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GAJET, a DRDC Evaluation Testbed for Navigation Electronic Warfare

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DRDC | RDDC

Canada

Outline

- Introduction
- CRPA project at DRDC Ottawa
- GAJET: An Evaluation Test bed for GPS Anti-Jam System
- An AJ simulation tool
- Concluding Remarks

Introduction - GPS as Military Enabler

- Military (L1 and L2, Y-code)
  - ***C4ISR critical enabler***
  - Aircraft, Ships, Tanks, Missiles, munitions
  - Precision targeting
  - Robotics
  - Surveillance, UAV's
  - ***Timing – Secure comms networks/ systems***
- Commercial (Mostly L1 C/A code)
  - Vehicle tracking, In-car, personal navigation,
  - mobile phones
  - Precision Survey (L1 & L2 codeless)
  - Farming
- Timing (L1 C/A code)
  - Communications (mobile, satellite),
  - Power Grids,
  - Financial transactions
  - ***Timing is the leading and fastest-growing use of GPS***

Introduction - GPS Vulnerability

GPS is vulnerable to:

- Non-intentional Interferences
  - Signal blockage (building, terrain)
  - Interferences due to :
    - Telecommunication equipment
    - TV broadcasting
    - Mobiles satellite services
    - UWB systems
    - Military tests
- Deliberate Jamming (state/non-state actors)

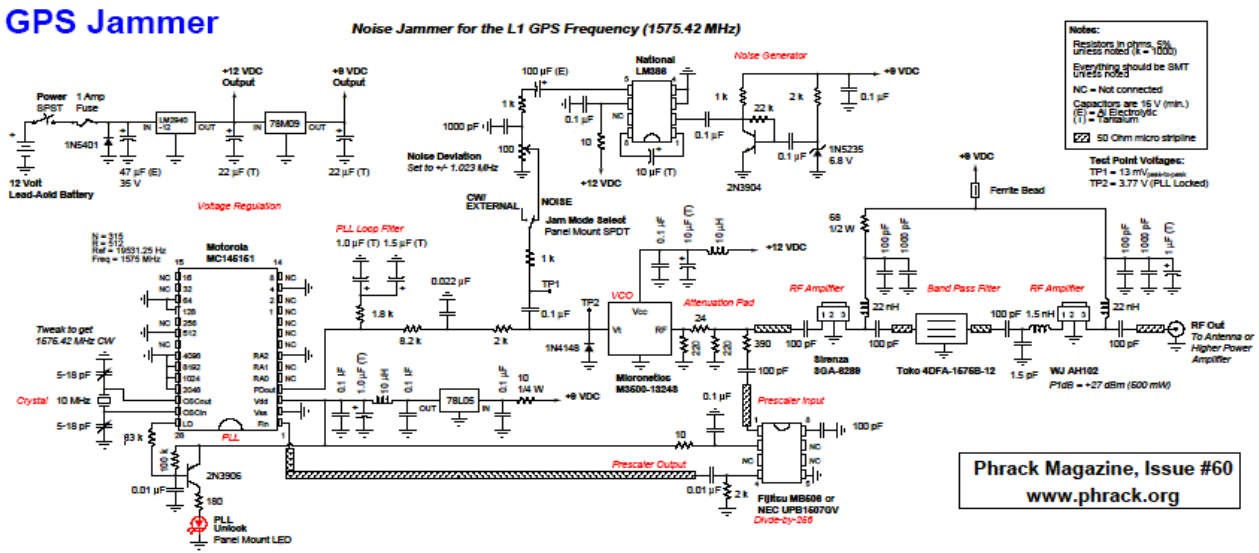
Source: National Air Intelligence Center
Figure 11: Russian handheld GPS jammers are available commercially worldwide.

GJ02
Car GPS Jammer
- Portable,small,compact & robust
- Easy to operate,no adjustment needed
- Jamming GPS signal to prevent from being tracked
- No harm to human health

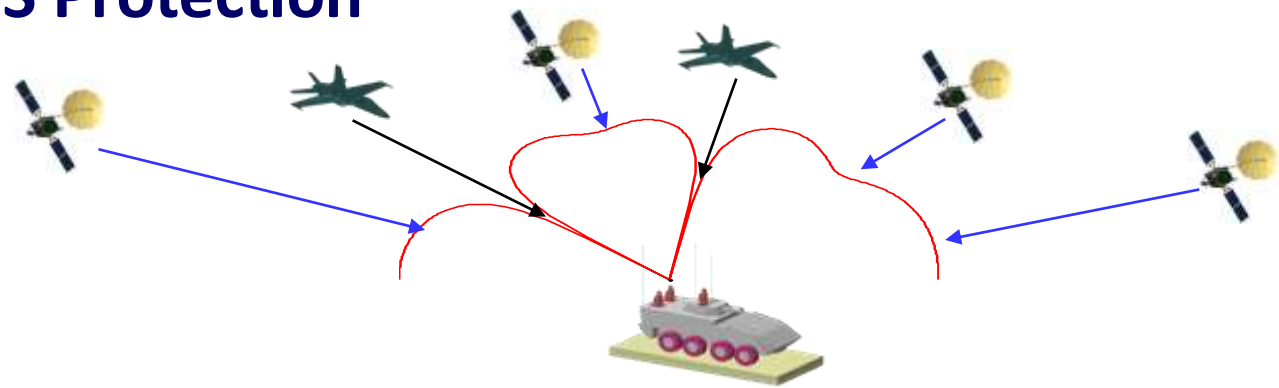
GJ01
Mini GPS Blocker
- Portable,small,compact & robust
- Easy to operate,no adjustment needed
- Jamming GPS signal to prevent from being tracked
- No harm to human health

Introduction – GPS Vulnerability

- Example plans available from internet: A 2 MHz Narrowband jammer (more effective than simple CW)
- Could be built by any competent electronics tinkerer

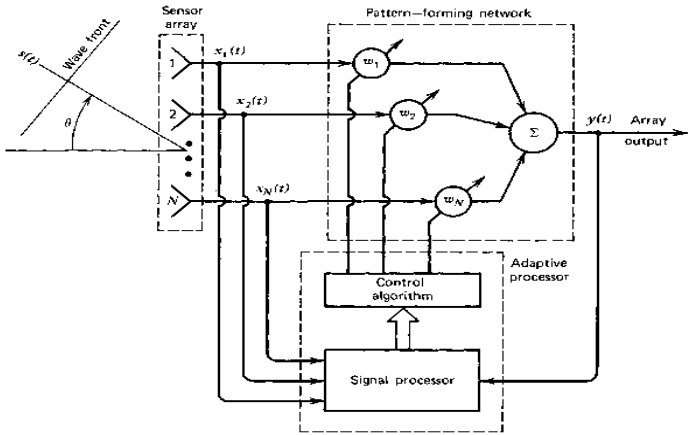


Introduction – GPS Protection



Controlled Reception Pattern Antenna (CRPA)

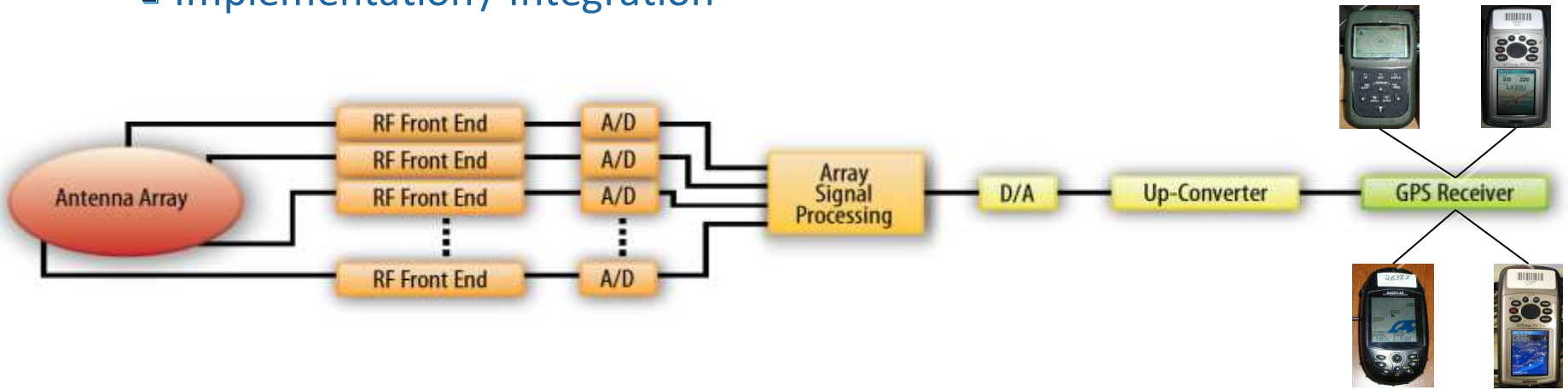
- A CRPA is a multi-antenna system with a signal processing unit having the capability to mitigate jammers



Introduction – GPS Protection: CRPA

The design of Controlled Reception Pattern Antenna requires R&D in various related technological areas :

- Elementary antenna and antenna arrays
- Antenna system architecture
- RF and digital electronic
- Signal processing
- Implementation / Integration



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  - Antenna Array
  - Signal Processing
- GAJET: An Evaluation Test bed for GPS Anti-Jam System
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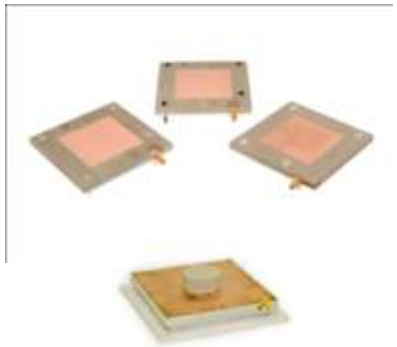
CRPA project at DRDC Ottawa

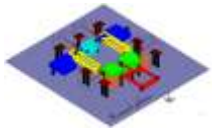
- R&D on antenna arrays

Antenna array

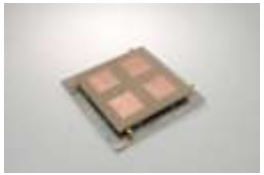
Radiating element



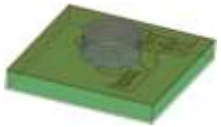
Feeding system

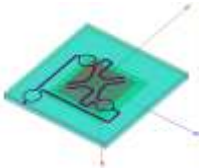


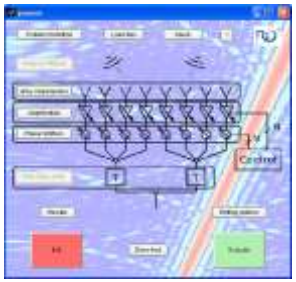
Architecture

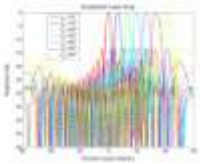


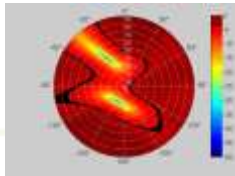
Analysis and simulation





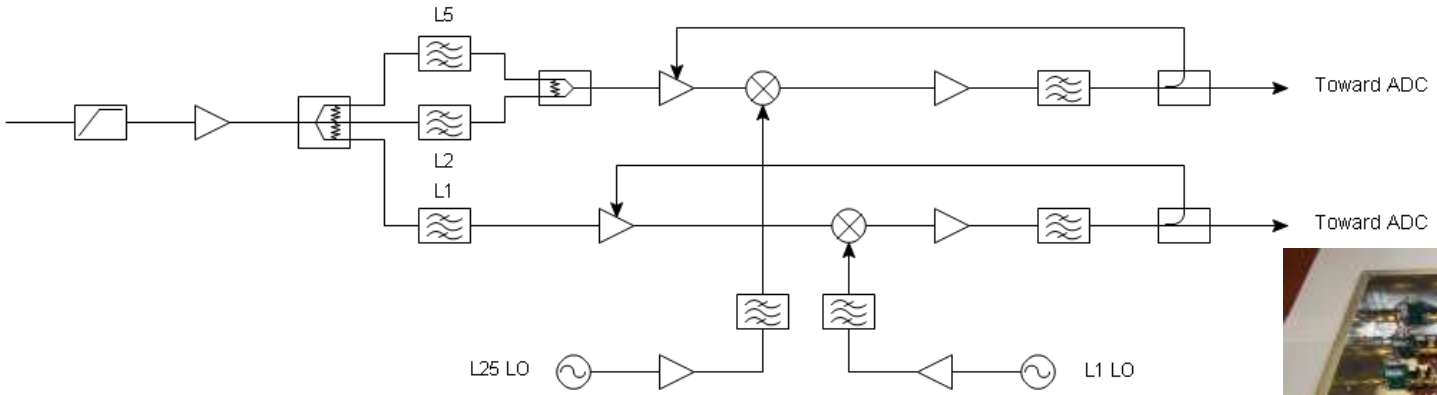


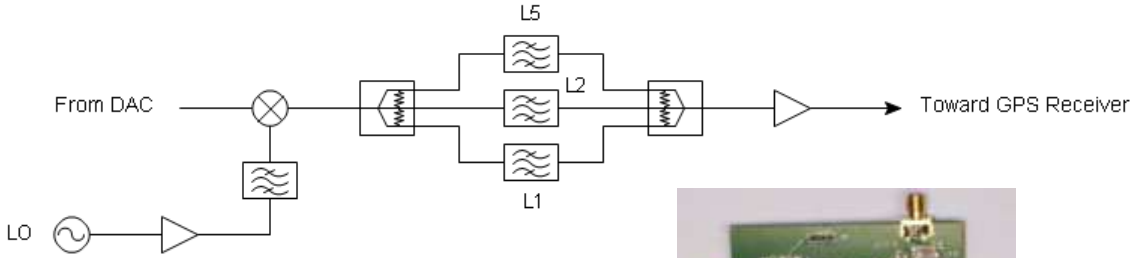


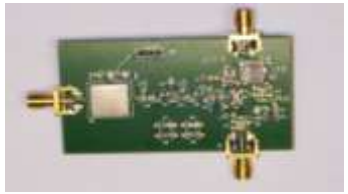


CRPA project at DRDC Ottawa

- RF front-end





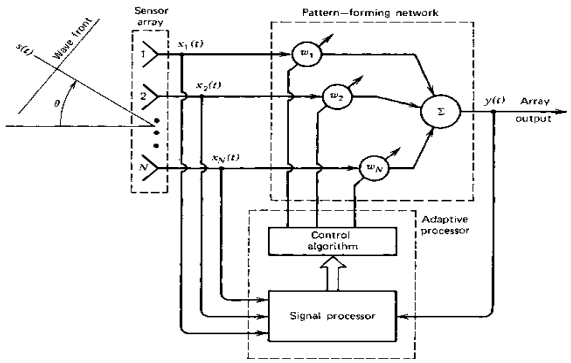


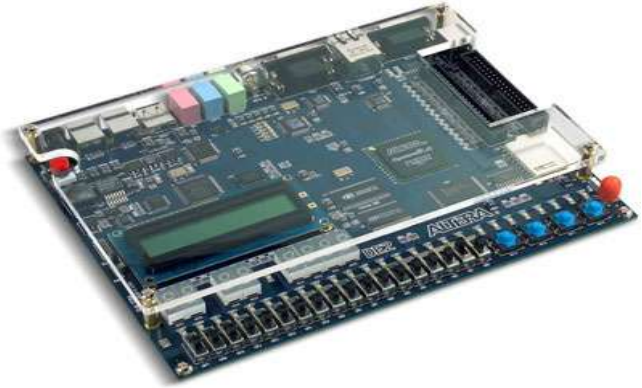
CRPA project at DRDC Ottawa

- Signal Processing

Signal Processing

Digital Data Formating	Algorithm Development	Algorithm Implementation (Software / Hardware)	Hardware development
Down-conversion Sampling Numerical Filtering	Beamforming Null steering Direction Finding	FPGA / DSP Softcore, Hardcore	FPGA / DSP board



