Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [**UWB-Chirp**]
Date Submitted: [21 July, 2005]
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Re: []

Abstract: [Time-Frequency Distribution of UWB-Chirp]

Purpose: [Contribution]

Time-Freq. Distribution of Chirp-Signal

(for optional UWB Chirp-radio)

2005. 7. 21.

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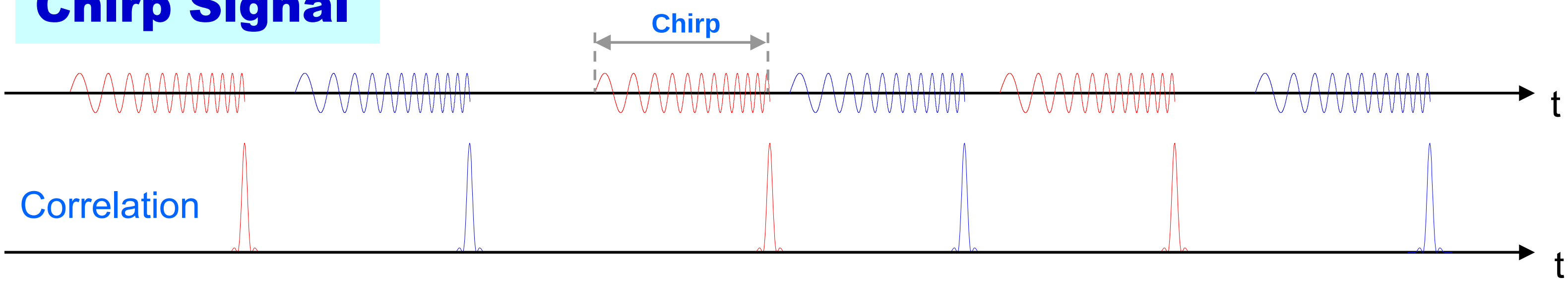
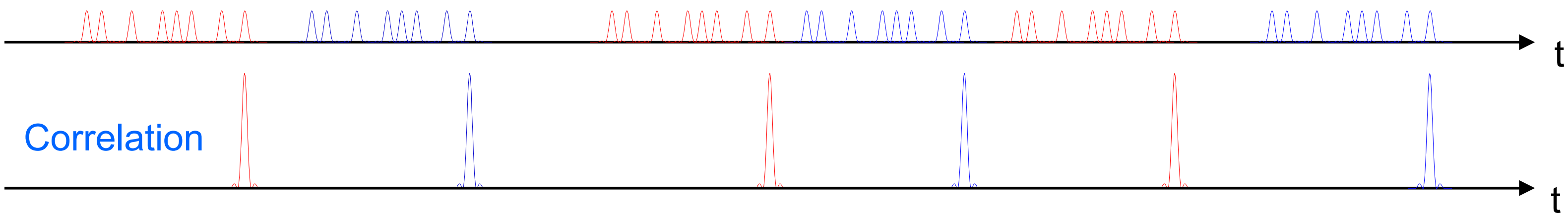
Properties of Chirp-Signal

Chirp vs Impulse

Chirp Signal



Impulse Radio



- **Similarities**
  - Spread-Spectrum: BW >> R_b (De-spreading Gain)
  - Impulsive Cross-correlation Pulse-width
  - (Pulse-width of Impulse Train) = (Pulse-width of Cross-Correlation of Chirp) @ Same BW
  - Great Resolvability of Multi-path

Properties of Chirp-Signal

- **Co-existence / Interference Mitigation Technique**
  - Orthogonal / Quasi-Orthogonal Signal Set
  - Ultra-High Processing Gain: UWB-Chirp
- **Interference Susceptibility**
  - Low Cross-Correlation property with Existing Signal
- **Robustness:**
  - Heavy Multi-path Environment: Resolvable in Correlation Domain
  - SOP: 3 x 2 (Code Division) = 6
- **Low Sensitivity for Component Tolerance**
  - Crystal : ± 40ppm
- **Mobility**
  - Ultra-Wide-Band Chirp: Insensitive for Fading & Doppler Shift
  - Easy to Maintain of Timing Sync. at the Receiver

