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EDGE Evolution
Technology Introduction

Application Note 1MA129

GPRS (General Packet Radio Service) and EDGE (Enhanced Data Rates for GSM Evolution) provide data capabilities in widely deployed 2G networks reaching peak and average data rates of 384kpbs and 200kbps, respectively. Within 3GPP Release 7, further improvements to GPRS/EDGE have been specified in the context of EDGE evolution. This application note introduces key features of EDGE evolution and outlines the changes to the radio interface.

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1 Introduction

The motivation expressed by operators on further enhancing EDGE data performance is mainly to ensure future competitiveness of the most dominating second generation technology and specifically that service continuity exists across different radio technologies (e.g. GERAN, UTRAN) supported by core network evolution e.g. IMS. 3GPP TSG GERAN – the responsible standardisation body for GSM/GPRS/EDGE - has performed a feasibility study identifying possible solutions to

- increase spectral efficiency,
- increase capacity and coverage,
- increase average data rates,
- reduce latency between the mobile station and the radio access network and to
- enhance service continuity with other radio access technologies.

The study item resulted into a total of 4 features specified within 3GPP Release 7. This application note introduces EDGE evolution and provides an overview of the different features with focus on the radio protocols.

Chapter 2 outlines the concept of introducing higher order modulation schemes in conjunction with new coding schemes as well as applying turbo coding in downlink (EGPRS2). Please find more detailed information on how to generate and analyze EGPRS2 signals using R&S®SMU Vector Signal Generators and R&S®FSG / FSU / FSQ Signal Analyzers in an additional Rohde & Schwarz application note at **1MA116.**

Chapter 3 explains the latency improvements solutions.

Chapter 4 describes the mobile station receive diversity scheme (MSRD).

Chapter 5 describes the downlink dual carrier solution.

The above features are independent and may find their way into the market at different times. Downlink data rates are expected to initially reach 1.2Mbps whereas the standard enables max. 1.9Mbps. Correspondingly uplink data rates may at first allow 474kps transmission while the maximum specified is 947kps.

This application note assumes basic knowledge of GSM/GPRS/EDGE and related radio protocols.

2 EGPRS2

EGPRS2 in general

EGPRS2 is a term introduced in GERAN 3GPP Release 7, which comprises the support of additional modulation and coding schemes (namely 16QAM and 32QAM) and the alternative support of an increased symbol rate of 325ksps compared to the legacy symbol rate of 270,833ksps. Regarding the new coding schemes EGPRS2 includes in addition the use of turbo coding, however turbo coding is used in downlink only. Note that the higher order modulation schemes do require good signal to noise/interference reception conditions, i.e. the use of resulting high data rates is restricted to appropriate cell areas. The same mechanism as for EDGE (8PSK) apply, i.e. based on MS feedback coding and modulation is adapted to current propagation and signal to noise/interference conditions.

3GPP specifies a two level support of EGPRS2. Level A always refers to the use of the legacy symbol rate, whereas Level B always refers to the use of the increased symbol rate. Level B will have a more significant impact to existing network deployments, i.e. distinguishing between Level A and B allows a phased introduction of the feature into deployed EDGE networks.

Table 1 Provides an overview of the modulation schemes and the resulting PDCH data rates.

Table 1 *New modulation schemes and resulting PDCH data rate*

Level A (legacy symbol rate)		**Level B (increased symbol rate)**	
Modulation	**PDCH data rate**	**Modulation**	**PDCH data rate**
GMSK	up to 17.6 kbps	GMSK	up to 17.6 kbps
8PSK	up to 32.8 kbps	QPSK	up to 29.6 kbps
16QAM	up to 54.4 kbps	16QAM	up to 67.2 kbps
32QAM (DL only)	up to 98.4 kbps	32QAM	up to 118.4 kbps

EGPRS2 support on the mobile side has been connected to support of EDGE. The MS declares a multislot class for GPRS and, if supported, EGPRS (EDGE). If additionally EGPRS2 is supported, the multislot class for EGPRS2 is the same as for EGPRS. Furthermore for all EGPRS2 packet control channels, the corresponding GPRS control channel coding is used. MSs supporting EGPRS2 in the downlink and/or the uplink shall support EGPRS (EDGE), i.e. modulation and coding schemes MCS 1 to 9.

The support of EGPRS2 is optional for the mobile station and the network. Specific modulation and coding schemes are mandatory for the MS when the MS is indicating EGPRS2 Level A or B support in DL or UL. A network supporting EGPRS2 may support only some of the specified modulation and coding schemes, i.e. the operator decides which schemes to use in his network.

EGPRS2 Coding and Modulation

For Downlink 16 additional modulation and coding schemes (DAS-5 to DAS-12 and DBS-5 to DBS-12) and for Uplink 13 additional modulation and coding schemes (UAS-7 to UAS-11 and UBS-5 to UBS-12) are defined for EGPRS2 packet data traffic channels. In the table below the code rates in brackets indicate the code rate for transmissions using Fast Ack/Nack Reporting (FANR), when the PAN (Piggy Packed Ack/Nack field) is present. The data rates given assume the basic TTI configuration. If reduced TTI (RTTI) is applied these data rates are doubled (see section 3 for details on FANR and RTTI).

The following tables provide the details of the new coding and modulation schemes specified in uplink and downlink direction.

