国家无线电监测中心
The State Radio Monitoring Center

Spectrum Map

A Big Data Application for Visualization of Radio Spectrum

Dr. Huang Xuemin

Spectrum Map

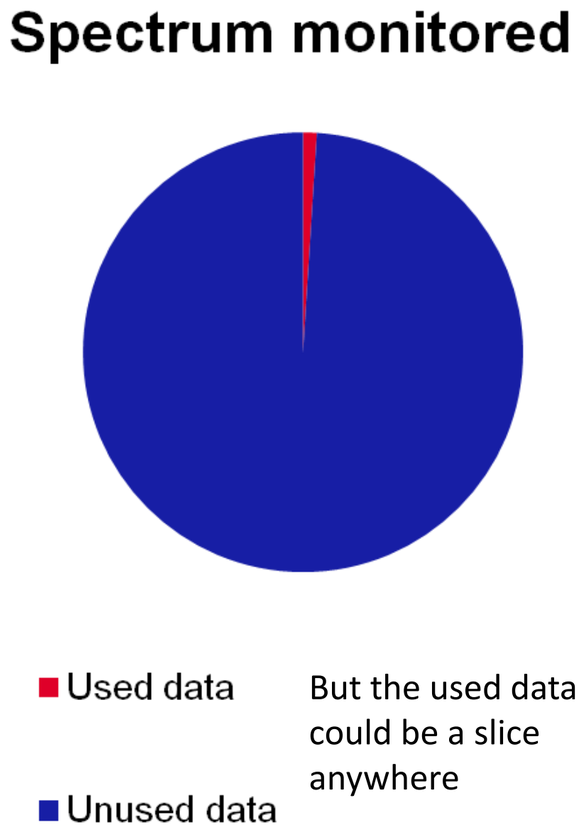
Modern Operational Spectrum Monitoring Requirements

- A distributed monitoring system that covers everything, everywhere.
- Flexible design, packaging, performance so devices can be matched to operational environment / requirement.
- Rich storage of spectrum data so historical picture can be built up.
- Small monitoring devices that can be placed anywhere, both antennas and receivers etc.
- Able to use equipment remotely, “other side of the world” as if we were directly connected to it.
- Purchase and running costs of monitoring system kept low.

Spectrum Map

The problems of data overloading in the sensor approaches

- High speed sensors produce vast data volume.
- 20MHz to 6 GHz = ± 12TB of data per 30 days
  - What use is it if we can not analyze it
  - Human analysis is pointless – too much data
  - Why record everything if you don't know what you want?
    - But I don't know what I need in the future!
  - How do I store / archive all this data?
  - How do I network this volume of data together?
- Is it worth collecting all this data?
- Is there value in the business case?



Spectrum Map

Existing approaches to sensors / monitoring analysis and use

- Many organisations are moving from large scale monitoring sites to multiple sensors / portable or drive test approaches.
- There are mixtures of equipment types, makers and models.
- Software is often tied to an individual manufacturer and so several programs are required to make use of these mixed systems
- Although remote control is quite normal, it’s often a one to one relationship that is one control station accesses one device at a time to make measurements or analysis having to access devices sequentially.
- Software is installed onto individual machines meaning either limited people having access or high costs / complexity of licensing.

Spectrum Map

What If….

- You've a sensor network of hundreds of devices.
- You don't care what the device is, you just want to analyse the spectrum.
- You have multiple vendors, multiple types, and a mix network of fixed, transportable, mobile, portable sensors.
- You want a big data approach of merging different sources of data.
- You want to quickly model, adapt and analyse the data based on differing requirements (location / time / frequency / coverage / interference).

AND YOU WANT NOW IS **SPECTRUM MAP !**

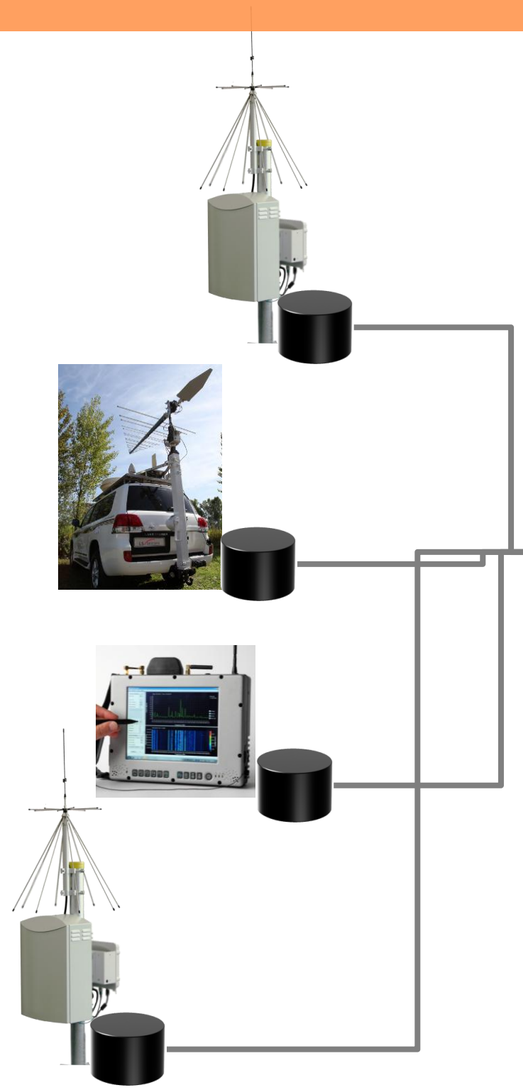
Spectrum Map

Background

- “**Building systems for dynamically displaying of radio spectrum**” is one of the tasks listed in the Chinese five-year plan for radio management (2016 - 2020).
- Investigate spectrum usage based on real data.
- Employ new technologies to improve the efficiency of radio management.

