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Source(s)	Ran Yaniv, Tal Kaitz, Danny Stopler **Alvarion Ltd.**

ran.yaniv@alvarion.com
tal.kaitz@alvarion.com
danny.stopler@alvarion.com

Re:	Call for comments, maintenance task group
Abstract	
Purpose	
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Corrections to CINR and RSSI measurements in OFDMA PHY

Ran Yaniv, Tal Kaitz, Danny Stopler

Alvarion Ltd.

1 Problem Statement

There are several problems with the description of CINR and RSSI measurements and reporting:

1. The text does not specify to what the CINR measurement relates. Measurements on the preamble, on pilots, and even on data subcarriers of different zones, will result in totally different values due to varying boosting levels, cell loading, and reuse factor. Further, when adaptive beamforming is employed, CINR measurements will vary greatly depending on the subchannel used for measurement (due to different beamforming on different subchannels).

   The BS should specify the unique zone (by means of zone type and PRBS_ID in order to differentiate between multiple zones), and subset of major groups (for PUSC reuse-1 zone) on which the SS shall measure CINR. Specifying the subset of major groups is important for sub-sectorized reuse-1 deployments.

2. The text states that CINR is measured on “messages”. It is not clear to which “messages” the text refers, as the SS is not required to decode or be aware of all messages in the frame.

3. Further, the time scale of the message time indices is not defined; as a result, the averaging parameter has no meaning.

4. The CINR report should reflect the channel conditions and SS implementation losses as much as possible, and in some ways should be seen as a soft metric for MCS selection. The text does not specify whether the reported CINR includes implementation losses or corrections due to channel conditions.

5. The text should specify that the CINR measurement should refer to non-boosted data subcarriers; hence the boost level of the preamble and pilots should be compensated for. One possible method for separating the noise from interference is shown in Appendix A.

6. It is not clear whether the averaging factor alpha applies to measurements reported through CQICH. We think that separate averaging factors should be specified for REP-RSP and for CQICH, for the following reason: While CQICH periodic reports continue, a BS may request a one-time CINR measurement through REP-RSP that

relates to a different zone and for a different purpose. This implies that the averaging factor specified for the REP-RSP should not affect the averaging factor used for periodic CQICH measurements.

In addition, the averaging factor is limited to the range 1/32…1/2 which does not permit instantaneous CINR measurement (important for H-ARQ schemes).

7. CINR estimates derived for CQICH should be kept distinct from reports triggered by REP-REQ/RSP. For example, we would want the ability to configure the CQICH to periodically report CINR on a specific zone, while triggering a one-time measurement on a different zone.

2 Detailed Text Changes

[Add the following text the end of section 6.3.2.2.6]

When the feedback type is '00', and no CINR type parameters were provided by a previous CQICH IE, the reported CINR estimate shall correspond to the first zone in the frame. Otherwise, the CINR type parameters provided by a previous CQICH IE shall be used.

[Modify section 6.3.17.4, page 51, beginning line 45, as follows]

6.3.~~17.4~~.18 ~~CQICH Operations~~ CINR Report Operation

[Add the following text before the 1st paragraph]

This section applies to OFDMA mode only. The SS transmits CINR reports using the REP-RSP MAC message or the fast-feedback (CQICH) channel. CINR measurement can be performed on the preamble or on a permutation zone. CINR measurement for a permutation zone can be done with pilots or data subcarriers. The SS shall implement at least one measurement scheme and negotiate its capability (refer to 11.8.3.7).

6.3.18.1 CINR report with REP-RSP MAC message

The REP-RSP message shall be sent by the SS in response to a REP-REQ message from the BS to report DL CINR estimation. Additionally, an SS can send an unsolicited REP-RSP to report the estimation of DL CINR.

REP-REQ indicates where the CINR measurement shall be performed: preamble or a specific permutation zone. For the measurement from the preamble, BS can request SS to report the CINR estimate from the preamble for the different frequency reuse factors or band AMC CINR. For the measurement from the specific permutation zones, the REP-REQ indicates the CINR type configuration, which includes the zone for which the CINR is to be estimated. The zone is identified by its type (PUSC with 'use all SC=0', PUSC with 'use all SC=1', FUSC, Optional FUSC, AMC AAS zone, Safety channel), and PRBS ID. The SS shall not measure CINR in a frame in which the specified zone does not exist, and shall retain the previous measurement. The BS shall not request a CINR report on a zone type that is not

supported by the SS. For PUSC permutation zones , the SS may be instructed to report CINR estimate for only a subset of the major groups. The SS may send a REP-RSP message in an unsolicited fashion. In such a case, the reported CINR shall correspond to the CINR type as instructed in the latest REP-REQ message sent by the BS.

