EECE695j Term Project를 위한 4×4 MIMO Testbed 소개

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1 Hardware Description

2 Software Description

3 Future Work

4×4 MIMO Testbed

Figure 1: 4×4 MIMO testbed and antenna array

Hardware Specifications

Number of transmit antennas	up to 4
Number of receive antennas	up to 4
Transmit antenna spacing	6.3 cm to 50.5 cm (3.15 cm step)
Receive antenna spacing	6.3 cm to 50.5 cm (3.15 cm step)
Center frequency	2.3765 GHz (up to 3.2 GHz)
Bandwidth	up to 27 MHz
Transmit power	up to 25 dBm/antenna
Arbitrary IF waveform generator (DAC)	Resolution: 12 bits Conversion rates: 300 MS/s, 150 MS/s, 75 MS/s, and external clock Memory: 1 MS/ch.
IF signal acquisition board (ADC)	Resolution: 12 bits Sampling rates: 200 MS/s,..., 50 kS/s, and external clock Memory: 512 MS/ch.

Table 1: Hardware specifications

Block Diagram

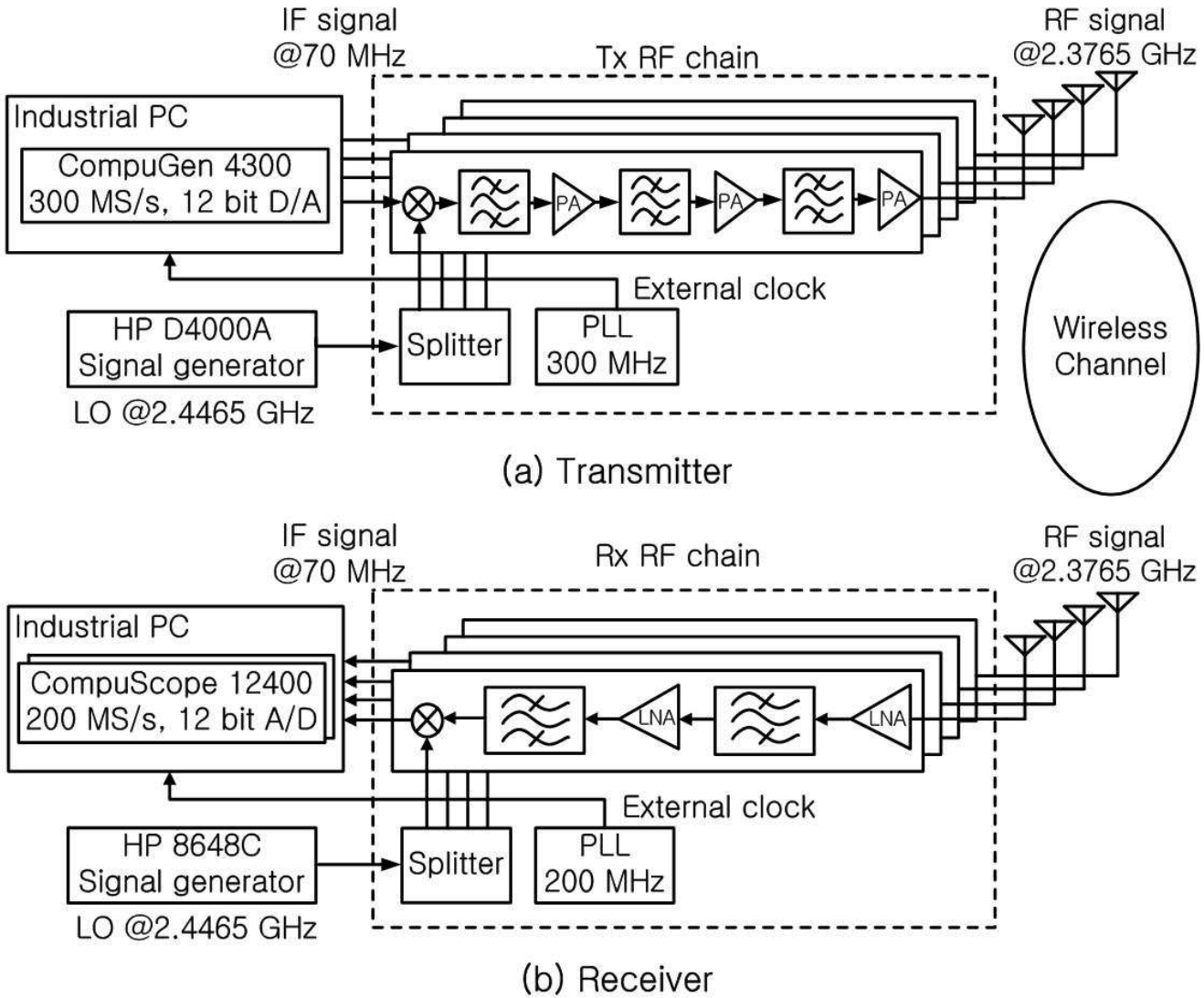


Figure 2: Block diagram of testbed

Arbitrary IF Waveform Generator - GaGe CompuGen 4300

- Conversion rates: 300 MS/s, 150 MS/s, 75 MS/s, and external clock
- Internal clock accuracy: $\pm$20 ppm
- Resolution: 12 bits
- Memory size: 1 MS/ch.
  (conversion rate가 300 MS/s일때 3 ms 동안 신호 발생 가능)

