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GNSS interference evaluation and mitigation for aviation

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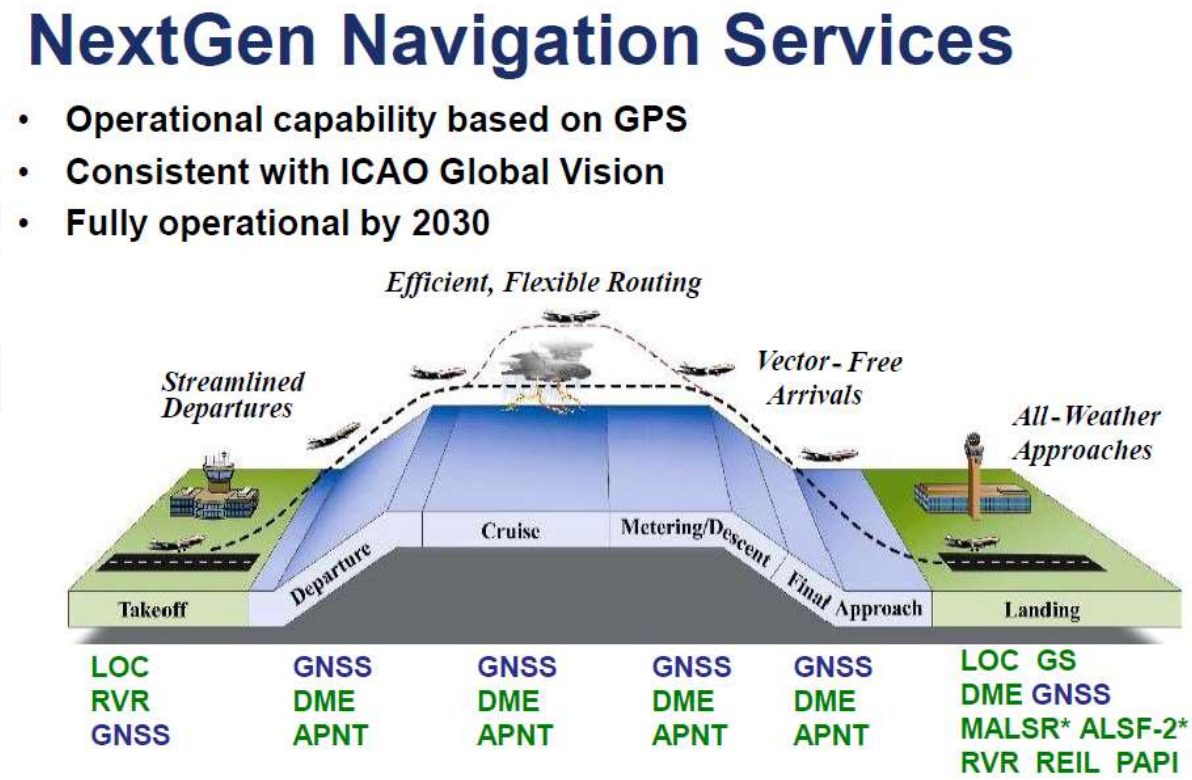
1. GNSS interference effects in aviation

- As development of world economy, number of airport, airline and airplane increase dramatically.
- Satellite navigation plays important role in civil aviation (mainly used in navigation and timing).



(from FAA)

GNSS can meet accuracy requirements of aviation.

Accuracy requirements of aviation

	Accuracy	
	Horizontal (95%)	Vertical (95%)
Airway (ocean)	3.7km	N/A
Airway (land)	3.7km	N/A
Terminal	0.74km	N/A
NPA	220m	N/A
APV I	16m	20m
APV II	16m	8m
CAT I	16m	6~4m
Aviation timing	Us level	

Example of GNSS interference to GBAS

- GNSS signal is weak (-160dBW on the ground), and vulnerable to interference.
- As safety-of-life service, aviation will be seriously affected when GNSS interfered.

