SIR ESTIMATION FOR CLOSED LOOP POWER CONTROL WITH SPACE TIME TRANSMIT DIVERSITY IN WCDMA FDD DOWNLINK

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Abstract - In this paper the SIR estimation for fast closed loop power control (CLPC) of WCDMA FDD downlink with space time transmit diversity (STTD) is analysed. It is shown that with out STTD encoding / decoding of the DPCCH pilot symbols of the two antennas, the SIR estimation suffers from inter-antenna interference. Without modifying the DPCCH pilot patterns in the current 3GPP standard [3], near-best performance is achieved by using all the pilot symbols for signal power estimation but only the STTD decoded shaded symbols for interference estimation to avoid the inter-antenna interference.

Keywords - SIR estimation, Closed Loop Power Control (CLPC), Space Time Transmit Diversity (STTD).

I. INTRODUCTION

WCDMA (Wideband Code Division Multiple Access) based UMTS (Universal Mobile Telecommunication System) is currently being deployed and optimised. A fundamental feature of UMTS is fast closed loop power control (CLPC) which for the forward link serves primarily as a performance enhancing method at low mobile speeds when other methods such as interleaving and error correcting codes do not work quite effectively due to the slow fading. To enhance the capacity of the forward link, another method, space time transmit diversity (STTD) is quite promising due to its simplicity. Both these methods CLPC and STTD are quite important particularly at low mobile speeds. In this paper the impact of STTD on SIR estimation for CLPC is studied. In particular, we focus on the dedicated physical control channel (DPCCH) pilot patterns of the two antennas that have been specified by the 3GPP [3] and are shown in Table 1 and Table 2 for a particular length of 4 symbols. It should be noted that shaded symbols of antenna 2 are obtained by STTD encoding the corresponding shaded symbols of antenna 1.

The paper is organised as follows. SIR is defined in section II and the signal model to be used in this paper in section III. In section IV, an analysis of the SIR estimation for single antenna transmission is presented whereas in section V, the SIR estimation methods for two transmit antennas are discussed. Simulation results are shown in section VI and the paper is concluded in section VII.

Table 1
DPCCH Pilot Pattern for 1st Antenna for the Pilot Length of 4 symbols [3]

	N_{pilot} = 8 bits			
Symbol #	0	1	2	3
Slot #0	11	11	11	10
1	11	00	11	10
2	11	01	11	01
3	11	00	11	00
4	11	10	11	01
5	11	11	11	10
6	11	11	11	00
7	11	10	11	00
8	11	01	11	10
9	11	11	11	11
10	11	01	11	01
11	11	10	11	11
12	11	10	11	00
13	11	00	11	11
14	11	00	11	11

Table 2
DPCCH Pilot Pattern for 2nd Antenna for the Pilot Length of 4 symbols [3]

	N_{pilot} = 8 bits			
Symbol #	0	1	2	3
Slot #0	11	00	00	10
1	11	00	00	01
2	11	11	00	00
3	11	10	00	01
4	11	11	00	11
5	11	00	00	10
6	11	10	00	10
7	11	10	00	11
8	11	00	00	00
9	11	01	00	10
10	11	11	00	00
11	11	01	00	11
12	11	10	00	11
13	11	01	00	01
14	11	01	00	01

II. SIR DEFINITION

Conventionally the SIR is defined as (see e.g. [1] and [2])

$$\mathrm{SIR} = \frac{E^2[\mathbf{X}]}{\mathrm{var}[\mathbf{X}]} = \frac{\left|\overline{\mathbf{X}}\right|^2}{E\left|\mathbf{X} - \overline{\mathbf{X}}\right|^2} = \frac{\left|\overline{\mathbf{X}}\right|^2}{E\left|\mathbf{X}^2\right| - \left|\overline{\mathbf{X}}\right|^2}, \ \overline{\mathbf{X}} = E[\mathbf{X}] \tag{1}$$

where $\mathbf{X}$ represents the received signal consisting of pilot symbols plus noise. For practical purposes, the statistical expectations can be replaced by arithmetic ones to get

