IEEE P802.22 Wireless RANs

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| Comment Resolution: Text for Section 13.2.3.1 (Spatial Multiplexing using 2 Antennas) |
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Abstract

This document partially addresses CID#20, CID#172 referent the MIMO section of 802.22b standard. More specifically, it provides text to section 13.2.3.1 on Spatial Multiplexing using 2 antennas considered in 802.22b standard.

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**Comments:**

CID#20

Section 13.2.3 is left as TBD.

CID#172

There is no description in "13.2.3 Spatial Multiplexing".

**Resolution:**

13.2.3 Spatial Multiplexing

13.2.3.1 Spatial Multiplexing using 2 Antennas

Previous sections have described methods to improve wireless link robustness against the deleterious effects of fading. Two spatial diversity techniques were described, namely Alamouti Code and a form of transmit diversity, which exploits the antenna array interference to obtain extra diversity gain. One application example of the aforementioned techniques is link-range extension between IEEE 802.22b CPEs in order to service a wider geographical area. This is fundamental whenever the antennas of both CPEs are positioned relatively low due to the strong signal attenuation characteristic to near ground wave propagation.

This section, however, describes a highly spectral efficient technique that significantly enhances the IEEE 802.22b system throughput. Spatial multiplexing transmits independent and separately encoded signals, i.e. streams, from each transmit antenna, therefore reusing (or multiplexing) the space dimension. In IEEE 802.22b systems, enhanced data-rate enables CPEs with bandwidth-hungry applications, e.g., such as wireless video transmissions for monitoring purposes, or it can increase the density of CPEs with data-rate comparable to legacy IEEE 802.22 standard.

Let us consider the 2x2 wireless communications depicted in Fig. 1. The channel gains between the ith transmit antenna and the jth receive antenna *hj,i* is represented by the MIMO channel matrix

***H*** = $\left[\begin{matrix}h\_{1,1}&h\_{1,2}\\h\_{2,1}&h\_{2,2}\end{matrix}\right]$.

Additionally, let both transmit antennas, namely antenna one and two, be spaced at least half-wave length from each other and from which two symbols *s1* and *s2*, taken from an arbitrary complex constellation *C*, are simultaneously transmitted. Representing the transmitted symbols by the vector ***s*** *=* [*s1 s2*]*T* and the noise at the receive antennas by ***w*** = [*w1 w2*]*T*, also illustrated in Fig. 1, we can represent the received signals as

$\left[\begin{array}{c}y\_{1}\\y\_{2}\end{array}\right] $= $\left[\begin{matrix}h\_{1,1}&h\_{1,2}\\h\_{2,1}&h\_{2,2}\end{matrix}\right]∙\left[\begin{array}{c}s\_{1}\\s\_{2}\end{array}\right] $+ $\left[\begin{array}{c}w\_{1}\\w\_{2}\end{array}\right]$, **(1)**

or

***y*** *=* ***H***$∙$***s + w****.*  **(2)**

Here, *wj* is the zero-mean white complex Gaussian distributed noise with variance σ2w/2 per dimension and T denotes transpose operation.



Figure 1 - Schematic Representation of Spatial Multiplexing technique.

Spatial Multiplexing Signal Detection:

Several receiver techniques exist to obtain the estimate of the transmitted symbols $\tilde{s\_{1}}$ and $\tilde{s\_{2}}$. In this section the linear zero-forcing (ZF) method is described along with its ordered successive interference cancelation (OSIC) variant. Employing the following weight matrix,

***Z = (HHH)-1HH****,* **(3)**

the ZF method intends to cancel the interference between symbols *s1* and *s2* by

$\tilde{s}=Z y$**. (4)**

Substituting (2) and (3) into (4), yields

$\tilde{s}= $***s* + *(HHH)-1HHw****.* **(5)**

or

$\left[\begin{array}{c}\tilde{s\_{1}}\\\tilde{s\_{2}}\end{array}\right] $= $\left[\begin{array}{c}s\_{1}\\s\_{2}\end{array}\right] $+ $(H^{H}H)^{-1}H^{H}\left[\begin{array}{c}w\_{1}\\w\_{2}\end{array}\right]$ **(6)**

Obviously, perfect recovery, i.e., nulling of interference, is not achieved due to the presence of an enhanced noise component ***(HHH)-1HHw*** in (5) and (6).

