LightSquared Can Complement GPS

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JAVAD GNSS

Presentation to PNT Board

November 9, 2011

Crowne Plaza Hotel, Alexandria, VA

Topics

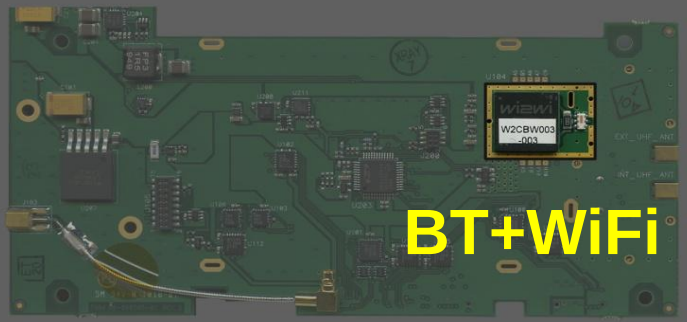
- Root of the technical problem
- Technical details of our solution
- Four ways to prove it works
- Interference analysis features
- Technology road map

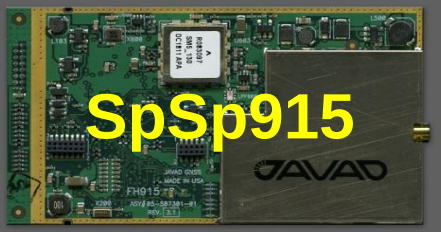
Positioning

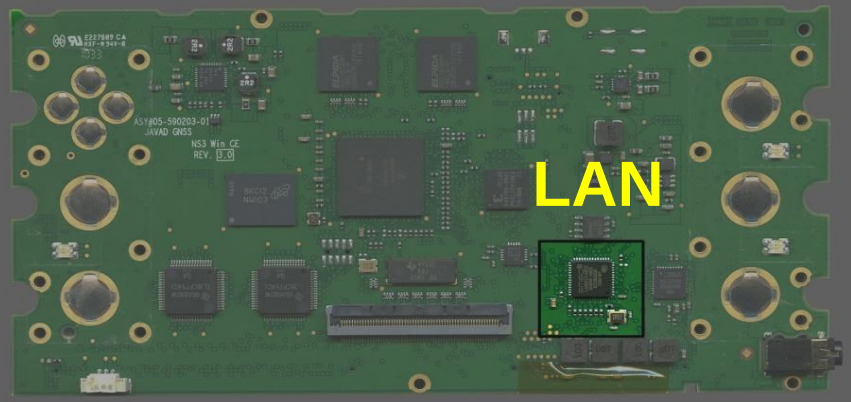
Navigation

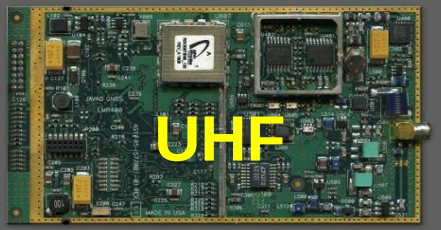
Timing

Communication









PNT

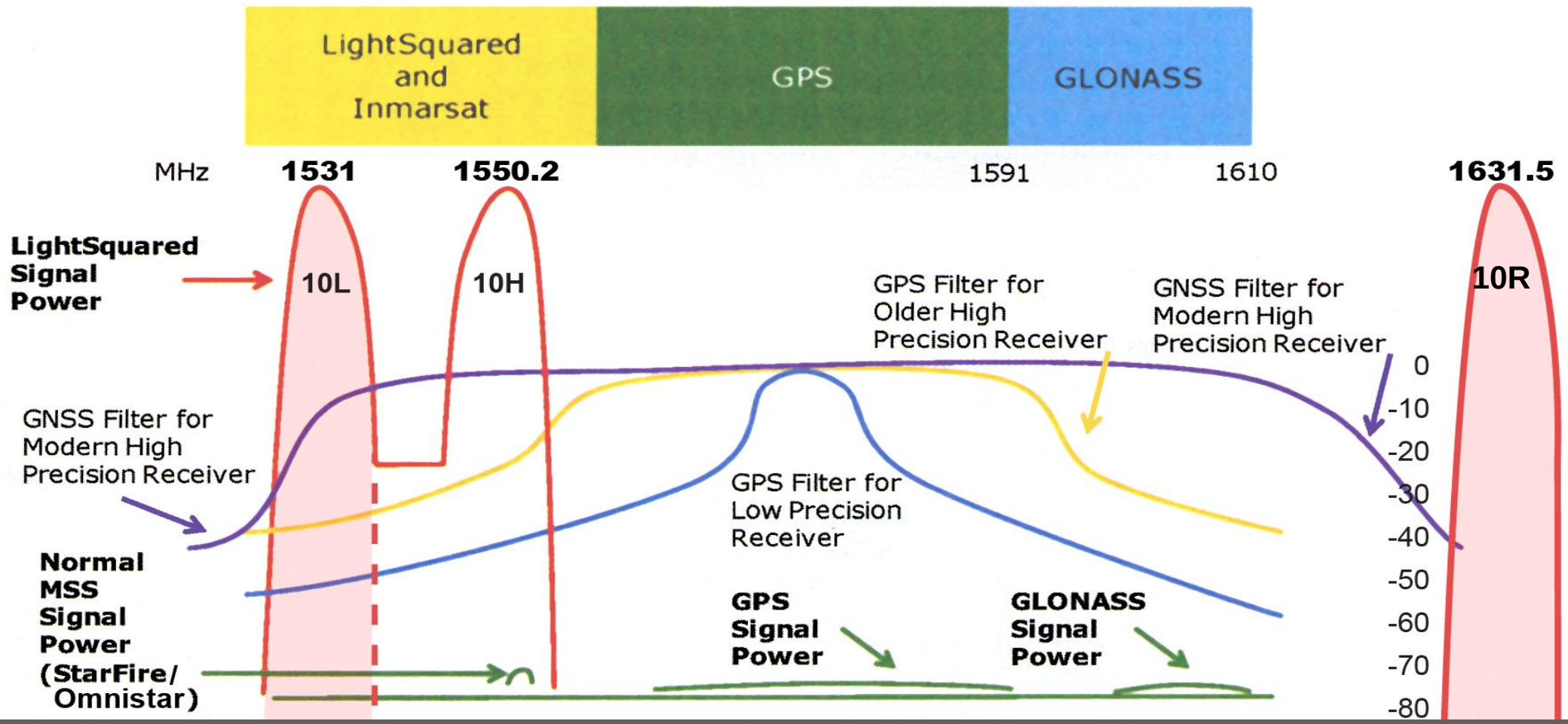
Communication


JAVAD


LightSquared

Technical Problem

Cast of Characters



DB Chart		
10db	10	
20db	100	
30db	1,000	
40db	10,000	
50db	100,000	
60db	1,000,000	1M
70db	10,000,000	
80db	100,000,000	
90db	1,000,000,000	1B
100db	10,000,000,000	
110db	100,000,000,000	
120db	1,000,000,000,000	1T
130db	10,000,000,000,000	
140db	100,000,000,000,000	

LSQ Power:

1/10 mw -10 dBm

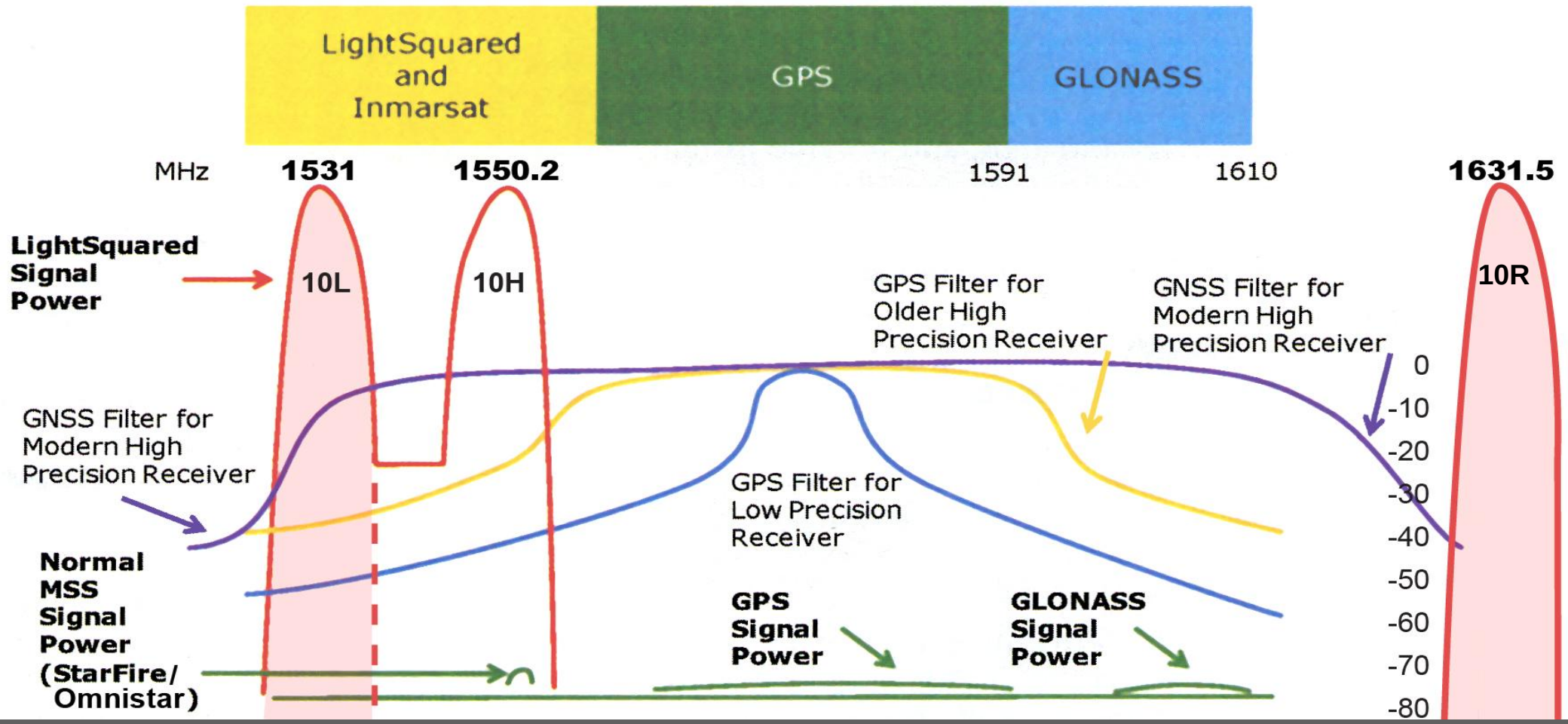
GPS Military & C/A Power:

1/20,000,000,000,000 mw -133 dBm

GPS Encrypted P-Code Power:

1/200,000,000,000,000 mw - 143 dBm

LSQ Is 20 Trillion Times Stronger (133 dB)

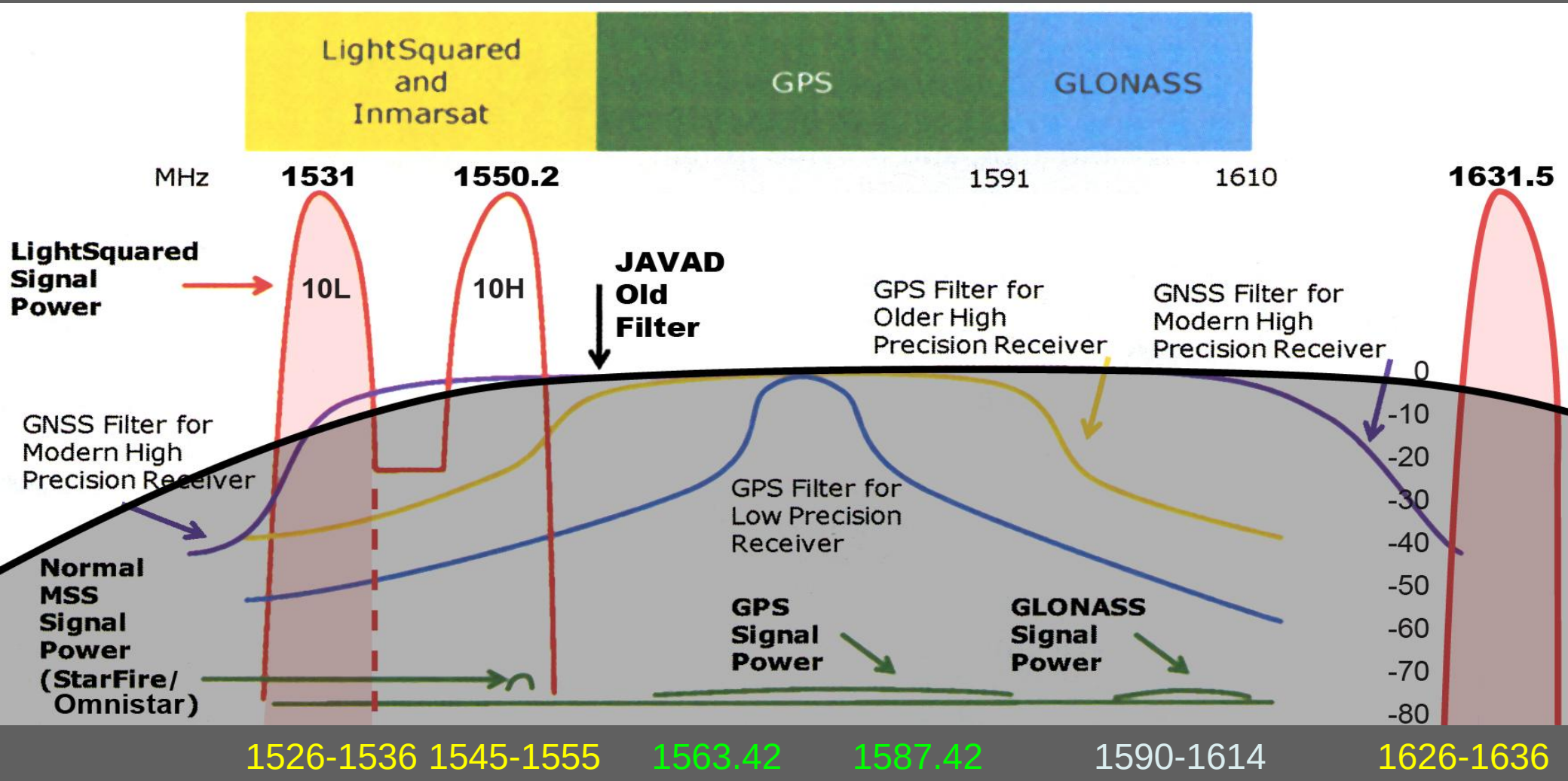


1526-1536 1545-1555 1563.42 1587.42 1590-1614 1626-1636

-10 dBm -143 or -133 dBm -10 dBm

0.1 mW 0.000,000,000,000,002 mW

GPS Receivers with No Protection



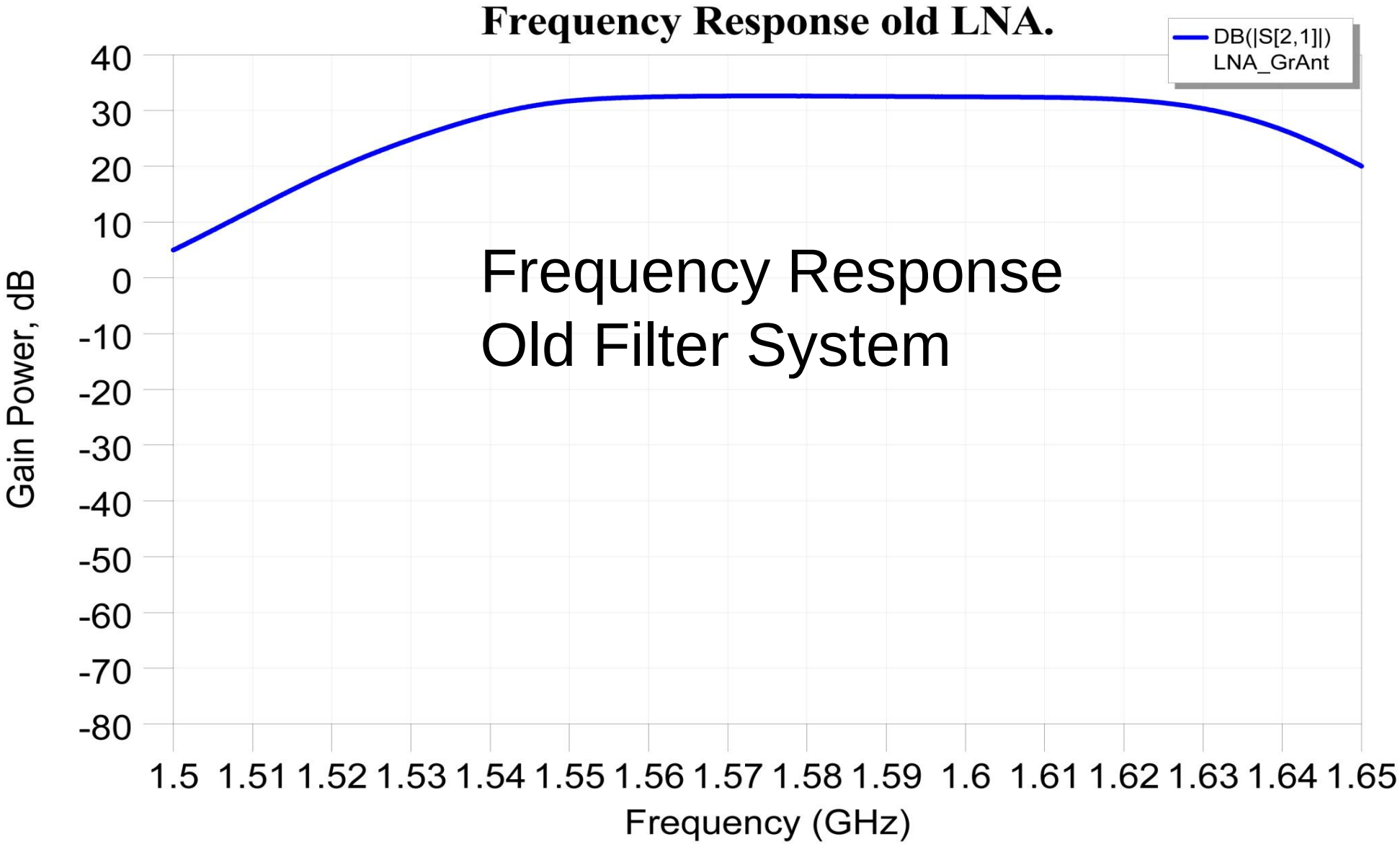
Even small interference can hurt Defenseless GPS Receivers