Table 2 *Coding parameters for the EGPRS2 downlink coding schemes*

Scheme	Code rate	Header Code rate	PAN code rate (if present)	Modulation	RLC blocks per Radio Block (20ms)	Raw Data within one Radio Block	BCS	Tail payload	HCS	PCS	Data rate kb/s
DAS-12	0,96 (0,99)	0,38	0.38	32QAM	3	658	3x12	(Note 1)	8	10	98,4
DAS-11	0,80 (0,83)	038	0.38		3	546	3x12	(Note 1)			81,6
DAS-10	0,64 (0,66)	0,33	0.38		2	658	2x12	(Note 1)			65,6
DAS-9	0,68 (0,70)	0,34	0.38	16QAM	2	546	2x12	(Note 1)			54,4
DAS-8	0,56 (0,58)	0,34	0.38		2	450	2x12	(Note 1)			44,8
DAS-7	0,54 (0,57)	033	0.38	8PSK	1	658	12	(Note 1)			32,8
DAS-6	0,45 (0,48)	0,33	0.38		1	546	12	(Note 1)			27,2
DAS-5	0,37 (0,39)	0,33	0.38		1	450	12	(Note 1)			22,4
DBS-12	0,98 (1,00)	0,37	0.54	32QAM	4	594	4x12	(Note 1)			118,4
DBS-11	0,91 (0,93)	0,37	0.38		4	546	4x12	(Note 1)			108,8
DBS-10	0,72 (0,75)	0,34	0.38		3	594	3x12	(Note 1)			88,8
DBS-9	0,71 (0,.73)	0,34	0.38	16QAM	3	450	3x12	(Note 1)			67,2
DBS-8	0,60 (0.63)	0,31	0.38		2	594	2x12	(Note 1)			59,2
DBS-7	0,47 (0,48)	0,31	0.38		2	450	2x12	(Note 1)			44,8
DBS-6	0,63 (069)	0,31	0.38	QPSK	1	594	1x12	(Note 1)			29,6
DBS-5	0,49 (0,53)	0,31	0.38		1	450	1x12	(Note 1)			22,4

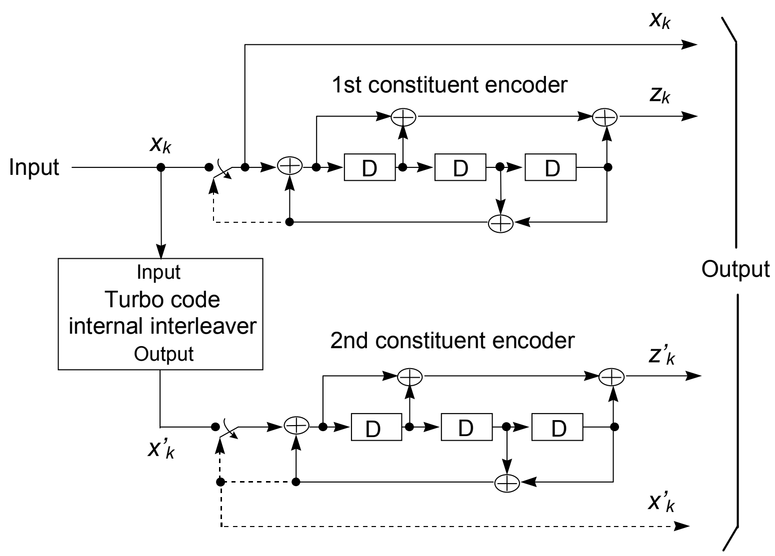
Note 1: The turbo code is terminated using 2x3 tail bits resulting in 12 coded bits per RLC block.

Table 3 Coding parameters for the EGPRS2 uplink coding schemes

Scheme	Code rate	Header Code rate	PAN code rate (if present)	Modulation	RLC blocks per Radio Block (20ms)	Raw Data within one Radio Block	BCS	Tail payload	HCS	PCS	Data rate kb/s
UAS-11	0,95 (0,99)	0,36	0.38	16QAM	3	514	3x12	3x6	8	10	76,8
UAS-10	0,84 (0,87	0,36	0.38		3	450	3x12	3x6			67,2
UAS-9	0,71 (0,74)	0,36	0.38		2	594	2x12	2x6			59,2
UAS-8	0,62 (0,64)	0,36	0.38		2	514	2x12	2x6			51,2
UAS-7	0,55 (0,57)	0,36	0.38		2	450	2x12	2x6			44,8
UBS-12	0,96 (0,99)	0,35	0.38	32QAM	4	594	4x12	4x6			118,4
UBS-11	0,89 (0,91)	0,35	0.38		4	546	4x12	4x6			108,8
UBS-10	0,71 (0,73)	0,35	0.36		3	594	3x12	3x6			88,8
UBS-9	0,70 (0,72)	0,32	0.36	16QAM	3	450	3x12	3x6			67,2
UBS-8	0,60 (0,61)	0,33	0.38		2	594	2x12	2x6			59,2
UBS-7	0,46 (0,47)	0,33	0.38		2	450	2x12	2x6			44,8
UBS-6	0,62 (0,67)	0,35	0.38	QPSK	1	594	12	6			29,6
UBS-5	0,47 (0,51)	0,35	0.38		1	450	12	6			22,4

In downlink turbo coding is applied whereas the same turbo coding scheme as in W-CDMA is used (see [1] for details). The scheme of the Turbo Coder is a Parallel Concatenated Convolutional Code (PCCC) with two 8 state constituent encoders and one Turbo Code internal interleaver. The coding rate of the Turbo Coder is 1/3. The following figure describes the structure of the turbo coder.

Figure 1 *Structure of rate 1/3 Turbo Coder*



The transfer function of the 8-state constituent code for PCCC is:

$$G(D) = \left[1, \frac{G9(D)}{G8(D)}\right] \quad \textit{whereas} \quad G8(D) = 1 + D2 + D3$$

$$G9(D) = 1 + D + D3$$

As mentioned two symbol rates are used, i.e. the legacy symbol rate of 270.833ksps and the increased symbol rate of 325ksps. The possible modulation schemes are partly different depending on the used symbol rate. GMSK modulation is possible with both symbol rates and the used symbol mapping is the same as specified for EDGE (see [2] for details). 8PSK modulation is used only with the legacy symbol rate whereas the symbol mapping is the same as specified for EDGE [2]. QPSK modulation is only applicable to the increased symbol rate. The symbol mapping is described in Table 5 below. 16QAM and 32QAM modulation is possible with both symbol rates and the symbol mappings are given in Table 6 and 7 hereafter. In order to allow blind detection of the modulation scheme the symbols are continuously rotated with φ radians per symbol before pulse shaping. The rotated symbols are defined as

$$\hat{s}_i = s_i \cdot e^{ji\varphi}$$

Table 4 provides φ for the different modulation schemes dependent on the used symbol rate. The constellation diagram for QPSK, 16QAM and 32QAM modulation is illustrated in Figure 2, 3 and 4, respectively.