For an improved bit-error-rate (BER) and packet-error-rate (PER) performance, OSIC technique successively cancels components from the received signal until one of the data streams is detected. Although this method leads to increase in complexity, it is however not significant in the face of BER and PER improvements.

From Fig. 2, it can be easily understood the principle of OSIC detection. The symbol, from a parallel stream, which is estimated first, is then subtracted from the originally received signal yielding a reduced interference signal. This reduced interference signal is used in the following stage of the OSIC detection where the other symbol will be estimated. Here, *i* refers to the estimation order which does not necessarily follows the same symbol order, i.e., *si* could be *s2*while *si+1*, *s1*. There are several criteria to select the symbol estimation order, e.g., SNIR-based order, SNR-based order, column norm-based order with the latter being adopted through this section.

In order to determine the estimation order we rewrite (1) as

$\left[\begin{array}{c}y\_{1}\\y\_{2}\end{array}\right] $= $\left[\begin{array}{c}h\_{1,1}\\h\_{2,1}\end{array}\right] s\_{1} $+ $\left[\begin{array}{c}h\_{1,2}\\h\_{2,2}\end{array}\right] s\_{2}+\left[\begin{array}{c}w\_{1}\\w\_{2}\end{array}\right]$. **(7)**



Figure 2 - Schematic diagram of SM detection based on OSIC technique.

From (7) it is clear that symbols *s1* and *s2* have their magnitude affected by the norm of ||***H:,1***||and||***H:,2***||,denoting first and second columns of ***H***, respectively. It is therefore obvious to estimate the symbols according to the order of the norms of ***H***.

The first symbol *si* is estimated by the ith row of ***Z****,*

$\tilde{s}\_{i}=Z\_{i,:}$ **y**,  **(8)**

yielding

$\tilde{s}\_{i}=s\_{i}+Z\_{i,:} w$,  **(9)**

which is then mapped to the possible transmitted symbol from the constellation *C* with the closest Euclidian distance to it.

Once the first estimation occurs, the mapped $\tilde{s}\_{i}$ is then used in the next stage to estimate $\tilde{s}\_{i+1}$,

$\tilde{y}\_{i}=y-H\_{:,i} \tilde{s}\_{i}$.  **(10)**

In the case that $\tilde{s}\_{i}$ is correctly estimated, mapping (10) to the symbol with closest Euclidian distance from *C* yields$\tilde{s}\_{i+1}$. For instance, consider that $\tilde{s}\_{i}= s\_{1}$ and it was correctly estimated. It can be easily seen that (10) becomes

$\tilde{y}\_{1}=\left[\begin{matrix}h\_{1,1}&h\_{1,2}\\h\_{2,1}&h\_{2,2}\end{matrix}\right]∙\left[\begin{array}{c}s\_{1}\\s\_{2}\end{array}\right] $+ $\left[\begin{array}{c}w\_{1}\\w\_{2}\end{array}\right]-\left[\begin{array}{c}h\_{1,1}\\h\_{2,1}\end{array}\right] s\_{1},$  **(11)**

yielding,

$\tilde{y}\_{1}=\left[\begin{array}{c}h\_{1,2}\\h\_{2,2}\end{array}\right] s\_{2} $+ $\left[\begin{array}{c}w\_{1}\\w\_{2}\end{array}\right].$ **(12)**

In the case that $\tilde{s}\_{i}$ is not correctly estimated, error propagation occurs thus compromising BER and PER performances.

Note that precoder-based spatial multiplexing could be employed by exploiting the channel reciprocity inherent to TDD systems. This is due to the fact that both the down-link (DL) and the up-link (UL) of TDD systems operate in the same frequency however in different time-slots and thus are highly correlated. The channel state information (CSI) can be obtained by the Tx side during (UL) transmissions.

Once CSI is known, the Tx transmits the $Ws$, where ***W*** is the NtxNs precoding matrix with Nt referring to the number of transmit antennas and Ns to the number of streams. For instance, for the 2x2 SM-MIMO with zero-forcing considered above, **W = αH-1**,

$α=\left(\frac{N\_{t}}{Tr(H^{-1}(H^{-1})^{H})}\right)^{1/2}$ , (9)

due to Tx power constraints and where *Tr* represents the trace of $\left(H^{-1}(H^{-1})^{H}\right).$

After dividing the received signal **α,**  it then becomes

$y=\frac{1}{α}(HWs+n)$ **(10)**

or

$y=s+\frac{1}{α}n.$ **(11)**