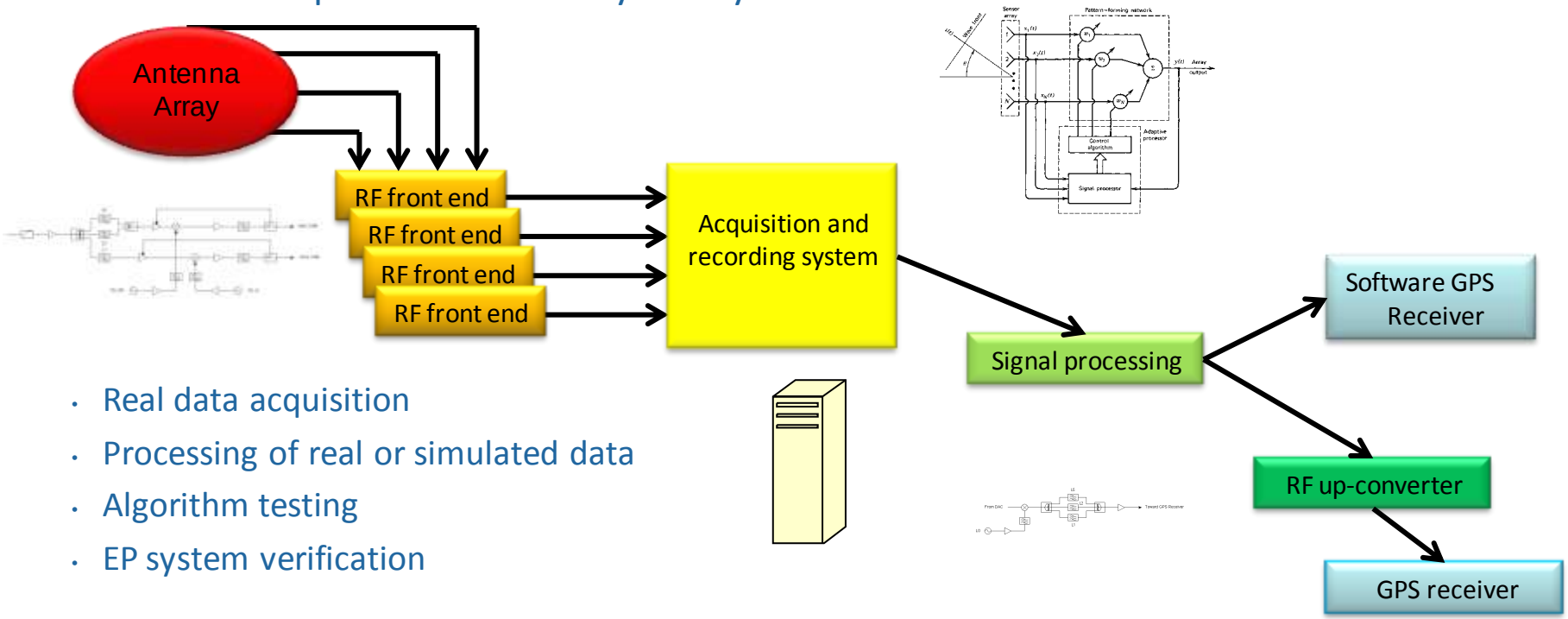


Outline

- Introduction
- CRPA project at DRDC Ottawa
- GAJET: An Evaluation Test bed for GPS Anti-Jam System
  - Overview
  - Antenna Array
  - Signal Processing
  - A Case Study
- An AJ simulation tool
- Concluding Remarks

GAJET - Overview

- GAJET (**GPS Anti-Jam Evaluation Testbed**) is a CRPA where each hardware and software component can be individually modified resulting in a customizable system that can be used to test improvements to any sub-systems



- Real data acquisition
- Processing of real or simulated data
- Algorithm testing
- EP system verification

GAJET - Overview

- Main Component: data acquisition and recording (and playback) system

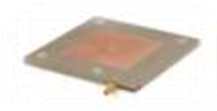
- GAJET C/A
  - 8 channels
  - 14 bit ADC
  - Fs = 125 MS/s max per channel
  - 4 GB internal memory
  - 10 TB storage capacity

- GAJET P(Y)
  - 16 channels
  - 16 bit ADC , Fs =130 MS/s
  - 4 FPGA (Xilinx Vertex 5)
  - 16 bit DAC, Fs = 500 MS/s
  - 30 TB storage capacity

GAJET - Antennas

- Different kinds of antennas are needed depending on the platform, the considered frequency bands (GPS L1, L2, L5) and the use of polarization discrimination or not.

- Radiating element specifications:
  - Frequency bands: at least L1 and L2;
  - Radiation: Omni-directional with strong attenuations at the horizon (±90°);
  - Polarization: Right Hand Circular Polarization;
  - Other:
    - Act as a filter
    - Feeding system compatible with electronic circuit integration.

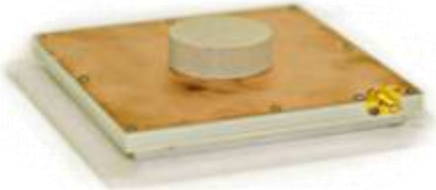


GAJET - Antennas

- Aperture-Coupled Stacked Patch Antenna (Carleton Univ.)

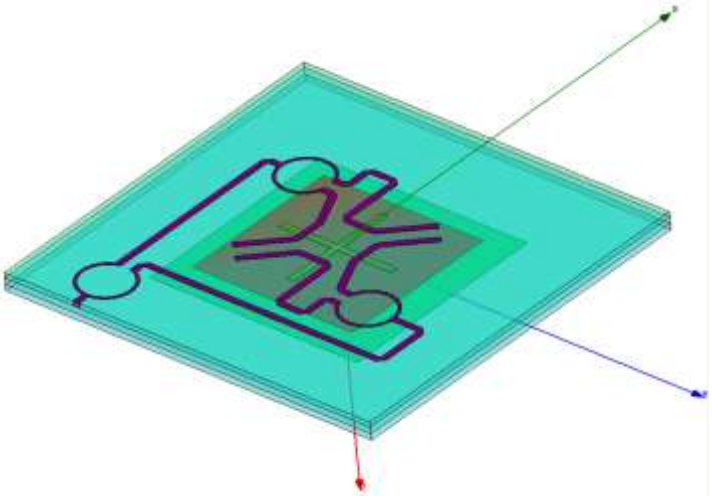
- Folded Printed Quadrifilar Helix Antenna (RMC, Univ. of Rennes)

- Hybrid Dielectric Resonator Antenna (RMC)



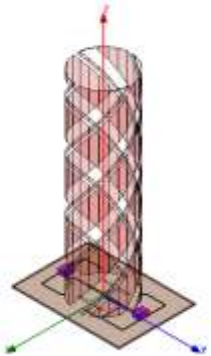
GAJET – Antennas : Stacked Patch

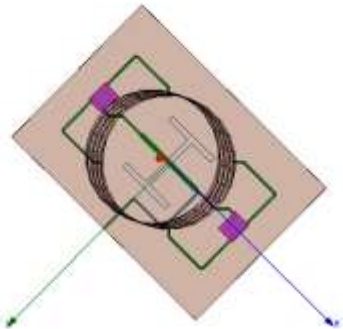
- 3 layers of substrate material
  - 2 layers 3.05 mm thick, Er = 2.94
  - 1 layer 1.9mm thick, Er = 9.8
- Upper patch size : 64 x 64 mm^2
- Lower patch size : 42 x 42 mm^2
- Slot size : 42 x 2 mm^2
- Substrate footprint : 107 x 107 mm^2



GAJET – Antennas : FPQHA

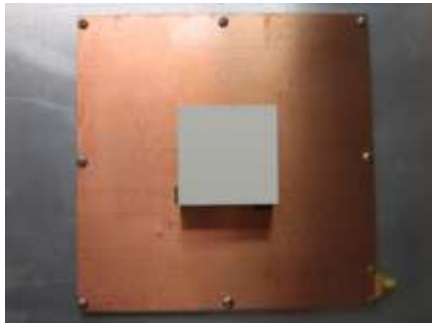
- Antenna printed on a thin film of dielectric material, rolled around a foam cylinder (Er # 1)
- The feeding circuit is realized on two layer of high permittivity material (Er = 9.8, t = 0.635 mm)
- Cylinder height : 130 mm
- Cylinder diameter : 36 mm
- Feeding circuit footprint : 50 x 50 mm^2

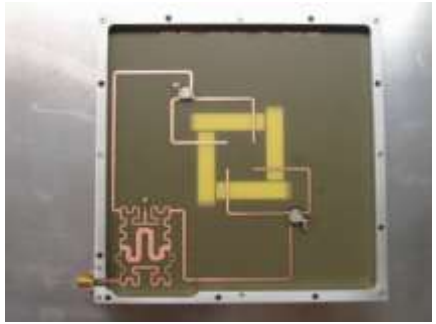


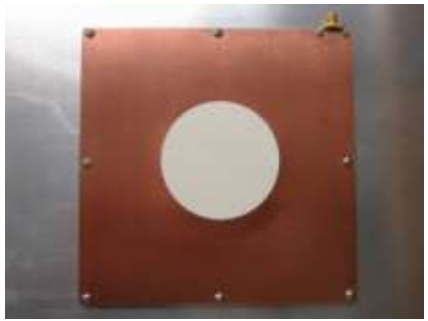


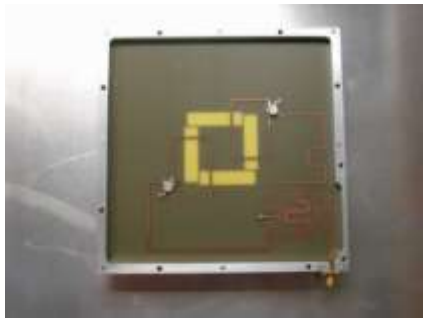
GAJET – Antennas : HDRA

- Antenna realised with a Er = 10 dielectric material
- The feeding circuit is realized on FR4 material (Er = 4.4, t = 0.762 mm)
- Resonator dimensions : 50 x 50 x 24 mm^3
- Slot dimensions : 41 x 9.4 mm^2
- Slot offset from centre : 19.1 x 7.1 mm^2
- Feeding circuit footprint : 160 x 160 mm^2



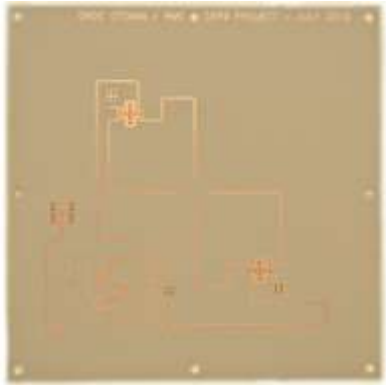


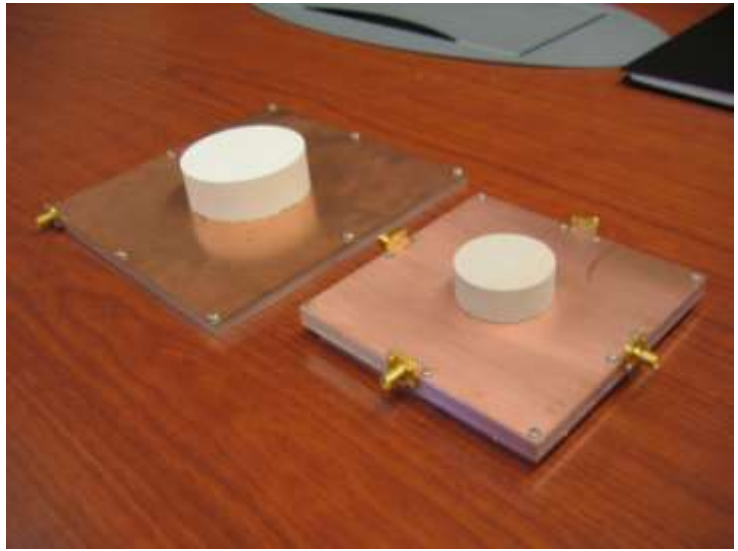




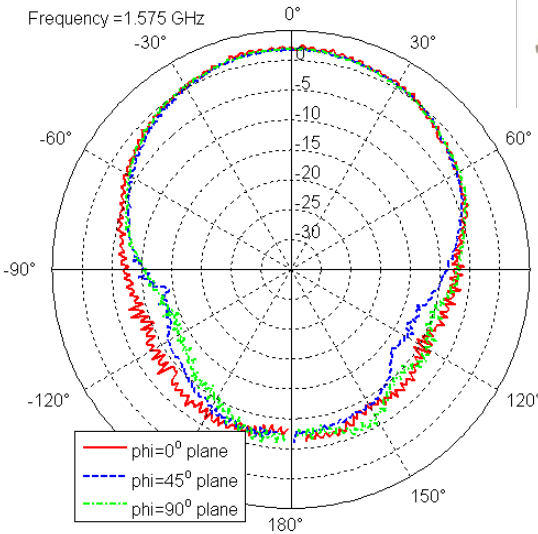
GAJET – Antennas : small HDRA

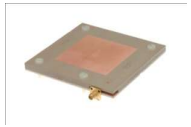
- Antenna realised with a Er = 30 dielectric material
- The feeding circuit is realized on Er = 10 dielectric material
- Resonator dimensions : Ø38.1 mm x 15 mm
- Arc shape slot
- Feeding circuit footprint : 100 x 100 mm^2