Regulatory Issue

FCC 05-58

Released: March 11, 2005

I. INTRODUCTION

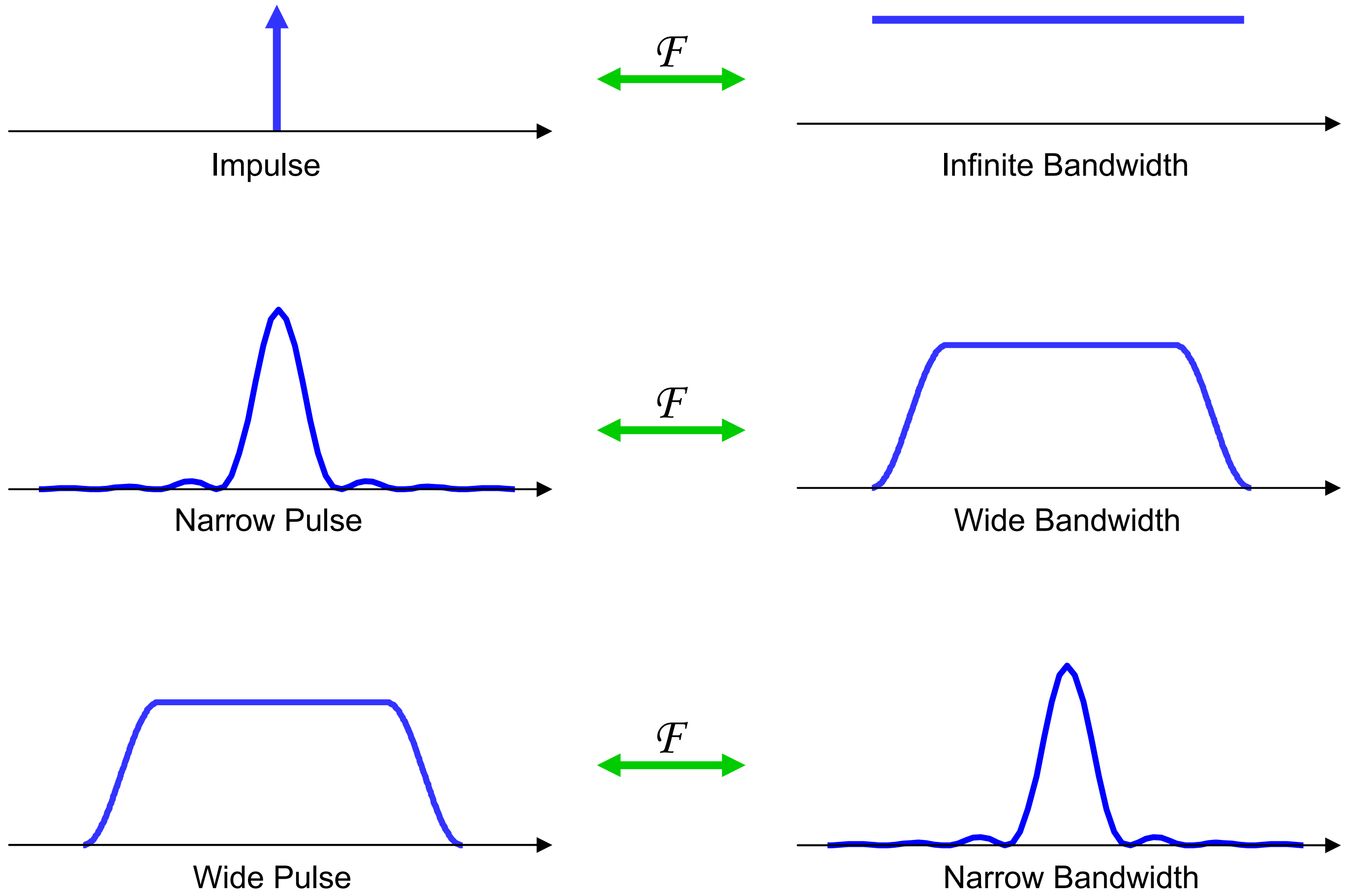
1. By this action, we are granting a waiver of the certain emission measurement procedures applicable to ultra-wideband ("UWB") transmitters that operate under Part 15 of our rules.[1] Specifically, we are permitting the emissions from UWB transmitters operating in the 3.1-5.03 GHz and 5.65-10.6 GHz bands that employ frequency hopping or stepped frequency modulation techniques, or that gate the transmitted signal,[2] to be measured with the transmitter operating in its normal transmission mode. This waiver applies to the measurement procedure applicable to UWB devices, permitting products to be tested based on the manner in which they are operated. This action is taken in response to a Petition for Waiver that was filed by the Multi-band OFDM Alliance Special Interest Group ("MBOA-SIG")[3] on August 26, 2004.

⋮

18. In summary, we are waiving the UWB measurement procedure that requires the emissions from UWB devices employing hopped, stepped or sequenced operation to be measured with the hop, step or sequenced function stopped. In addition, we are waiving that portion of 47 C.F.R. § 15.521(d) that requires the emissions from UWB devices that employ gating to be measured with the emission gated on. The emissions from such systems shall be measured in their normal operating mode. These waivers do not apply to systems that employ swept frequency modulation.[49] Further, UWB transmitters certified under these waiver provisions also shall comply with the following provisions:

[49] As stated in 47 C.F.R. § 15.31(c), the emissions from transmitters employing swept frequency modulation are required to be measured with the frequency sweep stopped. Swept frequency systems were not addressed in this waiver and are outside of its scope.

Time-Freq. Distribution



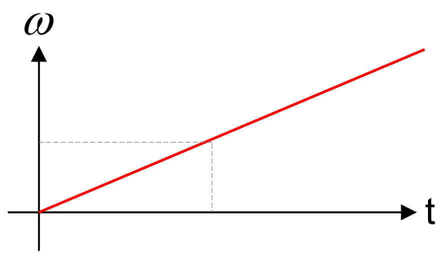
Time-Freq. Distribution

Wigner – Ville Distribution

$$W_x(t,f)=\int_{-\infty}^{\infty}x\left(t+\frac{\tau}{2}\right)x^*\left(t-\frac{\tau}{2}\right)e^{-j\omega\tau}d\tau$$ ···· Special case of Cohen's Class

$$Generalized\ \ Chirp:\ \ x(t)=a(t)e^{j\varphi(t)}$$

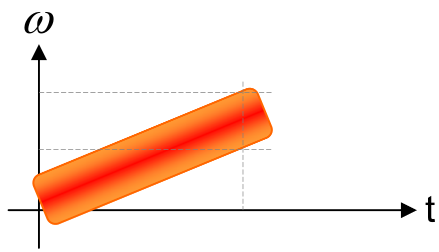
$$Linear\ \ Chirp:\quad x(t)=e^{j2\pi\left(\frac{\alpha}{2}t^2+\beta t+\gamma\right)}$$



