

Source: Ericsson

Fast Power Control for Speech in GERAN

1 Introduction

Power control is currently available in GSM speech through the SACCH, which enables a control interval of 480 ms.

ECSD uses inband signalling bits to enable fast power control (FPC) at a control interval of 20 ms. It has been proposed [1] to reuse the FPC mechanism for the 8-PSK voice bearer that is currently being standardized.

Another proposal [2] is to signal via the SACCH bursts to get a control interval of 120 ms. System level simulations have been presented [3] showing the potential gain of this control interval.

This document contains an evaluation of different fast power control alternatives for GERAN speech and suggests a solution based on signalling over the SACCH with 240 or 120 ms update interval, which can be used together with the new 8PSK fullrate and halfrate voice bearers as well as on the present GMSK fullrate and halfrate voice bearers.

2 Possible Solutions for Fast Power Control

The measurement reports and power control commands can either be sent over the SACCH or via inband signalling. SACCH signalling may impact the performance of the SACCH, while inband signalling will degrade the performance of the speech.

The power control commands can contain absolute power levels or delta modulated values. Absolute power levels will require higher signalling bandwidth, while delta modulation will limit the dynamics of the power regulation.

One SACCH burst is sent every 120 ms. Therefore, the lower limit of the update interval is 120 ms if SACCH signalling is used. For inband signalling, update intervals down to 5 ms is in principle possible during speech periods.

In the following section, the impact of these parameters are evaluated.

3 Impact on Link and System Performance

3.1 Impact of Signalling

The power control signalling must steal bandwidth from either the SACCH or the speech channel. For the SACCH, two unused stealing bits exist, which could be used for PC signalling. Additional bandwidth can be made available either by increasing the channel coding rate of the SACCH or by reducing the payload size, or both. Reducing the payload size of the speech channel is not possible, so for inband signalling on the speech channel the channel coding rate must be increased, which will degrade the link performance of the speech.

Inband signalling has the large drawback that it can not be used on the already defined GMSK halfrate and fullrate channels, since the channel coding on those should not be redefined. Further, it can only be used when speech is transmitted. During DTX periods, only SID_UPDATE frames are sent every 160 ms. Typically, one link is active at a time. This means that when the downlink is active, quality measurements can only be sent every 160 ms on the uplink, and the downlink regulation interval is in practice limited to that rate. When the uplink is active, power control commands can only be sent every 160 ms on the downlink, and the uplink regulation interval is in practice limited to that rate as well. Therefore, it is expected

that inband signalling will not give any additional gains when lowering the interval below 160 ms. Notice that this also requires new channel coding for SID_UPDATE frames.

3.1.1 Reducing the Payload of SACCH

The physical SACCH block can carry in total 23 octets of which 2 octets are used for L1 header and the rest, 21 octets, is used for the L2 frames [4]. The L2 frame consists of an L2 header and the actual L3 message. The L2 header is three octets for uplink and two octets for downlink [5]. This leaves 18 octets for L3 messages on the uplink and 19 octets on the downlink.

The L3 messages sent on the SACCH [6] are summarised in Table 1.

Message name	Direction	Size [octets]
MEASUREMENT REPORT	Uplink	18
EXTENDED MEASUREMENT REPORT	Uplink	18
ENHANCED MEASUREMENT REPORT	Uplink	Variable
SYSTEM INFORMATION TYPE 5	Downlink	19
SYSTEM INFORMATION TYPE 5bis	Downlink	19
SYSTEM INFORMATION TYPE 5ter	Downlink	19
SYSTEM INFORMATION TYPE 6	Downlink	19
EXTENDED MEASUREMENT ORDER	Downlink	19
MEASUREMENT INFORMATION	Downlink	Variable

Table 1. L3 messages sent over SACCH.

As can be seen, the L3 messages do not leave any space on the SACCH. Therefore, the payload of the SACCH can not be reduced without defining new L3 messages with less information.

