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**Agilent Technologies**

**Wireless Technology  
Seminar:  
EDGE/GPRS  
Basics**

**Paul Robertson**

## Agenda

- **Technology Drivers**
- **Acronym Definitions**
- **Technology Roadmap**
- **Technology Migration**
- **HSCSD & GPRS**
  - **Technology Implementation**
  - **Implementation Challenges**
- **EDGE**
  - **Technology Implementation**
  - **Implementation Challenges**

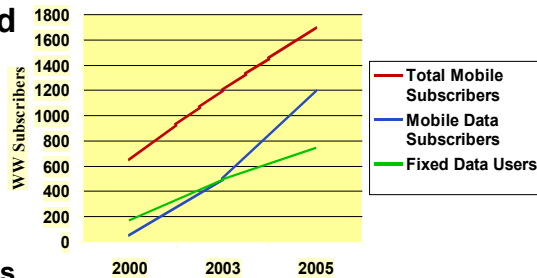


## Market Demand for Data Services

- 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. Wireless Access Protocol (WAP) is a newly defined standard that allows wireless devices to efficiently access the internet. Providing mobile internet access is seen as service that mobile users would be willing to pay for.

Current wireless systems (GSM, IS136, IS95) have relatively low data rate capabilities. For example the maximum data rate achievable over GSM is only 14.4kbps. This is considered a significant barrier to the successful adoption of data services by wireless users.

The network providers are keen to look for ways to increase revenues - data is seen as a huge opportunity to do this.

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## The Acronyms..

- **HSCSD** - **H**igh **S**peed **C**ircuit **S**witched **D**ata
- **GPRS** - **G**eneral **P**acket **R**adio **S**ervice
- **EDGE** - **E**nhanced **D**ata Rates for **G**SM  
**E**volution

These new technologies provide solutions to increase the data rates over existing GSM and IS-136 Networks.

HSCSD, GPRS & EDGE are collectively called 2.5G, however EDGE is regarded by many as a 3G technology.



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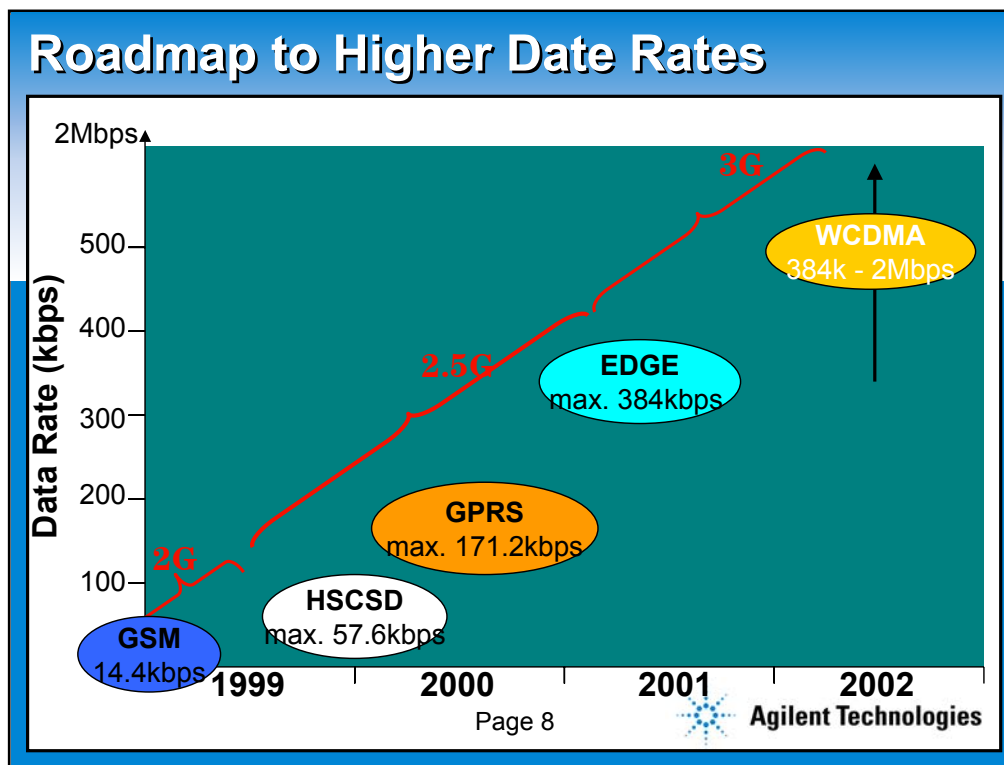
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## Standards Update

