RESEARCH PROGRESS IN SATELLITE-BASED MONITORING OF SMALL SIGNALS

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STATE RADIO MONITORING CENTER
Of China

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PROGRESS FOR SMALL SIGNALS

03

SUMMARY

CORE ADVANTAGES

01

Break through the "regional limitations". It can cover larger area(e.g.500 Km)once, and the covered area can be renewed continuously . This will greatly expand the monitoring scope and lay the foundation for global monitoring.

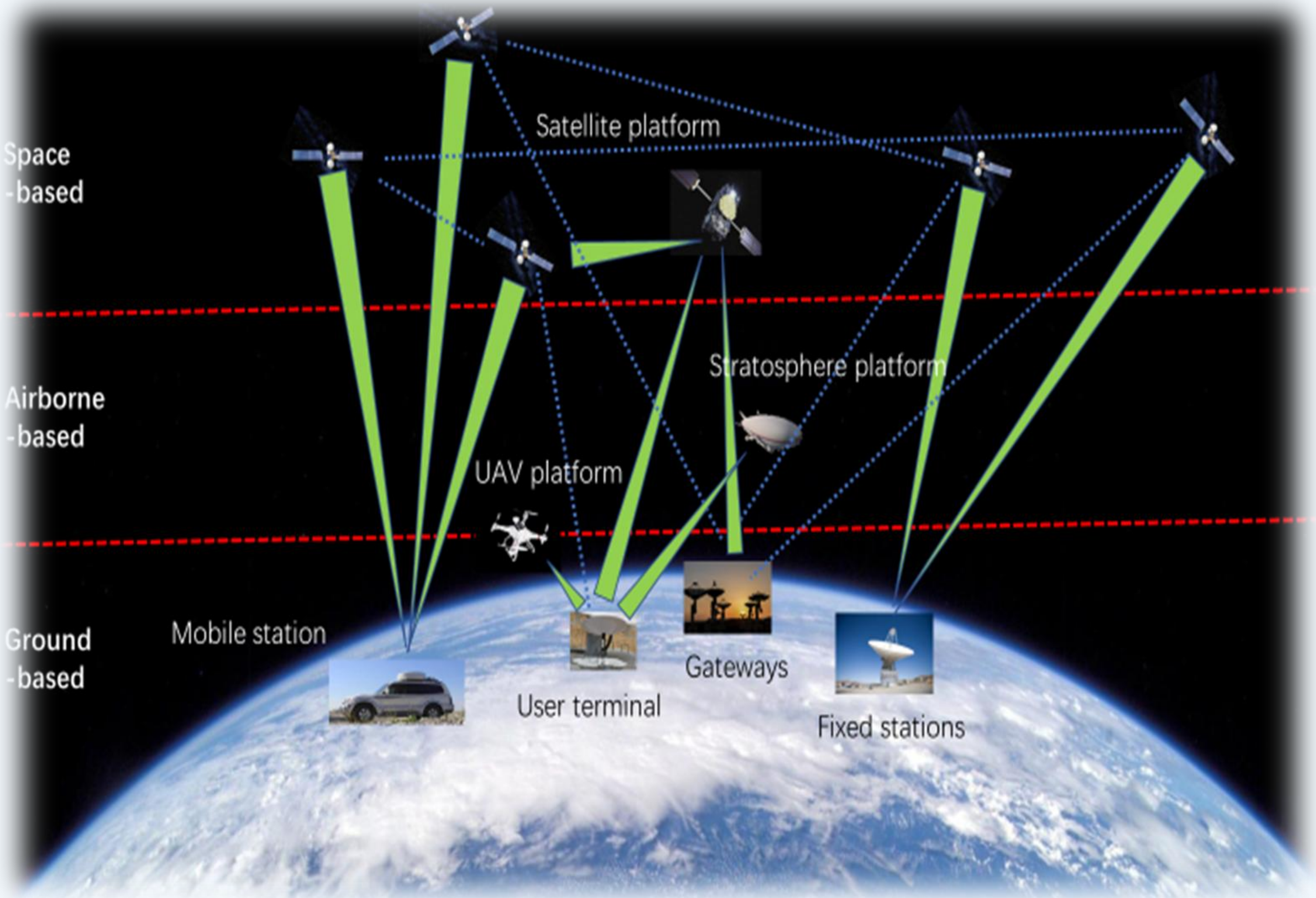
02

Not affected by complex terrains. Mountains, oceans, deserts etc. are usually blind spots of the ground-based network. Satellite-based monitoring has better reception stability regardless of the harsh terrain conditions, saving lots of labor and time costs.

