NIDays


NATIONAL
INSTRUMENTS™

2nd VST 와 초고대역폭 분석기술

고 재 일
RF System Engineer

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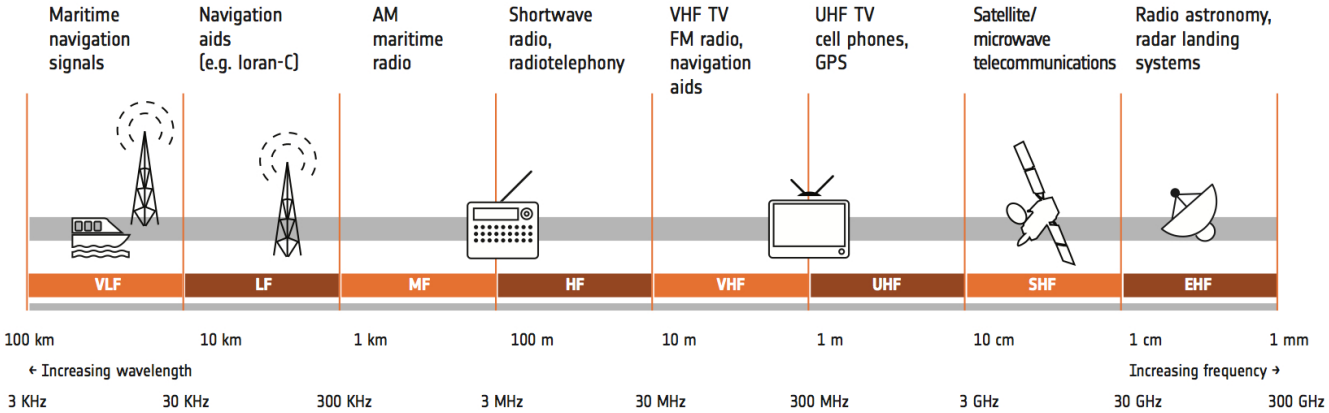
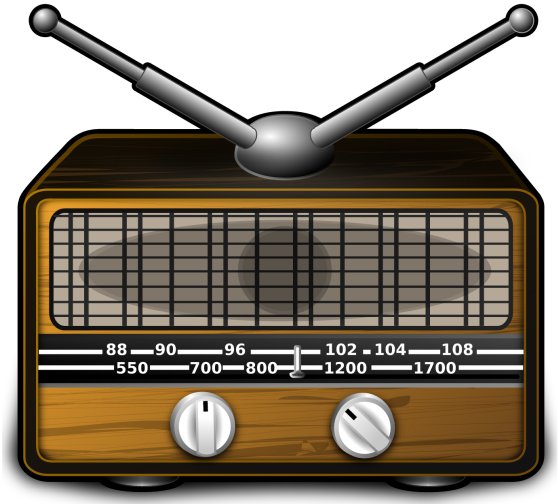
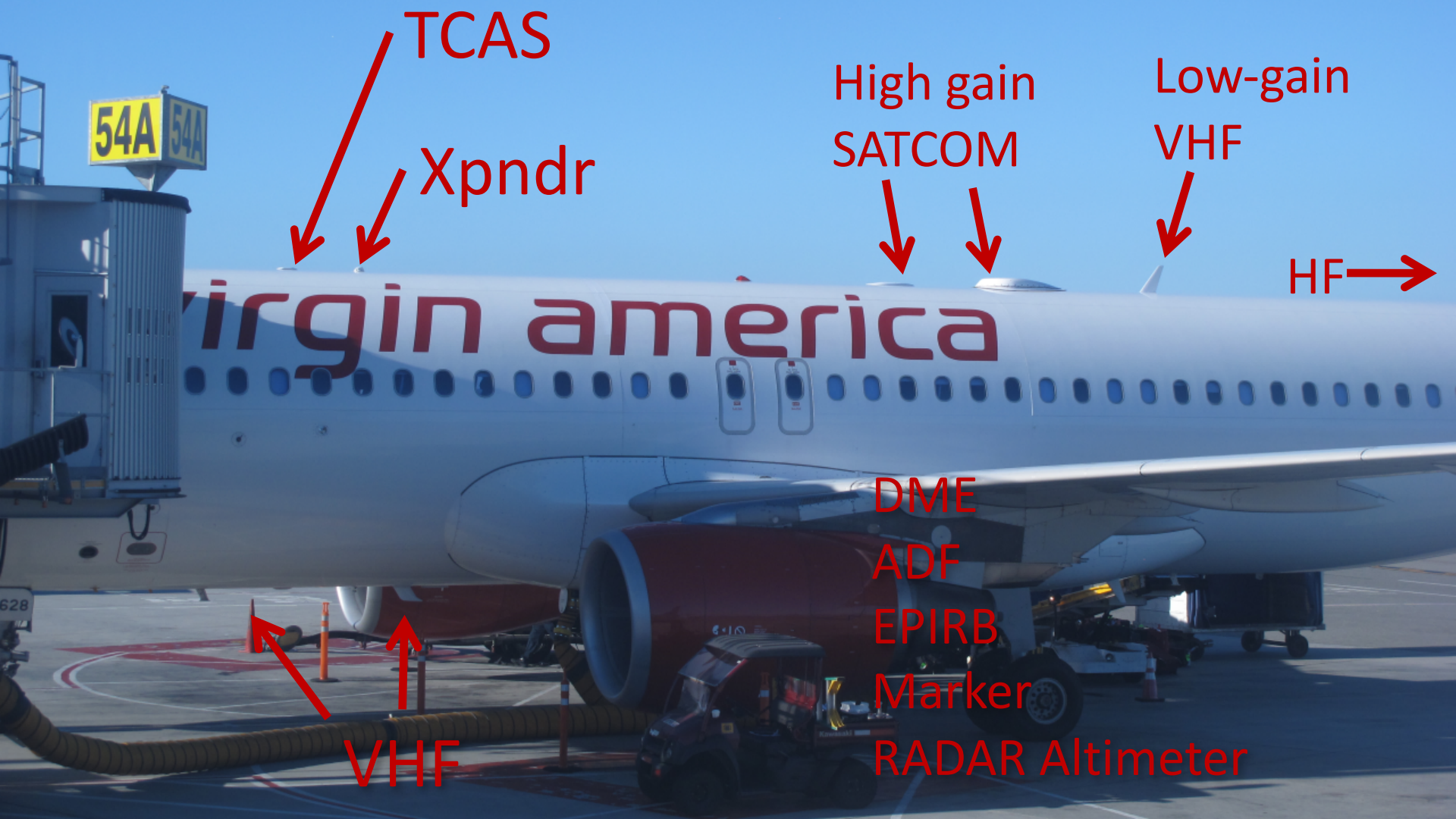
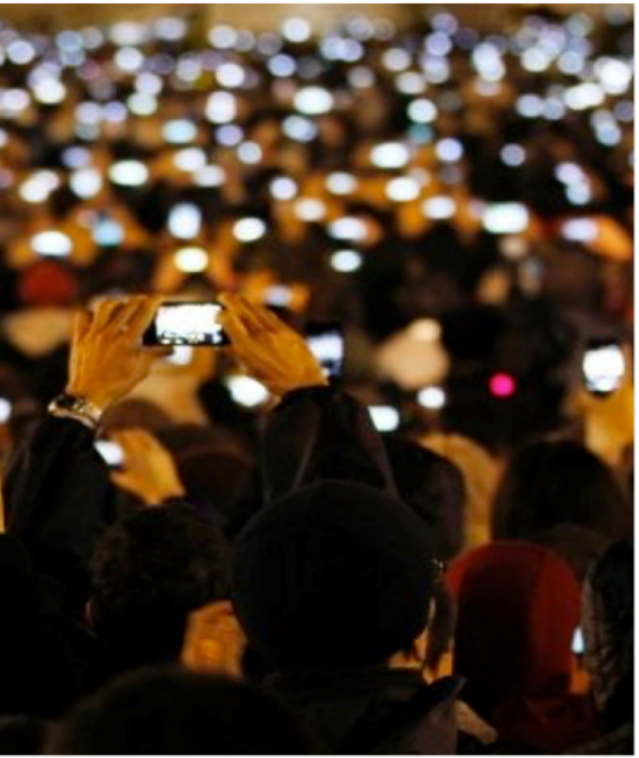

Maritime navigation signals
Navigation aids (e.g. loran-C)
AM maritime radio
Shortwave radio, radiotelephony
VHF TV FM radio, navigation aids
UHF TV cell phones, GPS
Satellite/ microwave telecommunications
Radio astronomy, radar landing systems
VLF
LF
MF
HF
VHF
UHF
SHF
EHF
100 km
10 km
1 km
100 m
10 m
1 m
10 cm
1 cm
1 mm
← Increasing wavelength
Increasing frequency →
3 KHz
30 KHz
300 KHz
3 MHz
30 MHz
300 MHz
3 GHz
30 GHz
300 GHz


88
90
96
102
104
108
550
700
800
1200
1700


TCAS
Xpndr
High gain
SATCOM
Low-gain
VHF
HF
DME
ADF
EPIRB
Marker
RADAR Altimeter
VHF
54A
54A
virgin america



50 BILLION
DEVICES CONNECTED BY 2020

1.9 BILLION
SMART PHONES

85%
EMBEDDED DEVICES TODAY ARE UNCONNECTED

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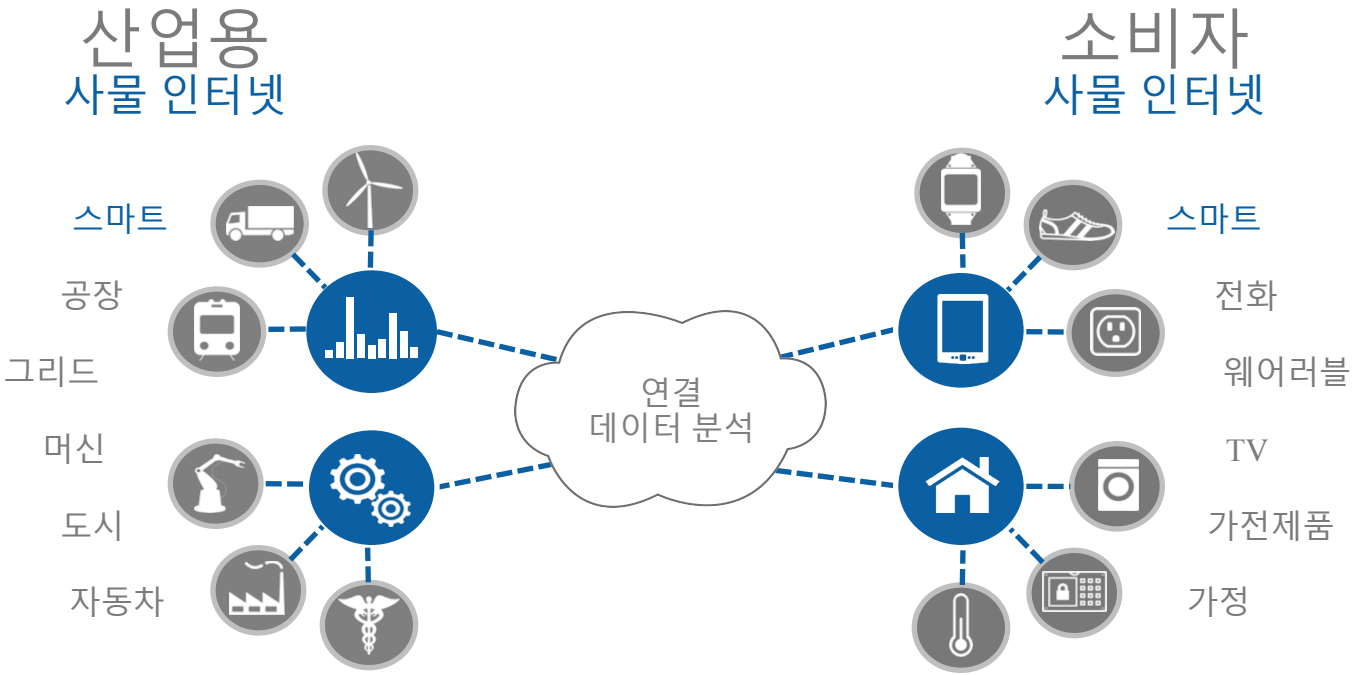
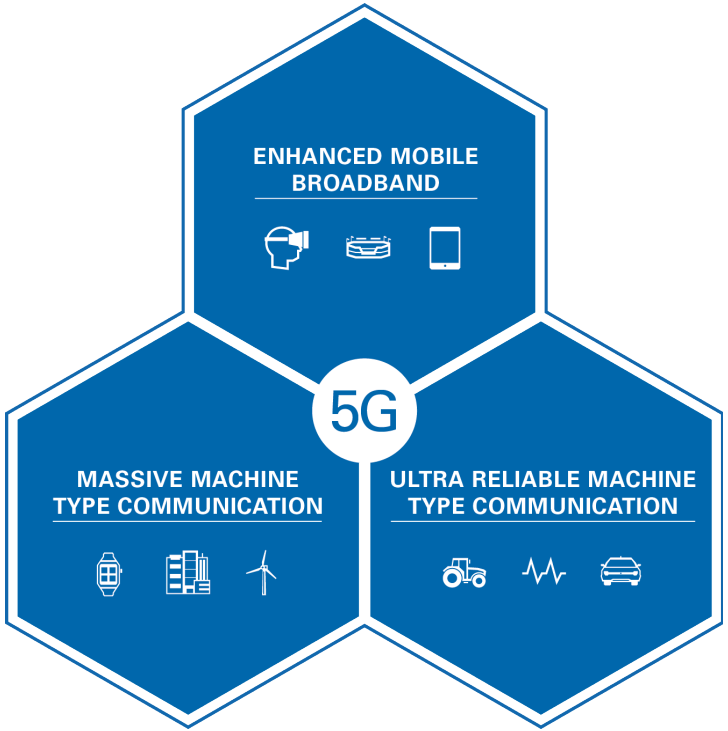
500억 개의 네트워크 연결 디바이스가 하는 일은?



Moor Insights & Strategy의 리포트 "Segmenting the Internet of Things (IoT)"에서 발췌

대규모 플랫폼 확장이 필요한 무선 환경?