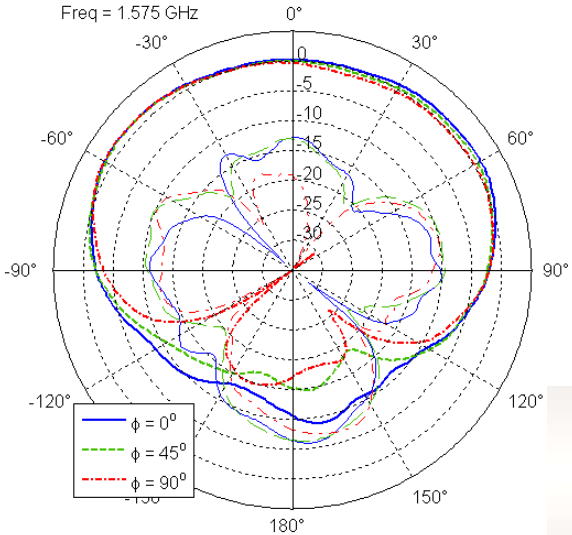


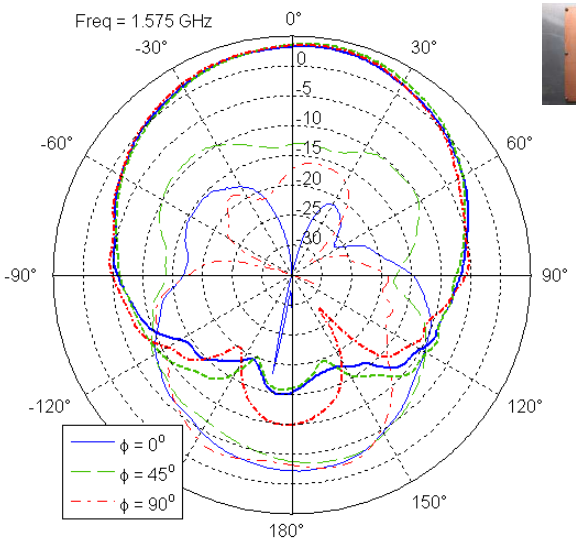
GAJET – Antennas : Radiation Patterns

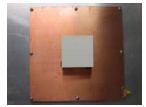




L1
(1.575 GHz)





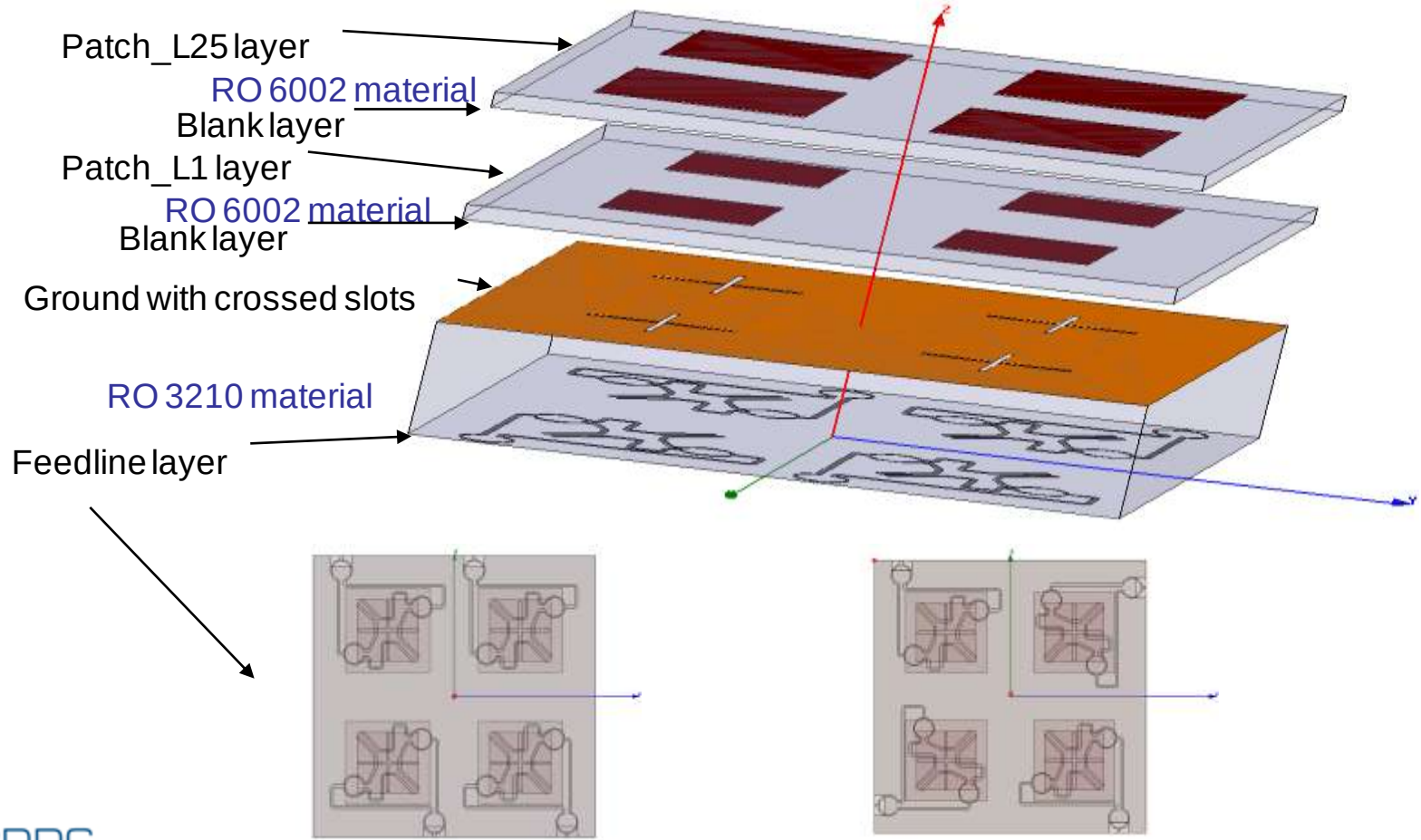


GAJET – Antennas : Characteristic Summary

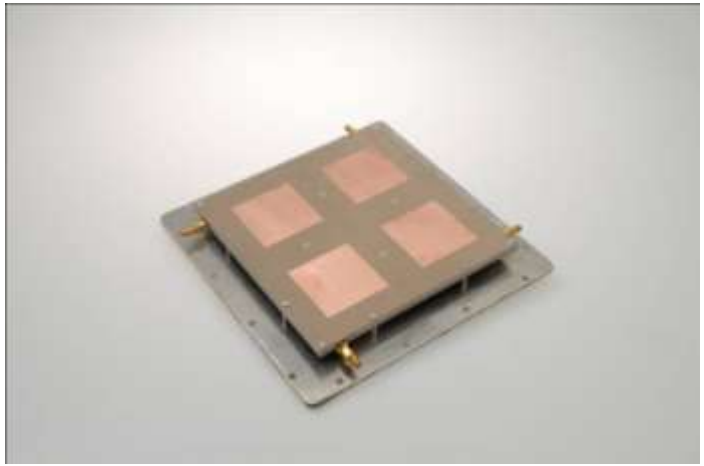
- Overall, the three radiating elements exhibit very good characteristics for GPS/GNSS applications.
- Depending on the required performance and the targeted platform, tradeoffs should be made to select the most appropriate antenna.

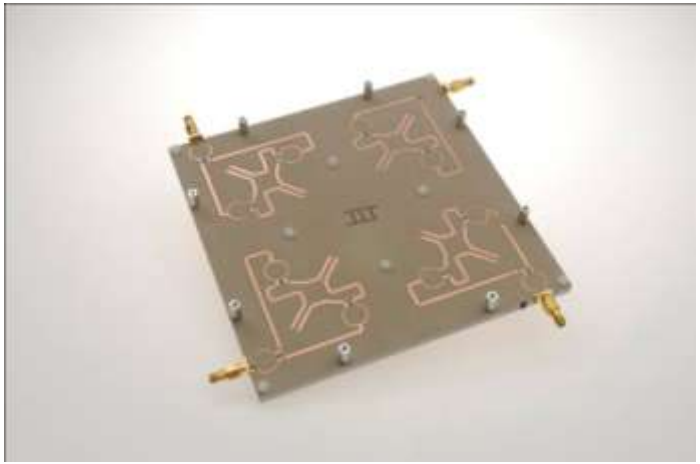
GNSS Bandwidth	**Patch**	**HDRA**	**FPQHA**
Reflection coefficient (dB)	< -7	< -14	< -12
Gain @ Boresight (dBic)	> 1.0	> 1.35	> -1.6
HPBW (deg.)	90	90	160
AR @ Boresight (dB)	< 3.5	< 1.6	< 2.0
Comment	Low profile	Reasonable profile (24 mm)	Important height (130 mm)

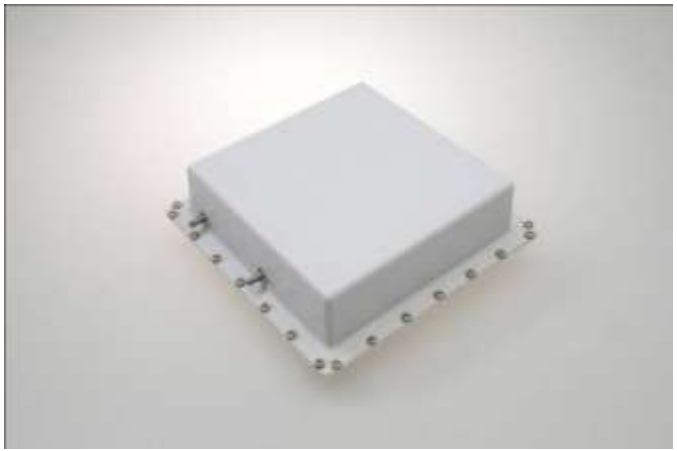
GAJET – Antennas : Patch Array



GAJET – Antennas : Patch Arrays

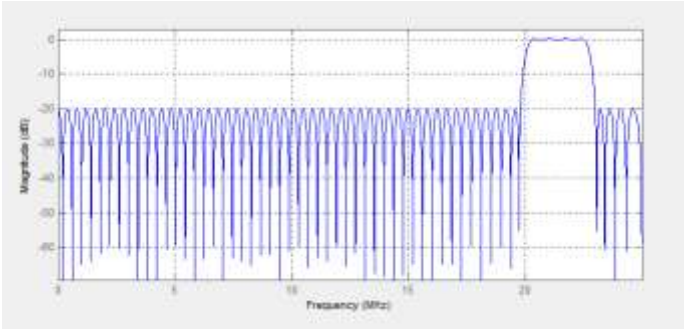


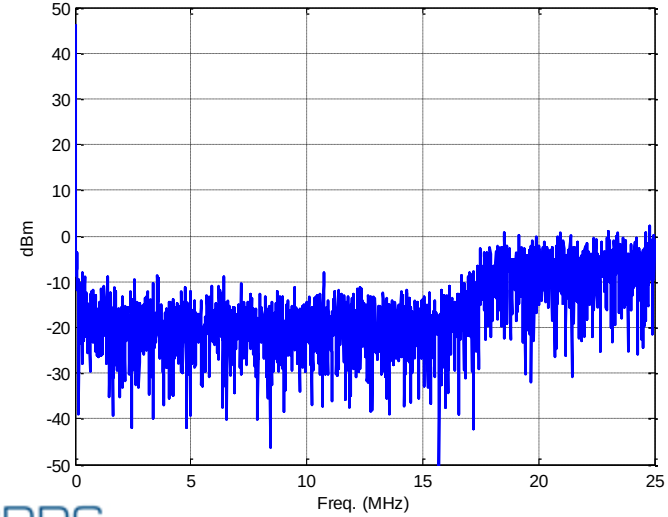


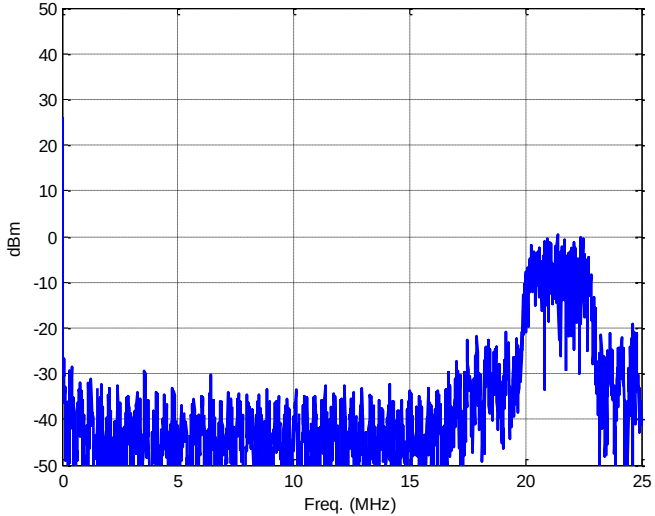


GAJET – Signal Processing : Digital Filtering

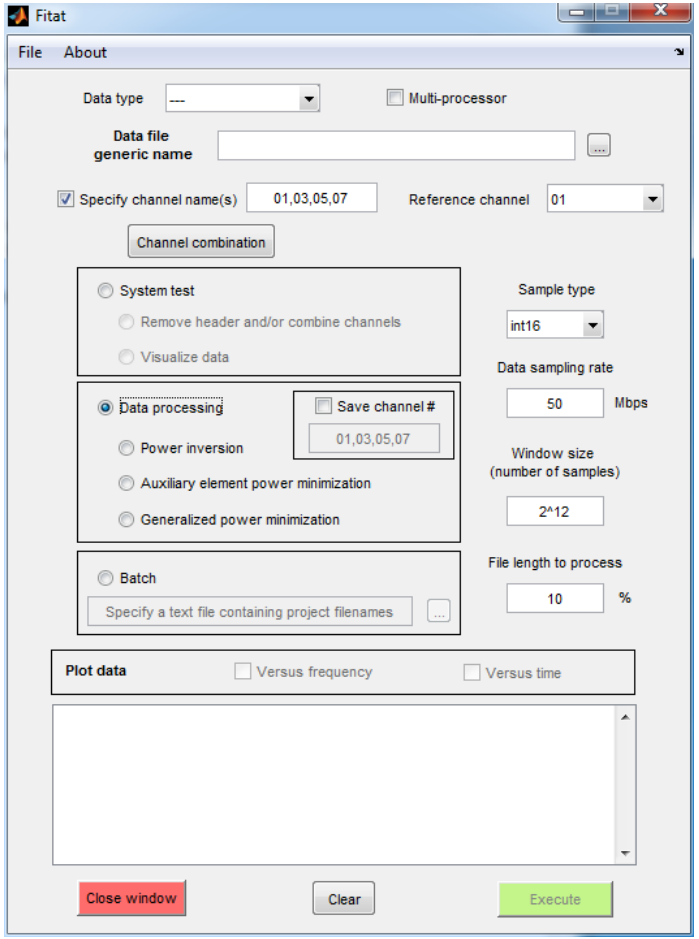
- Filter
  - Fs = 50 MS/s
  - FI = 21.4 MHz
  - BW = 2.2 MHz
  - Rejection : 20 dB

