GNSS interference identification, detection and localization for urban area and critical infrastructure

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Content

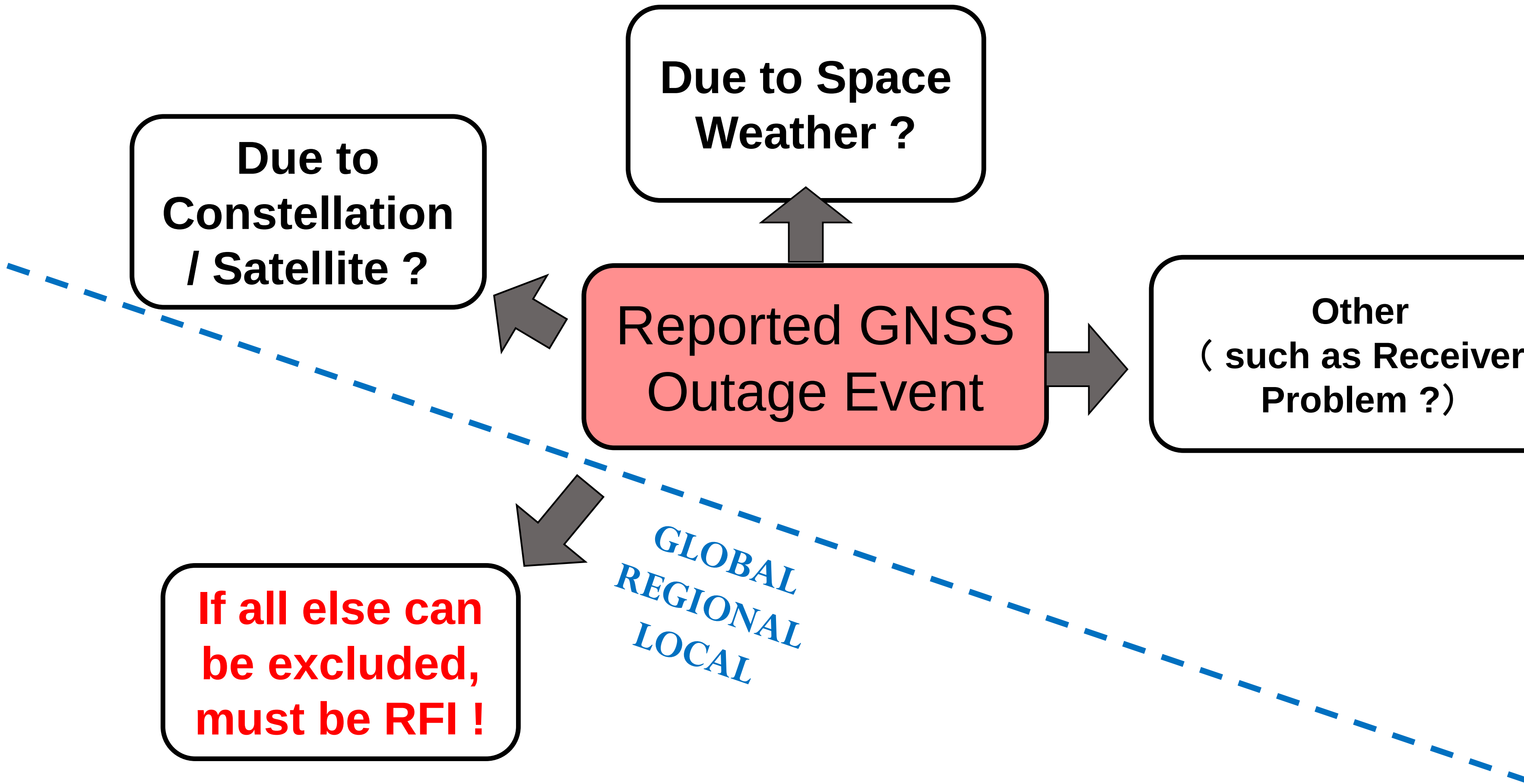
GNSS is vulnerable to interference. Main causes of GNSS anomaly can be categorized as follows:

- GNSS signal anomaly in constellation
- Receiver failure
- Radio frequency interference
- Space weather (mainly ionospheric scintillation)

1. GNSS interference identification

Identification of Probable Cause Through Elimination

- The 6th IDM workshop, Gerhard BERZ



Workflow of GNSS interference identification

Step 1.
Check whether it is the problem of receiver

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Step 2.
Identification of GNSS constellation anomaly

- Signal power
- Signal correlation peak
- Navigation message
- Quality of measurement

↓

Step 3.
Identification of space weather (ionospheric scintillation) and RFI

- Spatial and temporal distribution
- Amplitude of signal
- Duration time of signal
- Amplitude spectrum of signal

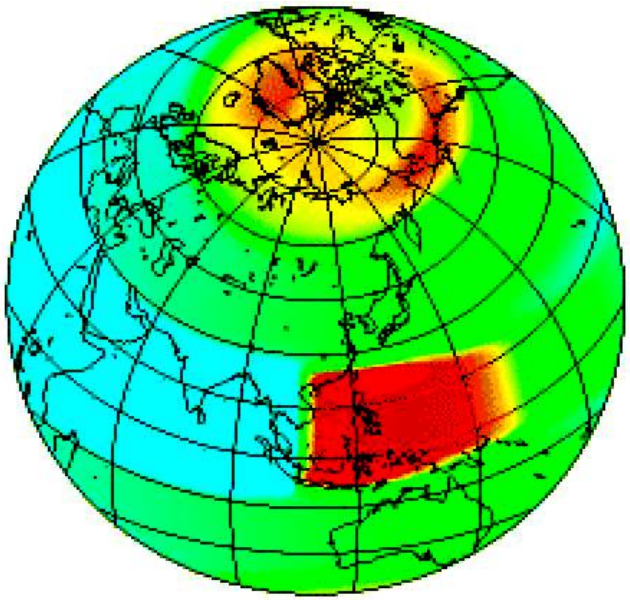
How to identify ionospheric scintillation and RFI?

