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Presentation on Simulation of OFDM Impairments using ADS WLAN

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Wireless Networking
Design Seminar

Simulation of OFDM Impairments using ADS WLAN 802.11a Design Library and DesignGuide

Agilent Technologies

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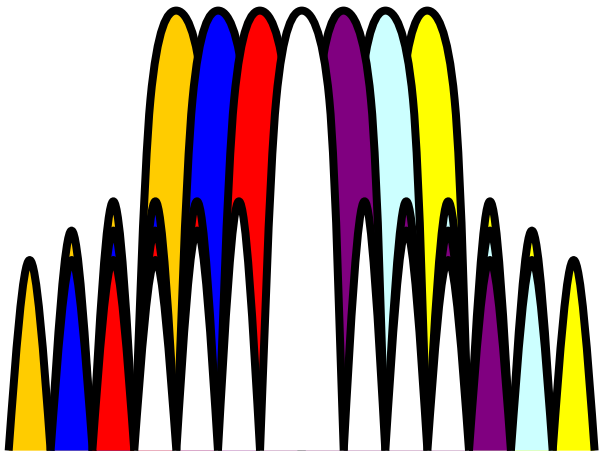
  - ⇨ WLAN 802.11a ADS DesignGuide (ADS 2002 software release)

OFDM Modulation Review

Concept of OFDM

- A type of multi-carrier modulation
- Single high-rate bit stream is converted to low-rate N parallel bit streams
- Each parallel bit stream is modulated on one of N sub-carriers
- Each sub-carrier can be modulated differently. For example, BPSK, QPSK or QAM
- To achieve high bandwidth efficiency, the spectrum of the sub-carriers are closely spaced and overlapped
- Nulls in each sub-carrier's spectrum land at the center of all other sub-carriers (orthogonal)
- OFDM symbols are generated using IFFT



OFDM Spectrum

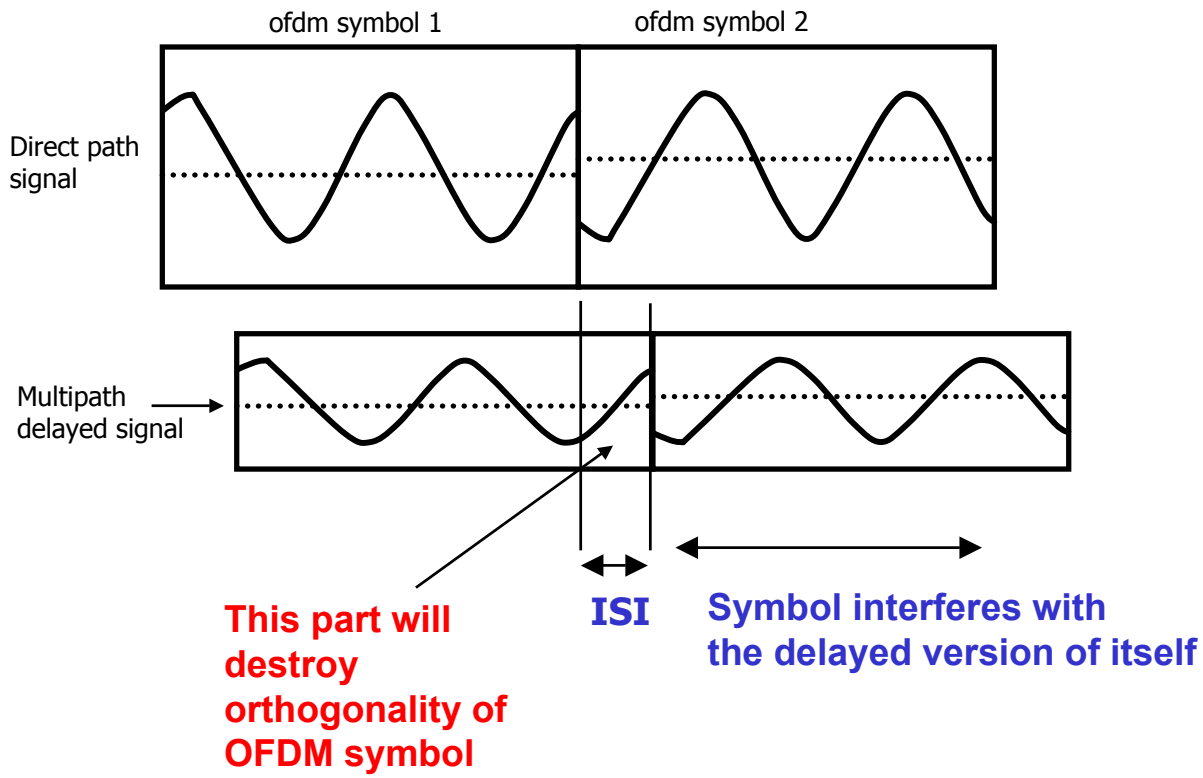
Advantages of OFDM

- **Robustness in muti-path propagation environment**
- **More tolerant of delay spread:**
  - ⇨ **Due to the use of many sub-carriers, the symbol duration on the sub-carriers is increased, relative to delay spread.**
  - ⇨ **Inter-symbol interference is avoided through the use of guard interval.**
  - ⇨ **Simplified or eliminate equalisation needs, as compared to single carrier modulation.**
- **More resistant to fading. FEC is used to correct for sub-carriers that suffer from deep fade.**

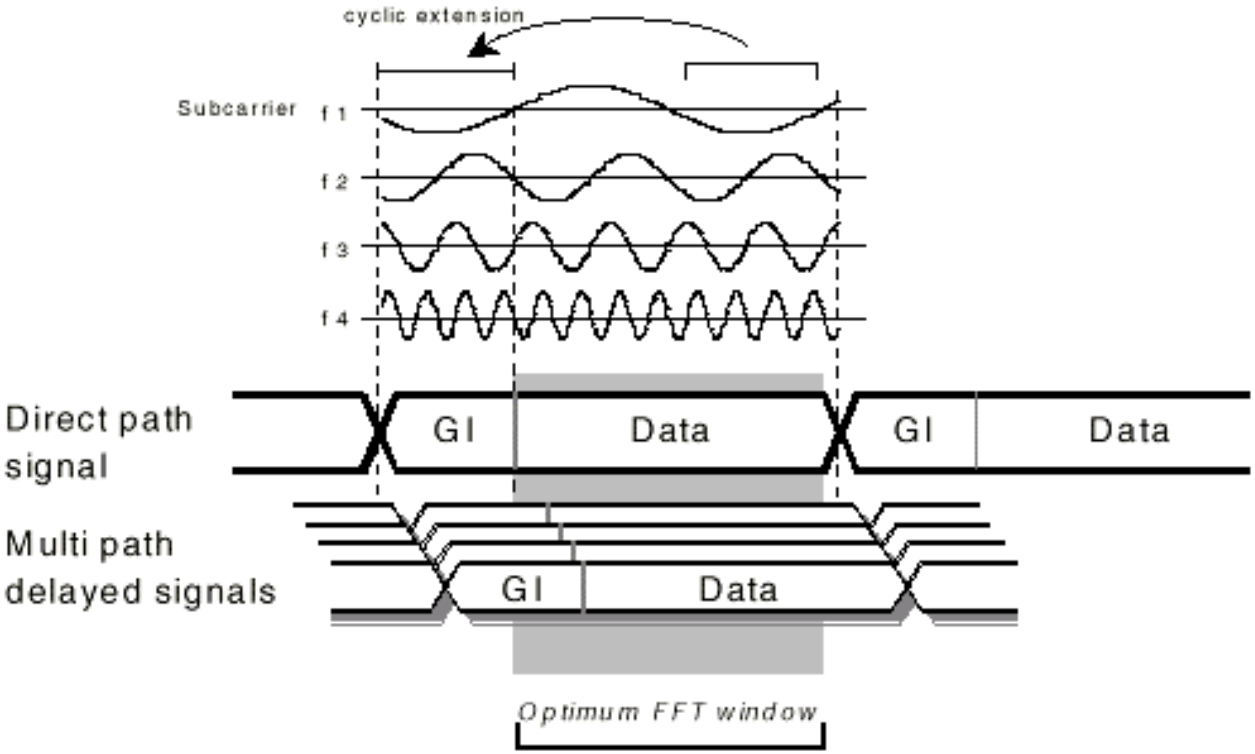
Design Challenges of OFDM Modulation

- **Sensitive to frequency offset – need frequency offset correction in the receiver.**
- **Sensitive to oscillator phase noise -- "clean" and stable oscillator required.**
- **Large peak to average ratio – amplifier back-off, reduced power efficiency.**
- **IFFT/FFT complexity -- fixed point implementation to optimize latency and performance.**
- **Intersymbol Interference (ISI) due to multipath-use guard interval.**

