Innovative GNSS Interference Mitigation Technique

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United Nations/Croatia Workshop on the
Applications of Global Navigation Satellite Systems
21 – 25 April 2013
Baška, Krk Island, Croatia

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GNSS Systems: State-of-the-art (1)

- **GPS (USA)**
  - **31** operational GPS satellites + **3 – 4** decommissioned satellites ("residuals") that can be reactivated if needed [http://www.gps.gov/systems/gps/space/]

- **GLONASS (RUSSIA)**
  - **24** operational GPS satellites + **3** spare satellites **+ 1** on flight tests phase.[http://glonass-iac.ru/en/GLONASS/]

- **Galilleo (EUROPE)**
  - **4** Galileo In-Orbit Validation (IOV) satellites { October 2012} currently in orbit represent the operational nucleus of the full **30-satellite** constellation.[http://www.esa.int/Our_Activities/Navigation/The_future_-_Galileo/Galileo_IOV_Launch/Overview]

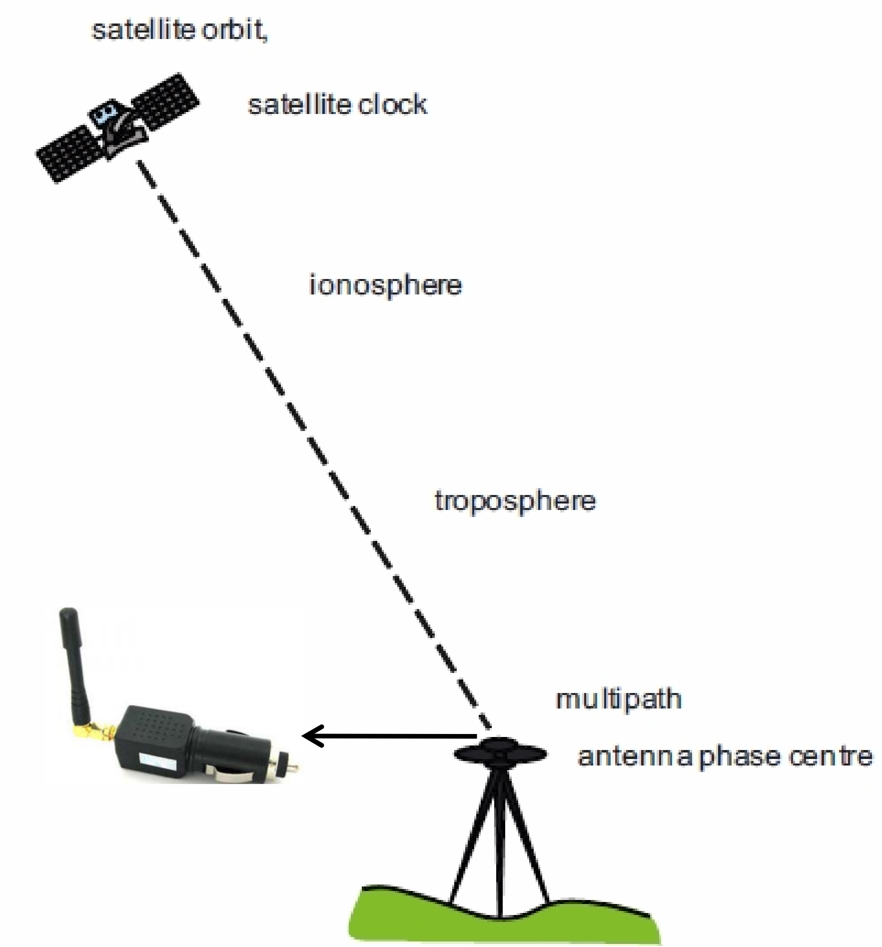
GNSS Systems: State-of-the-art (2)

- **BeiDou COMPASS (CHINA)**
  - As of December 2012,**16** satellites for BeiDou-2 have been launched, 14 of them are in service.[http://www.beidou.gov.cn/2013]

- **IRNSS (INDIA)**
  - An independent regional navigation satellite system [http://www.isro.gov.in/newsletters/contents/spaceindia/]
  - IRNSS constellation consists of **7** satellites:
    - 3 satellites will be placed in the Geostationary Equatorial orbit
    - 2 satellites will be placed in the Geosynchronous orbit (GSO)
    - 2 spare satellites are also planned to be realized.

- **QZSS (JAPAN)**
  - **3** satellites in Highly-inclined Elliptical Orbits [HEO].[http://qz-vision.jaxa.jp/USE/is-qzss/]

GNSS Biases Sources



Error Sources
Satellite Errors: • Satellite Orbit • Satellite Clock (~ 2 m) • Satellite Ephemerides (< 2 m)
Atmospheric Errors: • Inospheric refraction (~ 4 – 6 m) • Troposphere refraction (~ 0.7 m)
Receiver's Errors: • Multipath (~ 1.5 m) • Receiver's noise (~ 0.5 m)
Interference = variable and unknown