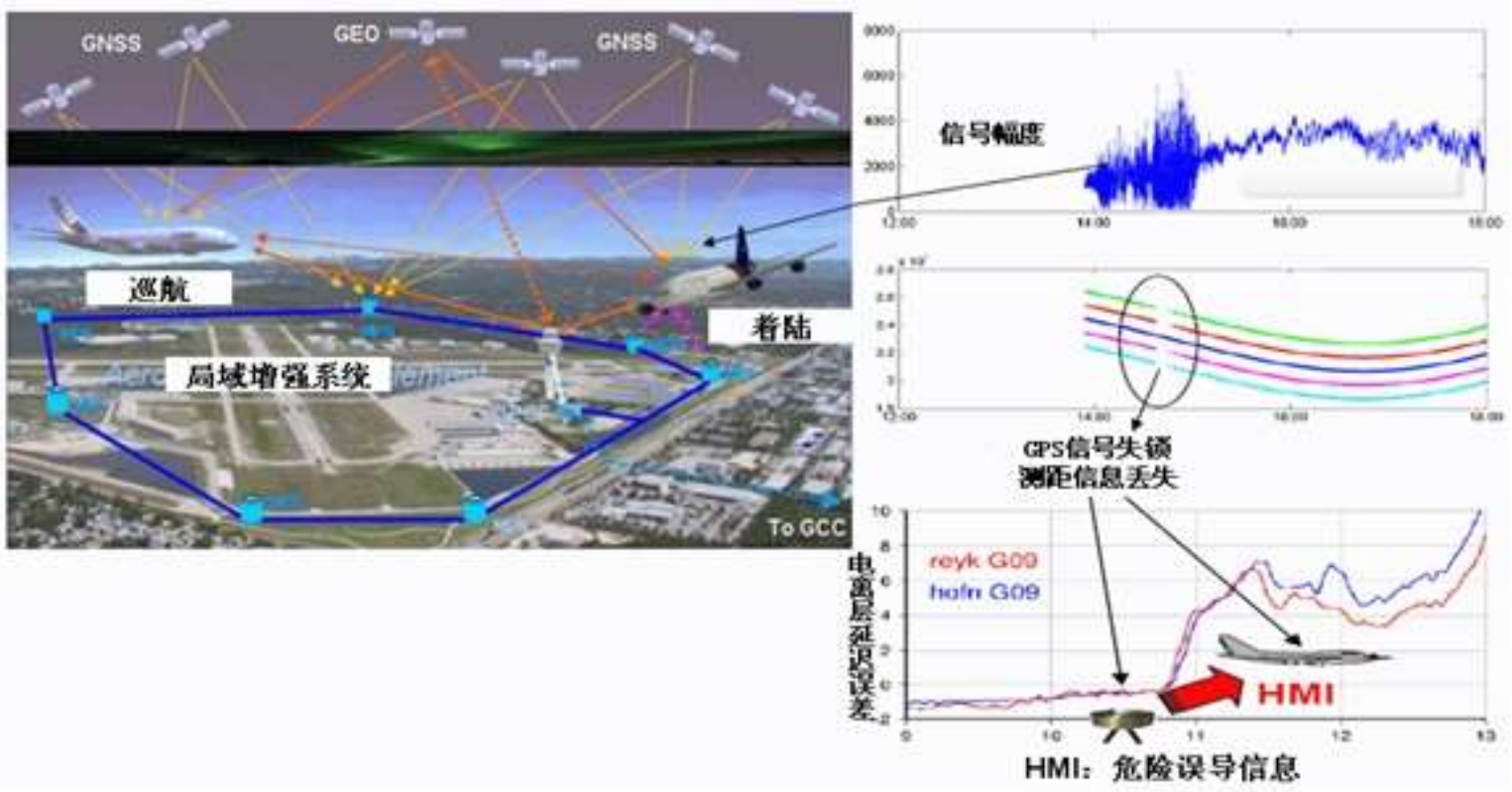
Example1 : GBAS interfered in Newark airport

- GPS ground augmentation system affected by RFI in 11.2009.
- RFI source: Personal private device (PPD) from truck driver.
- Three month investigation

Ionospheric scintillation effects to GNSS signal in airport

Example 2:

- GNSS signal loss of lock caused by ionospheric scintillation at a airport.
- loss of distance measurements (may cause misleading info.)



