International Committee on Global Navigation Satellite Systems

Spatial distribution of emissions in the frequency bands of GNSS

Stanislav Kizima
ITU-expert, Doctor of Technical Sciences
Deputy Director General
The R&D centre for systems and tools of measurement “Vector”

Вектор
Специализированное ОКБ

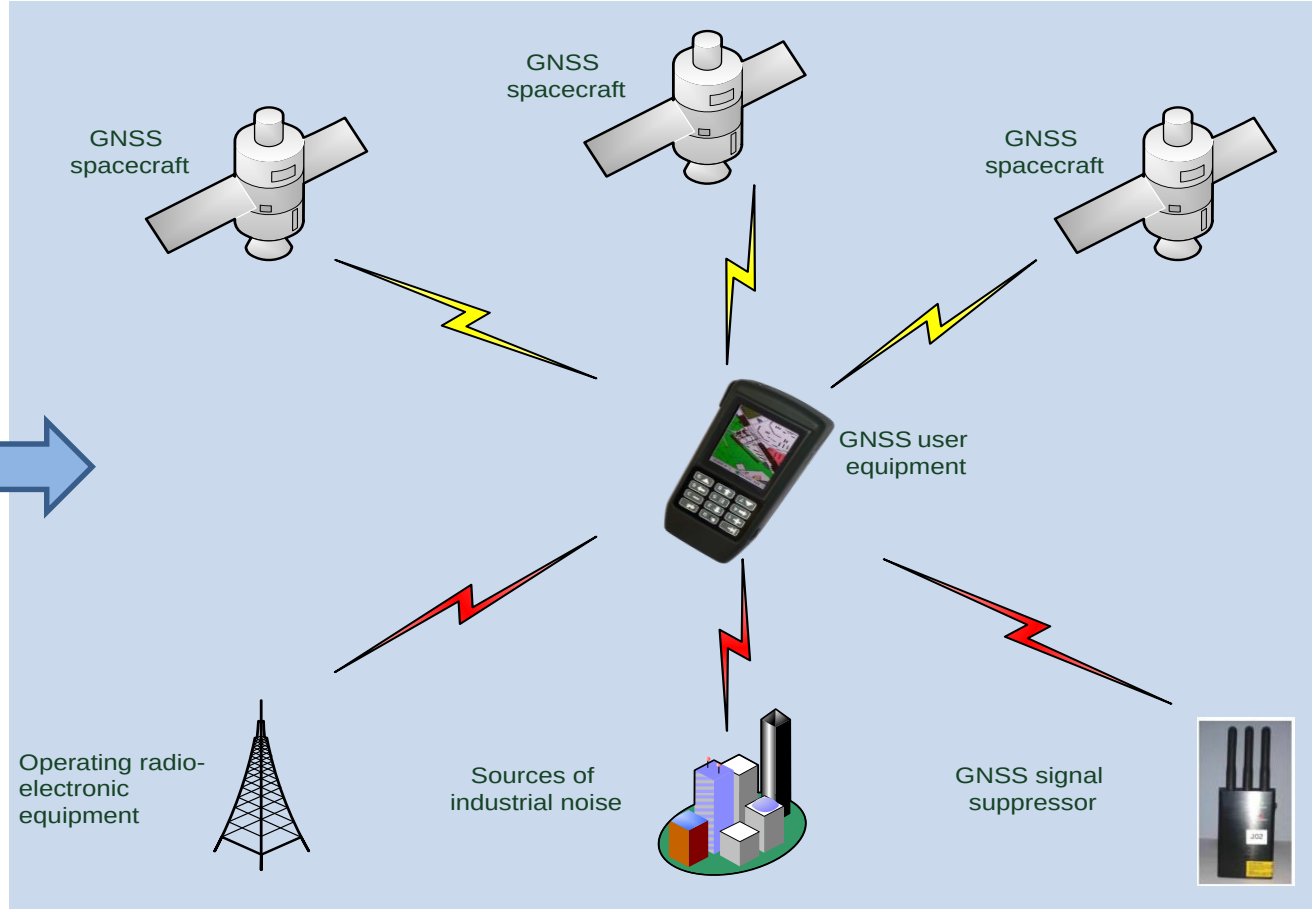
Spatial distribution of emissions in the frequency bands of GNSS

Navigation management background

Desired signal

Navigation

Negative impact



Spatial distribution of emissions in the frequency bands of GNSS

Spatial distribution of emissions in the frequency bands of GNSS
is defined
by spatial distribution of radio facilities and other sources of emission in the frequency bands of GNSS

Spatial distribution of emissions in the frequency bands of GNSS
is estimated
by the level and arrival direction of radio-frequency energy for intended azimuth and elevation angle in the point of measurement

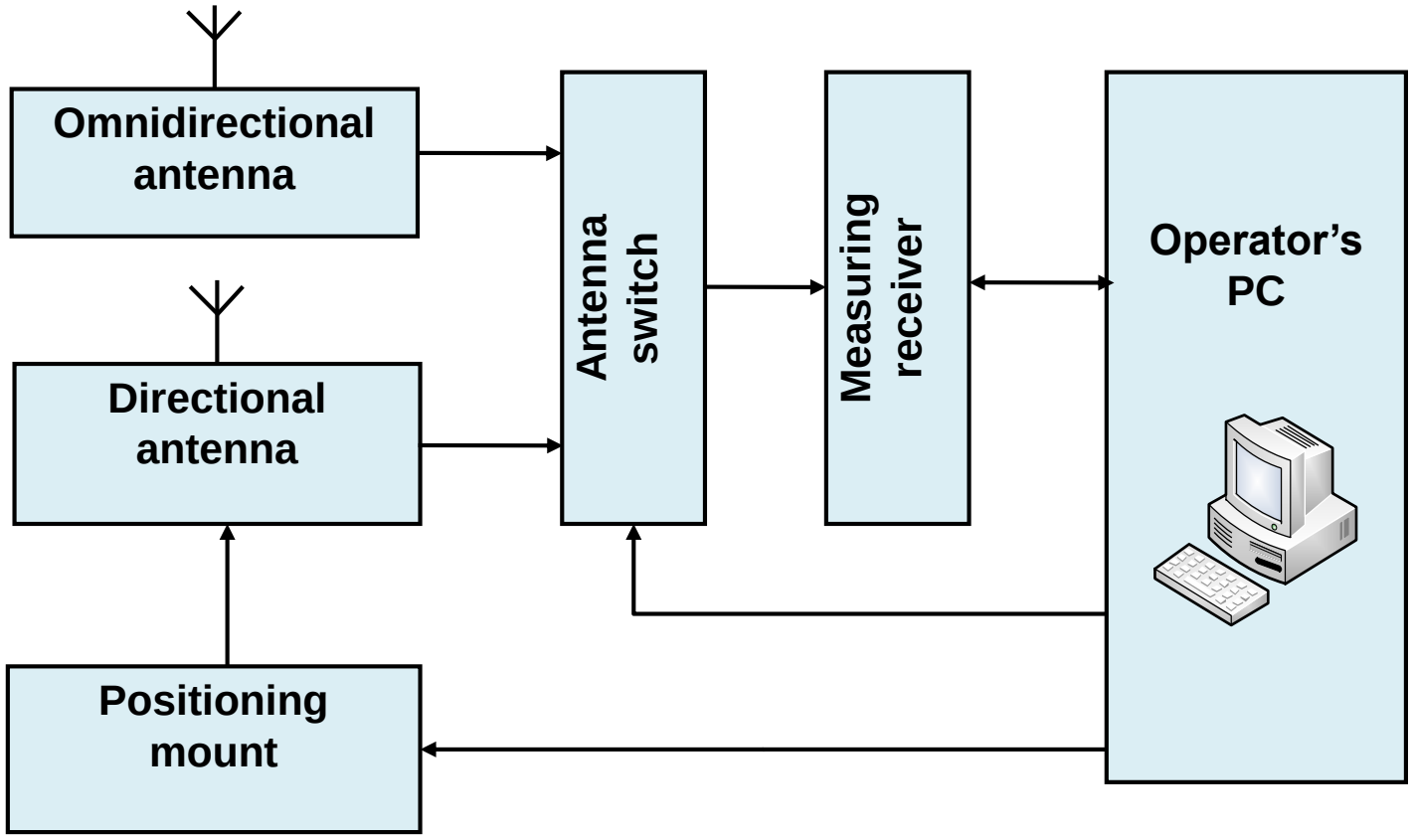
Spatial distribution of emissions in the frequency bands of GNSS

Goals and objectives of analysis

- Evaluation of navigation management background
- Parameter estimation of spatial distribution of emissions in the frequency bands of GNSS
- Parameter estimation of electromagnetic environment in the frequency bands of GNSS
- Electromagnetic noise background (electromagnetic noises) level estimation
- Detection of radio-frequency emission and interference source
- Parameter estimation of interfering impact