However, there are two spare bits in the L1 header of the SACCH. Further, the FPC bit is not needed in the considered cases. If necessary, removing these bits and thereby reducing the payload with three bits (six bits encoded) could be considered.

3.2 Impact of Type of Power Regulation

The impact of delta modulated power control commands is for further study.

3.3 Impact of Update Interval

To assess the impact of the update interval, system simulations have been run. The system performance is measured as the amount of speech users having Class 1a FER less than 1%. The power control is either turned off (nopc) or on at an interval of 480, 240, 120, 60 or 20 ms. Results for mobile speeds of 3 and 50 km/h are presented. At 3 km/h, the delay from measurement to actual change of power is three times the power control interval. In the simulations with 50 km/h, a delay of two times the power control interval is assumed. In this investigation, downlink power control is studied.

The simulations are ideal in the sense that measurements are assumed to be error free, that the measurement reports are never lost and that the speech or the SACCH is not degraded due to power control signalling. Further, the impact of limited information space in the measurement reports were not included. The BTS power span was limited to 14 dB and the regulation was performed with a granularity of 2 dB.

Table 2 summarises some important parameters.

Sectors (cells) per site	3
Sector antenna beam width	60 degrees @ -3 dB
Site-to-site distance	3000 m
Propagation model	21+35log(d), d [m]
Log-normal fading	6 dB (standard deviation)
Log-normal correlation distance	110 m
Handover margin	3 dB
Frequency hopping	random synthesiser
Mobile speed	3 or 50 km/h
Voice codec	MR59 full rate
Voice activity	0.6

Table 2. Simulation assumptions for system capacity evaluation.

In Figure 1 results are shown when all users are moving at a speed of 3 km/h. As seen, all gain of power control for the slowly moving users is achieved already at 480 ms control interval. Therefore, for low speed, there is no further gain of decreasing the power control interval.

Figure 2 shows the same simulations, but for users moving at 50 km/h. It can be seen that there is more gain of decreasing the power control interval below 480 ms. Note however that the largest gain is when going from 480 to 240 ms. The difference in fractional load between 240 and 120 ms is not very large. Decreasing the power control interval below 120 ms does not improve system performance for users moving at 50 km/h or less.

A shorter power control interval implies shorter measurement intervals, which could affect the accuracy of the measurements. This will likely reduce the already negligible gains from going for a shorter update interval than 120 ms.

