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Universal Requirements and Measurement Methods of Parameters for Radio Transmitting Equipment

无线电发射设备 参数通用要求和测量方法

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Universal Requirements and Measurement Methods of Parameters for Radio Transmitting Equipment

1 Scope

This Standard specifies the frequency tolerance, spurious domain emission power limit requirements and general measurement methods for radio transmitting equipment in the frequency band 9 kHz ~ 300 GHz. Meanwhile, it also determines the calculation formulas for the necessary bandwidths of different radio emission categories.

This Standard is applicable to radio transmitting equipment of different power levels and categories in the frequency band 9 kHz ~ 300 GHz. However, it does not apply to the detection of spurious domain emission indicators of safety services and special services, for example, survival craft stations or floating transmitters.

2 Normative References

The clauses in the following documents become clauses of this Standard through reference in this Standard. In terms of references with a specified date, all subsequent amendments (excluding corrigenda) or revisions do not apply to this Standard. However, parties to an agreement based on this Standard are encouraged to explore the possibility of adopting the latest versions of these documents. In terms of references without a specified date, the latest version applies to this Standard.

GB 9254-1998 Information Technology Equipment - Radio Disturbance Characteristics - Limits and Methods of Measurement

GB/T 6113.1-1995 Specifications for Radio Disturbance and Immunity Measuring Apparatus

3 Terms, Definitions, Symbols and Abbreviations

The following terms, definitions, symbols and abbreviations are applicable to this Standard.

3.1 Terms and Definitions

3.1.1 frequency tolerance

The maximum allowable deviation of the center frequency of the frequency band occupied by the emission from the assigned frequency, or the characteristic frequency of the emission from the reference frequency. The frequency tolerance is expressed in ($\chi \times 10^{-6}$) or hertz.

3.1.2 assigned frequency

the frequency meter or spectrum analyzer through an attenuator or appropriate coupling device (the spectrum analyzer of frequency meter shall have sufficient frequency accuracy);

---Set the operating frequency of the transmitter and set the transmitter to operate in continuous wave (CW) state;

---On the premise that the transmitter maintains normal operating status, read the frequency value as f. In accordance with the following formula, calculate the frequency deviation:

Deviation = $(f - f_0) / f_0$, in which, f_0 is the nominal transmission frequency;

---For systems like TDMA, if the system cannot output a single carrier, a vector signal analyzer with a high-stable time base shall be used for testing through the modulation domain.

5 Determination of Necessary Bandwidth of Transmitting Equipment

The following provisions clarify the calculation formulas, calculation examples and corresponding emission identification of necessary bandwidths for various emission categories.

5.1 AM Emission Signal

The calculation formula, calculation example and corresponding emission identification of the necessary bandwidth of AM emission signal are shown in Table 3.

5.2 FM Emission Signal

The calculation formula, calculation example and corresponding emission identification of the necessary bandwidth of FM emission signal are shown in Table 4.

In the multi-channel emission signal of FM frequency division multiplexing (FM / FDM), the calculation and determination of the multiplication factor used for the D value (peak frequency deviation) are shown in Table 5.

5.3 Pulse Modulated Emission Signal

The calculation formula, calculation example and corresponding emission identification of the necessary bandwidth of pulse modulated emission signal are shown in Table 6.

7 Measurement Methods for Spurious Domain Emission Power

7.1 Measurement Receiver

During the test, a measurement receiver or spectrum analyzer that satisfies the requirements of this test may be selected for the measurement of the spurious emission power of the transmitter. The basic requirements that shall be satisfied are:

a) All measurement receivers must have r.m.s and peak detection modes.

b) Provide multiple resolution bandwidth selection modes. During measurement, the resolution bandwidth of the measurement receiver (referring to the intermediate frequency final stage –3 dB bandwidth) shall be as close as possible to the reference measurement bandwidth recommended in 6.2.1. For measurement of emissions close to the operating frequency, a narrower resolution bandwidth needs to be selected. When the selected resolution bandwidth is much smaller than the reference measurement bandwidth, the power measurement result is the integrated power within the reference measurement bandwidth. When the selected resolution bandwidth is much larger than the reference measurement bandwidth, the broadband spurious emission power measurement result is the normalized power corresponding to the bandwidth ratio. However, the above principles are not suitable for spurious domain emission power measurement of discrete spectrum signals. In addition, the resolution bandwidth calibration factor must be provided based on the specific resolution bandwidth type of the measurement receiver (i.e., –6 dB resolution bandwidth) and the specific measurement spurious emission signal category (i.e., pulse signal or Gaussian noise).

c) The video bandwidth cannot be smaller than the resolution bandwidth, and the video bandwidth is usually selected to be 3 ~ 5 times the resolution bandwidth.

d) Provide a suitable filter waveform factor. The size of the filter waveform factor is mainly determined by the filter category selected by the receiver. In principle, try to use a highly selective filter. Generally, the typical range of the filter waveform factor (–60 dB/–3 dB ratio) of the spectrum analyzer using a 4-stage or 5-stage analog filter circuit is 5 : 1 to 15 : 1, and the typical value of the Gaussian digital filter waveform factor is 4.6.

7.2 Measurement Requirements

7.2.1 Resolution bandwidth requirements

In accordance with the provisions of 6.1 in this Standard, usually, the spurious emission power measurement starts at a frequency beyond the necessary bandwidth of the emission that is separated by ± 250% from the emission operating frequency. However, in some cases, measurement using this frequency limit will include non-spurious emission signals, resulting in erroneous measurement results, and it will be necessary to re-determine this frequency limit. The measurement bandwidth adopts the reference measurement bandwidth of spurious emission, and it is necessary to adjust and re-determine the frequency measurement limit that is different from the necessary emission bandwidth of ± 250%. To adopt the frequency limit of the necessary bandwidth of the emission that is separated by ± 250% from the emission operating frequency, it is necessary to select a smaller measurement resolution bandwidth. The correlation between the measurement resolution bandwidth and the spurious domain emission measurement frequency limit (out-of-band domain limit) is shown in Formula (1):

Measurement resolution bandwidth (RBW) × (filter waveform factor – 1) ≤ 2 × (out-of-band limit – necessary bandwidth/2) .... (1)

It can be seen from Formula (1) that if the measurement resolution bandwidth has been determined, then, calculate and determine the spurious domain emission measurement frequency limit; and vice versa. For example, for a measurement signal with a necessary bandwidth of 16 kHz, the frequency limit (i.e., ± 40 kHz) of the necessary emission bandwidth of ± 250% does not change, and the measured intermediate-frequency filter waveform factor (–60 dB/–3 dB) is equal to 15 : 1. Utilize Formula (1) to calculate and obtain that the measurement resolution bandwidth (RBW) is 4.5 kHz (RBW ≤ 2 × (40 – 16/2)/(15 – 1) ≌ 4.5 kHz). On the contrary, for the same measurement signal, it is determined that the measurement resolution bandwidth is 100 kHz, then utilize Formula (1) to calculate and obtain that the out-of-band frequency limit (OOB) is 708 kHz (OOB ≥ 100 × (15 – 1)/2 + 16/2 = 708 kHz).

7.2.2 Requirements for measurement sensitivity

Under certain conditions, adopting a conventional spectrum analyzer and considering the loss of the connecting cable will cause the measurement sensitivity to not satisfy the test requirements. Using a low-noise amplifier can solve this problem. In extreme situations in the frequency band above 26 GHz, the test system usually uses an external mixer. Sometimes the test system cannot provide the appropriate sensitivity to measure the equipment under test (EUT) under specific modulation conditions. The calibration measurement of the spurious domain emission power can be carried out under the carrier frequency state, and the measurement results must consider the modulation loss of the EUT.

7.2.3 Modulation requirements

Under normal test conditions, spurious domain emission power measurement is best performed in the maximum modulation mode of the EUT. In order to detect certain specific spurious emission frequencies, it is sometimes necessary to carry out measurements without modulation. However, it shall be noted that in this case, all spurious emission frequencies may not be detected, and new spurious emission products may be generated after modulation.

7.3 Measurement Methods

7.3.1 Measurement method 1---spurious domain emission power measurement provided with antenna ports

K_{sf}---the calibration factor of the test system at the measurement frequency *f*, expressed in (dB);

G_f---the standard gain of the measurement antenna at the measurement frequency *f*, expressed in (dB);

f---the spurious radiated emission frequency point, expressed in (MHz);

D---the measurement distance between the transmitter antenna and the measurement standard antenna, expressed in (m).

7.3.2.3 Alternative measurement method

When alternative measurement method is adopted, calibration of individual components of the test system is not required. In accordance with Figure 2 of test connection, change the height and polarization mode of the measurement antenna. The measurement receiver records the maximum test value of all spurious radiated emission power of the transmitter under test. Then, use the calibration generator and alternative antenna to equivalently replace the transmitter under test; repeat the above-mentioned measurement process, and meanwhile, adjust the output frequency and level of the calibration generator, so that the measurement receiver can obtain consistent spurious radiated emission power test values for all corresponding frequencies. In this way, the output power from the calibration generator at each recording frequency plus the alternative antenna gain equals the e. i. r. p. measurement values of all spurious emissions from the transmitter under test.

7.3.3 Spurious radiated emission measurement of designated cabinet

The designated cabinet refers to the main part of the transmitting equipment that does not contain the transmitting antenna. Using the measurement method of 7.3.2 can complete the spurious radiated emission power measurement of the transmitter cabinet. In the specific measurement, use a standard load to replace the transmitter antenna under test, and use the measurement method of 7.3.2 to obtain the e. i. r. p. measurement value of spurious radiated emission of the transmitter cabinet. However, during the measurement process, it shall be ensured that the radiated emissions of the alternative standard load and its RF cable do not affect the measurement results.

8 Measurement Methods for Spurious Emission Power of Radar System

8.1 Overview

For the spurious emission power measurement of radar system, two methods are provided: direct measurement and indirect measurement.

The direct measurement method is applicable to spurious emission power measurement of integrated design radar systems that are inconvenient to be measured at intermediate points, for example, those radar systems that use distributed transmitter arrays to constitute a shared antenna, etc.

The indirect measurement method is to respectively measure each constituent part of the radar system and add them together to obtain the final measurement result. It is usually specified that the radar system under test is separated at the "coupling" to measure the spurious emission output power of the transmitter at the "coupling" and synthesize the gain characteristic value of the transmitting antenna. When the indirect measurement method is used, the measurement frequency band can be easily extended to 40 GHz or a higher frequency band.

Under the same measurement conditions, re-measure the specified radar emission spectrum. At any given frequency, the repeated measurement error of these measurement methods is required to be within ± 2 dB.

8.2 Measurement System Resolution Bandwidth and Detection Parameter Settings

When conducting the spurious emission measurement on a radar system, the measurement resolution bandwidth must be calculated and determined based on the specific radar system. For three common types of pulse modulated radars used for radio navigation, radio positioning, acquisition, tracking and other radio determination functions, the measurement resolution bandwidth is calculated as follows:

---For fixed-frequency non-pulse coded radar, it is equal to the reciprocal of the radar pulse width (i.e., if the radar pulse width is 1 μs, then, the measurement resolution bandwidth is 1/(1 μs) = 1 MHz);

---For fixed-frequency phase-coded pulse radar, it is equal to the reciprocal of the phase slice width (i.e., if the phase slice width is 2 μs, then, the measurement resolution bandwidth is 1/(2 μs) = 500 kHz);

---For frequency modulation (FM) or chirp frequency scanning radar, it is equal to the square root value of the frequency scanning width divided by the pulse length (i.e., if the frequency scanning range is from 1,250 MHz to 1,280 MHz or 30 MHz, the pulse length is 10 μs, then, the measurement resolution bandwidth is $(30 \text{ MHz}/10)^{1/2}$ = 1.73 MHz).

When the measurement resolution bandwidth determined in accordance with the above method is greater than 1 MHz, then, the measurement resolution bandwidth shall be 1 MHz. The video measurement bandwidth shall be greater than or equal to the measurement resolution bandwidth; the detection mode is set to positive peak detection.

8.3 Direct Measurement Method

8.3.1 Composition and requirements of measurement system

The typical configuration and measurement block diagram of the measurement system for direct measurement are shown in Figure 3, and the radar antenna can be normally rotated. The functions and requirements of each constituent part of the measurement system are as follows:

a) Select a parabolic antenna with a special-purpose feed source as the measurement receiving antenna. The measurement receiving antenna shall have a good broadband frequency response, at least satisfying the basic requirements of the measurement frequency band; the antenna gain must be high; the main lobe beam of the antenna must be narrow; the polarization selection of the antenna feed source must maximize the response level of the received radar signal. When the polarization mode of the radar signal cannot be determined, it is best to use circular polarization as the antenna feed source. In addition, a low-loss RF cable shall be selected as the connecting cable between the measurement antenna and the RF front-end of the measurement system. If the environment and site allow, reduce the connection length of low-loss RF cable as much as possible.

b) Configure special-purpose RF front-end part. The RF front-end consists of three parts: a variable RF attenuator, a frequency-tuned bandpass filter (tuned tracking variable filter), and a low-noise amplifier (LNA). Each component shall have good broadcast frequency response characteristics. The RF attenuator shall provide a variable attenuation range with a fixed step size. The use of RF attenuators can extend the dynamic range of the measurement system. The RF attenuator can be manually controlled or automatically controlled by a computer. When measuring the low-level spurious emission spectrum beyond the radar signal band, using a frequency-tuned bandpass filter can suppress the high-power radar fundamental frequency signal and achieve the linear characteristic measurement requirements of the measurement system. The frequency-tuned bandpass filter can be manually controlled, or it can be automatically controlled by a computer or a frequency-controlled voltage generated by the spectrum analyzer. Using a low-noise amplifier can enhance the receiving sensitivity of the measurement system, and usually, it can reduce the noise coefficient by about 10 dB ~ 15 dB.

c) Select a wide-band spectrum analyzer to complete the measurement of all spurious emission signals in the frequency band that needs to be measured. The computer is controlled through the GPIB bus and adopts the step frequency algorithm to complete automatic measurement. Reasonably set the attenuator and preselector parameters built into the spectrum analyzer, so as to ensure that the spectrum analyzer is used to satisfy the measurement requirements for sensitivity and linear dynamic range of the measurement system.

---Set the spectrum analyzer frequency span: 0 Hz. (the spectrum analyzer is set to work in the time domain)

---Set the spectrum analyzer scanning time: greater than the radar beam rotation gap. (For example, if the radar rotational speed is 40 r. p. m., that is, each rotation is 1.5 s, then, the scanning time needs to be greater than 1.5 s, usually 2 s is selected)

The system measurement procedure is:

a) The radar antenna system rotates in accordance with the normal requirements. In accordance with the above requirements, connect the measurement system and set the measurement parameters. Start the measurement of the first set of data. Each set of data contains measured power levels and corresponding frequency points. For example, if the measurement result of the first set of data is a power value of −93 dBm measured at the 2,000 MHz frequency point, this power value is the radar emission power level corresponding to the measurement frequency point, which is obtained when the measurement gap is larger than the radar rotational speed period and the frequency span is 0 Hz. The test displays the time / level trajectory of the radar beam rotation on the spectrum analyzer display screen, where the maximum trajectory level value represents the received power level value when the radar beam is facing the measurement system. The control computer automatically records the maximum received power level value. In addition, the calibrated measurement result is obtained from the gain calibration characteristic value of the above-mentioned measurement system.

b) Set the measurement frequency to the second frequency point and start the measurement of the second set of data. The measurement center frequency is best set to the result of the first measurement frequency plus the measurement bandwidth (if the first measurement frequency is 2,000 MHz and the measurement bandwidth is 1 MHz, then, the second measurement center frequency is 2,001 MHz). At the second measurement frequency, repeat the measurement process in Step 1 to obtain the second set of calibrated measurement results.

c) Step by step in sequence in accordance with the measurement bandwidth, repeat the measurement process of Step 1 and Step 2, until all the frequencies that need to be measured are tested, and the spurious emission power measurement results of all radar systems corresponding to each measurement frequency are obtained.

NOTE: adopt the step measurement method, when the measurement frequency is close to the central fundamental wave frequency of the radar system, a fixed RF attenuator can be inserted at the front end of the measurement system to increase the attenuation of the fundamental wave signal and expand the dynamic measurement range of the measurement system, so as to achieve the measurement of adjacent low-power spurious emission signals. Undoubtedly, the best mode is to insert a fundamental-wave trap or bandpass filter at the front end of the measurement system to suppress the fundamental wave high-power signal without affecting the measurement of low-power spurious emission signals.

Appendix A

(informative)

Units and Conversion Relations of Spurious Domain Emission

A.1 Representation of Spurious Domain Emission

Under the specified measurement bandwidth conditions, the size of spurious domain emissions is usually expressed in units, such as: power level, electric field intensity at a specified measurement distance, power flux density (pfd) at a specified measurement distance, etc.

A.1.1 Power magnitude

There are many modes to express the power level of the measured spurious emissions, which mainly depend on the measurement connection mode and measurement method. Commonly used expressions include:

1) Feed-in antenna power (p. s. a): often used in equipment with antenna connectors operating below 30 MHz and above 30 MHz. The feed-in antenna power measurement reflects the actual power level of the spurious signal transmitted by the transmitter to the antenna. However, it does not consider the impact of the antenna and cannot obtain the radiated emissions at non-antenna operating frequencies.

2) Equivalent isotropic radiated power (e. i. r. p.): mainly used in equipment operating above 30 MHz (more often above 80 MHz). Equivalent isotropic rated power measurement better reflects the radiation of spurious emission signals from the transmitter system (including the antenna part) and the harmful interference caused to other wireless services. However, the conversion relations between the feed-in antenna power and the equivalent isotropic radiated power are not easy to obtain, mainly because the radiation characteristics beyond the antenna's operating frequency band are unknown. Equivalent isotropic radiated power is a power parameter commonly used in integrated antenna transmitting equipment to represent spurious emission characteristics.

3) Effective radiated power (e. r. p.): the difference between e. r. p and e. i. r. p. is that a half-wave dipole tuned antenna is used instead of an isotropic antenna. The conversion relations between them are as follows: e. i. r. p. (dBm) = e. r. p. (dBm) + 2.15.

A.1.2 Electric field intensity

It is theoretically possible to measure the interference field strength E or H value of spurious emissions at the receiving antenna. However, it is extremely difficult to obtain the corresponding relations between e. i. r. p. and electric field intensity suitable for various occasions, because the phenomena of radio wave propagation and inductive coupling are extremely complex. On the test site, the electric field intensity value is usually measured at a specified distance. For the measurement of unwanted radiated emissions and interference field strength from radio equipment and information technology equipment (ITE), CISPR stipulates that the electric field intensity value shall be measured at a distance of 10 m on a calibrated open area test site (OATS) with a flat reflective ground.

A.1.3 Power flux density

Power flux density (pfd) is suitable for spurious emission measurements from transmitting equipment operating above 1 GHz, such as: wireless satellite links and radio astronomy services.

A.2 Parameter Units and Mutual Relations

A.2.1 Parameter units

The international standard measurement unit of power is watt (W). The power parameters often used in spurious emission measurements are as follows: feed-in antenna power (p. s. a.), equivalent isotropic radiated power (e. i. r. p.) and effective radiated power (e. r. p.). The power units include: dBpW, dBnW, dBm, dBW or power density of a specified reference bandwidth.

The standard unit of electric field intensity *E* is V/m, and the commonly used units are μV/m and dBμV/m. The standard unit of magnetic field intensity *H* is A/m, and the commonly used units are μA/m and dBμA/m. The standard unit of power flux density (pfd) is W/m^2, and the commonly used unit is dBW/m^2.

A.2.2 Interrelations among different units

Under ideal conditions (referring to satisfying free space propagation and far-field measurement conditions), the mutual conversion relations among electric field intensity, measurement distance, equivalent isotropic radiated power and power flux density parameters are as follows:

$$E = \frac{\sqrt{30(\text{e. i. r. p.})}}{D} \qquad \cdots\cdots\cdots (\text{A.1})$$

Where,

E---the electric field intensity, expressed in (V/m);

D---the measurement distance, which refers to the distance between the radio transmitting equipment and the measurement point, expressed in (m);

e. i. r. p.---the equivalent isotropic radiated power, expressed in (W);

pfd---the power flux density, expressed in (W/m^2).

Calculate the maximum value (*E*) of the electric field intensity, which represents the maximum measurement value that can be achieved in the calibrated open area test site by adjusting the height of the measurement antenna, that is:

------ The End ------