Tests

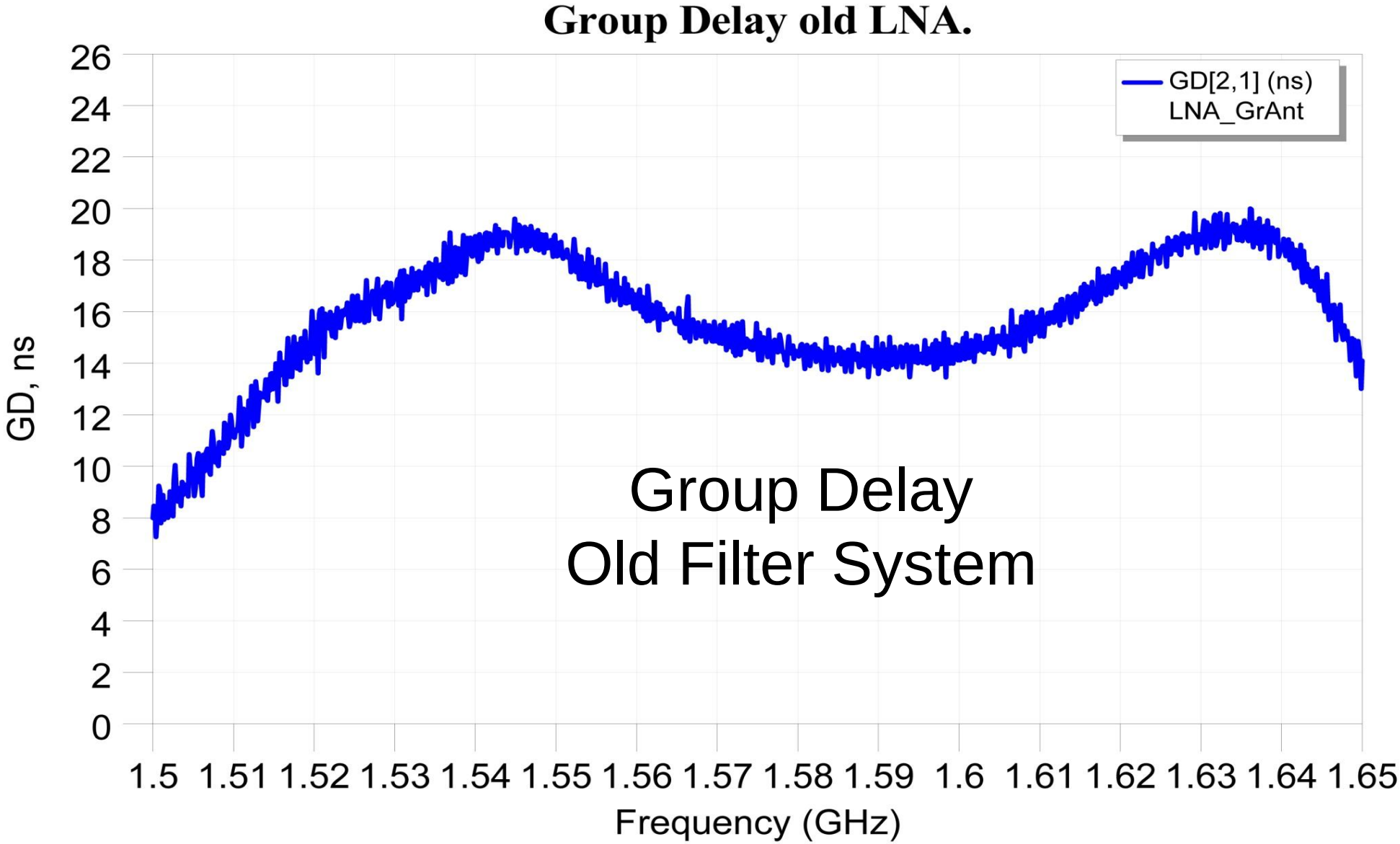
1. Component analysis and simulation
2. Sine wave in-circuit measurements
3. Anechoic chamber (more than NTIA)
4. The ultimate test

1.Component analysis and simulation

(Old Filter System)



Frequency Response
Old Filter System

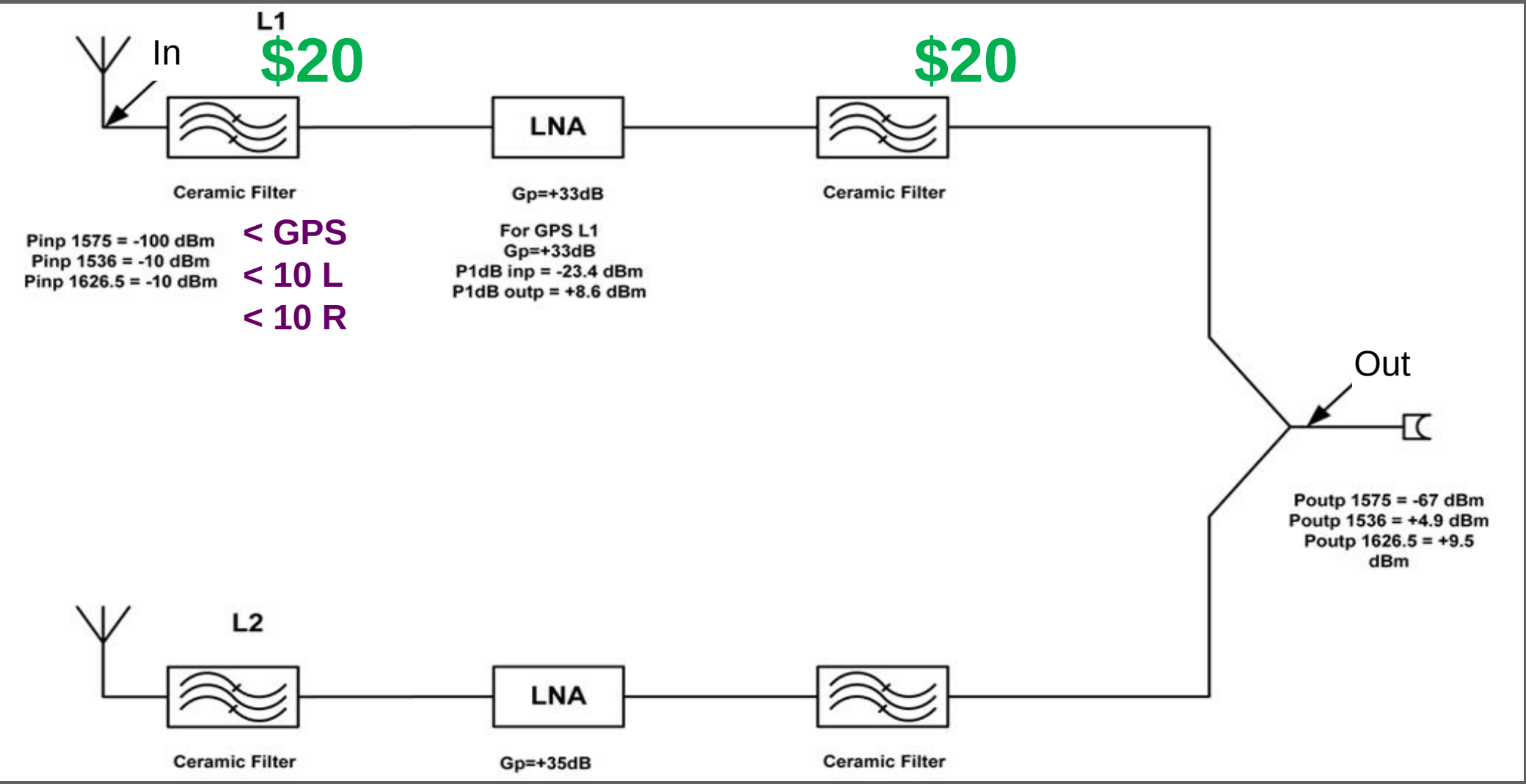


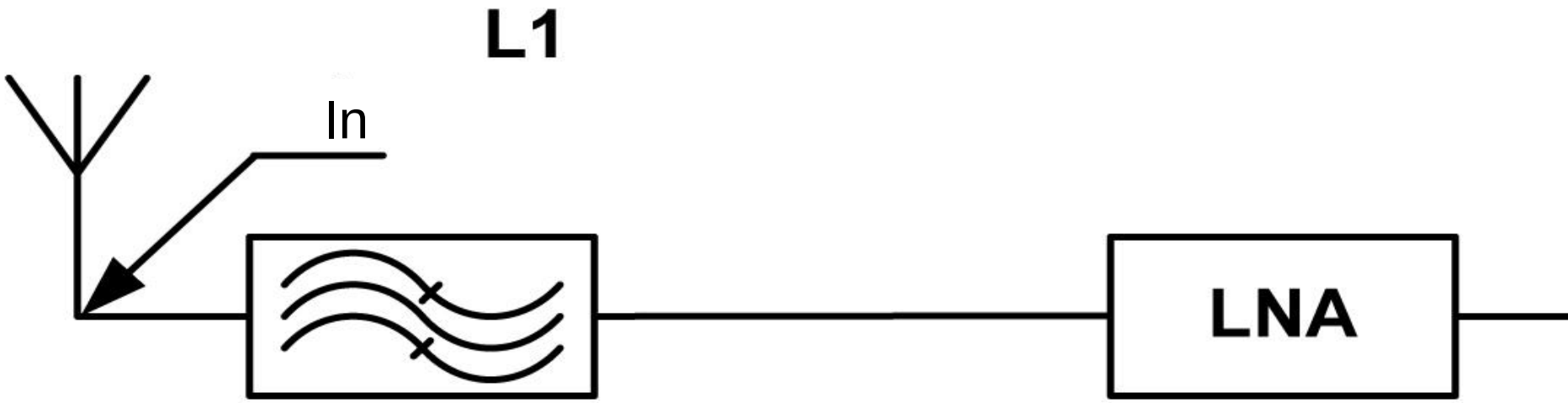
Group Delay
Old Filter System

2. Sine Wave In-Circuit Measurements

(Old Filter System)

Old Filter System



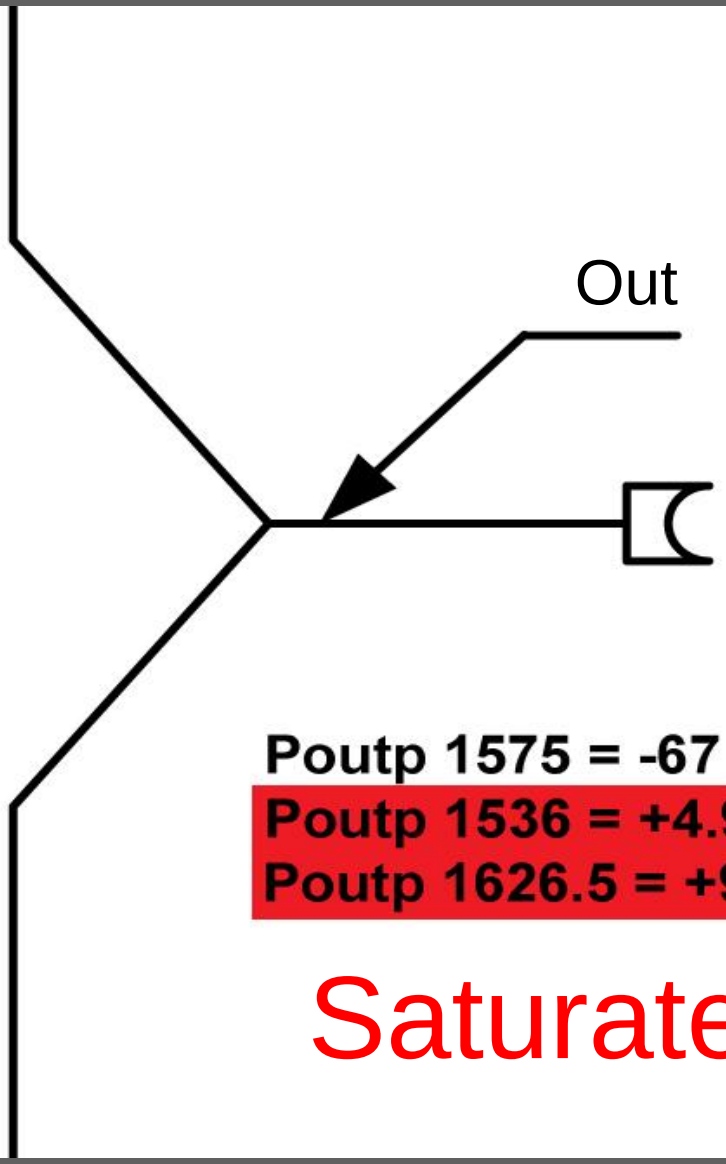


Ceramic Filter

Gp=+33dB

Pinp 1575 = -100 dBm < GPS
Pinp 1536 = -10 dBm < 10 L
Pinp 1626.5 = -10 dBm < 10 R

For GPS L1
Gp=+33dB
P1dB inp = -23.4 dBm
P1dB outp = +8.6 dBm



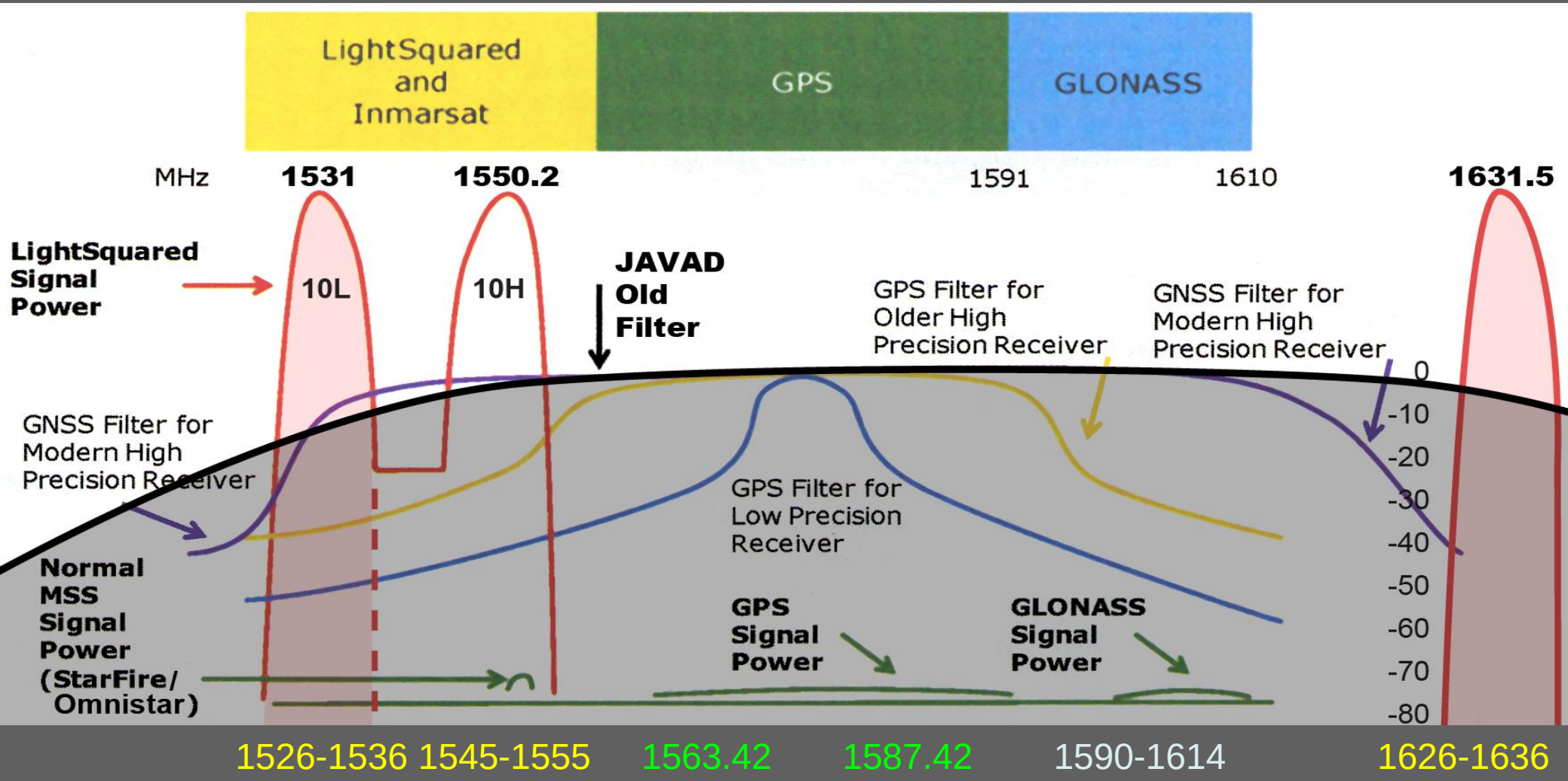
Poutp 1575 = -67 dBm **< GPS**

Poutp 1536 = +4.9 dBm **< 10 L**

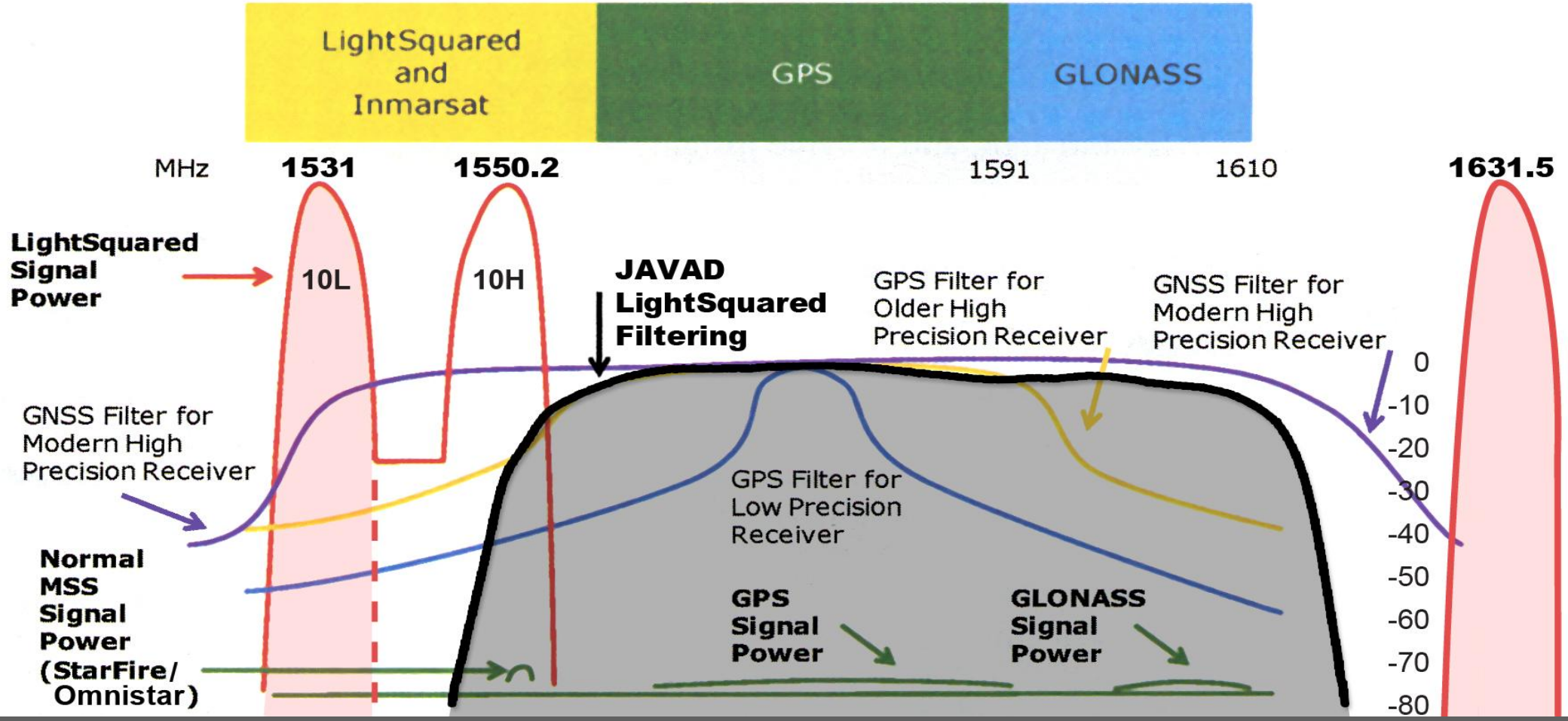
Poutp 1626.5 = +9.5 dBm **< 10 R**

Saturated!

