페이딩 환경에서 Soft Limited Detection을 이용하는 다중사용자 FH/MFSK 시스템의 성능

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1. FH/MFSK concept

<Advantage>

· Resistant to <u>Frequency selective fading</u>, <u>Near-far problem</u>

· Anti-jamming, LPD, LPI

· High spectral efficiency

<Method>

· M frequency slots for M symbols ($M = 2^k$ for k-bit word)

· L chips per a symbol (Fast FH)

· $1 \times L$ dimensional hopping vector

$$X = a + m1 \quad \text{where} \quad a \text{ is a address vector}$$

$$1 \text{ is a all 1 vector.}$$

$$X = m \cdot 1 + a$$

$$= 4 \cdot (1,1,1,1,1) + (1,2,3,4,5)$$

$$= (5,6,7,0,1)$$

$$m \cdot 1 \quad = \qquad\qquad X \quad - \qquad\qquad a$$

$$= \quad (\,5,6,7,0,1\,) \quad - \quad (\,1,2,3,4,5\,)$$

$$= \quad (\,4,4,4,4,4\,)$$

· Optimal Hopping Pattern (RS-code)

$$X = \gamma \; \beta + m1 \quad \text{where} \quad \beta = (\,1,\; \beta,\; \beta^2,\; \beta^3,\; \cdots \beta^{(L-1)}\,)$$

$$\beta \text{ is a primitive root over GF(} 2^k)$$

$$\gamma \text{ is a user index,}$$

$$m \text{ is a message symbol}$$

for $L < 2^k$, $[L, 2, L-1]$ shortened RS-code

2. Detection Scheme for Multiuser Environment

figure 4 Detector for FH/MFSK Receiver

(1) Hard limiter: $f_H(R) = \begin{cases} 0, & 0 \leq R \leq T_H \\ 1, & T_H < R < \infty \end{cases}$

(2) Soft limiter: $f_S(R) = \begin{cases} R, & 0 \leq R \leq T_S \\ T_{S,} & T_S < R < \infty \end{cases}$

∗ The performance of soft limiter is better than hard limiter

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3. Interference Cancellation

3.1 **REC**(**RE**duction of the number of **C**andidate) algorithm by U.-C. G. Fiebig

< STEPS >

(1) Generate all despread matrix D_k**,** $k = 1, 2, 3, \cdots, K$ **users.**

Identify all $n_k^{(0)}$ candidate rows in D_k

(2) Apply s**−th iteration,** $s = 1, 2, 3, \cdots, s_{\max}$:

① For each use, generate transmit matrices $T_{k,i}$, $1 \leq i \leq n_k^{(s-1)}$

② Generate $B^{(s)}$ whose elements $b_{ml}^{(s)}$ are

$$b_{m,l}^{(s)} = \sum_{k=1}^{K} \sum_{i=1}^{n_k^{(S-1)}} t_{m\,l}^{(k,i)}$$

③ For each user with $n_k^{(s-1)} > 1$, generate $D_k^{(s)}$ from $B^{(s)}$

if candidate row has '1', which will be regarded as correct one,

if any $D_k^{(s)}$ has no '1' in candidates, choose randomly and exit.

A example for REC algorithm

Figure 5 Visualization of the REC algorithm

< Main idea for REC algorithm >

" Among all ambiguity rows,
only the correct row may provide elements valued 1. "

< Atfer Reuction of the numder Candidate >

· REC+CD (Conventional Decoding):

· REC+MLJD (Maximum Likelihood Joint Detection) :

3.2 Proposed Soft-limited REC algorithm

\<Modified STEPS\>

(1) If one candidate row from conventional hard limiter is different to soft-limited detector output, **Add this as a candidate**.

(2) If the iteration ends with an ambiguous matrices, **Select a candidate whose soft-limited output is maximum.**

4. Simulation Results

\<assumption\>

- Synchronous Transmission for Chip and Symbol
- Frequency Selective Fading
- No Doppler Effect

\<System Model\>

- Bandwidth 20MHz
- Bit rate 32Kbps
- RS code hopping pattern.
- REC+CD

(1)   Hard limiter VS. Soft limiter

· For $P_b \leq 10^{-3}$, Eb/No=25dB

Hard-limiter: 167 users

Soft-limiter :   190 users

=> 14 % increasement

· The performance of 25dB soft-limited detector is similar to 30dB hard-limited one.

그림 6 M=512, L=11 일 때 hard-limited 검출기와 soft-limited 검출기를 사용하는 수신기의 성능비교

(2) Hard-limited REC+CD VS. Soft-limited REC+CD over M=512, L=11

그림 7 M=512, L=11, Eb/No=25dB에서
hard REC와 hard+soft REC의 성능비교

· For $P_b \leq 10^{-3}$, Soft-limited REC accommodate about 7 users more

· For $P_b \leq 10^{-4}$, about 10 users more

(3) Hard-limited REC+CD VS. Soft-limited REC+CD over M=256, L=19

그림 8 M=256, L=19, Eb/No=25dB에서
hard REC와 hard+soft REC의 성능비교

· For $P_b \leq 10^{-3}$, Soft-limited REC accommodate about 15 users more

· For $P_b \leq 10^{-4}$, about 20 users more

표 1 Eb/No=25dB, BER=10E-3에서 각 방식의 최대 사용자 수

	M=512, L=11	M=256 L=19
hard CD	167	163
soft CD	190	177
hard REC+CD	220	191
hard+soft REC+CD	227 (220+7)	206 (191+15)

· M=256, L=19 system has more increasing ratio between hard REC+CD and hard+soft REC+CD.

· M=512, L=11 system shows better performance in every aspect.

(4) The ratio of new candidate insertion.

그림 9. M=256, L=19, Eb/No=25dB, soft+hard REC
방식의 BER과 새로운 후보행렬 발생비율

· Conventional REC candidate : Ambiguity Row Event from hard-limited detector
· Added REC candidate   : Added Candidate Event from soft-limited detector

5. Conclusion

- Soft-limited detector can accomodate more users than hard-limited detector without users information.

- Modified REC algorithm increase reliable candidates with soft-limited detector
  --> More Users

- More sophisticated candidate selection & reduction have to be studied.