Intersymbol Interference(ISI) Due to Multipath

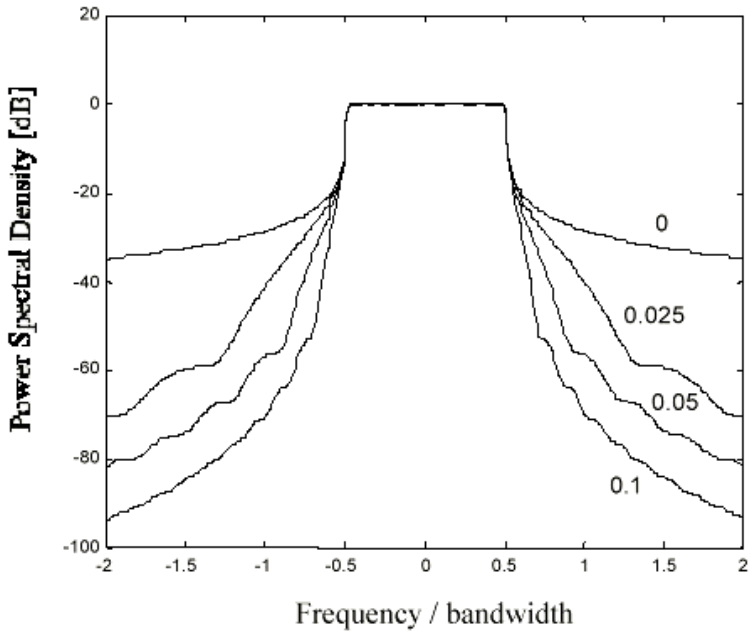


Guard Interval



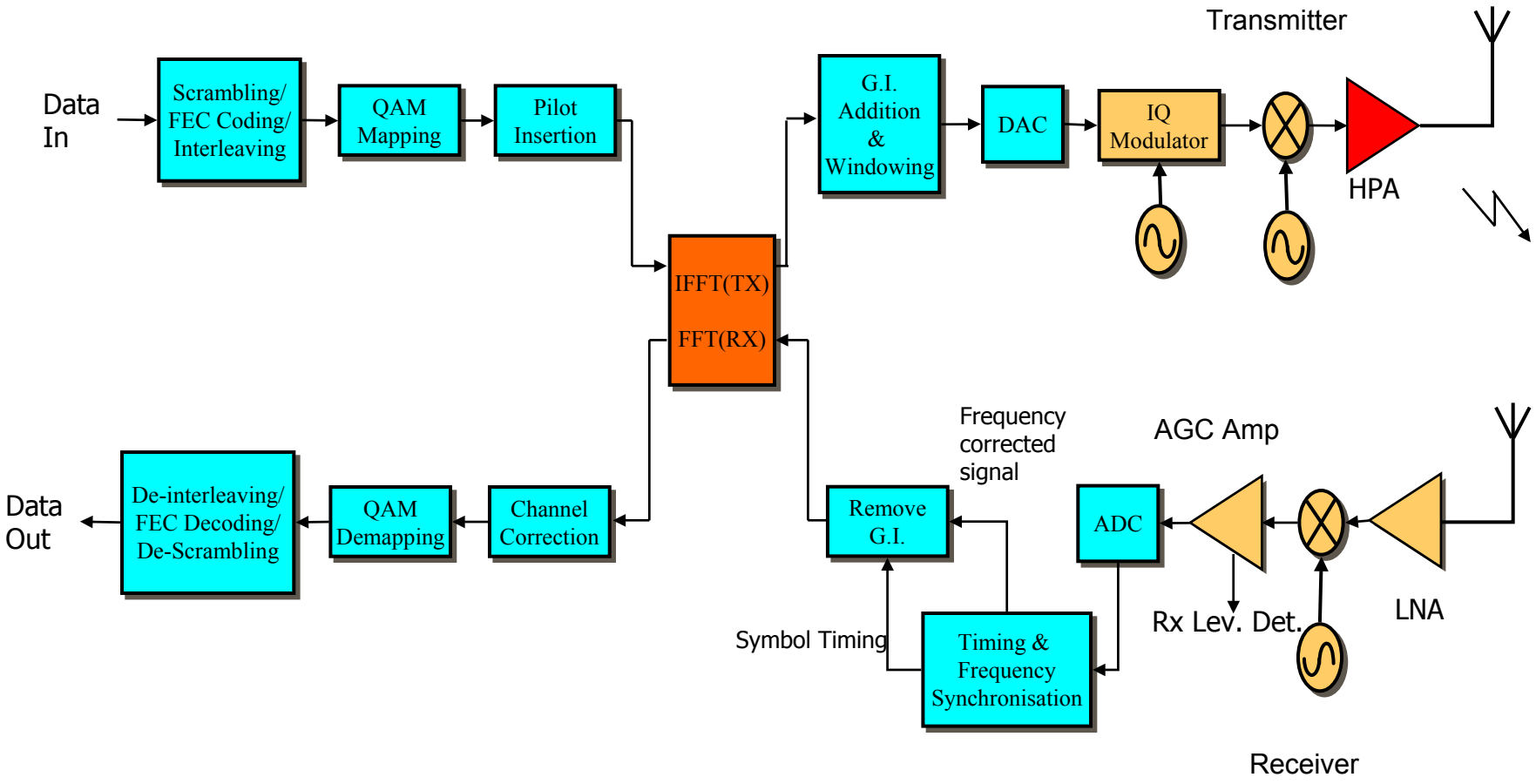
- **Multipath delays up to the guard time do not cause Inter-Symbol Interference**
- **Sub-carriers remain orthogonal for multipath delays up to guard time (no Inter-Carrier Interference)**

Windowing

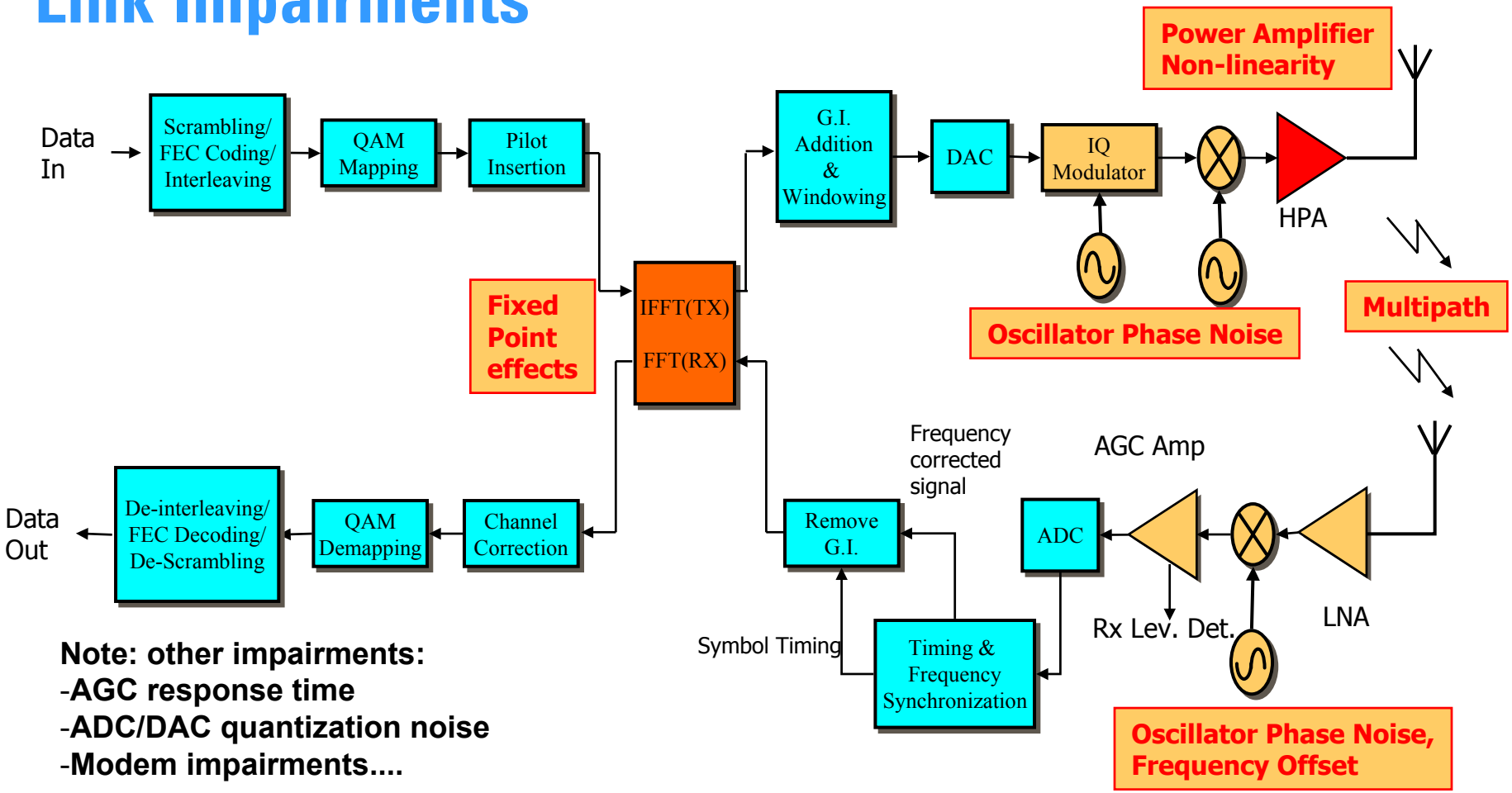


- To reduce spectrum splatter, the OFDM symbol is multiplied by a raised-cosine window, w(t) before transmission to more quickly reduce the power of out-of-band sub-carriers.
- Figure above shows spectra for 64 sub-carriers with different values of the rolloff factor, β of the raised cosine window.
- Larger β, better spectral roll-off.
- However, a roll-off factor of β reduces delay spread tolerance by a factor of βT_S.