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Effects of GNSS interference to receiver

Type of interference:

- continuous wave interference,
- frequency modulated interference,
- white nose interference,
- deceptive interference etc.

Parameters for interference evaluation:

- effective carrier noise ratio,
- acquiring performance、
- tracking performance,
- timing performance etc.

Results:

- decrease of carrier and noise ratio of visible satellites,
- wrong acquiring of receiver,
- decrease of number of acquired satellite,
- increase of searching and acquiring time,
- distortion of code correlator and carrier phase tracker,
- result from discriminator tracking loop,
- decrease of timing performance.

2、Evaluation of GNSS interference to aviation

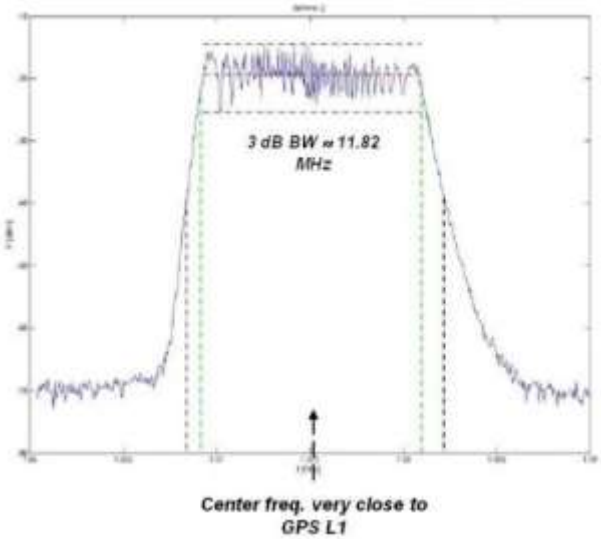
Evaluation of interference to navigation device in aviation

Personal private device (PPD)

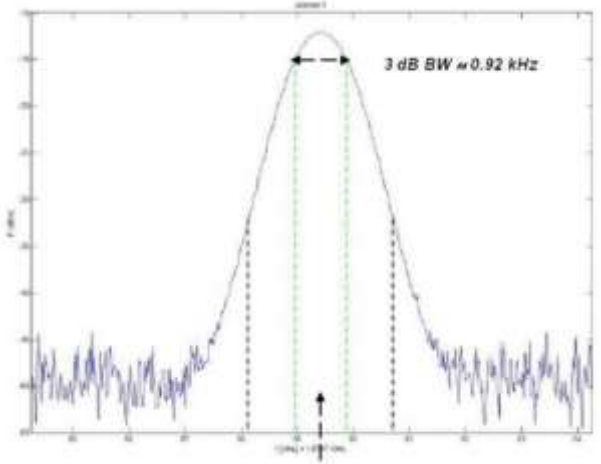
PPD in market:

- Frequency: 1575.42MHz (GPS L1, BDS B1, Galileo E1)
- Transmitting power: -10dBm
- Much effects on GNSS application in aviation

Spectrum of PPD and GPS L1



Center freq. very close to GPS L1



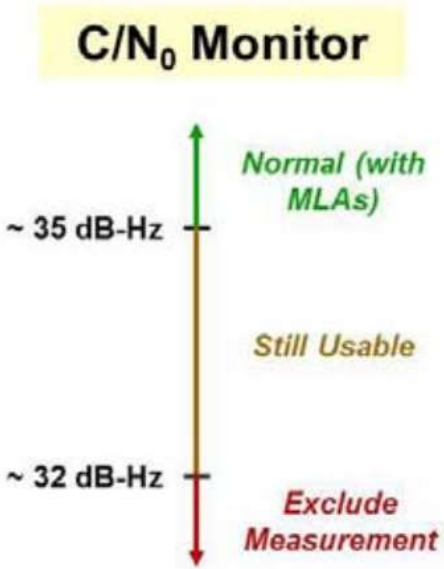
Center freq. very close to GPS L1 (varies with temperature)

2、Evaluation of GNSS interference to aviation

Effects of PPD RFI to reference station of GBAS

- Receivers in reference station will be threatened by PPD in truck passed by
- C/N0 of multi satellites will be decreased by PPD and unusable

- Keep distance between two antennas to 500~1000m, to avoid jamming of two receivers by single PPD at the same time.



