FURUNO
GNSS Multipath and Spoofing rejection
Using array antenna
June 20,2018
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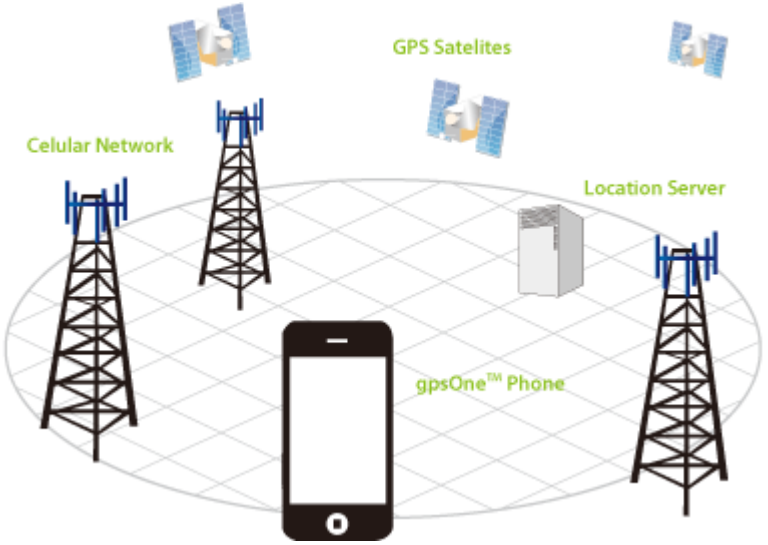
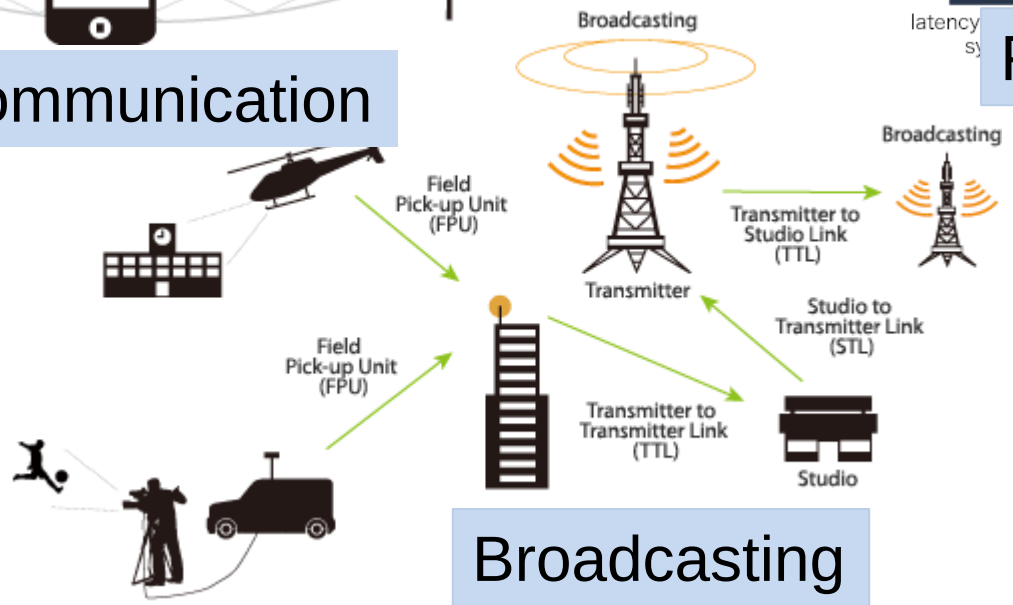
FURUNO ELECTRIC CO., LTD.

GNSS timing is used in various field



Telecommunication

Financial transaction



Broadcasting

⇒ It becomes more important

GNSS faces various threats

GNSS threats

- Multipath
- Spoofing
- Jamming
- GNSS system trouble
- Antenna trouble

In case of using NLOS satellites, with the multipath, the timing error (TE) may reach several hundreds of nano seconds.

Spoofing causes serious incident. We've recently heard a lot in the news about GPS spoofing.

- Black Sea
  October, 2017
- Eastern Mediterranean Sea
  March, 2018

Receiver can't work

Some satellites of GPS sent out 13.7μsec faulty UTC correction parameters on January 26, 2016

Lightning strike

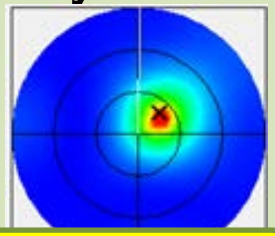
How should the threats be eliminated?

