

**Source:** Motorola  
**Title:** Further Discussion of Multiplexing of EGPRS2-B with EGPRS2-A and EGPRS on the Downlink  
**Document for:** Discussion

## **1. Introduction**

In GERAN #36, there was discussion of allowing the EGPRS2-B mobile to switch between EGPRS2-B and EGPRS2-A modulation and coding schemes within the TBF. This discussion has been expanded upon in [1] in which it is suggested that both DAS 5-12 and EGPRS modulation and coding schemes MCS 5-9 be allowed within the EGPRS2-B TBF. In the proposal in [1], there is no modulation scheme compatible with DBS-12 (118.2 kbps) and DBS-10 (88.8 kbps) other than MCS-6 (29.6 kbps) which can be used to signal PAN to the EGPRS2-A mobile while sending data to the EGPRS2-B mobile, and the resulting loss in data rate is quite significant. The situation is somewhat better when signalling USF to the EGPRS2-A mobile, as MCS-9 is compatible with both DBS-12 and DBS-10. However, if the EGPRS2-B mobile is using DBS-12, the data rate is reduced from 118.4 kbps to 59.2 kbps when MCS-9 is used to signal USF to the EGPRS2-A mobile. More generally, neither Chase nor incremental redundancy combining is possible between radio blocks encoded using MCS 5-9 and radio blocks encoded using DAS and DBS modulation and coding schemes, and thus we consider some alternative methods for multiplexing EGPRS2-B, EGPRS2-A and EGPRS.

## **2. USF Multiplexing EGPRS2-B and EGPRS2-A Mobiles**

The proposal in [1] addresses the multiplexing issues between EGPRS2-B, EGPRS2-A, and EGPRS associated with both the USF and the PAN. In order to simplify the discussion here, we focus on the USF and PAN multiplexing between the EGPRS2-B and EGPRS2-A mobiles. As indicated in [1], the PAN multiplexing issue is similar to the USF multiplexing issue in that the target mobile for the PAN can be different than the target mobile for the data. One difference, of course, is that the PAN is not supported for MCS-9. The USF and PAN multiplexing options for EGPRS2-B and EGPRS2-A from [1] are given below.

As can be seen from Table 1, for an EGPRS2-B mobile using DBS-12, the data rate is reduced from 118.4 kbps to 59.2 or 29.6 kbps when signalling USF and PAN, respectively, to the EGPRS2-A mobile. Similarly, for an EGPRS2-B mobile using DBS-10, the data rate is reduced from 88.8 kbps to 29.6 kbps when signalling PAN to the EGPRS2-A mobile.

There is also a disadvantage in using the EGPRS modulation and coding schemes MCS 5-9 to send the USF and PAN to the EGPRS2-A mobile in that it is not possible to use incremental redundancy to combine DBS 5-12 with MCS 5-9 transmissions. In the event that at least two retransmissions of a given RLC block are required, incremental redundancy and/or Chase combining can be used in the receiver as at least two of the transmissions will be encoded using either the DBS modulation and coding scheme or the MCS 5-9 modulation and coding scheme. However, in order to do so, it would be necessary to maintain separate HARQ buffers for the DBS 5-12 transmissions and the MCS 5-9 transmissions.

**Table 1: Modulation and Coding Schemes for USF and PAN multiplexing of EGPRS2-B and EGPRS2-A from [1]**

DBS selected by LA for RL-EGPRS2-B capable MS	RLC block size (bytes)	Data Rate (kbps)	EGPRS2-A capable MS needs to receive USF	Data Rate (kbps)	EGPRS2-A capable MS needs to receive PAN	Data Rate (kbps)
DBS-5	56	22.4	DAS-5	22.4	DAS-5	22.4
DBS-6	74	29.6	MCS-6	29.6	MCS-6	29.6
DBS-6 pad	68	27.2	DAS-6	27.2	DAS-6	27.2
DBS-7	56	44.8	DAS-8	44.8	DAS-8	44.8
DBS-8	74	59.2	MCS-6	29.6	MCS-6	29.6
DBS-8 pad	68	54.4	DAS-9	54.4	DAS-9	54.4
DBS-9	56	67.2	DAS-8	44.8	DAS-8	44.8
DBS-10	74	88.8	MCS-9	59.2	MCS-6	<b>29.6</b>
DBS-10 pad	68	81.6	DAS-9	54.4	DAS-9	54.4
DBS-11	68	108.8	DAS-11	81.6	DAS-11	81.6
DBS-12	74	118.4	MCS-9	<b>59.2</b>	MCS-6	<b>29.6</b>

