Russian metrological institute of technical physics and radio engineering (FSUE «VNIIFTRI»).

Final Report on supplementary comparisons of standards of the power flux density unit of electromagnetic field (W/m^2) at frequencies 2.45 GHz and 10 GHz. COOMET № 267/RU/-a/02 (COOMET.EM.RF-S1)

Content

1. Introduction

Supplementary comparisons of the standards of the power flux density unit of the electromagnetic field (W/m^2) at frequencies of 2.45 and 10 GHz. COOMET.EM.RF-S1 have been conducted from 2007 to 2012 after coordinating the form of the topic and specifying the list of participants. Three national metrological institutes of the countries of the regional metrology organization COOMET - Ukraine, Belarus and Russia took part in the comparisons. Pilot laboratory was FSUE "VNIIFTRI" - Russia.

2. Comparison participants

Table 1

№	NMI	Address	NMI abbreviation	Contact person	E-mail, telephone, fax
1	Russian Metrological Institute of Technical Physics and Radio Engineering	141570, Russia, Moscow region, Solnechnogorsk district, Solnechnogorsk, w.s. Mendeleevo	FSUE «VNIIFTRI»	Kolotygin Sergei Aleksandrovich	Lab202@vniiftri.ru (495) 526-63-12 (495) 526-63-12
2	Belarusian State Institute of Metrology	220053, Minsk, Starovilenskii trakt, 93	BelGIM	Galygo Aleksandr Vasilievich	galygo@belgim.by (37517) 233-63-783 (37517)288-09-38
3	All-Ukrainian State Research and Production Centre of Standardization, Metrology, Certification and Consumer s' Rights Protection	Ukraine, 03143, Kyiv, 4, Metrologichna Str.	State Enterprise "Ukrmetrteststandard"	Simonov Oleksandr Pavlovych	Simonov@ukrcsm.kiev.ua (38044) 526-21-85 (38044) 526-21-85

3. Travelling standard.

Travelling standard consists of an alternating electric field-to-constant voltage antenna converter, ADC converting a DC voltage into a digital code, a fiber optic transmission line of a digital code into a measuring unit, and a measuring unit performing digital signal processing and output of a measurement result to the LCD screen.

An 8 mm dipole antenna with a Schottky diode operating in the frequency range from 1 to 18 GHz is used as a converter antenna. At the output of the diode, a low-pass filter is connected to the RC chain, then a resistive line 250 mm long with a resistance per unit length of at least 1 kΩ / cm is located. The resistive line eliminates the influence of the measuring circuit on the result of measuring the field strength by a dipole with a diode detector. The output DC voltage is applied to the ADC with a high-resistance input, then the signal is transmitted through the fiber optic transmission line to the measuring unit.

In the measuring unit, the signal is processed taking into account the normalizing frequency and dynamic coefficients and the result of the measurement is displayed on a liquid crystal display.

Fig.1. General view of the travelling standard

4. Comparison protocol and measurement results

In 2009 in the State Enterprise “Ukrmetrteststandard», in 2010 in BelGIM, in 2011, the standard returned to VNIIFTRI. It turned out that the instrument indicator stopped working.

After the repair by the manufacturer of the device, repeated measurements have been conducted at FSUE "VNIIFTRI", that confirmed the stability of the calibration coefficients of the device. In BelGIM, measurements at a frequency of 10 GHz were not performed, but measurements were made at a frequency of 11.5 GHz. In this regard, in 2012, the travelling standard was sent to BelGIM for repeated measurements. As a result, measurements at a frequency of 10 GHz in BelGIM were not carried out.

The correction factors defined determined for each frequency 2.45 and 10 GHz.

Levels for power flux density measurements from 10 to 26.5 μW/cm^2.

The correction factors Ki is obtained using the following formula:

$$Correction\ Factor = \frac{Actual\ power\ flux\ density\ (\mu W/cm^2)}{Indicated\ power\ flux\ density(\mu W/cm^2)}$$

The measuring results are shown in Table 2.

