Turbo Product Code Forward Error Correction: Capability and Benefit

IEEE 802.16 Presentation Submission Template (Rev. 8)

Document Number:

802.16.3p-00/45

Date Submitted:

2000-11-07

Source:

Dave Williams, Sean Sonander
Advanced Hardware Architectures
2365 NE Hopkins Court
Pullman, WA 99163-5601

Voice: +1-509-334-1000
Fax: +1-509-334-9000
E-mail: davew@aha.com, sean@aha.com

Venue:

802.16 : Session 10, Tampa, Florida

Base Document:

802.16.3c-00/45

Purpose:

This proposal is offered as a basis for FEC in the 802.16.3 PHY layer.

Turbo Product Code Forward Error Correction: Capability and Benefit

Sean Sonander & David Williams
Advanced Hardware Architectures

Sean@aha.com

Davew@aha.com
7 Nov. 2000
Based on 802163c-00_45.pdf

Presentation Structure

- Properties of Turbo Product Codes
- Performance of TPC's in AWGN Channel
- Performance of TPC's in Rayleigh Fading Channels
- Availability of TPC's
- Conclusion

Properties of TPCs

- Turbo Product Codes (TPCs) are very flexible
- Can support any data block size, resolution 1 bit
- TPCs can support a very wide range of code rates with a single, unified encoder/decoder strategy
- From below rate 1/3 to as high as rate 0.98
- Multiple vendor support exists
- Product Codes were described in 1948 by Elias

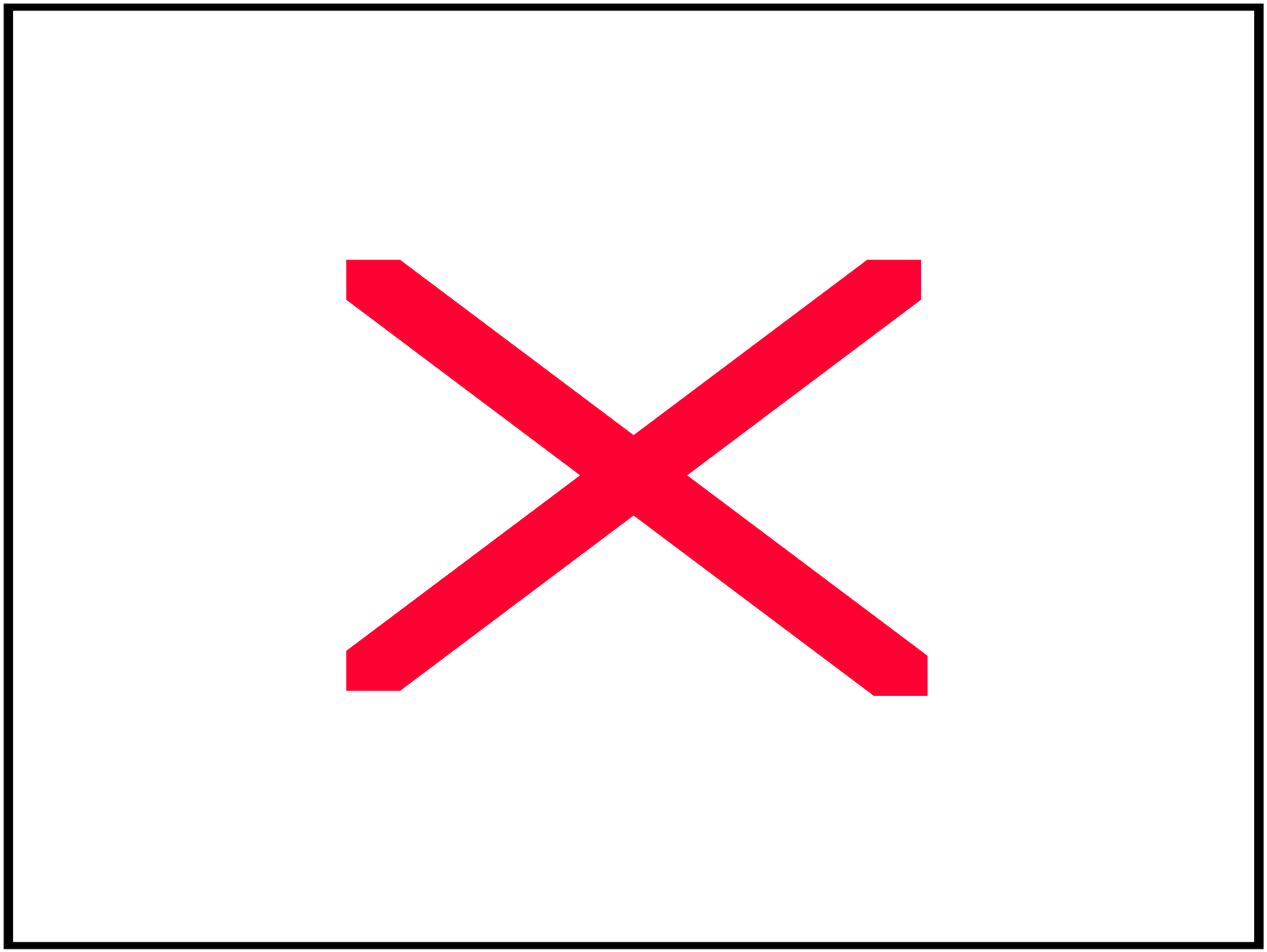
Properties (continued)

