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Title	Downlink switched beam support in IEEE802.16e
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Re:	P802.16e Ballot Resolution Committee Recirculation Announcement
Abstract	Definition of new information element (IE) and MAC management messages to support switched beamforming in downlink.
Purpose	Optional support of new switched beam selection mechanism in downlink.
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Optional Closed-loop Downlink Switched Beam Selection Mechanism

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1. Introduction

Smart antennas are widely used to steer the beam patterns toward individual users. Since smart antenna technologies yield not only the enhanced antenna gain but also the co-channel interference reduction, systems with antenna arrays can provide better network performance than those with omni or sector antennas. Switched and fully adaptive beamforming are two major applications of the smart antenna systems and each has it's own advantages and disadvantages. In many cases transmit switched beam forming is widely used in the downlink and receive adaptive beam forming is widely used in the uplink. In this contribution an efficient beam selection algorithm of downlink transmit switched beam smart antenna system is proposed. In order to support the proposed algorithm, we don't need any physical changes or additions. We can reflect this contribution by defining a new information element (SBF_DL_Support_IE) and two MAC management messages (SBI-REQ & SBI-RSP).

2. Closed-loop Downlink Switched Beam Selection Mechanism

The most important task in designing the switched beam system is to develop an efficient method of beam selection, in such a way that the base station (BS) can quickly and accurately switch to the correct beam, which covers the area where the target mobile subscriber station (MSS) belongs. The conventional methods of selecting the beam are based on the BS's measurements such as the received signal strength indicator (RSSI) and the direction of arrival (DOA) using the uplink signal. But this contribution proposes a new switched beam selection algorithm in which MSS determines the best beam and informs the beam index to BS so as for the BS to steer it to the corresponding MSS. The criterion of selecting the best beam at MSS side is the maximization of received signal-to-noise ratio (SNR) and in this case in order to evaluate received SNR individual channel estimation between each array element constituting the smart antenna and MSS is required.

Fig. 1 illustrates the linear array antenna configuration for switched beam forming. The h_i in Fig. 1 represents the channel between the *i*-th antenna element of array and the MSS. In order to support K fixed switched beams the BS uses N element array antenna and preset K weighting vectors. For the switched beam of index k, the BS shall apply the weighting vector, W_k.

$$W_k = \begin{bmatrix} w_{k,1} \\ w_{k,2} \\ w_{k,3} \\ \cdots \\ w_{k,N} \end{bmatrix}, \quad k = 1, 2, \ ..., K \tag{1}$$

Assuming the N element array antenna at BS side, the received signal at MSS side is given by

$$r = \sqrt{\gamma} HWx + n \tag{2}$$

where $H\left(= \begin{bmatrix} h_1 & h_2 & \cdots & h_N \end{bmatrix}\right)$ is the $1 \times N$ channel vector, W is the $N \times 1$ weighting vector and r, x, n, γ represent received signal, transmitted signal, additive white Gaussian noise and input SNR, respectively. In order to obtain downlink channel vector H, we need to define downlink pilot signals identifying array elements. Equation (3) represents the instantaneous SNR of the received signal at the MSS.