$$\mathrm{SIR} = \frac{\left|\overline{x}\right|^2}{\frac{1}{M}\sum_{i=0}^{M-1}\left|x_i - \overline{x}\right|^2} \text{ where } \overline{x} = \frac{1}{M}\sum_{i=0}^{M-1} x_i \tag{2}$$

$$\mathrm{SIR} = \frac{\left|\frac{1}{M}\sum_{i=0}^{M-1} x_i\right|^2}{\frac{1}{M}\sum_{i=0}^{M-1} x_i^2 - \left|\frac{1}{M}\sum_{i=0}^{M-1} x_i\right|^2} \tag{3}$$

where x_i is the despread and phase compensated pilot symbol and M is the number of pilot symbols. We call this definition as conventional definition of SIR estimation.

III. SIGNAL MODEL

Complex baseband signal representation is used throughout this paper. Let the pilot patterns for the two antennas for the k-th slot be

$\underline{p}_k^{(1)} = \left(p_{1,k}^{(1)}, ..., p_{M,k}^{(1)}\right)^T$ and $\underline{p}_k^{(2)} = \left(p_{1,k}^{(2)}, ..., p_{M,k}^{(2)}\right)^T$. The two pilot patterns are assumed to be orthogonal and having the same squared norm, i.e.

$$\underline{p}_k^{(1)^H}\,\underline{p}_k^{(2)} = \underline{p}_k^{(2)^H}\,\underline{p}_k^{(1)} = 0 \tag{4}$$

$$\left|p_{i,k}^{(1)}\right|^2 = \left|p_{i,k}^{(2)}\right|^2 = \left|p_{i,k}\right|^2 \tag{5}$$

The received pilot signal after the despreader for the l-th Rake Finger and k-th slot can be written as

$$\underline{r}_{l,k} = \left(r_{1,l,k}, ..., r_{M,l,k}\right)^T \text{ where} \tag{6}$$

$$r_{i,l,k} = \sqrt{E_s/2}\left(p_{i,k}^{(1)} h_{i,l,k}^{(1)} + p_{i,k}^{(2)} h_{i,l,k}^{(2)}\right) + n_{i,l,k} \tag{7}$$

where $h_{i,l,k}^{(1)}$ and $h_{i,l,k}^{(2)}$ are the complex fading coefficients associated with the signal from the 1st and 2nd transmit antenna, respectively, for the l-th path, i-th symbol and kth slot. The symbol $n_{i,l,k}$ represents AWGN plus interference.

IV. SINGLE ANTENNA TRANSMISSION (NO STTD)

First, we analyse the case when there is only one transmit antenna. For this case, Eq. (7) reduces to

$$r_{i,l,k} = \sqrt{E_s}\, p_{i,k}^{(1)} h_{i,l,k}^{(1)} + n_{i,l,k} \tag{8}$$

Now SIR is calculated as follows

$$\mathrm{SIR} = \frac{S_k}{\overline{I}_k} = \frac{\left|\overline{s}_k\right|^2}{\overline{I}_k} \text{ where} \tag{9}$$

$$\overline{s}_k = \frac{1}{M}\sum_{i=0}^{M-1}\sum_{l=0}^{L-1} r_{i,l,k}\,\hat{h}_{i,l,k}^{(1)^*}\, p_{i,k}^{(1)^*} \tag{10}$$

After putting Eq. (8) in Eq. (10) and expanding, we get

$$\overline{s}_k = \frac{1}{M}\sum_{i=0}^{M-1}\sum_{l=0}^{L-1}\sqrt{E_s}\left|p_{i,k}^{(1)}\right|^2\left|h_{i,l,k}^{(1)}\right|^2 + u_k \tag{11}$$

where u_k is the AWGN noise after linear processing and we have assumed that the channel estimate is noise free. Next the instantaneous interference is calculated as the average of the squared error of received pilot symbols.

$$I_k = \frac{1}{M}\sum_{i=0}^{M-1}\left|\sum_{l=0}^{L-1} r_{i,l,k}\,\hat{h}_{i,l,k}^{(1)^*}\, p_{i,k}^{(1)^*} - \overline{s}_k\right|^2 \tag{12}$$

