International Committee on
Global Navigation Satellite Systems

Practical recommendations applicable to radio monitoring for the purposes of interference environment estimation in the frequency bands of GNSS

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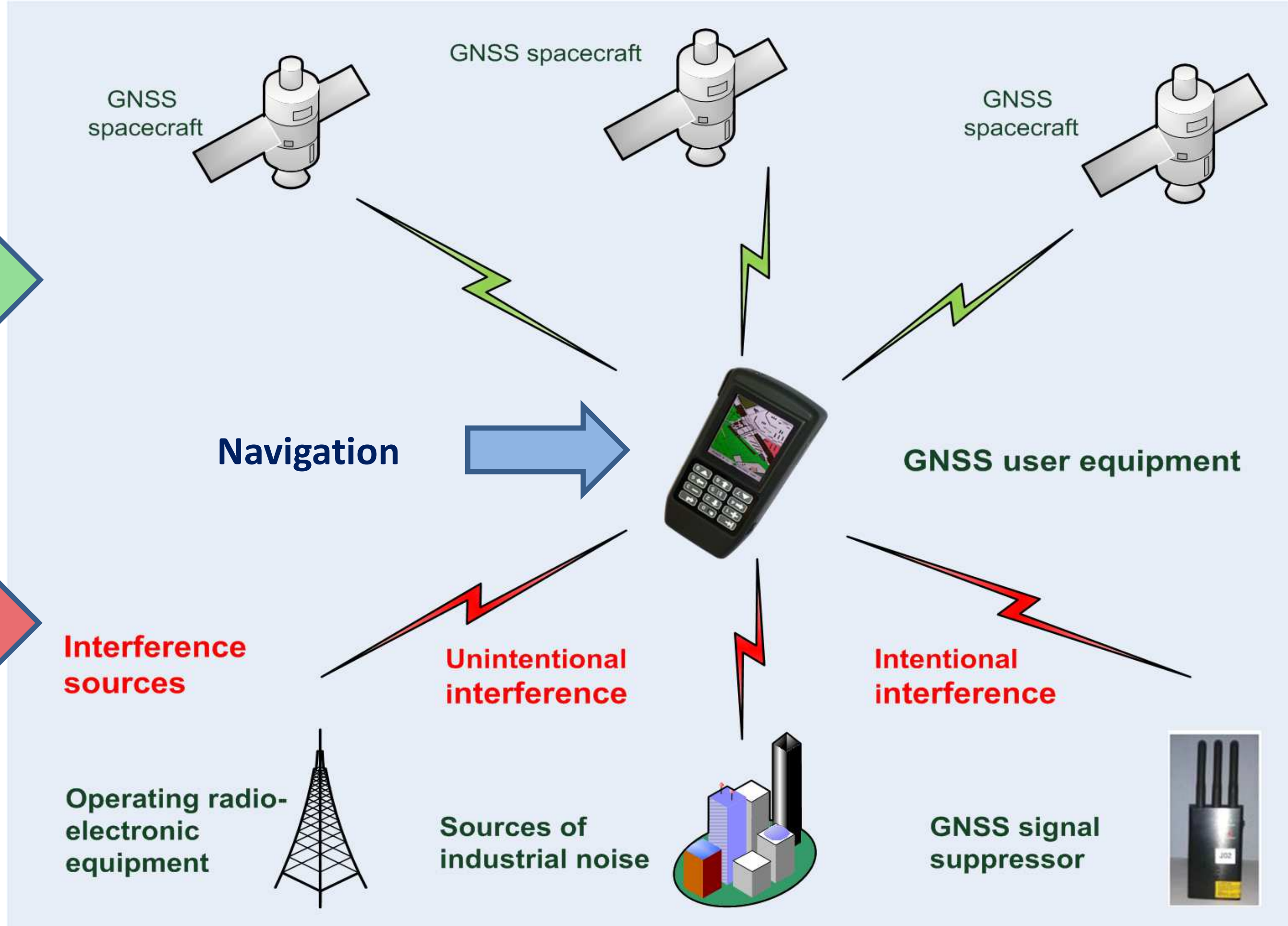
Вектор
Специализированное ОКБ

Navigation management conditions.
Aggregated emissions at the input of receiving antenna of GNSS user equipment

Include:

Desired signals

Negative impact



Recommendations applicable to maintaining of non-interference operation of satellite navigation systems should include:

Statutory and regulatory decisions

on a worldwide basis

on a national basis

Techniques

on a worldwide basis

on a national basis

Equipment and systems

on a worldwide basis

on a national basis

Practical performance

on a worldwide basis

on a national basis

Practical effects

Stable non-interference operation of satellite navigation systems

Recommendations applicable to radio monitoring in GNSS frequency bands should include:

1. Definitions applicable to goals and tasks of radio monitoring
2. Recommendations concerning radio monitoring arrangement and planning
3. Recommendations concerning equipment and systems of radio monitoring
4. Recommendations concerning execution of necessary measurements
5. Recommendations concerning secondary processing of measuring results
6. Recommendations concerning interference detection and integral estimation of interference environment
7. Recommendations concerning cooperation in this field

Goals of radio monitoring in GNSS frequency bands

Near real-time detection of interferences for GNSS signal propagation and reception, termination of its operation to the benefit of stable non-interference operation of navigation satellite systems

Tasks of radio monitoring in GNSS frequency bands :

1. Monitoring of GNSS frequency bands
2. GNSS frequency bands occupancy estimation. Estimation of levels of electromagnetic background noise. Emission detection in the frequency bands of GNSS
3. Identification of emissions and interference sources in GNSS frequency bands
4. Measurements of interference parameters. Identification of interference sources. Interference source locating
5. Estimation of the level of impact noise levels and interference on navigation satellite systems
6. Initialization of procedures focused on deactivating interference to GNSS signal propagation and reception

Recommendations concerning equipment and systems of radio monitoring should include:

1. **Recommendations concerning measuring equipment for procedures of radio monitoring in GNSS frequency bands.**

   List and values of specified characteristic of measuring equipment

2. **Recommendations concerning interoperation of measuring equipment and integration into the radio monitoring system.**

   Requirements relating to interfaces and equipment control protocol

3. **Recommendations concerning aggregation, processing and storage of the results of radio monitoring.**

   Requirements relating to data transmission and storage formats

Recommendations concerning measurements, processing of measurement results and interference environment estimation

Recommendations are determined basing on the implemented model of radio monitoring object.