OFDM Transceiver Block Diagram



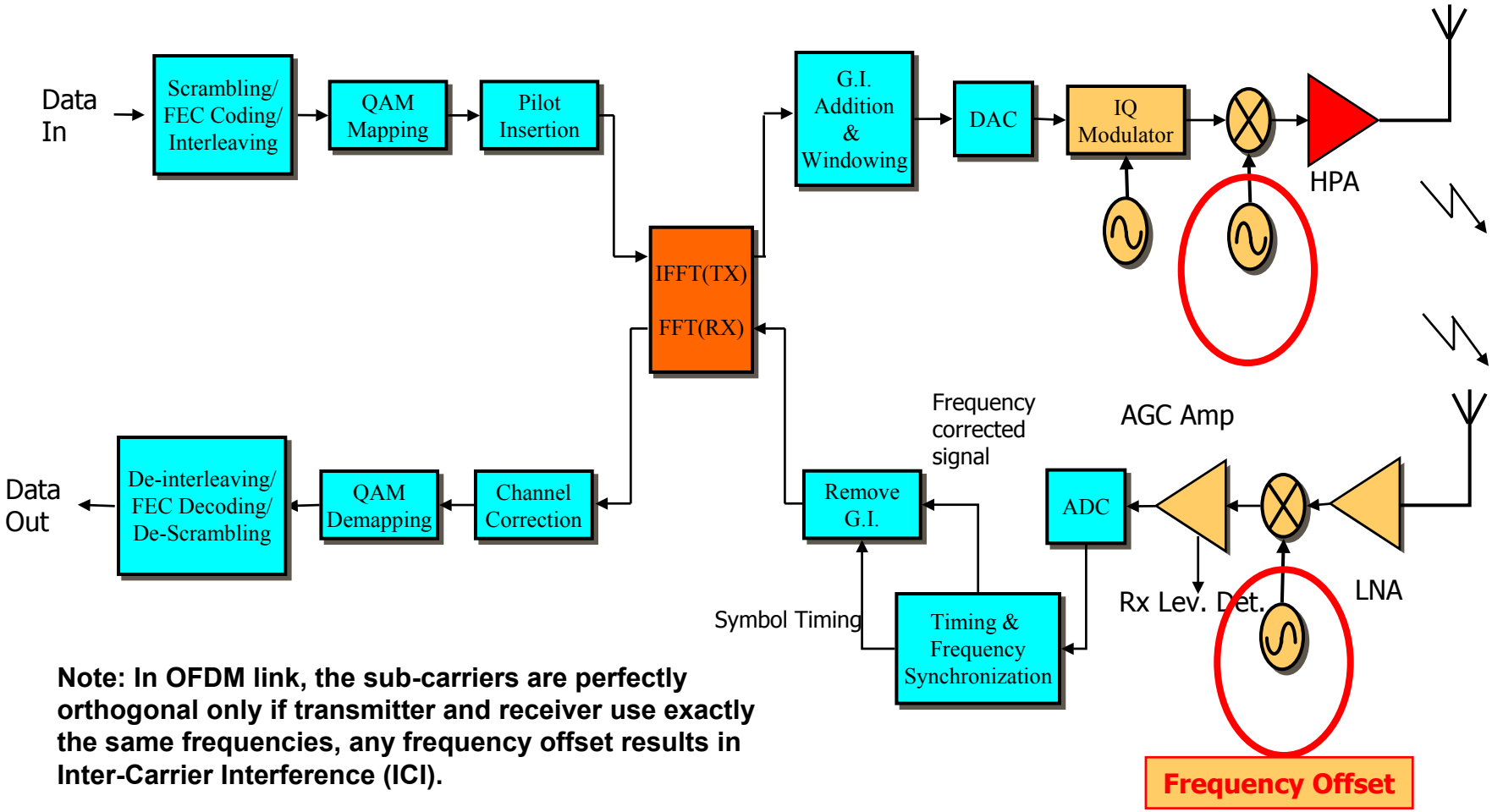
OFDM Transceiver Block Diagram: Sources of Link Impairments



Note: other impairments:
-AGC response time
-ADC/DAC quantization noise
-Modem impairments....

Using Simulation to Evaluate Effects of Link Impairments on OFDM Modulation

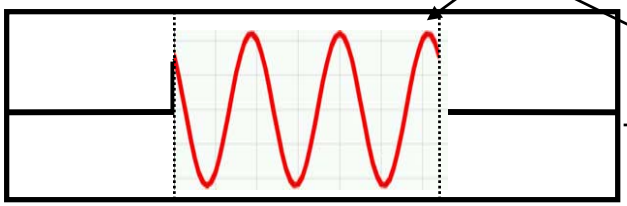
Effects of Frequency Offset



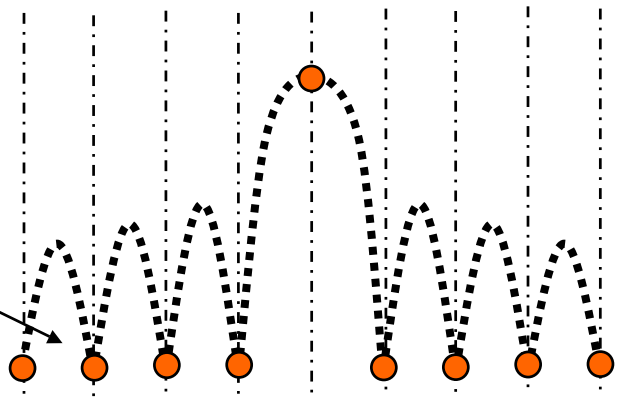
Note: In OFDM link, the sub-carriers are perfectly orthogonal only if transmitter and receiver use exactly the same frequencies, any frequency offset results in Inter-Carrier Interference (ICI).

Inter-Carrier Interference(ICI) Due to Frequency Offset

Integer number of cycles of the sub-carrier ensures that the nulls of the spectrum lands on the FFT bin, condition to avoid inter-carrier interference (ICI)



