TSG-RAN WG1#10 **TSGR1#10(00)0140**
Beijing, China, Jan. 18 – 21, 2000

Agenda Item:
Source: SAMSUNG
Title: Empirical study on small Turbo interleaver size
Document for Discussion

1. Introduction

In this document, we study small Turbo interleaver sizes, which is one of the delayed-99' issues as indicated last WG1#9 meeting in Dresden, Germany[1]. More specifically, we apply offset controlled PN Interleaver (OCPNI) to low data rate service. The interleaver size we are concerned with is less than 320. The interleaver we use is the one in [2] but slightly modified to generate small Turbo interleavers. Purpose of this Tdoc is to investigate utility of Turbo codes for low data rate service.

2. Offset Controlled PN Interleaver (OCPNI)

OCPNI is a 2-dimensional PN interleaver. It is simple in concept and implementation requires only a set of shift registers and small control circuitry. Basic idea of OCPNI is that frame to be encoded is segmented into groups of size 2^m such that for each group a PN shift register (PNSR) with a primitive polynomial of order m is used to generate $2^m - 1$ random addresses from 0 to $2^m - 2$ for the group. The last address in each group, $2^m - 1$, is augmented to access entire addresses of the frame. If a frame is not in the form of *NG*´2^m, where *NG* is the number of groups and 2^m the group size *(GS)*, the frame length *L* is extended so as to be the size, *L'=NG*´2^m. For example, considering *L* not in the form of *NG*´2^m, we define *L'=L+OSV=NG*´2^m with the smallest integer NG, given *m*. *OSV* is an offset value for *L'*. More detailed descriptions including algorithm, implementation, complexity analysis are explained in [2] and [3]. Fig. 1 shows frame segmentation, conceptual OCPNI structure and a PNSR of order 6 with primitive polynomial $p(x)=1+x+x^6$ generating addresses in the group.

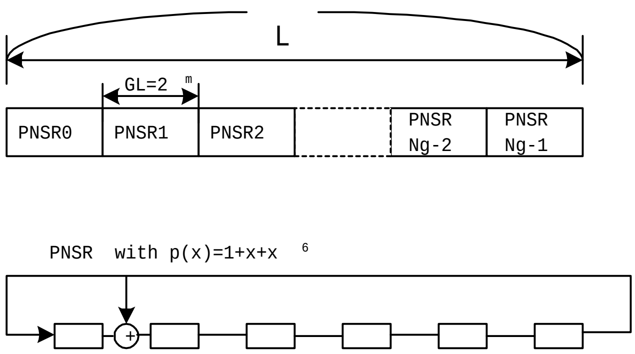

Fig. 1. OCPNI general concept.

3. Parameters of OCPNI

Since we are designing Turbo interleaver size less than 320, a new set of parameters is selected and shown in Table

1. In Table 1, *L* is the input block sizes for a channel encoder and *GL*($=2^m$) is the group size for each *NG* group which is calculated from *L* and *OSV*[1].

TABLE 1. TURBO INTERLEAVER PARAMETERS FOR *L*=40, 80, 160.

No.	Interleaver size L	m	NG	GL	OSV
1	40	3	5	8	0
2	80	4	5	16	0
3	160	5	5	32	0

4. Simulation results

Based on the design parameters, we performed simulation for Turbo interleaver sizes of *L=40, 80, 160* and compared with simulation results of convolutional codes over AWGN. For Turbo codes and convolutional codes, the simulation conditions are as follows.