[All existing text within 6.3.17.4 should go under the following title (6.3.18.2)]

6.3.18.2 CINR report with Fast Feedback (CQICH) channel

[Modify the first paragraph following 6.3.17.4 as follows]

This section describes the operation scenarios and requirements of CQICH fast-feedback.~~, which is designed for H-ARQ enabled SS. After an SS turns on its power, the only appropriate subchannels that can be allocated to the MSS are normal subchannels. To determine the M/C level of normal subchannels, the average CINR measurement is enough for the BS to determine the M/C levels of uplink and downlink.~~ As soon as the BS and the SS know the capabilities of both entities modulation and coding, the BS may allocate a CQICH subchannel using a CQICH IE (CQICH Allocation IE or CQICH Control IE). CQICH IE may indicate on what portion of the signal the CINR measurement shall be performed: preamble or a specific permutation zone. For measurement from the preamble, BS can request SS to report the CINR estimate from the preamble for the different frequency reuse configurations. For the measurement from the specific permutation zones, the CQICH IE indicates the CINR type configuration, which includes the zone for which the CINR is to be estimated. The zone is identified by its type (PUSC with 'use all SC=0', PUSC with 'use all SC=1', AMC AAS zone, FUSC, Optional FUSC, Safety channel), and PRBS ID. The SS shall not measure CINR in a frame in which the specified zone does not exist, and shall retain the previous measurement. The BS shall not request a CINR report on a zone type that is not supported by the SS. For PUSC permutation zones , the SS may be instructed to report CINR estimate for only a subset of the major groups. For the differential CINR report of Band AMC mode, a separate procedure is defined for the report configuration change. The first CQICH IE sent to the SS shall indicate the CINR report type configuration. Only a subsequent CQICH IE may update the CINR report type configuration for CQI channel based reports. See sections 8.4.5.4.12 and 8.4.11 for details. ~~Then, the MSS reports the average CINR of the BS preamble. From then on, the BS is able to determine the M/C level.~~ The CINR measurement encoding and quantization onto the Fast-Feedback channel is defined in section 8.4.5.4.10. ~~A CINR measurement is quantized into 16 levels and encoded into 4 information bits.~~

[Add the following entries to table 300, immediately following the 'Duration' entry]

Syntax	Size	Notes
…		
CINR type included	1 bit	
If (CINR type included == 1) {		
CINR type	1 bit	0: CINR measurement from preamble 1: CINR measurement from permutation zones (refer to 8.4.11.3)
If (CINR type=0) {		
Preamble report type	1 bit	The report type of CINR estimate measured from preamble 0b 0 – Frequency reuse factor=1 configuration. 0b 1 – Frequency reuse factor=3 configuration.

else {		
Report type	1 bit	0: CINR measurement from pilot subcarriers (refer to 8.4.11.3) 1: CINR measurement from data subcarriers (refer to 8.4.11.3)
Zone type	3 bits	The type of zone over which CINR is to be reported 0b 000 – PUSC with 'use all SC = 0' 0b 001 – PUSC with 'use all SC = 1' / PUSC AAS zone 0b 010 – FUSC 0b 011 – Optional FUSC 0b 100 – Safety Channel region 0b 101 – AMC AAS zone 0b 110-111 – Reserved
Zone PRBS_ID	2 bits	The PRBS_ID of the zone over which CINR is to be reported
If (Zone type == 0b000 or 0b001) {		
Major group indication	1 bit	If '0' then CINR report may refer to any subchannel in the PUSC zone.
If (Major group indication == 1) {		
PUSC Major group bitmap	6 bits	Reported CINR shall only be estimated for the subchannels of PUSC major groups for which the corresponding bit is set. Bit #*k* refers to major group *k*.
}		
}		
}		
}		
Averaging parameter included	1 bit	
If (Averaging parameter included == 1) {		
Averaging parameter	4 bits	Averaging parameter α_{avg} used for deriving CINR estimates reported through CQICH.
}		
Padding	Var	Number of bits required to align to byte length

[Add the following text to page 112, line 8]

CINR type included

Indicates whether an update to the CQI report configuration exists in the IE. A value of '0' indicates that the SS shall perform CINR measurements using the latest received CQI configuration.