Solution


LightSquared and Inmarsat
GPS
GLONASS
MHz
1531
1550.2
1591
1610
1631.5
LightSquared Signal Power
10L
10H
JAVAD Old Filter
GPS Filter for Older High Precision Receiver
GNSS Filter for Modern High Precision Receiver
GNSS Filter for Modern High Precision Receiver
GPS Filter for Low Precision Receiver
Normal MSS Signal Power (StarFire/ Omnistar)
GPS Signal Power
GLONASS Signal Power
0
-10
-20
-30
-40
-50
-60
-70
-80
1526-1536
1545-1555
1563.42
1587.42
1590-1614
1626-1636

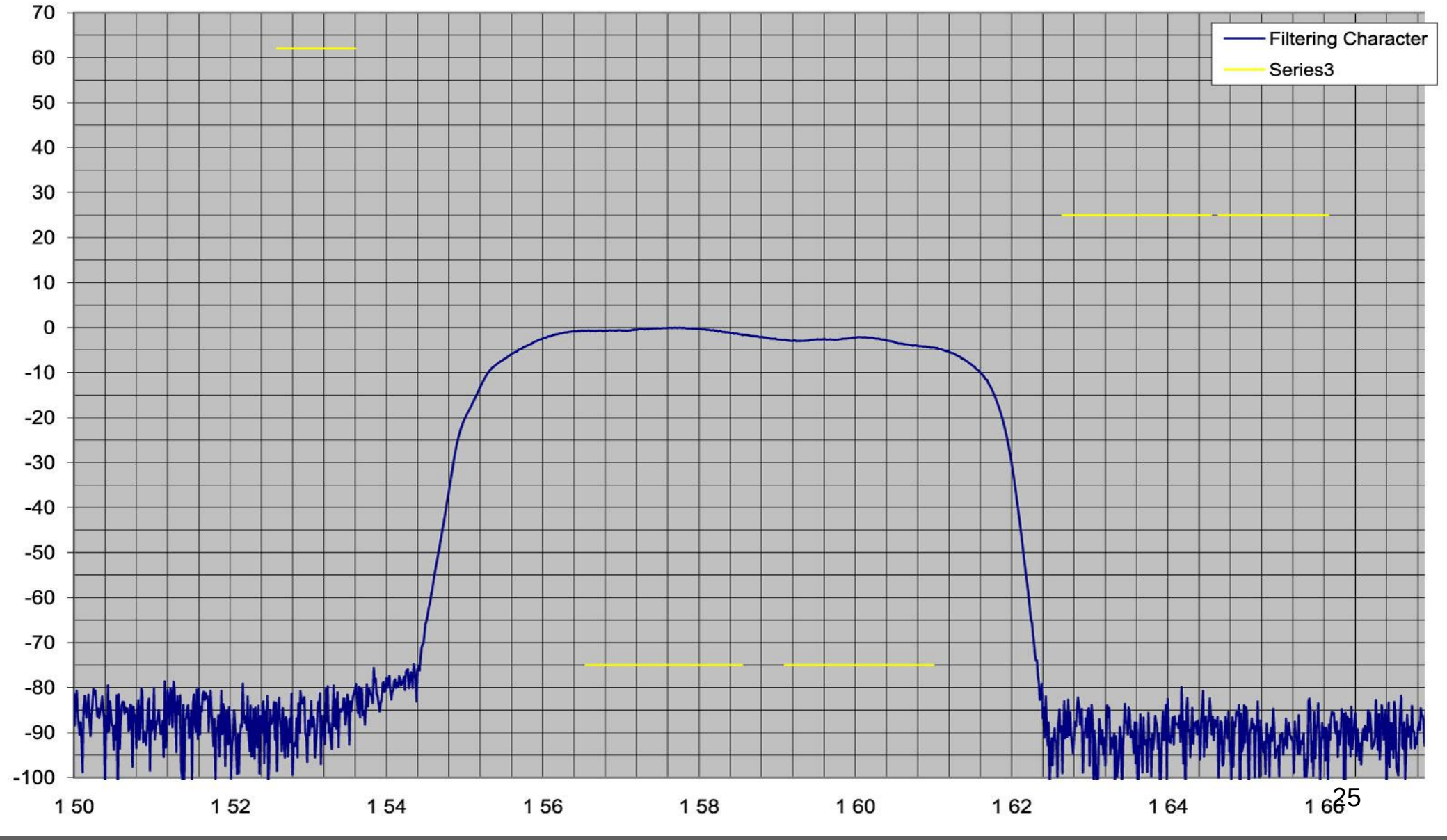
New Filter System



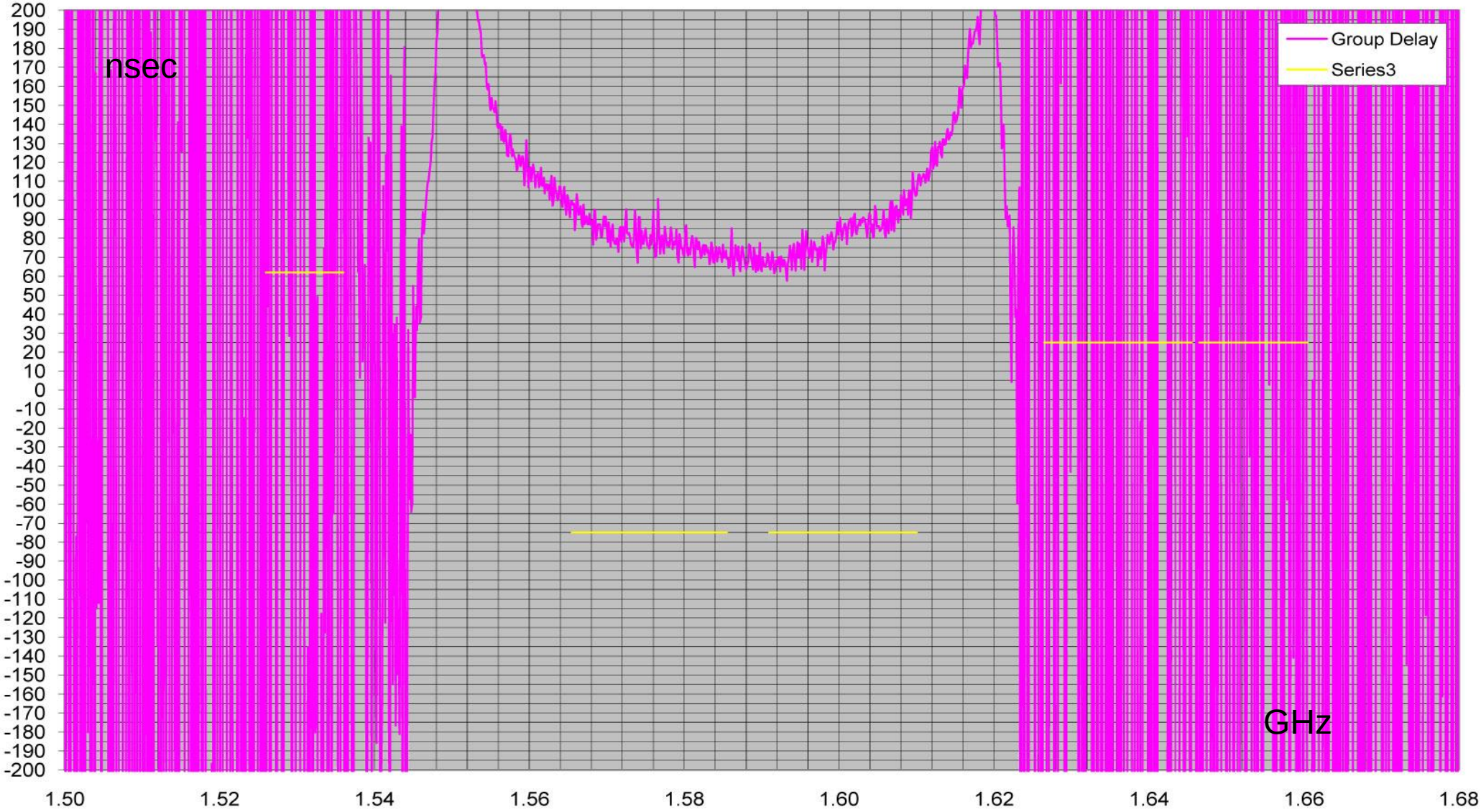
1.Component analysis and simulation

(New Filter System)

Frequency Response of the New Filter System

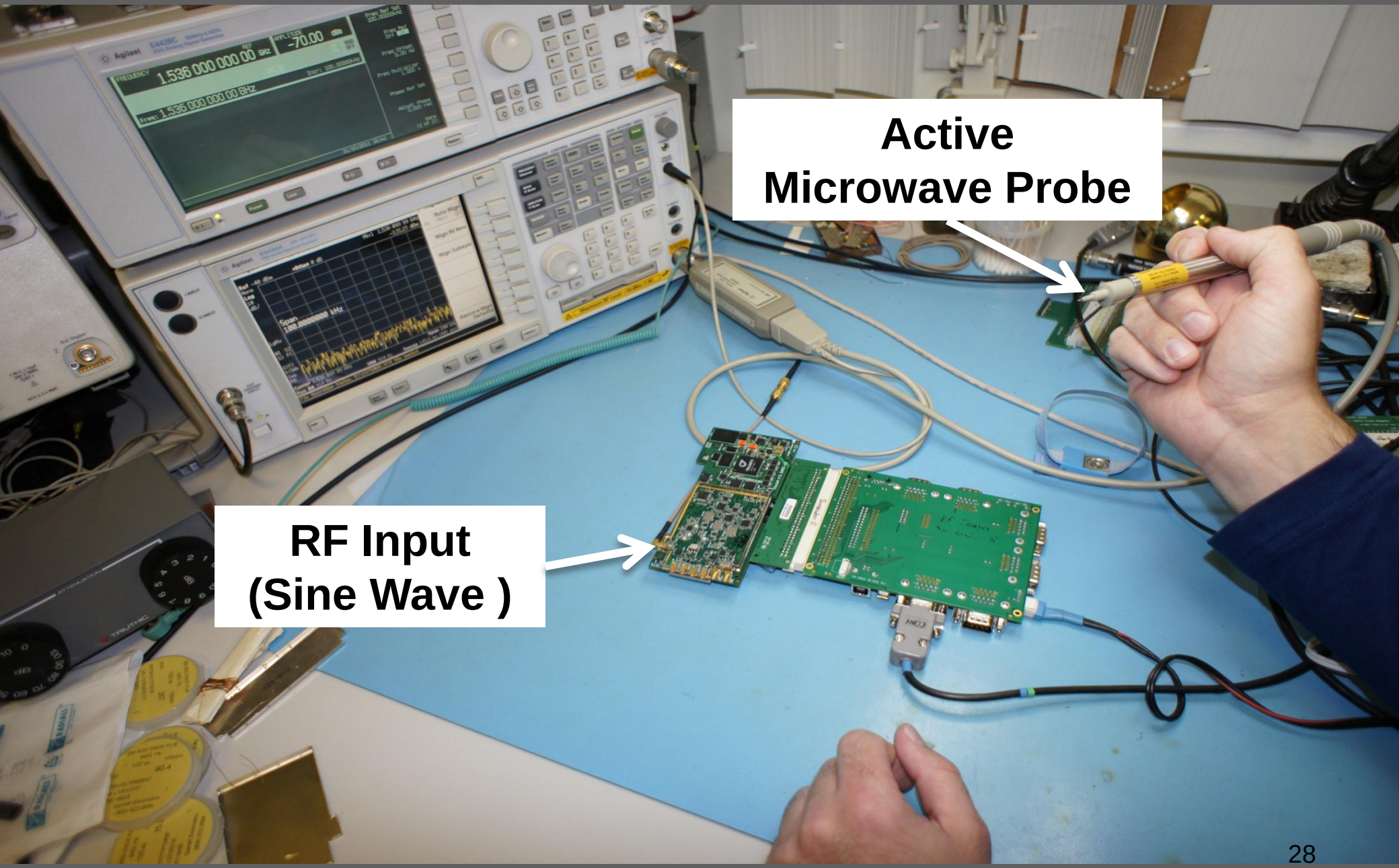


Group of the New Filter System

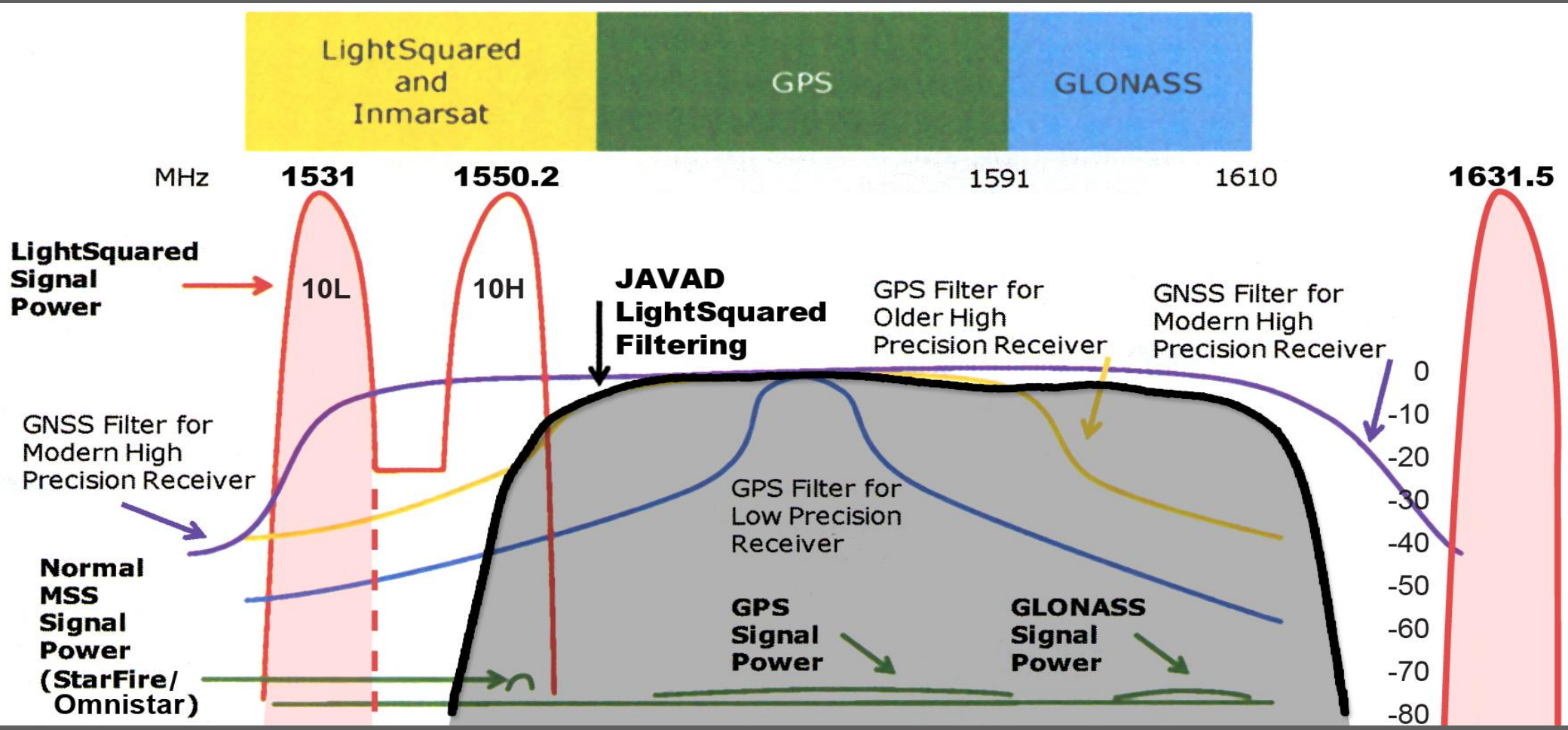


2. Sine Wave In-Circuit Measurements

(New Filter System)


Active
Microwave Probe
RF Input
(Sine Wave)

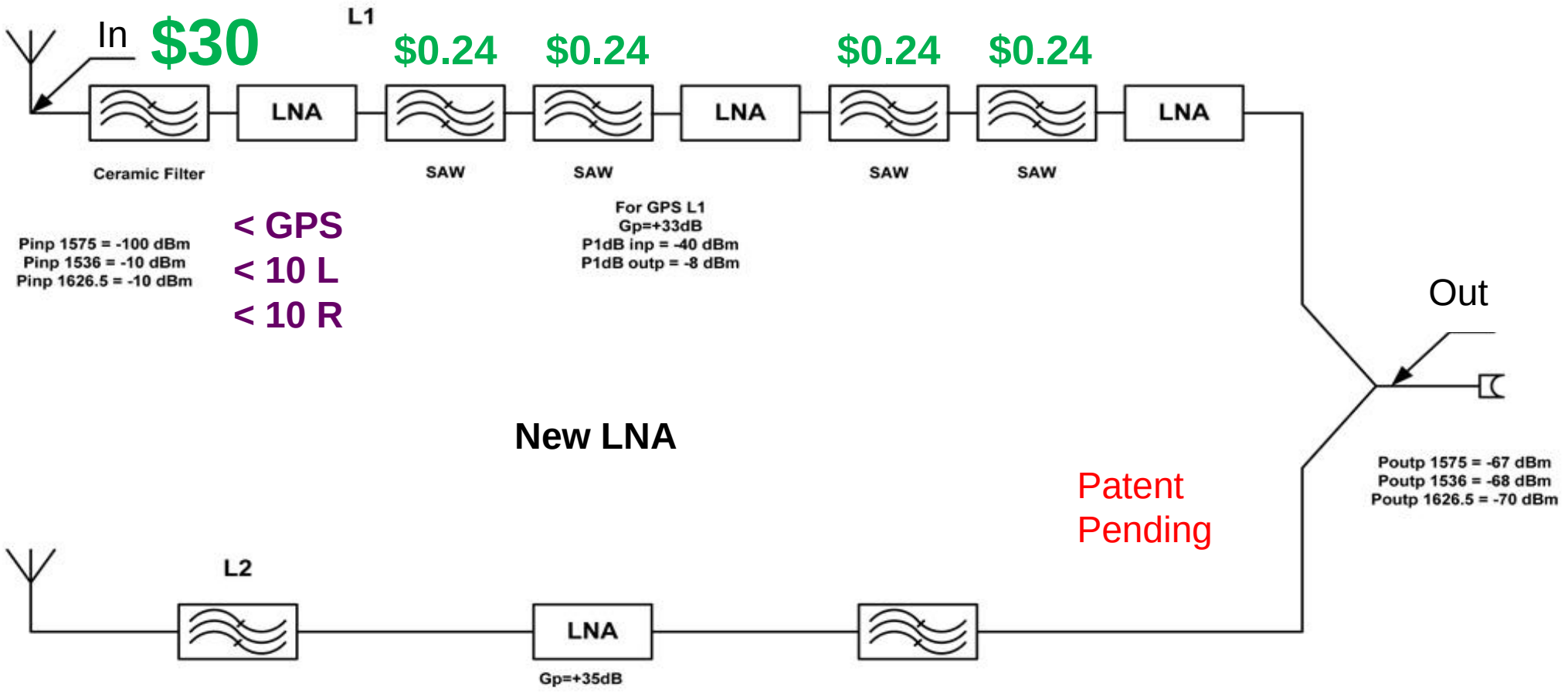
Tested for Closest Edges of 10L and 10R to GPS