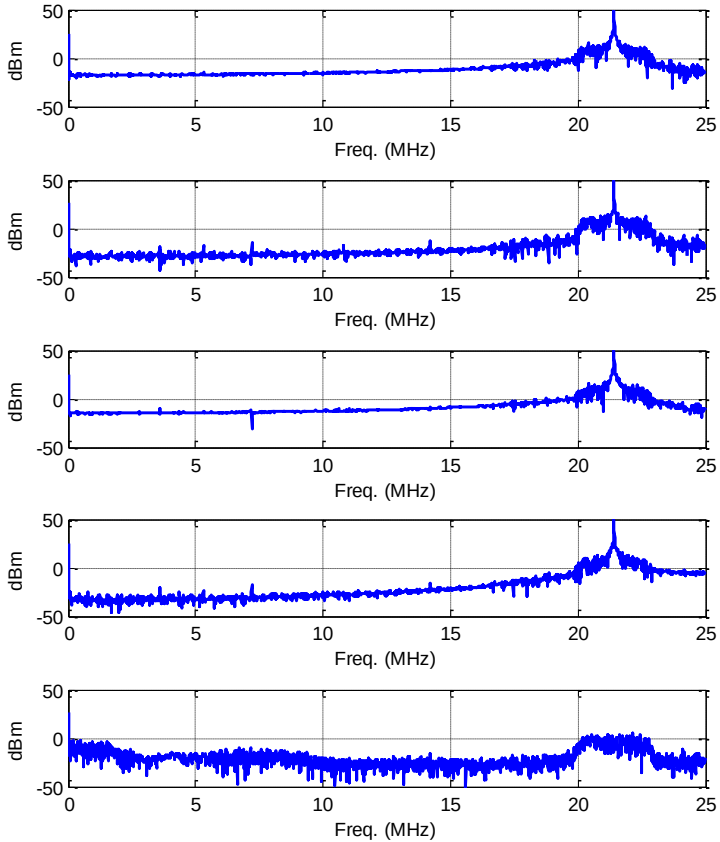






GAJET – Signal Processing : Null steering





GAJET – System Verification

- Existing GPS Receivers

GAJET – System Verification

- GSNRx™ (GNSS Software Navigation Receiver) (University of Calgary)

Receiver Time : 393396.303

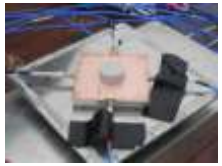
Latitude :	45 56 43.38794	North Velocity :	-0.143 m/s
Longitude :	-77 19 50.03571	East Velocity :	0.057 m/s
Height :	90.771 m	Vertical Velocity :	0.008 m/s
Clock Bias :	24.195 m	Clock Drift :	5.019 m/s

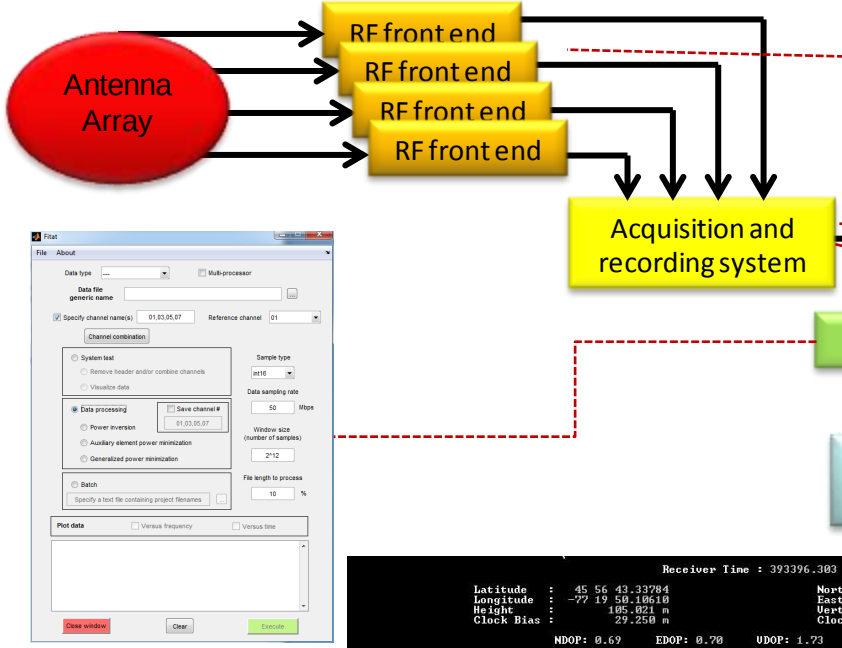
NDOP: 0.75 EDOP: 0.98 VDOP: 2.41 GDOP: 3.15

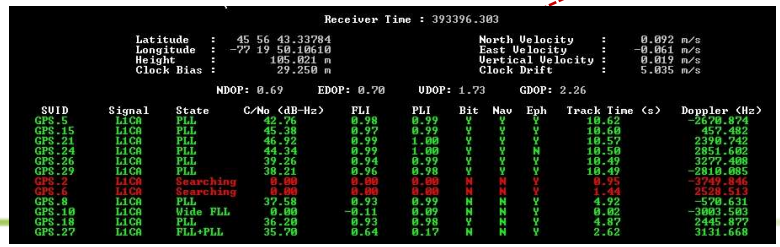
SVID	Signal	State	C/No (dB-Hz)	FLI	PLI	Bit	Nav	Eph	Track Time (s)	Doppler (Hz)
GPS.5	L1CA	PLL	41.17	0.97	0.99	Y	Y	Y	10.62	-2669.486
GPS.15	L1CA	PLL	45.12	0.99	1.00	Y	Y	Y	10.60	456.962
GPS.21	L1CA	PLL	41.35	0.98	0.99	Y	Y	Y	10.57	2390.731
GPS.26	L1CA	PLL	42.12	0.98	0.99	Y	Y	Y	10.49	3276.521
GPS.18	L1CA	PLL	38.87	0.96	0.99	Y	Y	Y	10.37	2446.743
GPS.24	L1CA	PLL	39.95	0.94	0.98	Y	Y	N	10.28	2851.336
GPS.29	L1CA	PLL	40.57	0.96	0.99	Y	Y	Y	10.22	-2810.059
GPS.2	L1CA	Searching	0.00	0.00	0.00	N	N	Y	0.53	-3749.884
GPS.6	L1CA	Wide FLL	19.12	-0.08	0.38	N	N	Y	0.26	2356.631
GPS.8	L1CA	PLL	37.74	0.93	0.96	Y	N	Y	4.95	-568.231
GPS.10	L1CA	Searching	0.00	0.00	0.00	N	N	Y	0.55	-3291.758
GPS.27	L1CA	Searching	0.00	0.00	0.00	N	N	Y	0.57	3129.404

GAJET – Summary

- GAJET (GPS Anti-Jam Evaluation Testbed) is a CRPA platform whereby each hardware and software component can be individually modified resulting in a customizable system that can be used to test improvements to any sub-systems







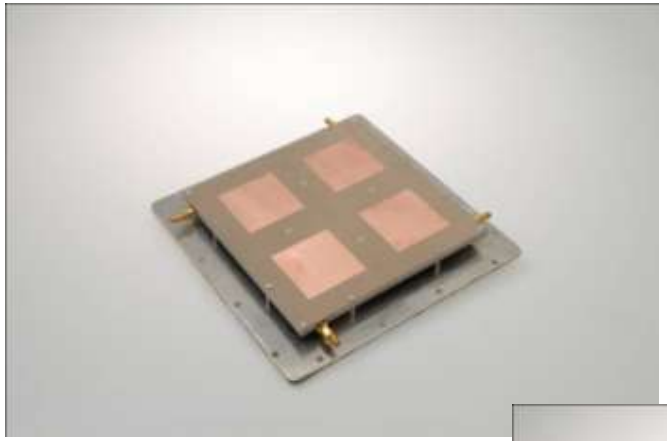
```
Receiver Time : 393396.303

Latitude      :   45 56 43.33784        North Velocity     :     0.092 m/s
Longitude     :  -77 19 50.10616        East Velocity      :    -0.061 m/s
Height        :      105.021 m          Vertical Velocity  :     0.019 m/s
Clock Bias    :       29.250 m          Clock Drift        :     5.035 m/s

NDOP: 0.69    EDOP: 0.70    VDOP: 1.73    GDOP: 2.26

SVID     Signal  State      C/No (dB-Hz)  FLI   PLI   Bit  Nav  Eph  Track Time (s)  Doppler (Hz)
GPS.5    L1CA    PLL          42.76       0.98  0.99   Y    Y    Y      10.62        -2670.874
GPS.15   L1CA    PLL          45.38       0.97  0.99   Y    Y    Y      10.60         457.482
GPS.21   L1CA    PLL          46.92       0.99  1.00   Y    Y    Y      10.57        2398.742
GPS.24   L1CA    PLL          44.34       0.99  1.00   Y    Y    N      10.50        2851.602
GPS.26   L1CA    PLL          39.26       0.94  0.99   Y    Y    Y      10.49        3277.408
GPS.29   L1CA    PLL          38.21       0.96  0.98   Y    Y    Y      10.49       -2810.085
GPS.2    L1CA    Searching     0.00       0.00  0.00   N    N    Y       0.75       -3747.846
GPS.6    L1CA    Searching     0.00       0.00  0.00   N    N    Y       1.44        2528.513
GPS.8    L1CA    PLL          37.58       0.93  0.99   N    N    Y       4.92         -570.631
GPS.10   L1CA    Wide FLL      0.00      -0.11  0.09   N    N    Y       0.02       -3003.583
GPS.18   L1CA    PLL          36.20       0.93  0.98   Y    N    Y       4.87        2445.877
GPS.27   L1CA    FLL+PLL      35.70       0.64  0.17   N    N    Y       2.62        3131.668
```

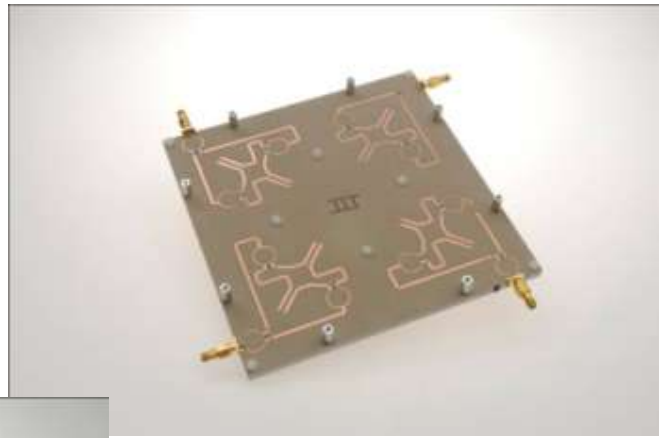
GAJET – A Case Study

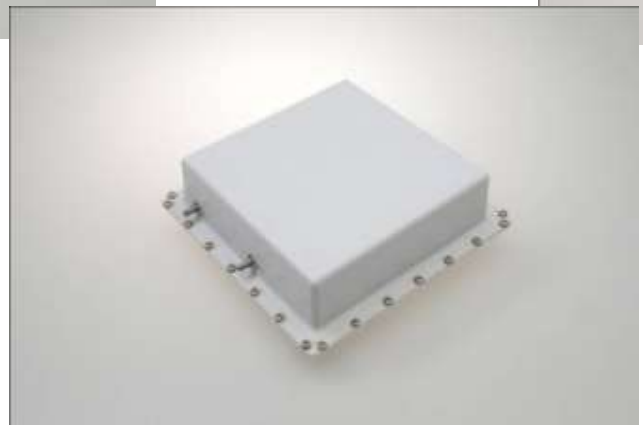
- Array of 4 radiating elements
- 3 jammers at L1
- Verification with GSNRx