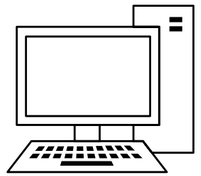
Spectrum Map

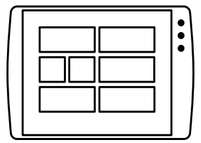
System Architecture



Cloud Data
Store
Processing

Internet



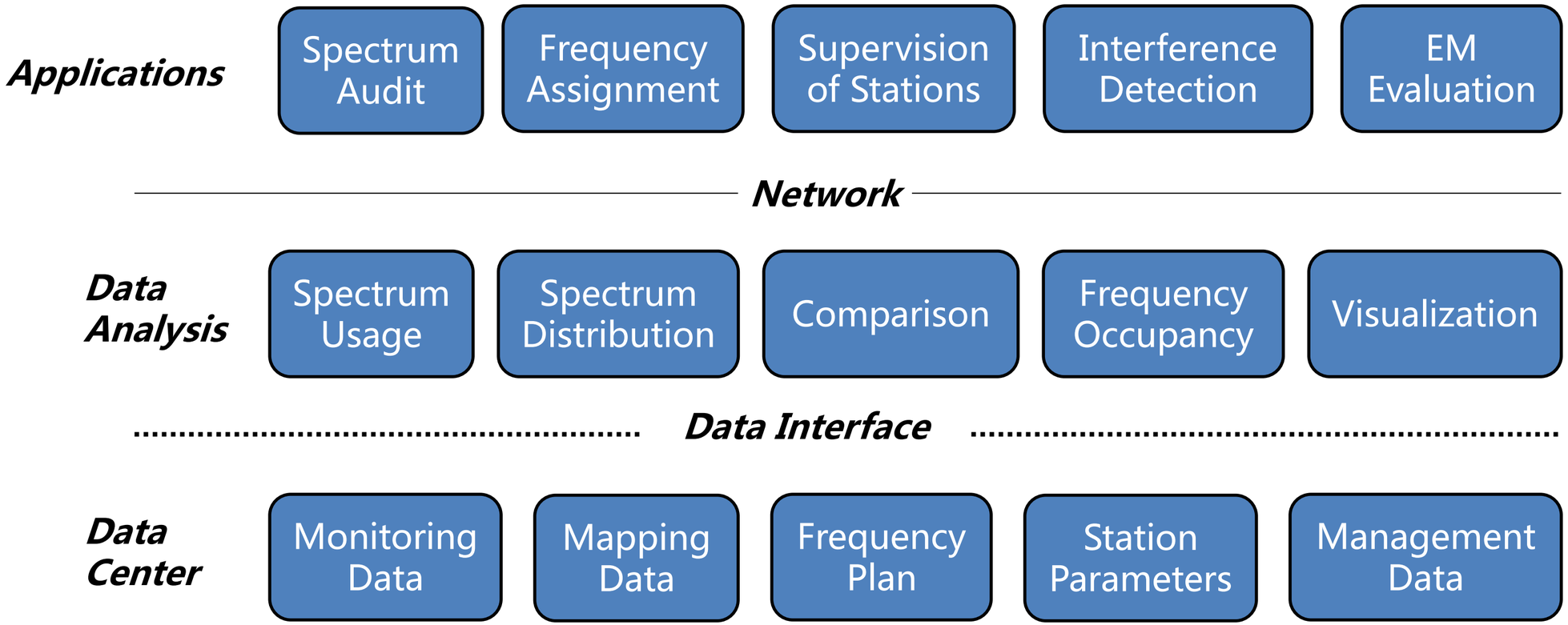


Web apps

Of course there are multiple flavours of public cloud / private cloud / intranet as required.

Spectrum Map

Spectrum Map Software Platform



Spectrum Map

Spectrum Map Process

RF Data Collection

- Fixed Stations
- Grid Monitoring nodes
- Vehicle/UAV Measurement
- Other RF Sensors

Data Mining / Fusion

- Data Processing
- Fusion on Location
- Fusion on Time
- Fusion on Frequency

Data Rendering / Visualization

- 2D/3D Display
- Dynamic Display
- Comparison on Time/Frequency Domain

Spectrum Map

Spectrum Map Server

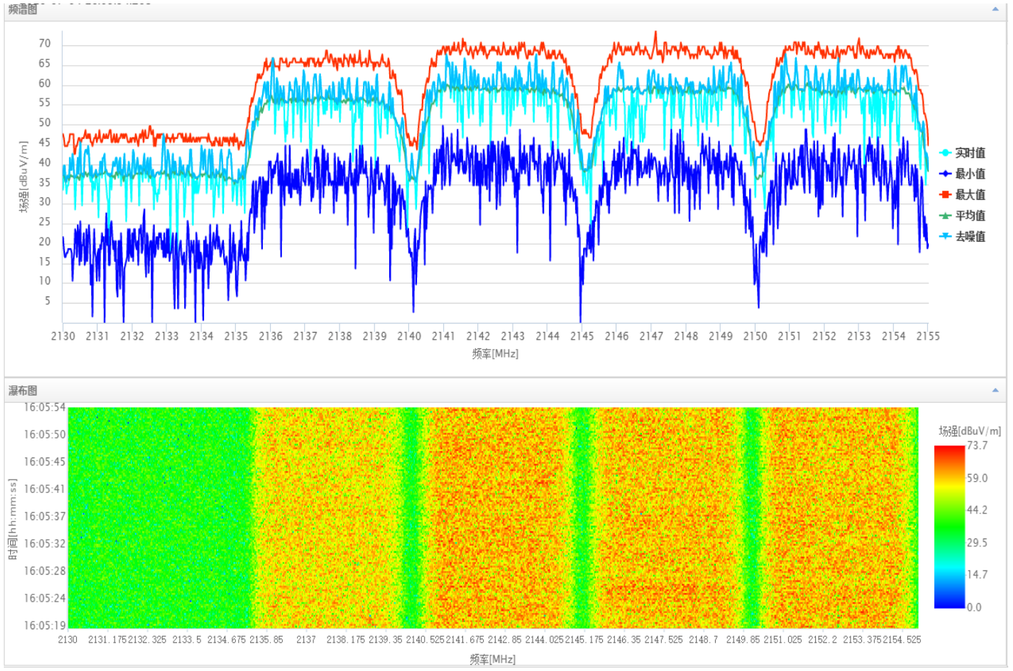
Data Processing Algorithms:

- Automated data pre-processing: data filtering, data correction, ……
- Adaptive interpolation algorithm
- Data correlation, data mining, ……
- Data fusion based on location/time/frequency
- Parallelization

