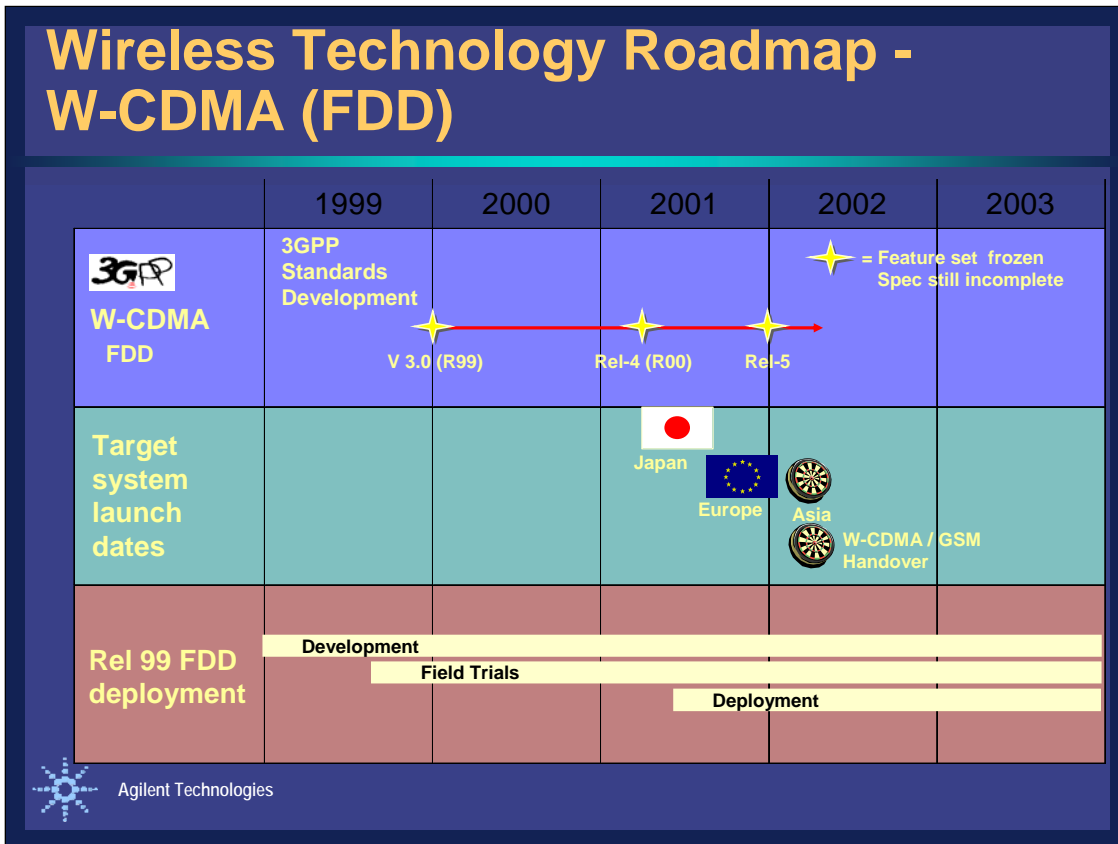
Although GPRS has been slow to take off in GSM markets, it is still expected to be the forerunner of data delivery prior to the introduction of W-CDMA. GPRS deployment has been delayed over original expectations but should start commercial service during 2001.



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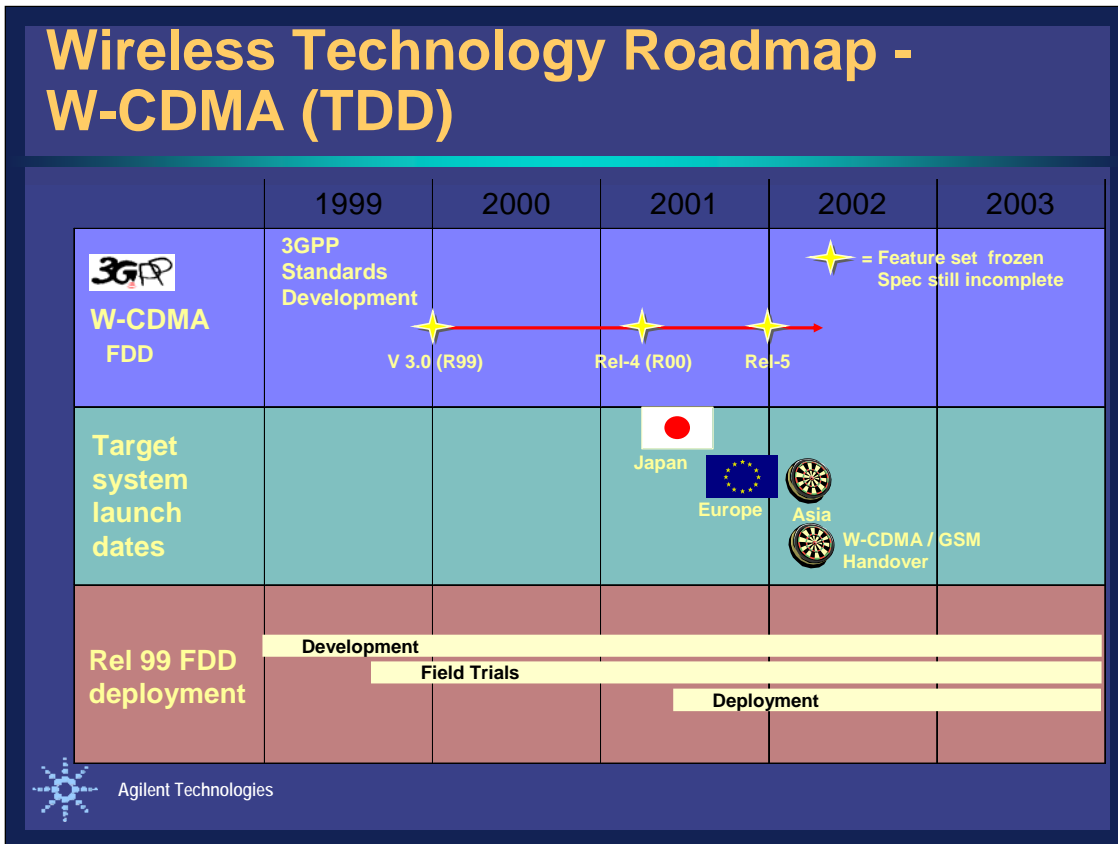


