Anritsu Advancing beyond

Approaching 300-GHz band Spectrum Analysis

~For 5G-Advanced and 6G

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R&D Background & Objectives

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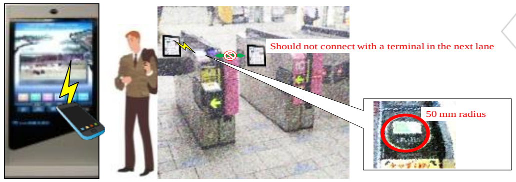
Applications



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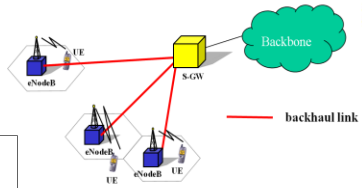
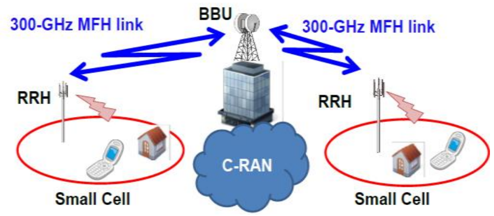
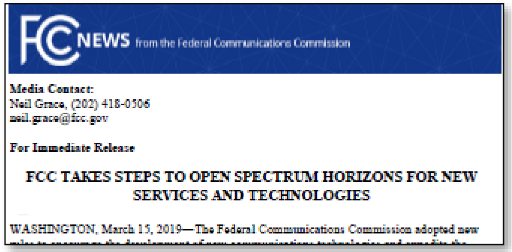




5G-Advanced / Mobile Backhaul/Fronthaul


FCC NEWS from the Federal Communications Commission

Media Contact:
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For Immediate Release

FCC TAKES STEPS TO OPEN SPECTRUM HORIZONS FOR NEW SERVICES AND TECHNOLOGIES

WASHINGTON, March 15, 2019—The Federal Communications Commission adopted new

FCC Experimental Station License

Advances in mmWave communications applications

- 5G-Advanced expected to support larger-capacity communications than 5G by using frequencies higher than 100 GHz
- IEEE 802.15.3d-2017 standardized at 252 to 325 GHz for high-speed wireless multimedia networks (IEEE Standard for High Data Rate Wireless Multi-Media Networks-Amendment 2: 100 Gb/s Wireless Switched Point-to-Point Physical Layer was approved for use of 252 GHz to 325 GHz frequency band for mobile backhaul/fronthaul and point to point communication) Reference: IEEE 802.15 Doc Number 14/0304r16
- WRC-19 added sharing of frequencies from the 275 to 450-GHz bands between land-mobile and fixed-service applications
- USA licenses experimental stations at 95 GHz to 2 THz to stimulate mmWave advances

Anticipating use of frequency bands >100 GHz

R&D Background & Objectives

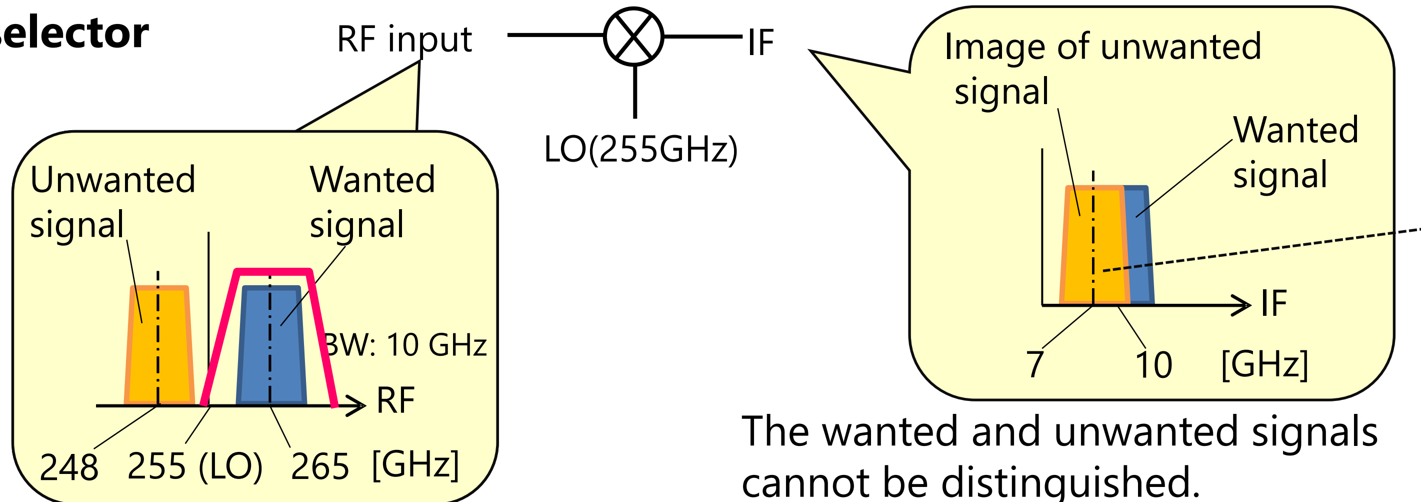
For frequency bands above 100 GHz, spurious measurement required to prevent system interference but faces following issues:

- **The spectrum measurement without a pre-selector results in the combination between unwanted signal responses from the test equipment and wanted signal responses from the actual signal.**
- **NOT possible to separate between unwanted and wanted responses.**
- **Suppressing unwanted responses requires switching the frequency relationship (Local/IF). Since conversion losses differ as a function of frequency, the preparation in the calibration data of conversion losses is necessary with complex procedures.**

Develop new pre-selector to configure 300-GHz spectrum analysis system

Pre-selector Role

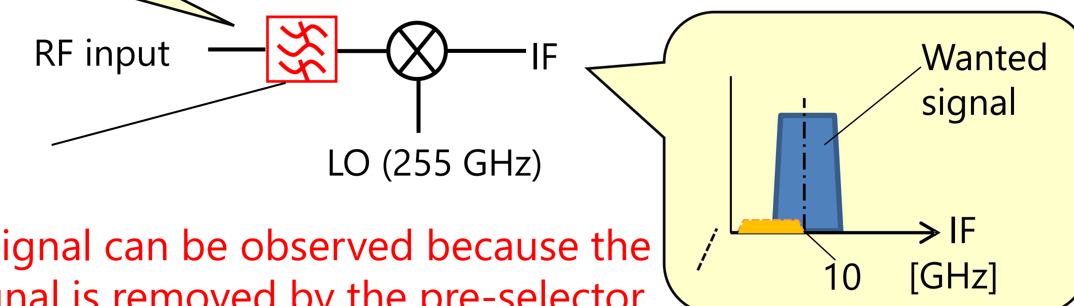
1. Without pre-selector



The wanted and unwanted signals cannot be distinguished.

2. With pre-selector

Pre-selector
(Rejection band: 245 to 255 GHz)

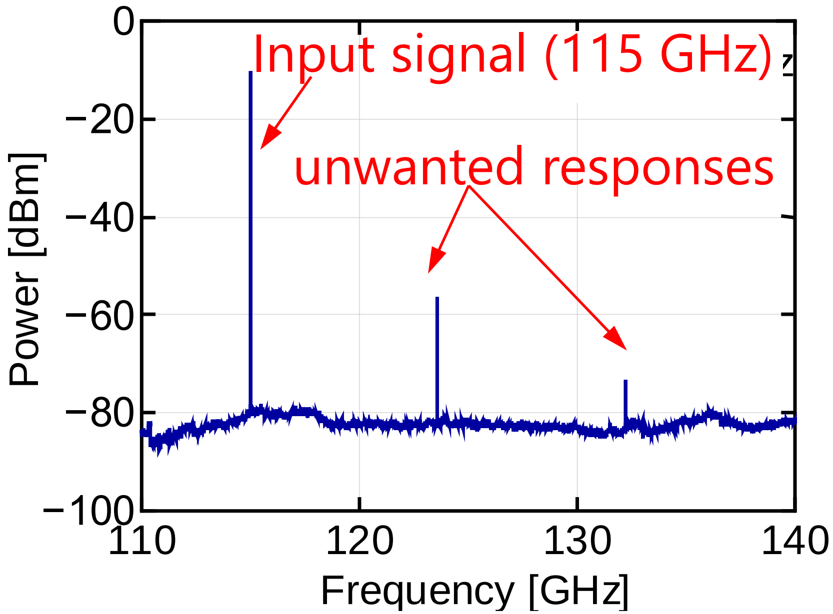


The wanted signal can be observed because the unwanted signal is removed by the pre-selector.