GNSS threats

- Multipath
- Spoofing
- Jamming
- GNSS system trouble
- Antenna trouble

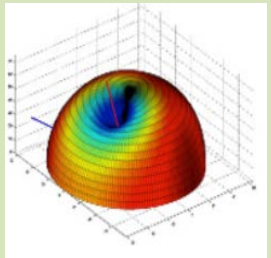
Solutions

- Multipath mitigation
- DOA Array antenna



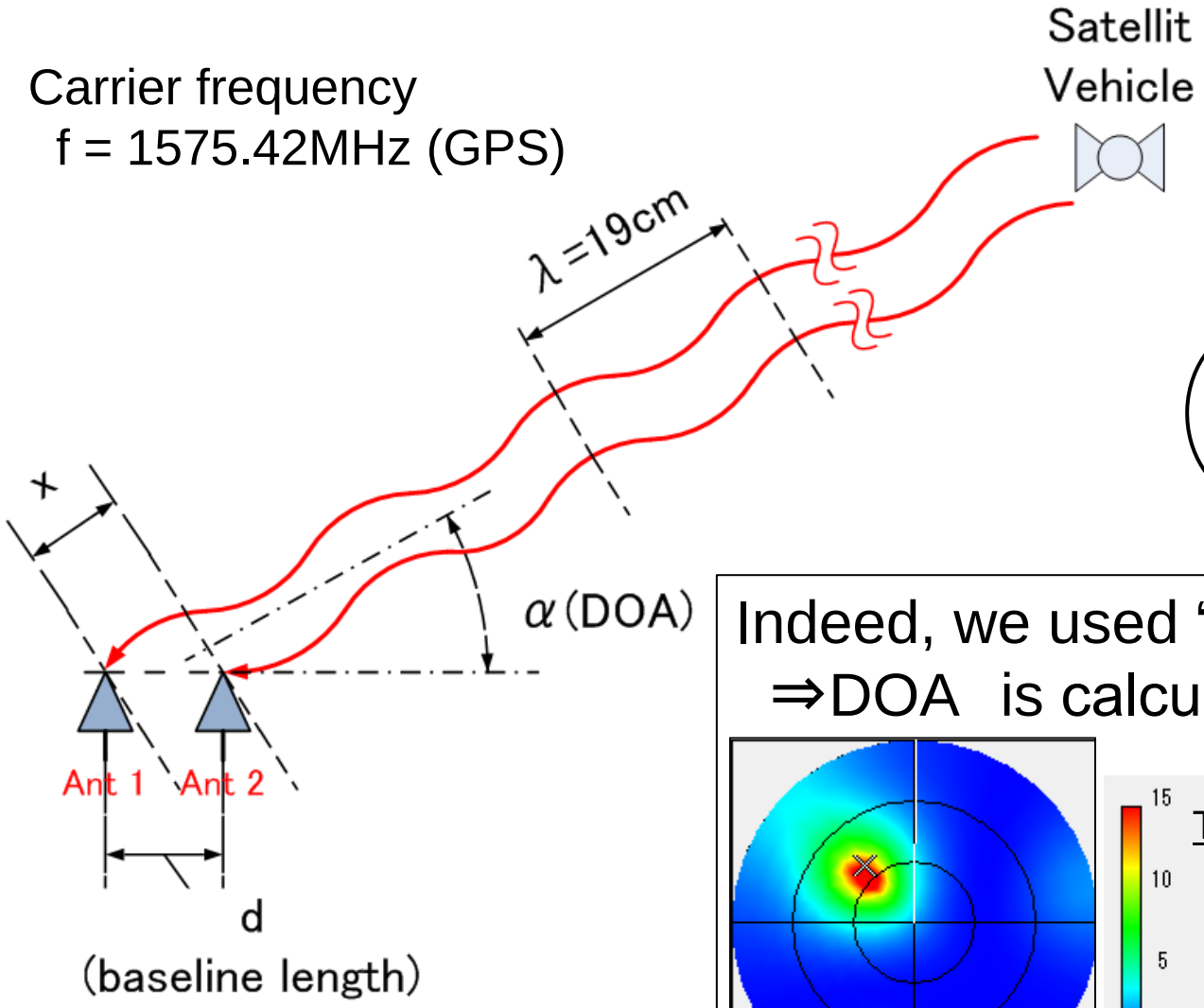
Today's suggestion

- Multi constellation Multi band
- RAIM
- DGPS SBAS
- Holdover Short term HO
- Null-steering Array antenna



What's DOA(direction of arrive) Array antenna?

Carrier frequency
f = 1575.42MHz (GPS)



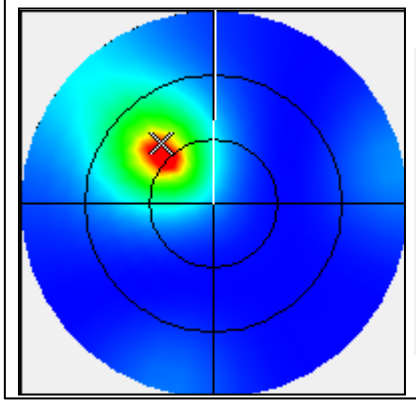
Ant 1 Carrier phase = Φ1
Ant 2 Carrier phase = Φ2

$X = d \cdot \cos\alpha$

$X = \lambda \cdot (\Phi 1 - \Phi 2) / 2\pi$

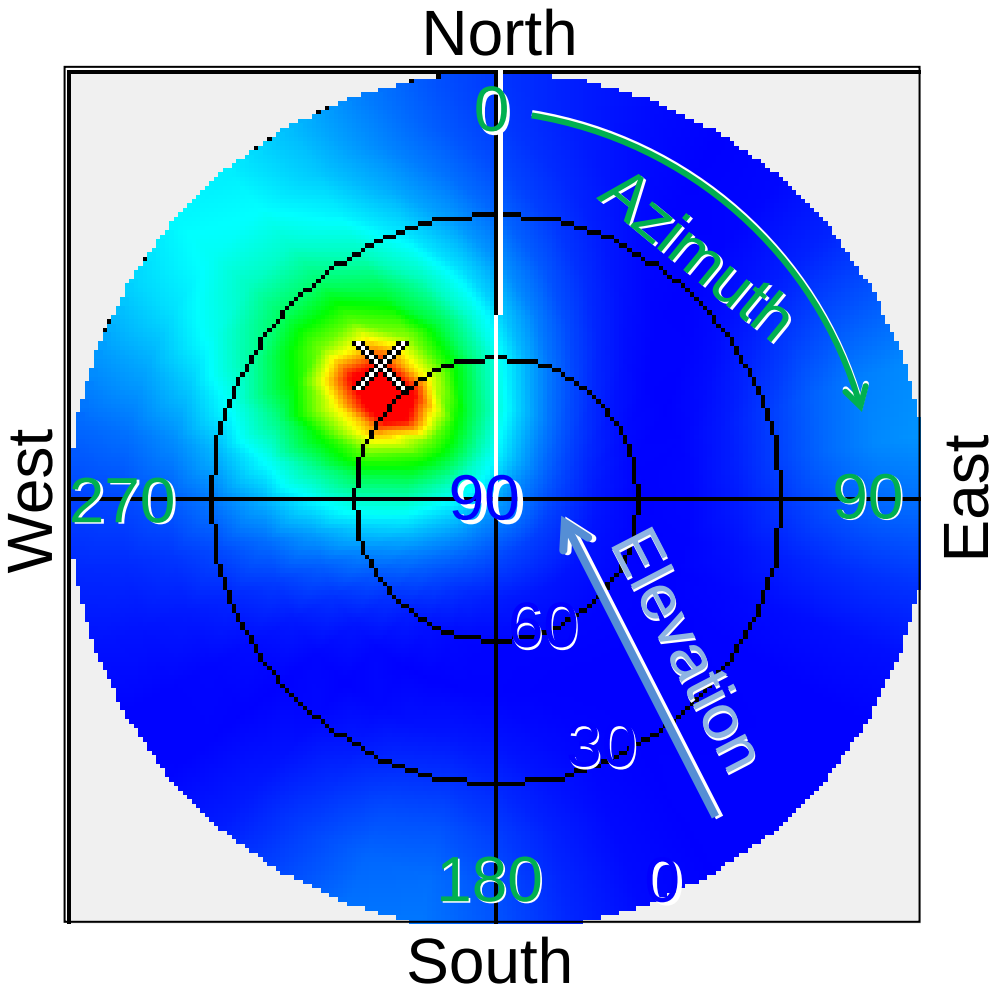
α can be calculated

Indeed, we used "MUSIC" method.
⇒DOA is calculated as angular spectrum



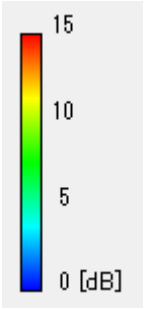
This is a skyplot of one Satellite
The color scale is DOA spectrum.
- Red is strong signal, Blue is weak
X mark is Satellite Vehicle position