Table 4 *Rotating φ depending on modulation scheme*

Level A (legacy symbol rate)		Level B (increased symbol rate)	
Modulation	**Rotating φ**	**Modulation**	**Rotating φ**
8PSK	$+3\pi/8$	QPSK	$+3\pi/4$
16QAM	$+\pi/4$	16QAM	$+\pi/4$
32QAM (DL only)	$-\pi/4$	32QAM	$-\pi/4$

Table 5 *Mapping between modulating bits and QPSK symbols*

Modulating bits d_{2i}, d_{2i+1}	QPSK symbol s_i I	Q
(0,0)	$1/\sqrt{2}$	$1/\sqrt{2}$
(0,1)	$1/\sqrt{2}$	$-1/\sqrt{2}$
(1,0)	$-1/\sqrt{2}$	$1/\sqrt{2}$
(1,1)	$-1/\sqrt{2}$	$-1/\sqrt{2}$

Table 6 *Mapping between modulating bits and 16QAM symbols*

Modulating bits $d_{4i}, d_{4i+1}, d_{4i+2}, d_{4i+3}$	16QAM symbol s_i I	Q
(0,0,0,0)	$1/\sqrt{10}$	$1/\sqrt{10}$
(0,0,0,1)	$1/\sqrt{10}$	$3/\sqrt{10}$
(0,0,1,0)	$3/\sqrt{10}$	$1/\sqrt{10}$
(0,0,1,1)	$3/\sqrt{10}$	$3/\sqrt{10}$
(0,1,0,0)	$1/\sqrt{10}$	$-1/\sqrt{10}$
(0,1,0,1)	$1/\sqrt{10}$	$-3/\sqrt{10}$
(0,1,1,0)	$3/\sqrt{10}$	$-1/\sqrt{10}$
(0,1,1,1)	$3/\sqrt{10}$	$-3/\sqrt{10}$
(1,0,0,0)	$-1/\sqrt{10}$	$1/\sqrt{10}$
(1,0,0,1)	$-1/\sqrt{10}$	$3/\sqrt{10}$
(1,0,1,0)	$-3/\sqrt{10}$	$1/\sqrt{10}$
(1,0,1,1)	$-3/\sqrt{10}$	$3/\sqrt{10}$
(1,1,0,0)	$-1/\sqrt{10}$	$-1/\sqrt{10}$
(1,1,0,1)	$-1/\sqrt{10}$	$-3/\sqrt{10}$
(1,1,1,0)	$-3/\sqrt{10}$	$-1/\sqrt{10}$
(1,1,1,1)	$-3/\sqrt{10}$	$-3/\sqrt{10}$

Table 7 *Mapping between modulating bits and 32QAM symbols*

Modulating bits	32QAM symbol s_i	
$d_{5i}, d_{5i+1}, d_{5i+2}, d_{5i+3}, d_{5i+4}$	I	Q
(0,0,0,0,0)	$-3/\sqrt{20}$	$-5/\sqrt{20}$
(0,0,0,0,1)	$-1/\sqrt{20}$	$-5/\sqrt{20}$
(0,0,0,1,0)	$-3/\sqrt{20}$	$5/\sqrt{20}$
(0,0,0,1,1)	$-1/\sqrt{20}$	$5/\sqrt{20}$
(0,0,1,0,0)	$-5/\sqrt{20}$	$-3/\sqrt{20}$
(0,0,1,0,1)	$-5/\sqrt{20}$	$-1/\sqrt{20}$
(0,0,1,1,0)	$-5/\sqrt{20}$	$3/\sqrt{20}$
(0,0,1,1,1)	$-5/\sqrt{20}$	$1/\sqrt{20}$
(0,1,0,0,0)	$-1/\sqrt{20}$	$-3/\sqrt{20}$
(0,1,0,0,1)	$-1/\sqrt{20}$	$-1/\sqrt{20}$
(0,1,0,1,0)	$-1/\sqrt{20}$	$3/\sqrt{20}$
(0,1,0,1,1)	$-1/\sqrt{20}$	$1/\sqrt{20}$
(0,1,1,0,0)	$-3/\sqrt{20}$	$-3/\sqrt{20}$
(0,1,1,0,1)	$-3/\sqrt{20}$	$-1/\sqrt{20}$
(0,1,1,1,0)	$-3/\sqrt{20}$	$3/\sqrt{20}$
(0,1,1,1,1)	$-3/\sqrt{20}$	$1/\sqrt{20}$
(1,0,0,0,0)	$3/\sqrt{20}$	$-5/\sqrt{20}$
(1,0,0,0,1)	$1/\sqrt{20}$	$-5/\sqrt{20}$
(1,0,0,1,0)	$3/\sqrt{20}$	$5/\sqrt{20}$
(1,0,0,1,1)	$1/\sqrt{20}$	$5/\sqrt{20}$
(1,0,1,0,0)	$5/\sqrt{20}$	$-3/\sqrt{20}$
(1,0,1,0,1)	$5/\sqrt{20}$	$-1/\sqrt{20}$
(1,0,1,1,0)	$5/\sqrt{20}$	$3/\sqrt{20}$
(1,0,1,1,1)	$5/\sqrt{20}$	$1/\sqrt{20}$
(1,1,0,0,0)	$1/\sqrt{20}$	$-3/\sqrt{20}$
(1,1,0,0,1)	$1/\sqrt{20}$	$-1/\sqrt{20}$
(1,1,0,1,0)	$1/\sqrt{20}$	$3/\sqrt{20}$
(1,1,0,1,1)	$1/\sqrt{20}$	$1/\sqrt{20}$
(1,1,1,0,0)	$3/\sqrt{20}$	$-3/\sqrt{20}$
(1,1,1,0,1)	$3/\sqrt{20}$	$-1/\sqrt{20}$
(1,1,1,1,0)	$3/\sqrt{20}$	$3/\sqrt{20}$
(1,1,1,1,1)	$3/\sqrt{20}$	$1/\sqrt{20}$