- **HSCSD**
  - All standards work complete.
  - Limited service has started.
- **GPRS**
  - Standards work complete.
  - Limited service intro Q4'00 (Sonera, Finland).
  - Full commercial deployment delayed to Q3/4'01
- **ECSD (Enabled by EDGE)**
  - Standardization process well underway.
  - Doubtful if ECSD will be adopted.
- **EGPRS (Enabled by EDGE)**
  - Standardization process well underway.
  - Unclear when EGPRS services may start.





The first generation (1G) cellular systems were introduced in the early to mid 1980's, and were based around analog radio interfaces. AMPS (Advanced Mobile Phone System), NMT (Nordic Mobile Telephone) and TACS (Total Access Communication System) are defined as 1G, or first generation systems.

As subscriber growth increased, the need for more capacity grew. This resulted in the need for 2nd generation cellular systems that could provide additional capacity. GSM, IS-136 & IS95 are examples of 2G, or 2nd generation systems.

The need to provide higher data rates over wireless systems is the driving factor behind 3G. 2.5G is considered an interim step to 3G. 2.5G provides existing 2G systems with an upgrade path to higher data rates. The goal of 2.5G was to provide GSM and IS-136 with a path to supporting the basic 3G data rate of 384kbps.

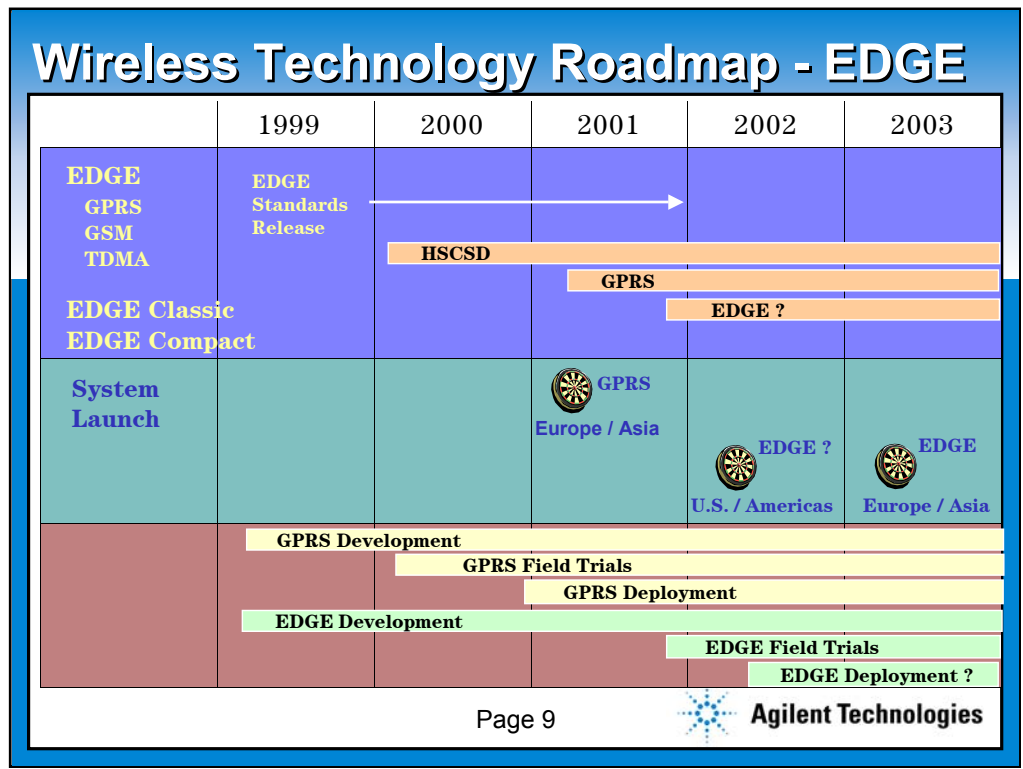
Note: PDC (Pacific Digital Cellular) is also a 2G system. There is no equivalent 2.5G migration strategy for PDC. The evolution path to higher data is to go straight to 3G.

