System Requirements and Configurations
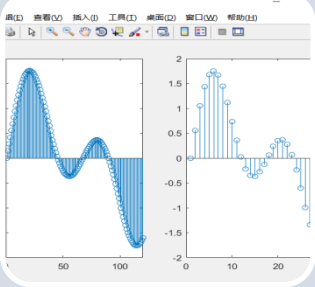
ADC Configuration

- RF SoC supports Fs in range of 1024 MHz - 4096 MHz.
- Our LTE Cell search IP needs Fs of 1.92MHz.
- ADC Fs is configured to 3932.16MHz as it is a multiple of 30.72MHz (LTE Rate). Reference ADC clock needed 491.52MHz.
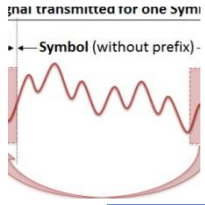
Decimation

- Our System needs decimation of 2048.
- 8x decimation in RF Soc. From 3932.16MHz to 491.52MHz.
- 256x decimation in our custom IP to achieve Fs of 1.92MHz at LTE Cell search IP.

NCO (Numerically Controlled Oscillator)
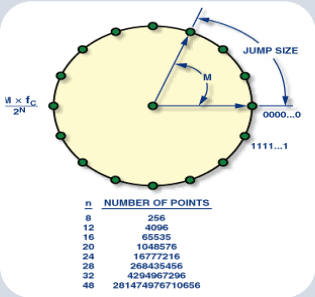
- NCO configured to down convert carrier frequency to DC.
- 48-bit NCO per RF-ADC.
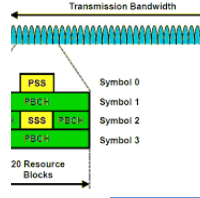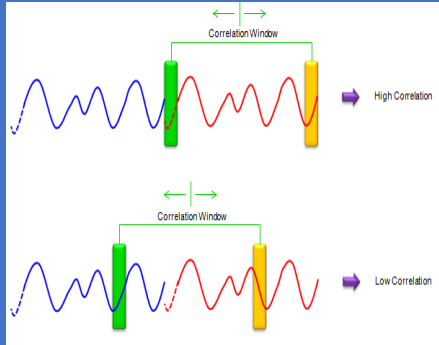- Mixer is programmed to fine mode.

Main LTE Blocks – For Cell Search

CP Correlation

- Cyclic Prefix is an exact copy of the last part of OFDM symbol

PSS

- 3 Zadoff-Chu root sequences defined in Frequency domain.

- IFFT to get time domain sequences which reduces HW complexity.

- Correlate Rx signal with 3 known time domain PSS sequences.

SSS

- 1 of 168 known sequences.

- Polynomial based 3 binary sequences on Galois field.

- Correlation in frequency domain by taking 128-point FFT on Rx Symbol.
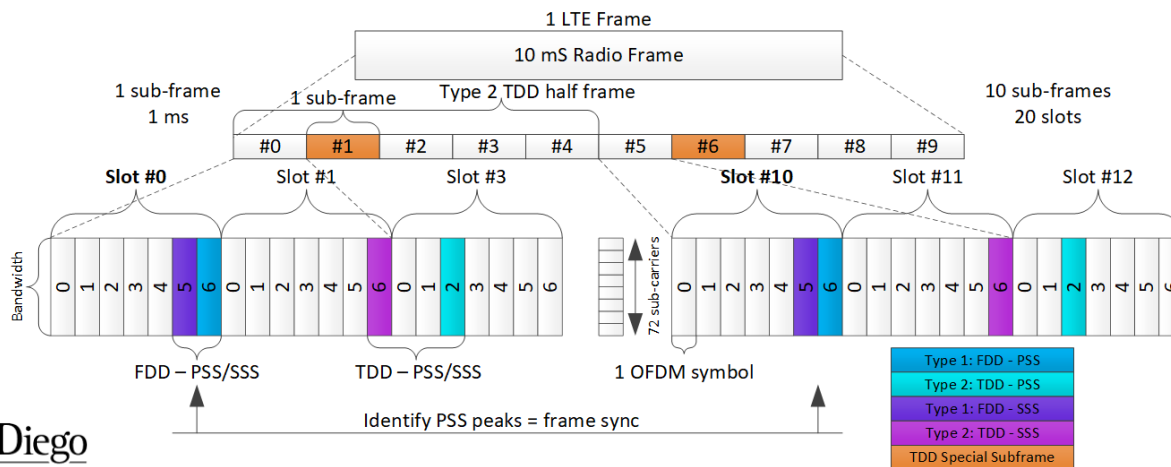
$$= 3N_{ID}^{(1)} +$$

