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# Preamble Specifications for the Standard FH-SS System and for Higher Speed System

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## Abstract

This paper proposes the preambles for the standard FH-SS System and for higher speed FH-SS systems considering false detection probability which might degrade packet reception capability siginificantly. The computer simulation results show that 16 bit Unique Word patterns selected from 5-th stage M series can achieve enough low false and miss detection capability for high throughtput packet transmission by assuming the three potential Bit Timing Recovery patterns proposed during the last meeting held in Atlanta.

## 1 Introduction

In Wireless Local Area Networks Communications, spectral efficiency is one of the most important parameters to specify the systems in addition to the cost of the system. Along with this purpose, a family of off-set QPSK modulation, FQPSK, FQPSK-KF have been proposed (1)-(4) and discussed assuming not expensive hardware implementation of the modem. In addition to modulation schemes, preamble patterns must be reduced as much as possible since the longer preambles will degrade transmission efficiency significantly especially in packet mode tramsmissioin, resulting in low throughput performance.

In designing preamble patterns, special consideration must be paid to the following conditions:

(1) Realization of optimum length and patterns for good enough performance in demodulation process as not to affect to the througput performance - not too long and not too short

(2) Realization of general applicability of the preamble - not only to the standard FH-SS system but also to higher bit rate FH-SS systems and other possible different systems.

The first condition is the minimum requirement and the second condition is preferrable since we need to change bit rates and modulation schemes but not preampbles for higher bit rate systems.

Based on the (candidate) length and patterns which reached to agreement during the last (September) meeting, what should be finalized are (1) selection of a preamble among three candidates for antenna power measeurement, DC offset compensation and bit timing recovery and (2) selection of unique word length and design of the optimum unique word pattern.

The important issue in designing the unique words is finding the optimum pattern and compromising the miss detection probability and false detection capability as not to affect the throuput performance.

This paper shows the exact unique word miss detection and false detection peroformance which has not been studied completely in IEEE 802. 11.

## 2 Unique word design

The preamble study for burst mode communication, such as packet transmission, was studied thoroughly in satellite time division multiple access (TDMA) communication systems by W. Schremp and T. Sekimoto in 1968(5). Since then, various studies have been carried out on the subject designing unique words in various environments and hardware implementation including the references (6)-(9).

### (1) False detection

In general, the probability of unique word false detection which might occur when the digital correlator receives the part of bit timing recovery word and part of the unique word. In this case, just conventional false detection probability of the unique word in random errors is no more valid and Hamming distance between incoming signals and a unique word pattern must be considered for false detection probability calculation.

False detection probability of the unique word, F, in random errors is given by Eq. (1).

$$F = \frac{1}{2^N}\sum_{i=0}^{\varepsilon}\binom{N}{i} \quad (1)$$

Here, N represents the length of the unique word in bit, E represents the correlation threshold.
Miss detection probability of the unique word in fixed pattern signals within the aperture window, H-b is given by Eq. (2).

$$H_{-b} = \sum_{i=Hd-\varepsilon}^{Hd}\binom{Hd}{i}P_e^{\,i}q_e^{\,Hd-i} X \sum_{j=0}^{\varepsilon-Hd+i}\binom{N-Hd}{j}P_e^{\,j}q_e^{\,N-Hd-j} \quad (2)$$

Here, Hd represents Hamming distance between the unique word and the received signal at detection point. Pe represents bit error probability of the received signals. Thus, the overall false detection probability, Ht is given by Eq. (3).

$$H_T = 1-\prod_{-b=-1}^{-W}(1-H_b) = \sum_{-b=-1}^{-W} H_b \quad (3)$$

Where, W represents the aperture window size in bit.

**(2) Miss detection**

Unique word miss detection will occur if false detection does not occur and if detection signal is not obtained after passing through the last bit of the unique word. This probability is given Eq. (4)

$$P = \sum_{i=0}^{\varepsilon}\binom{N}{i}P_e^{\,i}(1-P_e)^{N-i}$$

$$Q = 1-P$$

$$= \sum_{i=\varepsilon+1}^{N}\binom{N}{i}P_e^{\,i}(1-P_e)^{N-i} \quad (4)$$

## 3 Detection Performance

The unique word miss and false detection performances have been evaluated at the bit error rate of $10^{-5}$ in additive white Gaussian noise environment. In order to achieve neglible small contribution to the throuput, less than a miss or false probability of $10^{-4}$ is selected as the threshold of the their probabilityies assuming a packet length of 1000 bit. Also assumed is an employment of aperture. This is possible for the system sunder discussioin since it has a burst signal detector for antenna space diversity and power mesurement for this. This leads the employment of the aperture window for reducing false detection of the unique word significantly.

