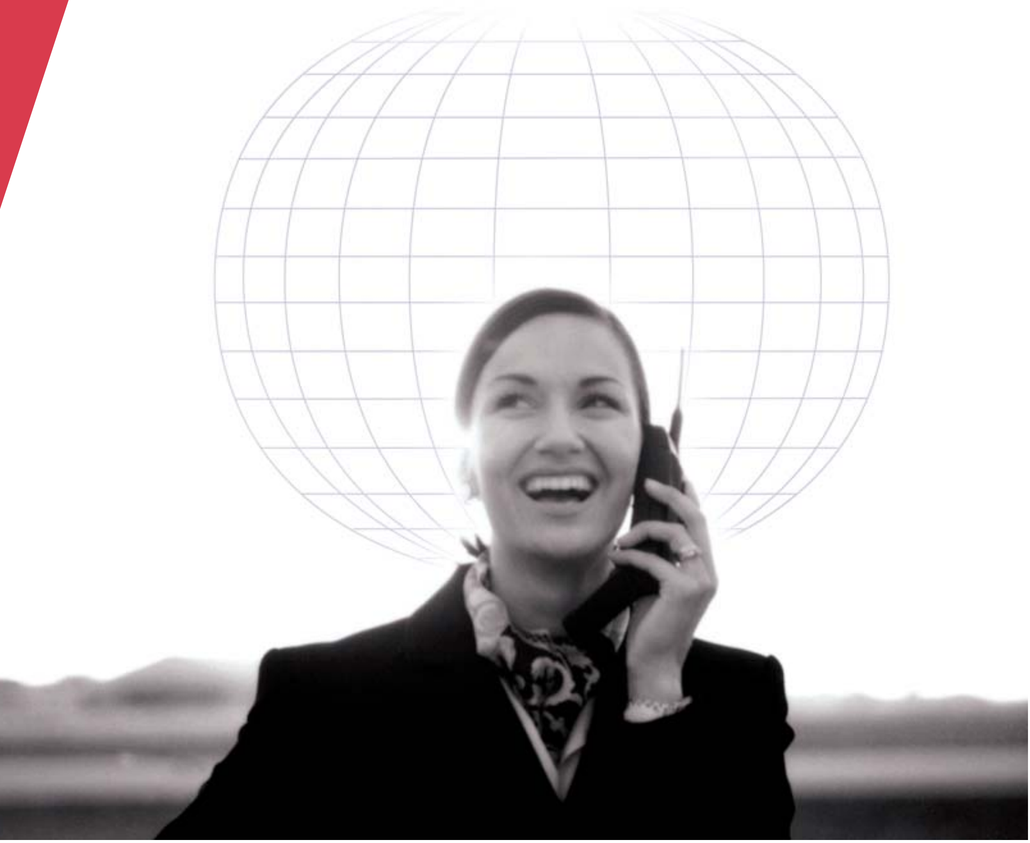
Seminar Booklet

GSM Introduction



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GSM Introduction

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Global System for Mobile Communications

The name says it all. GSM is a system for connecting mobile communications, such as mobile phones, on a worldwide basis.

The History of GSM

The history of GSM stretches back as far as 1982, when Groupe Spéciale Mobile, (which originally gave the standard its acronym) was formed within the European Conference of Postal and Telecommunications Administrations (CEPT). The Memorandum of Understanding (MoU) Group was set up in September 1987 and subsequently evolved into the GSM (MoU) Association, a non-profit organization with its headquarters in Dublin. Starting as a GSM network operators' club, the GSM Association now also roofs equipment manufacturers, suppliers and operators for satellite and 3G systems, as well as regulators and administrative bodies.

The GSM Association represents over 460 members from 150 countries, with 200 networks currently in operation worldwide. It claims to represent 66% of the digital cellular market, a total of more than 360 million subscribers.

The GSM standard was set when the major players in the European telecommunications industry got together and discussed a new digital mobile communications standard, which would suit everybody. The standard evolved with a lot of work by different groups of engineers, combining their ideas. These committees comprised of experts from manufacturers, future network providers and some permanent expert staff assigned from European Telecommunication Standard Institute (ETSI).

The GSM standard, originally aimed at the 900 MHz band in Europe, has proved so robust that it has been adopted for the PCN service at 1800 MHz, initially in Europe and later for one of the 1900 MHz PCS services in North America. New bands have been identified where analog networks are being phased out: in the 450/480 MHz range in Europe and Asia, and at 850 MHz in America.