Spatial distribution of emissions in the frequency bands of GNSS

Measurement equipment



Spatial distribution of emissions in the frequency bands of GNSS

Essential instrumental requirements

Parameter	Value
Operating Frequency range	1180-1640 MHz
Frequency range for harmonic interference source analysis	550 – 3280 MHz
Frequency accuracy	$\leq \pm 1 \cdot 10^{-7}$
Frequency resolution	1 Hz
Level accuracy	$\leq \pm 2.0$
Sensitivity, bandwidth = 1 kHz	$\leq$ -115 dBm
Displayed Average Noise Lavel (DANL), bandwidth = 1 Hz	$\leq$ -155 dBm
IF rejection	≥ 80
Noise figure	≤ 12
Second-order intercept point	≥ 40
Third-order intercept point (TOI)	≥ 10

According to the Russian Federation standard 53373-2009, ITU-R SM.1753 Recommendation

International Committee on Global Navigation Satellite Systems

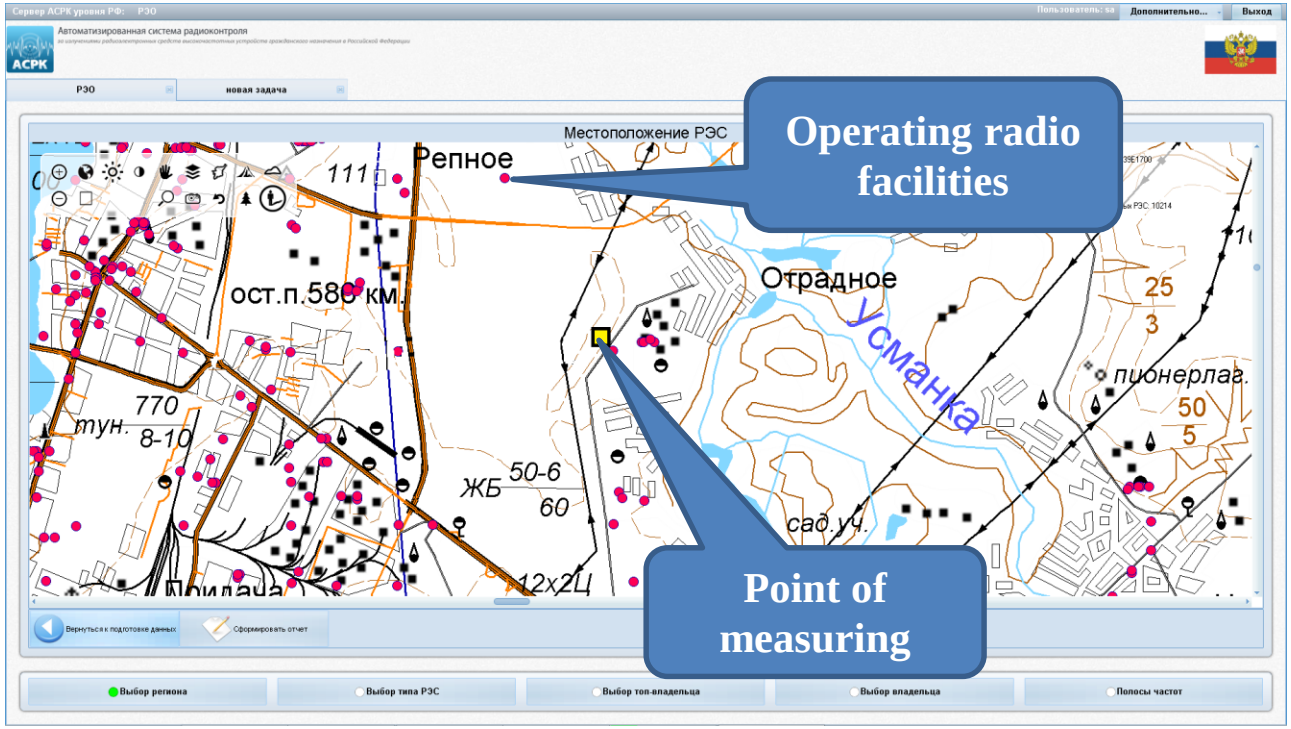
Spatial distribution of emissions in the frequency bands of GNSS

Methodological approach

Practical measurements and evaluation

Point of measuring

A town with average density of population, middle-altitude urban area, high density of operating radio facilities



Spatial distribution of emissions in the frequency bands of GNSS

Emission parameters estimation for terrestrial radio facilities

Measurements conditions

Parameters	Value
Start time	02.06.2015 20:29:14
Final time	03.06.2015 3:29:07
Antenna installation latitude	51°39'59'' N
Antenna installation longitude	39°19'47'' E
Antenna suspension height	2.85m
Antenna type	1. Directional horn antenna П6-59: 2. Omnidirectional double-cone antenna П6-62
Measurement equipment	Spectrum analyzer Tektronix RSA6106B
Measuring technique	Measurement in azimuth plane in increments of 15 degrees
Frequency band	1597 - 1607 MHz (L1 GLONASS)
Frequency resolution	1000 Hz
Sweep count	100
Sweep mode	max and average
Detector	Peak

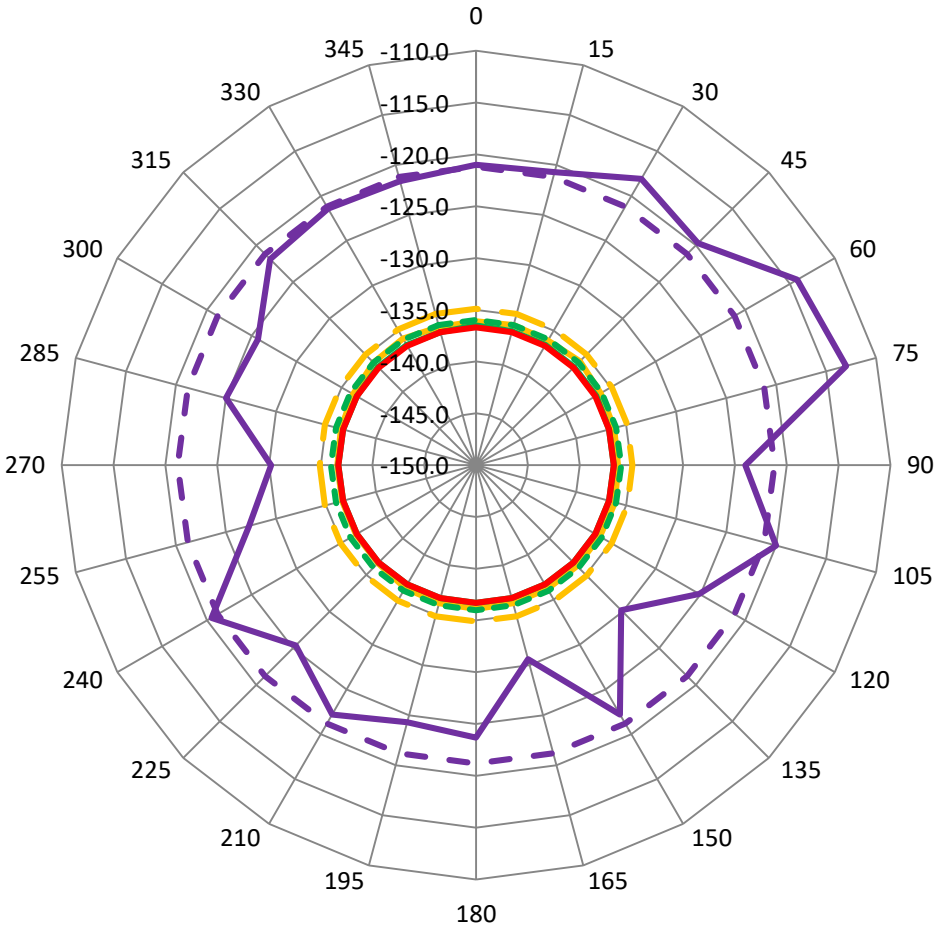
International Committee on Global Navigation Satellite Systems

Spatial distribution of emissions in the frequency bands of GNSS

Spatial distribution of terrestrial radio facilities emission

Methodological approach. Azimuth base diagram. Practice-oriented example

Radio emission level distribution in azimuth plane



Measured quantities :

Measurements made by directional antenna

- Peak power
- Average power
- Noise level

Measurements made by omnidirectional antenna

- Peak power
- Average power
- Noise level

- Measuring receiver noise level

Spatial distribution of emissions in the frequency bands of GNSS

Spatial distribution of emissions

Radio noise level measurement. Practice-oriented example.

Directional antenna

Azimuth	Noise level
0	-136,5
15	-136,6
30	-136,6
45	-136,6
60	-136,6
75	-136,7
90	-136,7
105	-136,7
120	-136,7
135	-136,7
150	-136,7
165	-136,7
180	-136,7
195	-136,7
210	-136,7
225	-136,7
240	-136,7
255	-136,7
270	-136,7
285	-136,7
300	-136,7
315	-136,6
330	-136,6
345	-136,7
Average	**-136,6**

Omnidirectional antenna

Azimuth	Noise level
-	**-136,0**

Noise level measurements in the frequency bands of GNSS are made according to ITU-R SM.1753.

The results of noise background level measurements made by directional and omnidirectional antenna are identical and do not depend on azimuth.

