MATLAB EXPO

5G+ 주파수대역 RF 송수신기 모델링과 검증

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MathWorks

CONTENTS

3GPP Release 17 Requirement

Introduction

Release 16

3GPP TR 38.807 V16.0.0 (2019-12)

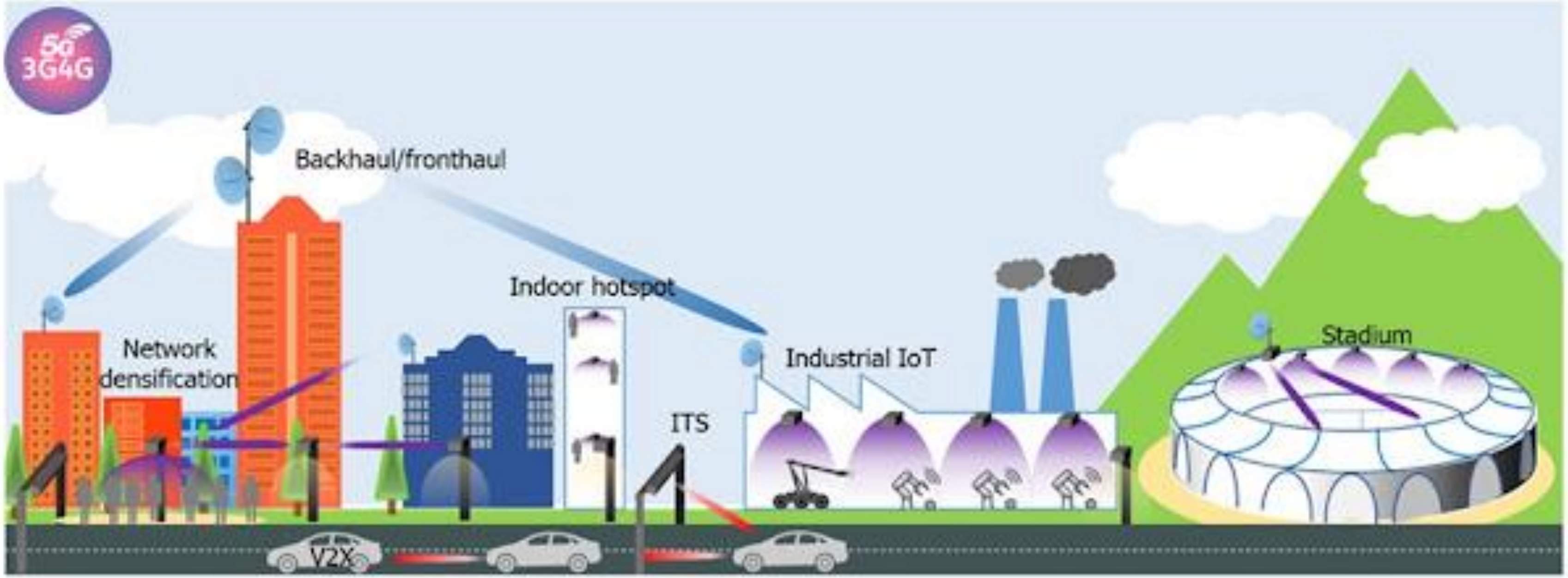


Figure 5.1-1: Use Cases for NR above 52.6GHz

Rel-16 : Technical Report

Introduction

5G NR, Release 15 and Release 16 : Supports up to 52.6 GHz designed to be optimized under 52.6 GHz.

Difficult challenges for beyond 52.6 GHz (Rel-17) :

- **higher phase noise** (PN),
- larger propagation loss due to high atmospheric absorption
- lower power amplifier (PA) efficiency
- strong power spectral density regulatory requirements in unlicensed bands

Benefits for beyond 52.6 GHz (Rel-17) :

- **very large frequency spectrum** for both unlicensed and licensed bands.
- various high-capacity use cases, integrated access and backhaul (IAB), ultra-high data rate mobile broadband, device-to-device communications, industrial internet-of-things (IIoT), mobile data offloading, broadband distribution networks, wireless display transfer, augmented reality (AR)/virtual reality (VR), intelligent transport systems (ITS)

Overview of 5G NR Rel 17, Frequency Band Beyond 52.6 GHz

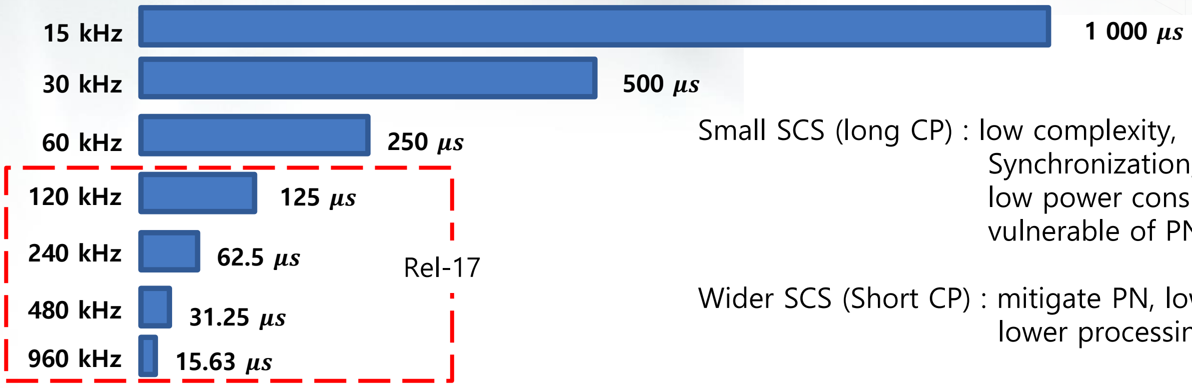
Global Harmonization → Including Unlicensed Band → Economies of Scale

Max Available Bandwidth : 14 GHz

Channel Bandwidth of IEEE 802.11ad/ay : 2.16 GHz

Country	Frequency (GHz)							
	52.6-57	57-58.2	58.2-59	59-59.3	59.3-64	64-65	65-66	66-71
Europe/CEPT		Mobile						
Israel								
South Africa		Mobile						
USA		Mobile						
Canada		Mobile						
Brazil		Mobile						
Mexico		Mobile						
China				Mobile				
Japan		Mobile						
Korea		Mobile						
India								
Taiwan		Mobile						
Singapore		Mobile						
Australia		Mobile						

Overview of 5G NR Rel 17, Physical Layer and Evolution Beyond 52.6GHz



Small SCS (long CP) : low complexity,
Synchronization, beam switching time,
low power consumption, large coverage
vulnerable of PN

Wider SCS (Short CP) : mitigate PN, lower processing time (Short Slot)
lower processing latency, reduce baseband processing complexity

PHYSICAL LAYER NUMEROLOGY FOR 5G NR REL-15.

SCS (kHz)	15	30	60	120
Frequency band (GHz)	0.45 – 6		0.45 – 6 24 – 52.6	24 – 52.6
Symbol duration (µs)	66.67	33.33	16.67	8.33
Slot duration (µs)	1 000	500	250	125
CP duration (µs)	4.69	2.34	1.17	0.60
Max. bandwidth (MHz)	50	100	200	400
Sampling rate (MSPS)	61.44	122.88	245.76	491.52

PHYSICAL LAYER NUMEROLOGY FOR 5G NR REL-17.

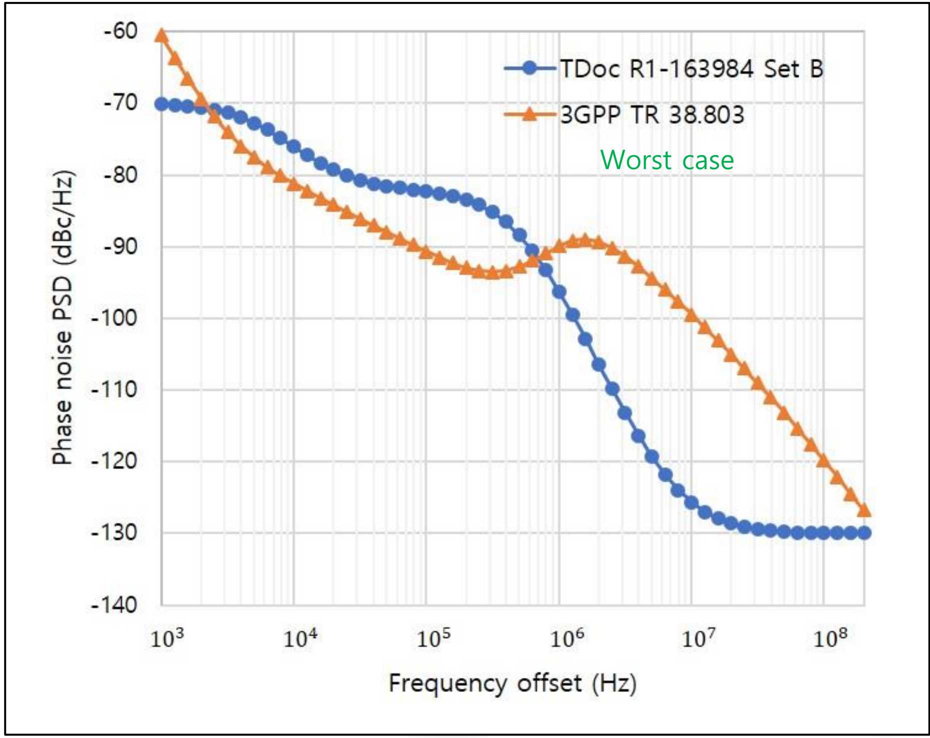
SCS (kHz)	120	240	480	960
Frequency band (GHz)	52.6 – 71			
Symbol duration (µs)	8.33	4.16	2.08	1.04
Slot duration (µs)	125	62.5	31.25	15.63
CP duration (µs)	0.60	0.30	0.15	0.07
Max. bandwidth (MHz)	400	400	2 000	2 000
Sampling rate (MSPS)	491.52	983.04	1966.08	3932.16

Phase Noise and Its Modeling

Typically, characteristics of PN in frequency domain are expressed in terms of single-side-band (SSB) PN spectrum, which is defined as the noise power within 1 Hz bandwidth at a certain frequency offset, relative to the noise power at the carrier frequency.

The PN model has been investigated for mmWave frequency band based on recently published data to improve the analysis of the RF impairments in 3GPP.

It proposes a PN model to provide the analysis frequency range from 7 to 100 GHz and reflects performances of a single PLL or a set of PLLs with different frequency divider structures [1], [2], [3].



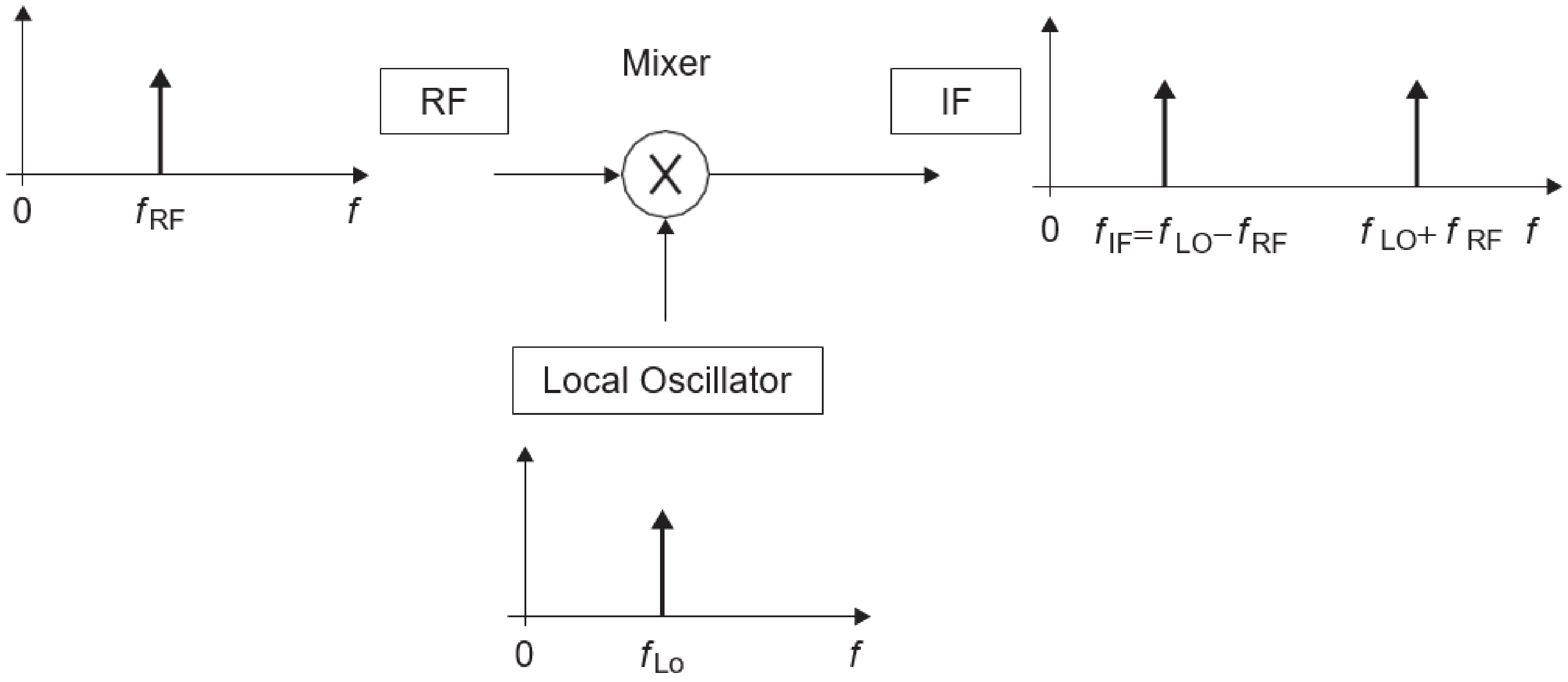
[1] R1-2003851, Enhanced phase noise modeling, Ericsson, 3GPP TSG RAN WG1 meeting #101, May. 2020.