- Codes described here are the same type that are included in the 802.16.1 specification
- Data rates are lower, hence decoder is potentially less complex/lower cost than 802.16.1 codes
- Depending on codes chosen, the decoder can be implemented with < 150 Kgates (includes memory)

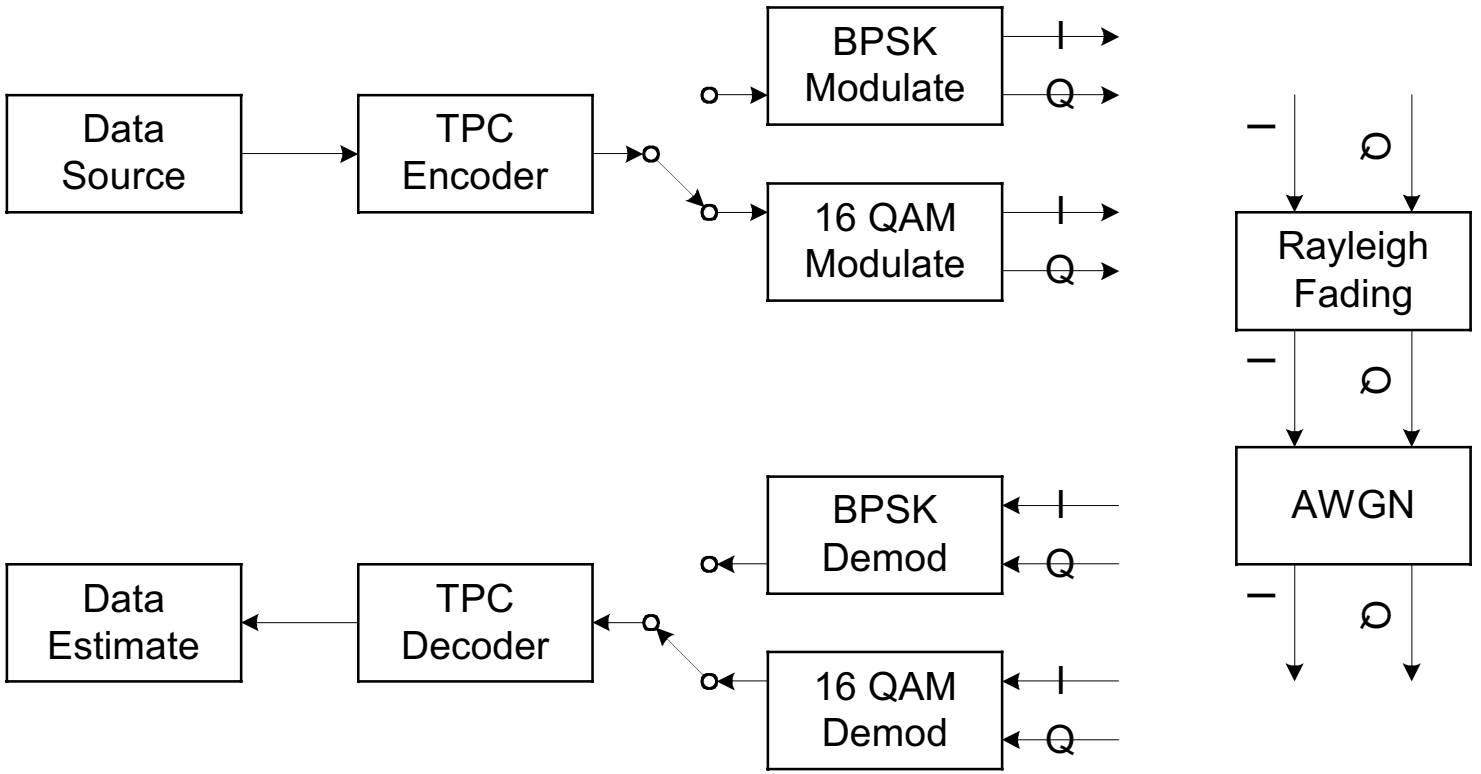
Large Block Code AWGN Performance

- Large Block can provide significant code rate and coding gain advantages
- Code rates as high as R = 0.98 for higher bandwidth efficiency
- Optimal efficiency for large bursts or continuous downstream transmission
- A single unified decoder design will also support any small block code
- Will also support codes specified in 802.16.1
- Enhanced burst error performance without interleaving