03

Good accuracy. By selecting the appropriate constellation configuration, formation method and location algorithm ,we can reduce the location error to kilometers-level.

VISION OF SATELLITE-BASED MONITORING



3D MONITORING NETWORK

- **Coordinate** with other platforms to do the "last mile finding";
- **Supplement** to the ground-based monitoring network.
- **Full-time, full-airspace, and high-precision** monitoring and interference location for global radio signals.

TYPICAL APPLICATION REQUIREMENTS

01

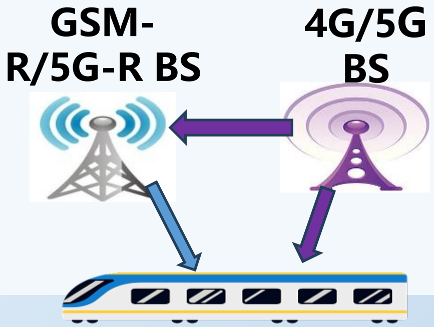
FREQUENT GNSS INTERFERENCE INCIDENTS

- **Impact safety and order of air and shipping route traffic** all over the world, cause outage of communication systems, etc.
- **Interference sources can be dozens of kilometers** far from the affected sites, which makes it difficult to effectively detect and locate them using ground-based equipment.

02

GSM-R INTERFERED BY MOBILE COMMUNICATION BASE STATIONS

- **GSM-R DL/UL interfered by** the China Mobile 4G/5G DL and China Telecom 3G/4G/5G DL.
- Communication failures will seriously **threaten the safety of train operations**.
- National high-speed railway lines extend up to 40,000 kilometers, Using ground-based equipment for full-line monitoring means ever-increasing costs.



03

MARITIME ILLEGAL AND CRIMINAL CASES

- **IUU fishing\Smuggling\Illegal waste dumping** occur frequently, and the amount involved in cases is increasing.
- **The shore-based AIS monitoring range is limited** （30~50miles） also **AIS can be shut or changed.**
- Case investigation and evidence collection are difficult and take a long time.

PROMINENT DIFFICULTIES

Insufficient capability in weak signal detection and location

- Path loss over several hundred kilometers makes the signal arriving at the receiver to be extremely weak, resulting in difficulties in detection and location.

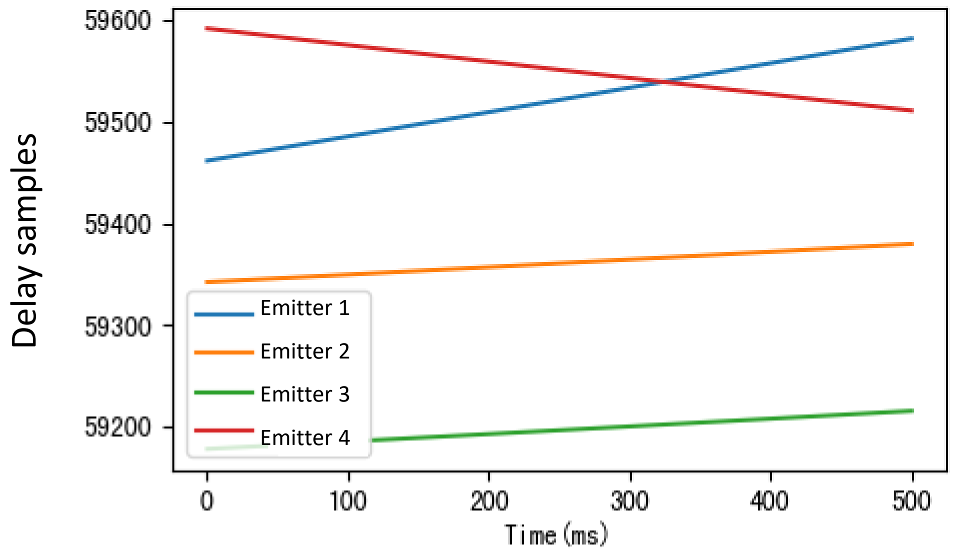
Challenges in distinguishing co-frequency interferences