GLOBAL SYSTEM FOR
MOBILE COMMUNICATIONS

GSM Standard

The GSM standard is an evolving standard, continually being worked on and updated. Phase 1 was completed in 1992 with the following features:

Phase 1

Service Category	Service	Comment
Teleservices	Telephony (Speech)	So-called 'full-rate', 13 kbit/s
	Emergency Calls (Speech)	Alphanumeric Information: user-to-user and 'Network' to all users
	Short Message Services: 'Point-to-Point' and 'Point-to-Multipoint' (Cell Broadcast)	
	Telefax	
Bearer Services	Asynchronous Data	300 to 9600 bit/s, 1200/75 bits 300 to 9600 bit/s
	Synchronous Data	300 to 9600 bit/s
	Asynchronous PAD (PacketSwitched, Packet Assembler/Disassembler) Access	300 to 9600 bit/s
	Alternate Speech and Data	
Supplementary Services	Call Forwarding	All calls, calls when a subscriber is busy, not reachable or not available
	Call Barring	e.g. all calls, international calls, incoming calls

Phase 2 specifications were completed at the end of 1997 and are currently being implemented on networks and terminals with the following additional features:

Phase 2

Service Category	Service	Comment
Teleservices	Telephony (Speech)	'half-rate', 6.5 kbit/s
	Short Message Services	General improvements
Bearer Services	Synchronous Dedicated Packed Data Access	2400 to 9600 bit/s
Supplementary Services	Calling/Connected Line Identity Presentation	Display of calling/called party's directory number before/after call connection
	Calling/Connected Line Identity Restriction	Restricts the display of the calling/called party's number at called party's side before/after call connection
	Call Waiting	Informs the user about a second (incoming) call and allows to answer it
	Call Hold	Puts an active call 'on hold' in order to answer or originate another (second) call
	Multi-Party Communication	Conference calls
	Closed User Group	Establishment of groups with limited access
	Advice Of Charge	On-line charge information
	Unstructured Supplementary Services Data	Offers an open communications link for use between network and user for operator-defined services
	Operator Determined Barring	Restriction of different services, call types by the operator

ETSI members are still working to extend the range of applications and enhance the quality of service with amendments and new specifications. Every year, a new set of specifications is released as 'Phase 2+ Release xxxx'. Below are some of the features:

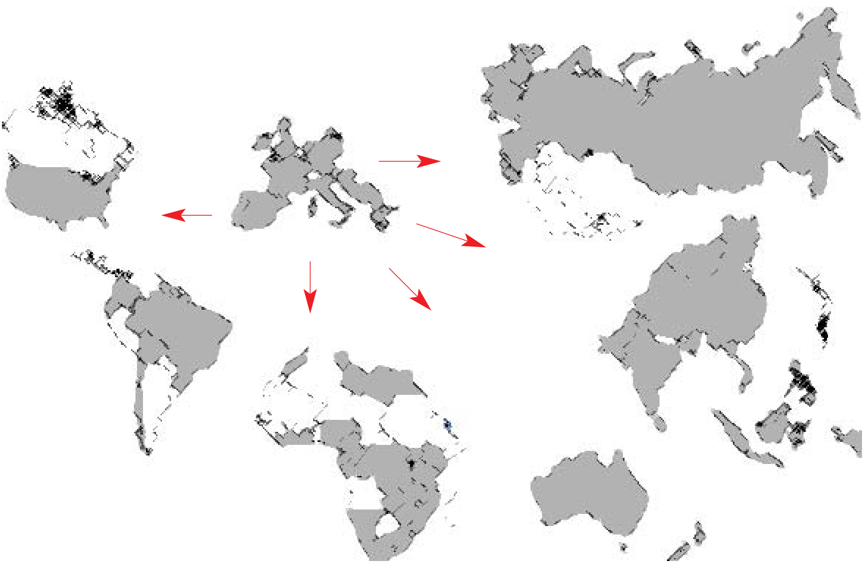
Phase 2+

Service Category	Comment
EFR (Enhanced Full Rate)	Even better speech quality
Language-specific	Allow for special characters in SMS and SS, alphabet extensions e.g. Chinese characters (UCS-2)
Higher data rates through multislot operation	Symmetric or asymmetric
High-speed circuit switch data (HSCSD)	Increases data ratios up to 57.6 kbit/s
EDGE (Enhanced Data rates for GSM Evolution)	Involves new modulation format
Voice broadcast	Application: GSM-R for the railways
Voice group call	Application: GSM-R for the railways
Adaptive MultiRate (AMR)	More flexible codec algorithms to optimize for voice quality or channel bandwidth
General Packet Radio Service (GPRS)	Better channel utilization for data applications through the use of packet data
Wireless Local Loop	Needed for the deregulated telecommunication industry in Europe
Multiband operation of GSM at 450/480, 850, 900, 1800 and 1900 MHz	Provides greater flexibility
Dual mode of operation for various systems, e.g. GSM/MSS, GSM/PHS	Allows for truly international roaming

Growth of GSM

At the start of GSM in 1992, it was a system intended to ensure that Europeans could roam their continent and use their handset wherever they chose to travel. A system designed by Europeans for deployment in Europe.

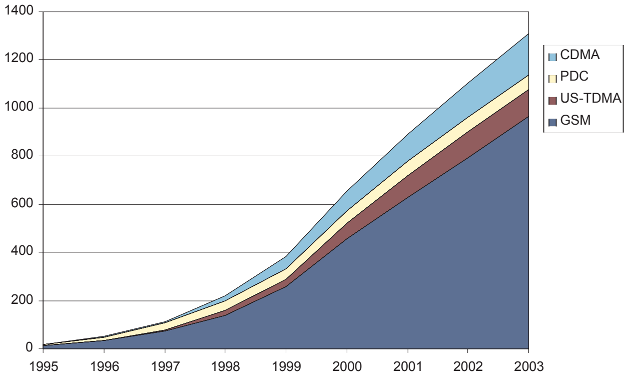
Four years later the GSM network had over one million subscribers. The worldwide trend towards the deregulation and liberalization of telecommunications meant that a host of new players were entering the mobile market. The GSM specifications were feature-rich and offered a range of services that would enable new operators to differentiate themselves from their rivals. And at the heart of the trend towards GSM ascendancy was its capacity for global roaming. In short, the world was ready for GSM. By the middle of the nineties GSM had expanded beyond Europe and Australia, establishing a presence in areas as diverse as India, Africa, Asia and the Arab world and it is not stopping there.



Global Cellular Market Trends

As you can see on the diagram below, GSM is the largest cellular system, with some market research organizations predicting users of 1 billion by the year 2005

GSM Subscribers in Millions



Benefits and Features of GSM

Users benefit from the following capabilities:

- Superior speech quality
  (equal to or better than the analog cellular technologies)
- Low terminal, operational and service costs
- High level of security (confidentiality and fraud prevention)
- International roaming
  (under one subscriber directory number)
- Support of low-power hand-portable terminals
- Long talk time and standby time due to constant envelope modulation

GSM Architecture

The functional architecture of GSM can be broadly divided into:

- Mobile station (MS)
- Base station (BS)
- Network subsystem

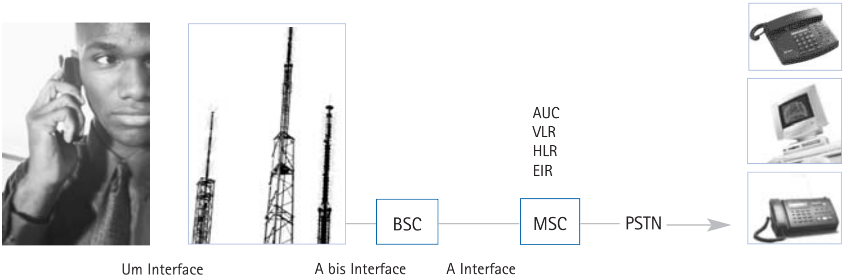
Mobile Station

The mobile station can be divided into two parts. The first part is the mobile equipment, which in network terms is anonymous. The subscriber information, which includes a unique identifier called the International Mobile Subscriber Identity (IMSI) is stored in the Subscriber Identity Module (SIM). The SIM is a smart card with a processor and memory chip permanently installed in a plastic card, which is either the size of a credit card, or in a smaller version called the plug-in SIM (see next page).

Certain subscriber parameters are stored on the SIM card, together with personal data used by the subscriber, such as personal phone directory numbers. The SIM card identifies the subscriber to the network. Since only the SIM can personalize a phone, it is possible to travel abroad, taking only the SIM card, rent a mobile phone at the destination, and then use the phone just as if it were a personal mobile phone at home.