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Motivation

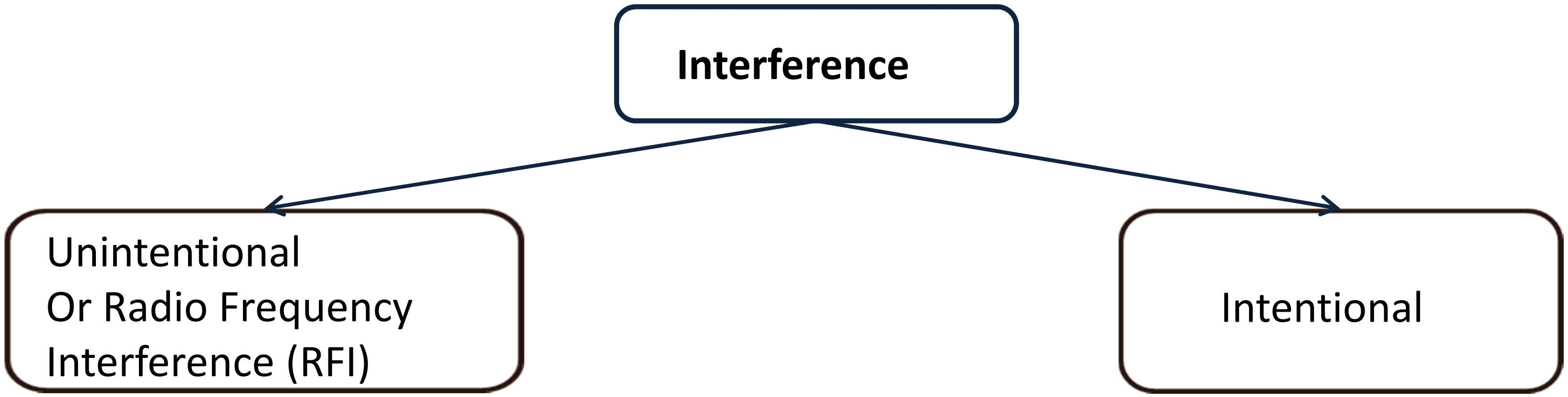
- The received GNSS signal power at ground level is approximately −130 dBm.

- This fundamental weakness makes the signals vulnerable to both accidental and deliberate interference.

- Legal Situation on Jammers is still not properly defined.

- Simple models that plug into 12-volt car receptacle connectors can be purchased for as little as $30 online and can render GPS systems inoperable for miles around.

A brief introduction to Interference



Wideband phase/frequency modulation	**Television transmitter's harmonic or nearband microwave link transmitters**
Wideband pulse	**Burst transmitters such as radar or ultra wideband (UWB)**

Wideband Gaussian	**Intentional noise jammers**
Wideband spread spectrum	**Intentional spectrum jammers or nearfield of pseudolites**
Narrowband continuous wave	**Intentional CW jammers**

Jammer Mitigation Techniques

- Which are the possible solutions to mitigate the jammer?

Pre – Correlation Techniques	Post-Correlation Techniques
1. Amplitude Domain Processing	1. Adaptive Loop Bandwidth
2. Temporal/FFT domain Filters	2. Data Wiping
3. Dual Polarisation Antenna	3. Open Loop Carrier Tracking
4. Spatial Filters	4. Vector loops
5. SpaceTime Filters	5. Integration with INS

Digital Polarization Null- Steering technique

- **Key Idea** :

Reject the Interference by adaptively matching the polarization response of the antenna to the polarization of the interference signal.

- **Steps** :

1. A dual polarized patch antenna, whose input signal (RHCP) is splitted in Horizontal and Vertical Components.
2. Orthogonal Projection.
3. Adaptive Algorithm.

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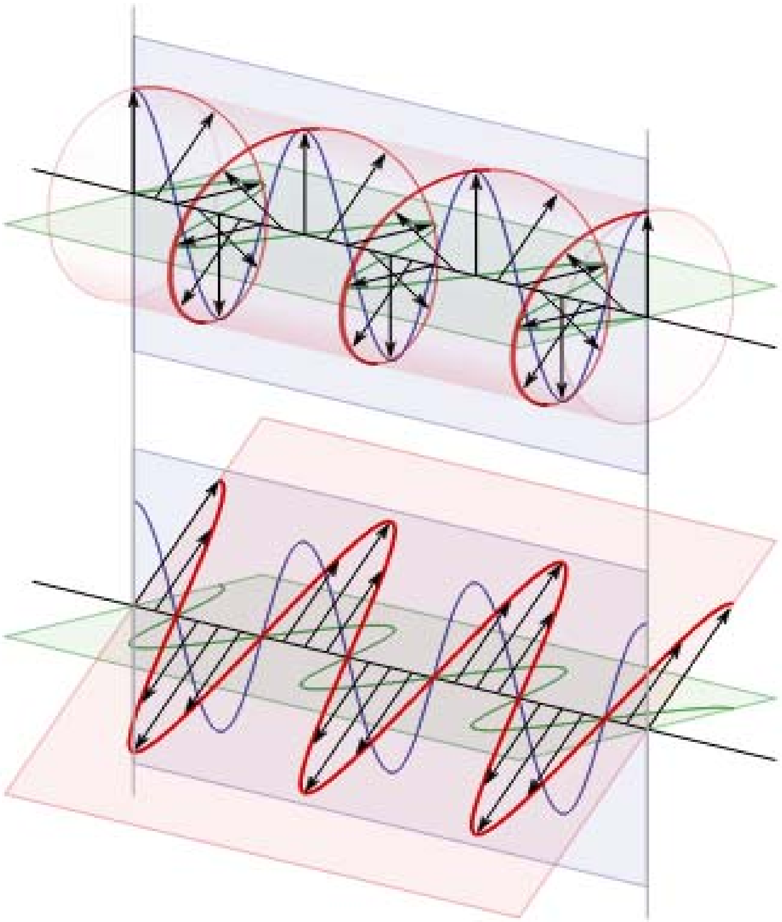
RHCP and LHCP