① Spatial and temporal distribution

- Scintillation

Scintillation will affect GNSS at a large area of several hundreds kilometers to two thousands kilometers:

- Usually occurs at geomagnetic low latitude and polar region, seldom in mid latitude;
- Generally occurs after sunset.

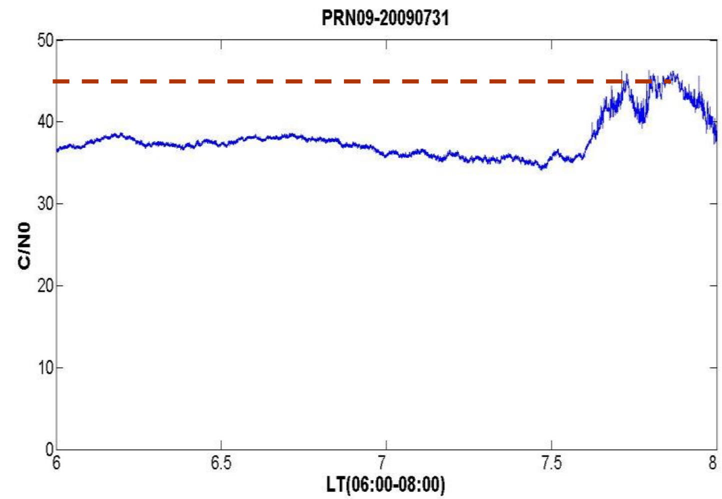


- RFI

RFI will not have a significant effect of spatial and temporal distribution, the affected area is usually visual distance of several tens of kilometers.

How to identify ionospheric scintillation and RFI?

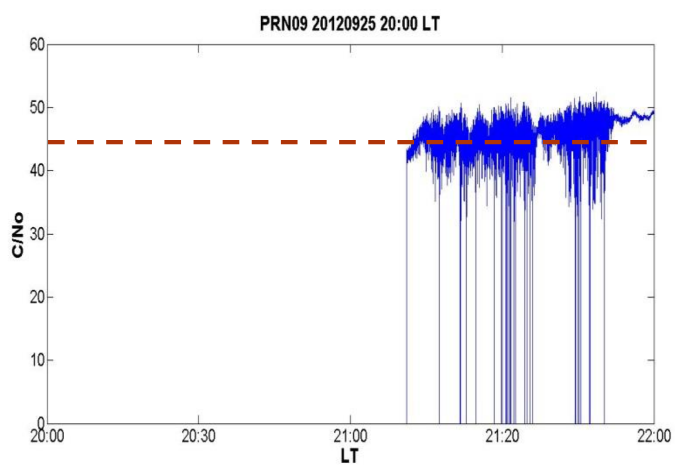
② Amplitude of signal



GPS anomaly scenario 1
(GPS PRN9， Haikou, 2009.7.31, 6:00~8:00LT)

- RFI

The amplitude of signal decreases due to RFI, the C/No is lower than normal value.



GPS anomaly scenario 2
(GPS PRN9， Haikou 2012.9.25, 20:00-22:00LT)

- Scintillation

The amplitude of signal fluctuates due to the scintillation, the C/No keeps changing and becomes higher or lower than normal value.

How to identify ionospheric scintillation and RFI?