Figure 2 *16QAM constellation diagram*

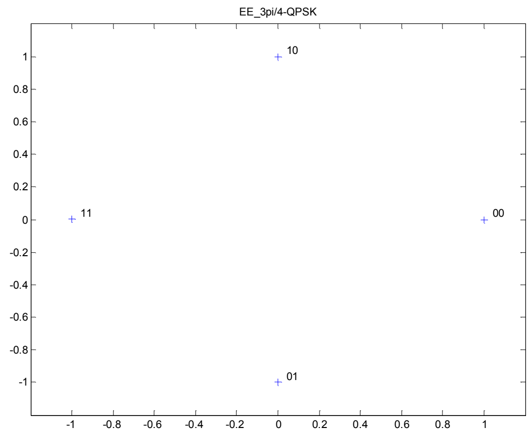


Figure 3 *16QAM constellation diagram*

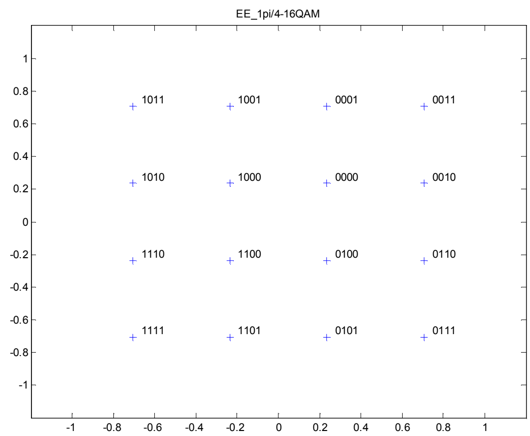
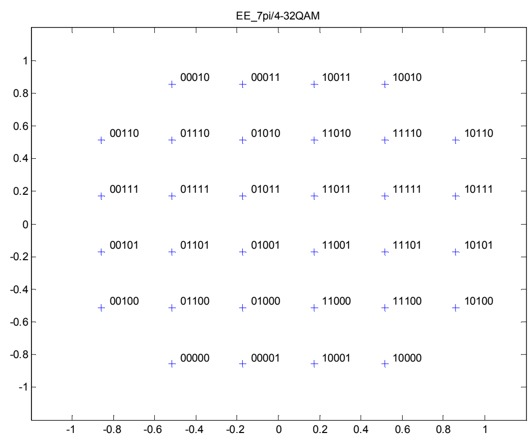


Figure 4 *32QAM constellation diagram*



EGPRS2 Pulse Shaping

Introduction of an increased symbol rate calls for a wider pulse shape filter compared to the GMSK filter in order to exploit full performance gain. However a wider pulse shape results into an increased adjacent power leakage, while at the same time co-channel interference is reduced. Comprehensive studies were performed investigating in which scenarios a wider pulse shape is acceptable. Results depend significantly on the underlying scenario and/or specific network deployment. On the edge channels in operator allocations where there is no guard channel, or in networks or cells which might exhibit higher levels of adjacent channel interference than normal the use of a wider pulse shape was judged critical. In order to allow flexibility for adaptation to certain scenarios the following solution was found.

The modulating symbols as represented by Dirac pulses excite one of the following linear pulse shaping filters:

- A spectrally wide pulse shape c'(t) as described in more detail below or
- a spectrally narrow pulse shape $c_o(t)$ which is the linearised GMSK pulse as defined for GSM/EDGE (see [2] section 3.5 for details).

The base band signal is

$$y(t) = \sum_i \hat{s}_i \cdot c'(t' - iT + 2.5T)$$ for the wide pulse shape

and

$$y(t) = \sum_i \hat{s}_i \cdot c_0(t' - iT + 2.5T)$$ for the narrow pulse shape.

For the wide pulse shape signal c'(t) is the continuous time representation of a discrete pulse shape $c_n = c'((n-1)T_s)$ where T_s is the sampling period equal to T/16 and n = 1, 2, …97. A closed form expression of c'(t) is not available because the spectrally wide pulse shape was numerically optimized based on a set of discrete filter coefficients. The continuous time function can be obtained by

- low-pass filtering the discrete time function with a pass-band of 400kHz and a stop-band beginning at 2600 kHz and
- truncating the duration to the time interval [0, 6T].

An example for such a low-pass filter is a raised cosine filter with the impulse response

$r(t) = si(2\pi t \cdot 2600\text{ kHz}) \cdot \cos(2\pi t \cdot 2200\text{ kHz}) / (1-(4t \cdot 2200\text{ kHz})^2)$

with si(x)=sin(x)/x,

resulting in

$c'(t) = \sum_{n=1}^{97} c_n r(t-(n-1)T_s)$ for $0 \le t \le 6T$ and $c'(t) = 0$ for $t < 0$ or $t > 6T$.

For the uplink, the pulse shape that shall be used when transmitting a burst is dependent on the parameter 'Pulse format' that is sent to the mobile during assignment of resources. In consequence the choice is left to the operator in which scenarios to use the wide pulse shape filter on a case by case basis. For the downlink the spectrally narrow pulse shape shall always be used avoiding possible critical scenarios at cell borders.