[2] “3GPP TR 38.803 V14.2.0,”Study on new radio access technology: Radio Frequency (RF) and co-existence aspects,” Tech. Spec. Group Radio Access Network, Rel. 14, Sept.,2017.

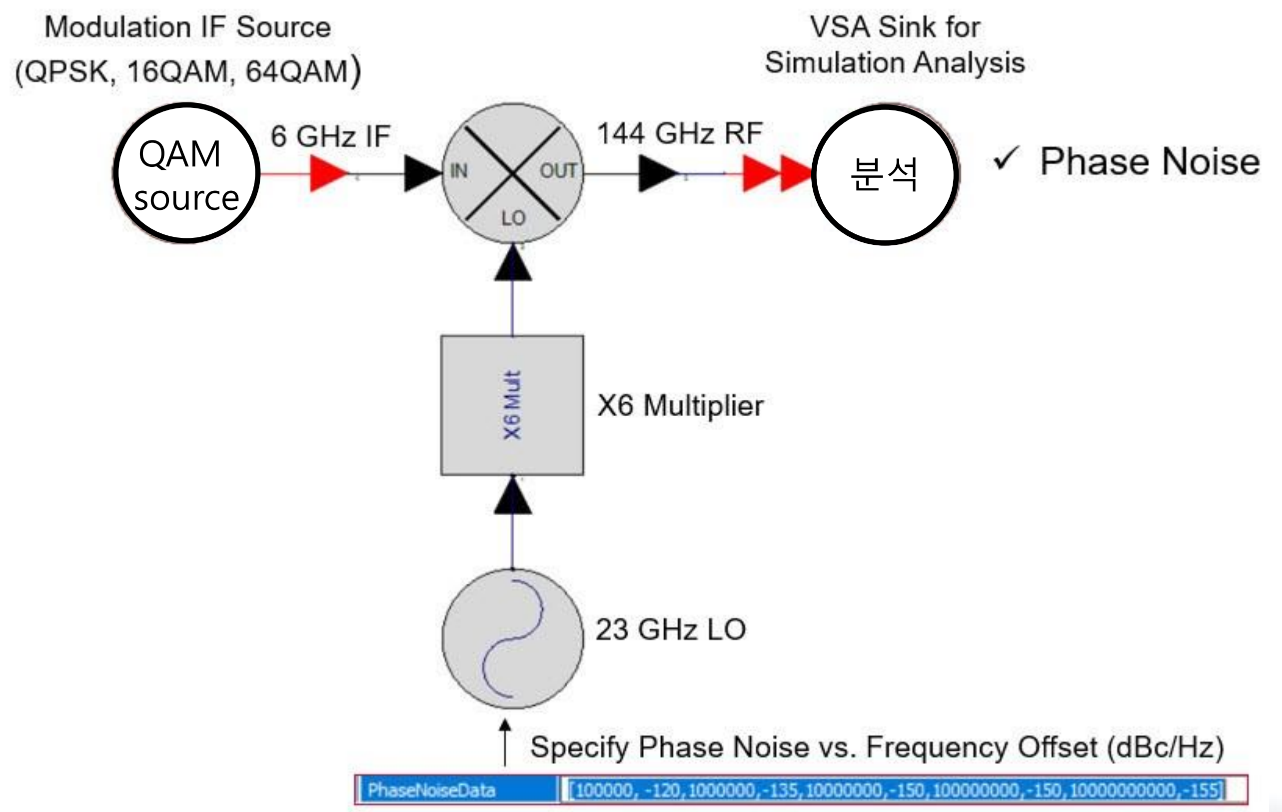
[3] R1-163984, Discussion on phase noise modeling, Samsung, 3GPP TSG RAN WG1 meeting #85, May. 2016.

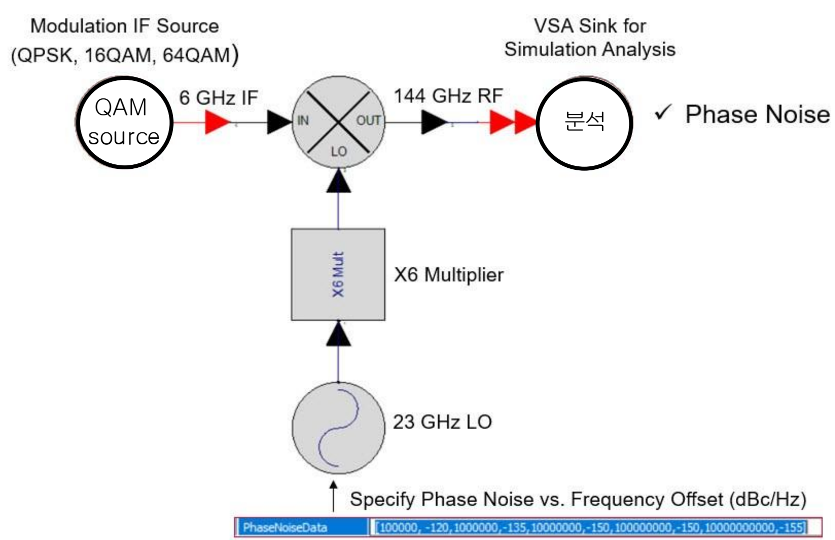
mmWave RF Down and Up Converter Design

Conceptual diagram of an ideal mixer that operates as downconverter.