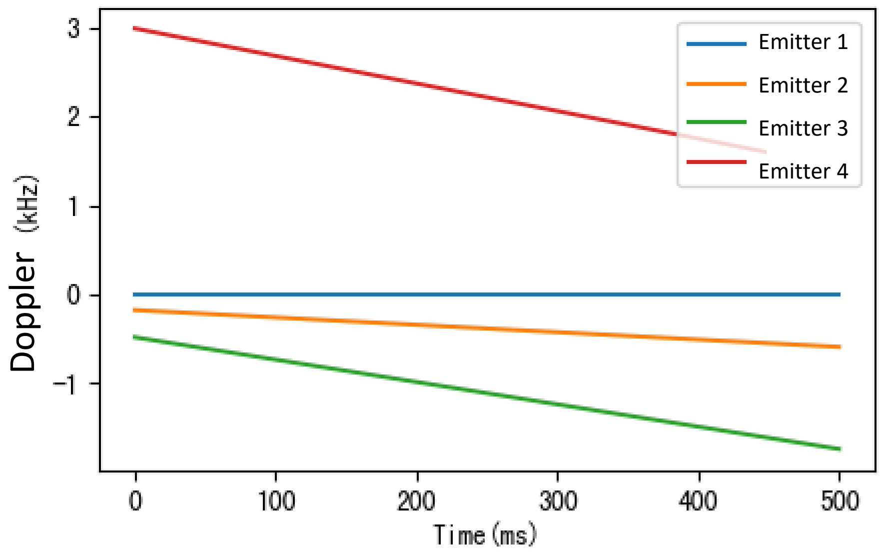
- It is hard to isolate the characteristics of interference signals when multiple sources occupy the same band.

CONTENTS ★★★

Position Domain Algorithm Application

Basic Fact : As the satellite moves continuously, the time delay and Doppler shift of the received signals will continuously vary**.** Especially, **when the emitter locations are different**, **the hole variation processes** (of the time delay and Doppler shift) **will be different too**.

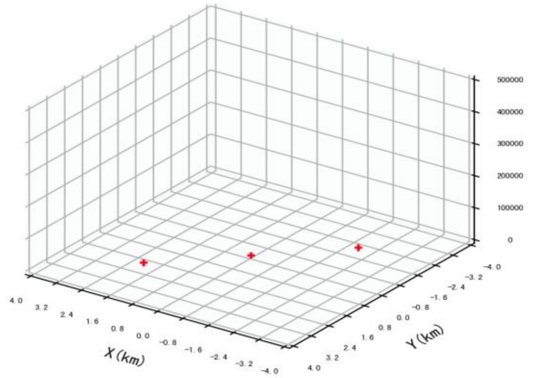




The variation process of time delay and Doppler frequency shifts generated by signals with different locations