EGPRS2 Time Slots and Bursts

The time slot is a time interval of ≈ 576,9 µs, that is 156,25 symbols when using the normal symbol period or 187,5 symbols when using the reduced symbol period. A burst is a period of a RF carrier which is modulated by a data stream. A burst therefore represents the physical content of a timeslot. The new higher symbol rate burst (HB) is used to carry information on full rate packet data traffic channels using higher symbol rate. The following Table 8 compares the normal bursts structure (legacy symbol rate) and high symbol rate burst structure. Normal burst for 8-PSK is described for completeness.

Table 8 *Burst Structure for EDGE and EGPRS2*

	Normal symbol rate (270.833ksps) Level A			**High symbol rate (325ksps) Level B**		
	8PSK (EDGE)	**16QAM**	**32QAM**	**QPSK**	**16QAM**	**32QAM**
Tail (left)	3 symbols 9 bits	3 symbols 12 bits	3 symbols 15 bits	4 symbols 8 bits	4 symbols 16 bits	4 symbols 20 bits
PRBS data (left)	58 symbols 174 bits	58 symbols 232 bits	58 symbols 290 bits	69 symbols 138 bits	69 symbols 276 bits	69 symbols 345 bits
Training Sequence	26 symbols 78 bits	26 symbols 104 bits	26 symbols 130 bits	31 symbols 62 bits	31 symbols 124 bits	31 symbols 155 bits
PRBS data (right)	58 symbols 174 bits	58 symbols 232 bits	58 symbols 290 bits	69 symbols 138 bits	69 symbols 276 bits	69 symbols 345 bits
Tail (right)	3 symbols 9 bits	3 symbols 12 bits	3 symbols 15 bits	4 symbols 8 bits	4 symbols 16 bits	4 symbols 20 bits
Guard	8.25 symbols 24.75 bits	8.25 symbols 33 bits	8.25 symbols 41.25 bits	10.5 symbols 21 bits	10.5 symbols 42 bits	10.5 symbols 52.5 bits
Total	156.25 symbols **468.75 bits**	156.25 symbols **625 bits**	156.25 symbols **781.25 bits**	187.5 symbols **375 bits**	187.5 symbols **750 bits**	187.5 symbols **937.5 bits**
Frame (8 bursts)	1250 symbols **3750 bits**	1250 symbols **5000 bits**	1250 symbols **6250 bits**	1500 symbols **3000 bits**	1500 symbols **6000 bits**	1500 symbols **7500 bits**

EGPRS2 Performance Specification

The introduction of new coding and modulation schemes specifically using an increased symbol rate require adaptation of the existing performance requirements. The changes are manifold and the most dominant ones are described in the following.

The introduction of 16QAM and 32QAM results into an increased peak to average ratio affecting the power amplifier (PA) performance. In order to allow reuse of existing PA - most importantly at the mobile station (MS) - a certain reduction of the maximum output power of the MS is tolerated. The maximum output power of MS depends on the supported frequency band

(GSM 900 or DCS1800/PCS1900) and its power class. Most mobile stations provide 2Watt (33dBm) in GSM 900 and 1Watt (30dBm) in DCS1800/PCS1900 frequency bands. A correction factor is introduced allowing the mobile to reduce its power by 2dB if 16QAM and 32QAM modulation schemes are supported. For all other new modulation schemes (QPSK, 8PSK) the maximum output power shall be as specified by the relevant power class. On base station side the manufacturer usually declares the maximum power capability, i.e. a certain power class, which is then verified during testing.

As mentioned above the allowance of a wider pulse shaping filter has an impact on the adjacent channel power leakage affecting both spectrum due to modulation / wide band noise as well as spectrum due to switching. The requirements for high symbol rate using narrow pulse or wide pulse shape filter will be different compared to legacy symbol rate. However detailed requirements have not been agreed in 3GPP GERAN standardization yet.

With the introduction of new modulation schemes new modulation accuracy requirements are needed. The magnitude of the error vector (EVM) is computed by measuring the error vector between the vector representing the transmitted waveform and the vector representing the ideal one on the useful part of the burst (excluding tail symbols). When measuring the error vector a receive filter at baseband is used which is different for normal symbol rate and high symbol rate. For normal and high symbol rate using narrow pulse shape it is a raised–cosine filter with roll-off 0.25 and a single side band 6dB bandwidth of 90kHz. For high symbol rate and wide pulse shape filtering it is a raised–cosine filter with roll-off 0.25 and a single side band 6dB bandwidth of 108kHz.

The measurement filter is windowed by multiplying its impulse response by a raised cosine window given as:

$$
\mathrm{w}(t) = \begin{cases} 1, \quad 0 \le |t| \le 1.5T \\ 0.5\left(1+\cos\left[\pi(|t|-1.5T)/2.25T\right]\right), \quad 1.5T \le |t| \le 3.75T \\ 0, \quad |t| \ge 3.75T \end{cases}
$$

where *T* is the normal symbol period.

The measured EVM need to fulfill more stringent requirements for mobile station and base station, however concrete values have not been specified in 3GPP GERAN standardization yet.

Finally new receiver performance requirement will be introduced in [3] for the new modulation and coding schemes, i.e. receiver sensitivity and reference performance in different propagation conditions (static, typical urban, rural area, hilly terrain).

3 Latency Improvements

Latency has become an important key performance indicator in mobile networks. End-user satisfaction while e.g. surfing the internet depends strongly on the responsiveness of the network. Within EDGE evolution two approaches have been specified in order to further improve latency, namely

- Fast Ack/Nack Reporting (FANR) and
- Reduced TTI configuration (RTTI).

Both solutions are independent and may or may not be applied depending on operator choice and terminal capability. If both features are commonly referenced the term “Reduced Latency EGPRS” (RL- EGPRS) is used.