The model of radio monitoring object could be based on spatial distribution of emissions in the frequency bands of GNSS

Spatial distribution of emissions in the frequency bands of GNSS:

1. Is defined

by spatial distribution of radio facilities and other interference sources in GNSS frequency bands

2. Is estimated

by the level and direction of arrival of emission energy according to the azimuth and elevation angle at the point of estimation

Goals and tasks of analysis of spatial distribution in GNSS frequency bands

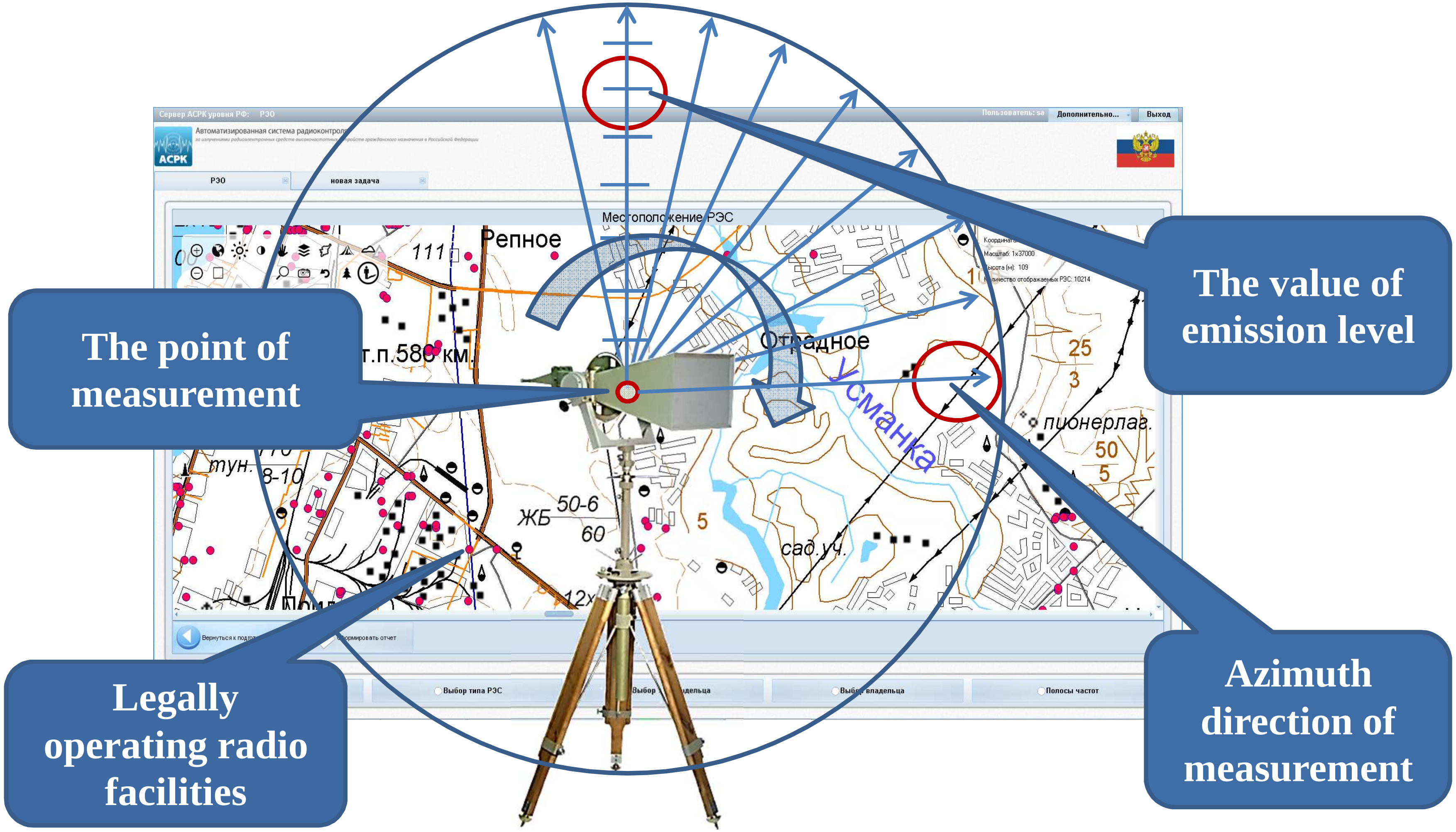
- **Spatial scanning of spectrum in the frequency bands of GNSS by directional antennas at the point of measurement:**
  - *in azimuth plane – for analysis of terrestrial emissions*
  - *in semi sphere in azimuth and elevation angle - for analysis of airspace and outer space emissions*
- **Building-up the total collection of initial data for tasks execution of electromagnetic and interference environment estimation in GNSS frequency bands**
- **Estimation of integral spectral energy parameters in GNSS frequency bands in the directions of energy arrival**
- **Special diagrams construction of distribution of integral spectral energy parameters in GNSS frequency bands according to the directions of energy arrival**
- **General estimation of electromagnetic and noise environment**
- **Detection of emissions and interference sources. Estimation of parameters of interference impact**

Measurement planning.
The content of measuring tasks at the point of estimation of interference environment

№	Measurements conditions			Measurements results					
	Coordinate of the measure-ment point	Measu-rement time	Freque ncy bands GNSS	Azimuth	Eleva-tion angle	Spectrum In the band	Noise level In the band	Peak level of emissions in the band	Average level of emissions in the band
	Longitude, latitude	*minutes, hours, day, month, year*	*Min., Max.*	*degree*	*degree*	*Frequency -level*	*dBm*	*dBm*	*dBm*
1									
2									
…									
k									

Measurement planning. Measurement procedure at the point of interference environment estimation:

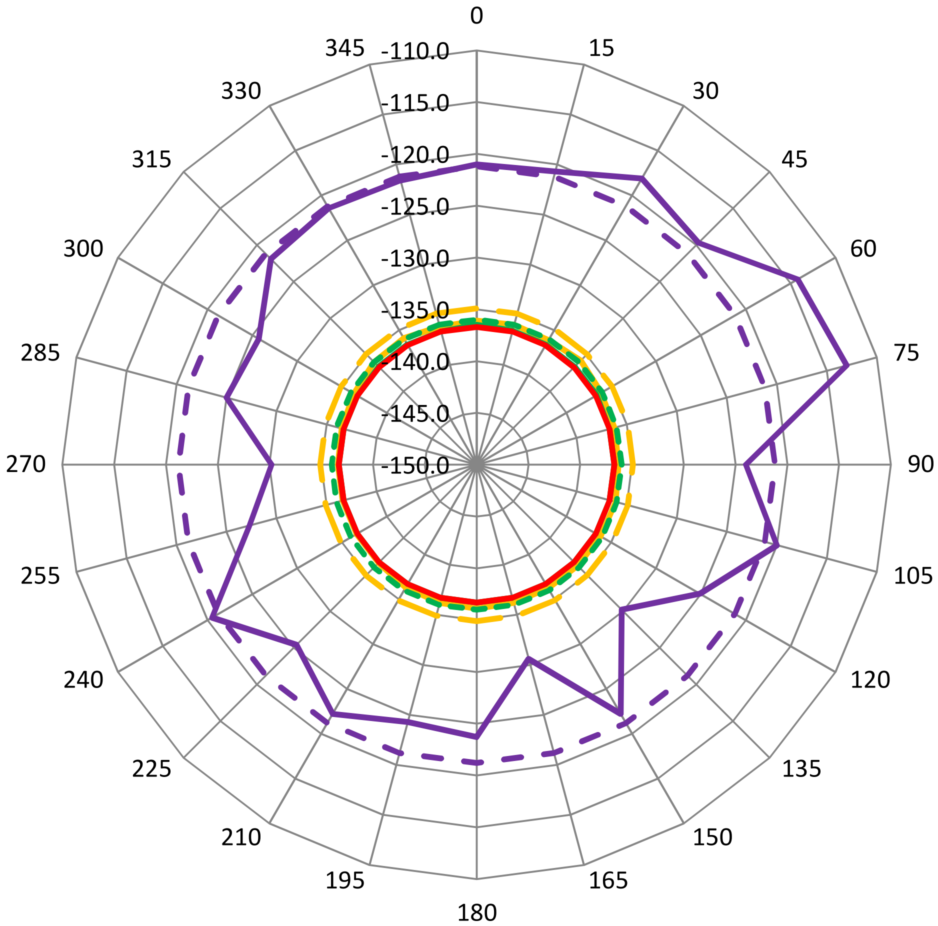
Spatial scanning by directional antenna



Spatial scanning of emission of terrestrial radio facilities

Methodological approach. Azimuth diagram. Practice-oriented example

Radio emission level distribution in azimuth plane.
Summary results of measurements data processing