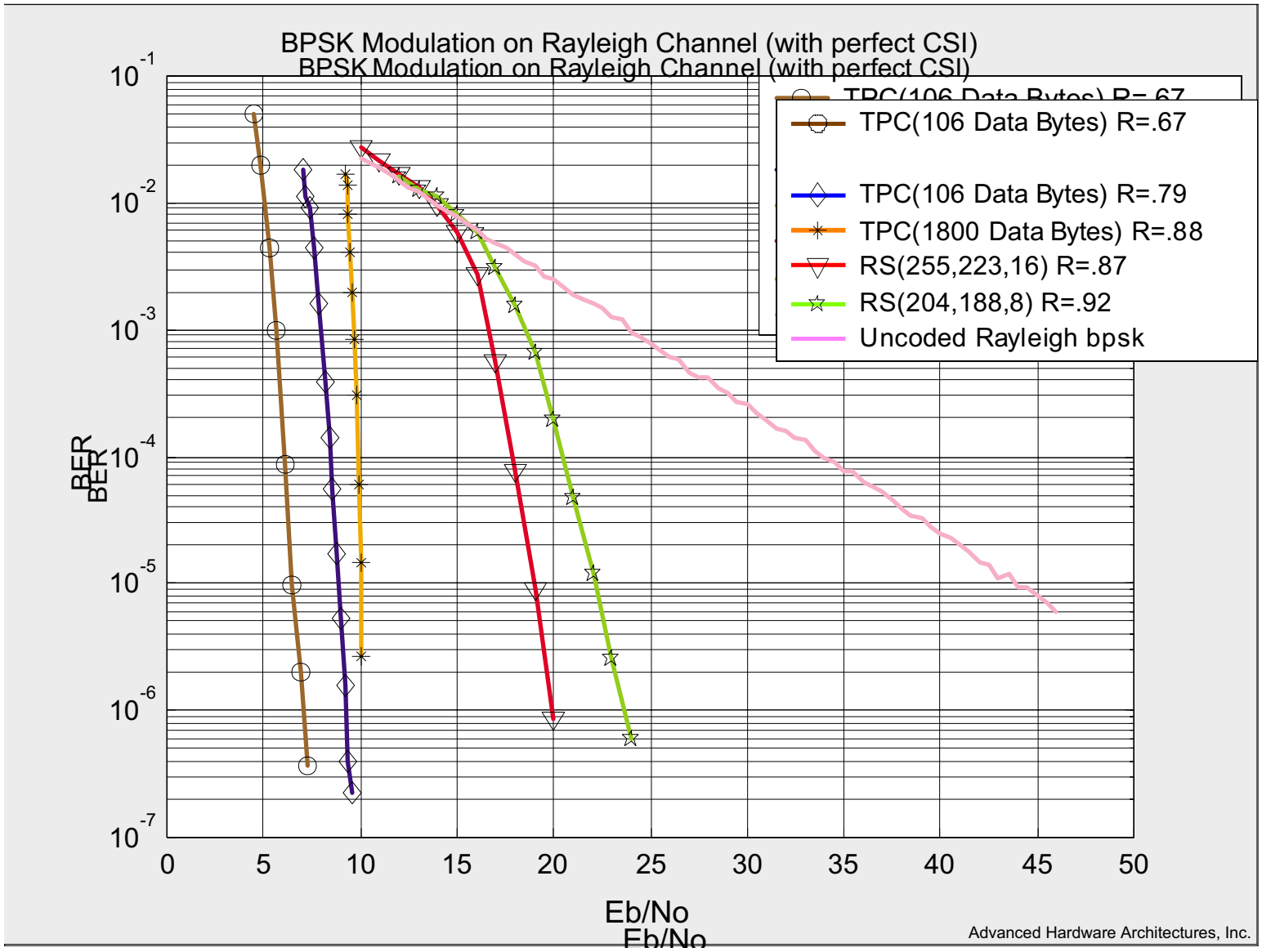
Representative Large Block AWGN Performance