CINR type

Indicates where the CQI report shall be measured. SS can measure the estimation of the CINR from the preamble ('0') or the permutation zone indicated ('1').

Averaging parameter included

Indicate whether a new averaging parameter α_{avg} exists in the IE. A value of '0' indicates that the SS shall perform CINR measurements using the latest received averaging parameter.

[Modify the text in section 8.4.11.3 as follows]

When CINR measurements are mandated by the BS, an SS shall obtain a CINR measurement (implementation-specific). From a succession of these measurements, the SS shall derive and update estimates of the mean and/or the standard deviation of the CINR, and report them via REP-RSP messages and/or report the estimate of the mean of the CINR via the fast-feedback channel (CQICH).

Mean and standard deviation statistics for CINR shall be reported in units of dB. To prepare such reports, statistics shall be quantized in 1 dB increments, ranging from a minimum of –10 dB (encoded 0x00) to a maximum of 53 dB (encoded 0x3F). Values outside this range shall be assigned the closest extreme value within the scale.

The method used to estimate the CINR of a single message is left to individual implementation, but the relative and absolute accuracy of a CINR measurement derived from a single message shall be ±1 dB and ±2 dB, respectively. The specified accuracy shall apply to the range of CINR values starting from 3 dB below SNR of the most robust rate, to 10 dB above the SNR of the least robust rate. See Table 336. In addition, the range over which these single-packet measurements are measured should extend 3 dB on each side beyond the –10 dB to 53 dB limits for the final reported, averaged statistics.

If CINR report from the preamble was instructed by CQICH IE or by the REP-RSP message, then the reported CINR shall be an estimate of the CINR over the subcarriers of the preamble. For the frequency reuse configuration=3 type, the reported CINR shall be the estimate of the CINR over the modulated subcarriers of the preamble. For the frequency reuse configuration=1, the reported CINR shall be the estimate of the CINR over all subcarriers of the preamble. In other words, the signal on the unmodulated subcarriers shall also be considered as noise and interference for the CINR estimate of the frequency reuse configuration=1. The reported value shall represent the CINR on non-boosted data subcarriers of the first zone in the frame; hence preamble boosting shall be compensated for in both desired signal and interference + noise calculation.

In case CINR report on specific permutation zone was instructed, then the reported CINR shall be an estimate of the average CINR over the pilot or data subcarriers of the zone as instructed by the CQICH IE or by the REP-RSP message. The reported value shall represent the CINR on non-boosted data subcarriers of the zone on which measurement was requested; hence pilot boosting shall be compensated for in both desired signal and interference + noise calculation. If the BS instructs CINR reporting on an AAS zone with AMC permutation, then the SS shall report the estimate of the CINR on pilot or data subcarriers that belong to slots allocated to it.

The SS shall add all implementation losses to the CINR measurement, so that if the reported value is higher or equal to a CINR value appearing in table XXX (‘Normalized CINR per MCS’) then the SS is able to successfully decode data in the respective modulation and coding rate with its associated FEC type in an AWGN channel with BER 10^{-5}. For example, a SS reporting CINR=5dB for CTC FEC should be able to decode QPSK rate 1/2 with CTC FEC with BER=10^{-5} in an AWGN channel.

Table XXX – normalized CINR per MCS

MCS	Normalized CINR [dB]
QPSK 1/3	3dB
QPSK ½	5dB
QPSK ¾	6.5dB
16-QAM ½	11dB
16-QAM ¾	14dB
64-QAM ½	16dB
64-QAM 2/3	17.5dB
64-QAM ¾	19dB
64-QAM 5/6	21dB

The default associated FEC type is CC. The default normalized C/I values per MCS are given in table XXX. The SS's associated FEC type and the values in table XXX may be overridden by the BS using a dedicated REP-REQ message TLV.

[Add the following text at the end of section 8.4.11.3]

The message time index is incremented every frame. The SS shall maintain separate message time index counters and mean CINR estimates for REP-RSP-based reports and for Fast-Feedback-based reports. When the CINR type is changed, the SS shall reset the corresponding message time index to zero.