### 3. New Padded Modulation and Coding Schemes for EGPRS2-A

In [2], three new padded modulation and coding schemes have been proposed and these are DAS-7 pad, DAS-10 pad, and DAS-12 pad. As the DAS-7, DAS-10, and DAS-12 radio blocks carry B pad 2 RLC blocks of length 82 bytes, they can be used to carry the 74-byte A RLC block along with 8 bytes of padding. With the inclusion of these three padded modulation and coding schemes, USF signalling to EGPRS2-A mobiles can be implemented as in Table 2 below (from [2], Table 4). Note that if we consider link adaptation for the EGPRS2-B mobile in the absence of USF and/or PAN multiplexing with EGPRS2-A and/or EGPRS mobiles, DBS-6 pad, DBS-8 pad, and DBS-10 pad would not be used due to the inefficiency of padding. However, when the EGPRS2-B mobile is USF multiplexed with an EGPRS2-A mobile, there may be some advantage in using DBS-8 pad in combination with DAS-9 rather than DBS-8 in combination with either MCS-6 or DAS-7 pad as the data rate for DBS-8 is 59.2 kbps while the data rate for MCS-6 and DAS-7 pad is only 29.6 kbps. Thus, only DBS-8 pad has been included in Table 2 below.

The relevant comparisons between the Tables 1 and Tables 2 with respect to the inclusion of DAS-7 pad, DAS-10 pad and DAS-12 pad can be found in Table 3. It can be noted that there is no rate advantage with the inclusion of DAS-7 pad, though there may be some advantage with respect to the possible use of HARQ, as will be discussed in the next Section.

**Table 2: Modulation and Coding Schemes for USF and PAN multiplexing of EGPRS2-B and EGPRS2-A with the inclusion of DAS-7/10/12 pad.**

DBS selected by LA for RL-EGPRS2-B capable MS	Family	Data Rate (kbps)	EGPRS2-A capable MS needs to receive USF	Data Rate (kbps)	EGPRS2-A capable MS needs to receive PAN	Data Rate (kbps)
DBS-5	B	22.4	DAS-5	22.4	DAS-5	22.4
DBS-6	A	29.6	DAS-7 pad	29.6	DAS-7 pad	29.6
DBS-7	B	44.8	DAS-8	44.8	MCS-7	44.8
DBS-8 pad	Ap	54.4	DAS-9	54.4	DAS-6	27.2
DBS-9	B	67.2	DAS-8	44.8	MCS-7	44.8
DBS-10	A	88.8	DAS-10 pad	59.2	DAS-10 pad	<b>59.2</b>
DBS-11	Ap	108.8	DAS-11	81.6	MCS-8	54.4
DBS-12	A	118.4	DAS-12 pad	<b>88.8</b>	DAS-12 pad	<b>88.8</b>

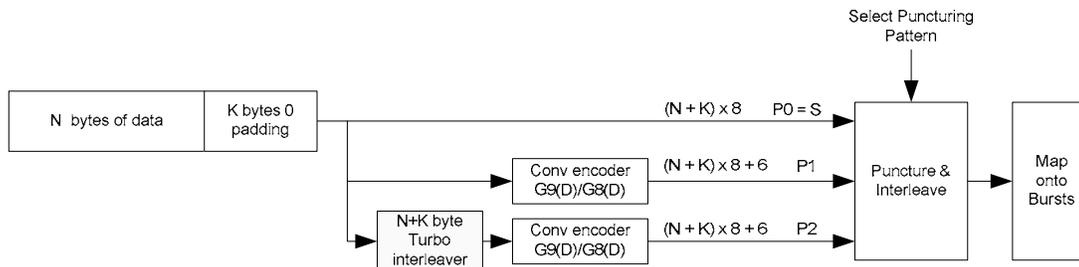
**Table 3: Comparison of possible USF and PAN multiplexing methods for DBS-6, DBS-10, and DBS-12**

DBS selected by LA for RL-EGPRS2-B capable MS	RLC block size (bytes)	Data Rate (kbps)	EGPRS2-A capable MS needs to receive USF	Data Rate (kbps)	EGPRS2-A capable MS needs to receive PAN	Data Rate (kbps)
DBS-6	74	29.6	MCS-6	29.6	MCS-6	29.6
DBS-6	A	29.6	DAS-7 pad	29.6	DAS-7 pad	29.6
DBS-10	74	88.8	MCS-9	59.2	MCS-6	<b>29.6</b>
DBS-10	A	88.8	DAS-10 pad	59.2	DAS-10 pad	<b>59.2</b>
DBS-12	74	118.4	MCS-9	<b>59.2</b>	MCS-6	<b>29.6</b>
DBS-12	A	118.4	DAS-12 pad	<b>88.8</b>	DAS-12 pad	<b>88.8</b>