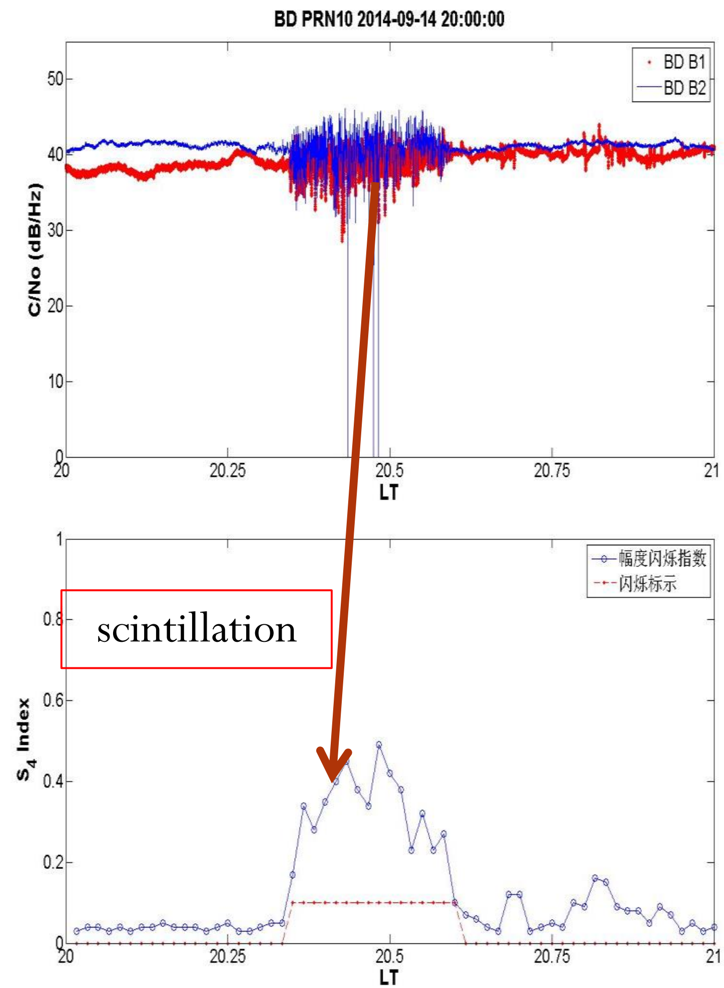
③ Duration time of signal

- Scintillation

The effect of scintillation may last half to several hours.

- RFI

The duration time of the effect of RFI is uncertain (several minutes to several years).



BD satellite original amplitude
Haikou 2014.9.14，20:00-21:00LT）

How to identify ionospheric scintillation and RFI?

④ Amplitude spectrum of signal

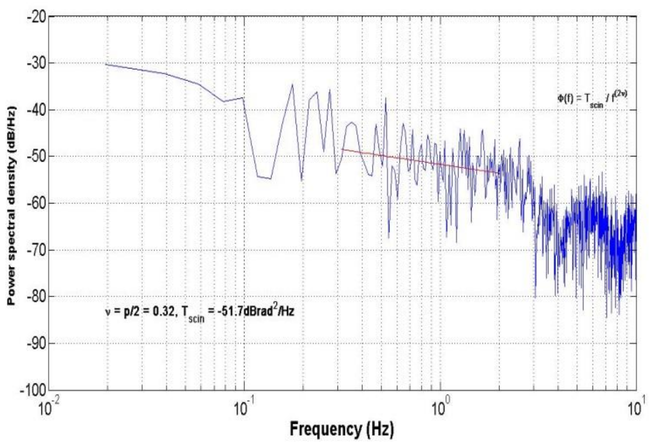
In our statistical work, a threshold can be found in the slope of scintillation amplitude spectrum which is about 1.33:

- Scintillation

Dramatic trend of linear decrease, with spectrum slope > 1.33;

- RFI

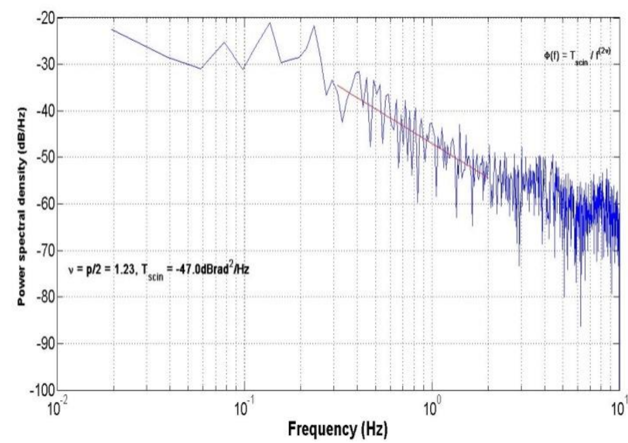
No obvious trend of linear decrease, with spectrum slope <1.33.



GPS anomaly scenario 1

(GPS PRN9, Haikou 2009.7.31, 6:30)