Skyplot of DOA spectrum and SV orbital position

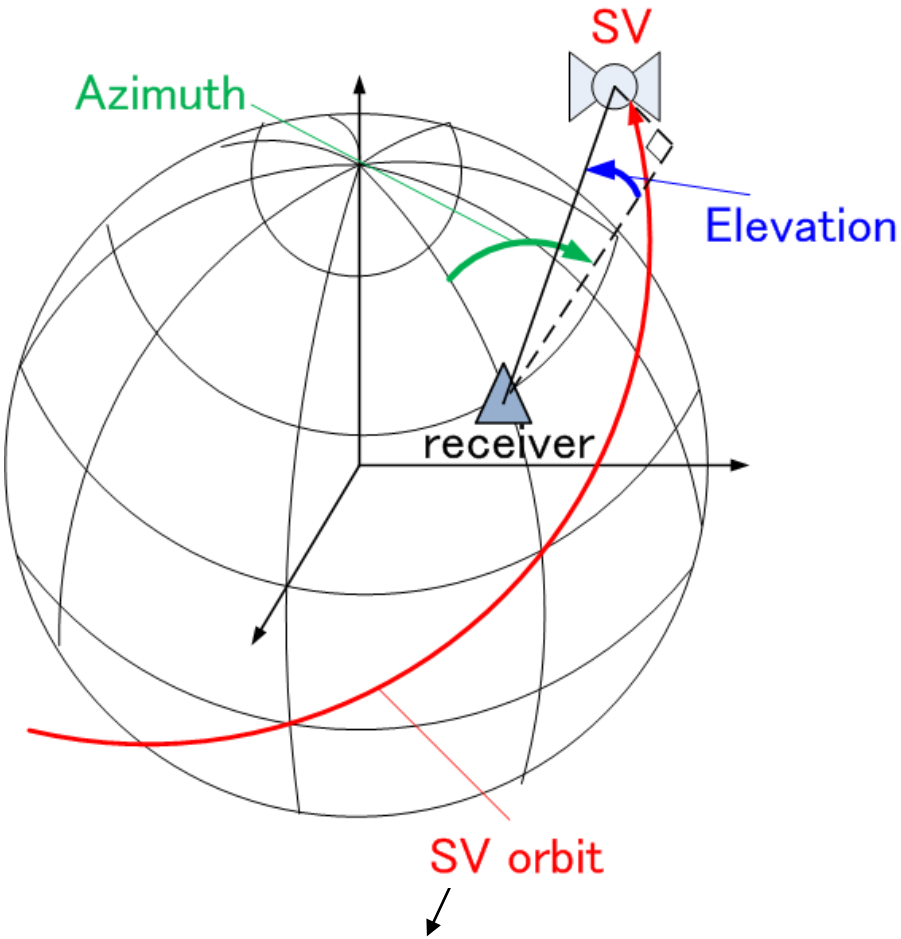


CH16(25) C/N0=46, 47, 46, 45

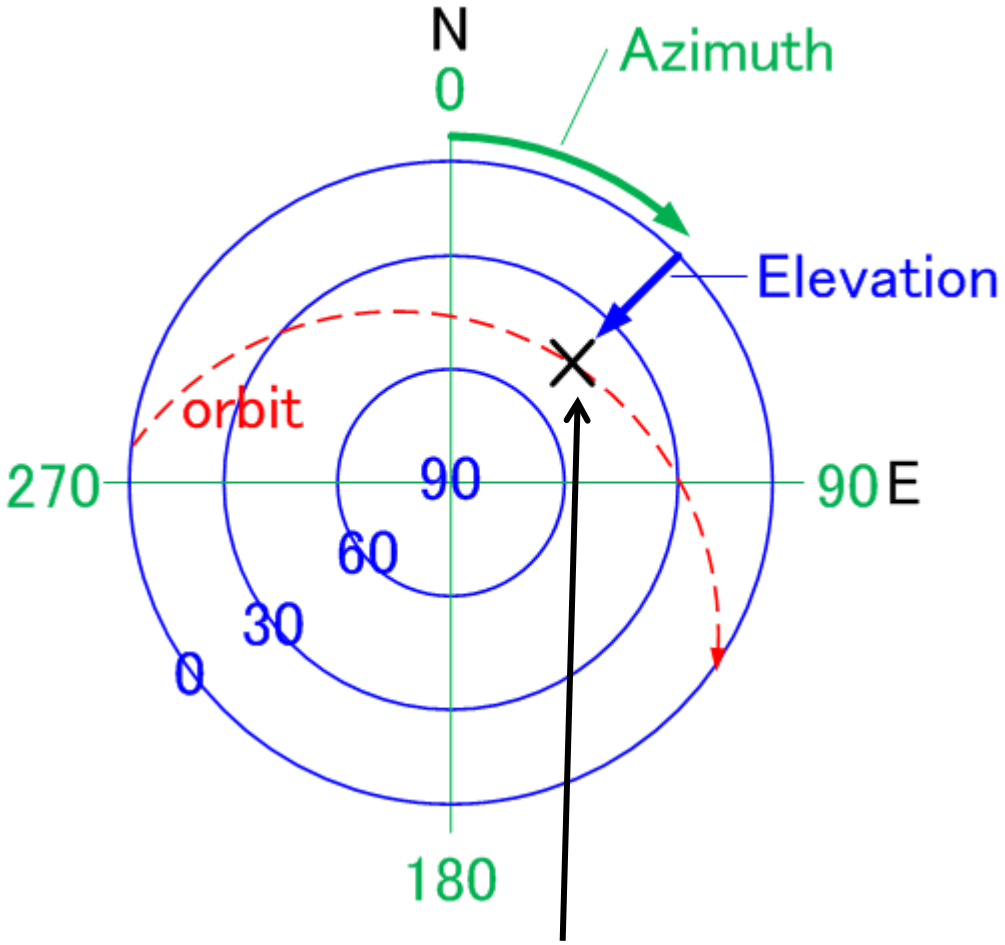
PRN number

Symbol	description
X	Satellite Vehicle position (Calculated from Orbital information)
	DOA spectrum (Calculated from Array antenna)

How to calculate SV position from Orbital information



Each SV broadcast Orbital information
(Almanac data)



SV Orbital position

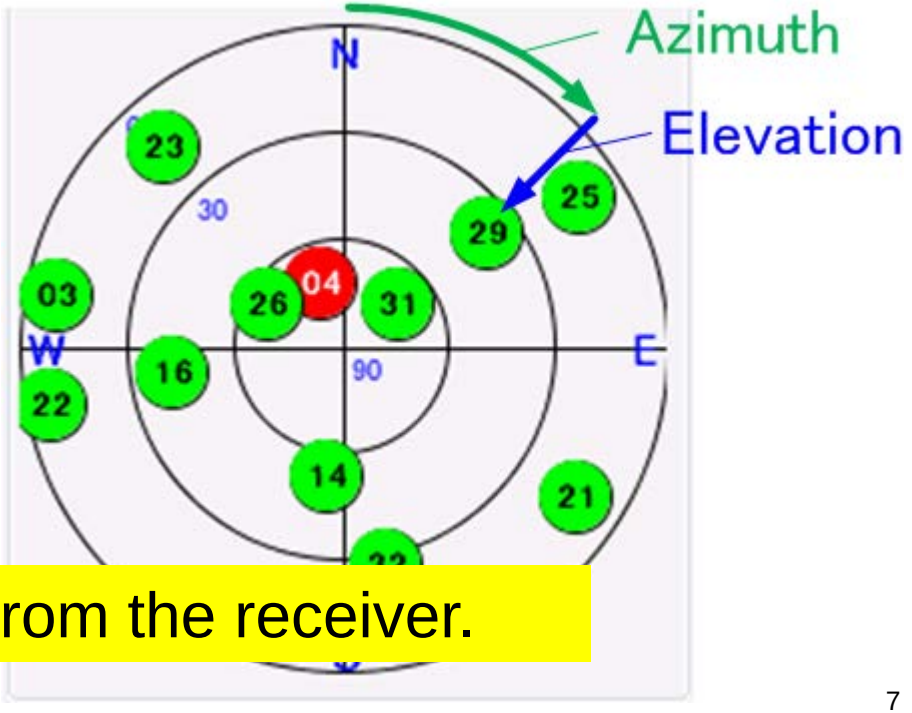
How to get SV position from receiver?