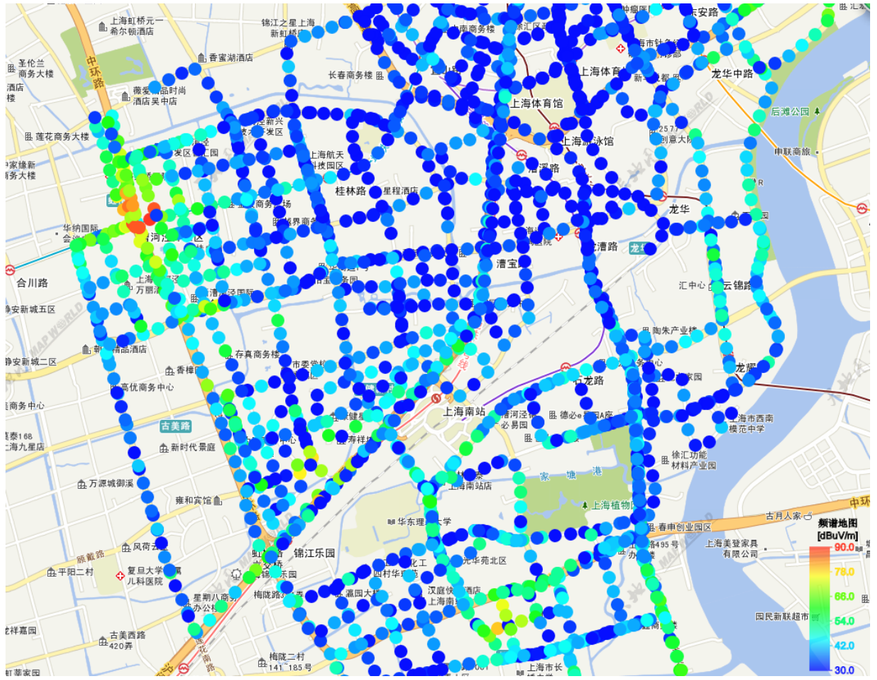
Spectrum Map

Monitoring Data

Monitoring data from multiple sources can be aggregated seamlessly.



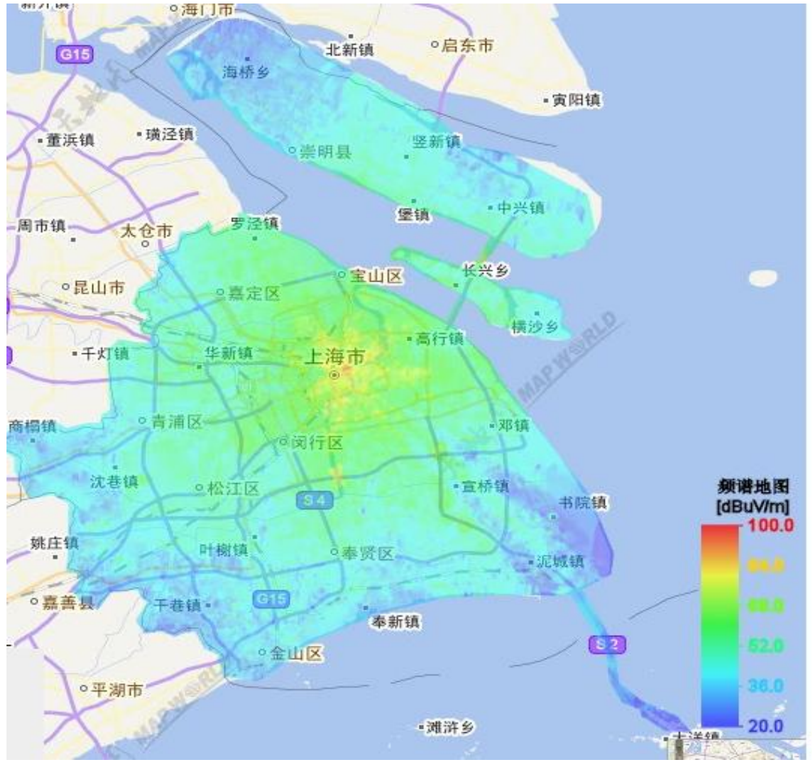
Raw monitoring data
from fixed station



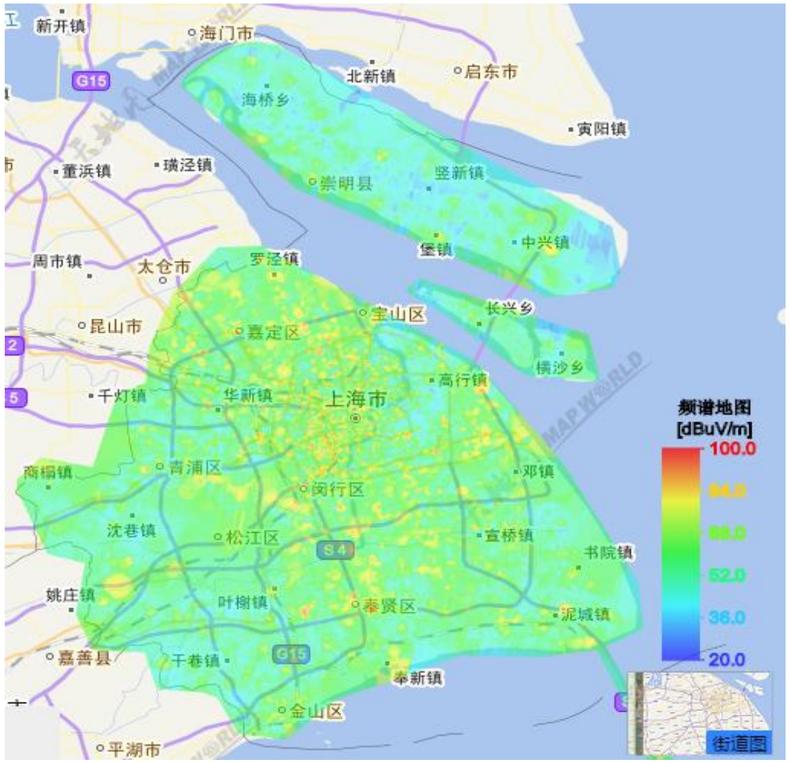
Vehicle measurement data
aggregating all drive tests