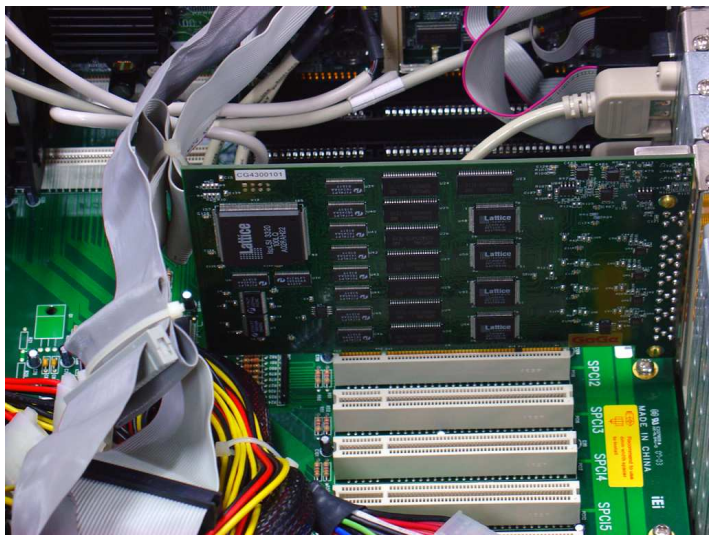


Figure 3: Industrial PC에 장착된 CompuGen 4300

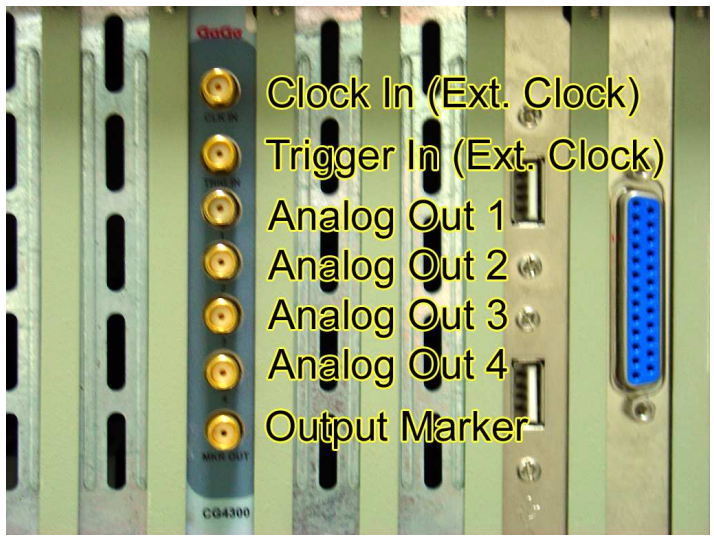


Figure 4: Connectors for the CompuGen 4300

IF Signal Acquisition Board - GaGe CompuScope 12400

- Sampling rate: 200 MS/s, 100 MS/s,. . . , 50 kS/s and external clock
- Internal clock accuracy: ±25 ppm
- Resolution: 12 bits
- Memory size: 512 MS/ch.
  (sampling rate가 200 MS/s 일때 2.5 s 동안 신호 저장 가능)

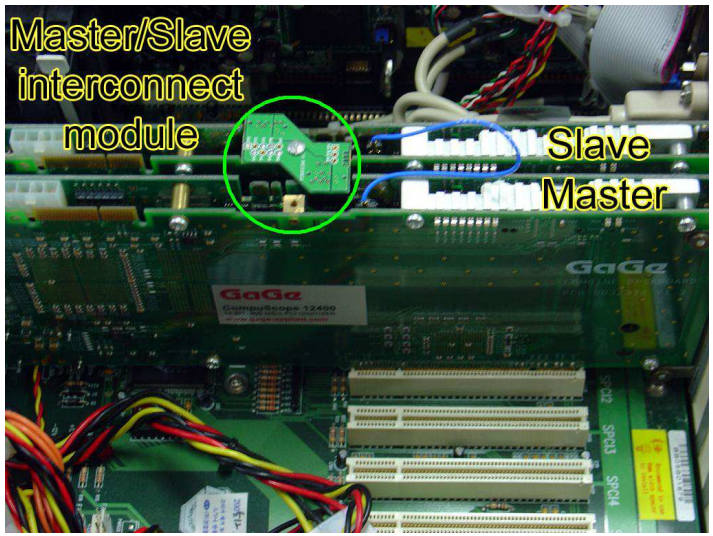


Figure 5: Industrial PC에 장착된 CompuScope 12400

Figure 6: Connectors for the CompuScope 12400

RF Chain Boxes

- 300 W power supply 내장
- Mini-Circuits사의 power amplifier, LNA, mixer, power splitter
- ASB사의 HPA, LNA, SAWNICS사의 RF SAW filter

