Millimeter Wave Spectrum Analyzer with Built-in >100 GHz Preselector

Yukiyasu Kimura, Masaaki Fuse, Akihito Otani

[Summary] Fifth-generation (5G) mobile communications technologies are being actively developed worldwide and measuring instruments supporting frequency bands above 100 GHz are urgently needed. However, there is as yet no tunable filter for use as a preselector at spectrum analysis in the requency bands above 100 GHz. To meet this need, we have developed a mechanically tuned filter using a Fabry-Perot resonator incorporated into a waveguide for use as a preselector. Additionally, we have greatly reduced distortion to generate a high-purity local signal, supporting more accurate measurement by using a millimeter wave generation method using an optical 2-tone signal produced by the coherent interference method at generation of a local signal using a block down converter. This has been used to develop a millimeter wave spectrum analyzer supporting frequencies above 100 GHz. Using this system, we have successfully measured a 120-GHz, 20-Gbps band QPSK modulation spectrum, verifying that the developed preselector suppress spurious response and assures accurate measurement.

1 Introduction

Research and development of fifth-generation mobile communications methods (5G) targeting 1000 times the capacity of present-day LTE methods is pressing ahead in recent years. Development of the millimeter band is making rapid progress as a frequency band supporting delays of less than 1 ms at data rates about 10 Gbps, and there have been positive results in implementing wireless systems at speeds exceeding 100 GHz. However, there is no spectrum analyzer with a built-in preselector for spectrum analysis of wireless signals exceeding 67 GHz. Consequently, these measurements are generally made by connecting either an external mixer or a block down converter[1), 2)]. In these cases, signal components that don’t exist in the original input signal are observed. As a result, the functions of the spectrum analyzer are inadequate for monitoring unknown signals. To solve this problem, we have developed a millimeter-wave with newly fabricated built-in preselector supporting frequencies above 100 GHz. We have demonstrated the ability of this specyrum analyzer to measure the spectrum of 20-Gbps band QPSK modulation wave at 120 GHz as well as suppression of spurious response using the preselector.

2 Millimeter Wave Spectrum Analyzer

This spectrum analyzer supports signals from 110 GHz to 140 GHz.

Figure 1 shows the external appearance and Figure 2 shows the block diagram. As seen in Figure 1, the system is composed of a Head with WR-08 waveguide input, a commercially available spectrum analyzer, (SA) and an optical local signal source (Optical LO Signal Generator). As seen in Figure 2, the Head is composed of a tunable Preselector, directional coupler (Isolator), reference wave mixer (Mixer), amplifier for tuning the level (Amplifier), and UTC-PD (Uni-Traveling-Carrier Photodiode)[3)] for converting the optical local signal to an electrical signal. Using the down-conversion method, the mixer creates multiple mixing products in the output IF signal determined by the mixer LO frequency f_{LO} and the RF signal f_{RF}. The RF frequency is obtained as both local frequency ± IF[4)]. As a result, a conventional SA is constructed using a preselector to suppress the sensitivity to unwanted frequency components. However, unlike the YIG Tuned Filter (YTF) used as a preselector in the microwave band, there is still no tunable filter available for frequency bands above 100 GHz. We have developed a mechanically tuned Fabry-Perot resonator[5)] fabricated in a waveguide as the preselector for the Head used with this SA.

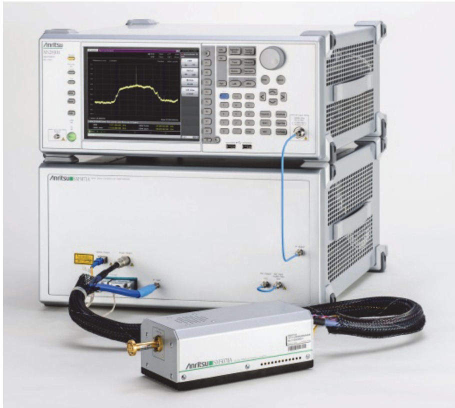


Figure 1 Millimeter Wave Spectrum Analyzer

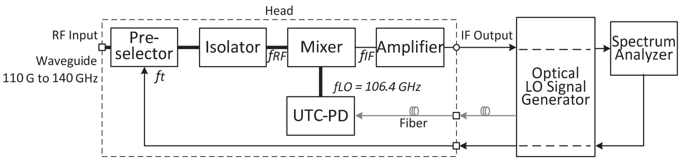


Figure 2 Millimeter Wave Spectrum Analyzer Block Diagram

2.1 Preselector

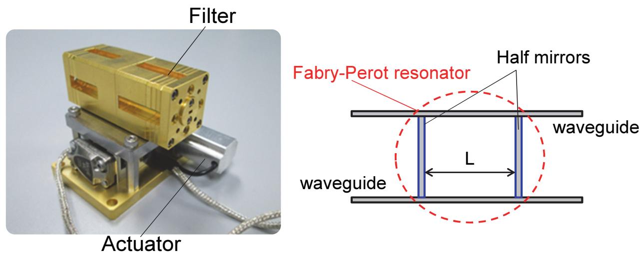
The developed preselector controls the oscillator length L to function as a millimeter-wave tunable filter with variable tuning frequency f_{TUNE}.