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3、Mitigation of GNSS interference in aviation

1) Scheme of GNSS interference detection system for aviation

2) Other measures for mitigation of GNSS interference

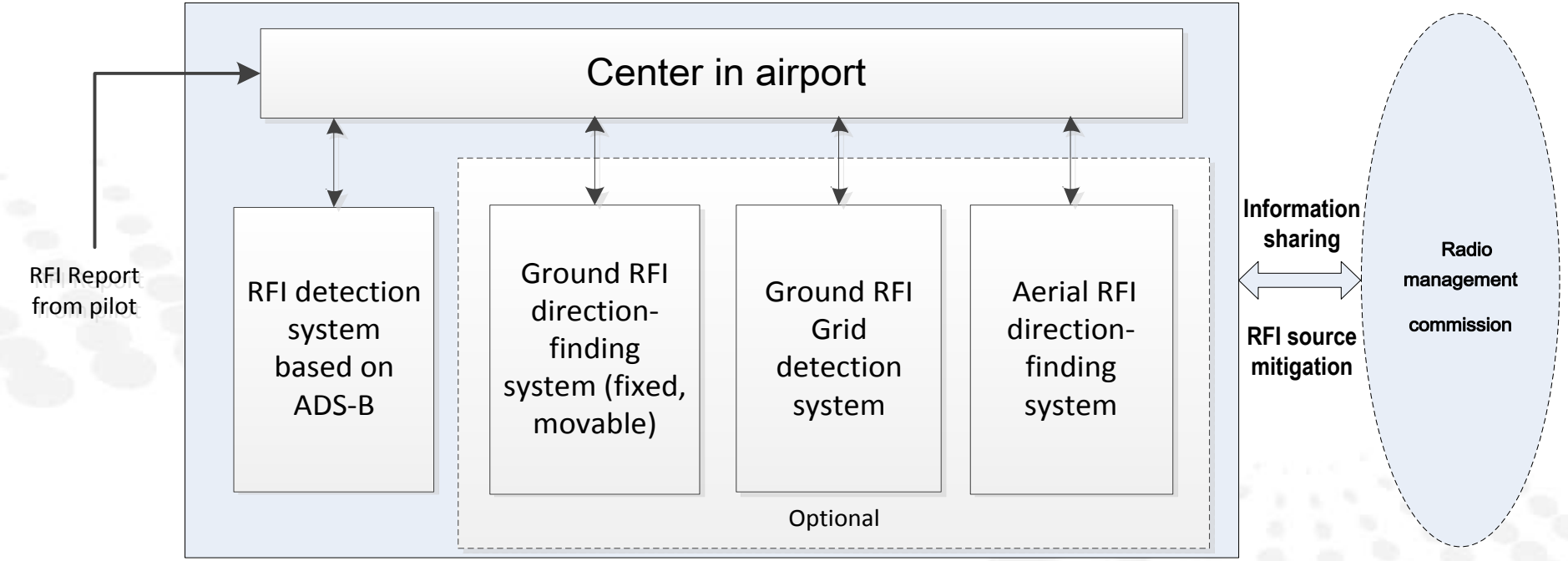
- **Spectrum management:** protect GNSS frequency use in aviation, electromagnetic compatibility of GNSS receiver on vehicle with other electronic device incase of interference
- **Multi-frequency & anti jamming GNSS receiver**
- **Backup system:** INS, eLoran etc.
- **Use of ground radio navigation system:** DME etc.