$$SNR = \gamma\left(W^{H} R W\right),\ R = H^{H} H \tag{3}$$

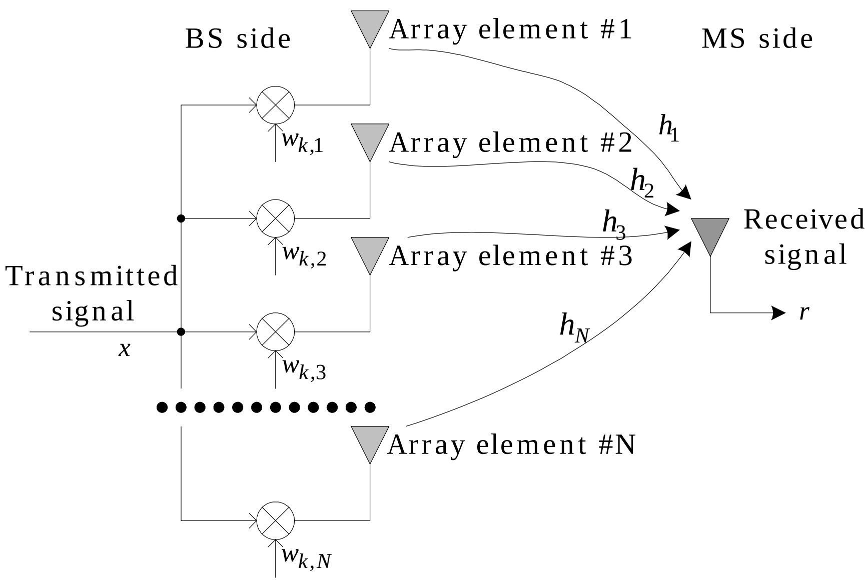

Fig. 1. Linear array antenna for switched beam forming.

Using the estimation channel and the preset K weighting vectors, the MSS can select the beam, which shall maximize the received SNR at the MSS side. A selection criterion is such that the MSS estimates the SNR for each weighting vector using (4) and finds the best one, which gives the best SNR.

$$BeamIndex = \arg\max_{k}\left\{\gamma\left(W_k^{H} R_L^{i} W_k\right)\right\},\ R_L^{i} = \rho R_L^{i-1} + (1-\rho) R^{i} \tag{4}$$

The R^i and ρ in (4) represent the i th calculated $H^H H$ in the time sequence and an averaging parameter, respectively. And the selected switched beam index at the MSS shall be informed to the BS using the feedback channel. Note that the pilot signals to measure downlink channels are commonly used by MSSs.

3. Advantages

Followings are the advantages of this algorithm:

- In the DOA based algorithm there is a limitation to assign enough power to uplink signal for reliable DOA measurement because MSS is powered by battery. On the other hand in this algorithm BS can assign enough power to downlink pilot signals for the MSS to measure downlink channel vector.
- Since the downlink channel estimation takes into account the discrepancies associated with each antenna element, the proposed switched beam selection algorithm does not need BS array transmitter calibration.
- In the conventional downlink switched beam algorithms, the BS is responsible for selecting the appropriate downlink beam for each target MSS based on such uplink signal measurements as DOA and RSSI. But in the proposed algorithm every MSS selects the downlink switched beam based on the channel measurement using the common downlink pilot signal. So the proposed algorithm needs not to assign individual bandwidths in the uplink to MSSs for the dedicated measurements of DOA and RSSI

4. Specific text changes

In order to estimate downlink channel and identify array element, BPSK modulated Hadamard sequence shall be transmitted using the assigned AMC subchannel.

The Hardamard sequences are obtained as the rows in a matrix H_k constructed recursively by:

$$H_0 = (1),\ H_k = \begin{pmatrix} H_{k-1} & H_{k-1} \\ H_{k-1} & -H_{k-1} \end{pmatrix},\ k \geq 1. \tag{5}$$

The rows are numbered from the top starting with row 0 (the all ones sequence). The n th array element shall transmit the n th row Hadamard sequence, denoted by $H_k(n)$. For a given k the number of defined Hardmard sequences are 2^k. So, for a N element array antenna, the number k should be defined in such a way that $N \leq 2^k$.

The Hadamard sequence mapping to subcarriers shall be performed in such a way that the corresponding sequence shall occupy the consecutive bins in the frequency domain first and if the remainder of the bins of the first OFDM symbol still can occupy the sequence, then the same sequence shall occupy it repeatedly. Continue the mapping such that the OFDM symbol index of the AMC subchannel is increased. Fig. 2 and 3 are the examples of sequence mapping to AMC subchannel.

If the AMC subchannel is defined by 3 bins over 2 OFDM symbols and for a Hadamard matrix H_3, the n th antenna element shall transmit the sequence $H_3(n)$ as in Fig. 2.