P=0.64 < threshold



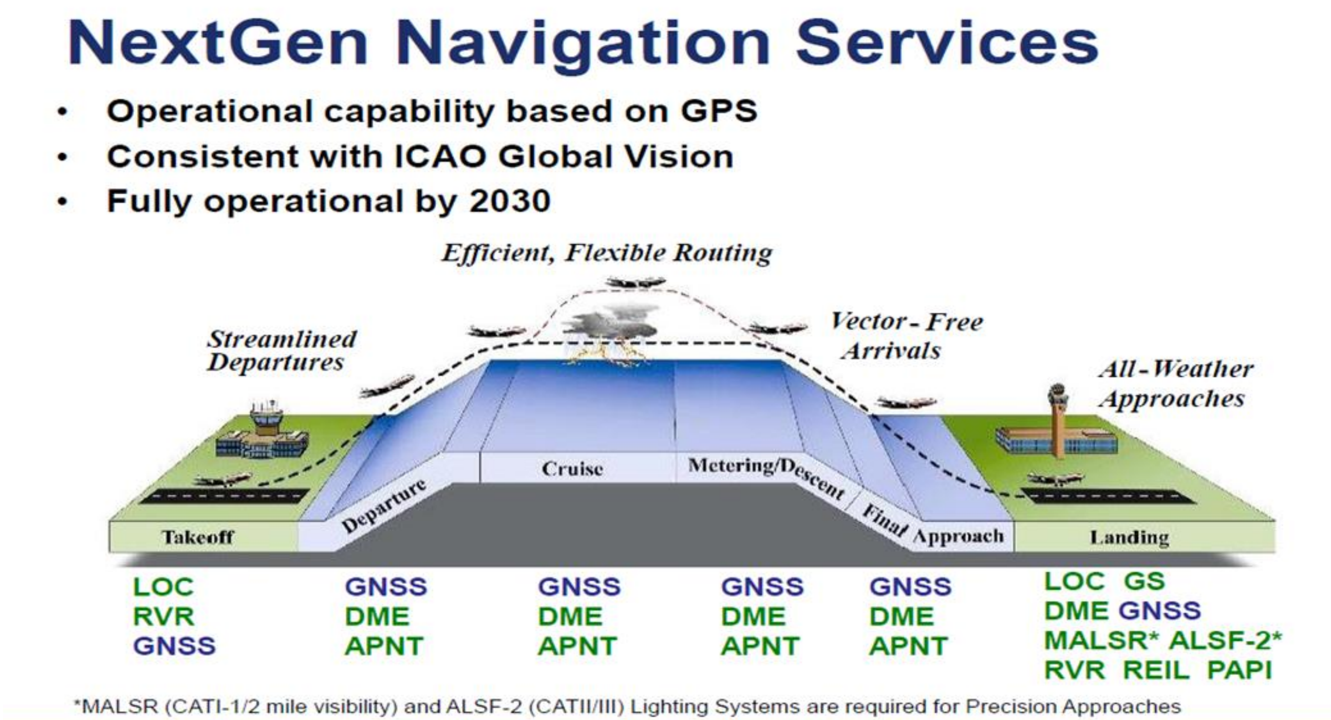
GPS anomaly scenario 2

(GPS PRN9, Haikou 2012.9.25, 20:42)

P=2.46 > threshold

2. Interference detection and localization for urban area and critical infrastructure

GNSS will be used as main navigation method in all the phases of flight in the future. The landing and takeoff phases at airport are of most important. So we **take airport as an example of critical infrastructure**.

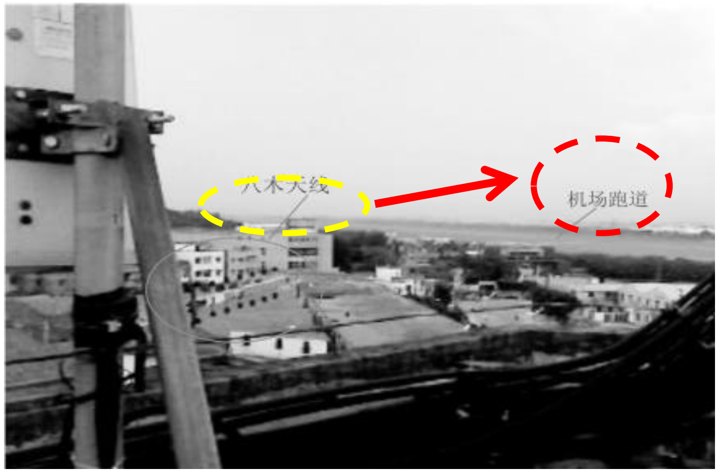


Most results show that GNSS interference in the airport contains unintentional and intentional interference. Private jammers are found to have significant effect on civil aviation.

Typical cases of GNSS interference at airports

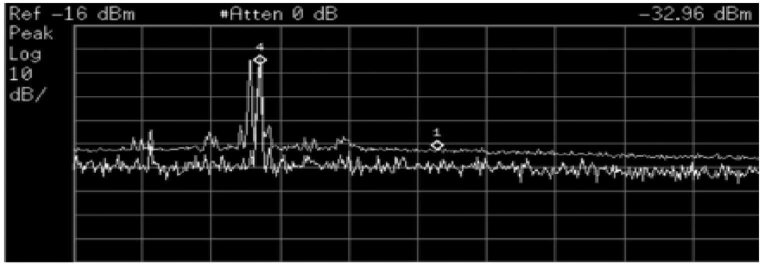
time	location	Description	RFI source	RFI source belongs to
1997	Lucano airport ,Switzerland	GPS L1、L2 were interfered at civil/military airport	Permanent transmitter	Italian military
2002	Frankfurt airport Germany	Received signal at L1 band was interfered around the airport with coverage of 150km	unclear	Unclear
2009~2011	Newark, USA	GBAS system anomaly often	GPS private jammer	personal
2009.9	Shadi airport,foshan, Guangdong,China	GPS interfered during takeoff phase	yagi directional antenna	district policeman