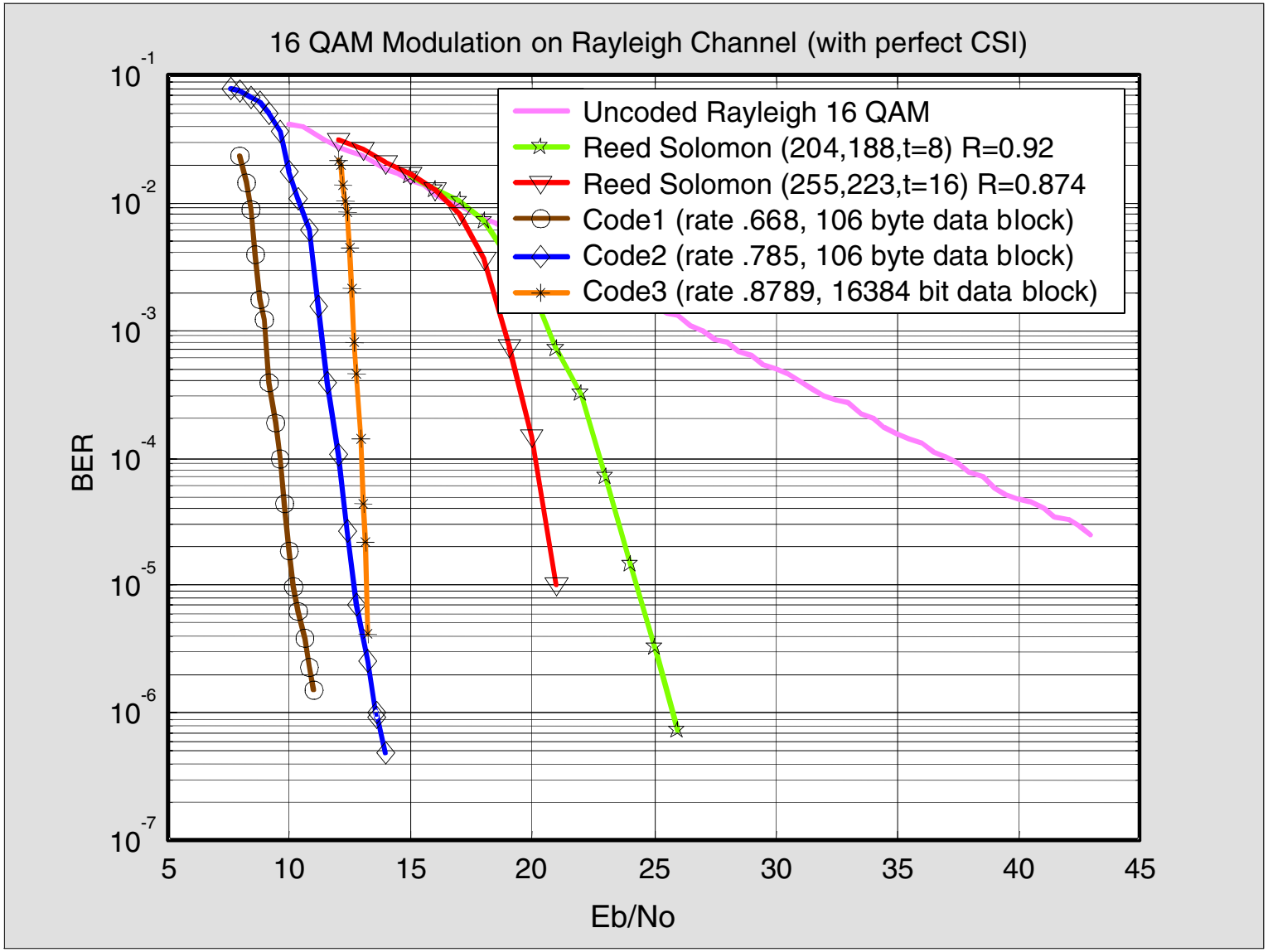
Rayleigh Fading Simulation Model



BPSK Performance in a Rayleigh Channel



16 QAM Performance in a Rayleigh Channel



Availability and Time to Market

- TPC hardware is available and fielded for almost 2 years
- Two different TPC evaluation systems are available
- TPC cores available for ASIC integration
- VHDL or Verilog targeted to any foundry
- Simulation tools available
- Includes high order modulation support
- Includes C/C++ and/or Matlab support
- Facilitates system level simulations for channel models, phase jitter, burst noise and other impairments

Conclusions

- TPCs provide excellent performance at high code rates and can offer a very wide range of block sizes and code rates with no change in coding strategy
- TPCs provide excellent performance in fading channels
- TPCs are easily implemented in either single carrier or multiple carrier (OFDM) systems
- TPC's are ideally suited to continuous or burst data transmission modes
- Recommend to perform further simulations based on selected modulation and channel models