Measurement quantities:

Measurement by directional antenna

- Peak power
- Average power
- Noise level

Measurement by omnidirectional antenna

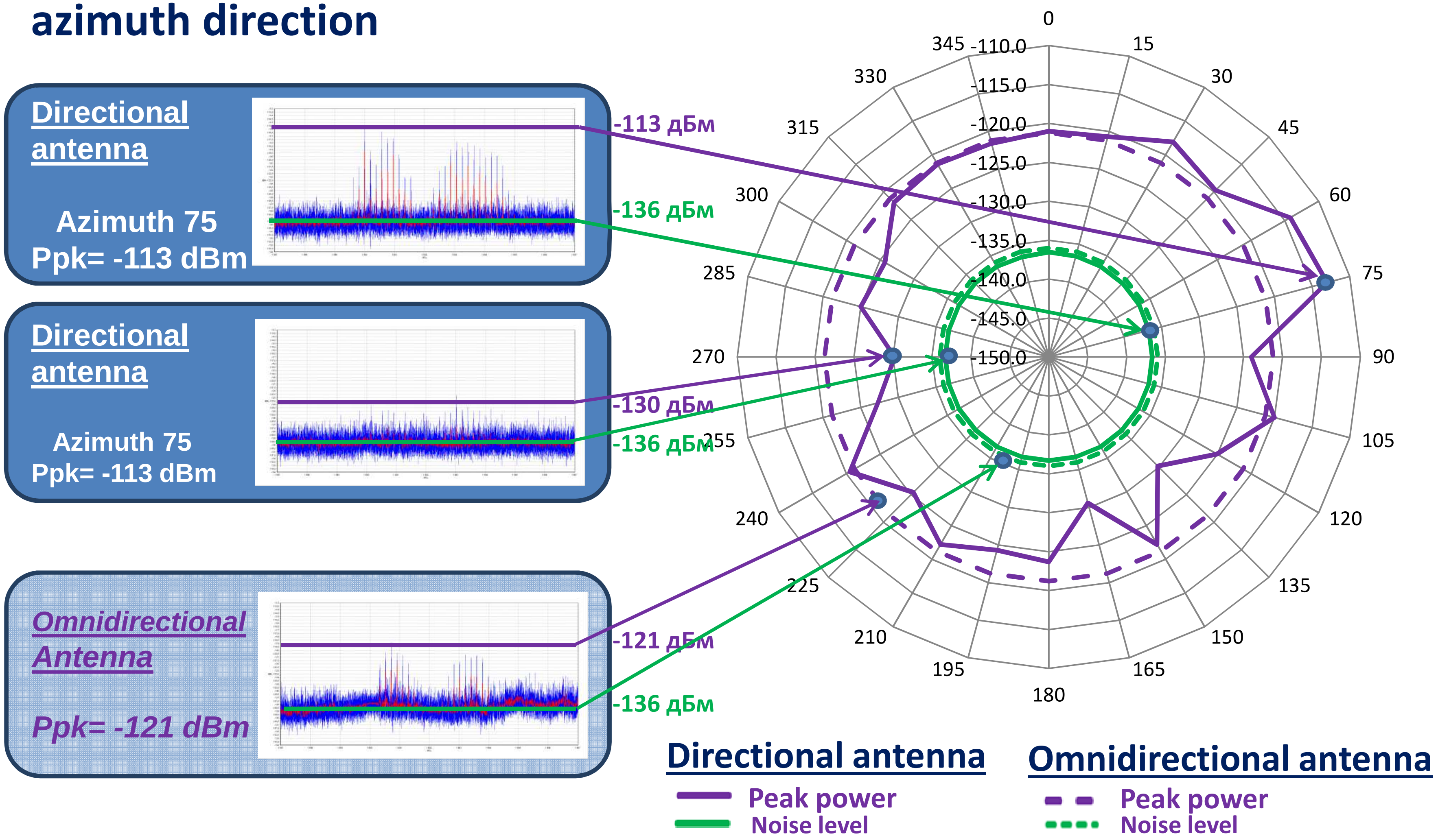
- Peak power
- Average power
- Noise level

Noise level of measuring receiver

Spatial scanning of emission of terrestrial radio facilities

Methodological approach. Azimuth diagram. Practice-oriented example

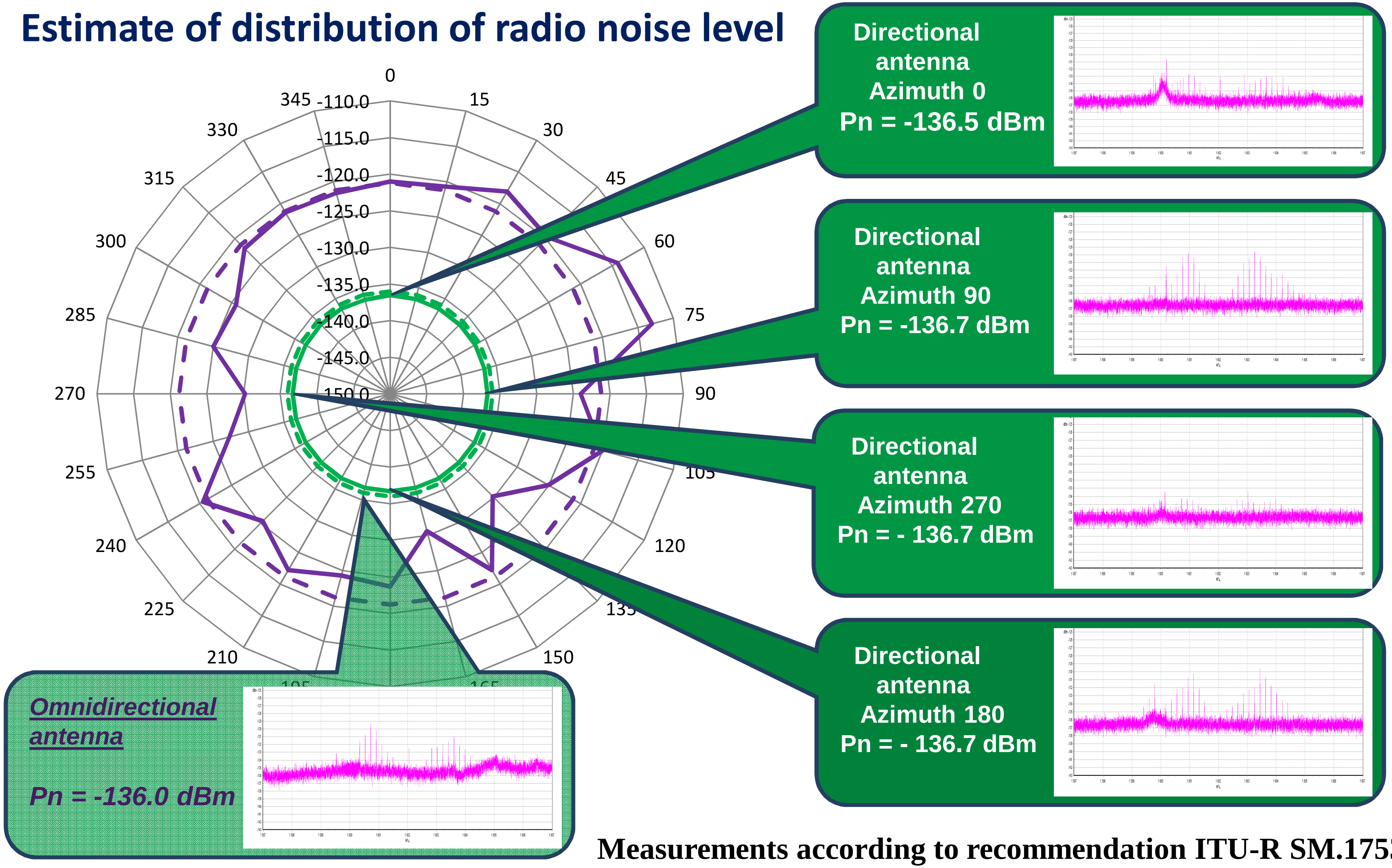
Estimate of distribution of the peak power energy of emissions in azimuth direction



