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| Project | **IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>** |
| Title | **Reuse of CQICH Fast Feed-back Sub-channels** |
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| Re: | Recirculation of P802.16 REVe/D6 |
| Abstract | Reuse scheme is proposed to increase the spectral efficiency of CQICH fast feed-back sub-channels. The proposed scheme is fully backward compatible and useful for base stations with diversity antenna reception. |
| Purpose | Adoption of suggested changes into P802.16e/D7 |
| Notice |  |
| Release |  |
| Patent Policy and Procedures |  |

(The text change during the revision is in red for reader's convenience. More text for clock offset is added.)

## Problem Definition

The required number of fast feed-back sub-channels increases as the number of data streams increases. To reduce the uplink bandwidth signaling overhead, there needs to utilize the SNR gain from multiple antenna reception at BS.

## Proposed Solution

The operating point of CQICH fast feedback channels, which can be specified as signal to noise ratio per antenna, decreases as the number of received antennas at BS increases and it can be well below 0 dB SNR. Under this situation, one sub-channel region for CQICH feedback can be allocated for multiple CQICH signaling when the BS provision multiple receive antennas, wherein each of multiple CQICH sub-channels has its own codeword set and covering sequence clock offset for co-channel interference averaging. To keep backward compatibility, we use fast feedback orthogonal modulation vectors in Table 295 of P802.16-REVd/D5, which has been proposed for non-coherent detection in low SNR regime.

The simulations results in Fig. 1 below are obtained by shifting the BS-specific covering sequences in Sec 8.4.9.4.1. For the second user, covering sequence clock offset of 40 was applied and two antenna diversity reception at BS was assumed. The simulation was carried out in PUSC and O-PUSC permutation zone and non-coherent energy detection was employed in the receiver to avoid performance degradation from channel estimation error in low SNR regime. We can observe that the operating point of 1 % error rate increases to -1.5 dB when CQICH code words are reused by factor two in AWGN channels. The original point (not shown here) was -5.0 dB. The SNR degradation of 3.5 dB would be compensated when we employ more than two receive antennas at BS. To verify this argument, additional performance simulations were carried out for 4 antenna diversity reception. The results are illustrated in Fig. 2.