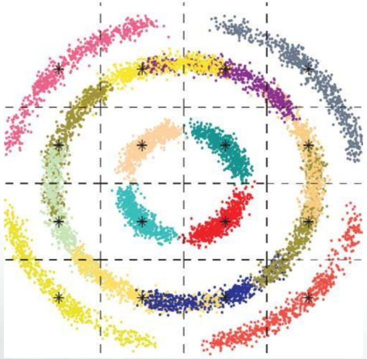
Ex) Sub-Terahertz Upconverter Design



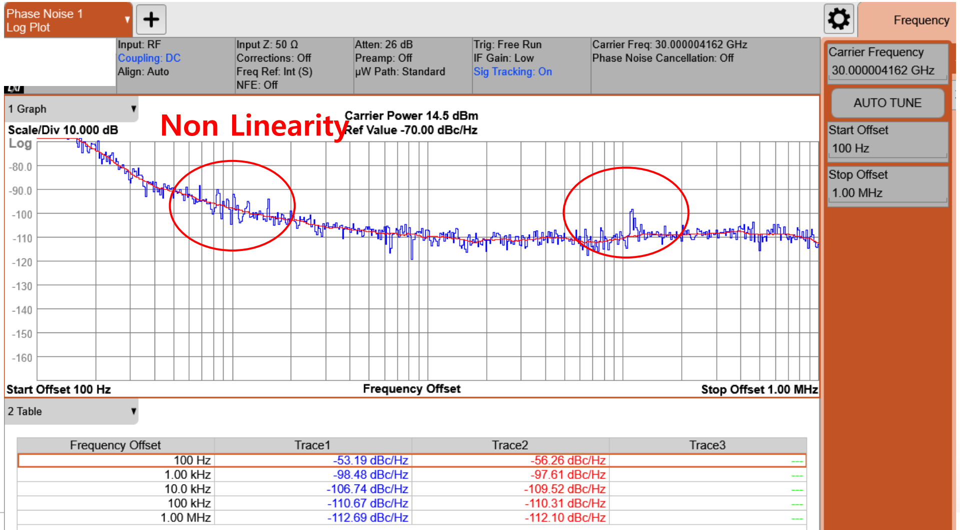


132 GHz = 138 GHz - 6 GHz   144 GHz = 138 GHz + 6 G

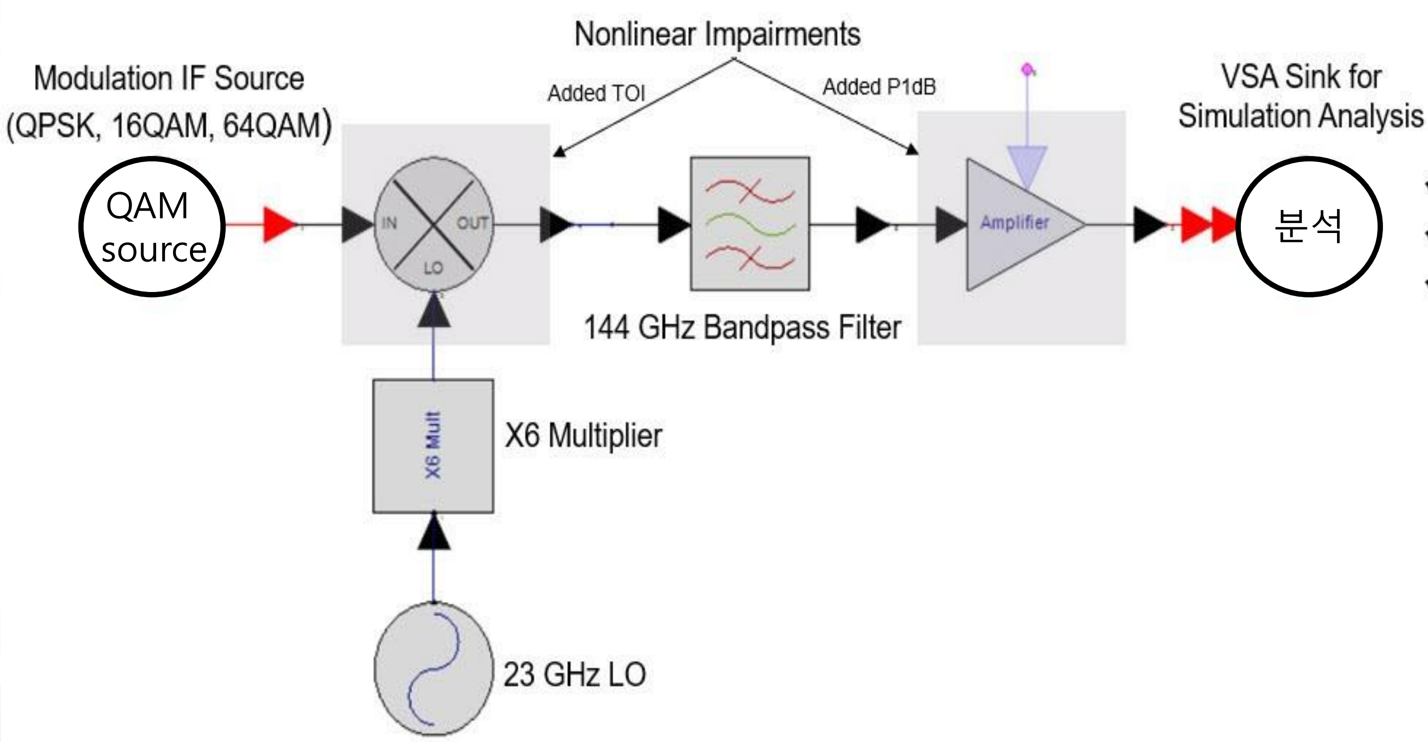
EVM Error



예) 30GHz phase noise of LO

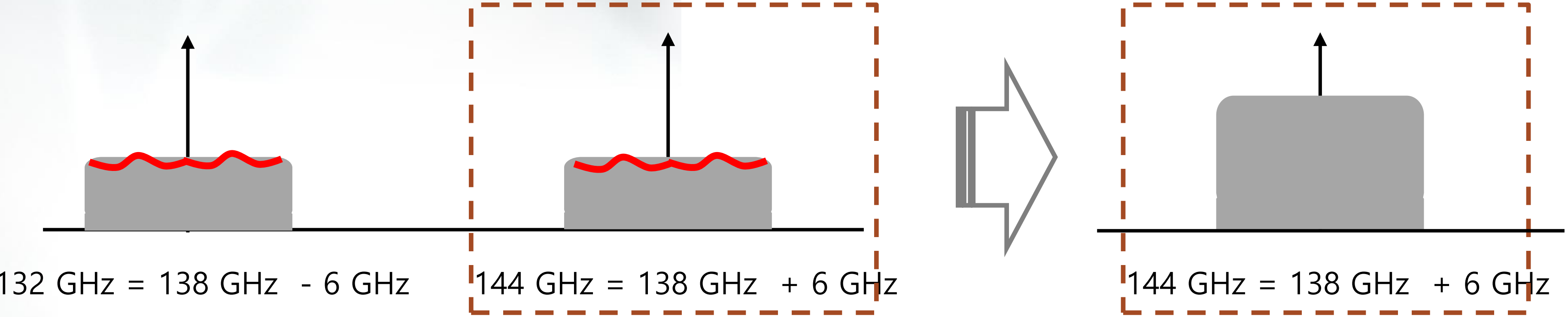


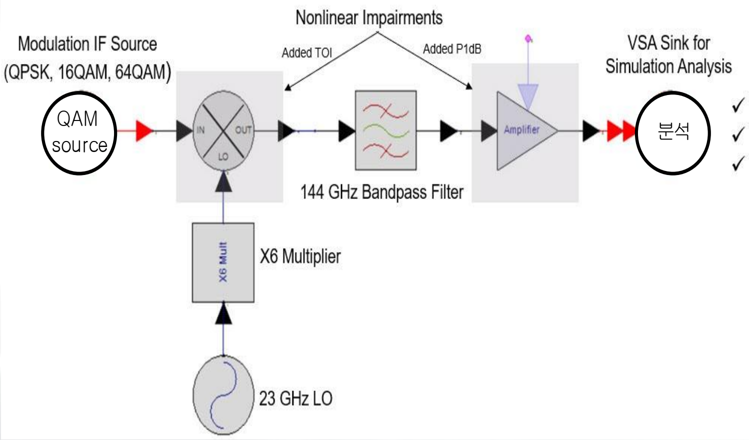
Ex) Sub-Terahertz Upconverter Design



- ✓ Phase Noise
- ✓ Linear Impairments
- ✓ Nonlinear Impairments

RF Flatness
Dynamic Range



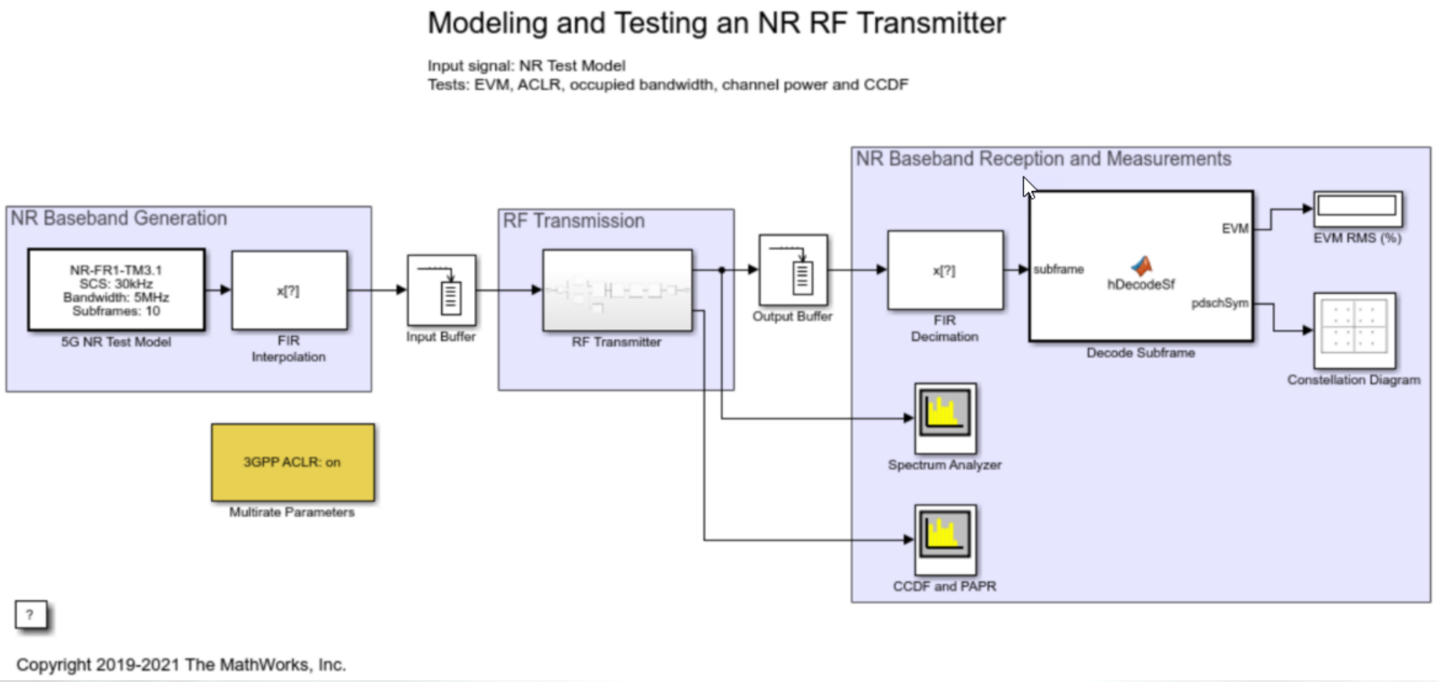


- ✓ Phase Noise
- ✓ Linear Impairments
- ✓ Nonlinear Impairments

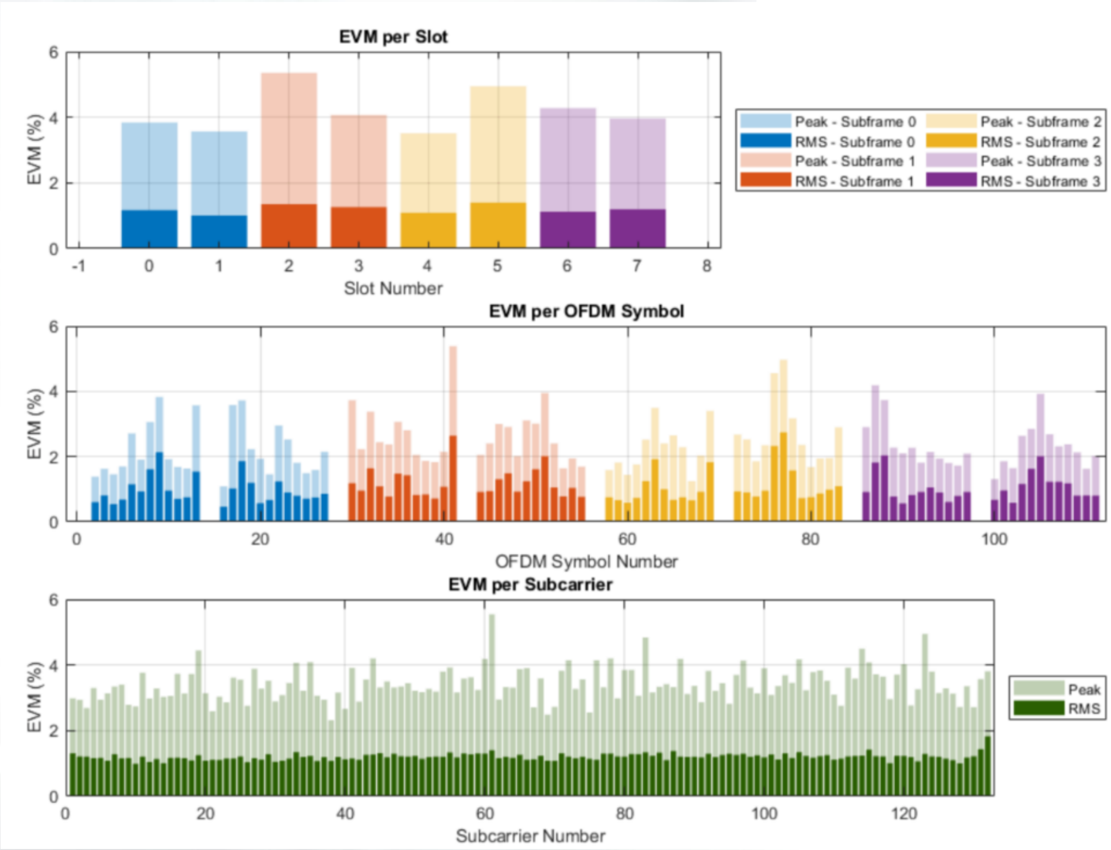
mmWave RF Down and Up Converter Model

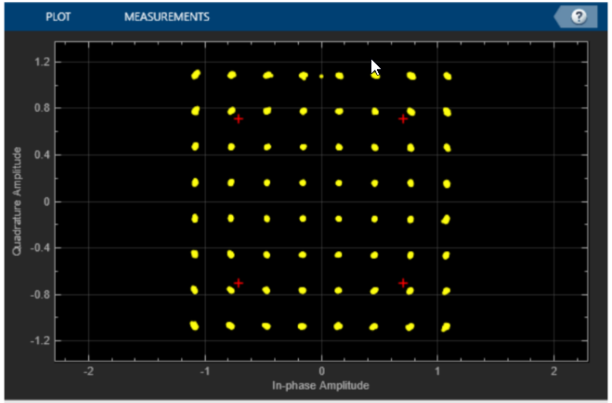
Simulink Modeling and Simulation – Upconverter

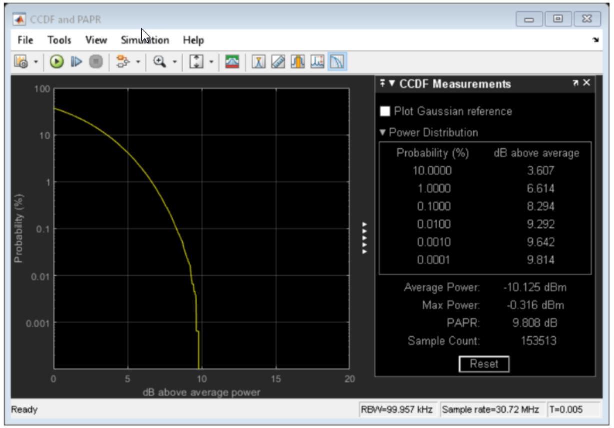
- CCDF, PAPR and EVM measurements
- Characterize the impact of RF impairments
  - IQ imbalance, phase noise, PA nonlinearities