---Scheme of GNSS interference detection system for aviation in the following.

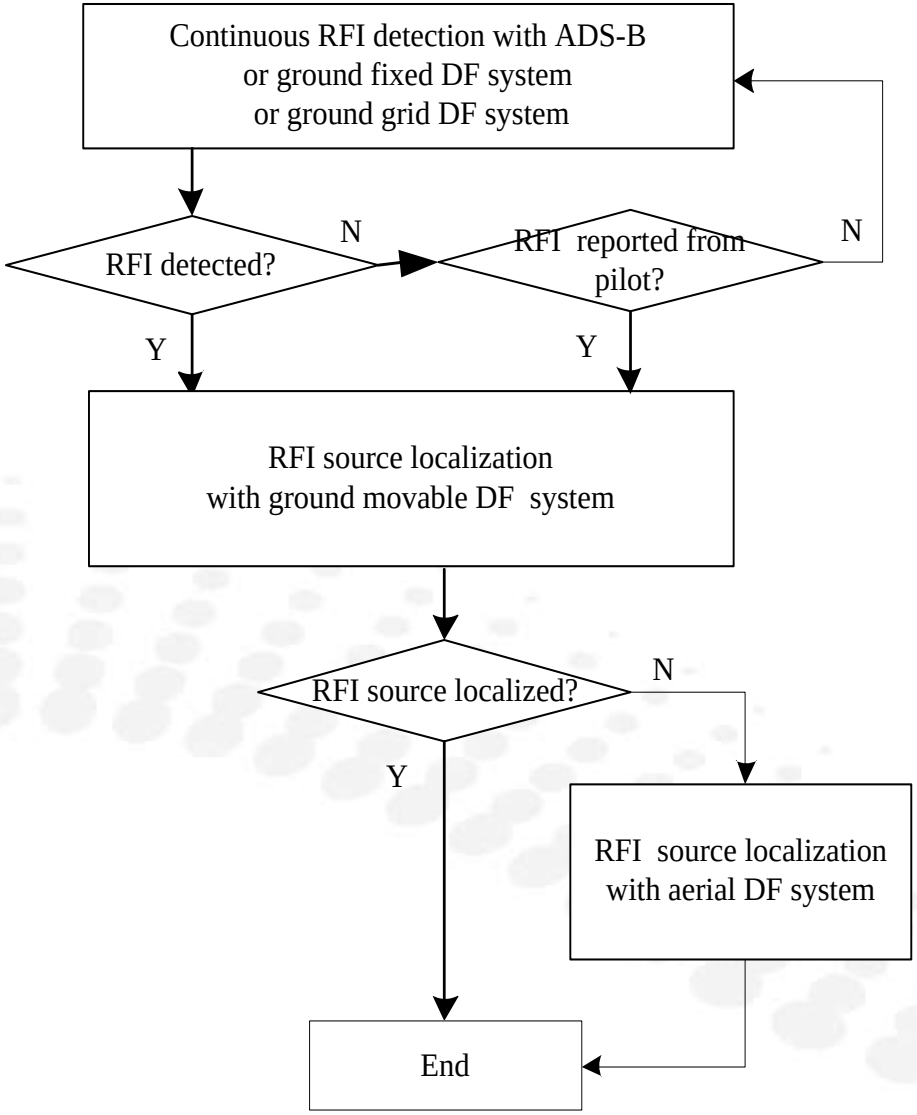
3、Mitigation of GNSS interference in aviation