Spectrum Map

Spectrum Map Example



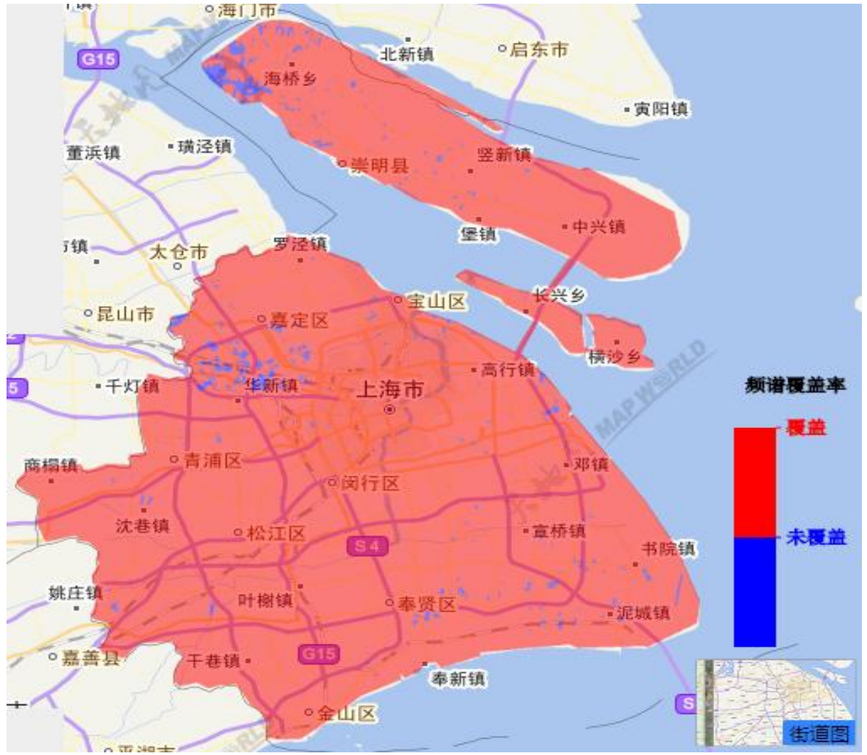
Field Strength of a Single Frequency
(89.9MHz)



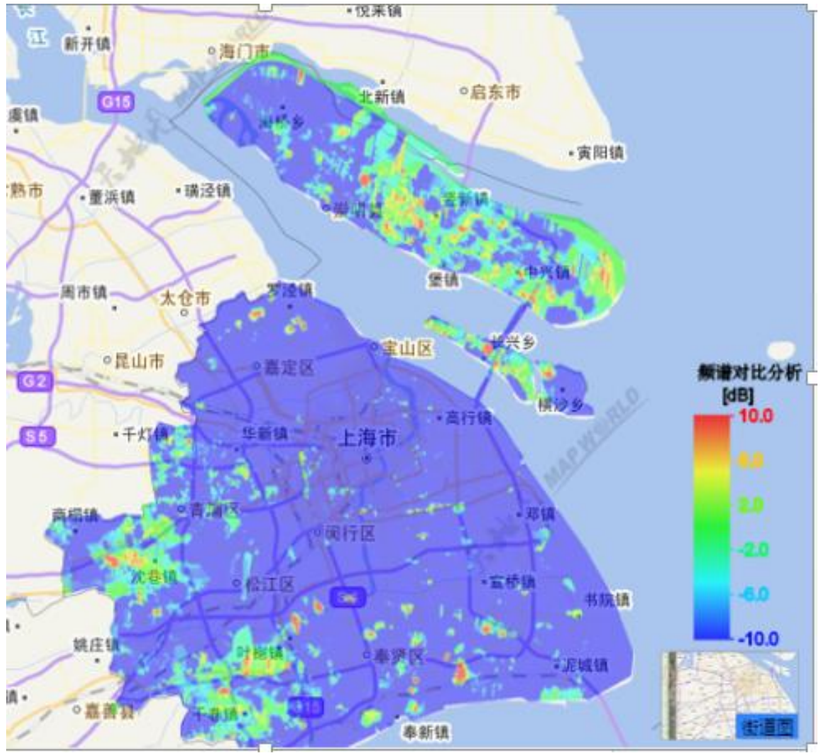
Field Strength of a Frequency Band
(934MHz-936MHz)

Spectrum Map

Spectrum Map Example



Coverage of a Frequency Band
(954MHz-960MHz)



Comparison of Field Strength
on Frequency (935MHz/958MHz)

Spectrum Map

Spectrum Map Example

Dynamic display allows you to “step” through a frequency band or a time period at desired increments.

Dynamic Display (87MHz-108MHz, Step: 100kHz)

Spectrum Map

Application: Spectrum Audit

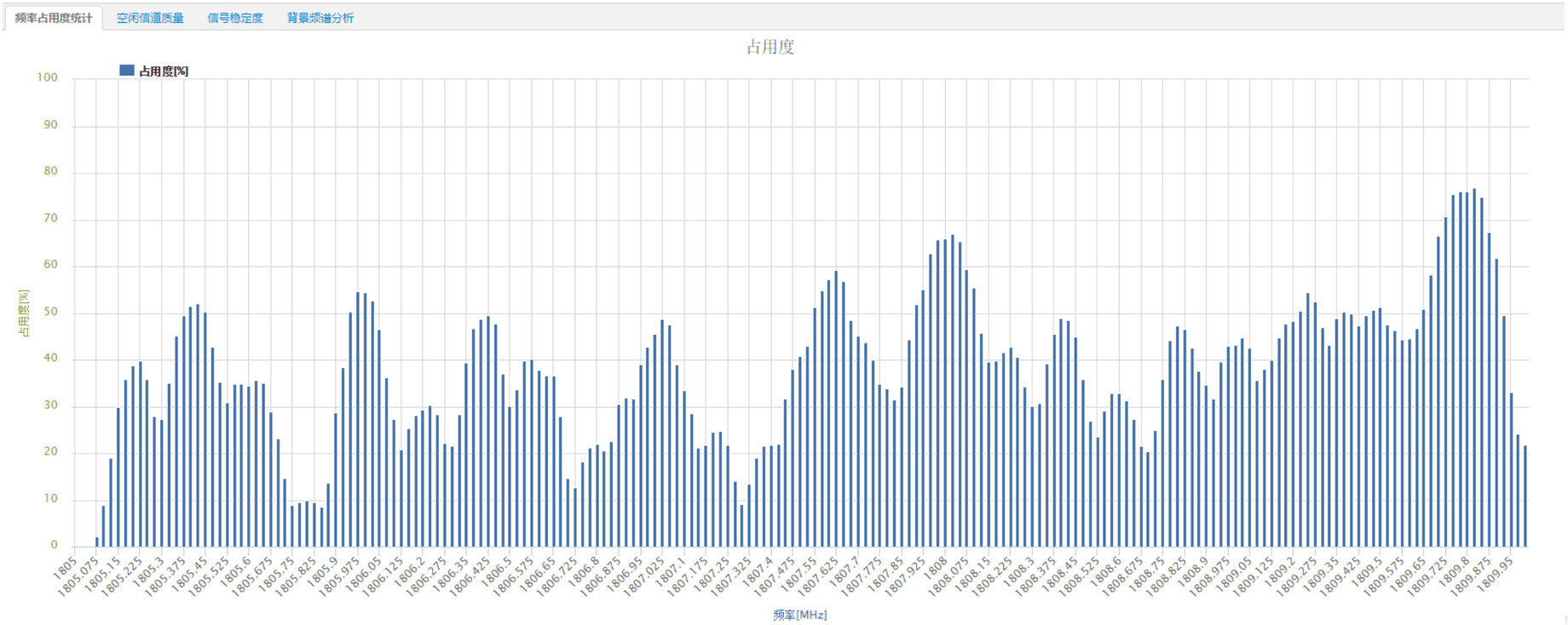
- Collect monitoring data for a radio service
- Analyze frequency usage for a single channel or a frequency band