The feature set for the first W-CDMA release - called Release 99 - was frozen in December 1999. Since then considerable work has been done to draft the detailed standard which consists of over 400 documents. The stability of the Dec 2000 version of R99 is sufficient for Layer 1 equipment to be built. Delays in the standards work resulted in a re-naming of future releases, R00 is now Rel-4, R01 becomes Rel-5 etc. Typically there is at least two years delay between freezing the feature set of a release and finishing the drafting work. Deployment then follows later.

NTT DoCoMo starts deploying network infrastructure in May 2001 with first service in early 2002. This service will be based on a minimal version of R99, with no inter-operability to GSM.

The Spanish operator Xfera has announced plans for service in August, 2001, but this schedule is being questioned by other operators in Spain. All UK and German operators paid approx. \$6B for licenses and they are under severe pressure to get revenues from this as quickly as possible.

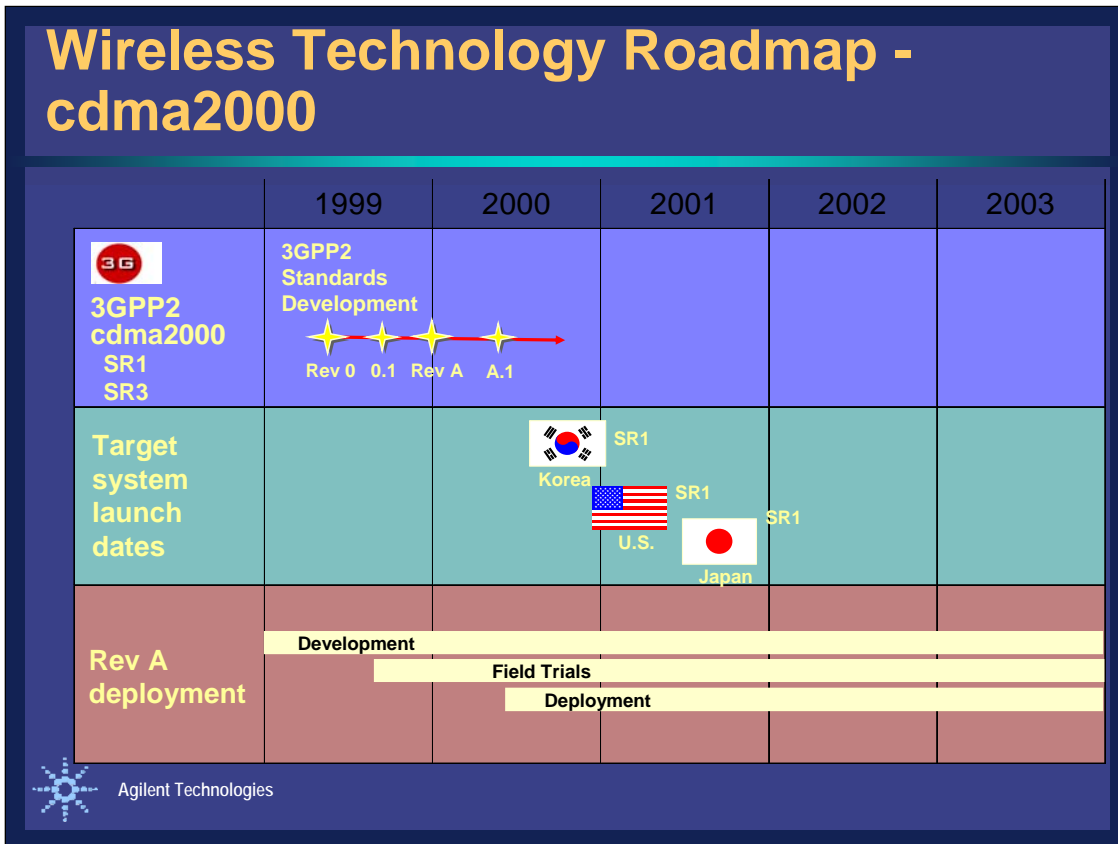
Initial deployment in GSM markets will be based on a limited set of R99 features, however, unlike Japan, it is essential that GSM inter-operability is included.



There is an alternate candidate for using unpaired spectrum allocations, this is called Time Division Synchronous CDMA, or TD-SCDMA, which has been proposed by groups within China. TD-SCDMA is getting a lot of attention because China has such a large population. TD-SCDMA is a Rel-4 work item "Low chip rate TDD" being included in the 3GPP W-CDMA specs.

Either system could be a candidate for use in unpaired spectrum in Europe. The chip rate of TD-SCDMA is 3.84/3 making it easier to "fit in".

TDD is also being touted as a low mobility standard. The Time Domain Duplex (TDD) version of W-CDMA is expected to be released in the second half of 2001 but is behind FDD. TDD is being considered by the European operators whose licenses include unpaired spectrum. TDD is useful for applications where there is an unbalance in capacity between the uplink and downlink, such as for Internet access rather than full cellular.