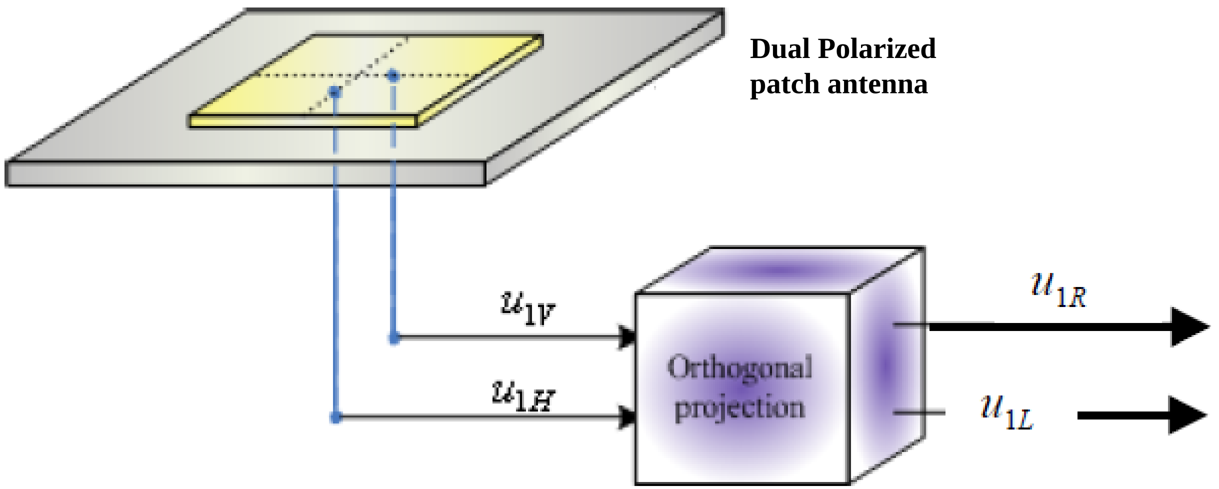


To obtain circular polarization:

- Split the signal in two equal parts.
- Feed one signal to a horizontal radiator and the other to a vertical radiator.
- Change the phase of one of the signals by 90°.

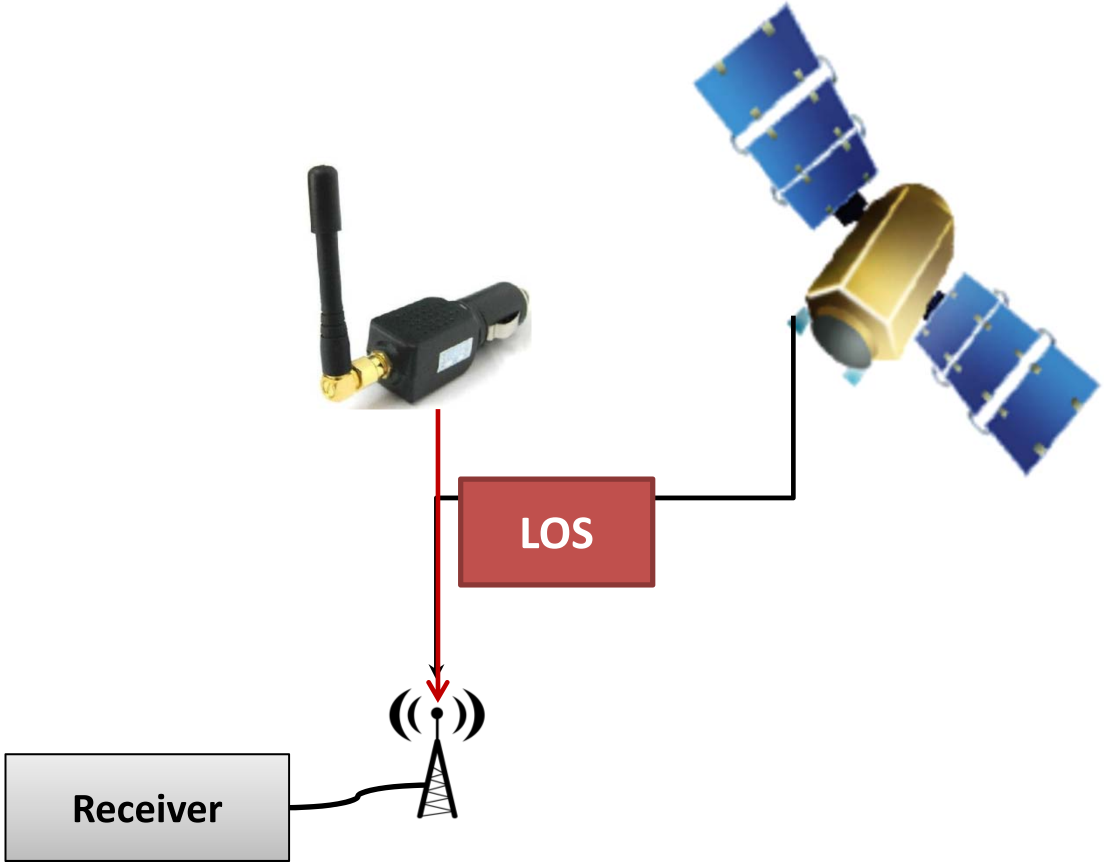
Null Polarizing scheme

- This transformation occurs in two steps:
  1. The horizontally and the vertically polarized complex signals are taken from the dual polarized antenna;
  2. Conversion to RHCP and LHCP (orthogonal to RHCP).