Frequency Usage

Spectrum Map

Application: Spectrum Audit

Frequency Occupancy for a given location

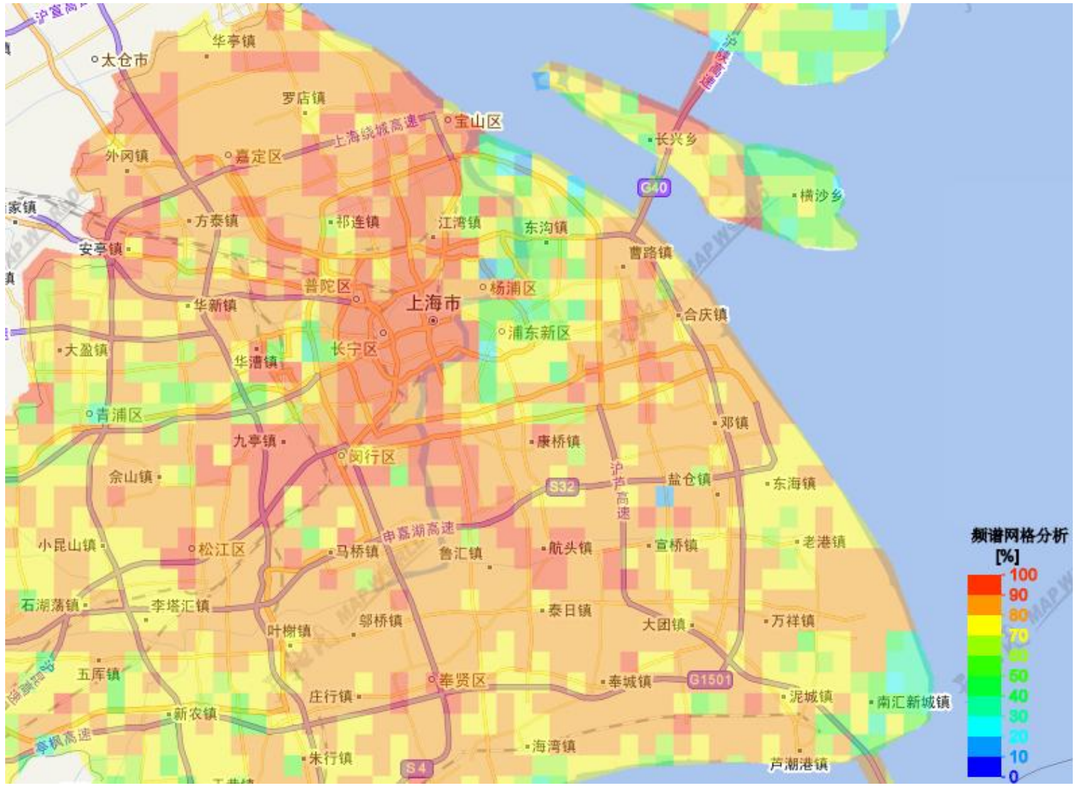


Frequency Occupancy (1805MHz-1830MHz)

Spectrum Map

Application: Spectrum Audit

Frequency Occupancy for grids



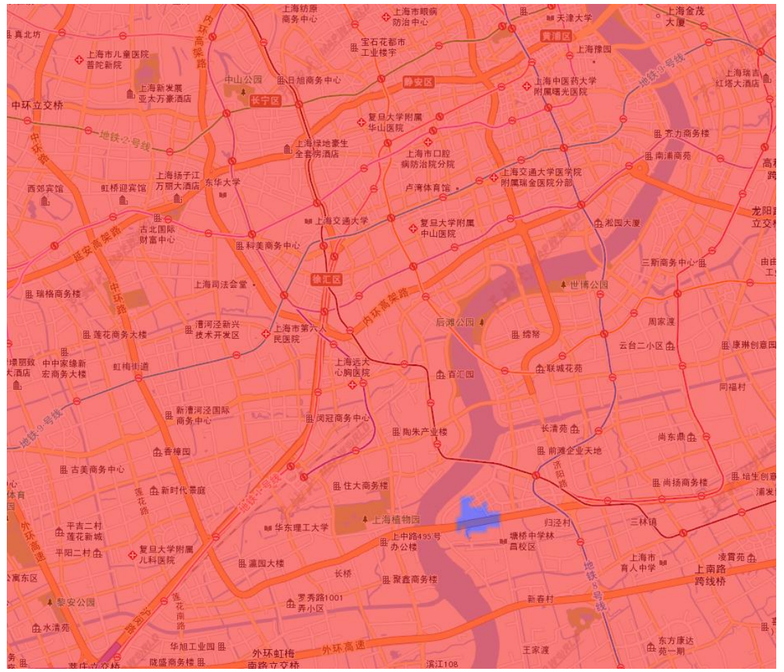
Grid Analysis (936MHz-954MHz; 1km*1km)

Spectrum Map

Application: Spectrum Audit

Coverage Analysis

Coverage of a single frequency



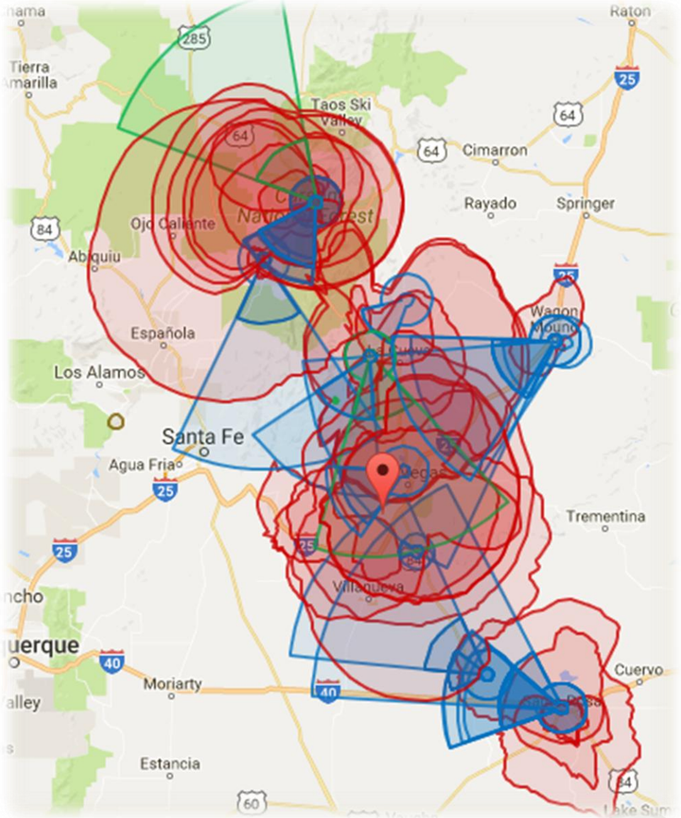
Coverage of a radio service

Spectrum Map

Application: Spectrum Audit

Advantages & benefits:

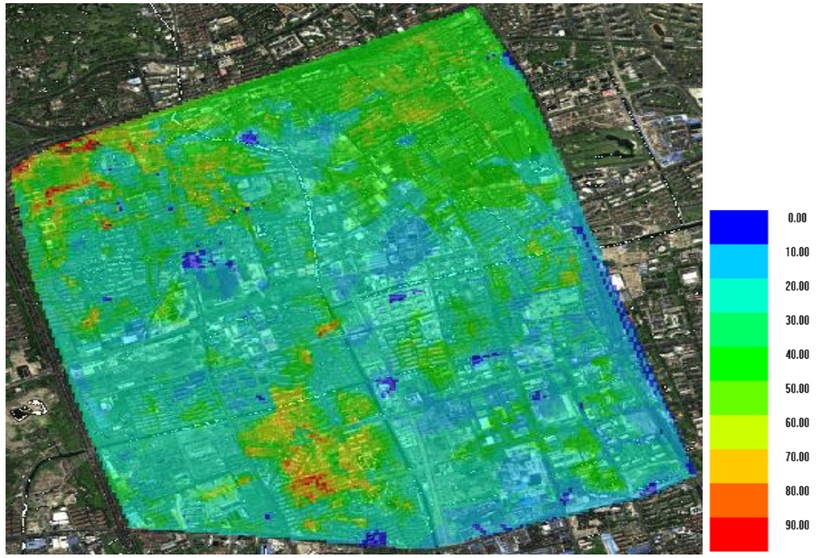
- Solve the problem of low spectrum utilization.
- Optimize frequency planning and allocation.
- Improve the allocation mechanism and usage standards to establish more fair and reasonable use of spectrum resources.
- Lay the foundation for future marketization of spectrum resources.
- Pave the way to dynamic spectrum allocation, thereby improve the efficiency of spectrum usage.



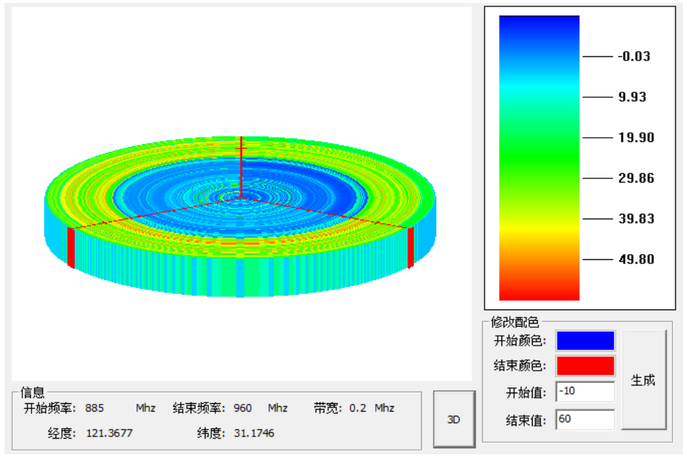
Spectrum Map

Application: Frequency Assignment

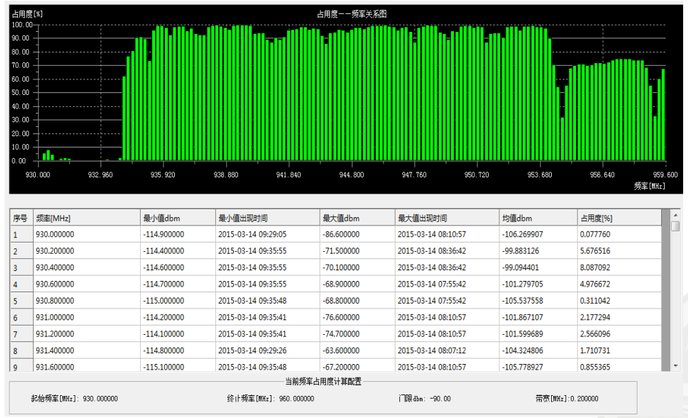
- Check channel availability based on the frequency occupancy.
- Process frequency application based on the frequency occupancy and channel availability.



Frequency Occupancy



Site Analysis



Channel Availability

Spectrum Map

Application: Frequency Assignment

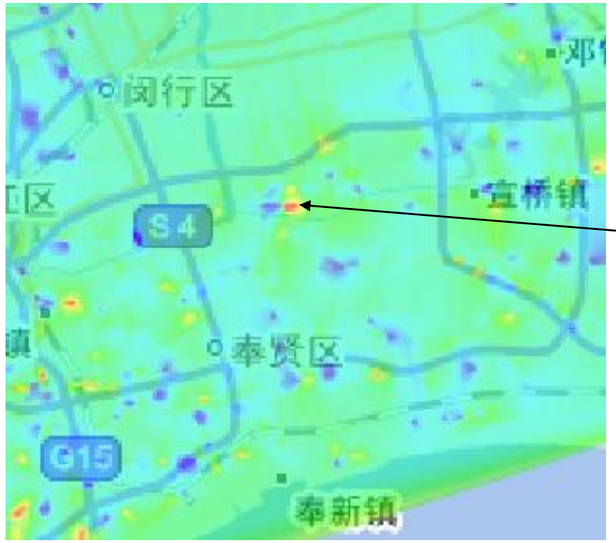
Advantages & benefits:

- Visually display the frequency availability to improve the frequency assignment process.
- Automatic data analysis instead of traditional manual work, thereby improve work efficiency.
- Process frequency assignment based on "real world" monitoring data, therefore improve the accuracy.
- Sophisticated algorithm and accurate calculation guarantee more efficient usage of spectrum resources.