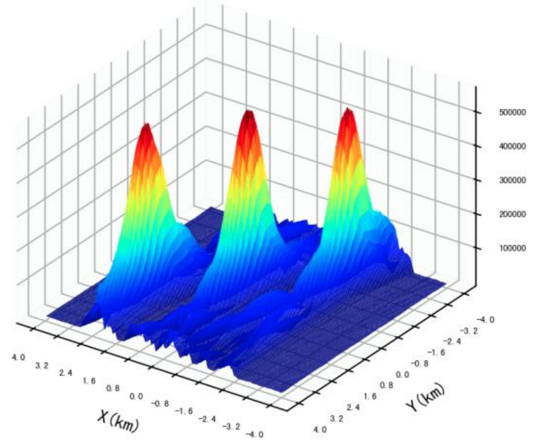
Position Domain Algorithm Application

- **STEP1:** Chose one area where the emitters may be , divide it into grids, the center of each grid representing a possible location of the target emitter；
- **STEP2:** Calculate the value of the correlation function with signals from two satellites assuming a emitter is at a certain position (x, y) on the ground, compensate for the Doppler difference and delay difference (of the received signal on one satellite) relative to another satellite.
- **STEP3:** The positions of the emitters can be obtained.



Three transmitters

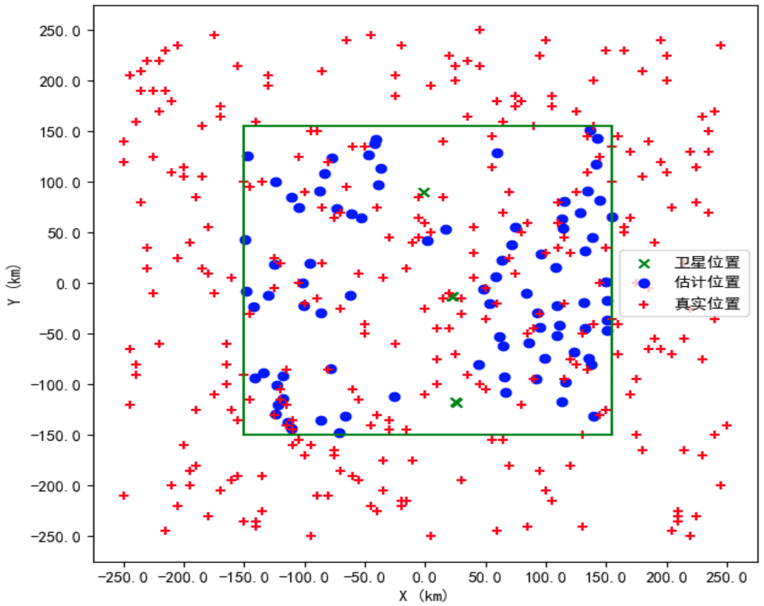
$$S_{x,y}=\sum_{k=0}^{N-1} r_1[k]r_2{}^*[k+\Delta\tau_{k,x,y}]e^{-j2\pi\Delta\theta_{k,x,y}}$$



Correlation results

SIMULATION RESULTS WITH SMALL&MULTI TERMINALS

Interference number	Signal duration	S/N	Detect Area	Distribution Area
300	100ms	-8dB	330km*330km	550km*550km