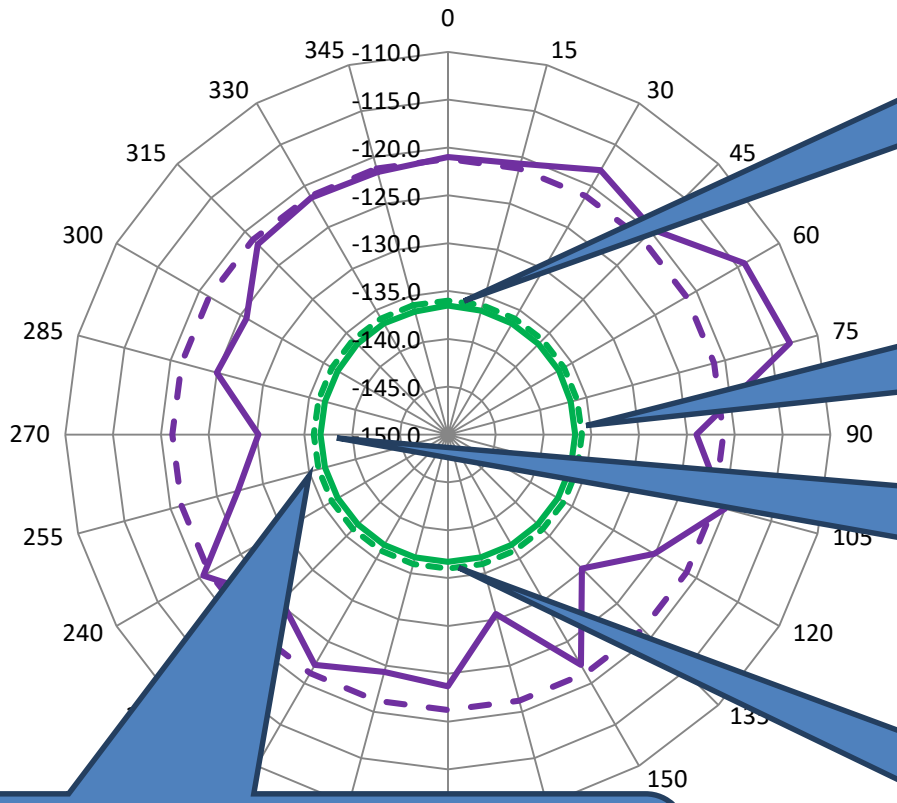
The Difference in measurement results is circa 0.6 dB.

Spatial distribution of emissions in the frequency bands of GNSS

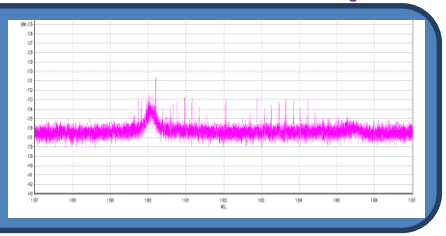
Spatial distribution of emissions

Methodological approach. Azimuth base diagram. Practice-oriented example

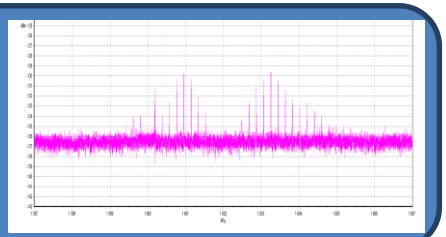
Distribution of radio noise level



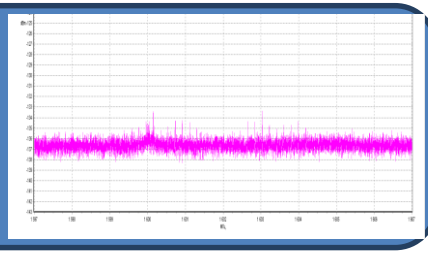
Directional antenna Azimuth 0
Pn = -136.5 dBm



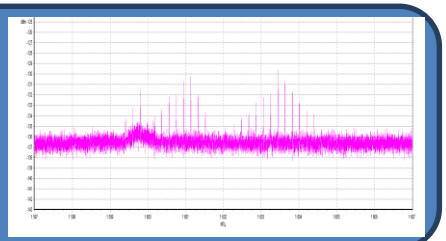
Directional antenna Azimuth 90
Pn = -136.7 dBm



Directional antenna Azimuth 270
Pn = - 136.7 dBm

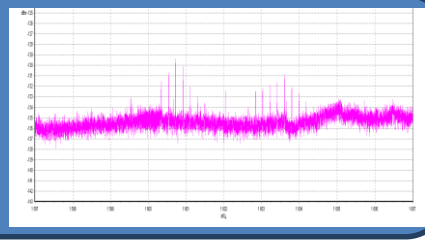


Directional antenna Azimuth 180
Pш = - 136.7 dBm



Omnidirectional antenna

Pn= -136.0 dBm



Spatial distribution of emissions in the frequency bands of GNSS

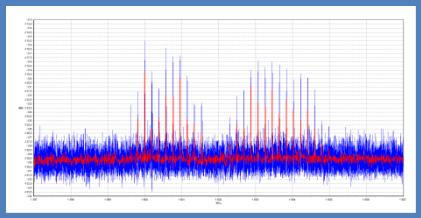
Spatial distribution of terrestrial radio facilities emission

Methodological approach. Azimuth base diagram.

