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Title: Comparison of preamble modulation schemes
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1. Introduction

In the previous WG1 meeting at Cheju, two schemes for modulation of preamble part were proposed [1][2]. One is a new modulation scheme for reducing the peak-to-average power ratio and for not changing the auto-correlation values of preamble part [1]. And the other is a modification of HPSK for reducing the peak-to-average power ratio and for simplifying the modulation structure [2]. In Ad Hoc #3 meeting, it was determined that the effects of the modified auto-correlation on preamble detection performance should be further studied. So we present some results of comparison between HPSK and Ericsson's proposal.

2. Auto-correlation properties

As discussed in the Cheju Adhoc #3 meeting, BPSK modulation of HPSK can vary the auto-correlation characteristics of the preamble spreading code at odd time offset between the received code and the reference code of the matched filter. The auto-correlation of HPSK at odd time offset can be expressed as

$$R(\tau) = -j2\{R_{a,even}(\tau) - R_{a,odd}(\tau)\}$$

where t=2m+1 is an odd number and with $a(k)$ of preamble spreading having length N (=even number)

$$R_{a,even}(t) = \sum_{k=0}^{\frac{N}{2}-1-m} a(2k)a(2k+t)$$

and

$$R_{a,odd}(t) = \sum_{k=0}^{\frac{N}{2}-2-m} a(2k+1)a(2k+1+t)$$

If the preamble spreading code is optimised in terms of auto-correlation, we can say that the modification may give worse effects on the performance of preamble detection. However, the segmented long code that became the working assumption as the preamble spreading code in the Cheju meeting is not optimised in terms of absolute value of its auto-correlation. Moreover, it is not so even for the Golay complementary sequence. So we need to investigate the auto-correlation properties by computer simulations. We will consider both Golay complementary sequence presented in [3] and the long code (4096 chips) [4], as the preamble spreading code.

2.1 Golay complementary sequence

Ericsson proposed a Golay complementary sequence with length 4096 as preamble spreading code and signatures when the constituent sequences are of length T_{max}=256, the permutation vector P_n and the weighting vectors W_n are of length 16. The proposed Golay sequences consists of 8 times repeated sequences $A(k)$ and $B(k)$, which are multiplexed according to some equivalent binary "interleaving" function $I_0(k)$ depending on the permutation vector P_n. The orthogonal set of 16 Golay sequences of length 4096, having the *common* constituent sequences $A(k)$ and $B(k)$ of length 256 (and a common interleaving function), can be obtained by choosing a single permutation vector of length 16, along with 8 appropriately chosen weighting vectors.

In [3], the maximum absolute aperiodic autocorrelation sidelobes (MAS) were presented both for the new preamble codes based on Golay sequences and for the concatenated orthogonal Gold sequences. From the results of [3], it was found out that the preamble codes based on Golay complementary sequence are superior to the current preamble sequences (concatenated orthogonal Gold sequences) in a specific condition such as the limited round-trip delay to 256 chips. In other words, the preamble codes based on Golay sequences have the excellent auto-correlation characteristics. Therefore, in order to evaluate the effects of the modified auto-correlation characteristics due to HPSK modulation, the preamble codes based on Golay sequences are considered.

According to the results, both HPSK and Ericsson's modulation scheme have the same MAS in the +/- 255 chips region for all preambles. This is the same as the results presented in [3] as shown in table 1. Accordingly, it can be found out that even if HPSK modifies the auto-correlation, the performance is not changed on statistics.

Table 1. MAS in the +/- 255 chips region for 8192 available preambles

Ericsson's proposal & HPSK				
Number of occurrences	MAS	Number of occurrences	MAS	Statistics of MAS
64	**27**	512	**41**	The average of MAS is 37, and 65% of the MAS values are between 27 and 37. The largest MAS is 53, and the smallest MAS is 27.
128	**29**	576	**43**	
1280	**31**	256	**45**	
1024	**33**	320	**47**	
1600	**35**	192	**49**	
1280	**37**	64	**51**	
832	**39**	64	**53**	

2.2 Long code (4,096 chips)

In [4], Nokia proposed the segmented long code by 4096 chip as preamble spreading code, instead of 256-chip Orthogonal Gold code and the preamble sequence based on Golay sequence, and was accepted as working assumption of preamble spreading code in the previous Ad Hoc #3 physical meeting. So we also consider the 4096-chip long code in order to verify that there is no effect of the modified auto-correlation of the general pseudo noise codes due to HPSK modulation on the preamble detection performance.

The evaluating method is the same as the last section. The results are shown in figure 1 and summarised in table 2. As shown in the results, there is no effect of the modified auto-correlation due to HPSK modulation on the MAS characteristics when the long codes (4096 chips) are applied to preamble spreading sequences.

