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Update of GNSS IDM research

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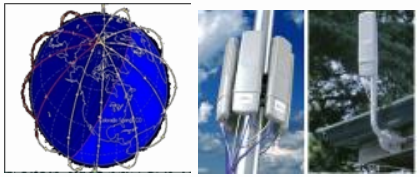
Outline

1. **The effect analysis of GNSS interference to the infrastructure sectors**
   - **Communication**
   - **Electric power**
   - **Transportation**
   - **Agriculture**
2. **Interference detection technology with unmanned aerial vehicle**
3. **Summary**

1. The effect analysis of the GNSS interference to the infrastructure sectors

Since the GNSS applications are developing fast, GNSS interference becomes more common nowadays. The initial effect of GNSS interference to four kinds of critical infrastructure has been presented here.



Communications

Transportation

GNSS applications

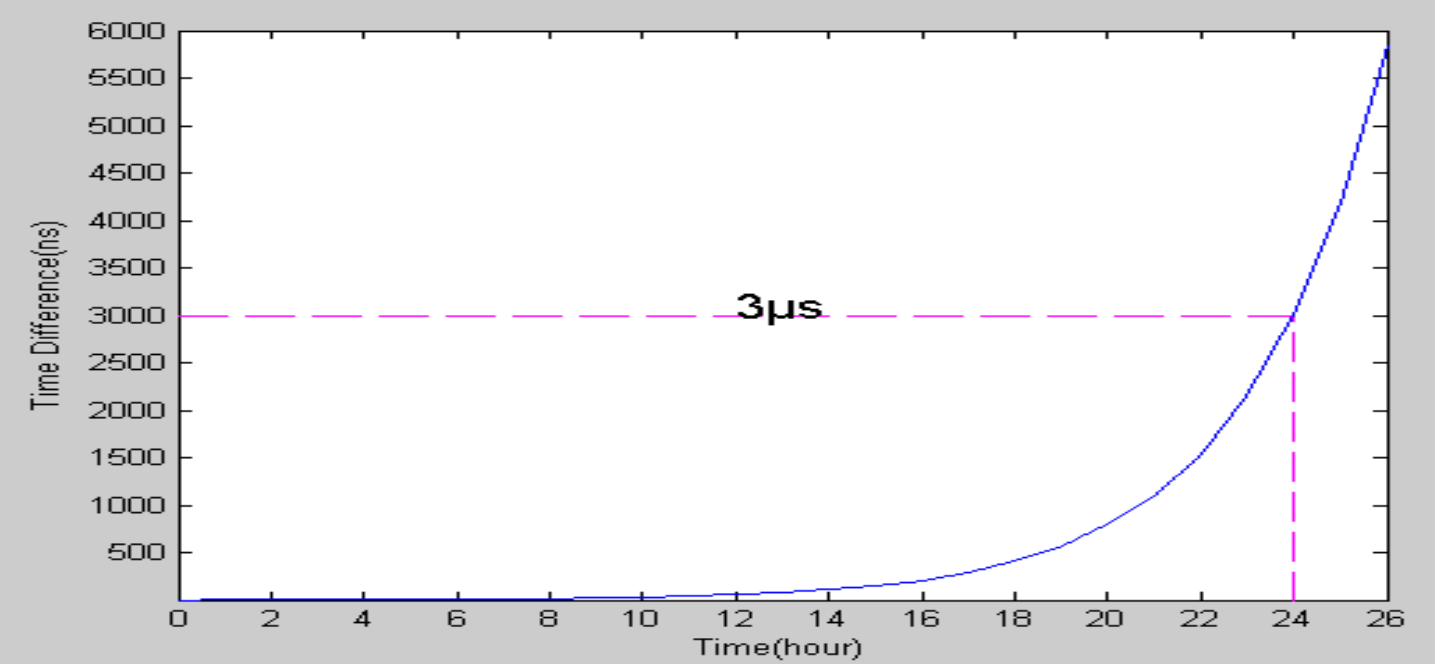
Energy Power

Agriculture

1） Impact to mobile communication system when GNSS is interfered

In communication system, GNSS is mainly used for timing: Synchronization for communication network and base station.

Short-term GNSS interference will not cause great damage in the communication system, since it has backup method. However, the long-time GNSS interference over 24 hours or longer will cause service quality degradation even interruption.