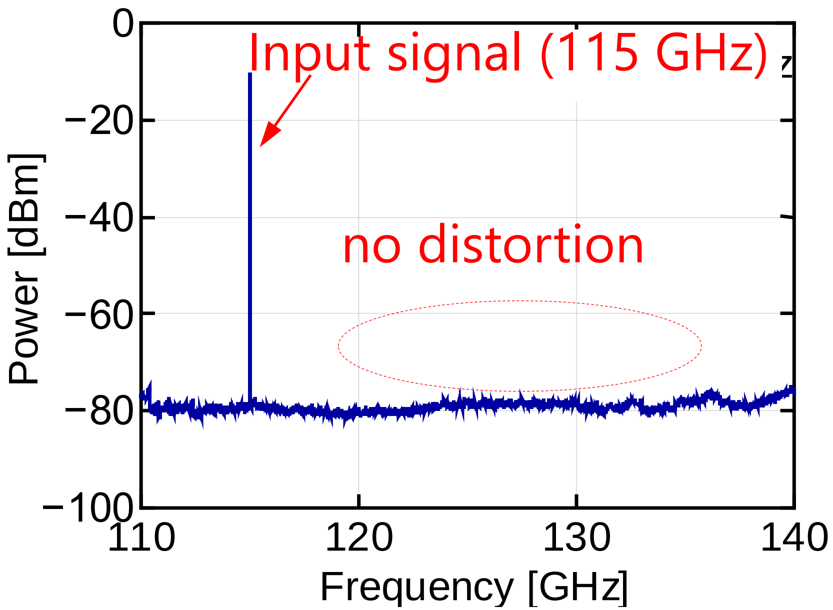
The wanted signal can be observed because the pre-selector reduces the unwanted signal response (image/multiple responses).

Pre-selector Effect (CW)

➢ **Without pre-selector**



➢ **With pre-selector**



condition

input signal
Pin: –10 dBm
Fin: 115 GHz

SPA setting:
Center frequency: 125 GHz
Span: 30 GHz
RBW: 1 MHz
Detection: Positive

Inserting a pre-selector enables extraction of just the wanted signal.

Pre-selector Effect (Modulated Wave)

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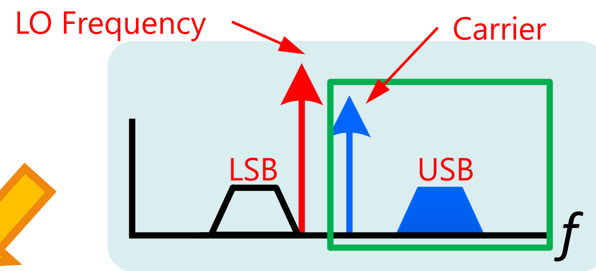
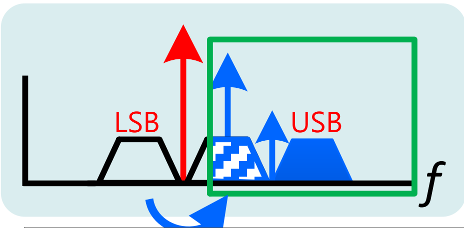
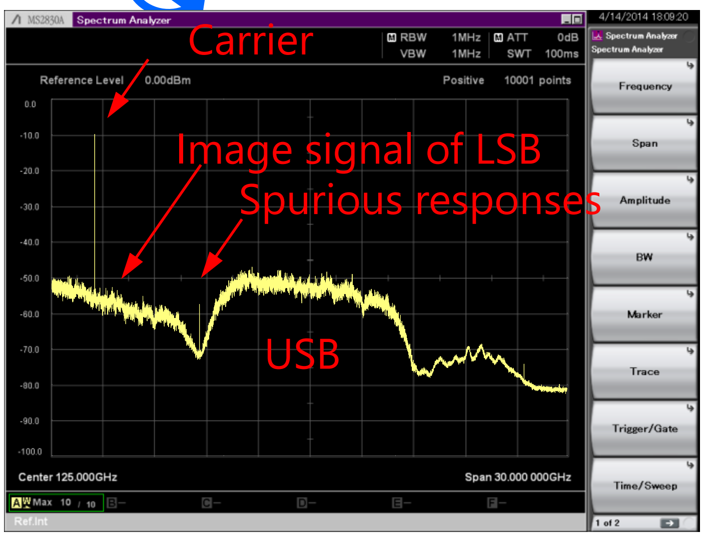
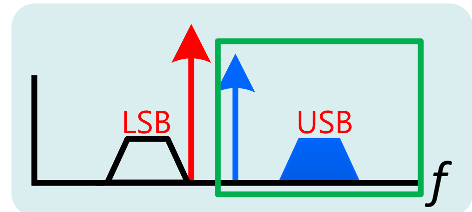


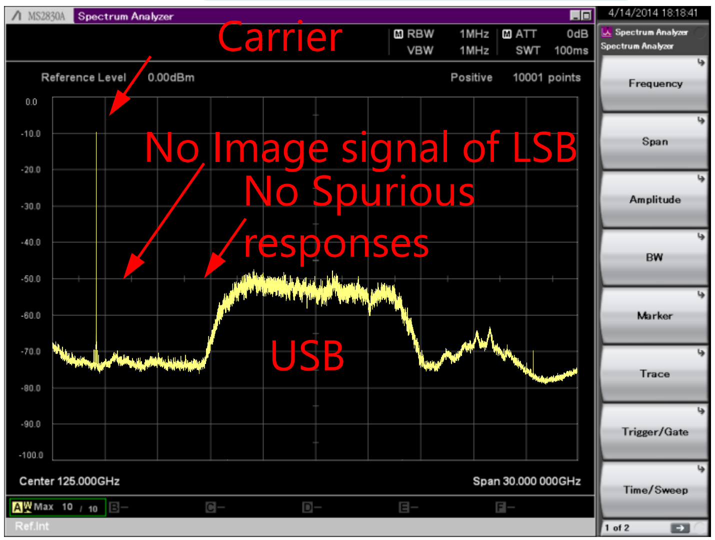
Without pre-selector





With pre-selector





The need for a pre-selector is even greater when using modulated signals.

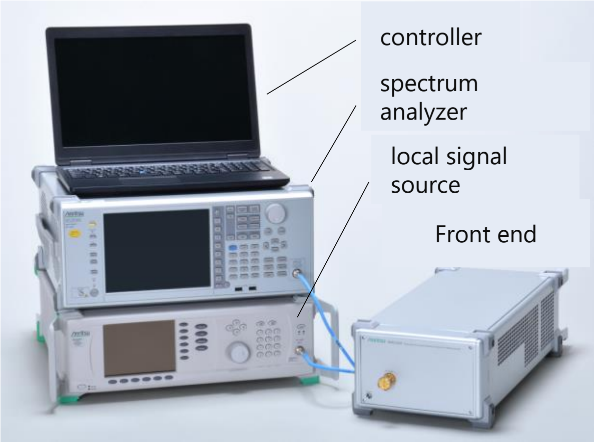
2. 300-GHz Band Spectrum Measurement System

- Block Diagram
- Frequency Diagram

300-GHz Spectrum System Performance Target

Item	Units	G-band	H-band	J-band
Frequency Range	[GHz]	140 - 190	185 - 260	255 - 315
Dynamic Range	[dB]	158	153	148
DANL	[dBm/Hz]	−140	−137	−134
TOI*1	[dBm]	+18	+16	+14
Spurious Response*2	[dBc]	−60	−60	−60

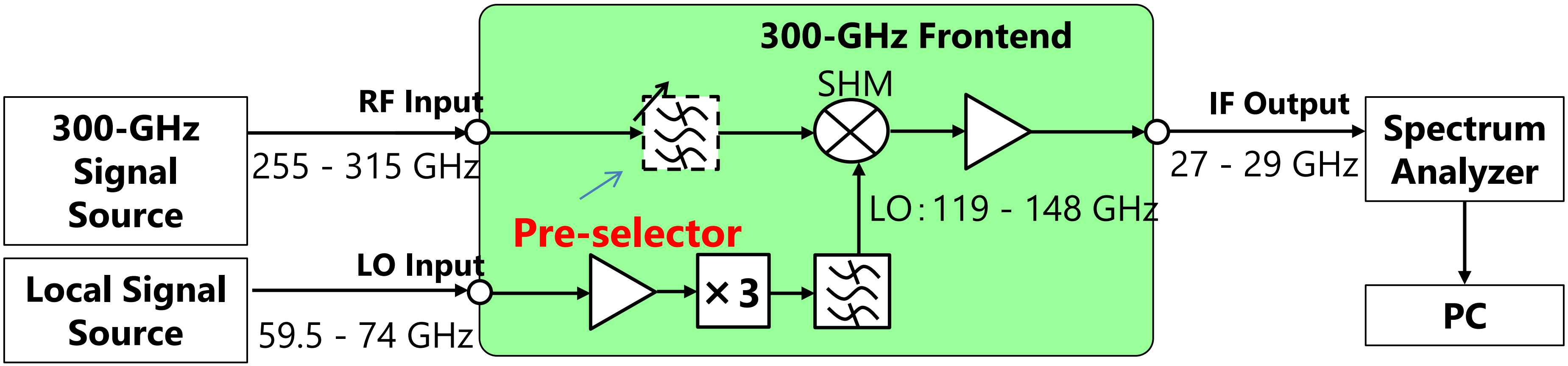
@ −15 dBm input



J-band Spectrum Analyzer Setup

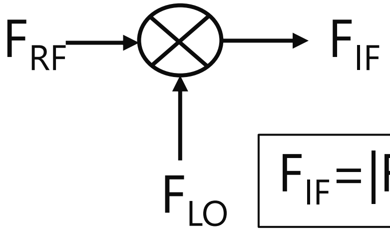
Configured spectrum measurement system with built-in pre-selector for each G-, H-, and J-band

Block Diagram



Synchronizing spectrum analyzer sweeping and pre-selector switching reduces unwanted responses.