To protect the SIM card from improper use, a security feature is built-in. Before the mobile phone can be used, a four-digit personal identification number (PIN) must be entered. The PIN is stored on the card.

Base Station and Network Subsystem



With the SIM card, each mobile phone is given a unique identity. As soon as the mobile phone is switched on, it registers with the network and is authenticated. This way the network can always find the mobile phone.

A large amount of data is transferred to and from the following:

Visitor Location Register (VLR)

Contains the relevant data of all mobiles currently located in a serving Mobile Services Switching Center (MSC), but not belonging to the area.

Home Location Register (HLR)

Stores the identity and user data of all the subscribers belonging to the area.

Authentication Center (AC)

Provides the HLR with different sets of parameters to complete the authentication of a mobile station.

Equipment Identity Register (EIR)

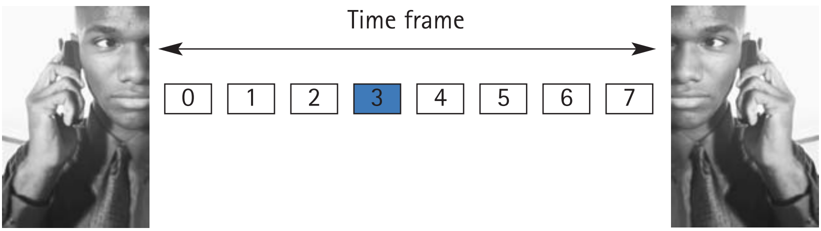
An option that the network operator can use to enforce security. With this feature the network can identify whether the mobile phone is stolen or due to some defect in the hardware, may not be used in the network.

A subscriber wishing to make an outgoing phone call, dials the requested number, sending a signal to the nearest base station. The base station sends the data to the MSC, whose job is to switch calls between the mobile users and between mobile and fixed network users. In this case the data is transferred over the Public Switched Telephone Network (PSTN) to a fixed telephone.

Channel Utilization

A key feature of GSM is channel utilization. Each radio frequency (RF) channel of 200 kHz uses TDMA (Time Division Multiple Access) to provide 8 time slots. FDMA (Frequency Division Multiple Access) is used to provide other 200 kHz wide RF channels. On each RF channel, a stream of bits is transmitted, carrying information to/from various mobile stations. This bit stream is divided into units called time frames and then each frame is split into eight time slots. When you make a phone call, the information is compressed into one of these time slots, which is then transported to the person you are having a conversation with, and then decompressed. It all happens incredibly quickly, at a rate of 4.615 ms for a whole frame. This means that eight people can be having a conversation at the same time, using the same carrier frequency.

One time frame consists of eight time slots. Data is compressed and sent, for example, in time slot 3, as shown in the figure below.



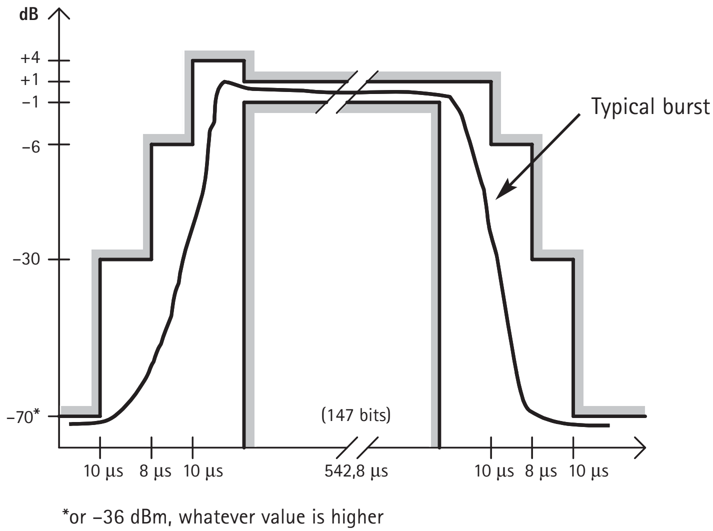
One time frame duration = 8 × time slot duration

4.615 ms = 8 × 0.5769 ms

Burst

A mobile station may only transmit data during the time slot assigned to it. Apart from this, it must not emit any power. Therefore, it must increase the transmitted power very quickly (within less than 30 ms) from zero to nominal. And once it has transmitted data, it must abruptly decrease the power again. This radio pulse is called a burst.