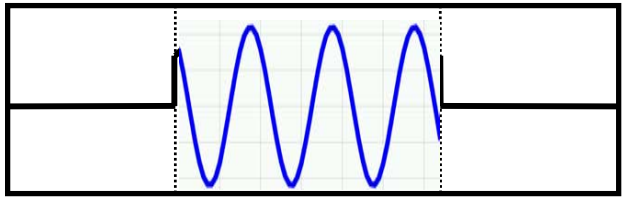
FFT



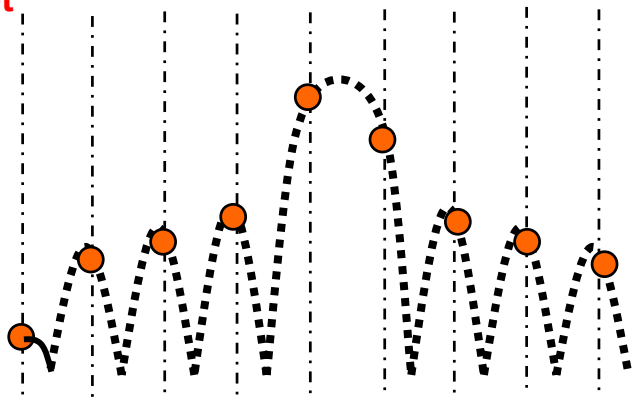
T

FFT window

No frequency offset



FFT

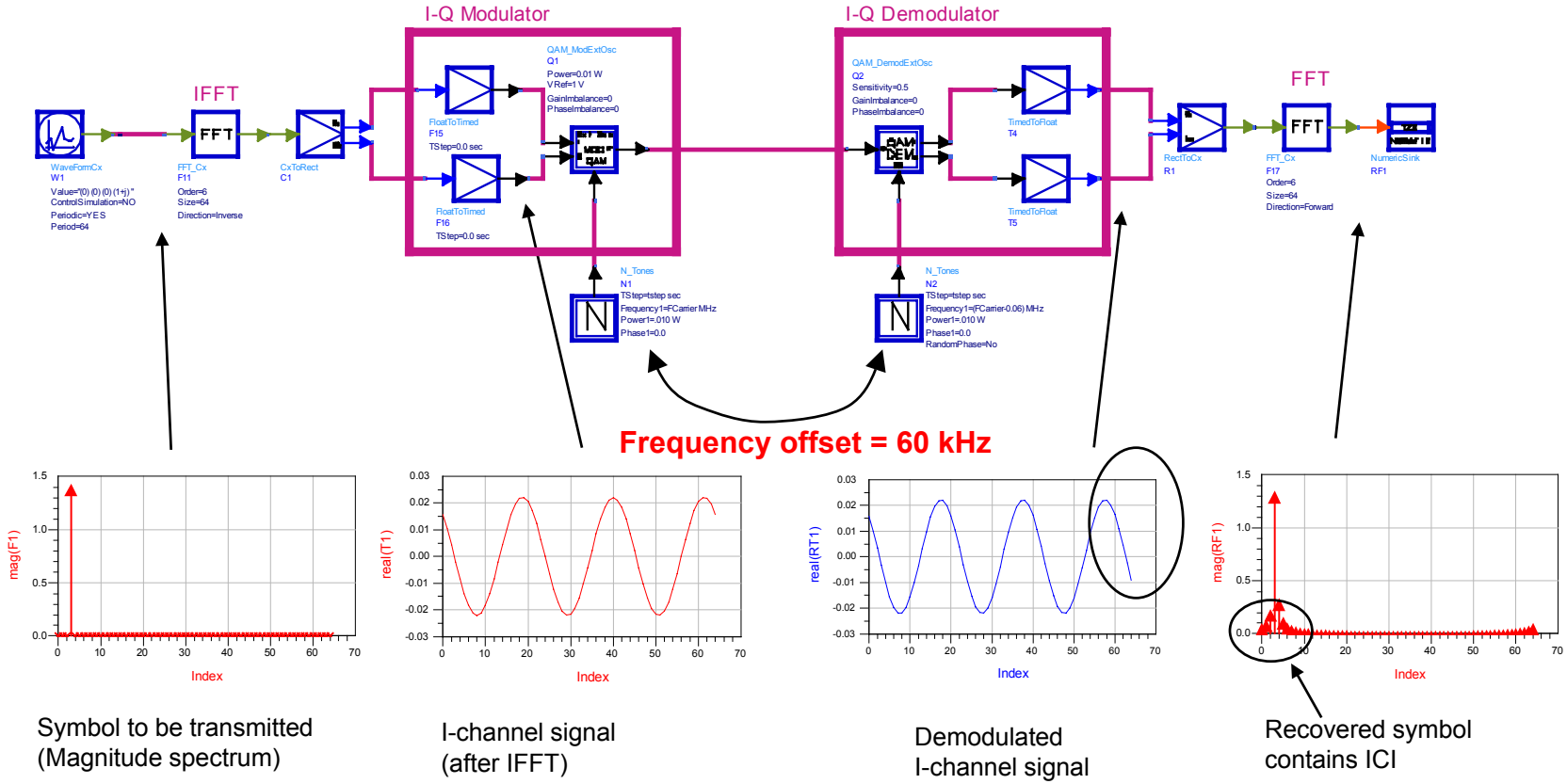


T

1/T

With frequency offset

OFDM Operation (ICI problem)



Symbol to be transmitted (Magnitude spectrum)

I-channel signal (after IFFT)

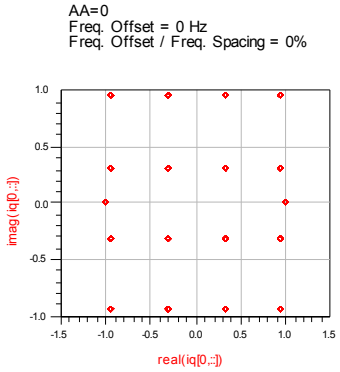
Demodulated I-channel signal

Recovered symbol contains ICI

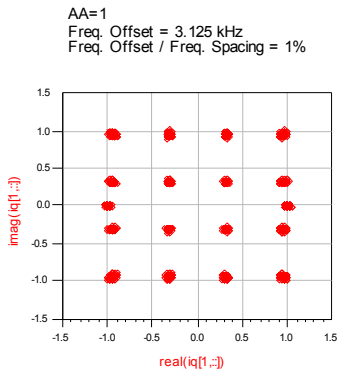
Effects of Frequency Offset – Without Frequency Correction

Frequency offset expressed as a percentage of sub-carriers frequency spacing (Δf=312.5kHz):

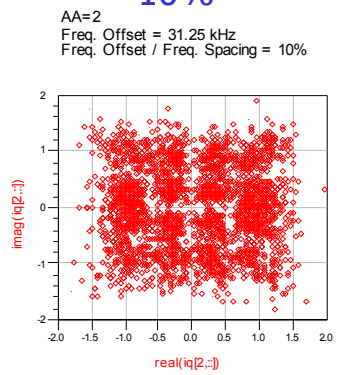
0%



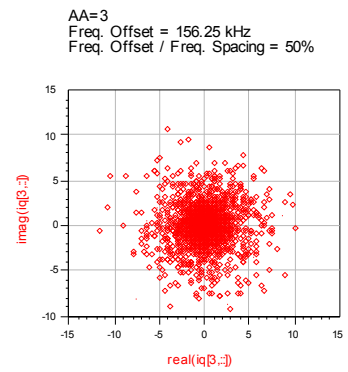
1%



10%



50%



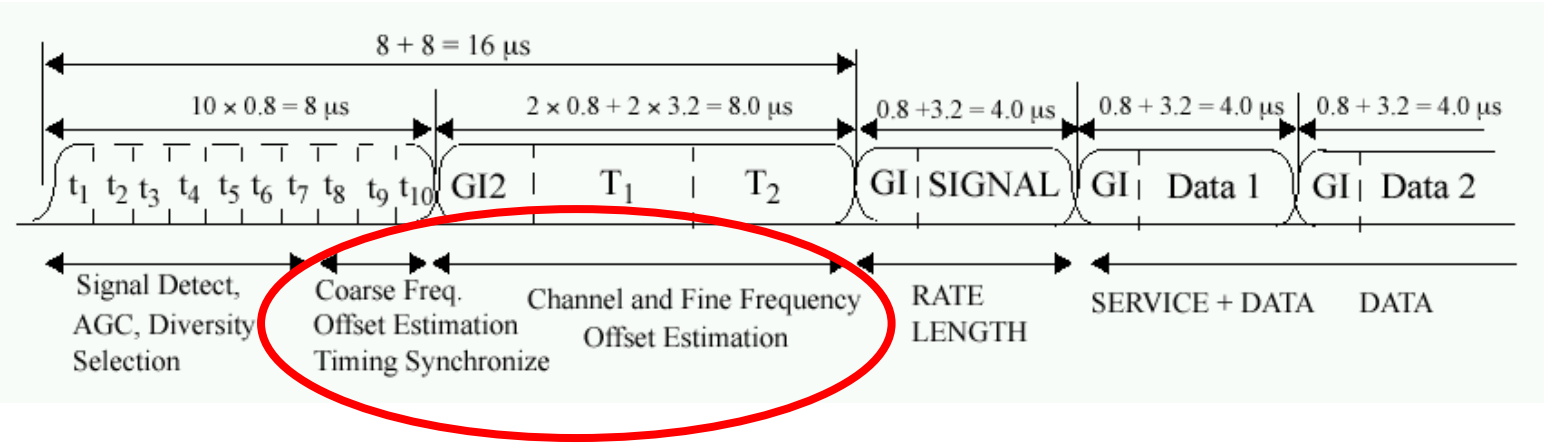
Index		ReceiverEVM
AA=0.000	40	1.198E-5
AA=1.000	40	0.025
AA=2.000	40	0.268
AA=3.000	40	2.840

Freq. Offset / Freq. Spacing
0%
1%
10%
50%

Why you need frequency offset correction:

assume freq. offset=3kHz (1%), requires:
oscillator stability: 3k/5.8G=0.5ppm!

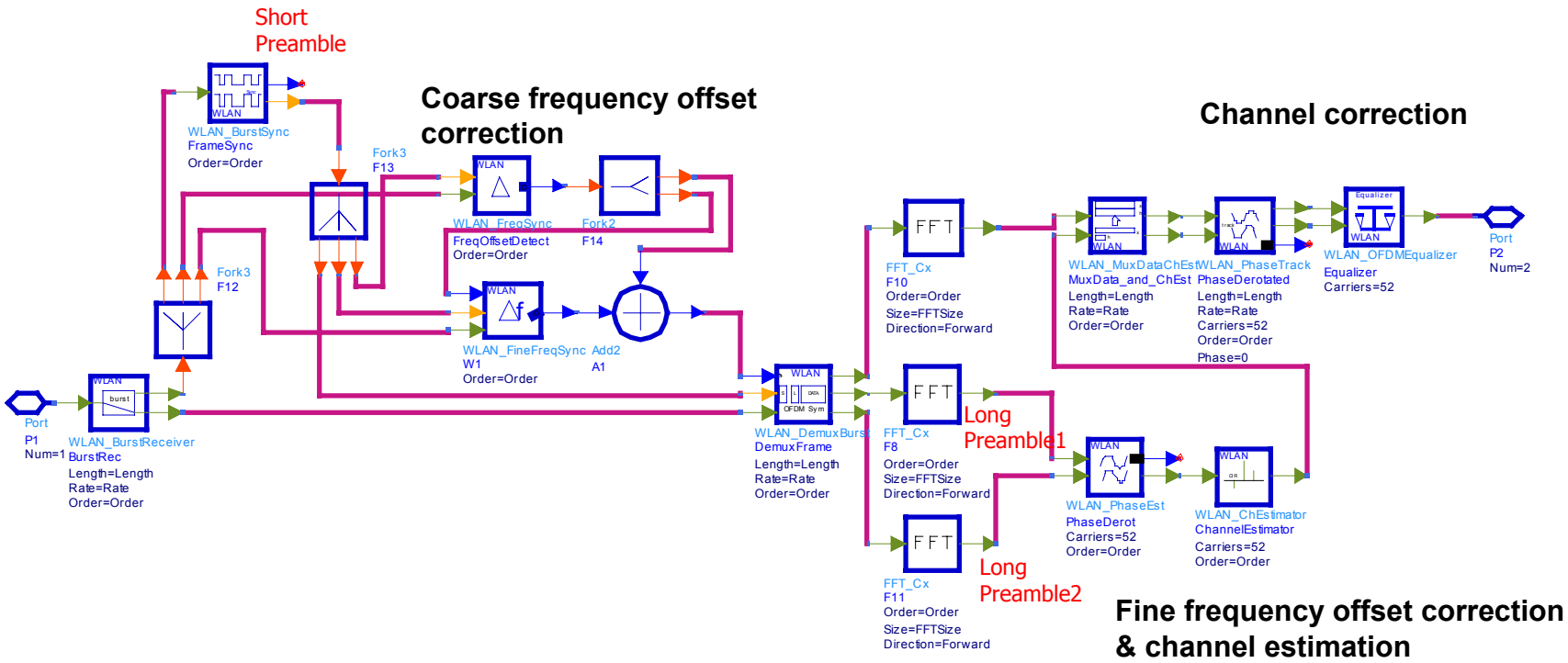
Frequency Offset Estimation Using Preambles