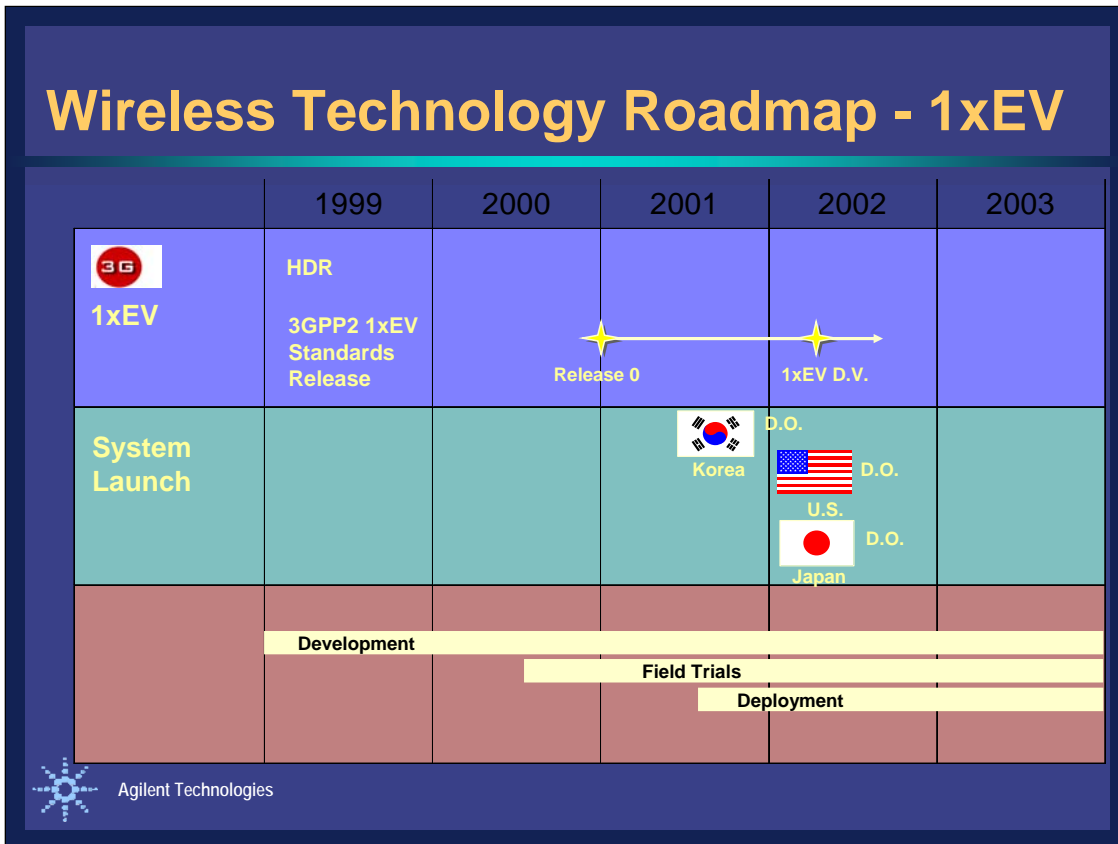


Within Korea and the US cdma2000 is going to undergo a rapid rollout. The cdma2000 technology can be considered to be an upgrade to the existing IS-95 systems. IS-95 network operators will be able to convert existing systems from IS-95 to cdma2000 by installation of new cards in their current base stations without the need for investing in totally new equipment. The conversion of handsets from IS-95 to cdma2000/IS-95 will be very quick once service starts.

SK Telecom in Korea is ahead in their rollout plans, with field trials completed in December 1999 and have launched commercial service in October 2000 using 3Com and Samsung equipment.

Numerous US and Canadian fields trials have been conducted using Lucent and Nortel equipment in the year 2000, with service expected in the first quarter of 2001. Telstra in Australia will conduct field trials during the second half of 2001. Surprisingly, perhaps, the independent Japanese operator DDI/IDO expects to begin service in the IMT2000 band during the third quarter of 2002.





1xEV D.O. is a new coding format for packet data only. It cannot carry voice or any circuit switched application. It requires one IS-95 channel dedicated for 1XEVD.O. services but in return offers data capacity six to ten times that available from IS-95, and three times cdma2000.

As with cdma2000, SK Telecom leads the rest of the world by about three months. Sprint and Verizon plan to launch service in the US early 2002. There is major interest in this system in both Japan and Taiwan. KDDI, a consortium of KDD, IDO and DDI, plan to launch service in Japan early 2002.

The 1xEV schedule is limited by the availability of ASICs from Qualcomm. Sample quantities are expected by June 2001 followed by production quantities available in late 2001. 1xEV requires an easy conversion from serial port to USB on the bottom of the phone. The 1xEV ASICs are pin-compatible with IS-95 and IS-2000 ASICs, and the RF sections are the same.

The 3GPP2 standards body plans to release the data and voice standard, 1xEV D.V. during the first half of 2002.



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### Acronyms and Terms (i)

- **ITU** - International **T**elecommunications **U**nion
- **ETSI** - **E**uropean **T**elecommunications **S**tandard Institute
- **IMT2000** - International **M**obile **T**elecommunications **2000**
- **UMTS** - **U**niversal **M**obile **T**elecommunications **S**ystem
- **W-CDMA** - Next Generation CDMA system developed at **ARIB** and **ETSI** standards committee
- **UTRA** - **UMTS** **T**errestrial **R**adio **A**ccess
- **FDD** - **F**requency **D**omain **D**uplex
- **TDD** - **T**ime **D**omain **D**uplex
- **TD-SCDMA** - **T**ime **D**omain - **S**ynchronized **CDMA**
- **UE** - **U**ser **E**quipment (mobile terminal)
- **Node B** - equivalent to **BTS** in W-CDMA system



Here is a list of some of the more common acronyms and terms. Many come directly from the standards. Others come more from the ITU and its documentation.