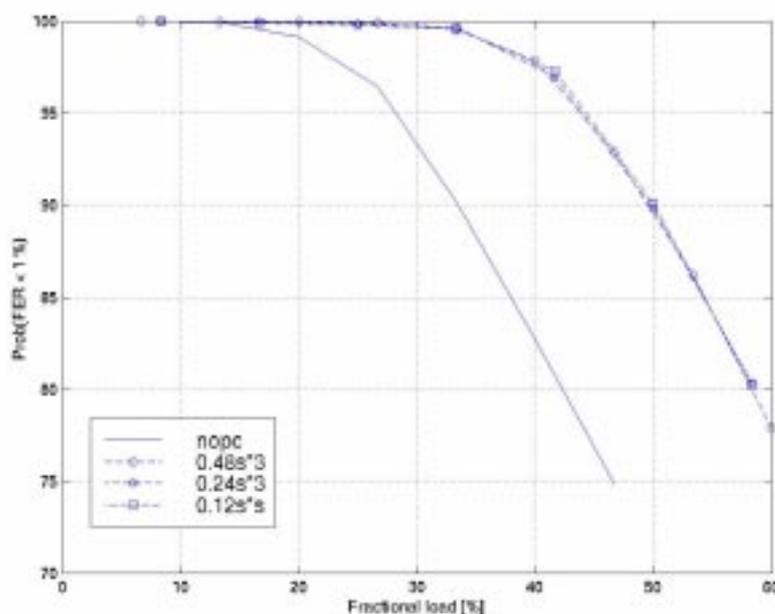


Figure 1: System performance for slow mobiles, 3 km/h

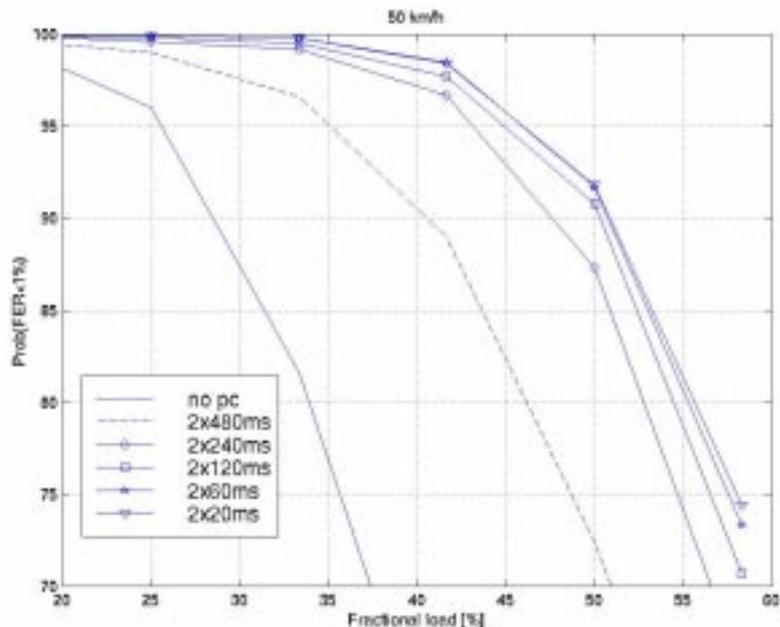


Figure 2: System performance for fast mobiles, 50 km/h.

4 Proposed Solution

Based on the investigations above, it is concluded that an update interval of 240 or 120 ms is sufficient, and that the gain from reducing it further is small, if any. Further, SACCH signalling is preferred over inband signalling since it enables fast power control on all speech channels, whether 8PSK AMR, GMSK AMR, EFR, FR or HR is used. Inband signalling also has the disadvantage that it will not work well together with DTX.

In the following, different alternatives for power control signalling over the SACCH are evaluated.

4.1 Considered Cases

Bandwidth for PC signalling can be made available on the SACCH by using the existing stealing bits, which are not used today (8 bits per SACCH), increasing the code rate of the SACCH (i.e., puncturing), and/or reducing the payload size.

In all the evaluated cases, the eight available stealing bits are used for PC signalling. To get more bits, the following alternatives have been considered:

- A. Puncturing the encoded SACCH block (if necessary).
- B. Reducing the SACCH payload with 3 bits (two spare bits and the FPC bits are removed from the SACCH L1 header). If necessary, the encoded SACCH block is also punctured.

The number of uncoded and encoded PC bits per burst depends on the update interval, the needed granularity of the reports and the number of encoded bits in the PC word needed for sufficiently low word error rate. The following alternatives were considered:

1. One word per burst (i.e., 120 ms interval), 4 words, encoded to 4 bits
2. One word per burst (i.e., 120 ms interval), 4 words, encoded to 8 bits
3. One word per burst (i.e., 120 ms interval), 4 words, encoded to 12 bits
4. One word per burst (i.e., 120 ms interval), 8 words, encoded to 12 bits
5. One word per burst (i.e., 120 ms interval), 8 words, encoded to 24 bits

6. One word per two bursts (i.e., 240 ms interval), 4 words, encoded to 4 bits
7. One word per two bursts (i.e., 240 ms interval), 4 words, encoded to 8 bits
8. One word per two bursts (i.e., 240 ms interval), 4 words, encoded to 12 bits
9. One word per two bursts (i.e., 240 ms interval), 8 words, encoded to 12 bits
10. One word per two bursts (i.e., 240 ms interval), 8 words, encoded to 24 bits

4.2 Simulation Results

Link simulations were run to assess the word error rate of the PC signalling and the degradation of the SACCH BLER. A TU3 channel with ideal frequency hopping in a co-channel interference point limited environment was assumed. 10000 SACCH blocks were run in each simulation point (together with 20000 or 40000 PC words, depending on the interval).