- **Make use of short preamble for coarse frequency offset estimation and long preamble for fine frequency offset estimation.**
- **Short preamble symbol duration of 0.8µs allows frequency correction up to 1/(2x0.8µs)=±625kHz**
- **Assume RF frequency=5.8GHz, the tolerable frequency offset (worst case) =0.5x625k/5.8G=±53.8ppm > ±20ppm specified in 802.11a.**

Frequency Offset Estimation and Correction

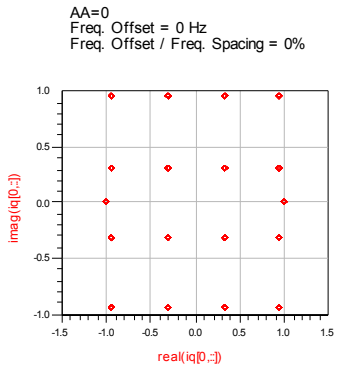
Frequency offset compensation network:



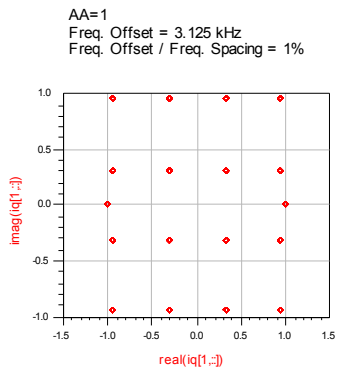
Effects of Frequency Offset – with Frequency Correction

Frequency offset expressed as a percentage of sub-carriers frequency spacing (Δf=312.5kHz):

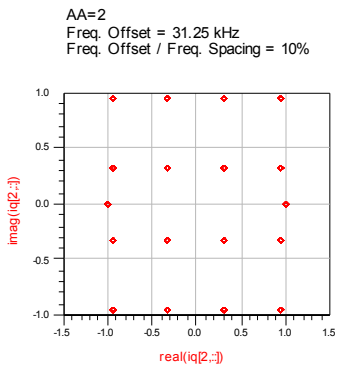
0%



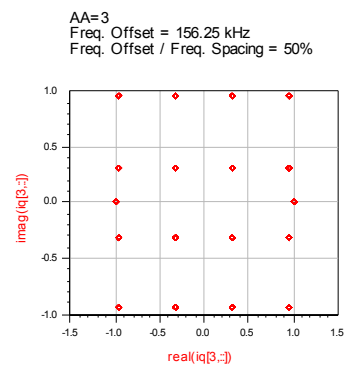
1%



10%

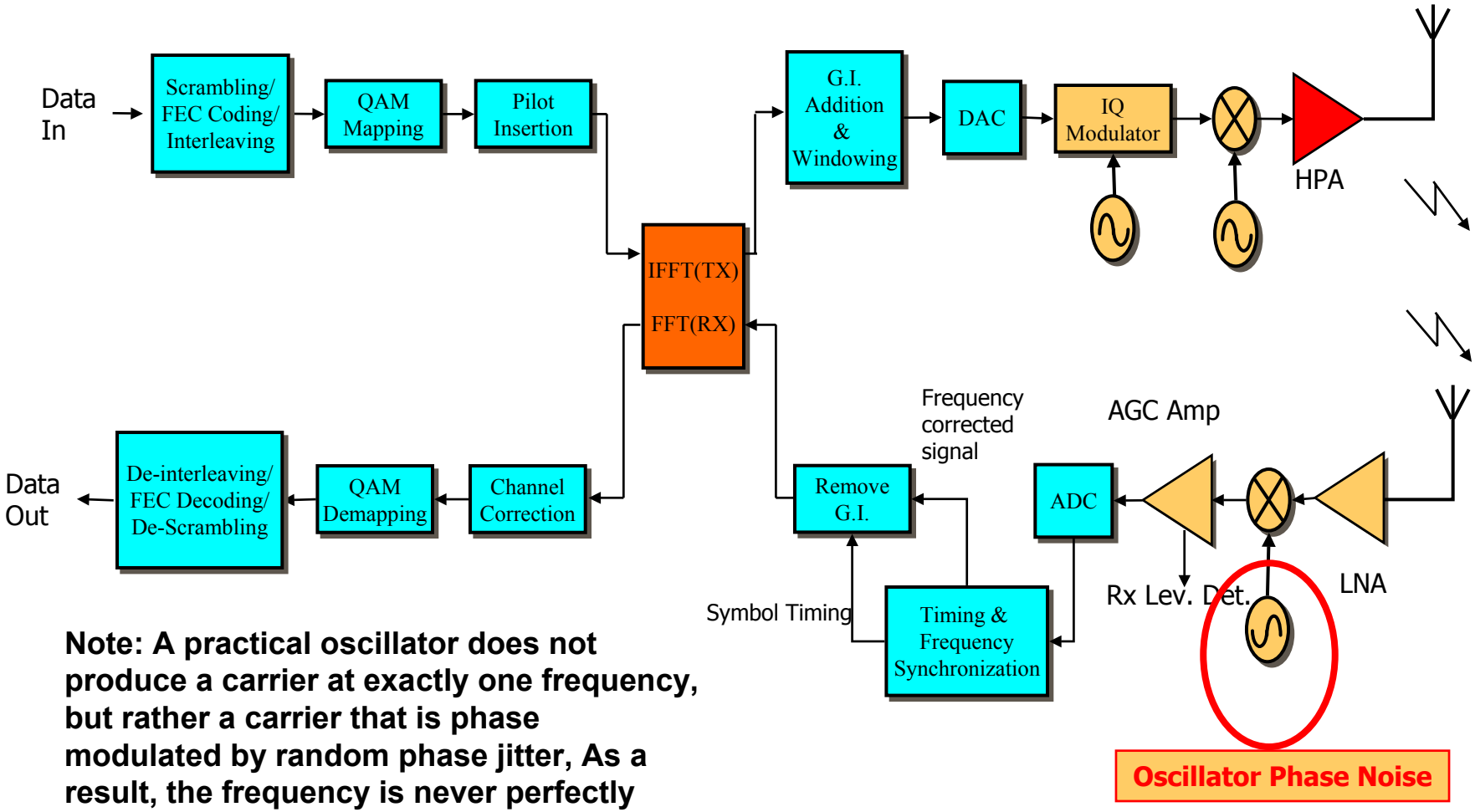


50%



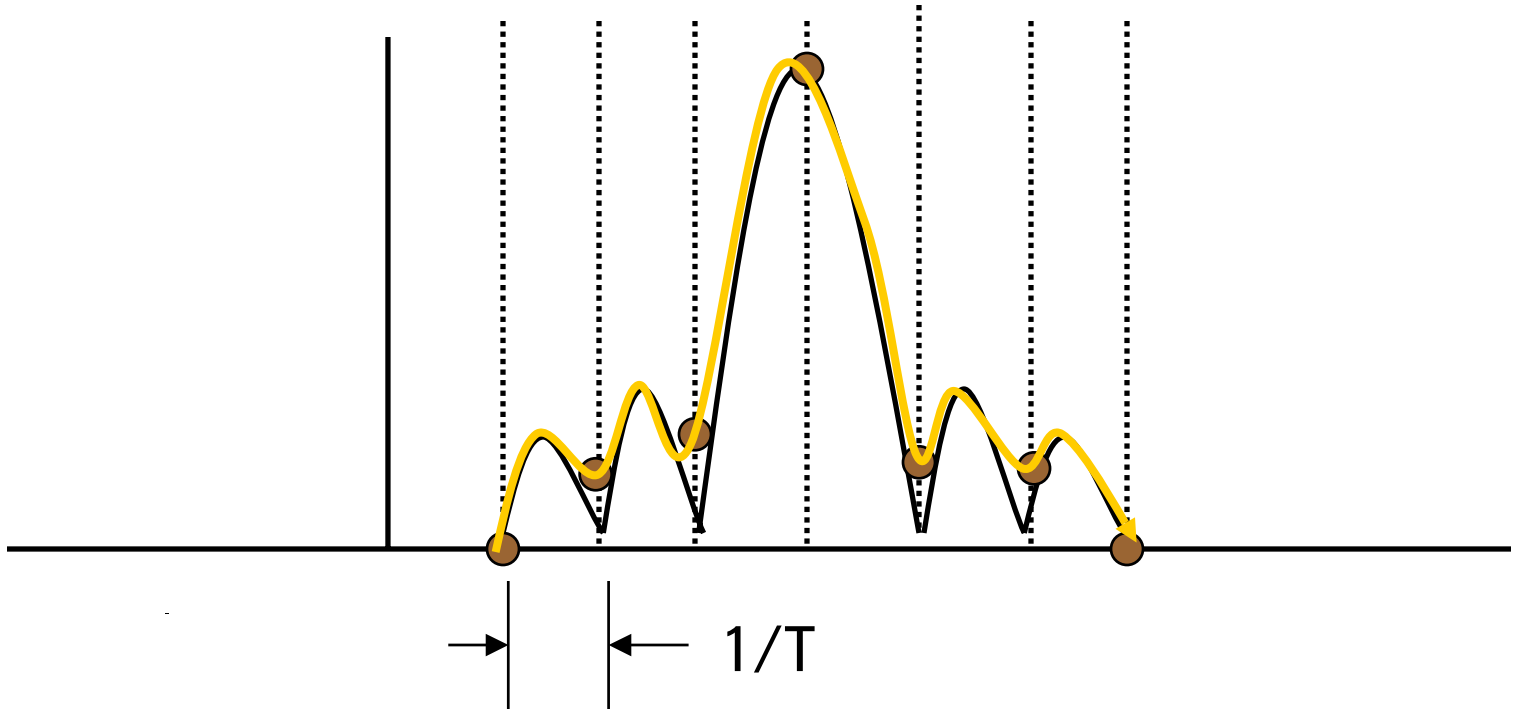
Index	ReceiverEVM	Freq. Offset / Freq. Spacing
AA=0.000 40	1.199E-5	0%
AA=1.000 40	1.214E-5	1%
AA=2.000 40	1.211E-5	10%
AA=3.000 40	1.210E-5	50%