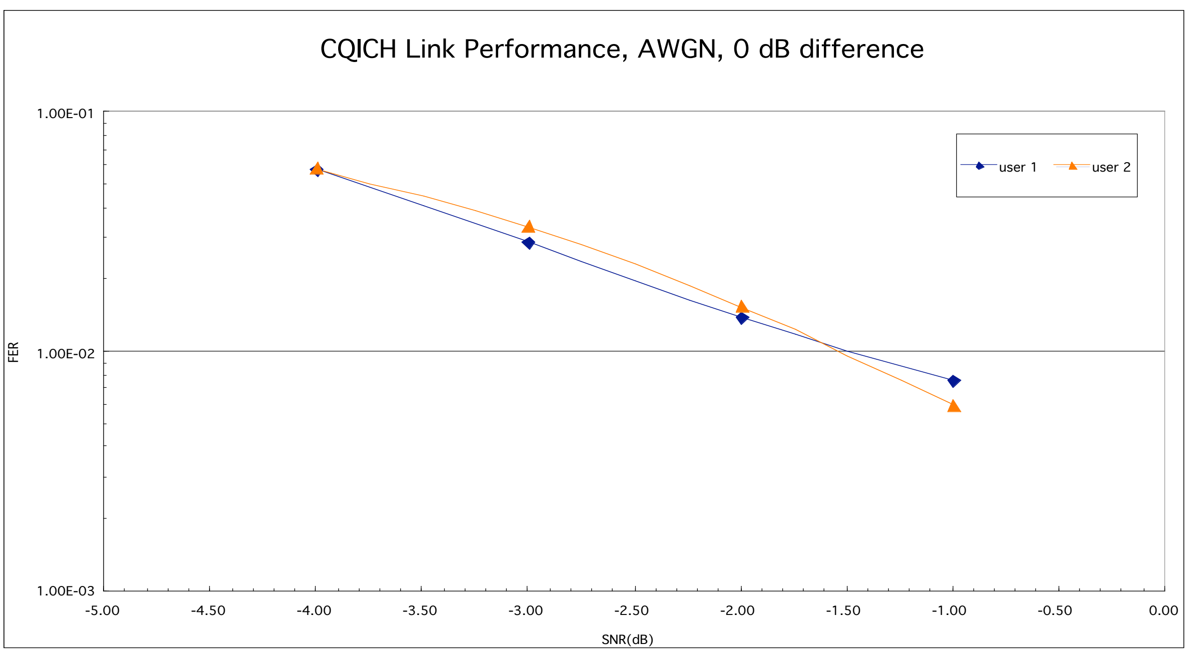


Fig.1. 5 bit codeword (only covering sequence clock offset applied)

In the second simulation, the 6 bit codeword set in the current text was employed when the number of receive antenna at BS is 2 and 4. For the proposed sub-channel reuse scheme, the second user employed the optimized second 6 bit codeword set with covering sequence clock offset of 40. The results in Fig. 2 show that the SNR gain from 4 receive antenna is enough to accommodate two users in a single sub-channel although the performance curve of 4 Rx. antenna with 2 user case was not steeper than 2 Rx. antenna with one user case. This is a final compromise between diversity reception and jamming effects cased by interference between co-channel users. Table I summarized the whole simulation results in terms of required SNR per antenna for 1 % error rate. In conclusion, under the operation point of 1 % PER and -4.0 dB SNR per antenna, one sub-channel for CQICH signaling can be allocated to different two users using the proposed scheme. Alternatively, one fast feedback sub-channel can be used for the signaling of channel quality information of two different DL MIMO layers of one user. In this scenario, the proposed scheme doesn't suffer performance degradation from power imbalance between co-channel users. For 2 user allocations, BS may reduce the performance loss from power imbalance by employing SIC (serial-interference cancellation) and/or receiver beam-forming after estimating user's spatial signature.