$$N_{ID}^{(1)} \in \{0,1,\dots,335\}$$

The physical cell identity, N_{ID}^{cell}, is defined by the equation:
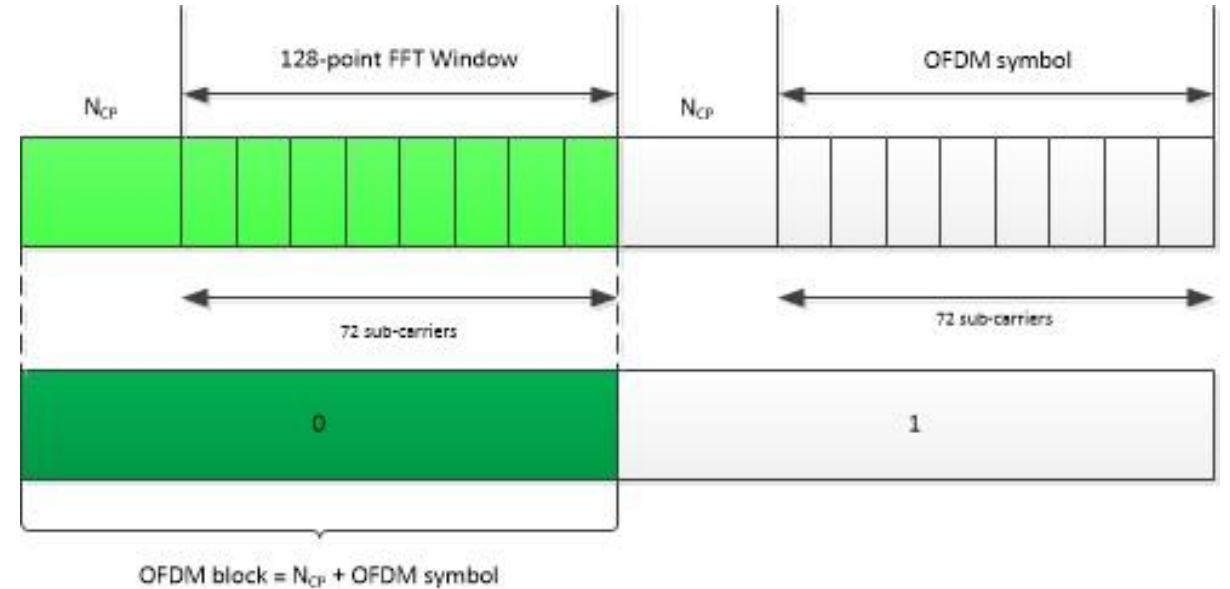
$$N_{ID}^{CELL} = 3N_{ID}^{(1)} + N_{ID}^{(2)}$$

- $N_{ID}^{(1)}$ is the physical layer cell identity group (0 to 167).

- $N_{ID}^{(2)}$ is the identity within the group (0 to 2).

Frequency Estimation

Test Bench: Verified HLS code with Matlab Simulated results


```
cp_corr_csim.log ×
 96 555.542602539062500  555.533203125000000
 97 572.667480468750000  572.657836914062500
 98 575.054260253906250  575.044494628906250
 99 576.773376464843750  576.763488769531250
100 574.544860839843750  574.534851074218750
101 566.088073730468750  566.077758789062500
102 580.017028808593750  580.006408691406250
103 587.009460449218750  586.998352050781250
104 590.618041992187500  590.606750488281250
105 612.359985351562500  612.349243164062500
106 --------------------------------------------
107   RMSE(R)
108 0.005147035699338
109 --------------------------------------------
110 ****************************************
111 PASS: The output matches the golden output!
112 ****************************************
113 The maximum depth reached by any of the 3 hls::stream() instances in the design is 96000
114 INFO: [SIM 1] CSim done with 0 errors.
115 INFO: [SIM 3] *************** CSIM finish ***************
116
```