Peak emission power estimation in azimuth heading

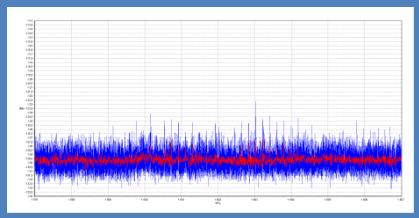
Directional antenna

Azimuth 75
Ppk= -113 dBm



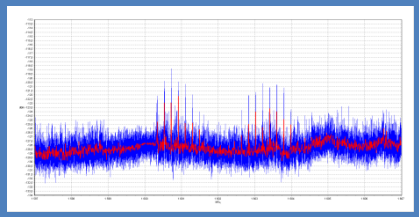
Directional antenna

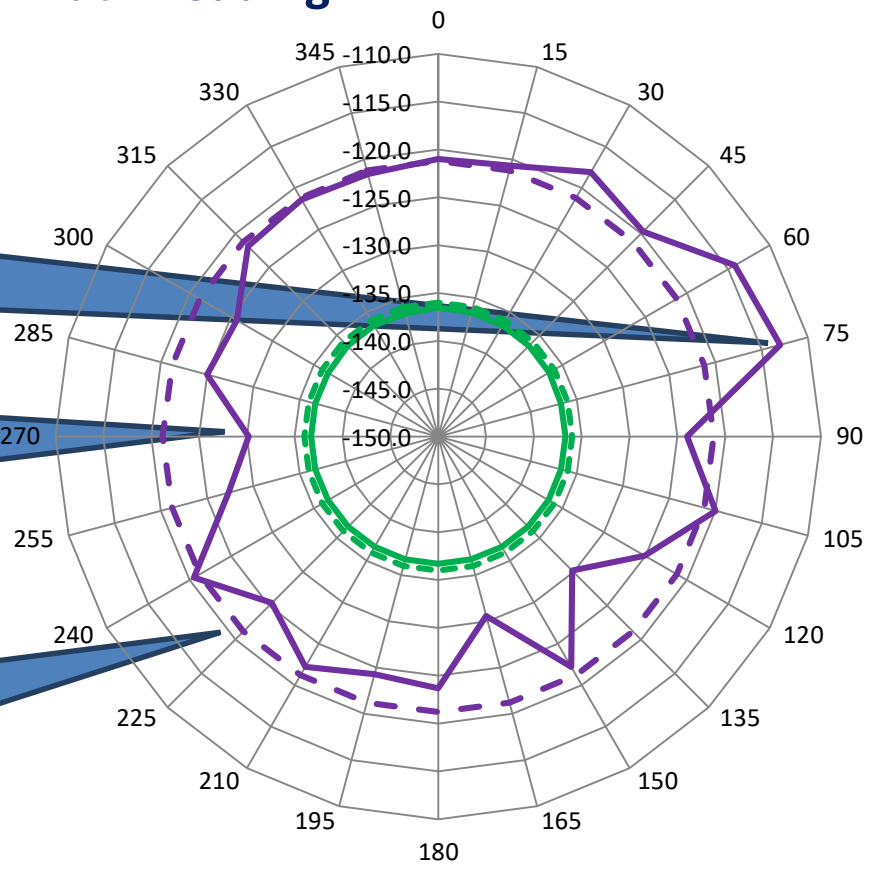
Azimuth 270
Ppk = -130 dBm



Omnidirectional antenna

Ppk= -121 dBm



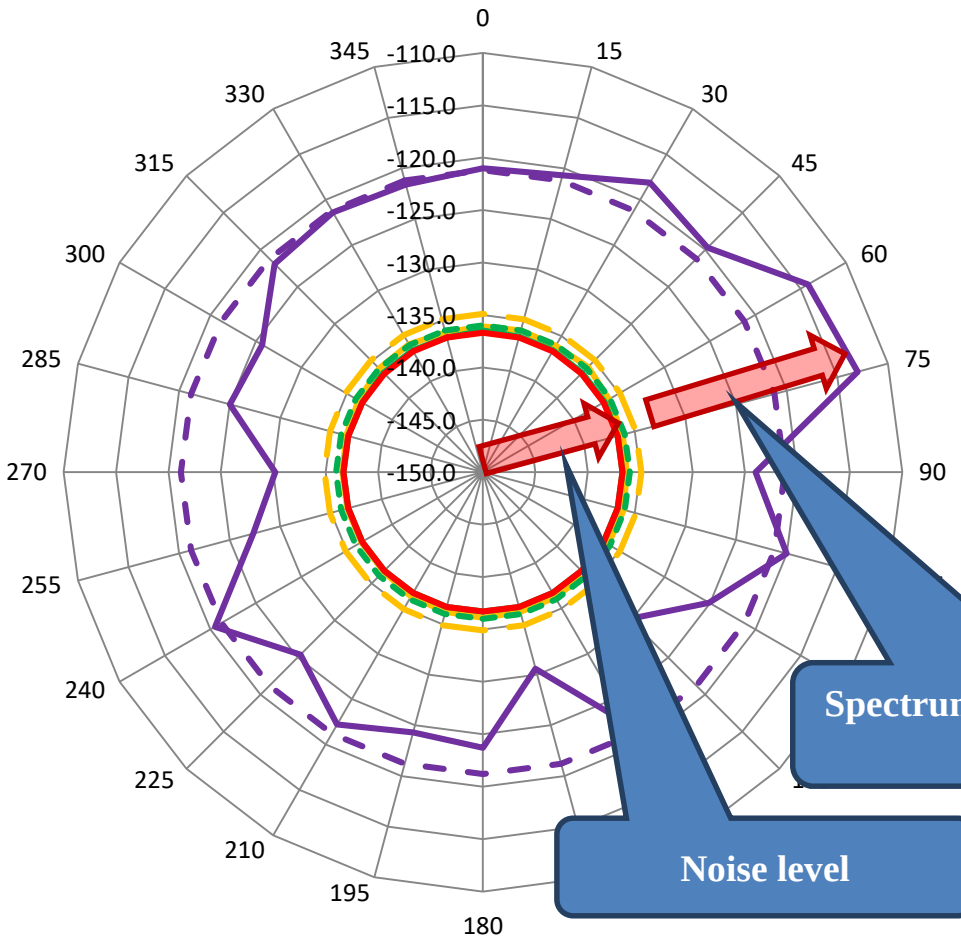


Spatial distribution of emissions in the frequency bands of GNSS

Spatial distribution of terrestrial radio facilities emission

Methodological approach. Azimuth base diagram. Practice-oriented example

Radio emission and interference source detection.



Radio emission source and interference detection gage:

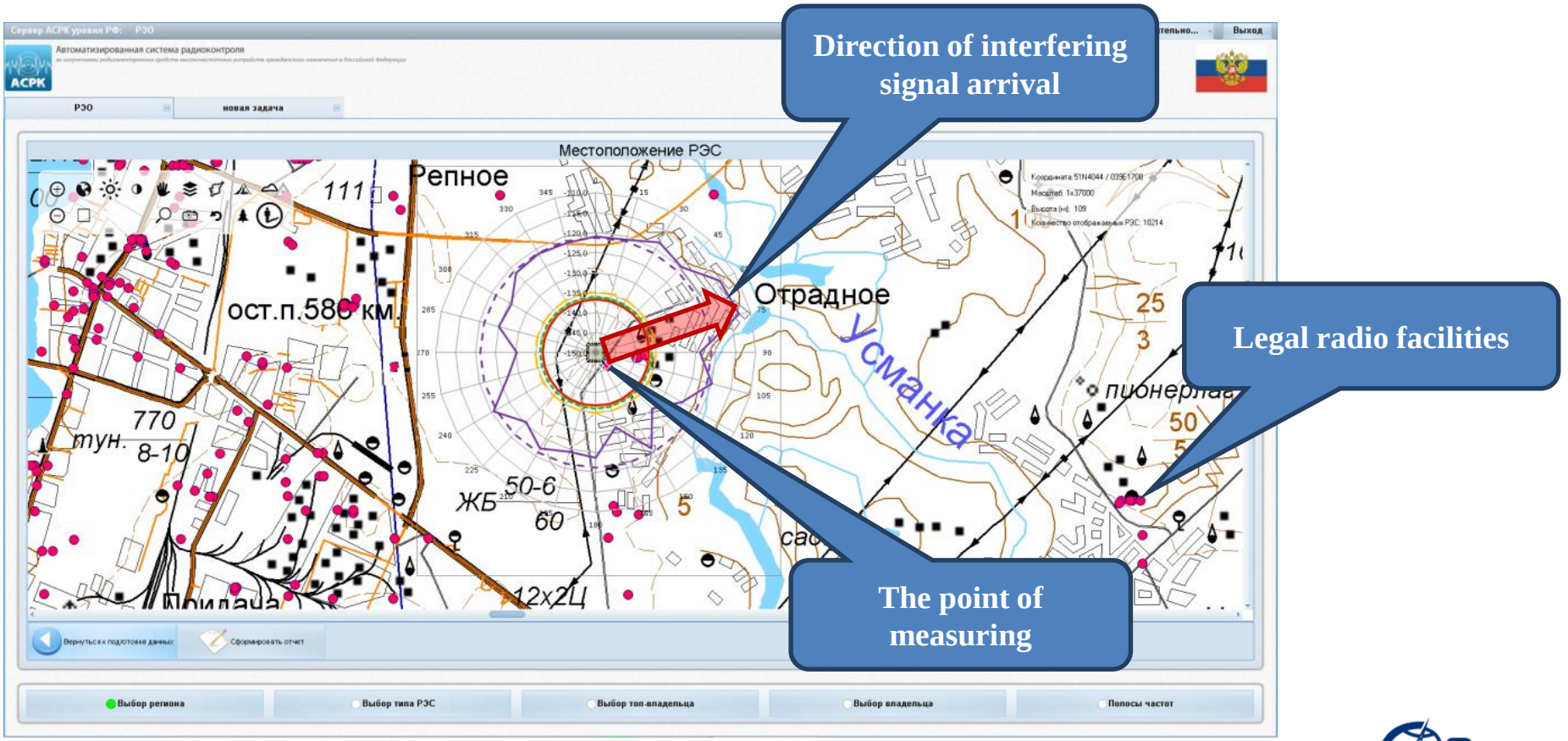
electromagnetic field strength level increase over noise level in azimuth heading on quantity which exceeds fixed threshold value

Spatial distribution of emissions in the frequency bands of GNSS

Spatial distribution of terrestrial radio facilities emission

Methodological approach. Azimuth base diagram. Practice-oriented example

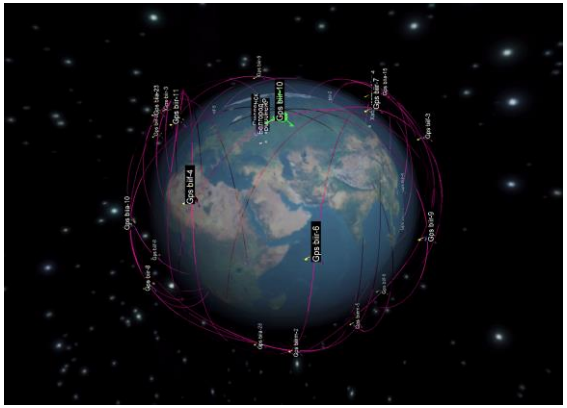
Detection of interfering signal arrival direction.

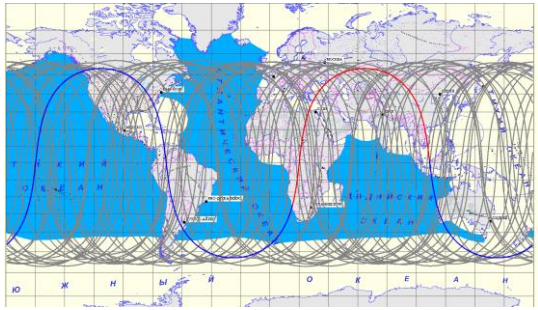


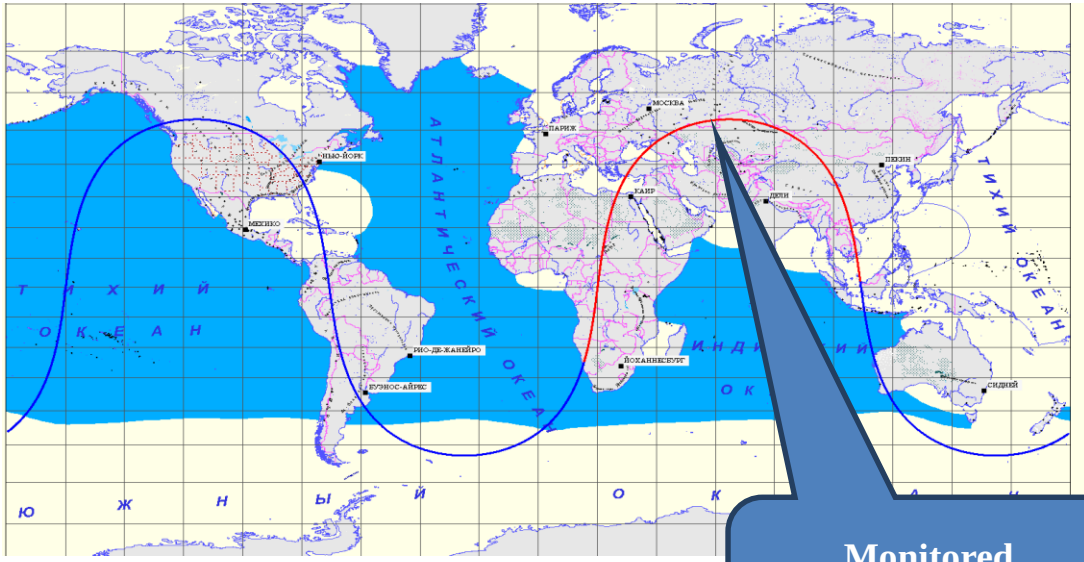
Spatial distribution of GNSS spacecraft emission

The objects of target-specific signal level measuring in the bands of GNSS.