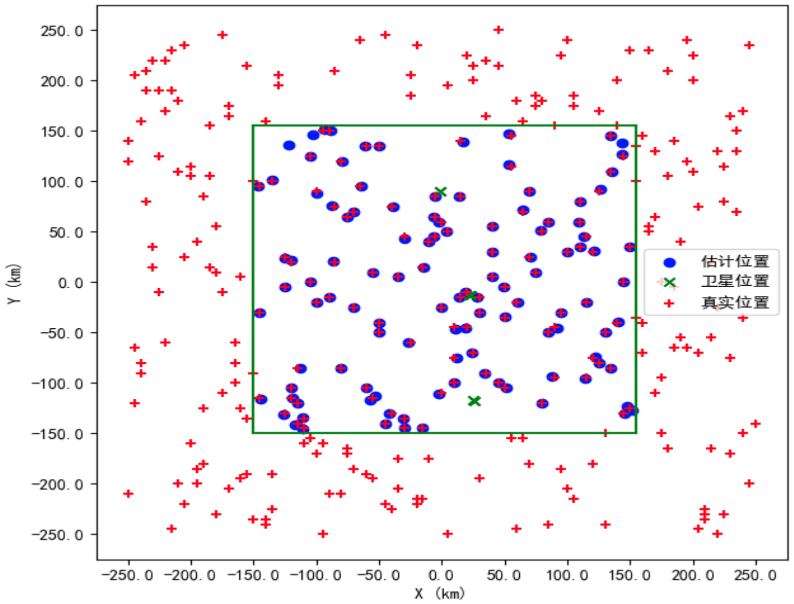


Traditional TDOA/FDOA location

Detection probability :3.6%

False detection probability :74.6%

Average location accuracy (m):3833



Position Domain Algorithm

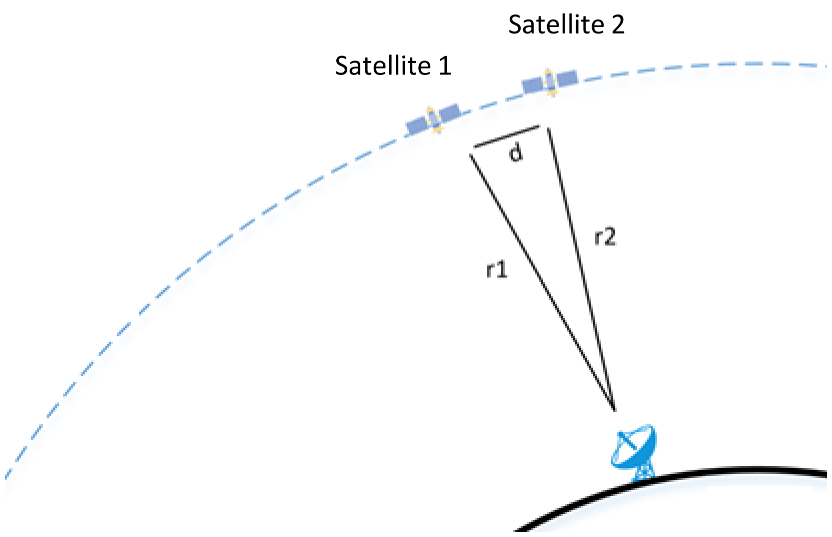
Detection probability :**99.36%**