To reduce the SACCH, new puncturing and interleaving schemes were designed. It should be noted that not much effort was spent on optimising the schemes, and therefore the results may be slightly pessimistic.

4.2.1 PC signalling performance

The word error rate for the PC signalling has been evaluated for case 1-10 above. The results can be found in Figure 3. It can be seen that all cases give a word error rate (WER) around 10% or less at 2 dB C/I. At 10 dB C/I, the WER is 1% or less. For an interval of 240 ms, the performance is better than for 120 ms in all cases, due to the frequency hopping.

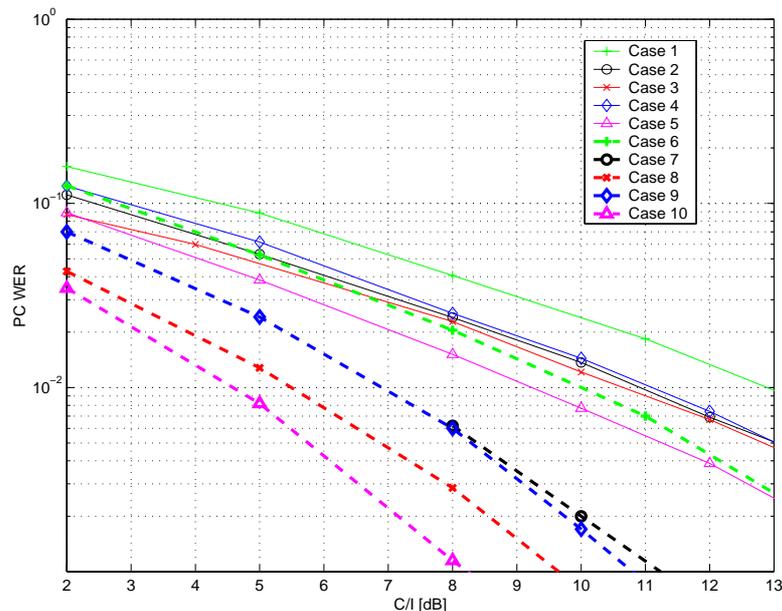


Figure 3. PC word performance. The curves show the word error rate with different number of encoded bits (4, 8, 12 and 24), different number of code words (4 and 8) and different transmission period (120 and 240 ms).

Notice also that the performance of case 3 and 4 (120 ms interval) are very similar, despite that case 4 has eight code words while case 3 has four. This is likely due to that the code words are sent over only one burst in these cases. With a 240 ms interval, the corresponding cases (8,9) differ about 1 dB from each other.

The conclusion from this is that it may be enough to use a codeword length of 4 (or possibly 8) bits with 120 ms interval, and 4 bits with 240 ms interval.

4.2.2 SACCH performance

The SACCH performance has been evaluated for cases A and B together with cases 1-10 above. Detailed simulation results can be found in Annex A . The results are summarised in Table 3. SACCH for case 6 is not simulated since it does not affect the SACCH performance.

Case	Number of bits in encoded and punctured SACCH block	Number of punctured bits in encoded SACCH block		Degradation compared to normal SACCH @ 1% FER	
		A	B	A	B
1,7	448	8	2	0.0 dB	0.0 dB
2	432	24	18	0.6 dB	0.5 dB
3,4,10	416	40	34	1.0 dB	0.8 dB
5	368	88	82	2.9 dB	2.8 dB
6	456	0	-	0.0 dB	-
8,9	440	16	10	0.4 dB	0.1 dB

Table 3. Link performance of SACCH.