#### 4. Padded Modulation and Coding Schemes and Incremental Redundancy

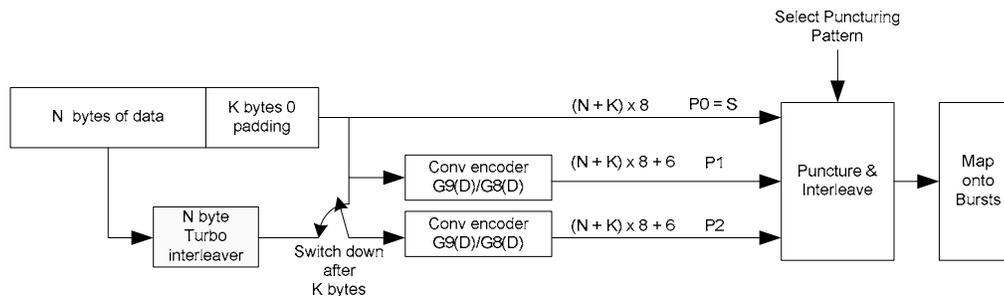
If padding for DBS-6/8/10 pad were to be implemented in the same manner as for MCS-6 pad, then the 6 bytes of padding would enter the encoder first as indicated in Figure 1 below. Since, DBS-6/8/10 use a 74 byte turbo interleaver for the A RLC blocks, this same 74-byte interleaver would be used for DBS-6/8/10 pad. In Table 1, DBS-6 pad, DBS-8 pad, and DBS-10 pad are multiplexed with DAS-6 and DAS-9, which both use a 68-

byte interleaver for their A pad 6 RLC blocks. As a consequence, given the same 68 byte payload, the last 68 bytes of the DBS-6/8/10 pad P0 sequence are the same as the DAS-6/9 P0 sequence. Similarly, the last 68 bytes + 6 bits of the DBS-6/8/10 pad P1 parity sequence are the same as for the DAS-6/9 P1 sequence. However, because the turbo interleaver used for DBS-6/8/10 pad is 74 bytes while the turbo interleaver for DAS-6/9 is 68 bytes, the P2 parity sequences are not the same for DBS-6/8/10 pad and DAS-6/9. Thus, while the P0 and P1 parity sequences can be combined between a DBS-6/8/10 pad transmission and a DAS-6/9 retransmission, the P2 parity sequence cannot. Thus, only partial HARQ is possible between transmission and retransmission, as only 2/3 of the parity sequences can be combined.



**Figure 1: Implementation of padded modulation and coding schemes with zero padding preceding data into the encoder. N=68 and K=6 for DBS-6/8/10 pad. N=74 and K=8 for DAS-7/10/12 pad.**

A similar issue would exist with the inclusion of DAS-7/10/12 pad for retransmission of DBS-6/10/12 RLC blocks, since an 82-byte turbo interleaver is used for DAS-7/10/12 while a 74-byte turbo interleaver is used for DBS-6/10/12. Thus, it would only be possible to combine the P0 and P1 parity sequences between a DBS-6/8/10 transmission and a DAS-7/10/12 pad retransmission. However, this would be a very significant improvement relative to the existing situation in which no HARQ is possible between DBS-6/8/10 and MCS-6 and MCS-9. In order to enable combining of the P2 parity sequence between an unpadded DBS-6/8/10 transmission and a DAS-7/10/12 pad retransmission, it would be necessary to modify the turbo interleaver for DAS-7/10/12 pad as indicated in Figure 2, so that a 74-byte turbo interleaver is used on the data only. With this modification, the DBS-6/8/10 turbo decoder would be re-used for DAS-7/10/12 pad, and full HARQ would be possible between DBS-6/8/10 transmission and DAS-7/10/12 pad retransmission. With this implementation of DAS-7/10/12 pad, it would be possible to significantly improve USF and PAN multiplexing for DBS-10 and DBS-12 without the need to define any new puncturing or interleaving schemes. Furthermore, it would be possible to re-use the existing turbo encoders and decoders.



**Figure 2: Modified implementation of padded modulation and coding schemes with turbo interleaving of data only. N=68 and K=6 for DBS-6/8/10 pad. N=74 and K=8 for DAS-7/10/12 pad.**

### 5. The Efficiency of Padding for USF and PAN Multiplexing

For DBS-6/8/10 pad, 6 bytes of zero padding are added to 68 bytes of data. For DAS-7/10/12 pad, 8 bytes of zero padding would be added to 74 bytes of data. Since the padded bytes are assigned equal transmit power as the payload bytes, bandwidth and power are wasted in equal proportion. Thus, regardless of the signal-to-noise ratio, the theoretical capacity of the link is reduced by  $6/78 = 7.7\%$  for DBS-6/8/10 pad relative to DBS-6/8/10. Similarly, the theoretical capacity of the link is reduced by  $8/82 = 9.8\%$  for DAS-7/10/12 pad relative to DAS-7/10/12 regardless of the signal-to-noise ratio.