Spatial scanning of emission of terrestrial radio facilities

Methodological approach. Azimuth diagram. Practice-oriented example

Estimate of distribution of radio noise level



Measurements according to recommendation ITU-R SM.1753

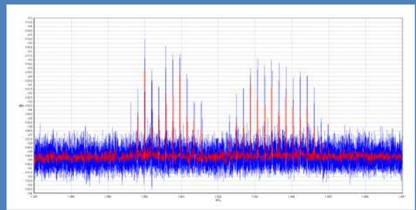
Spatial scanning of emission of terrestrial radio facilities

Methodological approach. Azimuth diagram. Practice-oriented example

Estimate of distribution of the peak power energy of emissions in azimuth direction

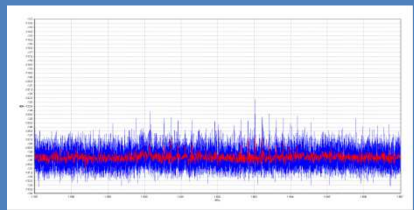
Directional antenna

Azimuth 75
Ppk= -113 dBm



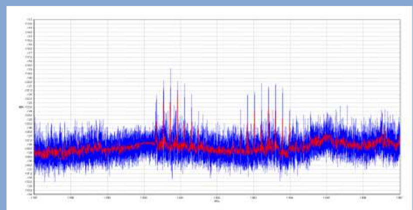
Directional antenna

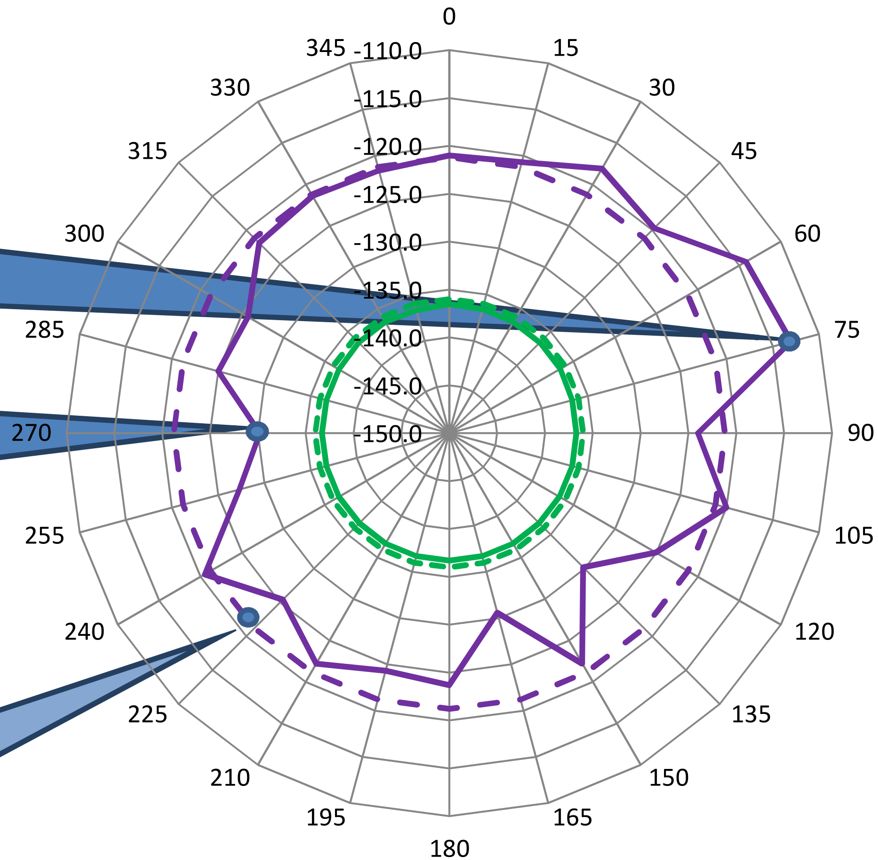
Azimuth 270
Ppk= -130 dBm



Omnidirectional Antenna

Ppk= -121 dBm





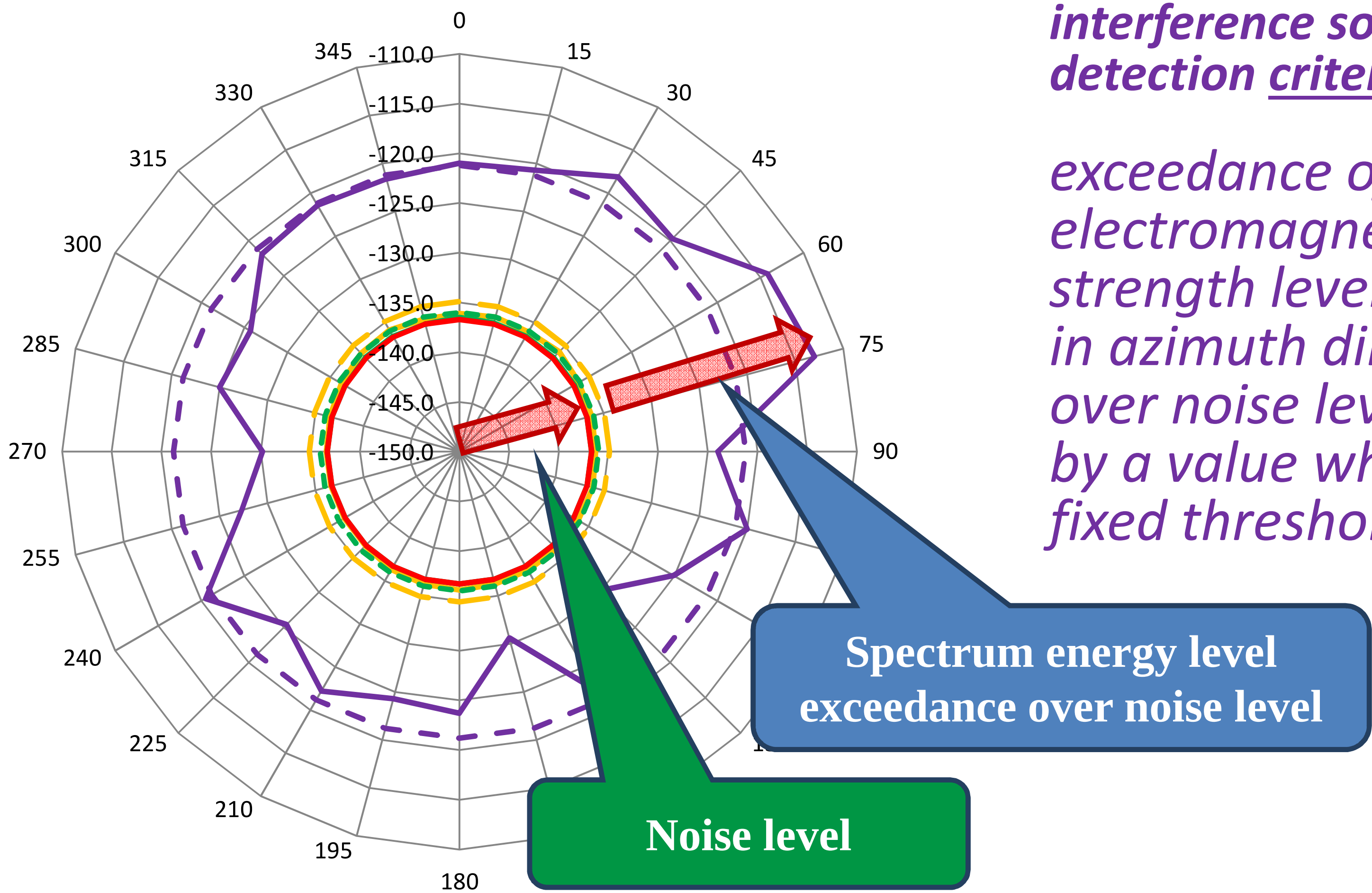
Directional antenna
- Peak power
- Noise level