- Input block sizes *(L)* for a channel encoder: 40, 80, 160.
- Code rate: *R=1/3*.
- Constraint length:
  - Turbo codes: *K=4*,
  - Convolutional codes: *K=9*.
- Tail bit termination is used for both Turbo codes and convolutional codes
- Decoding algorithm:
  - Log MAP decoder for Turbo codes with a floating point frame mode decoding
  - Viterbi decoder for convolutional codes with a floating point frame mode decoding
- Number of iterations for Turbo decoder: 10
- Number of frame errors in Turbo decoder:
  - greater than 100 for L=80, 160
  - greater than 200 for L=40
- Channel model: AWGN

Fig. 2 shows bit error rates and frame error rates of Turbo codes with OCPNI interleaver and convolutional codes with *K=9* for *L=160*. As can be seen, Turbo code outperforms convolutional codes in term of BER and FER with L=160. Also, Fig 2 shows similar performance in [4]. Fig. 3 shows bit error rates and frame error rates of Turbo codes with OCPNI interleaver and convolutional codes with *K=9* for *L=80*. As can be seen, Turbo code gives slightly worse performance than that of convolutional code in terms of BER and FER with L=80. Fig. 4 shows bit error rates and frame error rates of Turbo codes with OCPNI interleaver and convolutional codes with *K=9* for *L=40*. Also, Fig 4 shows similar performance in [4]. In this case, convolutional code outperforms Turbo code in terms of BER and FER. OCPNI parametes are not fully optimized for *L=40, 80, 160*. However, the trend may not be much different from the current simulation results. Therefore, one may use Turbo codes instead of convolutional code for *L ³ 80*. For *L£40,* it may be better to use convolutional codes for better performance.

To see the maximum performance for *L=40*, we applied 20 iterations until we finally declare that a frame being decode is all corrected or a frame error. Fig. 5 shows bit error rates and frame error rates of Turbo codes with OCPNI interleaver according to the number of iteration for *L=40*.