더 높은 처리량



더 낮은 비용 및 전력

낮은 지연 시간

모바일 발전: 1990–2020

GSM (1991): 9.6 Kbps

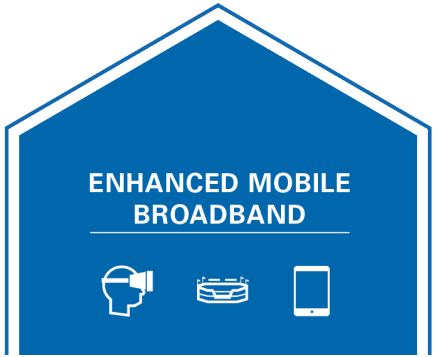
GPRS (1998): 40 Kbps

UMTS (2001): 384 Kbps

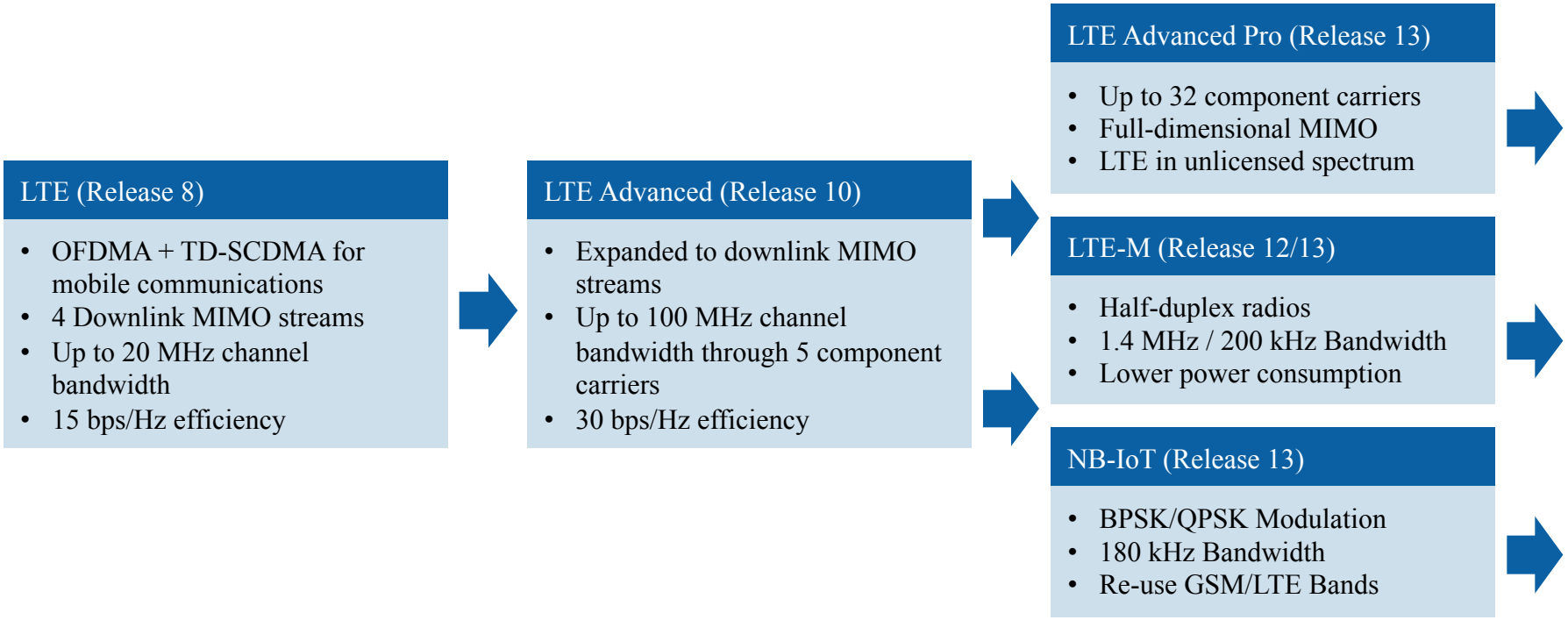
HSPA (2008): 42 Mbps

LTE (2010): 100 Mbps

5G (2020)
10 Gbps, 최고 데이터 속도
100 Mbps, 높은 휴대성
10,000배 더 많은 트래픽

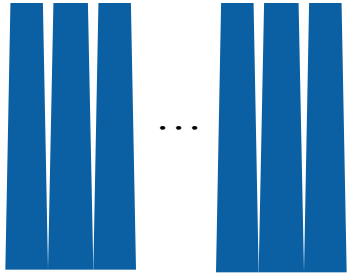


LTE 표준은 변화중

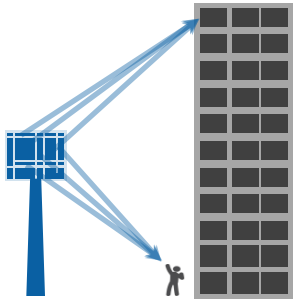

LTE (Release 8)
• OFDMA + TD-SCDMA for mobile communications
• 4 Downlink MIMO streams
• Up to 20 MHz channel bandwidth
• 15 bps/Hz efficiency
LTE Advanced (Release 10)
• Expanded to downlink MIMO streams
• Up to 100 MHz channel bandwidth through 5 component carriers
• 30 bps/Hz efficiency
LTE Advanced Pro (Release 13)
• Up to 32 component carriers
• Full-dimensional MIMO
• LTE in unlicensed spectrum
LTE-M (Release 12/13)
• Half-duplex radios
• 1.4 MHz / 200 kHz Bandwidth
• Lower power consumption
NB-IoT (Release 13)
• BPSK/QPSK Modulation
• 180 kHz Bandwidth
• Re-use GSM/LTE Bands

새로운 4.5G 통신: LTE-Advanced Pro

Carrier Aggregation



Full-Dimensional MIMO



Licensed Assisted Access

더 많은 컴포넌트 캐리어

LTE Advanced Pro는 최대 32개의 컴포넌트 캐리어를 지원하고 여러 eNB에서의 전송을 허용합니다.

더 많은 공간 스트림

LTE Advanced Pro는 최대 16개 다운링크 공간 스트림을 지원하며, eNB는 3D 빔포밍을 수행할 수 있습니다.

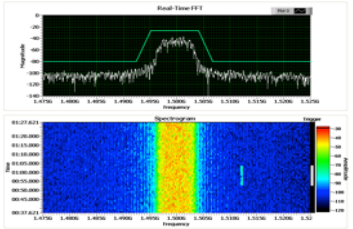
새로운 스펙트럼

LTE Advanced Pro는 WiFi 네트워크를 조정하여 셀룰러 네트워크 사용을 위한 5 GHz 스펙트럼을 지원합니다.

NI Platform for RF Instrumentation

Interactive User Interfaces

Programming APIs & Examples



Test Executive Software

Signal Analyzers

Signal Generators

Vector Signal Transceivers

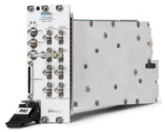
Network Analyzers

Switches

Power Meters

NI Vector Signal Analyzers Family





	NI 5661	NI 5663	NI 5644/45/46R	NI 5665	NI 5668R
Frequency Range	9 kHz to **2.7 GHz**	10 MHz to 6.6 GHz	65 MHz to 6 GHz	20 Hz to 3.6 / 14 GHz	20 Hz to 14 / **26.5 GHz**
Bandwidth	**20 MHz**	50 MHz	80/200 MHz	25 MHz or 50 MHz	Up **to 765 MHz**
Phase Noise (10 kHz offset) at 1 GHz	-90 dBc/Hz	-105 dBc/Hz	-112 dBc/Hz	-129 dBc/Hz*	-129 dBc/Hz*
Onboard Reference Clock	±50 ppb	±3 ppm	±200 ppb	±50 ppb	±50 ppb
Architecture	**Multi Stage**	Single Stage (no Image rejection)	Zero-IF (no Image rejection)	**Multi Stage**	**Multi Stage**
List Mode	No	No	Yes	Yes	Soon
Peer to Peer Streaming	No	Yes	**Yes	Yes	Yes
Absolute Amplitude Accuracy	±0.6 dB	±0.65 dB	± 0.35 dB to ± 0.55 dB	± 0.1 dB	± 0.2 dB
Average Noise Floor	-122 dBm/Hz	-158 dBm/Hz	-161 dBm/Hz	-165 dBm/Hz	-167 dBm/Hz

*NI 5665 Phase Noise Measurement is at 800 MHz

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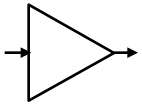
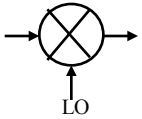
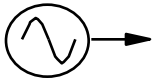
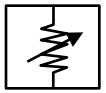
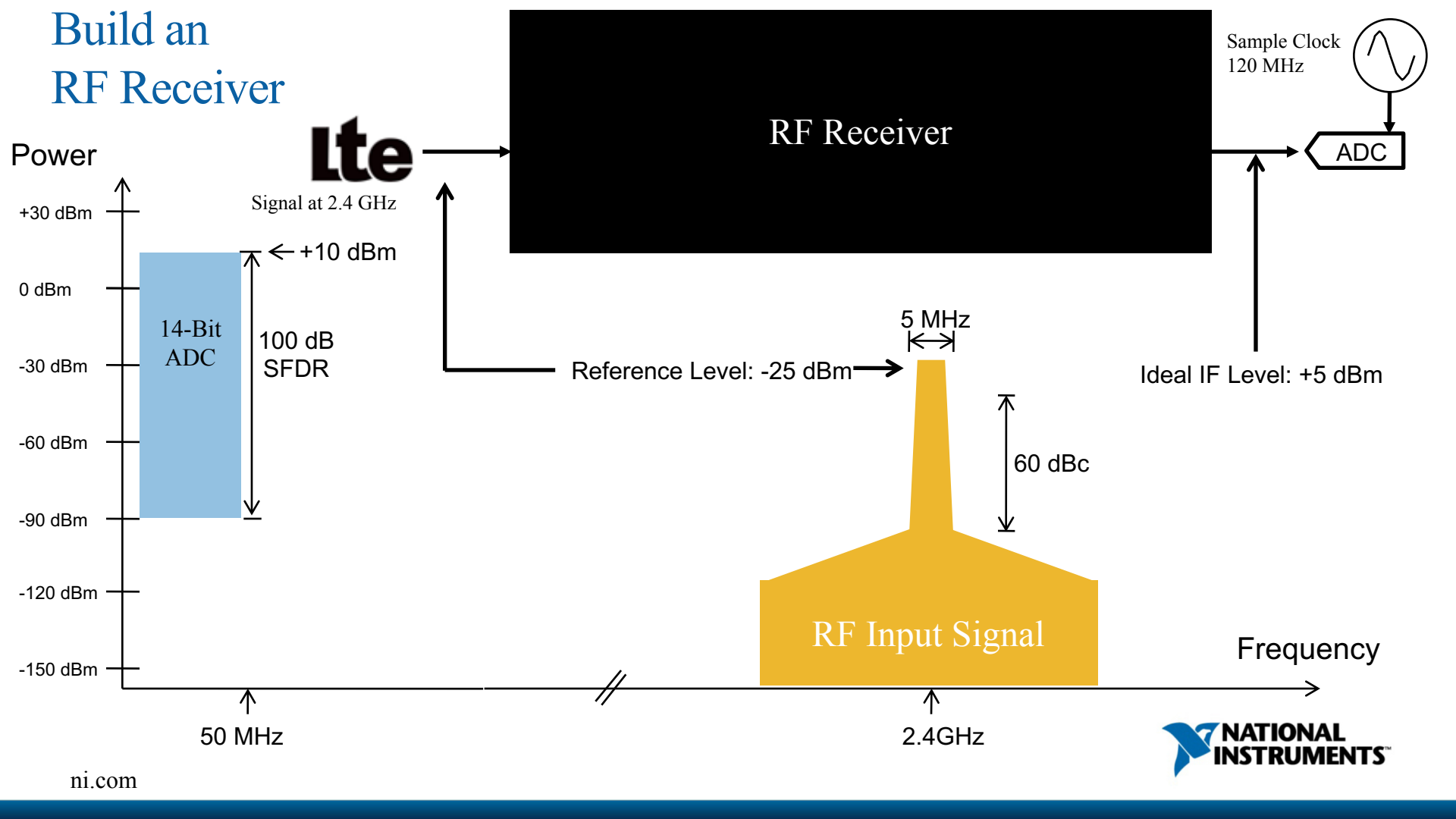
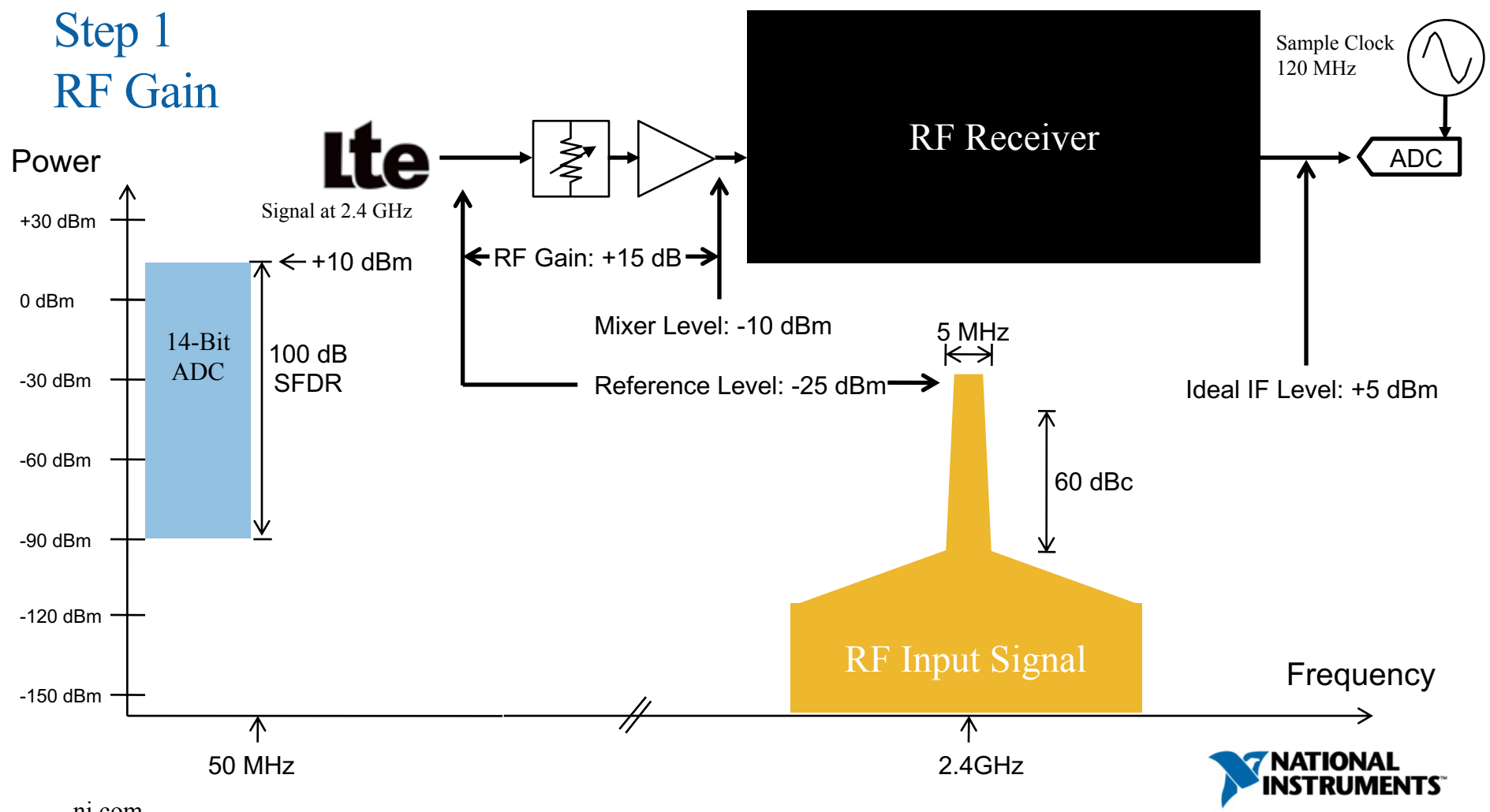
Key RF Building Blocks