By using Eq. (3) and Eq. (11), the above equation becomes

$$I_k = \frac{1}{M}\sum_{i=0}^{M-1}\left|\sum_{l=0}^{L-1}\sqrt{E_s}\left|h_{i,l,k}^{(1)}\right|^2\left|p_{i,k}^{(1)}\right|^2\right|^2 - \left|\frac{1}{M}\sum_{i=0}^{M-1}\sum_{l=0}^{L-1}\sqrt{E_s}\left|h_{i,l,k}^{(1)}\right|^2\left|p_{i,k}^{(1)}\right|^2\right|^2 + N_k \tag{13}$$

where N_k is the noise term. Expression for SIR is thus obtained by plugging Eq. (11) and Eq. (13) in Eq. (9).

The instantaneous interference estimate given by Eq. (13) can be further averaged (as is done in [1] and [2]) by using a first-order filter with forgetting factor μ (less than one) to obtain

$$\overline{I}_k = \mu\,\overline{I}_{k-1} + (1-\mu) I_k \tag{14}$$

V. TWO ANTENNA TRANSMISSION (STTD MODE)

Now, the SIR estimation performance is analysed when two transmit antennas are in STTD mode. Three cases are defined below.

A. UMTS Pilot Pattern for the 2nd Antenna without STBC Decoding the Shaded Symbols

In this scheme, the same pilot patterns for the two antennas are used that have been recommended by the 3GPP in [3] and are shown in Table 1 and Table 2 for a particular length of 4 symbols. In the following analysis, it is assumed that there is no space time block coding (STBC) relationship between the pilot patterns of the two antennas, but they are still orthogonal to each other.

The received signal is shown in Eq. (6) and Eq. (7) and the SIR expression in Eq. (9). We proceed as follows

$$\overline{s}_k = \frac{1}{M}\sum_{i=0}^{M-1}\left[\sum_{l=0}^{L-1} r_{i,l,k}\,\hat{h}_{l,k}^{(1)^*}\, p_{i,k}^{(1)^*} + \sum_{l=0}^{L-1} r_{i,l,k}\,\hat{h}_{l,k}^{(2)^*}\, p_{i,k}^{(2)^*}\right] \tag{15}$$

After putting Eq. (7) in Eq. (15) and expanding, we get

$$\overline{s}_k = \frac{1}{M}\sum_{i=0}^{M-1}\left[\sqrt{\frac{E_s}{2}}\left|p_{i,k}\right|^2\left(\sum_{l=0}^{L-1}\left|h_{l,k}^{(1)}\right|^2 + \sum_{l=0}^{L-1}\left|h_{l,k}^{(2)}\right|^2\right) + N_{i,k}\right] \tag{16}$$

where the orthogonality condition of Eq. (4) has been used and the fact that squared norm of the pilot symbols are the

same as shown in Eq. (5). It is also assumed that the channel doesn't vary over the duration of pilot symbols and hence the dependence of channel estimates on the symbol index *i* is omitted. The interference estimate is calculated as

$$I_k = \frac{1}{M}\sum_{i=0}^{M-1}\left|\left[\sum_{l=0}^{L-1} r_{i,l,k}\hat{h}_{l,k}^{(1)^*} p_{i,k}^{(1)^*} + \sum_{l=0}^{L-1} r_{i,l,k}\hat{h}_{l,k}^{(2)^*} p_{i,k}^{(2)^*}\right] - \bar{s}_k\right|^2 \quad (17)$$