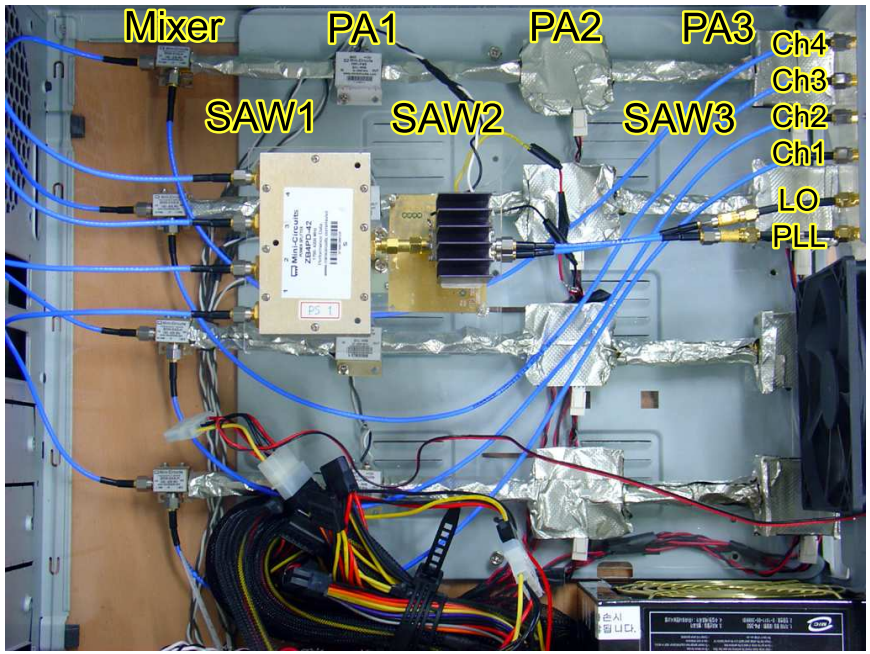


Figure 7: Transmitter RF chains

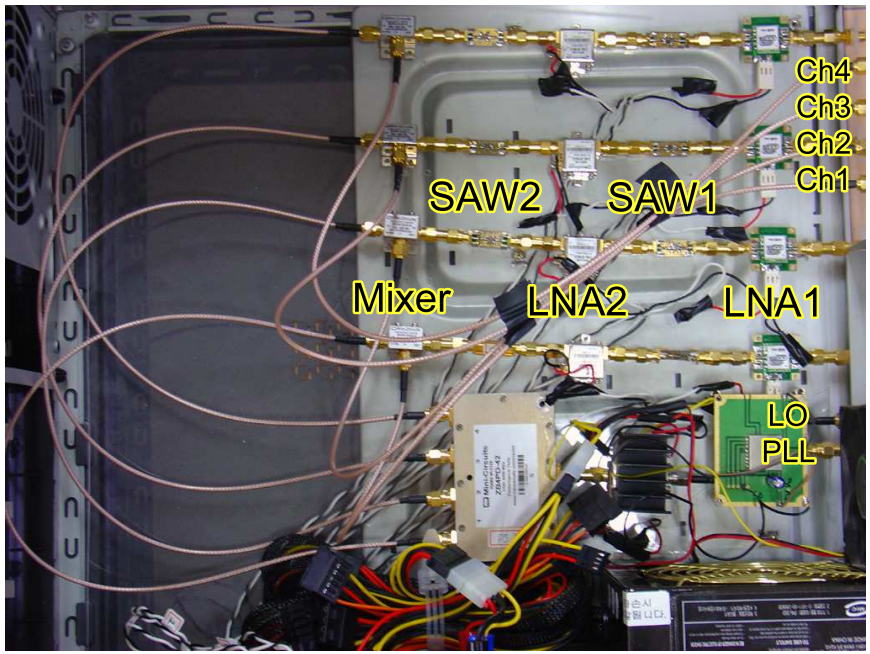


Figure 8: Receiver RF chains

Antenna Array (1)

- Unicorn사의 WLAN용 무지향성 안테나 (OSI-05A)

Frequency range	2.4 ~ 2.5 GHz
Impedance	50 Ω
VSWR	1.92 Max.
Return loss	-10 dB Max.
Electrical wave	1/2λ Dipole
Gain	5 dBi @ 2.45 GHz
Polarization	Linear vertical
Radiation pattern	Omni-directional
Max. power	30 dBm
Connector	SMA

Table 2: Antenna specification

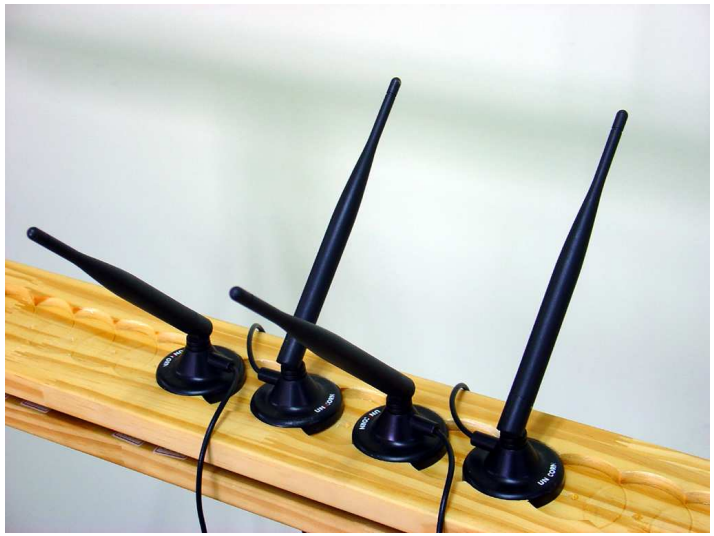


Figure 9: Vertical and horizontal polarization

Antenna Array (2)

- Unicorn사의 WLAN용 지향성 안테나 (OSI-06A)

Frequency range	2.4 ~ 2.5 GHz
Impedance	50 Ω
VSWR	1.92 Max.
Return loss	-10 dB Max.
Electrical wave	Patch
Gain	6 dBi @ 2.45 GHz
Polarization	Linear vertical
Radiation pattern	Directional
Max. power	30 dBm
Connector	SMA

Table 3: Antenna specification

Figure 10: Patch antenna

Antenna Array (3)