5 Conclusions

Initial system simulations show that there may be a considerable gain when reducing the power control interval from 480 ms (as in GSM of today) to 240 ms. By reducing the interval to 120 ms, additional but less significant gains can be achieved. Going below 120 ms gives very small additional gains.

It is proposed to use the SACCH bursts for PC signalling. Compared to signalling by additional speech stealing bits, this has the advantage that it can be used not only for new 8PSK bearers, but also on the existing GMSK halfrate and fullrate channels. Further, due to the DTX, it is not expected that inband signalling will give higher update rates of the PC than 160 ms in practice in most cases.

The link performance of the PC signalling via SACCH bursts was evaluated by simulations. It is shown that a few bits per burst is sufficient to get sufficiently low error rate, assuming that four messages are enough in the PC command (uplink PC) and/or the measurement report (downlink PC). With a 240 ms PC interval, the existing stealing bits of the SACCH are enough, leaving the SACCH and its performance unchanged. If a 120 ms interval is needed, eight additional bits could be stolen per SACCH word. Simulations show that this does not degrade the SACCH performance significantly.

It is not possible to reduce the payload size of the SACCH block without defining new L3 messages with less information. This should be avoided. Three bits in the L1 header could be removed, but this does not seem necessary.

Further system simulations are needed to fully evaluate the gains from fast power control. The system impact of inaccuracy in quality measurements, of delta modulated PC signalling with four or eight levels and of word errors in PC should be evaluated.

In principle, the proposed fast power control can be used for quarter rate channels as well. The details and performance of this is for further study.

6 References

- [1] ETSI SMG2, Tdoc 1105/00, Fast Adaptation Mechanisms for 8PSK Speech Bearer, source Nokia
- [2] 2g00-052, "SACCH Stealing Bits for 120ms EGPRS Voice Power Control", source AT&T
- [3] 2g00-061, "System performance impact of power control interval", source Ericsson
- [4] GSM 04.04, "Digital cellular telecommunications system (Phase 2+); Layer 1; General Requirements"
- [5] GSM 04.06, "Digital cellular telecommunications system (Phase 2+); Mobile Station - Base Station System (MS - BSS) interface; Data Link (DL) layer specification"
- [6] GSM 04.18, "Digital cellular telecommunications system (Phase 2+); Mobile radio interface layer 3 specification, Radio Resource Control Protocol"