False detection probability :**5.45%**

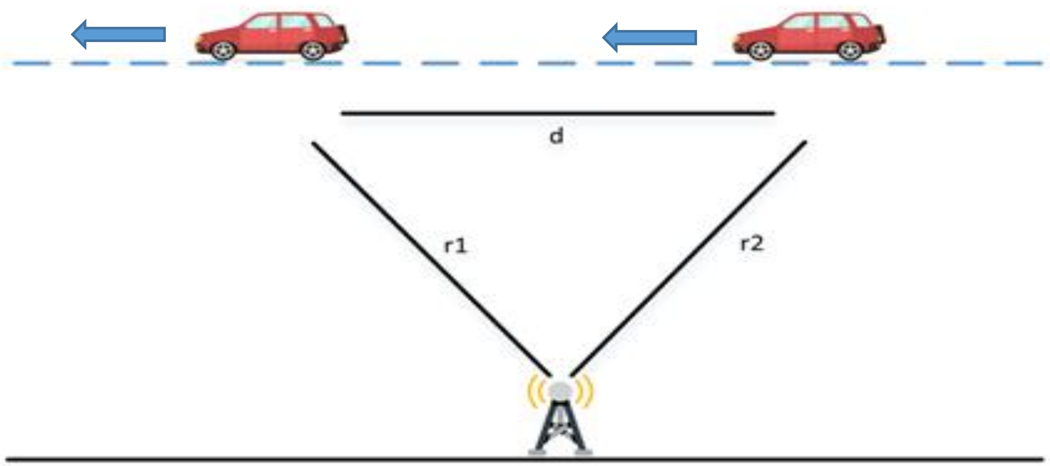
Average location accuracy (m):**981**

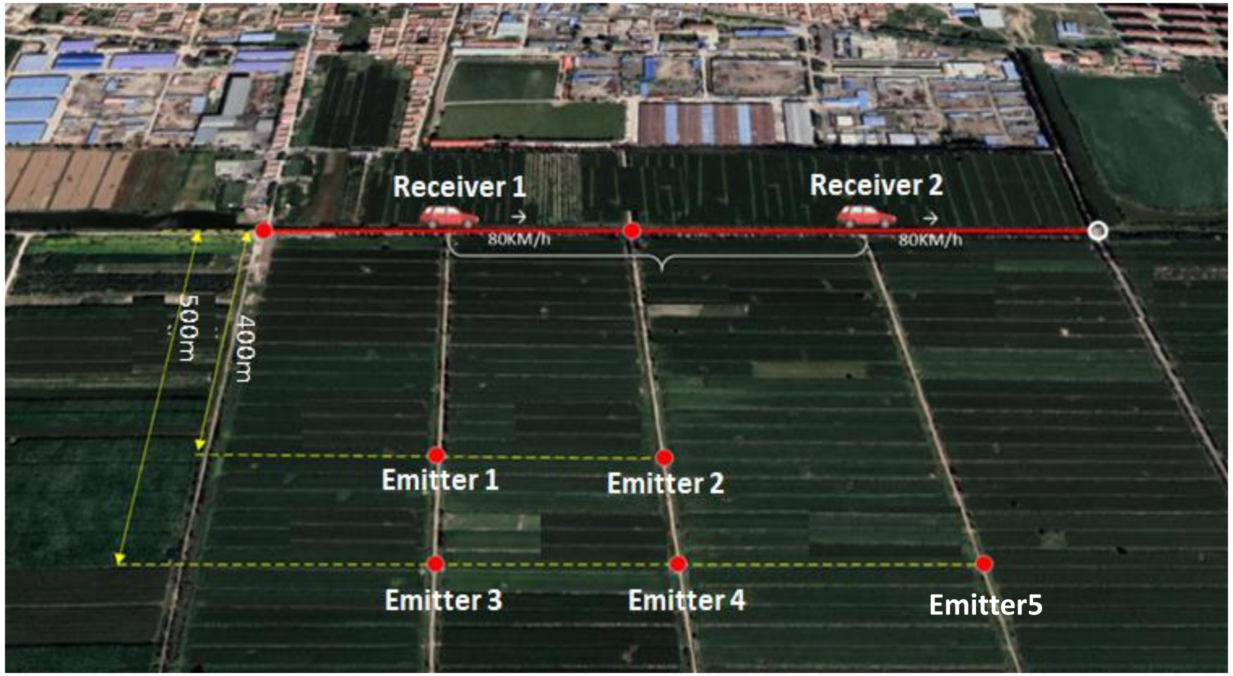
SEMI-HARDWARE EXPERIMENT(SNR = -10dB)

Satellite-based scenario



Experiment scenario





SEMI-HARDWARE EXPERIMENT(SNR = -10dB)