The averaging parameter (α_{avg}) may be sent as a DCD message TLV for REP-RSP or CQICH based CINR reports.Unless specified otherwise, the default averaging parameter (α_{avg}) is ¼. When the averaging parameter (α_{avg}) is given to a SS through REP-REQ, this value shall only be used for deriving CINR estimates reported through REP-RSP, and can further only be changed through another REP-REQ message. When the averaging parameter is given to a SS through the CQICH_Alloc_IE, this value shall only be used for deriving CINR estimates through Fast-Feedback channel (CQICH), and can further only be changed through another CQICH_Alloc_IE. An averaging parameter value sent through DCD shall not override the averaging parameter value sent in a dedicated REP-REQ or CQICH_Alloc_IE message.

[Add the following entries to the end of table 358, section 11.4.1]

Default RSSI and CINR averaging parameter	ZZZ	1	Bit #0~3: Default averaging parameter α_{avg} for CINR and RSSI measurements, in multiples of 1/16 (range [1/16, 16/16], 0x0 for 1/16, 0xF for 16/16). Bit #4-#7: Reserved	OFDMA

[Add the following new section]

11.8.3.7.X OFDMA SS CINR measurement capability

[Add the table as follows at pp.135, line 27]

Type	Length	Value	Scope
XXX	1	Bit #0: CINR measurement from the preamble Bit #1: CINR measurement for a permutation zone from pilot subcarriers Bit #2: CINR measurement for a permutation zone from data subcarriers Bit #3~7: *Reserved*; shall be set to zero	SBC-REQ (see 6.3.2.3.23) SBC-RSP (see 6.3.2.3.24)

[Modify the 2nd table in section 11.11 (REP-REQ) of 802.16-2004 as follows]

11.11 REP-REQ management message encodings

Report type	1.1	~~1~~ 2	Bit #0 =1 Include DFS Basic report Bit #1 =1 Include CINR report Bit #2 =1 Include RSSI report Bit #3–6 α_{avg} for CINR measurements, in multiples of 1/~~32~~ 16 (range ~~[1/32, 16/32]~~ [1/16,16/16]) Bit #7–10 α_{avg} for RSSI measurements, in multiples of 1/16 (range [1/16,16/16]) Bit # ~~7~~ 11 =1 Include current transmit power report Bits #12-15 = reserved
Channel number	1.2	1	Physical channel number (see 8.5.1) to be reported on. (license-exempt bands only)
~~Channel~~ Zone-specific CINR type request	1.3	~~1~~ 2	~~00 = Normal subchannel,~~ ~~01 = Band AMC Channel,~~ ~~10 = Safety Channel,~~ ~~11 = Reserved,~~ Bit #0 = 1: Report the CINR estimate for PUSC zone with 'use all SC=0' Bit #1 = 1: Report the CINR estimate for PUSC zone with 'use all SC=1' / PUSC AAS zone Bit #2 = 1: Report the CINR estimate for FUSC Bit #3 = 1: Report the CINR estimate for Optional FUSC Bit #4 = 1: Report the CINR estimate for Safety Channel region Bit #5 = 1: Report the CINR estimate for AMC AAS zone Bit #6: data/pilot-based measurement: 0-Report the CINR estimate from pilot subcarriers, 1-Report the CINR estimate from data subcarriers Bits #7-8 : PRBS_ID of the zone for which CINR should be estimated. Ignored for Safety Channel. Bits #9-14 : When bit #1 is '1', reported CINR shall only be estimated for the subchannels of PUSC major groups for which the corresponding bit is set. Bit #*(k+11)* refers to major group *k*. Ignored if bit #1 is '0'. Except the case that Bit#1 is 1, they shall be set to zeros and ignored. Bit #15: reserved
Preamble CINR type request	1.4	1	Bit #0=1: Report the estimation of CINR measured from preamble for frequency reuse configuration=1 Bit #1=1: Report the estimation of CINR measured from preamble for frequency reuse configuration=3 Bit #2 = 1: Report the estimation of CINR measured from preamble for band AMC Bit #3-7: Reserved (shall be set to zero)
CINR-report FEC parameter update	1.5	10	Bits #0-71: Normalized CINR per MCS override (see table XXX) This is a list of numbers, where each number is encoded by one byte, and interpreted as a signed integer in units of 0.25dB. The bytes correspond in order to the list defined by table XXX, The number encoded by each byte is the normalized CINR for the corresponding MCS, for the FEC type defined by bits #72-73. Bit #72-73: CINR report associated FEC type. Indicates the FEC type to which the normalized CINR values in section 8.4.11.3, table XXX, apply: 0b00 = CC 0b01 = BTC 0b10 = CTC 0b11 = reserved Bit # 73-79 : Reserved