GAJET – A Case Study

- Array of 4 aperture-coupled stacked patch antennas

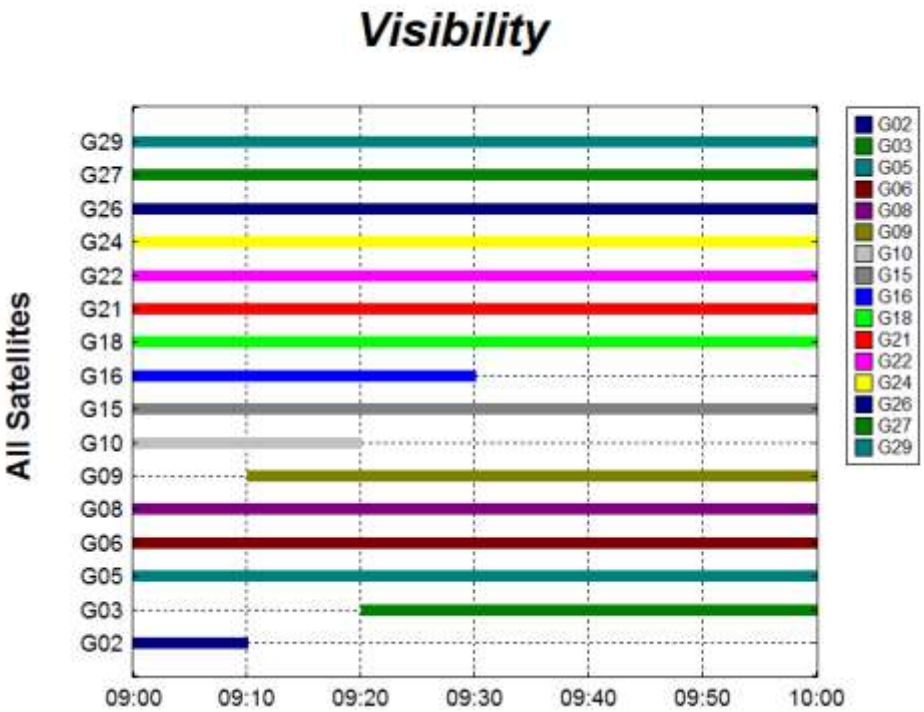


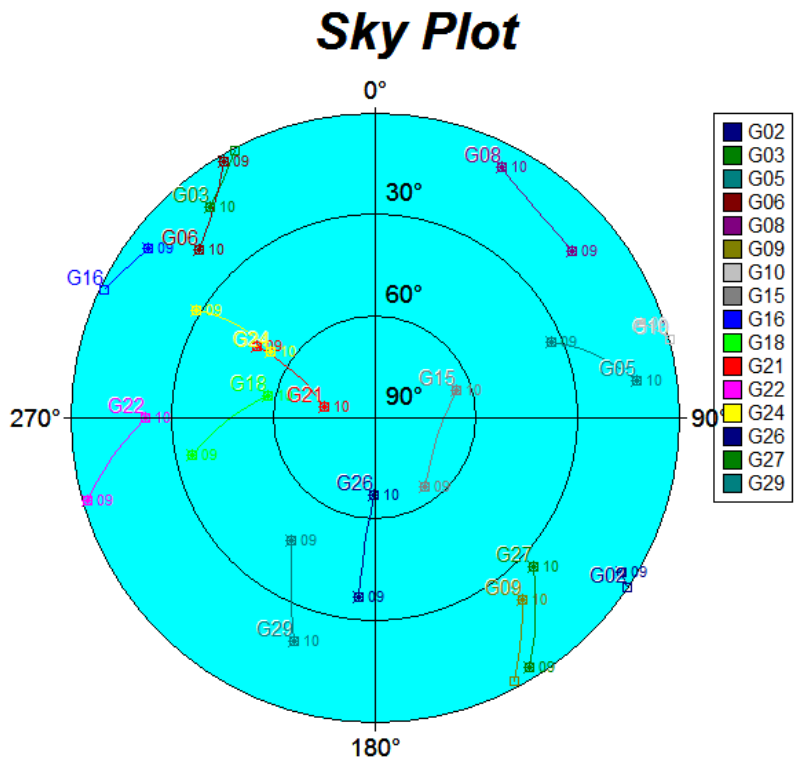




GAJET – A Case Study

- Satellites in Visibility

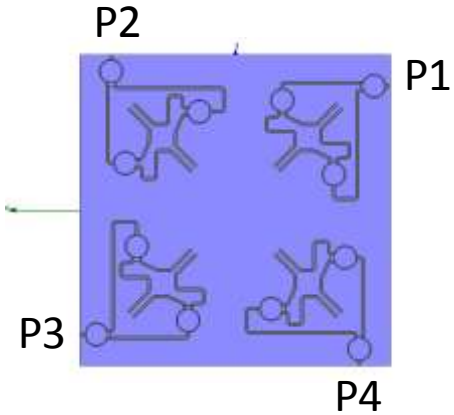




Station Petawawa, ON North 45° 56' West 77° 19' Height 0m Elevation cutoff 0° Obstacles 0%
Time 06/05/2010 09:00 - 06/05/2010 10:00 (UTC-4.0h) Satellites 30 GPS 30 [Almanac.alm (30/07/2010)]

GAJET – Signal Captures with GAJET C/A

- Signals captured simultaneously using GAJET C/A
- No jammers



Port 1

Receiver Time : 393396.304

Latitude :	0 00 00.00000	North Velocity :	0.000 m/s
Longitude :	0 00 00.00000	East Velocity :	0.000 m/s
Height :	0.000 m	Vertical Velocity :	0.000 m/s
Clock Bias :	0.000 m	Clock Drift :	0.000 m/s

NDOP: 0.00 EDOP: 0.00 VDOP: 0.00 GDOP: 0.00

SVID	Signal	State	C/No (dB-Hz)	FLI	PLI	Bit	Nav	Eph	Track Time (s)	Doppler (Hz)
GPS.15	L1CA	PLL	41.66	0.96	0.99	Y	Y	Y	10.60	457.646
GPS.21	L1CA	PLL	43.72	0.99	1.00	Y	Y	Y	10.57	2390.768
GPS.24	L1CA	PLL	39.12	0.97	0.99	Y	Y	N	10.53	2851.093
GPS.5	L1CA	PLL	39.91	0.97	0.99	Y	Y	Y	10.40	-2670.576
GPS.26	L1CA	PLL	37.13	0.91	0.97	N	N	Y	6.99	3282.183
GPS.29	L1CA	FLL+PLL	34.86	0.85	0.56	N	N	Y	6.93	-2821.900

Port 2

Receiver Time : 393396.303

Latitude :	45 56 43.38794	North Velocity :	-0.143 m/s
Longitude :	-77 19 50.03571	East Velocity :	0.057 m/s
Height :	90.771 m	Vertical Velocity :	0.008 m/s
Clock Bias :	24.195 m	Clock Drift :	5.019 m/s

NDOP: 0.75 EDOP: 0.98 VDOP: 2.41 GDOP: 3.15

SVID	Signal	State	C/No (dB-Hz)	FLI	PLI	Bit	Nav	Eph	Track Time (s)	Doppler (Hz)
GPS.5	L1CA	PLL	41.17	0.97	0.99	Y	Y	Y	10.62	-2669.486
GPS.15	L1CA	PLL	45.12	0.99	1.00	Y	Y	Y	10.60	456.962
GPS.21	L1CA	PLL	41.35	0.98	0.99	Y	Y	Y	10.57	2390.731
GPS.26	L1CA	PLL	42.12	0.98	0.99	Y	Y	Y	10.49	3276.521
GPS.18	L1CA	PLL	38.07	0.96	0.99	Y	Y	Y	10.37	2446.743
GPS.24	L1CA	PLL	39.95	0.94	0.98	Y	Y	N	10.28	2851.336
GPS.29	L1CA	PLL	40.57	0.96	0.99	Y	Y	Y	10.22	-2810.059
GPS.2	L1CA	Searching	0.00	0.00	0.00	N	N	Y	0.53	-3749.884
GPS.6	L1CA	Wide FLL	19.12	-0.08	0.38	N	N	Y	0.26	2356.631
GPS.8	L1CA	PLL	37.74	0.93	0.96	Y	N	Y	4.95	-568.231
GPS.10	L1CA	Searching	0.00	0.00	0.00	N	N	Y	0.55	-3291.758
GPS.27	L1CA	Searching	0.00	0.00	0.00	N	N	Y	0.57	3129.404

Port 3

Receiver Time : 393396.304

Latitude :	45 56 40.34289	North Velocity :	0.000 m/s
Longitude :	-77 19 58.02918	East Velocity :	0.000 m/s
Height :	533.438 m	Vertical Velocity :	0.000 m/s
Clock Bias :	0.000 m	Clock Drift :	0.000 m/s

NDOP: 0.00 EDOP: 0.00 VDOP: 0.00 GDOP: 0.00

SVID	Signal	State	C/No (dB-Hz)	FLI	PLI	Bit	Nav	Eph	Track Time (s)	Doppler (Hz)
GPS.15	L1CA	PLL	46.98	0.99	1.00	Y	Y	Y	10.60	457.886
GPS.21	L1CA	PLL	42.02	0.97	0.99	Y	Y	Y	10.57	2390.467
GPS.24	L1CA	PLL	41.17	0.98	0.99	Y	Y	N	10.56	2851.437
GPS.26	L1CA	PLL	41.43	0.98	0.99	Y	Y	Y	10.50	3277.181
GPS.29	L1CA	PLL	43.37	0.98	0.99	Y	Y	Y	10.49	-2809.038

Port 4

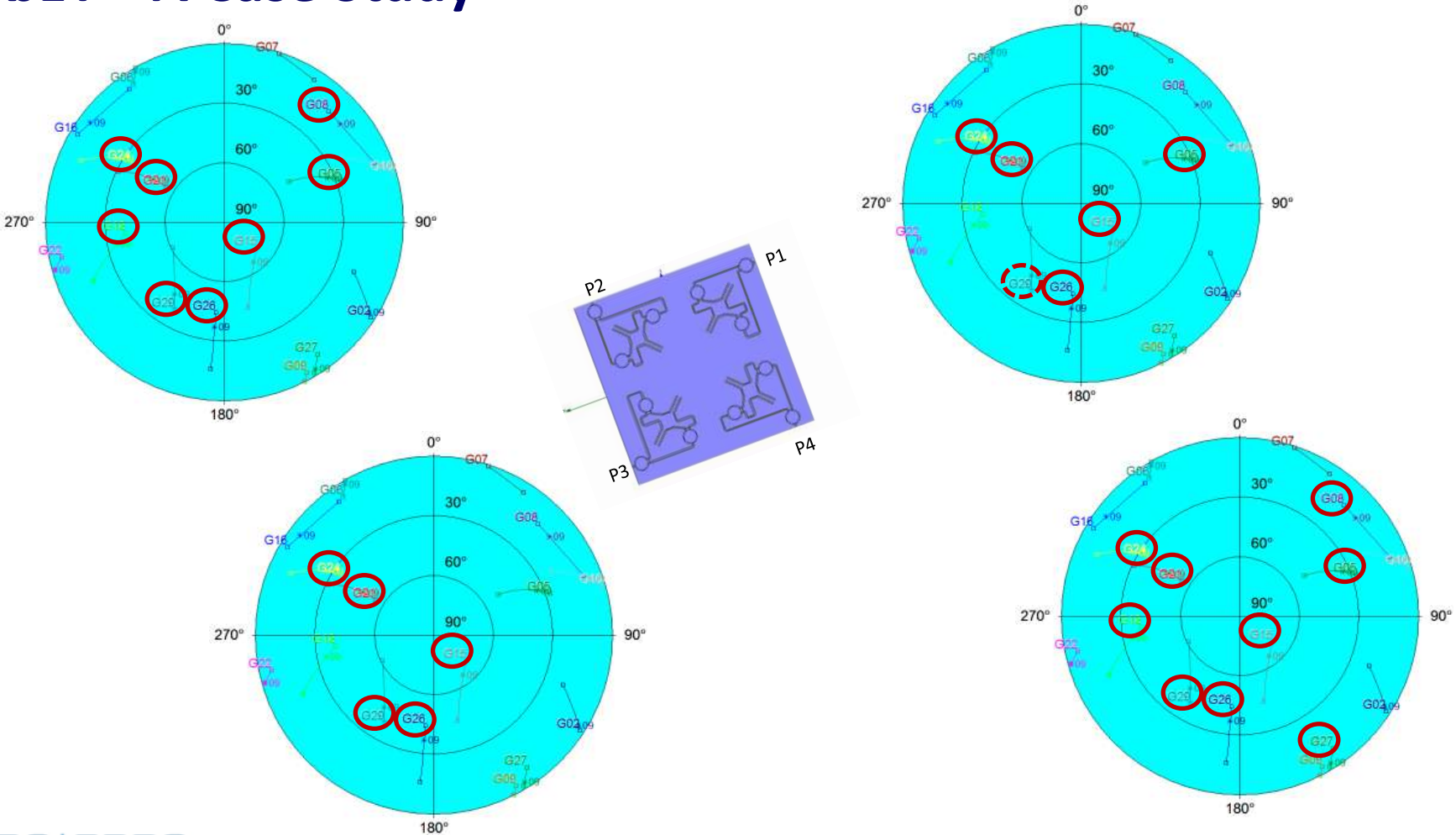
Receiver Time : 393396.303

Latitude :	45 56 43.60119	North Velocity :	-0.043 m/s
Longitude :	-77 19 50.34718	East Velocity :	0.071 m/s
Height :	91.248 m	Vertical Velocity :	-0.115 m/s
Clock Bias :	25.368 m	Clock Drift :	4.951 m/s

NDOP: 0.73 EDOP: 0.65 VDOP: 2.22 GDOP: 2.05

SVID	Signal	State	C/No (dB-Hz)	FLI	PLI	Bit	Nav	Eph	Track Time (s)	Doppler (Hz)
GPS.5	L1CA	PLL	42.97	0.97	1.00	Y	Y	Y	10.62	-2670.281
GPS.15	L1CA	PLL	47.27	0.99	1.00	Y	Y	Y	10.60	456.918
GPS.18	L1CA	PLL	40.69	0.98	0.99	Y	Y	Y	10.56	2445.515
GPS.21	L1CA	PLL	41.65	0.98	0.99	Y	Y	Y	10.57	2390.675
GPS.24	L1CA	PLL	40.21	0.96	0.99	Y	Y	N	10.50	2853.174
GPS.26	L1CA	PLL	46.09	0.99	1.00	Y	Y	Y	10.50	3277.514
GPS.29	L1CA	PLL	44.72	0.99	0.99	Y	Y	Y	10.49	-2809.958
GPS.2	L1CA	Searching	0.00	0.00	0.00	N	N	Y	1.04	-3747.928
GPS.6	L1CA	Wide FLL	16.38	-0.10	0.13	N	N	Y	0.44	2131.042
GPS.8	L1CA	PLL	37.71	0.94	0.98	Y	N	Y	4.98	-569.328
GPS.10	L1CA	Searching	0.00	0.00	0.00	N	N	Y	0.75	-3291.153
GPS.27	L1CA	PLL	34.91	0.89	0.98	N	N	Y	4.98	3131.073