**Notes:**

- 1) HSCSD max data rate of 57.6kbps = 4 timeslots @ 14.4kbps. HSCSD mobiles will only support up to 4 timeslots due to need to have a 2nd receiver to support more than 4 timeslots.
- 2) GPRS max data rate of 171.2kbps = 8 timeslots @ 21.4kbps - assumes no error correction and 2 receivers.



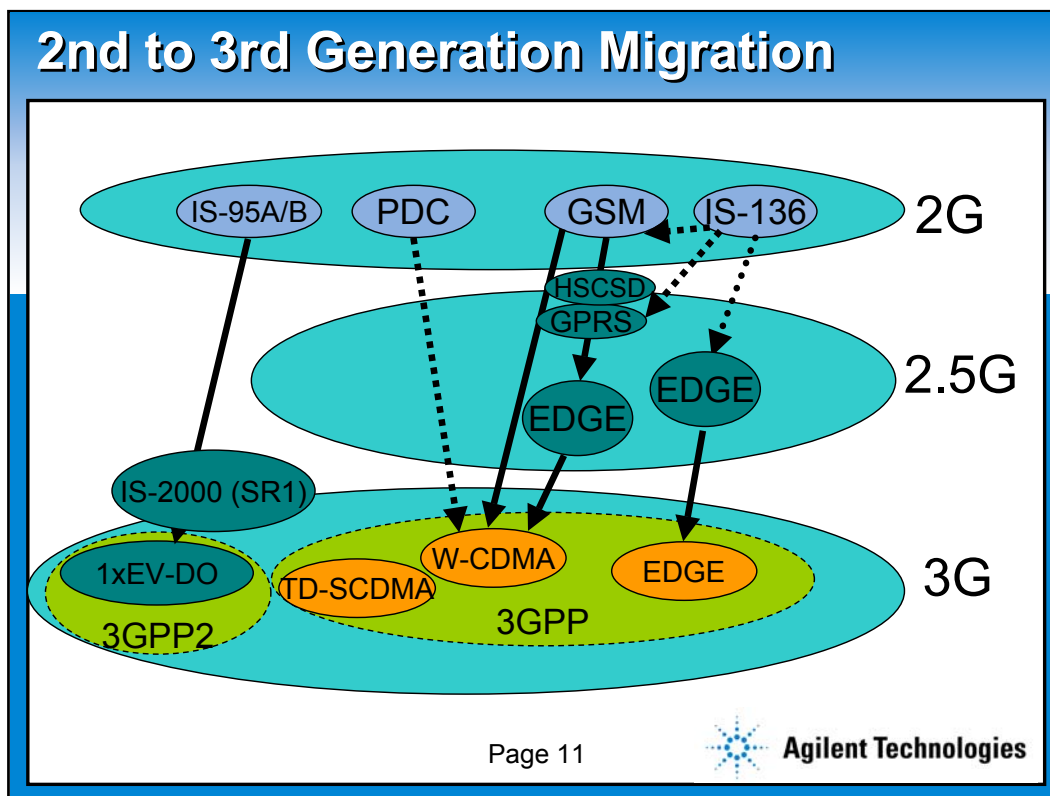
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A look at the evolutionary path from 2G to 3G shows the likely migration path for service providers of each major format. The W-CDMA system looks like it will receive the most subscribers as operation is started in the IMT-2000 band. The SR3 (Spread 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 (1xEV-DV). Future versions of this will be capable of data and voice (1xEV-DV). The IS-136 operators do not have a direct evolution path to 3G. Instead, they will transition first to GPRS-capable networks then on to W-CDMA.

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 much 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 W-CDMA, and there are no plans for dual-mode PDC/W-CDMA terminals unlike most all other evolution paths.