Simulink Modeling and Simulation – Upconverter

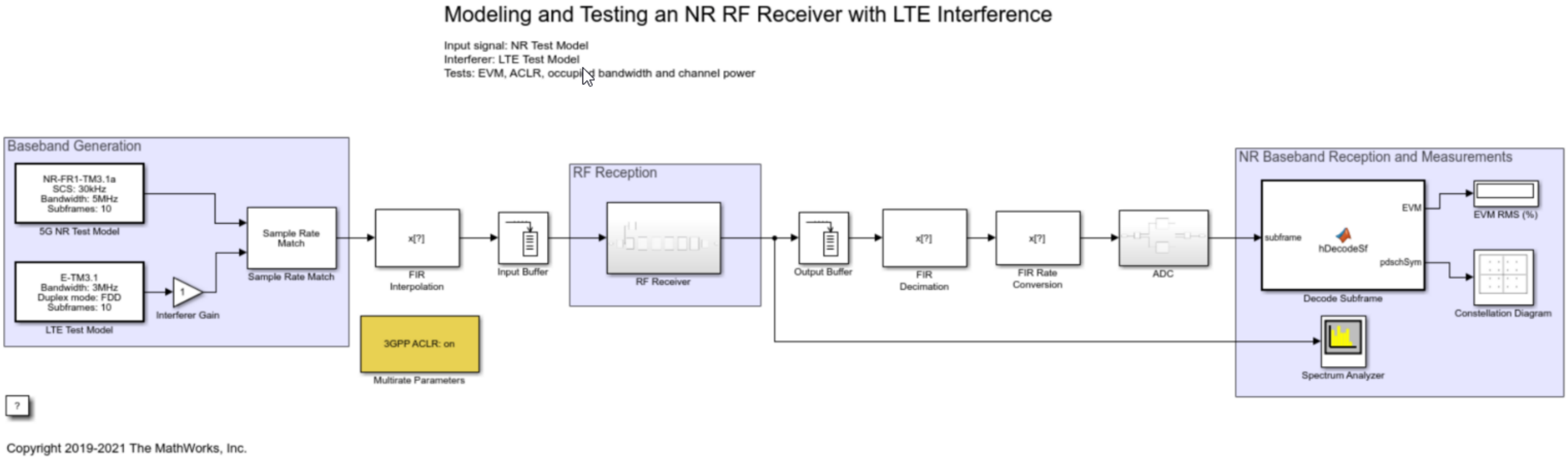




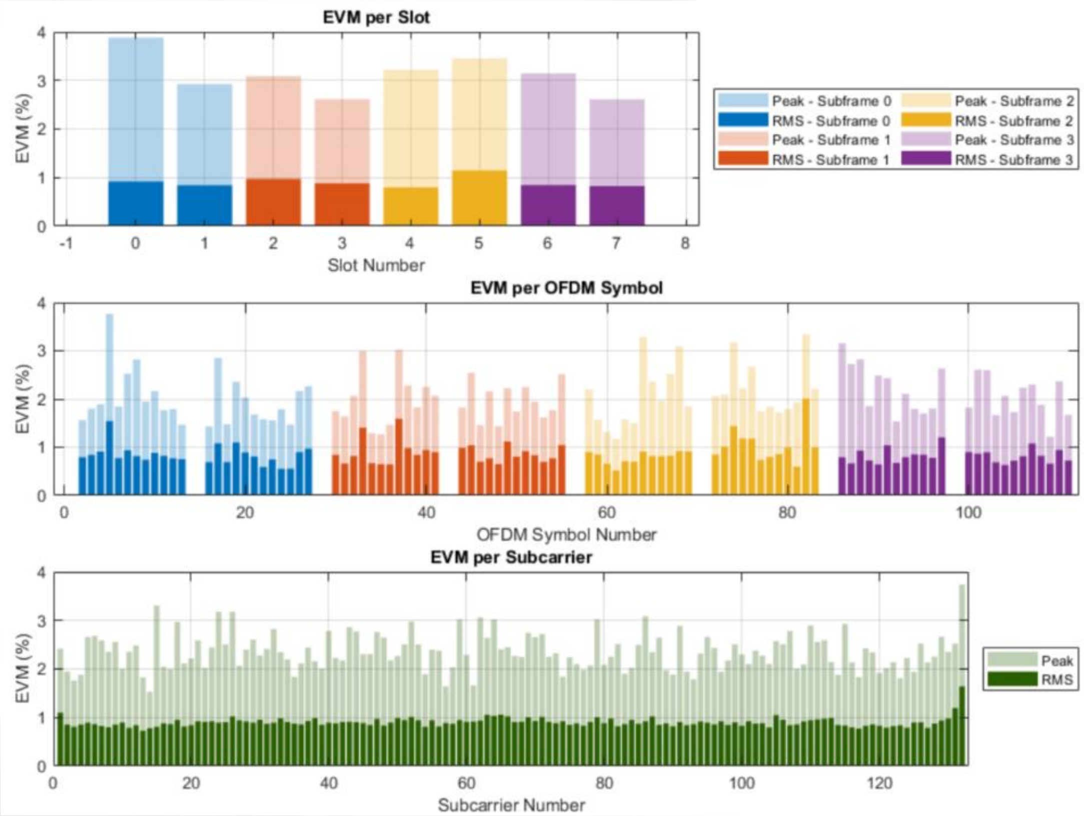


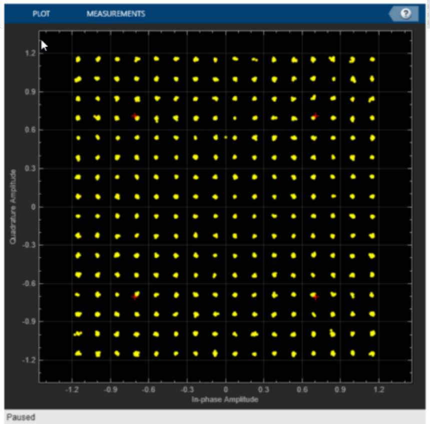
Simulink Modeling and Simulation – Downconverter

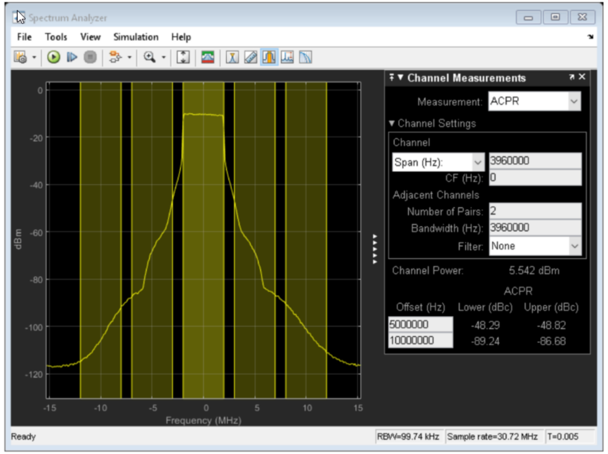
- ACLR and EVM measurements
- Explore the impact of altering the RF impairments
- LTE Interference



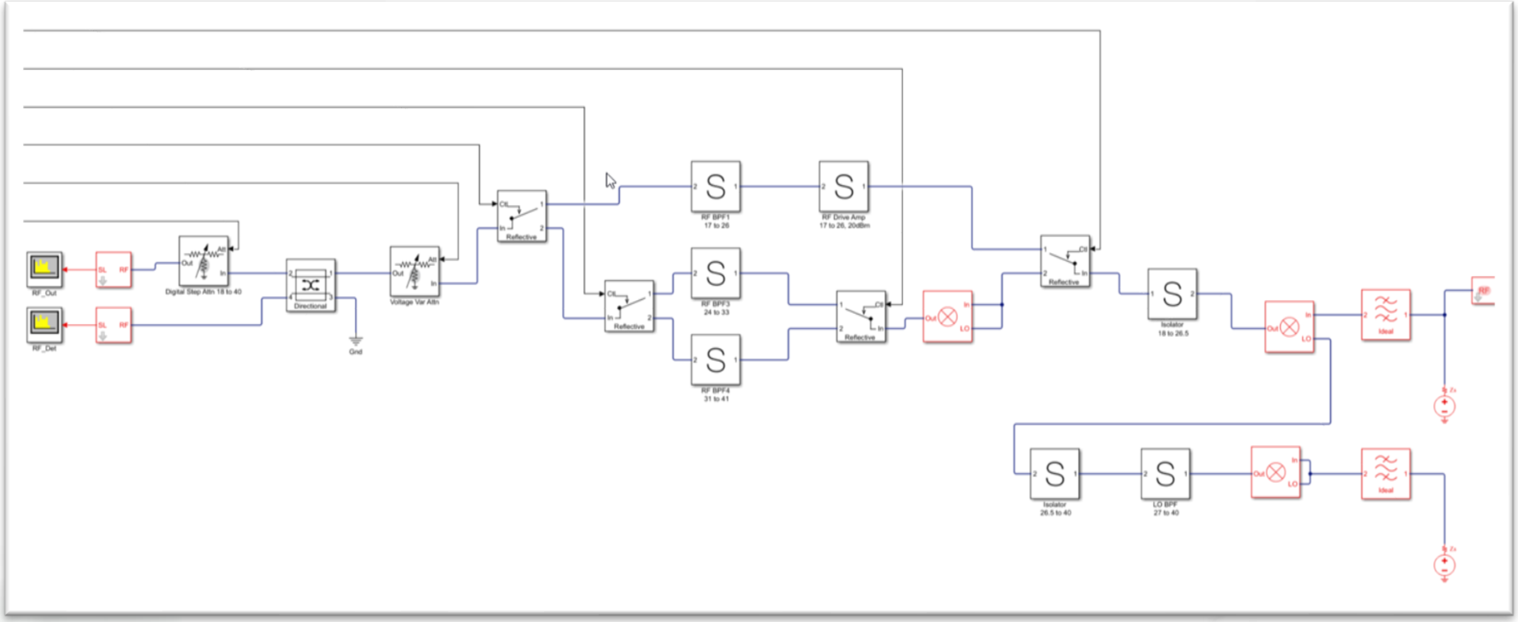
Simulink Modeling and Simulation – Downconverter



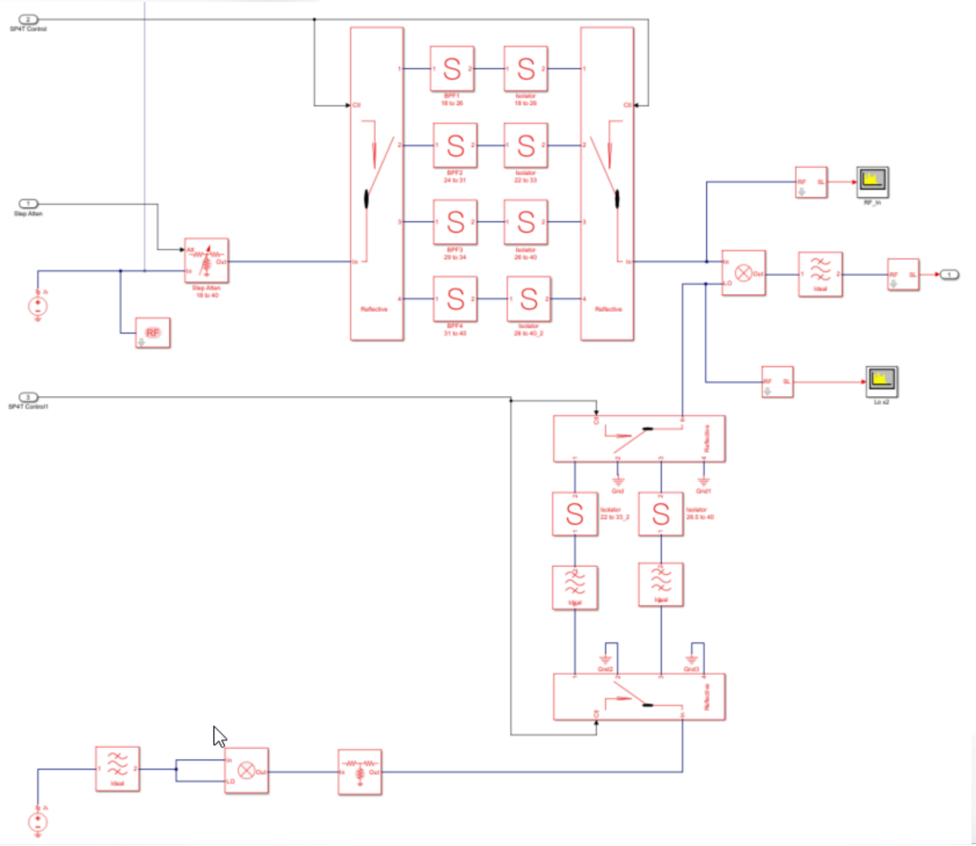




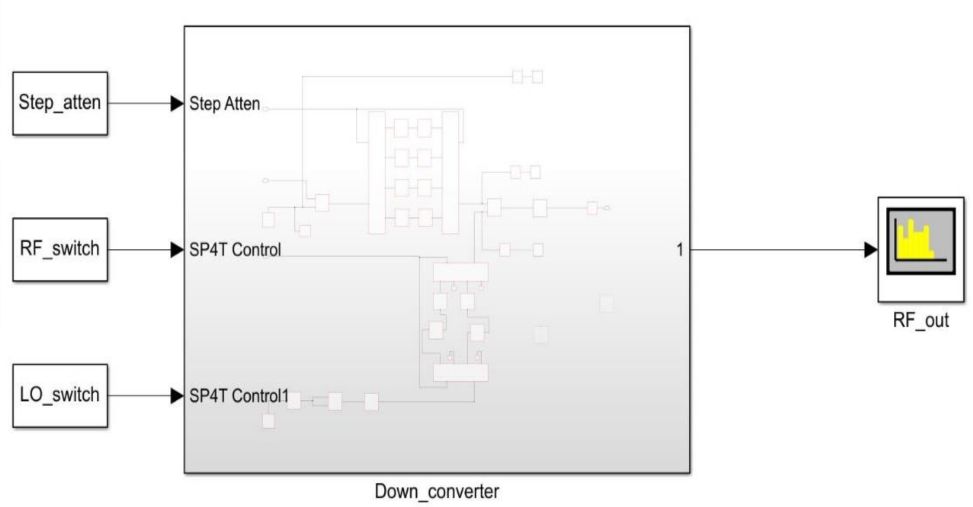
Ex) Sub-Terahertz Upconverter Modeling



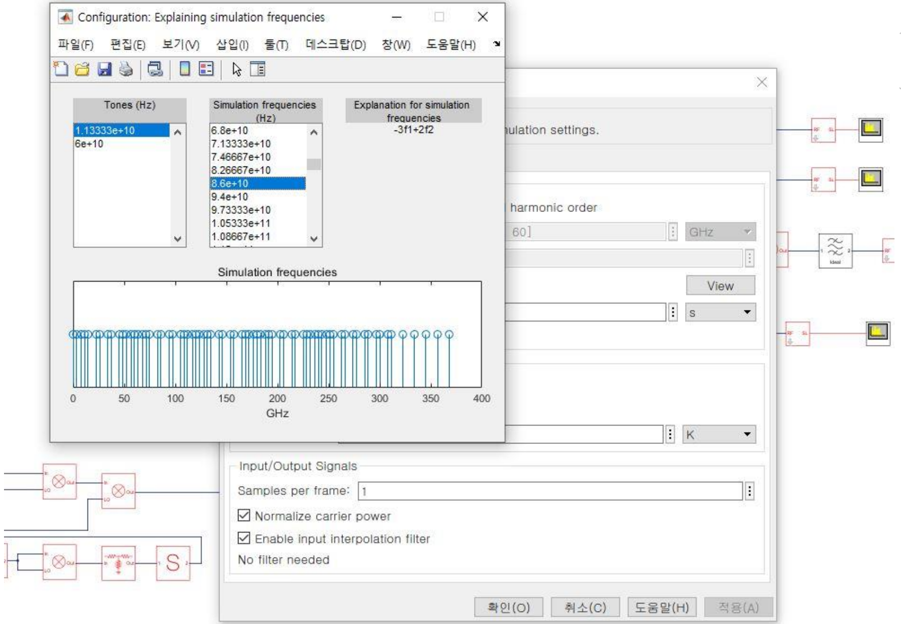
Ex) Sub-Terahertz Downconverter Modeling