1526-1536 1545-1555 1563.42 1587.42 1590-1614 1626-1636

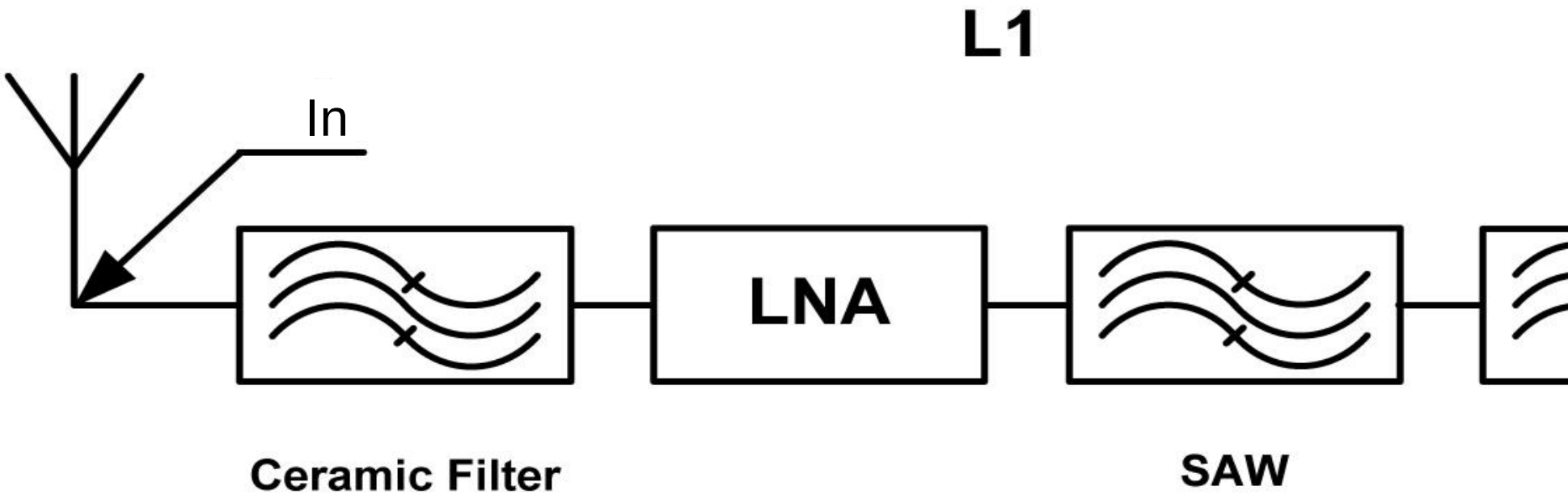
^^^^ ^^^^

New Filter System

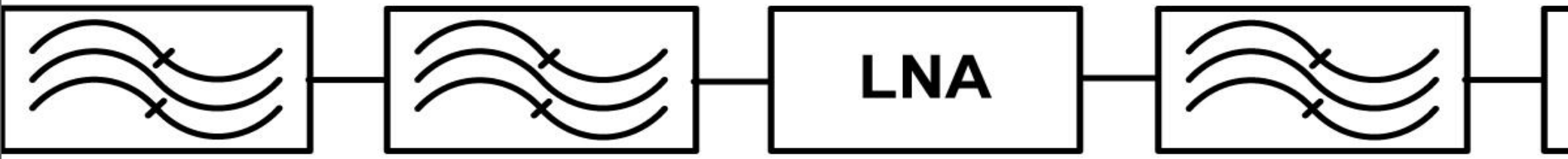


Innovation saved $10 too

Six SAW Filters

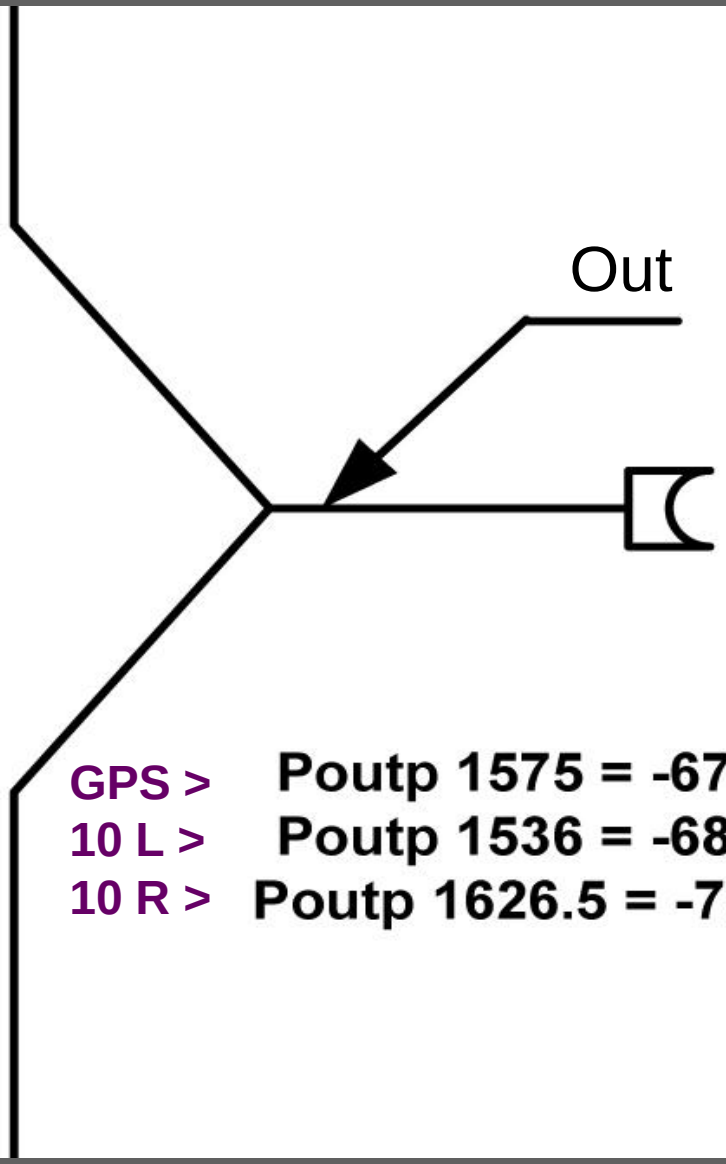


GPS > Pinp 1575 = -100 dBm
10 L > Pinp 1536 = -10 dBm +10 dBm P1dB
10 R > Pinp 1626.5 = -10 dBm +8 dBm P1dB



SAW SAW SAW

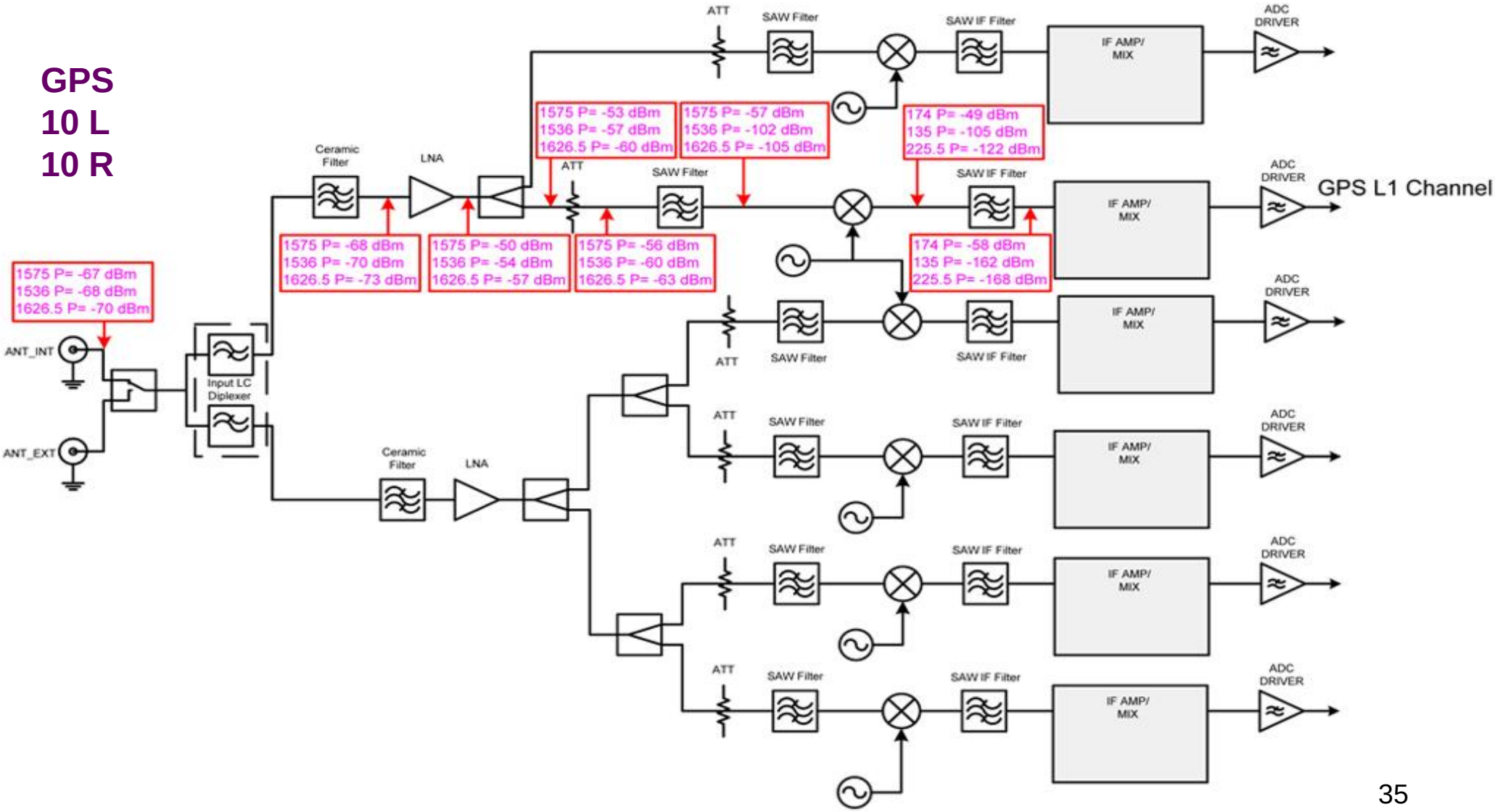
For GPS L1
Gp=+33dB
P1dB inp = -40 dBm
P1dB outp = -8 dBm

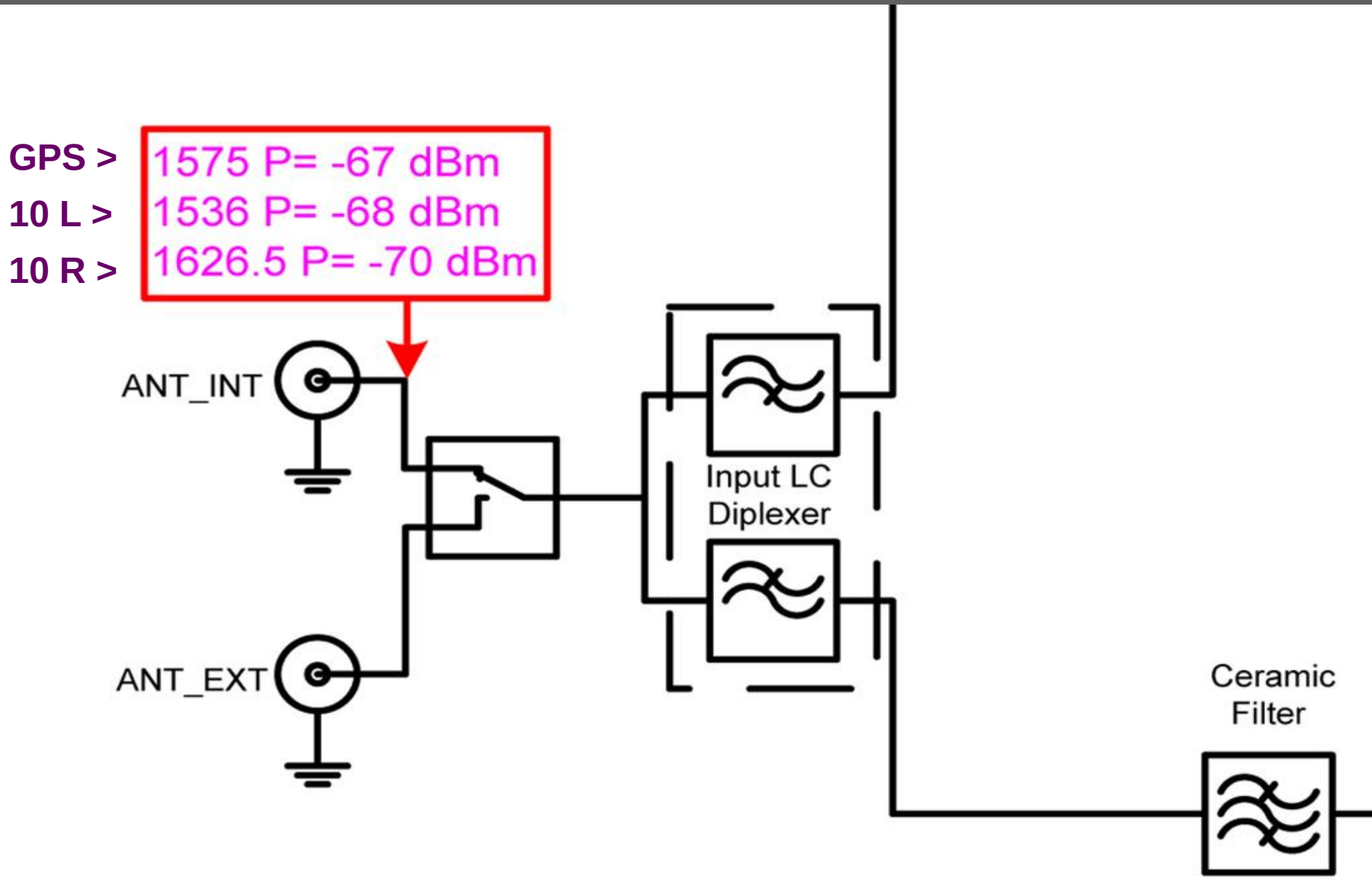


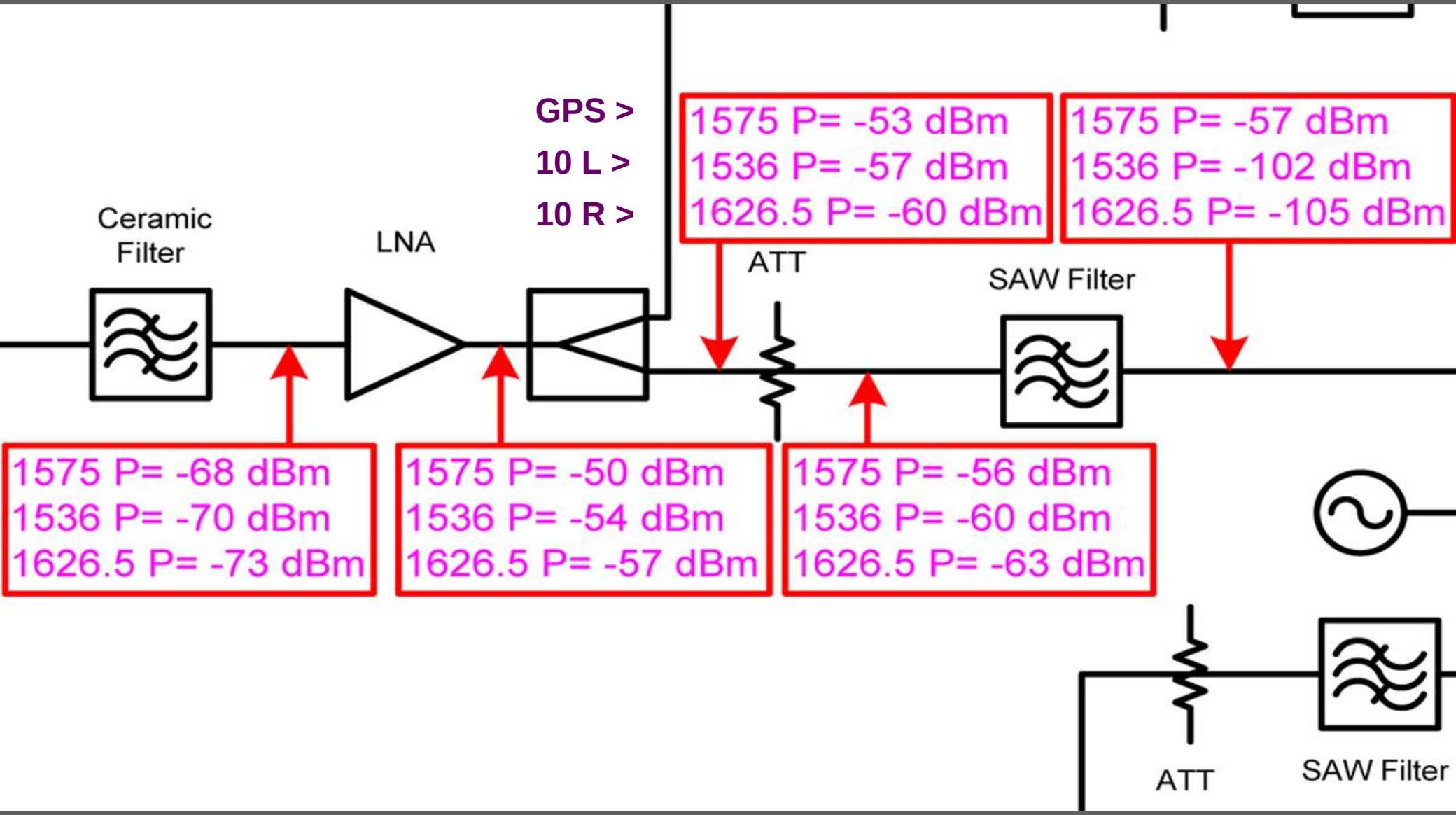
GPS > **Poutp 1575 = -67 dBm**
10 L > **Poutp 1536 = -68 dBm**
10 R > **Poutp 1626.5 = -70 dBm**

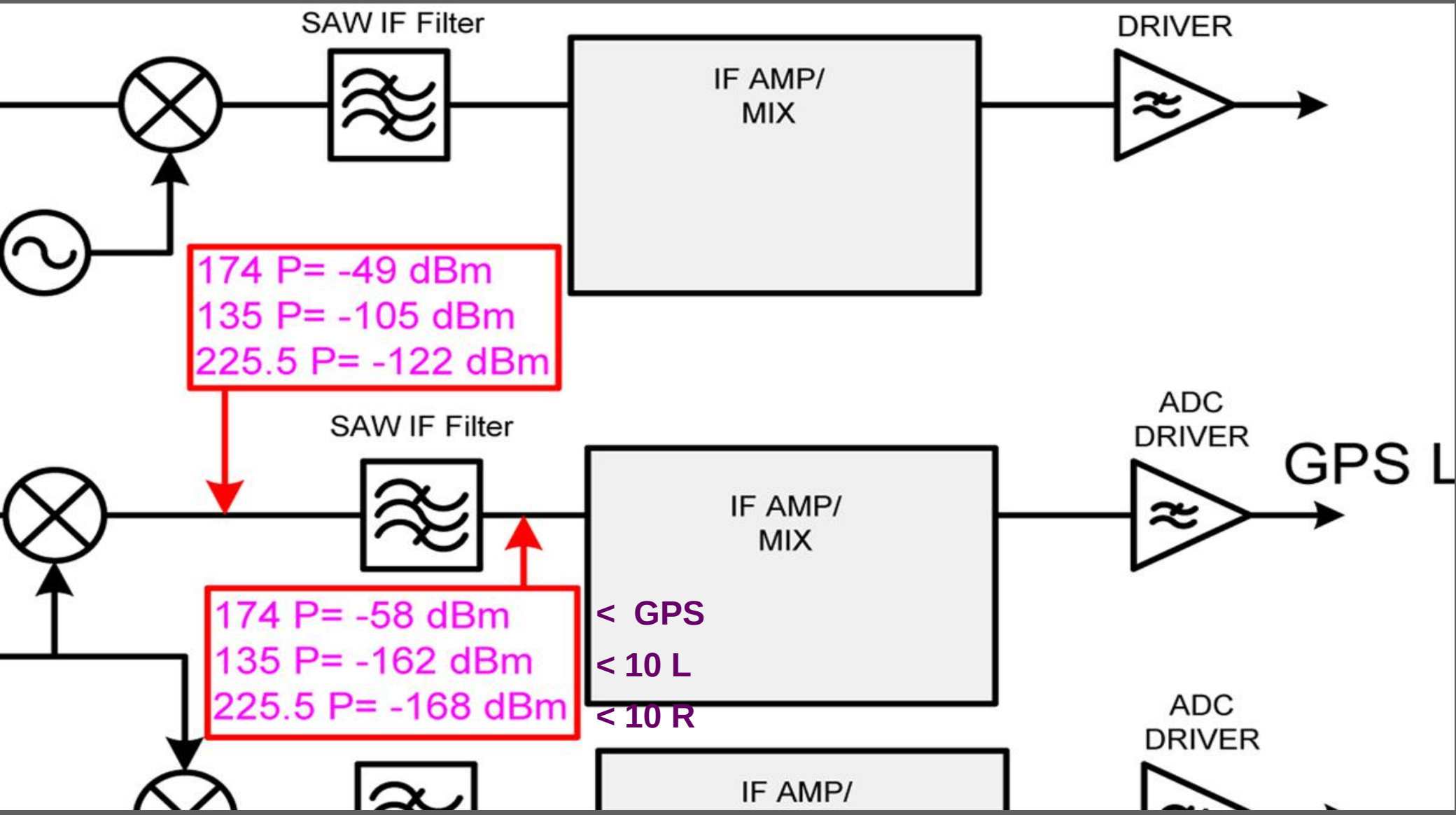
The RF Chain

GPS
10 L
10 R




GPS >
10 L >
10 R >
1575 P= -67 dBm
1536 P= -68 dBm
1626.5 P= -70 dBm
ANT_INT
ANT_EXT
Input LC
Diplexer
Ceramic
Filter