By putting Eq. (7) in Eq. (17) and expanding, we get

$$I_k = \frac{1}{M}\sum_{i=0}^{M-1}\left|\sqrt{\frac{E_s}{2}}\left[\left|p_{i,k}^{(1)}\right|^2\sum_{l=0}^{L-1}\left|h_{l,k}^{(1)}\right|^2 + p_{i,k}^{(2)}p_{i,k}^{(1)^*}\left(\sum_{l=0}^{L-1} h_{l,k}^{(2)}\hat{h}_{l,k}^{(1)^*}\right)\right] + \sqrt{\frac{E_s}{2}}\left[p_{i,k}^{(1)}p_{i,k}^{(2)^*}\left(\sum_{l=0}^{L-1} h_{l,k}^{(1)}\hat{h}_{l,k}^{(2)^*}\right) + \left|p_{i,k}^{(2)}\right|^2\sum_{l=0}^{L-1}\left|h_{l,k}^{(2)}\right|^2\right] + N_{i,k}\right|^2 - \left|\bar{s}_k\right|^2 \quad (18)$$

The above equation is very important as it shows that there is inter-antenna interference in the form of cross-multiplication of the pilot patterns of the two antennas, as variance is being calculated in which first the individual terms (including the cross-multiplication of the pilot patterns from the two antennas) are squared and then added together and since

$$\frac{1}{M}\sum_{i=0}^{M-1}\left|p_{i,k}^{(2)}p_{i,k}^{(1)^*}\right|^2 \neq 0 \text{ and } \frac{1}{M}\sum_{i=0}^{M-1}\left|p_{i,k}^{(2)}p_{i,k}^{(1)^*}\right|^2 \neq 0 \quad (19)$$

i.e. the squared addition of the cross-multiplication of the pilot patterns from the two antennas is no longer zero even though they are orthogonal, therefore Eq. (18) contains extra terms due to the presence of inter-antenna interference and hence it is expected that this SIR estimation will result in the highest transmission power due to the presence of extra terms in the interference estimate. The next two sections discuss ways to overcome the above-mentioned problem.

B. STBC Coding of the Pilot Pattern of Antenna 1 to get the Pilot Pattern of Antenna 2

In this section, it is shown that by STBC coding of the pilot pattern of antenna 1 to get the pilot pattern for antenna 2, the inter-antenna interference is removed during the STBC decoding process before the SIR estimate is made and hence the SIR estimate is inter-antenna interference free. In the following analysis it is assumed that all the pilot bits of antenna 1 are STBC encoded to obtain the pilot bits of antenna 2 whereas for the 3GPP defined patterns [3], shown in Table 1 and Table 2, only the shadowed bits of the two antennas hold STBC relationship between them. Some comments on this issue will be made later on in the discussion of results.

The received signal vector is shown in Eq. (6) and Eq. (7). The consecutive symbols hold the following relationship

$$r_{i,l,k} = \sqrt{E_s/2}\left(p_{i,k}^{(1)}h_{i,l,k}^{(1)} + \left(-p_{i+1,k}^{(1)^*}\right)h_{i,l,k}^{(2)}\right) + n_{i,l,k} \quad (20)$$

$$r_{i+1,l,k} = \sqrt{E_s/2}\left(p_{i+1,k}^{(1)}h_{i,l,k}^{(1)} + p_{i,k}^{(1)^*}h_{i,l,k}^{(2)}\right) + n_{i+1,l,k} \quad (21)$$

where again the assumption is that the channel is constant over two symbols duration.

To get an estimate of the transmitted pilot symbols, usual STBC decoding is applied to get

$$\hat{p}_{i,k}^{(1)} = \sum_{l=0}^{L-1}\left(\hat{h}_{i,l,k}^{(1)^*}r_{i,l,k} + \hat{h}_{i,l,k}^{(2)}r_{i+1,l,k}^*\right) \quad (22)$$

$$\hat{p}_{i+1,k}^{(1)} = \sum_{l=0}^{L-1}\left(\hat{h}_{i,l,k}^{(1)^*}r_{i+1,l,k} - \hat{h}_{i,l,k}^{(2)}r_{i,l,k}^*\right) \quad (23)$$