“Research activity in the Institute of Space Technologies & Space Applications (ISTA) of Universität der Bundeswehr München, 2012”

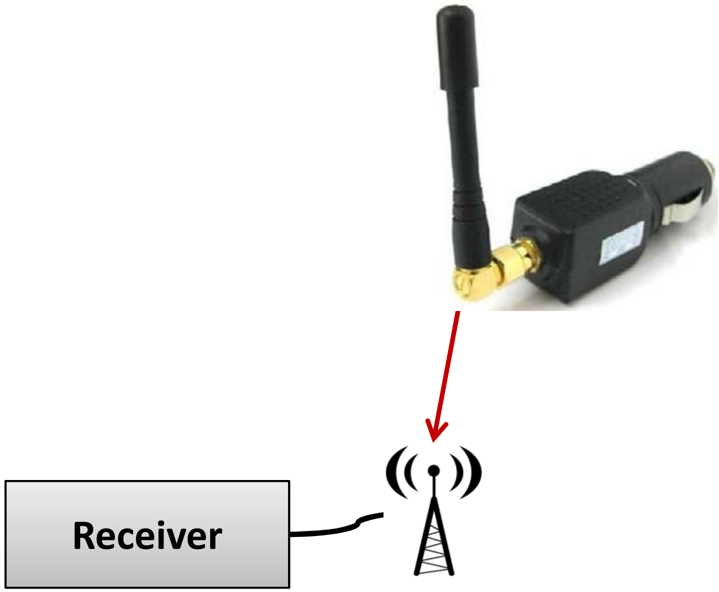
From Space to Ground



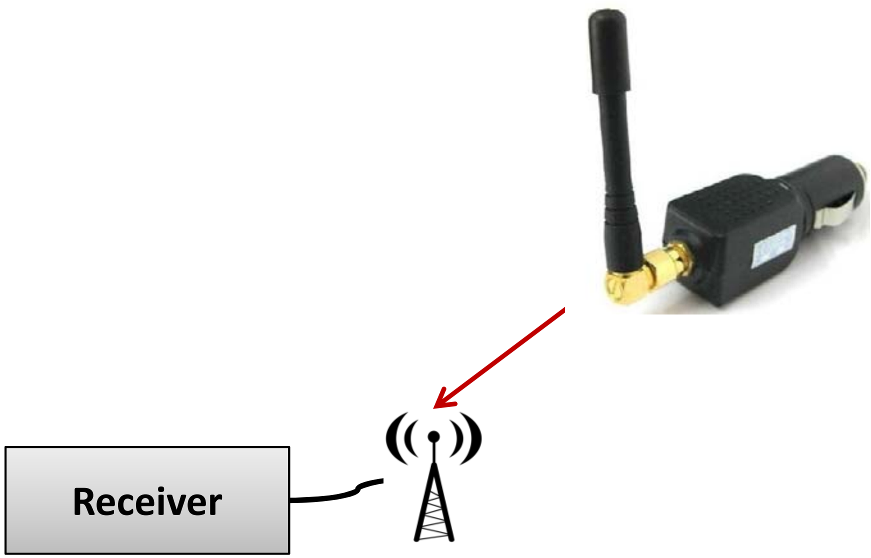
Ideal Scenario

In Real Scenarios is the Jammer in LOS with the Reciever‘s Antenna ?

