

Proposal for the modulation accuracy in IEEE 802.16

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Purpose:

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

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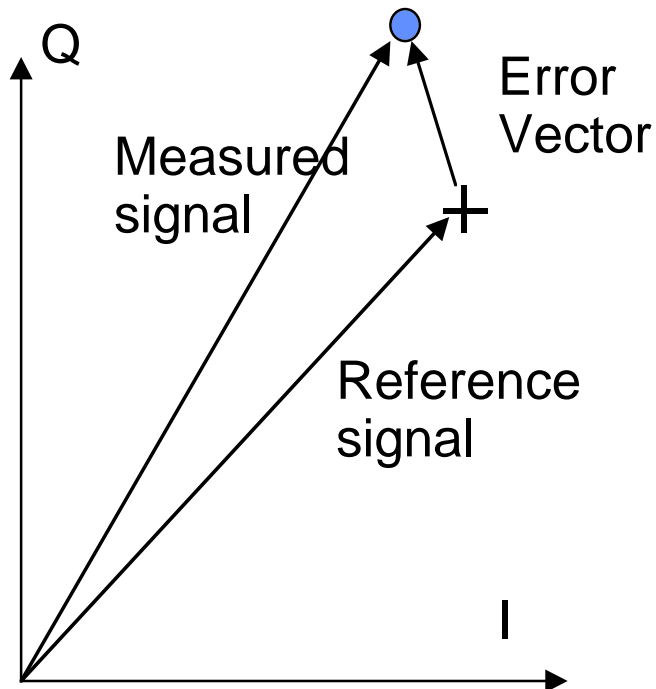
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IEEE 802.16 PHY

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 one 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 inaccuracies 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 inaccuracies 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 inaccuracies 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 than MER
- EVM includes the following: PA nonlinearities, untracked phase noise, inband amplitude ripple, DA-converter inaccuracies
- EVM cannot be 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