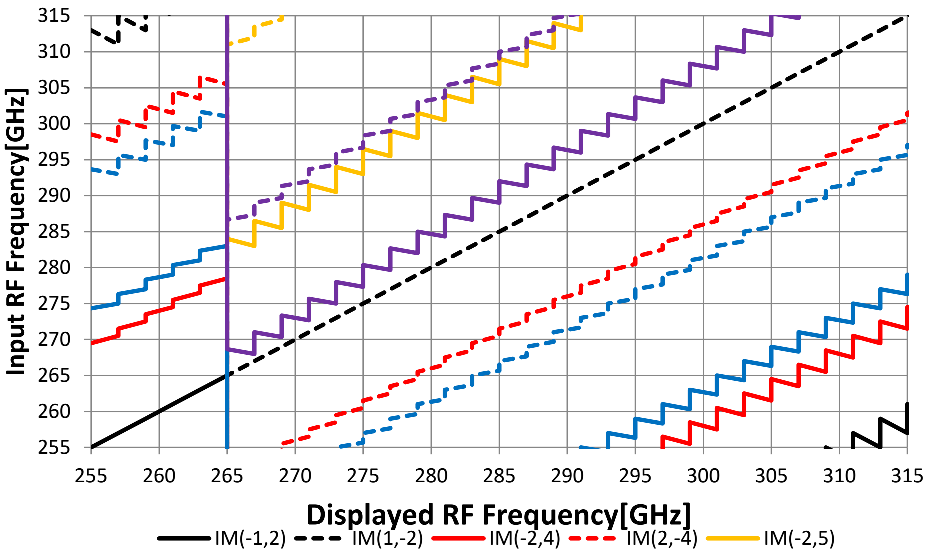
Frequency down-conversion using sub-harmonic mixer



$$F_{IF} = |F_{RF} - 2 \times F_{LO}|$$

Spurious generated by input signal and local signal harmonic distortion due to mixer (non-linear device)

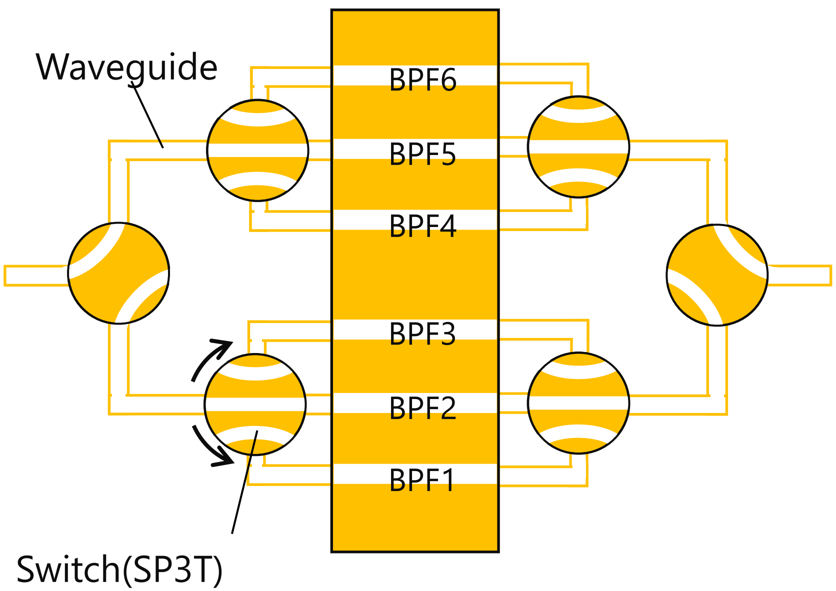
$$IM(m,n) = m \times F_{RF} + n \times F_{LO}$$



Suppressing unwanted response requires determining F_{RF} and F_{LO} relationship

3. Core Technology ~ Pre-selector

Previous Method

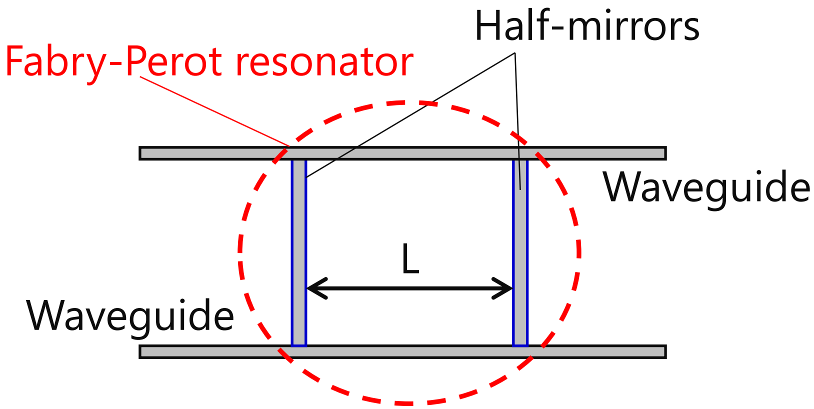


Filter Bank Configured Using SPxT SW

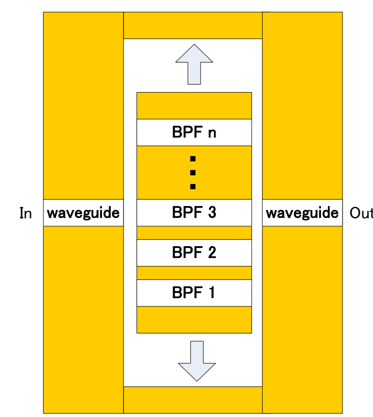
Issues with previous method:

- **Large (= heavy)**
- **High insertion loss**

Proposed Method

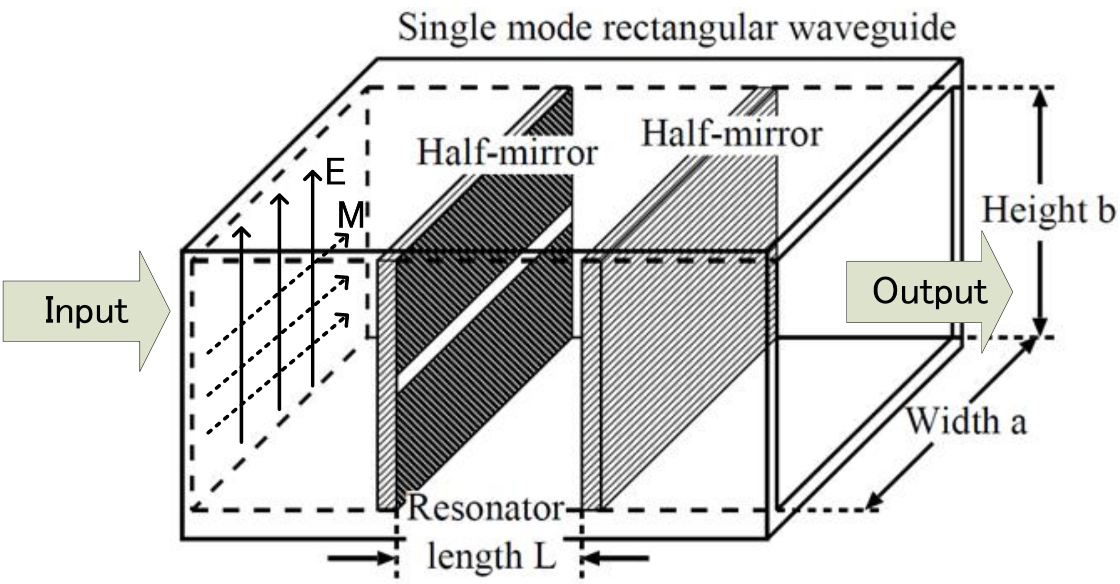


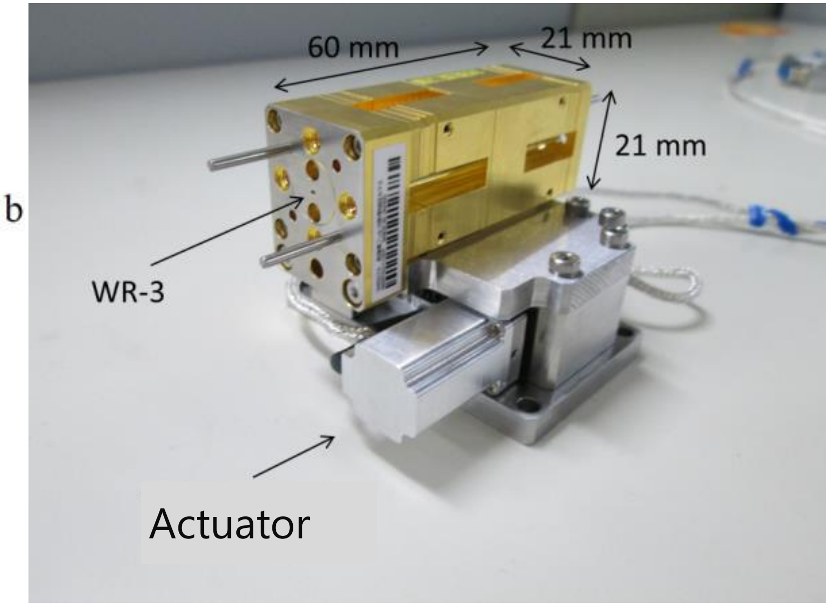
Tunable Fabry-Perot Filter



Filter Bank

Core Technology ~ Pre-selector

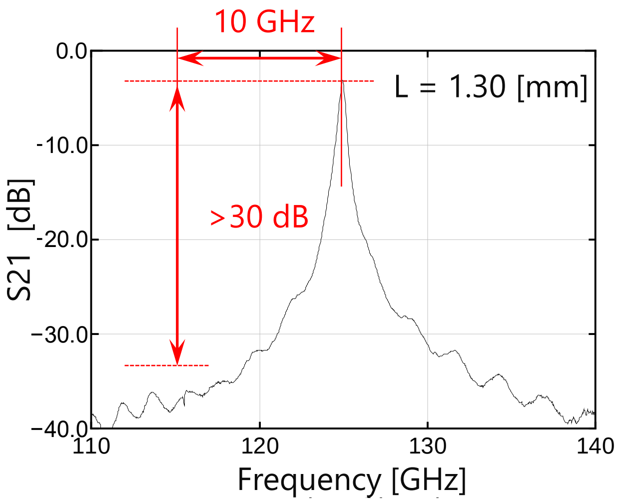


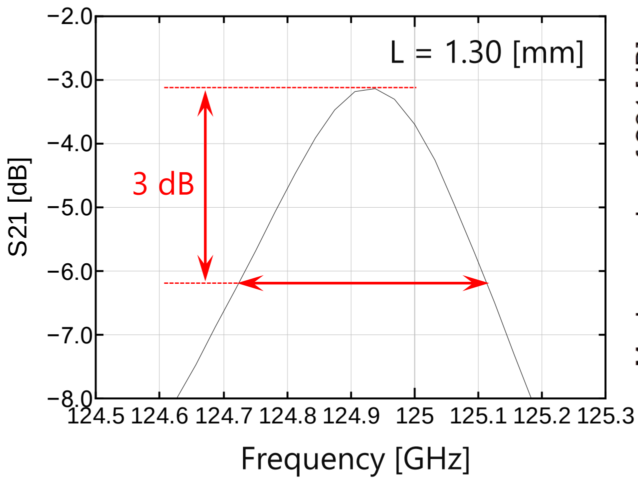


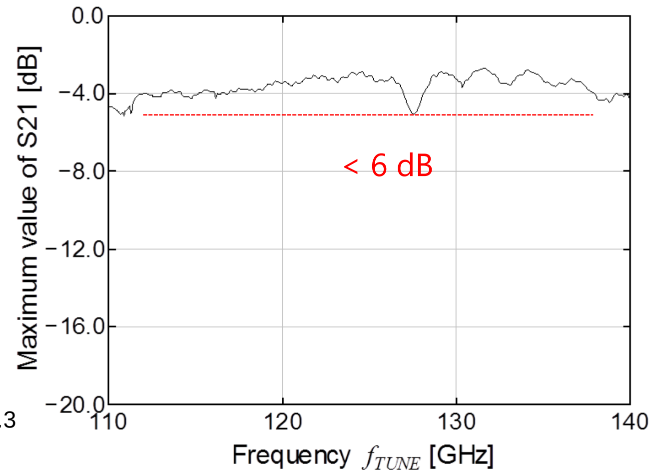
Two half-mirrors in waveguide form Fabry-Perot resonator

Resonator frequency changed by changing distance between two half-mirrors

Core Technology ~ Pre-selector







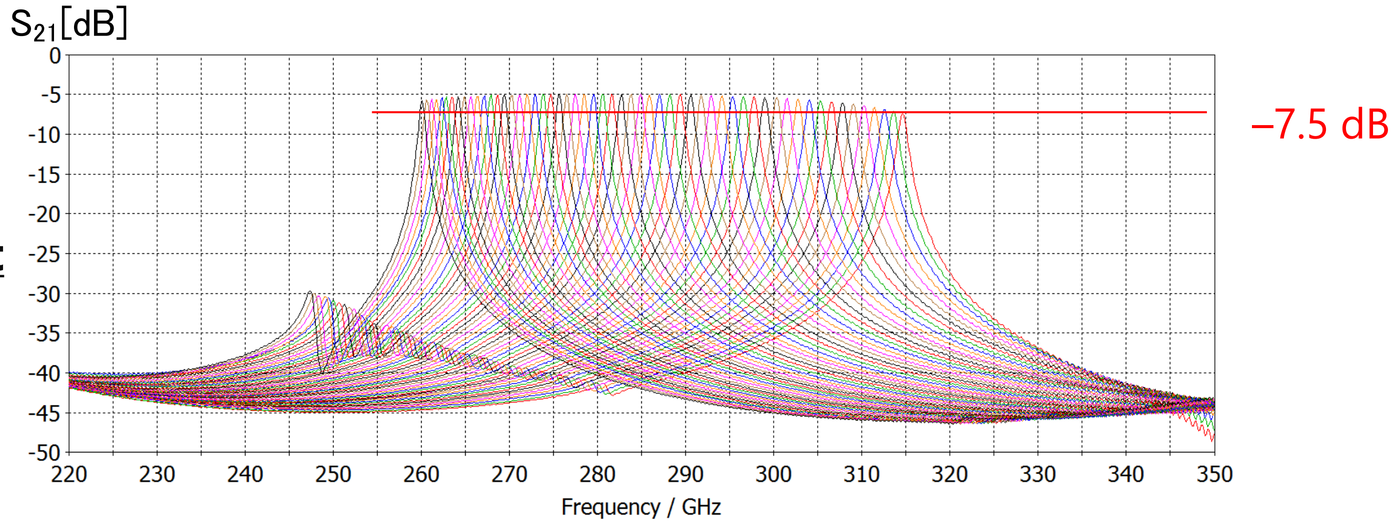
100-GHz Band Implementation Example

- **3-dB bandwidth: 400 MHz**
- **Attenuation: >30 dB @ 10-GHz offset**
- **Insertion loss: <10 dB**

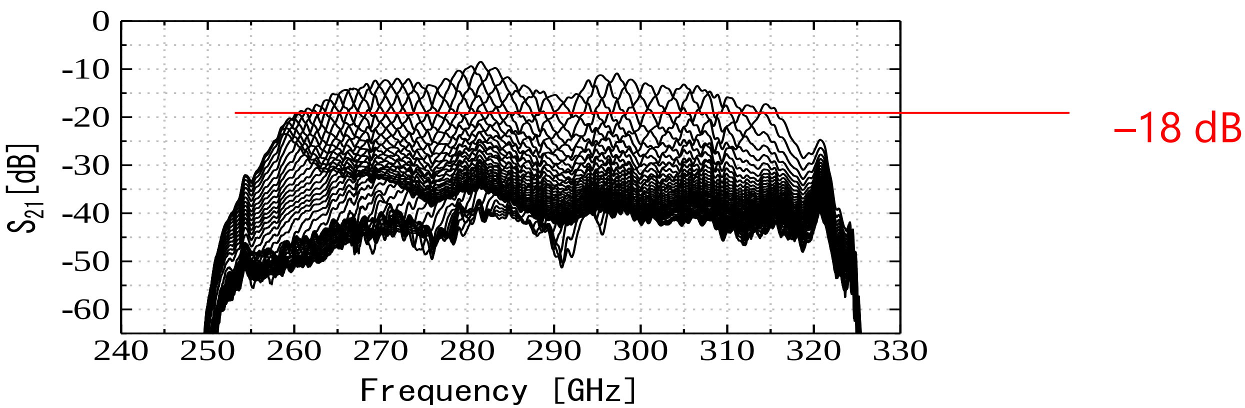
Excellent frequency selectivity and insertion loss performance