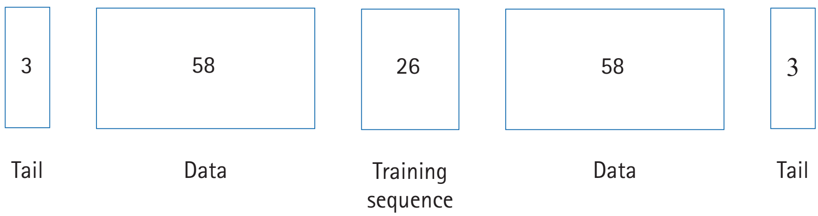
Below you can see a diagram of the Power/Time Template. The radio is only allowed to transmit RF power contained within the Power/Time Template shown.



There are five types of burst defined in GSM. These carry data or process speech or provide other network functions within the time slot.

Normal Burst

With the normal burst the actual information about the conversation is carried. 116 of the 148 bits are the real data, the other bits are basically for synchronization. The normal burst is shown in the figure below.



Frequency Correction Burst

Since frequency timing is critical in the system, the BS has to allow an MS to synchronize with the master frequency of the system. To do this, the BS transmits a pure sine wave signal for one time slot. It is 148 bits long and made up of zeros to provide a reference carrier.

Synchronization Burst

This burst helps the MS to synchronize its timing with the network, using a longer training sequence.

Random Access Burst

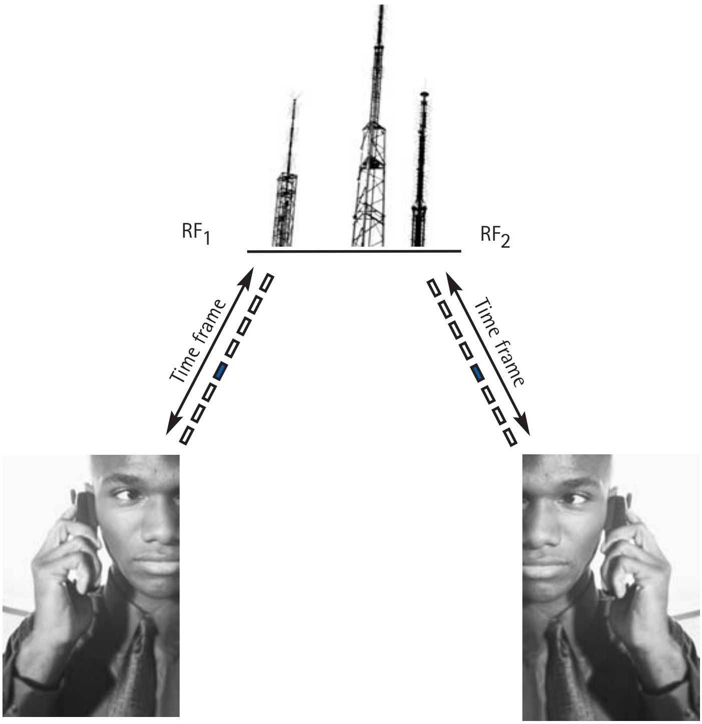
The MS transmits this kind of burst randomly and only when the MS is trying to gain initial access to the system.

Dummy Burst

Basically, this burst is transmitted by the BS on unused time slots.

In order to increase the system capacity, GSM utilizes TDMA in combination with FDMA. This means that *n* different carrier frequencies are used within a radio cell to establish communication. Consequently, the combined use of TDMA and FDMA increases the number of possible concurrent calls within one radio cell by a factor of *n*.

Example of the TDMA being used in combination with FDMA.



Same time slot, but different frequency avoids interference.

Speech Transmission

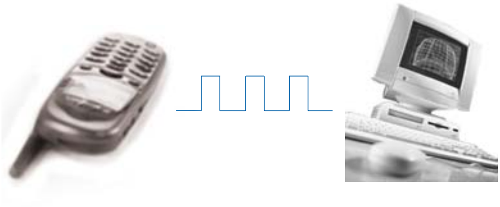
Three different algorithms are currently in use for speech transmission:

- Full Rate Speech (TCH/FS)
  The TCH/FS was the first method for speech transfer over a digital GSM channel. The algorithm is called RPE-LTP (Regular Pulse Excited Codec with Long Term Prediction), with a data rate of 13 kbit/s before channel encoding.
- Half Rate Speech (TCH/HS)
  The TCH/HS codec uses the VSELP (Vector Sum Excited Linear Predictor) algorithm which can be used to multiplex two calls into one time slot, so that more calls can be made on the same number of carriers. It usually saves some power from the battery as well. The bit rate is 5.6 kbit/s.
- Enhanced Full Rate Speech (TCH/EFS)
  The TCH/EFS codec uses an ACELP (Algebraic Code Excited Linear Prediction) algorithm at 12.2 kbit/s. It is a development of the mid-90s yielding superior voice quality.

