IEC TR 63352

Edition 1.0 2022-04

TECHNICAL REPORT

colour inside

Transmitting and receiving equipment for radiocommunication – Radio spectrum measurement method – 300-GHz spectrum measurement equipment

IEC TR 63352:2022-04(en)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC TR 63352

Edition 1.0 2022-04

TECHNICAL REPORT

colour inside

Transmitting and receiving equipment for radiocommunication – Radio spectrum measurement method – 300-GHz spectrum measurement equipment

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 33.060.20

ISBN 978-2-8322-1096-0

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

TRANSMITTING AND RECEIVING EQUIPMENT FOR RADIOCOMMUNICATION – RADIO SPECTRUM MEASUREMENT METHOD – 300-GHz SPECTRUM MEASUREMENT EQUIPMENT

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.

3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.

6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.

8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TR 63352 has been prepared by IEC technical committee 103: Transmitting equipment for radiocommunication. It is a Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
103/206/DTR	103/223/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This document describes a high-dynamic-range spectrum measurement system to measure spectra in the frequency range 140 GHz to 300 GHz. Although millimeter-wave (mmWave) technology has high potential for both industries and users, there are no developed techniques for evaluating spectra suppressing the unwanted response generated in the measurement system. In addition, the commercialized spectrum analyser for this frequency band cannot accurately measure low power input signals due to the insufficient dynamic range while high power signals are input to the spectrum analyser simultaneously. This document describes the high-dynamic-range spectrum measurement system with low unwanted response for measuring spectra in the frequency range 140 GHz to 300 GHz, and proposes an mmWave pre-selector to suppress the unwanted response generated in the measurement system.

TRANSMITTING AND RECEIVING EQUIPMENT FOR RADIOCOMMUNICATION – RADIO SPECTRUM MEASUREMENT METHOD – 300-GHz SPECTRUM MEASUREMENT EQUIPMENT

1 Scope

This document specifies spectrum measurement methods in the frequency range 140 GHz to 300 GHz. This document also provides background information, describes system configurations, key mmWave pre-selector technology, as well as some examples of the spurious measurement of antennas under test (AUTs) over the air.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.2 Abbreviated terms

mmWave	millimetre-wave
ACLR	adjacent channel leakage power ratio
ATT	attenuator
AUT	antenna under test
DANL	displayed average noise level
DUT	device under test
FCC	Federal Communications Commission
FOD	foreign object debris
IF	intermediate frequency
IR	infra-red
LIDAR	light detection and ranging
LO	local oscillator
OOK	on-off-keying
OTA	over the air
PC	personal computer
PHY	physical layer
QAM	quadrature amplitude modulation

RBW	resolution bandwidth
RF	radio frequency
SHM	sub-harmonic mixer
SPA	spectrum analyser
TE mode	transverse electric mode
TOI	third-order intercept
YIG filter	yttrium-iron-garnet filter
WRC	World Radiocommunication Conference

4 Background to measurement up to 300 GHz

4.1 IEEE Std 802.15.3d

The IEEE SA Standards Board approved the first edition of the IEEE Std 802.15.3 standard on March 15, 2016; it was also adopted and approved by the ISO/IEC national bodies. There are three amendments to IEEE Std 802.15.3. IEEE Std 802.15.3d-2017 (Amendment 2) considers non-coherent OOK and coherent QAM up to 64 on the 300-GHz band. Two PHY modes are defined that enable data rates of up to 100 Gb/s using eight different bandwidths between 2,16 GHz and 69,12 GHz. The current frequency plan is depicted in Figure 1, although it considers a broad range of possible channel allocations.

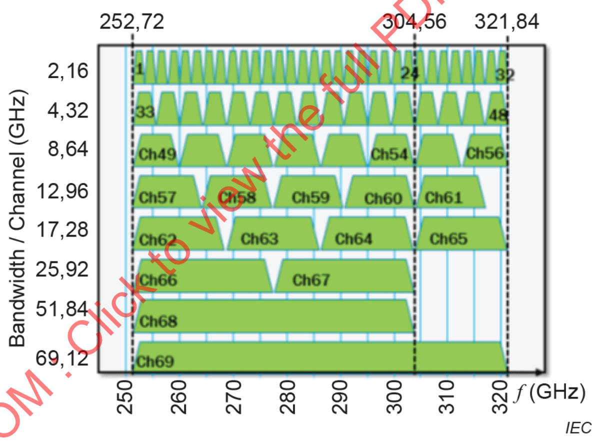


Figure 1 – IEEE Std 802.15.3d-2017 (Amendment 2) frequency plan

4.2 FOD radar

After the Air France Concorde crash in 2000, which was caused by engine ingress of runway debris, airport operators focused on the use of foreign object debris (FOD) detection systems. Several technologies, such as cameras, IR, LIDAR, and other sensors are being tested. One candidate is the mmWave radar because it can detect small metallic objects using converted automotive radar in the 77-GHz band. If the system requires finer resolution, the 92-GHz to 100-GHz band for radio location services should be used for the purpose.

4.3 Experimental frequency license above 95 GHz

The Federal Communications Commission (FCC) announced new rules to encourage the development of new communication technologies and expedite the deployment of new services in the spectrum above 95 GHz, such as data-intensive, high-bandwidth applications, as well as imaging and sensing operations. To enable innovators and entrepreneurs to readily access this spectrum, the Spectrum Horizons First Report and Order creates a new category of experimental licenses for use of frequencies between 95 GHz and 3 THz. These licenses will give innovators the flexibility to conduct experiments lasting up to 10 years, and to more easily market equipment during the experimental period.

4.4 ITU WRC-19 agenda item 1.15

Agenda item 1.15 covers the identification of frequency bands for use by administrations for land-mobile and fixed services applications operating in the 275-GHz to 450-GHz frequency range.

The 275-GHz to 296-GHz, 306-GHz to 313-GHz, 318-GHz to 333-GHz, and 356-GHz to 450-GHz frequency bands are identified for land-mobile and fixed service applications, where no specific conditions are necessary to protect Earth exploration-satellite service (passive) applications.

The 296-GHz to 306-GHz, 313-GHz to 318-GHz, and 333-GHz to 356-GHz frequency bands may only be used by land-mobile and fixed service applications when specific conditions to ensure protection of Earth exploration-satellite service (passive) applications are determined in accordance with Resolution 731 (Rev.WRC-19).

In those parts of the 275-GHz to 450-GHz frequency range where radio-astronomy applications are used, specific conditions (e.g. minimum separation distances and/or avoidance angles) may be necessary to ensure protection of radio-astronomy sites from land-mobile and/or fixed service applications on a case-by-case basis in accordance with Resolution 731 (Rev.WRC-19). Use of the above-mentioned frequency bands by land-mobile and fixed service applications does not preclude the use by, and does not establish priority over, any other applications of radio services in the 275-GHz to 450-GHz range.

4.5 Issue of conventional spectrum measurement for mmWave

Unwanted responses in the spectrum-analyser RF front-end prevent accurate spectrum observation of target signals. There are three main unwanted responses. The first is image response, which occurs when a signal is input to the spectrum analyser at the image frequency. The second is multiple response. The frequency components | m * RF frequency – n * Local frequency | (where m and n are integers) occur due to spectrum-analyser circuit non-linearity. The multiple response occurs when the frequency of the components equals the IF frequency. The third is residual response, which occurs due to multiples of internal frequency components, such as local oscillator frequency and local oscillator intermediate frequency. A pre-selector can be used to suppress image response. (The two other unwanted responses can be suppressed by frequency design.) However, there is no tunable pre-selector like a YIG filter for frequencies above 80 GHz. Figure 2 shows the results of observing a signal using a spectrum analyser without a pre-selector. Unwanted responses can be seen in addition to the wanted signal, making it difficult to recognize the wanted signal.