GPS >
10 L >
10 R >
1575 P= -53 dBm
1536 P= -57 dBm
1626.5 P= -60 dBm
1575 P= -57 dBm
1536 P= -102 dBm
1626.5 P= -105 dBm
Ceramic Filter
LNA
ATT
SAW Filter
1575 P= -68 dBm
1536 P= -70 dBm
1626.5 P= -73 dBm
1575 P= -50 dBm
1536 P= -54 dBm
1626.5 P= -57 dBm
1575 P= -56 dBm
1536 P= -60 dBm
1626.5 P= -63 dBm
ATT
SAW Filter


SAW IF Filter
DRIVER
IF AMP/
MIX
174 P= -49 dBm
135 P= -105 dBm
225.5 P= -122 dBm
SAW IF Filter
ADC
DRIVER
GPS L
IF AMP/
MIX
174 P= -58 dBm
135 P= -162 dBm
225.5 P= -168 dBm
< GPS
< 10 L
< 10 R
ADC
DRIVER
IF AMP/

Overall Results

Relative to GPS+Noise					
FRQ	L1	10L	10R	L1-10L	L1-10R
Ant Filter input	-100	-10	-10	-90	-90
Ant Filter output	-67	-68	-70	1	3
Ceramic Filter	-68	-70	-73	2	5
LNA	-50	-54	-57	4	7
splitter	-53	-57	-60	4	7
Attenuator	-56	-60	-63	4	7
SAW filter	-57	-102	-105	45	48
Mixer	-49	-105	-122	56	73
SAW Filter	-58	-162	-168	104	110
Overall Gain:				194	200

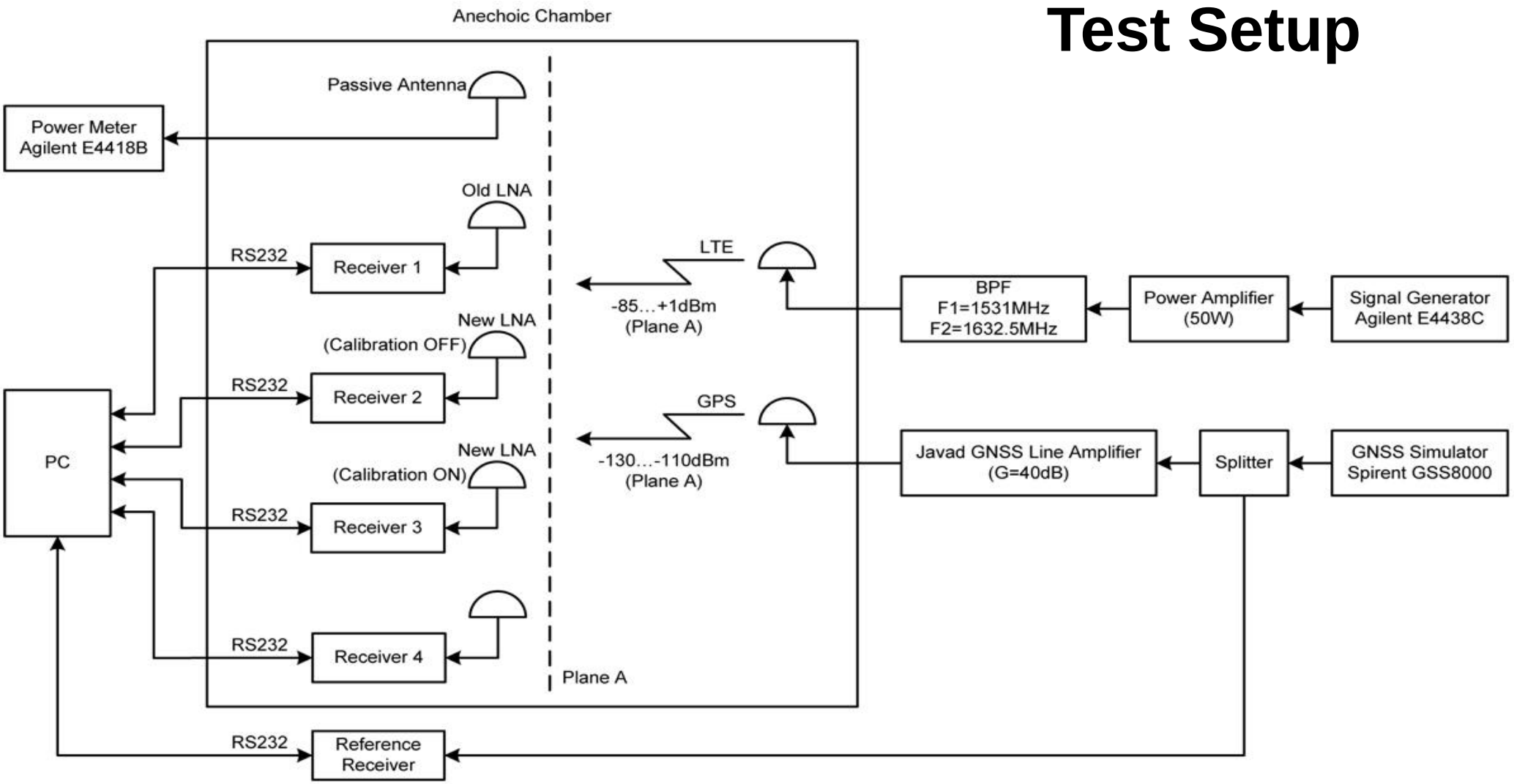
Relative to C/A and Military P-codes					
FRQ	L1	10L	10R	L1-10L	L1-10R
Ant Filter input	-133	-10	-10	-123	-123
Ant Filter output	-100	-68	-70	-32	-30
Ceramic Filter	-101	-70	-73	-31	-28
LNA	-83	-54	-57	-29	-26
splitter	-86	-57	-60	-29	-26
Attenuator	-89	-60	-63	-29	-26
SAW filter	-90	-102	-105	12	15
Mixer	-82	-105	-122	23	40
SAW Filter	-91	-162	-168	71	77

Relative to Encrypted P-codes					
FRQ	P	10L	10R	P-10L	P-10R
Ant Filter input	-143	-10	-10	-133	-133
Ant Filter output	-110	-68	-70	-42	-40
Ceramic Filter	-111	-70	-73	-41	-38
LNA	-93	-54	-57	-39	-36
splitter	-96	-57	-60	-39	-36
Attenuator	-99	-60	-63	-39	-36
SAW filter	-100	-102	-105	2	5
Mixer	-92	-105	-122	13	30
SAW Filter	-101	-162	-168	61	67

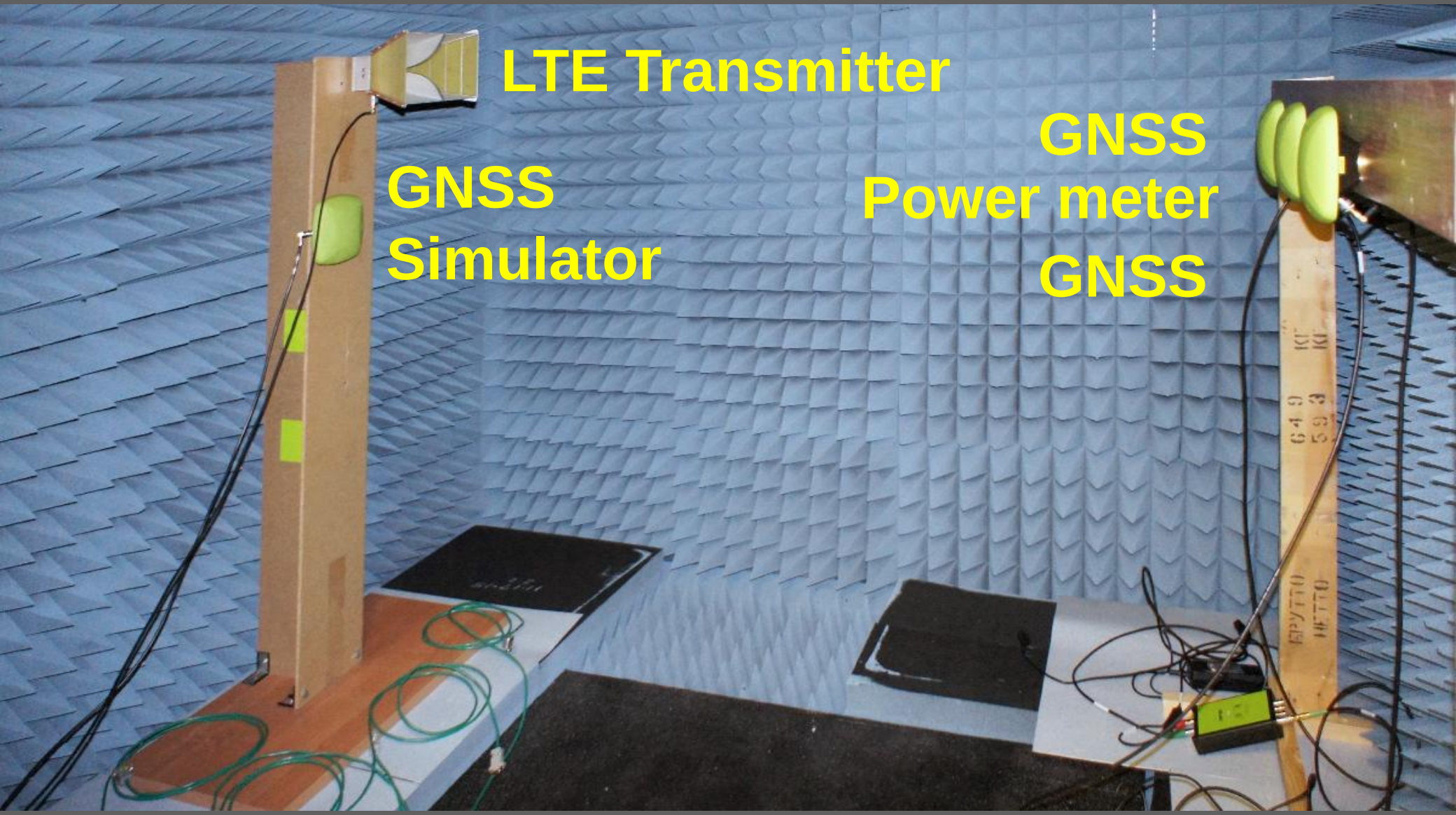
3. Anechoic Chamber System Test

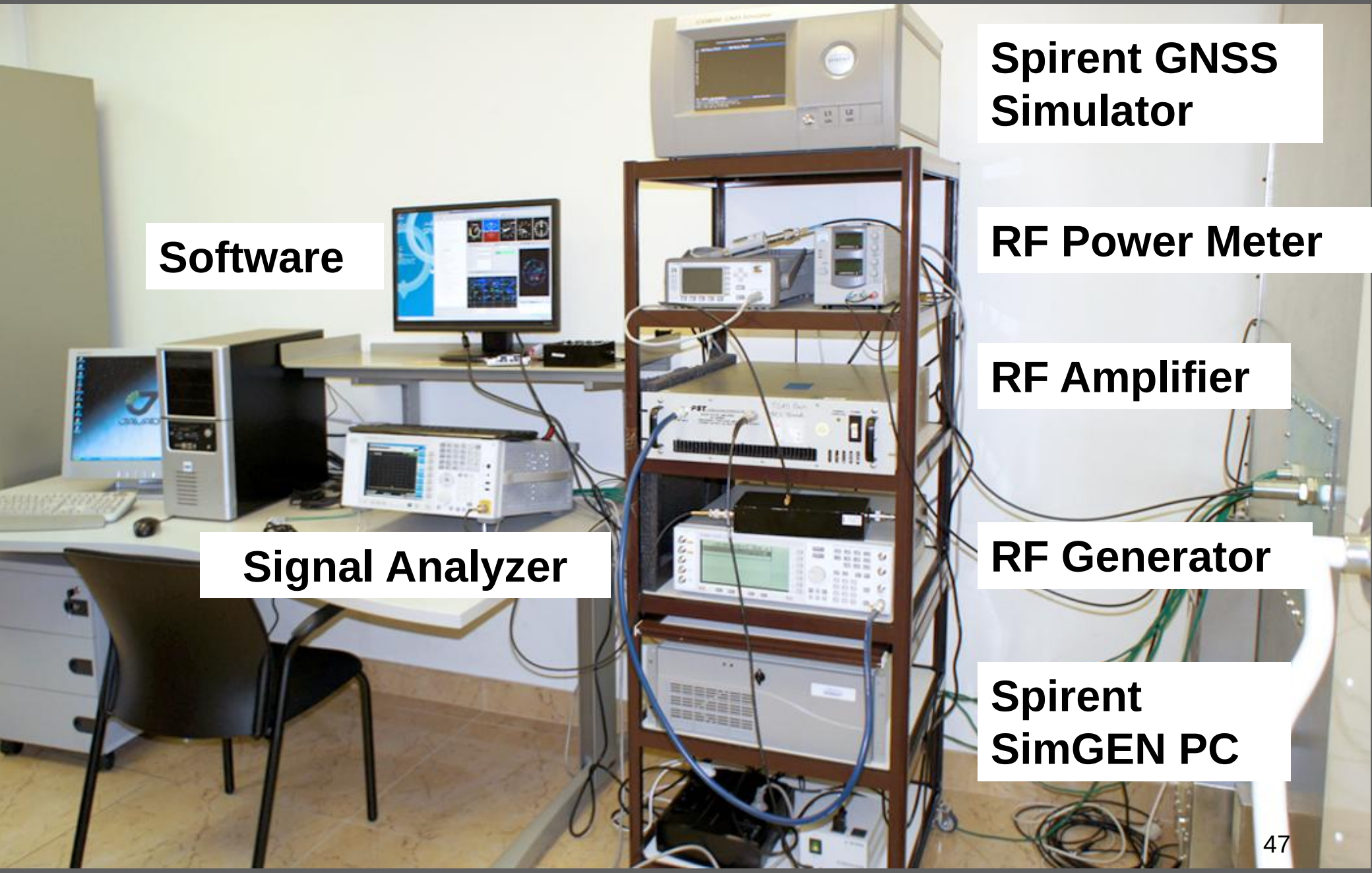
(New Filter System)