Omnidirectional antenna
- Peak power
- Noise level

Spatial scanning of emission of terrestrial radio facilities

Methodological approach. Azimuth diagram. Practice-oriented example

Emission and interference sources detection



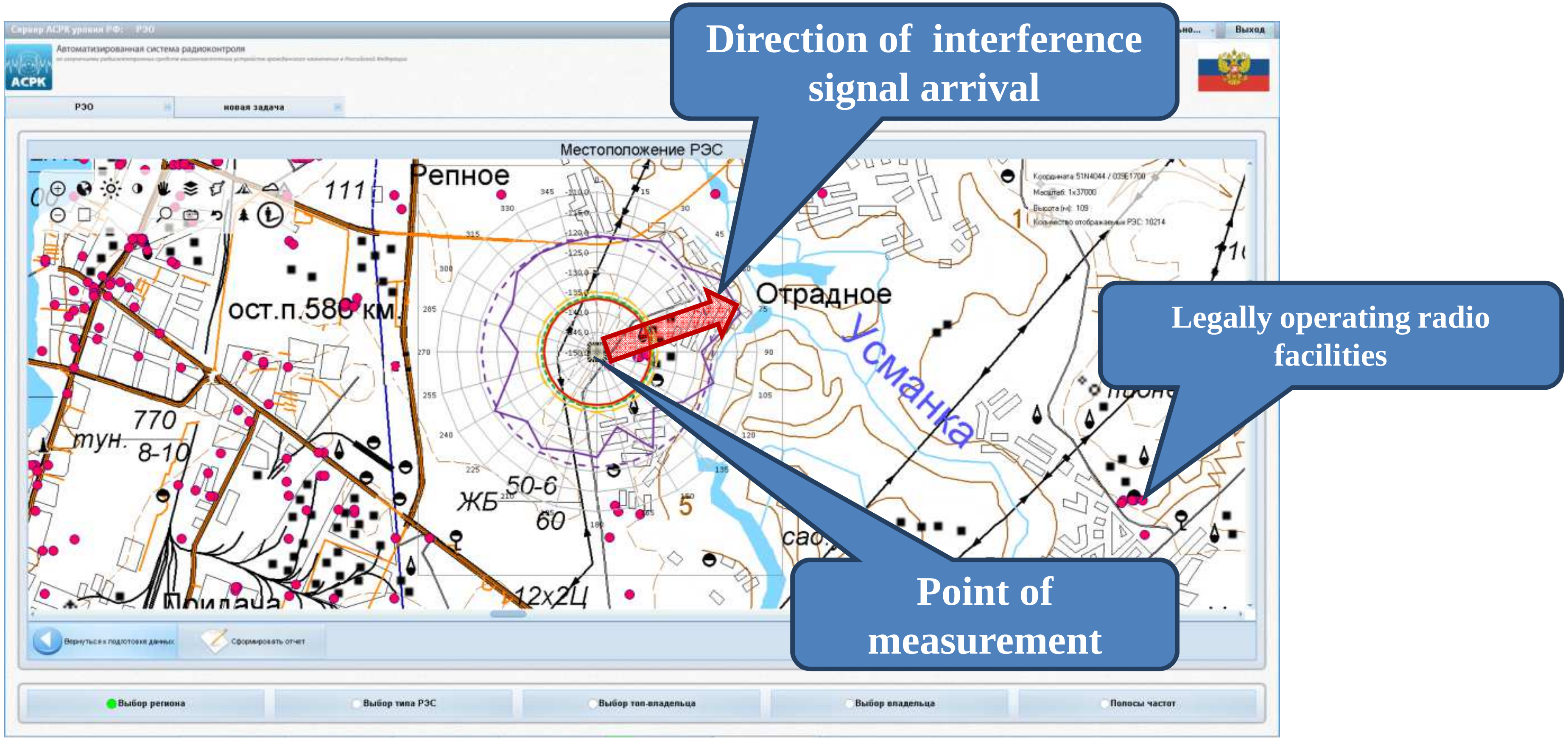
Possible emission and interference sources detection criteria:

exceedance of electromagnetic field strength level in azimuth direction over noise level by a value which exceed fixed threshold value

Spatial scanning of emission of terrestrial radio facilities

Methodological approach. Azimuth diagram. Practice-oriented example.

Definition of direction of interference signal arrival.



What's next? The following steps :

1. Definition (normalization) limits values of levels of unwanted emissions for navigation receivers :
   - for radio noise level,
   - for peak power and average power energy of emissions in GNSS frequency bands

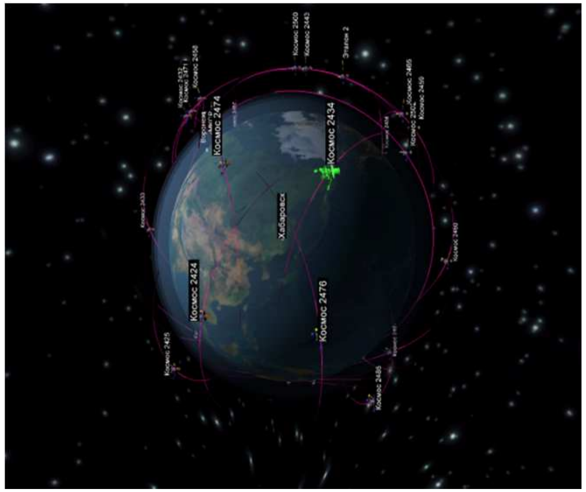
2. Navigation receivers testing for resistance estimation to values of levels of unwanted emissions.