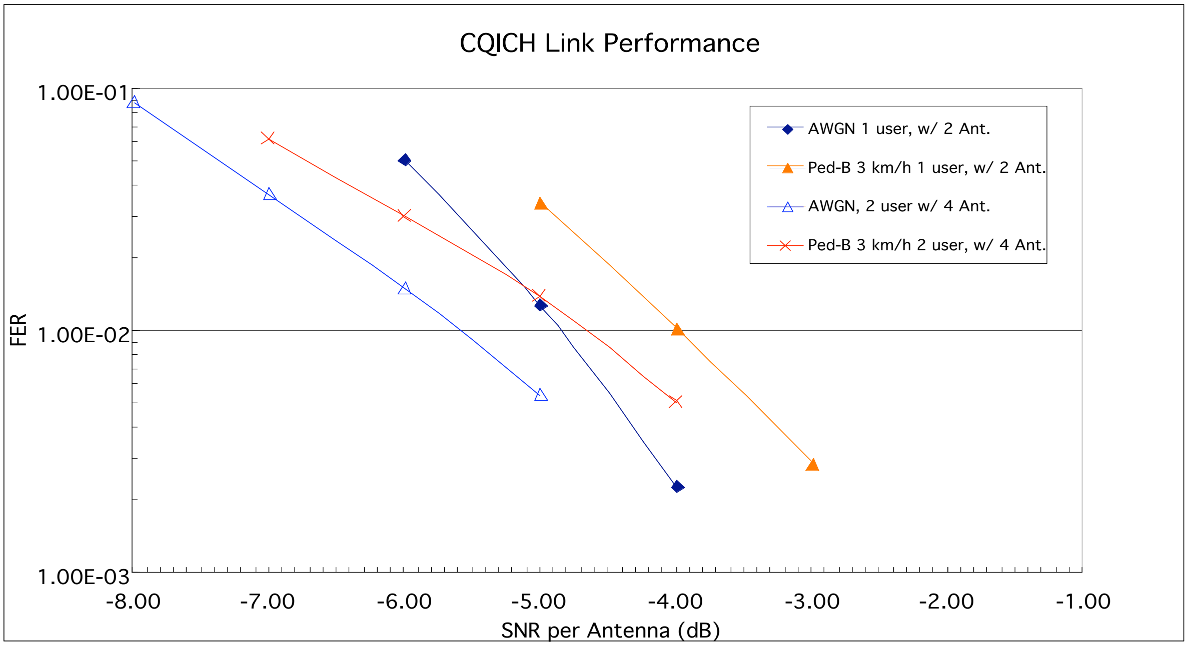


Fig. 2. 6 bit codeword (covering sequence clock offset and different code-word set)

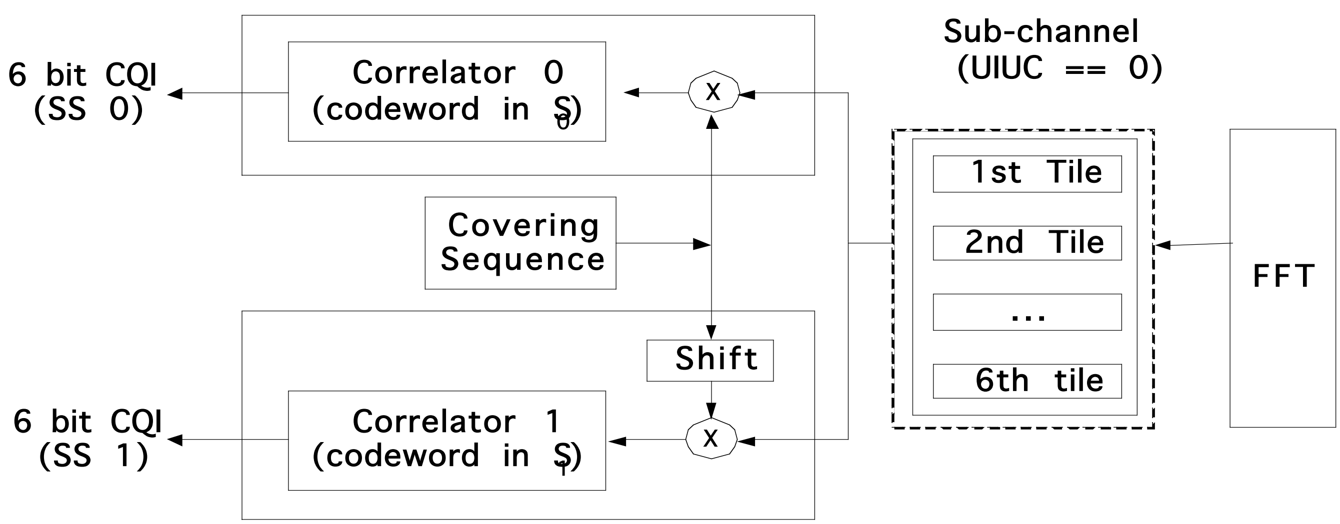


Fig. 3. Operation at BS in the proposed scheme

Table I. Required SNR per Antenna for 1 % Error

| **Simulation Case** | **Applied Scheme for 2nd User** | **AWGN** | **PED-B 3 km/h** |
|---|---|---|---|
| 1 User, 2 Rx. Ant at BS, 5 bit CQICH | NA | – 5.0 dB | - |
| 1 User, 2 Rx. Ant at BS, 6 bit CQICH | NA | – 4.8 dB | – 4.0 dB |
| 2 User, 2 Rx. Ant at BS, 5 bit CQICH | Covering Sequence Clock Offset | – 1.5 dB | - |
| **2 User, 4 Rx. Ant at BS, 6 bit CQICH** | **Covering Sequence Clock Offset and Codeword Set** | **– 5.5 dB** | **– 4.6 dB** |

## Suggested text changes to 16.e standard

**[Create Sec. 8.4.5.4.10.10 as follows]**

### 8.4.5.4.10.xx FAST_FEEDBACK channel reuse for 6-bit payload

If BS supports multiple receive antenna for uplink reception, the number of Fast Feedback channels for a given uplink sub-channel with UIUC = 0 can be increased by using different codeword set and different covering sequences as in Table aaa. The covering sequences for sub-carriers in reused sub-channels are obtained by choosing three symbol advance offset for the initialization vector of BS-specific covering sequences in Sec 8.4.9.4.1.