GPS spacecrafts







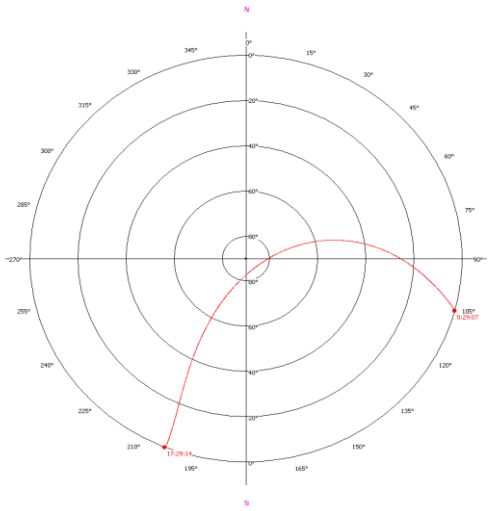
Monitored spacecraft. Monitoring time

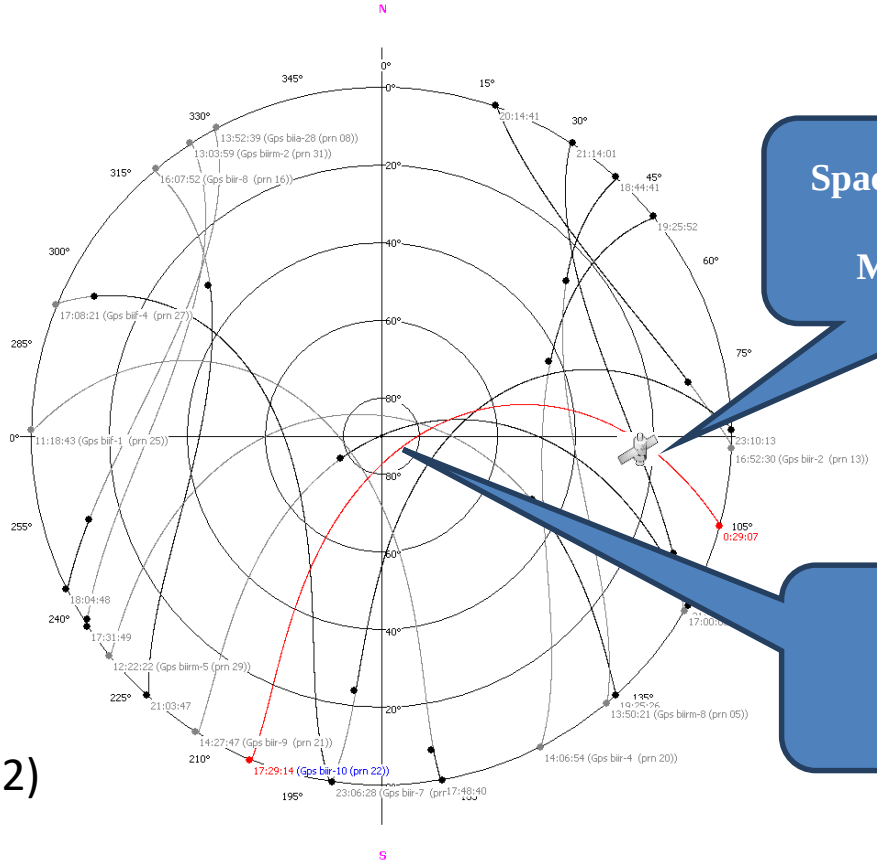
Spatial distribution of GNSS spacecraft emission

Methodological approach. Azimuth and elevation angle base diagram.

Paths of monitored spacecrafts and measuring directions in coordinate representation: azimuth - elevation angle in the point of measuring.

GPS spacecrafts





GPS spacecraft
"USA-175" (Block IIR-10/PRN 22)

International Committee on Global Navigation Satellite Systems

Spatial distribution of emissions in the frequency bands of GNSS

Emission parameter estimation for target-specific measurement dedicated to monitored GNSS spacecrafts.

Measuring conditions
for GPS "USA-175" (Block IIR-10/PRN 22)

Parameter	Value
Start time	02.06.2015 20:29:14
Final time	03.06.2015 3:29:07
Antenna installation latitude	51°42'44.2"N
Antenna installation longitude	39°08'53.6"E
Antenna suspension height	65.2 m
Antenna type	Active directional (Supral 1,65 + Tallysman TW3440)
Measurement equipment	Spectrum analyzer Rohde & Schwarz FSV
Measuring technique	Spacecraft tracking
Frequency band	1570,25 - 1580,25 MHz (GPS L1)
Frequency resolution	10 Hz
Sweep count	10
Sweep mode	max
Detector	peak

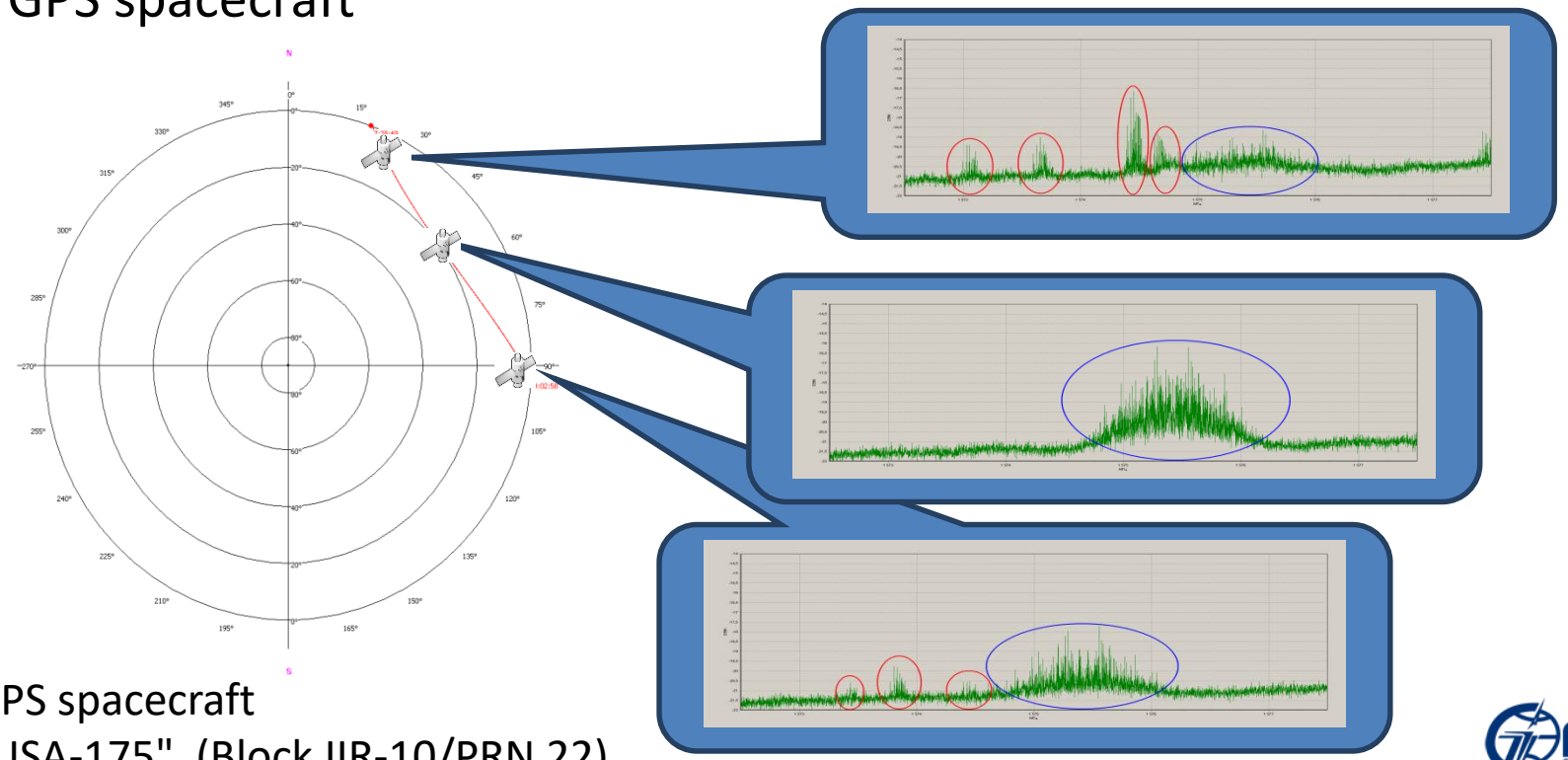
Вектор
Специализированное ОКБ

Spatial distribution of GNSS spacecraft emission

Methodological approach. Azimuth and elevation angle base diagram.