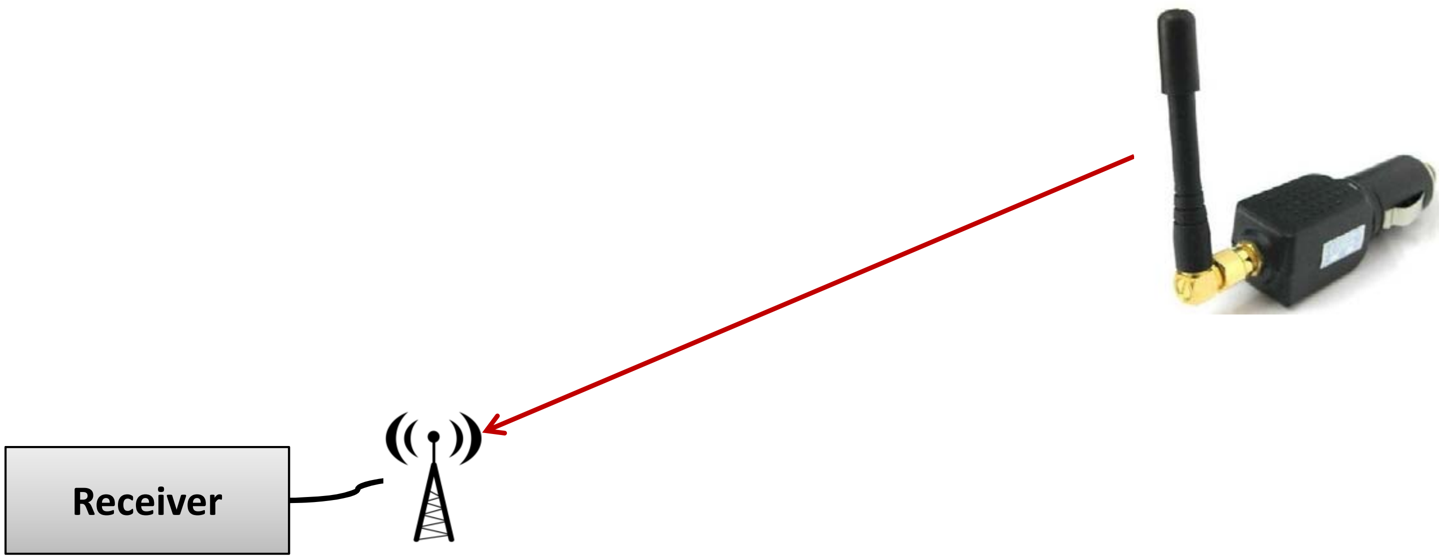
Jammer´s Mitigation Solutions



Jammer´s Mitigation Solutions



Jammer´s Mitigation Solutions



Jammer´s Mitigation Solutions

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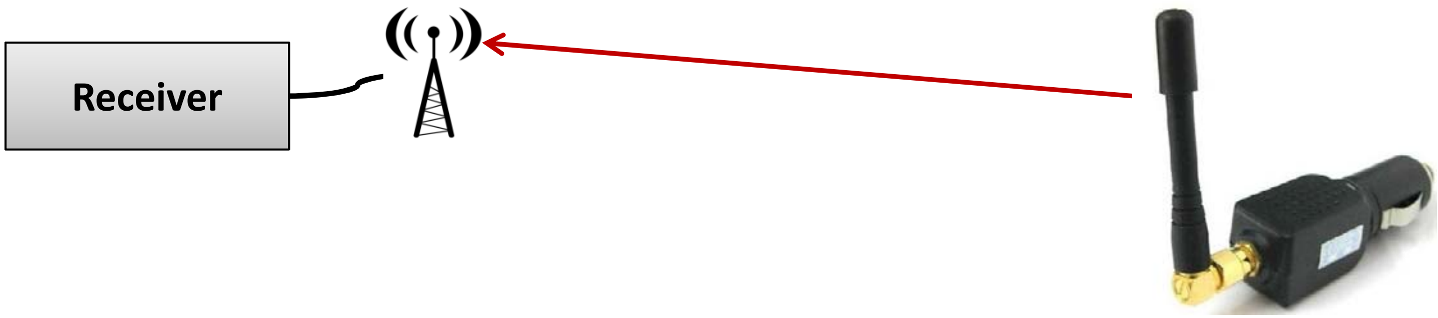
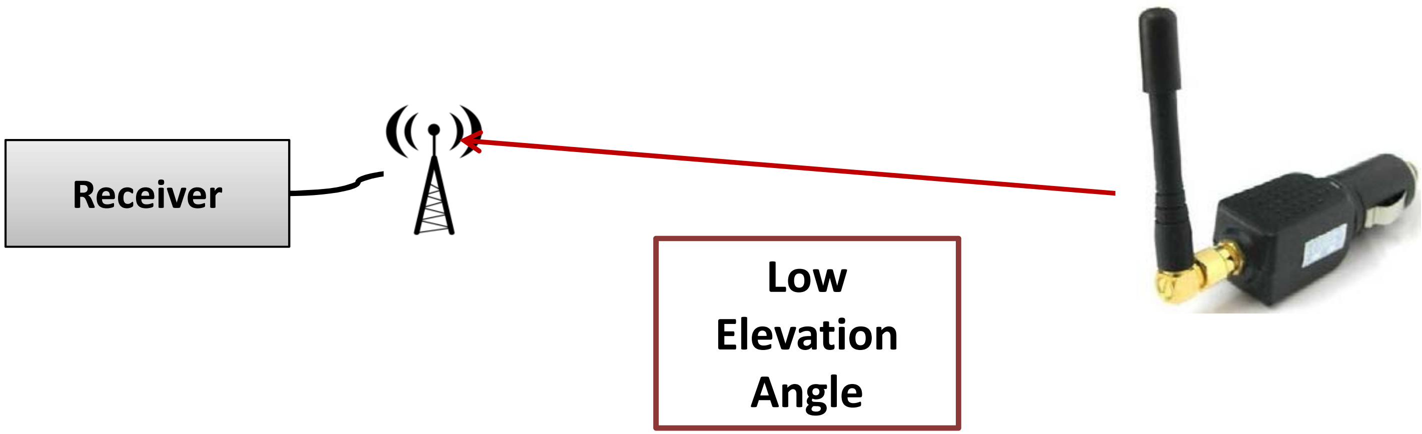


Jammer´s Mitigation Solutions



Jammer`s Mitigation solutions

1. Physical Rotation of the antenna in synchronised way to the jammer´s location.

Cons :