### Acronyms...ii

- **IS-2000** - Next Generation CDMA System based on IS-95
- **cdma2000** - Branding Name for IS-2000
- **SR1** - **S**preading **R**ate **1** (x time IS-95 spread rate)
- **SR3** - **S**preading **R**ate **3** (x time IS-95 spread rate)
- **1XRTT** - **1** times (IS-95) **R**adio **T**elephone **T**echnology
- **3X MC** - **3** times (IS-95) **M**ulti **C**arrier
- **1xEV** - **1** times (IS-95) **E**volution
- **HDR** - **H**igh **D**ata **R**ate



Here is a list of some more common acronyms. Many, such as IS-2000, SR1, and SR3 come directly from the standards. Others come more from the ITU and its documentation.



### Acronyms ...iii

- **MC-MAP** - cdma2000 running on GSM network
- **DS-41** - W-CDMA running on IS-41 network
- **Cross Mode** - MC-MAP and DS-41
- **Greenfield** - New Spectrum

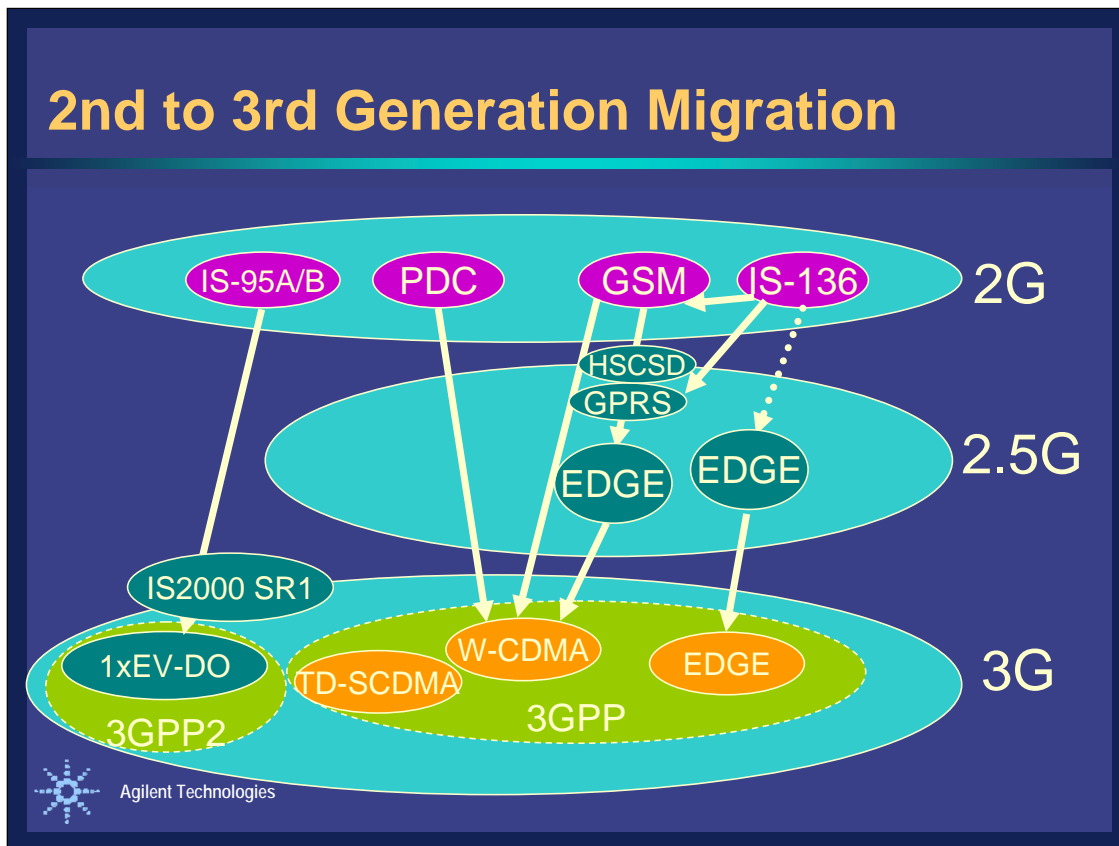




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A look at the evolutionary path from 2G to 3G shows the likely migration path for service providers of each major format. The W-CDMA system looks like it will receive the most subscribers as operation is started in the IMT-2000 band. The SR3 (Spread Rate 3) multi-carrier standard appears to be dead. The delivery of higher data rates for the current IS-95 community will be met with 1x Evolution (1xEV). The first version of this is Data Only (DO). Future versions of this will be capable of data and voice (1x EV-DV). The IS-136 operators do not have a direct evolution path to 3G. Instead, they will transition to GSM and GPRS.

EDGE, originally envisaged as a high data rate, evolutionary path for GSM, was for a while adopted as a way for IS-136 operators to offer data services to existing subscribers. This now looks less certain to happen but it is still expected that EDGE will be implemented to complement data services in 2G and combined 2G/3G networks.

Note, there is no technical evolution from PDC to WCDMA, and there are no plans for multi-mode terminals unlike most all other evolution paths.



### Where will be deployed?

cdma2000		WCDMA
<ul style="list-style-type: none"><li>• United States</li><li>• Latin America</li><li>• Korea</li><li>• Japan</li><li>• Scandinavia?</li><li>• China?</li></ul>		<ul style="list-style-type: none"><li>• Europe</li><li>• Japan</li><li>• Korea</li><li>• USA?</li><li>• China?</li></ul>



In Europe, many GSM operators will migrate to W-CDMA for increased data capabilities. While voice capacity is the immediate need for Japan's NTT, data is seen as a major force in the near future.

Korea is evaluating W-CDMA along with cdma2000. The Korean government has ruled at least one of the three 3G licenses will go to a service provider using cdma2000 technology. China is also exploring several options including W-CDMA, cdma2000, and TD-SCDMA

In the Americas, existing IS-95 operators will migrate to cdma2000 for increased voice capacity and the added bonus of data capabilities. Korea has the highest concentration of IS-95 users in the world. They will continue in this technology with the rollout of cdma2000. Japan will deploy its cdma2000 system in the IMT2000 band.