The last time of crystal oscillator after GNSS lose lock

1） Impact to mobile communication system when GNSS is interfered

Application domain	Interference effects to GNSS			System operation when GNSS interfered	
	Frequency affected	Effects of RFI	Effects of ionospheric scintillation	Other methods to sustain operation of system	Time duration that can keep normal operation
Synchronization of communication network	GPS L1; BDS B1	1) Degree: Decrease of timing accuracy/loss of lock; 2) Continuous time : uncertain; 3) Coverage: Within several km to a few tens of km	1) Degree: Decrease of timing accuracy/ loss of lock/ interruption of service; 2) Continuous time : several hours; 3) Coverage: within hundreds of km	Atomic clock	Cesium clock: several years Rubidium clock: 7.5 month
Synchronization of base station	GPS L1; BDS B1			Crystal oscillator	About 24 hours

2）Impact to electric power system when GNSS is interfered

The main applications of GNSS in electric power system:

- Timing:
  - electrical power transmission;
  - electrical power distribution;
  - power grid management.

With the increasing dependence of newly smart electronic netting on GNSS , the effects will be more and more serious if GNSS is interfered.

2）Impact to electric power system when GNSS is interfered

Application domain	Interference effects to GNSS			System operation when GNSS interfered	
	Frequency affected	Effects of RFI	Effects of ionospheric scintillation	Other methods to sustain operation of system	Time duration that can keep normal operation
Electrical power system	GPS L1; BDS B1、S	1) Degree: Decrease of timing accuracy/loss of lock; 2) Continuous time: uncertain; 3) Coverage: within several hundred meters to hundreds of km	1) Degree: Decrease of accuracy/loss of lock/ interruption of service; 2) Continuous time : several hours; 3) Coverage: within hundreds of km	Crystal oscillator etc.	About 24hours

3）Impact to transportation system when GNSS is interfered

GNSS applications in transportation include:

- Navigation;
- Timing.

In different applications, systems are affected at different levels when GNSS is interfered.

Impact to aviation when GNSS is interfered

GNSS main applications in aviation: Navigation, Timing .

At present GNSS is an assistant for aviation navigation, and the system can keep normal operation for a long time by ground-based navigation method.

Application domain	Interference effects to GNSS			System operation when GNSS interfered	
	Frequency affected	Effects of RFI	Effects of ionospheric scintillation	Other methods to sustain operation of system	Time duration that can keep normal operation
Aviation	GPS L1; BDS B1;	1) Degree: Decrease of positioning and timing accuracy/ interrupt of service ; 2) Continuous time: uncertain, 3) Coverage : whole airport and nearby	1) Degree: Decrease of accuracy/ loss of lock/ interruption of service; 2) Continuous time : several hours; 3) Coverage: within hundreds of km	DME/ILS etc. (ground based navigation method)	Long term.

Impact to road transportation when GNSS is interfered

GNSS main applications in road transportation: Navigation.

Application domain	Interference effects to GNSS			System operation when GNSS interfered	
	Frequency affected	Effects of RFI	Effects of ionospheric scintillation	Other methods to sustain operation of system	Time duration that can keep normal operation
Road transportation	GPS L1; BDS B1;	1) Degree: Decrease of positioning and timing accuracy/ interrupt of service ; 2) Continuous time: uncertain; 3) Coverage: within several km to a few tens km	1) Degree: Decrease of accuracy/loss of lock/ interruption of service; 2) Continuous time : several hours; 3) Coverage: within hundreds of km	Hardly no other method	Very short time

4）Impact to precise agriculture system when GNSS is interfered

GNSS is mainly used in location based agriculture service.
At present, GNSS applications in agriculture can keep a short time (within 12 hours).

Application domain	Interference effects to GNSS			System operation when GNSS interfered	
	Frequency affected	Effects of RFI	Effects of ionospheric scintillation	Other methods to sustain operation of system	Time duration that can keep normal operation
Precise agriculture	GPS: L1、L2 BDS: B1、B2	1) Degree: Decrease of positioning accuracy/loss of lock/interrupt of service; 2) Continuous time : uncertain; 3) Coverage: Within whole farm or landmass	1) Degree: Decrease of accuracy/loss of lock/ interruption of service; 2) Continuous time: several hours; 3) Coverage: within hundreds of km	Mechanic navigation, laser navigation, Visual Nvigation	Short term (within 12 hours)