Another method is currently being implemented:

Adaptive Multirate (AMR) (TCH/AFS, TCH/AHS)
The AMR codec allows fast switching between full and half-rate operation, depending on the network operator's priority for either higher capacity or higher quality (especially at bad reception quality). In the full-rate mode, it gives the radio link 4 to 6 dB more sensitivity, whereas in the half-rate mode, there is still wireline quality at low error conditions.

User Data Transmission



In addition to speech, mobile phones may also be able to transmit user data, e.g. from a connected PC or Personal Digital Assistant (PDA). The standard rate supported by GSM is 9.6 kbit/s. This rate may be sufficient for fax transfer but seems inadequate in today's high-speed communications world, where e-mails may contain large attachments and the World Wide Web is multimedia-oriented.

A higher data rate of 14.4 kbit/s has been introduced lately. This 50% gain is, however, achievable under good radio conditions only, and the data rate perceived by the user may drop below the 9.6 kbit/s rate under less than ideal conditions. So many operators are hesitant to introduce 14.4 kbit/s over a single channel, and are looking for other, improved ways to offer better data communications.

HSCSD

High Speed Circuit Switched Data (HSCSD) bundles several time slots to achieve higher data rates (e.g. three time slots can carry 28.8 kbit/s). This mechanism is called multislot operation. The multislot operation demands of the network only a software update, but novel mobile phones supporting HSCSD are required. The downlink typically carries more data than the uplink, so HSCSD can have asymmetric time slot usage – normally two or three slots in the downlink and one in the uplink.

The HSCSD is not very widespread yet. Just 20 to 25 networks worldwide deploy the service or plan to install it, starting in 1999. First handsets came on the market in September 2000. The disadvantage of the HSCSD from the user's point of view is that the user pays as long as he or she is connected, even if no data are transferred – just as with a speech call. Consequently, this makes it rather expensive for Web browsing. Network operators, on the other hand, have to contend with congested cells in some urban areas and are not able to afford to make more channels available to a single user.

GPRS

General Packet Radio Service (GPRS) proves to be a solution to this problem. Using the GPRS, one or more channels are offered to all users for data transfer, but the channel is dynamically shared between multiple users. The mobile phone or network assigns a time slot for a block of data only when there is data to be transferred. Channel assignment is very fast and the mechanism is similar to the Ethernet on a Local Area Network, where many users share a physical line.

GPRS is a completely new protocol reusing the lowest (physical) GSM layer. Running on a single channel, it does not offer higher data rates, but in conjunction with channel bundling (multislot operation), it can be very powerful, cost and bandwidth-efficient.

Depending on the channel coding algorithm chosen for a given network and radio channel situation, a data rate of 9 to 22 kbit/s is achievable for each time slot; so in a data transfer using two slots, the resulting rate may be 18 to 44 kbit/s, at least for a short period of time.

As GPRS uses radio resources only when data needs to be transmitted, it allows a user to be virtually always connected, which is an advantage when e.g. browsing the World Wide Web.

EDGE

Enhanced Data rates for the Global Evolution (EDGE) involves a new modulation format, 8PSK, that will provide three times the data rate of GSM/GPRS on the same physical channel. It can be used together with GPRS to result in EGPRS. It is expected on the market in late 2001.