Core Technology ~ Pre-selector

Simulation result

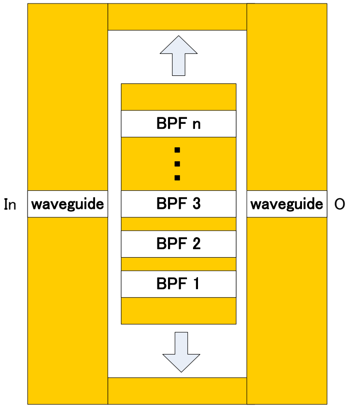


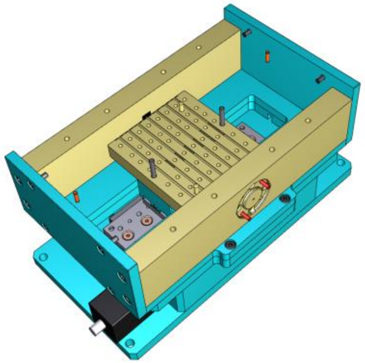
Measured result

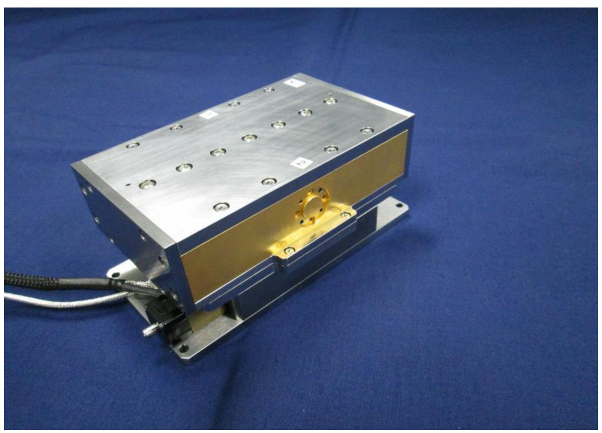


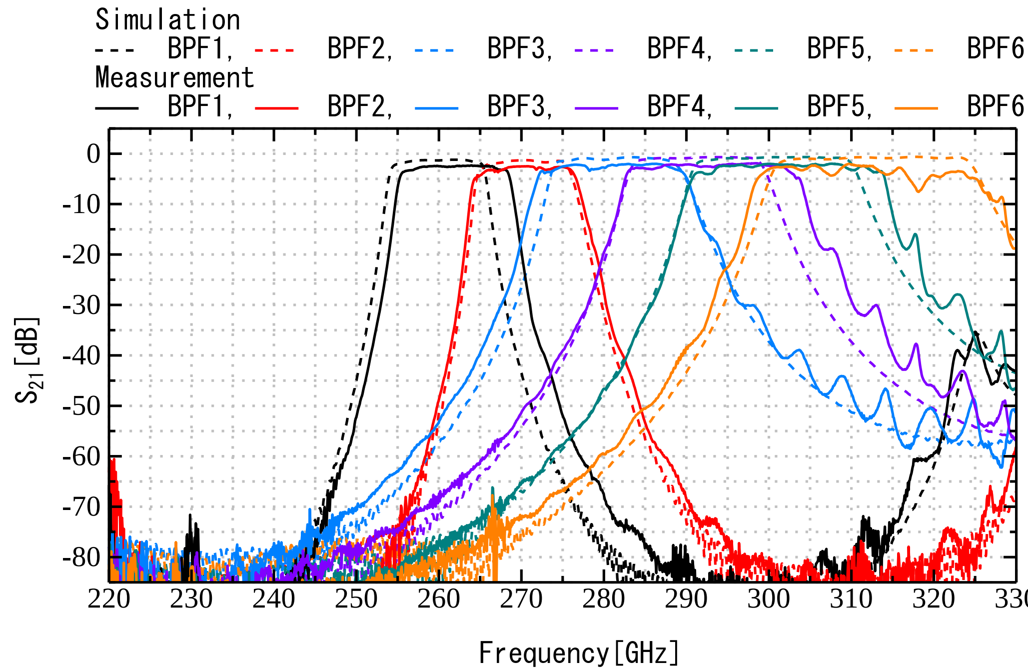
Fabry-Perot method with good performance up to 140 GHz
unsuitable for 300-GHz spectrum analyzer with large insertion loss

Core Technology ~ Pre-selector









Simulation vs Experimental Results

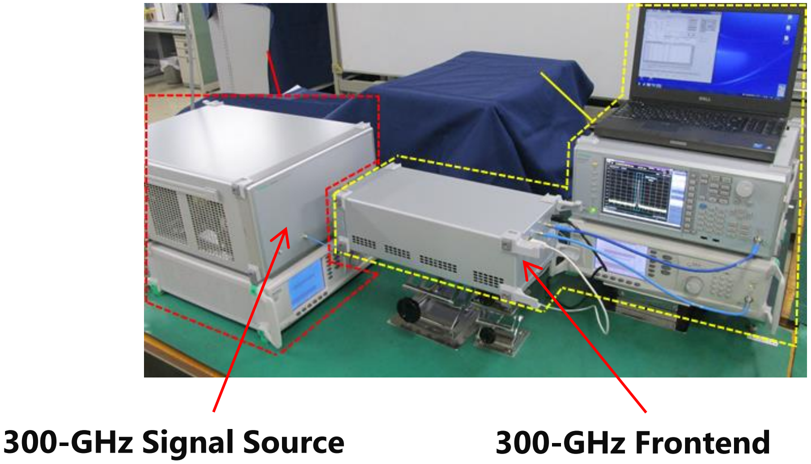
Possible to reduce insertion loss using proposed filter-bank method

Issues: Drift in frequency domain and maintain attenuation in attenuation region

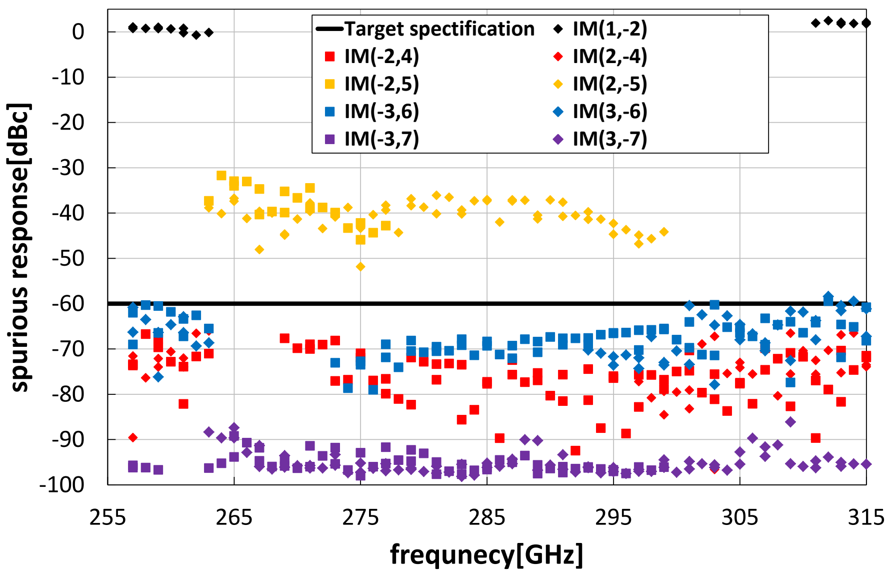
4. Evaluation Results

The following items were evaluated after calibrating the level of the 300-GHz spectrum measurement system.

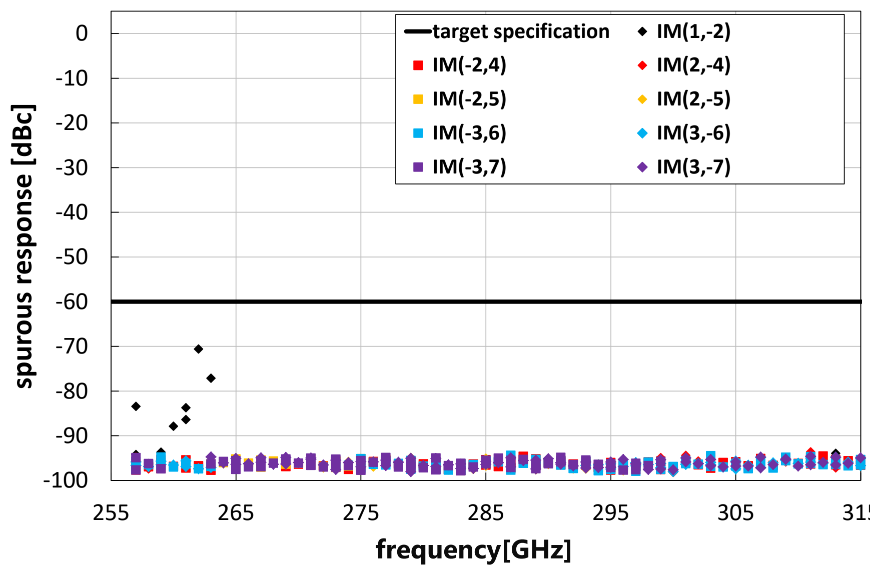
- ✓ Spurious response
- ✓ Display average noise level (DANL)
- ✓ Third order intercept point (TOI)