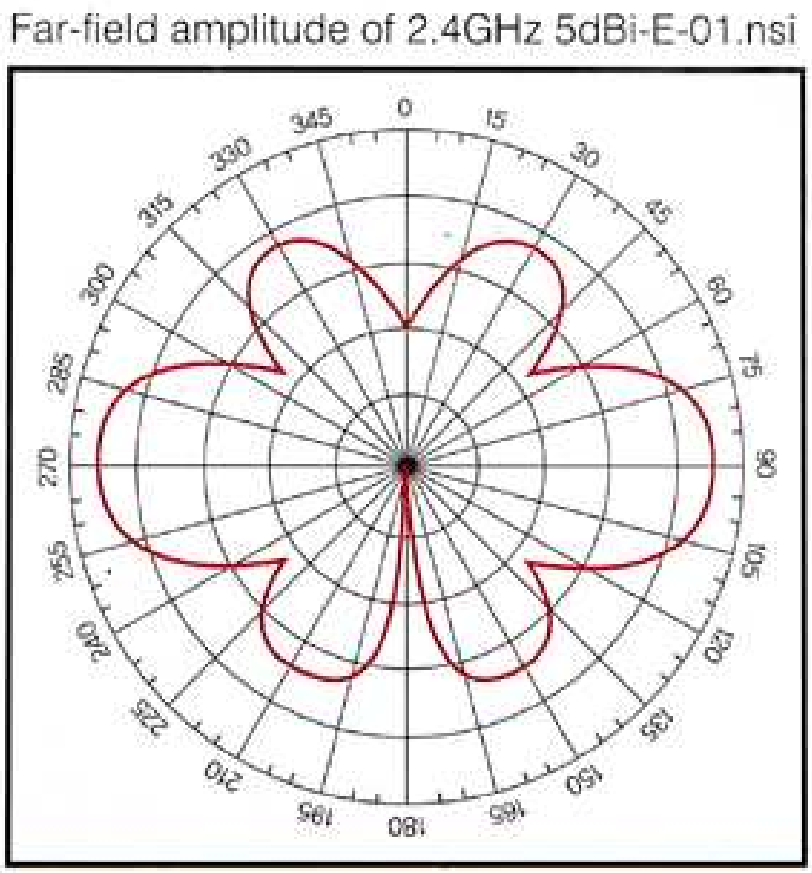


Figure 11: Radiation pattern of dipole antenna

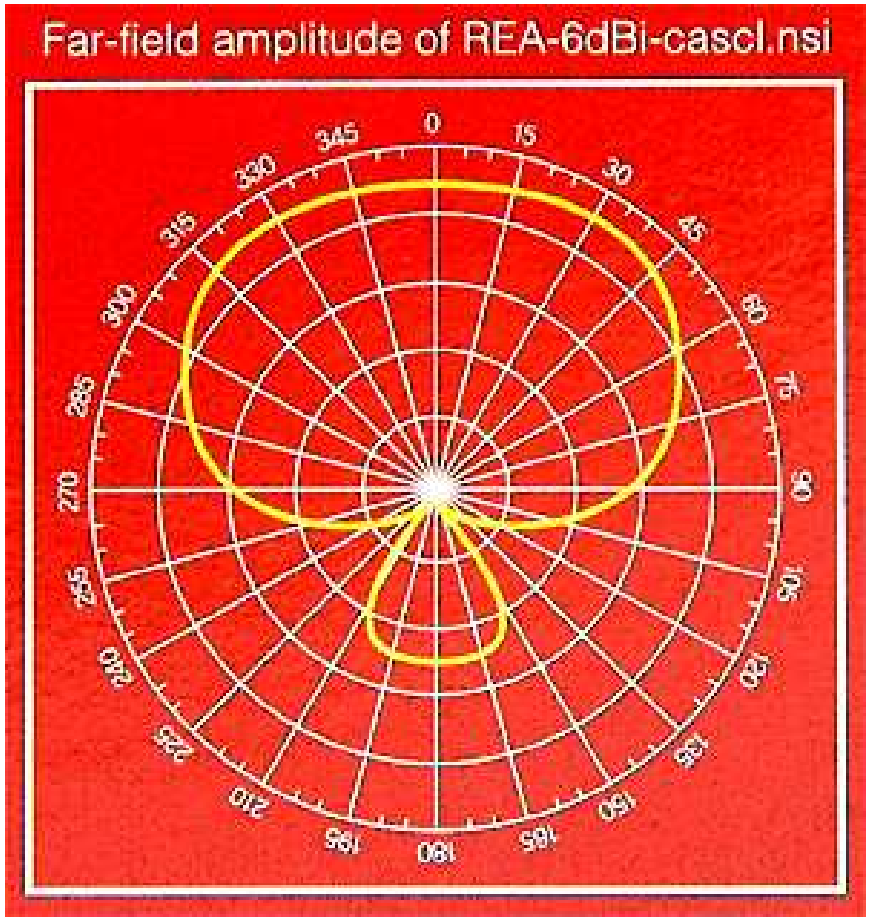


Figure 12: Radiation pattern of patch antenna

Antenna Array (4)

- Antenna spacing: 6.3 cm to 50.5 cm (3.15 cm step)

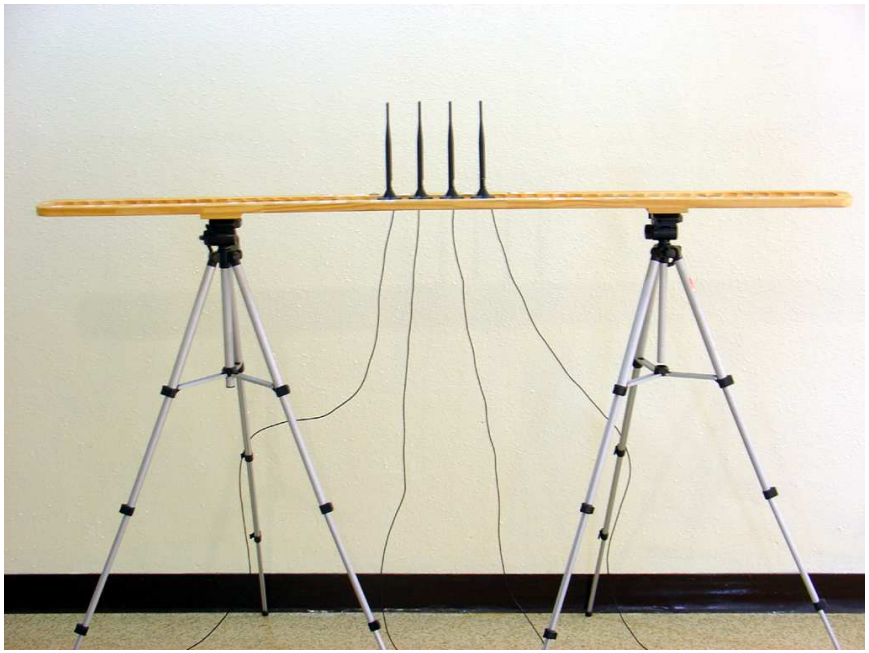


Figure 13: Antenna spacing: 6.3 cm (0.5 λ when the center frequency is 2.3765 GHz)