Table 2. MAS characteristics in the +/- 255 chips region for 8192 long codes (4096 chips)

	HPSK	Ericsson's proposal
The largest MAS	312	311
The smallest MAS	130	130
Average of MAS	191.69	191.62
95 % of MAS	Above 157	Above 157

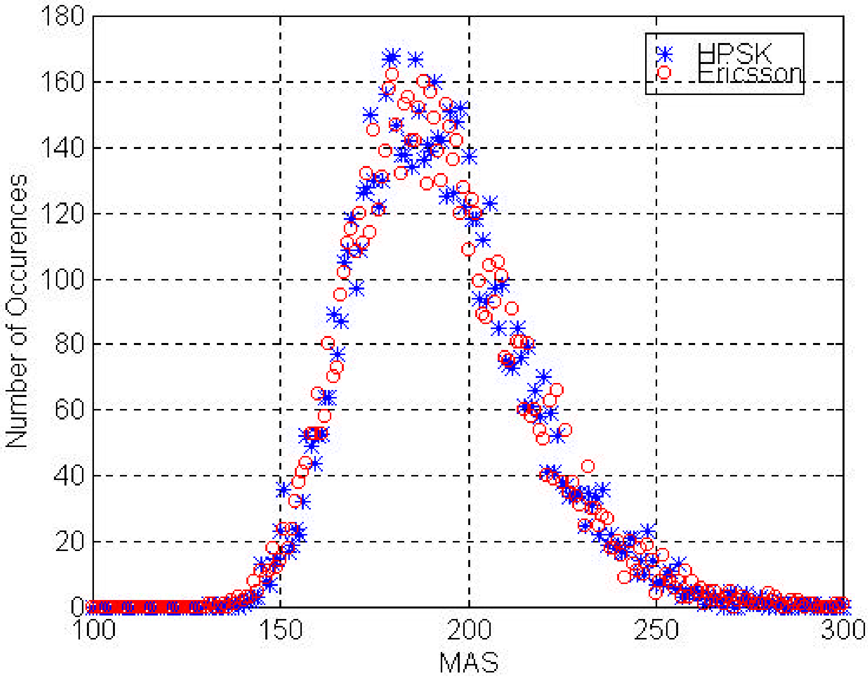

Figure 1. MAS in the +/- 255 chips region for 8192 long codes as preamble spreading code

2.3 Differentially encoded signatures

In [5], Interdigital proposed the differentially encoded signature in order to reduce the disturbance of the orthogonality between different signatures due to frequency shift or spread. As shown in [5], the auto-correlation characteristics can be modified due to the differential detection of the preamble.

From simulation results, Figure 2 shows the MAS performance of the new preamble based Golay sequences with differentially encoded signature, as preamble spreading code. We multiplied the current correlation by the conjugate of the previous one instead of dividing the current correlation by the previous one in order to avoid the division by zero. Therefore, the maximum correlation value reaches to 3840 (=256X15). From the result, the MAS performance of HPSK is exactly same as that of Ericsson's preamble modulation scheme. The average value of MAS is about 450, the largest is 699, and the smallest is 313. And 95% of the MAS is located above 322.

Figure 3 shows the MAS performance of the long preamble sequences with differentially encoded signature [6], as preamble spreading code. The maximum correlation value is also 3840 (=256X15). From the result, the MAS performances of HPSK & Ericssons's proposal are described in Table 3.

Table 2. MAS characteristics in the +/- 255 chips region for 8192 long codes (4096 chips)

	HPSK	Ericsson's proposal
The largest MAS	279	264
The smallest MAS	134	131
Average of MAS	177.0	176.8
95 % of MAS	Above 151	Above 151

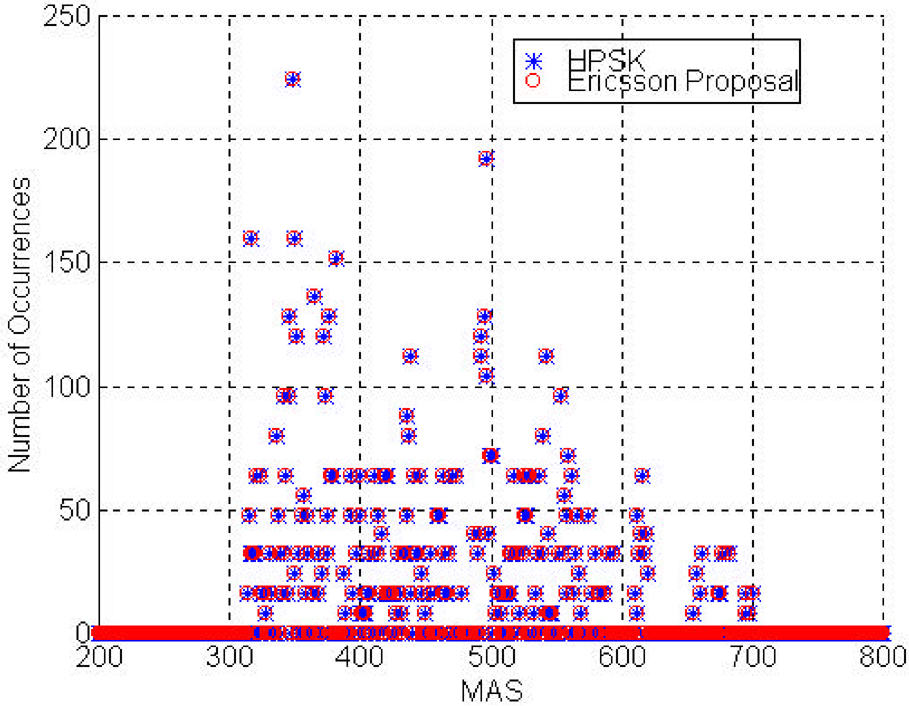

Figure 2. MAS in the +/- 255 chips region for 8192 new preambles based Golay sequences with differentially encoded signature, as preamble spreading code