Annex A Detailed Link Simulation Results for SACCH

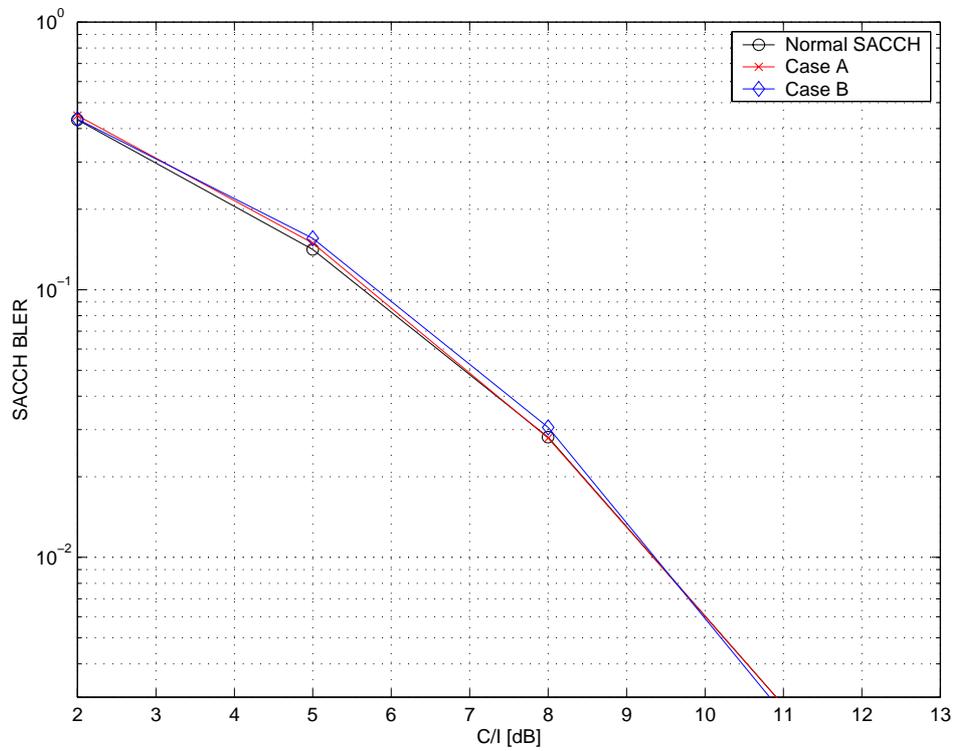


Figure 4. SACCH performance, case 1 and 7. The curves show the normal SACCH, and the degradation from puncturing 8 bits (case A, payload size is unchanged) and 2 bits (case B, payload size is reduced by 3 bits).

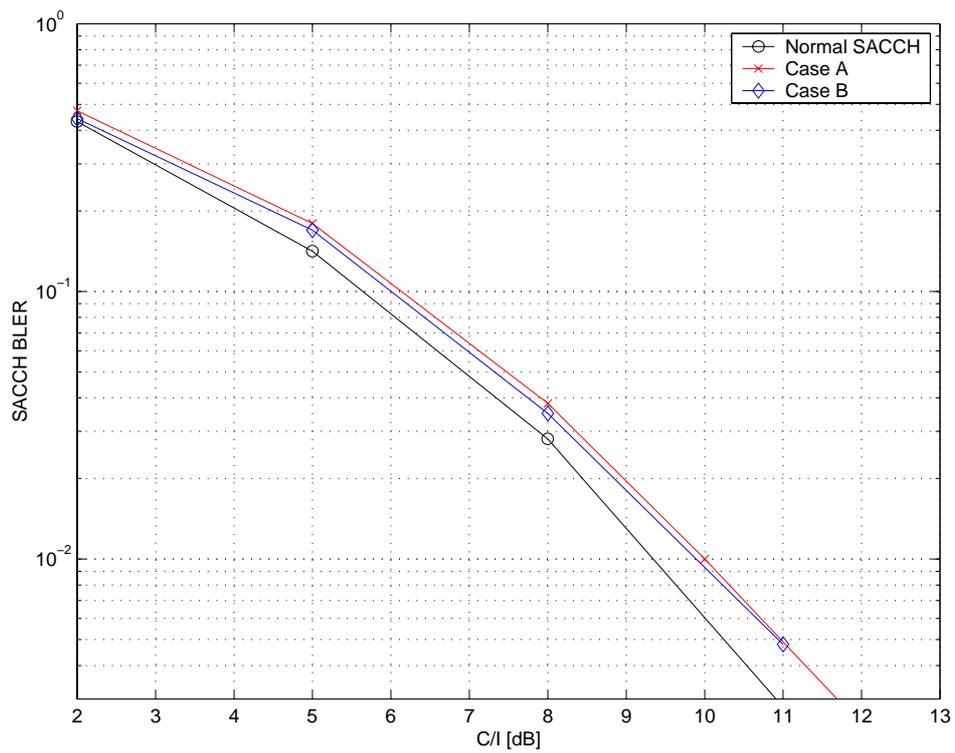


Figure 5. SACCH performance, case 2. The curves show the normal SACCH, and the degradation from puncturing 24 bits (case A, payload size is unchanged) and 18 bits (case B, payload size is reduced by 3 bits).