GAJET – A Case Study



GAJET – A Case Study

Port 1

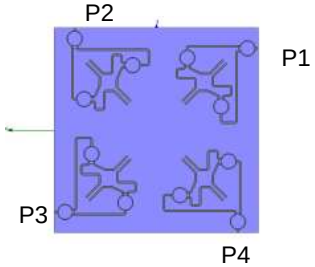
Receiver Time : 393396.304

Latitude :	0 00 00.00000	North Velocity :	0.000 m/s
Longitude :	0 00 00.00000	East Velocity :	0.000 m/s
Height :	0.000 m	Vertical Velocity :	0.000 m/s
Clock Bias :	0.000 m	Clock Drift :	0.000 m/s

NDOP: 0.00 EDOP: 0.00 VDOP: 0.00 GDOP: 0.00

SVID	Signal	State	C/No (dB-Hz)	FLI	PLI	Bit	Nav	Eph	Track Time (s)	Doppler (Hz)
GPS.15	L1CA	PLL	41.66	0.96	0.99	Y	Y	Y	10.60	457.646
GPS.21	L1CA	PLL	43.72	0.99	1.00	Y	Y	Y	10.57	2390.768
GPS.24	L1CA	PLL	39.12	0.97	0.99	Y	Y	N	10.53	2851.093
GPS.5	L1CA	PLL	39.91	0.97	0.99	Y	Y	Y	10.40	-2670.576
GPS.26	L1CA	PLL	37.13	0.91	0.97	N	N	Y	6.99	3282.183
GPS.29	L1CA	FLL+PLL	34.86	0.85	0.56	N	N	Y	6.93	-2821.900

Port 1 after digital filtering



Receiver Time : 393396.303

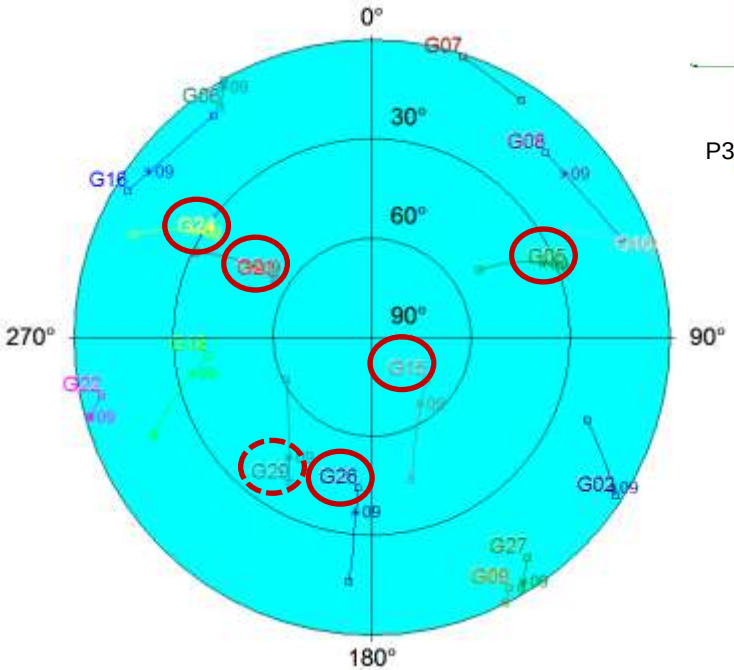
Latitude :	45 56 43.33784	North Velocity :	0.092 m/s
Longitude :	-77 19 50.10610	East Velocity :	-0.061 m/s
Height :	105.021 m	Vertical Velocity :	0.019 m/s
Clock Bias :	29.250 m	Clock Drift :	5.035 m/s

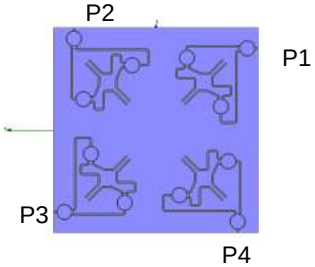
NDOP: 0.69 EDOP: 0.70 VDOP: 1.73 GDOP: 2.26

SVID	Signal	State	C/No (dB-Hz)	FLI	PLI	Bit	Nav	Eph	Track Time (s)	Doppler (Hz)
GPS.5	L1CA	PLL	42.76	0.98	0.99	Y	Y	Y	10.62	-2670.874
GPS.15	L1CA	PLL	45.38	0.97	0.99	Y	Y	Y	10.60	457.482
GPS.21	L1CA	PLL	46.92	0.99	1.00	Y	Y	Y	10.57	2390.742
GPS.24	L1CA	PLL	44.34	0.99	1.00	Y	Y	N	10.50	2851.602
GPS.26	L1CA	PLL	39.26	0.94	0.99	Y	Y	Y	10.49	3277.408
GPS.29	L1CA	PLL	38.21	0.96	0.98	Y	Y	Y	10.49	-2810.085
GPS.2	L1CA	Searching	0.00	0.00	0.00	N	N	Y	0.95	-3749.846
GPS.6	L1CA	Searching	0.00	0.00	0.00	N	N	Y	1.44	2528.513
GPS.8	L1CA	PLL	37.58	0.93	0.99	N	N	Y	4.92	-570.631
GPS.10	L1CA	Wide FLL	0.00	-0.11	0.09	N	N	Y	0.02	-3003.503
GPS.18	L1CA	PLL	36.20	0.93	0.98	Y	N	Y	4.87	2445.877
GPS.27	L1CA	FLL+PLL	35.70	0.64	0.17	N	N	Y	2.62	3131.668

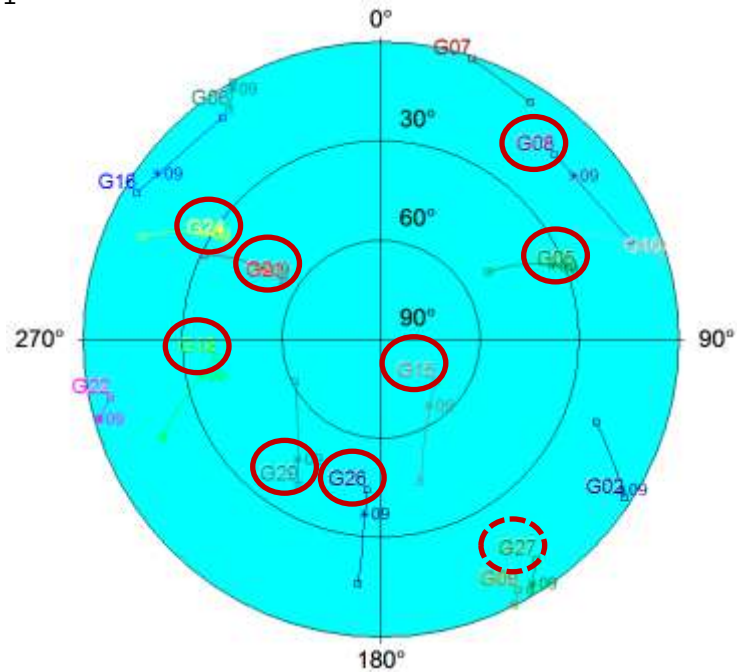
GAJET – A Case Study

Port 1



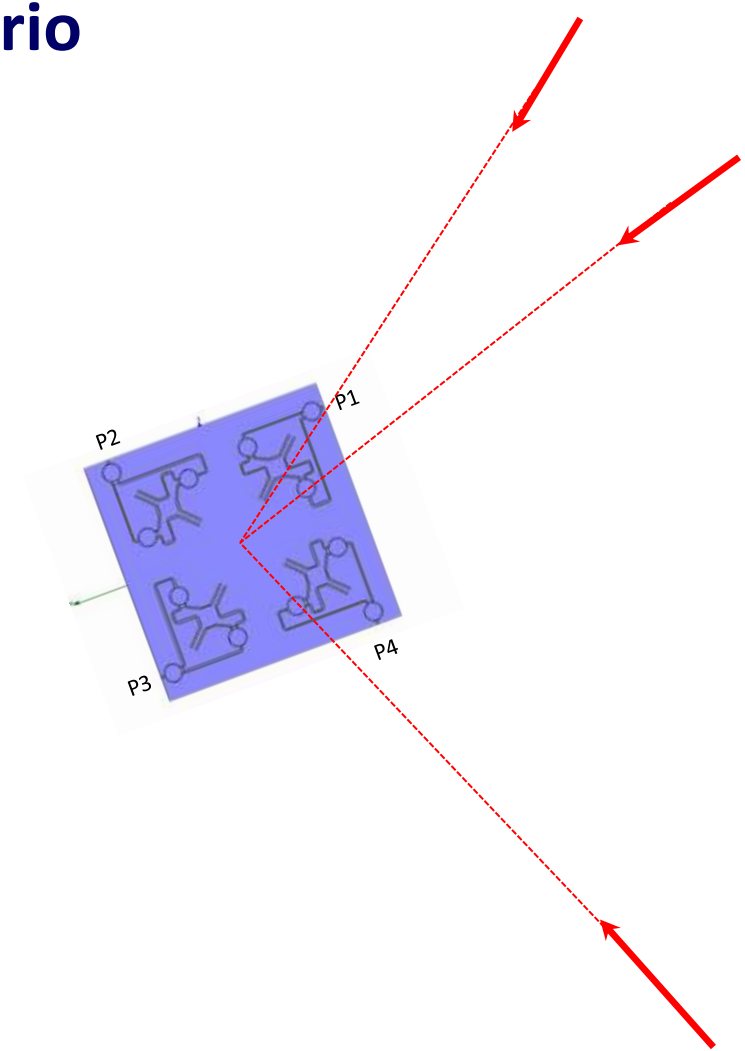


Port 1 after digital filtering



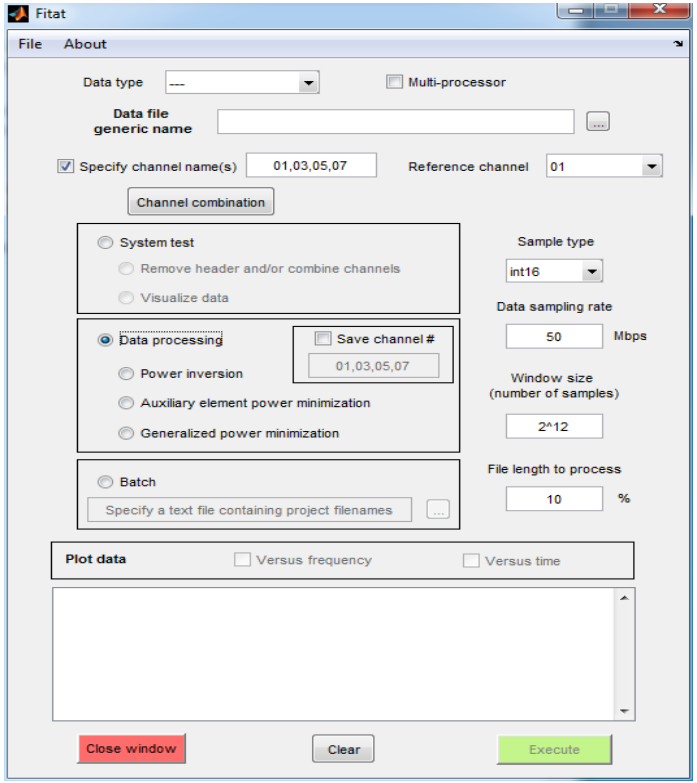
GAJET – A Case Study : scenario

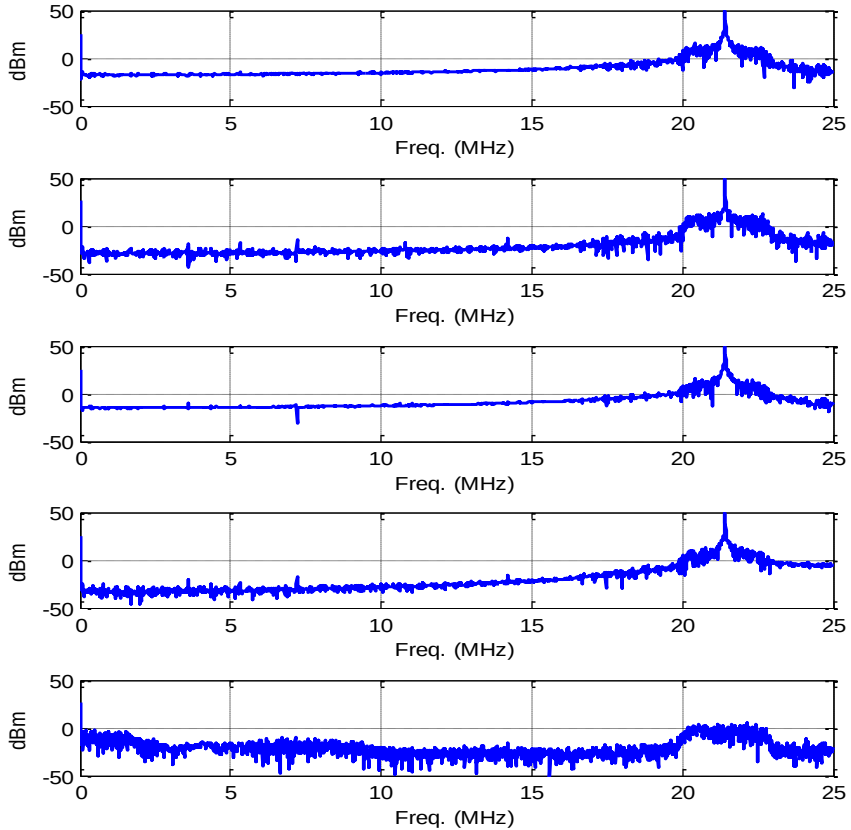
- Signals captured simultaneously using GAJET C/A
- 3 CW jammers



GAJET – A Case Study : digital processing

- Null Steering after digital filtering





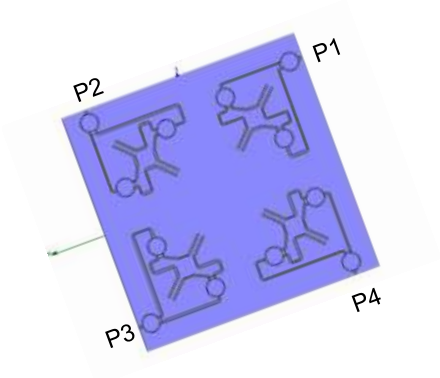
GAJET – A Case Study :System Verification