Symbol	Name	Types	Function
	Amplifier (2 port)	Power Amplifier Low Noise Amplifier	Amplify signal before transmission (high power). Amplify weak received signal (add little noise).
	Mixer (3 port)	Upconverter Downconverter	Translate lower frequency to higher frequency. Translate higher frequency to lower frequency.
	Oscillator (1 port)	Voltage-controlled oscillator Quartz crystal	Generate frequency based upon voltage input. Generate a single stable frequency.
	Filter (2 port)	Passive Active Digital	Filter out undesired signal content.
	Attenuator (2 port)	Mechanical Solid State	Adjust Signal Level

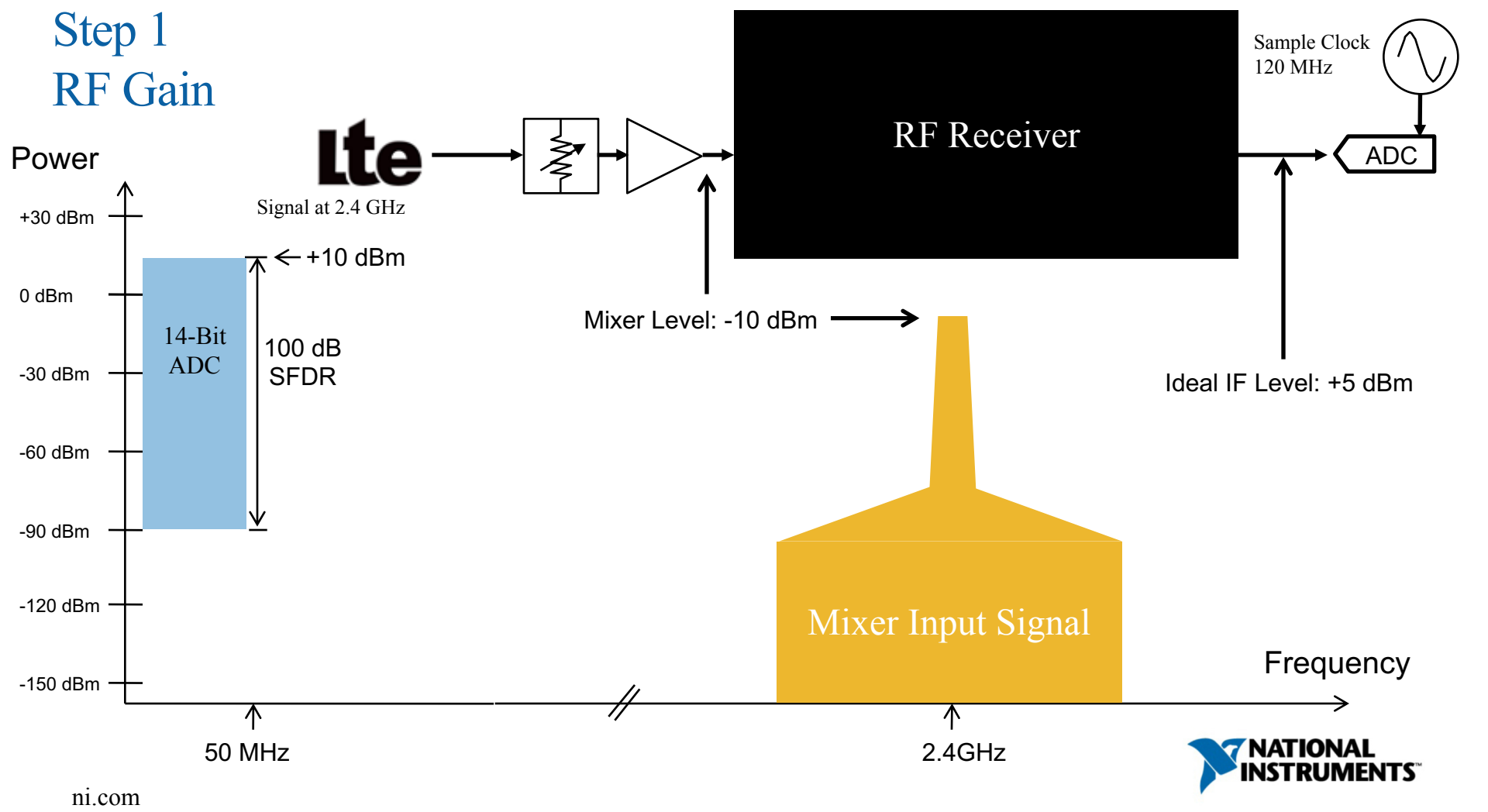