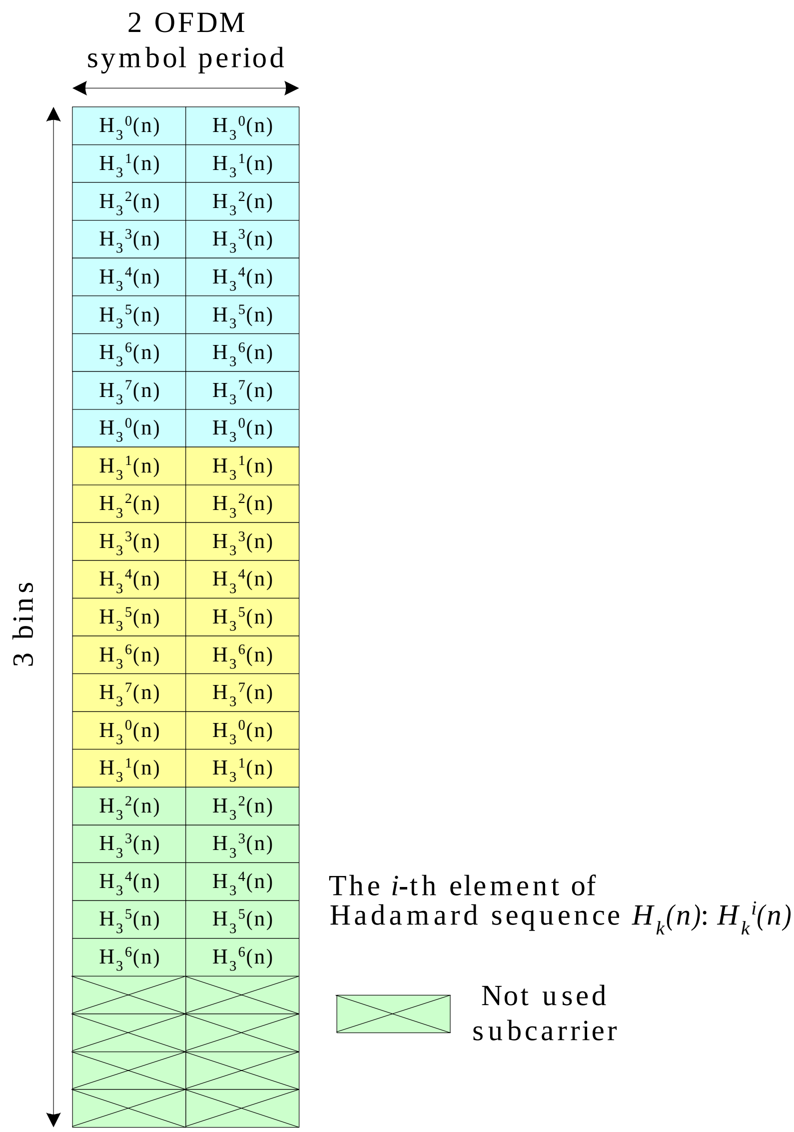

Fig. 2. n th antenna pilot transmission on the AMC subchannel of 3 bins over 2 OFDM symbols when k=3.

If the AMC subchannel is defined by 2 bins over 3 OFDM symbols and for a Hadamard matrix H_4, the n th antenna element shall transmit the sequence $H_4(n)$ as in Fig. 3.