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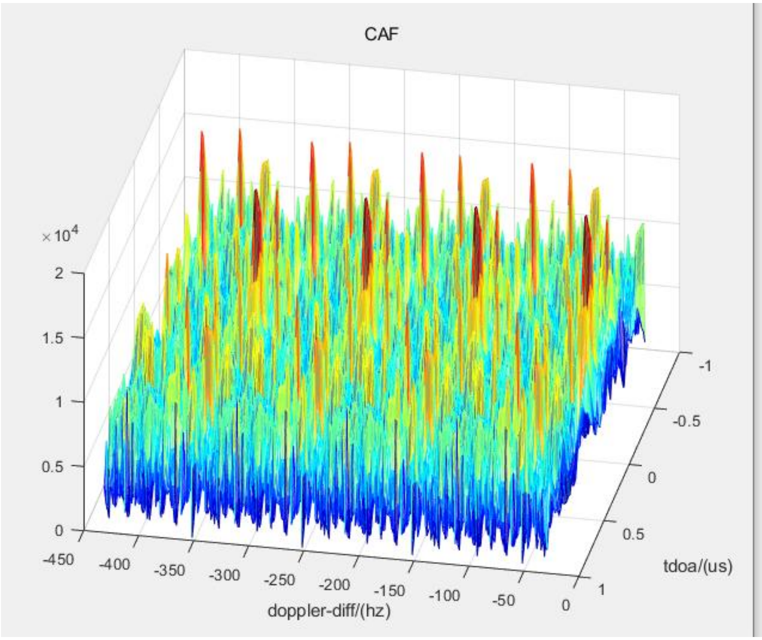
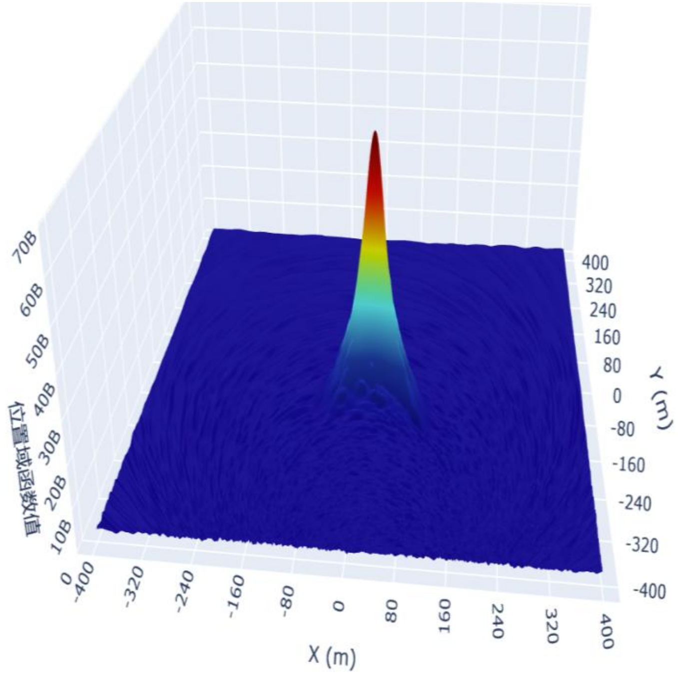


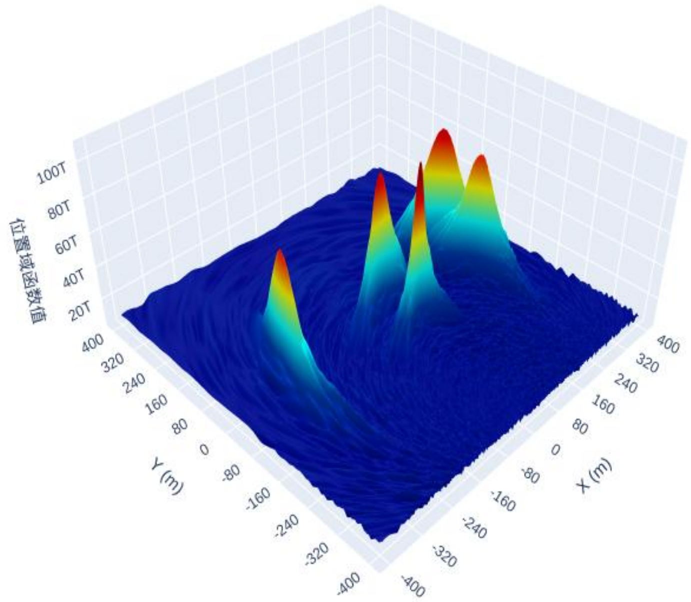
No results

Position Domain Algorithm



Average location accuracy：

3.13m(10 times)



Average location accuracy：

2.6m、2.88m、3.09m、4.8m、

7.62m(10 times)