Table 2

NMI	2.45 GHz		10.0 GHz		11.5 GHz	
	K_{Ref_i}	$u\ (K_{Ref_i})$	K_{Ref_i}	$u\ (K_{Ref_i})$	K_{Ref_i}	$u\ (K_{Ref_i})$
BelGIM	1.018	0.071	-	-	1.110	0.0752
Ukrmetrteststandard	0.723	0.143	1.407	0.143	-	-
VNIIFTRI	1.051	0.054	1.376	0.063	1.041	0.063

In the technical protocol, measurements were provided at frequencies of 2.45 and 10 GHz, and there is no at frequency of 11.5 GHz. In this case, the BelGIM results are proposed to be recalculated to the frequency 10 GHz through measurements in VNIIFTRI using the formula:

$$\mathrm{K}_{10\ \mathrm{BelGIM}} = \frac{K_{11,5\,VNIIFTRI}}{K_{11.5\ \ VNIIFTRI}} \cdot K_{10\ \ BelGIM} \qquad (1)$$

5. Calculation of the reference value and degree of equivalence

The weighted average of the calibration coefficients of the travelling standard is determined by the formula:

$$K_{av} = \sum_{i=1}^{N} \frac{K_{Ref_i}}{u^2(K_{Ref_i})} \cdot u^2(K_{av}) \qquad (2)$$

Where K_{Ref_i}, $u\ (K_{Ref_i})$ - are the values provided by the laboratory *i*.

The uncertainty of the weighted average is determined by the formula:

$$u^2(K_{av}) = \frac{1}{\sum_{i=1}^{N} \frac{1}{u^2(K_{Ref_i})}} \qquad (3)$$

The results of the calculations are presented in the table 3.

The values of the coefficients for the travelling standard at a frequency of 10 GHz for BelGIM are calculated by the formula (1).

Table 3

NMI	2.45 GHz		10.0 GHz	
	K_{Ref_i}	$u\ (K_{Ref_i})$	K_{Ref_i}	$u\ (K_{Ref_i})$
BelGIM	1.018	0.071	1.467	0.0752
Ukrmetrteststandard	0.723	0.143	1.407	0.143
VNIIFTRI	1.051	0.054	1.376	0.063
Weighted average	**1.013**	**0.041**	**1.413**	**0.046**

The degree of equivalence of each NMI D_i and the corresponding standard uncertainty u(D_i) with respect to the reference value were determined by the formulas:

$$D_i = K_{Ref_i} - K_{av} \tag{4}$$

$$u^2(D_i) = u^2\left(K_{Ref_i}\right) + u^2(K_{av}) \tag{5}$$

The degree of equivalence D_i for NMI participants with extended uncertainty U (D_i) (k = 2, p = 0.95) on relation to RV at frequencies of 2.45 and 10 GHz are presented in Table 4 and in the diagrams of Fig. 2 and Fig. 3.

Table 4 The degree of equivalence with respect to RV

NMI	2.45 GHz		10.0 GHz	
	D_i	$U(D_i)$	D_i	$U(D_i)$
BelGIM	0.005	0.164	0.054	0.176
Ukrmetrteststandard	-0.290	0.298	-0.006	0.300
VNIIFTRI	0.038	0.136	-0.037	0.156

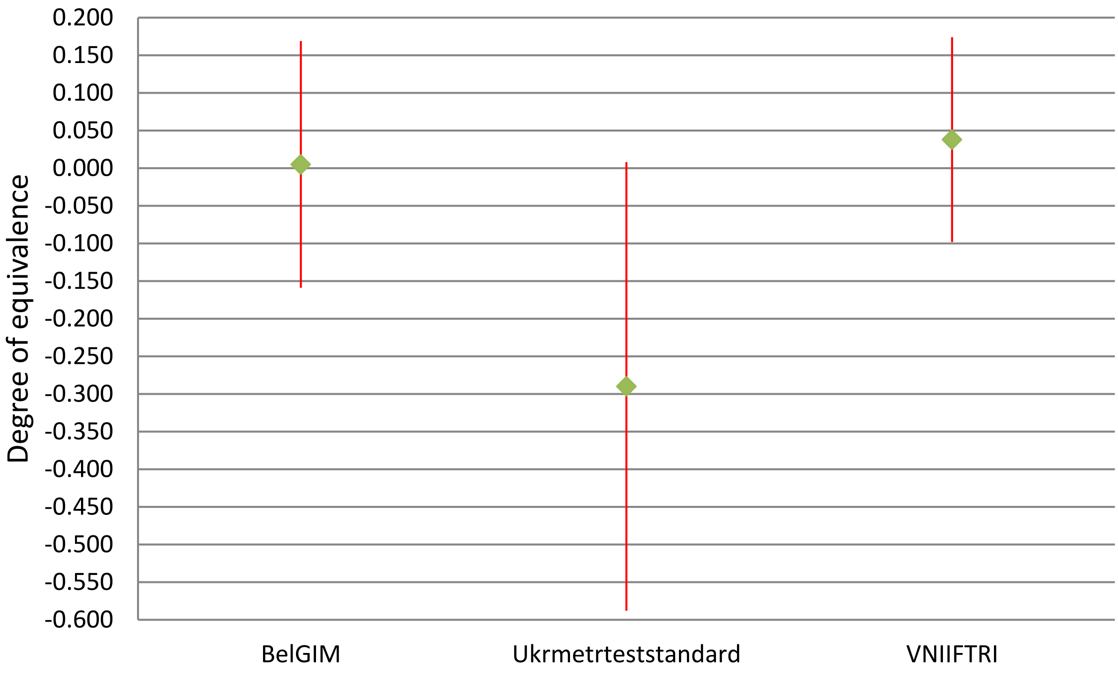

Fig.2 Degree of equivalence for NMI at a frequency of 2.45 GHz

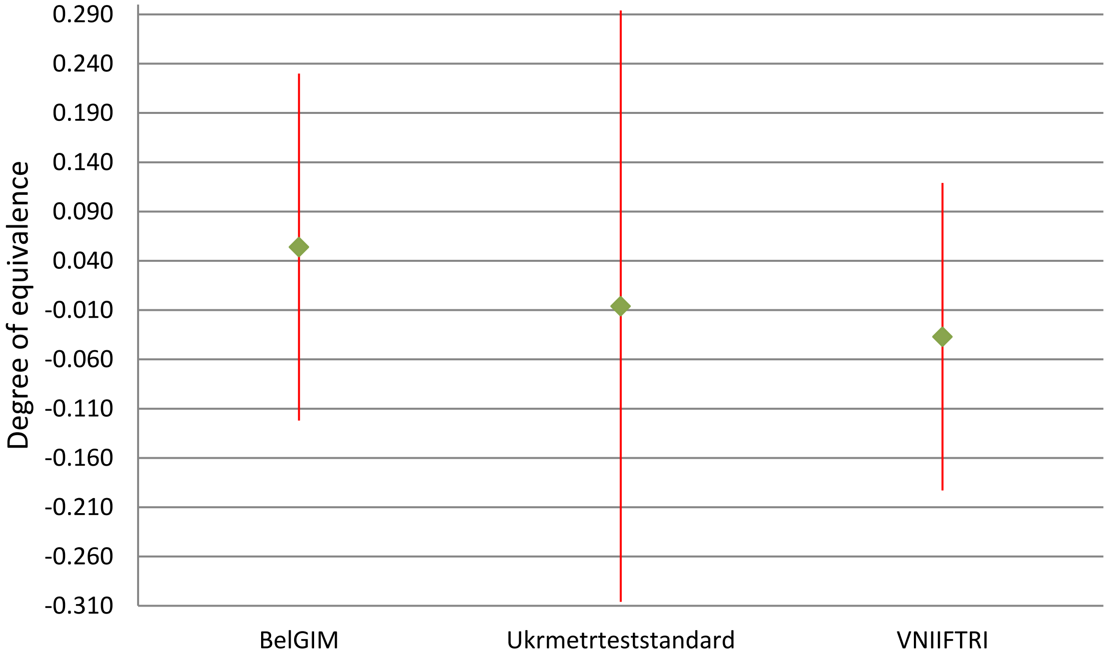

Fig.3 Degree of equivalence for NMI at a frequency of 10 GHz

The degree of equivalence of NMI D_{ij} pairs and the corresponding standard uncertainty $u\,(D_{ij})$ were determined by the formulas:

$$D_{ij} = K_{Ref_i} - K_{Ref_j} \quad (6)$$

$$u^2(D_{ij}) = u^2(K_{Ref_i}) + u^2(K_{Ref_j}) \quad (7)$$

The equivalence degree D_{ij} for pairs of NMI participants with extended uncertainty $U(D_{ij})$ (k = 2, p = 0.95) ~~in relation to KCRV~~ at frequencies of 2.45 and 10 GHz are presented in Table 5 and 6.

Table 5. Degree of equivalence of NMI at a frequency of 2.45 GHz

NMI	NMI					
	BelGIM		Ukrmetrteststandart		VNIIFTRI	
	D_{ij}	$U(D_{ij})$	D_{ij}	$U(D_{ij})$	D_{ij}	$U(D_{ij})$
BelGIM			-0.295	0.319	0.033	0.178
Ukrmetrteststandard	0.295	0.319			0.328	0.306
VNIIFTRI	-0.033	0.178	-0.328	0.306		

Table 6. Degree of equivalence of NMI at a frequency of 10 GHz

NMI	NMI					
	BelGIM		Ukrmetrteststandart		VNIIFTRI	
	D_{ij}	$U(D_{ij})$	D_{ij}	$U(D_{ij})$	D_{ij}	$U(D_{ij})$
BelGIM			-0.060	0.323	-0.091	0.196
Ukrmetrteststandard	0.060	0.323			-0.031	0.313
VNIIFTRI	0.091	0.196	0.031	0.313		