Proposal for the modulation accuracy in IEEE 802.16

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Lars Lindh
Nokia Research Center
P.O. Box 407, FIN-00045
NOKIA GROUP, Finland

Jay Klein
Ensemble Communications, Inc
6256 Greenwich Dr,. Ste 400
San Diego, CA 92122 USA

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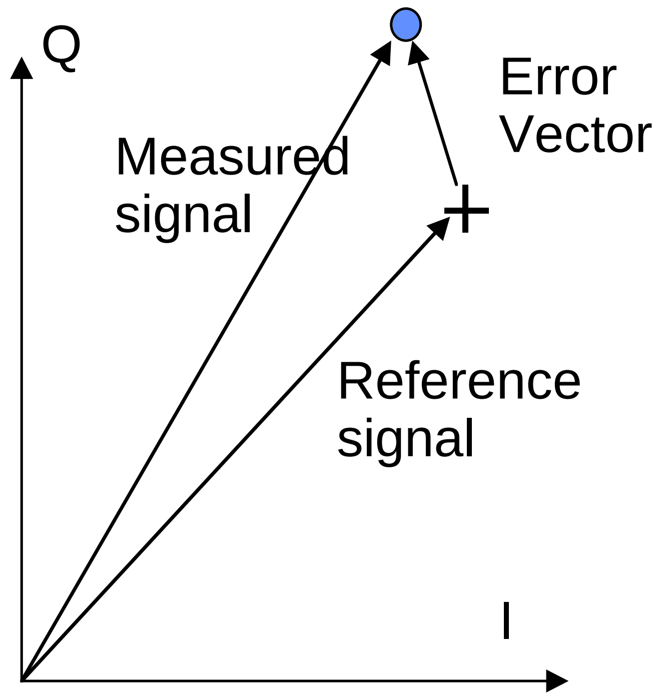
Purpose:

This document is a contribution about the modulation accuracy needed in 802.16

IEEE 802.16 PHY

Modulation Accuracy

Error Vector



- Two modulation accuracy measures are used, **EVM** and **MER**

- Error Vector Magnitude (**EVM**) is defined as

$$EVM = \sqrt{\frac{\frac{1}{N}\sum_{1}^{N}(\Delta I^2 + \Delta Q^2)}{S_{\max}^2}} \times 100\%$$

where $\mathbf{S_{max}}$ is the vector to the outermost constellation point

- Modulation Error ratio (**MER**) is defined as

$$MER(dB) = 10\log\frac{\frac{1}{N}\sum_{1}^{N}(I^2 + Q^2)}{\frac{1}{N}\sum_{1}^{N}(\Delta I^2 + \Delta Q^2)}$$

EVM or MER

- Error vector Magnitude (**EVM**) and Modulation Error Ratio (**MER**) are closely related and express the same kind of information. In fact, there is a ono to one relationship between **EVM** and **MER**.
- MER is perhaps easier to understand as it relates directly to the S/N
- EVM is used in several standards like DVB, UMTS and EDGE

Waveform accuracy

- The accuracy of the modulation waveform is affected by
  - root raised cosine filter length and coefficients accuracy
  - DA-converter accuracy
  - modulator imbalances
  - synthesizer phase noise
  - PA nonlinearities
- The spectrum mask specifies the accuracy of the out of band signal -> coexistence parameter
- EVM specifies the accuracy of the waveform at the sampling instances -> affects the BER and is in fact an inter-operability parameter

Estimating the EVM

- The required EVM can be estimated from the transmitter implementation margin if the error vector is considered noise which is added to the channel noise

$$\frac{C \cdot k}{N + EV} = \frac{C}{N}$$

where k = implementation margin, C/N = threshold signal to noise ratio, EV = noise from error vector, p is peak-to-avg for the constellation

$$EVM = \sqrt{\frac{N(k-1)}{S_{\max}^2}}100 = \sqrt{\frac{k-1}{C/N \cdot p}}100$$

EVM for 4-QAM, 16-QAM and 64-QAM

4-QAM EVM		
DEGR dB	0.5	Accepted degradation due to inaccuaries in constellation points
C/N dB	10	Threshold C/N
p_avg dB	0	peak to avg for constellation
EVM %	11.0462	Avg error magnitude / Max symbol magnitude

16-QAM EVM		
DEGR dB	1	Accepted degradation due to inaccuaries in constellation points
C/N dB	16.5	Threshold C/N
p_avg dB	2.55	peak to avg for constellation
EVM %	5.676588	Avg error magnitude / Max symbol magnitude

64-QAM EVM		
DEGR dB	1.5	Accepted degradation due to inaccuaries in constellation points
C/N dB	22.5	Threshold C/N
p_avg dB	3.7	peak to avg for constellation
EVM %	3.145805	Avg error magnitude / Max symbol magnitude

Excel tables for computing the EVM as a function of degradation and C/N

Conclusions

- We propose EVM because it is more common then MER
- EVM includes the following: PA nonlinearities, untracked phase noise, inband amplitude ripple, DA-converter inaccuries
- EVM cannot by measured at the antenna connector but should be measured by an "ideal" receiver with a carrier recovery loop bandwidth of 1% of the symbol rate
- Modulation accuracy can be specified only by considering the acceptable transmitter implementation margin and the physical realities given by the transmitter components like PA and frequency synthesizer