The inefficiency of padding is due to the fact that the padded bytes could be used to transmit a larger payload and/or for stronger coding of the existing payload. However, any normal symbol rate modulation and coding scheme that is to be multiplexed with one of the DBS modulation and coding schemes using A RLC blocks *must have a payload which is a multiple of 74 bytes*, or equivalently, a data rate which is a *multiple of 29.6 kbps*. Thus, the payload is fixed and only the code rate can be changed. Thus, the claim in [3] that the reduction of the data rate for DAS-10 pad by 6.4 kbps relative to DAS-10 is equivalent to a 2 dB performance loss is quite difficult to interpret given that no coding scheme that can be multiplexed with DBS-6/8/10/12 can have a data rate which is not a multiple of 29.6 kbps.

An additional consideration with respect to the padded modulation and coding schemes DAS-7/10/12 pad is that as these modulation and coding schemes would operate at normal symbol rate, the energy per symbol would be  $10 \log(1.2) = 0.8$  dB greater given the same transmit power. In Table 4 below, the relevant comparisons of the code rate and energy per symbol are made for DBS-10/12 and DAS-10/12 pad. It should be noted that all of these modulation and coding schemes use 32-QAM. A similar comparison for DBS-6 and DAS-7 pad is complicated by the fact that DBS-6 and DAS-7 pad do not use the same modulation, since DBS-6 uses QPSK while DAS-7 pad uses 8PSK modulation.

In Table 4, it can be seen that for DAS-10 pad and DAS-12 pad the RLC blocks are both more strongly encoded and received with greater energy per modulation symbol (given the same transmit power) than DBS-10 and DBS-12, respectively. Thus, when it is necessary to use DAS-10 pad and DAS-12 pad to multiplex USF and/or PAN, the RLC blocks will be more robustly encoded and received with greater energy per symbol than if DBS-10 and DBS-12 were used. The reason for this increased robustness is that DAS-10 pad and DAS-12 pad radio blocks include 2 and 3 RLC blocks, respectively, whereas DBS-10 and DBS-12 radio blocks include 3 and 4 RLC blocks. Thus, the increased robustness is achievable (even with zero padding) because one less RLC block is included in the DAS-10 pad and DAS-12 pad radio blocks.

**Table 4: Comparison of code rates and relative energy per modulation symbol for DBS-10/12 and DAS-10/12 pad**

	Code Rate w/o PAN	Code Rate with PAN	Modulation Type	Energy Per Symbol Increase Relative to HSR
DBS -12	0.98	1.00	32 QAM	0 dB
DAS-12 pad	0.96	1.00	32 QAM	0.8 dB
DBS-10	0.72	0.75	32 QAM	0 dB
DAS-10 pad	0.64	0.66	32 QAM	0.8 dB

## 6. Conclusions

In order to improve the USF multiplexing efficiency between EGPRS2-B and EGPRS2-A, it has been proposed that, whenever possible, turbo codes and incremental redundancy HARQ be supported when signalling USF information to the EGPRS2-A within the EGPRS2-B TBF. Towards this end, it is proposed that new padded modulation and coding schemes DAS-7 pad, DAS-10 pad, and DAS-12 pad be defined and allowed within the EGPRS2-B TBF. The use of DAS-12 pad in place of MCS-6 and MCS-9, respectively, will significantly improve the efficiency of USF and PAN multiplexing for DBS-12. Similarly, the use of DAS-10 pad in place of MCS-6 will significantly improve the efficiency of PAN multiplexing for DBS-10. With a slight modification to the length of the turbo interleaver for DAS-7/10/12 pad, full HARQ can be implemented between DBS-6/10/12 and DAS-7/10/12 pad, respectively, while still using the already existing turbo interleavers, deinterleavers, and decoders. However, even without this change to the turbo interleaver, DAS-10 pad and DAS-12 pad provide a better multiplexing rate match for DBS-10 and DBS-12 than is currently possible, and HARQ can still be implemented for two of the three parity sequences.

## 7. References

- [1] GP-080184, "Multiplexing EGPRS and EGPRS2 MS in DL", source Nokia Siemens Networks, Nokia, Research in Motion, Vodafone, GERAN #37, Seoul, Korea, February 18-22, 2008.
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- [3] AHG1-08035, "Multiplexing EGPRS and EGPRS2 MS in DL", source Nokia Siemens Networks and Nokia, Ad Hoc on EGPRS2/WIDER/MUROS/MCBTS, Sophia Antipolis, April 8-11, 2008.