[Modify the 3rd table in section 11.12 (REP-RSP) of 802.16-2004 as follows]

REP-REQ CINR ~~Channel~~ Type request	Name	Type	Length	Value
~~Channel type=00~~	~~Normal subchannel Report~~	~~2.1~~	~~1~~	~~First 5 bits for the CINR measurement report and the rest for don't care~~
~~Channel type=01~~	~~Band AMC Report~~	~~2.2~~	~~4~~	~~First 12 bits for the band indicating bitmap and Next 20 bits for CINR reports (5 bits per each band)~~
~~Channel type=10~~	~~Safety Channel Report~~	~~2.3~~	~~5~~	~~The first 20 bits for the reported bin indices and the next 20 bits for CINR reports (5bits for each bin)~~
Bit #0 = 1	PUSC zone with 'use all SC=0'	2.1	1	Bit #0-4: CINR estimate for PUSC zone with 'use all SC=0' and PRBS_ID indicated by 'CINR type request'. Bit #5: Report type: 0 - CINR estimated from pilot subcarriers, 1- CINR estimated from data subcarriers Bit #6-7: reserved
Bit #1 = 1	PUSC zone with 'use all SC=1' / PUSC AAS zone	2.2	1	Bit #0-4: CINR estimate for PUSC zone with 'use all SC=1' (or PUSC AAS zone) and PRBS_ID indicated by 'CINR type request'. CINR reported corresponds to a subset of major groups as specified in 'CINR type request'. Bit #5: Report type: 0 - CINR estimated from pilot subcarriers, 1- CINR estimated from data subcarriers Bit #6-7: reserved
Bit #2 = 1	FUSC zone	2.3	1	Bit #0-4: CINR estimate for FUSC zone with PRBS_ID indicated by 'CINR type request' Bit #5: Report type: 0 - CINR estimated from pilot subcarriers, 1- CINR estimated from data subcarriers Bit #6-7: reserved
Bit #3 = 1	Optional FUSC zone	2.4	1	Bit #0~4: CINR estimate for Optional FUSC with PRBS_ID indicated by 'CINR type request'. Bit #5: Report type: 0 - CINR estimated from pilot subcarriers, 1- CINR estimated from data subcarriers Bit #6-7: reserved
Bit #4 = 1	Safety channel	2.5	5	The first 20 bits for the reported bin indices and the next 20 bits for CINR reports (5 bits for each bin).
Bit #5 = 1	AMC AAS zone	2.6	1	Bit #0~4: CINR estimate for AMC AAS zone. Bit #5: Report type: 0 - CINR estimated from pilot subcarriers, 1- CINR estimated from data subcarriers Bit #6-7: reserved

[Add the following tables at the end of 11.12, page 171 line 40]

REP-REQ	Name	Type	Length	Value

Preamble CINR type request				
Bit #0 = 1	The estimation of CINR measured from preamble for frequency reuse configuration=1	3.1	1	Bit #0~4: The estimation of CINR measured from preamble for frequency reuse configuration=1. Bit #5~7: reserved.
Bit #1 = 1	The estimation of CINR measured from preamble for frequency reuse configuration=3	3.2	1	Bit #0~4: The estimation of CINR measured from preamble for frequency reuse configuration=3. Bit #5~7: reserved.
Bit #2 = 1	The estimation of CINR measured from preamble for Band AMC zone.	3.3	4	The estimation of CINR measured from preamble for band AMC subchannel. First 12 bits for the band indicating bitmap and Next 20 bits for CINR reports (5 bits per each band).

CINR-report FEC parameter update	Name	Type	Length	Value
Acknowledge	Acknowledge receipt of updated associated FEC type and 'normalized CINR per MCS' table.	4.1	1	Bit #0-#7: reserved.

[Add the following text at the end of section 11.12]

For the type 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, the following 5 bit CINR measurement encoding shall be used:

$$Payload\ bits = \begin{cases} 0, & CINR \le -3dB \\ n, & (n-4) < CINR \le (n-3), \quad 0 < n < 31 \\ 31, & CINR > 27 \end{cases}$$

Appendix A

The proposed text requires that the SS correctly distinguish between noise and interference in order to scale the CINR report correctly. This requires to that the SS obtain an estimate of the noise level separate from the interference level. Here we propose one method to achieve this by utilizing the different boosting levels in the preamble and the pilots. Obviously, other schemes are possible as well.