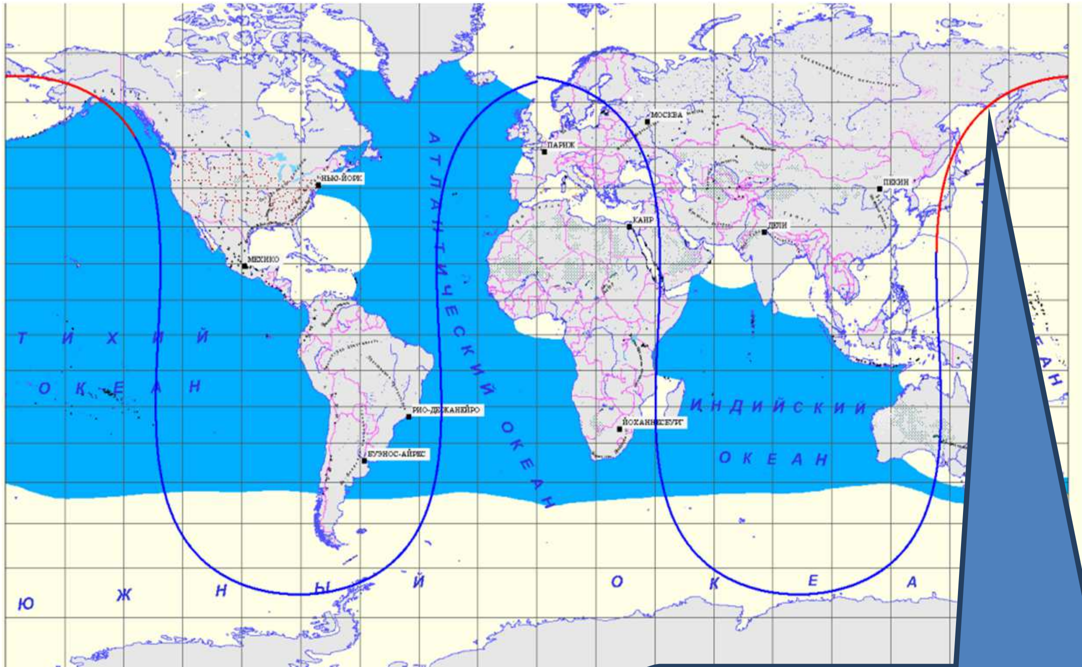
3. Practical radio monitoring.
   Estimation of conditions for navigation.
   Detection of interference.

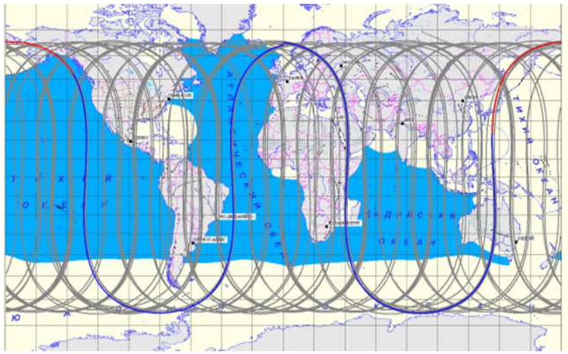
Spatial scanning of GNSS satellites emissions

Objects of intent measurements of signal levels in the frequency bands.

GLONASS satellites







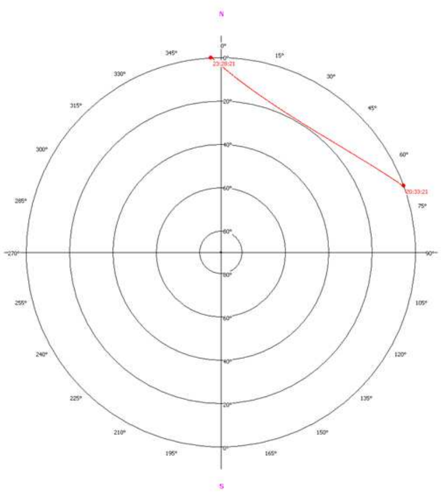
Monitored satellite. Time range of monitoring

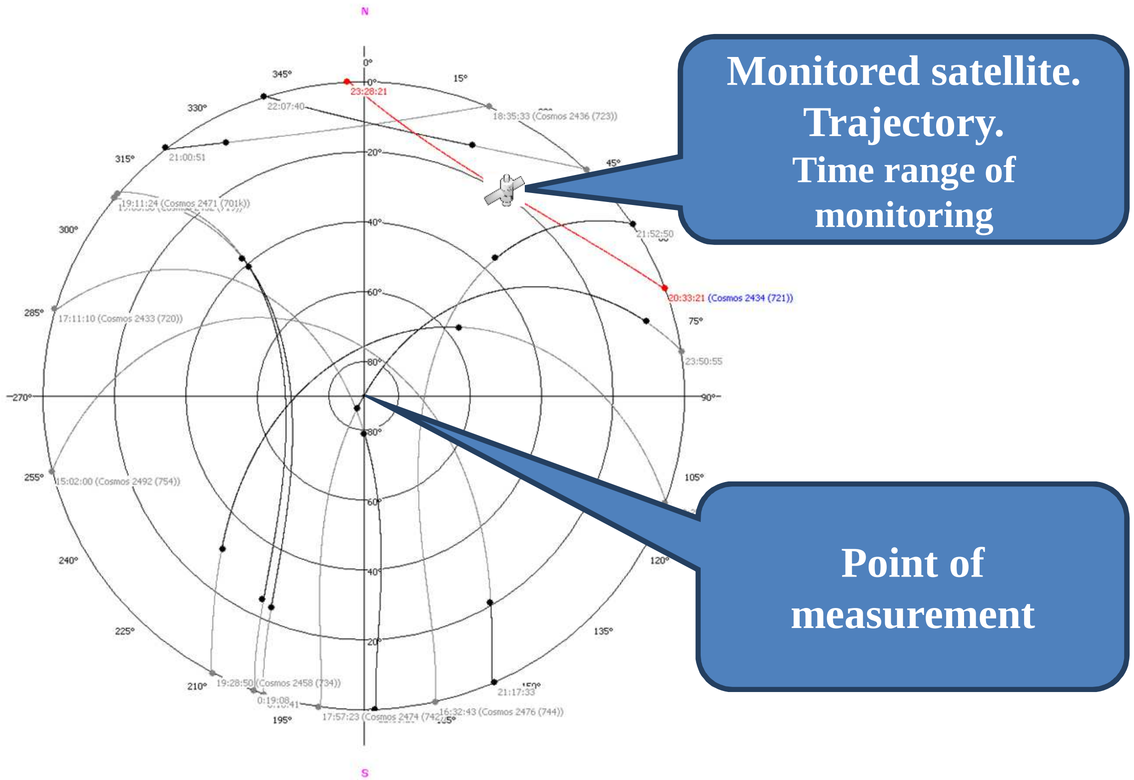
Spatial scanning of GNSS satellites emissions

Methodological approach. Azimuth and elevation angle diagram

Trajectory of monitored satellites and directions of measurements in azimuth – elevation angle coordinates at the point of measurements.