Effects of Oscillator Phase Noise



Note: A practical oscillator does not produce a carrier at exactly one frequency, but rather a carrier that is phase modulated by random phase jitter, As a result, the frequency is never perfectly constant, thereby causing ICI.

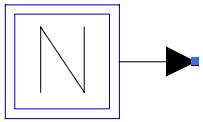
Effects of Oscillator Phase Noise



FFT Bin Spacing is 1/T

Effects of Oscillator Phase Noise (continued)

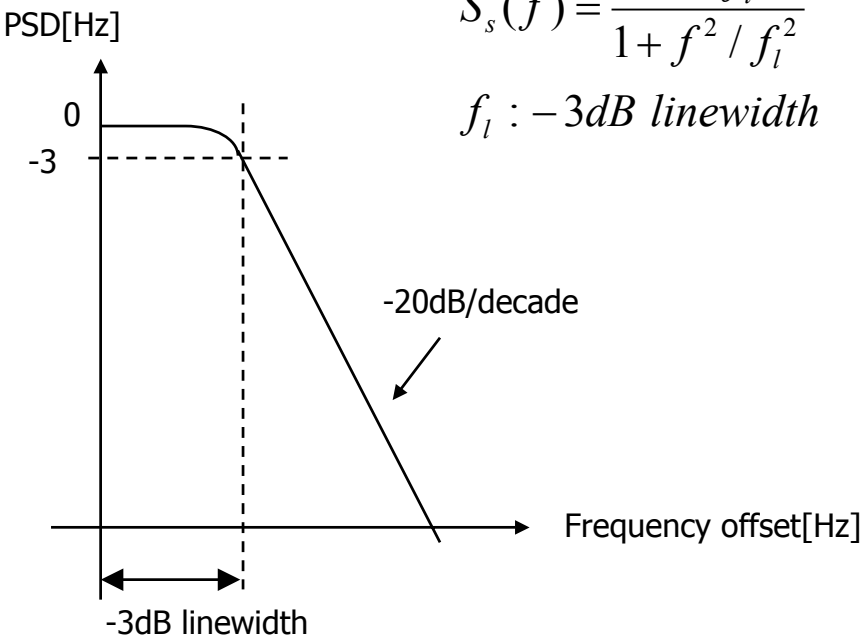
- **N_Tones model is used to model the phase noise**
- **Based on Lorentzian spectrum**
- **Characterized by –3dB-linewidth, -20dB per decade slope**



N_Tones
N1
TStep=50 nsec
Frequency1=FCarrier MHz
Power1=.010 W
Phase1=0.0
AdditionalTones=""
RandomPhase=No
PhaseNoiseData=PN
PN_Type=Random PN

$$S_s(f) = \frac{2/\pi f_l}{1 + f^2/f_l^2}$$

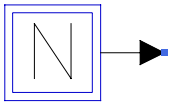
$$f_l : -3dB\ linewidth$$



Phase noise profile based on Lorentzian spectrum

Effects of Oscillator Phase Noise (continued)

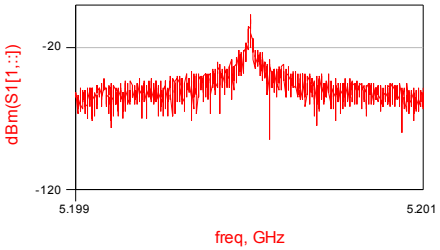
- 3 profiles of phase noise were simulated:



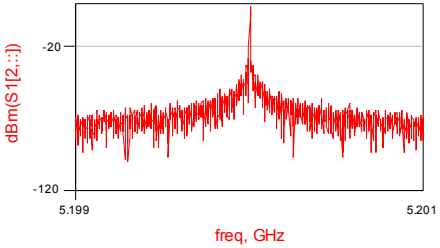
N_Tones
N1
TStep=50 nsec
Frequency1=FCarrier MHz
Power1=.010 W
Phase1=0.0
AdditionalTones=""
RandomPhase=No
PhaseNoiseData=PN
PN_Type=Random PN

Var Eqn VAR
VAR4
AA=1
PN0=" "
PN1=" 120 -15 300 -23 3000 -43 30000 -63 300000 -83 1200000 -95"
PN2=" 120 -35 300 -43 3000 -63 30000 -83 300000 -103 1200000 -115"
PN=if (AA==0) then PN0 elseif (AA==1) then PN1 else PN2 endif

Ideal



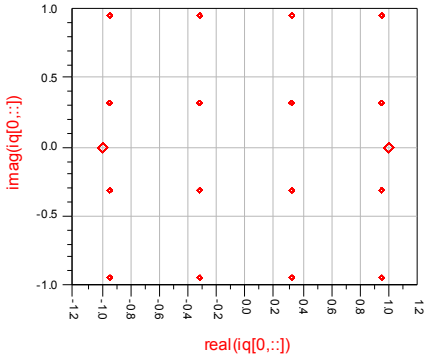
-3dB linewidth=30Hz
=0.01% of sub-carrier spacing



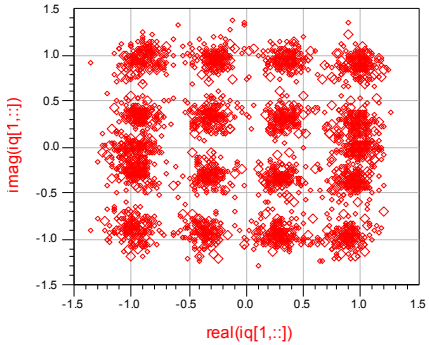
-3dB linewidth=3Hz
=0.001% of sub-carrier spacing

Effects of Oscillator Phase Noise (continued)