Scheme of GNSS interference detection system for aviation

GNSS interference detection system for aviation



Working flow of GNSS interference detection system for aviation



Report from Pilot

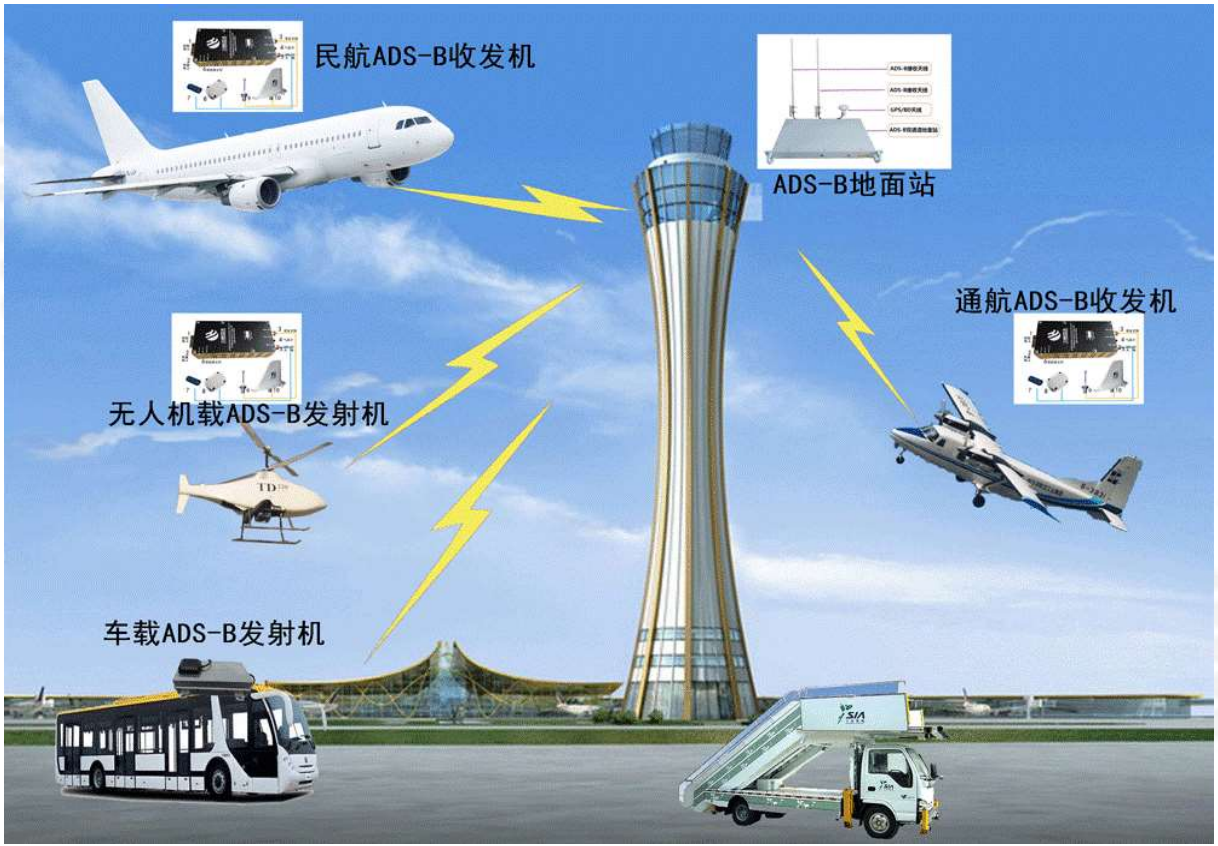
- Pilot can report interference info according to standard template.
- Info should be included: Name, Email, Time, Altitude, Heading etc.