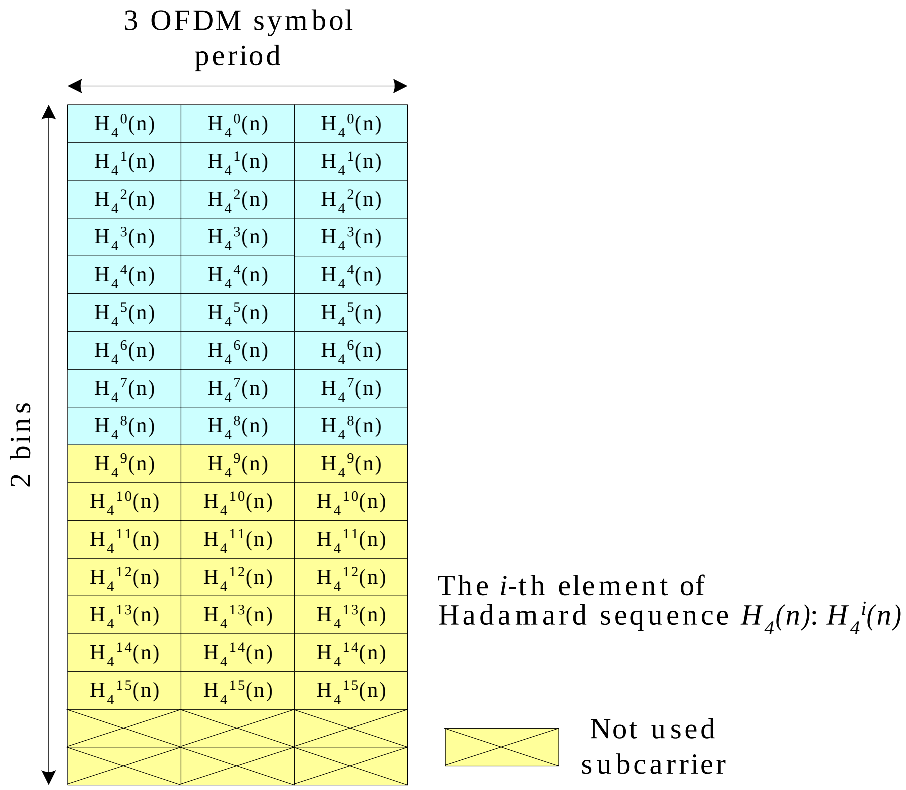

Fig. 3. n th antenna pilot transmission on the AMC subchannel of 2 bins over 3 OFDM symbols when k=4.

Make section 8.4.5.3.12 and insert the following text

8.4.5.3.12 Downlink Switched Beam Support IE (optional)

An extended IE with an extended DIUC value of x is issued by the BS to assign AMC subchannels to transmit the Harамard sequences to measure the downlink channels and identify array antenna elements.

Table xxx – SBF_DL_Support_IE format

Syntax	Size	Scope
SBF_DL_Support_IE() {		
Extended DIUC	4 bits	
Length		
Number BS array elements		Number of array elements constituting the array antenna

Number of Hadamard sequences		This field identifies the subscript k of H_k. The Hardamard sequences are obtained as the rows in a matrix H_k constructed recursively by: $H_0 = (1)$, $H_k = \begin{pmatrix} H_{k-1} & H_{k-1} \\ H_{k-1} & -H_{k-1} \end{pmatrix}$, $k \geq 1$. The rows are numbered from the top starting with row 0 (the all ones sequence). The nth array element shall transmit the nth row Hadamard sequence, denoted by $H_k(n)$. For a given k the number of defined Hardmard sequences are 2^k. So, for a N element array antenna, the number k should be defined in such a way that $N \leq 2^k$. The Hadamard sequence mapping to subcarriers is performed such a way that the sequence occupies the consecutive bins first in the frequency domain and if the remainder of the bins of the first OFDM symbol still can occupy the sequence, then the same sequence occupies it repeatedly. Continue the mapping such that the OFDM symbol index of the AMC subchannel is increased.
Number of preset switched beams		Number of switched beams in this sector
AMC subchannel assignment		Bit-mapped AMC subchannel assignment. MSB means the AMC subchannel number 0. The 2nd MSB means the AMC subchannel number 1. …. Bit=1: Corresponding AMC subchannel is assigned to transmit Hadamard sequence. Bit=0: Corresponding AMC subchannel is not assigned to transmit Hadamard sequence.
}		

Make section 11.8.3.7.12 and insert the text

11.8.3.7.12 Downlink Switched Beam Forming Support

The MSS can notify the best switched beam index and the AMC subchannel number on which it measured the downlink channel to evaluate the beam.

Type	Length	Value	Scope
xxx	2	Bits#0-7:Request beam index by MSS Bits#8-15: Used AMC subchannel#	REG-REQ

Make section 6.3.2.3.9 and insert the following two MAC management messages, switched beam index request

6.3.2.3.9 Switched Beam Index Request (SBI-REQ) message

A SBI-REQ shall be transmitted by a BS in the form shown in Table xx.

Table xxx – SBI-REQ message format

Syntax	Size	Notes
SBI_REQ_Message_Format() {		
Management Message Type =	8 bits	
}		

Make section 6.3.2.3.10 and insert the following two MAC management messages, switched beam index r esponse

6.3.2.3.10 Switched Beam Index Response (SBI-RSP) message

A SBI-RSP shall be transmitted by the MSS in response to received SBI-REQ.

Table xxx – SBI-RSP message format

Syntax	Size	Notes
SBI_RSP_Message_Format() {		
Management Message Type =	8 bits	
Beam index	8 bits	Downlink switched beam index determined by MSS
AMC subchannel number	8 bits	AMC subchannel number on which MSS measured the do wnlink channel to evaluate the best switched beam
}		