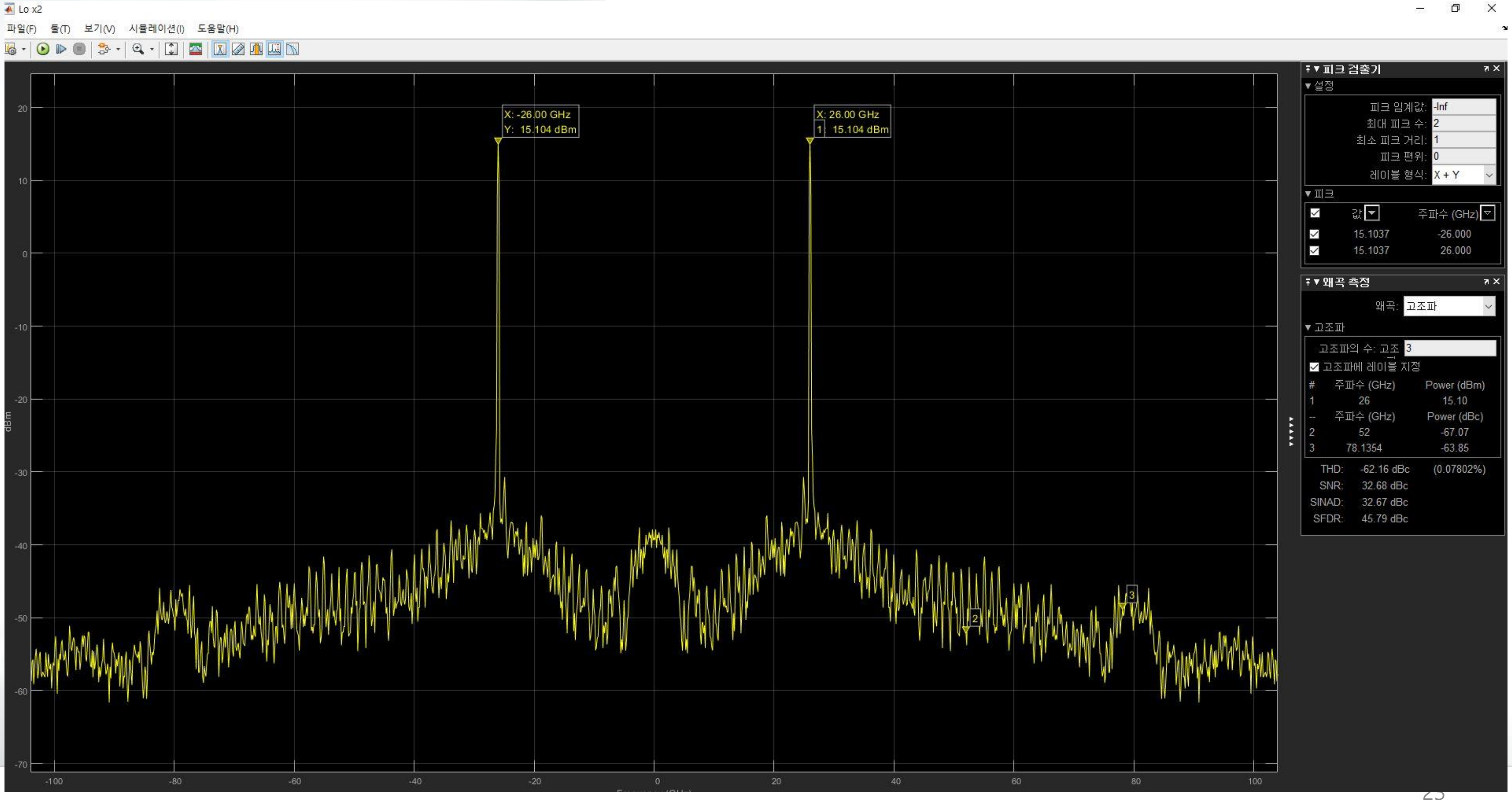
Modeling



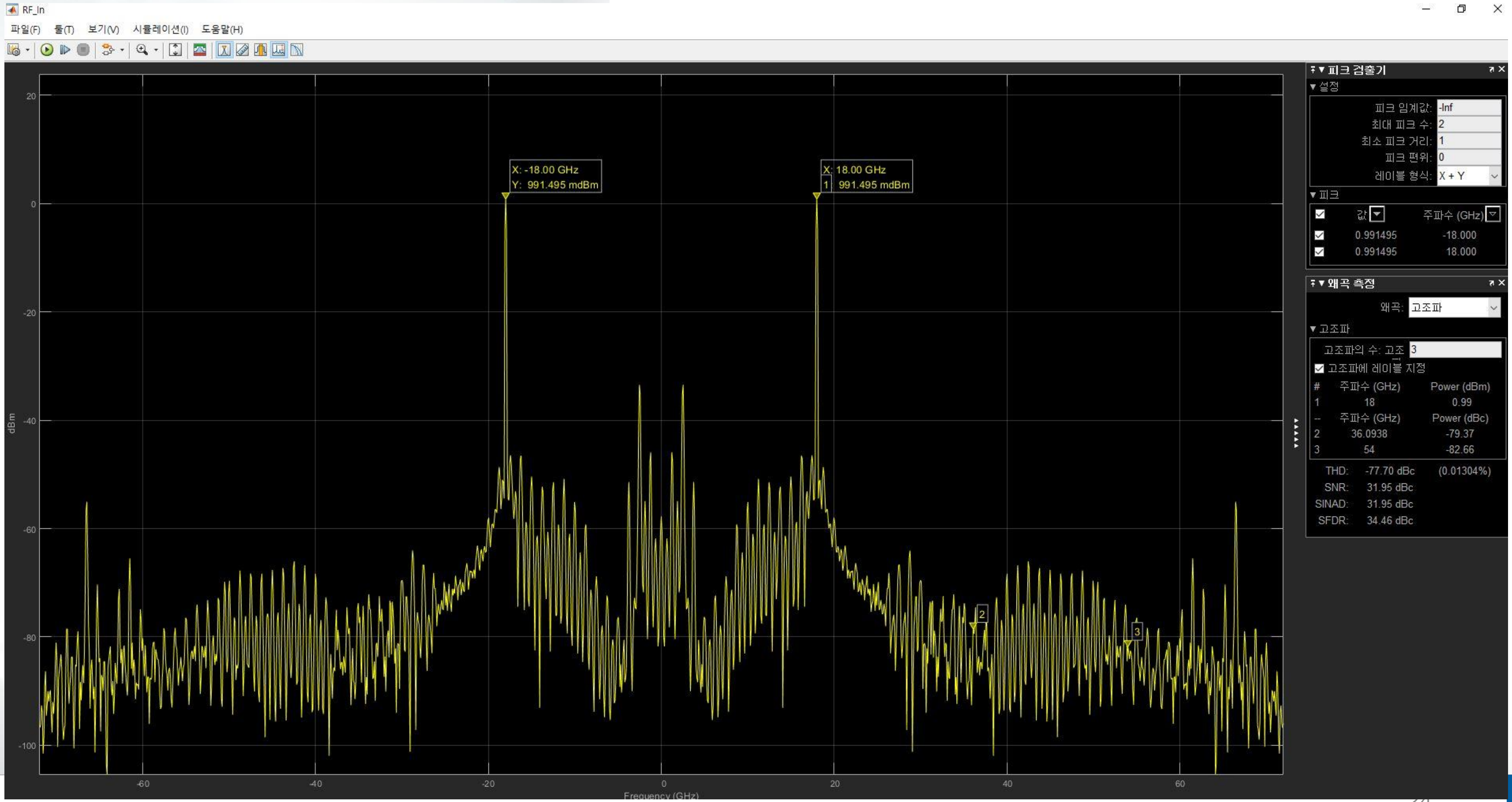
Analysis



LO X 2 Characteristics   18 GHz – 40 GHz model

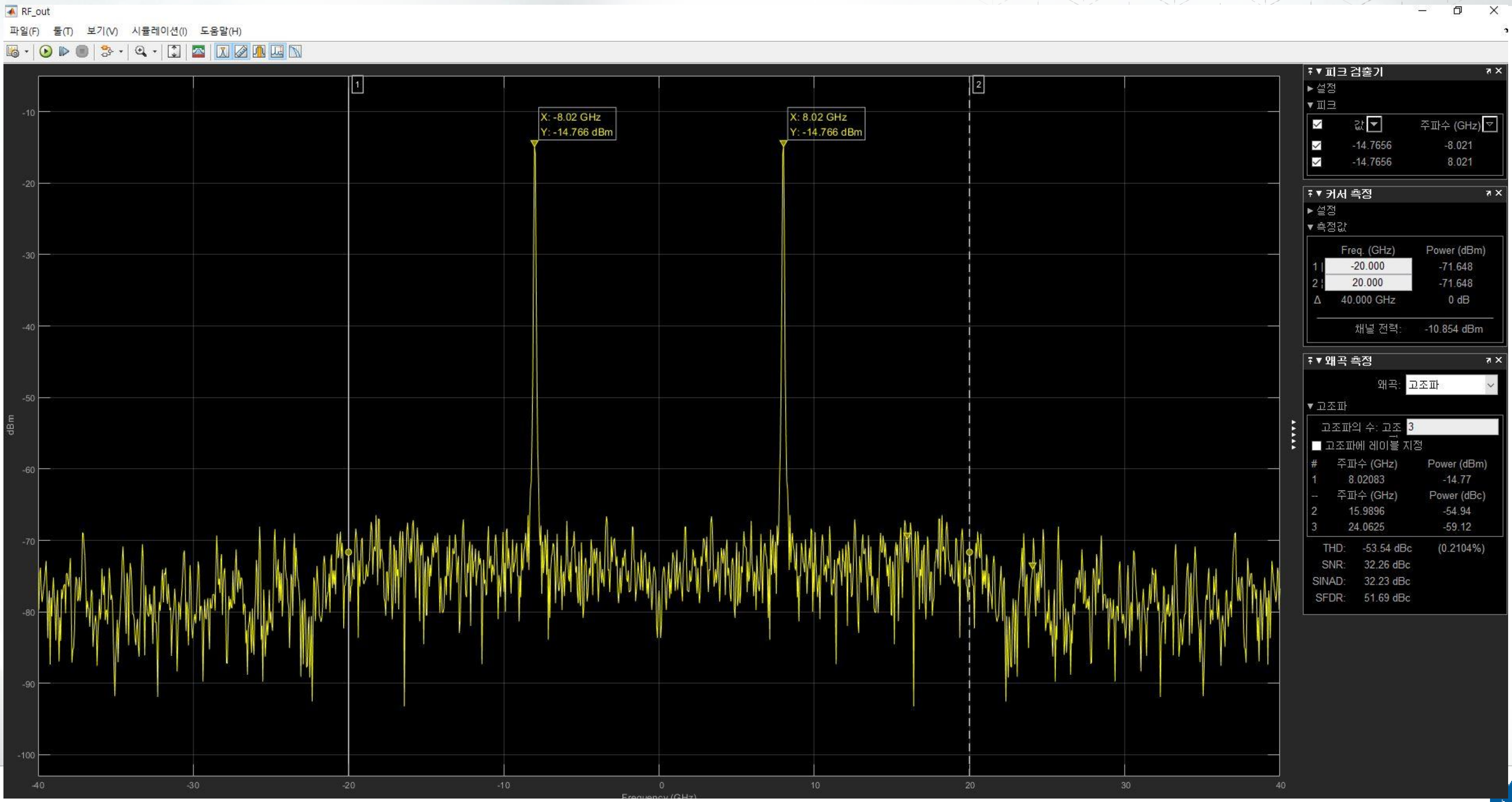


RF IN Characteristics 18 GHz – 40 GHz model