Build an RF Receiver



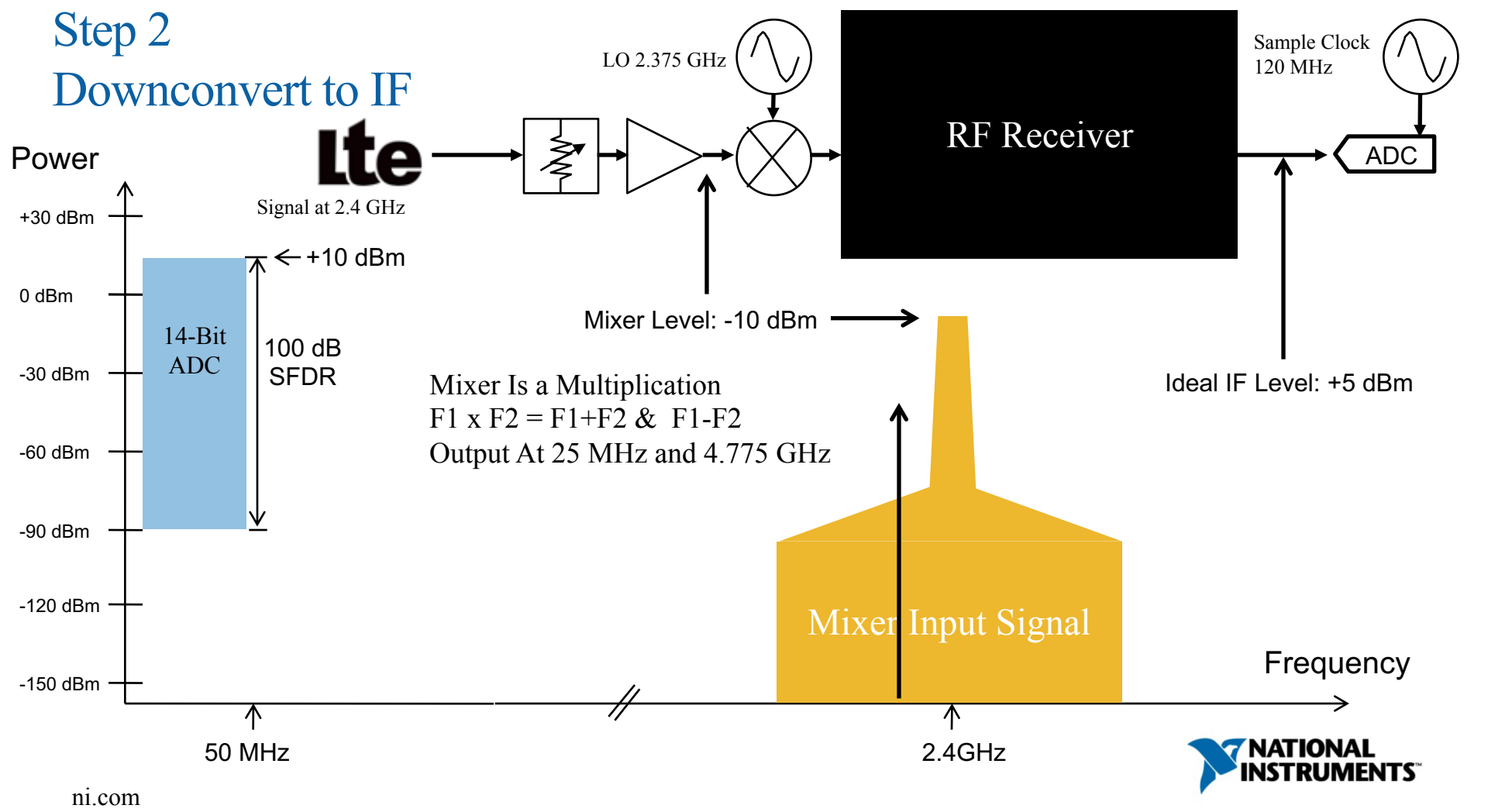
Step 1
RF Gain



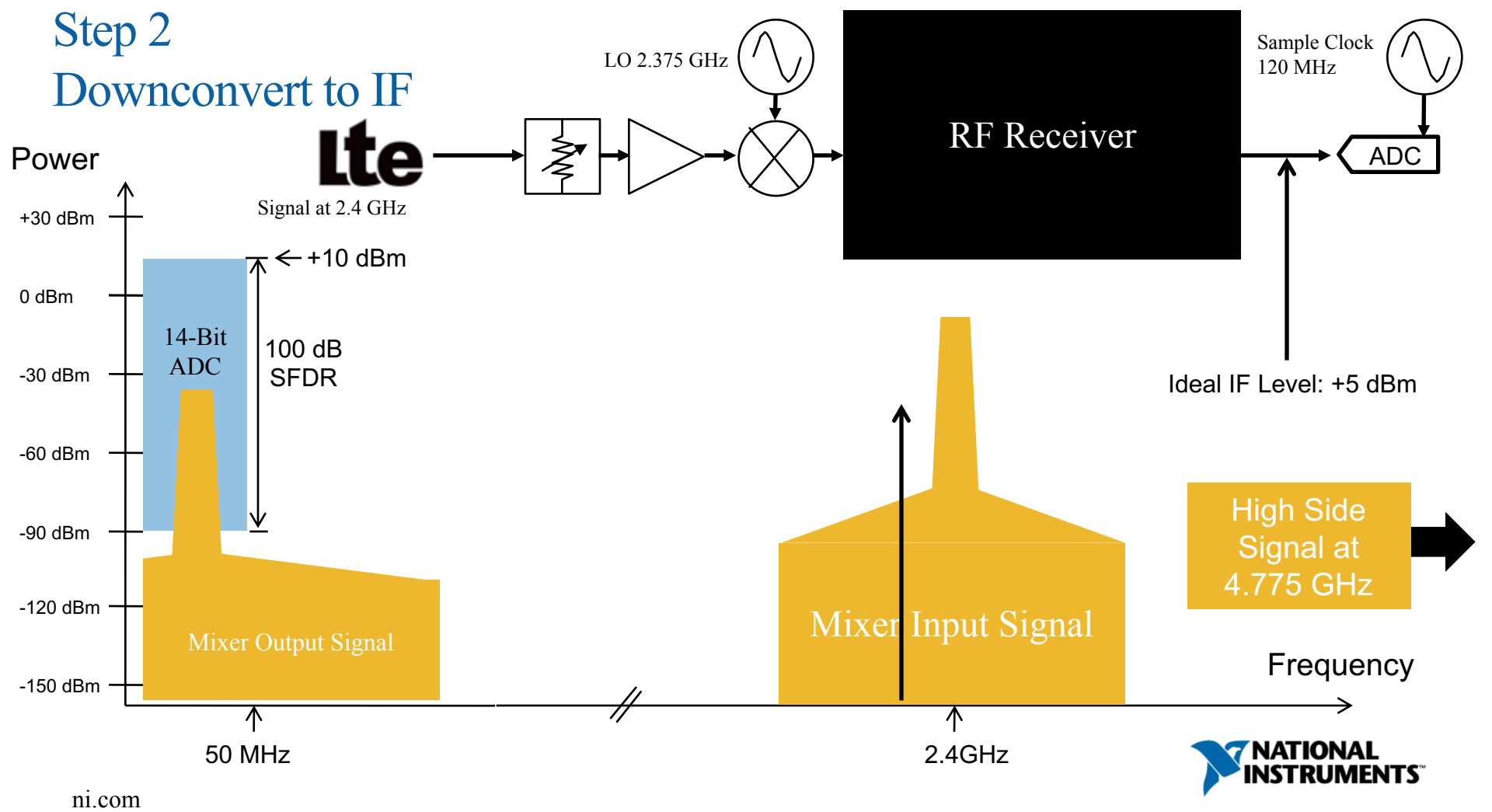
Step 1
RF Gain



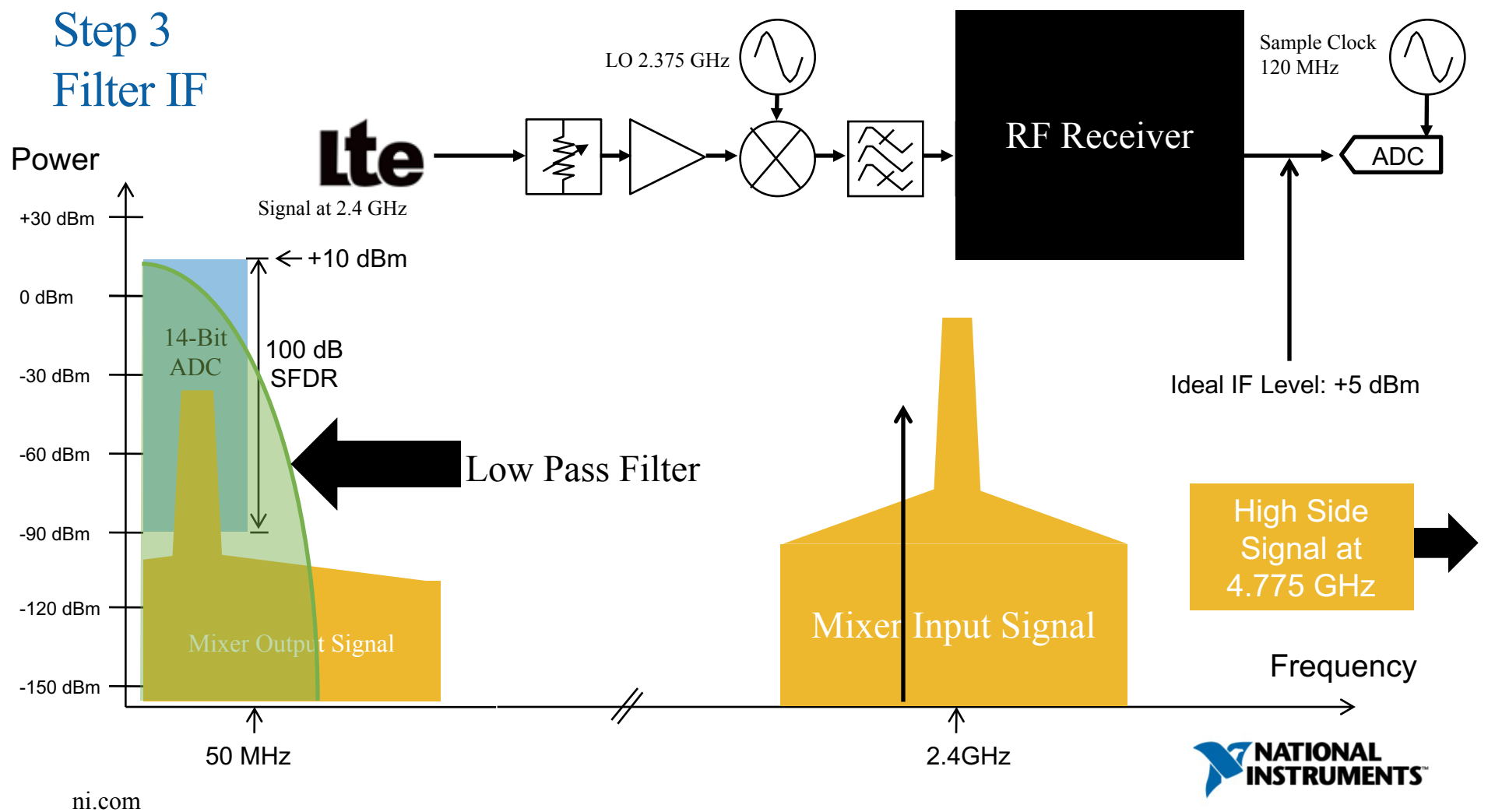
Step 2
Downconvert to IF



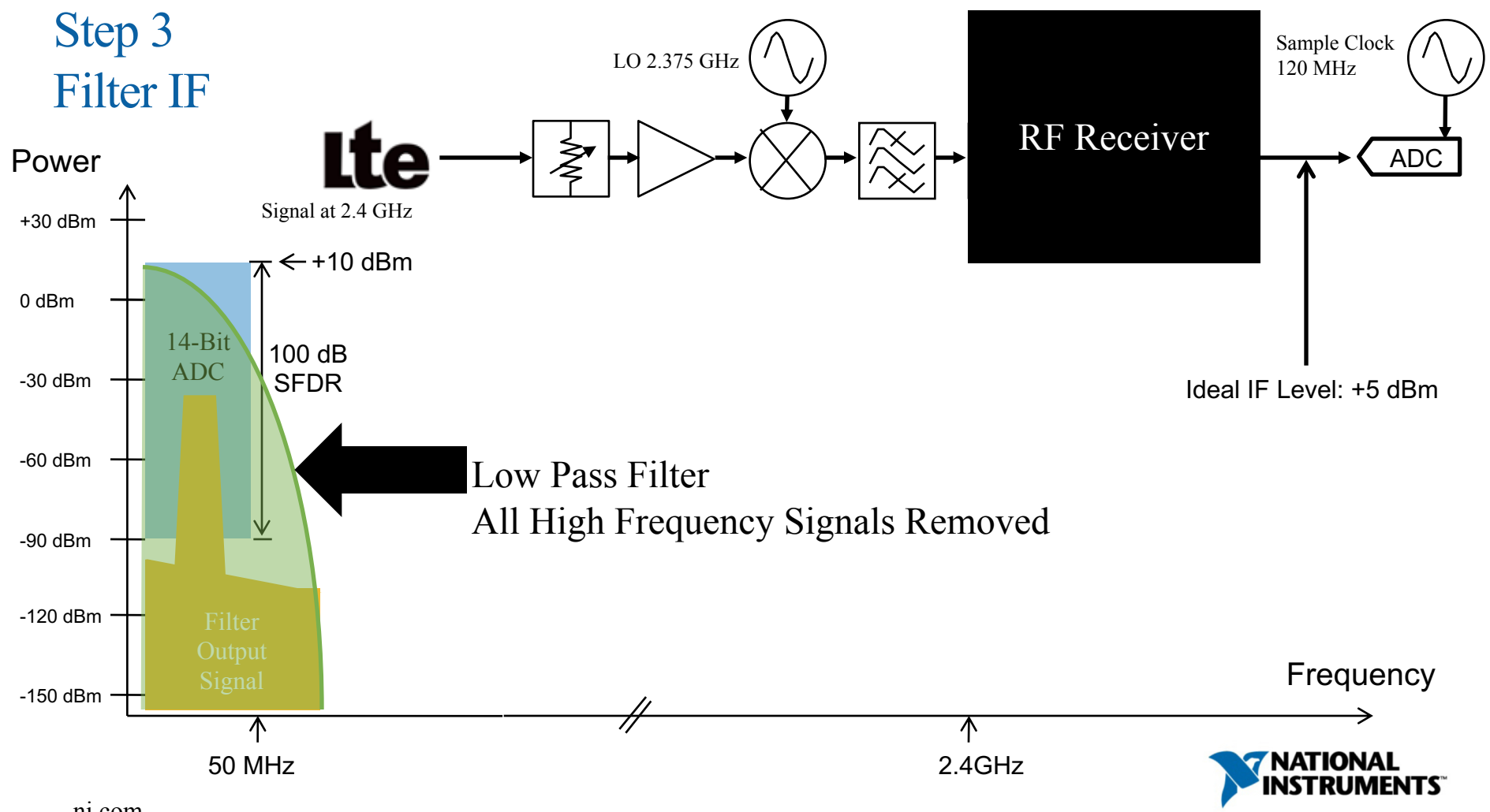
Step 2
Downconvert to IF



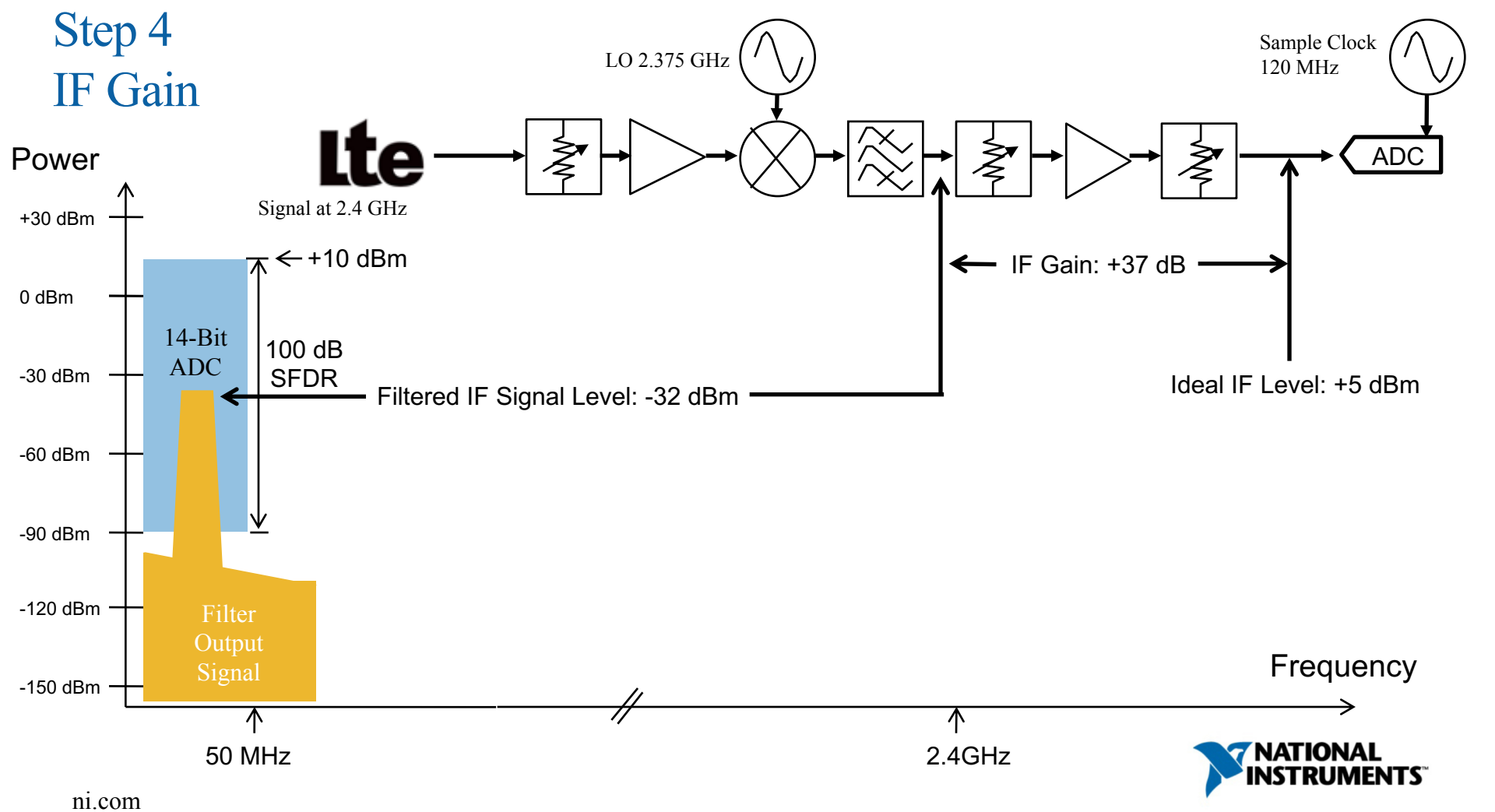
Step 3
Filter IF



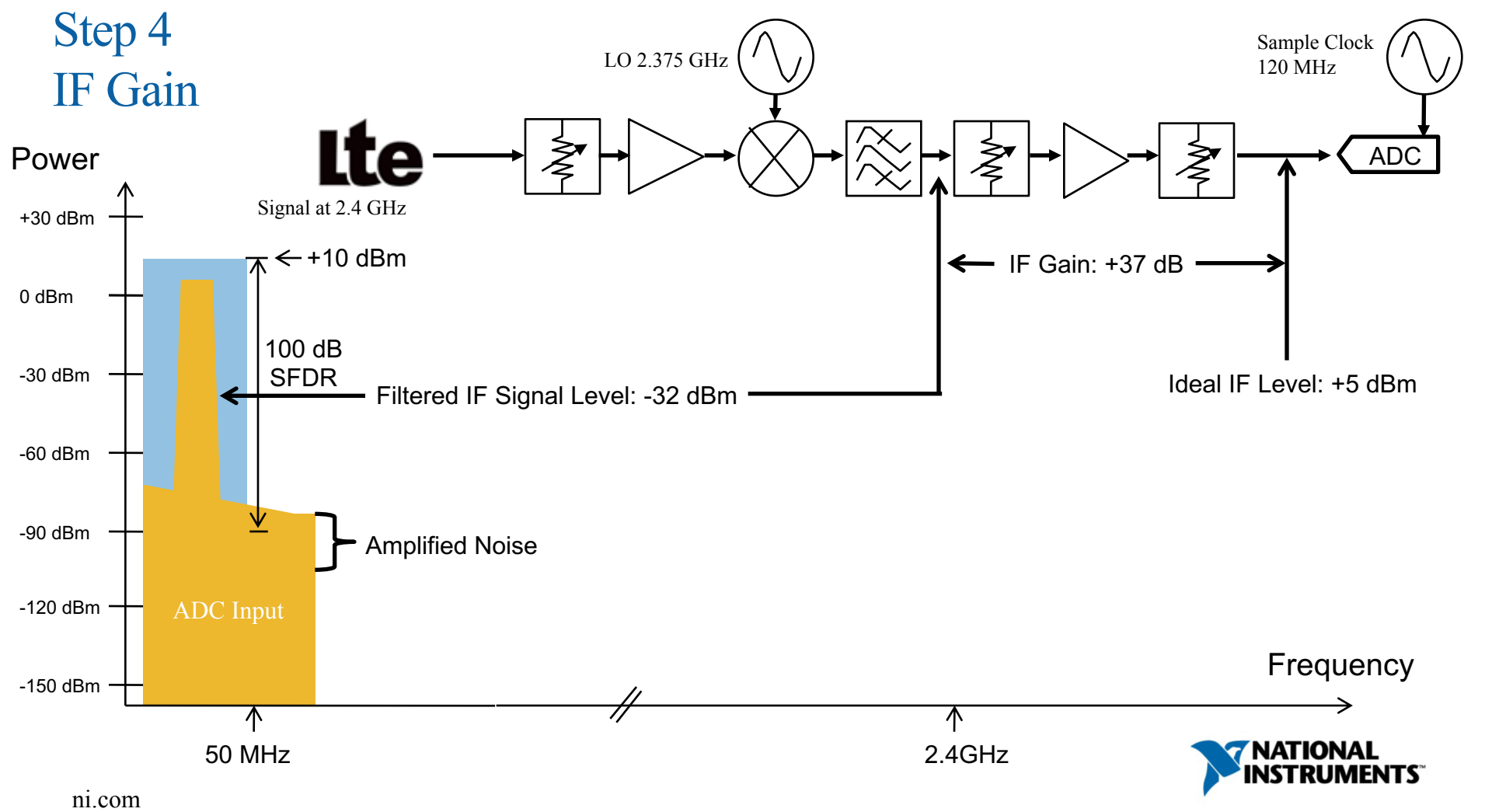
Step 3
Filter IF



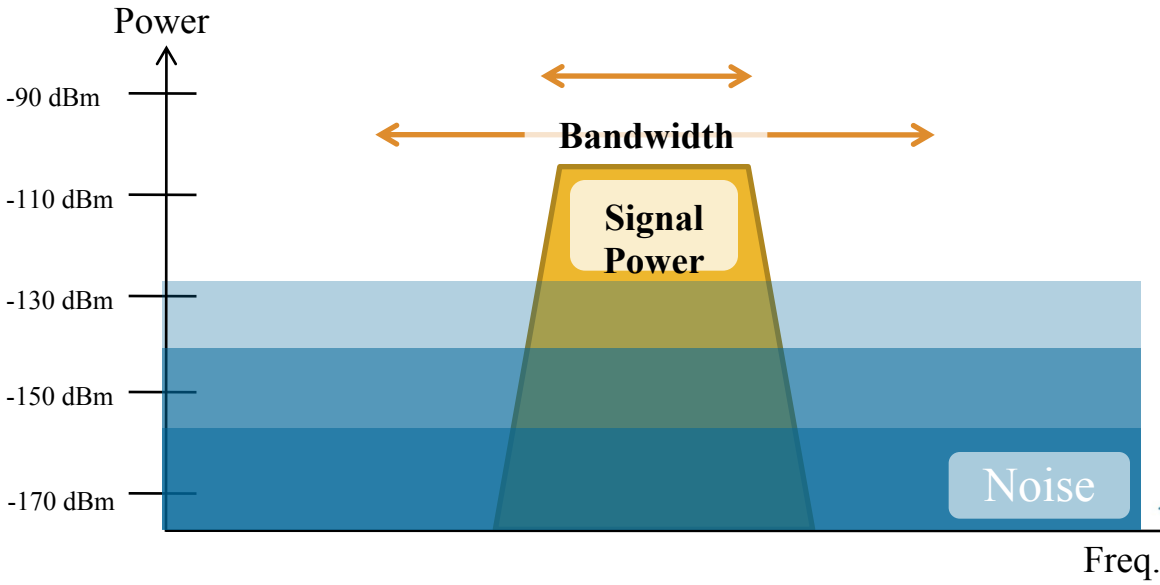
Step 4
IF Gain



Step 4
IF Gain

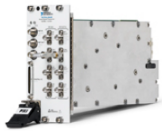


1세대(2005~)	2세대(2008~)	3세대(2010~)
PXI-5660/1	PXIe-5663	PXIe-5665
2.7GHz	6.6GHz	3.4GHz/8.5GHz/13.5GHz
20MHz Bandwidth	50MHz Bandwidth	50MHz Bandwidth