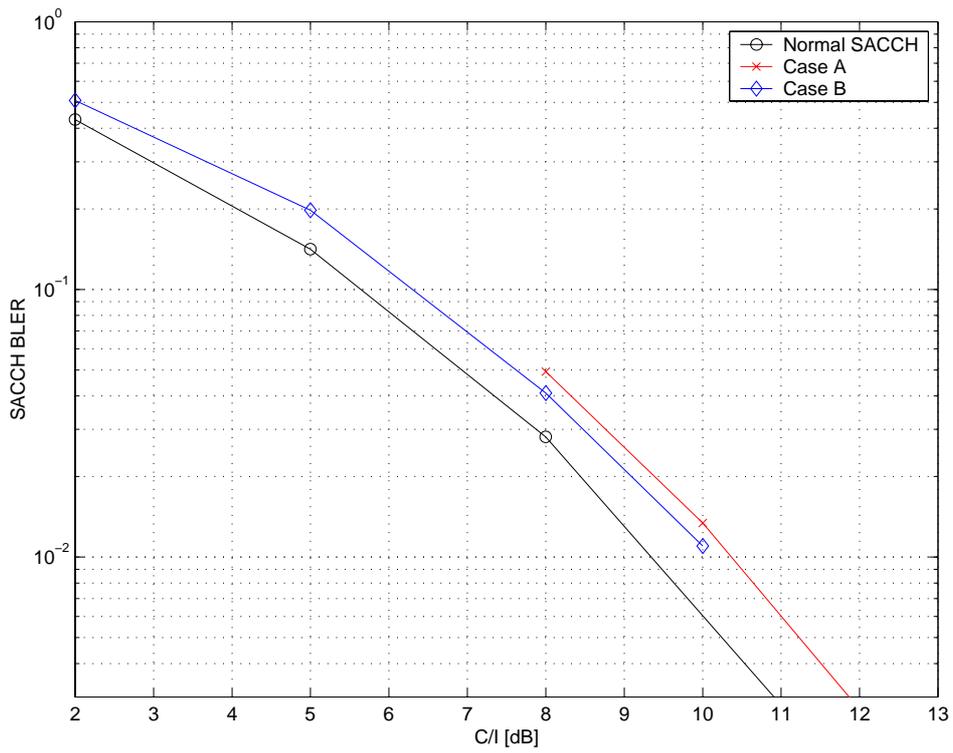


Figure 6. SACCH performance, case 3, 4 and 10. The curves show the normal SACCH, and the degradation from puncturing 40 bits (case A, payload size is unchanged) and 34 bits (case B, payload size is reduced by 3 bits).