**Table aaa Modulation Scheme for Fast feedback channels**

| Reuse Index | Code word set | Symbol offset | Description |
|---|---|---|---|
| 0 | $S_0$ | 0 | Use codeword set $S_0$ and BS-specific covering sequences in Sec 8.4.9.4.1. |
| 1 | $S_1$ | 3 | Use codeword set $S_1$ and BS-specific covering sequences, which are obtained by applying three additional symbol offset for the initialization vector of PRBS in Sec 8.4.9.4.1 |

The reuse indexes are assigned by CQICH Enhanced allocation IE. At SS, each modulated sub-carrier in the assigned sub-channel is multiplied by the corresponding covering BPSK signals in Table aaa. SS should utilize 64 code-words in Table 296b for $S_0$ and those in Table 296d for $S_1$, respectively.

**Table 296d – Additional Fast-Feedback channel sub-carrier modulation with 6 bit**

| **6 bit payload** | **Fast Feedback vector indices per Tile Tile(0), Tile(1), … ,Tile(5)** |
|---|---|
| 0b000000 | 4,6,5,2,3,1 |
| 0b000001 | 5,7,4,3,2,0 |
| 0b000010 | 6,4,7,0,1,3 |
| 0b000011 | 7,5,6,1,0,2 |
| 0b000100 | 0,2,1,6,7,5 |

| | |
|---|---|
| 0b000101 | 1,3,0,7,6,4 |
| 0b000110 | 2,0,3,4,5,7 |
| 0b000111 | 3,1,2,5,4,6 |
| 0b001000 | 6,2,6,4,4,4 |
| 0b001001 | 7,3,7,5,5,5 |
| 0b001010 | 4,0,4,6,6,6 |
| 0b001011 | 5,1,5,7,7,7 |
| 0b001100 | 2,6,2,0,0,0 |
| 0b001101 | 3,7,3,1,1,1 |
| 0b001110 | 0,4,0,2,2,2 |
| 0b001111 | 1,5,1,3,3,3 |
| 0b010000 | 0,5,3,5,6,0 |
| 0b010001 | 1,4,2,4,7,1 |
| 0b010010 | 2,7,1,7,4,2 |
| 0b010011 | 3,6,0,6,5,3 |
| 0b010100 | 4,1,7,1,2,4 |
| 0b010101 | 5,0,6,0,3,5 |
| 0b010110 | 6,3,5,3,0,6 |
| 0b010111 | 7,2,4,2,1,7 |
| 0b011000 | 7,0,2,7,2,3 |
| 0b011001 | 6,1,3,6,3,2 |
| 0b011010 | 5,2,0,5,0,1 |
| 0b011011 | 4,3,1,4,1,0 |
| 0b011100 | 3,4,6,3,6,7 |
| 0b011101 | 2,5,7,2,7,6 |
| 0b011110 | 1,6,4,1,4,5 |
| 0b011111 | 0,7,5,0,5,4 |
| 0b100000 | 2,1,0,3,1,5 |
| 0b100001 | 3,0,1,2,0,4 |
| 0b100010 | 0,3,2,1,3,7 |
| 0b100011 | 1,2,3,0,2,6 |
| 0b100100 | 6,5,4,7,5,1 |
| 0b100101 | 7,4,5,6,4,0 |
| 0b100110 | 4,7,6,5,7,3 |
| 0b100111 | 5,6,7,4,6,2 |
| 0b101000 | 3,3,4,0,7,2 |
| 0b101001 | 2,2,5,1,6,3 |
| 0b101010 | 1,1,6,2,5,0 |
| 0b101011 | 0,0,7,3,4,1 |
| 0b101100 | 7,7,0,4,3,6 |
| 0b101101 | 6,6,1,5,2,7 |
| 0b101110 | 5,5,2,6,1,4 |
| 0b101111 | 4,4,3,7,0,5 |
| 0b110000 | 1,7,7,6,0,7 |
| 0b110001 | 0,6,6,7,1,6 |
| 0b110010 | 3,5,5,4,2,5 |
| 0b110011 | 2,4,4,5,3,4 |
| 0b110100 | 5,3,3,2,4,3 |
| 0b110101 | 4,2,2,3,5,2 |
| 0b110110 | 7,1,1,0,6,1 |
| 0b110111 | 6,0,0,1,7,0 |
| 0b111000 | 5,4,1,1,5,6 |