By putting Eq. (20) and Eq. (21) into Eq. (22) and Eq. (23) and expanding, we get

$$\hat{p}_{i,k}^{(1)} = \sum_{l=0}^{L-1}\sqrt{E_s/2}\left(\left(\left|h_{i,l,k}^{(1)}\right|^2 + \left|h_{i,l,k}^{(2)}\right|^2\right)p_{i,k}^{(1)} + u_{i,l,k}\right) \quad (24)$$

$$\hat{p}_{i+1,k}^{(1)} = \sum_{l=0}^{L-1}\sqrt{E_s/2}\left(\left(\left|h_{i,l,k}^{(1)}\right|^2 + \left|h_{i,l,k}^{(2)}\right|^2\right)p_{i+1,k}^{(1)} + v_{i,l,k}\right) \quad (25)$$

For calculating signal power, shown in Eq. (9), we first find

$$\bar{s}_k = \frac{1}{M}\sum_{i=0}^{M-1}\hat{p}_{i,k}^{(1)}p_{i,k}^{(1)^*} \quad (26)$$

Putting Eq. (24) into Eq. (26), we get

$$\bar{s}_k = \frac{1}{M}\sum_{i=0}^{M-1}\left[\sum_{l=0}^{L-1}\sqrt{E_s/2}\left(\left(\left|h_{i,l,k}^{(1)}\right|^2 + \left|h_{i,l,k}^{(2)}\right|^2\right)\left|p_{i,k}^{(1)}\right|^2 + N_{i,l,k}\right)\right] \quad (27)$$

Next the instantaneous interference is calculated as

$$I_k = \frac{1}{M}\sum_{i=0}^{M-1}\left|\hat{p}_{i,k}^{(1)}p_{i,k}^{(1)^*} - \bar{s}_k\right|^2 \quad (28)$$

After putting Eq. (24) into Eq. (28), we get

$$I_k = \frac{1}{M}\sum_{i=0}^{M-1}\left|\sum_{l=0}^{L-1}\sqrt{E_s/2}\left(\left(\left|h_{i,l,k}^{(1)}\right|^2 + \left|h_{i,l,k}^{(2)}\right|^2\right)\left|p_{i,k}^{(1)}\right|^2 + N_{i,l,k}\right)\right|^2 - \left|\bar{s}_k\right|^2 \quad (29)$$

By comparing Eq. (29) with Eq. (18), one can see that there is no inter-antenna interference and hence this scheme is expected to provide the best performance.

C. UMTS Pilot Pattern for the 2nd Antenna with Interference Estimation only on Shaded Pilot Symbols

In *Case A*, it was pointed out that the interference estimate consists of inter-antenna interference and *Case B* showed that one doesn't get this interference if one were to STTD encode the pilot symbols of antenna 1 to get the pilot symbols of antenna 2. But the downside is that the 3GPP standard [3] needs to be changed as only the shaded pilot symbols of the two antennas hold STBC relationship between them. In this section it is shown that within the current standard, one obtains the best possible performance by STBC decoding the shaded symbols and using only them in the interference estimate. The non-shaded symbols are not used in the interference estimate as *Case A* shows they create inter-antenna interference. Nevertheless, both the shaded as well as the non-shaded symbols can be used for

signal power estimation as the averaging cancels out the undesired terms and the average signal power estimation given by *Case A* and by *Case B* shown in Eq. (16) and Eq. (24) respectively, are the same.

By finding the signal power on non-shaded symbols, one gets an expression, which is similar to Eq. (16) but with the difference that the averaging length is reduced to half, i.e.

$$\bar{s}_k^{ns} = \frac{2}{M}\sum_{i=0}^{M-1}\left[\sqrt{\frac{E_s}{2}}\left|p_{i,k}\right|^2\left(\sum_{l=0}^{L-1}\left|h_{l,k}^{(1)}\right|^2 + \sum_{l=0}^{L-1}\left|h_{l,k}^{(2)}\right|^2\right) + N_{i,k}^{n}\right] \quad (30)$$

for $i = 0,2,...$

Similarly, for finding the signal power expression on shaded symbols that are first STTD decoded, one obtains an expression similar to Eq. (27), also with the averaging length reduced to half.