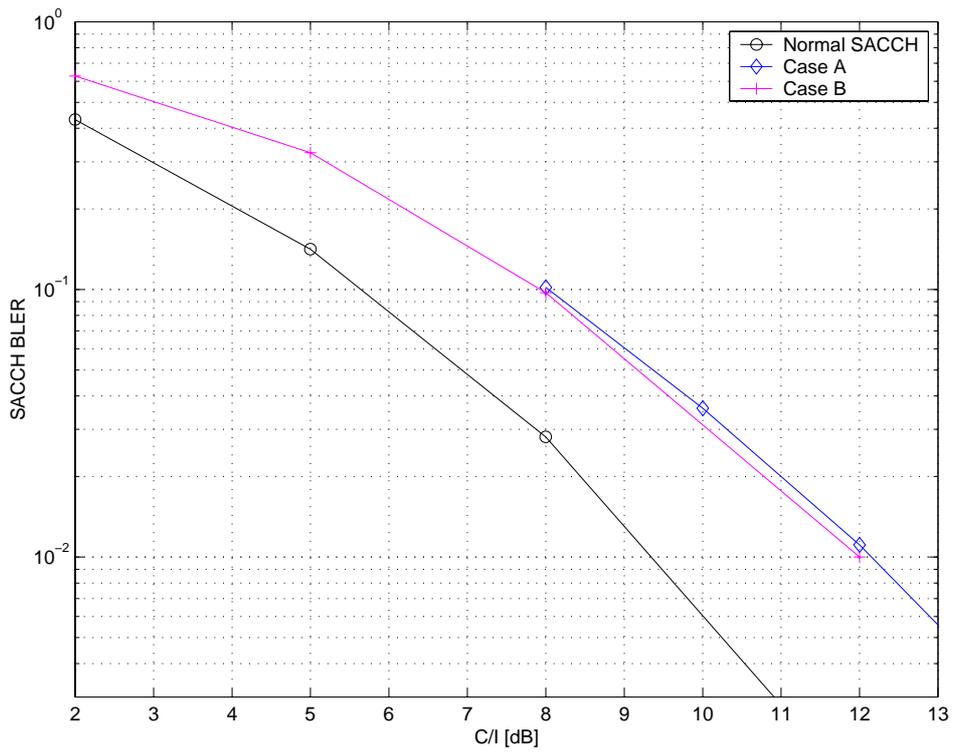


Figure 7. SACCH performance, case 5. The curves show the normal SACCH, and the degradation from puncturing 88 bits (case A, payload size is unchanged) and 82 bits (case B, payload size is reduced by 3 bits).

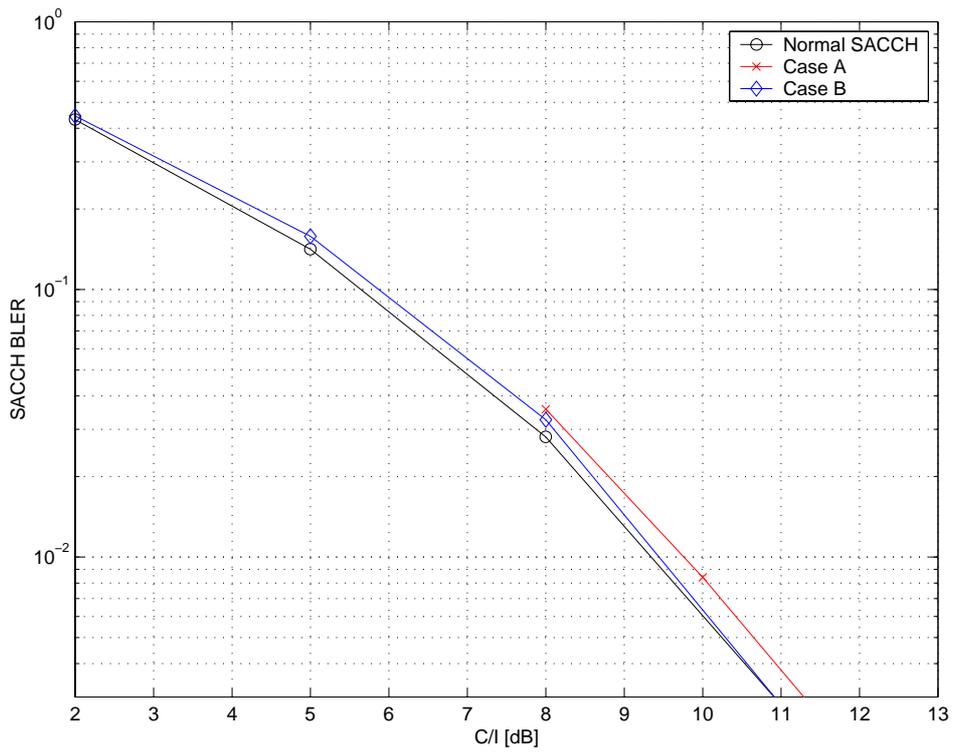


Figure 8. SACCH performance, case 8 and 9. The curves show the normal SACCH, and the degradation from puncturing 16 bits (case A, payload size is unchanged) and 10 bits (case B, payload size is reduced by 3 bits).