Development of High Performance Waveguide Mixer MA2806A/08A

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[Summary] The mm-Wave frequency band is becoming the subject of increased attention as a candidate band supporting next-generation wireless communication systems. On the other hand, not only are there no measuring instruments meeting users' mm-Wave measurement requirements, but also users are forced to perform evaluations by configuring individual measurement environments. As a result, many users in the R&D and certification markets are still waiting for development of measuring instruments supporting these next-generation communications systems. To meet these needs, we have developed the High Performance Waveguide Mixer and extended existing external mixer functions as well as developed a high-dynamic-range receiver meeting market requirements.

1 Market and Requirements

Annual wireless data traffic volumes are increasing rapidly due to the spread of wireless infrastructure. To meet this demand, R&D is progressing into 5G communications technologies offering 1000 times more capacity than today's LTE technology. Part of this R&D is focused on using the mm-Wave band to achieve data rates in excess of 1 Gbps.

Frequency resources are very congested at frequency bands of 6 GHz or less, which limits the frequency range. However, the mm-Wave band can support wideband signals. Consequently, future large-capacity wireless communications systems must consider using mm-Wave and R&D in this field is progressing actively.

On the other hand, due to the mm-Wave noise floor and distortion performance, there has been no measuring instrument meeting customers' requirements. As a result, Anritsu has developed the High Performance Waveguide Mixer MA2806A/MA2808A to support various mm-Wave evaluations, and extending the MS2830A Spectrum Analyzer's external mixer functions.

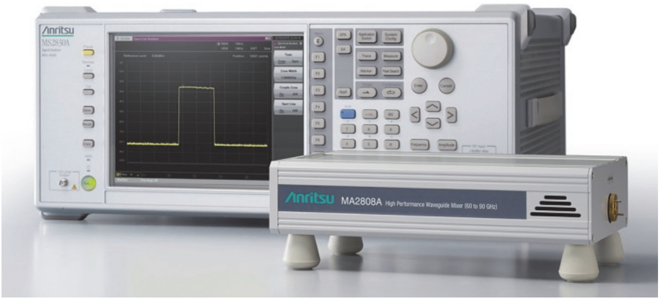

Figure 1 MS2830A Signal Analyzer and High Performance Waveguide Mixer MA2806A/08A (50 GHz to 75 GHz)/(60 GHz to 90 GHz)

2 Development Concept

mm-Wave application developers require multi-function measuring instruments. In particular, wireless application developers need measuring instruments that can verify application communications quality and compliance with standards regulating radio usage. Communications quality tests require modulation analysis and other functions for verifying that each communications standard is met. Regulatory compliance requires verification that the power, spurious, etc., satisfy the specified ranges, as well as functions for determining electrical performance such as sensitivity, distortion, and phase noise.

The developed High Performance Waveguide Mixer MA2806A/08A is targeted at the latter requirement.

2.1 Electrical Performance

Capturing wideband mm-Wave signals requires a higher dynamic range than other measurement applications. For example, the normalized Spectrum Density of a signal with a total power of –10 dBm and a bandwidth of 1 GHz is –100 dBm/Hz (–10 dBm – 10*log (1 GHz) ≈ –100 dBm/Hz).

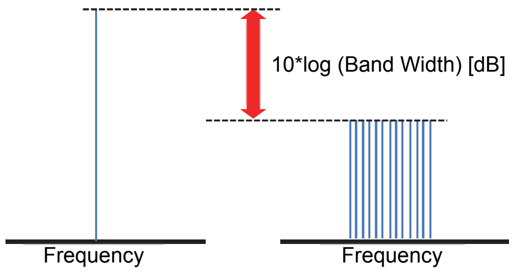

Figure 2 CW and Wideband Signal Spectrum Density

To accurately measure this type of signal, the measuring instrument must have low noise performance to observe the –100 dBm/Hz signal, as well as high distortion performance supporting a total input power of –10 dBm. In other words, mm-Wave measurements require high dynamic-range performance.

(1) Low Noise Performance

The spectrum density of a signal with a mixer input level of –10 dBm and a bandwidth of 1 GHz is –100 dBm/Hz (–10 dBm/1 GHz). Consequently, the measuring instrument requires a sensitivity performance sufficiently below –100 dBm/Hz (when measuring a signal with an SNR of 40 dB, the instrument requires a noise performance below –140 dBm/Hz). The High Performance Waveguide Mixer satisfies this sensivity requirement with a Noise Figure (NF) performance of ≤15 dB.

(2) High Distortion Performance

Generally, spectrum analyzers using the microwave band and above have a preselector to remove unwanted responses (mainly image responses). The preselector stability and insertion loss can cause degraded level accuracy and poor NF. On the other hand, band-limiting the input signal can effectively limit the input power to the mixer. When measuring wideband signals using a measuring instrument without a preselector, input of the full signal power to the mixer can degrade the distortion performance of the first mixer stage, having a large effect on the measurement results.

The High Performance Waveguide Mixer has a distortion performance of P1 dB ≥ 0 dBm targeting mixer input levels of –10 dBm. Moreover, due to the high distortion performance, sidelobe characteristics can be measured adequately when measuring wideband signals.

(3) Low Spurious

Spurious generation in measurement systems is a problem when measuring SEM and spurious. The High Performance Waveguide Mixer reduces spurious in the region close to the input signal by frequency conversion based on fundamental mixing, and by filtering using the built-in LO Multiplier Chain provided internally.

2.2 Extended Measurement Performance

To simplify measurement in the difficult mm-Wave band, we extended the measurement functions for correcting frequency characteristics.

Additionally, when using an external mixer, image response effects can be generated due to the lack of a preselector as previously mentioned. As a result, we added a function for identifying required and unwanted signals, helping increase usability. Moreover, general user convenience was improved by adding support for various Measure functions to the High Performance Waveguide Mixer.

(1) Added Correction Functions

The following correction functions were added to simplify measurement by suppressing level errors in the measurement system.

- Conversion Loss correction
- Cable Loss correction

(2) Extended Signal Identification Function

Measuring instruments without a preselector suffer from generation of various types of spurious typified by image response. Consequently, previous systems have a Signal ID function for separating the required signal from signals caused by the measurement system. This previous Signal ID function (Image Suppress mode) cannot perform measurement in combination with the Measure function requiring RMS detection because Min. Hold processing is performed as a basic principle of the operation. As a result, we implemented a new Signal ID function (PS function) to evade spurious. This improves measurement convenience because Measure functions can be used simultaneously.

(3) Added Calibration Function for External Mixer Connection Port

An external mixer is used by connecting it to the MS2830A 1st Local Output port; however, level correction is not performed at this point. As a result, we have included a function for correcting measuring instrument level differences and reducing display level errors by directly inputting a signal that has been corrected with a power meter to the 1st Local Output port.

(4) Extended Signal Analysis Function

Adding the High Performance Waveguide Mixer supports signal analyses such as SEM measurement, OBW measurement, TOI measurement, chirp signal analysis, defined by the ETSI and IEEE 802.11ad[1) to 3)] specifications for mm-Wave band, helping increase usability at mm-Wave measurement.

(5) Extended Phase Noise Measurement Function

mm-Wave phase noise measurement is difficult without the use of specialized equipments. Consequently, we have added a function supporting phase noise measurement when using an external mixer to simplify phase noise measurements.

3 Design Requirements

3.1 System Design Concept

The High Performance Waveguide Mixer uses fundamental mixing to achieve the high dynamic range required by mm-Wave measurement. Figure 3 shows a block diagram of the High Performance Waveguide Mixer. Due to the differences in the captured frequency, the structure of the LO Multiplier Chain is different between the MA2806A and M2808A; in the MA2806A, the input LO signal is multiplied 8 times, whereas it is multiplied 12 times in the MA2808A for fundamental mixing. Earlier harmonic mixers used harmonics generated by the mixer for frequency conversion so that the LO frequency could be suppressed. As a result, though they were advantageous in terms of price and structure, their conversion loss and spurious performance were badly degraded by the harmonic mixing.

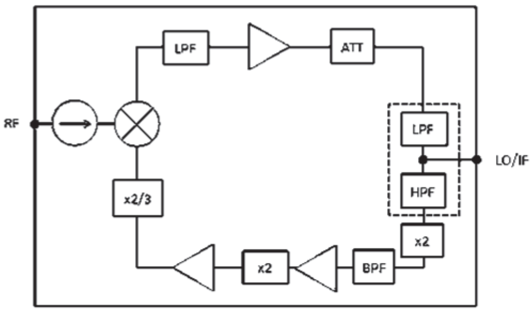

Figure 3 High Performance Waveguide Mixer Block Diagram

3.2 Low Noise Performance

The fundamental mixing method is used to achieve a high dynamic range with low noise characteristics. The frequency response at the mixer is found by Equation (1), indicating the well-known fact that conversion loss becomes larger as the conversion degrees (m, n) increase.

$$\mathrm{IF} = \mathrm{mRF} \pm \mathrm{nLO} \qquad (1)$$

Accordingly, to reduce losses at the mixer stage, it is best to perform fundamental wave conversion using small conversion degrees, or in other words m=n=1. On the other hand, performing mm-Wave fundamental wave conversion requires increasing the LO frequency to the used frequency band.

Figure 4 shows MA2806A and MA2808A conversion loss characteristics.

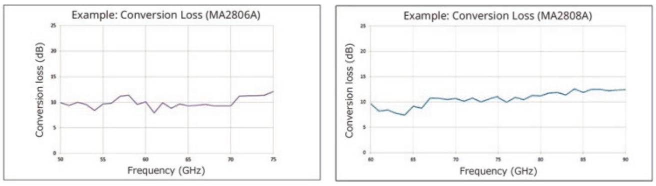

Figure 4 MA2806A/MA2808A Conversion Loss Characteristics

3.3 High Distortion Performance

High distortion performance is required to accurately measure sidelobe characteristics of wideband signals as well as for accommodating the previously described –10 dBm mixer input level.

3.4 Low Spurious

For mm-Wave measurements using either a harmonic mixer or an external down-converter, spurious performance is very important. Since these measurement methods do not use a preselector, various types of spurious typified by image responses are generated. When users observe spurious in the wanted signal frequency range, they are forced to evaluate whether the spurious is due to the measurement system, or is being generated by the device under test (DUT).

Additionally, when handling wideband signals, if spurious is generated close to the input signal, there is a risk of spurious overlapping the wanted signal as shown in Figure 5.

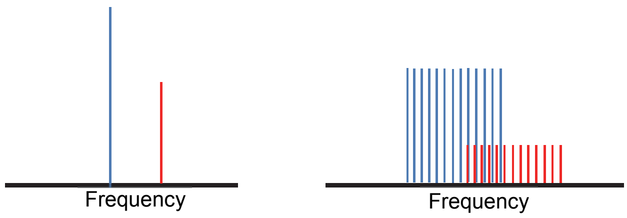

Figure 5 CW Signal and Modulated Signal Spurious

Using the High Performance Waveguide Mixer reduces spurious caused by the LO through filtering in the internal LO path. As described later, the image response can be evaded using the PS function while other spurious types are kept at –50 dBc or below.

4 Extended External Mixer Functions

4.1 Correction Functions

The existing external mixer function did not correct frequency response; instead, the user performed evaluations that included the measurement system performance. The extended MS2830A external mixer function improves usability by the addition of the following correction functions.

(1) Conversion Loss Correction

Previously, the conversion loss value was determined only by a single fixed value for the mixer being used, and by the mixer frequency response. This function extension adds Fixed and Table modes to the MS2830A. The Table mode can be used when the MS2830A is combined with the MA2806A/08A.

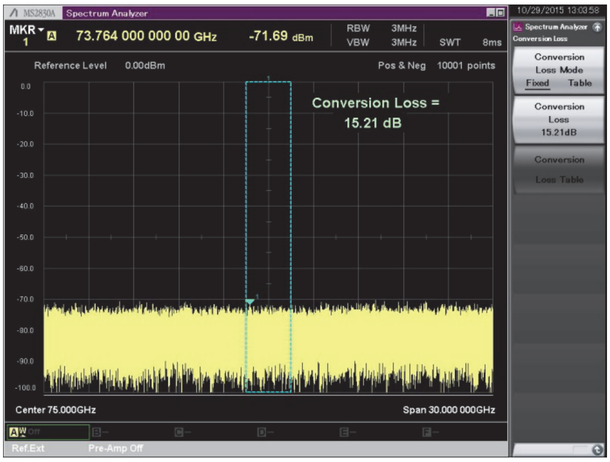

Figure 6 Setting Fixed Conversion Loss

In Table mode, the conversion loss of the connected High Performance Waveguide Mixer is input to correct the mixer frequency response. The conversion loss table data can be loaded automatically into the MS2830A from a USB memory stick provided with the MA2806A/08A.

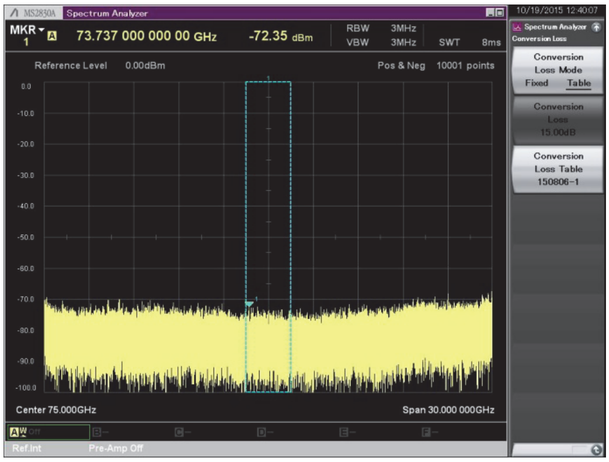

Figure 7 Setting Conversion Loss Table

(2) Cable Loss Correction

Using the High Performance Waveguide Mixer in combination with the MS2830A supports adjustment of the previously described Conversion Loss function parameters. However, the loss in the cable connecting the MS2830A and the High Performance Waveguide Mixer is not corrected. The user can check the predetermined loss of the connection cable through a power meter, and the measurement results can be corrected by inputting this value to the Cable Loss correction function.

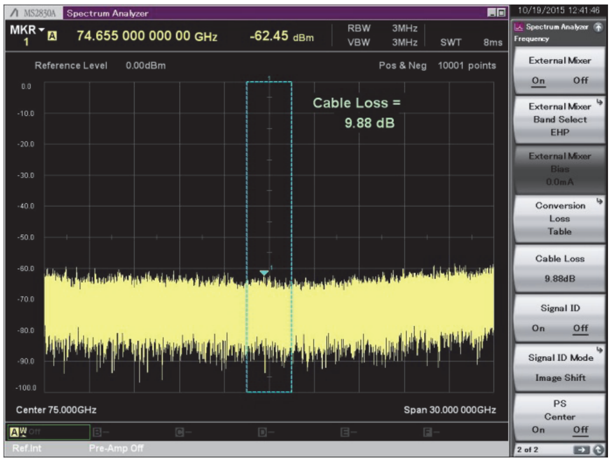

Figure 8 Setting Cable Loss

(3) User Correction

The MS2830A has a basic User Correction function that corrects the frequency response of external modules (attenuators, antennas, etc.) not covered by other correction functions; it can be enabled even when using external mixer functions.

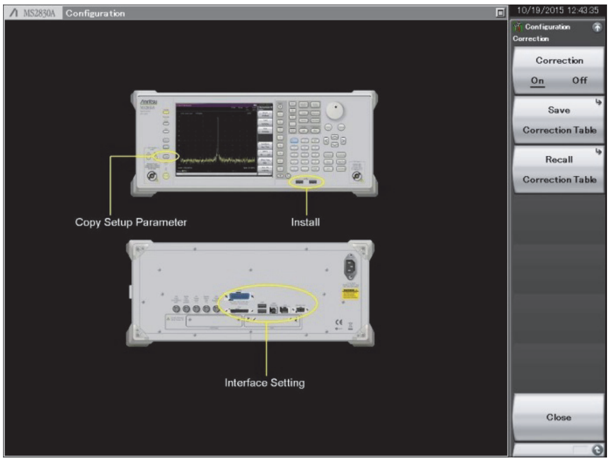

Figure 9 Setting User Correction

4.2 Extended Signal ID Function

When using the existing Signal ID function (Image Shift mode), the mixer response changes with each sweep and the displayed position of the spurious caused by the measurement system drifts. Figures 10 and 11 show the results for each mixer response when using the Signal ID function (Figure 12 shows the trace results for both conditions).

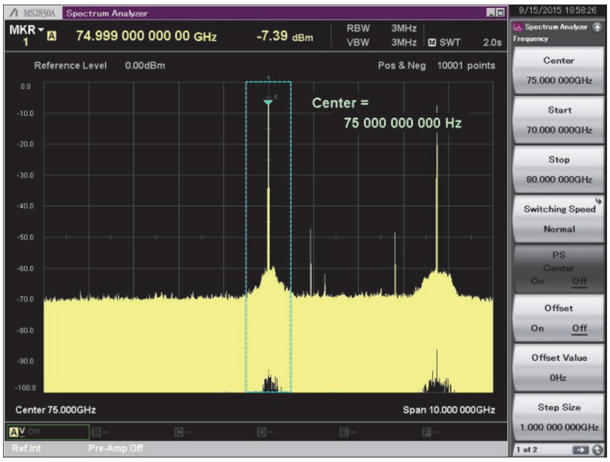

Figure 10 First Signal ID Function Sweep

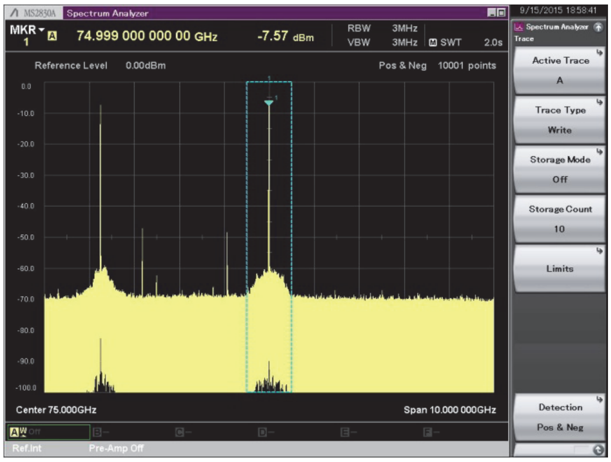

Figure 11 Second Signal ID Function Sweep

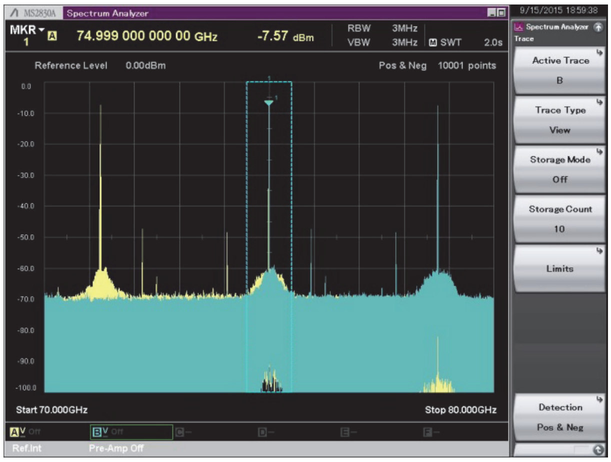

Figure 12 Signal ID Function Trace

The other existing Signal ID function (Image Suppress mode), as mentioned before, uses Min. Hold processing of these results to remove display of spurious caused by the measurement system. However, measurement results are not displayed correctly at RMS detection, etc., due to the Min. Hold processing.

The new PS function changes the mixer response at the screen display center frequency to perform measurement without spurious caused by the measurement system. As a result, it can be used together with the various Measure functions, which was impossible with previous Signal ID functions.

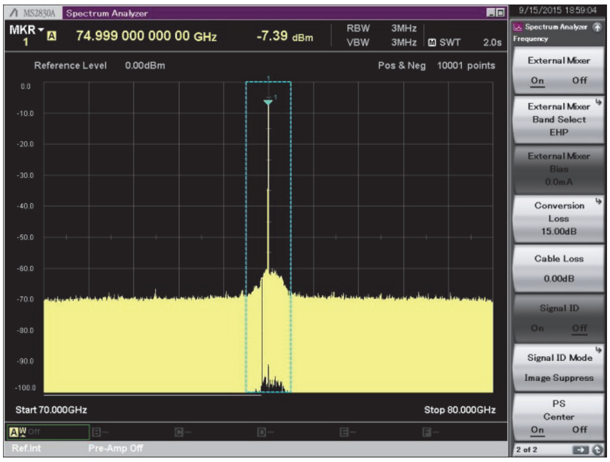

Figure 13 PS Function Sweep

4.3 Calibration Function for External Mixer Connection Port

Since the previous External Mixer function does not perform level correction for the port used to connect the external mixer, the displayed level may be incorrect.

Adding a function for correcting the level at the connected external mixer connection port improves the accuracy of the displayed level.

Using this function, inputting a CW signal (1875 MHz) corrected to a level of –20 dBm with a power meter to the external mixer connection port corrects the level at the port. Figure 14 shows the measurement results after executing the External Mixer Calibration function.

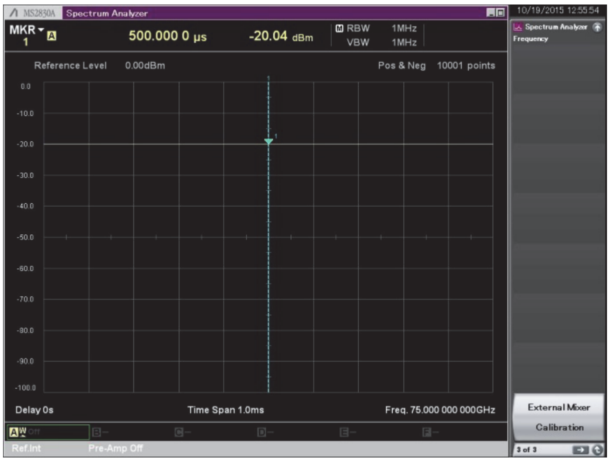

Figure 14 External Mixer Calibration Function

The External Mixer Calibration function is useful when requiring more accurate level measurements when using the High Performance Waveguide Mixer.

4.4 Signal Analysis Function

The spectrum analyzer Measure functions and signal analyzer functions can be used when using the High Performance Waveguide Mixer. The existing Measure functions support SEM measurement, OBW measurement, and TOI measurement. In addition, Chirp signals, etc., can be analyzed using the signal analyzer functions. Since most Measure functions require measurements using RMS detection, they cannot be used with the existing Signal ID functions. Adding the new PS function allows the use of the Measure functions alongside the High Performance Waveguide Mixer, increasing the usability for mm-Wave measurements. Figure 15 shows the results of SEM measurement using the external mixer function as an example of measurement using a Measure function.

Figure 15 SEM Measurement (IEEE802.11ad)

4.5 Phase Noise Measurement Function

Installing the Phase Noise Measurement function option (Opt-010) in MS2830A allows phase noise measurements. This Phase Noise Measurement function can also be used with the High Performance Waveguide Mixer. Consequently, phase noise performance is easily measured in the V-band (50 GHz to 75 GHz) and E-band (60 GHz to 90 GHz).

The MS2830A phase noise performance for a center frequency of 1 GHz is –95 dBc/Hz at an offset of 10 kHz, and –113 dBc/Hz at an offset of 100 kHz. For phase noise measurements using the High Performance Waveguide Mixer, the 20*log (multiplier) [dB] performance may be degraded depending on the configuration of the internal multiplier circuit of each model. Since the MA2806A uses an 8x multiplier circuit configuration, the phase noise performance is degraded by about 18 dB. The MA2808A performance is degraded by about 22 dB due to the 12x multiplier circuit. Figure 16 shows an example of the phase noise measurement results when using the High Performance Waveguide Mixer.

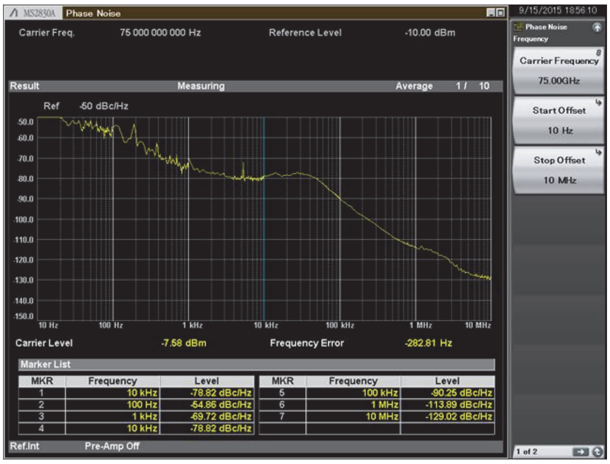

Figure 16 Measured Phase Noise for Input CW 75 GHz Signal

5 Main Specifications

Table 1 shows the main MA2806A/08A specifications.

6 Conclusion

The mm-Wave band is essential for high-speed wireless transmission systems exceeding 1 Gbps and development of mm-Wave applications is being pursued actively to achieve even faster wireless transmission systems. We have developed this High Performance Waveguide Mixer and extended the external mixer functions to meet the measurement requirements for mm-Wave applications and play a role in future commercialization of mm-Wave products and services.

References

1) Fixed Radio Systems; Point-to-Point equipment; Radio equipment and antennas for use in Point-to-Point Millimeter wave applications in the Fixed Services (mmwFS) frequency bands 71 GHz to 76 GHz and 81 GHz to 86 GHz, ETSI TS 102 524, V1.1.1 (2006-07)

2) Fixed Radio Systems; Point-to-Point equipment; Radio equipment and antennas for use in Point-to-Point High Density applications in the Fixed Services (HDFS) frequency band 64 GHz to 66 GHz, ETSI TS 102 329, V1.2.1 (2007-06)

3) Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, Amendment 3: Enhancements for Very High Throughput in the 60 GHz Band, IEEE Standard 802.11ad-2012, 2012

4) Y. Kimura, M. Fuse, A. Otani, "Millimeter Wave Spectrum Analyzer with Built-in >100 GHz Preselector", ANRITSU TECHNICAL REVIEW No. 23 (2015.9)

5) CQ Publishing, "わかるマイクロ波通信システム", RF ワールド No.19 (in Japanese)

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Table 1 MA2806A/08A High Performance Waveguide Mixer Specifications

Electrical Characteristics

	MA2806A	MA2808A
Applicable Model	MS2830A-044, MS2830A-045	
Frequency Range	50 GHz to 75 GHz	60 GHz to 90 GHz
LO Amplitude Range	>+10 dBm	
Multipler	8	12
Conversion Loss*	<15 dB	
1 dB Gain Compression (P1dB)*	>0 dBm	
LO Leakage	<–30 dBm (nom.)	
RF Input VSWR	<1.5 (nom.)	
IF/LO Port VSWR	<2.0 (nom.) 1.875 GHz for IF <2.0 (nom.) 5 GHz to 10 GHz for LO	<2.0 (nom.) 1.875 GHz for IF <2.4 (nom.) 5 GHz to 10 GHz for LO
Maximum Input Level (CW)	+10 dBm	

*: At assured performance temperature range

Interfaces

RF	Wave Guide (WR15)	Wave Guide (WR12)
IF/LO	SMA	

Environmental Performance

Temperature Range	Assured performance range: 18° to 28°C
	Operating: 5° to 45°C (no condensation)
	Storage: –20° to 60°C (no condensation)
EMC	EN61326-1, EN61000-3-2:+A1:+A2

Case

Dimensions	51 mm (H) × 134 mm (W) × 229 mm (D)
Mass	<2 kg

Power

Power Supply	AC 100 V to AC 240 V, 50 Hz/60 Hz, 40 VA