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PECULIARITIES OF METROLOGY IN MILLIMETER RANGE COMMUNICATION SYSTEMS

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Abstract
The main advantages of the equipment of the millimeter range in perspective communication systems are considered. Here, usage the method of microwave radiometry is used for measuring of radiation level and carrying out radio monitoring in the telecommunication channel. The functional diagram of the modulation radiometer with the transformation of the input signal and the parameters of the developed and certified radiometric systems are given.

Keywords: millimeter frequency range, communication channel, radiometric method, modulation radiometer.

INTRODUCTION

In modern technologies there is a tendency of steady increase of information signals frequency. With increasing data traffic, the range used for their transmission (3-38 GHz) has become overloaded, and the mm range of 40 to 100 GHz is currently still practically unoccupied now. It is exactly that part of the electromagnetic spectrum the leading specialists in the field of communication pay attention to [1,2]. The advantages of the waves of the millimeter range are: possibility of increasing the data transfer speed (up to 10 Gbit / s) and channel noise protection, reduction of dimensions and mass of radio frequency devices.

It should be noted that the range of the millimeter waves is perspective for their usage also in medical technologies and biological research [3-5], as well as in the latest methods and means of contactless research of the structure of materials and control of their properties [6].

For today's communication systems, the V-band (57-64 GHz) is most intensively used, for which several industry standards (Wireless HD, ECMA-387, IEEE 802.15.3c and IEEE 802.11ad) and the E-band (71 -76, 81-86 and 92-95 GHz) are adopted [1, 2, 7].

The nature of propagation of radio waves of the millimeter range is determined by the influence of climatic (seasonal) conditions, resonant and non-resonant attenuation of radio waves in the troposphere.

Resonant attenuation is due to the property of molecules to absorb and emit the electromagnetic field of their own absorption spectra. Energy absorption occurs when the frequency of the electromagnetic field of the propagating wave coincides with one of the discrete frequencies of intramolecular transitions. The reverse transition from a higher energy level to a lower one is accompanied by electromagnetic radiation field at its own resonant frequency, which is one of the noise fields in the radio band.

Non-resonant attenuation is due to thermal energy losses during the propagation of an electromagnetic wave in various meteorological conditions. These conditions mean heavy rain, fog, snow, hail, clouds and other meteorological phenomena in the lower layers of the troposphere [8].

Features of the attenuation of millimeter waves for vertical and inclined trac are as follows: the equivalent thickness of the atmosphere does not exceed 1.5 km, which corresponds to all-weather transparency in almost the entire millimeter range [9].

With strong rain or monsoons, the attenuation factor for most of the millimeter range can be taken at about 50 dB / km, with an average of 10 dB / km in the rain. Atmospheric attenuation is 0.5 dB / km (even for fog) [10].

The use of millimeter waves also increases the noise protection, concealment of communication channels, transmission reliability information and reduces the power consumption of used systems [7].

The use of signals from the millimeter range is accompanied by processes of measuring signal parameters and conducting monitoring of the radio channel, which is connected with the measurement of sufficiently weak signals, whose integral power can be within 10-12 - 10-16 W, which is a significant metrological problem. Due to the wide band of operating frequencies in communication systems, traditional tools used at low frequencies in a millimeter range require significant hardware and time resources. In addition, measuring instruments of this type have a great price.

EXPOSITION

At present, the V-band (59-64 GHz) is considered to be perspective for the creation of microsatellite and picoset lines in urban territories. It is defined that under the most unfavorable conditions of signal propagation, the length of the communication line at a frequency of 60 GHz is always greater than 500 m, and under favorable conditions it reaches up to 800 m (maximum is less than 2 km). At the same time, it is possible to provide information transfer at speed up to 1 Gbit / s through optical (1000 Base-SX / LX) or electric (10/100/1000 BASE-T) interfaces with hundreds of mW of radiation and antenna gain of 35-38 dBi of the antenna amplification . Communication equipment has a compact design and easy for the installation and adjustment.

Radoimetric systems (RS) are widely used in various fields of science for measuring of low-intensity signals, the level of which may be lower than the level of noise of their own systems. For the construction of radiometric apparatus, three basic methods of measurement are used: compensation, correlation and modulation.

Usually, MS are used to measure signals from sources of radiation located at significant distances from receiving devices (although for a millimeter wavelength range of this distance can be only 800 - 2000 m). The analysis of the possibilities of classical schemes for the construction of highly sensitive RS showed the perspective usage of the method of modulation transformations (by periodic comparison) taking into account the features of the range of millimeter waves and due to the high sensitivity and accuracy of measurements, as well as the availability of functional capabilities and flexibility of constructing a structural scheme construction [6, 11]. Broadband modulative PCs of the direct amplification (without incoming frequency conversion) are mainly used in the frequency range up to 30 GHz [3, 5], and in the shorter wavelength range, narrow bandwidths with single or double input frequency transformations are more often used, since broadband amplification of incoming signals is quite complicated [11].

The consideration of the theoretical basis for measuring signals with periodic comparison of signals at the input of the RS was made for schemes of direct transformation of harmonic signals of the microwave band [6], but the features of the transformation of noise signals in an extremely high frequency range were not taken into consideration.

To the opinion of the authors, for solving problems of metrological support of communication systems, it is expedient to use the radiometric method that provides measurement of parameters of low intensity information signals. This method allows you to determine the intensity and other parameters of broadband noise-like signals, including low spectral density.

For the construction of radiometric apparatus, three basic methods of measurement are used: compensation, correlation and modulation. The high sensitivity and accuracy of measurements is provided by the modulation method. The advantages of this method include the possibility of compensating the hardware noise of the radiometric channel, which increases the sensitivity of such apparatus on 1-2 higher degree of magnitude.

In addition, this method is quite simple for apparatus implementation [6]. FIG. 1 shows a functional scheme of a highly sensitive RS of millimeter range.

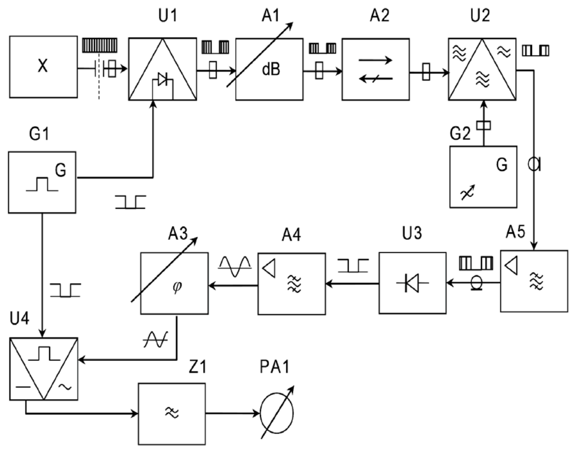

***Fig. 1**–Scheme of modulative radiometer with transformation of input signal*

A microwave signal from the source X, which is modulated by an electrically controlled modulator U1 under the control of the rectangular pulse generator G1, enters the RS input. In case of exceeding the level of the input signal, the attenuator A1 provides its attenuation to the level of 10^{-9} W. Also, this attenuator is used to measure the power of the input signal by the substitution method.

From the output of the attenuator A1 microwave signal comes to one of the inputs of the converter U2, the second input of which receives the signal of the heterodyne G2. The valve A2 provides an electrodynamic isolation of the transducer with the input path of the PC. From the U2 output, the intermediate frequency signal is amplified by A5 and is given to the U3 quadratic detector. The received signal in the form of rectangular pulses with the frequency of 1 kHz passes through the bi-square filter A4, on the output of which the generated sinusoidal signal passing through the phase rotator A3 enters one of the inputs of the synchronous detector U4. A signal from the generator G1 is given to the other input U4. The spectrum of the signal at the output of the synchronous detector U4 has a constant component that is proportional to the power of the source of the microwave signal X and the noise dispersion in the passband of the A4 filter at the output of the radiometric channel, and is described by the formula:

$$U_{U4} = K_{\Sigma}\left[\frac{U_0^2}{\pi}\sum_{n=1}^{k}\frac{\sin\left(2n-1\right)\Omega\, t}{2n-1} + \Delta U_w^2\left(t\right)\right]. \quad (1)$$

Where U_0 - amplitude of the input signal

Ω - switching frequency

K_{Σ} - total conversion rate of the measuring channel to the Z1 filter,

$\Delta U_w^2(t)$ - dispersion of noise passing in the band pass of the A4 filter.

The constant component of the U4 output signal is proportional to the power (intensity) of the input signal of the source of the UHF X signal , and the low frequency fluctuations, which can significantly distort the measurement result and reduce the sensitivity of the radiometric system. To eliminate this shortcoming, the scheme of a bi-square filter on the operative amplifiers, which has the operating frequency of 1 kHz, an adjustable bandwidth and amplifier coefficient of 15-20 dB, is used. The Z1 filter allocates the constant component which level (determined by the RA1 indicator) is proportional to the power of the input microwave signal. For calibrating the RS, worked out and metrologically certified reference signal generator is used.

According to the described scheme, RSs are constructed in the frequency bands: 26-38 GHz, 37.5-54 GHz and 53.5-78 GHz, which have the sensitivity threshold (10^{-14}-10^{-13}) W, and allow to measure of broadband signals in the dynamic range of 70 dB.

One of the developed radiometric systems for the range of working frequencies 37-53 GHz at the threshold of sensitivity is no more than $\mathbf{3 \cdot 10^{-14}}$W and has the following characteristics [12]:

- range of measured power $\mathbf{10^{-13} - 3 \cdot 10^{-6}}$ W;
- relative errors of power measurement up to ± 3.0 dB and frequency up to ± 3.0%;
- the band of analyzed frequencies, up to 100MHz.

The worked out generator of the reference signal (noise) has got the working frequency range of 37-78 GHz and is used for periodical calibration of the PC. Its application has given possibility to reduce the measurement error by means of RS in 2,5-3 times.

CONCLUSION

1. Use of the millimeter band for the transmission of signals in telecommunication systems requires the development and improvement of methods and means of measuring parameters of transmitted signals. One of them can be a radiometric method that allows you to determine the parameters of low-intensity as deterministic and broadband signals.
2. The modulatory radiometers of the millimeter range worked out by the authors have the threshold of sensitivity 10 W and a dynamic range of 70 dB. This allows us to solve tasks concerning with the metrological support of the millimeter range communication systems and to monitor them.

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