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

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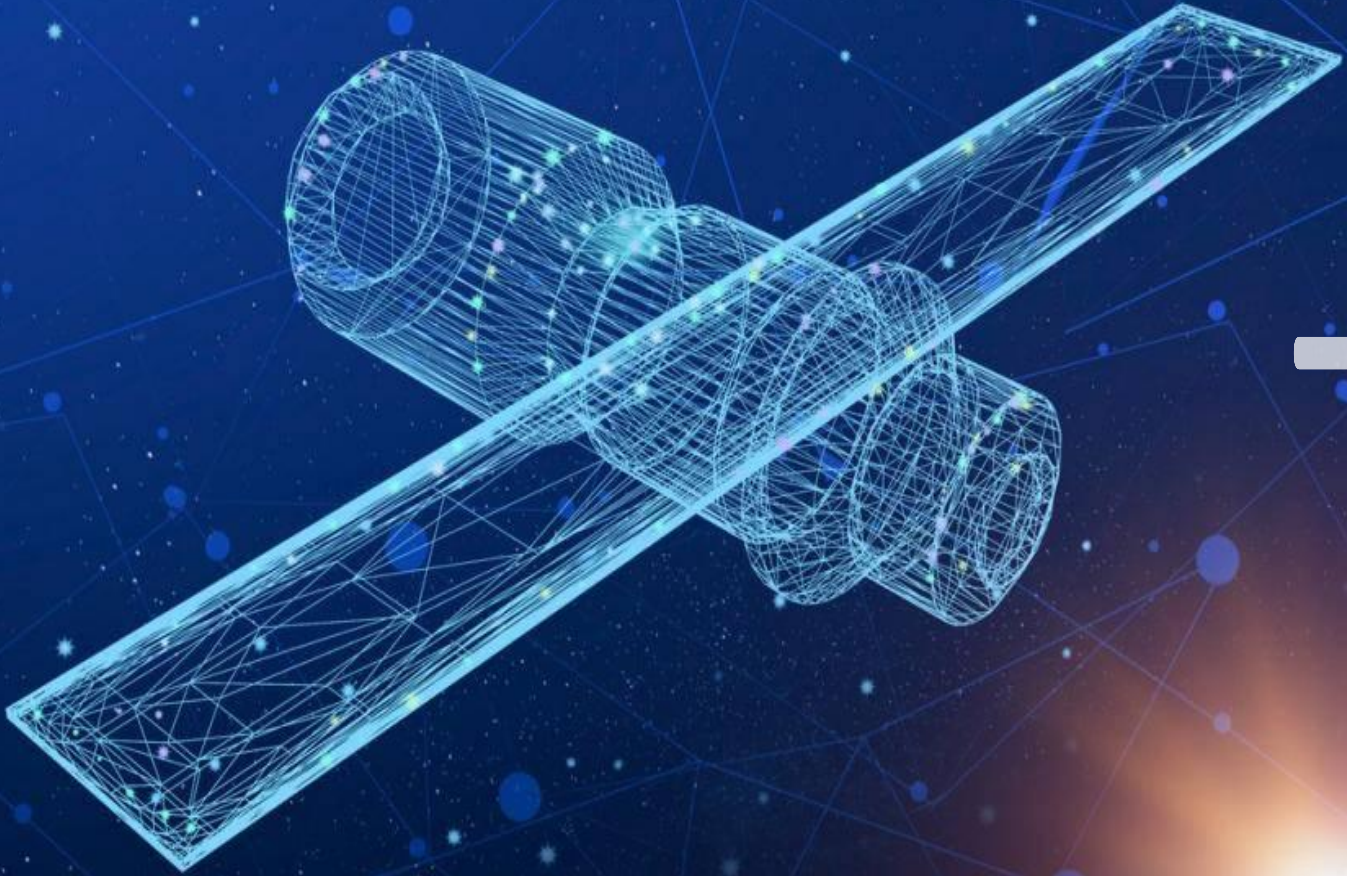
SUMMERY

- **With the purposed algorithm, satellite-based monitoring could improve the ability for locating small signals and distinguishing co-frequency interferences .**
- **This algorithm needs to be verified via actual payload onboard next.**
- **Satellite-based monitoring cannot do every thing, it is a good supplement for ground-based monitoring network.**
- **With the quick development of NGSO satellite, the cost-effectiveness of satellite-based monitoring will make it possible to be applied in radio management.**



Thanks

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