NI Vector Signal Analyzers Family





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Onboard Reference Clock	±50 ppb	±3 ppm	±200 ppb	±50 ppb	±50 ppb
Architecture	**Multi Stage**	Single Stage (no Image rejection)	Zero-IF (no Image rejection)	**Multi Stage**	**Multi Stage**
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Absolute Amplitude Accuracy	±0.6 dB	±0.65 dB	± 0.35 dB to ± 0.55 dB	± 0.1 dB	± 0.2 dB
Average Noise Floor	-122 dBm/Hz	-158 dBm/Hz	-161 dBm/Hz	-165 dBm/Hz	-167 dBm/Hz

*NI 5665 Phase Noise Measurement is at 800 MHz

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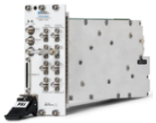
NI Signal Generators Family





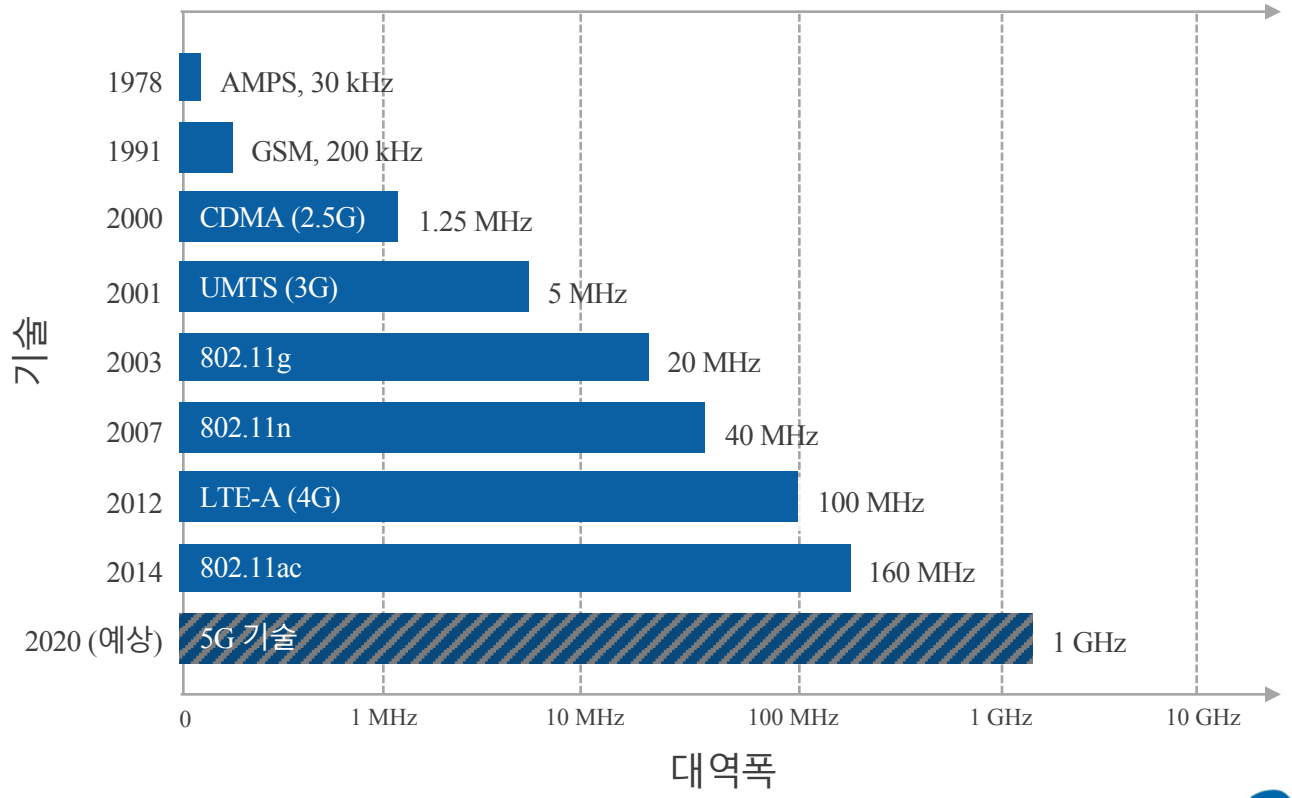


	NI 5650/1/2	PXIe-5654/5696	NI 5671/2	NI 5673	NI 5644/45/46R
Frequency Range	500kHz to 1.1/3.3/6.6 GHz	250 kHz to 10 / 20 GHz	250 kHz to 2.7 GHz	85 MHz to 6.6 GHz	65 MHz to 6 GHz
Bandwidth	N/A	N/A	20 MHz	100 MHz	80 / 200MHz
Amplitude Accuracy	±1 dB	± 0.35 dB	±0.8 dB	±0.75 dB	±0.5 dB
Frequency Reference	±50 ppb	±0.1 ppm	±50 ppb	±3 ppm	±200 ppb
Phase Noise (10 kHz offset)	-112 dBc/Hz	-133 dBc/Hz phase	-95 dBc/Hz	-112 dBc/Hz	-112 dBc/Hz
Modulation Capabilities	CW, 2-FSK, OOK	AM/FM/φM and Pulse modulation	Vector Modulation	Vector Modulation	Vector Modulation
Maximum Output Power (CW)	+10 dBm	+27 dBm	+10 dBm	+10 dBm	+10 dBm
Minimum Output Power	-100 dBm	-110 dBm	-147 dBm/Hz	-154 dBm/Hz	-168 dBm/Hz
RF List Mode Support	Yes	Yes	No	Yes	Yes
Tuning Time	200 µs	<100 µs	2 ms	200 µs	380 µs

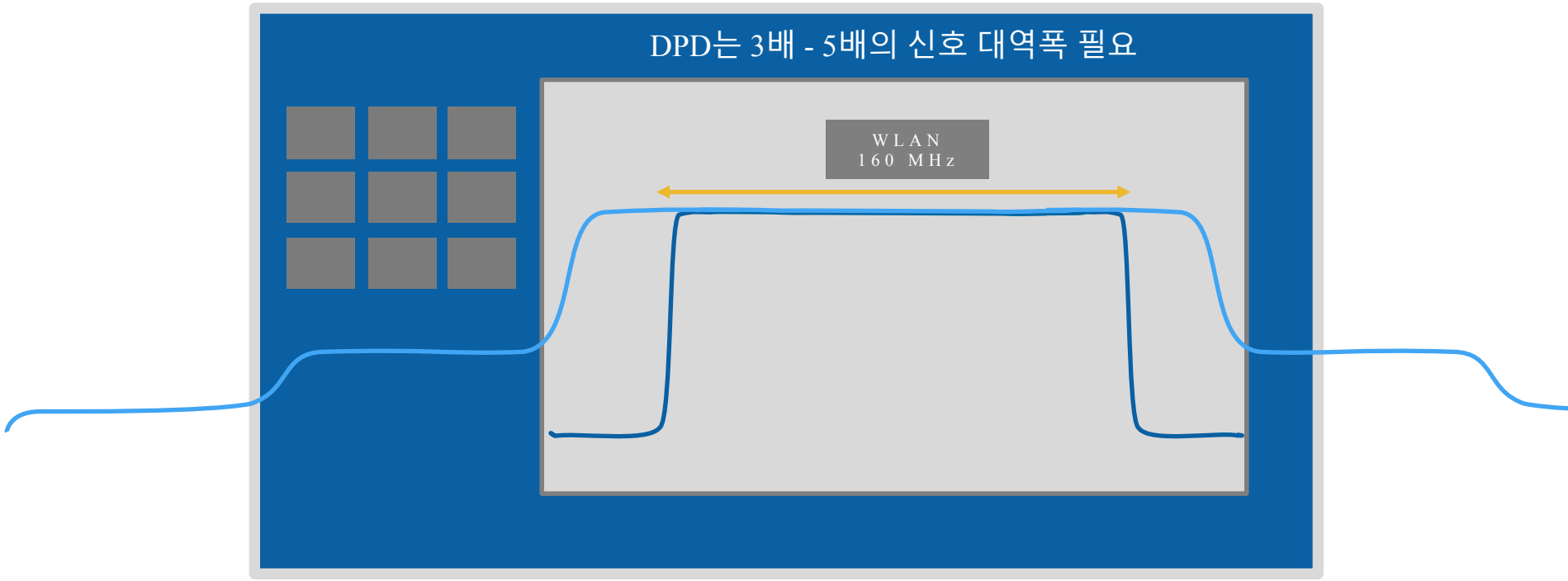
NI Vector Signal Transceiver Family

	PXIe-5644R	PXIe-5645R	PXIe-5646R
Bandwidth	80 MHz	80 MHz	200 MHz
Sample Rate	120 MS/s	120 MS/s	250 MS/s
Baseband IQ Support	No	40 MHz	No
Frequency Range	65 MHz – 6 GHz		
Max Unsaturated Output Power	+10 dBm		
EVM (802.11ac 80 MHz, MCS9)	-45 dB		
WCDMA ACP	-65 dBc		
Phase Noise (1GHz/10 kHz, typ)	-112 dBc/Hz		
Noise Floor	-158 dBm/Hz (RX) & -168 dBm/Hz (TX)		

더욱 폭넓은 계측기 대역폭이 필요한 4.5G+



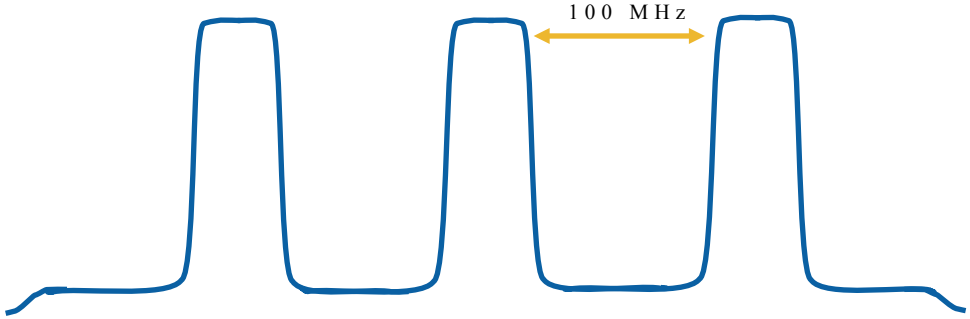
RF 계측 대역폭



폭넓은 순간 대역폭

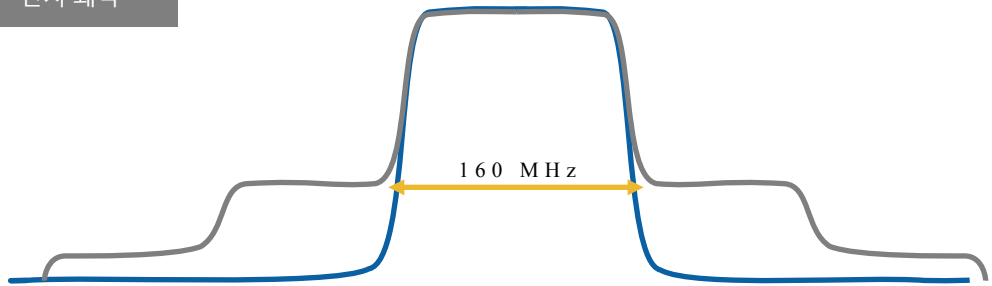
LTE 캐리어 어그리게이션

간격이 넓은 캐리어의 캐리어 어그리게이션



디지털 전치 왜곡

DPD는 3배 - 5배의 신호 대역폭 필요



어플리케이션 IP

디지털 전치 왜곡	자동차 레이더
LTE 캐리어 어그리게이션	5G 통신
WLAN 테스트	레이더 타겟 시뮬레이션
Channelizer	맞춤형 IT

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벡터 신호 트랜시버

1세대?? 2세대??

2012: PXIe-5644/45R
- 80 MHz 대역폭
- 65 MHz ~ 6 GHz

2014: PXIe-5646R
- 200 MHz 대역폭
- 65 MHz ~ 6 GHz

2016: PXIe-5840
- 1 GHz 대역폭
- 9 kHz ~ 6.5 GHz

NI의 2세대 VST??

단지 2개의 PXI 슬롯!!

6.5 GHz VSG
(1 GHz 순시 BW)

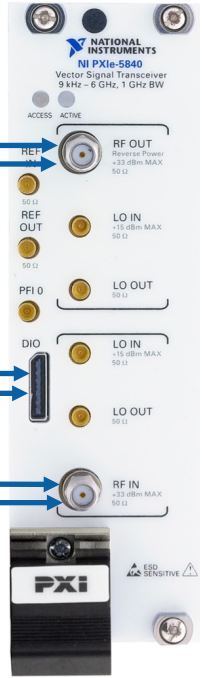
+23 dB 출력 전력

60 MHz, 8-채널 디지털 I/O

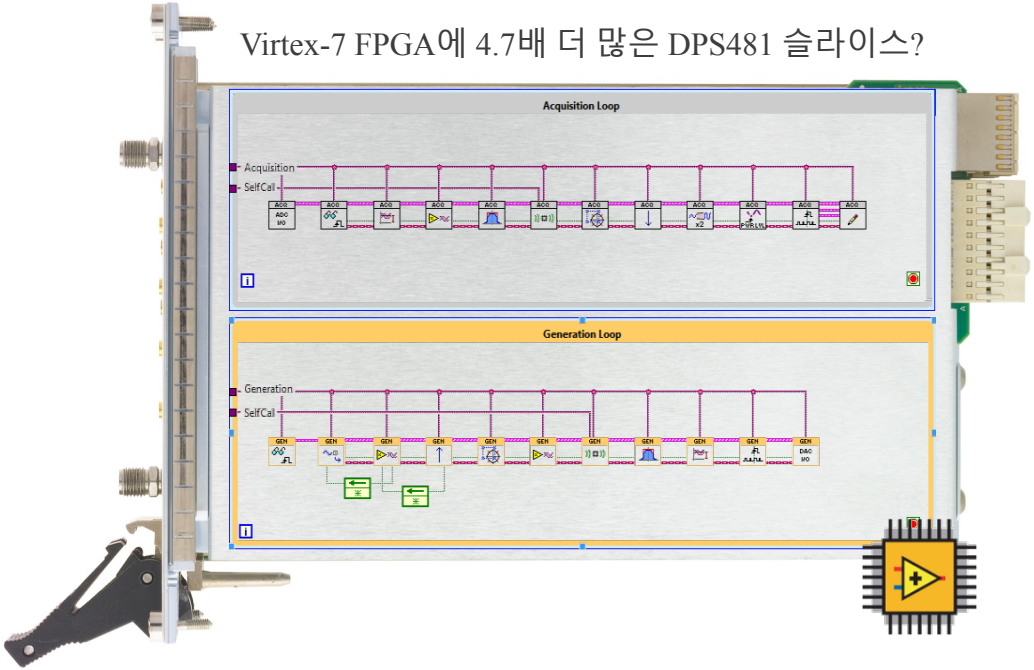
새로운 고속 시리얼 I/O
(12 Gbps, 4 TX 및 4 RX Lanes)

6.5 GHz VSA
(1 GHz 순시 BW)

향상된 EVM 성능?