NMEA GSV sentences from GNSS receiver

```
$GPGSA,A,3,31,26,14,16,29,32,23,21,25,03,22,,1.3,0.8,0.8,1*25
$GPZDA,011238.000,18,05,2018,+00,00*73
$GPGSV,3,1,12,04,70,341,52,31,70,051,52,26,65,300,53,14,54,188,48,1*6A
$GPGSV,3,2,12,16,41,262,48,29,38,051,48,32,28,169,46,23,14,318,41,1*6A
$GPGSV,3,3,12,21,13,123,39,25,12,057,38,03,08,280,42,22,06,259,41,1*6B
```

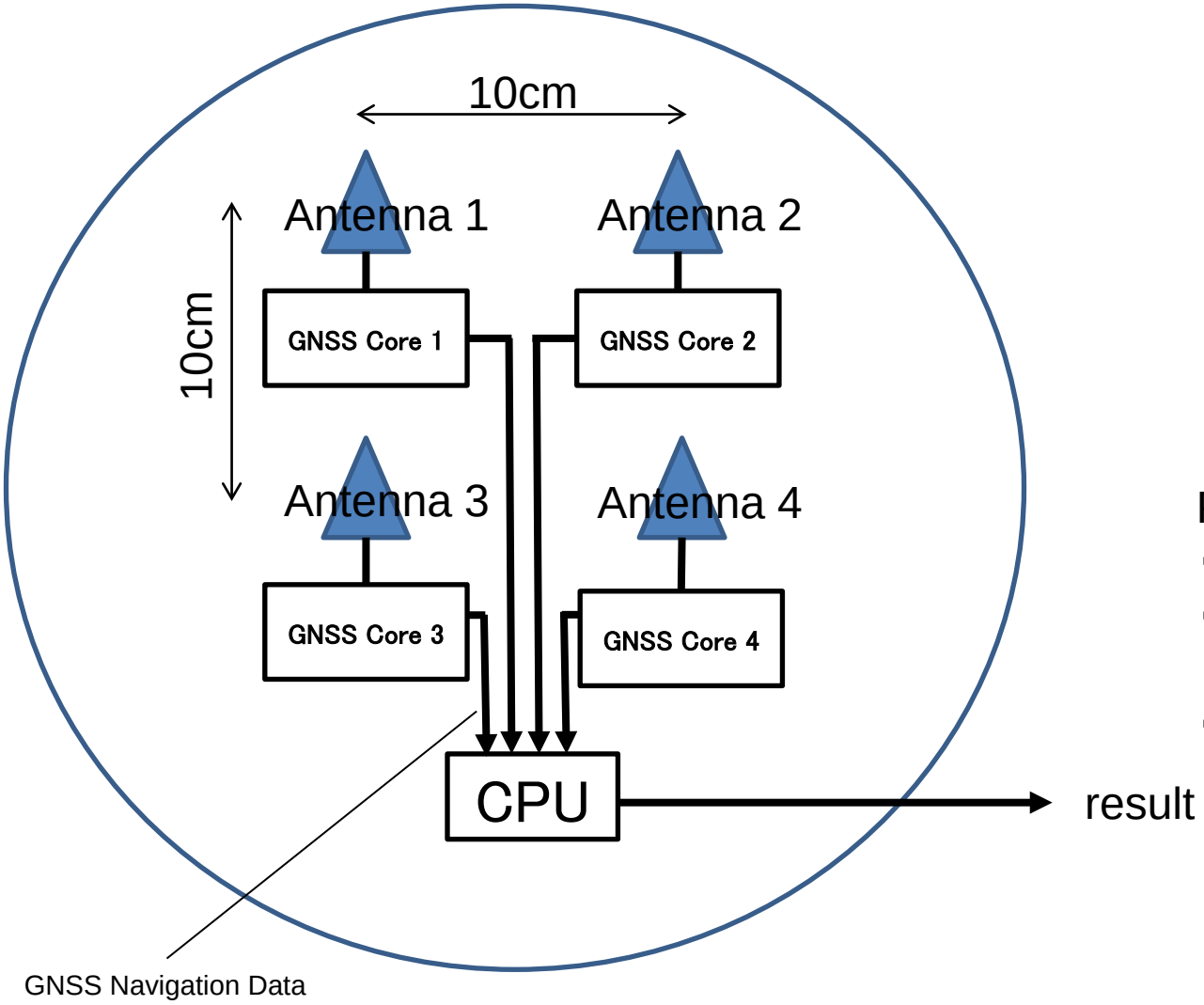
29,38,051,48

- Satellite PRN number
- Elevation[degrees]
- Azimuth[degrees]
- SNR[dB/Hz]



it indicates a position of each satellite from the receiver.

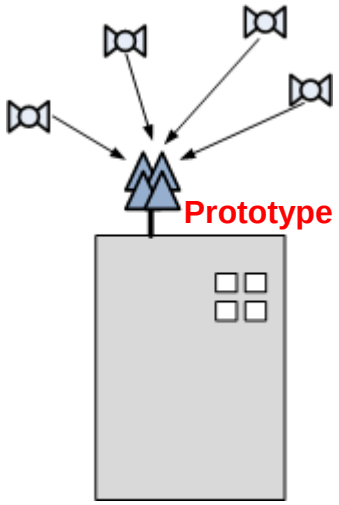
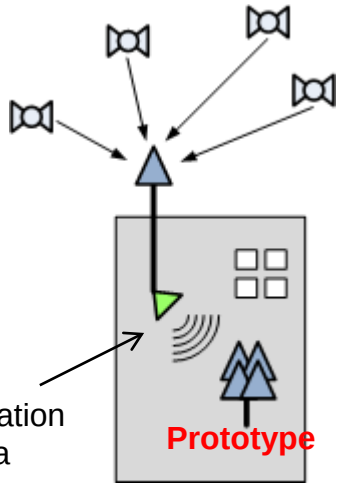
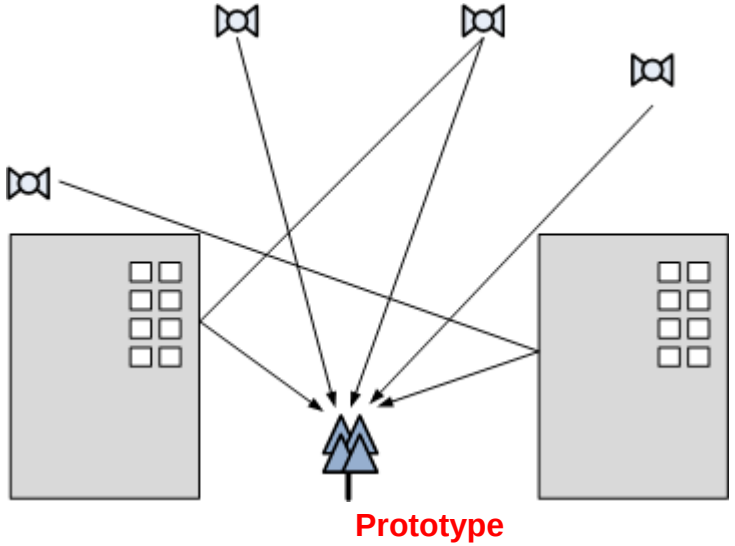
Prototype of DOA Array antenna