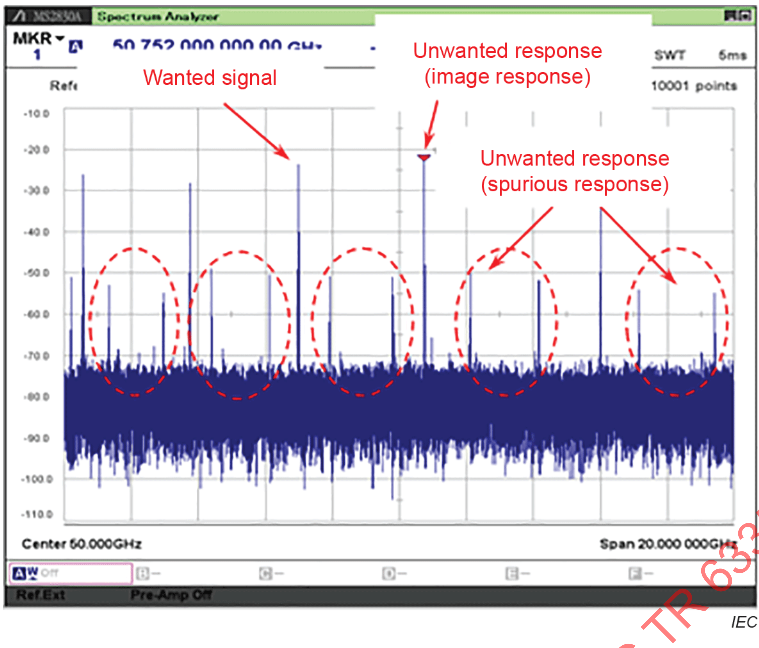


Figure 2 – Spectrum observed by spectrum analyser without pre-selector

5 300-GHz band spectrum measurement

5.1 Overview

The 300-GHz spectrum analyser supports signals from 140 GHz to 300 GHz; the 160-GHz bandwidth is split into three bands and each band is covered by a spectrum analyser. Table 1 shows mmWave frequency band for G-band, H-band and J-band.

Table 1 – Frequency bands covered by spectrum analyser

Frequency [GHz]	140 to 190	185 to 260	255 to 315
Band	G-band	H-band	J-band
Waveguide	WR-5	WR-4	WR-3

Figure 3 shows the external appearance of the J-band spectrum analyser and signal source used for evaluation. The target specifications for the J-band spectrum analyser are given in Table 2.

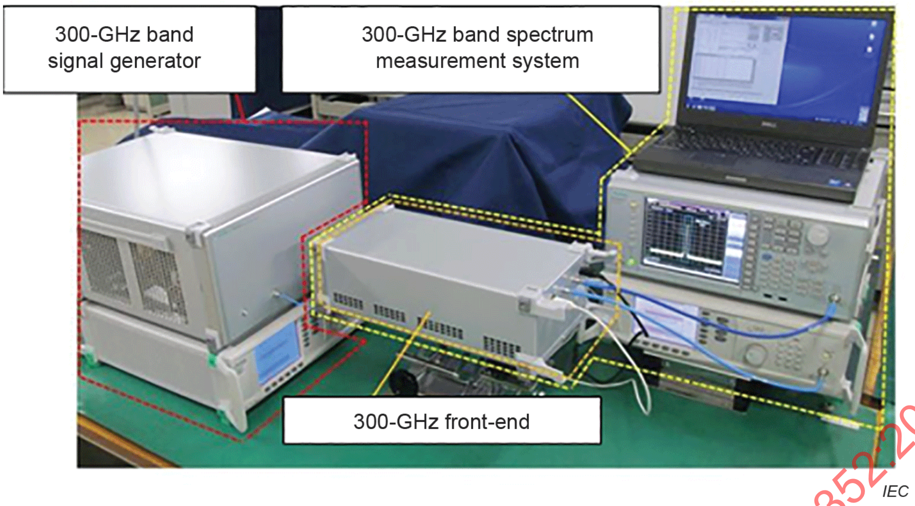


Figure 3 – External appearance of 300-GHz band spectrum analyser

Table 2 – J-band spectrum analyser target specifications

Frequency band	255 GHz to 315 GHz
Unwanted response	< –60 dBc at –15 dBm input
Displayed average noise level	< –130 dBm/Hz
Third-order intercept point	> +15 dBm

5.2 300-GHz spectrum analyser configuration

A standard spectrum analyser is composed of an RF front-end including a pre-selector and mixer, a local oscillator, an IF processing part, and the display as shown in Figure 4.

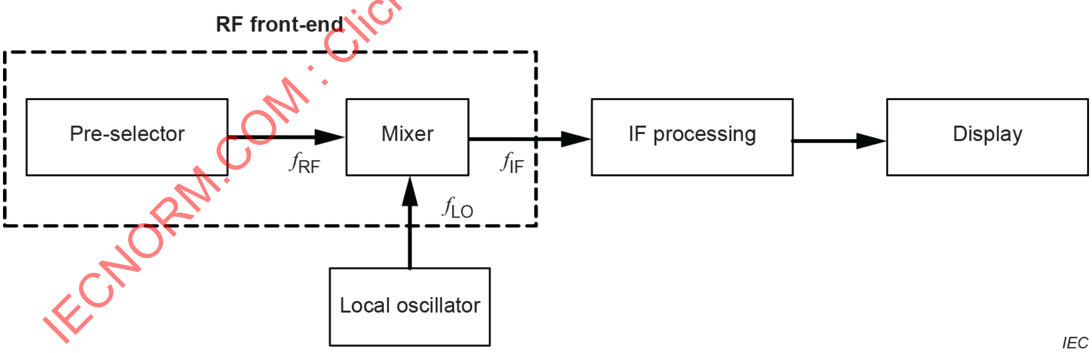


Figure 4 – Standard spectrum analyser configuration

There are two options for generating local signals above the 100-GHz band. Figure 5 shows the configuration for generating an optical local signal, and Figure 6 shows the configuration for generating an electrical local signal.

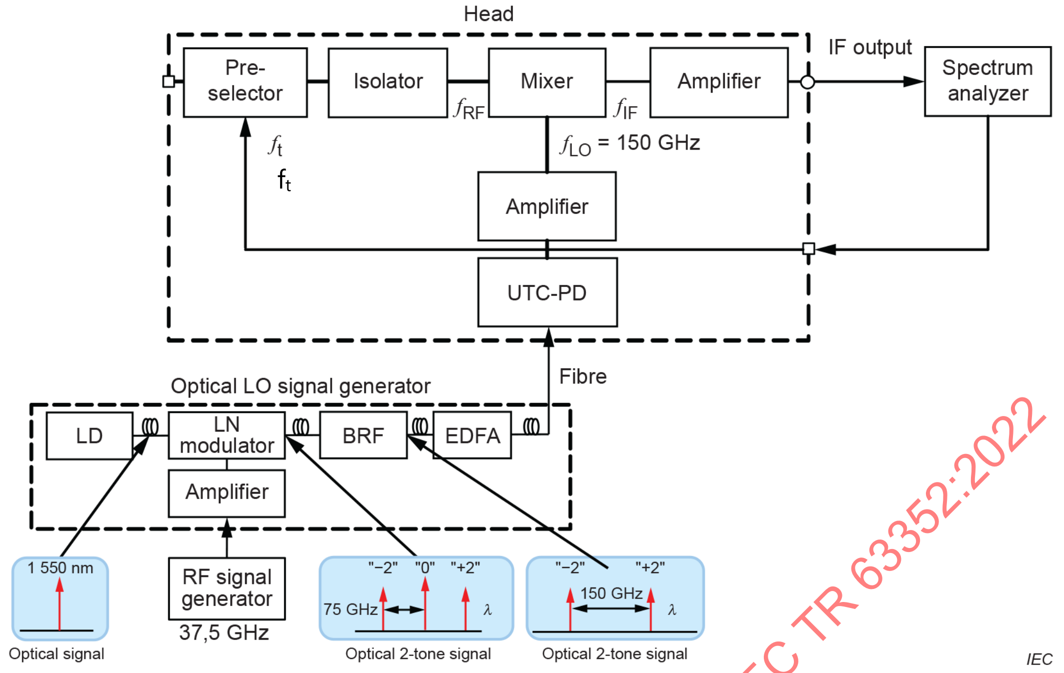


Figure 5 – 300-GHz spectrum analysis system with optical local signal generation

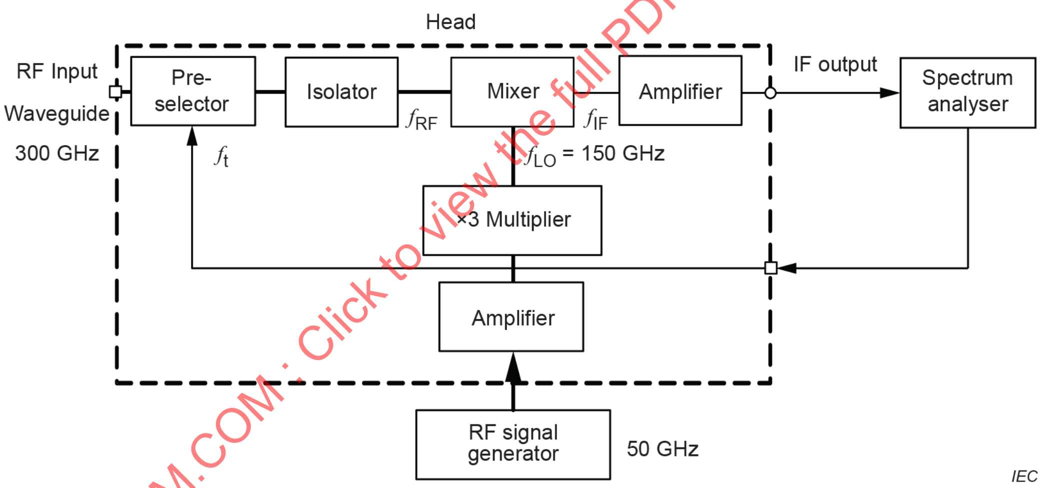


Figure 6 – 300-GHz spectrum analysis system with electrical local signal generation

Table 3 compares these methods for generating the spectrum-analyser local signal. Optical local signal generation has the advantage, from a frequency extendibility perspective, while other performances are similar. Future discussions are based on a system using electrical local signal generation based on the cost advantage.

Table 3 – Comparison of two local signal generation methods

	SPA with electrical LO oscillator	SPA with electrical optical LO oscillator	Comment
Dynamic range	++	++	Equivalent output level and local signal purity
Measurement speed	++	+	Takes time to switch frequency
Frequency extendibility	++	+++	Optical method easier to extend frequency range
Footprint	+++	++	Equivalent head size but optical method needs extra box
Cost	++	+	Electrical: Optical = 1:1.5
Key +: Average ++: Good +++: Excellent			

5.3 mmWave pre-selector

Figure 7 shows a standard spectrum-analyser configuration. Distortion components occur due to the use of non-linear parts, such as the mixer and amplifier, and are displayed as spurious in the spectrum.

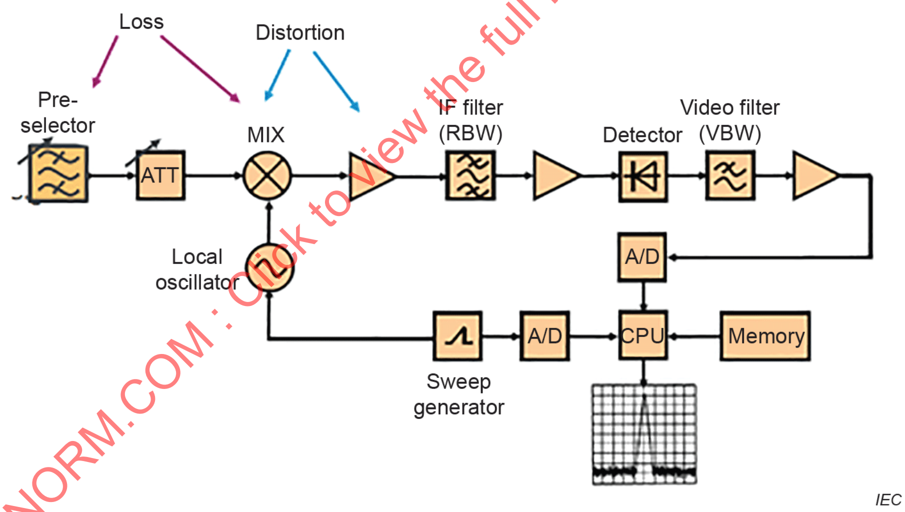


Figure 7 – Standard spectrum-analyser configuration

As explained in 4.5 a pre-selector can suppress image responses. Fomula (1) shows the frequency relationship of the local signal, RF signal, and IF signal, where the frequencies of the IF signal, RF signal, and local signal are expressed as f_{IF}, f_{RF}, and f_{LO}, respectively.

$$f_{\mathrm{IF}} = f_{\mathrm{RF}} - f_{\mathrm{LO}} \tag{1}$$

Fomula (2) shows the relationship for the image frequency f_{IMG} and Figure 8 shows the relationship of each frequency component. When the component f_{IMG} is input to the spectrum analyser, a pseudo-response is observed, making it difficult to separate the wanted response due to f_{RF} and pseudo-response due to f_{IMG}.

$$f_{IMG} = 2 \times (f_{LO} - f_{RF}) \quad (2)$$

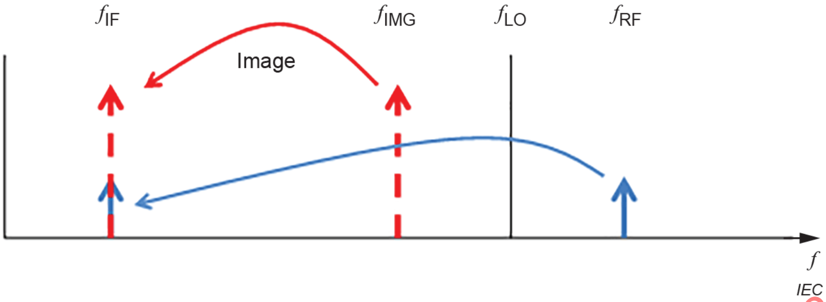


Figure 8 – Image response mechanism

Since the non-linear parts, such as the mixer and amplifier, generate harmonic components, higher-order image response components are represented by Formula (3).

$$f_{IMG} = (m \times f_{RF}) - (n \times f_{LO}) \quad (3)$$

The pre-selector is key to reducing spurious response displayed on the spectrum analyser because it suppresses image responses.

Figure 9 shows the conventional pre-selection method for the mmWave band. Figure 10 shows a newly developed filter-bank-type pre-selector that is smaller with faster switching and lower insertion loss compared to the conventional method. Figure 11 shows the measured result of the filter bank; the insertion loss is less than 5 dB up to 315 GHz.

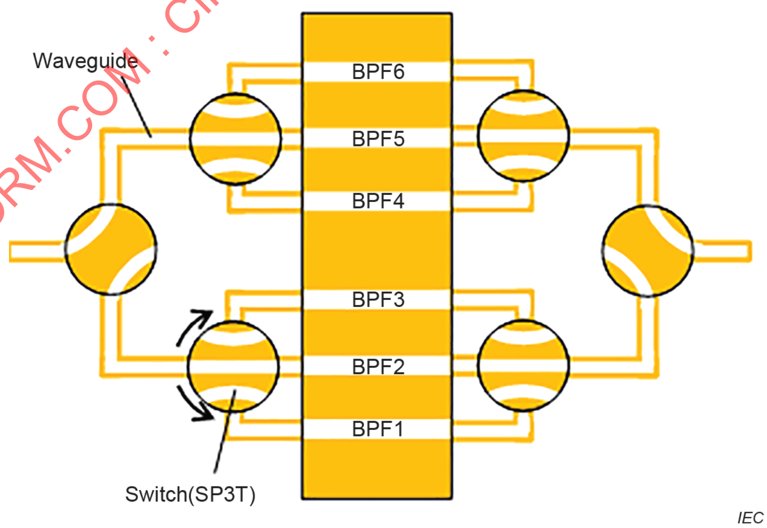


Figure 9 – Conventional preselection method

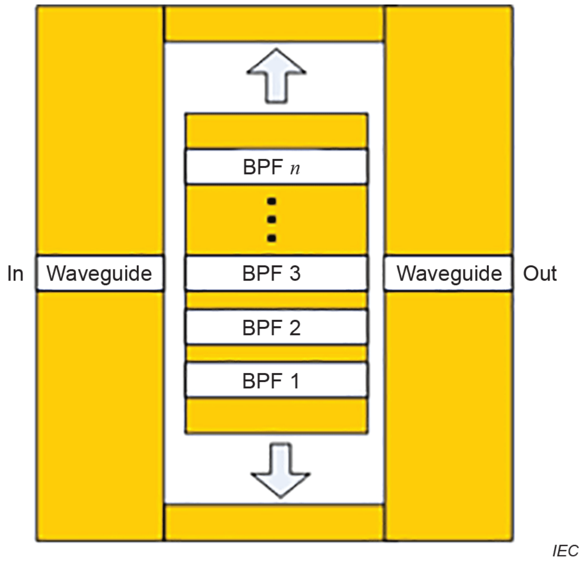


Figure 10 – Filter-bank type pre-selector

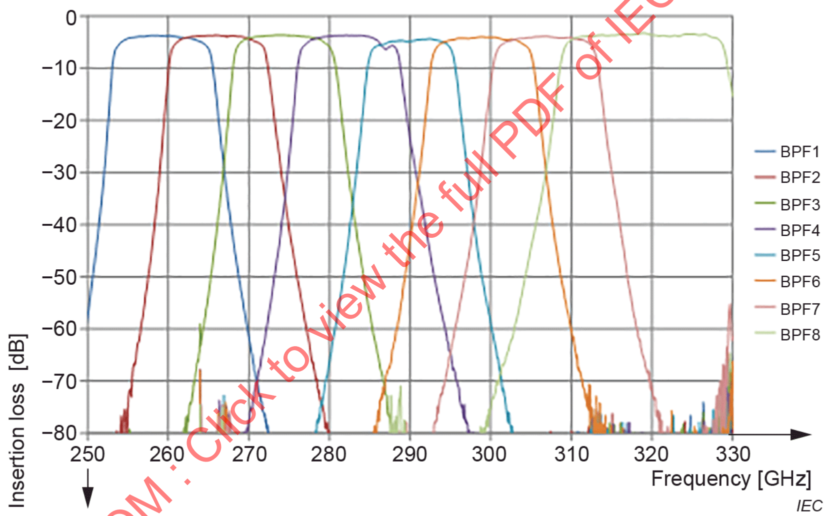


Figure 11 – Measurement results

5.4 Performance of mmWave spectrum analyser

5.4.1 General

Figure 12 shows the measurement system configured from a 300-GHz front-end, spectrum analyser, local signal source, and personal computer (PC). The front-end is configured from a pre-selector, sub-harmonic mixer (SHM), and IF amplifier to convert the input RF signal to the IF output. The part generating the local signal includes amplifiers, multipliers, and bandpass filters. The SHM is used for frequency down-conversion, and the IF frequency relationship is shown by Fomula (4).

$$f_{IF} = |f_{RF} - 2 \times f_{LO}| \tag{4}$$

The spectrum analyser processes the IF signal to display the spectrum on the PC.

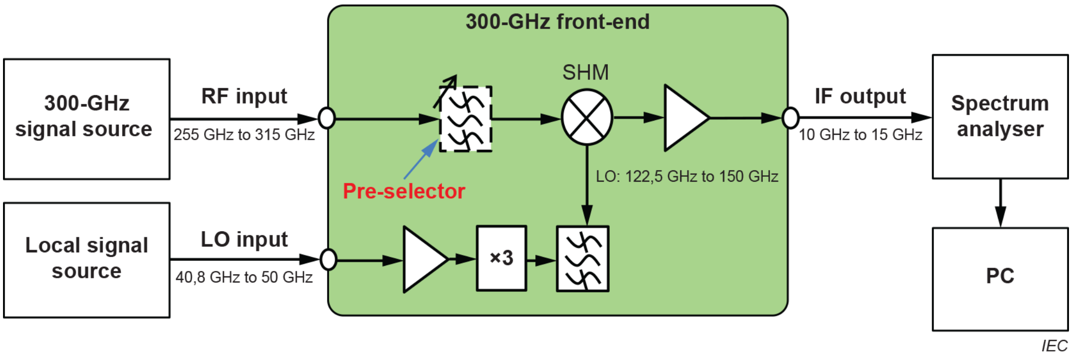


Figure 12 – Measurement set-up

5.4.2 Signal source for calibration and test

Figure 13 shows the set-up for the level calibration. The signal generator outputs a signal with a frequency of 42,5 GHz to 52,5 GHz to the frequency converter which multiplies the signal to 255 GHz to 315 GHz. The controller adjusts the level of the signal from the frequency converter to more than –15 dBm. The output signal level is measured simultaneously by the detector in the frequency converter and the calorimeter. The level can be copied from the calorimeter to the power meter by simultaneous measurement, supporting fast level calibration. Figure 14 shows the test signal source configuration. The calorimeter miminum detection range is −17 dBm, therefore ensuring a sufficient signal level to the calorimeter is important for improving measurement uncertainty. The minimum required output from the signal source is −15 dBm and an output of −8 dBm is ensured by the test signal source of the 300-GHz band power amplifier.

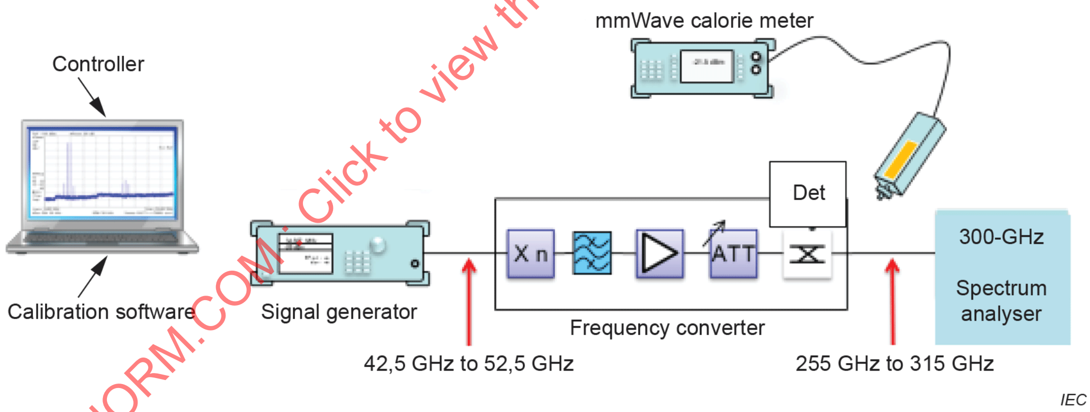


Figure 13 – System set-up for level calibration

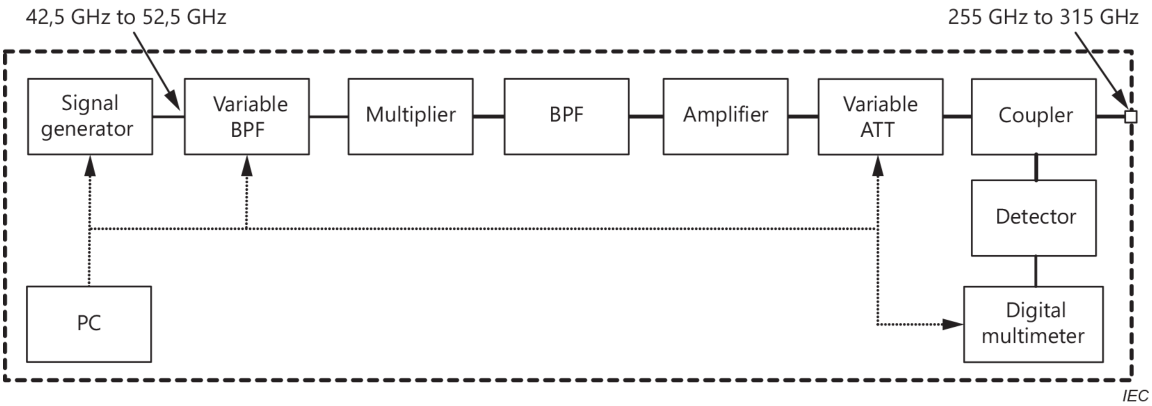


Figure 14 – Signal source for level calibration and evaluation

Figure 15 shows the output power when the output level is controlled to within −15 dBm ± 0,5 dB. Figure 16 shows the spurious level. The signal-source purity should be better than the target spectrum analyser spurious level. The spurious level is less than −70 dBc, which is 10 dB better than the spectrum analyser's unwanted response (Table 1). Consequently, the spurious performance is sufficient for the test signal source.

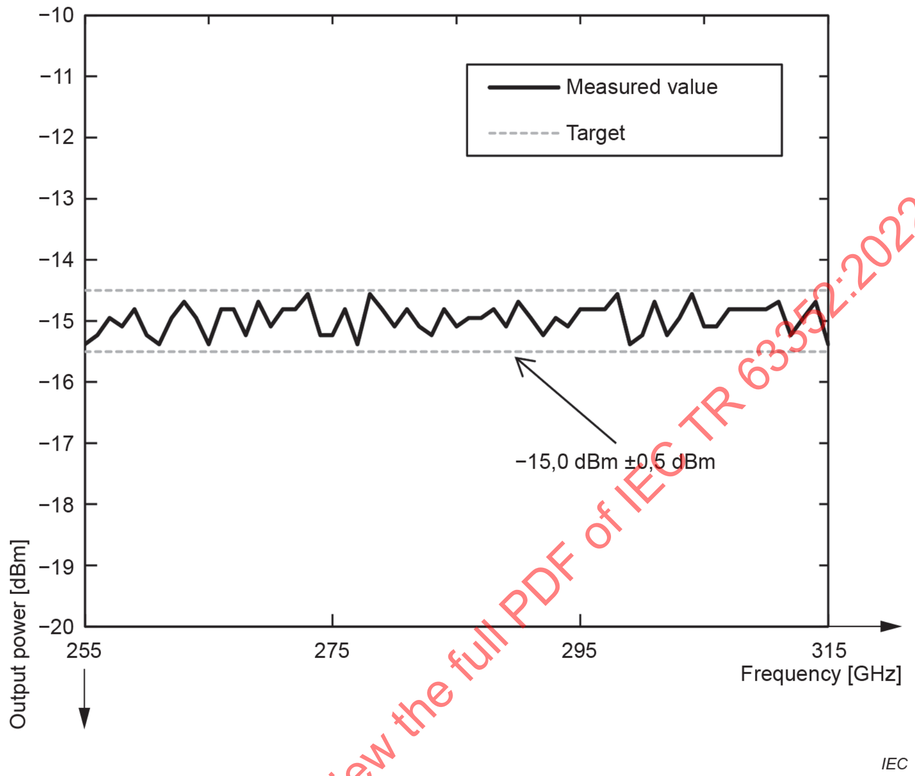


Figure 15 – Signal source output power

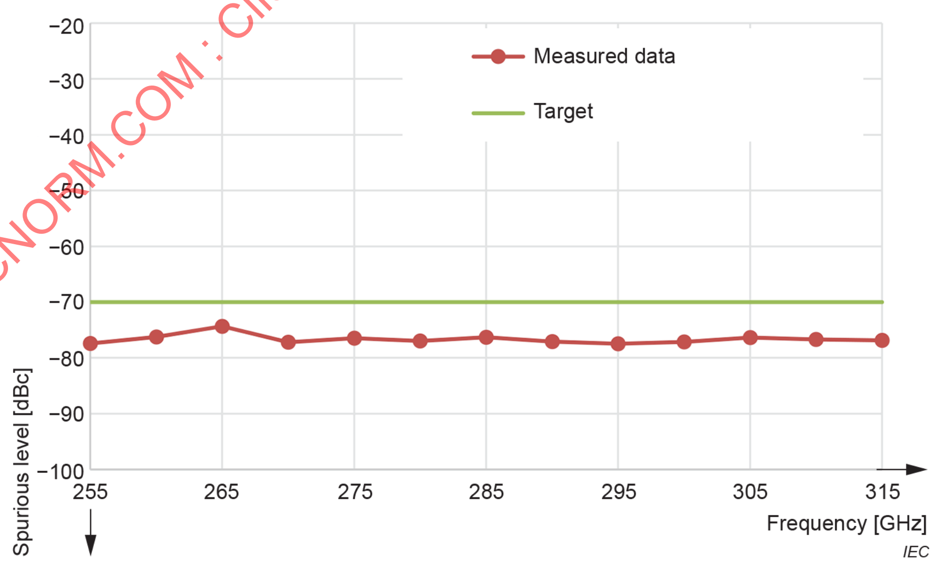


Figure 16 – Signal source spurious performance

5.4.3 Spectrum measurement

Figure 17 shows the spectrum measurement results. At an RBW of 1 MHz, the spectrum from 255 GHz to 315 GHz can be measured in 70 s.

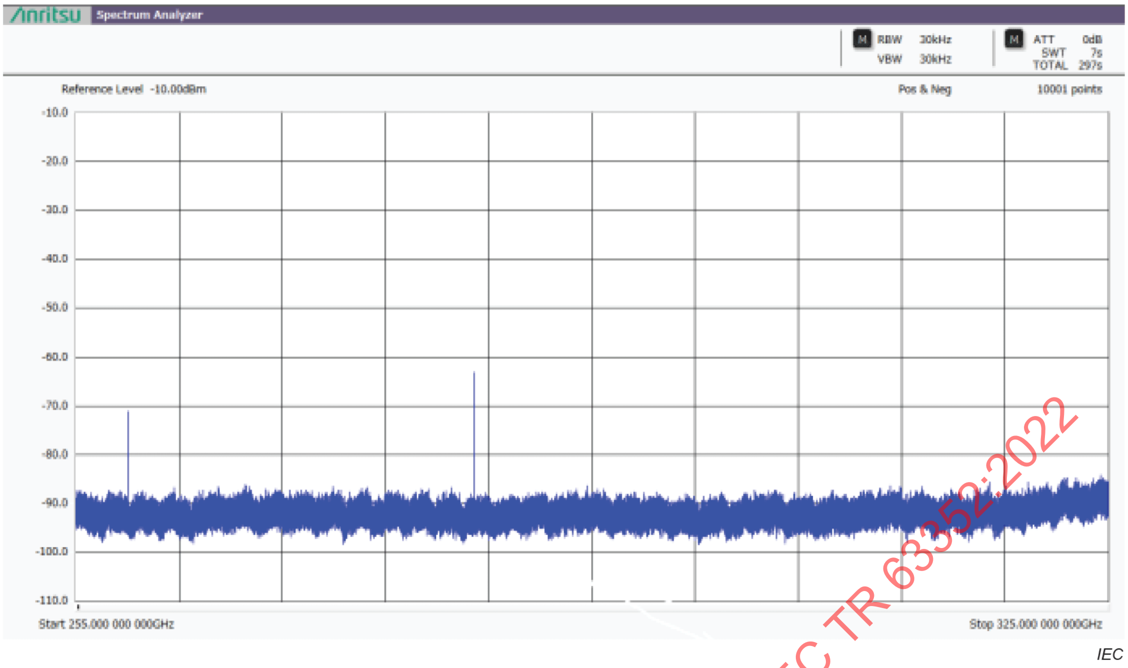


Figure 17 – Spectrum measurement result from 255 GHz to 315 GHz

5.4.4 Unwanted response

Figure 18 shows the relationship between the input RF frequency and the response due to higher-order distortion of the input RF signal and local signal. IM(m,n) represents the response of higher-order components due to the RF signal and local signal (Formula (5)). IM(1,2) is the target signal observed when f_{RF} is > 2 × f_{LO}. This frequency relationship is called the "local lower". The target signal's response is IM(1,2); the frequency for IM(1,2) is from 27 GHz to 29 GHz and depends on the observed signal frequency.

$$\text{IM}(m,n) = (m \times f_{RF}) - (n \times f_{LO}) \tag{5}$$

For example, f_{LO} is set to 142 GHz when observing 256 GHz. This is called the "local upper". Consequently, the target response is −IM(1,2). The spectrum is displayed at 256 GHz when the input signal frequency is 256 GHz. IM(1,2) is the image frequency at the "local lower" case. An image response occurs when observing 256 GHz with an input signal frequency of 312 GHz, so the spectrum is displayed at 256 GHz.

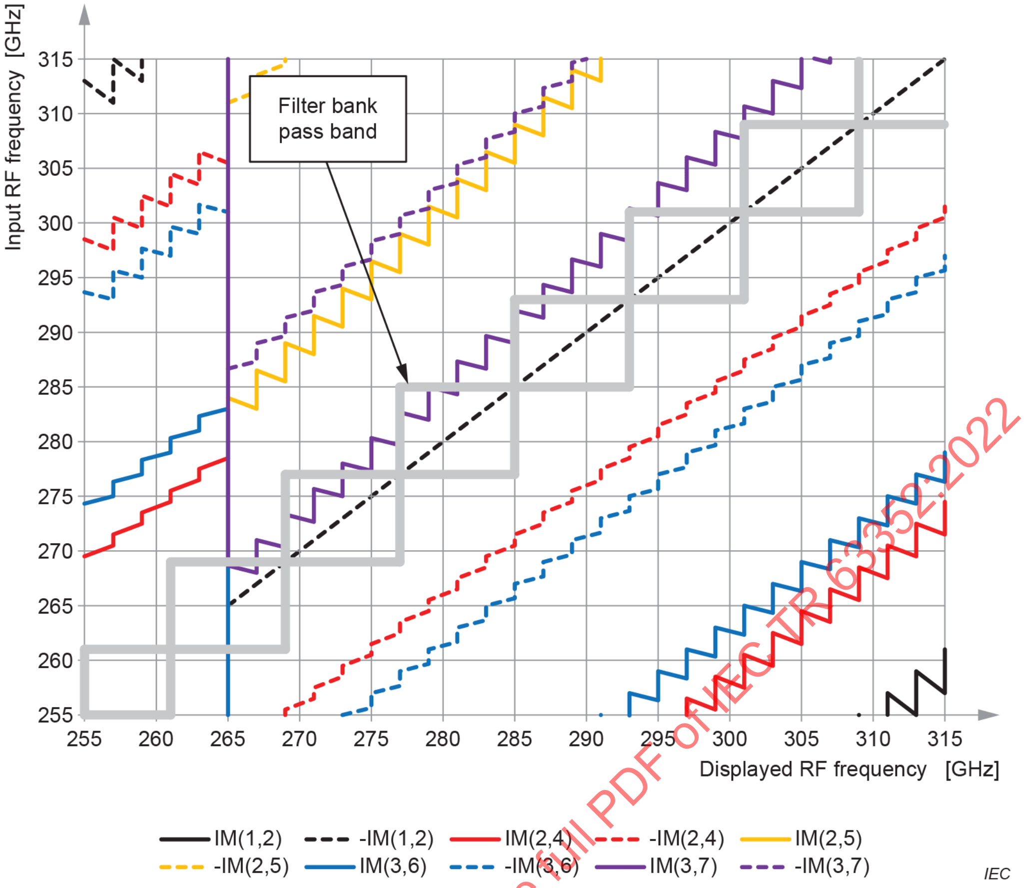
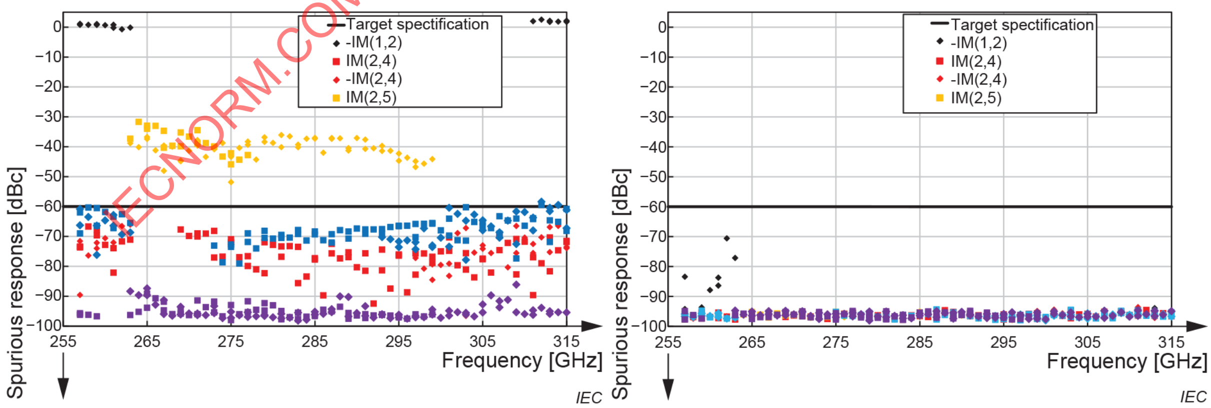


Figure 18 – Relationship between input RF signal and displayed frequency

Figure 19 compares the spurious response performance for each IM(m,n) component generated in the spectrum analyser. A typical spurious performance of –90 dBc is achieved across the full frequency band excluding the image component. The image response performance can be measured with and without the pre-selector, excluding the 265-GHz to 310-GHz band due to test set-up limits.



a) **Without pre-selector** b) **With pre-selector**

Figure 19 – Comparison of spurious response with and without pre-selector (RBW = 1 MHz, Detection = Positive/Negative)

5.4.5 Displayed average noise level

The displayed average noise level (DANL) is an important index of spectrum-analyser performance. Figure 20 shows the measured DANL for the J-band spectrum measurement system with no RF signal input. The measurement results when RBW = 300 Hz have been converted to RBW = 1 Hz. The worst DANL is −145 dBm/Hz.

Figure 20 – Displayed average noise level

5.4.6 Third-order intercept point

Non-linear circuits generate harmonic components. The third-order intercept (TOI) point is the value where the levels of the fundamental components and distortion are the same. Devices with a high TOI have high linearity performance. The combination of TOI and DANL determines the spectrum analyser dynamic range, so the balance is important. A spectrum analyser with better TOI can measure a signal with lower distortion. The TOI is important when observing the adjacent channel leakage power ratio (ACLR) of modern transmitters because the ACLR indicates the degree of interference with neighbouring channels. When measuring the ACLR using a spectrum analyser, the spectrum analyser's TOI performance should be better than the transmitter's distortion performance. Figure 21 shows the TOI definition. When two signals, f_1 and f_2, are input to a non-linear device, distortion signals are observed. The components, $2 \times f1 - f2$ and $2 \times f_2 - f_1$ are the third-order distortion components. Any increase (n) in the device fundamental level doubles ($2n$) the third-order distortion level.

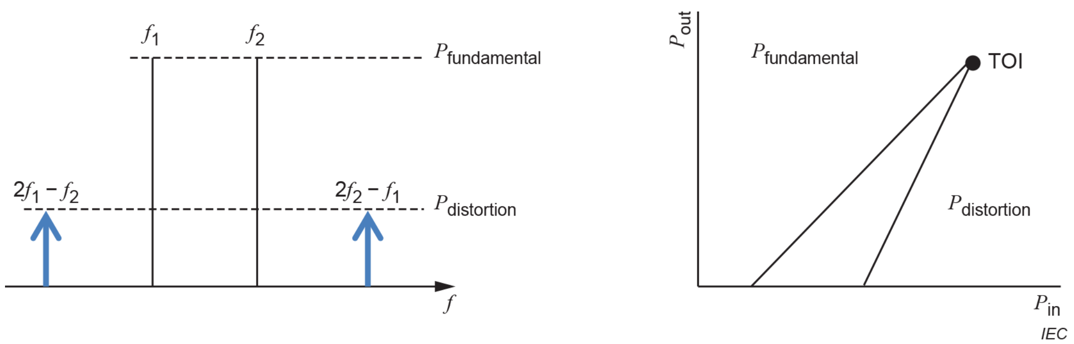


Figure 21 – Third-order intercept point

Figure 22 shows the measured TOI. The TOI performance at a frequency separation of 10 GHz is better than +23 dBm; at a frequency separation of 10 MHz, it is better than 10 dBm over the entire frequency range.

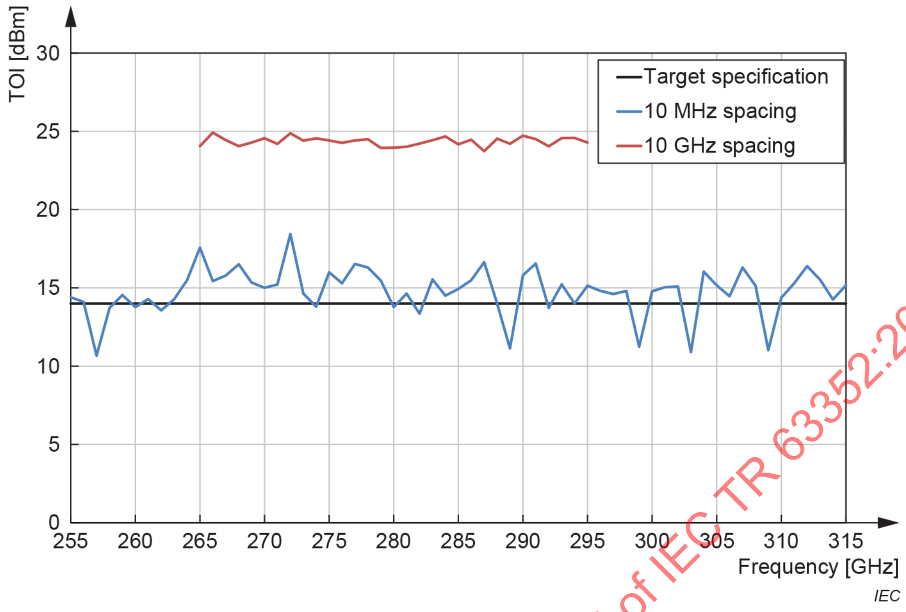


Figure 22 – TOI measurement results (Span 0 Hz, ATT 0 dB, RBW 300 Hz)

6 Spectrum analyser overall performance

6.1 General

Table 4 shows the overall performance of the spectrum analysis system from 140 GHz to 315 GHz. This document does not explain G-band and H-band spectrum analysers, but both have the same pre-selector type.

Table 4 – Frequency bands covered by spectrum analyser

Band	G-band	H-band	J-band
Frequency [GHz]	140 to 190	185 to 260	255 to 315
DANL [dBm/Hz]	< –142	< –140	< –144
TOI [dBm]	> +13	> +13	> +11
Waveguide	WR-5	WR-4	WR-3

6.2 Measurement examples

Figure 23 shows the configuration of the integrated spectrum measurement system. The purpose of spectrum measurement by the system is to both measure the occupied bandwidth of the fundamental wave component and to measure out-of-band unwanted emissions. The microwave band radio standards specify the device under test (DUT) T_X power and unwanted emission values at the antenna connector, but the number of the devices without antenna connector increases. Consequently, an integrated spectrum measurement system was configured consisting of assembled spectrum analysers to measure the spectrum over the air (OTA) for each band from 140 GHz to 315 GHz and the measurement system effectiveness was evaluated.

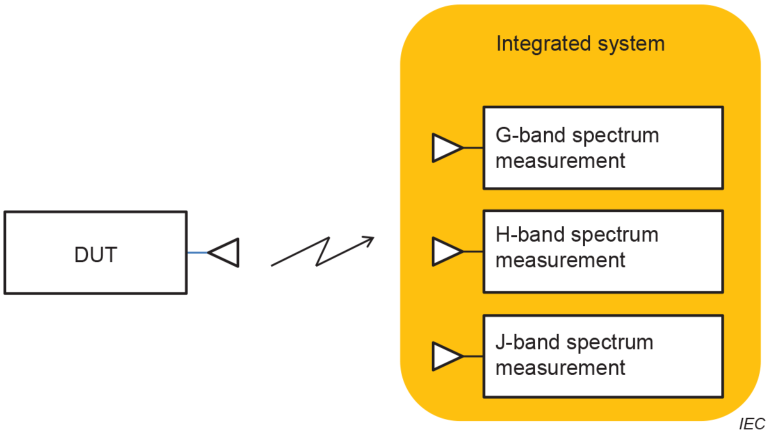


Figure 23 – Integrated spectrum measurement system

6.3 Integrated spectrum measurement system evaluation

The usability of the integrated spectrum measurement system was evaluated by comparing the propagation losses found from the theoretical fomula with the propagation loss calculated from the measured T_X power, antenna gain, and R_X power.

First, the integrated spectrum measurement system evaluation method is shown in Figure 24. A DUT was configured from a standard gain horn antenna and a signal source with a known T_X power for each of the G-, H-, and J-bands. Similarly, a standard gain horn antenna was connected to each spectrum analyser in the integrated spectrum measurement system. The propagation loss L_m was found from Fomula (6), derived from the Friis transmission formula, where G_t and G_r are the T_X and R_X antenna gain, respectively, and P_t and P_r are the T_X and R_X power, respectively.

$$L_m = P_r/(P_t \times G_t \times G_r) \tag{6}$$

On the other hand, L_t in the propagation loss theoretical formula for free space was calculated by Fomula (7), where λ is the wavelength and d is the distance between the T_X and R_X antennas.

$$L_t = (4\pi d/\lambda)^2 \tag{7}$$

The values of the propagation loss L_m found from Fomula (6), based on the measured R_X power, and of the propagation loss L_t found from Fomula (7) were compared.

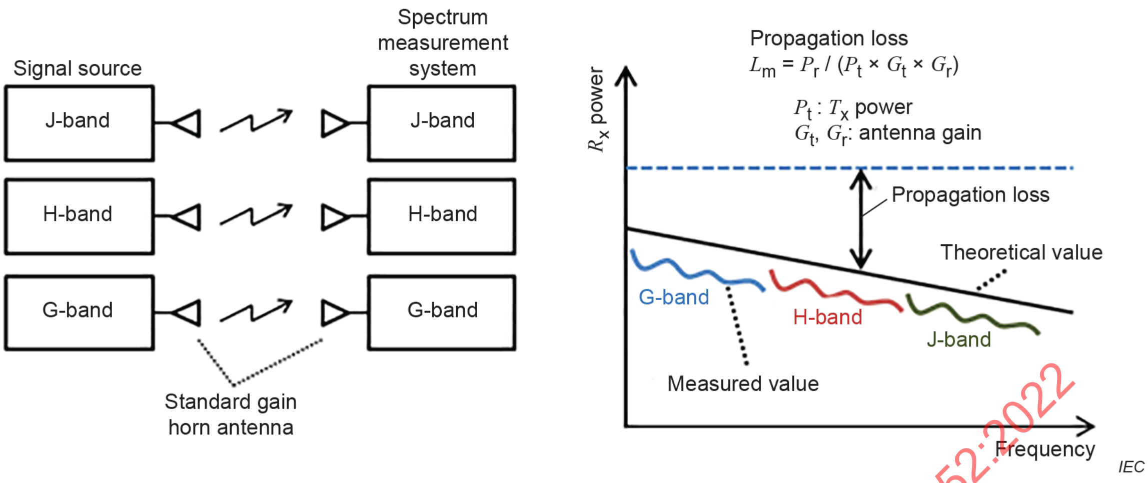


Figure 24 – Integrated spectrum measurement system evaluation

6.4 Propagation loss measurement results

Figure 25 shows the propagation loss measurement system for evaluating the integrated spectrum measurement system. The distance d between the T_X and R_X antennas at the signal source side and front-end side was 500 mm, which is a relatively short distance for the far-field region and is based on the antenna physical aperture. In addition, a radio-wave absorbent material was attached to the front face of the signal source and front-end to reduce the effect of the standing wave.

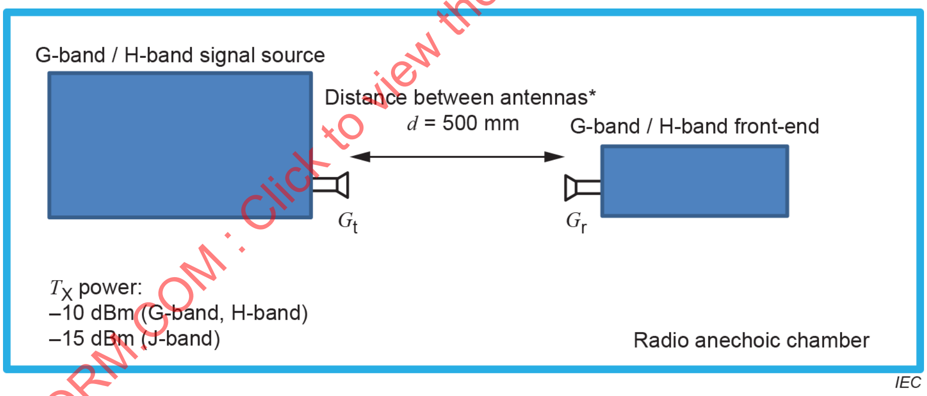


Figure 25 – Propagation loss measurement system

Table 5 – Standard gain horn antenna specifications

	Model	Frequency [GHz]	Gain [dB]	Aperture Dimensions W × H [mm]
G-band	HO5R	140 to 220	22 to 24	12,5 × 9,6
H-band	HO4R	170 to 260	22 to 24	10,6 × 8,1
J-band	HO3R	220 to 325	22 to 24	8,4 × 6,4

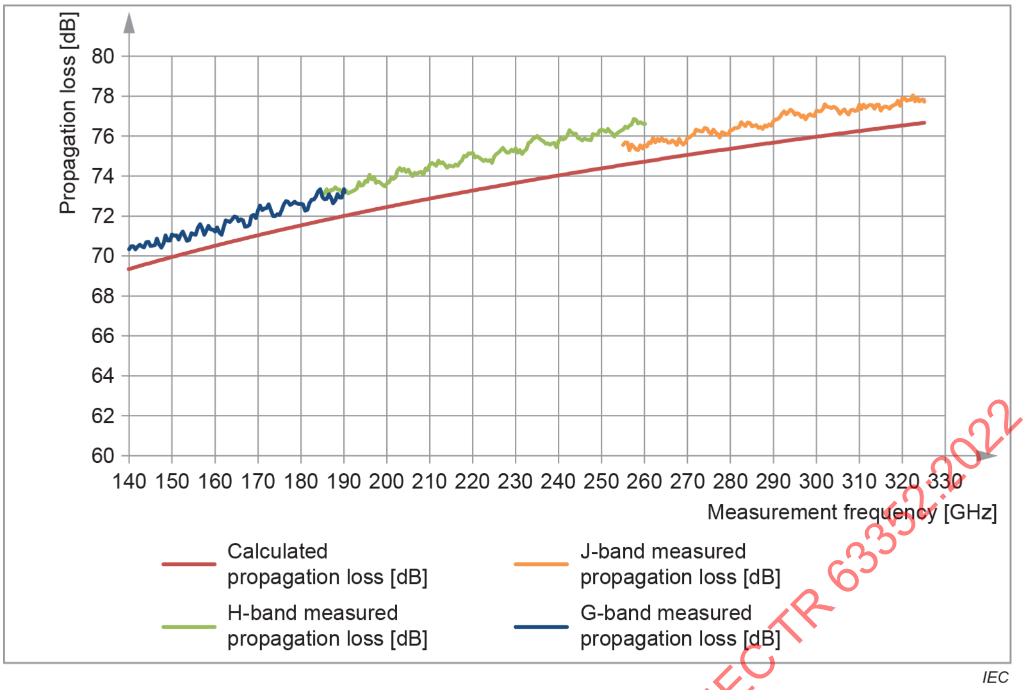


Figure 26 – Propagation loss (propagation distance d = 500 mm)

Figure 26 shows the comparison between the propagation loss L_{m} found from Formula (6) based on the measured R_{X} power and the propagation loss L_{t} found from Formula (7). L_{m} found from the R_{X} power is well matched with the theoretically calculated value L_{t} with an offset tendency of 1,4 dB (G-band), 2,0 dB (H-band), and 1,2 dB (J-band). The difference between L_{m} and L_{t} includes antenna gain errors between simulation values and the actual antenna gain. This error can be suppressed by the introduction of measured antenna gain.

6.5 Evaluation with integrated spectrum measurement system

The DUT was configured by mounting the G-band standard gain horn antenna listed in Table 5 on the output flange of a 12x multiplier and the OTA spectrum was measured. Table 6 lists the 12x multiplier specifications. Figure 27 shows the system for measuring the DUT output using the integrated spectrum measurement system. In addition, each antenna was set to the same height. This measurement used an input frequency to the DUT of 11,75 GHz. Consequently, it was expected that 12x multiplier components and spurious response including harmonics would be observed within the 140-GHz to 315-GHz frequency range of the integrated spectrum measurement system. Table 7 lists the theoretically calculated frequency components generated in the multiplier. Figure 28 shows the observed spectrum measurement screens with the DUT output section facing the RF front-end input section of the measurement system. Only expected frequency components are observed, meaning that the measurement system did not generate unwanted responses and works well.

Table 6 – 12 Multiplier specifications[1]

Model	SGX105
RF output flange	WR-5.1, UG-387/U-M
RF frequency	140 GHz to 220 GHz
Output power	+4 dBm (typ.), 0 (min.)
Multiplier	12
Input frequency	11,67 GHz to 18,33 GHz
Maker	Virginia Diodes Inc.

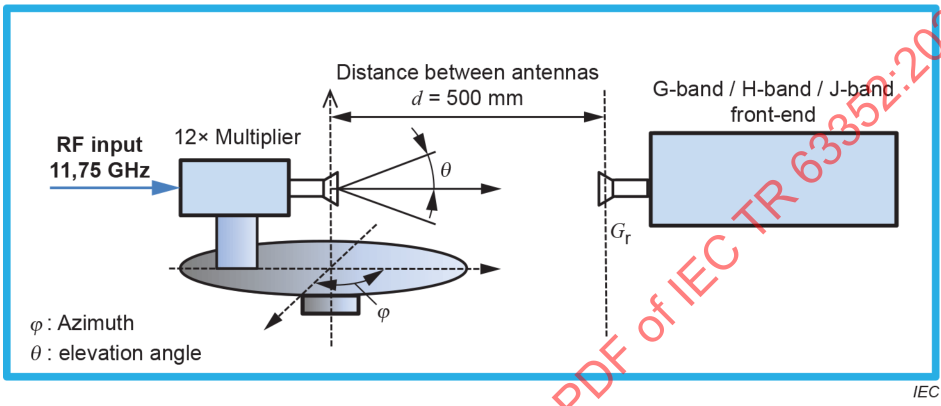


Figure 27 – Spectrum evaluation in OTA measurement environment

Table 7 – Output signal and spurious frequency (11,75 GHz input frequency)

Theoretically calculated frequency [GHz]	**Multiplier**	**Theoretically calculated frequency** [GHz]	**Multiplier**
141,0	12x (output)	235.0	20x
152,75	13x	246.75	21x
164,5	14x	258.5	22x
176,25	15x	270.25	23x
188,0	16x	282.0	24x
199,75	17x	293.75	25x
211,5	18x	305.5	26x
223,23	19x		

1 This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the product named.