1. Not a practical solution.
2. Analog solution and not a digital one

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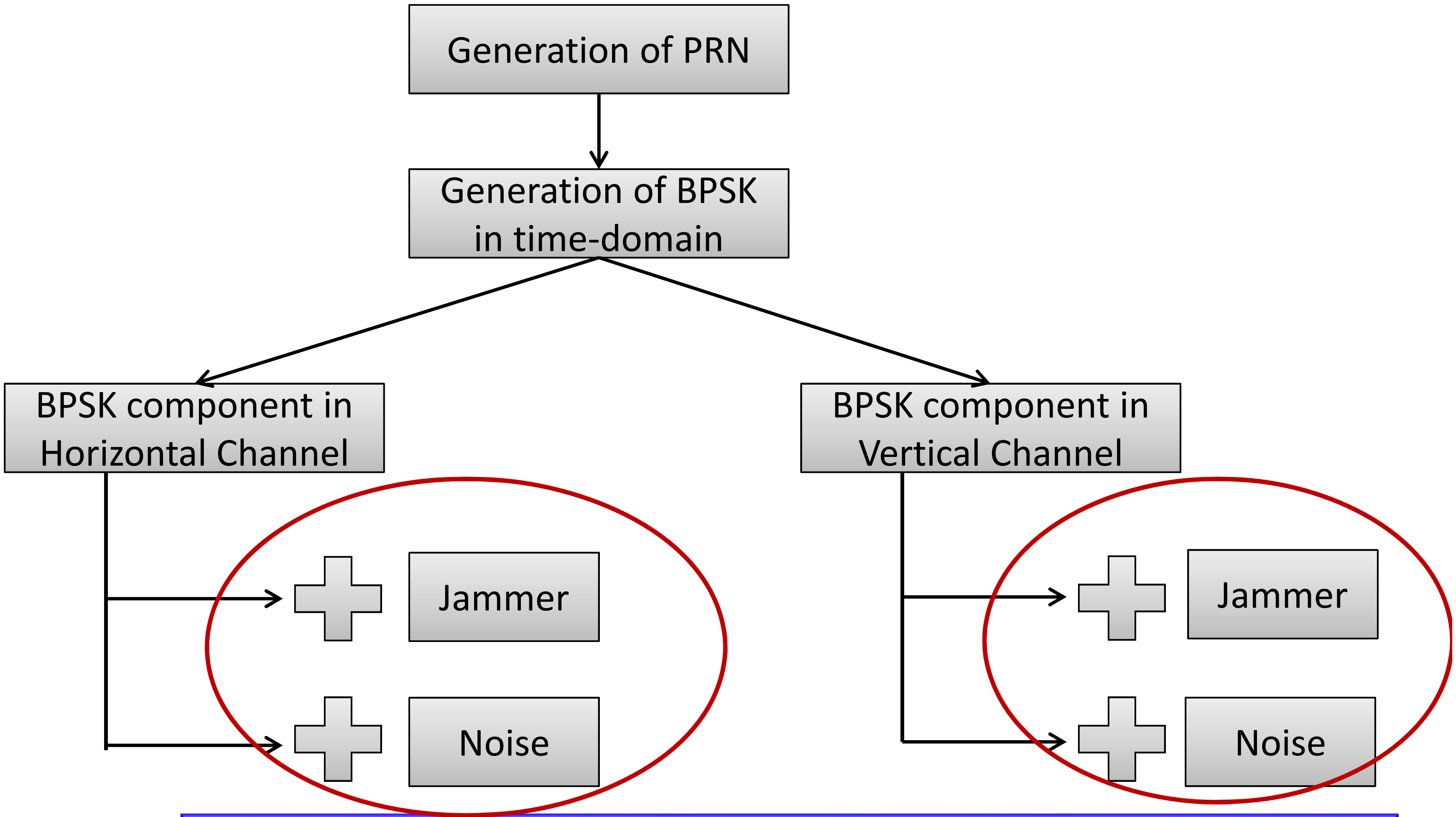
2. Digital Rotation of the antenna in time- domain

How is this possible ?

- Through a phase shift of the antenna‘s Horizontal or Vertical channel, implemented as an index shift in the centre frequency of the GNSS signal´s main lobe.

Simulation of Electric Field Vector Cancellation technique in Matlab

Flowchart of the Transmitter´s Side



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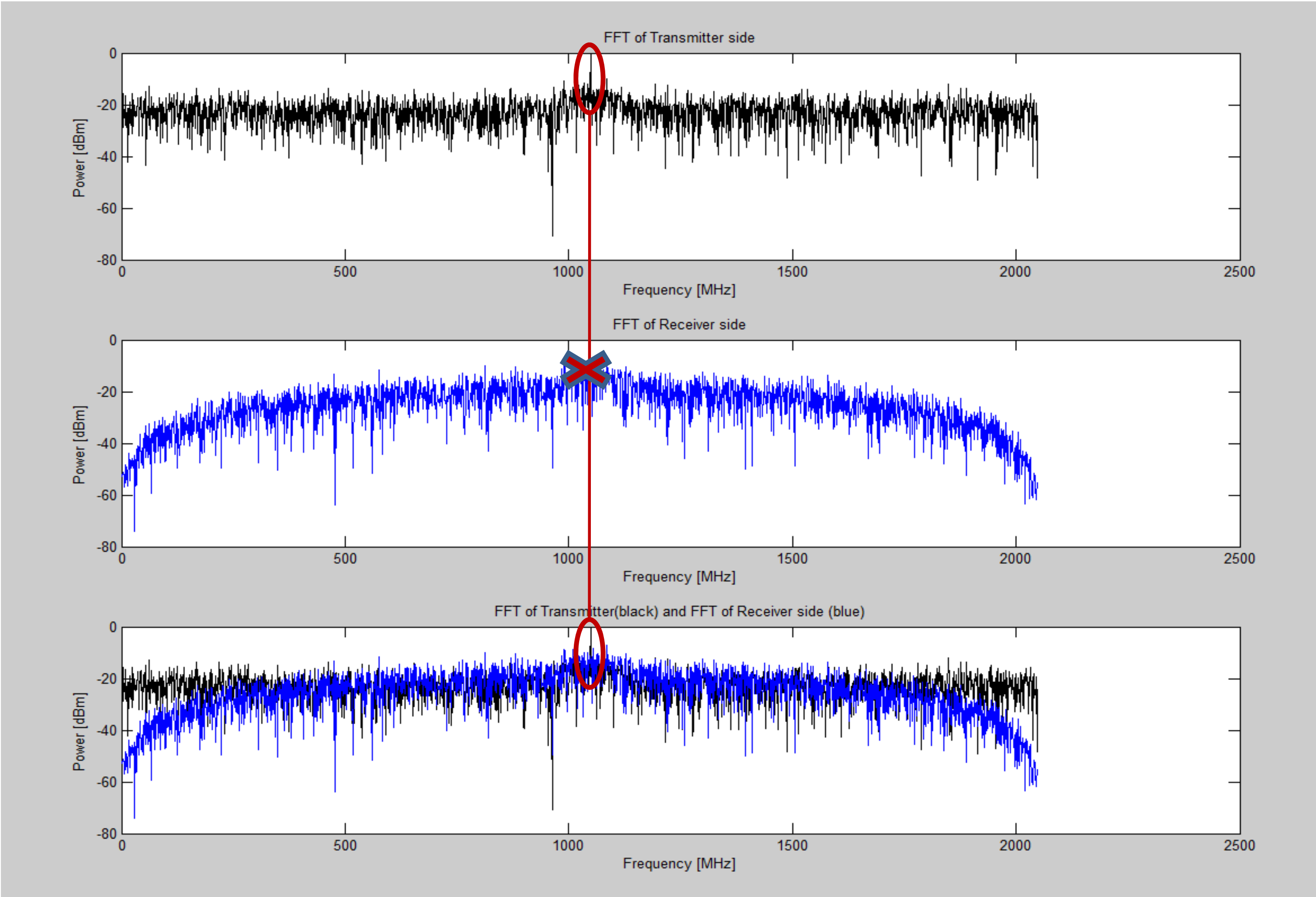
TX / RX Scenarios