Radiofrequency spectrum in case of target-specific measurements dedicated to monitored spacecrafts in the point of measuring.

GPS spacecraft



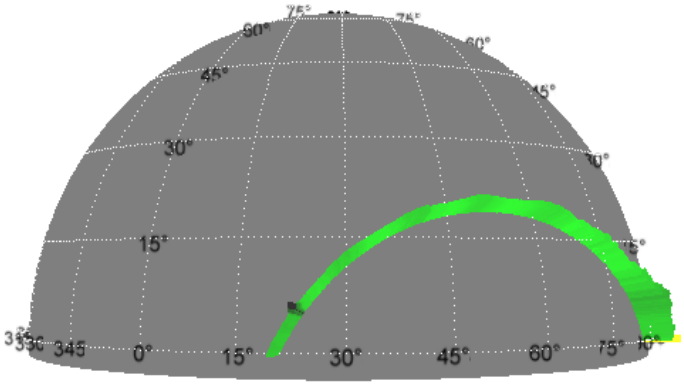
GPS spacecraft
"USA-175" (Block IIR-10/PRN 22)

Spatial distribution of GPS spacecraft emission

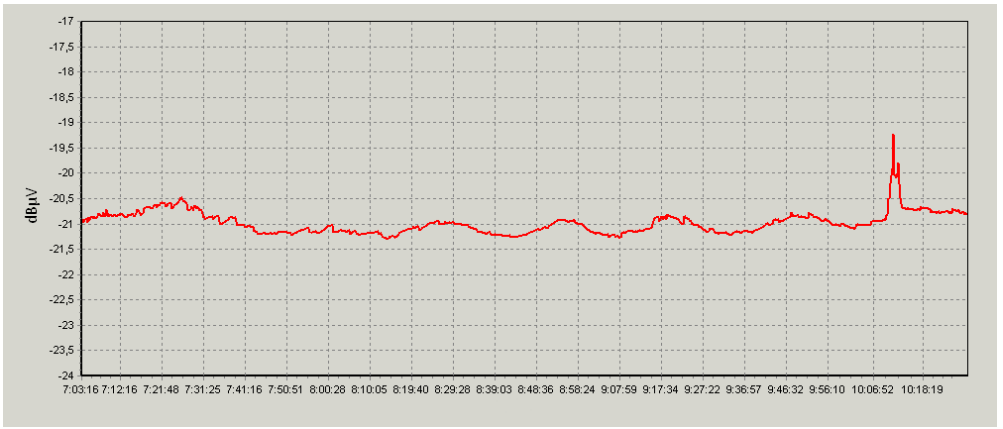
Methodological approach. Azimuth and elevation angle base diagram.

Emission power estimation in case of target-specific measurements dedicated to monitored GNSS spacecrafts in the point of measuring.

GPS



Average power of emission towards monitored spacecraft over a period of monitoring



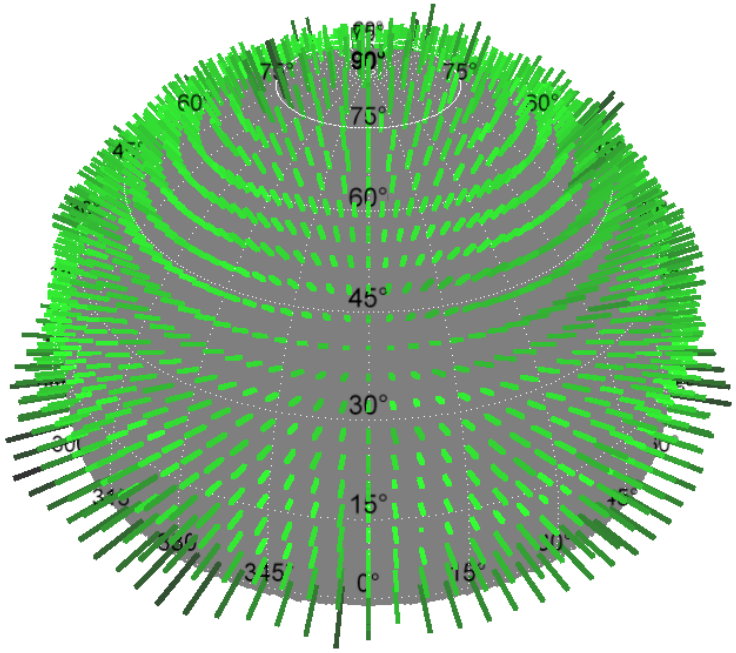
GPS spacecraft
"USA-175" (Block IIR-10/PRN 22)

Spatial distribution of GPS spacecraft emission

Methodological approach. Azimuth and elevation angle base diagram.

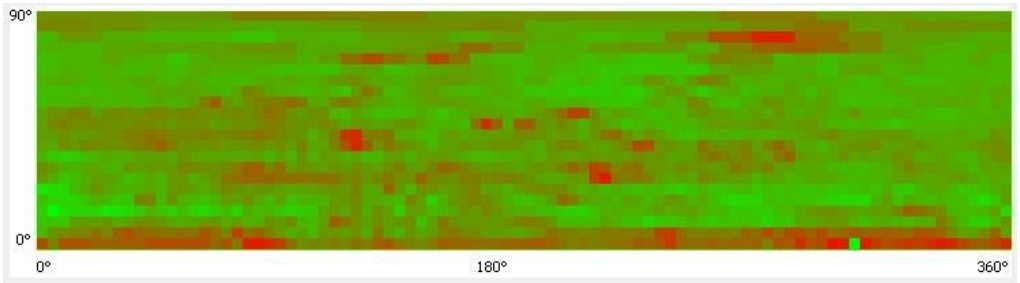
Average emission level allocation to azimuth and elevation angle base in the GNSS frequency band.

To the North



GPS. L1 band

Semisphere sweep

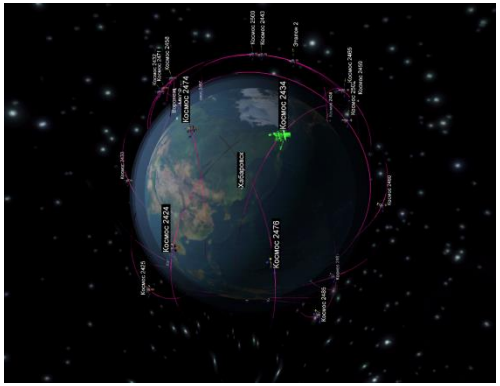


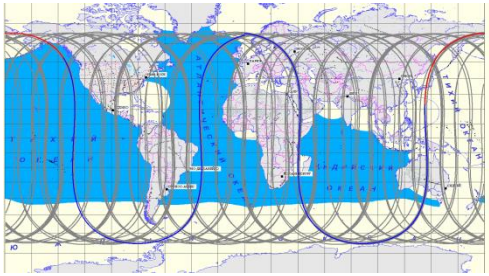
Spatial distribution of emissions in the frequency bands of GNSS

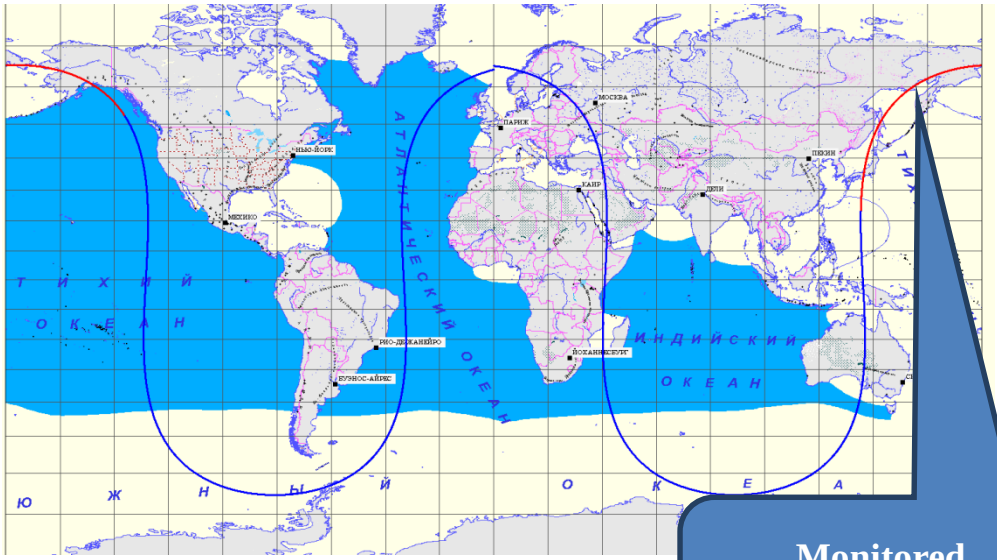
Spatial distribution of GNSS spacecraft emission

The objects of target-specific signal level measuring in the bands of GNSS.

