Initial GNSS IF Recorder Analysis Larry Wurtz, Phd 2 July 2020

Following is a very short discussion of GPS L1 data analysis using a MAX2769C as a RF front-end. Figures 1 and 2 show the MAX2769C placed in a pelican case of portability. The circuit board to the right with blue ADC board attached buffers MAX2769C 2-bit IQ output to Ethernet packets which are recorded by a host PC. 2-bit IQ data is at an IF of 4.092 MHz and sampled at 16.368 MHz. A UBlox ANN-MB series active GNSS antenna was used with the MAX2769C RF front-end.

The first recording event was focused on quickly gathering data for analysis to determine if the MAX2769C was even a candidate for RF down conversion. Perhaps more time should have been given to antenna placement in that the laboratory building completely blocked the line-of-sight to most GPS satellites. Figure 3 shows the GPS satellite





Figure 1. GNSS IF Recorder - top view

Figure 2. GNSS IF Recorder - Inside view



Figure 3. GPS Satellite Position during Data Capture

positions when data was recorded.

Figure 4 shows a FFT of the first 65536 samples of recorded 2-bit IQ data. As expected, the spectrum is centered at an IF of 4.092 MHz and demonstrates a 2.5 MHz bandpass filtration as were the configuration settings of the MAX2769C. 90% of the GPS L1 information spectrum is within a 2 MHz band centered at 1575.42 MHz. The GPS L1 signal levels are in the -125 to -110 dBm range at the receiver antenna. Along with the spread spectrum from the PRN codes, visual identification of GPS signals from spectral plots would not be possible. Figures 5 and 6 report the 1023 chip pseudorandom noise (PRN) codes generated and used to identify each satellite's data stream in the collected data.



Figure 4. FFT of sampled 2-bit IQ data from MAX2769C

Recorder / Analysis GU	x
GPS L1 PRN Codes Tab2 Tab3 GPS L1 2-bit IQ Analysis	
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Close Program	
Processing Notes Wittz Survey 28 June 2020 1 19	м
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Generating GPS L1 PRN Codes	÷.
(reporting 1st 300 chips of 1023 in octal format)	
Satellite 1 PRN Code (chip delay = 5) => 14407122362423725504252621723755633712502003522115701727147540136372461334336505301001006166016157764 Passed Check	
Satellite 2 PRN Code (chip delay = 6) => 16207017514557626277645410426170603160434216474055032274160370671432700361505621463323013611124300524 Passed Check	
Satellite 3 PRN Code (chip delay = 7) => 17107041223521667502042104164662217255463310013035367411573464512352670747210373712272015166571227004 Passed Check	
Satellite 4 PRN Code (chip delay = 8) => 17447066174116647274741742305527011303044753220405201323376322463422604554156516666616416211357674654 Passed Check	
Satellite 5 PRN Code (chip delay = 17) => 11330433053436535746765076710544727544414007007173644667313363671155470401112177416266434735067050055 Passed Check	
Satellite 6 PRN Code (chip delay = 18) => 14550653040151322356412337033474245047473214626466050614046061112121304437017414724610606534510743270 Passed Check	
Satellite 7 PRN Code (chip delay = 139) => 11317764464416243045123217455742671163057234437015176062455212101121663747777003072665743113434600120 Passed Check	
Satellite 8 PRN Code (chip delay = 140) => 14543334657541055017331207551177222254252701032415305516725015666117201154325062516411371227735067206 Passed Check	=
Satellite 9 PRN Code (chip delay = 141) => 16265110742126552032234203513261407703750157630215230360651116115500030251500052364527164371675754755 Passed Check	
Satellite 10 PRN Code (chip delay = 251) => 150450470332040204354664430055712637500502642711174343176201743452468534203373251027755712272522141 Passed Check	
Satellite 11 PRN Code (chip delay = 252) => 164260650/0244164623153521//5062645/532//600403645/0133332/251/030/15401061553116415362/66016430642286 Passed Check	
Satellite 12 PHN Code (chip delay = 254) => 1/5/032/04/10/413//6/62/23641//305400645/140511/25146//33364/064/341450/10/72/06/611504/4/44336 Passed Check	
Satellite 13 PHN Code (chip detay = 253) => 17091720953701733090/10/200339/1050/132033710510/0102/4302/3/32091020143003/317220/1002091 Passed Check	
Satellite 14 PrNix Code (chip detay = 230) => 17/2005074722123130/340020170140022070243143/340693000120353007351144724044474044253100/00570371 Passed Check	
Satelline to FNN Code (ching delay = 257) => 1776935002203120032100700010002107031000100421174005011344014171041231050300312311413511 Fassed Ching	
Satellite to Finit Code (ching dead) = 230 = 17/02/0512/000302/11/000223710/002237110/02/10111947113002030142/0404015562074040455740702571104045574070257110404557407025711040455740702571104045574070257110404557407025711040455550000000000000000000000000000	
Satelline 17 millioue (chin deal) = 100002 motore 74 000 million (124002 million) 122 million (124002 million) 100002 million) 122 million (124002 million) 100002 million) 122 million (124002 million) 100002 million) 122 million (124002 million) 122	
Satelline 10 PDN (odd (chin delay = 471) => h8396416056160507104007105680134054785510547141753555586174147413387478472373140001 Descent Chark	
Satellite 0 PRV Code (chin delay = 472) = 17/5178/25558/01/03/5558/468/78/78/12/20/56577/01/3/80/5/20/02/67/07/27/22/256052/21/00/64/37/4/78/534/58/01/37/6	
Satellite 21 PBN Code (chip delay = 473) ⇒ 17460331543136131577107523040721147724407560610563533526430253313456417612733462202215761437704024721 Passed Check	
Satellite 22 PRN Code (chip delay + 174) => 1/634512204311120242323151757546575177476467121262127374711455363360137132707252022625380075661375106 Passed Check	
Satellite 23 PRN Code (chip delay = 509) => 10636740637373540364032632244142223465643720412477202740354361423566412061034266375775030063575265312 Passed Check	
Satellite 24 PRN Code (chip delay = 512) => 17064100321463661712767743053246750334770621133453051025457040532143203661466760561261015401601547413 Passed Check	
Satellite 25 PRN Code (chip delay = 513) => 17436406535177644370413061752335272773501107670636356135324130473526031107261713353213016062623504453 Passed Check	
Satellite 26 PRN Code (chip delay = 514) => 17613645633331656541565330412740423550035654511304615571051544413314524274162326446226017653232525073 Passed Check	Ŧ