TRANSMITTER SCENARIO	TRANSMITTER SIDE	RECEIVER SCENARIO	RECEIVER SIDE
1	Hchannel = BPSK Horizontal + Noise Vchannel = BPSK Vertical + Noise	1	RHCP
		2	LHCP
		3	RHCP (90 º) - LHCP
		4	RHCP – LHCP (90 º)
2	Hchannel = BPSK Horizontal + Jammer + Noise Vchannel = BPSK Vertical + Noise	1	RHCP
		2	LHCP
		3	RHCP (90 º) - LHCP
		4	RHCP – LHCP (90 º)
3	Hchannel = BPSK Horizontal + Jammer + Noise Vchannel = BPSK Vertical + Noise	1	RHCP
		2	LHCP
		3	RHCP (90 º) - LHCP
		4	RHCP – LHCP (90 º)
4	Hchannel = BPSK Horizontal + Jammer (45 º) + Noise Vchannel = BPSK Vertical + Jammer (45º) + Noise	1	RHCP
		2	LHCP
		3	RHCP (90 º) - LHCP
		4	RHCP – LHCP (90 º)

Scenario 1

- **Jammer in the Horizontal Channel of the Transmitter**

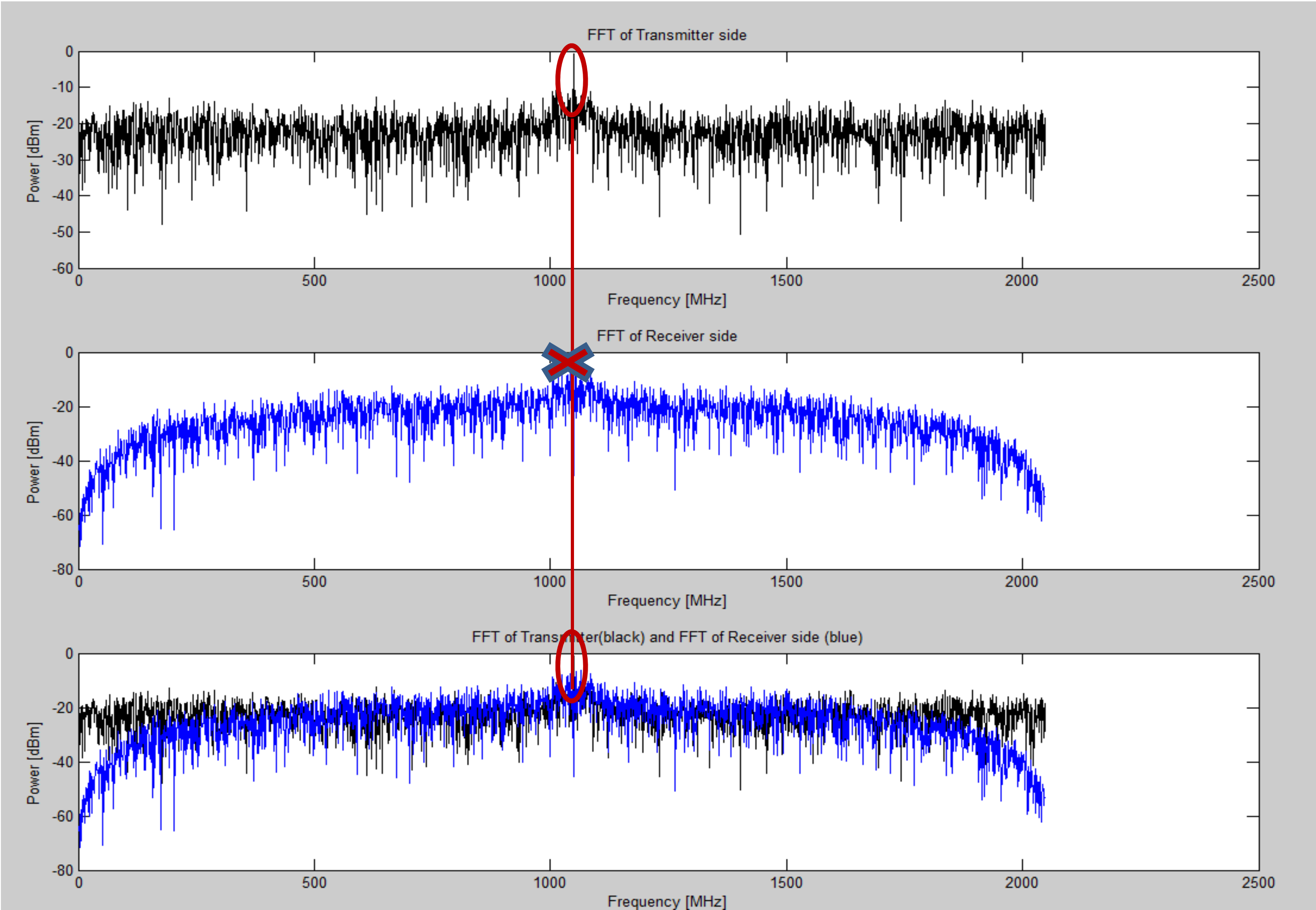
Jammer in the Horizontal Channel



Scenario 2

- **Jammer in the Vertical Channel of the Transmitter**

Jammer in the Vertical Channel