Figure 3 shows an external view of the preselector and the principle of operation. As seen in Figure 3, the preselector is composed mainly of a filter composed of waveguides and an actuator for driving the filter. The actuator drives one side of the half mirrors forming the Fabry-Perot resonator inside the waveguides to control the tuning frequency f_{TUNE} by controlling the oscillator length L.

Figure 4 shows the frequency characteristics of this preselector; Figure 4a shows the S21 transmission characteristic when the oscillator length L is 1.3 mm. Figure 4b shows a magnified view around the center frequency; 3 dB down from the peak level at about 124.9 GHz, the bandwidth is about 400 MHz and the attenuation at 5 GHz from the center frequency is about 30 dB. Figure 4c shows a plot of the maximum value of the S21 transmission characteristic vs tuning frequency f_{TUNE}. The degraded noise performance due to the preselector is less than 6 dB in the frequency band between 110 GHz and 140 GHz. Figure 4d shows the frequency setting deviation vs tuning frequency f_{TUNE}. It is less than 0.1 GHz in the frequency band between 110 GHz and 140 GHz.

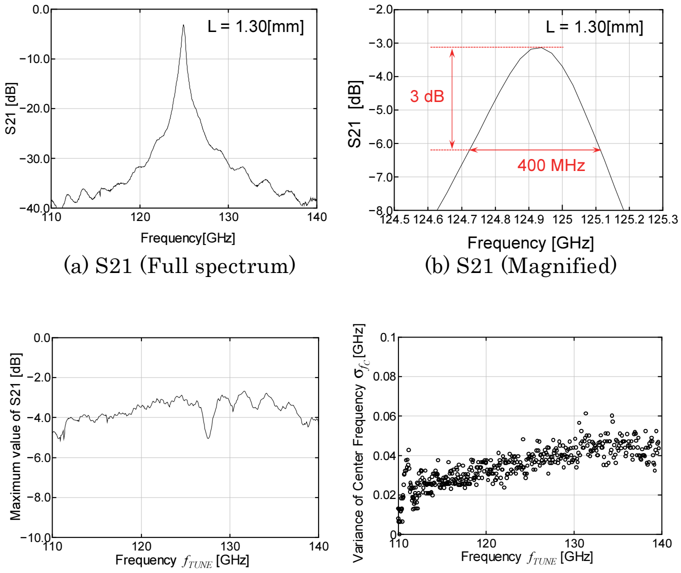
2.2 Synchronous Operation Principle

To analyze 110 GHz to 140 GHz RF signals, this system uses a method incorporating a preselector for suppressing generation of image signals into a block down converter. Conventionally, a sweep-type SA with built-in preselector uses method for synchronizing the mixer local frequency and preselector[4]. However, when sweeping the local frequency at frequencies above 100 GHz, complications such as the generation method and filter structure be expected. As a result, in this system, the preselector tuning frequency uses a step operation and the SA frequency range of 110 GHz to 140 GHz is division-swept. The preselector tuning frequency f_{TUNE} and SA analysis center frequency are tuned while separately sweeping the range of 110 GHz to 140 GHz to finally generate the measurement band spectrum. When using this type of divided sweeping method, the level reproducibility and sweep speed can be expected to be affected by the preselector tuning frequency f_{TUNE} step interval. In this system, the tuning frequency step gap was set to 0.1 GHz based on the based on the setting reproducibility of the used preselector (Figure 4d) and the passband width. When measuring at a frequency range (SPAN) of 30 GHz and resolution bandwidth (RBW) of 1 MHz, the sweep speed is about 15 seconds.



(a) External View (b) Operation Principle

Figure 3 Preselector



(a) S21 (Full spectrum) (b) S21 (Magnified)

(c) Maximum value of S21 (d) Frequency Setting Deviation

Figure 4 Preselector Frequency Characteristics

2.3 Optical Local Signal Source

This system generates the local signal using a millimeter wave generation method using coherent interference[7), 8)].

Figure 5 shows the block diagram of the optical local signal source. The optical local signal source is generated as an optical 2-tone signal (Optical LO Signal) with a frequency error of four times the signal frequency f_m generated by the signal generator; generated optical 2-tone signal is converted to an electrical local signal corresponding to the frequency error ($4 \cdot f_m$) by the UTC-PD in the head for use as the reference wave mixer local signal. Using this method makes it possible to generate a high-frequency millimeter wave signal easily and reduces the size of the Head size.

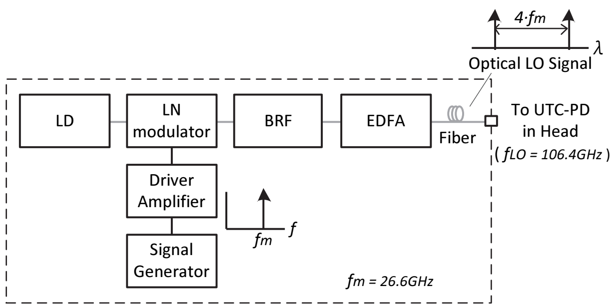


Figure 5 Optical Local Signal Source Block Diagram

Figure 6 shows a maximum values for low-frequency distortion ($1 \times f_m$, $2 \times f_m$, ・・・$n \times f_m$) due to coherent interference millimeter wave signal generation, and passive electrical ×4 and active electrical ×4 multipliers. When using an electrical multiplier, the maximum generated low-frequency distortion is about –3 dBc, but with the coherent interference millimeter wave generation method, it is only about –60 dBc. Assuming that the attenuation of the general filter is on the order of 40 dB, using the coherent interference millimeter wave generation method for the frequencies used by this SA (f_{LO} = 106.4 GHz), produces a much higher purity signal using a filter or more than one stage to eliminate spurious in comparison to the electrical multiplier method. Filter loss makes a big contribution to reducing the size of the detector built into the preselector and cutting power consumption.

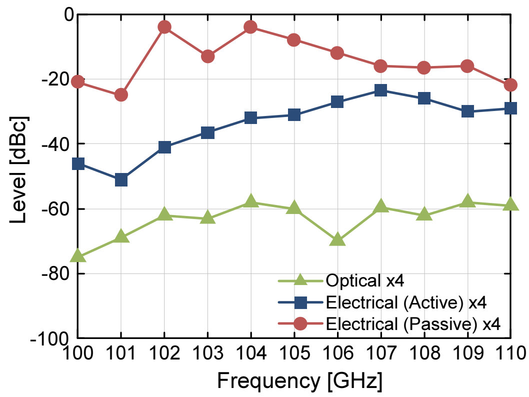


Figure 6 Comparison of Optical Local Signal Source Harmonic Distortion Level Results

3 Measurement Results

To confirm the effectiveness of the preselector in this system, we measured both the spurious of a CW signal, and the spectrum of a wideband modulation signal.

3.1 Spurious Measurement using CW Signal

A CW signal in the measurement band (110 GHz to 140 GHz) was input to the system and the observed spurious response level was measured.

Figure 7 shows the block diagram of the system for measuring spurious using a CW signal. The signal frequency from the signal generator (SG) is multiplied by 8 using the Multiplier and this frequency multiplied signal is passed though a bandpass filter (BPF), and variable attenuator (VATT) before input to the measurement system. The input level P_{in} at the Head input connector was adjusted to –10 dBm using the VATT to measure the spectrum at this time; analysis of the spectrum results was used to give the input level vs spurious level. Moreover, to suppress the spurious level in the measured signal source, measurement was performed while changing the BPF according to measured frequency.

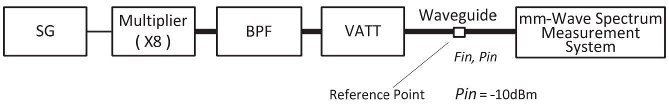
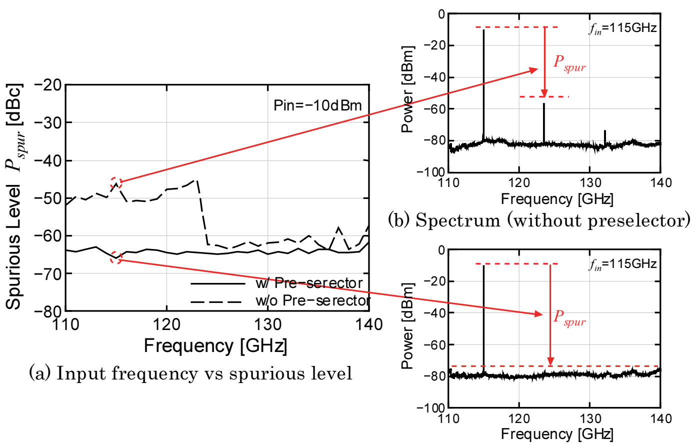


Figure 7 Block Diagram of Spurious Measurement System using CW Signal

Figure 8 shows the measured spurious level at the input frequency f_{in}. The solid line in Figure 8a indicates the spurious level with the preselector, while the dashed line shows it without the preselector. Figures 8b and 8c show the spectrum results when the input frequency f_{in} is 115 GHz. As shown in Figure 8b, without the preselector there are intermodulation distortion frequency components caused by the local signal and input signal. However, these distortion components are not observed with the preselector (Figure 8c). Using the developed preselector supports accurate observations with no signal components that were not present on the original input signal.



(a) Input frequency vs spurious level

(b) Spectrum (without preselector)

(c) Spectrum (with preselector)

Figure 8 Spurious Level Measurement Results

3.2 Spectrum Measurement using Wideband Modulation Signal

A millimeter wave wideband modulation signal was generated for testing and measurement. Wideband modulation signal generation used a coherent interference millimeter wave generation method like of optical local signal generation.

Figure 9 shows the block diagram of the system for measuring the spectrum using a wideband modulation signal. A difference frequency $4 \cdot f_m$ optical 2-tone signal generated by the Optical LO Signal Generator was modulated using the LN modulator and converted to a millimeter wave signal by the UTC-PD before output[9), 10)]. The modulation signal source used by the LN Modulator uses an arbitrary waveform generator (AWG). This type of configuration offers an easy way to generate a wideband modulation signal and can output a signal with both a $4 \cdot f_m$ carrier and a $4 \cdot f_m \pm$ double sideband from the UTC-PD.

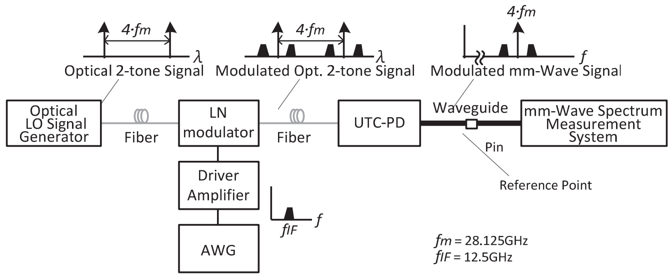


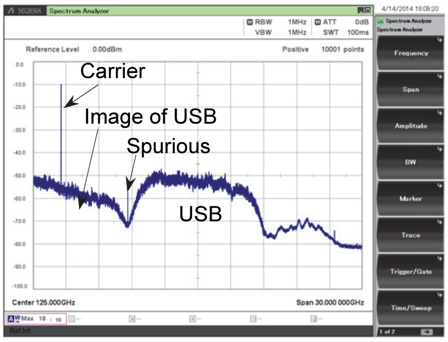
Figure 9 Block Diagram of Spectrum Measurement System using Wideband Modulation Signal

Figure 10 shows the measured spectrum of the wideband millimeter wave modulation signal used for testing measured by generating a QPSK modulation wave from the AWG with a 12.5 GHz center frequency, 10 Gsym/s symbol rate and roll-off rate of 0.3. Figure 10a shows the measured results with the preselector removed. Without the preselector, the lower sideband (LSB) has an image near 112.5 GHz and distortion components due to the carrier are also observed as spurious near 118.5 GHz. Figure 10b shows the measurement results with the preselector installed in the system, confirming that the carrier and upper sideband (USB) are correctly observed in the measured frequency range.

These results show that using the developed preselector in this system supports measurement without image signal components and spurious response.

4 Conclusion

We have successfully developed a millimeter wave spectrum analyzer system with new built-in preselector supporting measurements above 100 GHz. We have verified the effectiveness of this system in suppressing spurious responses thereby supporting accurate measurement of CW and wideband modulation signals.



(a) Without Preselector

(b) With Preselector

Figure 10 Wideband Modulation Signal Measurement Results (RBW: 1 MHz, Peak Search)

Acknowledgments

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Authors

Yukiyasi Kimura
R&D Division
R&D Center
1st Technology Development Dept.

Masaaki Fuse
R&D Division
R&D Center
1st Technology Development Dept.

Akihito Otani
R&D Division
R&D Center
1st Technology Development Dept.
and Technology Management Center

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