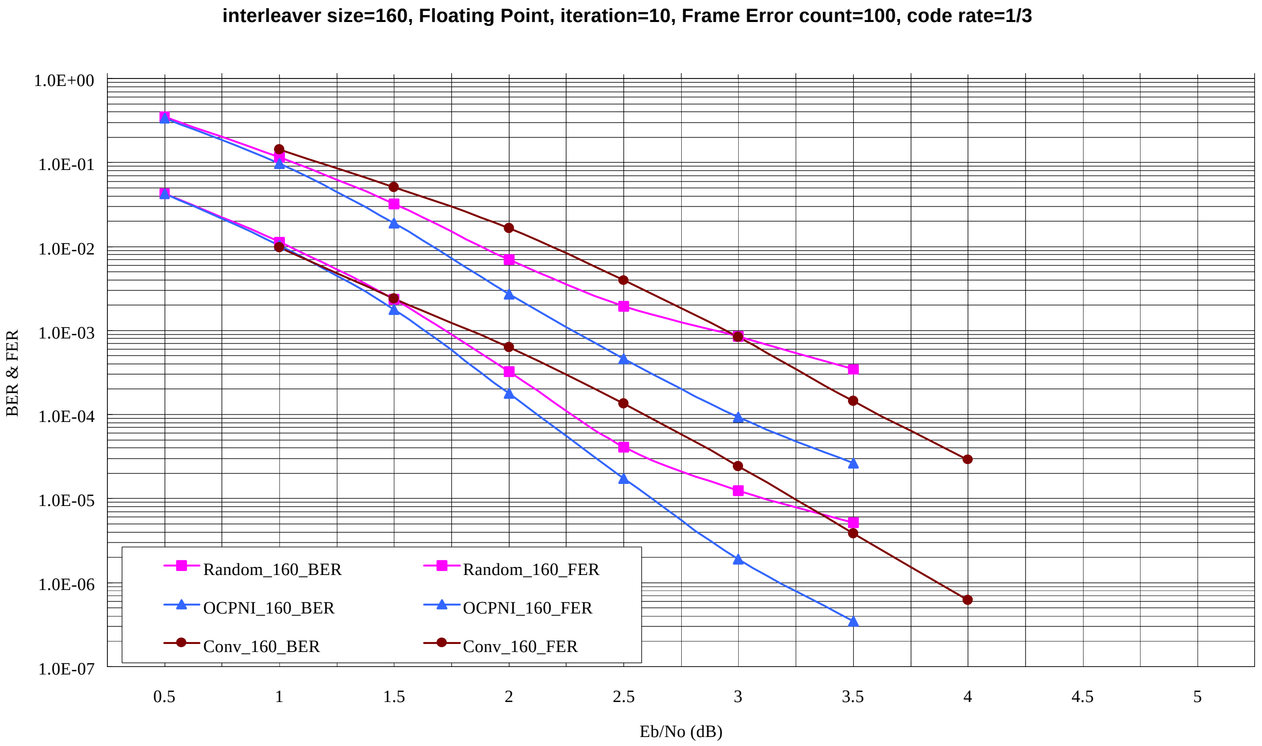

Fig. 2. Bit error rates and frame error rates of a Turbo code and a convolutional code with *L=160*.

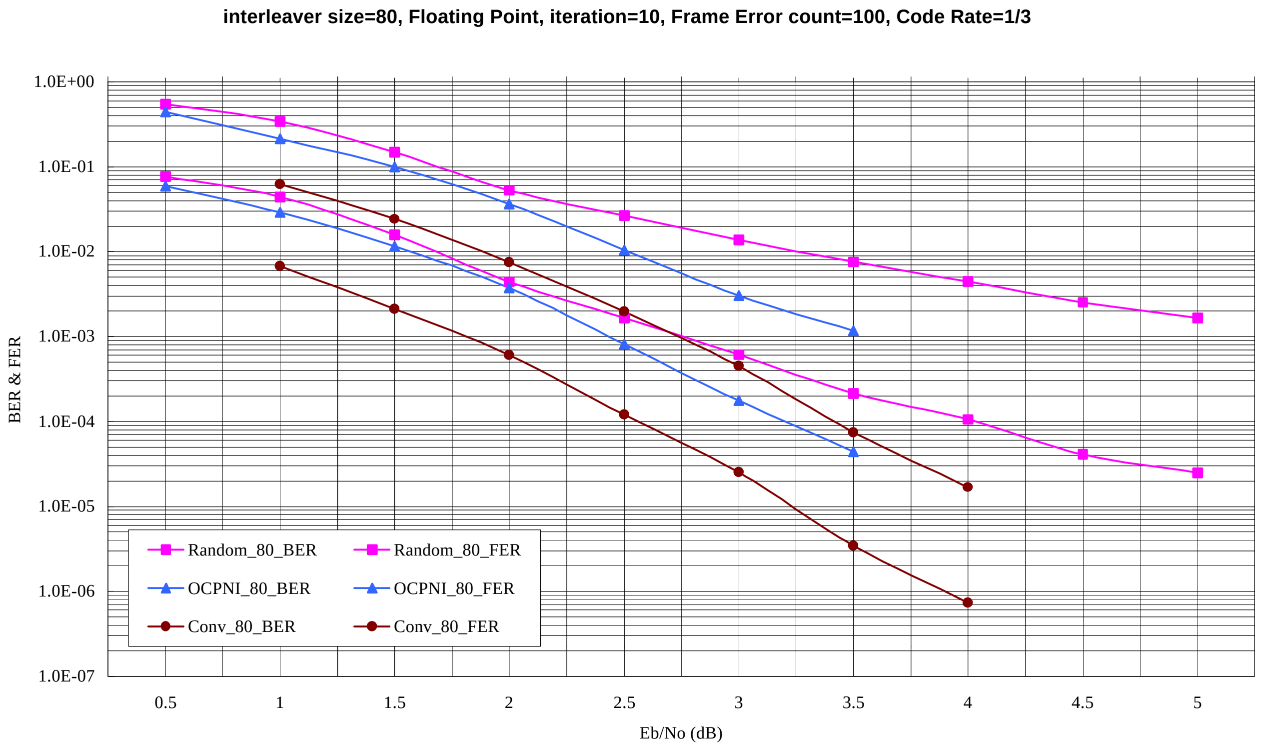

Fig. 3. Bit error rates and frame error rates of a Turbo code and a convolutional code with *L=80*.