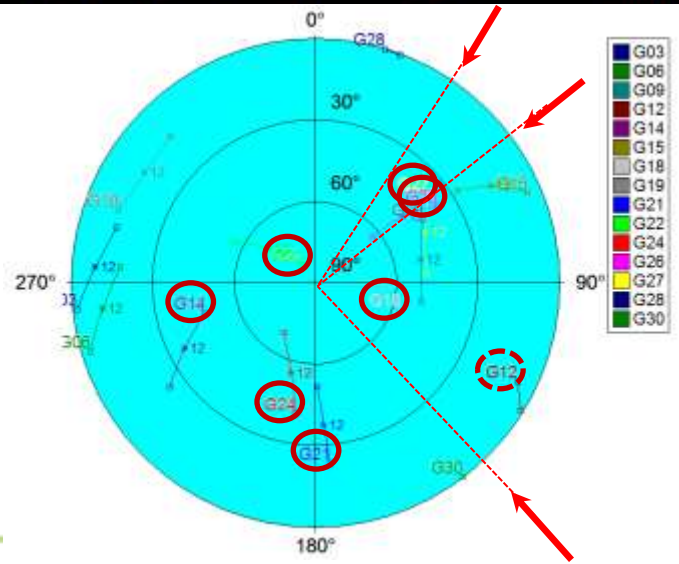
Receiver Time : 404930.386

Latitude :	45 56 43.18226	North Velocity :	-0.117 m/s
Longitude :	-77 19 49.96214	East Velocity :	-0.116 m/s
Height :	113.863 m	Vertical Velocity :	-0.167 m/s
Clock Bias :	41.006 m	Clock Drift :	4.240 m/s

NDOP: 0.83 EDOP: 0.88 VDOP: 1.54 GDOP: 2.29

SVID	Signal	State	C/No (dB-Hz)	FLI	PLI	Bit	Nav	Eph	Track Time (s)	Doppler (Hz)
GPS.14	L1CA	PLL	43.50	0.98	0.98	Y	Y	Y	10.57	2171.527
GPS.21	L1CA	PLL	42.70	0.97	0.98	Y	Y	Y	10.55	-3473.124
GPS.22	L1CA	PLL	42.99	0.97	0.98	Y	Y	Y	10.59	975.617
GPS.24	L1CA	PLL	44.64	0.99	0.99	Y	Y	Y	10.55	-2763.192
GPS.26	L1CA	PLL	40.25	0.97	0.97	Y	Y	Y	10.49	-2978.482
GPS.27	L1CA	PLL	39.91	0.92	0.91	Y	Y	Y	10.50	-2240.361
GPS.9	L1CA	Narrow FLL	35.27	0.48	-0.01	N	N	Y	0.28	-1558.864
GPS.12	L1CA	FLL+PLL	35.56	0.71	0.59	N	N	Y	0.83	2924.092
GPS.15	L1CA	Wide FLL	30.56	0.16	-0.17	N	N	Y	0.28	-3193.771
GPS.18	L1CA	PLL	39.13	0.92	0.98	N	N	Y	7.07	-1084.743
GPS.30	L1CA	Wide FLL	0.00	-0.12	0.09	N	N	Y	0.04	3087.072



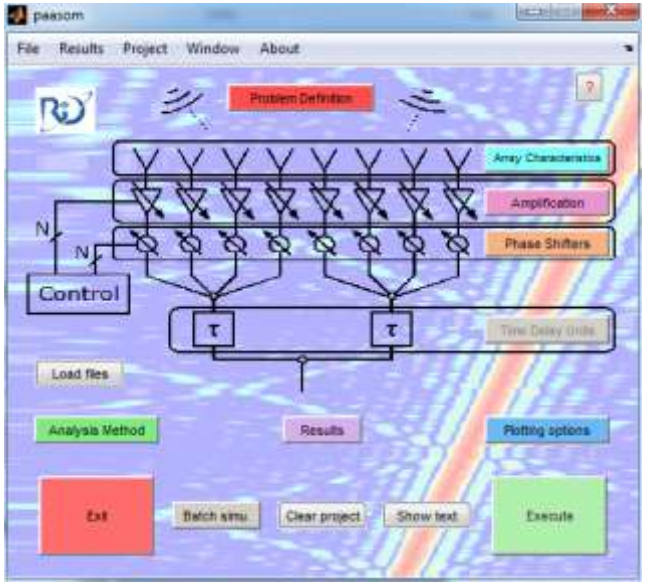


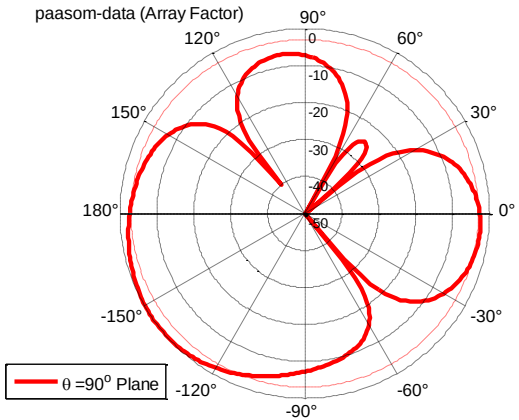
Outline

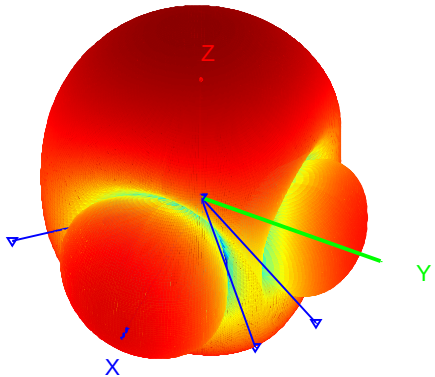
- Introduction
- The Global Positioning System (GPS)
- CRPA project at DRDC Ottawa
- GAJET: An Evaluation Test bed for GPS Anti-Jam System
- An AJ simulation tool
- Conclusion and future work

An AJ Simulation Tool

- Our AJ simulation tool is based on PAASoM (Phased Array Antenna Software tool in Matlab). It is an analysis and synthesis tool for phased array antennas.
- With PAASoM, one can study phased arrays of any geometry and lattices in considering the characteristics of the radiating elements, amplifiers and phase shifters.
- Radiation patterns can be generated considering several beam and/or nulls.







An AJ Simulation Tool

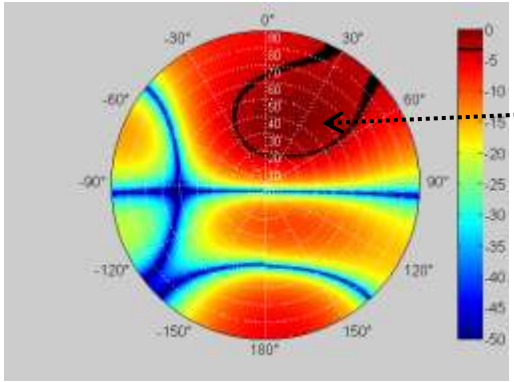
An AJ Simulation Tool : Beam-forming and Null-steering

3x2 rectangular array, half-wavelength spacing

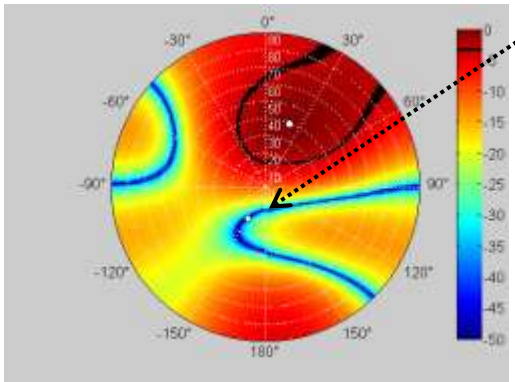
Parameters:

- Beam :
  - $\theta = 40^o$
  - $\varphi = 20^o$
  - SNR = 10 dB
  - N = -110 dBm
- 1st null :
  - $\theta = -21^o$
  - $\varphi = 30^o$
  - SNR = 20 dB
- 2nd null :
  - $\theta = -40^o$
  - $\varphi = 150^o$
  - SNR = 20 dB
- 3rd null :
  - $\theta = 60^o$
  - $\varphi = 90^o$
  - SNR = 20 dB

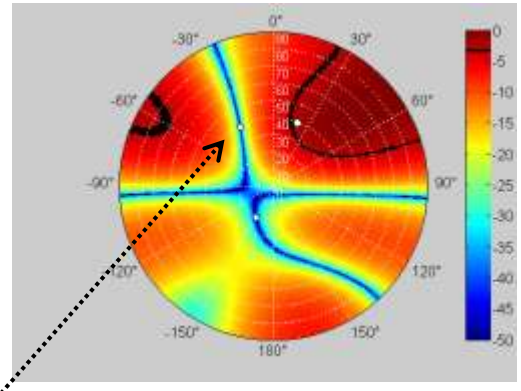
1 beam



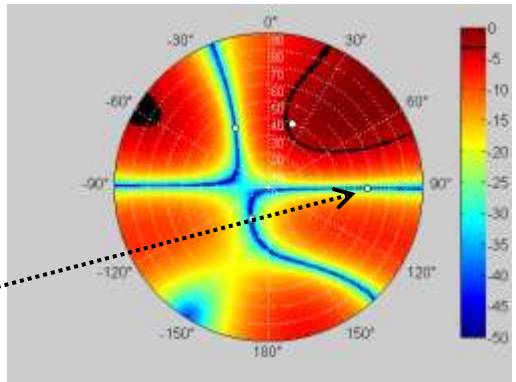
1 beam, 1 null



1 beam, 2 nulls



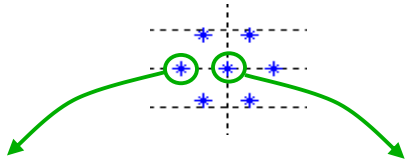
1 beam, 3 nulls



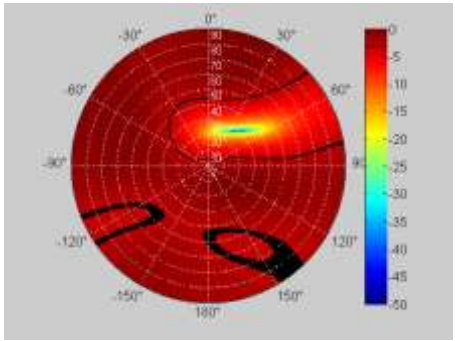
An AJ Simulation Tool : Null-steering using MVDR method

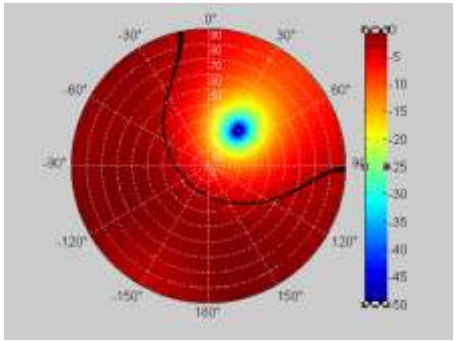
- Analyze radiation characteristics considering various scenarios

○ Reference antenna for the MVDR method



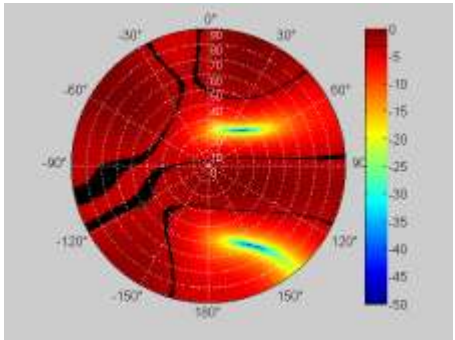
$\theta_{n1} = 30^o, \varphi_{n1} = 40^o$

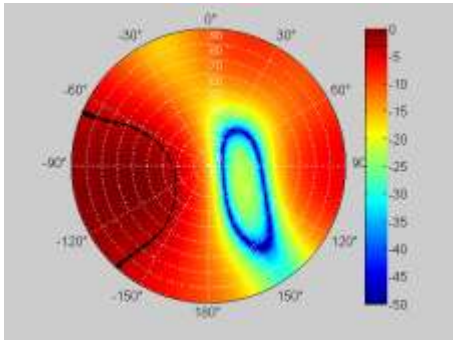




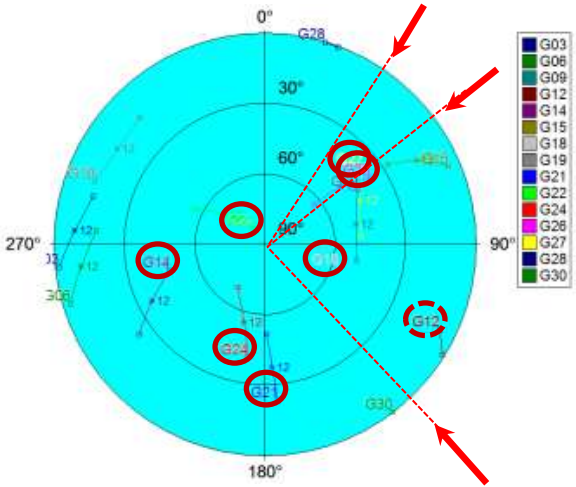
$\theta_{n1} = 30^o, \varphi_{n1} = 40^o$

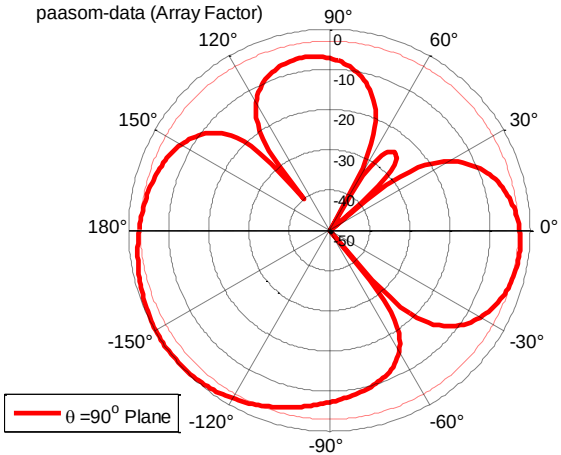
$\theta_{n2} = 60^o, \varphi_{n2} = 150^o$