Figure 5. PRN codes for GPS Satellites 1 through 26

😴 Multi_Band GNSS IF Recorder / Analysis GU	
GPS L1 PRN Codes Tab2 Tab3 GPS L1 2-bit IQ Analysis	
Generate GPS L1 PRN Codes	
Close Program	
Processing Notes	Wurtz, Sunday, 28 June 2020, 1:19 P.M.
Satellite 9 PRN Code (chip delay = 141) => 16265110742126552032234203513261407703750157630215230360651116115500030251500052364527164371675754755	. Passed Check *
Satellite 10 PRN Code (chip delay = 251) => 15045047033204020435466443005571726375005026427111743431762017434524263534203373275102775571227252141 .	Passed Check
Satellite 11 PRN Code (chip delay = 252) => 16426065070244164623153521775062645753277604036457013333272517030715401061553116415362766016430642236.	Passed Check
Satellite 12 PRN Code (chip delay = 254) => 17503270441074137767622364177305400645714051730105605112514677333647064734145071071206761150474744336.	. Passed Check
Satellite 13 PRN Code (chip delay = 255) => 17645172645370123346071672300354716507133233571051070162745627373264102561430057517220760206315005301.	Passed Check
Satellite 14 PRN Code (chip delay = 256) => 17726033747232125156754035237770251466220702451437346556661203353075571447246444764233760761065765716.	. Passed Check
Satellite 15 PRN Code (chip delay = 25/) => 1//5/453306253126052406/16660162032016/65156001604211/406330113431/13440141/164142516363680512511415511.	Passed Check
Satellite 10 PENI Code (chip delay = 258) \Rightarrow 1//63263/2666352/41056344/04/06/10362250/61/0225/116/624/61611434/13305263142634340/0336561412.	Passed Check
Satellite 17 PRN Code (Crip delay = 409) \rightarrow 113000211703442742105210041424302707122410137427525300557100205701424302273445153022741341007002340.	Danand Charle
Satellite to FRV Code (chip delay = 470) -> 140/440001202404202000023717940710015005072427170020270304600027020074140741900277030230400030 . Satellite to FRV Code (chip delay = 471) -> 140/440001202404202000023071794071005027724271700202703046000270200	Desced Check
Satellite 19 Friv Code (chin delay = 471) => 10050011000491130055447132051400710300213403947100001230104971537305320211434149131044713203140241	Passed Check
Satellite 21 PBN Code (chip delay = 473) => 17460331543136131577107533040721147724407560610583533528430253313456417612733462202215761437704024721	Passed Check
Satellite 22 PBN Code (chip delay = 474) \Rightarrow 1/634512204311120242323151757546575177476467121262127334711435563360737132707252022625360075661375106	Passed Check
Satellite 23 PRN Code (chip delay = 509) => 10636740637373540364032632244142223465643720412477702740354361423566412061034266375775030063575265312.	Passed Check
Satellite 24 PRN Code (chip delay = 512) => 17064100321463661712767743053246750334770621133453051025457040532143203661466760561261015401601547413 .	. Passed Check
Satellite 25 PRN Code (chip delay = 513) => 17436406535177644370413061752335272773501107670636356135324130473526031107261713353213016062623504453 .	Passed Check
Satellite 26 PRN Code (chip delay = 514) => 17613645633331656541565330412740423550035654511304615571051544413314524274162326446226017653232525073 .	. Passed Check
Satellite 27 PRN Code (chip delay = 515) => 17701364370212653655112254172576307041663531061551474353127372423001762701423530300630417147436135663 .	Passed Check
Satellite 28 PRN Code (chip delay = 516) => 17744134511643251313325626302461055205144443615677144442150065437147241577243237063437617201734331567.	Passed Check
Satellite 29 PRN Code (chip delay = 859) => 11274625566554245255606450562366336002344705517473240456571636121330210661101410201676743474744160537 .	Passed Check
Satellite 30 PRN Code (chip delay = 860) => 14532754216520056113063524106765041624717155462626252700777207676013434507012267023014771054241317001 .	Passed Check
Satellite 31 PRN Code (chip delay = 861) => 16251720562516153470351152334564536137532671414300657667674013111542326474057550532325764244003620656.	Passed Check
Satellite 32 PRN Code (chip delay = 862) => 1/120316614501111201604365221464341672020123423153455214235515262326463401475207376671362740122477171.	Passed Check
Satellite 33 PKN Code (chip detay = 863) => 1/454501/0350653013502726/01240/6110665246434/7615402141535631/414/0103/26416045441/1615021/2150622	. Passed Check
Satellite 34 PKN Code (cnip deta) = $500 \neq 1/133071003111200140127250745107/3264616014362371207001165565661516310566162747671144470615053307535107.$	Passed Uneck
Satellite 35 PKN Code (chip delay = 947) => 11341033412457300042437705047300544134151053457340713471341171051051245052253721230530349540513322252 . Satellite 35 PDN Code (chip delay = 049) => 14564059255617307145770564123712785155340578115394057341319651641114580113154011612512337215170130064011345770565143713786153940557321357861154940573413196574511145801131354011611254113540116128502323	Passed Check
Satellite 30 PKW Code (chip delay = 940) -> 14304005200301727149170000145713740/301153240257343731303104110153012212540110172012004011300537373.	Passed Check