Miss detection probability (Pmiss) and false detection probability (Pfalse) are summarized with parameters of bit error rate and the unique word length in Table 1. Moreover, recommended unique word patterns are also tabulated in the Table 1. Furthermore, unique word miss and false detection probability versus correlation threshold with a parameter of Hamming distance Hd which is a key parameter to decide false detection performance is shown in Fig. 1.

As seen from these Table and Figure, the unique word length of 16 bit is enough to achieve a unique word miss or false detection performance of less than $2x10^{-14}$ at bit error rate of $10^{-5}$. For achieving this performance, the unique patterns have been selected from the 5th stage M series. The computer simulation results show that these patterns have a Hamming distance of 6 whcih allows a correlation threshold of 3. With a unique word of 24 bit length, miss and false detection performances are improved by the order of from 2 to 9. But these performances will not be required for real systems.

## 4 Preambles

The recomended preamble patterns are shown inTable 1.
The unique word length is chosen as 16 bit and the patterns are selected from 5th stage M series as seen from Table 1. The pattern for BTR recommended in this paper is "1001"repeating. With these unique word patterns, miss and false detection probabilities are calculated as shown in Fig. 1
The reasons are shown follows.
(1) The bit timing recovery signal can be recovered by using only I or Q channel signals and the S/N of recovered bit timing signals can be improved by adding both I and Q channel recovered signals.
(2) The recommended pattern can be employed for offset QPSK type modulated signals easily- for possible higher bit rate systems.
The overall preamble is shown in Fig. 2.

## 5 Conclusion

This paper has analyzed unique word miss and false detection probability for 16 and 24 bit unique word in various bit error rate environments. The proposed a unique word is requires 16 bits and very good miss and false detection performance. The selection of "1001" repeating pattern for bit the timing recovery code word is recommended for continuity from the present standard FH-SS system to Higher Data Rate systems.

**References**

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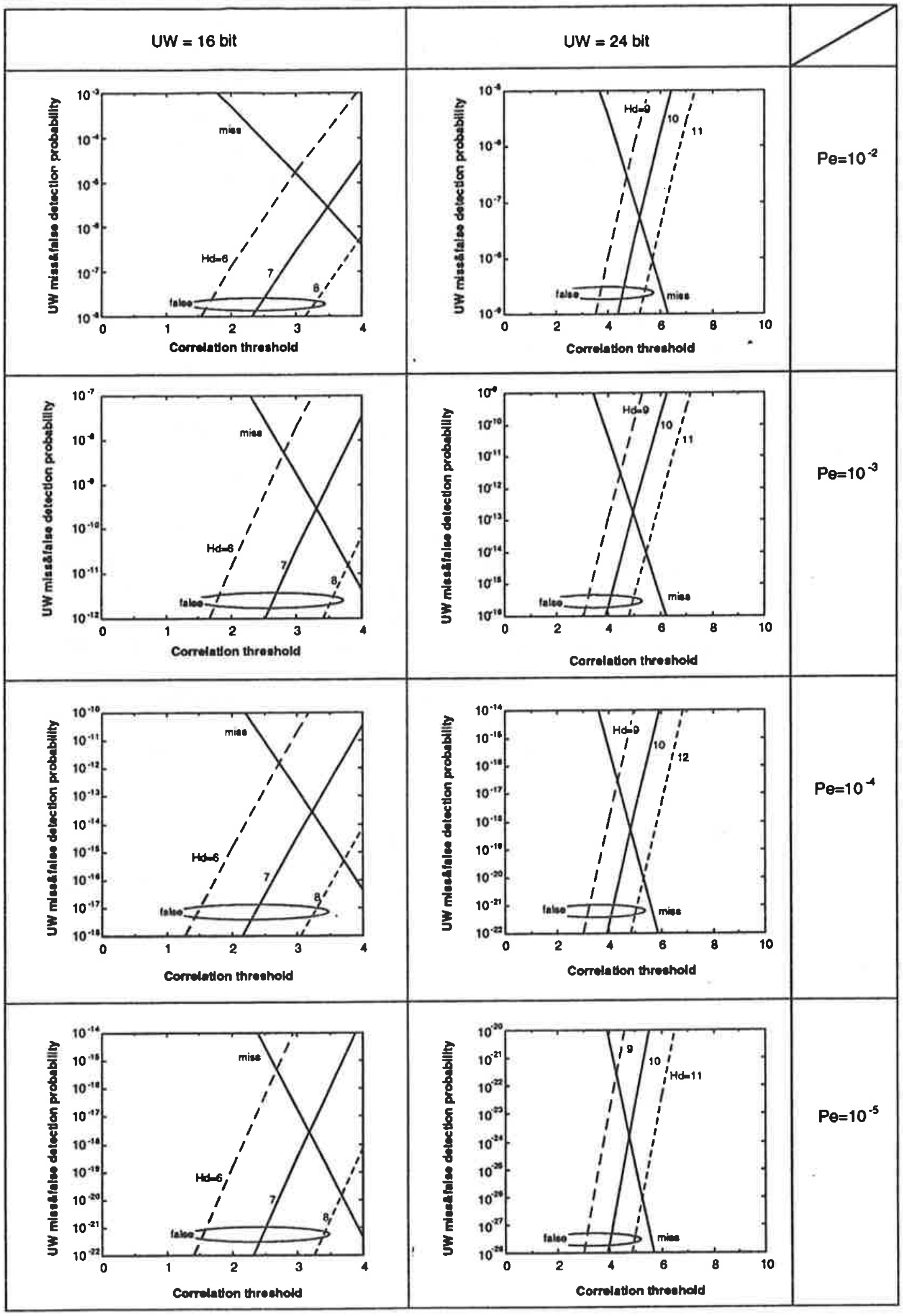


