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# CINR measurements using the EESM method

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## 1 Introduction

The current 802.16e SINR reporting mechanism requires the MSS to report a straightforward CINR measurement. This mechanism does not provide the BS with any knowledge on the frequency selectivity of the channel and noise (especially prominent with partially loaded cells and with multipath). This knowledge is important since, contrary to the AWGN channel, in a frequency selective channel there is no longer a 1 to 1 relation between amount of increase in power and amount of improvement in "effective SINR" [1]. Furthermore, the relation is dependent on MCS level. This lack of knowledge in the BS side results in larger fade margins, which translates directly to reduction in capacity.

In this contribution we propose a mechanism based on the EESM model that provides the BS with sufficient knowledge on the channel-dependent relationship between power increase, MCS change and improvement in effective SINR. The EESM method is a well known SINR predictor in the context of OFDM/A [1][2][3][4].

The contribution is organized as follows: in section 2 we introduce the EESM method. Section 3 discusses the accuracy of the EESM model. Section 4 gives an outline of the proposed solution, followed by a detailed description of the text changes.

## 2 Exponential Effective SIR Mapping (SIR)

To estimate demodulator performance in a channel with frequency selective signal and/or noise, a known method is the so-called "exponential effective SIR mapping" (EESM) [1][3][4]. In a sense, the EESM is a channel-dependent function that maps power level and MCS level to SINR values in the AWGN channel domain. This allows using this mapping along with AWGN assumptions (such as effect of increase in power, CINR/MCS threshold tables) in order to predict the effect of MCS and boosting modification. The method has been shown to yield an accurate estimation of the AWGN-equivalent SINR (henceforth referred to as "effective SINR") for frequency selective channels. Section 3 discusses the accuracy of the EESM model.

[1] Effective SINR = AWGN-equivalent SINR, i.e. Equivalent SINR in AWGN channel that results in the same error rate.

The EESM method estimates the effective SINR using the following formula:

$$\gamma_{eff} \equiv EESM(\boldsymbol{\gamma}, \beta) \equiv -\beta \cdot \ln\left( \frac{1}{N} \cdot \sum_{i=1}^{N} e^{-\frac{\gamma_i}{\beta}} \right)$$

where $\boldsymbol{\gamma}$ is a vector $[\gamma_1, \gamma_2, ..., \gamma_N]$ of the per-tone SINR values, which are typically different in a selective channel.

In general, we would like the MSS to report the effective SINR to the BS, and have the BS decide what modulation and coding to use and with what power boosting. However, as stated earlier, this is complicated by the fact that the relationship between increase in power and increase in effective SINR is both channel-dependent and MCS-dependent. **In contrast to the AWGN channel case, 1dB increase in transmit power does *not* translate to 1dB increase in effective SINR**.

In context of EESM, this implies that for each MCS a different $\beta$ should be utilized, and for each such $\beta$, different boosting should be considered. As a result, the BS is required to know the dependence of effective SINR on $\beta$ and power increase; thus computation of equivalent SNR can no longer remain solely in the MSS's territory.

The increase of $\gamma_{eff}$ due to boosting is $\beta$ dependent, as can be seen below (where $B$ denotes the boost ratio)

$$EESM(\boldsymbol{\gamma} \cdot B, \beta) \equiv -\beta \cdot \ln\left( \frac{1}{N} \cdot \sum_{i=1}^{N} e^{-\frac{\gamma_i \cdot B}{\beta}} \right) \neq EESM(\boldsymbol{\gamma}, \beta) \cdot B$$

This implies that EESM is a two-dimensional mapping of boost level and an MCS-dependent quantity ( $\beta$ ) to effective SINR. However, we can simplify by observing that

$$EESM(B \cdot \boldsymbol{\gamma}, \beta) \equiv -\beta \cdot \ln\left( \frac{1}{N} \cdot \sum_{i=1}^{N} e^{-\frac{\gamma_i \cdot B}{\beta}} \right) = B \cdot \left( -\frac{\beta}{B} \right) \cdot \ln\left( \frac{1}{N} \cdot \sum_{i=1}^{N} e^{-\frac{\gamma_i}{\beta / B}} \right) = B \cdot EESM(\boldsymbol{\gamma}, \beta / B)$$

which shows that given an SINR-per-tone vector it is sufficient for the BS to know the MSS-specific curve relating EESM to $\beta$. Both boosting and rate adaptation can be done based on the same curve, thus reducing the mapping problem to one dimension.

## 2.1 Linear approximation

In Figure 1 we plot EESM as function of $\beta$, for different cases. The first graph plots EESM for 4 different $\boldsymbol{\gamma}$ vectors, drawn from 24 independent Rayleigh distributions. Both EESM and $\beta$ are plotted in dB. It can be seen that the graphs can be approximated locally as linear (in dB=>dB), and have overall a linear shape with saturation at $\beta$ >15dB. Saturation occurs for practically unachievable $\beta$ values. This linear shape may be used for compressing the curve for transmission to the BS.