Without Pre-selector

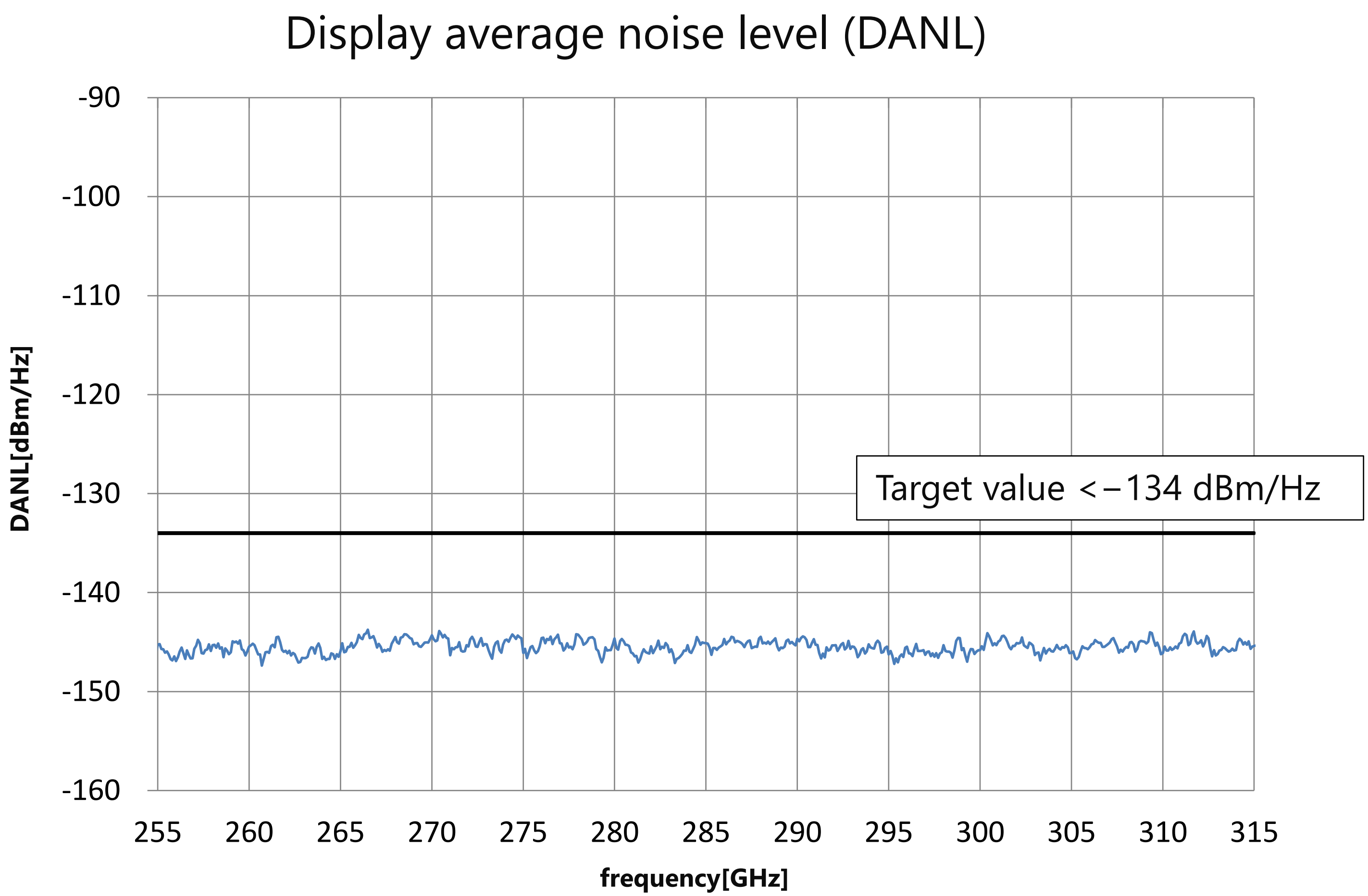


With Pre-selector



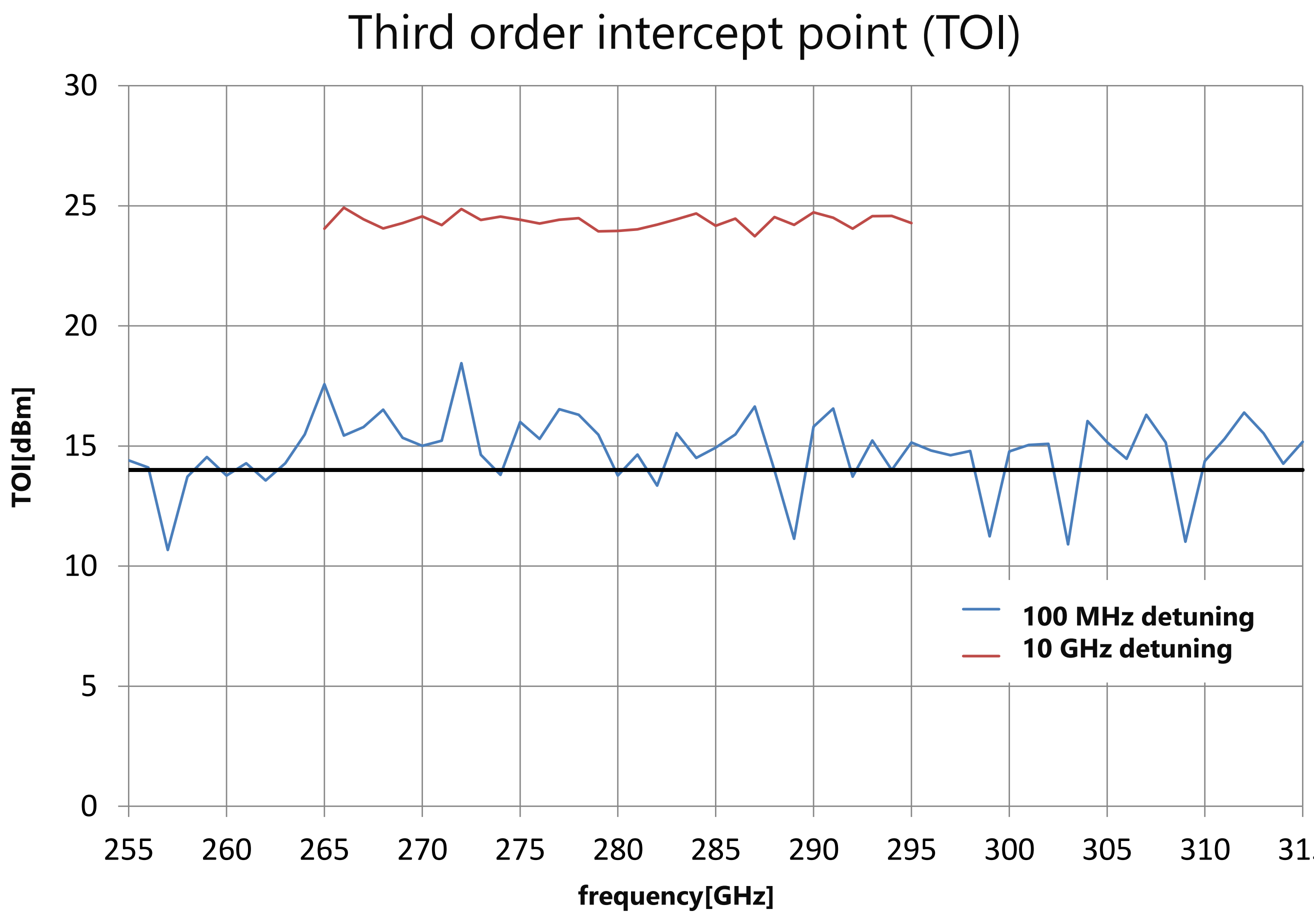
Achieve spurious response of <–70 dBc across all frequencies (@ −15 dBm input and including image response)

Evaluation Results ~ DANL



DANL <−144 dBm/Hz
Assure same performance as microwave SPA waveform

Evaluation Results ~ TOI

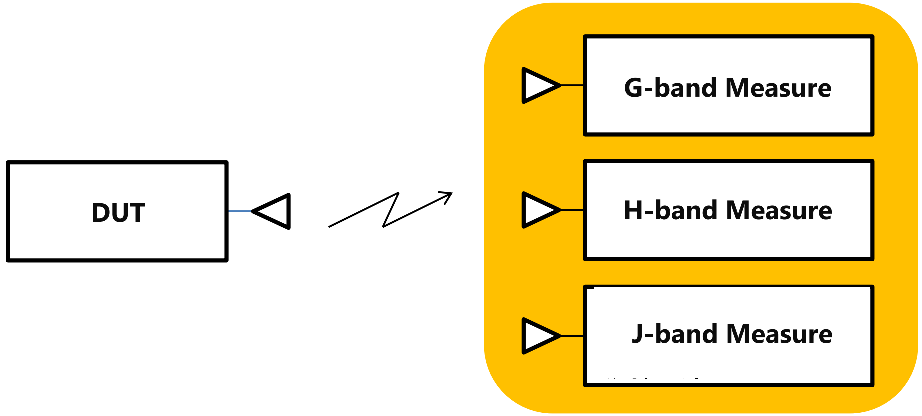


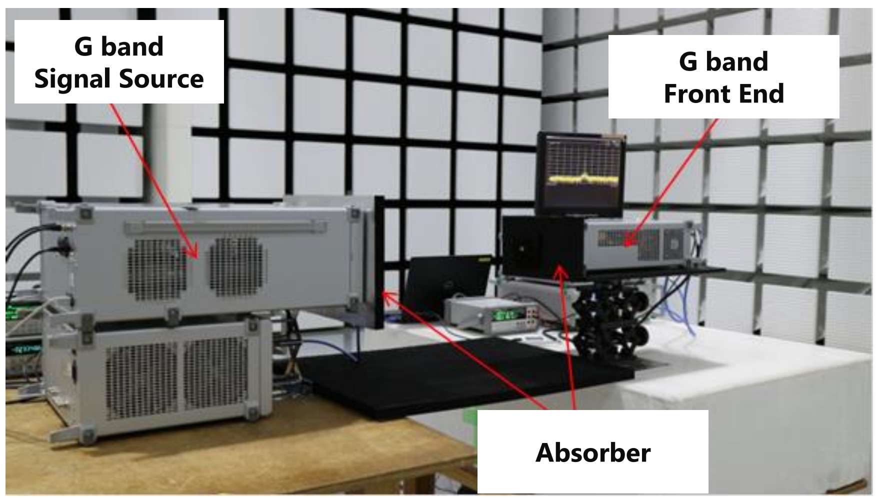
(Span 0 Hz, ATT 0 dB, RBW 300 Hz)

Third Order Intercept Point: >+11 to +18 dBm @10 MHz detuning
>+24 dBm @10 GHz detuning
Assure same performance as microwave SPA waveform