The preamble is boosted by B_1 = 9dB per subcarrier and the pilots are boosted by B_2 = 2.5dB+10log10(Nused/Nactive) where Nactive is the number of active subcarriers in the first zone and Nused is the total number of used subcarriers.

The same interference sources are assumed to exist in the preamble and the pilots of the first 2 symbols.
Let us define A_1 as the set of frequency indices of the active pilots in the first two symbols, and A_2 as the set of frequency indices of active preamble subcarriers that match the indices in A_1 (or are within 1 subcarrier offset from them).

The proposed method is as follows:

1. Obtain a measurement of the average interference+noise per subcarrier at frame *k* from the subcarriers in set A_2:
$$IN_{pream,k} = B_1 \cdot I_k + \hat{N}_k$$

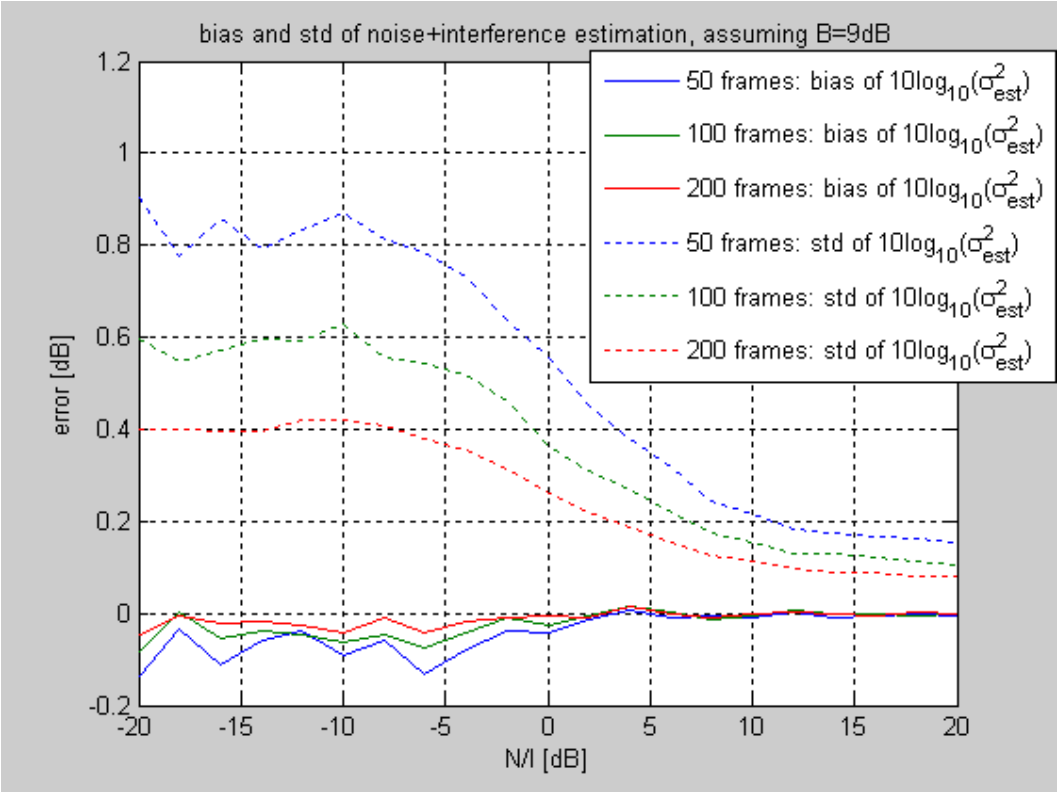
2. Obtain a measurement of the interference+noise per subcarrier from the active pilots of the first 2 symbols of frame *k* (set A_1):
$$IN_{pilots,k} = B_2 \cdot I_k + \hat{N}_k$$