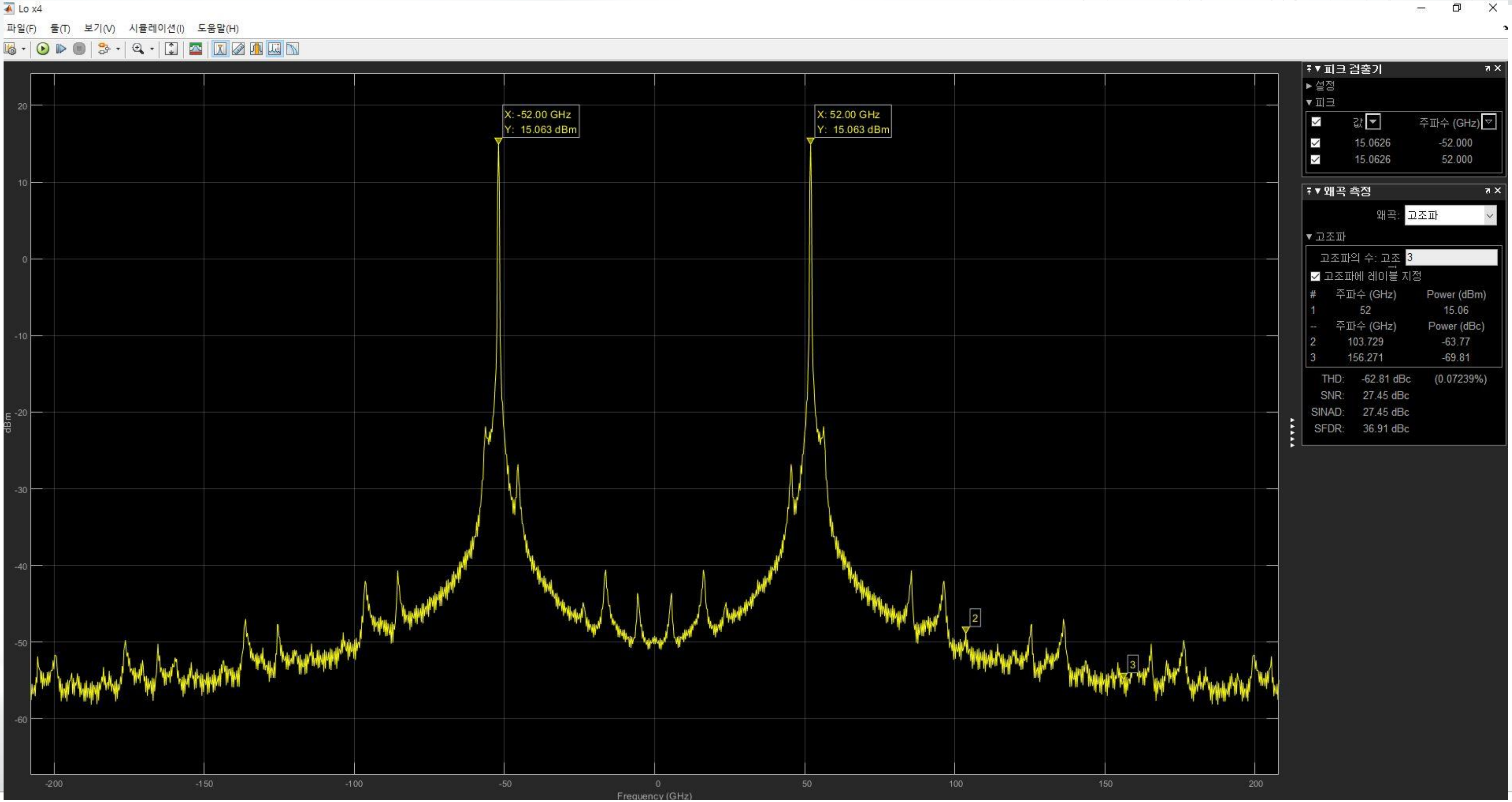


RF OUT Characteristics

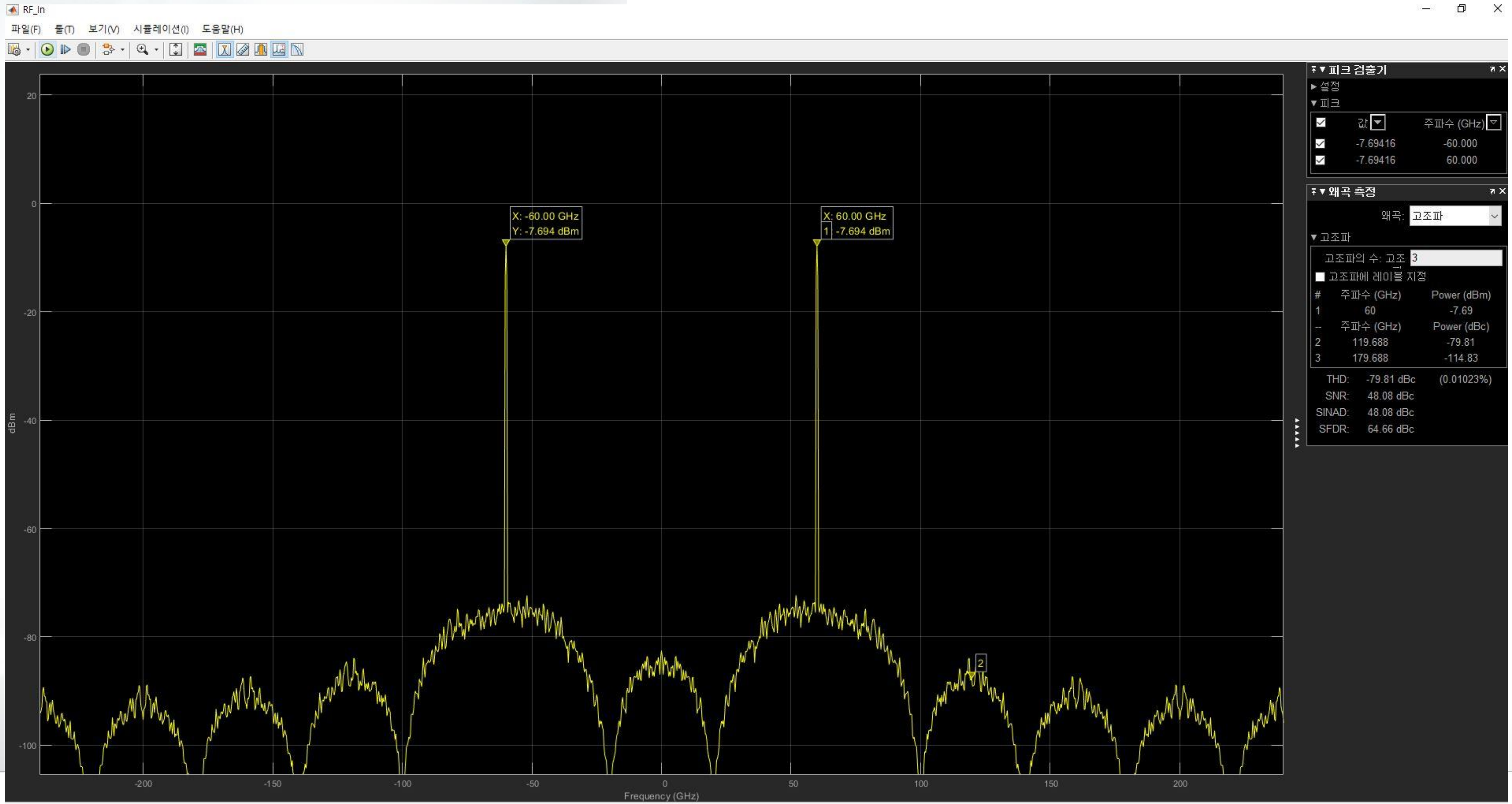
18 GHz – 40 GHz model



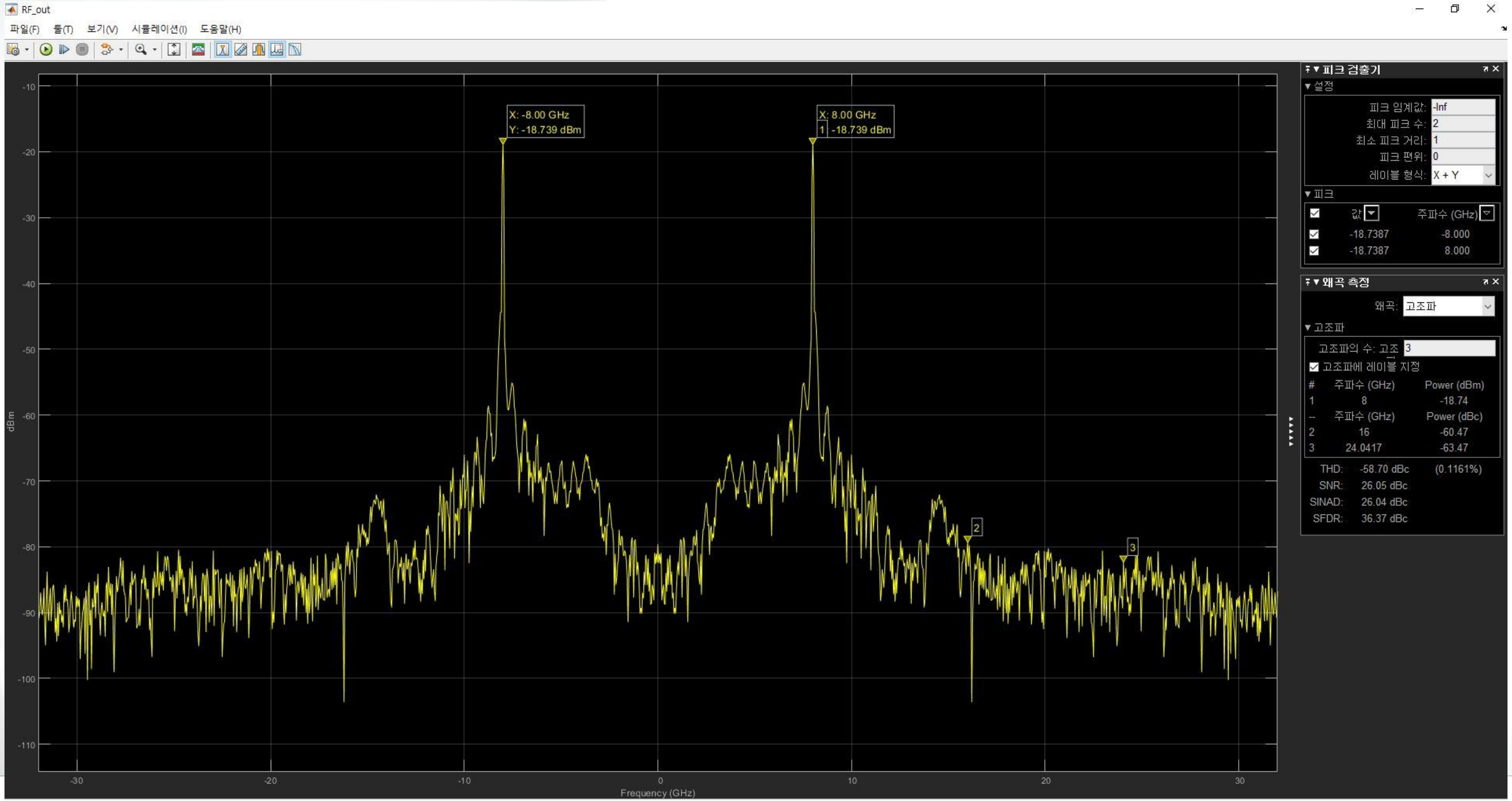
LO X 4 Characteristics   40 GHz – 60 GHz model