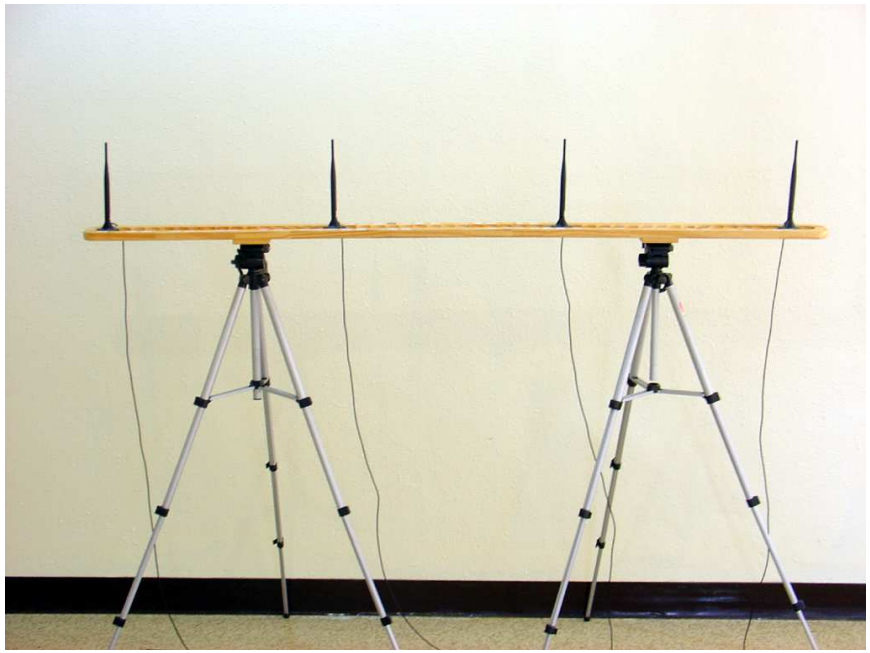
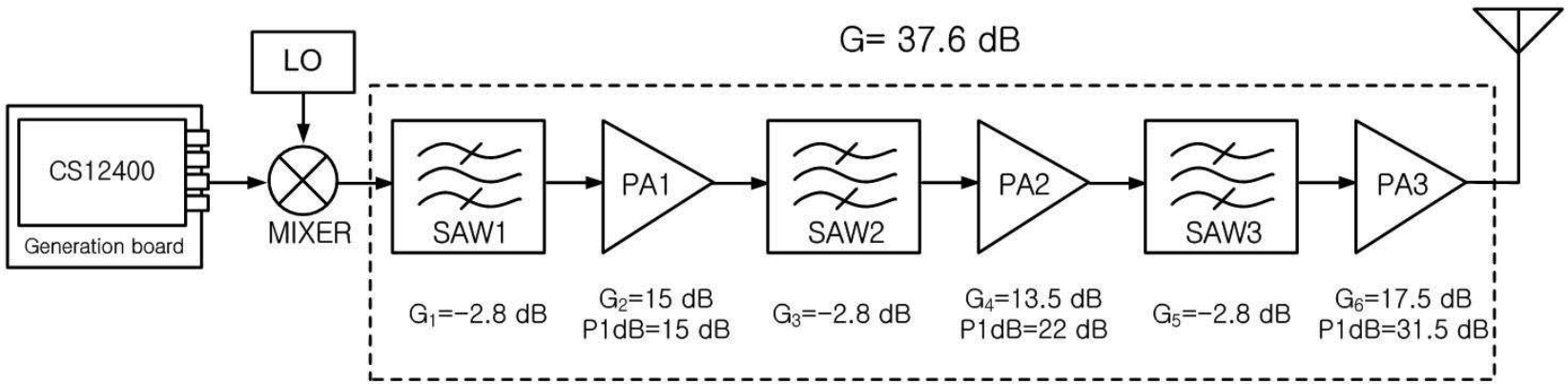


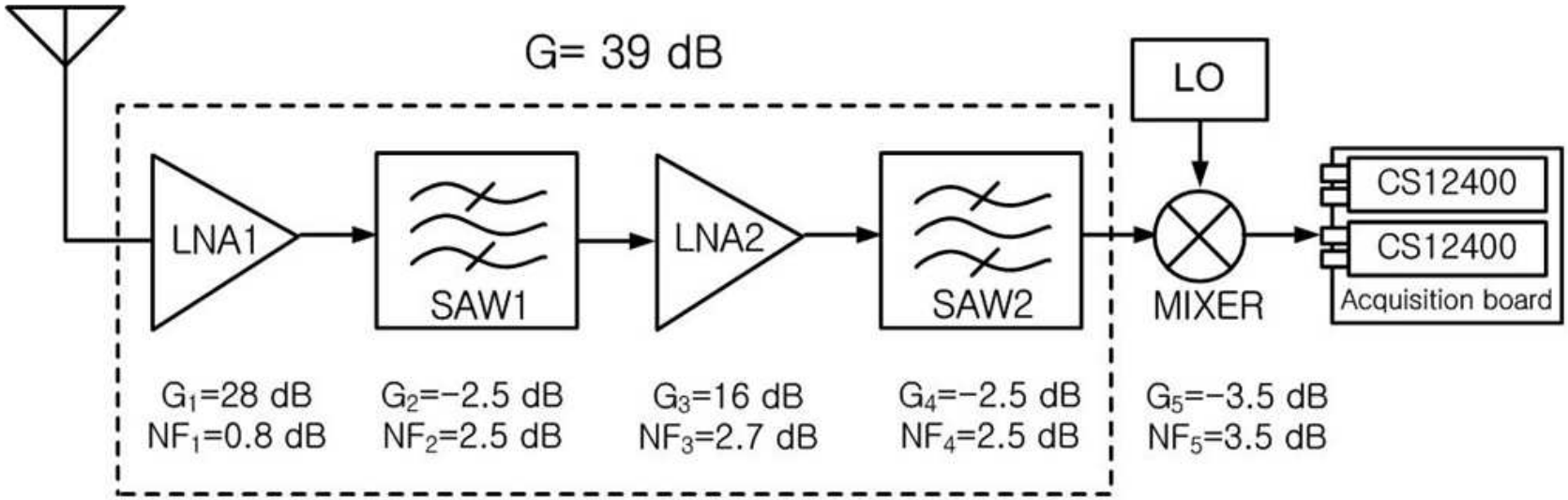
Figure 14: Antenna spacing: 50.5 cm (8 λ when the center frequency is 2.3765 GHz)