Fig. 1 UW miss and false detection probability.

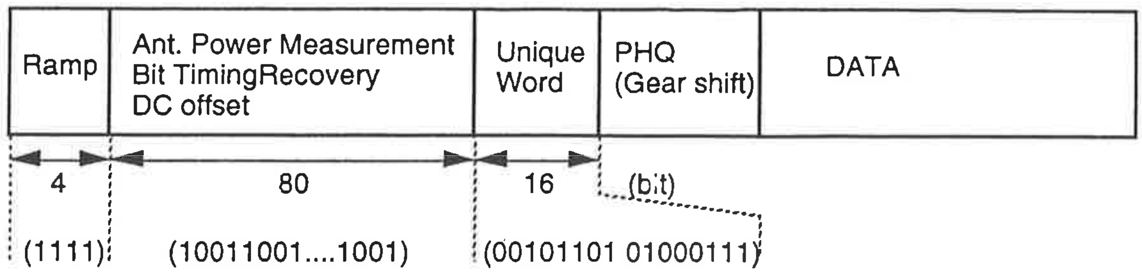


Fig.2 Recommended Frame Format.

Table I UW pattern and UW miss/false detection probability

(a) 16bit UW

| BTR | Detector | PATTERN | Hd | ε | MAX(Pfalse, Pmiss) | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Pe = $10^{-2}$ | Pe= $10^{-3}$ | Pe= $10^{-4}$ | Pe= $10^{-5}$ |
| 1010... | parallel | 10100011 | 6 | 3 | ~$2x10^{-5}$ | ~$3x10^{-8}$ | ~$2x10^{-11}$ | ~$2x10^{-14}$ |
| | serial | 1100100110000101 | | | | | | |
| 11010.. | parallel | 00010110 | | | | | | |
| | serial | 0111110010011000 | | | | | | |
| 1001... | parallel | 11110010 | | | | | | |
| | serial | 0010110101000111 | | | | | | |

Aperture window = UW length

(b) 24bit UW

| BTR | Detector | PATTERN | Hd | ε | MAX(Pfalse, Pmiss) | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Pe = $10^{-2}$ | Pe= $10^{-3}$ | Pe= $10^{-4}$ | Pe= $10^{-5}$ |
| 1010... | parallel | 101101010001 | 10 | 5 | ~$1x10^{-7}$ | ~$2x10^{-13}$ | ~$1x10^{-18}$ | ~$1x10^{-23}$ |
| | serial | 111110010011000010110101 | 10 | 5 | ~$1x10^{-7}$ | ~$2x10^{-13}$ | ~$1x10^{-18}$ | ~$1x10^{-23}$ |
| 11010.. | parallel | 110000101101 | 9 | 4 | / | ~$3x10^{-11}$ | ~$1X10^{-16}$ | ~$5X10^{-21}$ |
| | | | | 5 | ~$2x10^{-6}$ | / | / | / |
| | serial | 011111001001100001011010 | 10 | 5 | ~$1x10^{-7}$ | ~$2x10^{-13}$ | ~$1x10^{-18}$ | ~$1x10^{-23}$ |
| 1001... | parallel | 100110000101 | 10 | 5 | ~$1x10^{-7}$ | ~$2x10^{-13}$ | ~$1x10^{-18}$ | ~$1x10^{-23}$ |
| | serial | 010100011101111100100110 | 9 | 4 | / | ~$3x10^{-11}$ | ~$1X10^{-16}$ | ~$5X10^{-21}$ |
| | | | | 5 | ~$2x10^{-6}$ | / | / | / |

Aperture window = UW length