Effective AM/AM and AM/PM curves derived from EVM simulations or measurements on constellations

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Outline of talk

- Motivation of the study
- Classical display of constellation distortion and complex error
- Folding up of the constellation
- Application to 32 APSK modulation
- Computation of EVM for each class of symbols
- Effective AM/AM and AM/PM curves
- Polar plot of combined AM/AM and AM/PM curve
- Results for higher order modulations
- Use for non-linear equalization
- Conclusion

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Motivation of the study

- The goal of the study is to extract all possible information from EVM-like measurements
- Application to a complete space telecommunication payload with noise, phase noise, echos, filters and nonlinear amplifier distortion
- Research and Development study with Thales Alenia Space under CNES (French Space Agency) founding

- Presentation of a complement to the initial study for the extraction of nonlinear distortions and their effect on digital modulation

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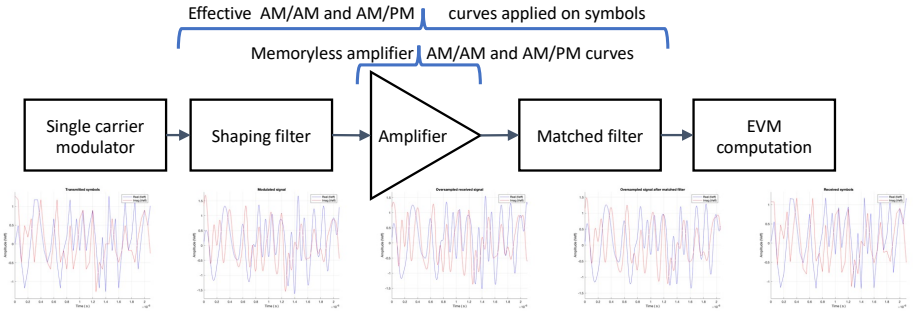
Simplified nonlinear transmission chain



- EVM is 0 if there is no amplifier
- Amplifier causes EVM through distortion due to AM/AM and AM/PM curves and because the matched filter is no longer optimum to remove inter-symbol interference (ISI)

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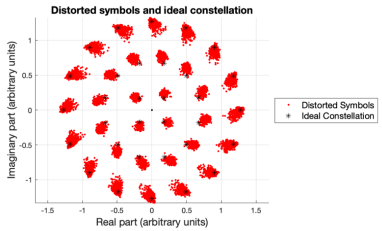
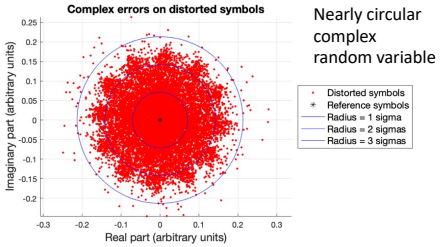
Classical display of constellation distortion and complex error

- The constellation display presents a lot of information on distortion but may not be easy to interpret
- The complex error display ignores correlations between signal phase and error phase. The noise seems to be additive circular normal noise





Nearly circular complex random variable

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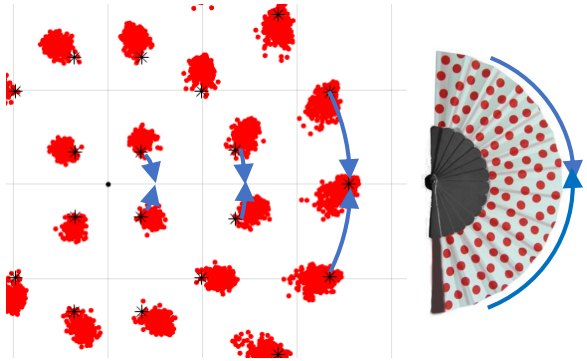
Folding up the constellation



- Folding fan like transformation
- Rotation of each ideal symbols to the positive real axis
- Rotation of distorted symbols y by the same angle $-\angle x$ as the ideal symbol x
- $x \Longrightarrow x\dfrac{x^*}{|x|} = |x|$
- $y \Longrightarrow y\dfrac{x^*}{|x|}$

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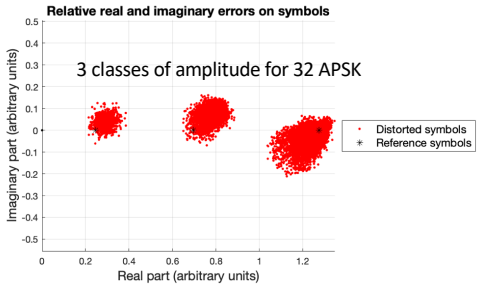
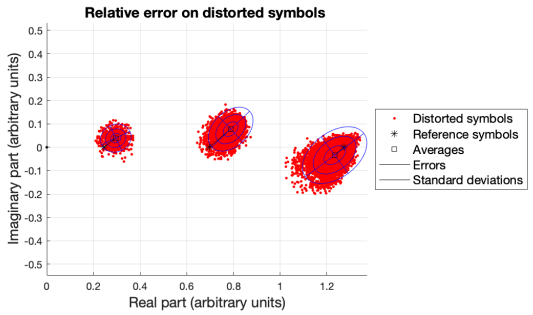
Application to 32 APSK modulation