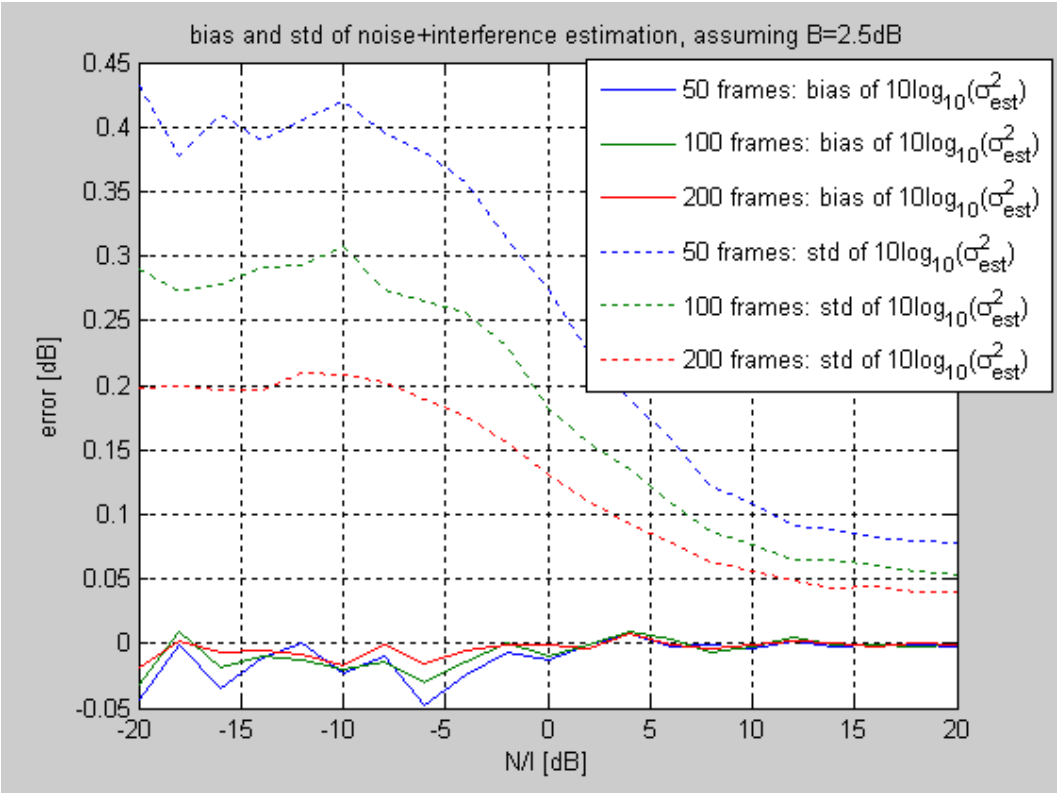
3. Compute noise variance measurement from frame *k*:
$$\hat{N}_k = \frac{\left[IN_{pilots,k} - \left(\frac{B_2}{B_1} \right) \cdot IN_{pream,k} \right]}{1 - \left(\frac{B_2}{B_1} \right)}$$

4. Filter over multiple frames to reduce estimation variance.

Assuming the first zone is reuse-3, we have B_1 = 9dB and B_2 = 2.5dB+10*log10(3) = 7.3dB.

Now assume we have some accurate measurement of $\left(B \cdot I + N\right)$, for boosting level B (say from preamble or from zone pilots), and we wish to use the estimator $\hat{N}$ to compute an estimate of $\hat{\sigma}^2 = \left(\hat{I} + \hat{N}\right)$. The figures below show the bias and the std of the estimated quantity $\hat{\sigma}^2$, where the estimator $\hat{N}$ was obtained by averaging over 50, 100, and 200 frames. The first figure assumes that B = 9dB (boosting level of the preamble), while the second figure assumes B = 2.5dB (boosting level of pilots in reuse-1 configuration).


bias and std of noise+interference estimation, assuming B=9dB
50 frames: bias of $10\log_{10}(\sigma^2_{est})$
100 frames: bias of $10\log_{10}(\sigma^2_{est})$
200 frames: bias of $10\log_{10}(\sigma^2_{est})$
50 frames: std of $10\log_{10}(\sigma^2_{est})$
100 frames: std of $10\log_{10}(\sigma^2_{est})$
200 frames: std of $10\log_{10}(\sigma^2_{est})$
error [dB]
N/I [dB]
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-20
-15
-10
-5
0
5
10
15
20


bias and std of noise+interference estimation, assuming B=2.5dB
50 frames: bias of $10\log_{10}(\sigma^2_{est})$
100 frames: bias of $10\log_{10}(\sigma^2_{est})$
200 frames: bias of $10\log_{10}(\sigma^2_{est})$
50 frames: std of $10\log_{10}(\sigma^2_{est})$
100 frames: std of $10\log_{10}(\sigma^2_{est})$
200 frames: std of $10\log_{10}(\sigma^2_{est})$
error [dB]
N/I [dB]
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-20
-15
-10
-5
0
5
10
15
20