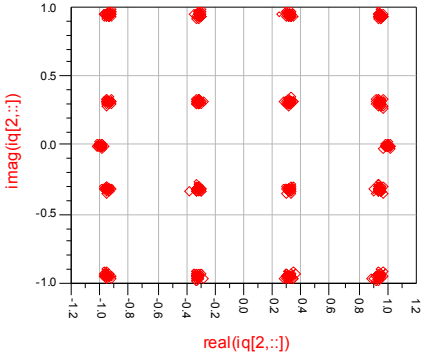
Ideal



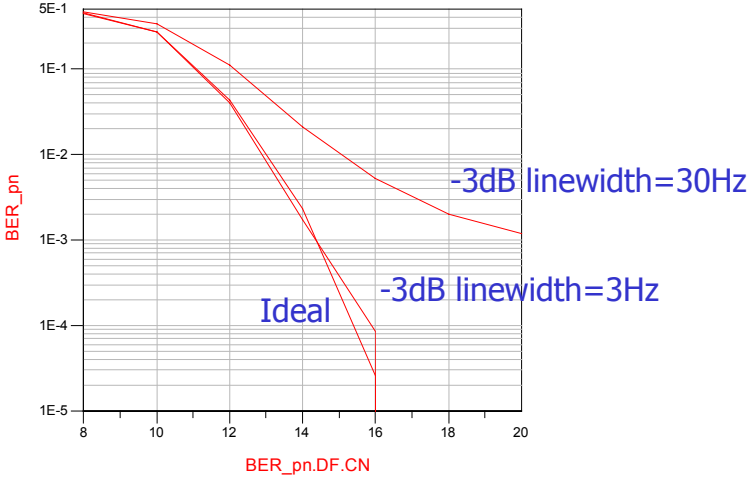
-3dB linewidth=30Hz



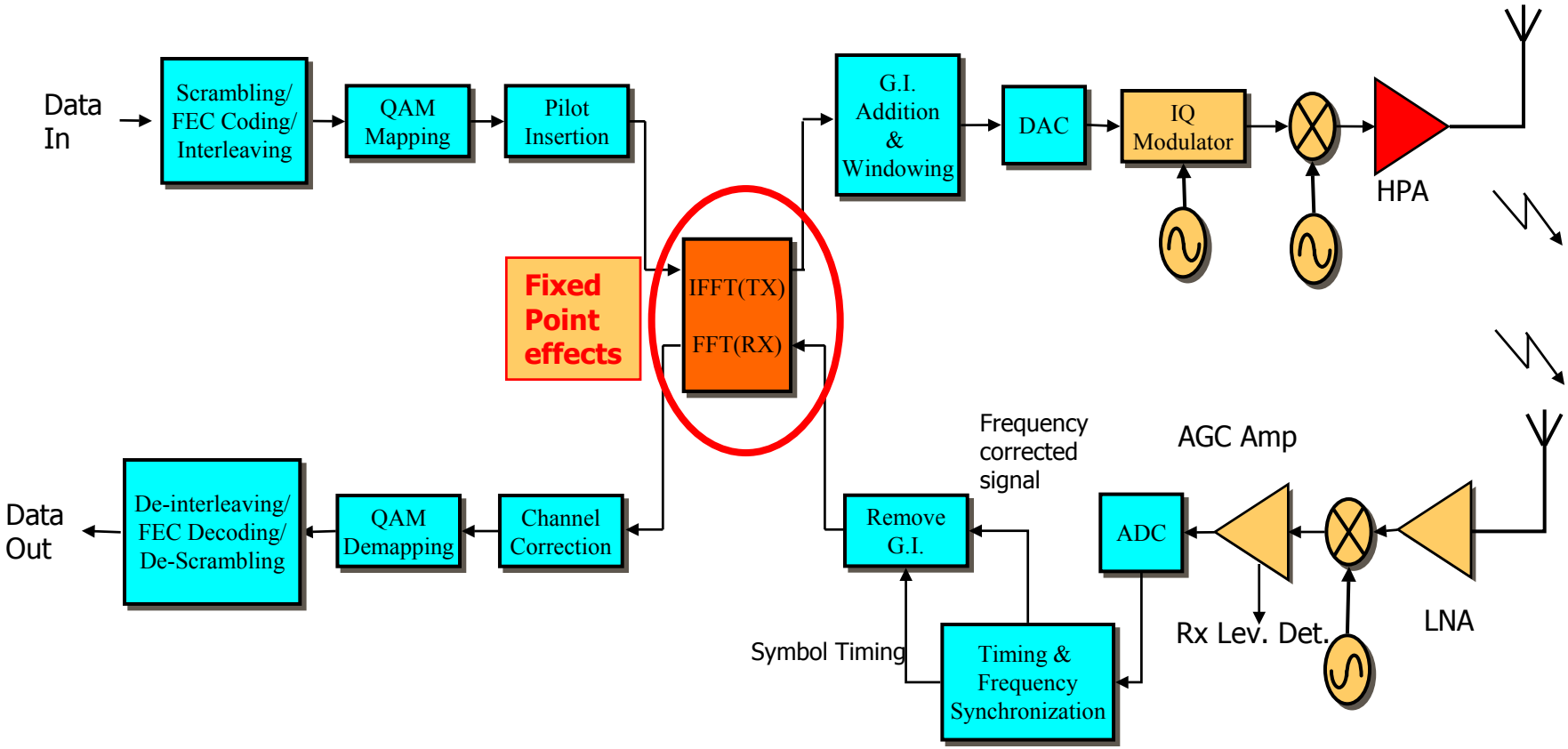
-3dB linewidth=3Hz



Index	ReceiverEVM_pn		
	AA=0.000	AA=1.000	AA=2.000
40	1.199E-5	0.143	0.014



Effects of Fixed Point Implementation of IFFT/FFT



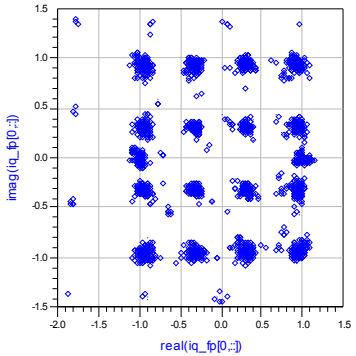
Effects of Fixed Point Implementation of IFFT/FFT

- 64-point IFFT/FFT in fixed-point arithmetic
- Decimation in Frequency, Radix-2 algorithm
- Parameterized bit precision

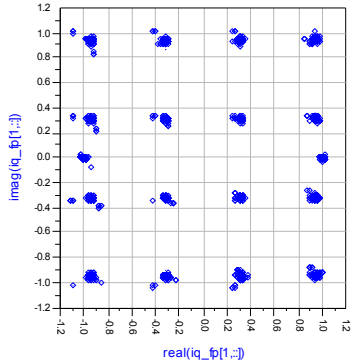
- Bit precision of “2.8”, “2.10”, “2.12” and “2.14” were simulated

Effects of Fixed Point Implementation of IFFT/FFT (continued)

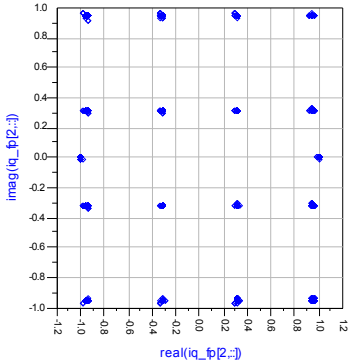
Bit precision: "2.8" "2.10" "2.12" "2.14"



