IEEE P802.22 Wireless RANs

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| MIMO Text for the Std.802.22b Standard |
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Abstract

This document provides text referent to transmit diversity in MIMO systems, considered in 802.22b standard.

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X. Multiple-input, multiple-output (MIMO)

X.1. MIMO channel estimation and synchronization

TBD

X.1.1. MIMO pilot allocation

X.1.1.1. Pilot allocation for 2 antennas

TBD

X.1.1.2. Pilot allocation for 4 antennas

TBD

X.2. Spatial Diversity/Multiplexing/Beam-Forming/Relaying

X.2.1. Space Time Coding (STC)

X.2.1.1. Transmit diversity using 2 antennas (Alamouti O-STBC)

TBD

X.2.1.2. Transmit Diversity with Array-Interference Gain

The technique disclosed in this subsection is full rate based on array-interference constructive aggregation. Its objective is to improve the link reliability over conventional transmit diversity, i.e., Space-Time Block Codes (STBC). This technique intentionally creates aligned array interference so as to exploit its energy in the form of added array gain. As a result, the overall gain (diversity gain + array gain) reduces the bit-error probability (BEP) as compared to the diversity gain only yielded by conventional STBC [1], [2] based systems.

X.2.1.2.1. Transmit Diversity with Array-Interference Gain for 2 antennas

In this subsection we describe the structure of a 2 transmit (TX) antennas (nt = 2) transmit diversity TDD system exploiting transmit array interference. Since the system is based on TDD, both transmitter and receiver operate in the same frequency channel, however, in different time-slots. In addition, in a communication system, transmitter and receiver alternate their roles, i.e., the transmitter in time “Tn” is the receiver in the consecutive time “Tn+1”. A direct consequence of the aforementioned, is that both transmitter and receiver can estimate the wireless channel **H** during the time in each they are acting as receiver.

The vector **H** = [h1 h2] represents the multiple-input-single-output (MISO) channel between the base station and the single antennae receiver (RX) white space device.In the analyses presented hereafter, **H** is considered to be quasi-static.

Symbols vectors are transmitted through **H** and noise is added at the receiver as shown in Fig. 1. The transmitter is composed of two blocks, namely, ‘array gain maximization’ and ‘transmit vector selector’. On the other hand, the receiver is composed of the blocks “channel estimator”, “combiner”, “array gain maximization” and “ML detection” in order to recover the transmitted symbols, however, with array-interference gain. The aforementioned blocks are described in the following subsections.

In 2 TX antennas systems, a total of two unique transmit vectors Gm, for *m* ∈ {0,1} exists. As it will be explained in the following, each Gm yields a single interference, which is aligned to the original signal thus inproving system robustness towards fading. The total interference has componets coming from all antennas in the array thus it is hereafter called aligned array interference IAm. It should be noted that IAm, where *m* ∈ {0,1}, are functions of the fading channel **H**, and both TX and RX can estimate **H** due to the duality of up-link/down-link. Consequently, IAm can be calculated beforehand and stored in RX device memory.



**Figure 1.** Transmit Diversity with Array-Interference Gain for 2 TX Antennas.

The ‘channel estimator’ block performs channel estimation based on pilots. The estimation is then provided to the ‘combiner’ block and the ‘array gain maximization’ block.

Both “Array Gain Maximization” blocks in TX and RX, perform



in order to compare all the IAm and selects the one that has the maximum value.

Following, the “array gain maximization” block at the transmitter sends *m* inherent to the maximum array interference to the “transmit vector selector” block, which selects Gm to be transmitted over the channel **H** since Gm will yield the maximum array gain. In addition, “the array gain maximization” block at the receiver sends the index *m*, in binary, to the ‘combiner’ block, which is collocated in the same RX device. For instance, if *m* = ‘1’, the ‘combiner’ block will utilize the weight *w1*, when it receives the signal from TX.

The ‘combiner block’ provides symbol estimate to the ‘maximum likelihood (ML) detector’ block.

##### Array Gain Maximization Block

In the array gain maximization block, the array interference IAm is stored as a function of **H.**

* Array Interference IA0



* Array Interference IA1

In order to select the most aligned interference, the ‘array gain maximization’ block performs



The ‘array gain maximization’ block at the TX directly sends *m* to the collocated ‘transmit vector selector’ while the ‘array gain maximization’ block at the receiver sends *m* to the collocated ‘combiner block’. For the following implementation examples co nsider that *m* is represented by 3 bits.

##### Transmit Vector Selector Block

* Transmit if *m* is ‘000’;

* Transmit if *m* is ‘001’;


##### Combiner Block

Let and denotes transpose operation and *n*, the zero-mean additive white Gaussian noise (AWGN).

* If the ‘combiner’ block receives *m = 000* from the ‘array gain maximization’ block, the received signal is

.