Scandinavian operators will displace the existing NMT system that operates in the 450 MHz band with newer generation (2, 2.5,3G) systems. If China deploys a cdma2000 system, it will be a new installation in an existing frequency band. The cdma2000 systems in the rest of the world will be deployed on top of existing IS-95 systems.

Also, recent announcements from AT&T mean the USA should also be on the W-CDMA list.

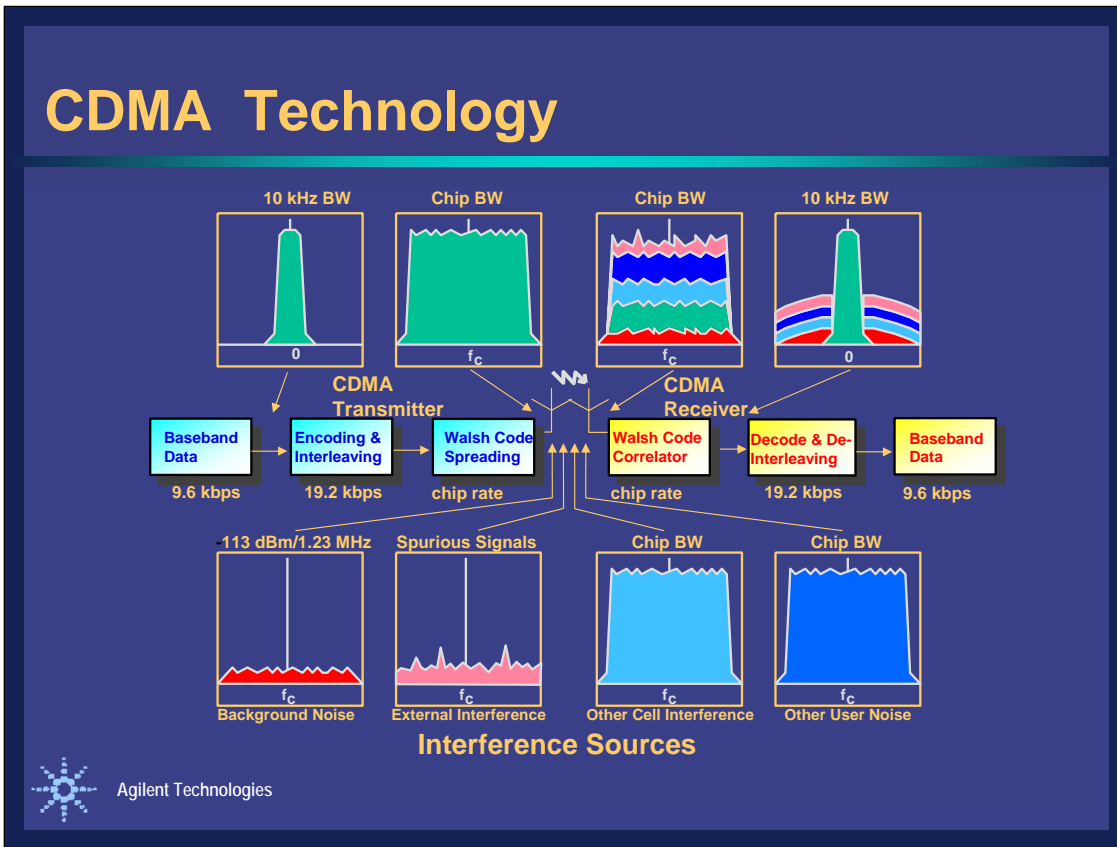




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The fundamental concept of CDMA is that each user is assigned a unique code. The data for that user is spread from a low data rate (shown here as 10 kbps) to the final spreading rate, either 1.2288 Mcps for cdma2000 or 3.84 Mcps for 3GPP FDD and 1.28 Mcps for TD-SCDMA.. In CDMA systems many users share the same frequency but use different ‘orthogonal’ codes to allow channels to be separated by decoding. When the de-code is applied, the proper code goes back to the 10 kHz bandwidth, while every other code stays at the full bandwidth. The portion of energy from the wide signal that falls into the 10 kHz is very small.

The spectrum view with stacked signals suggests measurement equipment that will analyze the transmission from a base station and display the constituent codes.

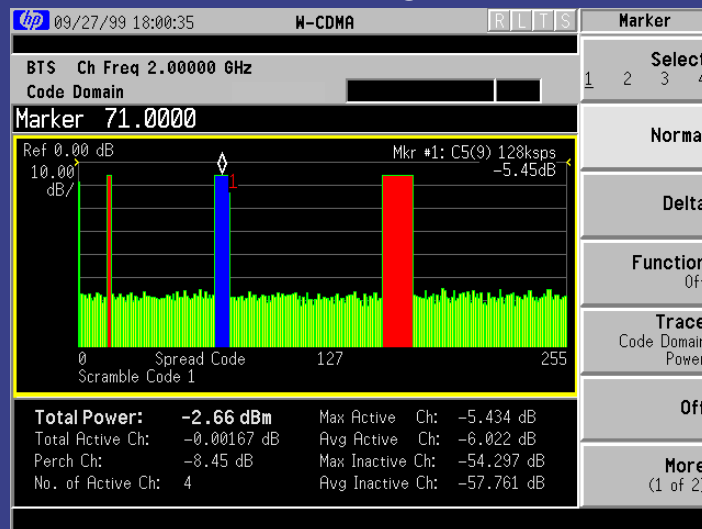
High data rate channels will use proportionally more power for transmission. This is shown in the next slide.

The key pint is that higher data rate channels use less coding, so need to be transmitted at a higher power to maintain SNR.