GNSS interference in Guangdong foshan airport

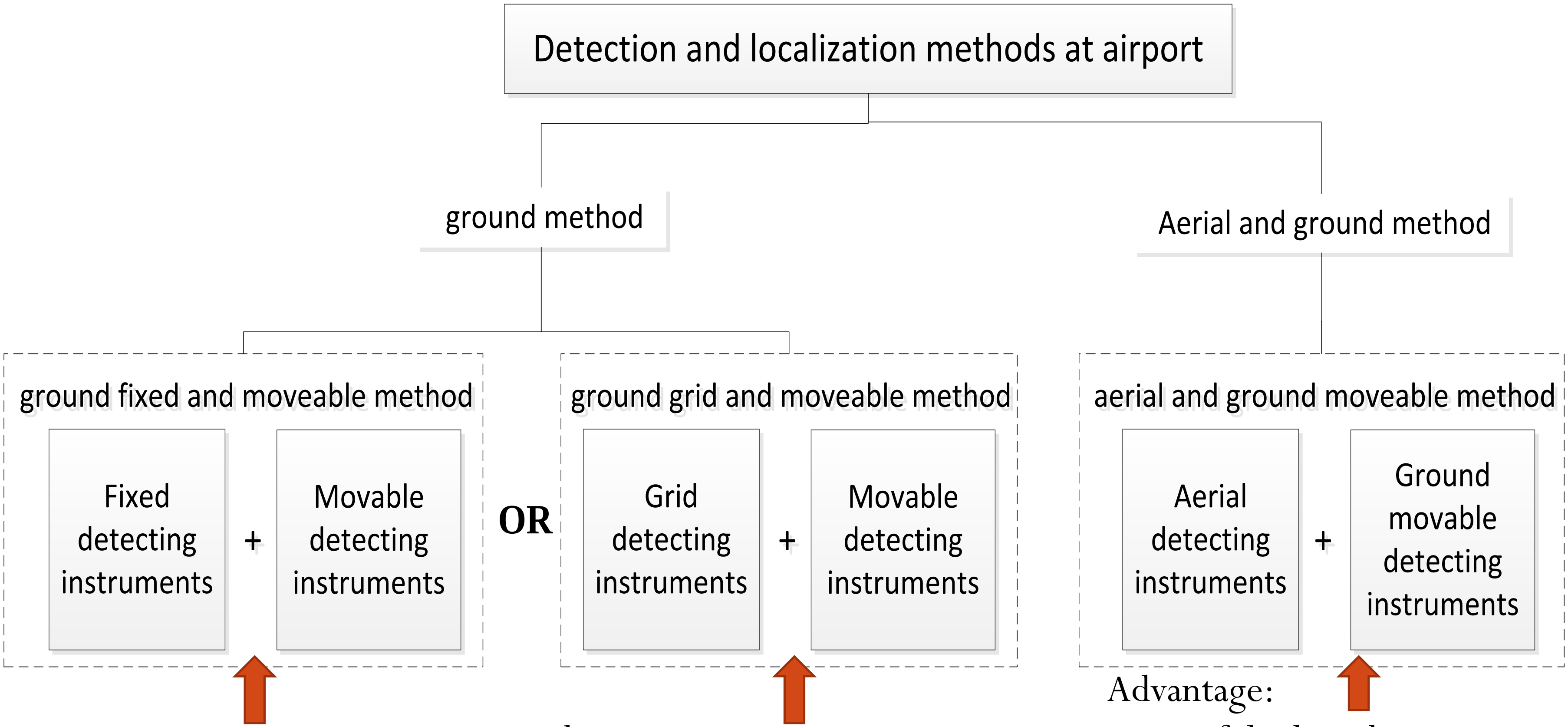


GPS navigation system in the airport was interfered at the takeoff and landing area. Positioning information lost.

RFI was transmitted by yagi directional antenna nearby for public communication.



Detection and localization methods of interference at airport



Advantage:
- Simple system;
- Relatively low cost.

Disadvantage:
- Need long time to locate.

Advantage:
- Detect and approximately locate the source in real time.

Disadvantage:
- Complicated system;
- Relatively high cost.

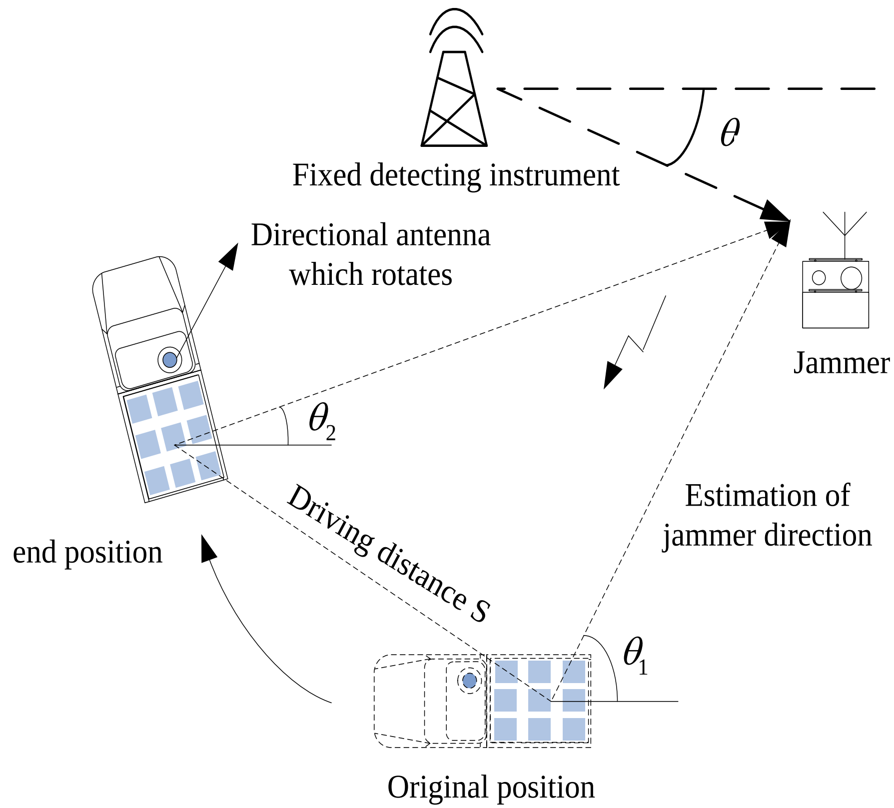
Advantage:
- Useful when the source can not be found by ground detecting instruments;

Disadvantage:
- Complicated implementing process.