The combiner, then, utilizes



for the combination. However, for the specific case of m = 000, multiplying vector *wm* is not necessary and left here for illustration purposes only. The ‘combiner’ block performs the following combination,

,

which is, then, passed to the MML detector to perform the symbol estimation.

* If the ‘combiner’ block receives m = 001, then,

The combiner, then, utilizes

yielding,

This is, then, passed to the MML detector to perform the symbol estimation.

X.2.1.1.2.2. Transmit Diversity with Array-Interference Gain for 4 antennas

##### Array Gain Maximization Block

In the case of 4 TX antennas, there are eight unique Gm together with their respective IAm as well as *wm*, m ∈ {0,1,2,3,4,5,6,7}.

In order to select the most aligned interference, the ‘array gain maximization’ block performs,

The ‘array gain maximization’ block at the transmitter sends *m* to the ‘transmit vector selector’ block collocated at the transmitter while the ‘array gain maximization’ block at the receiver sends *m* to the ‘combiner’ block collocated at the receiver.

##### Transmit Vector Selector Block

* Transmit if *m* is ‘000’;

* Transmit if *m* is ‘001’;

* Transmit if *m* is ‘010’;

* Transmit  if *m* is ‘011’;
* Transmit if *m* is ‘100’;

* Transmit if m is ‘101’;

* Transmit if *m* is ‘110’;

* Transmit if *m* is ‘111’;


##### Combiner Block

##### Letand for the sake of simplicity in the example, the channel estimation be perfect, i.e., .

* If the ‘combiner’ block receives m = 000 from the ‘array gain maximization’ block, it utilizes

to perform the combination





which is, then, passed to the MML detector to perform the symbol estimation.

* If the ‘combiner’ block receives m = 001 from the ‘array gain maximization’ block, it utilizes

and performs the following combination,



which is, then, passed to the MML detector to perform the symbol estimation.

* If the ‘combiner’ block receives m = 010 from the ‘array gain maximization’ block, it utilizes

and performs the following combination,



which is, then, passed to the MML detector to perform the symbol estimation.

* If the ‘combiner’ block receives m = 011 from the ‘array gain maximization’ block, it utilizes

and performs the following combination,





which is, then, passed to the MML detector to perform the symbol estimation.

* If the ‘combiner’ block receives m = 100 from the ‘array gain maximization’ block, it utilizes

and performs the following combination,



which is, then, passed to the MML detector to perform the symbol estimation.

* If the ‘combiner’ block receives m = 101 from the ‘array gain maximization’ block, it utilizes

and performs the following combination,



which is, then, passed to the MML detector to perform the symbol estimation.

* If the ‘combiner’ block receives m = 110 from the ‘array gain maximization’ block, it utilizes

and performs the following combination,



which is, then, passed to the MML detector to perform the symbol estimation.

* If the ‘combiner’ block receives m = 111 from the ‘array gain maximization’ block, it utilizes

and performs the following combination,



which is, then, passed to the MML detector to perform the symbol estimation.

The above procedure describes how to obtain diversity added with array gain for systems with multiple antennas at the transmitter, however, with single antenna at the receiver. Bellow, extension to system configuration consisting of multiple receiving antennas is presented.

If more than one antenna is available in the receiver terminal, maximum ratio combining (MRC) can be utilized to significantly enhance link reliability. For simplicity, in the following example consider that the number of antennas available at the receiver is 2. The technique, however, can be utilized for any number of receive antennas.

In order to use MRC, little modification is necessary to what has been presented. The ‘Array Gain Maximization’ block, now, performs



for 2 TX antennas, and



for 4 TX antennas. Here, IAm is the array interference in the first RX antenna, given in the previous sections and I’Am represents the array interferences in the second RX antenna. Since the channel to the second RX antenna is given by **H** = [h3 h4], for two TX antennas, and **H** = [h5 h6 h7 h8], for 4 TX antennas, I’Am becomes





or















.

The ‘array gain maximization’ block at the transmitter sends *m* to the collocated ‘transmit vector selector’ block while the ‘array gain maximization’ block at the receiver sends *m* to the collocated ‘combiner block’. The ‘combiner block’ will combine the received signal, just as described in the previous sections, in order to deliver  to the ML detector. Note that  is given in the previous sections and is given by



with y’ being the signal received by the second RX antenna and **H** = [h3 h4], for 2TX, or **H** = [h5 h6 h7 h8], for 4 TX.

The technique described above is full rate and yields full spatial diversity added to antenna array gain thus yielding better link reliability.

X.2.1.3. Spatial multiplexing using 2 antennas

TBD

X.2.1.4. Spatial multiplexing using 4 antennas

TBD

X.2.2.3. Beam-Forming

X.2.2.3.1 Beam Forming for 2 antennas

TBD

X.2.2.3.2 Beam Forming for 4 antennas

TBD

X.2.2.4. Relaying

X.2.2.4.1. Relaying for 2 antennas

TBD

X.2.2.4.2. Relaying for 4 antennas

TBD