Power Characteristic of Transmitter RF Chain



- Transmit power = up to 25 dBm

Gain and Noise Characteristic of Receiver RF Chain



- Total noise figure = 0.814 dB
- Total receiver gain = 35.5 dB
- Noise power at mixer output = -62.46 dBm

Outdoor 실험을 위한 무선국허가

- 허가유효기간: 2007.10.26 부터 2008.10.26 까지
- 주파수 대역: 2.363 GHz ~ 2.390 GHz (27 MHz)
- 최대 송신 파워: 30 dBm

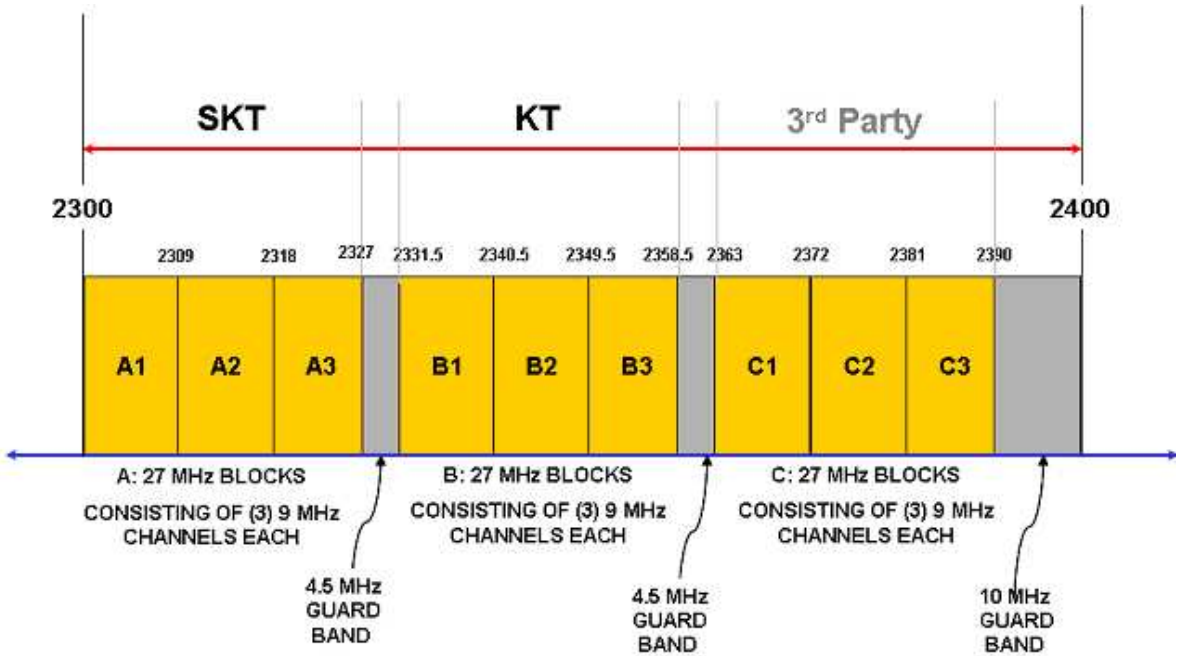


Figure 15: 2.3 ~ 2.4 GHz 대역의 주파수 분배

CGTest software for CompuGen 4300

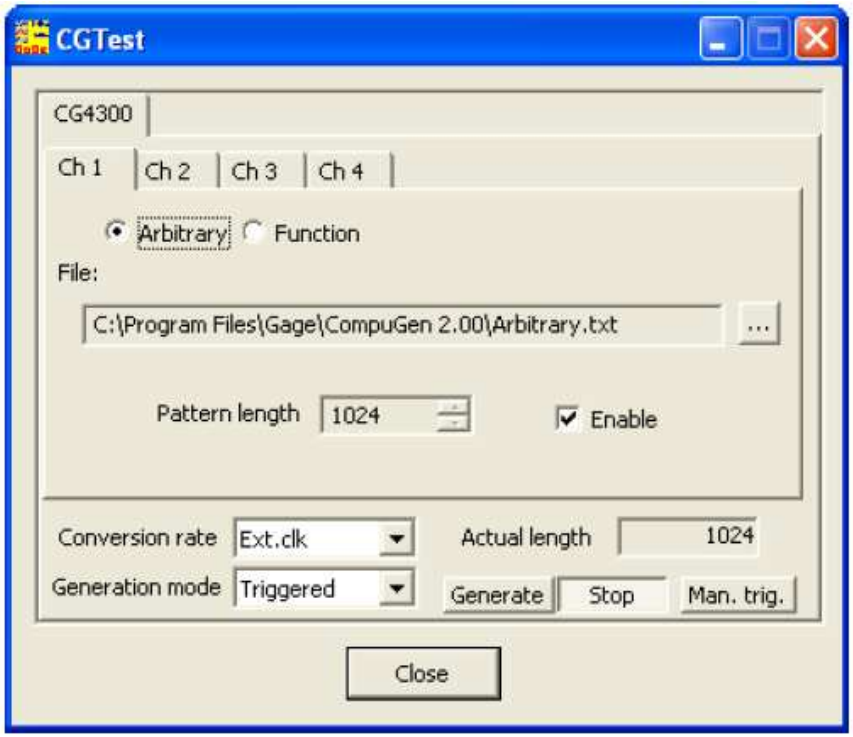


Figure 16: Arbitrary waveform mode

- The CompuGen 4300 can be operated in two generation modes: Free Run Mode and Triggered Mode.
- Waveform file must be a .txt file containing one column of data values between 0 and 4095.
- 0 corresponds to positive full scale, 4095 corresponds to negative full scale, and 2048 corresponds to 0 Volts.
- The total number of data values should be a multiple of 16 and be at least 64 points.