Virtex-7 FPGA에 4.7배 더 많은 DPS481 슬라이스?



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2세대 VST: PXIe-5840

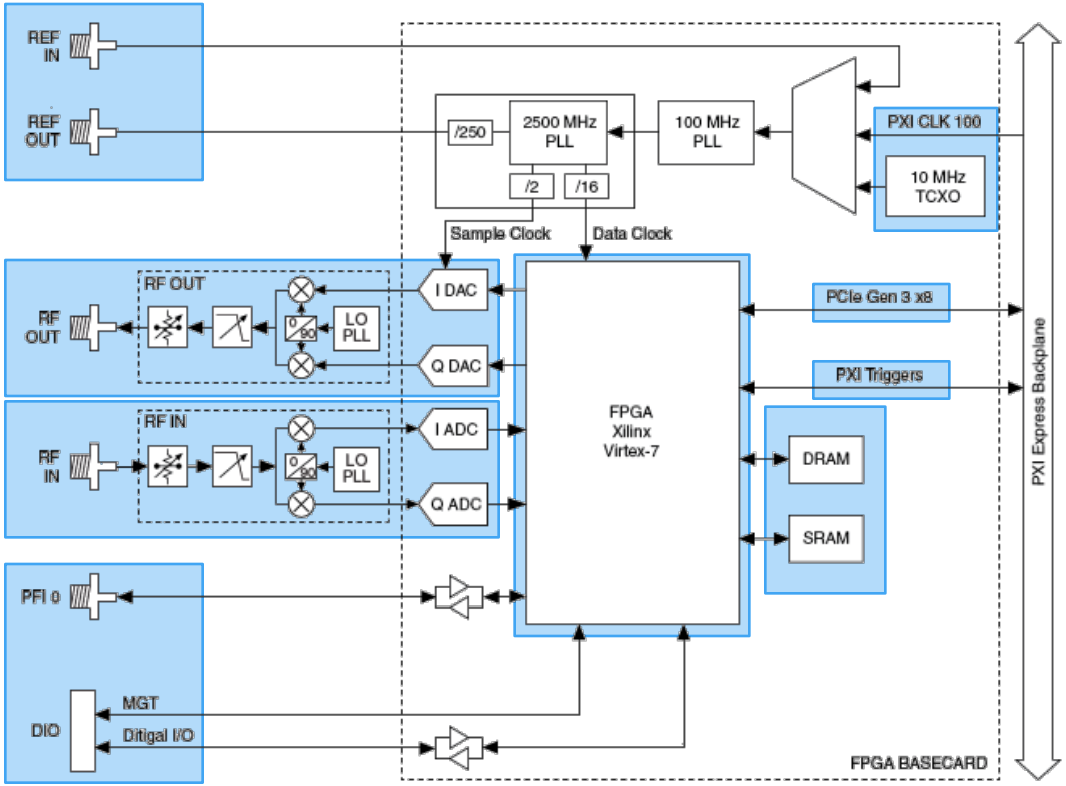
사양	PXIe-5840 성능
주파수 범위	9 kHz ~ 6.5 GHz
최대 출력 전력	+23 dBm
대역폭	1 GHz
EVM	-50 dB (루프백, 외부 LO)
TX/RX 증폭 정확도	±0.35 dB/±0.3 dB
튜닝 시간	250 µs
슬롯	2
FPGA	Virtex-7 X690T
디지털 I/O	8채널, 단일 종단, 60 MHz 4채널 고속 시리얼, 12 Gbps

* 사전 스펙 (16/6/13)

프로그래밍 가능 FPGA로 LabVIEW 코드를 계측기에 온보드 실행할 수 있습니다.

NATIONAL INSTRUMENTS

PXIe-5840 블록 다이어그램



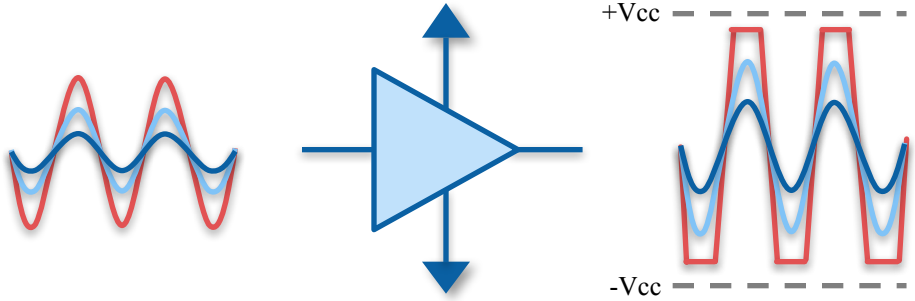
RF 계측기의 대역폭 활용 이점 극대화

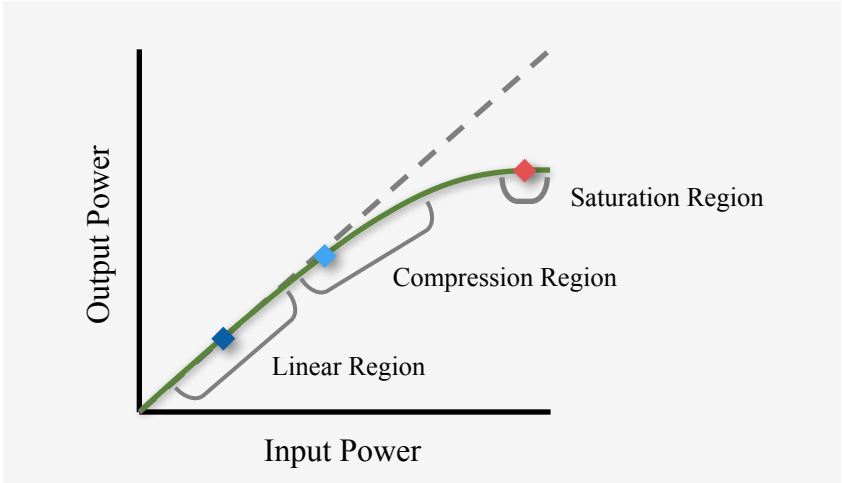
폭넓은 인접 대역폭이 필요한 적용 분야

- WLAN 802.11ac/ax with Digital Pre-Distortion
- LTE Advanced Carrier Aggregation with wide channel spacing
- 5G Research & Development
- Wideband RADAR
- Wideband RF Record and Playback

NATIONAL INSTRUMENTS

Digital Pre-Distortion (DPD) – Power Amplifier



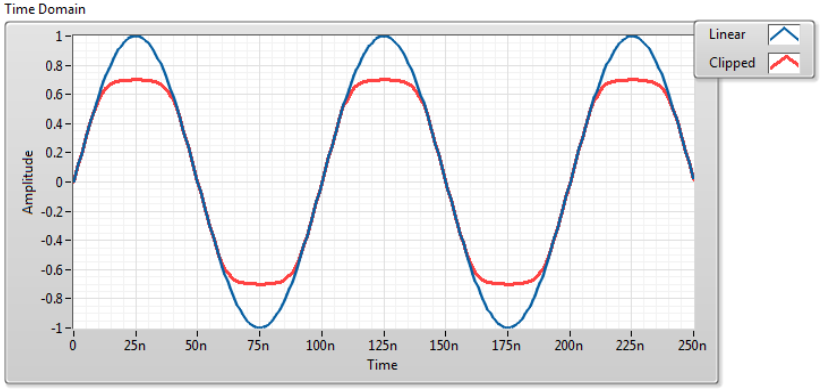


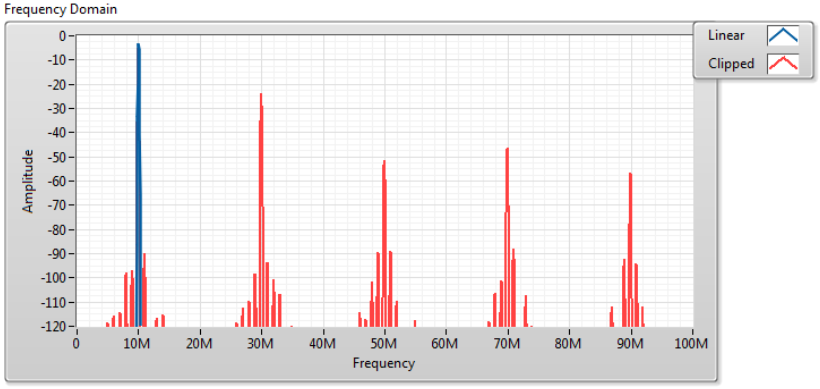
NATIONAL INSTRUMENTS

DPD – Power Amplifier Distortion

압축은 고조파 왜곡을 생성

사인파는 갈수록 “사각파”로 변화됨

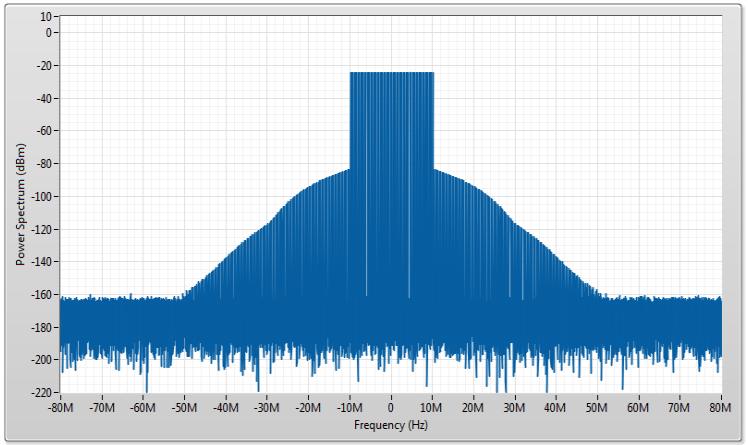


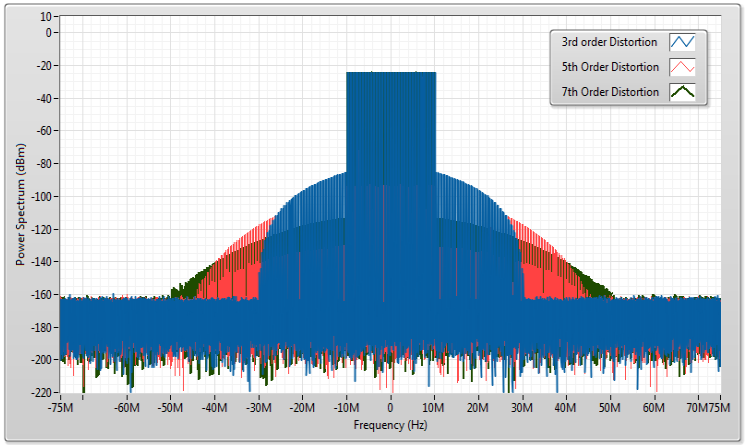


DPD - 변조된 신호가 있는 PA 왜곡

더 높은 차수의 왜곡은 더 높은 BW와 관련이 있음

- 3차 => ~3배 BW
- 5차 => ~5배 BW
- 7차 => ~7배 BW

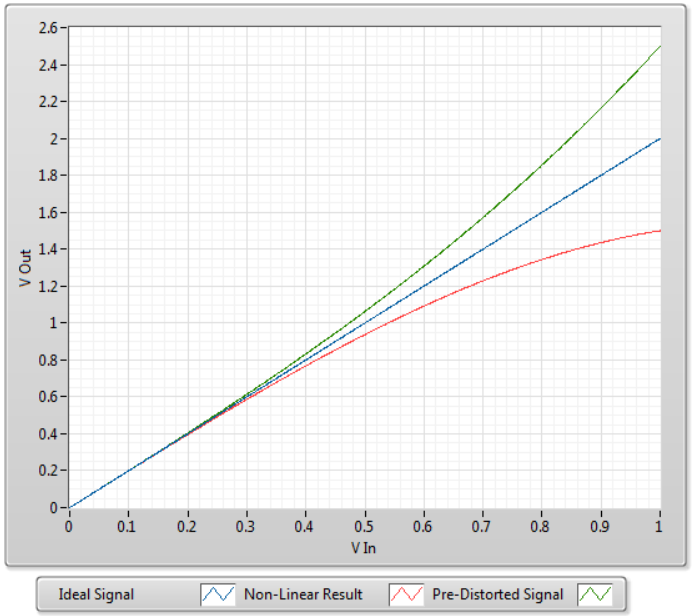




해결 방안: 디지털 전치 왜곡

비선형 시스템을 특성화할 수 있는 경우

- 이상적 신호: $Ae^{j\varphi}$
- 비선형 시스템:
  - 게인: **a**
  - 3차 구성요소: ?**c**
- Output = $|A'|.e^{j(\varphi+\varphi_{A'})}$, where $A' = (aA - 3cA^3/4) = (|A'|, \varphi_{A'})$



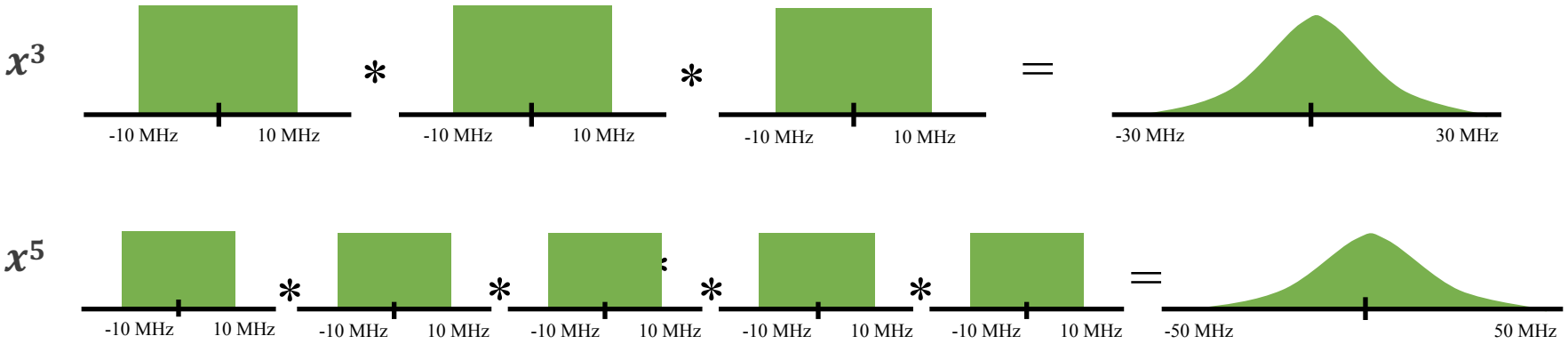
교정 능력 필요

- 전치 왜곡된 신호: $A"e^{j\varphi}$, 여기에서 $A" = (A + 3cA^3/4a)$
- 비선형 시스템:
  - 게인: **a**
  - 3차 구성요소: ?**c**
- Output = $|A"'|.e^{j(\varphi+\varphi_{A"'})}$, where $A"' = aA" + (3cA^3/4 - 3cA^3/4) +$ secondary effects
  - 대략적으로 선형 증폭된 신호인 aA를 얻게 됨