RF IN Characteristics 40 GHz – 60 GHz model

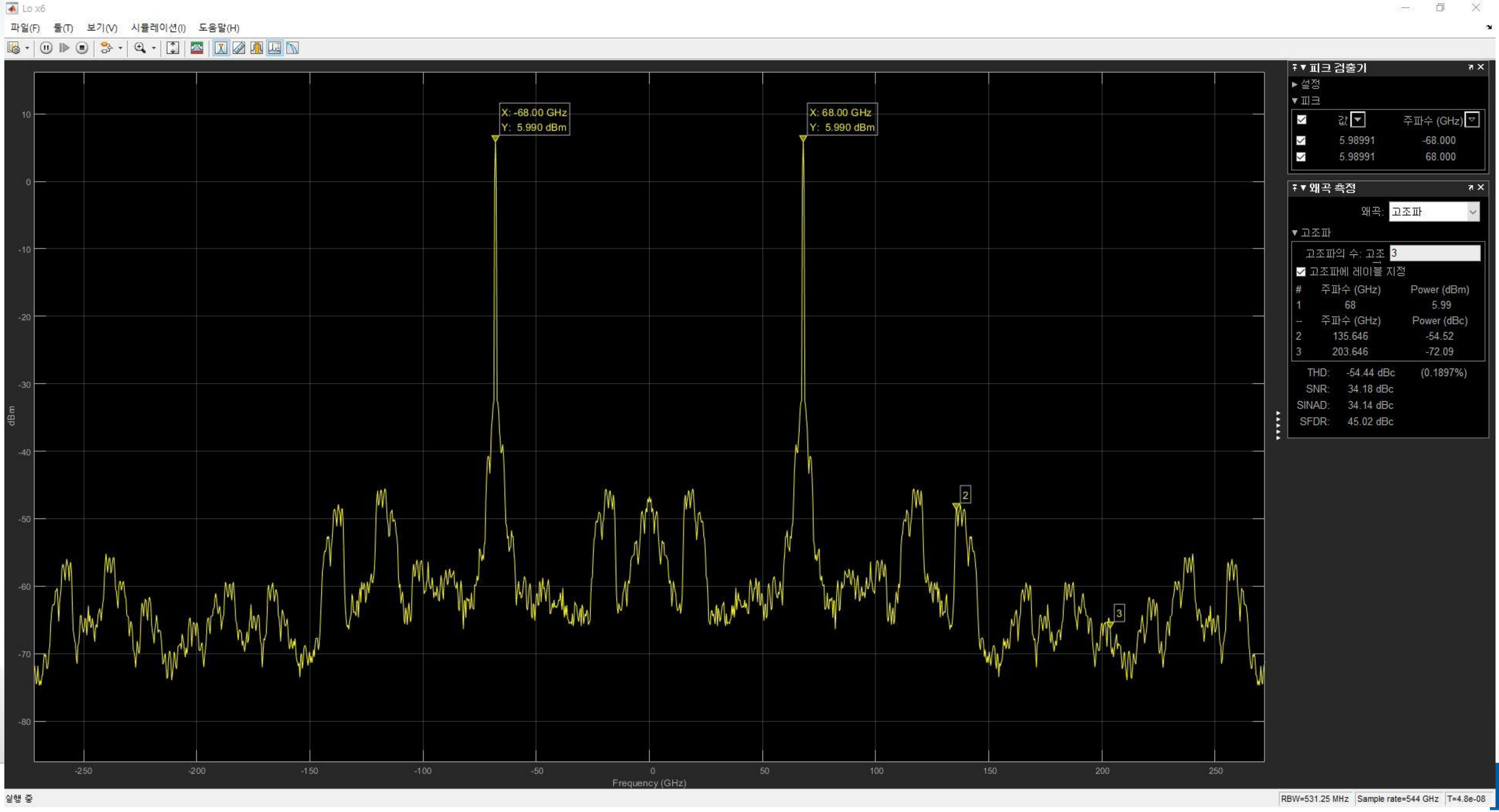


RF OUT Characteristics   40 GHz – 60 GHz model

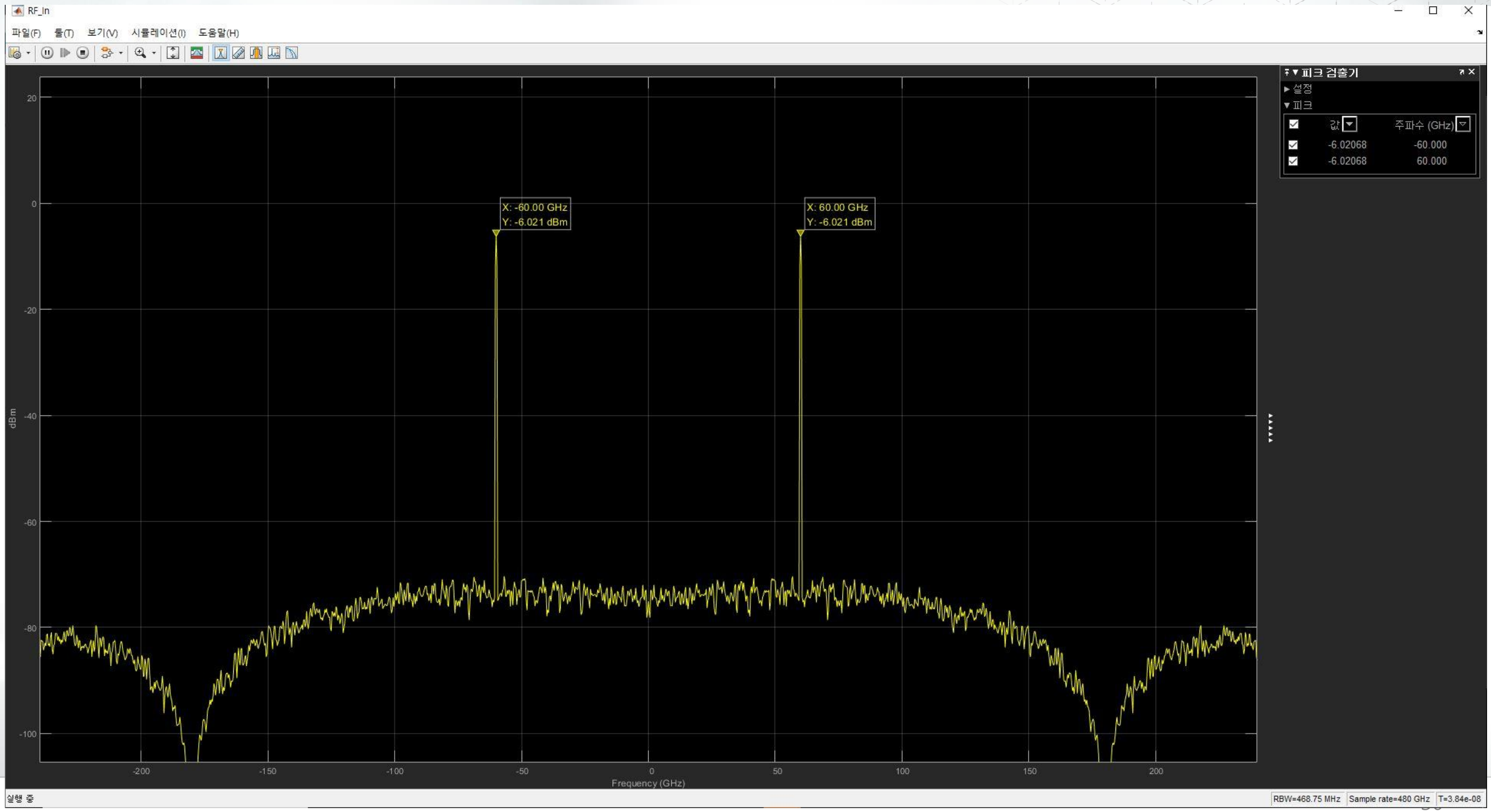


LO X 6 Characteristics

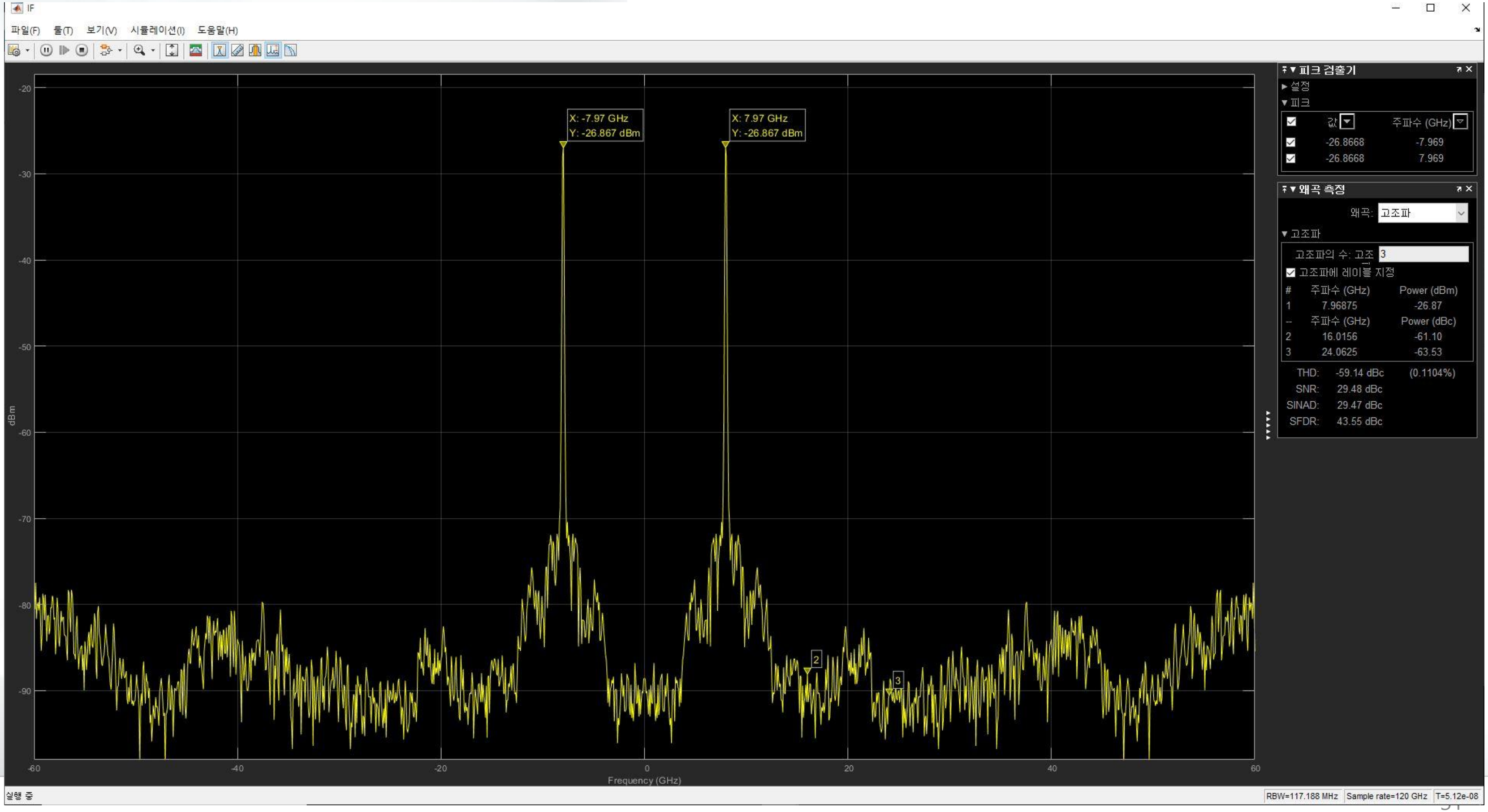
60 GHz – 90 GHz model



RF IN Characteristics 60 GHz – 90 GHz model



IF Characteristics 60 GHz – 90 GHz model



Benefits of Simulink Modeling and Simulation

- Simulate RF transceivers and front-ends

- RF amplifiers
  - Gain, noise, even-order, and odd-order intermodulation distortion, memory effects

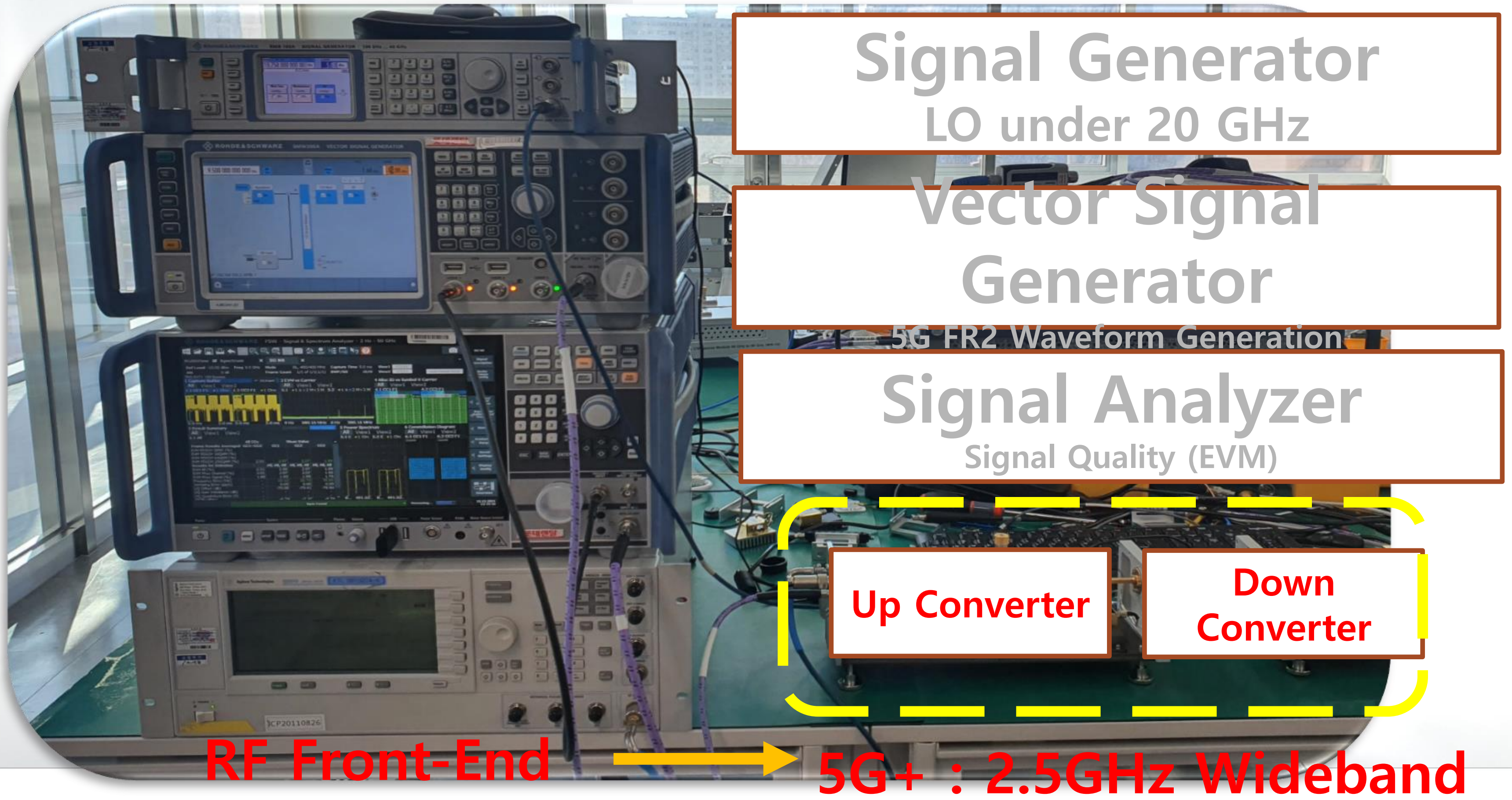
- RF mixers
  - image rejection, reciprocal mixing, local oscillator phase noise, DC offset

- Custom Models
  - Data sheet specifications or measured data(S-parameters)