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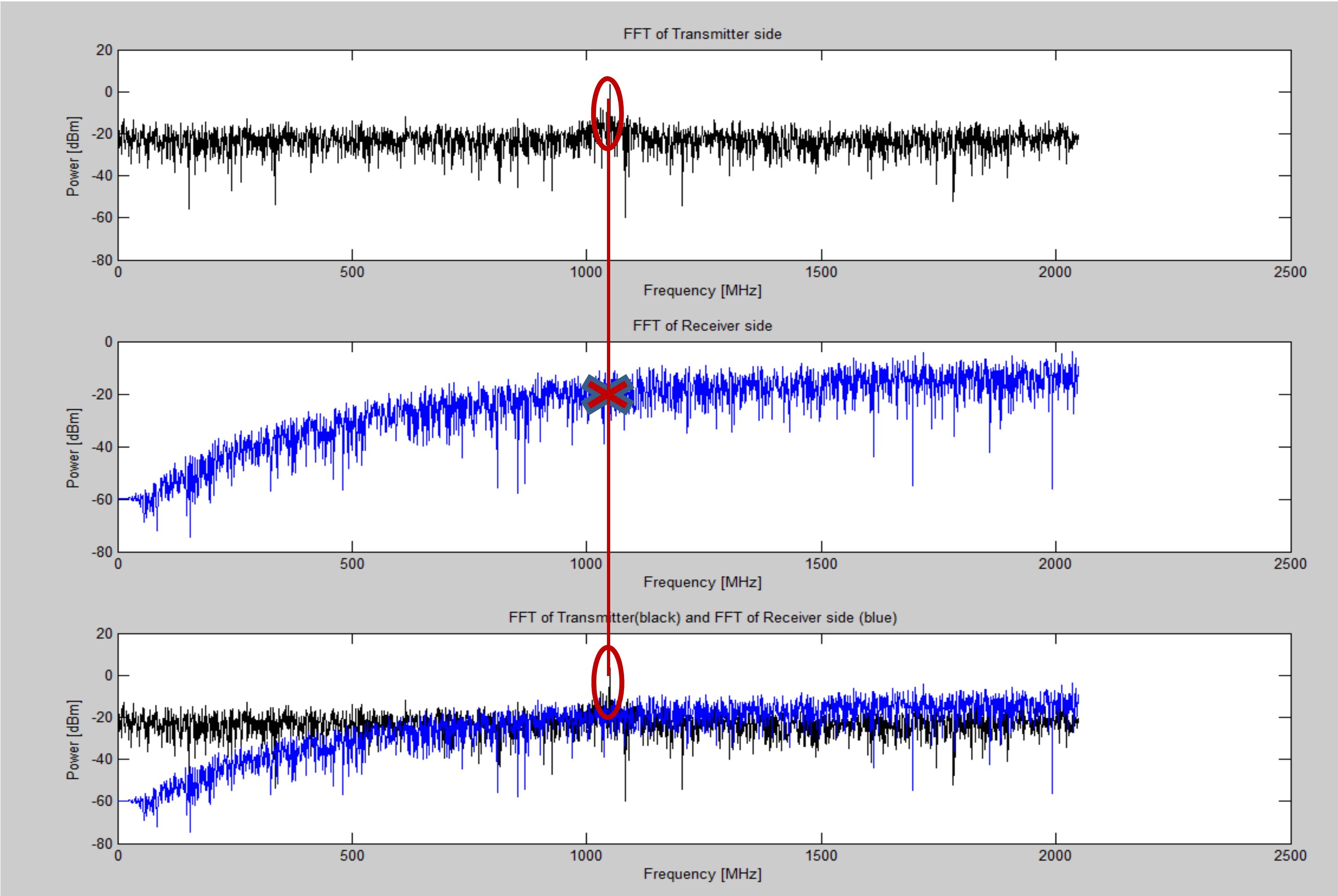
Scenario 3

- **Jammer in both the Horizontal and Vertical Channel of the Transmitter in 45^0**

Jammer in both channels in 45 º



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Closing Remarks

- Jammer‘s presence significantly deteriorates GNSS signal performance in terms of accuracy, integrity and availability.
- A stringent and better defined legal framework is needed regarding jammer‘s use.
- An innovative and very efficient GNSS interference mitigation technique based on polarization only, was proposed during this presentation.

Future Work

- Investigation of the Jammer effects on GNSS signal in low elevation angles.
- We will also test in the future this interference mitigation technique on Gallileo received signal.

Questions ?

Thank you for your attention!

Hvala na pažnji!