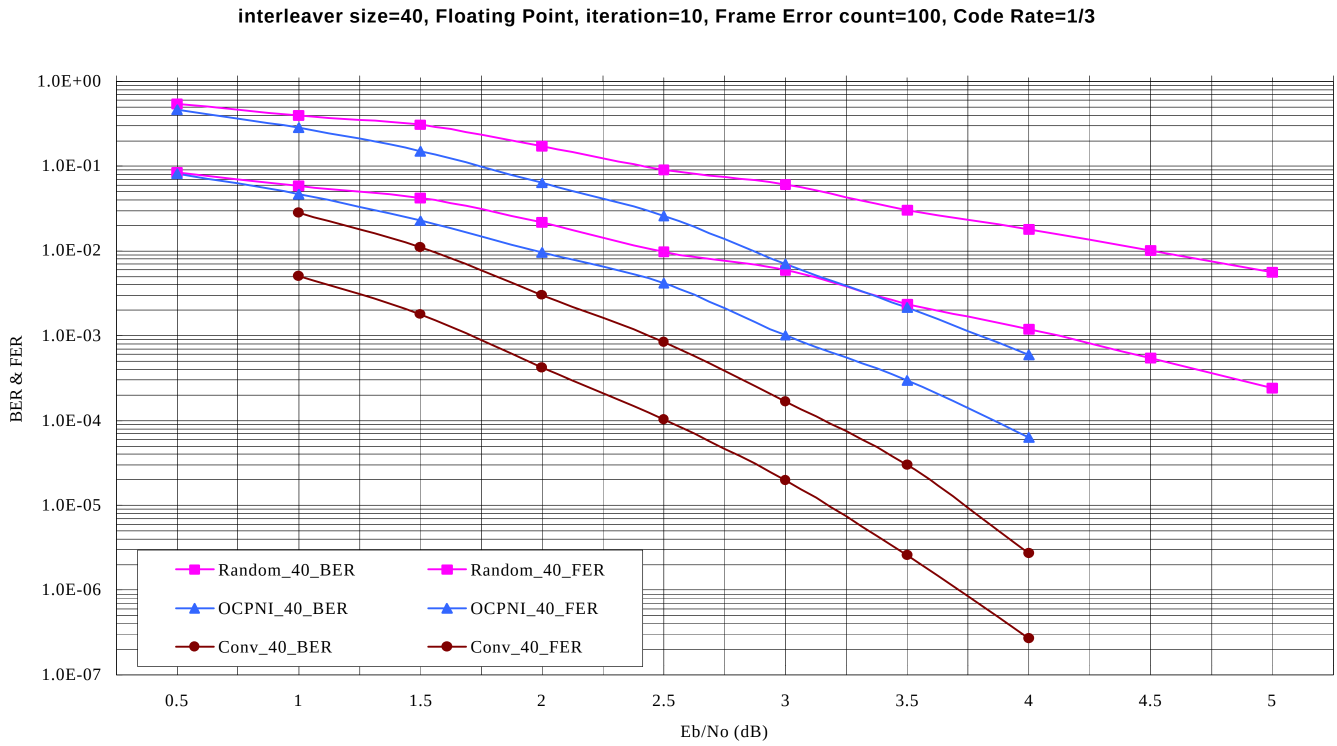

Fig. 4. Bit error rates and frame error rates of a Turbo code and a convolutional code with *L=40*.