## How To Get Higher Data Rates

- Code domain power display
- Broader code channels have higher data rates

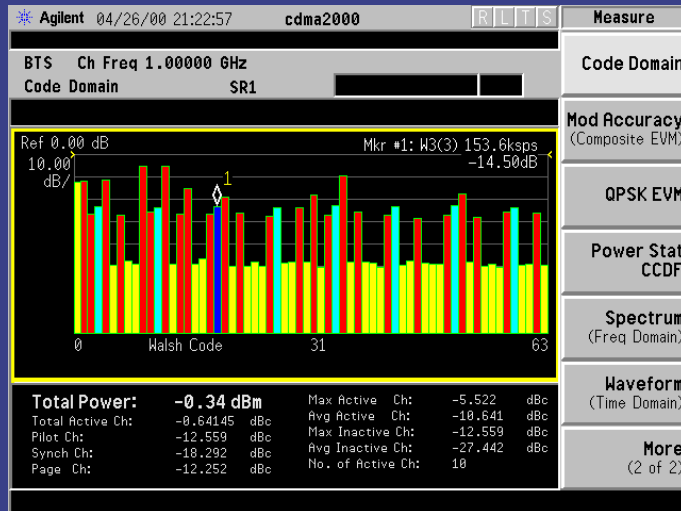


This is a display of the Code Domain Power curve of a W-CDMA system signal. A base station signal has been broken down into the orthogonal codes. The wide bar to the right is a high data rate channel. The spreading factor is lower thus supporting higher data rates. The broad "high data rate" channel shows that applying a lower spreading factor occupies the same code space as many lower rate channels. The total power is the area under the curve. The medium width bar, with the marker, would also be a data channel, but at half the data rate of the one to the right.



### Display of High Data Rates

- Code domain power display - Hadamard display
- Higher data rate channels occupy multiple code channels

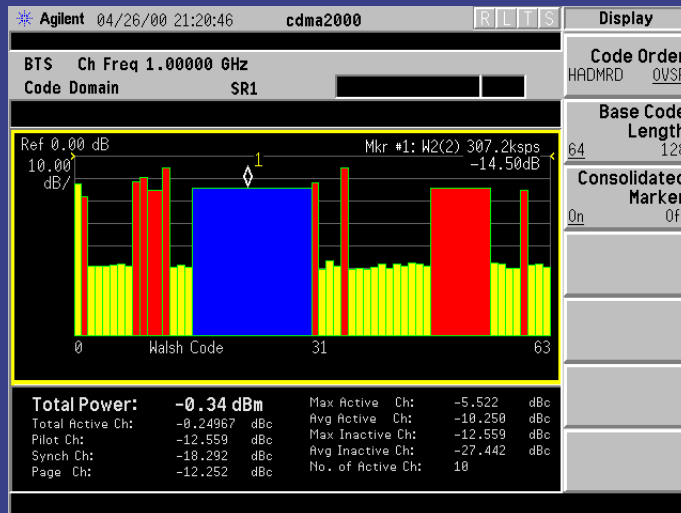


This is a display of the Code Domain Power plot of a cdma2000 system signal. This looks completely different from the picture we showed for 3GPP W-CDMA. However, this is really only a difference in presentation and the difference comes from the convention used for numbering the channel codes. Just as in the 3GPP case shown in the last slide the orthogonal code being used supports higher data rates by applying less coding. The total power of this traffic channel is the sum of the power in each of the blue codes. An easier method to view the Code Domain Power of cdma2000 signals is to alter the order of the code channels so that related code channels are adjacent to each other.



## How To Get Higher Data Rates

- Code domain power display - Bit reversed display
- Wider code channels have higher data rates



This is a “Bit-reversed” display of the Code Domain Power curve of the same cdma2000 signal shown in the last slide. The broad blue bar in the center is the same high data rate traffic channel that occupied the many blue colored code channels on the previous slide. The total power is the area under the curve. To accomplish this simplified display, the order of the code channels on the display is altered to a “bit-reversed” order. This is really only a display ‘trick’; in the receiver the codes are just used to define the coding.



### CDMA Frequency Reuse - The Key to Channel Capacity

**FDMA Reuse**                      **CDMA Reuse**

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The major capacity advantage of CDMA is realized by many technical innovations. One of the most important is the reuse of the same frequency in every sector of every cell. In IS-136 and analog cellular systems, there is a 7 cell repeat factor, with 3 sectors. This means that only one out of every 21 channels is available to each sector. GSM usually uses a repeat of 4, with 3 sectors, for a reuse of one out of twelve.

This is not the only factor that has influence on network capacity, but a good guess is that cdma2000 and W-CDMA will be about the same, which is about twice that of GSM and IS-95.



## W-CDMA and cdma2000 - differences

W-CDMA	cdma2000
3.84 MCPS	1.2288, 3.6864 MCPS
Self synchronized	GPS synchronized
New standard	Overlay to IS-95B
New Equipment	Upgrade Existing



3GPP W-CDMA and cdma2000 are both wideband CDMA systems with many similarities in the capabilities that they offer but with many differences in the details of the implementation. The most obvious difference is in the chip rates used for the carrier channel. W-CDMA uses a chip rate of 3.84 Mcps while cdma-2000 uses 1.2288 Mcps - the same rate used by the IS-95A standard with a 3x version version proposed as a future upgrade. At the detail level there are considerable differences in the coding, synchronization and BS identification methodologies adopted by the two standards.

W-CDMA is a major new system, designed only for use in new spectrum, typically the new IMT-2000 band. It will require major new equipment installation by the network operators.

The cdma2000 system is an upgrade to IS-95. It has been designed to share the same frequency in each sector of each cell. For each user that uses cdma2000 coding rather than IS-95, the system is more efficient. Existing equipment can be upgraded to install the new technology.