Anechoic Chamber Test Setup

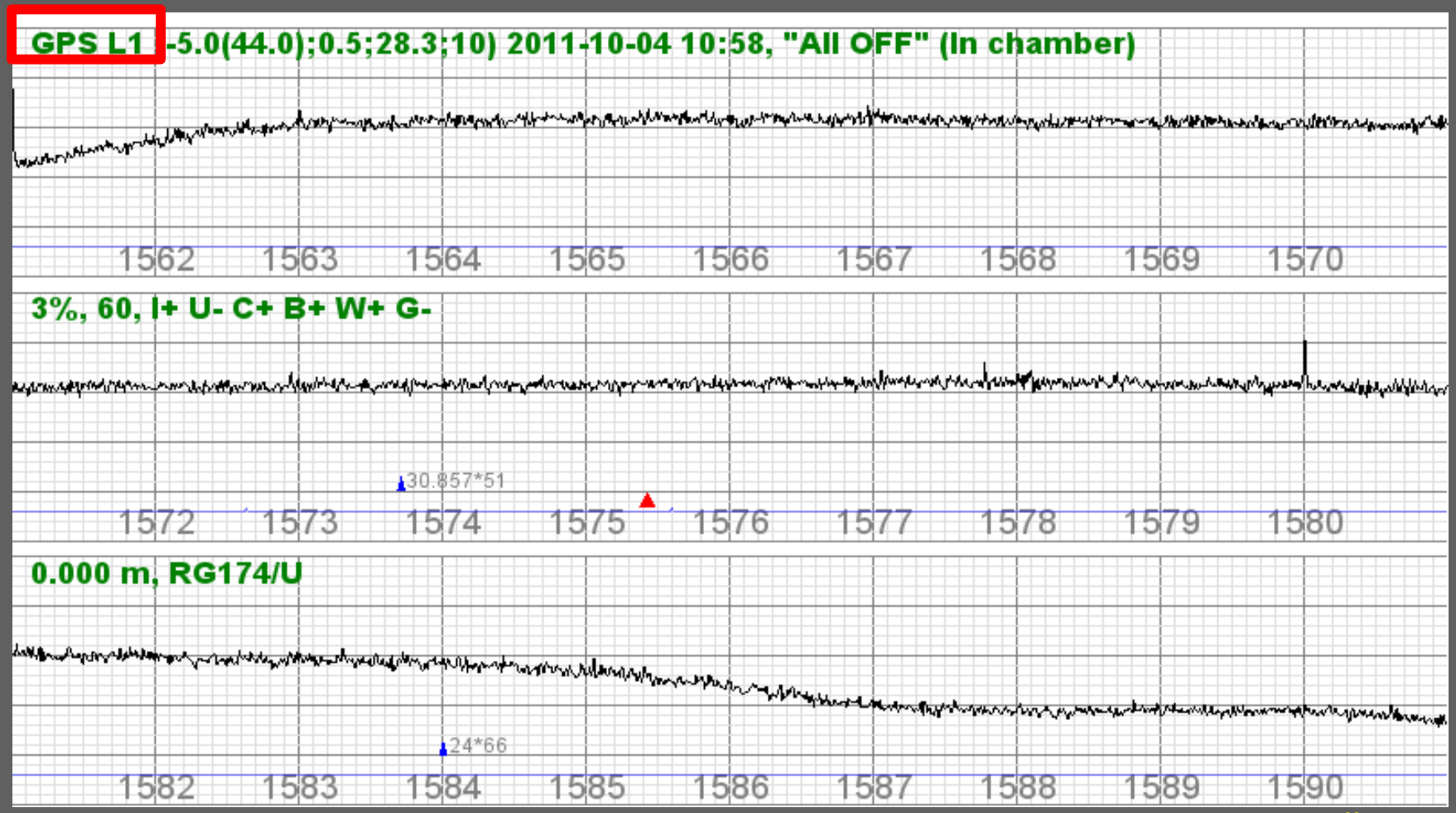



Power meter
GNSS
GNSS


LTE Transmitter
GNSS
Simulator
GNSS
Power meter
GNSS

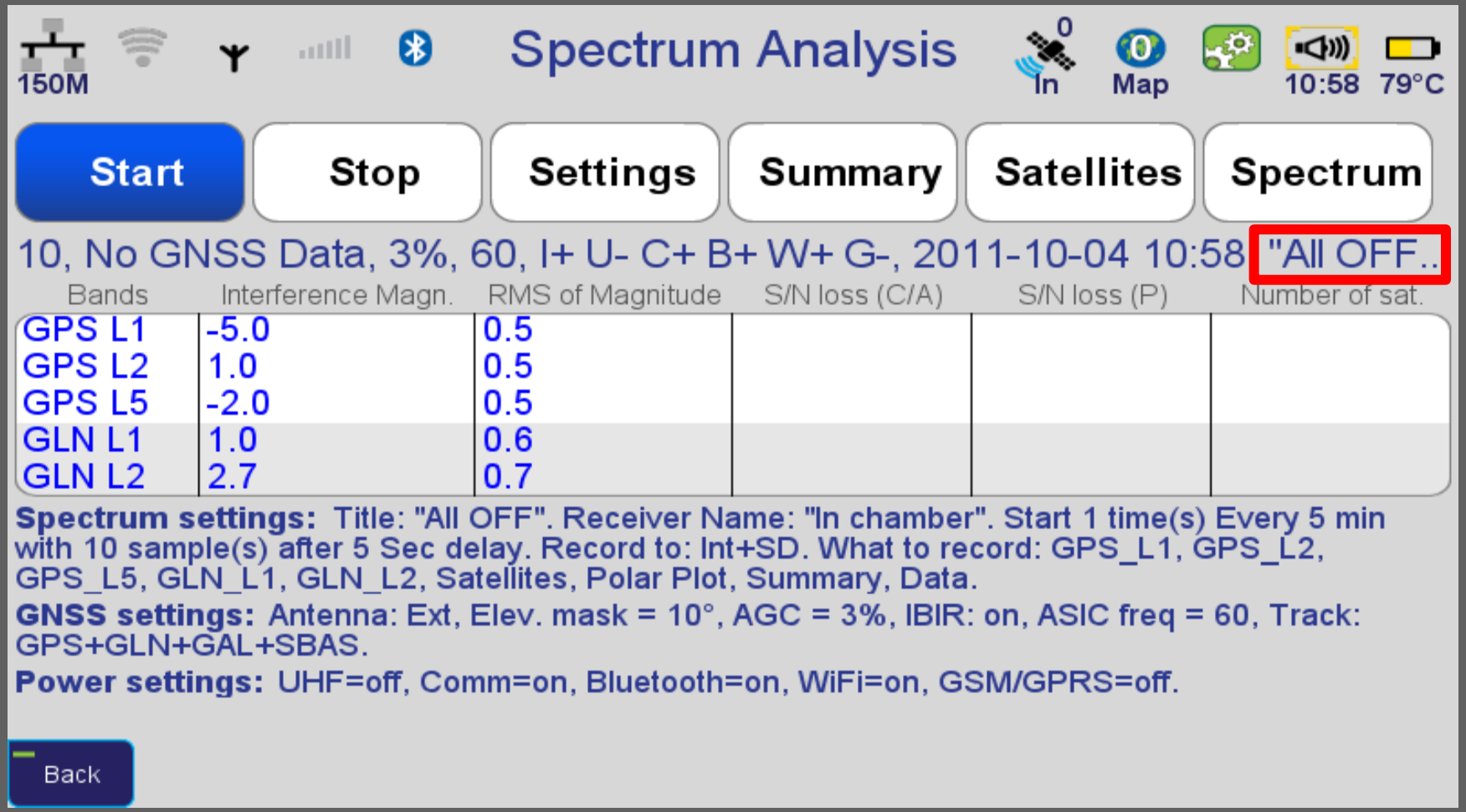

Spirent GNSS Simulator
Software
RF Power Meter
RF Amplifier
Signal Analyzer
RF Generator
Spirent SimGEN PC

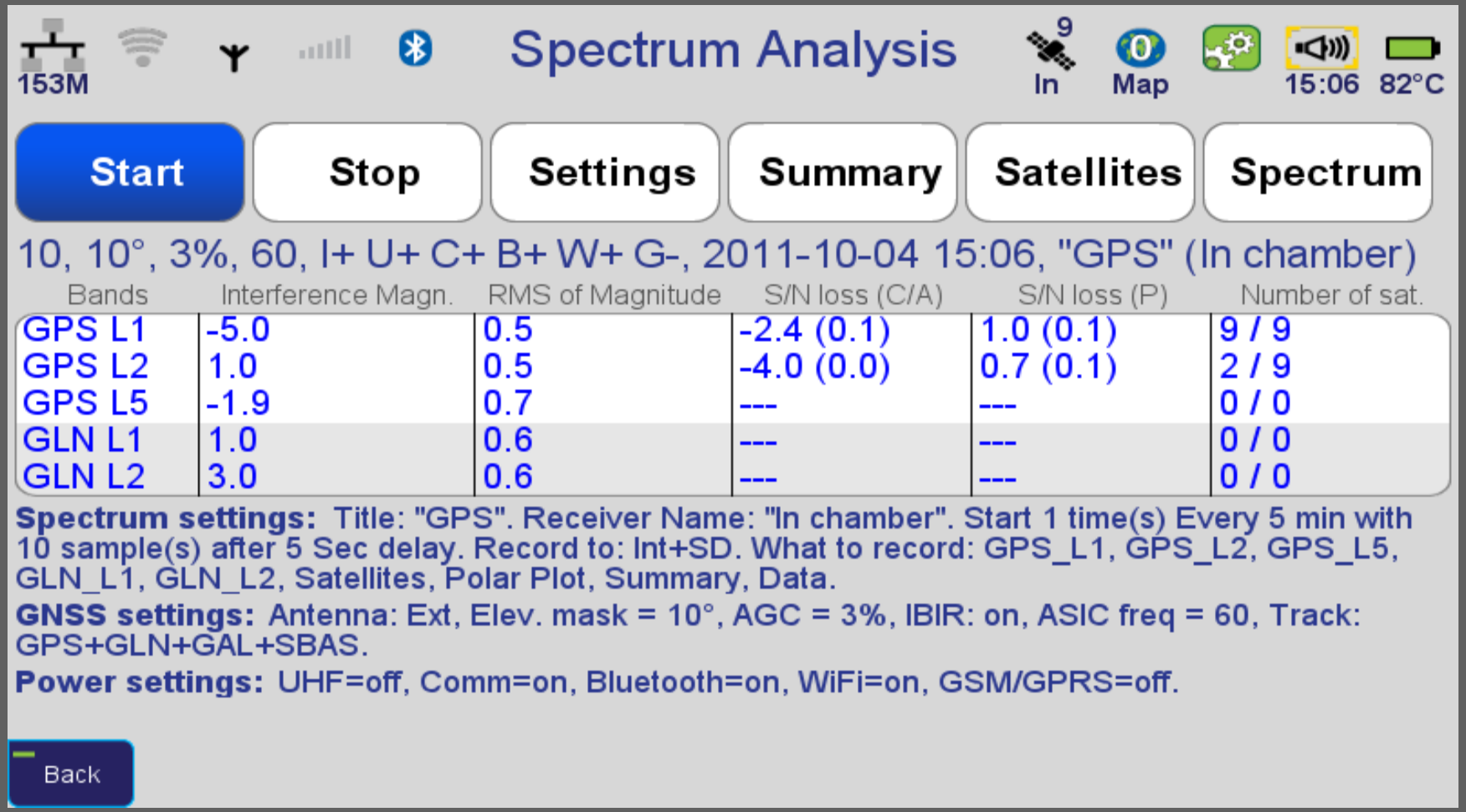
TRIUMPH-VS Interference Analyzer Screen



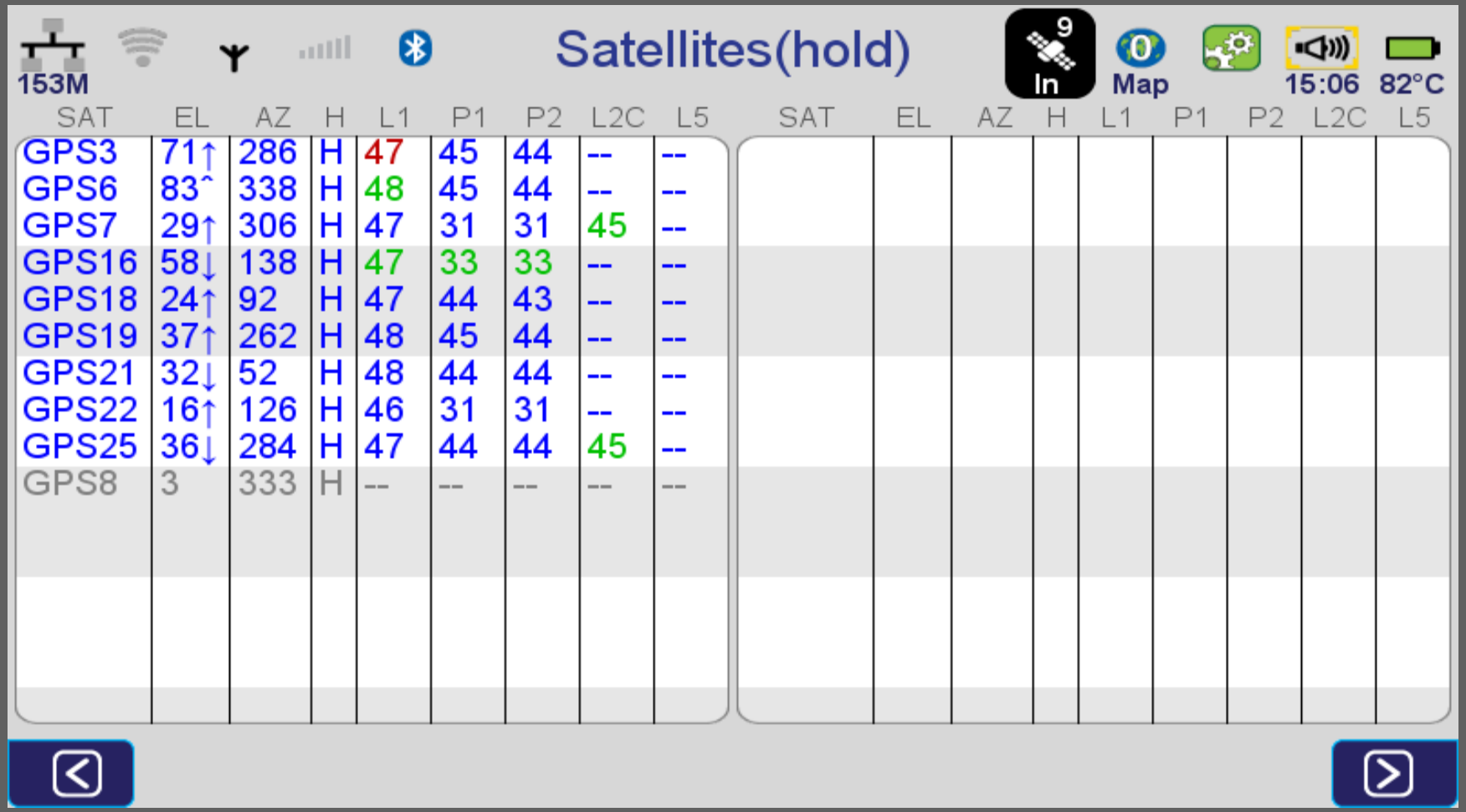
Patent Pending

TRIUMPH-VS Interference Analysis Screen




153M
Spectrum Analysis
9
In
Map
15:06
82°C
Start
Stop
Settings
Summary
Satellites
Spectrum
10, 10°, 3%, 60, I+ U+ C+ B+ W+ G-, 2011-10-04 15:06, "GPS" (In chamber)
Bands
Interference Magn.
RMS of Magnitude
S/N loss (C/A)
S/N loss (P)
Number of sat.
GPS L1 -5.0 0.5 -2.4 (0.1) 1.0 (0.1) 9 / 9
GPS L2 1.0 0.5 -4.0 (0.0) 0.7 (0.1) 2 / 9
GPS L5 -1.9 0.7 --- --- 0 / 0
GLN L1 1.0 0.6 --- --- 0 / 0
GLN L2 3.0 0.6 --- --- 0 / 0
Spectrum settings: Title: "GPS". Receiver Name: "In chamber". Start 1 time(s) Every 5 min with 10 sample(s) after 5 Sec delay. Record to: Int+SD. What to record: GPS_L1, GPS_L2, GPS_L5, GLN_L1, GLN_L2, Satellites, Polar Plot, Summary, Data.
GNSS settings: Antenna: Ext, Elev. mask = 10°, AGC = 3%, IBIR: on, ASIC freq = 60, Track: GPS+GLN+GAL+SBAS.
Power settings: UHF=off, Comm=on, Bluetooth=on, WiFi=on, GSM/GPRS=off.
Back

TRIUMPH-VS C/N0 Analysis Screen



SAT	EL	AZ	H	L1	P1	P2	L2C	L5
GPS3	71↑	286	H	47	45	44	--	--
GPS6	83^	338	H	48	45	44	--	--
GPS7	29↑	306	H	47	31	31	45	--
GPS16	58↓	138	H	47	33	33	--	--
GPS18	24↑	92	H	47	44	43	--	--
GPS19	37↑	262	H	48	45	44	--	--
GPS21	32↓	52	H	48	44	44	--	--
GPS22	16↑	126	H	46	31	31	--	--
GPS25	36↓	284	H	47	44	44	45	--
GPS8	3	333	H	--	--	--	--	--

SAT	EL	AZ	H	L1	P1	P2	L2C	L5

TRIUMPH-VS Interference Analyzer Features (6 Bands)

- Interference frequency
- Interference power
- Control voltage shape
- C/N0 loss
- Statistical data

Anechoic Chamber Test Result of 10L

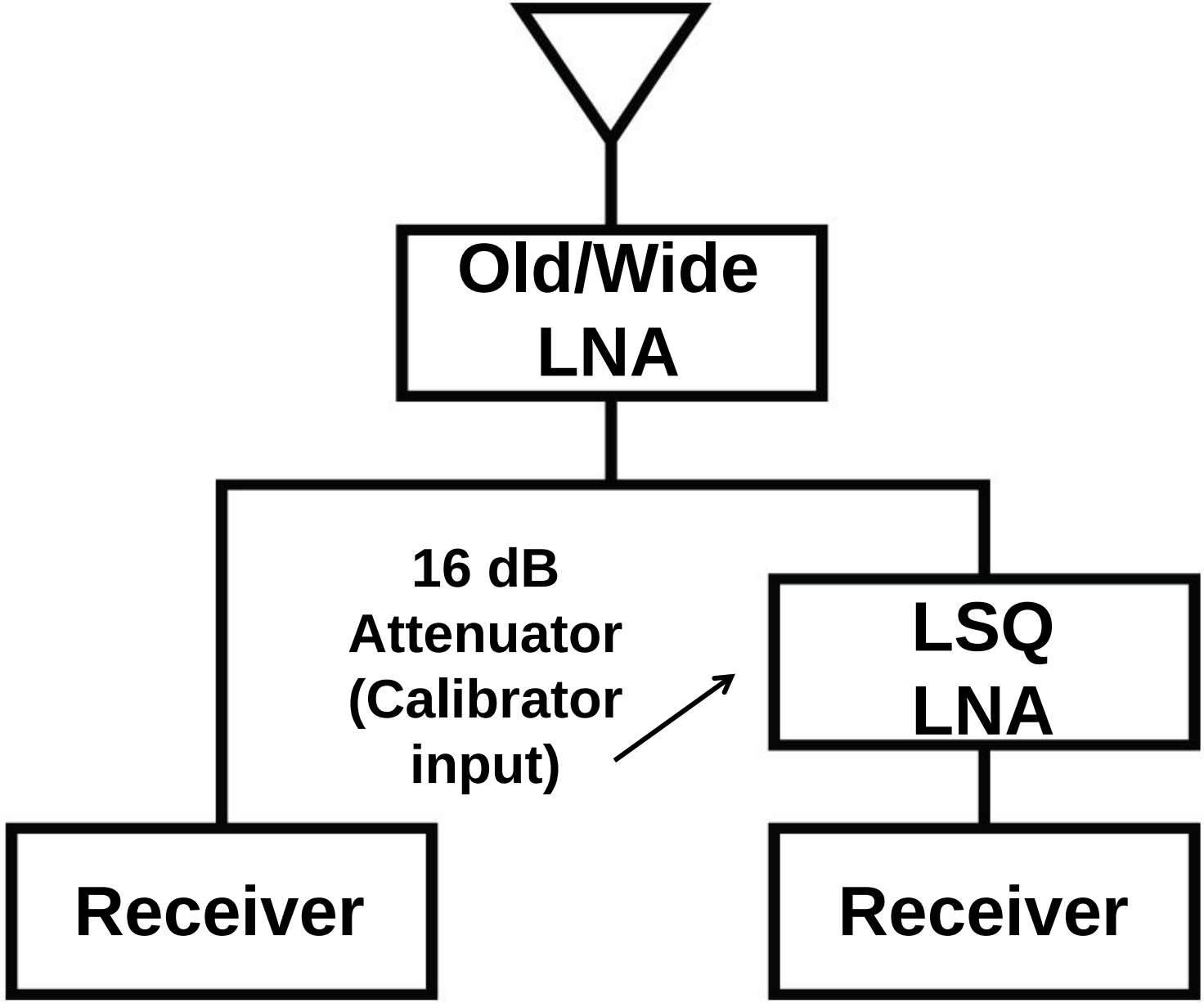
10L Power	AGC Change	C/N0 Loss
-10 dBm	None	None
-4 dBm	-0.6 dB	None
-1 dBm	-4.3 dB	1 dB
+1 dBm	-9.4 dB	2 dB
+3 dBm	-16.6 dB	4 dB
+4.5 dBm	-16.6 dB	6 dB