•Only rough region of interfered

•Can not report timely

RFI detection system based on ADS-B

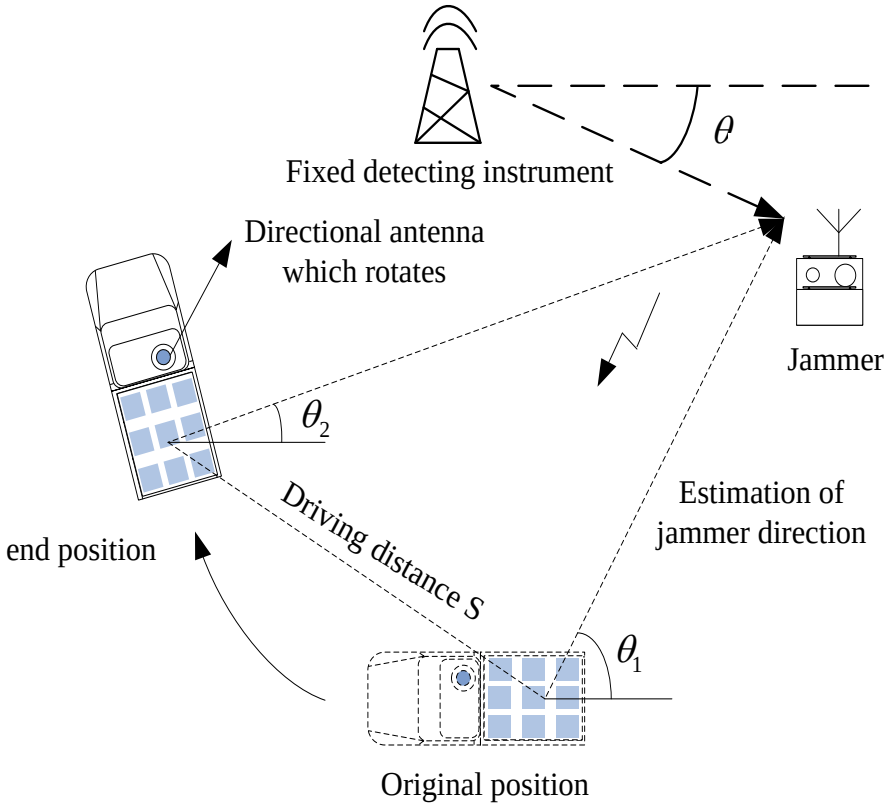
- All aircraft and vehicle with ADS-B transmitter can broadcast its own No. location, velocity and receive info from other aircraft and vehicle with ADS-B transmitter. Rough region of interfere source can be derived from interrupted latitude, longitude, height and time info of ADS-B.
- RFI source localization with ADS-B by Gerhard BERZ et. al



Ground RFI direction-finding system

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

Step 2: Cross localization will be used with moveable instruments to accurately localize RFI source.

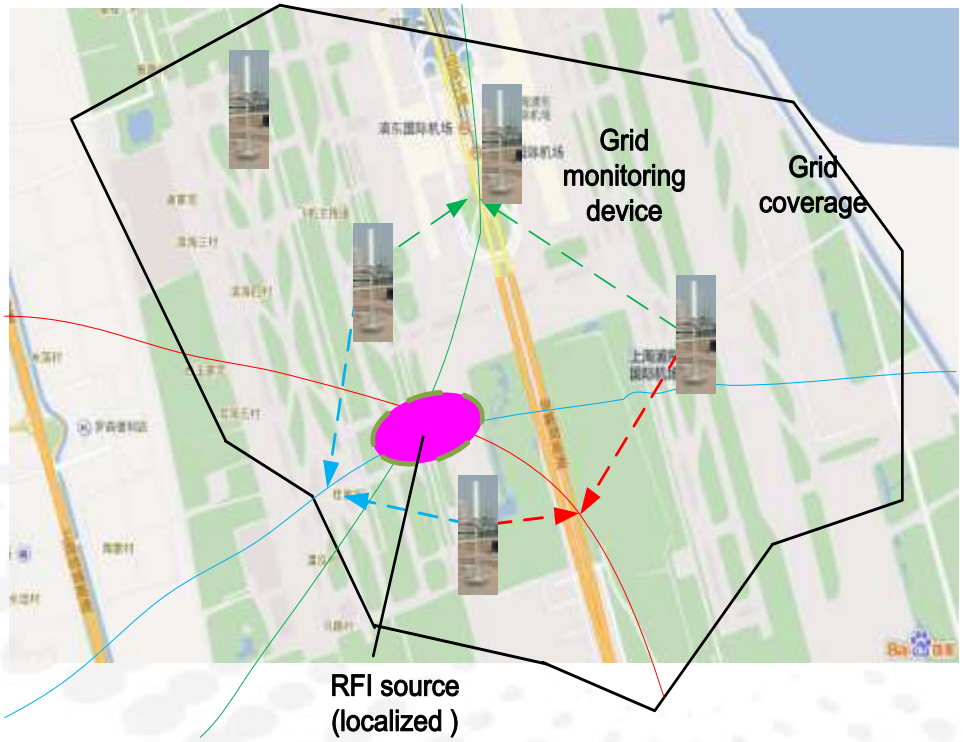


Advantage	Disadvantage
Simple system Relatively low cost	Need long time to locate