2. Interference detection technology with UAV

1）Introduction

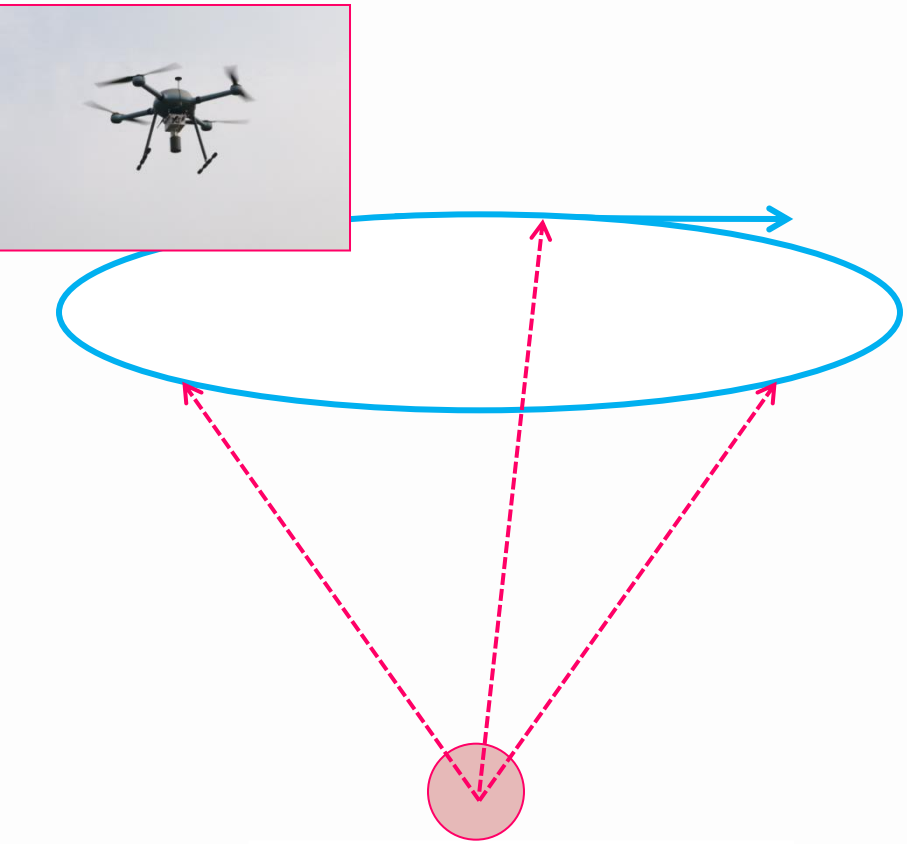
The main kinds of interference detectors developed include:

- **Fixed detector**
- **Vehicle detector**
- **Portable detector**

As a kind of interference detector, interference detection with UAV has been proved to be effective:

- **Wide area coverage**
- **Fast for localization**

2）Principle of system



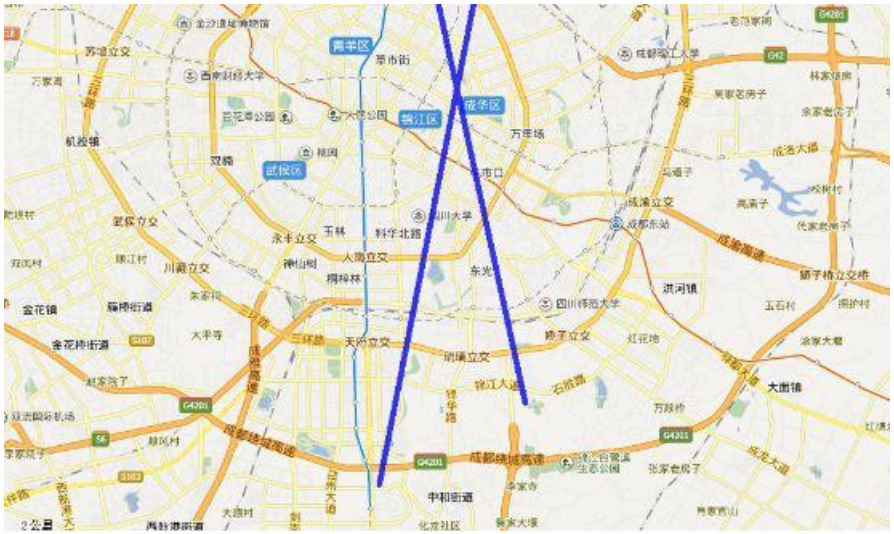
Schematic diagram for UAV direction finding

- **Direction finding technology include:**
  - ➢Amplitude comparison
  - ➢Coherent interferometer
  - ➢Space spectrum estimation
- **The method of amplitude comparison is used.**

  The UAV can rotate in the air to scan and sample in 360° with electronic compass. Vectorgraph of signal propagation can be recorded and displayed.

●Localization:

By using data from multi-point measurements of unmanned aerial vehicle, localization of RFI source can be realized by crossing on electronic map.