| | |
|---|---|
| 0b111001 | 4,5,0,0,4,7 |
| 0b111010 | 7,6,3,3,7,4 |
| 0b111011 | 6,7,2,2,6,5 |
| 0b111100 | 1,0,5,5,1,2 |
| 0b111101 | 0,1,4,4,0,3 |
| 0b111110 | 3,2,7,7,3,0 |
| 0b111111 | 2,3,6,6,2,1 |

**[Modify the following Table 298a in 8.4.5.4.15 "CQICH Enhanced Allocation IE Format"]**

**Table 298a. CQICH Enhanced allocation IE format**

| Syntax | Size (bits) | Notes |
|---|---|---|
| CQICH_Enhanced_Alloc_IE(){ | | |
| Extended DIUC | 4 | 0x09 |
| Length | 4 | Length in bytes of following fields |
| CQICH_ID | variable | Index to uniquely identify the CQICH resource assigned to the MSS |
| Period (=p) | 2 | A CQI feedback is transmitted on the CQICH every 2^p frames |
| Frame offset | 3 | The MSS starts reporting at the frame of which the number has the same 3 LSB as the specified frame offset. If the current frame is specified, the MSS should start reporting in 8 frames |
| Duration (=d) | 3 | A CQI feedback is transmitted on the CQI channels indexed by the CQICH_ID for 10 x 2^d frames. If d == 0, the CQICH is de-allocated. If d == 111, the MSS should report until the BS command for the MSS to stop. |
| CQICH_Num | 4 | Number of CQICHs assigned to this CQICH_ID is (CQICH_Num+1) |
| for (i=0;i<CQICH_Num;i++) { | | |
| Feedback_type | 3 | … |
| Allocation index | 6 | Index to the fast feedback channel region marked by UIUC=0 |
| Reuse index | 1 | Modulation scheme in Sec. 8.4.5.4.10.10<br>0 = Use $S_0$ and apply no additional symbol offset (Default)<br><br>1 = Use $S_1$ and apply three additional symbol offset for the initialization vector of PRBS in Sec 8.4.9.4.1<br>(This mode is only applied to CQICH Type 00 and 01 below) |
| CQICH Type | 2 | 00: 6 bit CQI<br>01: DIUC-CQI<br>10: 3 bit CQI (even)<br>11: 3 bit CQI (odd) |
| } | | |
| … | … | … |
| Padding | *variable* | The padding bits are used to ensure the IE size is integer number of bytes. |

**[Add a capability bit for "Uplink control channel support" in Sec. 11.8.3.7.9]**

| Type | Length | Value | Scope |
|---|---|---|---|
| xxx | 1 | Bit #0: Reserved; shall be set to zero<br>Bit #1: Enhanced FAST_FEEDBACK<br>Bit #2: UL ACK<br>Bit #3: Enhanced UL ACK<br>Bit #4: Optional FAST_FEEDBACK for the 4-bit payload<br>Bit #5: Optional FAST_FEEDBACK for the 5-bit payload<br>Bit #6: A measurement report shall be performed on the last DL burst, as described in 8.4.5.4.10.1<br>Bit #7: FAST_FEEDBACK reuse for 6-bit payload | SBC-REQ (See 6.3.2.3.23)<br>SBC-RSP (See 6.3.2.3.24) |