- Mono-component : both amplitude and frequency

$$Short-Time\ Linear\ \ Chirp:$$

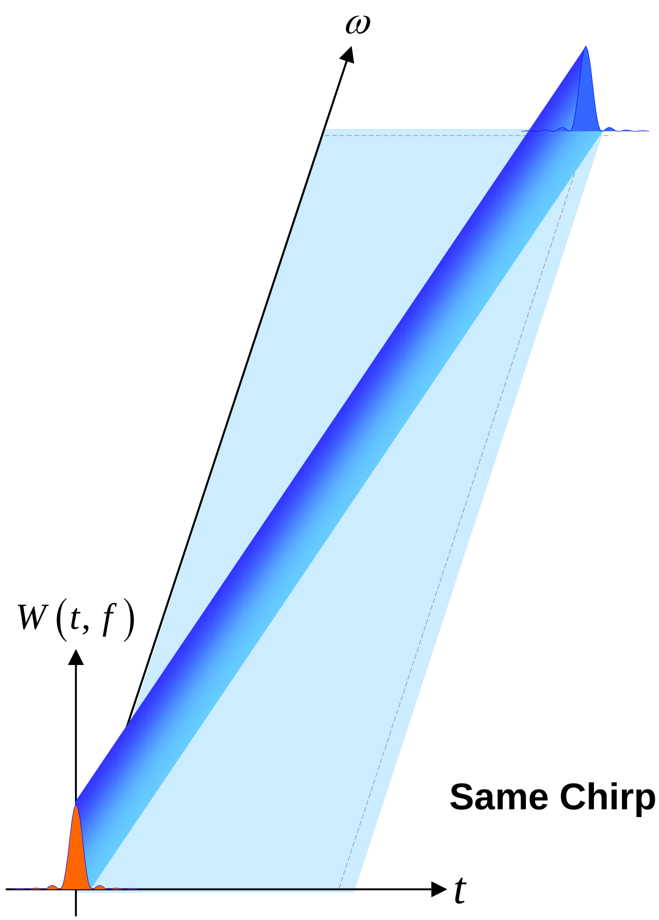
$$x(t)=e^{j2\pi\left(\frac{\alpha}{2}t^2+\beta t+\gamma\right)}p(t)$$



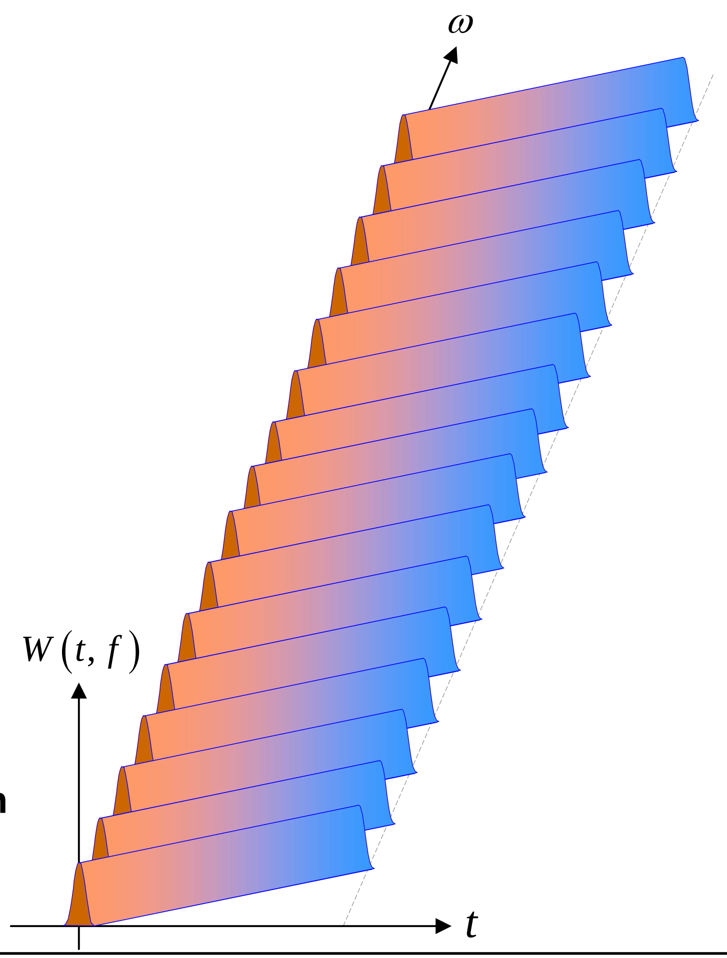
- Wide-Bandwidth component

Time-Freq. Distribution

Single-Chirp

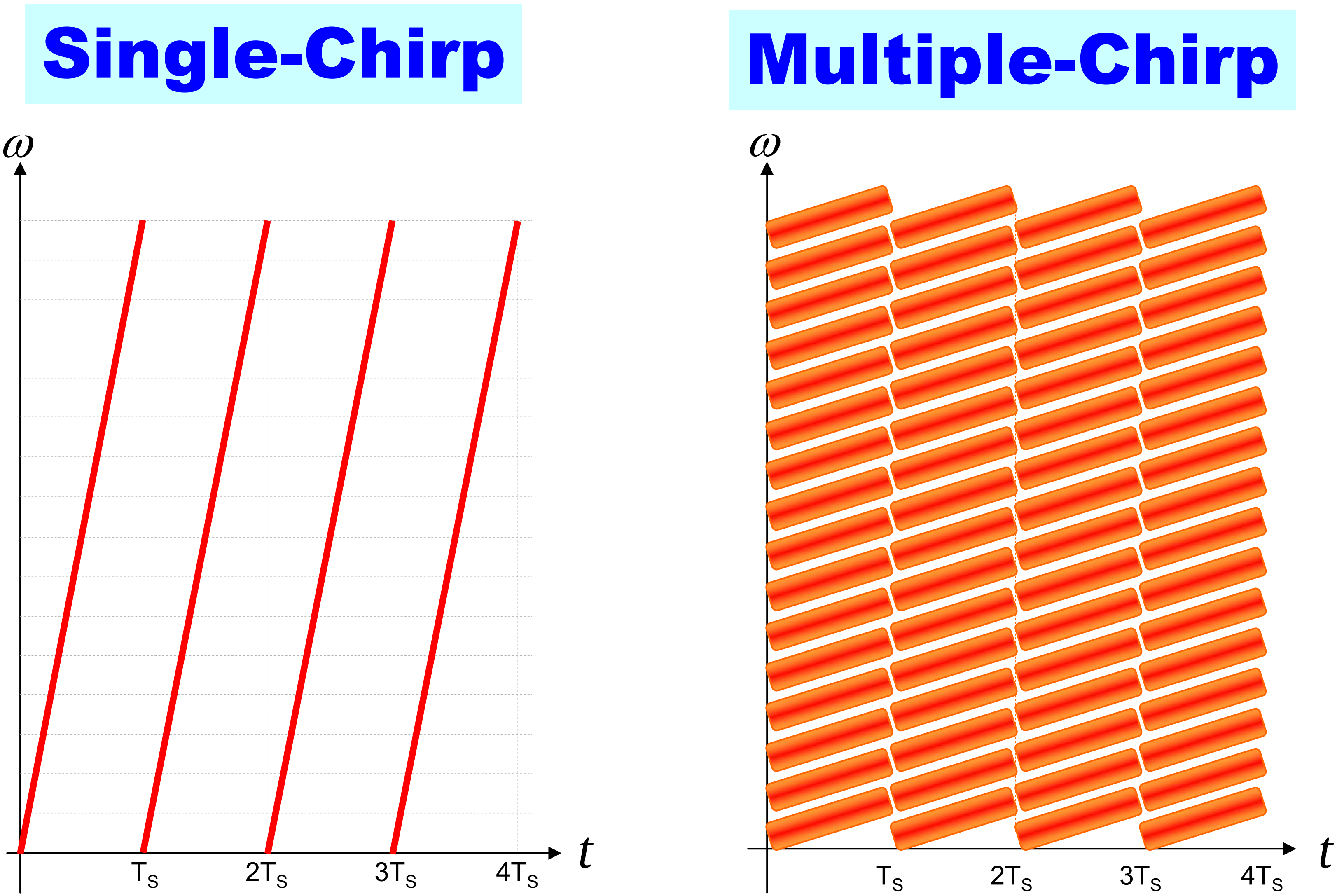


Multiple-Chirp



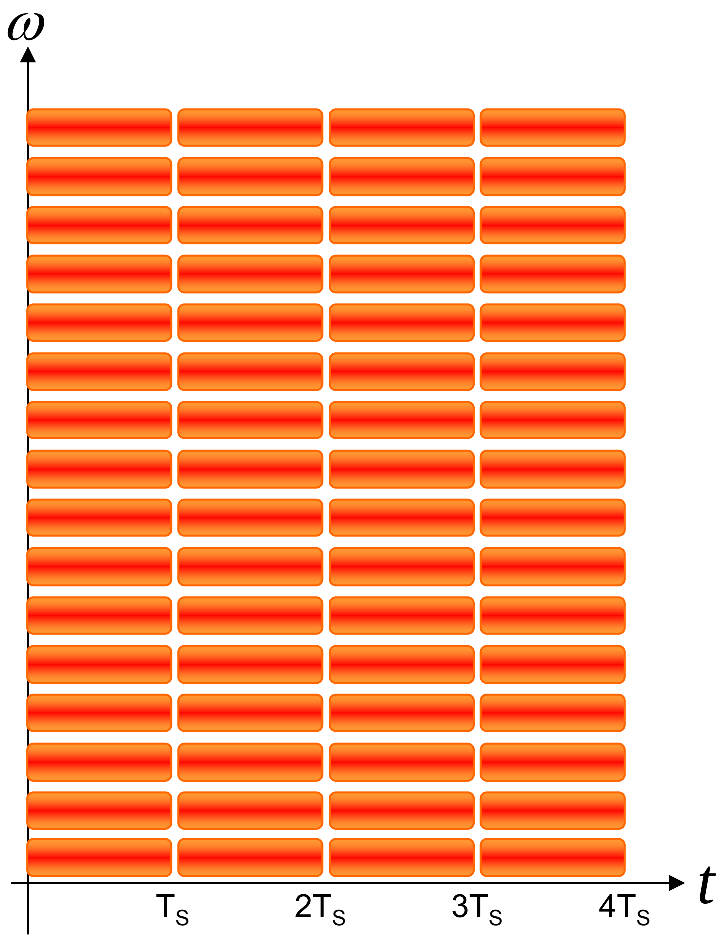
Same Chirp Duration

Time-Freq. Distribution

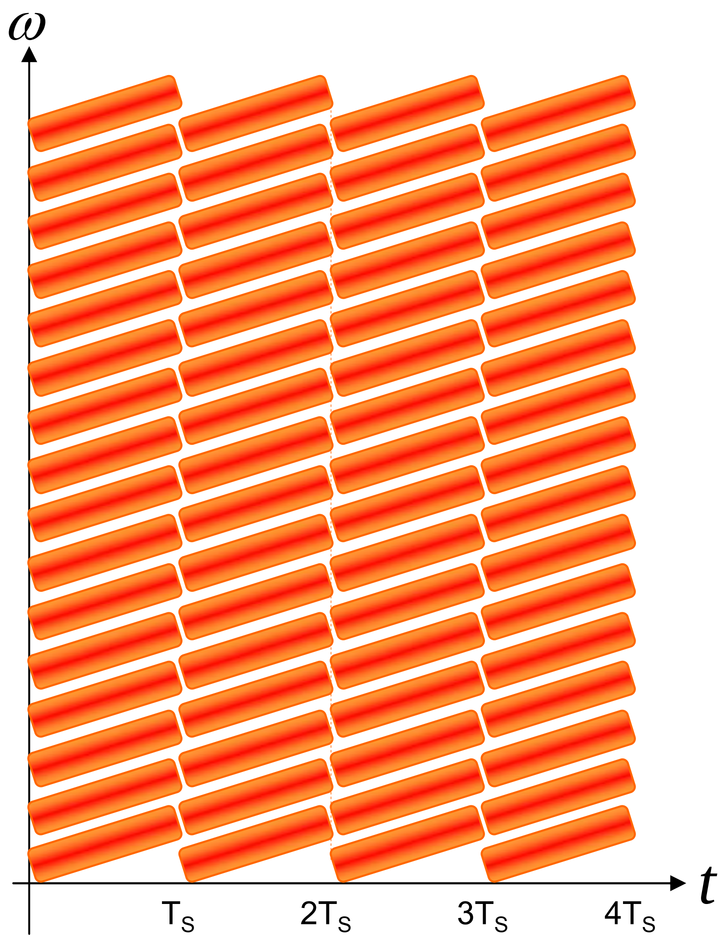


Time-Freq. Distribution

Multiple-Sine



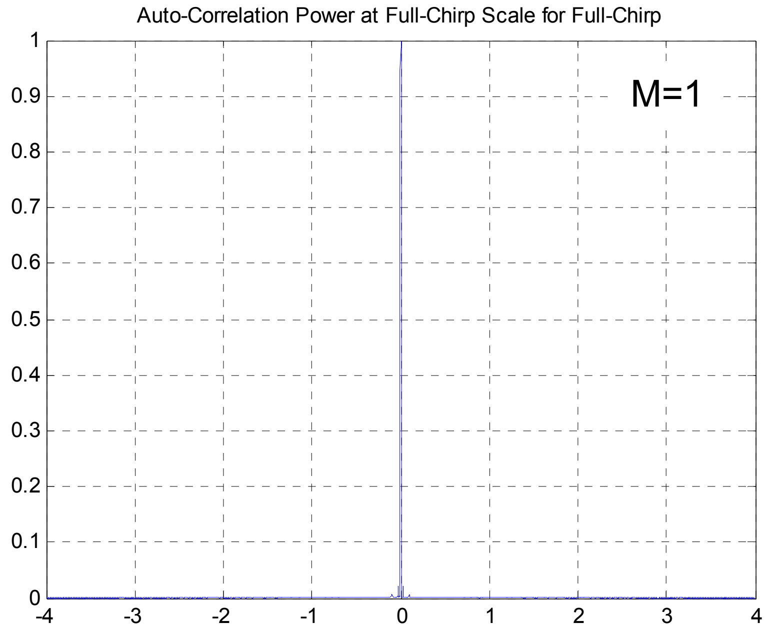
Multiple-Chirp

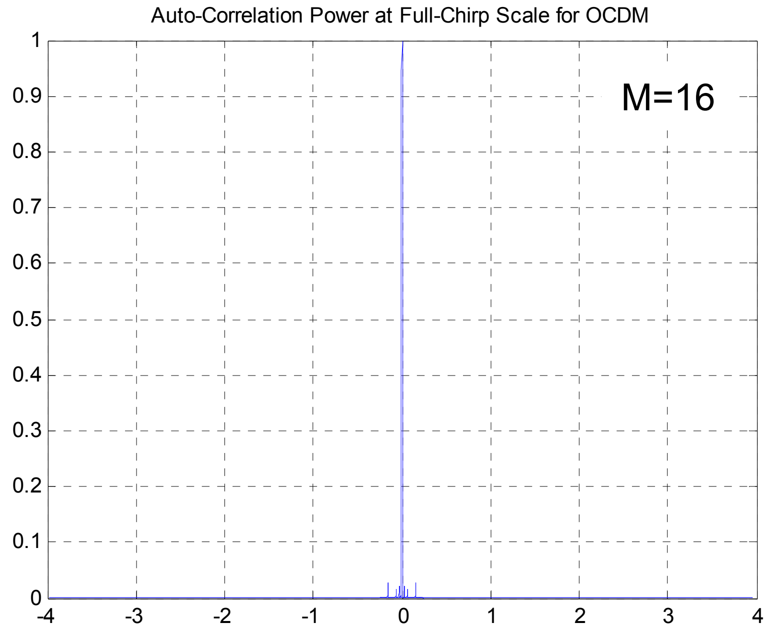


Correlation Property

Single-Chirp

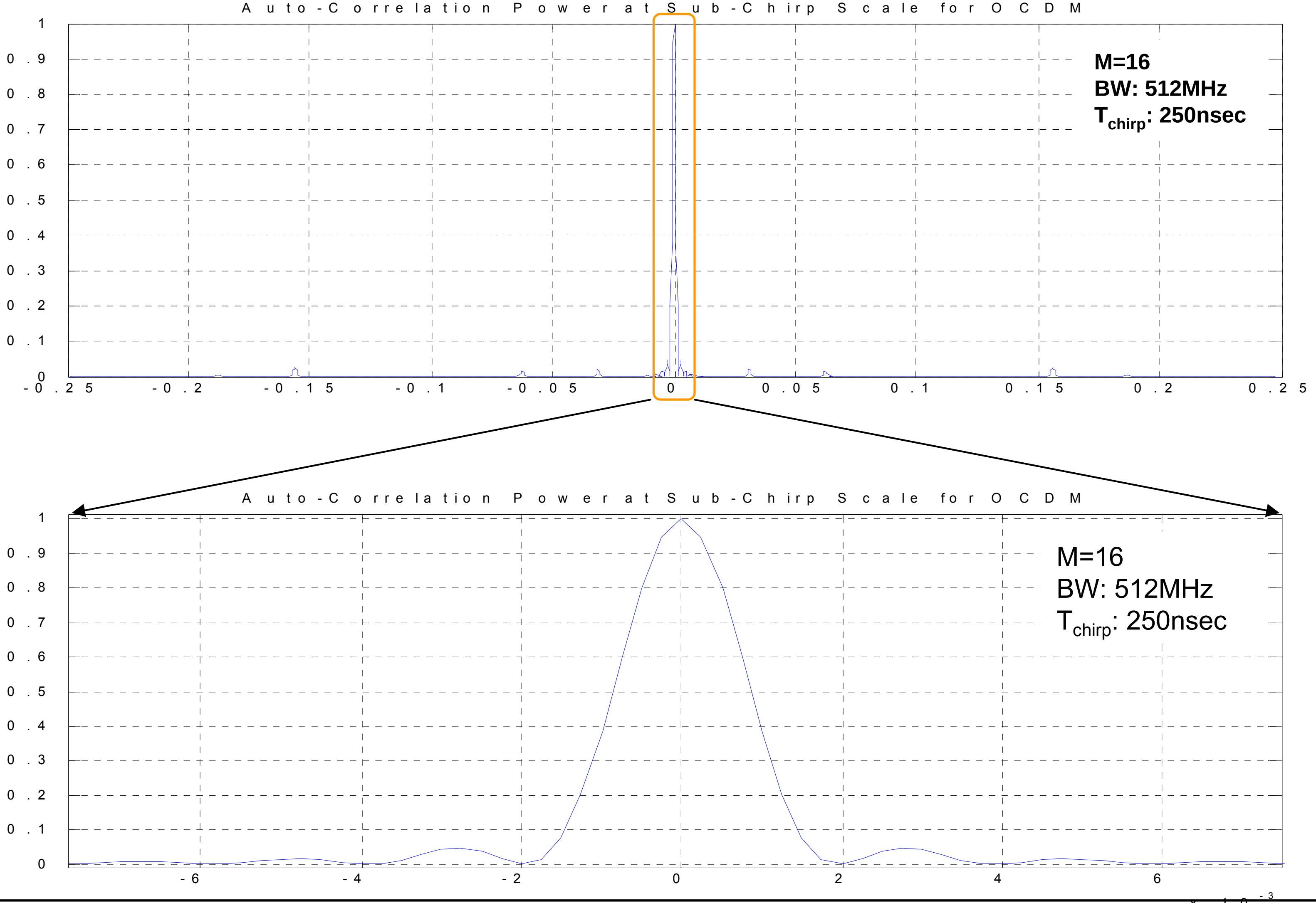
Multiple-Chirp



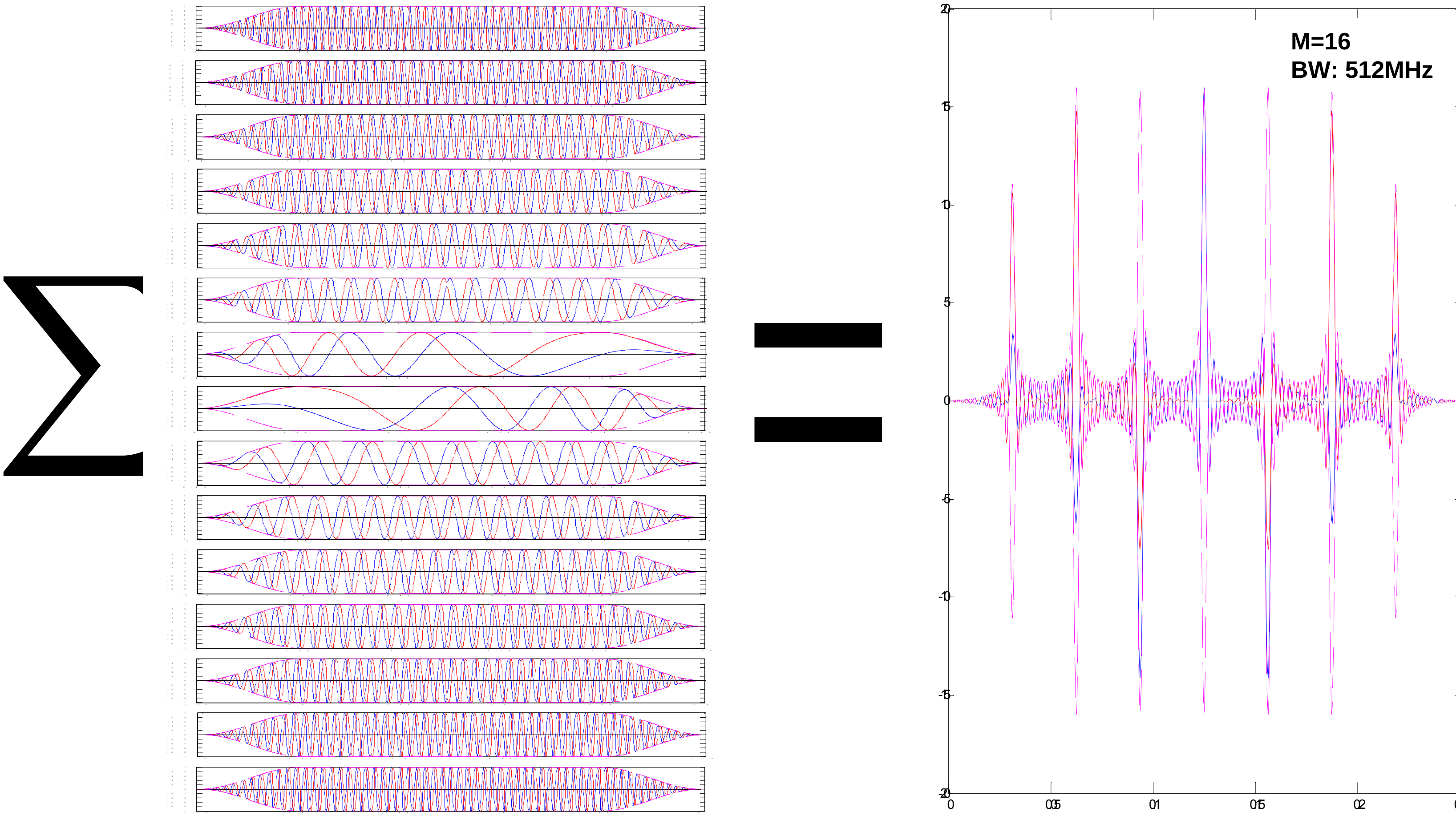


Auto-Correlation Property

Correlation Property



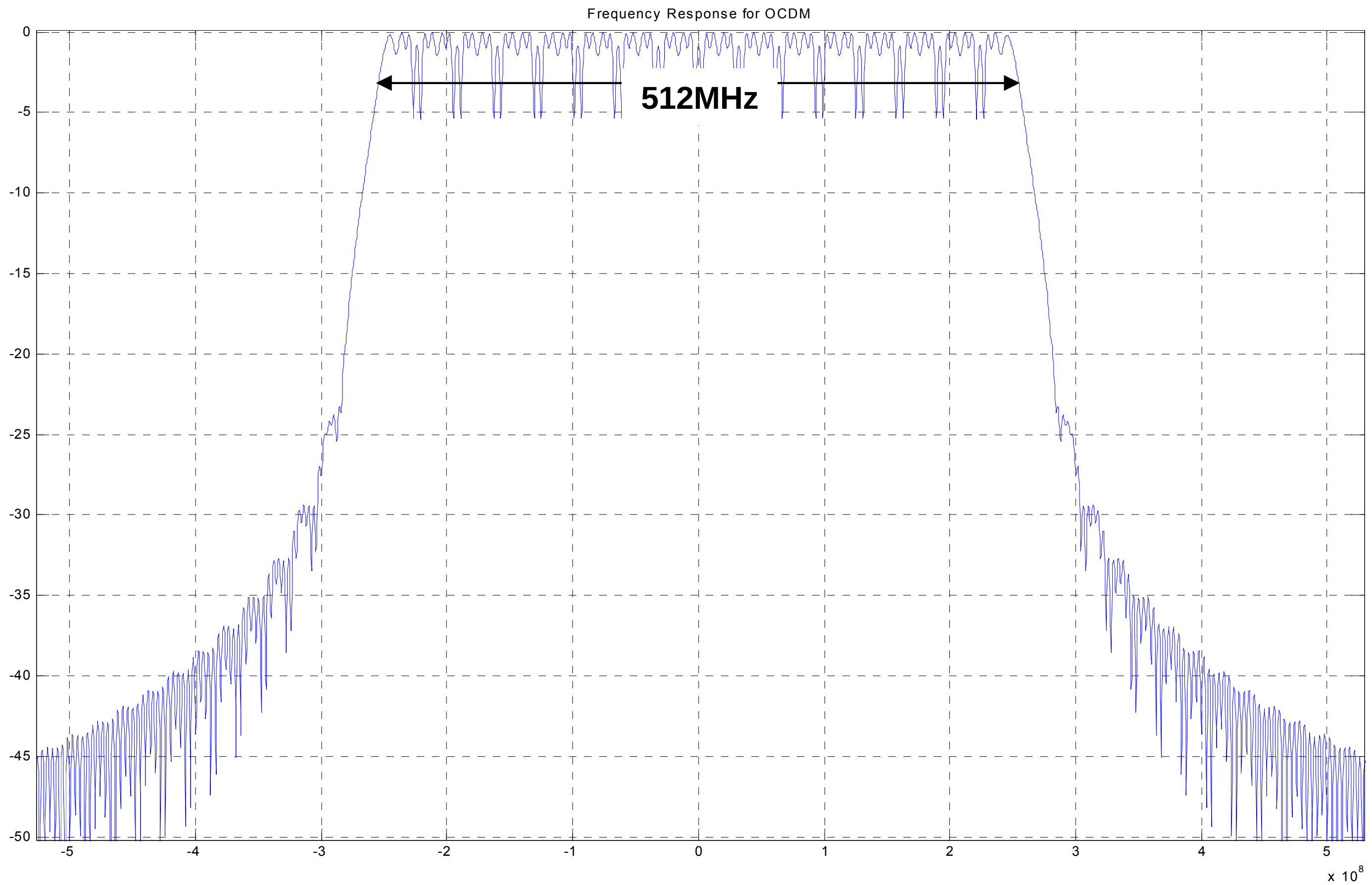
Temporal PAPR



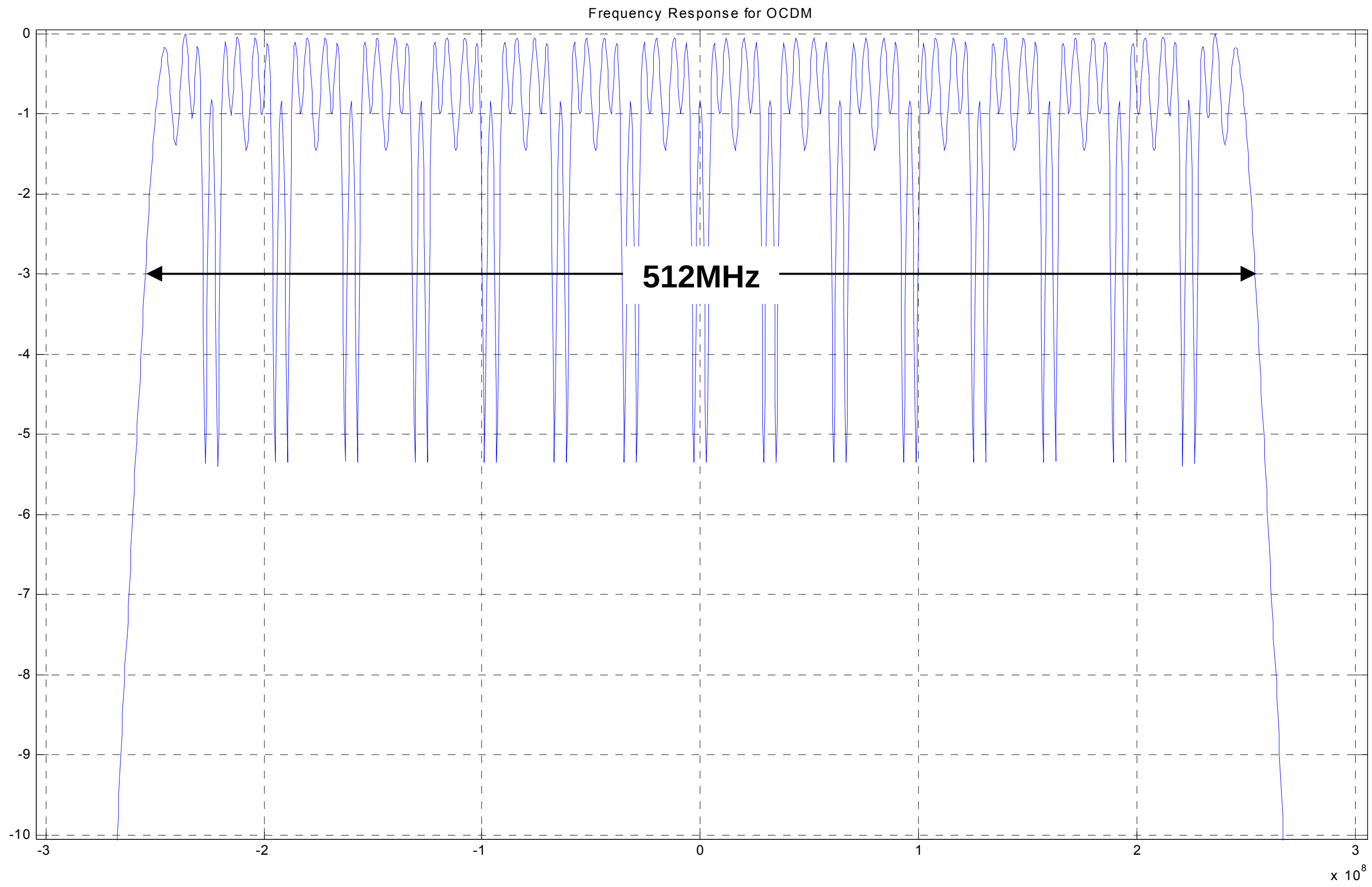
- T_{chirp} = 250nsec
- Roll-off factor = 0.25

Temporal PAPR : 21.5

Power Spectral Density



Spectral PAPR



Spectral PAPR < 1.5 dB

Link Budget

Parameter	UWB	UWB		
peak payload bit rate(Rb)	1000	250	kbps	
Signal Bandwidth	512	512	MHz	
Average Tx Power(Pt)	0.038	0.038	mW	
Average Tx Power(Pt)	-14.2	-14.2	dBm	
Tx antenna gain(Gt)	0	0	dBi	
fc' = sqrt(fminfmax) -10dB	4.20	4.20	GHz	
Path loss at 1meter(L1=10n*log10(4pifc'/c))	44.9	44.9	dB	
distance	50	50	m	
Path loss Exponent (d<=1m)	2	2		
Path loss Exponent (d>1m)	2	2		
Path loss at d m(L2=10n*log10(d))	34.0	34.0		
Rx antenna gain (Gr)	0	0	dBi	
Rx power(Pr = Pt+Gt+Gr-L1-L2(dB))	-93.1	-93.1	dBm	
Average noise power per bit	-114.0	-120.0	dBm	
Rx Noise Figure(Nf)	7	7	dB	
Average noise power per bit(Pn=N+Nf)	-107.0	-113.0	dBm	
Minimum Eb/No(S)	4.7	4.7	dB	r=1/2, k=5
Implementation Loss(I)	3	3	dB	
Link Margin (M=Pr-Pn-S-I)	6.2	12.2	dB	
Proposed Min. Rx Sensitivity Level	-99.3	-105.3		

Summary

- **Temporal PAPR**
  - Maximum Available Power @ $1V_{P\text{-}P}$:

$$P_{MAX} = \frac{\left(1/2\sqrt{2}\right)^2}{50} = 2.5\ [mW]$$

  - Maximum Achievable PAPR @ $1V_{P\text{-}P}$

$$PAPR_{MAX} = \frac{2.5}{10^{-41.3/10} \times 512} = \frac{2.5}{0.038} \approx 65.8\ >\ 21.5$$

- **Spectral PAPR < 1.5dB**

- **Sub-Chirp Bandwidth: 32MHz (M=16)**
  - (16MHz Base-Band)→ Low clock-rate DSP, ADC/DAC

- **Robustness**
  - Multi-path
  - Doppler Shift