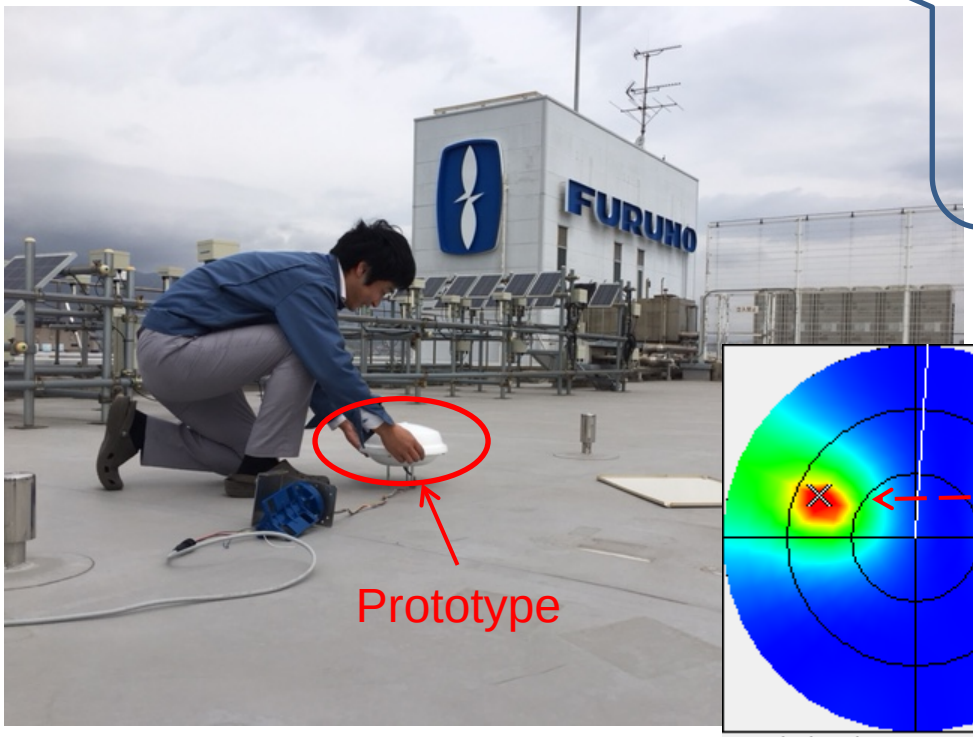
Prototype of DOA antenna is …

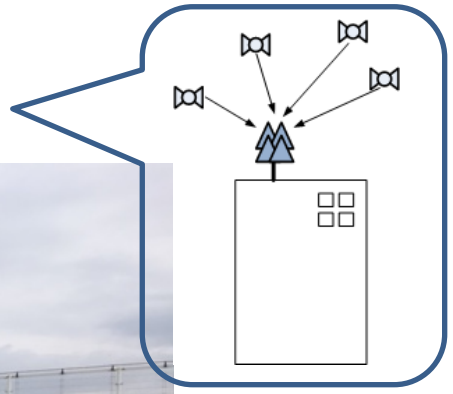
- 2x2 array antenna
- 4 antenna elements and 4 GNSS Core
- Baseline length is 10cm

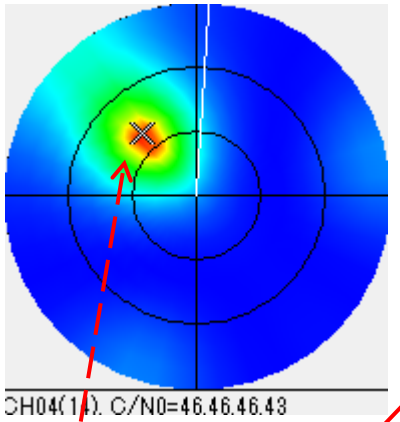
Experiment

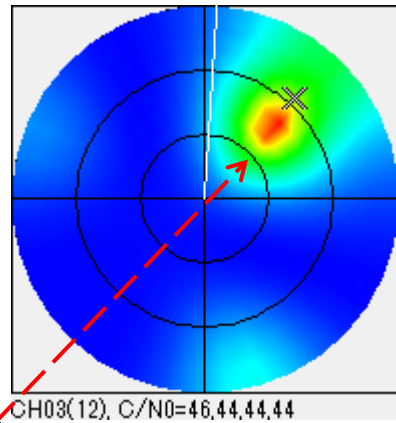
①Open sky	②Spoofing	③Multipath
	 (simulating spoofing)	