Basic Specifications of GSM Radio Communications

Frequency Bands (Carrier Frequencies), Channel Numbers

	MS → BS (Uplink)	MS ← BS (Downlink)	Channel Numbers
P-GSM 900	890.2 to 914.8 MHz	935.2 to 959.8 MHz	1 to 124
E-GSM 900	880.2 to 914.8 MHz	925.2 to 959.8 MHz	0 to 124, 975 to 1023
R-GSM 900	876.2 to 914.8 MHz	921.2 to 959.8 MHz	0 to 124, 955 to 1023
GSM 1800	1710.2 to 1784.8 MHz	1805.2 to 1879.8 MHz	512 to 885
GSM 1900	1850.2 to 1909.8 MHz	1930.2 to 1989.8 MHz	512 to 810
GSM 450	450.6 to 457.4 MHz	460.6 to 467.4 MHz	259 to 293
GSM 480	479.0 to 485.8 MHz	489.0 to 495.8 MHz	306 to 340
GSM 850	824.2 to 848.8 MHz	869.2 to 893.8 MHz	128 to 251

Duplex Spacing

P-GSM, E-GSM, R-GSM, GSM 850	45 MHz
GSM 1800	95 MHz
GSM 1900	80 MHz
GSM 450, GSM 480	10 MHz

Channel Spacing

200 kHz

Channel Utilization

TDMA. A channel is split into eight time slots. This allows eight calls simultaneously on one frequency.

Length of Time Slot

577 µs. Eight time slots form a TDMA frame (4.615 ms).

Modulation

GMSK (Gaussian Minimum Shift Keying). Phase shifts of $\pm\pi/2$ (90°) on symbol transitions.

Power Levels

Tolerance values apply to measurements under normal conditions (e.g. temperature between 15°C and 35°C). The allowable tolerance at the nominal maximum output power is ±2 dB.

Nominal Maximum Output Power			
Power Class	**GSM 450, GSM 480, GSM 850, GSM 900**	**GSM 1800**	**GSM 1900**
1	–	30 dBm (1 W)	30 dBm (1 W)
2	39 dBm (8 W)	24 dBm (0.25 W)	24 dBm (0.25 W)
3	37 dBm (5 W)	36 dBm (4 W)	33 dBm (2 W)
4	33 dBm (2 W)		
5	29 dBm (0.8 W)		

GSM 450, GSM 480, GSM 850, GSM 900

Power Control Level	Nominal Output Power (dBm)	Tolerance (dB)
0 – 2	39	±2
3	37	±3
4	35	±3
5	33	±3
6	31	±3
7	29	±3
8	27	±3
9	25	±3
10	23	±3
11	21	±3
12	19	±3
13	17	±3
14	15	±3
15	13	±3
16	11	±5
18	7	±5
19 – 31	5	±5

GSM 1800

Power Control Level	Nominal Output Power (dBm)	Tolerance (dB)
29	36	±2
30	34	±3
31	32	±3
0	30	±3
1	28	±3
2	26	±3
3	24	±3
4	22	±3
5	20	±3
6	18	±3
7	16	±3
8	14	±3
9	12	±4
10	10	±4
11	8	±4
12	6	±4
13	4	±4
14	2	±5
15 – 28	0	±5

GSM 1900

Power Control Level	Nominal Output Power (dBm)	Tolerance (dB)
22 – 29	Reserved	Reserved
30	33	±2
31	32	±2
0	30	±3
1	28	±3
2	26	±3
3	24	±3
4	22	±3
5	20	±3
6	18	±3
7	16	±3
8	14	±3
9	12	±4
10	10	±4
11	8	±4
12	6	±4
13	4	±4
14	2	±5
15	0	±5
16 – 21	Reserved	Reserved

Glossary

AC	Authentication Center
AMR	Adaptive MultiRate (codec standard)
BS	Base Station
BSC	Base Station Controller
BTS	Base Transceiver Station
ECSD	Enhanced Circuit Switched Data (an extension of HSCSD with EDGE (8PSK) modulation)
EDGE	Enhanced Data rates for Global Evolution
EFR	Enhanced Full Rate
EGPRS	Enhanced GPRS (i.e. GPRS protocol with EDGE (8PSK) modulation)
EIR	Equipment Identity Register
FDMA	Frequency Division Multiple Access
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
GSM MoU	GSM Memorandum of Understanding
HLR	Home Location Register
HSCSD	High Speed Circuit Switched Data (multislot operation)
IMSI	International Mobile Subscriber Identity
MS	Mobile Station

MSC	Mobile Services Switching Center
MSS	Mobile-to-Satellite System
PHS	Personal Handy Phone System
PIN	Personal Identification Number
PSTN	Public Switched Telephone Network
RF	Radio Frequency
SIM	Subscriber Identity Module
SMS	Short Message Services
TDMA	Time Division Multiple Access
UCS-2	Universal Character Set
VLR	Visitor Location Register

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