Ground RFI grid detection system

Use grid instruments to detect interference and approximately localize RFI source by TDOA localization method;

Optional



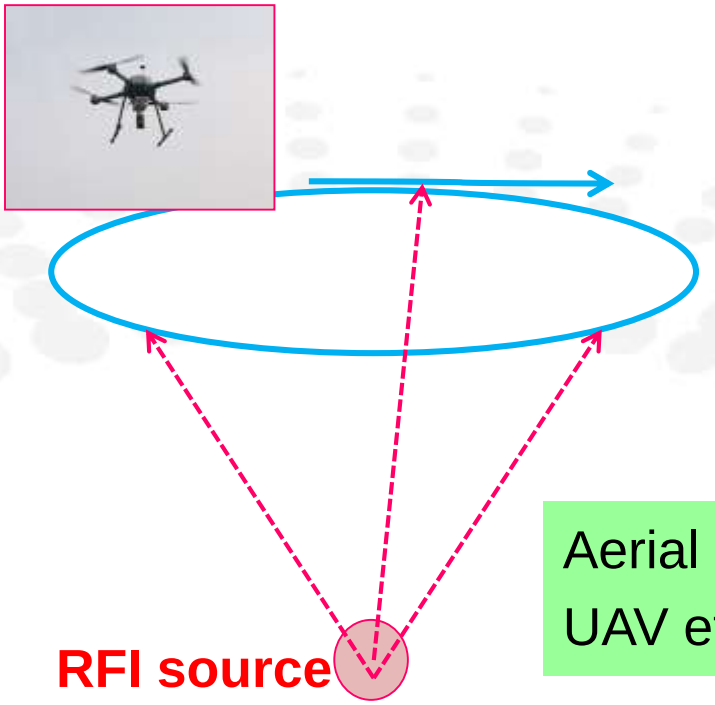
Advantage	Disadvantage
Detection and localization RFI source in real time.	Complicated system Relatively high cost

Aerial RFI DF system

When interference reported by pilot can not be detected with ground instruments, aerial interference detection system can be used for detection .

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

Step 2: Use ground moveable instruments to accurately localize RFI source.



Advantage	Disadvantage
Fast detection in large area;	Relative high cost

Aerial platform can be airplane or UAV etc.

Title: Recommendation on GNSS interference detection for civil aviation

Background/Brief Description of the Issue:

GNSS has been widely used in civil aviation, together with GBAS and WAAS. It plays important role in safety-of-life service in the whole phase of flight, especially in landing and approaching phase at airport. Yet GNSS is vulnerable to interference (mainly electromagnetic interference and ionospheric disturbance).As increasing use of personal private device, and many kinds of other electronic device at or nearby airport, interference has became serious threat to GNSS application in aviation.

Discussion/analysis

In the past IDM workshop and ICG meetings, WG-S participants have discussed a lot on interference detection at airport or on course.

In order to keep safer operation of civil aviation, discussion should be expanded to ICAO for further action. Scheme of interference detection system for aviation including usage of ADS-B information should be suggested to all nations by ICAO.

Recommendation

It is recommended that ICG should reach consensus on whether or not to endorse a scheme for interference detection system for aviation including usage of ADS-B information to illegal interference committee of ICAO. If the scheme is endorsed by WG-S, the ICG should:

Consider presenting this scheme to the appropriate meeting of ICAO.

Consider how data from the GNSS interference detection system for aviation can be integrated into national/governmental mitigation efforts.

Thank you !

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