Rayleigh Fading Channel

Received Vector $\overline{Y} = Y_1 + jY_2$

Components $\overline{Y} = (X_1 + jX_2)(A_1 + jA_2) + (N_1 + jN_2)$

$A_1 \sim N(0, \sigma_1^2)$

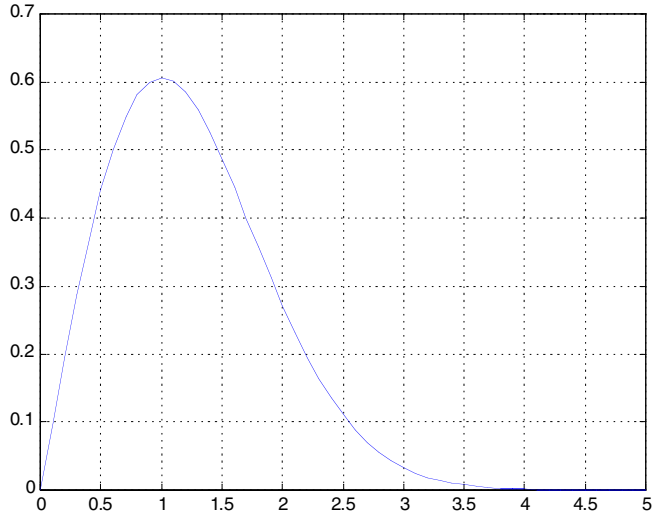
$A_2 \sim N(0, \sigma_2^2)$

Exp form $\left|\overline{Y}\right| e^{j\varphi_y} = \left|\overline{X}\right| e^{j\varphi_x} \leftrightarrow \left|\overline{A}\right| e^{j\varphi_A} + \left|\overline{N}\right| e^{j\varphi_N}$

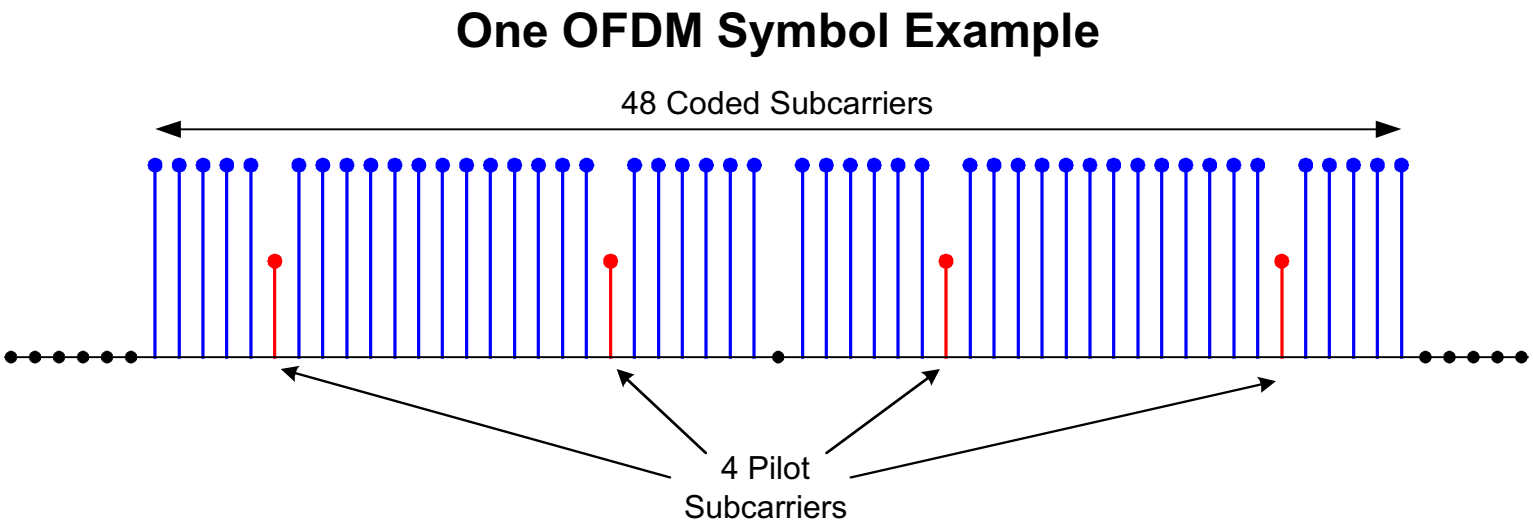
Received Transmitted Multiplicative AWGN

Probability Distribution $P_A(a) = \frac{a}{\sigma_a^2} e^{-a^2/2\sigma^2}$

Assume perfect Channel State Estimation (CSI)



TPC In OFDM Symbol Example



Coded Subcarrier modulation = 64QAM

Coded bits per symbol = 288 Bits

Rate 2/3 puncture convolutional code = 192 Info Bits

Almost identical TPC Code (288,187) R=0.64