Identify data to recover

- f_s = 1.92MHz, OFDM symbol = 128 samples
- N_{CP} > L, Channel impulse response
- CP = Cyclic Prefix, reduce likelihood of Inter-symbol Interference (ISI)
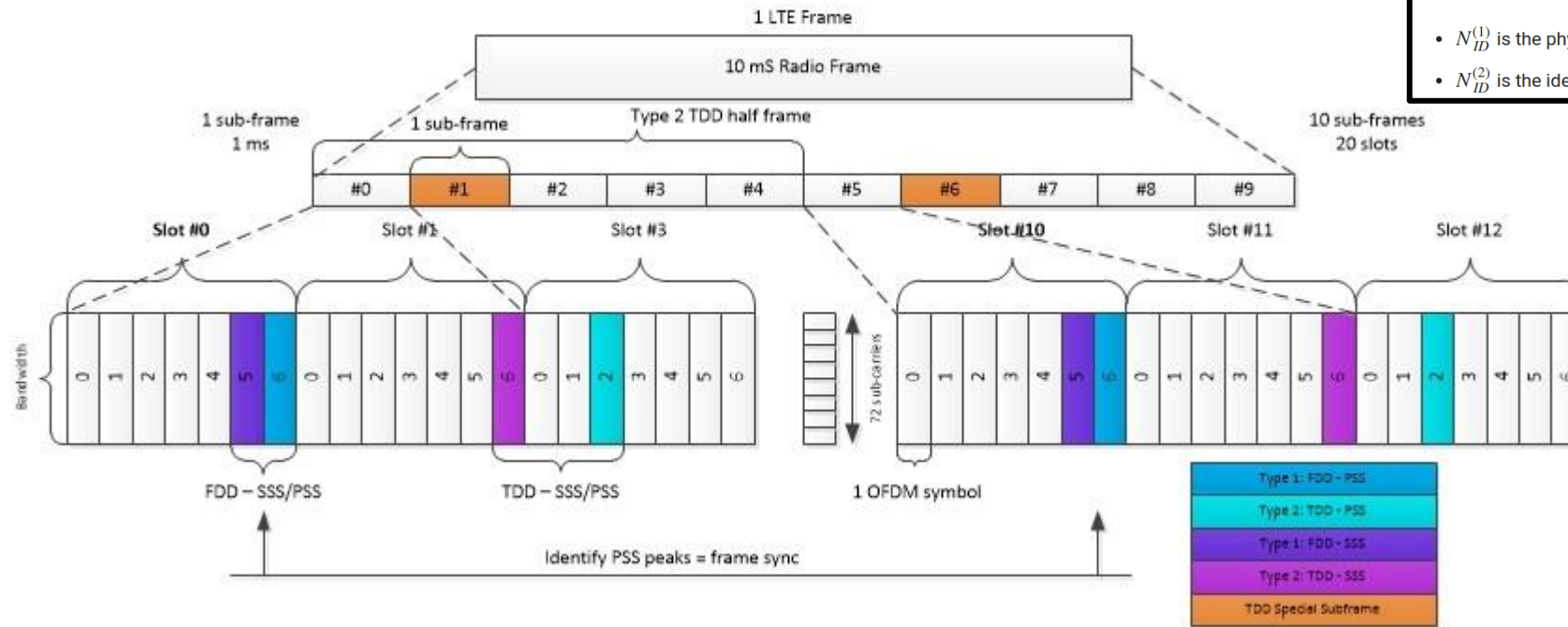
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Synchronization