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## Question and Answer Session

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## HSCSD

- **High Speed Circuit Switched Data - HSCSD**
  - **HSCSD is a *circuit switched* technology**
  - **All today's cellular networks are circuit switched**
  - **A physical channel is assigned for the duration of the call**
  - **Physical channel connection is maintained even if data is not being transferred**



**HSCSD (High Speed Circuit Switched Data) is the first data rate extension to GSM aimed at addressing the need for higher data rates.**

**All existing cellular systems (GSM, IS136, IS95 etc) are based on circuit switched technology. This means that a physical connection is permanently maintained for the duration of the call.**

**HSCSD is a circuit switched technology which makes it a relatively straight forward enhancement to standard GSM.**

## GPRS

- **General Packet Radio Service - GPRS**
  - **GPRS is a *packet switched* technology**
  - **This is very different to today's cellular network architectures**
  - **A physical channel is only assigned when data needs to be transmitted or received**
  - **Physical channels can be shared between different mobile users**

**GPRS (General Packet Radio Service) is expected to follow HSCSD in terms of market introduction.**

**GPRS is based on packet switching technology. Compared to HSCSD, GPRS is a far more complicated system.**

**Many fixed line telephone systems employ packet switching technology. Packet switching allows the various circuits to be shared between many users, and as such efficiently accommodates the bursty nature of data traffic.**

**Examples of packet switched networks include X.25, Frame Relay, the Internet and ATM (Asynchronous Transfer Mode).**

**GPRS allows the radio interface resources to be efficiently shared between many users.**

## Circuit versus Packet Switched

### Circuit Switched

- i.e. **HSCSD**
- Each physical channel is assigned
- Suitable for..
  - Time critical apps
  - e.g. videophone
- Complements..
  - PSTN & ISDN
- Charged by...
  - The minute

### Packet Switched

- i.e. **GPRS**
- Each physical channel is shared
- Suitable for..
  - Web browsing
  - Email
  - Stock Values, etc
- Complements..
  - TCP/IP, X25
- Charged by..
  - The BIT (& QoS)



For data applications packet switching makes more efficient use of network resources than circuit switched architectures. This is because data tends to be bursty in nature, which means there are periods when little or no data is being transferred. Rather than tying up a network resource when no data is being transferred, it is more efficient to share the resource with another user who has data to transfer.

There are some data applications that better suit circuit switched architectures. These are applications that rely on a constant and predictable transfer delay through the network. A good example is videophone - variable delays through the system would mean that video frame data would arrive in unpredictable bursts resulting in a jerky, disjointed video sequence.

There are some challenges that packet switching introduces when considering how customers are billed. Today cellular users are billed by the minute. In GPRS the number of bits transferred needs to be used as a measure of cost. Cellular networks have not been designed to allow for 'number of bits' to be used as a billing measure. Also quality of service (QoS) needs to be considered - should the customer pay for bad or corrupted data packets that have to be discarded and resent by the network?

No network operators have made any statements on how they will bill customers for GPRS services.



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## Physical Layer Aspects of HSCSD & GPRS

- Most changes to 'conventional' GSM are above layer 1 (i.e. protocol)
- However at the physical layer both HSCSD & GPRS...

**= 'Multi-slot'**

- In other words, for the first time Mobile Stations can transmit during *more* than one slot per frame.

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GSM is a TDMA (Time Division Multiple Access) system. A single GSM frame consists of 8 timeslots. During a call a single user occupies one timeslot out of the 8 available slots.

The maximum data rate that is available to a single user on a standard GSM call is 14.4kbps. (It used to be 9.6kbps until very recently).

The way HSCSD and GPRS are able to increase the data rate over GSM is to use more than one timeslot (multiple timeslots or multi-slot).

## Multi-slot = More data throughput

HSCSD & GPRS mobiles can transmit and receive on *multiple* GSM timeslots per frame.

The diagram illustrates the structure of a GSM frame. A blue double-headed arrow at the top is labeled "1 GSM Frame". Below it, the "Downlink" structure is shown with a teal bar representing the BCH (Broadcast Channel) slot, followed by two teal bars representing TCHTCH (Traffic Channels) slots. Below this, the text "e.g. 2 x 14.4Kbps = 28.8Kbps" is shown. Below the Downlink structure, the "Uplink" structure is shown with two teal bars representing TCHTCH slots. Below this, the text "e.g. 2 x 14.4Kbps" is shown. At the bottom of the diagram area, the text "Page 18" and the Agilent Technologies logo are visible.

Using multiple timeslots per user allows the data rate to be multiplied up to 28.8kbps (2 slots), 43.2kbps (3 slots) or 115.2kbps (8 slots).