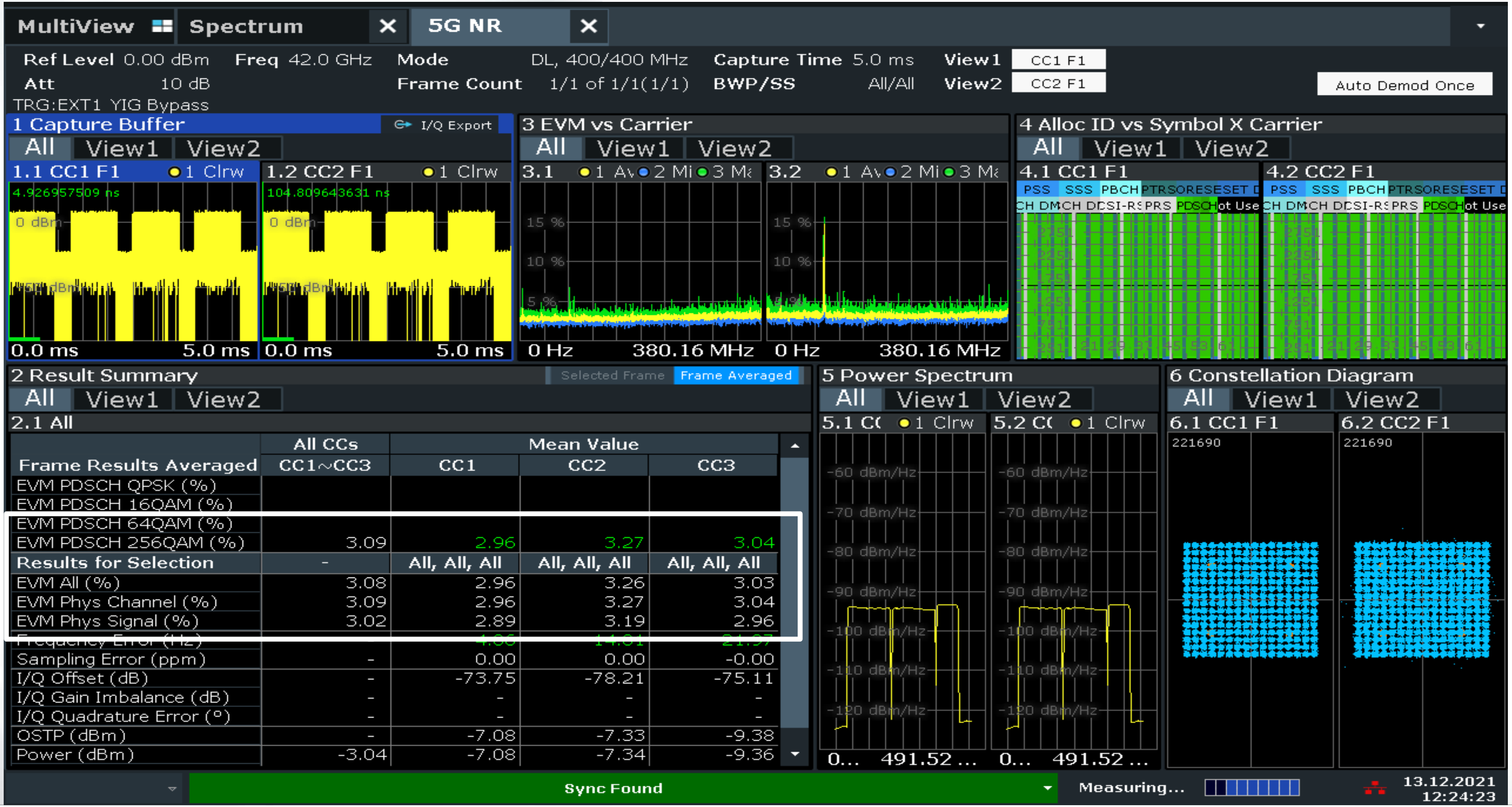
→ Validate design in early stage (without Hardware)

I.
Hardware Performance

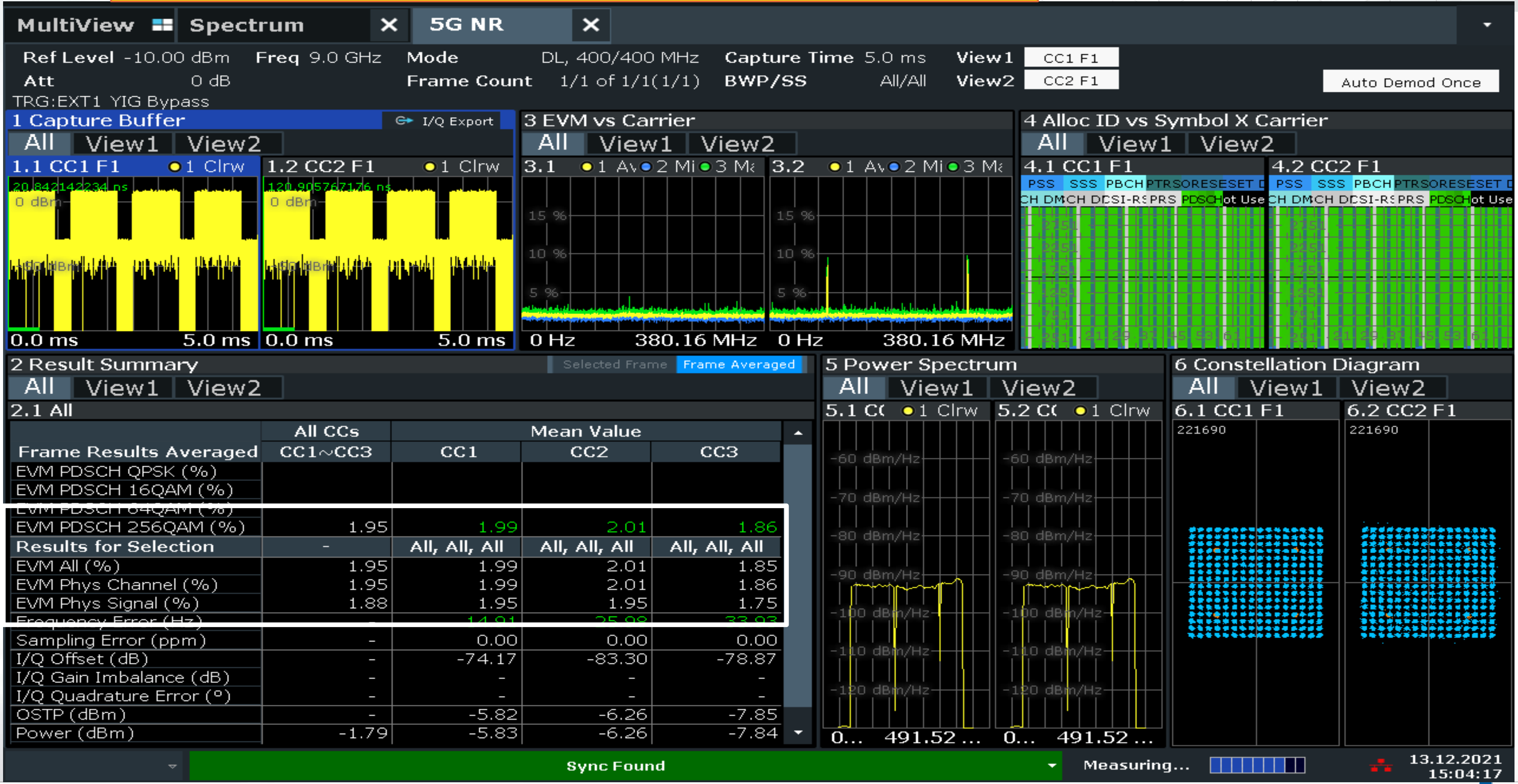
Hardware Feasibility



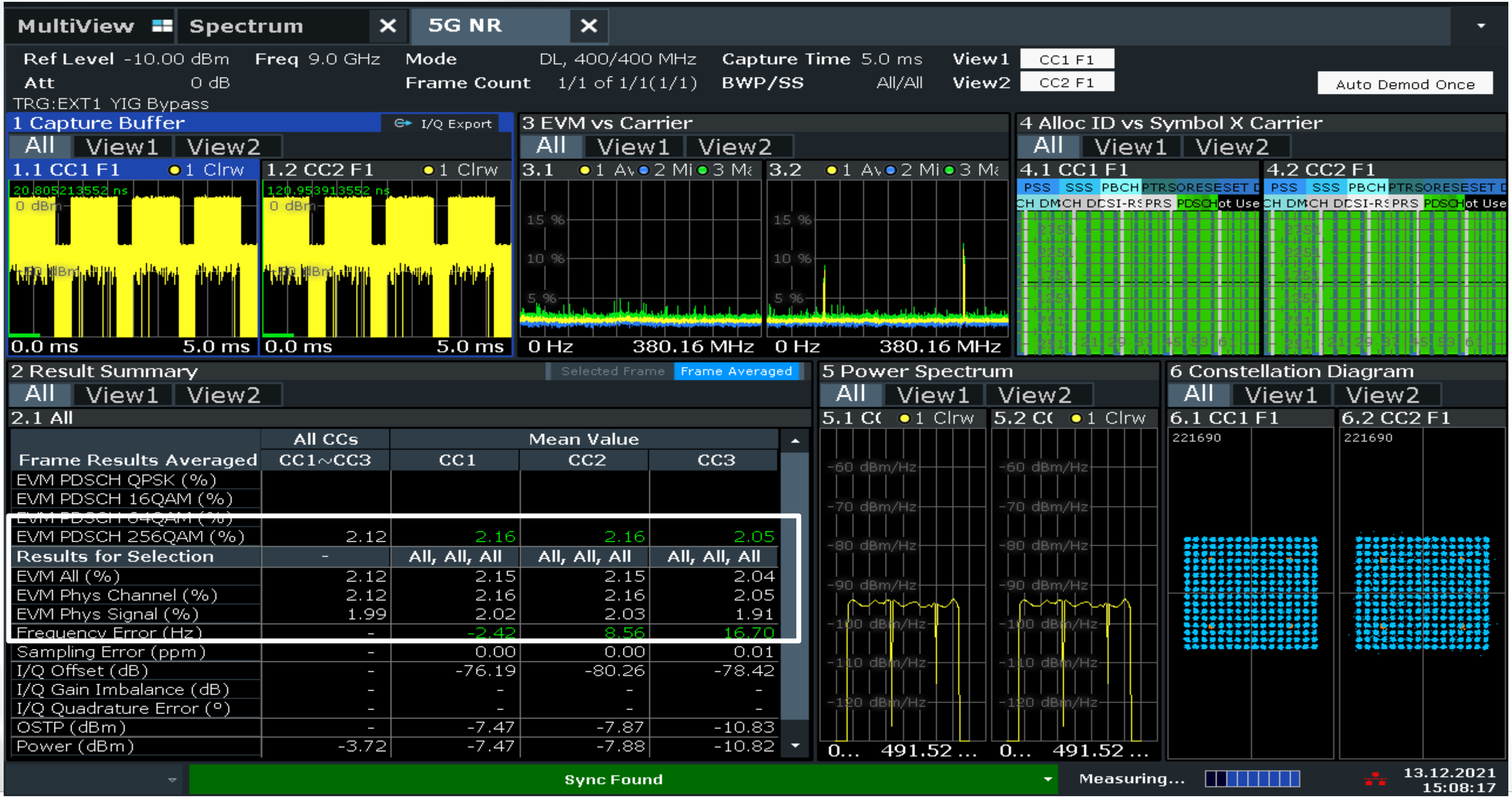
RF 42 GHz, 1GHz BW (400M+400M+200M)_ (256QAM)
(R&S SMW200A → FSW50)



RF 52 GHz, 1GHz BW (400M+400M+200M)_ (256QAM)
(SMW200A → 4060UC → 4060DC → FSW50)

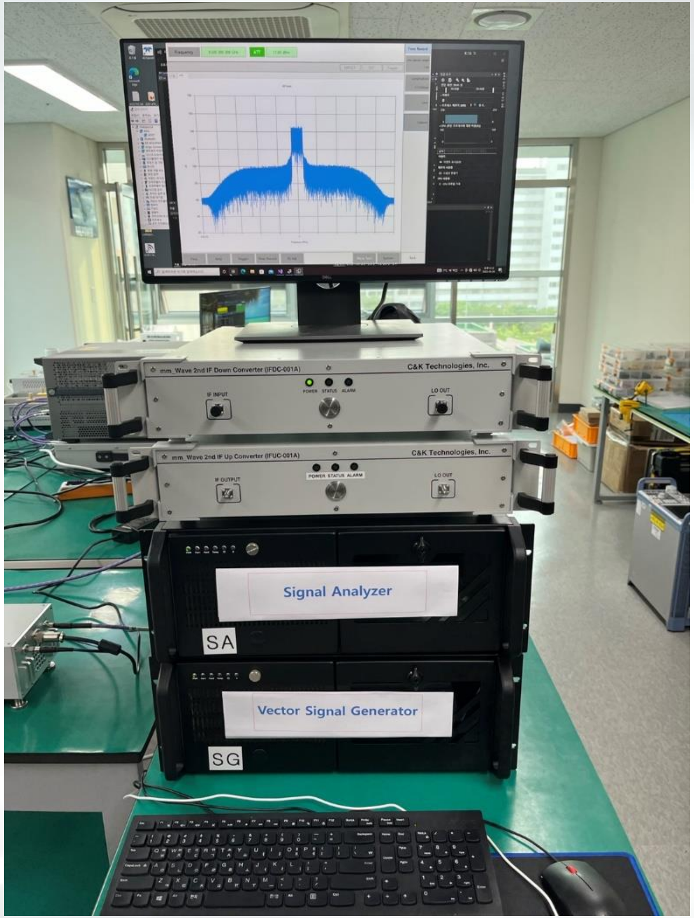


RF 56 GHz, 1GHz BW (400M+400M+200M)_ (256QAM)
(SMW200A → 4060UC → 4060DC → FSW50)



RF 59 GHz, 1GHz BW (400M+400M+200M)_ (256QAM)
(SMW200A → 4060UC → 4060DC → FSW50)

II
Hardware Performance


mm_Wave 2nd IF Down Converter (IFDC-001A)
C&K Technologies, Inc.
mm_Wave 2nd IF Up Converter (IFUC-001A)
C&K Technologies, Inc.
Signal Analyzer
SA
Vector Signal Generator
SG


RF Frequency: 82 GHz

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Thank you

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