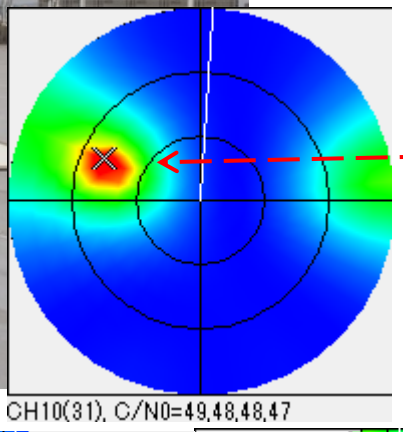
Result of Open sky

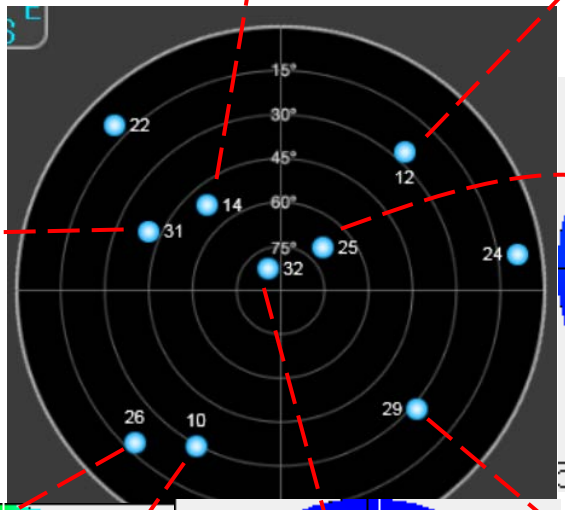


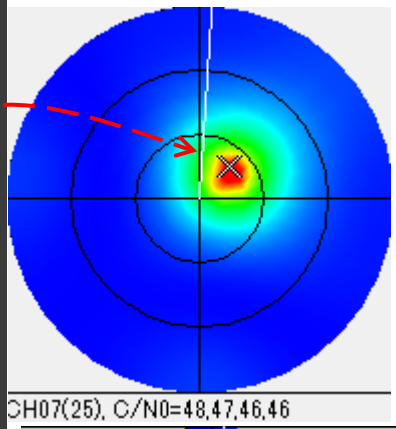




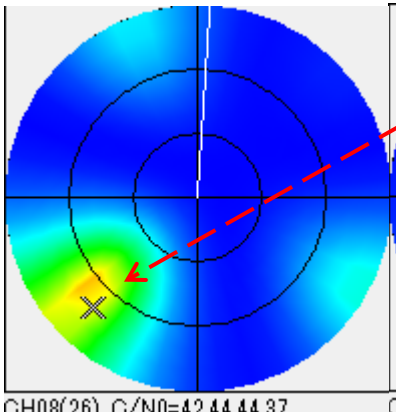


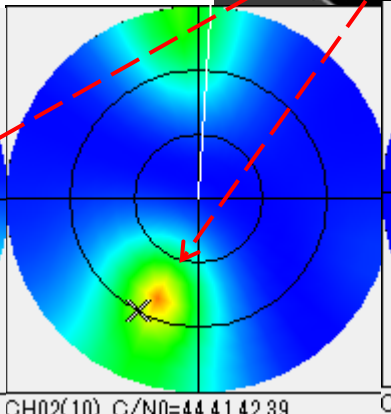


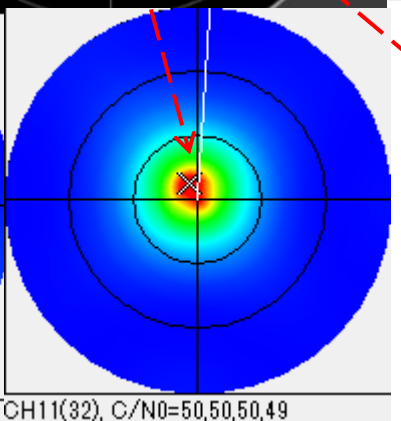


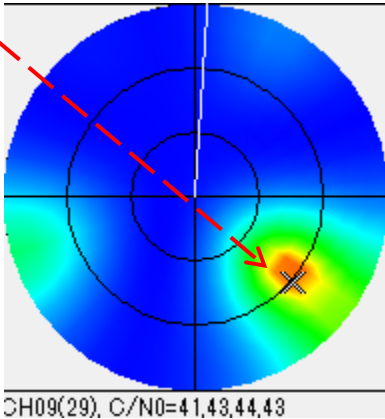


DOA spectrum and SV Orbital position are in good agreement.