Even higher data rates are achievable if less, or no, error correction is used.

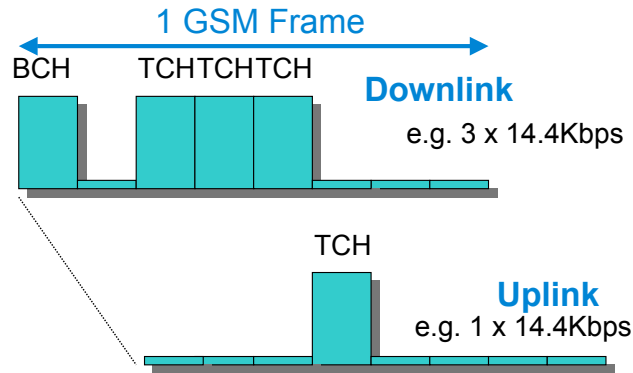
With no error correction the max data rate achievable =  $8 \times 21.4 = 171.2$  kbps.

There is another factor that limits the maximum achievable data rate. It relates to the mobile's receiver. During normal operation the mobile needs to share its time between receiving data, monitoring the local BCH, and measuring the level of adjacent cell BCH's. (BCH = Broadcast Channel). The maximum number of timeslots that a mobile can receive, while still managing to perform the local and adjacent cell BCH's is 4. To receive more than 4 timeslots a mobile requires a second receiver.

Initial mobile designs for HSCSD and GPRS will all be based on a single receiver.

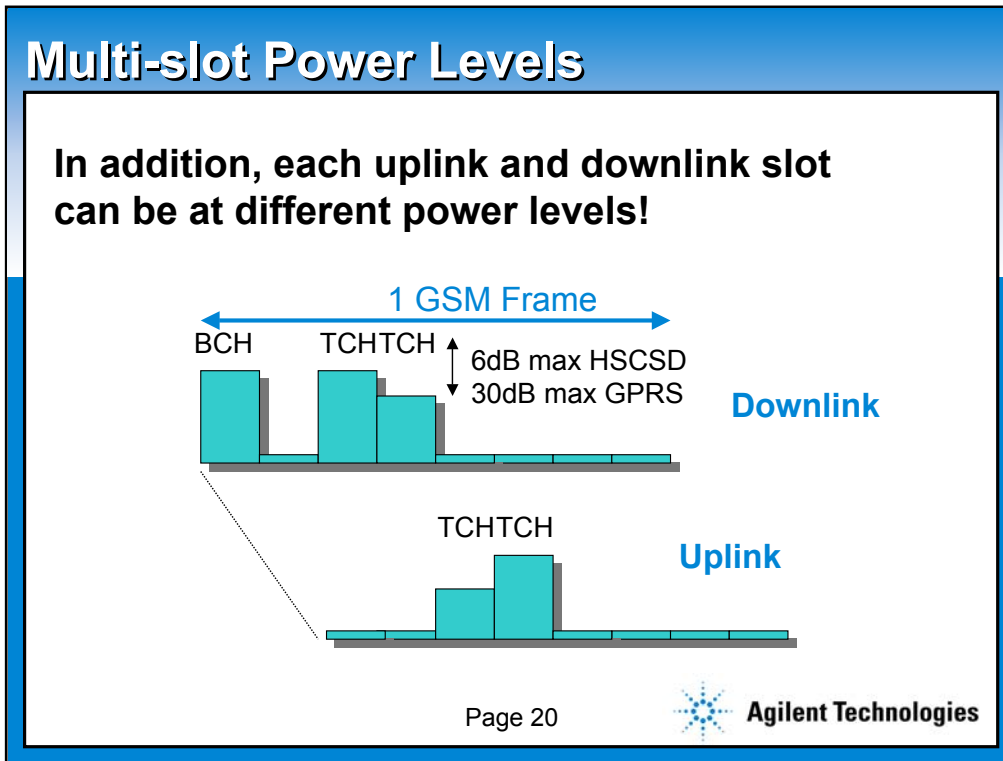
## Multi-slot Combinations

**Many combinations of Uplink and Downlink data rates are possible. For example a Web browser will require much higher downlink data rates than uplink.**



Depending on the type of data application that is being used the timeslot configurations of the uplink and downlink can be different. They can also be dynamically changed during the call depending on data application requirements and network capacity.