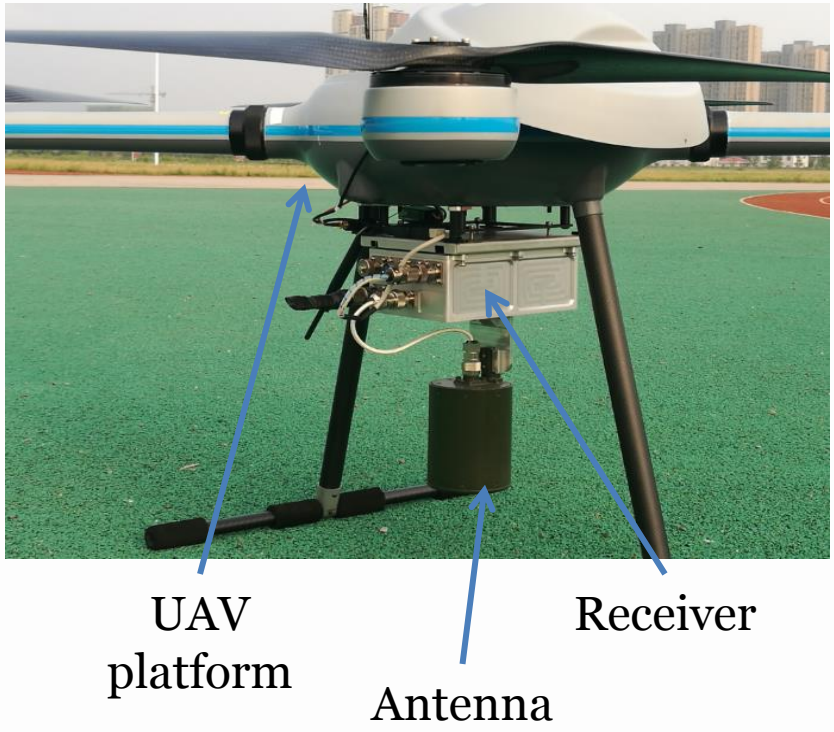


Cross localization of RFI source

3） Composition of system

Major composition:

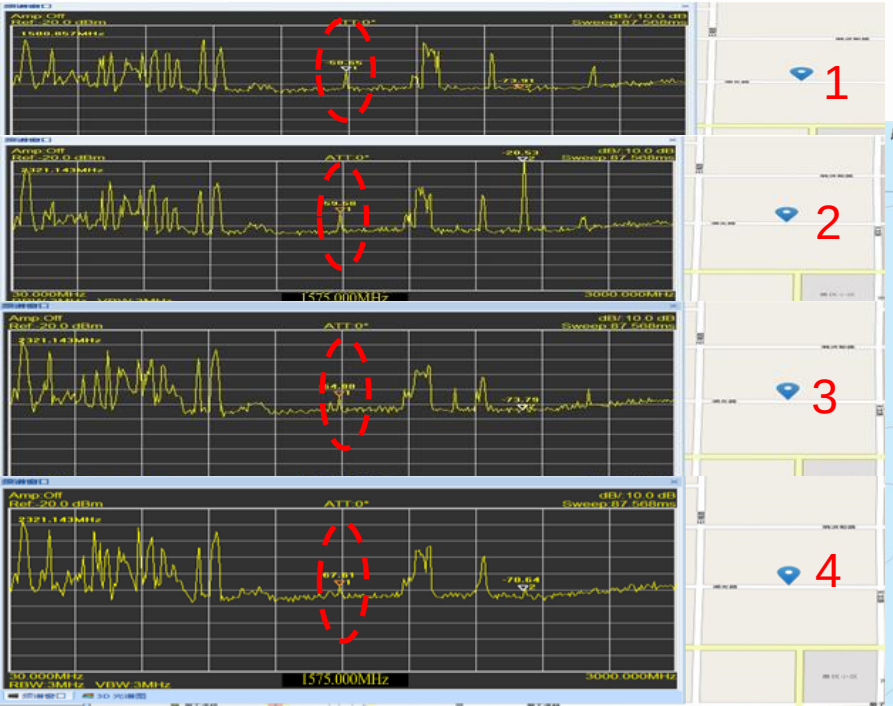
1. UAV platform
2. Antenna
3. Receiver
   - pre-selection unit
   - Receiving unit
   - Signal processing unit
   - Signal analysis and storage unit



4） RFI detection test based on UAV

Four test points have been selected in test area in Hefei city. Data from these points were sent to ground station.

- Signal spectrum at the four test points are achieved, Interference signal is found near 1575MHz.
- The source of interference is determined through following steps:
  - Find the rough region through cross localization by UAV;
  - Determine the exact location in rough region using portable detector.



Spectrum at four test points（Left）and result（Right）

3. Summary

① **In this presentation, the operational status and time duration of keeping normal operation after GNSS is interfered is analyzed.**

In different infrastructure, GNSS interference will affect the system at different levels which may depend on the backup method of the system.

② **Interference detection with UAV has been proved to be effective in wide area.**

Thanks a lot for your attention!