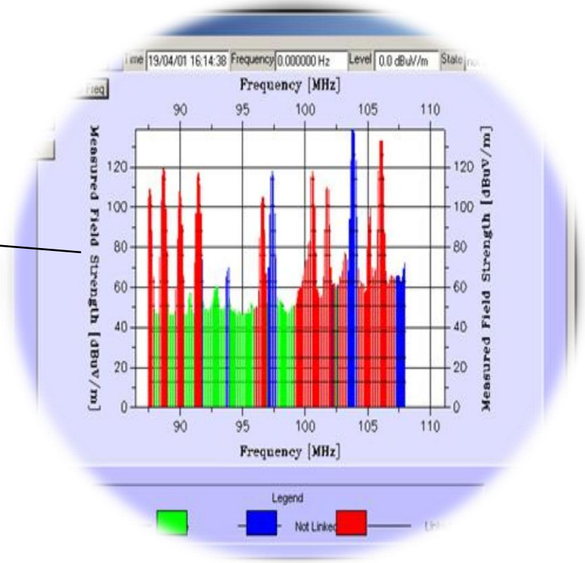
Spectrum Map

Application: Supervision of Stations

- Analyze the field strength or power distribution based on the monitoring data of a single channel or a radio service.
- Calculate the field strength or power based on the simulation of radio stations.
- Supervise the radio stations by means of comparing monitoring data and simulation in an automatic manner.



Field Strength



Comparison of simulation results with monitoring data

Spectrum Map

Application: Supervision of Stations

Advantages & benefits:

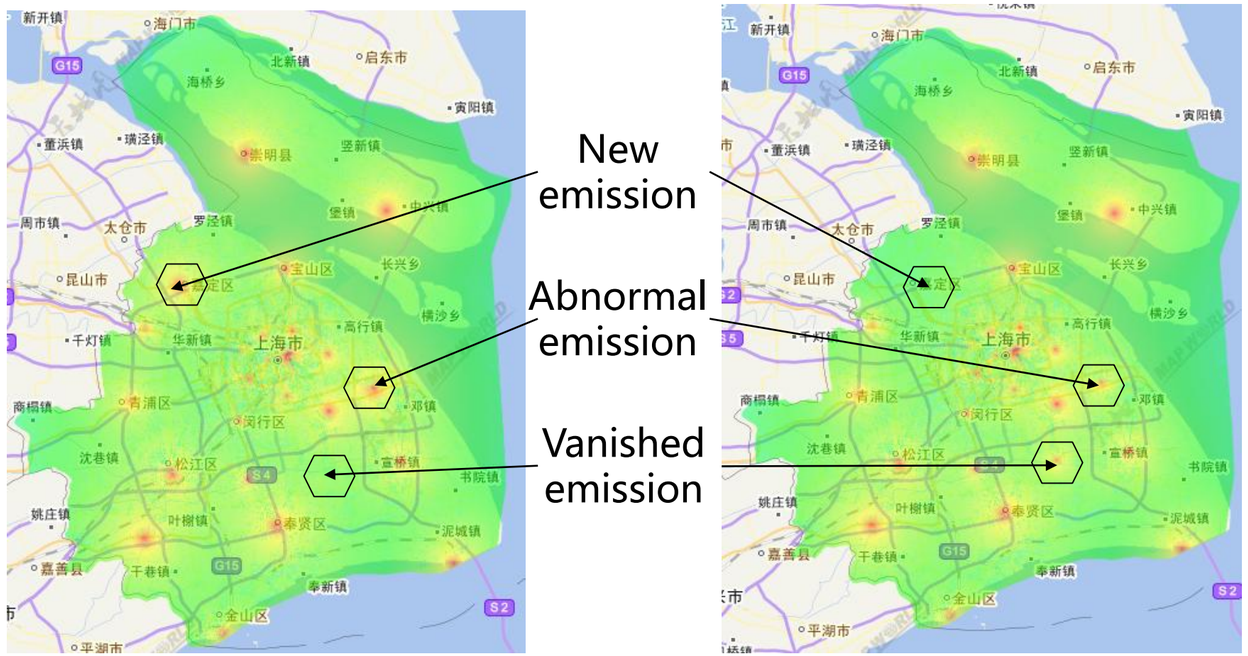
- Employ new technologies (big data & cloud computing) to supervise radio stations.
- Detect illegal stations timely.
- Clean up expired and idle stations to get more available sites and frequencies.
- Improve the accuracy and effectiveness of license database.
- Timely recycle frequencies to meet the increasing demand on spectrum resources.

Spectrum Map

Application: Interference Detection

For example: detecting illegal FM radio

- Generate spectrum maps for FM frequency (87 - 108MHz) in a given time interval.
- The system automatically indicates the area with significant change in energy and finds out the frequency.
- Check the license database to determine if there is an illegal station.