For example if the user was surfing the internet the majority of data being transferred would be on the downlink (from the network to the mobile). Therefore in this situation it would make sense to assign multiple timeslots on the downlink and only use one timeslot on the uplink.



HSCSD and GPRS are both required to support timeslots at different power levels. Each timeslot on the uplink and downlink can be a different power level.

There are some differences between HSCSD and GPRS in terms of timeslot power level differences on the downlink.

### HSCSD

Max difference between adjacent timeslots on downlink = 6dB

### GPRS

Max difference between adjacent timeslots on downlink = 10dB (Mode A) and 30dB (Mode B). Mode A & B refer to different power control modes on the mobile.

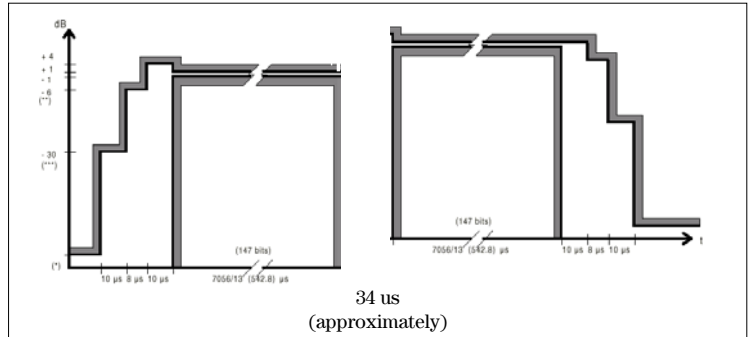
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## Mobile Transmitter Power Requirements

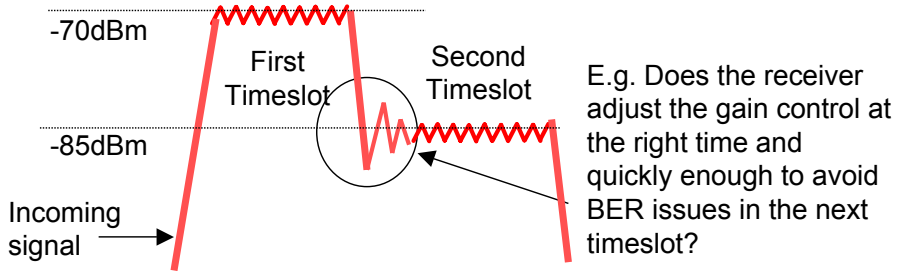
HSCSD & GPRS mobiles can now transmit on *multiple* uplink slots and these can be at *different power levels*.



A new multislot Power versus Time mask has been defined for mobile and base station transmitters.

## Multi-slot Receiver Requirements

The mobile can also receive on *multiple* downlink slots and these, too, can be at *different power levels*.



One of the key challenges of HSCSD & GPRS is designing a receiver that is capable of receiving adjacent timeslots that are at widely different power levels. This is more of an issue for GPRS since the max power difference between slots can be 30dB, compared to 6dB for HSCSD.

A key measurement to verify receiver design will be to perform BER on both slots while introducing a wide dynamic range.

## Multi-slot Test Requirements

The key RF measurements for multi-slot:

The diagram illustrates the key RF measurements for multi-slot testing. It shows a timeline of channels: BCH, TCHTCH, and TCHTCH. The TCHTCH channels are highlighted with red circles. Red arrows point from these circles to two measurement boxes: 'Transmitter Measurements' and 'Receiver Measurements'. The 'Transmitter Measurements' box lists: Power, P & F, P vs T, and ORFS. The 'Receiver Measurements' box lists: Bit Error Rate and Block Error Rate\*, with a note '\*GPRS Only' and a sequence of bits: ..,0,1,0,1,1,1,0,1,0,..'. The diagram also labels 'Downlink' and 'Uplink' directions. The Agilent Technologies logo and 'Page 24' are at the bottom.

**Transmitter Measurements:**

- Power
- P & F
- P vs T
- ORFS

**Receiver Measurements:**

- Bit Error Rate
- Block Error Rate\*

\*GPRS Only  
..,0,1,0,1,1,1,0,1,0,..