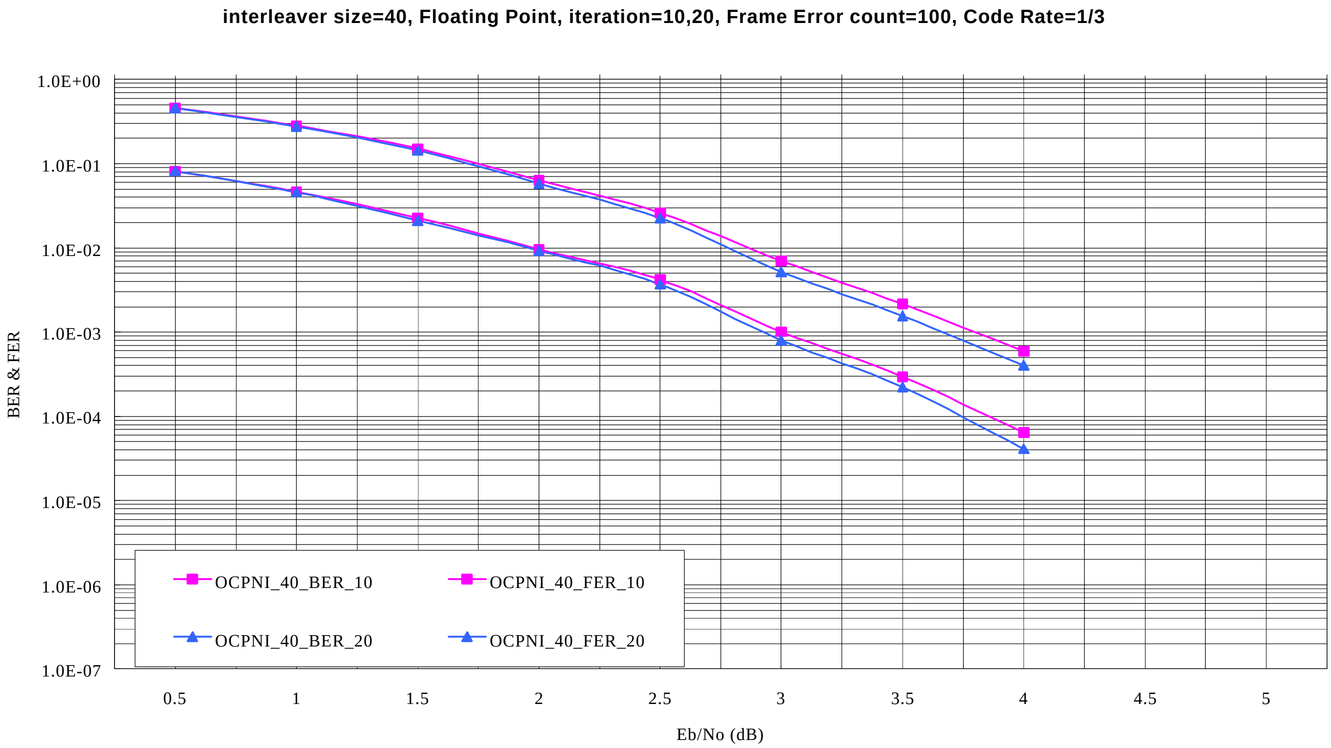

Fig. 5. Bit error rates and frame error rates of a Turbo code according to the number of iteration with *L=40*.

5. Conclusion

In this document, we applied OCPNI, a type of 2-dimensional pseudo-random interleaver, to Turbo codes for small interleaver sizes such as 40, 80, 160. One of the consistent results is that for $L \le 80$, it is somewhat difficult to obtain better BER/FER performance results than that of $K=9$ convolutional codes. Especially for $L=40$ or less, performance loss is expected to be more than 0.5 dB over an AWGN channel. However, for $L=160$, Turbo codes outperformed convolutional codes. In summary, to obtain performance gain over convolutional codes, Turbo codes seems to require interleaver size larger than 80. Furthermore, to reduce performance degradation of Turbo codes for small interleaver sizes, it seems that further study on Turbo interleaver is required.

References

[1] 3G TS 25.212 v3.1.0.

[2] “Proposal for offset controlled PN interleaver for Turbo codes,” Samsung Electronics Co., TSGR1#4(99)417.

[3] “Offset controlled PN interleaver (OCPNI) complexity analysis,” Samsung Electronics Co., TSGR1#5(99)558.

[4] “Performance comparison of 256-state Viterbi decoder and 8-State PCCC Turbo decoder for low data rate applications,” Lucent Technologies & Nortel Networks, TSGR1#4(99)736.

Contact inform:
Kimmingu@samsung.co.kr
Bjkim@telecom.samsung.co.kr