① Ground fixed and moveable method

Step 1: Use fixed instruments to detect interference and find direction of the source of interference;

Step 2: Cross localization will be used for moveable instruments to accurately locate and determine the source of interference.

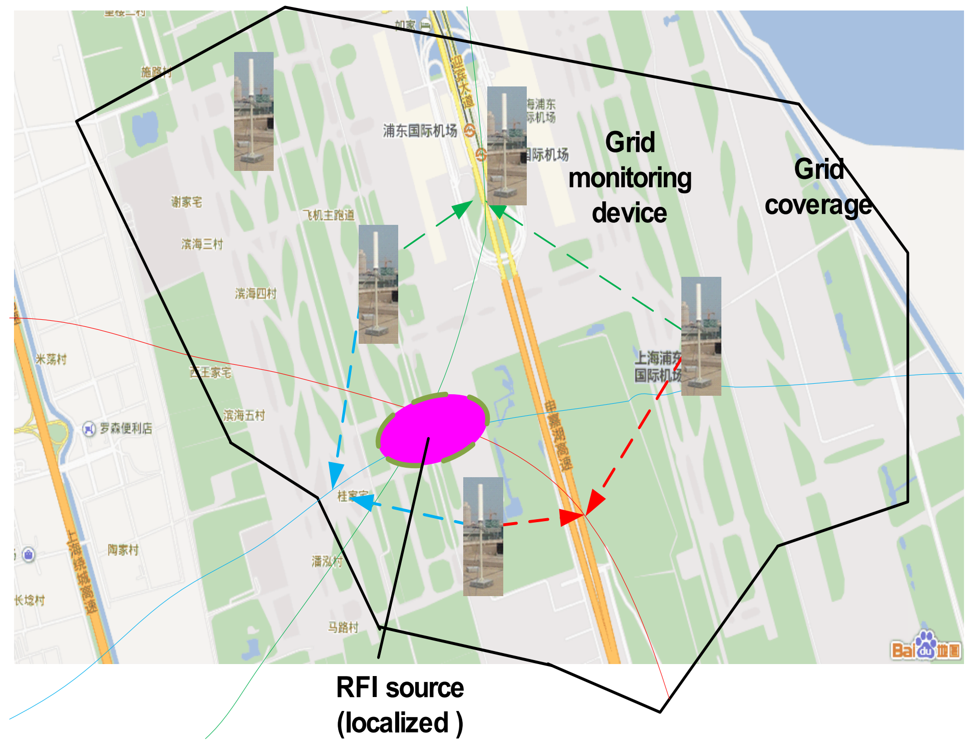


Advantage	Disadvantage
Simple system Relatively low cost	Need long time to locate

② Ground grid and moveable method

Step 1: Use grid instruments to detect interference and approximately locate of the source of interference by TDOA localization method;

Step 2: Use moveable instruments to accurately locate and determine the source of interference.

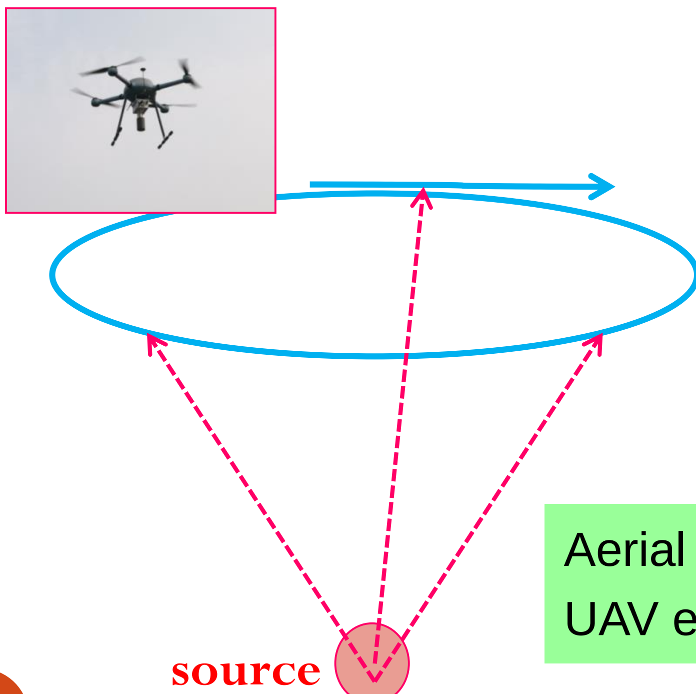


Advantage	Disadvantage
Detect and approximately locate the source of interference in real time.	Complicated system Relatively high cost

③ Aerial and ground moveable method

Step 1: Use aerial instruments to measure the direction of interference at different points and approximately locate the interference by cross localization;

Step 2: Use ground moveable instruments to accurately locate and determine the source of interference.