$$\bar{s}_k^{sh} = \frac{2}{M}\sum_{i=0}^{M-1}\left[\sum_{l=0}^{L-1}\sqrt{E_s/2}\left(\left(\left|h_{l,k}^{(1)}\right|^2 + \left|h_{l,k}^{(2)}\right|^2\right)\left|p_{i,k}\right|^2 + N_{i,l,k}^{s}\right)\right] \quad (31)$$

for $i = 1,3,...$

Eq. (30) and Eq. (31) are averaged to get the final expression for signal power as

$$\bar{s}_k = \frac{\left(\bar{s}_k^{ns} + \bar{s}_k^{sh}\right)}{2} \quad (32)$$

$$\bar{s}_k = \frac{1}{M}\sum_{i=0}^{M-1}\left[\sqrt{\frac{E_s}{2}}\left|p_{i,k}\right|^2\left(\sum_{l=0}^{L-1}\left|h_{l,k}^{(1)}\right|^2 + \sum_{l=0}^{L-1}\left|h_{l,k}^{(2)}\right|^2\right) + N_{i,k}\right] \quad (33)$$

Thus the average signal power expression is the same as in *Case A* and *Case B*.

For finding the interference, one needs to consider only the shaded symbols that are first STTD decoded to get an expression similar to Eq. (28)

$$I_k = \frac{1}{M/2}\sum_{i=0}^{M-1}\left|\hat{p}_{i,k}^{(1)} p_{i,k}^{(1)^*} - \bar{s}_k\right|^2 \text{ for } i = 1,3,\ldots \quad (34)$$

which when expanded becomes similar to Eq. (29)

$$I_k = \frac{1}{M/2}\sum_{i=0}^{M-1}\left|\sum_{l=0}^{L-1}\sqrt{\frac{E_s}{2}}\left(\left(\left|h_{i,l,k}^{(1)}\right|^2 + \left|h_{i,l,k}^{(2)}\right|^2\right)\left|p_{i,k}^{(1)}\right|^2 + N_{i,l,k}\right)\right|^2 - \left|\bar{s}_k\right|^2 \quad (35)$$

for $i = 1,3,...$

VI. SIMULATION RESULTS

We have developed a link level simulator according to the 3GPP specifications and verified its performance by extensively comparing our results for the reference measurement channels defined in [4] with those presented before 3GPP by various companies. As an example in Table 3, we compare our results (UniS) for CLPC verification with Nokia [5], [7] and Ericsson [6], [8] for different radio channels without STTD for the 12.2 kbps reference measurement channel.

Table 3
Simulator Verification for Single Transmit Antenna

Radio Channel	BLER Target	Average Ec/Ior (Nokia)	Average Ec/Ior (Ericsson)	Average Ec/Ior (UniS)
AWGN	1e–2	-18.6 dB	-18.6 dB	-18.6 dB
Case 1	1e–2	-20.8 dB	-20.9 dB	-21.6 dB
Case 2	1e–2	-13.1 dB	-12.5 dB	-13.4 dB
Case 3	1e–2	-13.9 dB	-12.8 dB	-13.0 dB

The results show reasonably close proximity between our results and those of Nokia and Ericsson. After simulator verification, we present the comparison of different SIR estimation methods for CLPC and STTD with the simulation parameters shown in Table 4.

Table 4
Simulation Parameters

Chip Rate	3.84 Mcps
3GPP Reference Channel	12.2 kbps
Radio Channel Used	ITU Pedestrian A (3kmph)
Number of Rake Fingers	4
Channel Estimation	Ideal
No. of Samples per Chip	1
Uplink TPC Error Rate	0 %
Min. Power Limit	-35 dB (compared to CPICH)
Maximum Power Limit	9.5dB (compared to CPICH)
Power Control Step Size	1 dB
Forgetting Factor	0
Geometry Factor: $\hat{I}_{or} / I_{oc}$	3 dB
Downlink Physical Channels & Power Levels	CPICH_Ec/Ior = -10 dB DPCH_Ec/Ior = varies due to power control OCNS_Ec/Ior = power needed to make Ior = 1