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The important RF measurements for HSCSD & GPRS are almost identical to those used for standard GSM.

- Power No different to standard GSM
- Phase and Frequency No different to standard GSM
- Power vs Time New multislot PvT mask has been defined
- ORFS No different to standard GSM
- Bit Error Rate (BER) New test loops defined in mobile
- Block Error Rate (BLER) Only applies to GPRS - new mobile test loop



## Question and Answer Session

### Wireless Technology Seminar: EDGE/GPRS Basics

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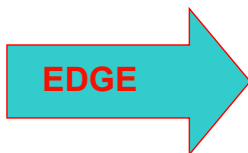


## What is EDGE?

- **EDGE = Enhanced Data rates for GSM Evolution**
- **EDGE is an extension to HSCSD and GPRS**

**HSCSD**

**GPRS**



**ECSD**

**EGPRS**

- **EDGE defines a new modulation format (8PSK) that allows services such as HSCSD & GPRS to go faster**



**EDGE (Enhanced Data Rates for GSM Evolution) is an extension to HSCSD and GPRS that provides a further data rate increase.**

**Since the data rate for HSCSD and GPRS is limited by the physical number of timeslots in a GSM frame (i.e.8), the only way the data rate can be further increased is to send more bits in each burst.**

**This is exactly what EDGE provides. EDGE allows more bits to be sent in each burst by defining a completely new modulation scheme. The EDGE modulation format is based on 8PSK (Phase Shift Keying). This increases the number of bits per symbol, and provides a 3-fold increase in data rate over GSM's GMSK (Gaussian Minimum Shift Keying) modulation format.**

**EDGE will be implemented on top of HSCSD and GPRS.**

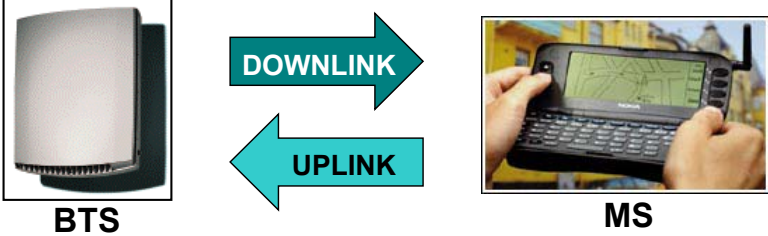
**EDGE on HSCSD is called ECSD, and EDGE on GPRS is call EGPRS.**

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## EDGE Classes



Class	Downlink	Uplink
A	8 PSK	GMSK
B	8 PSK	8PSK

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The EDGE standard defines to classes; Class A and Class B.

**Class A:** EDGE Class A defines an implementation where EDGE is only used on the downlink, I.e. from the base station to the mobile. Standard GMSK is used on the uplink (mobile to base station). Since some data applications involve more data being transferred on the downlink than the uplink (e.g. web browsing), this is a sensible limitation.

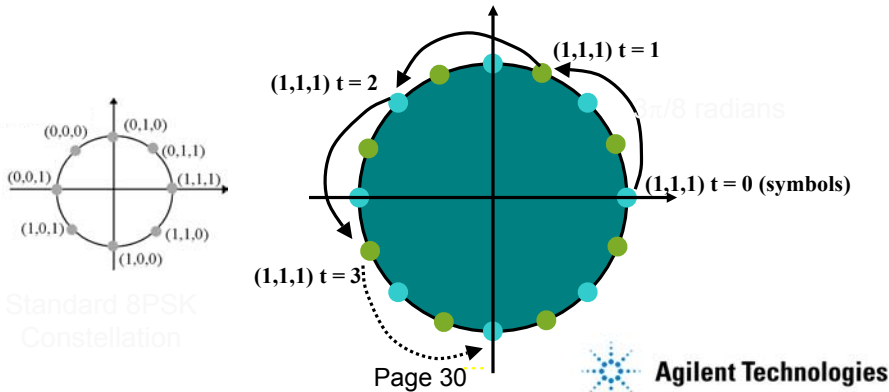
**Class B:** EDGE Class B defines a full EDGE implementation where EDGE can be used on both the uplink and downlink.

Some networks may introduce Class A only services first. This would enable networks to limit their investment risk exposure until EDGE based data services became established.

Mobile manufacturers are taking different approaches to their EDGE product plans.