FANR: The Fast Ack/Nack reporting procedure refers to the possibility to include, in a radio block for data transfer sent in one direction, piggy-backed Ack/Nack information relative to the data transfer, i.e. relative to the TBF, in the other direction. This is achieved by inserting a fixed-size Piggy-backed Ack/Nack (PAN) field in the RLC radio block. When a PAN field is inserted, a suitable puncturing scheme variant for the modulation and coding scheme in use is chosen, so that the RLC data field and the PAN field fit together in the radio block along with the RLC/MAC header. The presence of the PAN field, is signaled by the PAN indicator bit in the RLC/MAC header, which informs the MS to apply the corresponding puncturing scheme. Therefore for RL-EGPRS, a Radio Block for data transfer consists of one RLC/MAC header, one or two RLC data block(s) and, optionally, one PAN field. It is always carried by four normal bursts. The interleaving depends on the modulation and coding scheme used. The following Figure shows the radio block structure for RL-EGPRS.

Figure 5 *Radio Block Structure in for RL-EGPRS data transfer*

Radio Block				
RLC/MAC header	HCS	RLC data	BCS	PAN and PCS (optional)

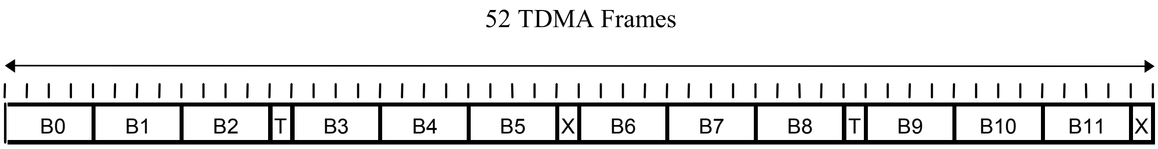
RTTI: In a reduced TTI configuration, a radio block consisting of four bursts is sent using two PDCHs, i.e. a PDCH-pair, in each of two consecutive TDMA frames. In consequence the time to transmit a radio block is half of a basic radio block period, i.e. 10ms instead of 20ms. A TBF assignment (downlink or uplink) consists of a number of PDCH-pairs. In a single carrier configuration up to 4 PDCH-pairs may be assigned per TBF whereas the two PDCHs constituting a PDCH-pair need not be contiguous. The two physical channels have the same parameters except for the timeslot number (TN) and need to be allocated on the same carrier frequency. Whereas the two PDCHs constituting a PDCH-pair need not be contiguous. In each direction, physical channels need to be assigned such that PDCH-pairs do not overlap. Note that for an assigned uplink PDCH-pair the network can use two modes for the transmission of the Uplink State Flag (USF), i.e. providing the information to the MS, which block to use for its uplink data transmission:

- Basic TTI (BTTI) USF mode: USFs are sent in a basic radio block period, i.e. a USF is mapped on four bursts transmitted on one of the PDCHs of a downlink PDCH-pair during four consecutive TDMA frames;
- Reduced TTI (RTTI) USF mode: a USF is sent in one reduced radio block period, i.e. a USF is mapped on four bursts transmitted

on both PDCHs of a downlink PDCH-pair during two consecutive TDMA frames.

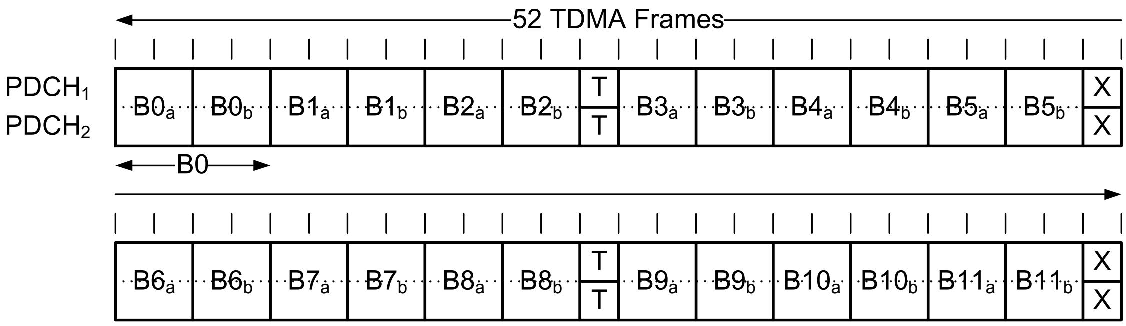
Figure 5 and 6 illustrate the 52-multiframe structure for a PDCH in comparison to a PDCH pair in RTTI configuration.

Figure 6 *52-multiframe for PDCH*



X = Idle frame
T = Frame used for PTCCH
B0 - B11 = Radio blocks

Figure 7 *52-multiframe for a PDCH pair (RTTI configuration)*



X = Idle frame
T = Frame used for PTCCH
B0 = BTTI radio block
$B0_a$ – $B11_b$ = RTTI radio blocks

4 Mobile Station Receive Diversity Solution (MSRD)

In GSM Rx diversity is widely used at the base stations improving the uplink link budget and balancing the lower output power of the mobile station. In principle the same performance increase is possible in the downlink direction, however implementing a second antenna at the mobile station is far more difficult due to size limitations of the device. In 3GPP Release 6 the introduction of Single Antenna Interference Cancellation (SAIC) characterized by the Downlink Advanced Receiver Performance (DARP) requirements has already shown that receiver enhancements in the MS can provide significant gains in terms of spectral efficiency. MSRD offers the possibility of enhanced channel diversity and the potential for further improved interference cancellation performance for GMSK modulated signals as well as significant gains for 8PSK-modulated signals. Consequently performance requirements based on mobile stations using two receive antennas are specified in the frame work of DARP phase 2.