### What is 1xEV D.O. or HDR?

- A high-speed, data only network that supports data rates up to 2.4 Mbps
  - Based on cdma2000 technology
  - Uses existing spectrum and base station equipment

*Data*



*Voice Voice*



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1xEV D.O. is a high-speed, data only network that supports data rates up to 2.4 Mcps and is based on cdma2000 technology. This system operates in existing spectrum, utilizes existing base station equipment with upgrades, and is on the fast track to reach the market. The 3GPP2 standards body spent only 6 months developing Release 0 of 1xEV D.O.

This data only version will be soon followed by a system that can handle both data and voice. This version is known as 1xEV D.V., which stands for 1xEV Data and Voice. Several wireless industry players have made 1xEV D.V. proposals to the 3GPP2.

The origin of 1xEV is a system developed by Qualcomm known as High Data Rate (HDR).





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### The Test Domains for Cellular

- ASIC
- RF
- Upper layer Protocols
- Integration
- Conformance
- Manufacturing



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The need of our customers have been broken down into six areas. Certainly, more areas exist, but these are the major ones.

The ASIC domain is covered by Agilent's Automatic Test Group (ATG). This topic is beyond the scope of this presentation.

Agilent's strengths are in RF test, with different needs for Integration, Conformance, and Manufacturing test.

The testing of the air link protocols is an area of interest from R&D customers that is not covered today. This is being investigated as an area of expansion for our products.



### RF Testing

- Wide Dynamic Range
- Real Time Control
- Calibration Data Required for Each Phone
- Battery Life vs Performance



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There are several differences in CDMA technologies from analog or either of the TDMA technologies. One of the biggest difference is the dynamic range requirement. GSM phones operate over no more than 40 dB transmit power range. CDMA phones have to operate over a much wider range, up to about 80 dB. In addition, there are design specs on the accuracy of this level, as well as the accuracy of the phone to measure the receive level over this entire range.

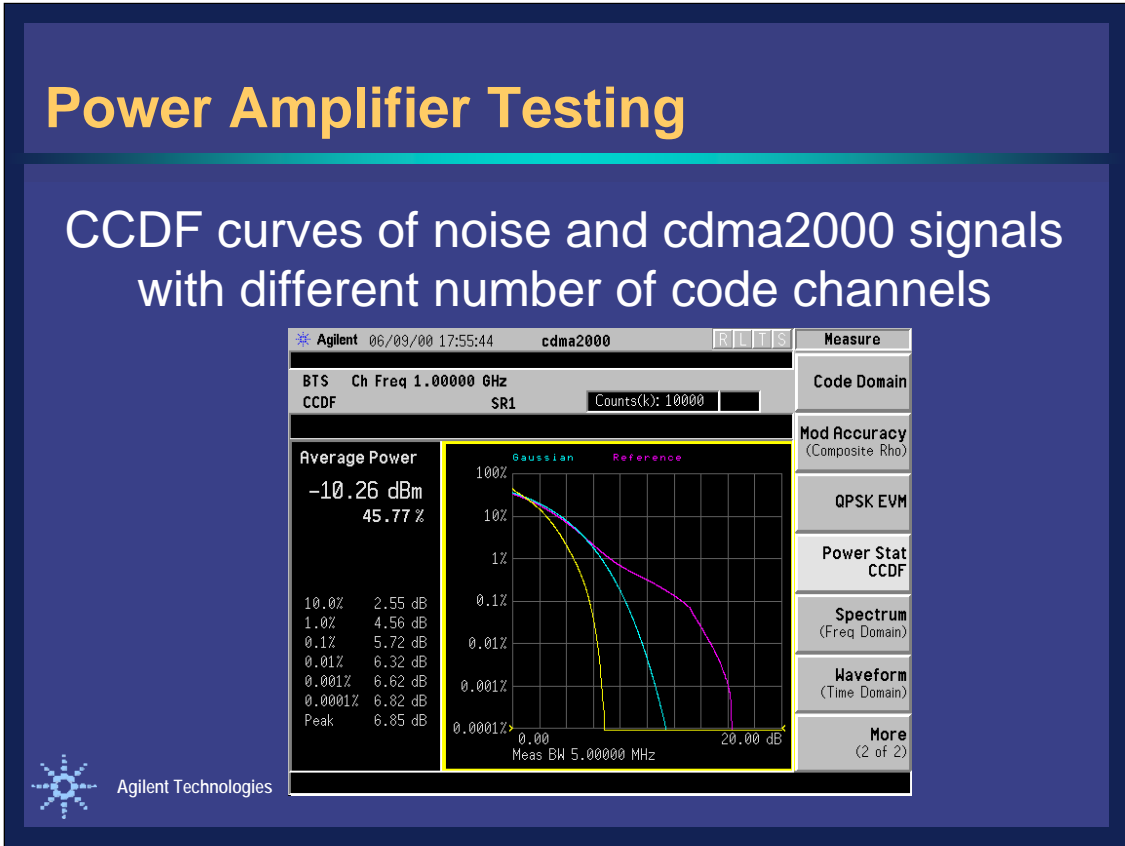
Typically, calibration of power on a per phone basis is needed.

Trade-offs are made between RF performance and battery life.



## Power Amplifier Testing

CCDF curves of noise and cdma2000 signals with different number of code channels



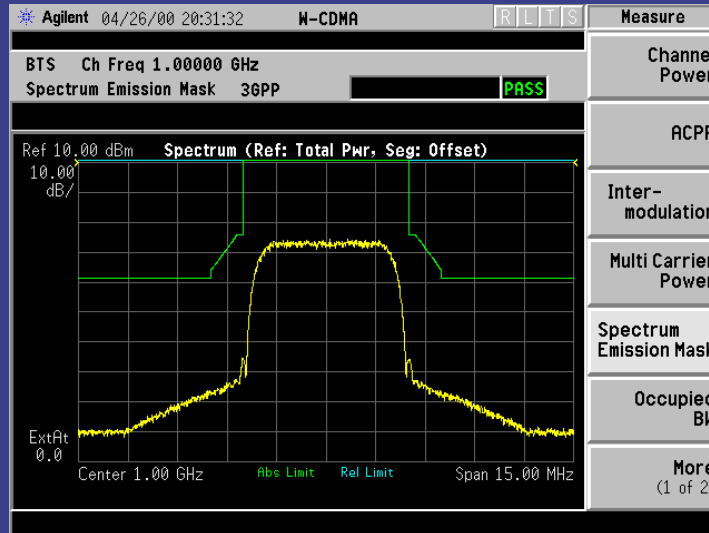
This is a measurement of 2 different cdma2000 base station signals. The blue line in the center is Additive White Gaussian Noise for comparison. The plot on the left is the base station signal containing only a few code channels. The plot on the right is a fully loaded base station signal.