## EDGE Physical Layer

- 8PSK constellation rotates  $3\pi/8$  radians per symbol period
- Rotation prevents zero crossings, reducing peak-to-average power



EDGE has an important characteristic that results in the need for new measurement techniques.

To avoid the problems associated with zero crossings, a rotation factor has been introduced. {A zero crossing is when the I/Q plot passes through the center during a symbol transition. The physical effect of this is that the signal power drops to zero for a brief period. This causes receiver design headaches and performance issues. Adding a rotation factor eliminates this problem}

The effect of adding a rotation factor to EDGE results in amplitude changes across the active part of the burst. On other words an EDGE modulated signal has a non-constant amplitude envelope.

In comparison the modulation format used for GSM (GMSK - Gaussian Minimum Shift Keying) generates a constant amplitude envelope. This means that a Power versus Time mask can be used to verify if the signal envelope meets specification or not. This mask can be specified to tight tolerances to ensure a rigid specification is met. The equivalent Power versus Time mask for EDGE has very wide pass / fail band to cope with the large amplitude variation of the signal.

The effect of the non-constant envelope of the EDGE modulated signal meant that a new measurement had to be defined to characterize the signal.

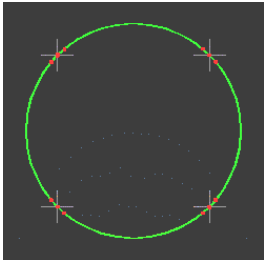
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## The Challenge of Moving to EDGE for Physical Layer Developers

<b>GSM</b> 0.3 GMSK		<b>EDGE</b> 3 $\pi$ /8 Shifted 8PSK
1 Bit / Symbol Constant Envelope	3 Bits / Symbol - -3X Data! Amplitude Changes 16+ dB	

- **EDGE is a non-constant amplitude signal!**
- **This introduces significant RF design & test challenges**

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Because EDGE signals are non-constant amplitude GSM developers are faced with new design and test challenges. EDGE signals are inherently more sensitive to, for example, non-linear amplifier behavior and other component imperfections.

Developers are also required to change existing GSM system infrastructure as little as possible. All EDGE capable equipment must also be GMSK capable.



## New Measurement for EDGE

- **New EVM measurement has been defined for EDGE**

**EVM = Error Vector Magnitude**

- **Provides a solution for measuring non-constant amplitude signals**
- **Agilent is playing lead role in EVM measurement definition at ETSI**



**A new measurement has been defined for EDGE. This new measurement is the Error Vector Magnitude (EVM) Measurement.**

**Agilent is playing a lead role at ETSI to define the EVM measurement.**

**The HP 8944x was the first instrument to prototype the EVM measurement, and will probably be the first to support the standardized measurement.**

## IS-136 EDGE

EDGE Compact      EDGE Classic

GPRS - 136HS EDGE  
(High Speed Packet Data)

- IS-136 EDGE Consists of 2 formats:
  - EDGE Compact = 3 Carriers
  - EDGE Classic = Standard EDGE

**U.S. IS-136 Operators are aggressively pursuing EDGE.**

**EDGE is needed to enable IS-136 operators to compete directly with IS-95 and IS-2000.**

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EDGE has also been adopted by the U.S. IS-136 standard.

There are 2 parts to IS-136 EDGE;

- a) EDGE Compact, and
- b) EDGE Classic.

EDGE Compact is a cut down version of ETSI EDGE that supports a limited number of carriers. This enables it to fit in to the existing IS-136 frequency plan with as few changes as possible.

EDGE Classic is identical to ETSI EDGE.

Early indications suggest that the first commercial EDGE services will be introduced on IS-136 networks.

## Market Summary - Dec '00

- **HSCSD**
  - Considered a niche market, only a few operators plan to introduce an HSCSD service
  - Orange (UK) planning to release HSCSD videophone Q1'01 (over 18 months later than planned)
- **GPRS**
  - Late introduction of mobiles has delayed service intro.
  - Trials having problems delivering promised data rates
- **EDGE**
  - Unclear if EDGE will happen in Europe
  - Recent AT&T announcement has put question mark over EDGE in US
  - Long term EDGE seen as a complement to W-CDMA



## Question and Answer Session

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