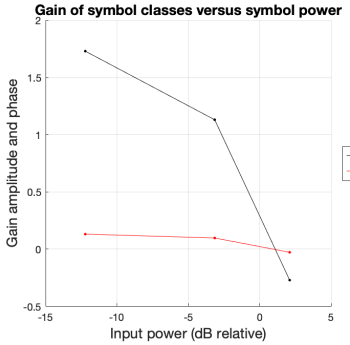
- Ideal symbols are on the real axis
- Average amplitude and phase of distorted symbols normalized through the IEEE standard 1765-2022 algorithm
- Distorted symbols average amplitude and phase depend on the amplitude of the ideal symbol
- Noise around average value comes from inter-symbol interference in the transmission chain.
- Filters gives memory to the chain

Computation of EVM for each class

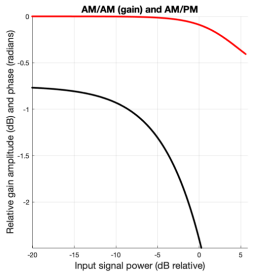


- For each class of ideal symbols amplitude, computation of the average value and EVM
- Root mean square is different on x and y axes
- Correlation of x and y coordinates of points
- Gives a tilted ellipsis around each average value
- Noise is not always Gaussian around average values

Effective AM/AM and AM/PM curves



- These curves give the amplitude and phase of the average gain for each class of ideal symbol amplitude



- Only 3 points for 32APSK

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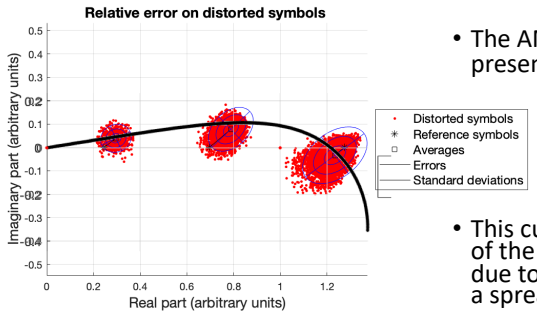
Polar plot of combined AM/AM and AM/PM curve and folded up relative errors



- The AM/AM and AM/PM curves are presented in a polar plot
- This curve fits the average positions of the symbols with a small error due to some integration because of a spread of input amplitudes

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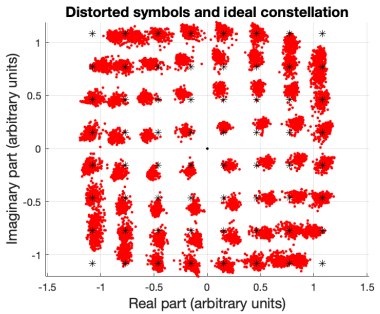
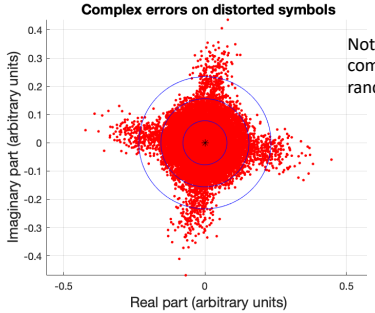
Results for higher order modulations 1/2





Not so circular complex random variable

- 64 QAM modulation and complex error

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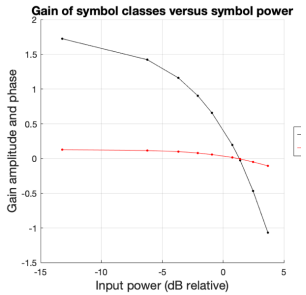
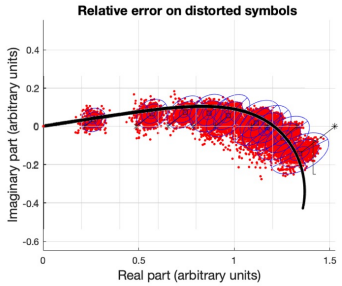
Results for higher order modulations 2/2





- More points on the AM/AM and AM/PM curves, 8 for 64 QAM
- Larger power range
- Cluttered polar curve but good fit with average values

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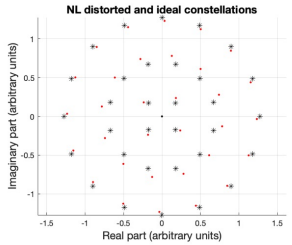
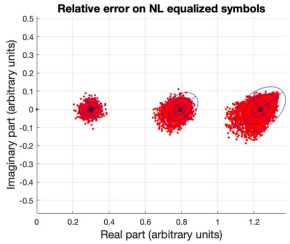
Use for receiver non-linear equalization





- The averaged distorted symbols are used as reference symbols in the nonlinear-equalized receiver (residual EVM in the standard)
- The residual errors only come from the ISI and represent about one half the EVM for this amplifier: a 6 dB improvement
- Slightly lower improvement (5dB) if the amplifier is more linear, peak at 2 dBc, 10° AM/PM

Conclusion

- New display of nonlinear distortions better reveals variation with ideal symbols amplitudes
- Good fit with AM/AM and AM/PM curves
- Can be used for receiver nonlinear equalization
- Further study on the exact distribution of ISI noise around average values with the objective of improving the prediction of bit or symbol error rate (BER, SER) from error values on symbols

References

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- [2] ETSI TS 134 121-1 V13.0.0 (2016-08), “UMTS User Equipment conformance specification”, August 2016
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- [6] B. Picinbono, “Random Signals and Systems”, Englewood Cliffs, N.J., Prentice-Hall, 1993
- [7] E. Ollila, “On the circularity of a complex random variable”, IEEE Signal Processing Letters, Vol. 15, 2008, pp. 841-844