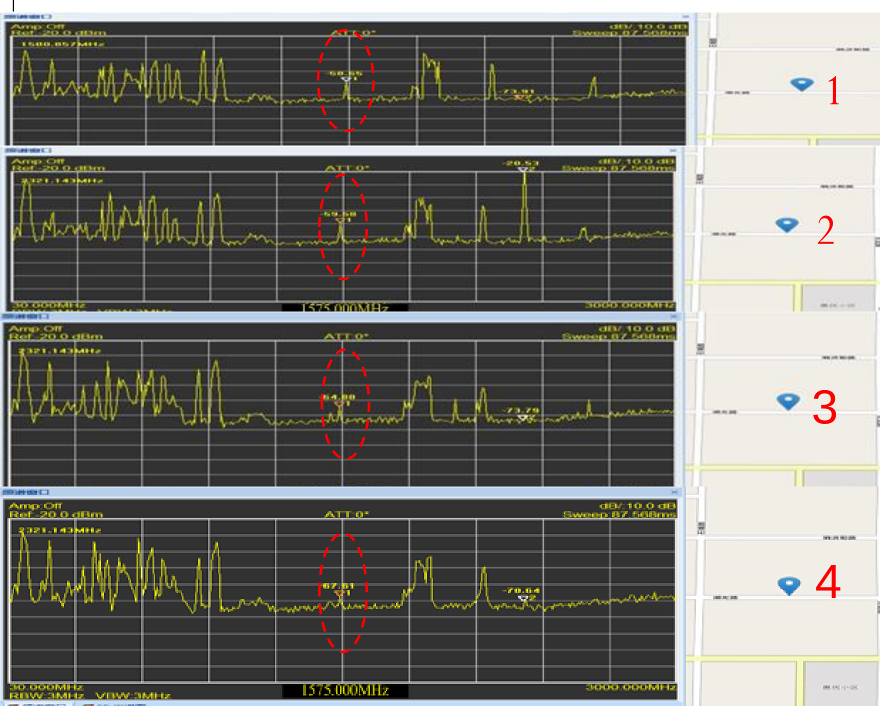
Advantage	Disadvantage
Useful when the source can not be found by ground detecting instruments;	Complicated implementing process.

Aerial platform can be aeroplane or UAV etc.

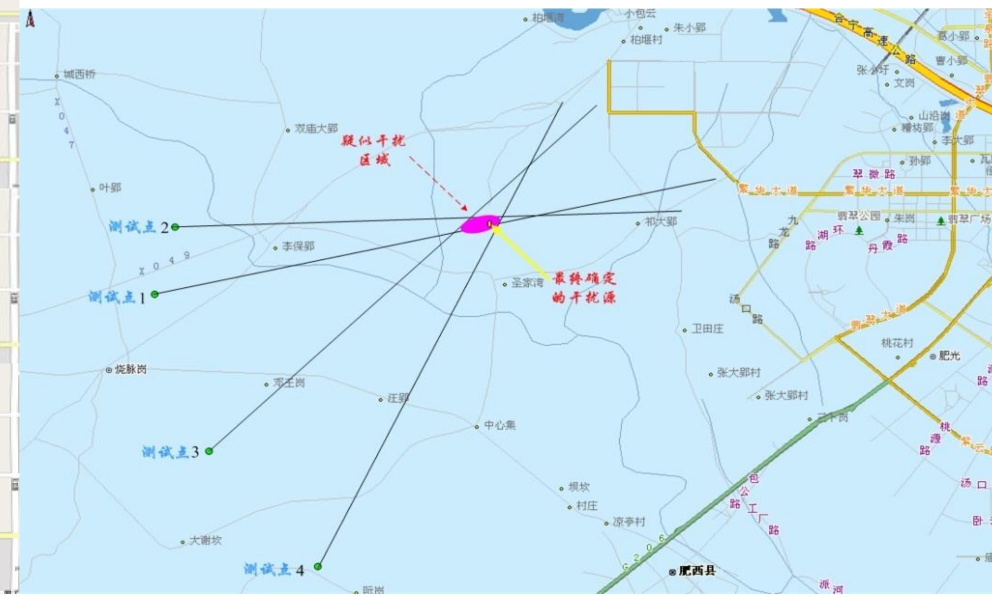
Aerial and ground moveable detection and localization experiment in Hefei, China

Interference signals are found near 1575MHz from the spectrum.

- The source of interference is determined through following steps:
  - Approximately locate the area through cross localization by UAV;
  - Determine the exact location in rough region using ground moveable detector.