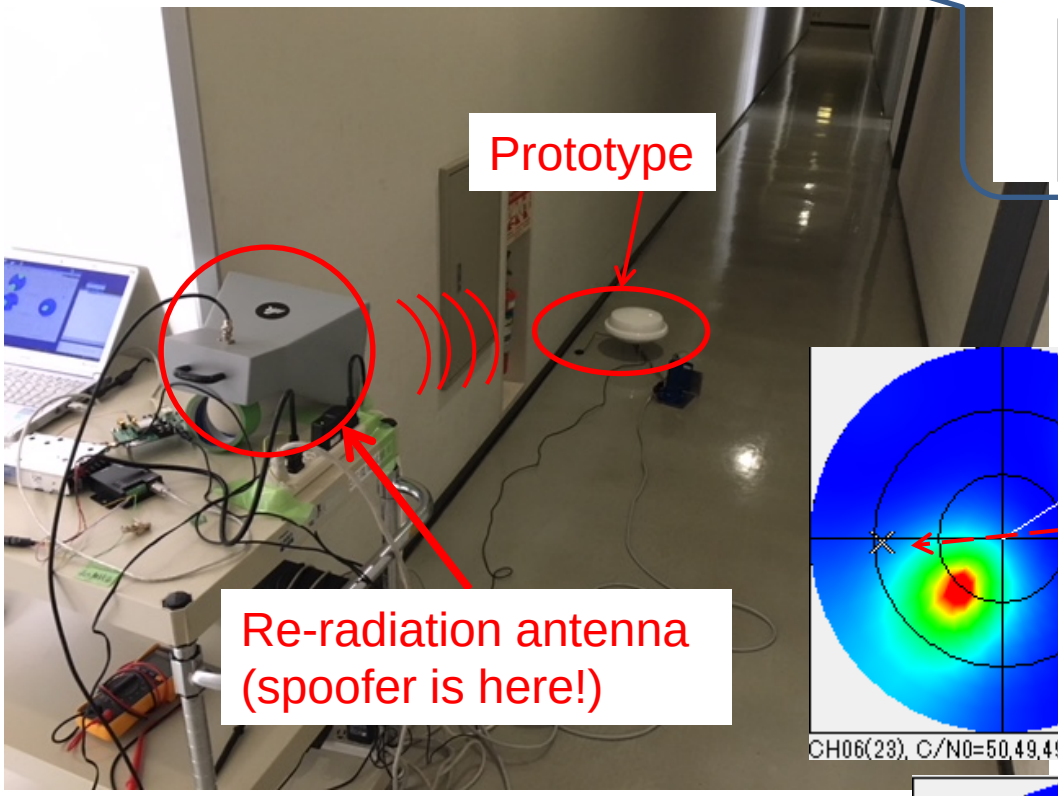


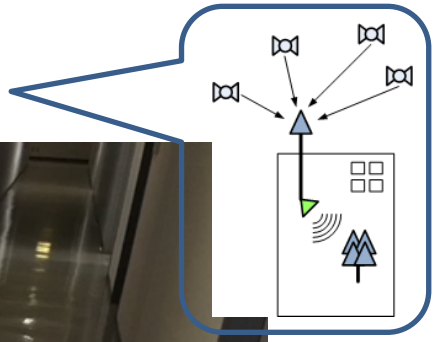


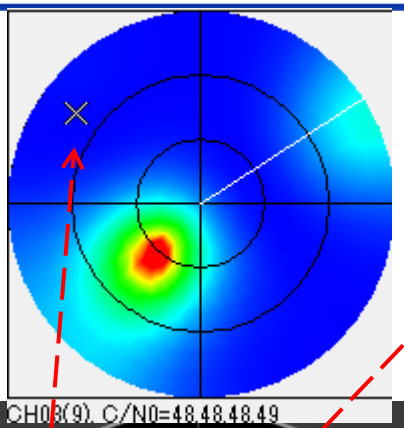


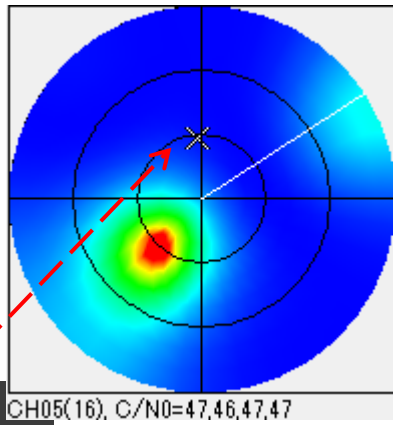


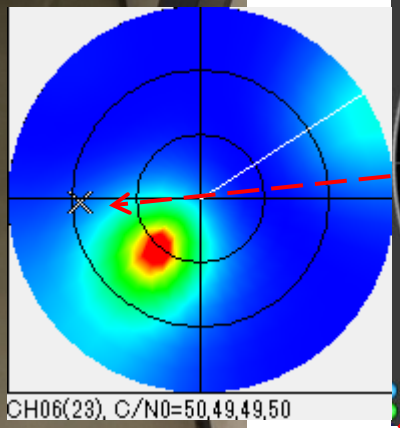
Result of spoofing

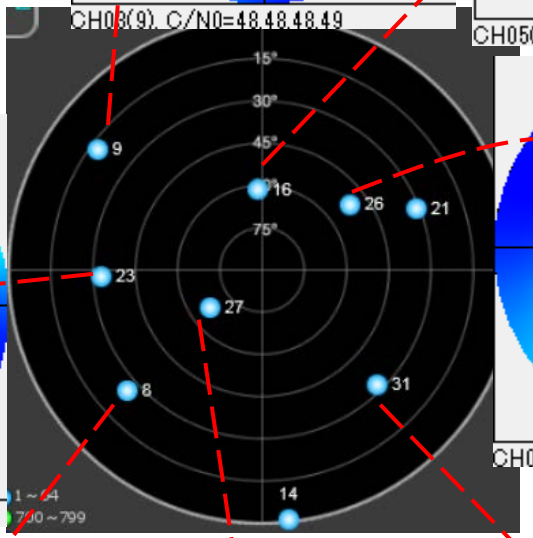


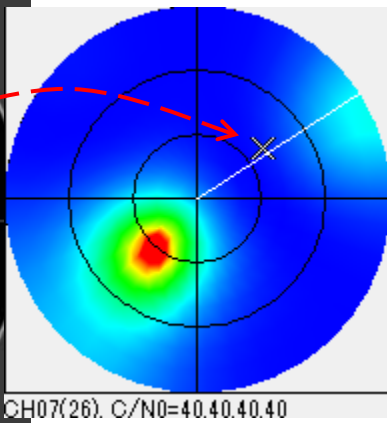


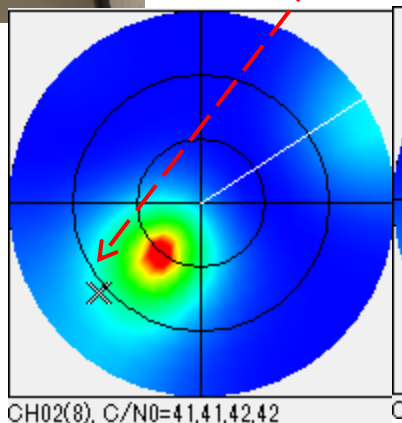


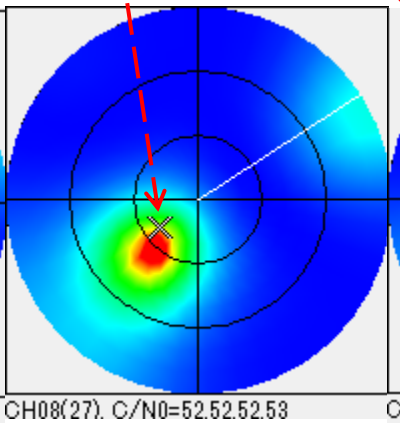


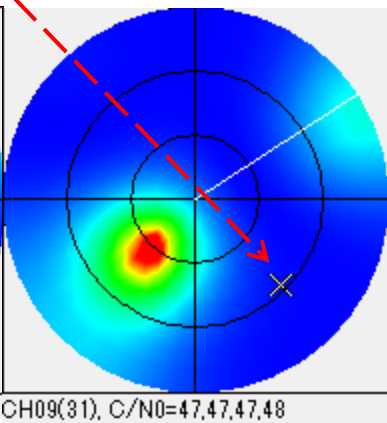








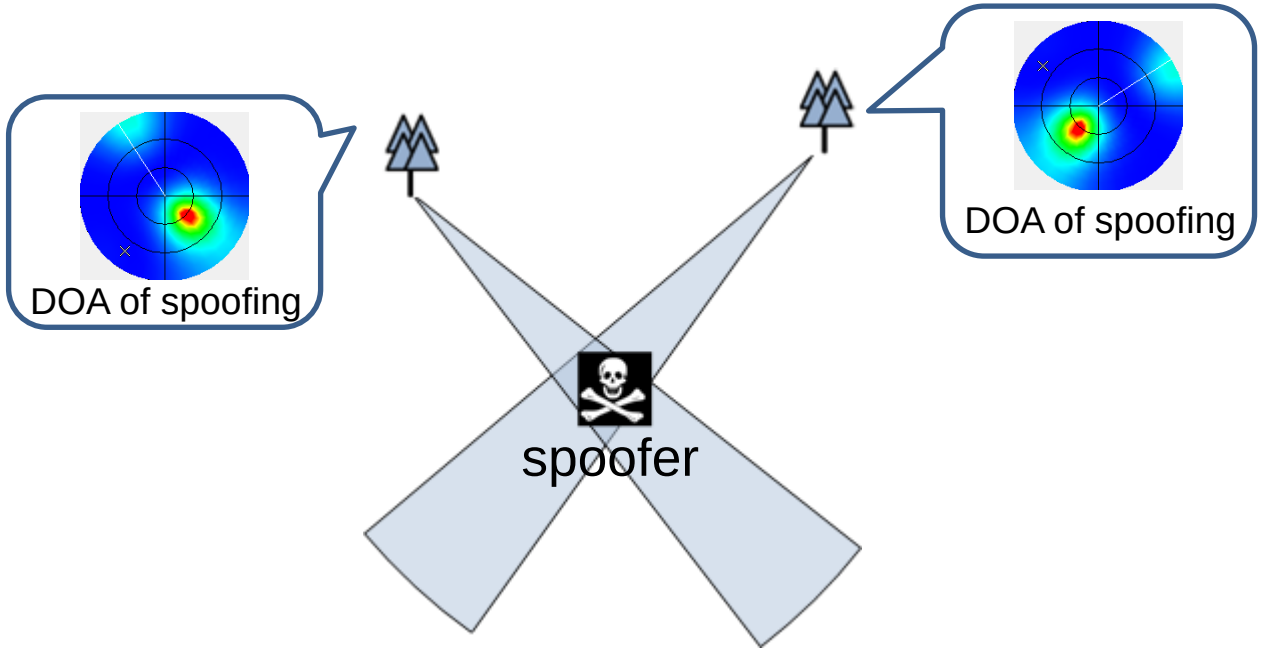




DOA spectrum of each satellite shows the same direction.
(not SV Orbital position)

It indicates the location of the spoofer.

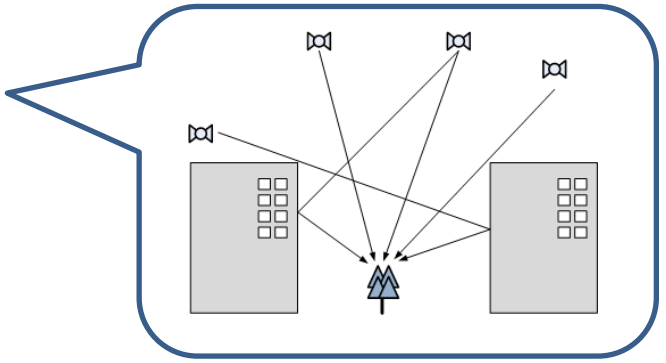
How to detect position of the spoofer?

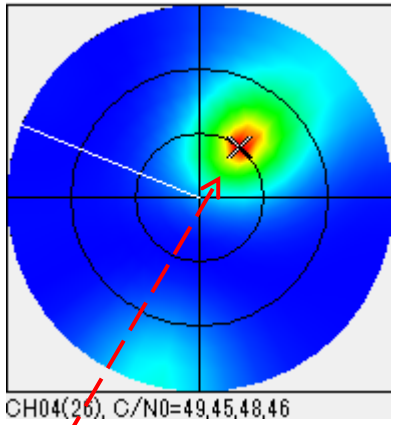


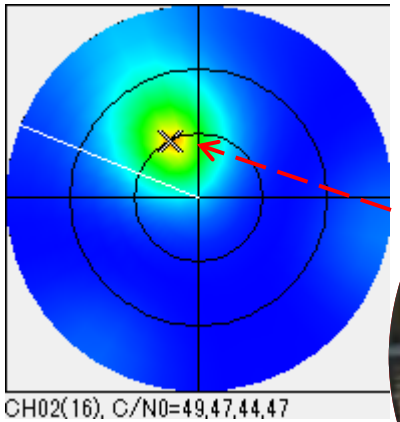
The position of the spoofer can be detected
by using two or more DOA array antennas.