5. Effective Evaluation of Spectrum Measurement System in OTA Environment

Effective Evaluation of Spectrum Measurement System in OTA Environment





External View of Complete System

signals radiated from the DUT are measured by the spectrum measurement system through free space coupling

Unified System Evaluation

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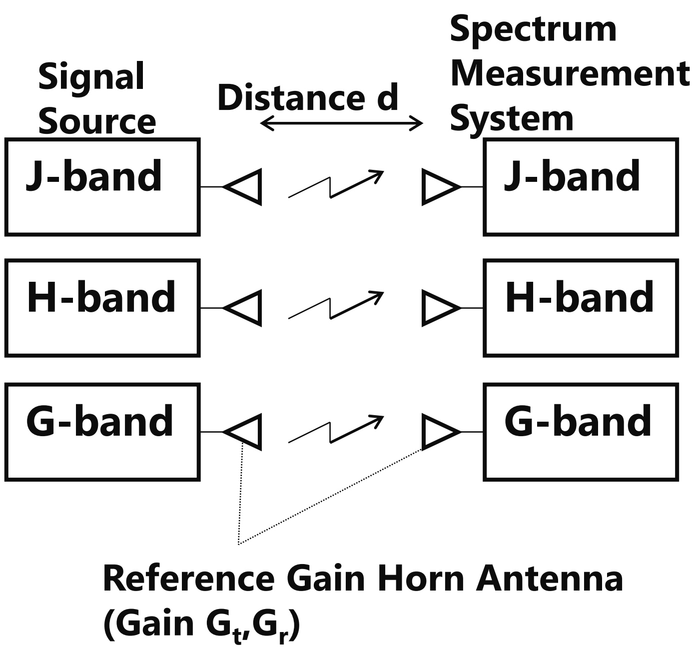
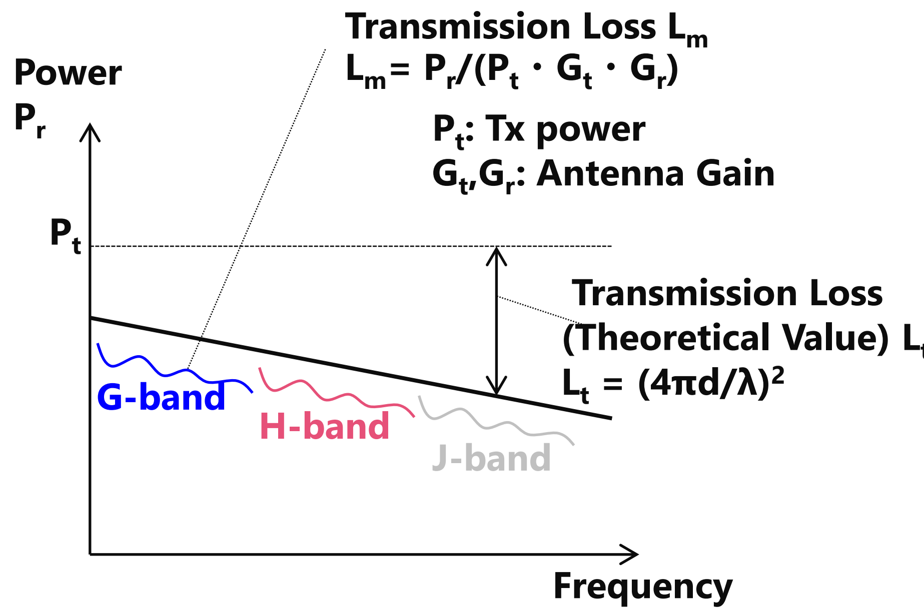
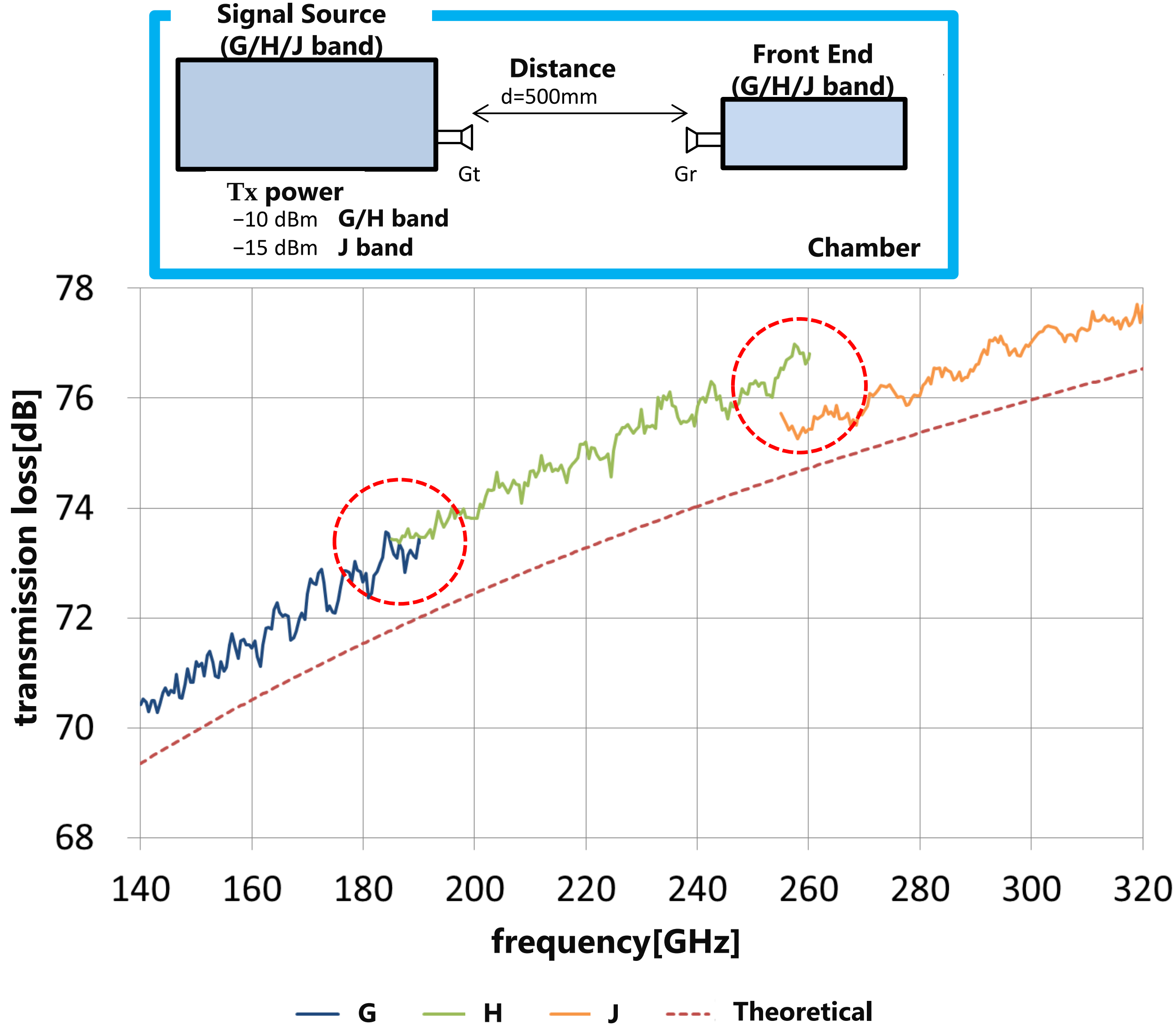
The actual transmission loss L_m (found from antenna gain G_t,G_r and Tx power) with reference gain horn antennas mounted at the signal sources and spectrum measurement systems is compared with the theoretical transmission loss L_t.





- **Evaluated match between actual and theoretical transmission losses**
- **Evaluated continuity between each G-, H-, and J-band transmission loss frequency characteristics**

Unified System Evaluation (Transmission Loss Measurement Results)



Suppressed difference in transmission loss to 0.3 dB between G- and H-band and to 1.1 dB between H- and J-band

Uncertainty Investigation

Since there are differences in the transmission loss results between the G- and H-band, and the H- and J-band, we investigated the following causes of measurement-system uncertainty.

Assumed Error Factors

1. **Measurement Environment Errors**
   - **Antenna setting error (distance)**
   - **Antenna setting error (elevation/azimuth)**
   - **Multi-reflection errors**
2. **Measurement Equipment Errors**
3. **Antenna Gain Errors**

Results

	(+ dB)	(- dB)
Combined standard uncertainty	0.41	0.76
Expanded uncertainty (k = 2)	0.82	1.52

The validity of the unified system is confirmed because the previously described 0.3 dB difference between the G- and H-band is included in the combined standard uncertainty.