This curve is called the Complimentary Cumulative Distribution Function (CCDF) and is a measurement that shows, on log scale, the percentage of the time the signal is above the average power of the cell. In order to never clip, there needs to be 6.85 dB overhead between peak and average power for the lightly loaded signal, and 16.2 dB overhead for the fully loaded signal.

It may be impractical and uneconomical to design a power amplifier that can operate with a 16dB of headroom and so there will be a trade off between the design of the base station power amplifier and the carrier loading that can be achieved.



## Spectral Purity

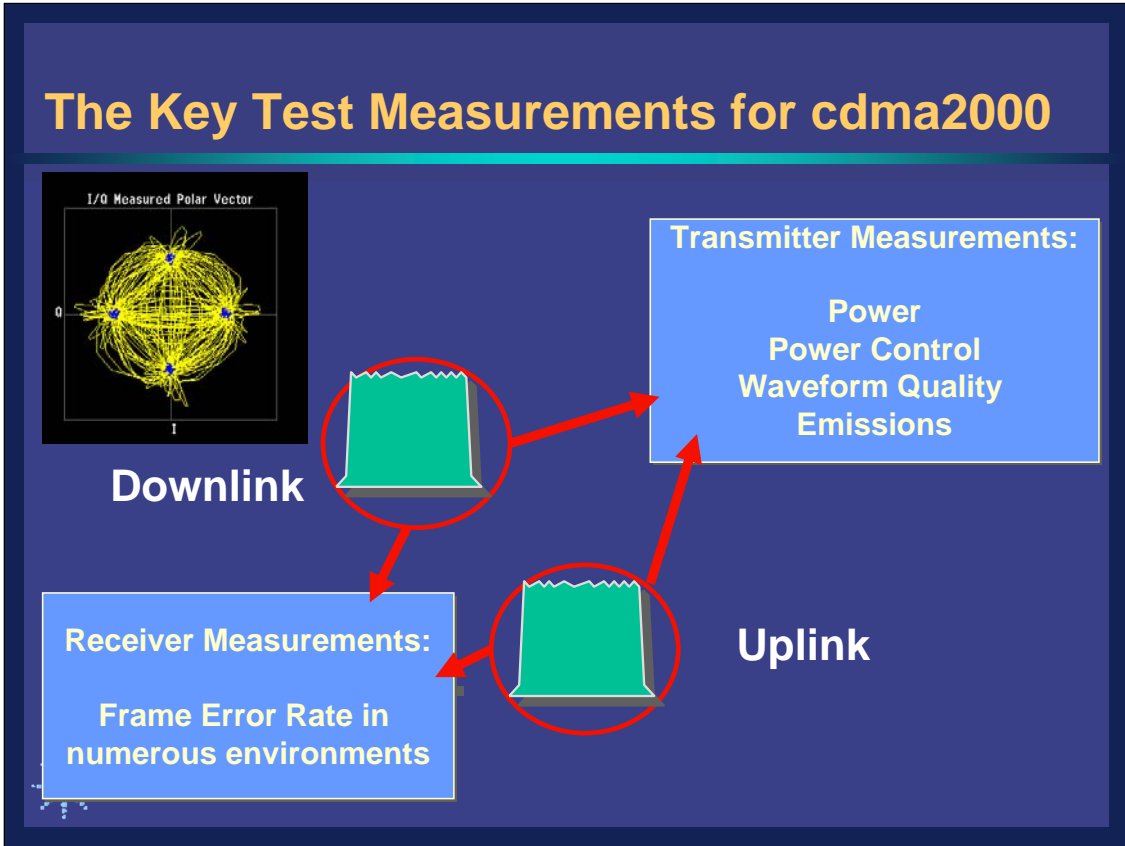


It is too expensive to have a power amplifier (PA) with 16 dB overhead. For a base station with 25 watts average power, this is 1 kilowatt of peak power. Instead, if we allow the base station to clip 0.1% of the time, the peak power can be reduced to only 260 watts. Whether this is acceptable depends on the spectral density outside the desired channel.

This is the spectrum of a W-CDMA signal. The signal must fit within a specified spectral mask. If we allow the PA to clip then 'spectral re-growth occurs and the amount of energy in the adjacent channel will increase.

It is desirable to provide the minimum power possible and still meet this spec.

The mobile has a similar problem, but trade bias current for the out of band emissions. This is usually a dynamic bias vs. output level and needs good equipment for characterization of its performance.



The important RF measurements for CDMA are shown here

- Power Wide dynamic Range
  - Power Control Open Loop and Closed Loop
  - Waveform Quality New metrics for both standards based on analysis of modulation accuracy and code domain error.
  - Emissions Tight specs with trade-offs
  - Frame Error Rate Requires call processing or test modes
- Receiver must operate properly in many different environments and FER is the fundamental measurement used for receiver performance.



### The Test Message

- Agilent is Involved in the development of all these Standards
- We Will have Test Equipment for all major Formats
- Early Test will Require Cooperation and Special Test Modes



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Agilent Technologies is well positioned in the test market for 3G.

We are involved in all the active standards.

We will have test equipment for all formats.



**Any Questions?**