DPD 대역폭 요구사항

전치 왜곡된 신호는 더 높은 BW 요구사항을 가지고 있음

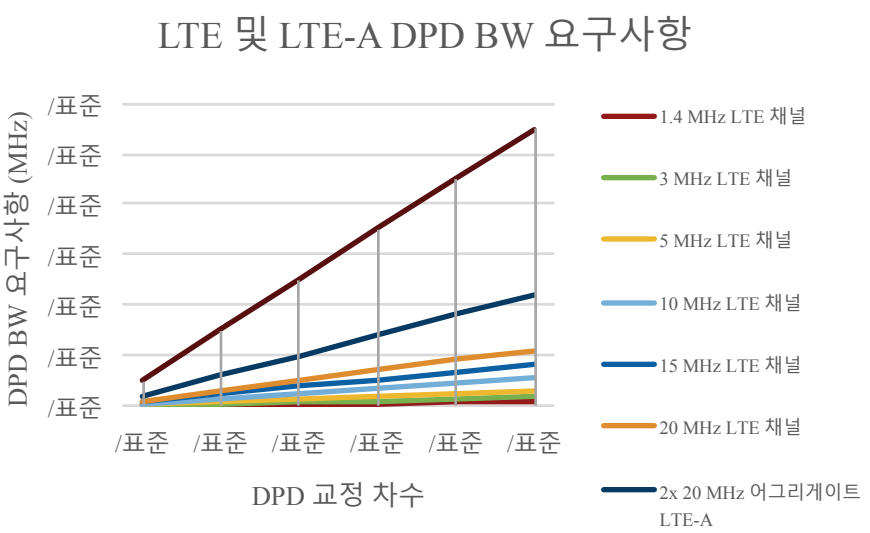
$$Signal\,(x) = Ax + Cx^3 + Ex^5 + \text{이차 효과*}$$



DPD 대역폭 요구사항

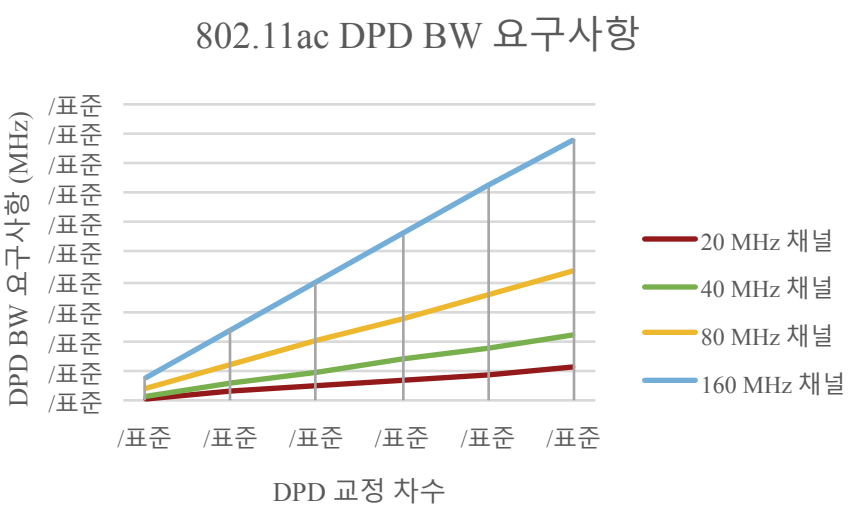
LTE 및 LTE-A

- 5차 DPD를 위해 최고 500 MHz의 BW 필요 ?

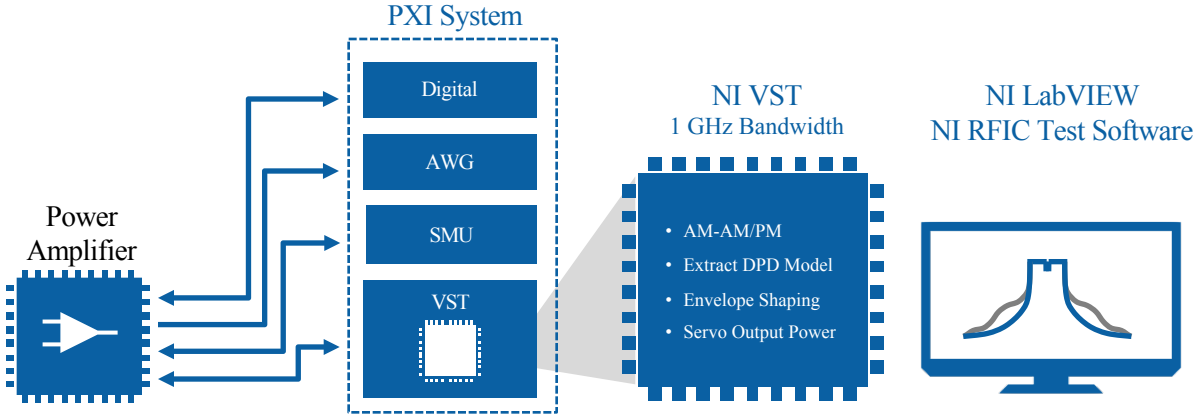


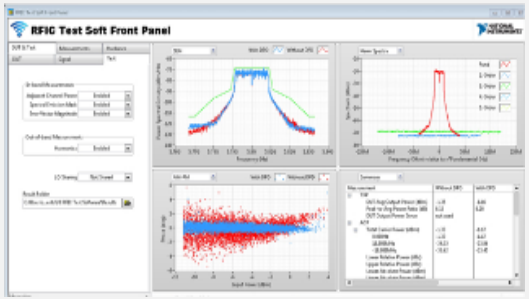
802.11ac/ax

- 5차 DPD를 위해 최고 800 MHz의 BW 필요 ?



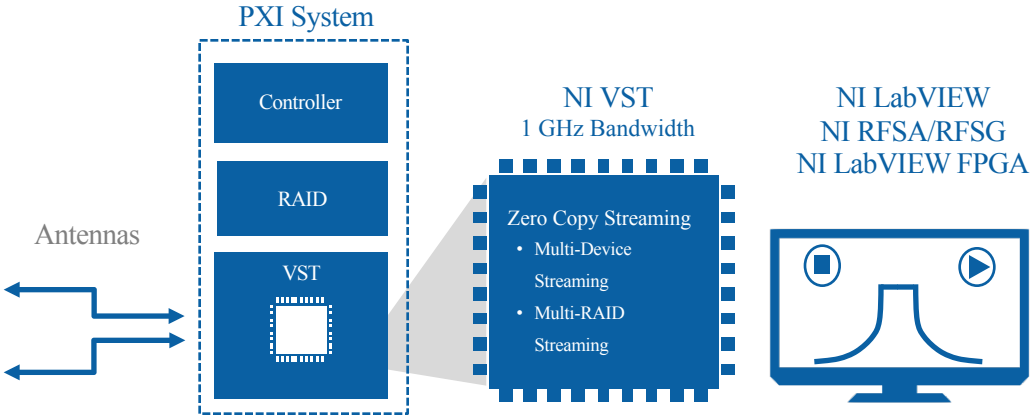
Real-Time DPD로 전력 증폭기(PA) 테스트

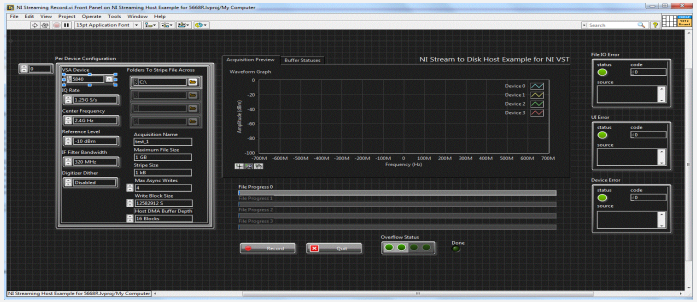




- Based on RFIC test software
- DPD examples for LTE and WLAN
- Faster test times with FPGA based accelerated measurements
- 3rd, 5th or 7th Order pre-distortion on 80MHz or 160 MHz WLAN signal

RF 기록 및 재생





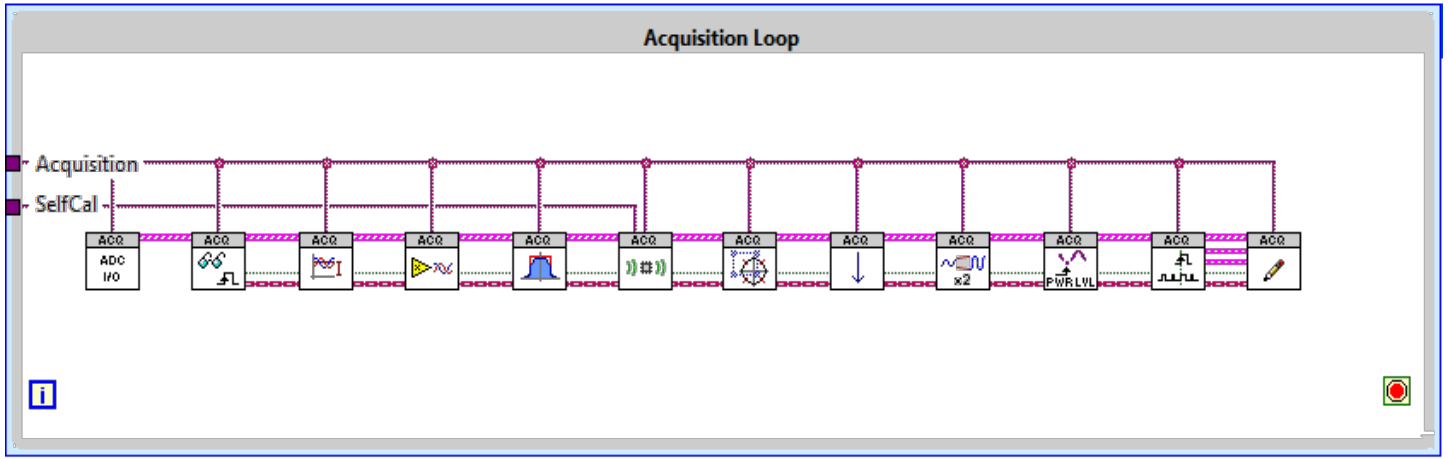
- Record and Playback up to 1 GHz of instantaneous BW with a single instrument
- Examples support streaming to N RAID volume simultaneously
- Analyze waveforms offline
- Stream 1 GHz BW from each of the 2 VSTs in 1085 Chassis @10GB/s to 2 SAS/SSD RAIDs

RF 계측기의 대역폭 활용 이점 극대화

- 대역폭 내에서 여러 신호를 사용하는 분야
  - Ultra-fast tuning
  - Multi-channel up & down conversion
  - LTE / WLAN / NB IoT Coexistence