Unified System Evaluation (Radiated Pattern)

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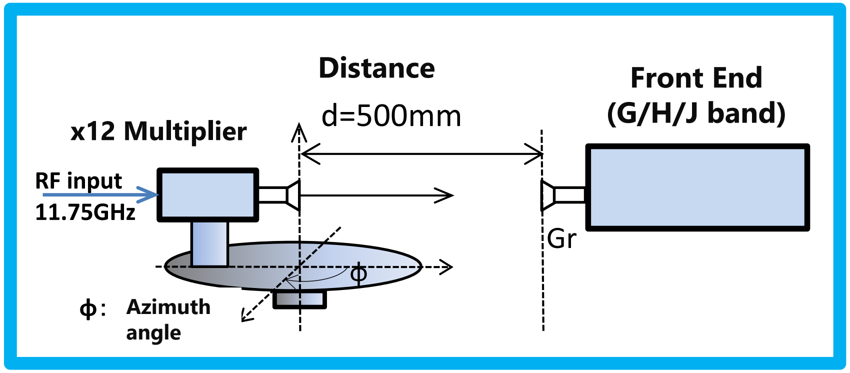
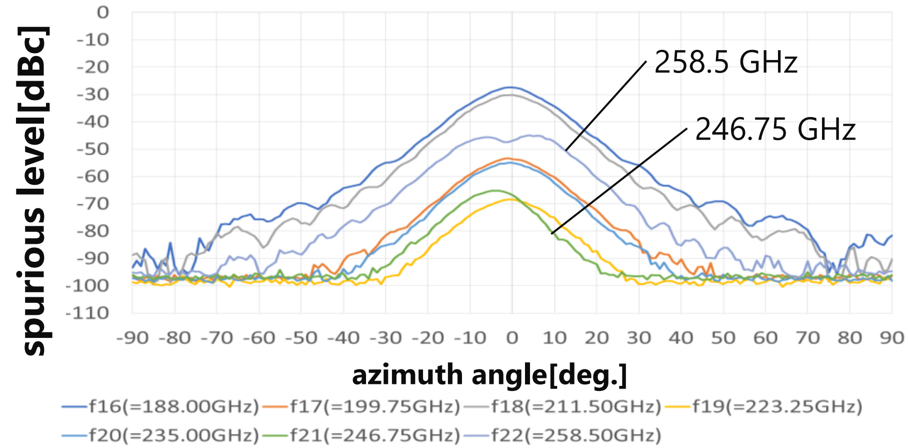
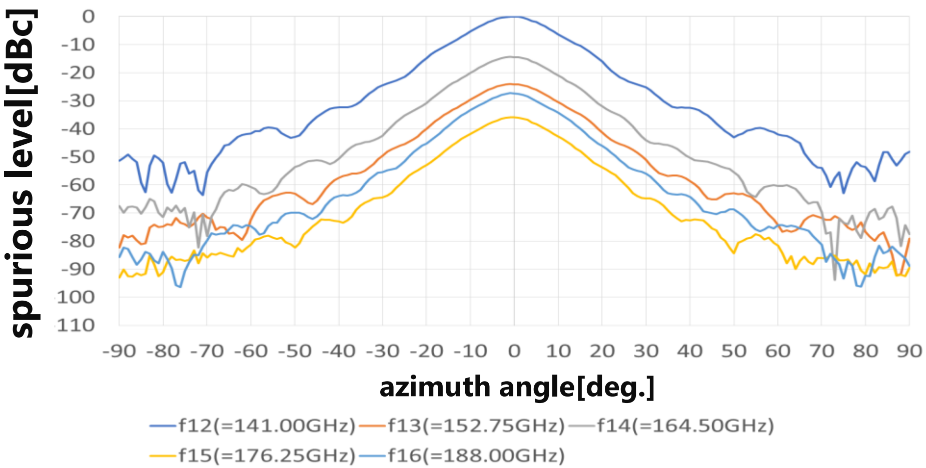
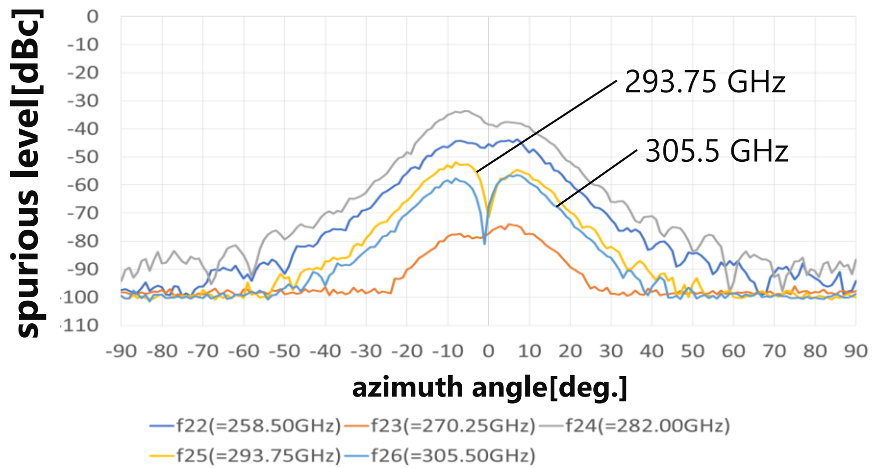




(b) H-band Measurement Results (185 to 260 GHz)



(a) G-band Measurement Results (140 to 190 GHz)

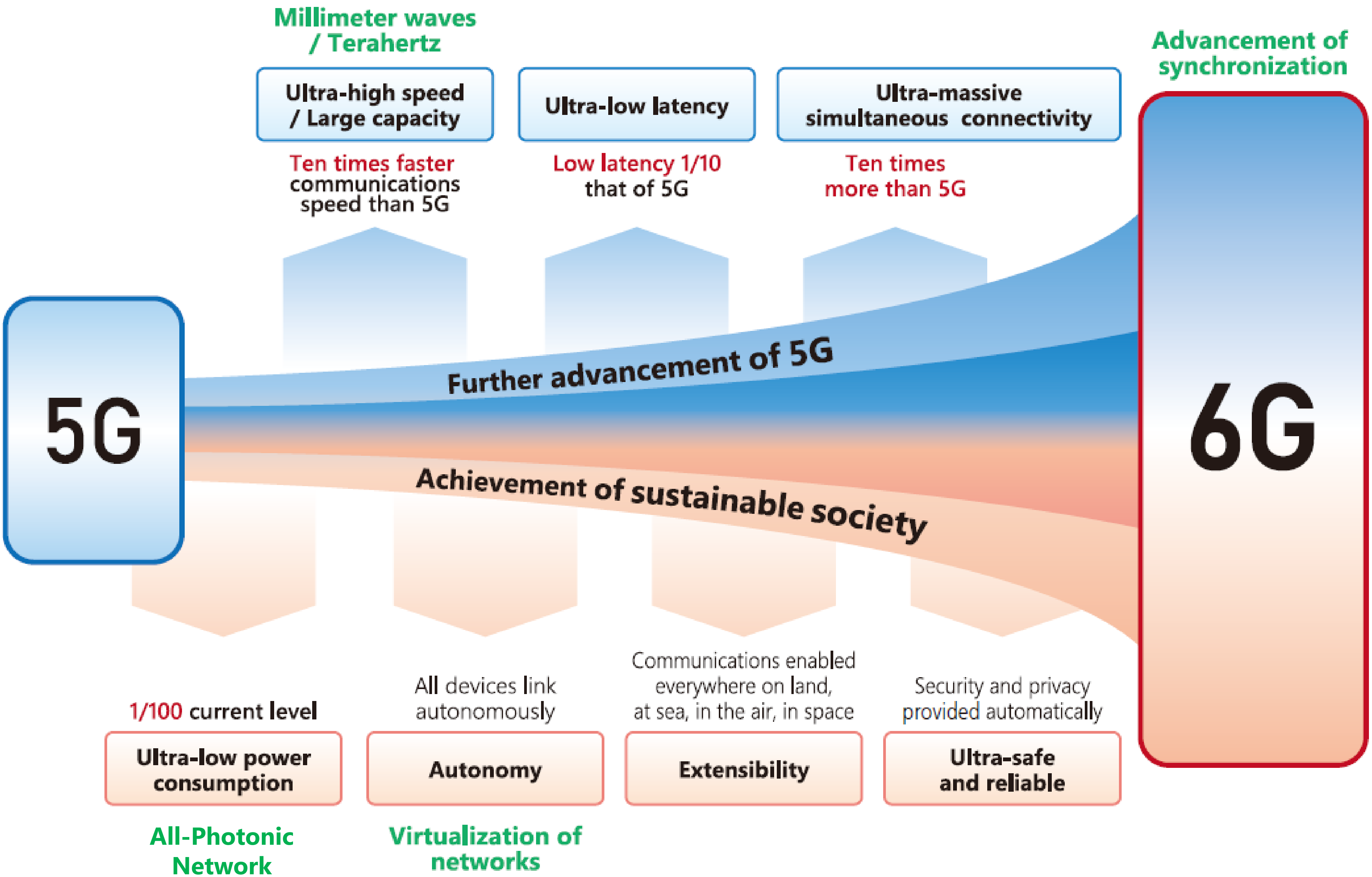


(c) J-band Measurement Results (255 to 315 GHz)

At ≤230.7 GHz, the WR5 waveguide fundamental propagation mode is TE10 only and unidirectionality is maintained. However, at >230.7 GHz, dips and asymmetry are observed due to TE20 mode generation.

6. Further mmWave Applications
~ 5G-Advanced, 6G

Towards 5G-Advanced



Conclusions

- Configured and evaluated new spectrum measurement system with inserted pre-selector.
- Configured OTA unified spectrum monitoring system combining G-, H-, and J-band spectrum measurement systems.
- Evaluated effectiveness of unified system and confirmed suitability of measurement system by measuring DUT radio-wave radiation and obtained expected results.

Anritsu is continuing with development of leading-edge technologies promoting 5G evolution to future 5G-Advanced.

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