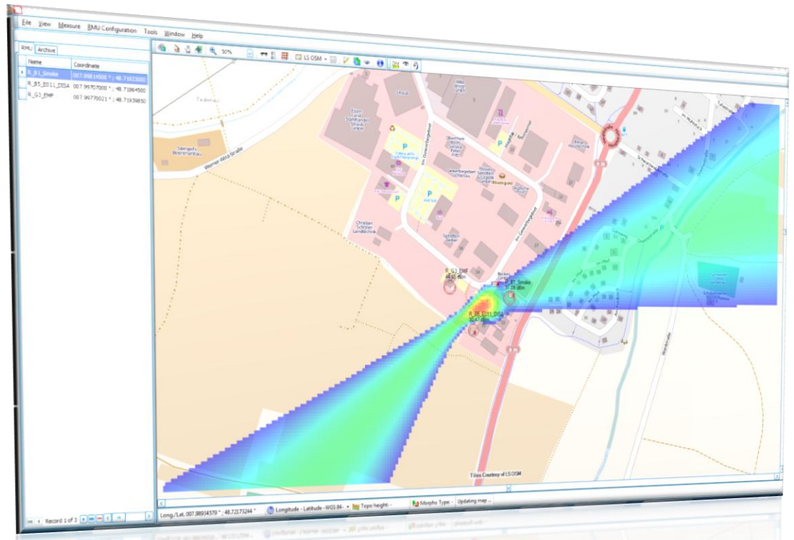


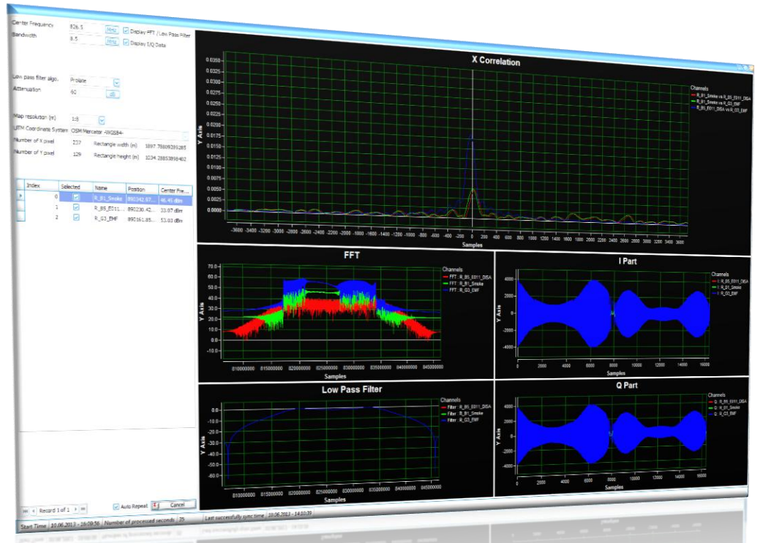
Spectrum Map

Application: Interference Detection

Advantages & benefits:

- Actively detect interference and deal with it timely.
- Reduce labor intensity and improve the efficiency of interference investigation.
- Make the radio management work change from the traditional rough and inefficient work mode to the modernized digital and intelligent work mode.





Spectrum Map

Application: EM Evaluation

Generate electromagnetic radiation intensity map periodically to describe EM environment.

频率范围	电场强度 E（V/m）	磁场强度 H（A/m）	磁感应强度 B（μT）	等效平面波功率密度 S_{eq}（W/m^2）
30MHz~3000MHz	12	0.032	0.04	0.4
3000MHz~15000MHz	$0.22f^{1/2}$	$0.00059f^{1/2}$	$0.00074f^{1/2}$	$f/7500$
15GHz~300GHz	27	0.073	0.092	2

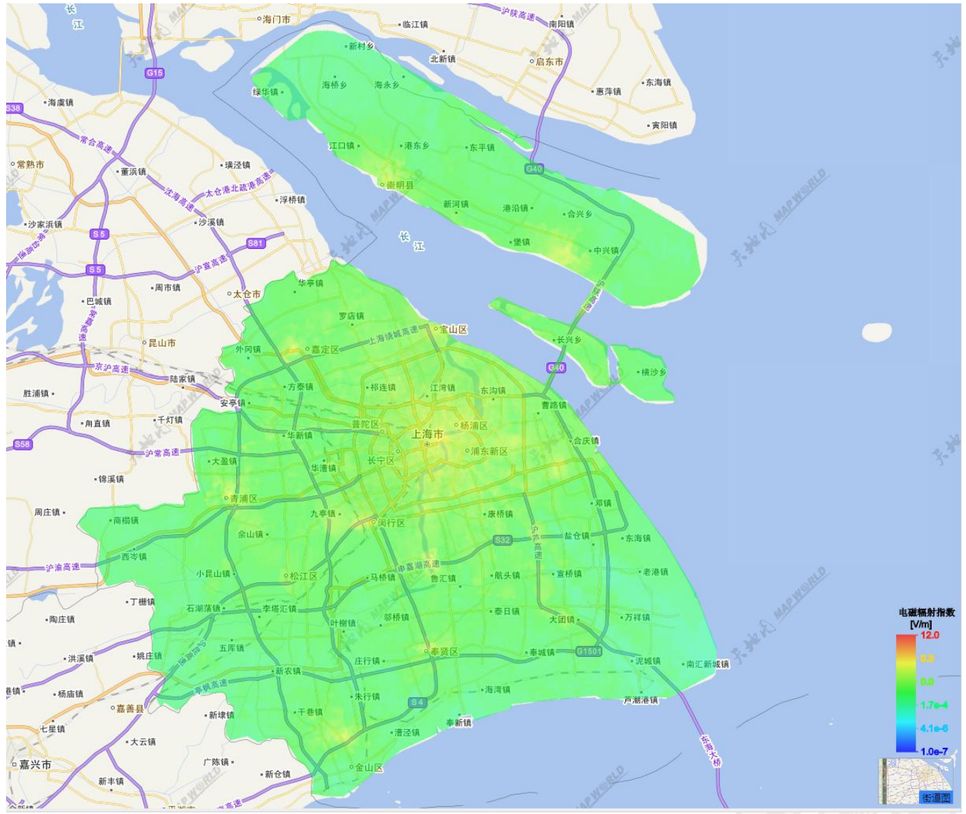
注 1：频率 f 的单位为所在行中第一栏的单位。电场强度限值与频率变化关系见图 1，磁感应强度限值与频率变化关系见图 2。

注 2：0.1MHz~300GHz 频率，场量参数是任意连续 6 分钟内的方均根值。

注 3：100kHz 以下频率，需同时限制电场强度和磁感应强度；100kHz 以上频率，在远场区，可以只限制电场强度或磁场强度，或等效平面波功率密度，在近场区，需同时限制电场强度和磁场强度。

注 4：架空输电线路线下的耕地、园地、牧草地、畜禽饲养地、养殖水面、道路等场所，其频率 50Hz 的电场强度控制限值为 10kV/m，且应给出警示和防护指示标志。

EM Radiation Safety Standards of China
GB8702-2014



EM Radiation Intensity
(87MHz-108MHz)

Spectrum Map

Application: EM Evaluation

Advantages & benefits:

- Improve public awareness of electromagnetic radiation.
- Publish authoritative information of electromagnetic environment, thereby ease public tension on radio stations.
- Regularly release electromagnetic radiation index as a public environmental information service.

Conclusions

- Spectrum map makes **full use of all data from all sensors. This is not a propagation prediction.**
- **Visualization of radio spectrum** as web GIS.
- Display the field strength distribution and spectrum usage on the **energy/time/ frequency/spatial** domains.
- It makes **full use of monitoring data** and integrates existing equipment incl. fixed stations, grid monitoring nodes and sensors.
- **Powerful data analysis capabilities** to generate spectrum maps from a huge amount of data.
- **Fast data processing capabilities** benefiting from cloud computing.
- **A variety of applications** can be implemented based on the spectrum map.

国家无线电监测中心
The State Radio Monitoring Center

Thanks

Dr. Xuemin Huang
NG Networks Co., Ltd.
Tel.: +86-512-69370010
Fax: +86-512-69370012
Email: huang.xuemin@ng-networks.cn