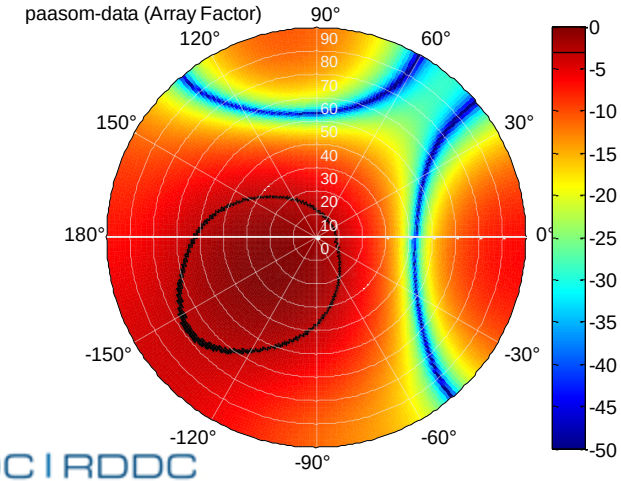


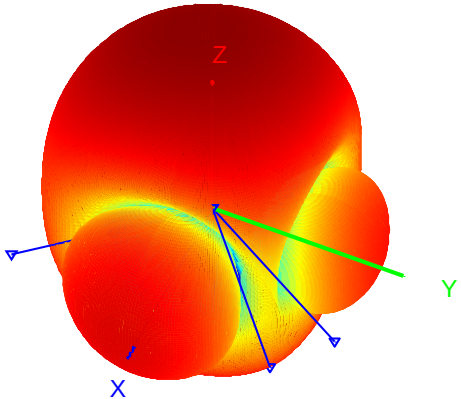


An AJ Simulation Tool: A Case Study









Outline

- Introduction
- CRPA project at DRDC Ottawa
- GAJET: An Evaluation Test bed for GPS Anti-Jam System
- An AJ simulation tool
- Concluding Remarks

Concluding Remarks

- Test bed for the study of technologies for protection of civilian and military GPS systems
- Each hardware and software component can be individually modified resulting in a customizable system that can be used to test improvements to any sub-systems
- Design new antenna elements and new antenna arrays
- Adaptive algorithm implementation for real time processing
- Development of direction finding algorithm
- Improvement of our phased array simulation tool (PAASoM)

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FOR CANADA'S DEFENCE AND SECURITY

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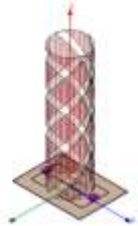
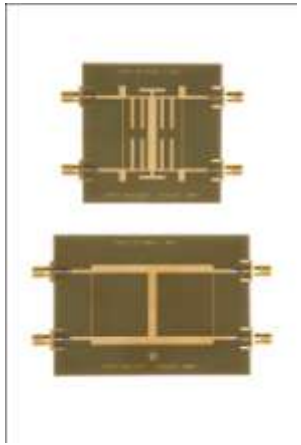
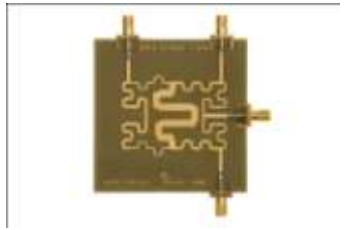
POUR LA DÉFENSE ET LA SÉCURITÉ DU CANADA

GAJET – Antennas : FPQHA

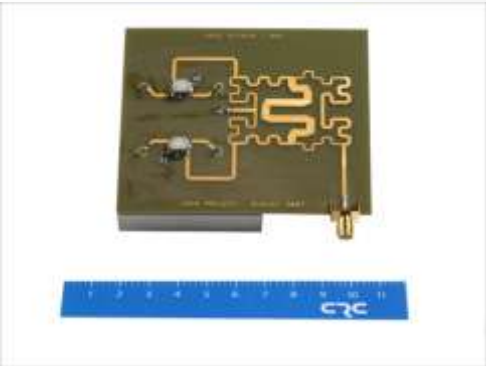


- Feeding system miniaturisation (RMC)

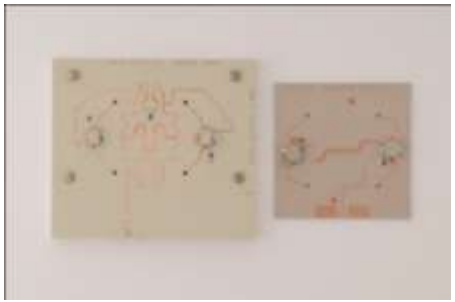




3,5'' x 3''



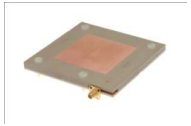
3'' x 2,5''

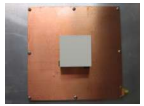


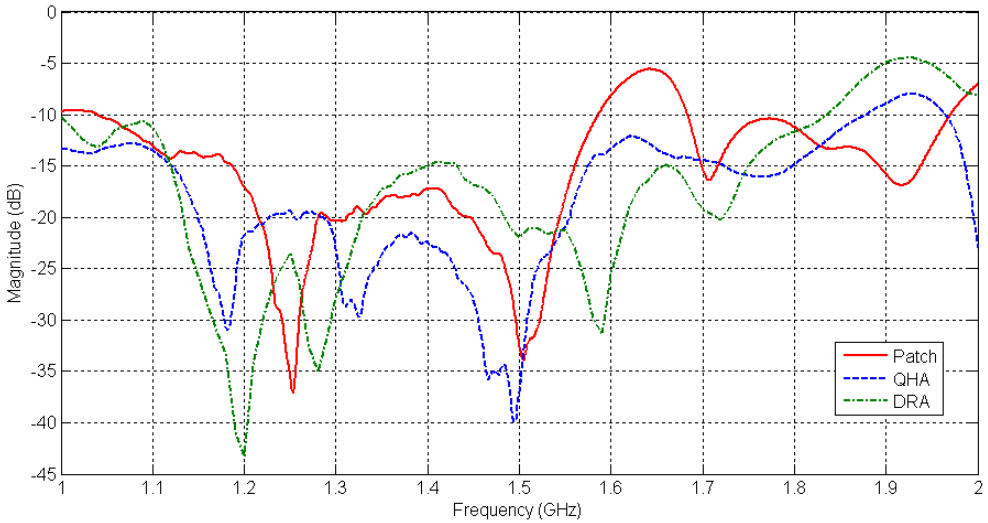
2'' x 2''

3mm x 3mm

GAJET – Antennas : Reflection Coefficient

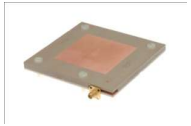


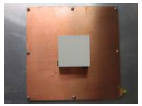


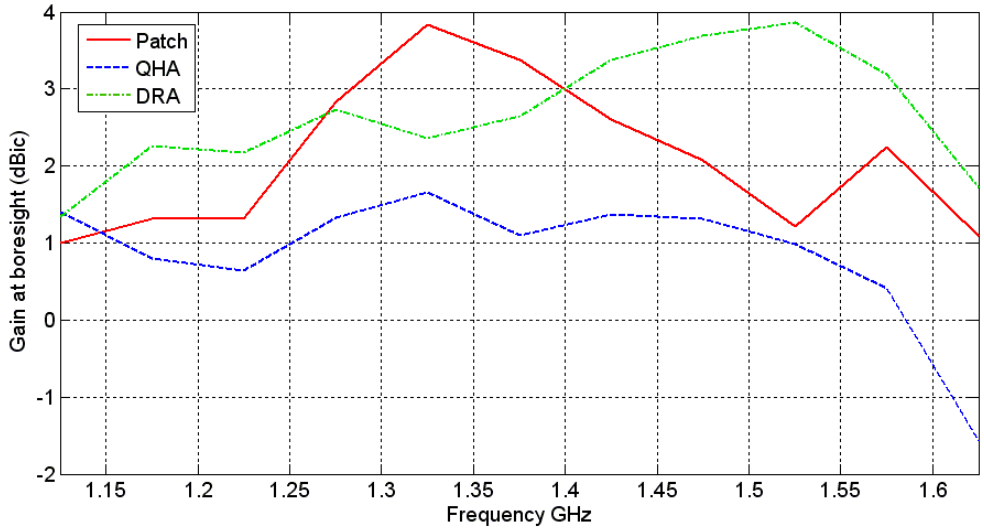


-RL (dB)	Fmin (GHz)	Fmax (GHz)	L5	L2	L1
Patch	1.04	1.59	-14	-24	-12
QHA	< 1.0	1.88	-29	-20	-15
DRA	< 1.0	1.84	-32	-28	-28

GAJET – Antennas : Gain

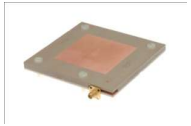


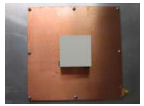


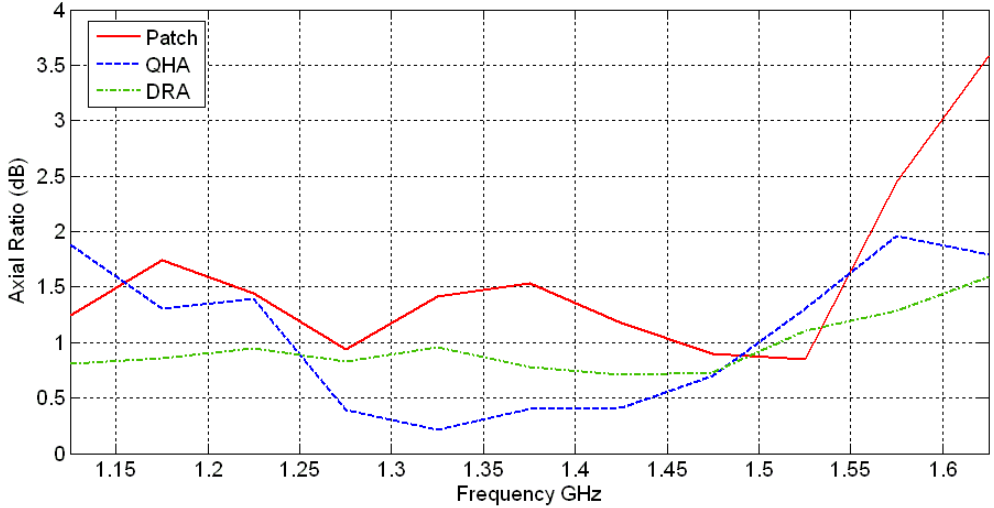


Gain dBic)	Min*	Max*	L5	L2	L1
Patch	1.0	3.8	1.3	1.3	2.25
QHA	-1.6	1.65	0.8	0.65	0.41
DRA	1.35	3.9	2.25	2.2	3.2

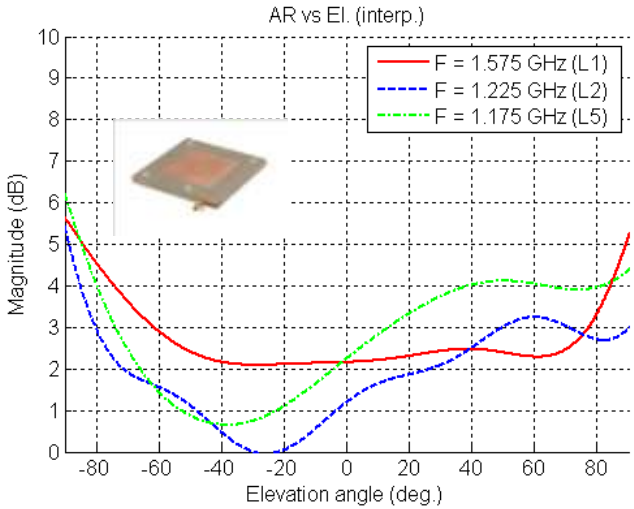
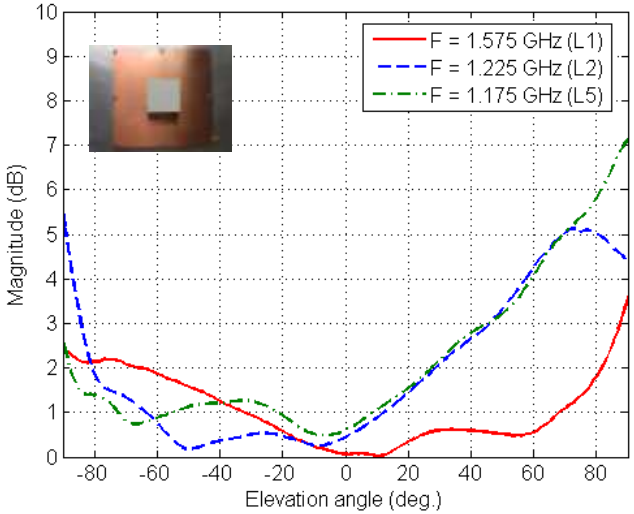
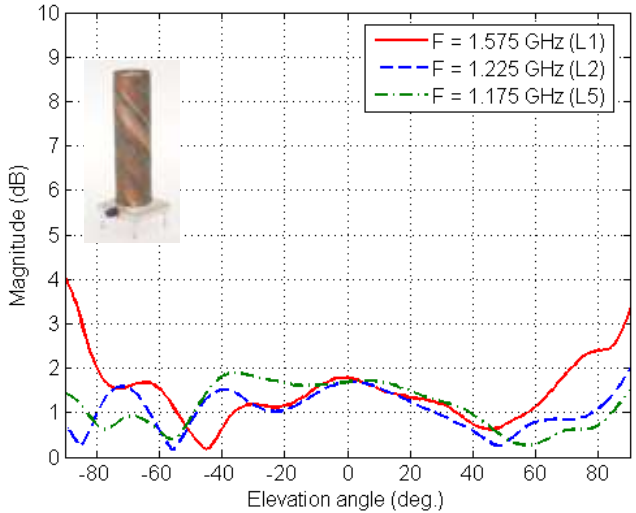
GAJET – Antennas : Axial Ratio







AR (dB)	Max*	L5	L2	L1
Patch	3.5	1.75	1.45	2.5
QHA	2.0	1.3	1.4	2.0
DRA	1.6	0.85	0.95	1.3

* Within GNSS frequency band (1.15-1.61 GHz)

GAJET – Antennas : Axial Ratio vs Elevation