GLONASS spacecrafts







Monitored spacecraft. Monitoring time

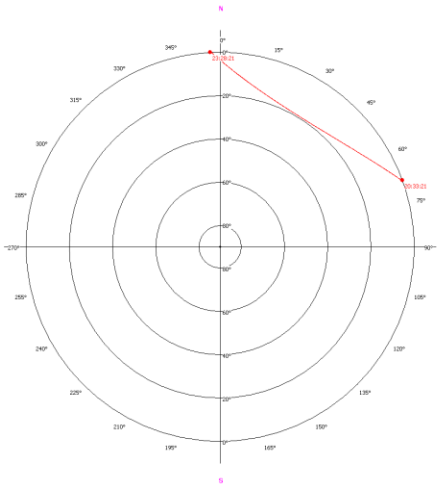
Spatial distribution of emissions in the frequency bands of GNSS

Spatial distribution of GNSS spacecraft emission

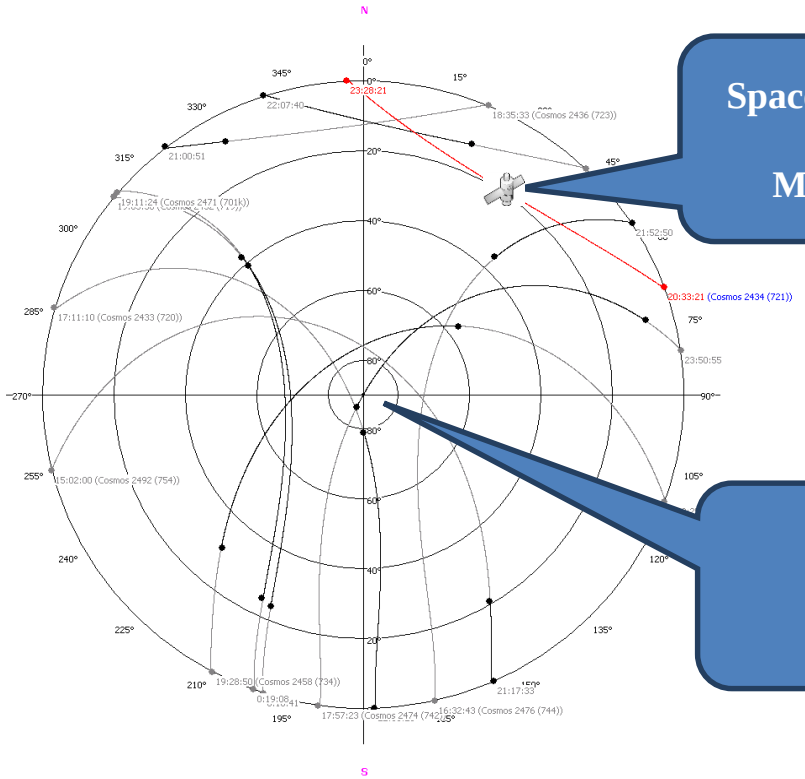
Methodological approach. Azimuth and elevation angle base diagram.

Paths of monitored spacecrafts and measuring direction in coordinate representation: azimuth - elevation angle in the point of measuring.

GLONASS spacecrafts



GLONASS spacecraft
“Cosmos-2434 (721)"



International Committee on Global Navigation Satellite Systems

Spatial distribution of emissions in the frequency bands of GNSS

Emission parameter estimation for target-specific measurement dedicated to monitored GNSS spacecrafts.

Measuring conditions
for GLONASS “Cosmos-2434 (721)"

Parameter	Value
Start time	08.06.2015 23:33:21
Final time	09.06.2015 2:28:21
Antenna installation latitude	51°42'44.2"N
Antenna installation longitude	39°08'53.6"E
Antenna suspension height	65.2 m
Antenna type	Active directional (Supral 1,65 + Tallysman TW3440)
Measurement equipment	Measuring Receiver Rohde & Schwarz EB500
Measuring technique	Spacecraft tracking
Frequency band	1597,0 – 1607,0 МГц (GLONASS L1)
Frequency resolution	1 kHz
Sweep count	10
Sweep mode	Averaging
Detector	Average signal level

Вектор Специализированное ОКБ

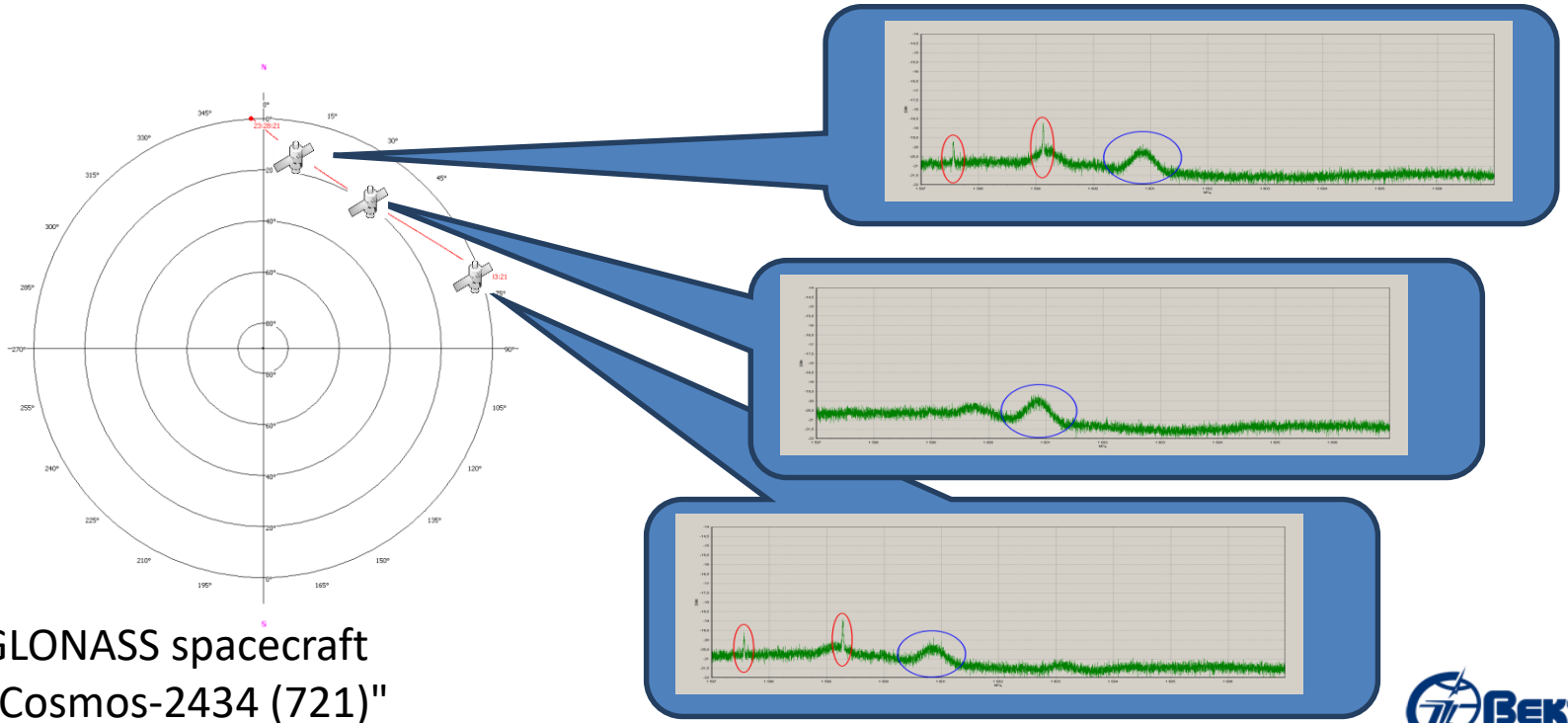
Spatial distribution of emissions in the frequency bands of GNSS

Spatial distribution of GNSS spacecraft emission

Methodological approach. Azimuth and elevation angle base diagram.

Radiofrequency spectrum in case of target-specific measurements dedicated to monitored spacecrafts in the point of measuring.

GLONASS spacecrafts



GLONASS spacecraft
“Cosmos-2434 (721)"

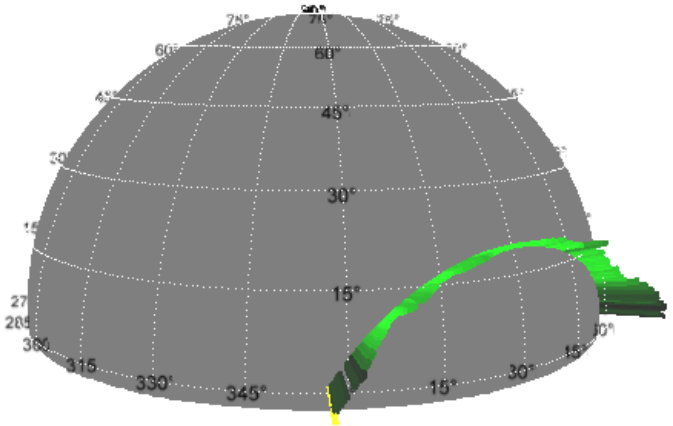
Spatial distribution of emissions in the frequency bands of GNSS

Spatial distribution of GLONASS spacecraft emission

Methodological approach. Azimuth and elevation angle base diagram

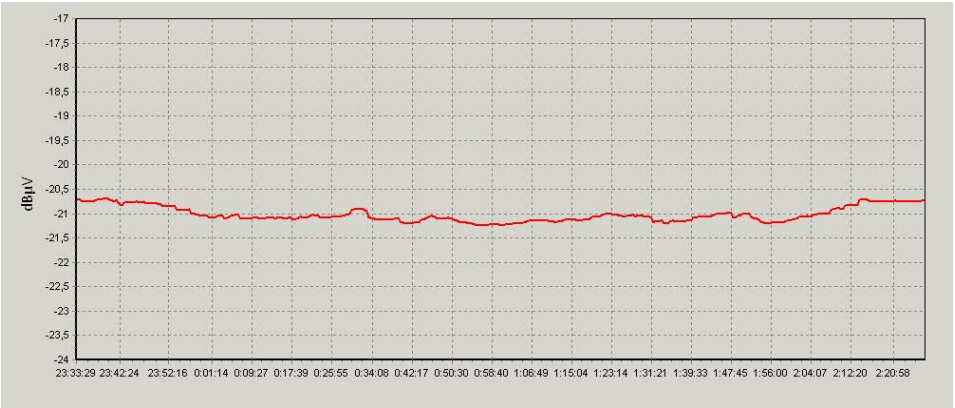
Emission power estimation in case of target-specific measurements dedicated to monitored GNSS spacecrafts in the point of measuring.