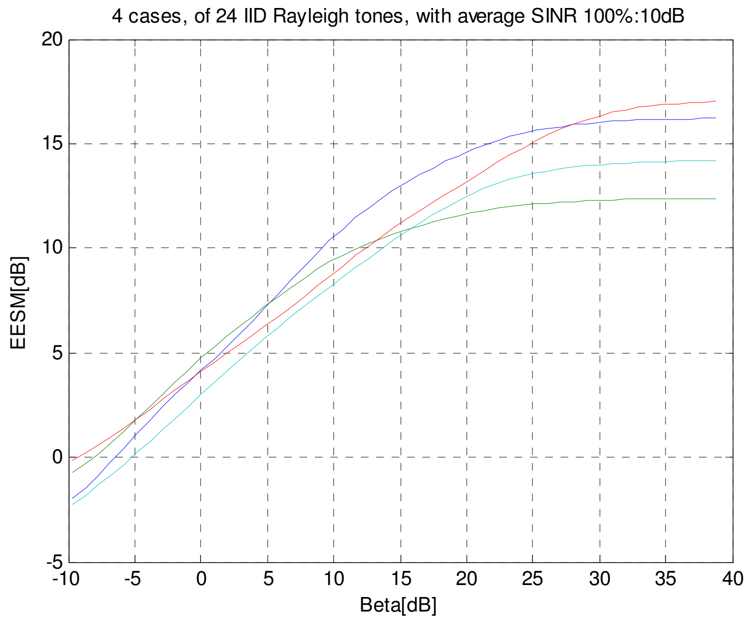


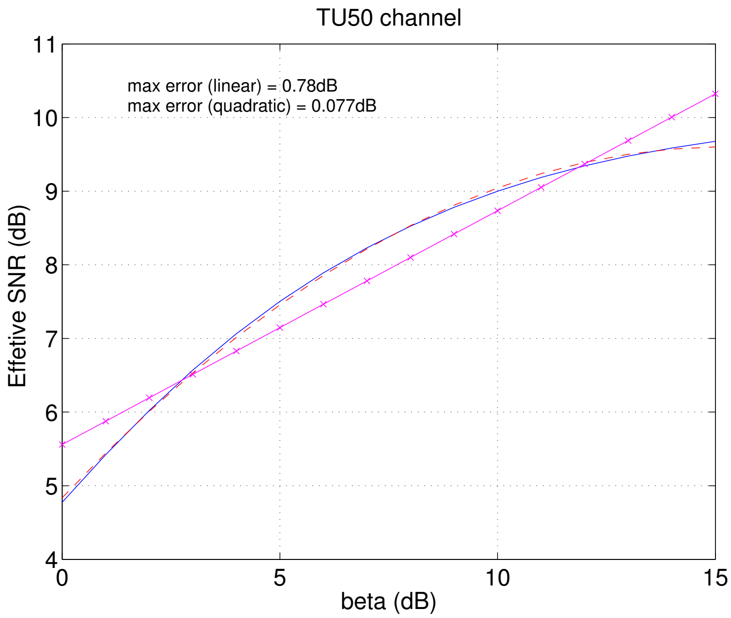

**Figure 1 – EESM as a function of $\beta$ for 4 channel realizations drawn from 24 independent Rayleigh distributions.**

For the purpose of fast rate adaptation or Hybrid ARQ, the MSS needs to provide instantaneous SINR and BS may decide rate and boosting, according to MSS instantaneous SINR. However the number of relevant rates is limited and their $\beta$ values are close. Furthermore, the boosting range is limited, so we are typically interested in a narrow region of the $\beta$ axis. Thus a local linear approximation suffices, and the graph may be compressed effectively. This implies one straightforward solution – the MSS can initially (e.g. on handover to a new cell) send a table of EESM SINR thresholds and $\beta$ values for each MCS, and then at a higher speed transmit a local linear approximation for the EESM($\beta$) curve. A more simplified solution is described in section 4.

## 2.2 Quadratic approximation

The fading channel curves shown in Figure 2 and Figure 3 illustrate that the quadratic approximation is more accurate than the linear approximation in the β (dB) range of interest. In fact, the quadratic approximation leads to an almost perfect curve fitting (a few hundredths of a dB, not noticeable when practical limitations are taken into account). It is important to minimize the curve-fitting error, because this easily controllable error is in addition to the EESM method error which is very difficult to further reduce. Since the EESM method error is less than 0.5 dB for all the 802.16 MCS, the advantage of using EESM will be lost if the curve-fitting error is more than a fraction of 0.5 dB.

Note that in Figure 2 and Figure 3, the slope of the linear approximation was selected to minimize the mean-square error (under the linear curve constraint) over the entire β range of [0 dB, 15 dB]. If the slope local to a specific β value was used instead, then errors on the order of several dBs may occur.


TU50 channel
max error (linear) = 0.78dB
max error (quadratic) = 0.077dB
Effetive SNR (dB)
beta (dB)
11
10
9
8
7
6
5
4
0
5
10
15

ERROR: undefined
OFFENDING COMMAND: II*

STACK: