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WIDEBAND MULTIPROBE MICROWAVE MULTIMETER

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Abstract

The device, sensors and mathematics permits to get new results in precision, performance function linearity, characteristics long term stability and so on. The multimeters for passing, incident, reflected power, reflection coefficient module and phase, wavelength could be designed in the three modification in dependence of propose: multimeter for fixed frequency, wideband one for wave guide, very wideband one for coaxial lines. It is necessary to solve next main questions: to choice sensor type and their dislocation, to elaborate signal processing algorithm, to work out functional scheme, to evaluate general error, ground metrological support.

Keywords: VHF signal and tract parameters measurement, microwave multimeter, transformation coefficient, frequency independence, sensor signal processing algorithm, sensor on the absorbing wall principle design.

1. INTRODUCTION

The multiprobe microwave multimeter is intended for an automated remote signal and transmission line mode checking for high level power in the wide frequency range and incident, reflected, passing to antenna power, reflection coefficient modulus and phase measurement, emergency situation prevention. The main technical characteristics are: frequency range – one-two octave, power measurement level – 0.5-50 W and more, reflection coefficient modulus – 0-1, main measurement error $\pm(3-5)\%$ (without verification error).

2. DEVICE AND ACTION CONCEPT

The action concept based on standing wave exploration in the wave guide between termination and generator with an aid of the universal broadband passing power sensors, build on absorbing wall principle [1]. The amplified signals from the sensors is transformed to measuring quantity of incident, reflected, passing power, reflection coefficient modulus and phase with a help of microprocessor system. There is opportunity to check a wavelength if necessary. The microprocessor implements the synthesized algorithms in accordance with program in real-time scale. Due to this it is possible to make up for many systematical and random errors. The main multimeter and sensors advantage are a high accuracy, a wide frequency range and dynamic range, a high speed of response, an electrical, thermal and radiation stability.

3. SIGNAL AND TRANSMISSION LINE PARAMETERS DEFINITION ALGORITHM

Sensor quantity and their dislocation definition is making on the mathematical model analysis base: a sensor signals are described by equations that are united into the system. To equation system solution procedure simplify the equations are linearized and a mediate variable are introduced, that characterizes constant and variable components of standing wave in the wave guide. The fixed frequency system is completely described by three parameters: passing power, reflection coefficient modulus and phase, so, the equation quantity is three. The distance between adjacent sensor is choiced equidistant and is equal $\lambda_W / 6$, that considers optimal from condionality number point of view in compare with more traditional dislocation $\lambda_W / 8$ [2].

The passing power expression was received for fixed frequency and $\lambda_W / 6$ phase distance

$$P_{pass} = \sqrt{\frac{1}{3}\left\{\left(\sum_{i=1}^{3} P_i\right)^2 - 2\sum_{i=1}^{3} P_i^2\right\}} \quad (1)$$

Other parameters are

$$P_{inc} = \frac{P + P_{pass}}{2} \qquad P_{ref} = \frac{P - P_{pass}}{2}$$
$$P = \frac{0.5(P_1 + P_3) - P_2 \cos\theta}{1 - \cos\theta} \qquad |\Gamma| = \sqrt{\frac{P_{inc}}{P_{ref}}} \quad (2)$$

During a wideband measurement besides main calculation function algorithm have to look after frequency change, that fulfills on the sensor signal

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processing base. The sensor quantity increases to four one, and on their signal base is calculated correction coefficient, that carry information about wavelength change, securing continuous measurement in continuous frequency sub range:

$$\cos\theta = \frac{P_1 - P_4 - P_2 + P_3}{2(P_2 - P_3)}.$$

The adaptive algorithms for fixed distance between sensors and changing in wide range frequency is

$$P_{pass} = \sqrt{P_2 \frac{P_1 + P_3 - P_2(1+\cos\theta)}{1-\cos\theta} - \frac{(P_1 - P_3)^2}{4\sin^2\theta}}$$

The other parameters are leave fair by expression (2)

Besides, possibility to express wavelenght in the evident appearance appears.

$$\lambda = \frac{k}{\arccos\theta}.$$

There are two emergency situations, giving restriction: when a wavelength increases and an adjacent sensors readings unintelligible and when a wavelength decrease so wave period placed between an adjacent sensors and their readings became equal one.

In occasion, when an adjacent sensor readings are equal or closely spaced quantity, to prevent zero in the denominator, the sensors commutation has to be executed in the microwave multimeter, shifting to the right or left side on distance equal to phase distance between a sensors. It require one more sensor. Besides this, an expression gives information about wavelength as $\arccos(\theta)$.

To prevent expression denominator into zero conversion is introduced additional fifth sensor, which allows to "move" left and right four sensor readings with aid of commutation. The correction coefficient becomes

$$\cos\theta = \frac{P_2 - P_5 + P_4 - P_3}{2(P_3 - P_4)}.$$

The device operate in a continuous frequency range. There are five sensors operate in the given sub range. There are three of them enough to define passing power on the fixed frequency, the fourth one is necessary to calculate correction coefficient (phase distance between adjacent sensors, calculated on the basis of sensor readings, for frequency change monitoring. The fifth one supply uncertainty exception. So an algorithm frequency independence is maintained in the given frequency range.

The very wideband system for coaxial tracts contains additional sensors, that dislocate on double distance relatively primary dislocation. The working sensors are five sensors, although more sensors assemble in the VHF block. For example, to provide four octave frequency range it is necessary nine sensor to provide same range with non equidistant sensor it is necessary about twice more sensors (sixteen ones).

In case, when working wavelength approaches to two time distance between an adjacent sensors, the sensors commutes so a working sensors became that ones, distance between which is two time less than first distance.

Sensor quantity might increases still, to increase frequency range. Quantity limitation lays in difficulty of providing constant transformation coefficient quarantine. If sensor quantity exceeds variable quantity, sensor signal processing recommends to fulfill, using least square methods [3].

4. Universal Sensor for Passing Power Measurement

The each of sensor consist of cylinder frame with absorbing element as a flat metallic plate, attached to working end of frame, ring thermocouple battery, sprayed on the dielectric base (Fig. 1). The battery is placed in the inner side of an absorbing element, so that its hot junctions are placed in the center of the ring. The cold ones are situated in the perimeter. There is a conductor in the center. There is a thread on the outer side of frame to screw the sensors into the pipe of an outer coaxial conductor and to fix its situation by a nut. The frame working end increases heat exchange. The little weigh, a better heat exchange and a cold junction offset increases speed of response. The sensitivity increases at the expense of great amount thermocouples in the battery. The high electrical stability is maintained due to a sensor screwing in the inner coaxial pipe or wave guide, so that the inner

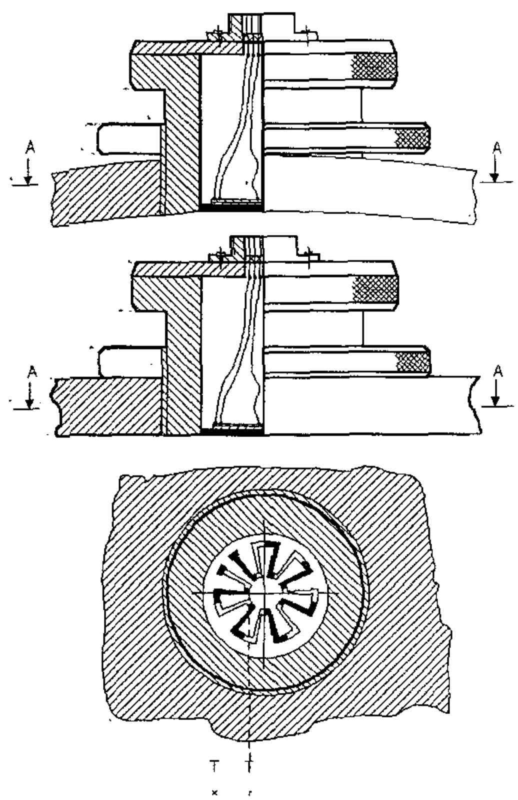

Fig. 1.

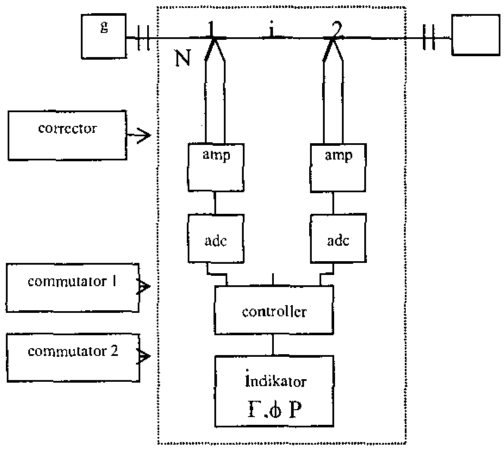

Fig. 2.

absorbing element surface and the inner wall surface are at the same level. It achieves by an end sensor frame curve follows an inner coaxial pipe, so increases thermal stability during high and very high power level measurement. To obtain minimal transformation coefficient frequency dependence, apply two layers absorbing wall.

The sensors operate in such a way: installed in the outer coaxial pipe, passing power sensor outputs a voltage at LF plug, the voltage is proportional to field intensity in its installation place. Running on absorbing element surface, VHF currents heat absorbing element. Because of the absorbing element perimeter is connected to a massive frame, the heat from this element part goes to wave guide faster, then from central part. So the center temperature will be higher, than one at the perimeter. The temperature difference converts into voltage by the ring film thermocouple battery, that hot connections are situated in the central absorbing element part, the cold one is in its perimeter [4].

Due to a transformations coefficient in wide frequency range stability, it is enough to calibrate only at the middle frequency. The reference calorimeter is used for this propose. There is conductor attached in the absorbing element center for its external heating through LF plug from DC or RF current source for periodical calibration, that easy to measure with needed accuracy.

5. Multimeter Functional Scheme

The functional scheme for all multimeter variants is almost same and consist of VHF-block (transmission line segment with sensors) and multi channel signal processing block: sensor characteristics corrector, amplifying and normalizing channels, which quantity corresponds to sensor quantity, amplifying weak signal to level necessary for ADS and microprocessor running. Besides functional scheme contains controller combined with ADC and input-output interface (Fig. 2).

The measurement unit has to maintain preliminary analog signals from sensors processing and signal transmission to the indicators. The input signal amplitudes are 0.01-10 mV. To match analog signal sources with digital processing devices is used A/D converter. The output voltage levels are 2.5-10 V. It is necessary maintain output sensor signal amplifying to full A/D converter scale. The normalization channel after sensor is to amplify and filter signal.

The main claims to DC measurement amplifiers are low noise level and zero drift absence. D/C amplifiers, built on a serial scheme basis has simple constructive design, but not great metrological characteristics and large zero drift.

The optimal solution is to use a differential amplifiers. Using of modern operational amplifiers allows to create high accuracy channels, which in relation to drift (about 1 $\mu V / C^{\circ}$) not concede, and exceed traditional amplifier in relation to speed of response (0.1 $V / \mu s$).

The signal from A/D converter in digital form arrive to micro controller, which consist of all units for autonomy processing [5].

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