GLONASS



GLONASS spasecraft
"Cosmos-2434 (721)"

Average power of emission towards monitored spacecraft over a period of monitoring



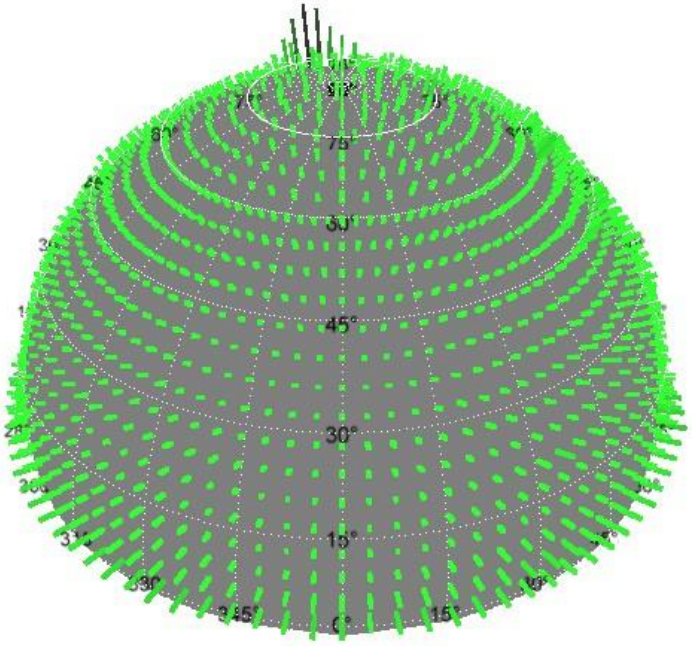
Spatial distribution of emissions in the frequency bands of GNSS

Spatial distribution of GLONASS spacecraft emission

Methodological approach. Azimuth and elevation angle base diagram

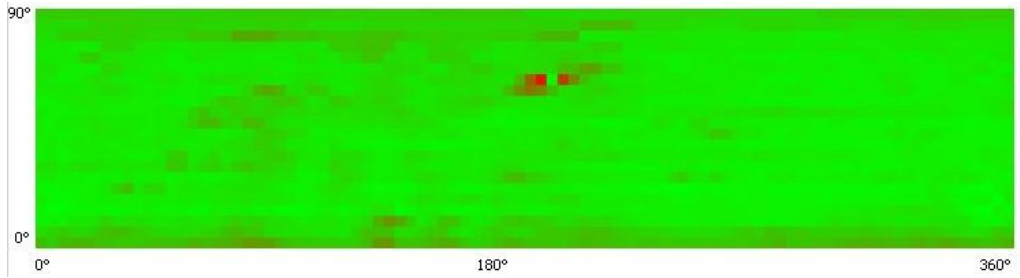
Average emission level allocation to azimuth and elevation angle base in the GNSS frequency band.

To the North



GLONASS. L1 band

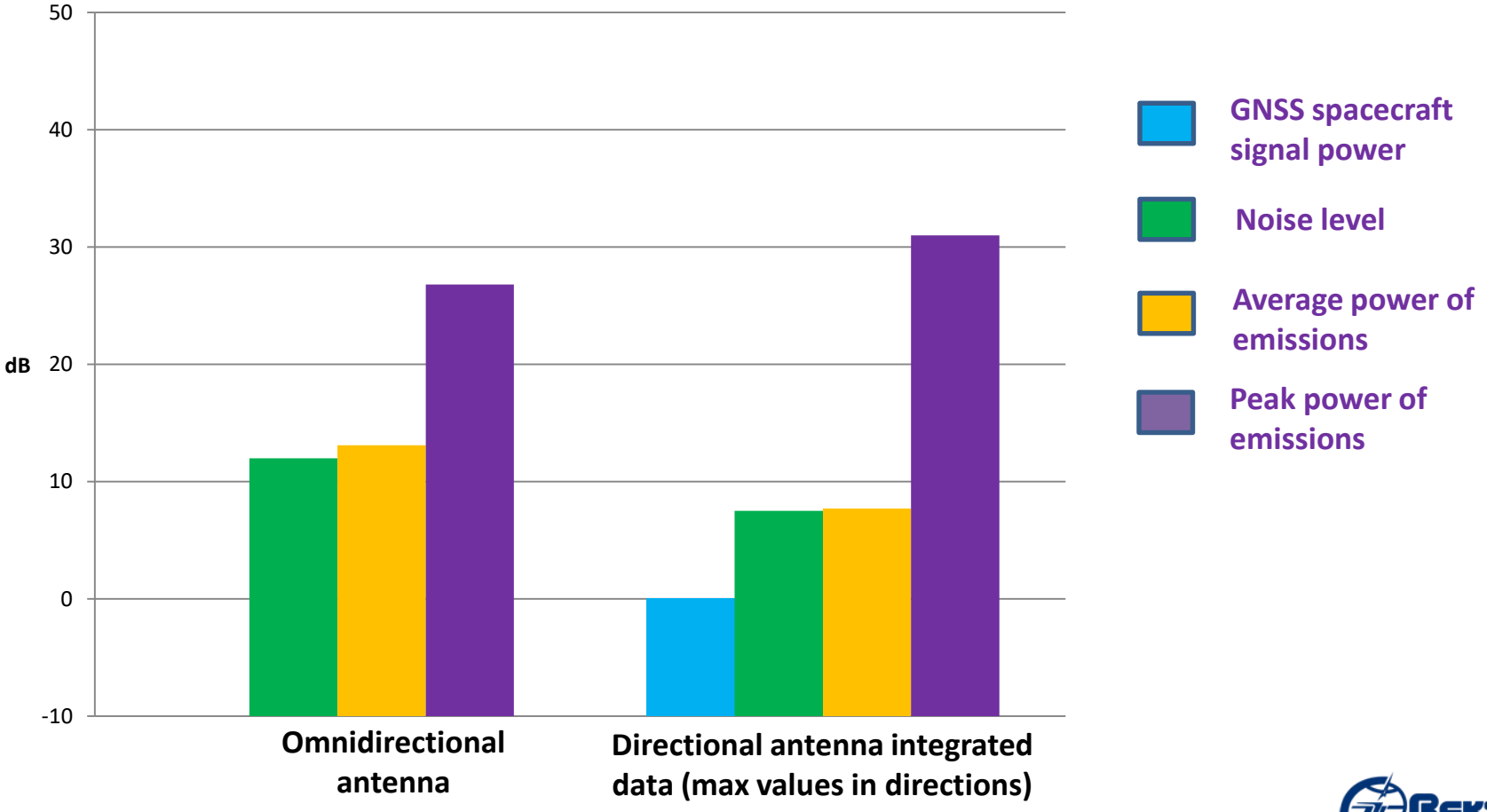
Semisphere sweep



Spatial distribution of emissions in the frequency bands of GNSS

GNSS legitimate signal emission level ratio to noise background and emission power.

Cumulative results for L1 GLONASS according to done measurements



Spatial distribution of emissions in the frequency bands of GNSS

CONCLUSIONS

Spatial distribution of emissions in the frequency bands of GNSS:

- provides meaningful characterization of electromagnetic environment in detail,
- helps to detect interferience impact on GNSS.

For the benefit of interferience detection technology progression is necessary to develop parametrical master form which includes:

- parametres of monitoring task,
- results of direct measuring of parameters of emission distribution in the frequency band of GNSS,
- results of measurements data reprocessing,

for the purposes of interferience detection and locating in the frequency band of GNSS according to the data of spatial distribution estimation.

CONCLUSIONS

Proposed methodological approach to execution of measurements

can be used in practice,

can be used as a base for guidance documents,

operational recommendations:

- relating to execution of measurements,
- relating to data reprocessing and making conclusions,
- relating to developing special monitoring equipment.

Spatial distribution of emissions in the frequency bands of GNSS

CONCLUSIONS

The proposed approach can be used:

- for create a global monitoring system,

- for accounting and prevention of interference to GNSS,

- in the framework of international cooperation in this area

International Committee on
Global Navigation Satellite Systems

Thank you for your attention

Stanislav Kizima
ITU-expert, Doctor of Technical Sciences
Deputy Director General
The R&D centre for systems and tools of measurement “Vector”
+7 916 531 43 68, 5314368@mail.ru