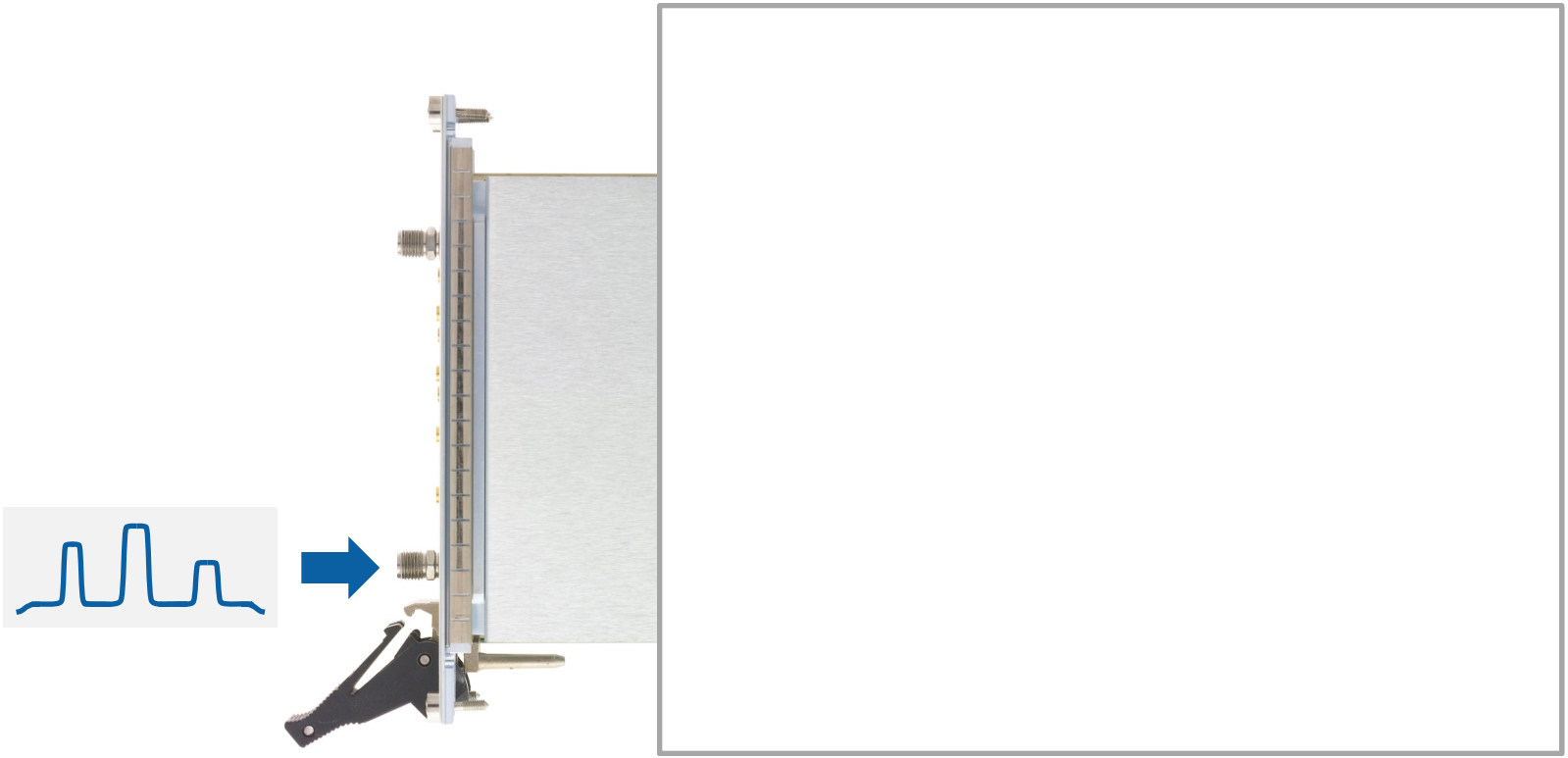
NATIONAL INSTRUMENTS

FPGA 신호 경로

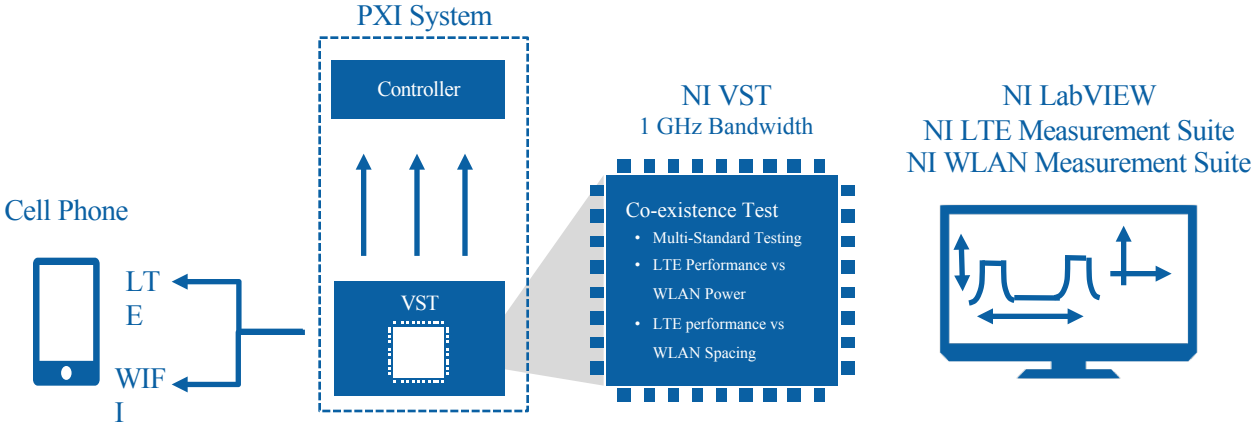


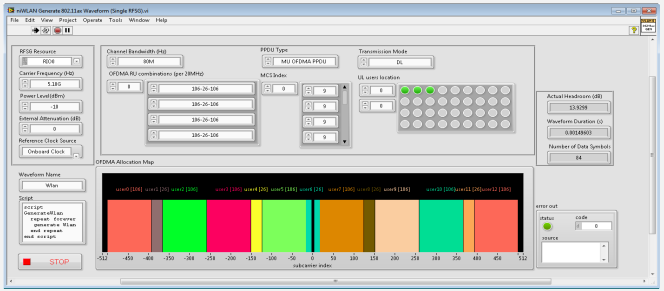
ADC의 데이터 → 교정: 게인, 오프셋, 주파수 이동, 균등화 → 부분 제거 → 수집

대역 내 재튜닝



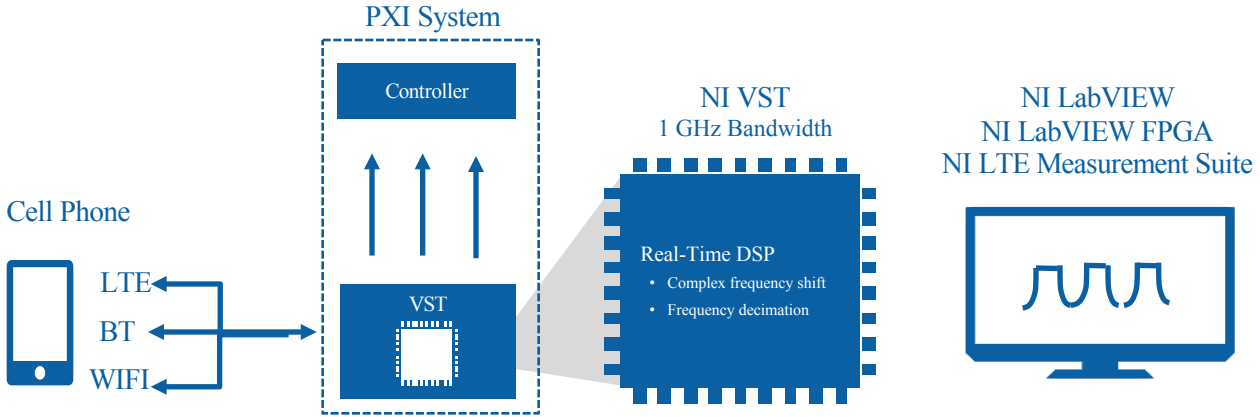
동시 LTE+WLAN 테스트

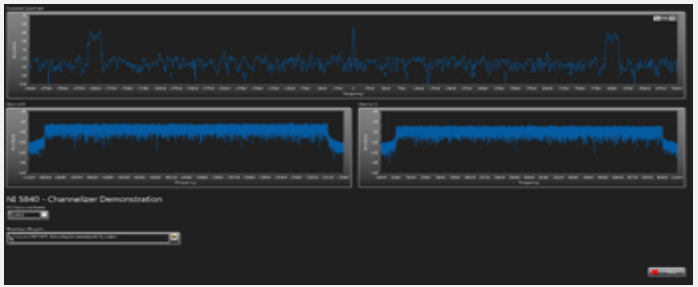




- Whole 2.4 and 5 GHz band coverage
- Multi-Standard Testing with software support
- Measure/Quantify the effects of one standard on the other in co-existence

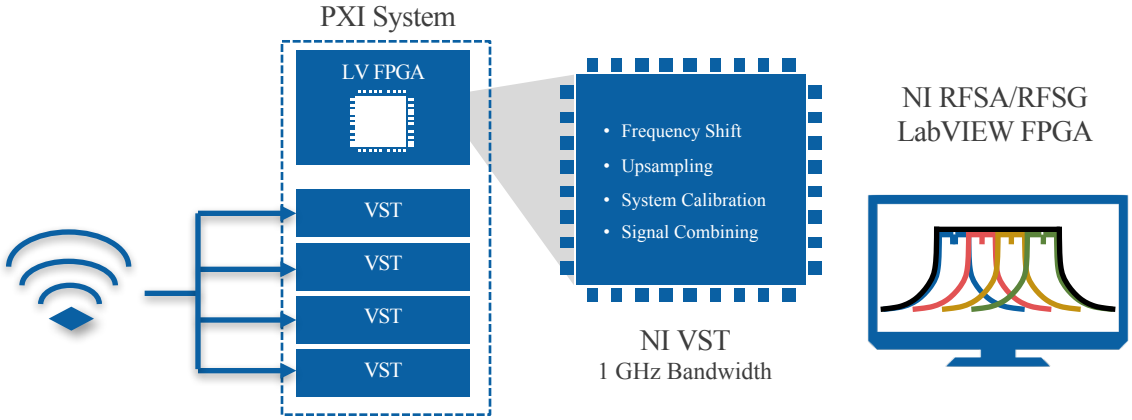
Multi-DDC Channelizer

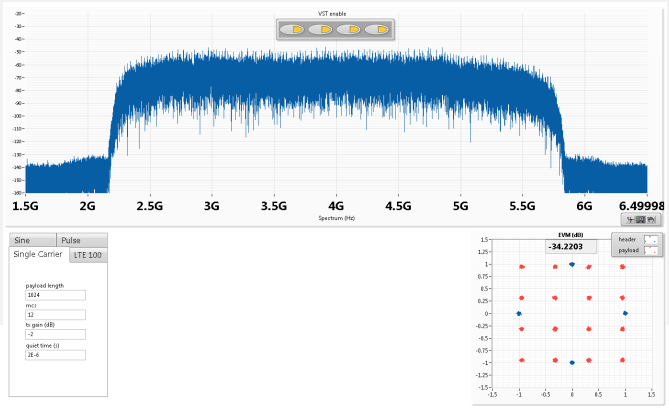




- Wideband signal acquisition of up to 1 GHz instantaneous bandwidth
- Individually configurable narrow channels
- FPGA based Multi-DDC channelization technique
- Future Support for DDC, Polyphase, PFT channelizer on FlexRIO

Spectral Stitching





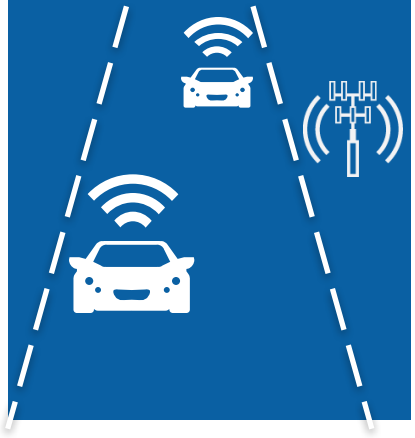
- LV FPGA for real-time signal combination and decomposition
- Bandwidth expansion across N devices while maintaining dynamic range
- NI Patented Technology

Smarter Test System for Smart Automobile

Automotive

AUTOMOTIVE RADAR & 5G

CONNECTED CAR V2X / V2V

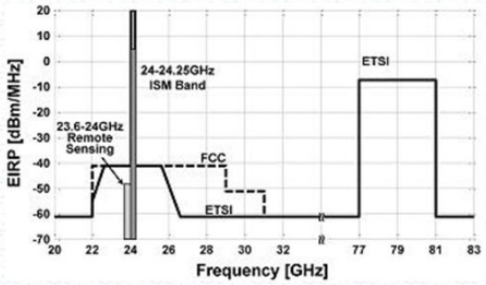


INFOTAINMENT & WIRELESS TEST

- Spectrum Monitoring
- Record & Playback
- Channel Emulator
- Radio Production
- 5G Test
- 8x8 MIMO WLAN
- Electronic Warfare
- Software Defined Radio
- Target Simulator
- IoT Device Test
- RADAR Prototyping
- DPD Prototyping
- Real-time DUT control
- Power Servoing
- Measurement Acceleration
- Channel Sounding
- Real-time Spectral Analysis
- Channelizing
- …

NATIONAL INSTRUMENTS

Automotive RADAR – Regulation

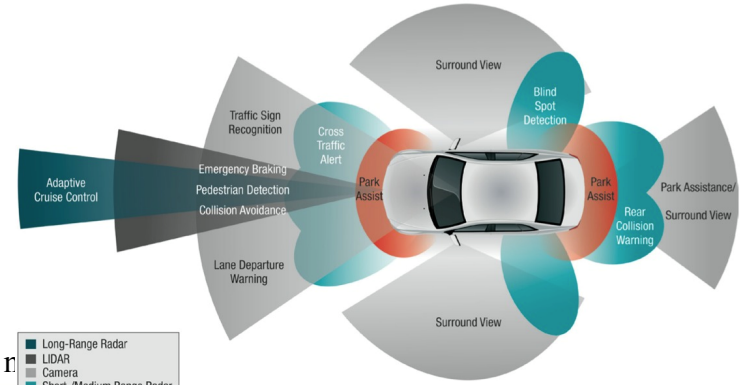


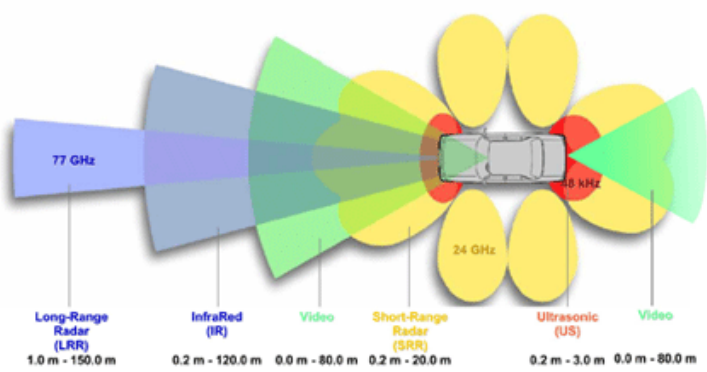
24 GHz and 77 GHz are the dominant bands for automotive

77-81 GHz is promising since offers 4 GHz bandwidth

Country	76-77 GHz	79-81 GHz
Europe (CEPT)	available	available
USA, Canada	available	discussions started
Russia	available	available
Japan	restricted to 0.5 GHz bandwidth	in discussions
China	available	-
Korea	available	-
Argentina	regulation in progress	-

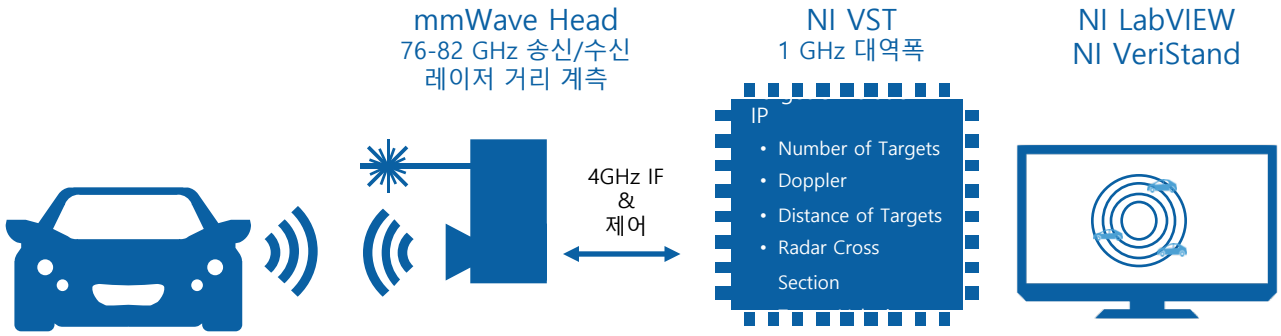
LRR3	MRR Front	MRR Rear
		
SOP: 2009	SOP: 2013	SOP: 2014
• Range: up to 250 m • SiGe MMICs (bare chip) • Opening Angle: 30° • Dimensions (HxWxD) 77 x 74 x 58 mm • Weight: 285 g	• Range: up to 160 m • SiGe MMICs (packaged chip) • Opening Angle: 45° • Dimensions (HxWxD) 60 x 70 x 30 mm • Weight: 200 g	• Range: up to 100 m • SiGe MMICs (packaged chip) • Opening Angle: 150° • Dimensions (HxWxD) 60 x 70 x 30 mm • Weight: 190 g





NATIONAL INSTRUMENTS™

77 GHz에서의 자동차 레이더 테스트



"업계 최대 대역폭과 저 지연(Low latency)의 기능을 가진 소프트웨어 기반의 계측기를 통해 자동차 레이더 센서를 기존과 다른 완전히 새로운 방식으로 탐색할 수 있고, 기존에는 파악할 수 없었던 문제를 설계 초기에 확인할 수 있습니다. LabVIEW로 프로그래밍이 가능한 FPGA와 VST로 광범위한 시나리오를 신속하게 에뮬레이션을 할 수 있고 자율주행의 안전 및 안정성을 높이는 데 도움이 되었습니다."
— 네일 코크(Neil Koch), Audi AG 컴포넌트 오너 레이더 시스템팀

ni.com/smarter-test

NATIONAL INSTRUMENTS

요약

- 새로운 무선 표준 시험을 위해 RF 시스템 대역폭의 한계를 끊임없이 확장시켜나가고 있습니다.
- 상용 IC 기술의 발전과 함께 RF 계측기술 또한 향상되고 있습니다.
- 폭넓은 대역폭을 지원하는 RF 계측 기술은 향상된 무선 통신 표준에 대한 시험 평가를 가능하게 합니다.