CGTest - example (1)

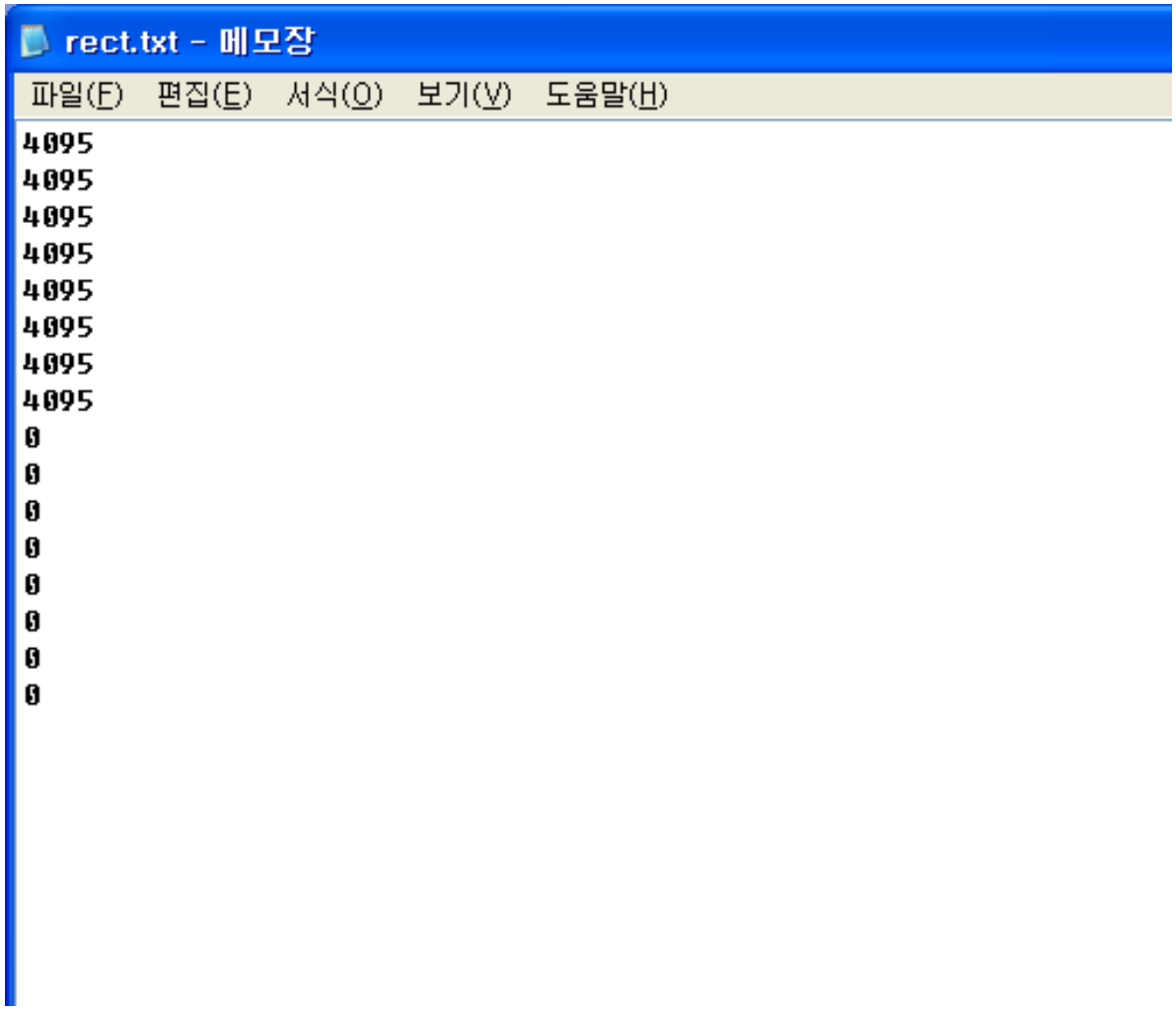


Figure 17: Example 1: rectangular pulse

CGTest - example (2)

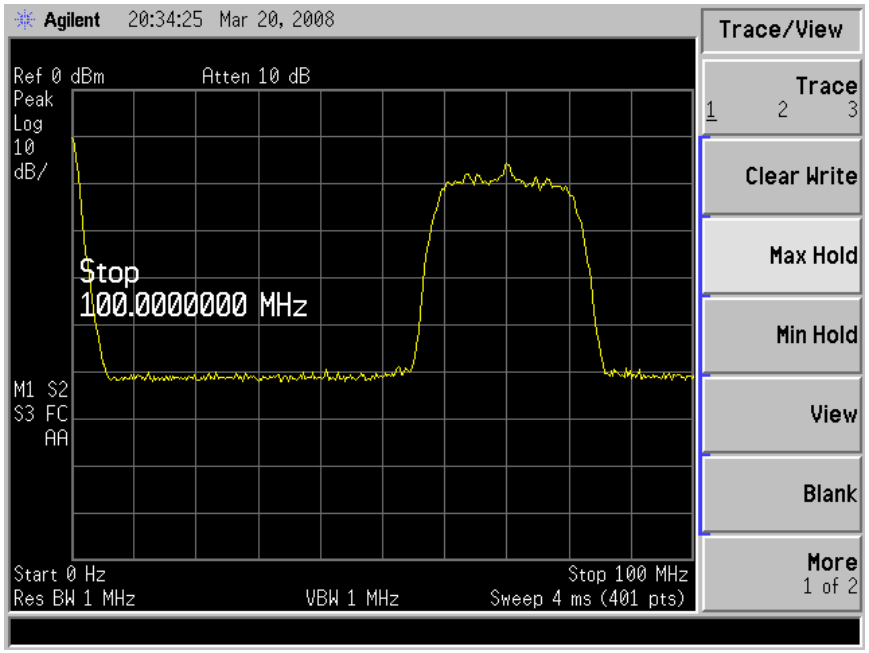


Figure 18: Example 2: Linearly modulated signal

- Conversion rate = 300 MS/s
- Tx over-sampling rate = 15
  $\longrightarrow$ 1/T = 20 MHz
- Square root raised cosine pulse with roll-off 0.35
- Intermediate frequency = 70 MHz