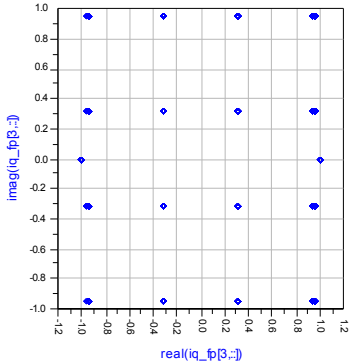
Bit Precision= 2.8



Bit Precision= 2.10

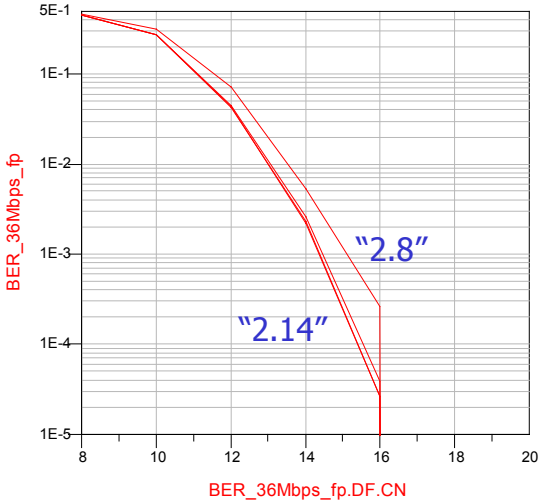


Bit Precision= 2.12

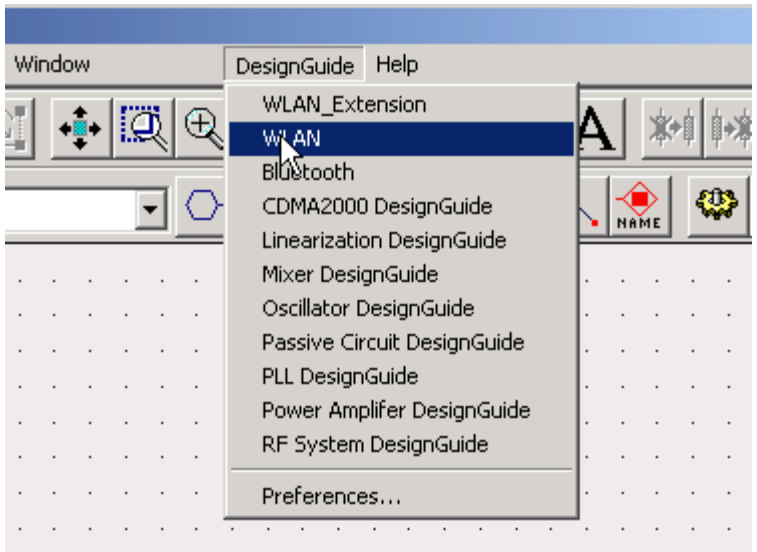


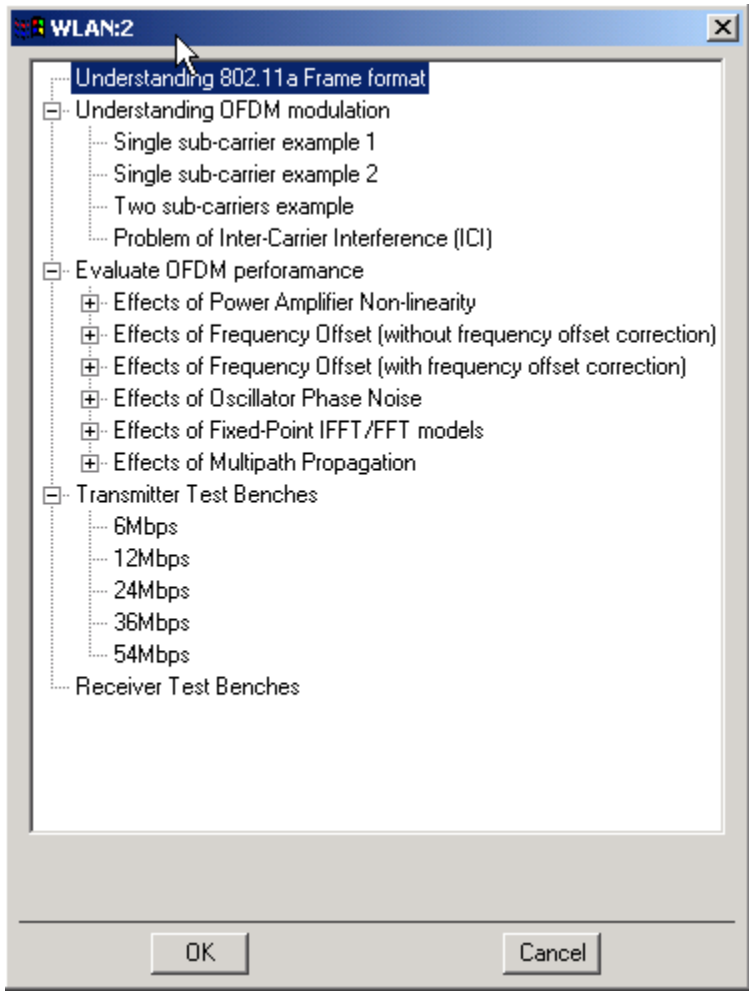
Bit Precision= 2.14

Index	ReceiverEVM_fp			
	AA=0.000	AA=1.000	AA=2.000	AA=3.000
40	0.118	0.027	0.006	0.001



WLAN 802.11a ADS DesignGuide – Schematic Menu





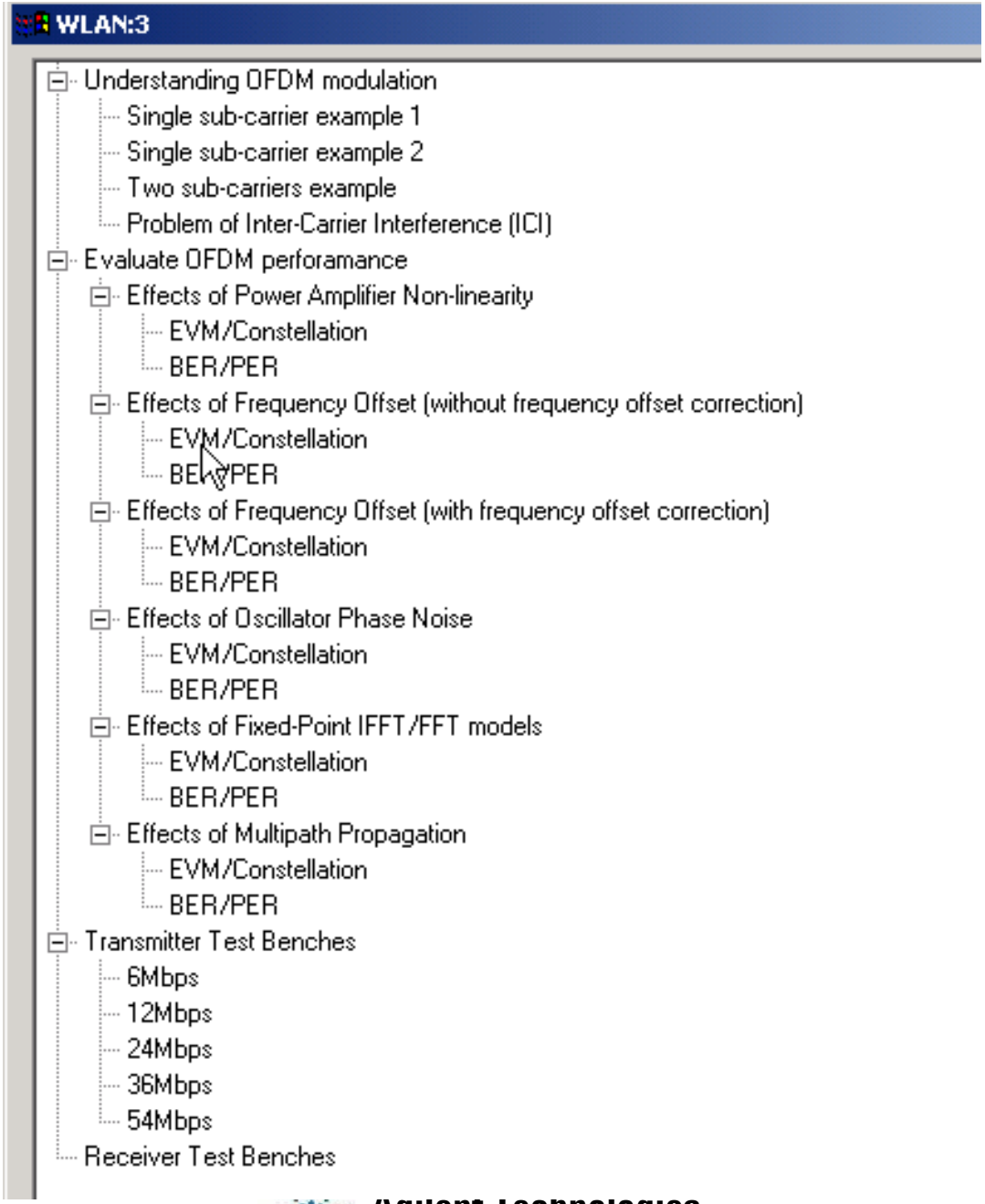
The Details

3 Parts:

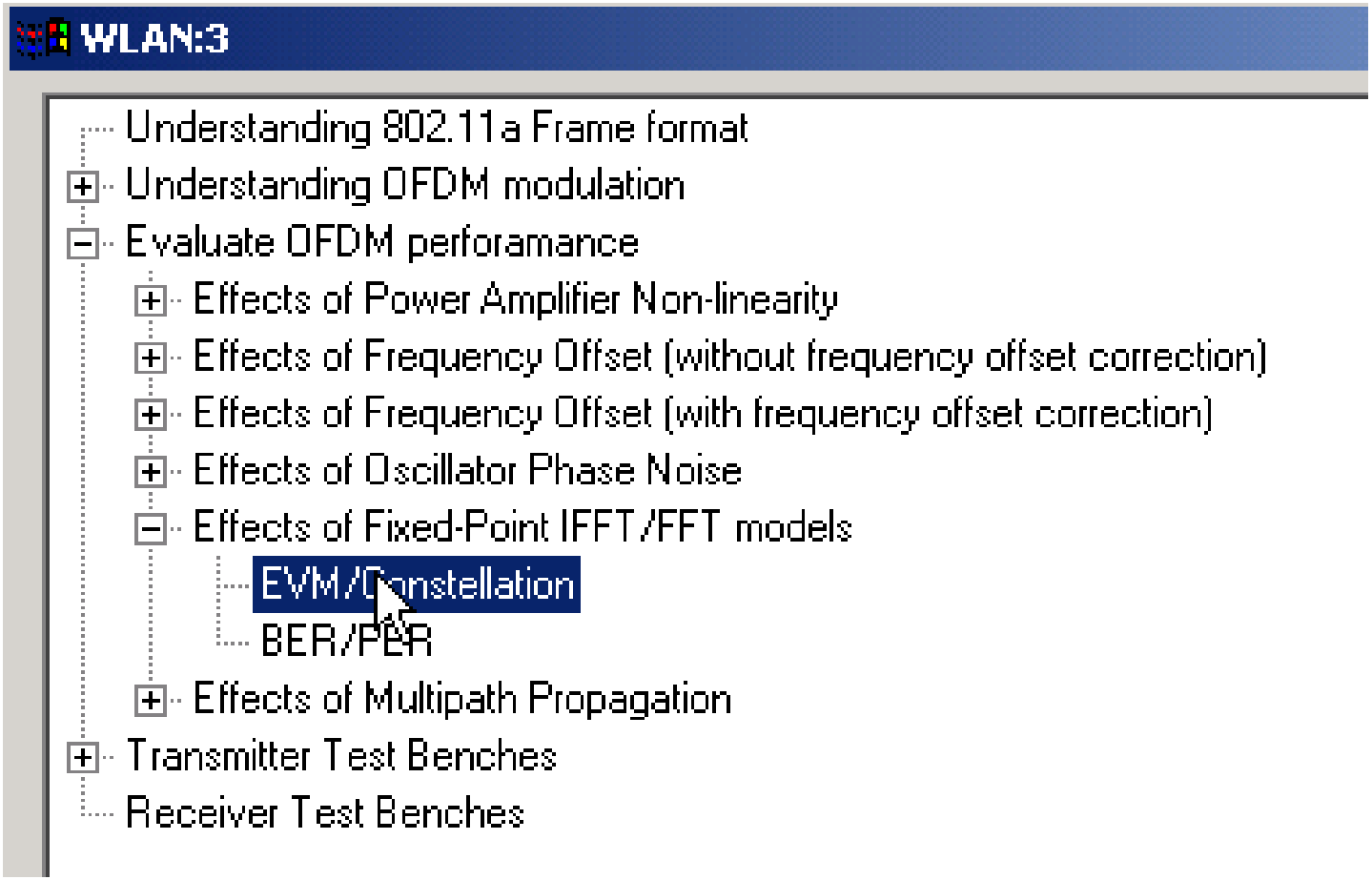
Tutorial

Impairments

Pre-built test benches



WLAN DesignGuide Example



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