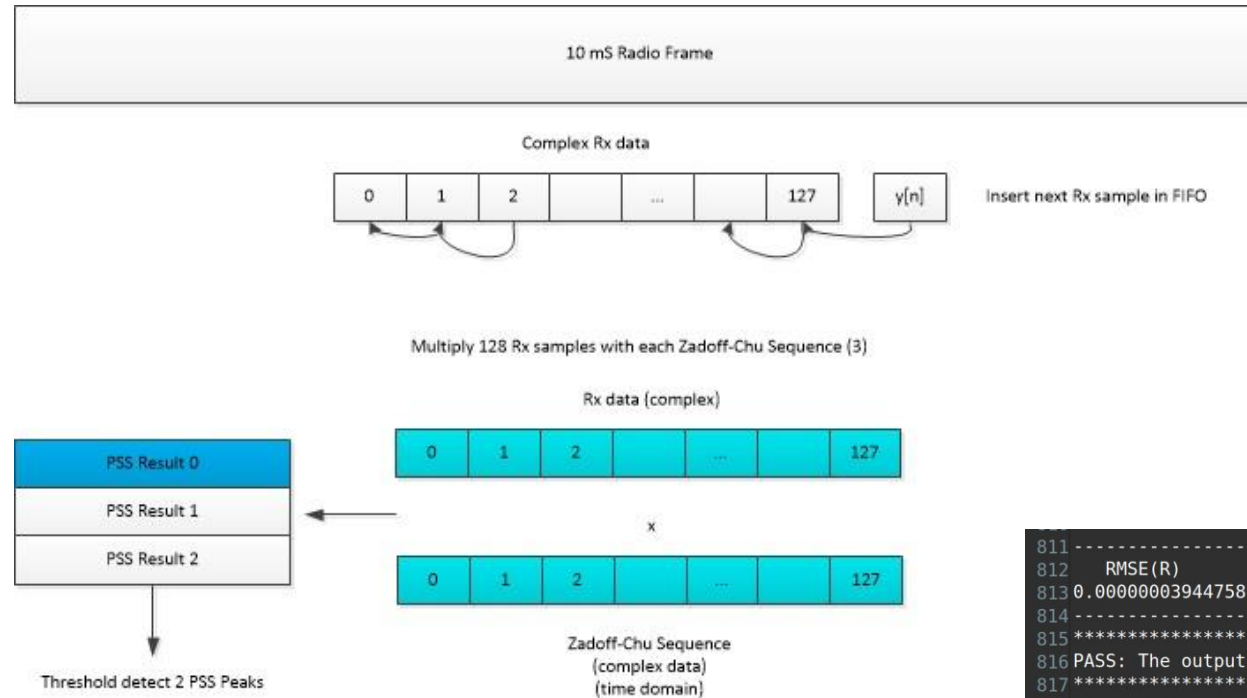The physical cell identity, N_{ID}^{cell}, is defined by the equation:

$$N_{ID}^{CELL} = 3N_{ID}^{(1)} + N_{ID}^{(2)}$$

- $N_{ID}^{(1)}$ is the physical layer cell identity group (0 to 167).
- $N_{ID}^{(2)}$ is the identity within the group (0 to 2).

Structure of LTE frame

- Identify 2 peaks over 10 slots (1 frame)
- Keep searching for pair of peaks to maintain sync using threshold detect - maintain sync
- Identify PSS / SSS to decode the Cell ID

Synchronization - PSS

The physical cell identity, N_{ID}^{cell}, is defined by the equation:

$$N_{ID}^{CELL} = 3N_{ID}^{(1)} + N_{ID}^{(2)}$$

- $N_{ID}^{(1)}$ is the physical layer cell identity group (0 to 167).
- $N_{ID}^{(2)}$ is the identity within the group (0 to 2).

Test Bench: Verified HLS code with Matlab Simulated results

10 mS Radio Frame

Complex Rx data

| 0 | 1 | 2 | ... | | 127 | y[n] |

Insert next Rx sample in FIFO

Multiply 128 Rx samples with each Zadoff-Chu Sequence (3)

Rx data (complex)

| 0 | 1 | 2 | | ... | | 127 |

x

Zadoff-Chu Sequence
(complex data)
(time domain)

| 0 | 1 | 2 | | ... | | 127 |

PSS Result 0
PSS Result 1
PSS Result 2

Threshold detect 2 PSS Peaks

```
📄 cp_corr_pss_sss_csim.log ×
 1 INFO: [SIM 2] *************** CSIM start ***************
 2 INFO: [SIM 4] CSIM will launch GCC as the compiler.
 3    Compiling ../../../../cp_corr_pss_sss_test.cpp in debug mode
 4    Compiling ../../../../cp_corr_pss_sss.cpp in debug mode
 5    Compiling ../../../../matmul_partition.cpp in debug mode
 6    Generating csim.exe
 7
 8  n=0
 9
10 Index      Description      Calculated            Gold
11 000        pss_rslts_0      0.011211848817766     0.011211834847927
12 000        pss_rslts_1      0.007450049743056     0.007450057193637
13 000        pss_rslts_2      0.008478664793074     0.008478645235300
14
15 001        pss_rslts_0      0.002562189241871     0.002562147332355
16 001        pss_rslts_1      0.005705999676138     0.005705954041332
17 001        pss_rslts_2      0.007109185680747     0.007109189871699
```

```
811 ------------------
812    RMSE(R)
813 0.000000039447585
814 ------------------------------------------------
815 ********************************************
816 PASS: The output matches the golden output!
817 ********************************************
818 The maximum depth reached by any of the 1188 hls::stream() instances in the des
819 INFO: [SIM 1] CSim done with 0 errors.
820 INFO: [SIM 3] *************** CSIM finish ***************
```