GLONASS satellites





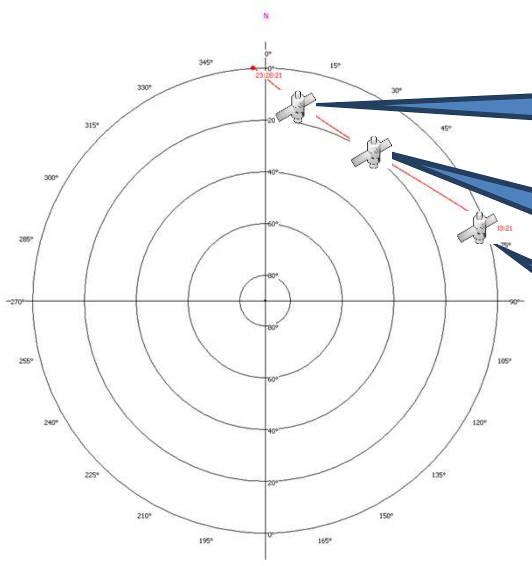
GLONASS satellite
“Cosmos-2434 (721)"

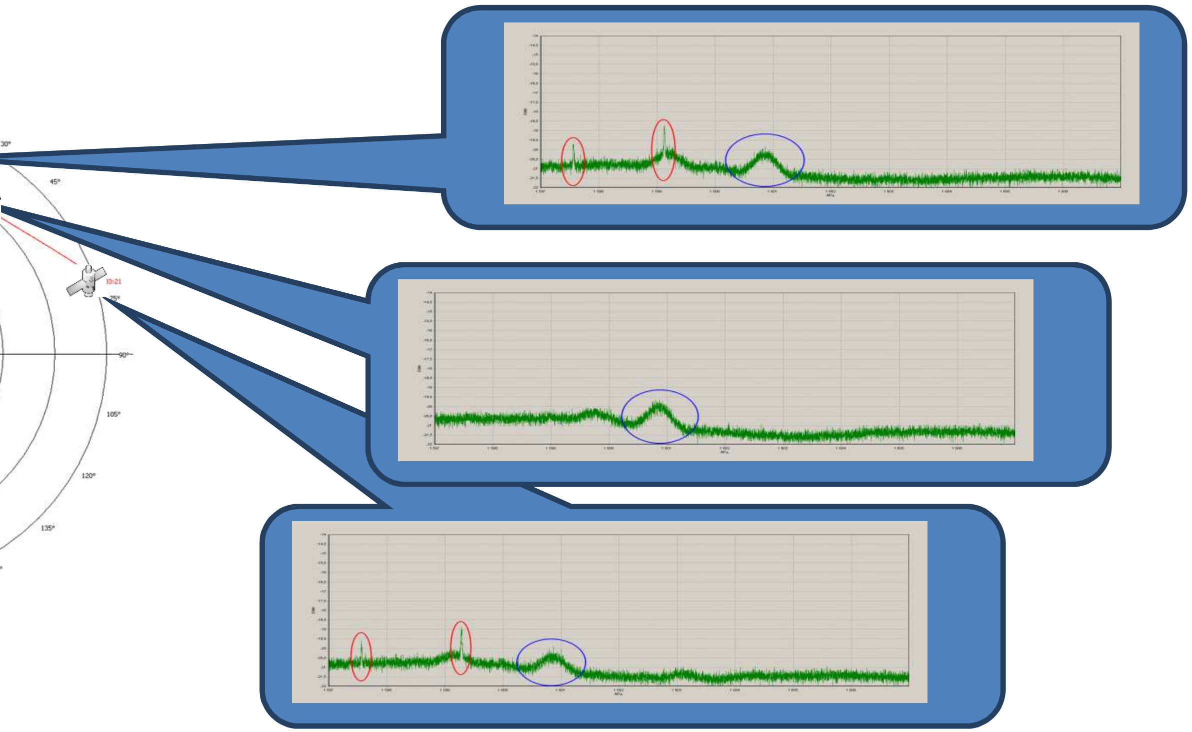
Spatial scanning of GNSS satellites emissions

Methodological approach. Azimuth and elevation angle diagram

Radio frequency spectra by intent measurements directed towards monitored satellites at the point of measurements.

GLONASS satellite





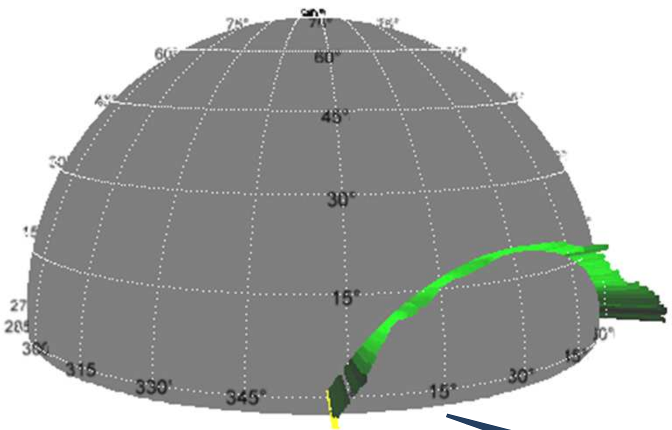
GLONASS satellite
“Cosmos-2434 (721)"

Spatial scanning of GNSS satellites emissions

Methodological approach. Azimuth and elevation angle diagram

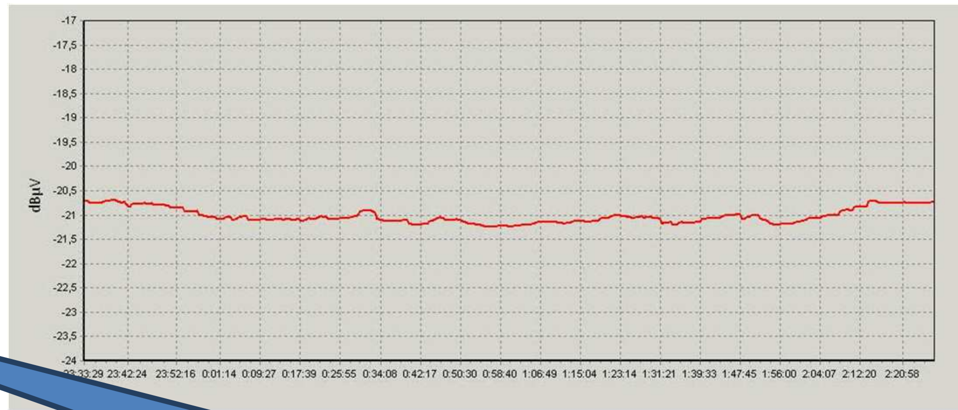
Estimation of average emission level by intent measurements directed towards monitored satellites at the point of measurements.

GLONASS



GLONASS satellite
“Cosmos-2434 (721)"

Average level of emissions towards monitored satellite within the time range



The semi sphere center – at the point of measurements

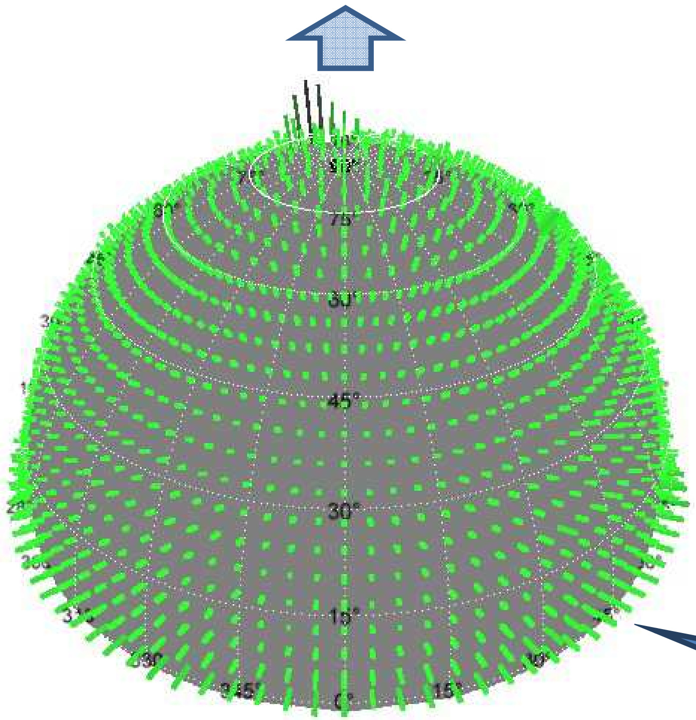
Spatial scanning of GNSS satellites emissions