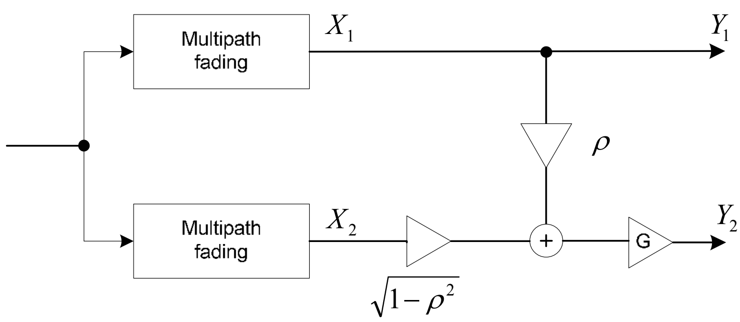
Performance requirements are specified based on the same scenarios as for DARP phase 1, i.e. with single and multiple as well as synchronous and asynchronous co-channel interferer. The following Table 15 provides as an example details of the reference test scenario DTS-5, i.e. for the test scenario with asynchronous multiple interferer.

Table 9 *Reference Test Scenario for Multiple Asynchronous Interferer*

Reference Test Scenario	Interfering Signal	Interferer relative power level	TSC	Interferer Delay
DTS-5	Co-channel 1	0 dB	none	74 symbols
	Co-channel 2	-10 dB	none	no delay
	Adjacent 1	3 dB	none	no delay
	AWGN	-17 dB	-	-

Since a DARP phase 2 mobile station utilizes receiver diversity by means of two antennas, a set of diversity specific parameters are needed. The sets consist of different values of antenna correlation and antenna gain imbalance. Furthermore a single input dual output channel model was developed as illustrated in Figure 7 below.

Figure 8 *Single Input – Dual Output Channel Model for MSRD*



The model consists of a single input signal, which is passed through two fading channels. The multipath fading are independent Rayleigh fading processes but the channel profile, e.g. TU50 is the same for each branch. The correlation between the two branches is generated using the weighting factor ρ . Table 16 provides details of the diversity specific parameter sets.

Table 10 *DARP Phase 2 Diversity parameters*

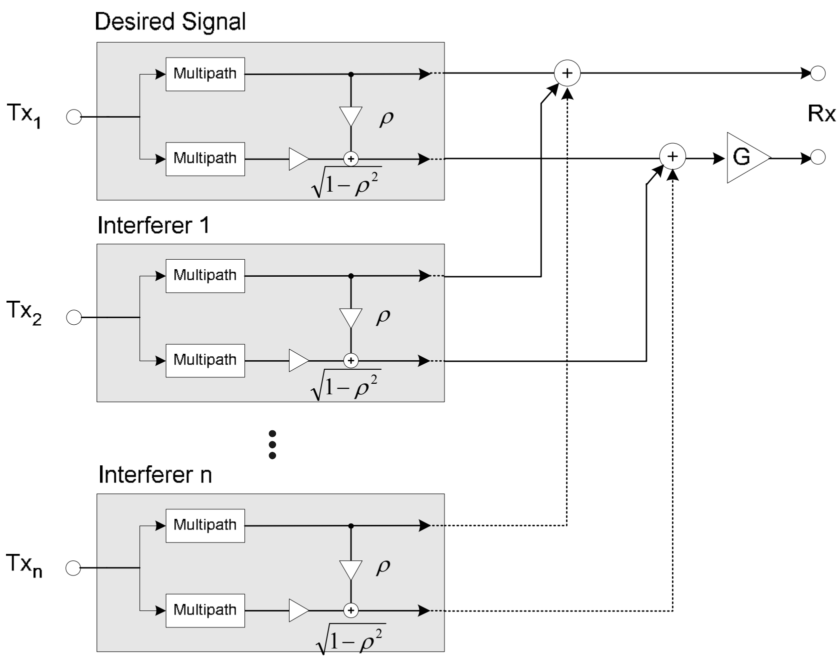
Parameter set	Antenna correlation, ρ	Antenna gain imbalance, *G*
Set 1	0	0 dB
Set 2	0.7	-6 dB

The correlation is defined as the magnitude of the complex correlation of the signals received at the two antenna connectors of the MS. A correlation value of 0 means the signals are uncorrelated. The antenna gain imbalance parameter reflects the difference in received signal level at the two antenna connectors. Thus, a value of -6 dB means that the signal on one antenna is attenuated by 6 dB compared to the signal on the other connector.

Increased performance of the mobile station using a second receive antenna is verified by testing based on same principles as for other features like SAIC / DARP phase 1. As an example a mobile station indicating support for DARP phase 2 needs to achieve the speech reference performance (FER ≤ 1%) at a minimum input signal of -105dBm (see [3] for details). Note that the reference sensitivity level of a GSM 33dBm mobile station is -102dBm. DARP phase2 performance requirements are specified for different services and under different conditions. Details can be found in [3], specifically in Table 1j.

The multi interferer scenarios are generated by expanding the single input-dual output model as shown below. The model uses instances of the single input dual output channel model to instantiate the interfering signals.

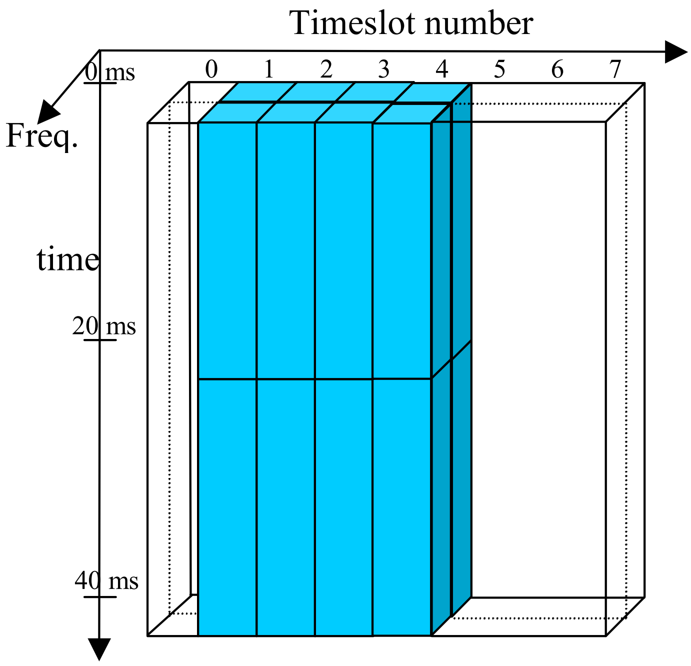
Figure 9 *Multi - Interferer Model for MS Receiver Diversity – DARP phase 2*



5 Downlink Dual Carrier Solution

Dual-carrier transmission allows for doubling downlink peak and average user throughputs in a flexible and backwards compatible manner. In a downlink dual carrier configuration, one or more PDCHs are assigned to a single MS on each of two different radio frequency channels. Please see Figure 9 for illustration.