GageScope software for CompuScope 12400

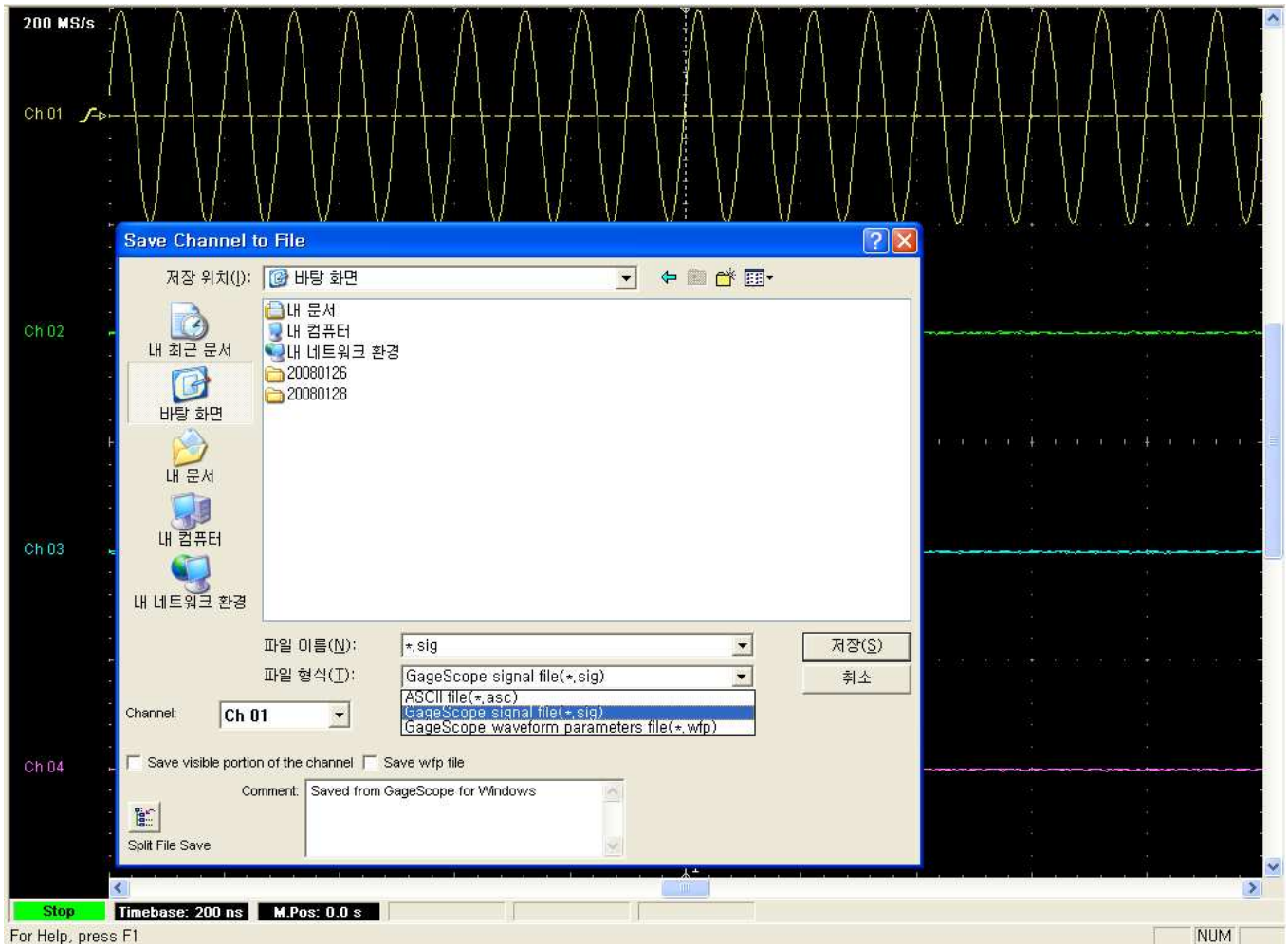


Figure 19: GageScope for CompuScope 12400

Future Work (1)

채널 측정 및 모델링

- Channel modeling 및 channel parameterization
- POSTECH 정보통신대학원 건물에서 채널 측정
- Outdoor to indoor, indoor to outdoor, outdoor to outdoor 채널 측정
- Mobile, pedestrian, vehicular environment 채널 측정
- LOS to NLOS transition 채널 측정
- Interference가 있는 환경에서 채널 측정
- Anechoic chamber에서 안테나의 수직 및 수평 패턴 측정
- ULA를 이용한 채널 측정 결과를 바탕으로 다양한 MIMO 안테나의 성능 예측 및 디자인 방법 제안

Future Work (2)

다양한 modulation scheme의 performance test

- 다양한 MIMO modulation and coding scheme의 performance test
- MIMO-OFDM, MIMO-SCFDE의 performance test
- Space-time code의 performance test
- Interfernce가 있는 환경에서 MIMO modulation scheme의 performance test
- Orthogonal overlay system의 performance test
- CP (Cyclic Prefix) length design
- ARQ system에서 back-off의 양을 결정