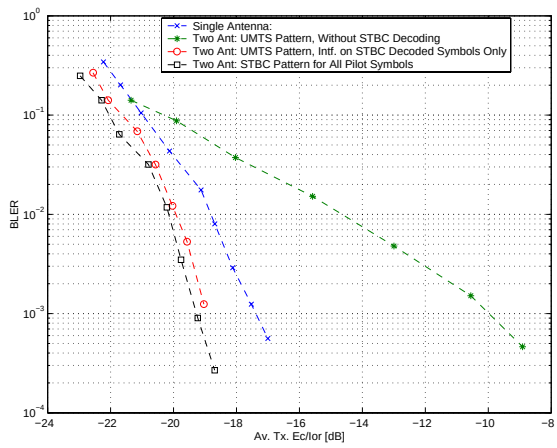

Fig. 1. BLER versus Average Transmit Ec/Ior

Figure 1 reveals that *Case A* results in the highest average transmission power. In fact at BLER of 1e-3 this scheme transmits about 7.5 dB more power than the single antenna case. Best performance (about 1.5 dB as compared to the single antenna at BLER of 1e-3) is achieved by *Case B* where STBC pilot pattern is used for the two antennas. Near-best performance is achieved by *Case C* that is using all the pilot symbols for signal power estimation but only the shaded ones for interference estimation.

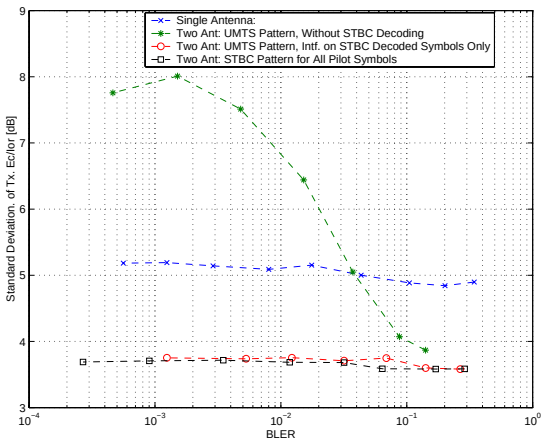

Fig. 2. Standard Deviation of Transmit Ec/Ior versus BLER

Figure 2 illustrates the standard deviation of the transmit power with respect to BLER and it is clear that both schemes *Case B* and *Case C* provide the lowest standard deviation values of the transmit power than those for the single antenna and *Case A.*

Although the results suggest that within the current 3GPP standard [3], SIR estimation scheme *Case C* performs very close to *Case B* but in *Case C* one has to deal with the non-shaded and shaded symbols differently and the interference is estimated only on shaded symbols. Current pilot patterns in the 3GPP come from a proposal by LG in [9] and the emphasis on the design of pilot patterns was on shaded symbols that act as frame synchronization words (FSW) for confirming the frame synchronization. The FSWs have the auto-correlation function of lowest out-of-phase coefficient and the lowest magnitude of cross-correlation function with minus peak value at middle shift as illustrated in [9]. The two correlation functions allow to double check frame synchronization at zero and middle shifts. The non-shaded pilot symbols of antenna 1 was chosen to be all "11" and a corresponding orthogonal pattern was chosen for antenna 2. It is easy to verify that if we do the STTD encoding of the non-shaded pilot symbols of antenna 1 to obtain the non-shaded symbols of antenna 2 like in shaded symbols, it'll not have any adverse effect on frame synchronization confirmation. Hence the pilot patterns for non-shaded symbols for the 2nd antenna could be modified by 3GPP that will allow to have a straightforward SIR estimation with slightly better performance.

VII. CONCLUSION

In this paper an analysis of the SIR estimation methods for the CLPC with STTD has been presented. It is shown that if one does not STBC decode the shaded symbols and use all the received pilot symbols for SIR estimation, the performance degrades due to inter-antenna interference. This problem can be avoided by if the pilot symbols of the two antennas hold STBC relationship between them. The results show that with in the current standard [3], near best performance is achieved when the interference is estimated only on the shaded symbols that are first STTD decoded. For signal power estimation all pilot symbols can be used.

ACKNOWLEDGEMENTS

The authors would like to thank Nicola Binucci of Hutchison 3G, UK for pointing our attention towards this problem and for useful discussions and comments.

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