Figure 10 *Illustration of radio blocks in a 2*4-slot dual-carrier allocation. The two frequencies are typically not adjacent.*



Mobile station and network support for Downlink Dual Carrier is optional. The mobile station indicates its support for Downlink Dual Carrier in the *MS Radio Access Capability* information element. If the network initially assigns a mobile station radio resources on only one carrier, it can extend this assignment to a downlink dual carrier configuration by sending a new single carrier assignment to the mobile station including assigned radio resources for the second carrier, without changing the resources already assigned for the initial carrier. Alternatively the network can include radio resources for two carriers in an initial or subsequent assignment message. Power control is applied independently on both radio frequency channels. Also channel quality measurements are performed for each radio frequency channel independently. With respect to USF handling the MS responds in the radio block indicated by the USF on the same radio frequency channel as the one where the USF was received. In the case of a downlink dual carrier configuration, up to 16 PDCHs or 8 PDCH-pairs may be assigned to one TBF at the same time.

GPRS/EDGE allows high flexibility in terms of supported Rx and Tx time slots, which a mobile station indicates towards the network. The network in turn takes this information into account when allocating resources to the mobile. In total 45 multislot classes have been specified in [4]. The multislot class indicates

- Rx, i.e. the maximum number of receive timeslots that the MS can use per TDMA frame
- Tx, i.e. maximum number of transmit timeslots that the MS can use

per TDMA frame

- Sum, i.e. the total number of uplink and downlink time slots that can actually be used by the MS per TDMA frame, whereas Sum may be smaller than Rx + Tx.

Additionally the multislot class information provides how much time a mobile station needs to get ready to transmit or receive with or without having the need to do adjacent channel measurements in between. In DL dual carrier the following applies for the multi-slot configuration.

- The DTM EGPRS multislot class applies when Dual Transfer Mode is used, otherwise the EGPRS multislot class applies.
- The maximum number of timeslots in a TDMA frame that the MS can receive is implicitly specified by the applicable multislot class, according to [4].
- The MS signals to the network whether it supports some reduced value relative to this maximum.

In consequence it is assumed that either the mobile station has exactly the same multislot capabilities as in EGPRS normal operation or the mobile indicates some reduced capability, which is explicitly signaled towards the network. 3bits are used to indicate the reduced capability allowing the mobile to indicate support of up to 6 fewer Rx time slots (one bit combination indication no reduction and one bit combination reserved for future use).

6 Abbreviations

3GPP	3rd Generation Partnership Project
BTTI	Basic Time Transmission Interval
BCS	Block Check Sequence
BN	Bit Number
DARP	Downlink Advanced Receiver Performance
DAS-i	EGPRS2 Downlink level A modulation and coding Scheme i
DBA	EGPRS2 Downlink level B modulation and coding Scheme i
DCS	Digital Cellular System
DTM	Dual Transfer Mode
DTS	Digital Test Sequence
EDGE	Enhanced Data for GSM Evolution
EGPRS	EDGE General Packet Radio Service
EVM	Error Vector Magnitude
FANR	Fast Ack/Nack Reporting
FER	Frame Erasure Rate
GERAN	GSM / EDGE Radio Access Network
GMSK	Gaussian Minimum Shift Keying
GSM	Global Service for Mobile Communication
HCS	Header Check Sequence
HB	High Symbol Rate Burst
IMS	Internet protocol Multimedia Subsystem
MAC	Medium Access Control
MS	Mobile Station
MSRD	Mobile Station Receive Diversity
QAM	Quadrature Amplitude Modulation
QPSK	Quadruple Phase Shift Keying
PA	Power Amplifier
PAN	Piggy-backed Ack/Nack
PCCC	Parallel Concatenated Convolutional Code
PCS	Personal Communication System
PDCH	Packet Data CHannel
PSK	Phase Shift Keying
PTCCH	Packet timing Advance Control Channel
RLC	Radio Link Control
RL-EGPRS	Reduced Latency EGPRS
RTTI	Reduced Time Transmission Interval
SAIC	Single Antenna Interference Cancellation

TBF	Temporary Block Flow
TDMA	Time Division Multiple Access
TN	Time slot Number
TSG	Technical Specification Group
TTI	Time Transmission Interval
TU50	Typical Urban 50km/h
UAS-i	EGPRS2 Uplink level A modulation and coding Scheme i
UBS-I	EGPRS2 Uplink level B modulation and coding Scheme i
USF	Uplink State Flag
UTRAN	UMTS Radio Access Network
WCDMA	Wideband Code Division Multiple Access

7 Additional Information

This application note is updated from time to time. Please visit the website **1MA129** to download the latest version.

Please send any comments or suggestions about this application note to **TM-Applications@rsd.rohde-schwarz.com**.

8 References

[1] 3GPP TS 25.212 V7.5.0 Multiplexing and Channel Coding (FDD) (Release 7)

[2] 3GPP TS 45.004 V7.1.0 Radio Access Network; Modulation (Release 7)

[3] 3GPP TS 45.005 V7.11.0 Radio Access Network; Radio Transmission and Reception (Release 7)

[4] 3GPP TS 45.002 V7.5.0 Radio Access Network; Multiplexing and Multiple Access on the Radio Path (Release 7)