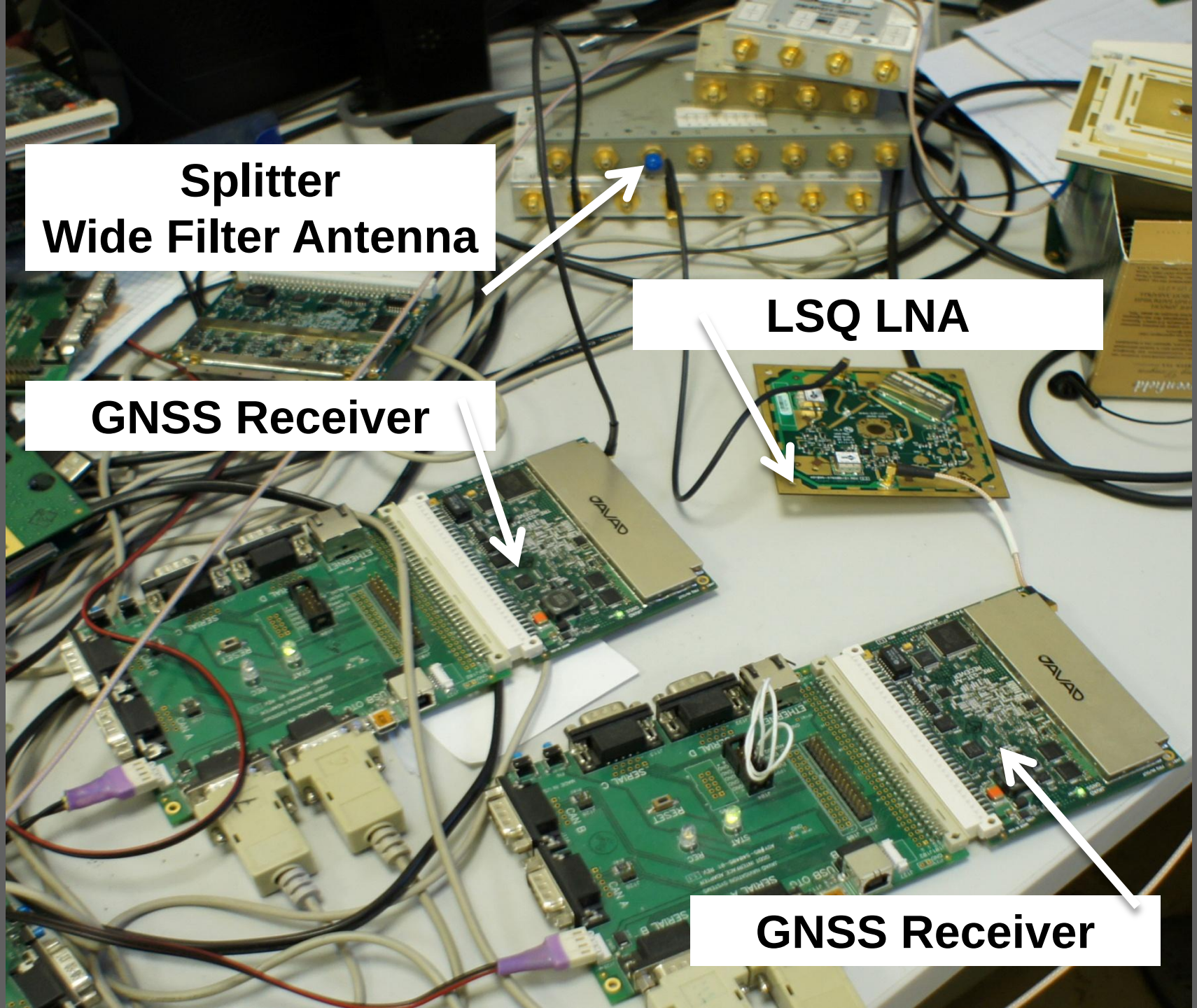
Anechoic Chamber Test Result of 10R

10R had no effect on GPS for the maximum power of 10R that we could generate (+4.5 dBm)

4. The Ultimate Test: Special Zero Baseline

(New Filter System)


Old/Wide
LNA
16 dB
Attenuator
(Calibrator
input)
LSQ
LNA
Receiver
Receiver


Splitter
Wide Filter Antenna
LSQ LNA
GNSS Receiver
GNSS Receiver

Comparative Performance

Zero Baseline Results (Carrier Phase), cm		
Calibrator	**Off**	**On**
GPS L1	0.02	0.02
GPS L2	0.01	0.01
GLN L1	0.39	0.14
GLN L2	0.01	0.01

Zero Baseline Results (Code Phase), cm		
Calibrator	**Off**	**On**
GPS P1	4.22	4.86
GPS P2	5.73	4.08
GLN P1	60.36	7.38
GLN P2	2.03	1.36

Aggregate Effect of 44,000 LSQ Transmitters on LEO Satellites

LEO Satellites		
Each LSQ transmitter (EIRP) *	61.5	dBm
Side lobe	-20	dB
Aggregate of 44,000 transmitters	46	dB
Min path loss for lowest LEO (200 miles)	-146	dB
Effective power at LEO	**-58.5**	**dBm**

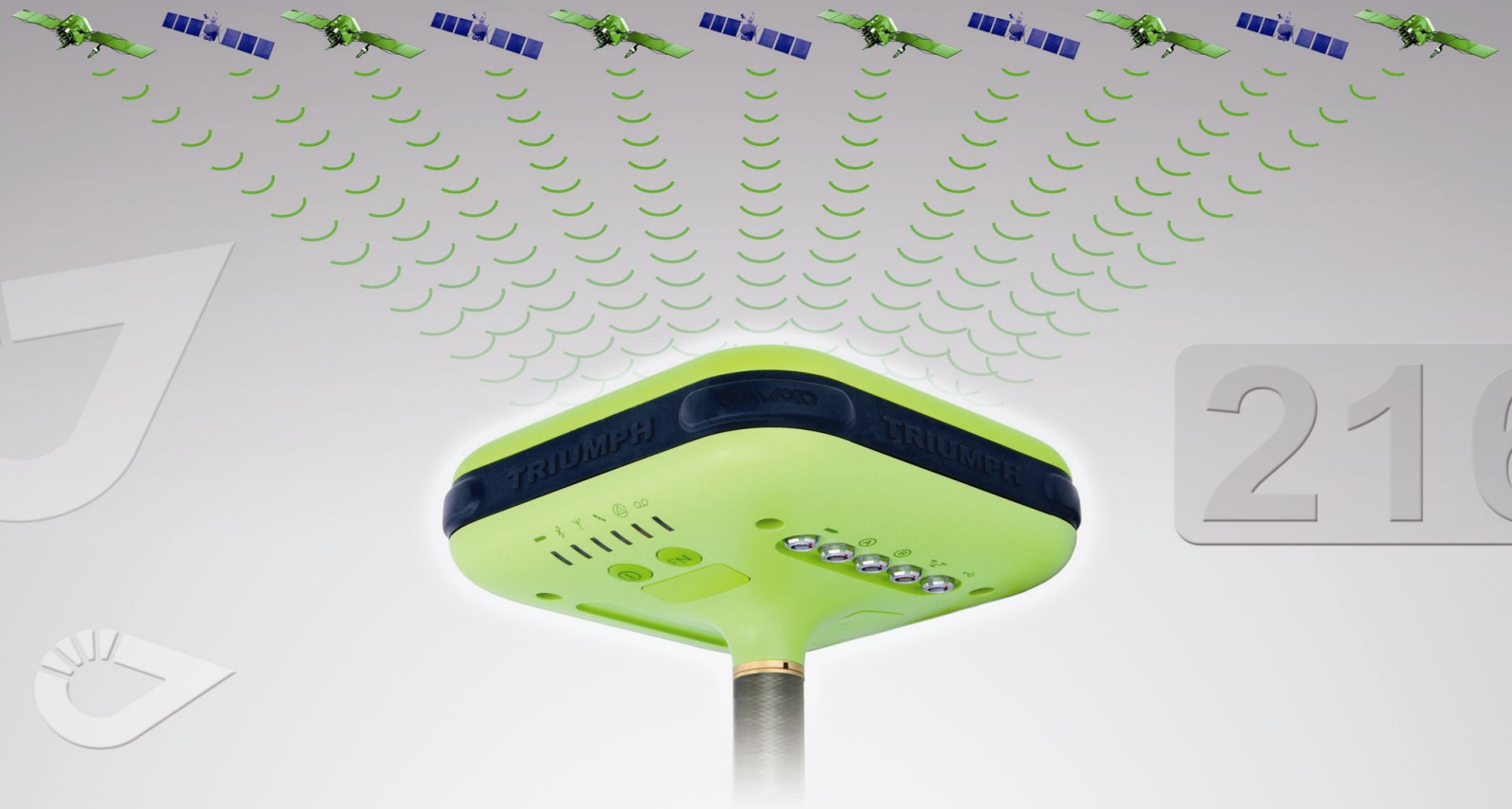
* Equivalent Isotropically Radiated Power

Measuring and Compensating for Group and Carrier Delays

Our GLONASS is as good as GPS

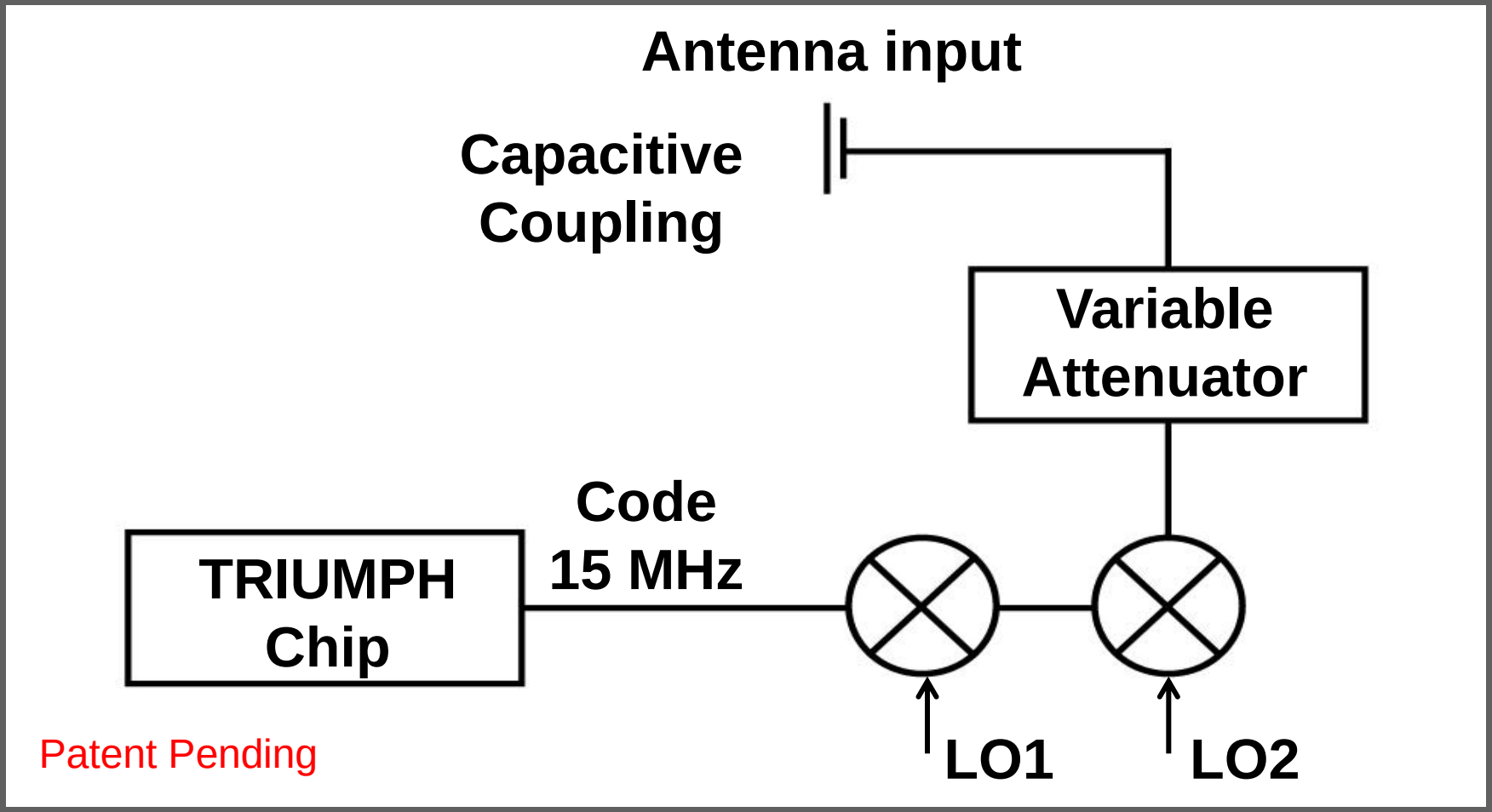
We dynamically and continuously calibrate GLONASS
inter-channel biases with accuracy of