Methodological approach. Azimuth and elevation angle diagram

Emissions average level lay-out in azimuth and elevation angle in the frequency bands of GNSS

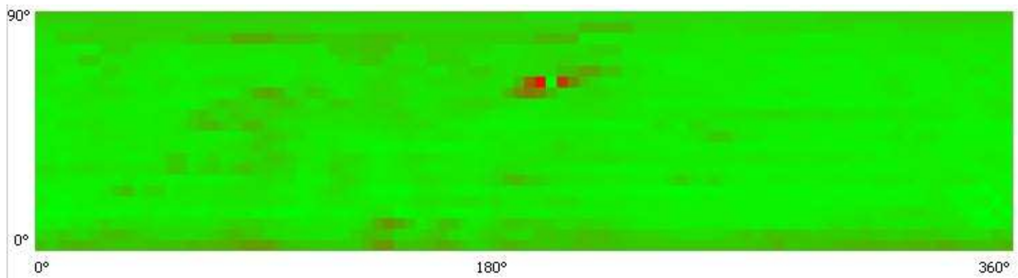
Consolidated data

Direction North



GLONASS. Frequency band L1

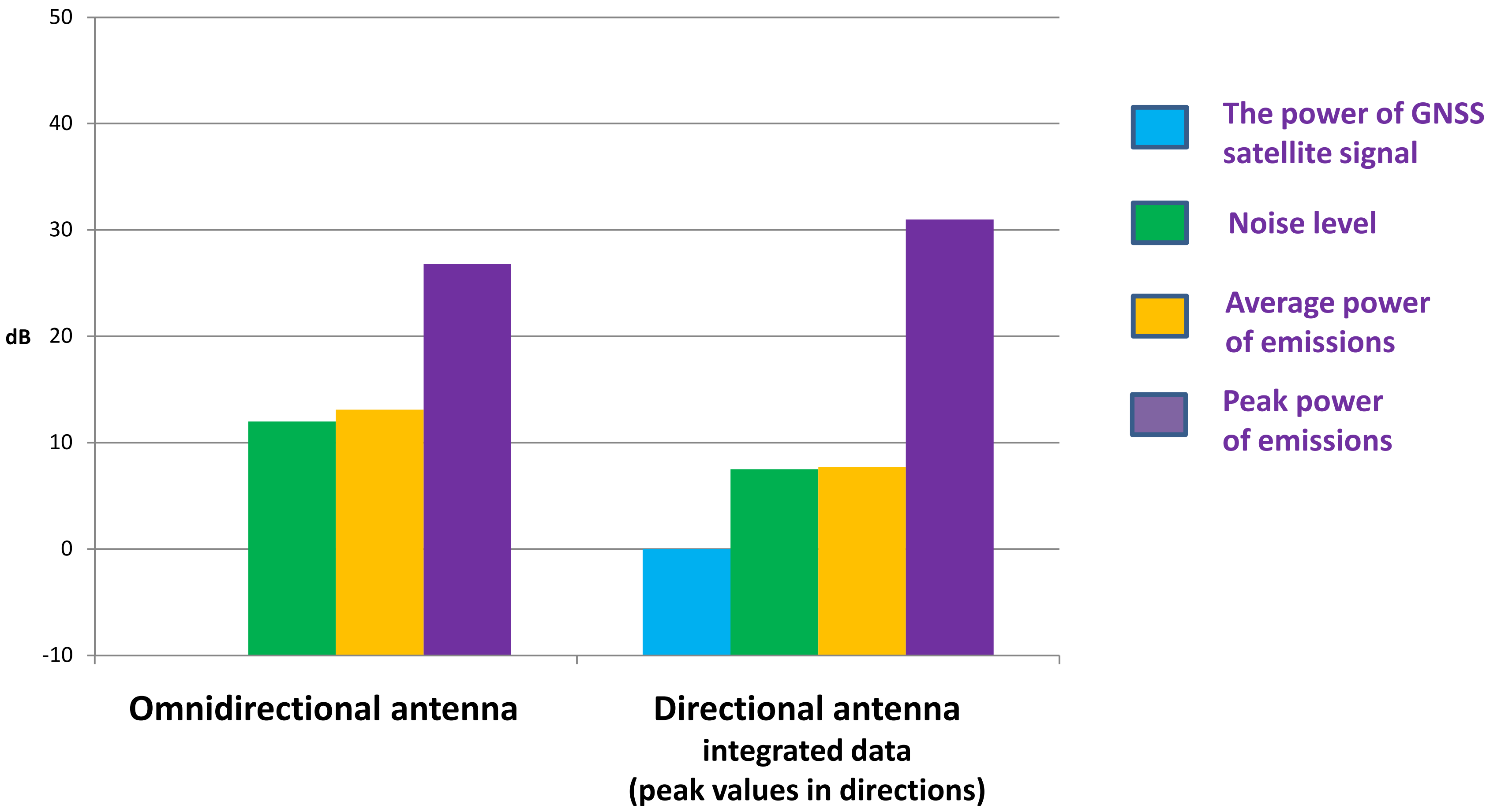
Semi sphere sweep



The semi sphere center – at the point of measurements

The correspondence of GNSS desired signal level, noise background level and power of emissions in the frequency bands of GNSS.

Integrated results for L1 GLONASS according to measurements results



CONCLUSIONS_1

It is of immediate interest to develop and use special recommendations concerning interference environment estimation in GNSS frequency bands for the purposes of supporting stable operation of navigation satellite systems

Recommendations should be aimed at

- ***near real-time detection of interference for GNSS signal propagation and reception,***
- ***interference identification, providing termination of its activity***

Recommendations should consider:

- ***special aspects of navigation satellite systems,***
- ***special aspects of GNSS frequency bands,***
- ***sensitivity of navigation satellite systems to electromagnetic noise level and interference emission level***

CONCLUSIONS_2

It is reasonable to take account of the following methodological approach during development of recommendations chapters concerning measurement procedures and secondary measurement results processing :

- **methodological approach based on estimation of spatial distribution of emissions in GNSS frequency bands;**
- **methodological approach based on 3-dimensional (spatial) scanning of emissions using directional antennas;**
- **methodological approach based on estimation of energy levels and directions of energy arrival in GNSS frequency bands in azimuth and elevation angle at the point of measurement (point of scanning).**

CONCLUSIONS_3

Complex representation of emission energy impacts in GNSS frequency bands is pictorially displayed by the diagrams of spatial view of energy impacts in semi sphere with the center at the point of measurements.

The diagrams are constructed according to the secondary processing of spectral measurements data in GNSS frequency bands.

The diagrams present aggregated data on directions of arrival and energy levels in GNSS frequency bands according to azimuth and elevation angle of emission energy arrivals.

The diagrams help to define informative criteria of interference detection and direction of arrival definition.

CONCLUSIONS_4

Comprehensive approach based on the spatial directional diagram of the review of energy impacts in semi sphere with the center at the point of measurement:

- provides estimation of conditions of navigation management,
- provides detailed and meaningful electromagnetic environment estimation,
- helps to detect interference impacts to GNSS signals propagation and reception.

International Committee on Global Navigation Satellite Systems

Thank you for your attention

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