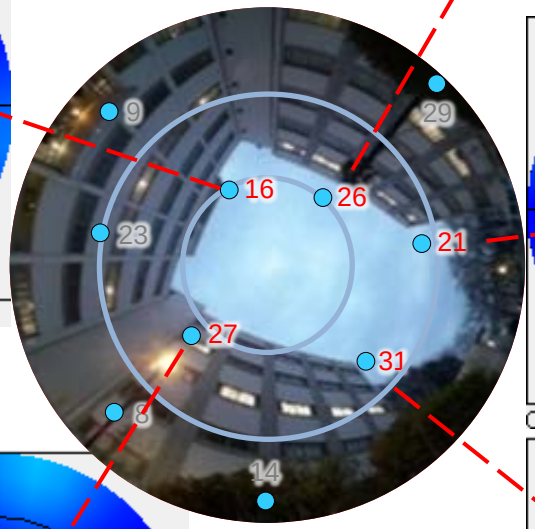
Result of multipath

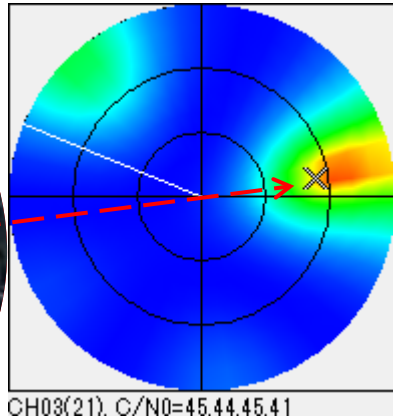
Test location : NTT R&D Center
(Musashino, Tokyo, Japan)

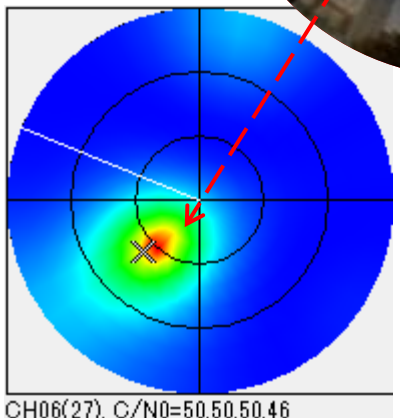


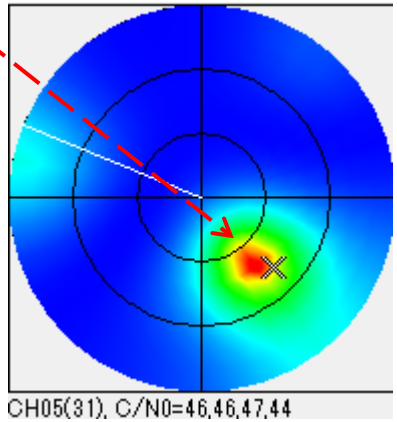












LOS satellite

PRN 16, 21, 26, 31

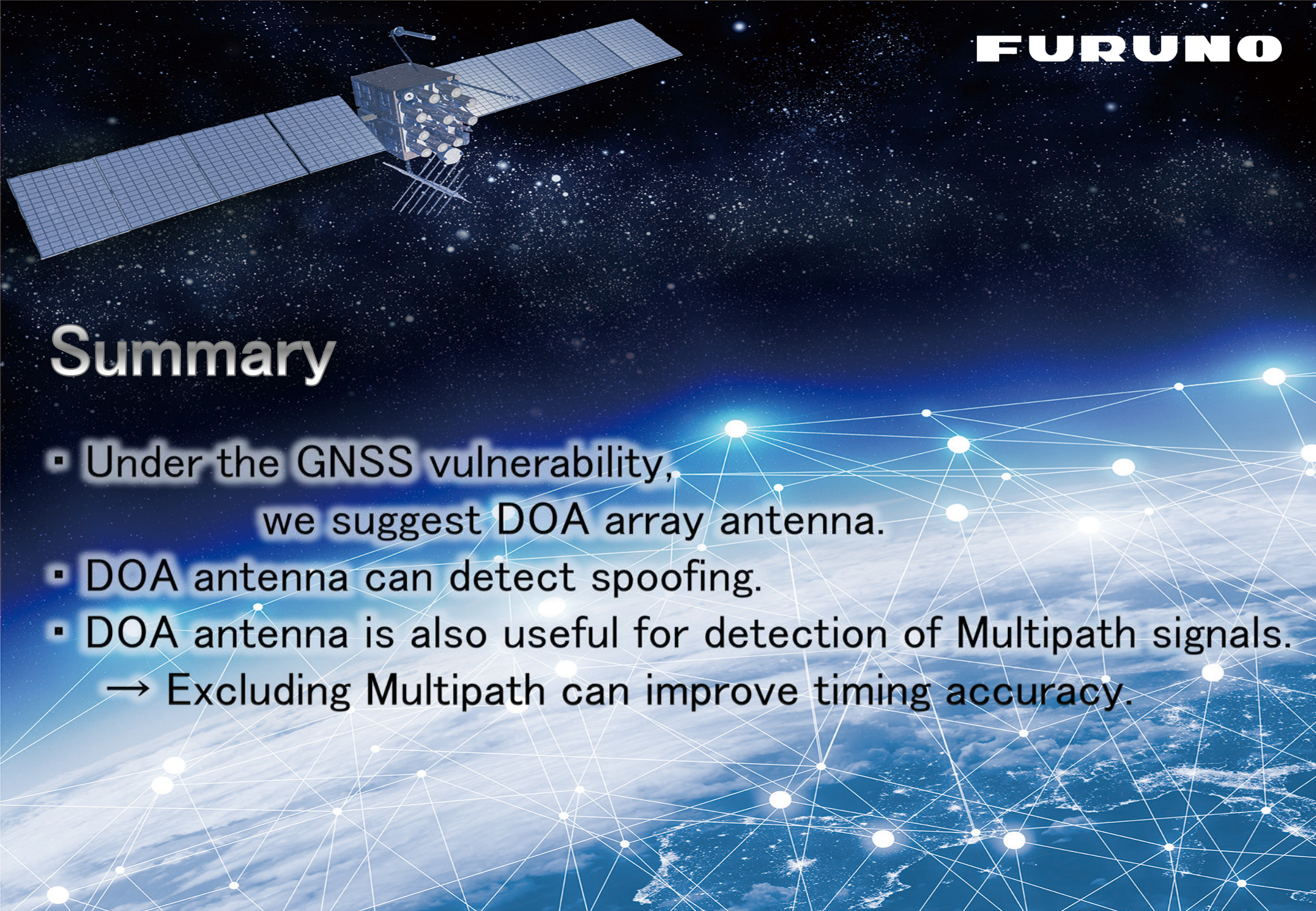
DOA spectrum and
SV Orbital position are in good agreement.

NLOS satellite

PRN 8, 9, 14, 23, 27, 29

We couldn't calculate DOA spectrum

Except PRN 27. It seems to be diffracted.


FURUNO
Summary
▪ Under the GNSS vulnerability,
we suggest DOA array antenna.
▪ DOA antenna can detect spoofing.
▪ DOA antenna is also useful for detection of Multipath signals.
→ Excluding Multipath can improve timing accuracy.