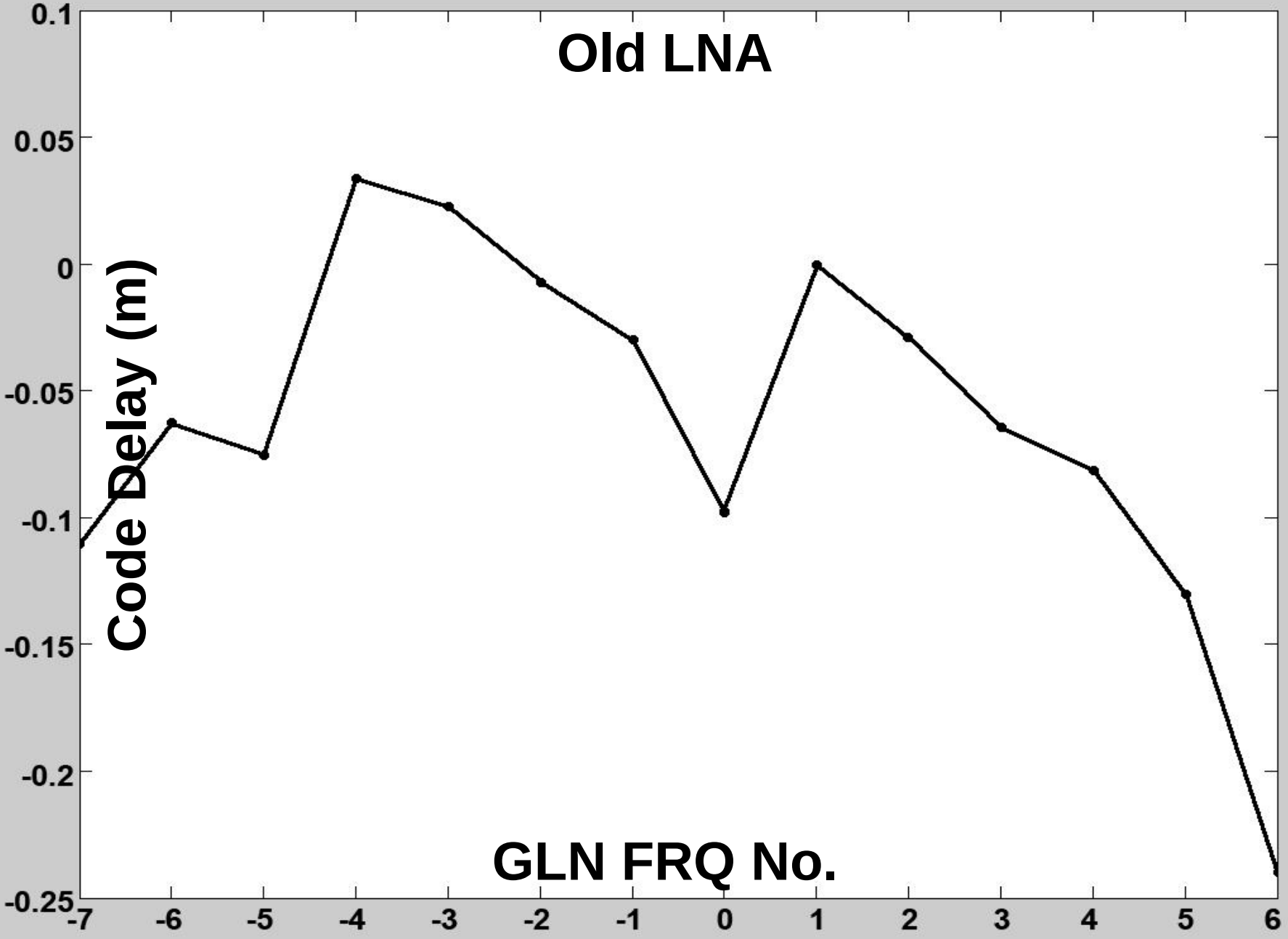
<u>0.2 millimeter</u>

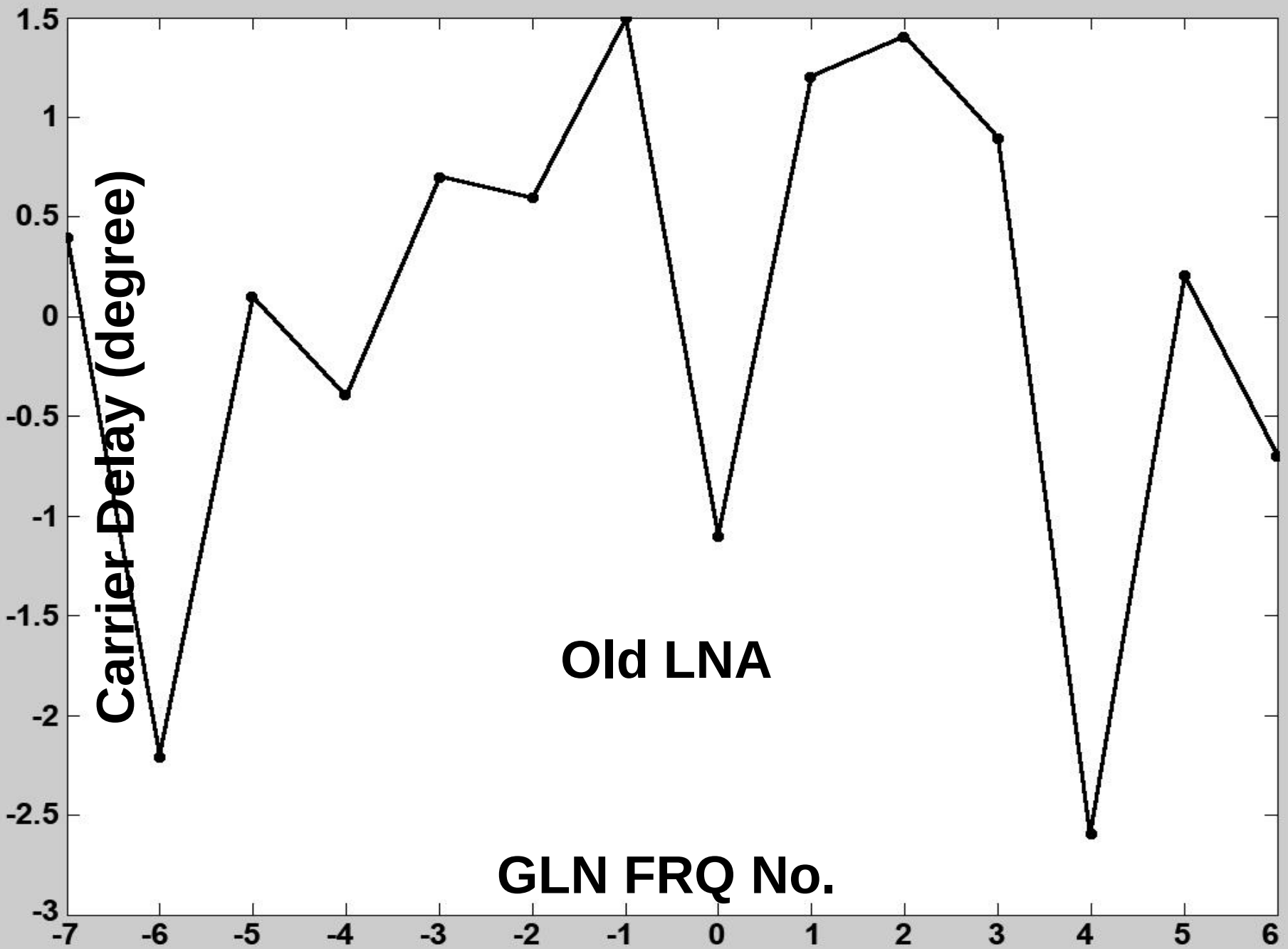


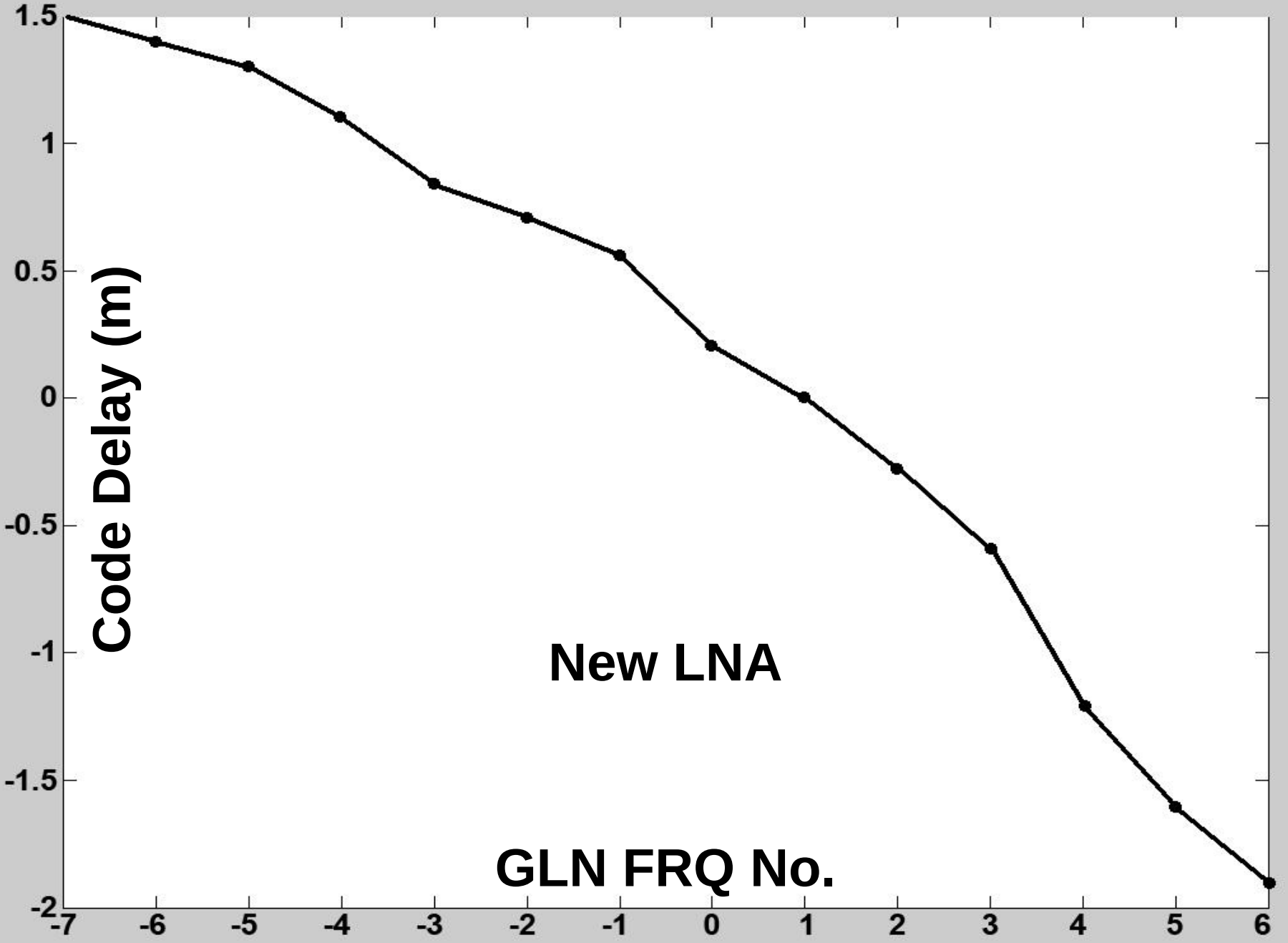
We dynamically and continuously calibrate GLONASS inter-channel biases with accuracy of **0.2 millimeter**

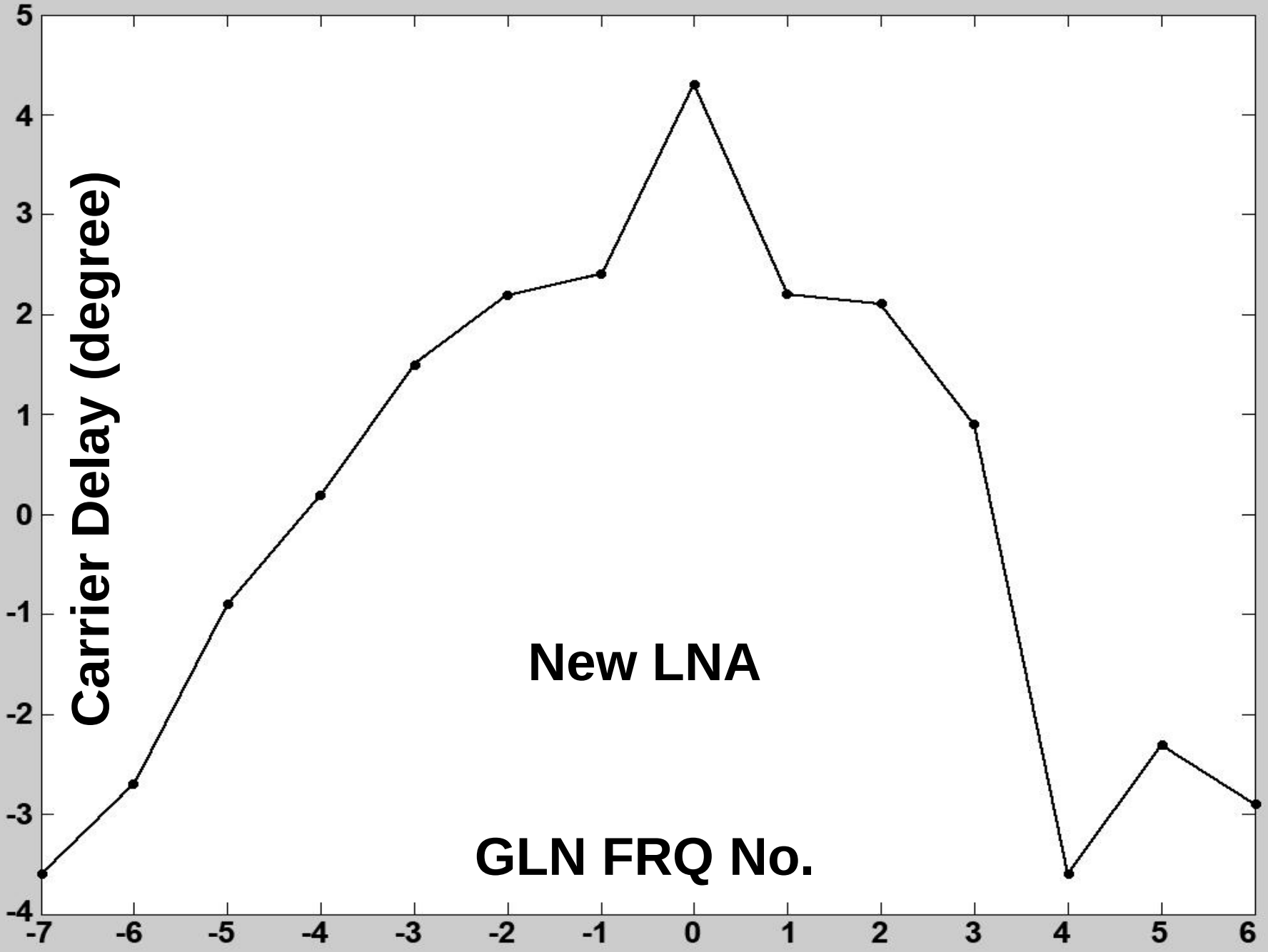
Group and Carrier Delay Measurement Block Diagram

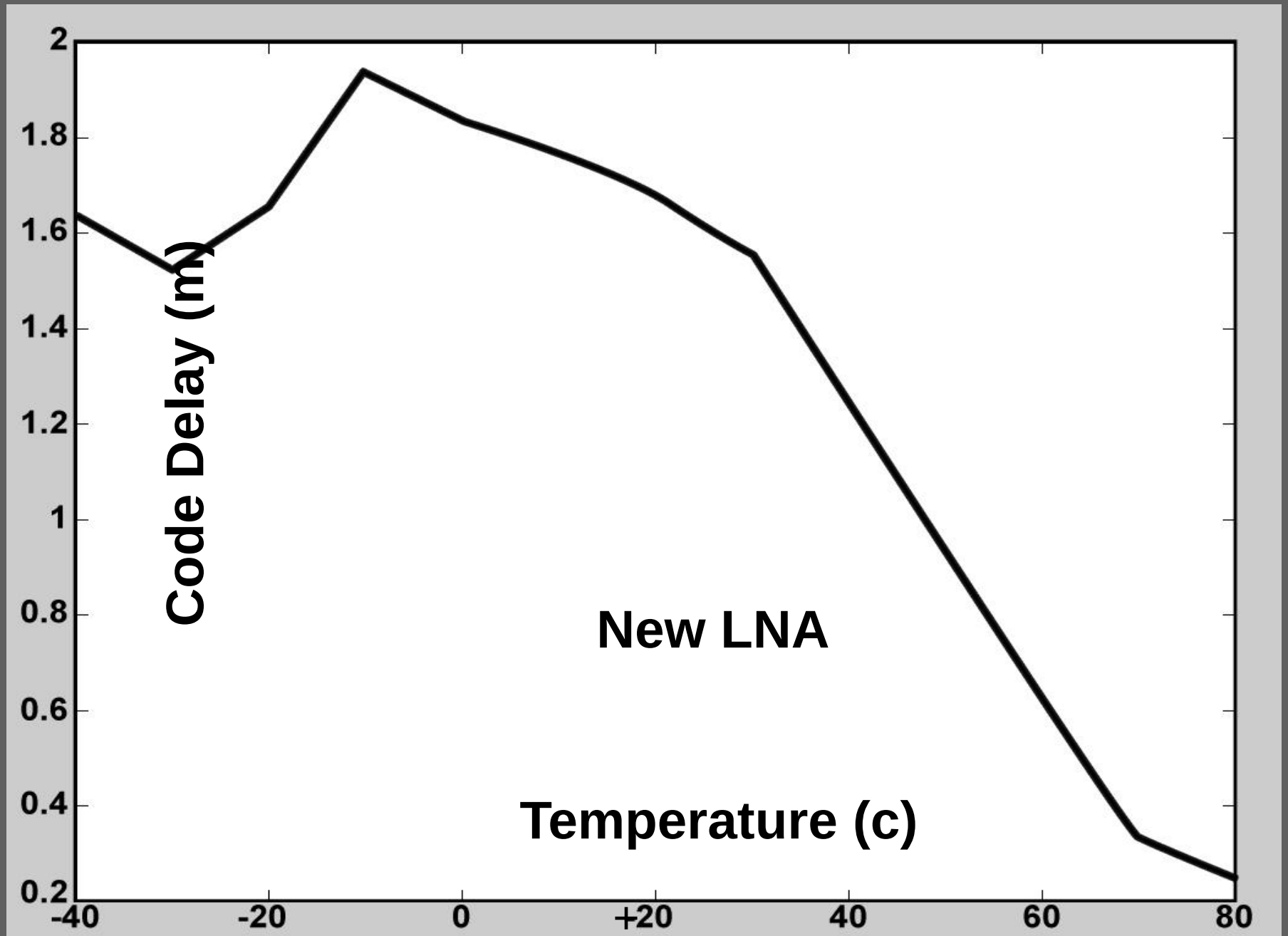


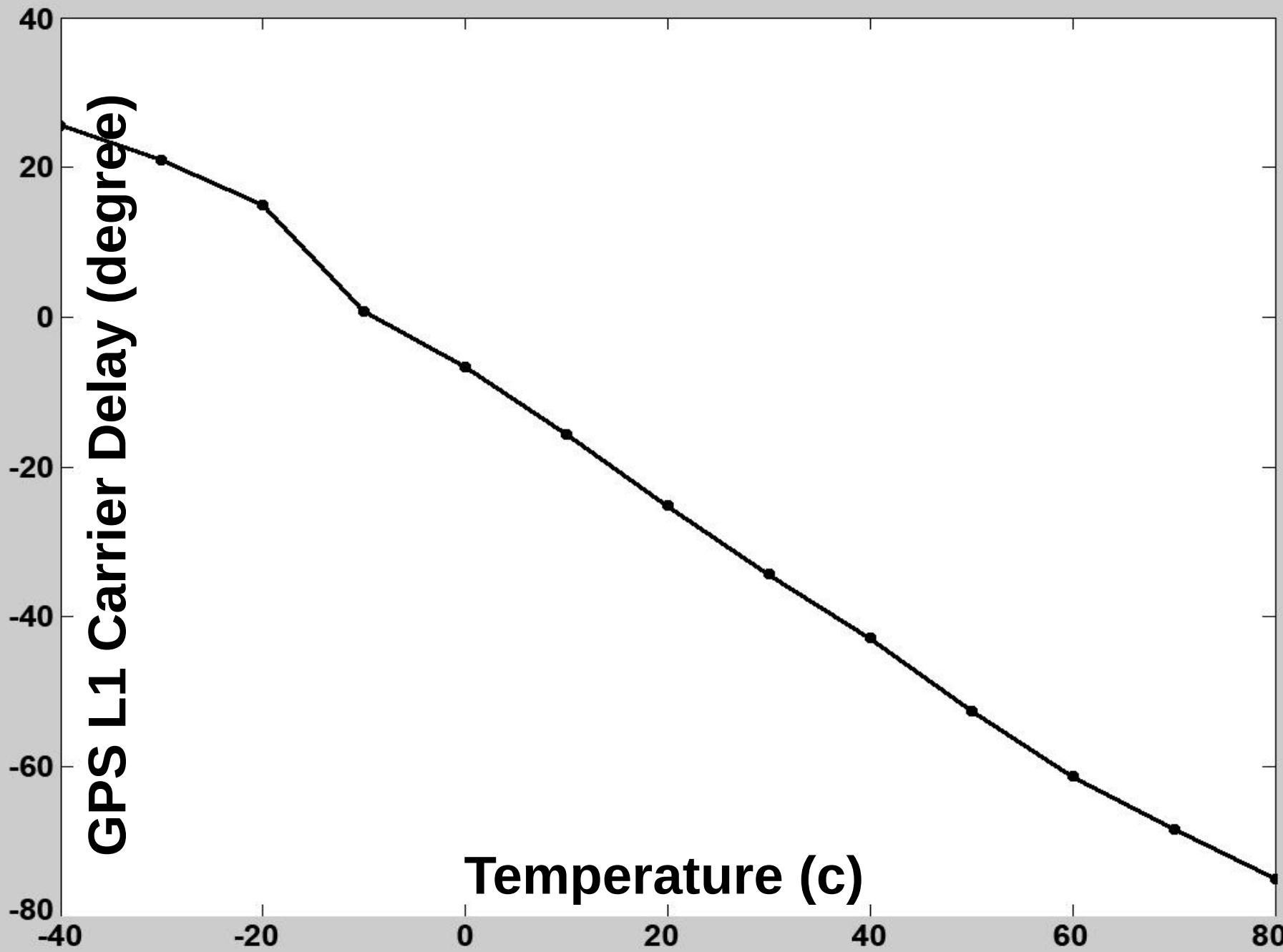

Old LNA
Code Delay (m)
GLN FRQ No.
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6


Carrier Delay (degree)
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
Old LNA
GLN FRQ No.


Code Delay (m)
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
New LNA
GLN FRQ No.


Carrier Delay (degree)
5
4
3
2
1
0
-1
-2
-3
-4
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
New LNA
GLN FRQ No.


2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
Code Delay (m)
New LNA
Temperature (c)
-40
-20
0
+20
40
60
80

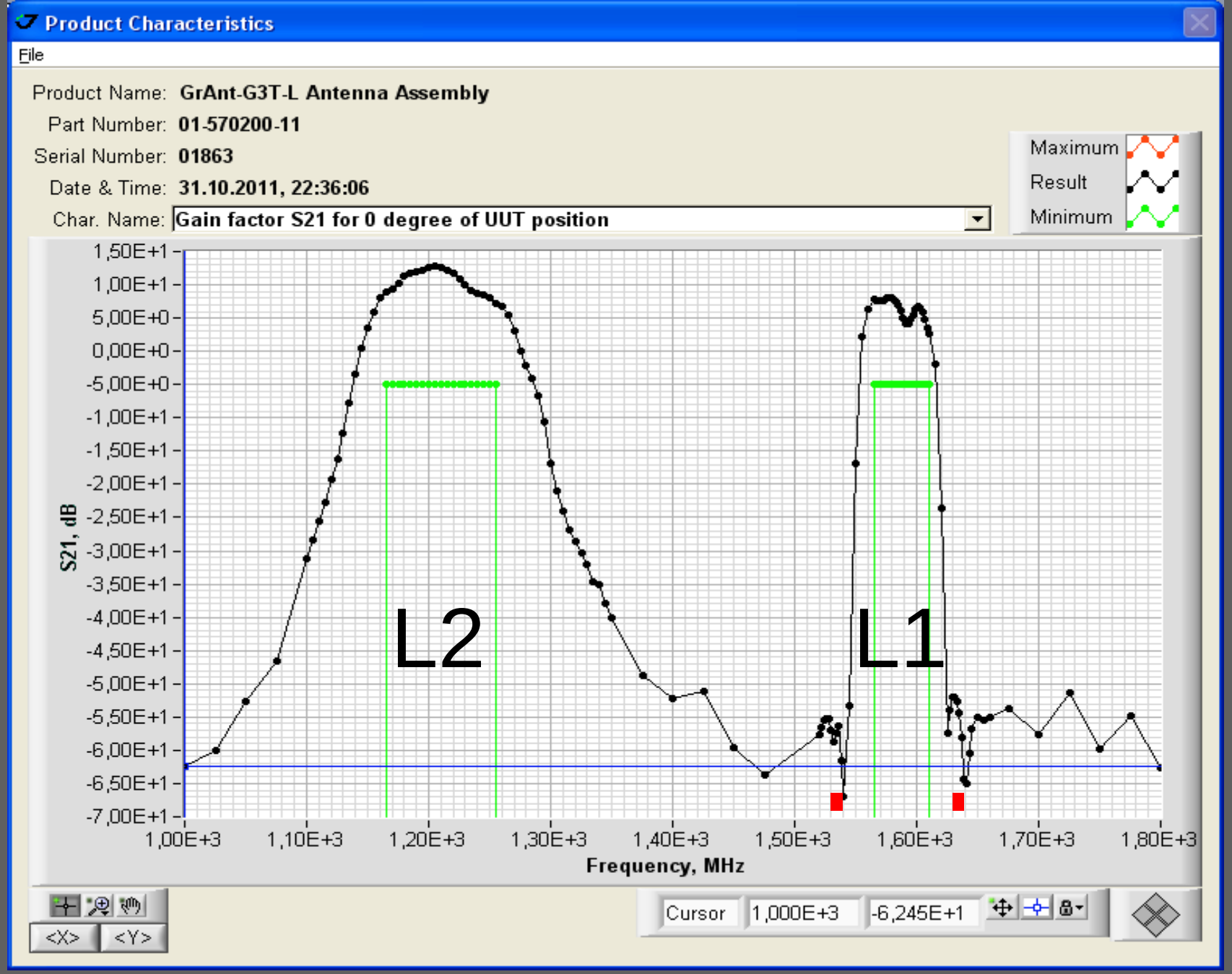

GPS L1 Carrier Delay (degree)
Temperature (c)
40
20
0
-20
-40
-60
-80
-40
-20
0
20
40
60
80

Technology Road Map

LightSquared-Protected:
Protected by the above JAVAD LNA system. For all precision positioning applications. Multipath mitigation features preserved.
November 2011

LightSquared-Compensated:
Protected by the above JAVAD LNA system and dynamically compensated for group delay variations (better than 100 picosecond). For precision timing applications.
March 2012

LightSquared-Integrated:
Same as two above plus LightSquared communication module inside.
June 2012



Made in San Jose, California

Made in the USA

You Can Conduct Your Own Tests

The technology is available, and I have 40 units here today.