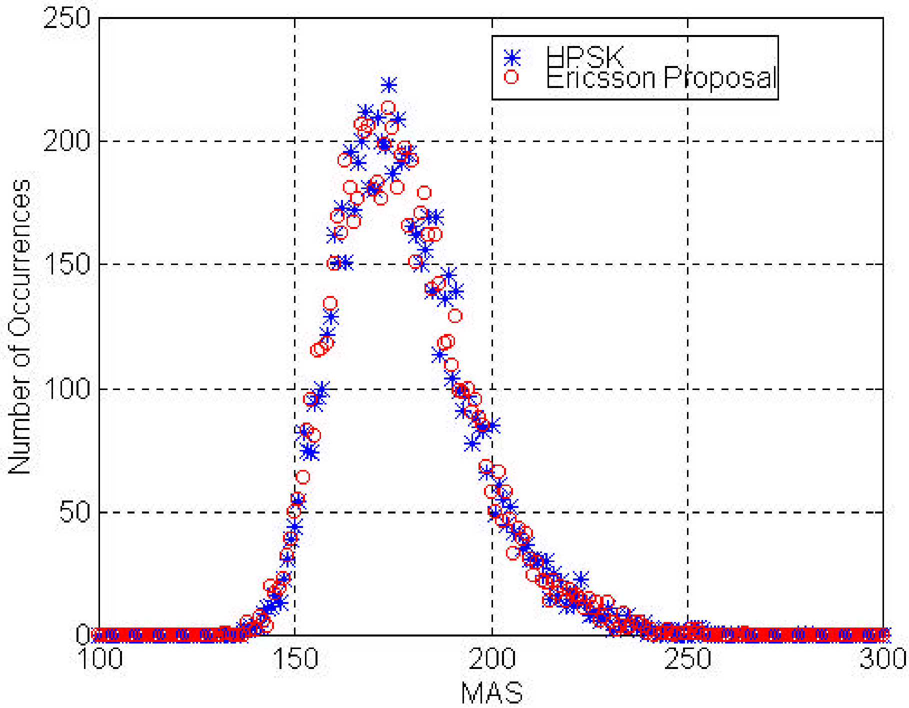

Figure 3. MAS in the +/- 255 chips region for 8192 long sequences (4096 chips) with differentially encoded signature, as preamble spreading code

3. Complexity Issues

In [1] and [2], each receiver structure was proposed for providing the each modulation and detection of preamble. In [1], the multiplier and adder for the PAPR reduction part, and compensation function of asynchronous phase offset are required for Ericsson's preamble detection scheme, compared with the current BPSK modulation. In [2], only additional subtractor for the calculation corresponding to the quadrature branch ($a(k) \cdot W_1(k)$) is required for HPSK preamble detection scheme, compared with the current BPSK modulation.

Also in the modulation side, the additional H/W complexity for HPSK preamble modulation is not required since HPSK can be modularly implemented, with the scrambling scheme of dedicated channel.

From the above description, it can be found out that the complexities of two schemes are almost same, so this issue need not be further discussed.

4. Conclusions

From the above results and descriptions, HPSK has the same PAPR and auto-correlation on statistics as those of Ericsson's proposal, both in the new spreading sequence based on Golay sequence and in the long code with length 4096 chips. For the advantages of HPSK modulation, the modular implementation can be shared by the preamble spreading structure, as well as message and dedicated channel spreading one. Therefore it is desirable that the HPSK modulation with the infinite decimated factor (BPSK modulation) is accepted as the preamble spreading scheme.

References

[1] Ericsson, "Modulation of RACH preamble for PAPR reduction," TSGR1#4(99)339, Shin-Yokohama, Japan, April 18-20, 1999

[2] ETRI, "Preamble modulation scheme with HPSK," TSGR1#5(99)717, Cheju, Korea, June 1-4, 1999

[3] Ericsson, "New RACH preambles with low auto-correlation sidelobes and reduced detector complexity," TSGR1#3(99)205, Nynäshamn, Sweden, March 22-26, 1999

[4] Nokia, "Further clarification of Nokia's RACH preamble proposal," TSGR1#5(99)599, Cheju, Korea, June 1-4, 1999

[5] Interdigital, "Differential Encoding of Golay Sequence Signature Sets," TSGR1#5(99)536, Cheju, Korea, June 1-4, 1999

[6] Interdigital, "Random access preamble detection in presence of Doppler," Tdoc SMG2 UMTS L1 620/98