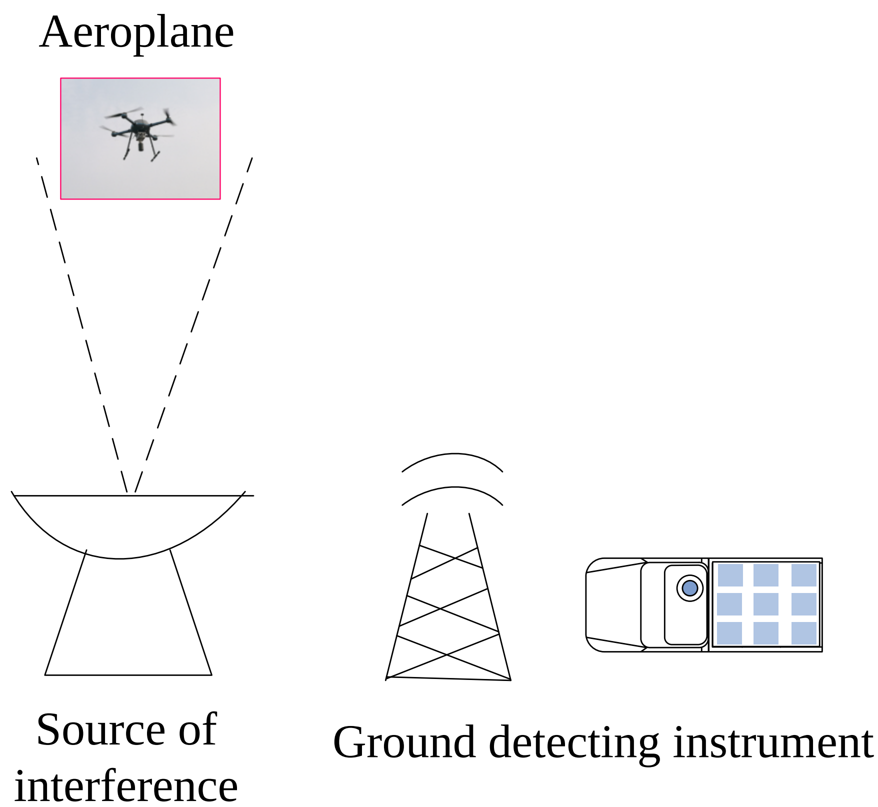


Spectrum at four test points（Left） and result（Right）

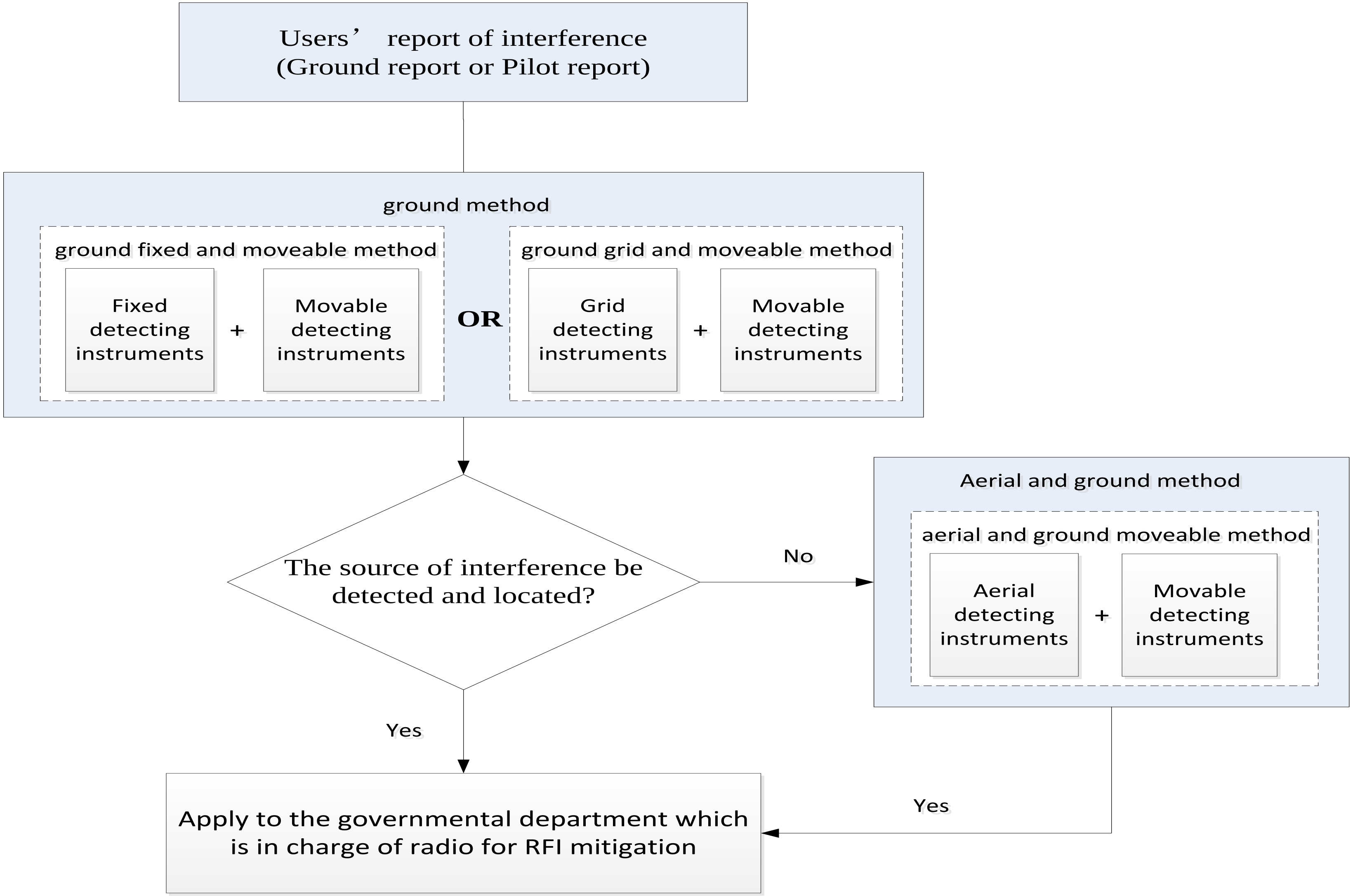


Aerial interference detection for GNSS at airport is important

Aerial interference detection is very important at airport, especially for the condition that pilot reports the interference but ground detecting instrument can not find the source of interference.



Workflow of GNSS interference detection at airport



3. Summary

1. How to identify the interference caused by ionospheric scintillation and RFI is important for IDM;

2. Airport has been taken as an example of critical infrastructure and the detection and localization methods of the interference have been introduced;

Aerial interference detection is important since the pilots will suffer such kind of interference which can not be detected by ground detecting instruments.

THANK YOU FOR YOUR ATTENTION!

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