Identity within the group (0 to 2)

- Identify known sequence in Rx data
    - 1 of 3 possible Zadoff-Chu sequences
- Part 1 of getting Physical Cell ID (504 Unique IDs)
- Complex multiply: Rx data and Zadoff-Chu sequences (converted to time domain)
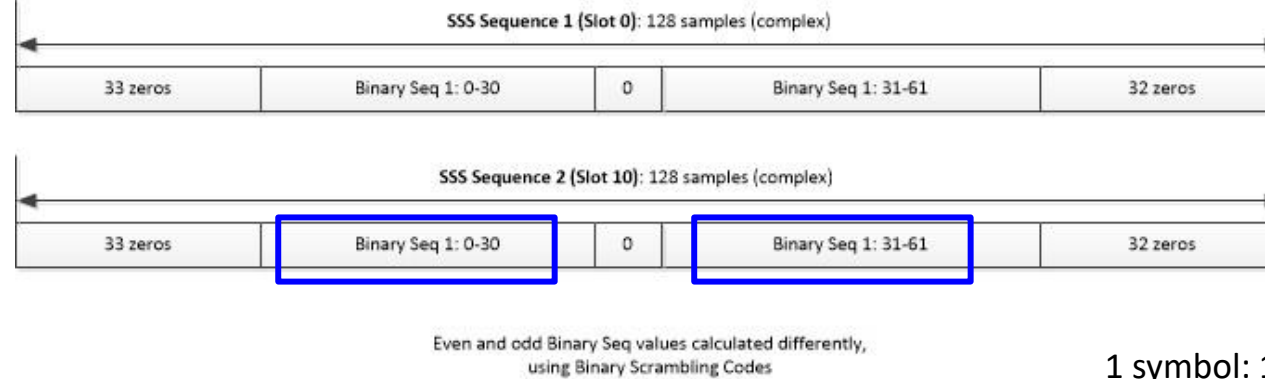- Threshold detection to determine correlation peaks

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Synchronization - SSS

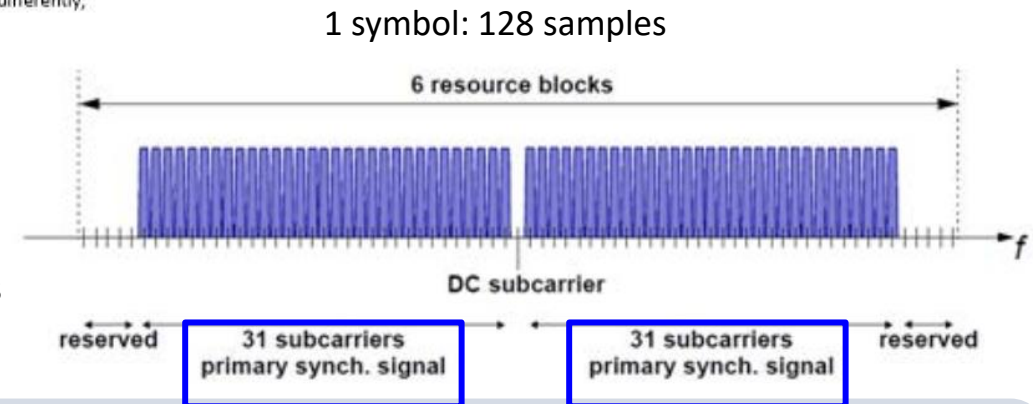Test Bench: Verified HLS code with Matlab Simulated results

The physical cell identity, N_{ID}^{cell}, is defined by the equation:

$$N_{ID}^{CELL} = 3N_{ID}^{(1)} + N_{ID}^{(2)}$$

- $N_{ID}^{(1)}$ is the physical layer cell identity group (0 to 167).
- $N_{ID}^{(2)}$ is the identity within the group (0 to 2).

1 symbol: 128 samples
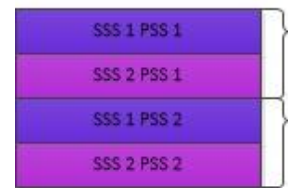
e.g. SSS 1 PSS 1 = SSS Seq 1 * PSS symbol samples

Physical layer cell identity group (0 to 167)

- FFT to demodulate OFDM data
- SSS Correlation: Multiply and accumulate 2 SSS Sequences (binary scrambling codes)
  - ■ Demodulated Rx data
- Threshold detection to determine correlation peaks
- Peak location range [0 167] = physical layer identity group