Figure 6. PRN codes for remaining GPS Satellites

The first step in data analysis is to acquire the GPS satellites. The acquisition phase requires a great deal of processing time in that each 1023 chip PRN code must be convolved across the collected data for one PRN code period of 1 msec for L1 at the 16.368 MHz sample rate following by a set of frequency shifts from the 4.092 MHz IF to account for Doppler effects between the satellite and receiver velocities. A number of papers report that increments of 500 Hz is sufficient to account for the Doppler effects.

A parallel acquisition search algorithm was used to cross and auto-correlate each satellite PRN code for one PRN code cycle across the collected data. Table 1 reports correlation results for a sampling of satellites. As expected, satellites 6 and 19 are strong since each is almost directly above the receiver. All other GPS satellites are weak either due to line-of-sight blockage or distance from the receiver. The next record event will have the antenna elevated for better satellite reception. Figures 7, 8, and 9 show the associated PRN plots for Satellites 6, 19, and 2, respectively.

Satellite No	Largest Magnitude	PRN code shift	Doppler shift +/- 500 Hz
	from Correlation		
2	17.878	501.500	-1499 Hz
6	26.270	487.375	0 Hz
19	21.430	273.938	0 Hz
13	14.749	775.875	+27973 Hz
17	14.274	267.375	-109893 Hz
3	13.932	546.250	+36464 Hz
12	14.129	592.875	-417592 Hz

Table 1. Sampling of searched GPS Satellites for L1 Band







Figure 8. Plot of PRN Correlation for Satellite 19



Figure 9. Plot of PRN Correlation for Satellite 2

The next phase of this analysis/research will continue with IF carrier and code tracking to retrieve navigation data for generation of ephemeris data. Eventual research will include comparative algorithms to enhance processing performance, anti-spoofing techniques, collection of multiple GPS and Galileo bands for improved position accuracy and satellite availability.

Continued IQ data collection will include the multi-band MAX2771 RF front-end receiver along with collections of bit resolutions ranging from 2 to 12 bits.