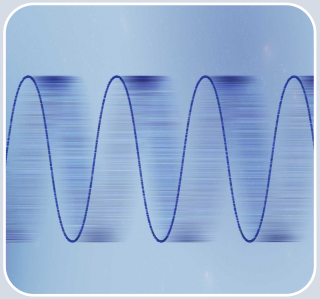
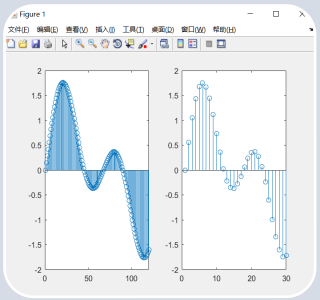
# System Requirements and Configurations



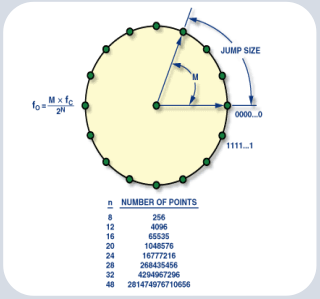
## ADC Configuration

- 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

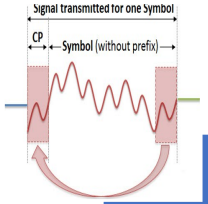
- Our System needs decimation of 2048.
- 8x decimation in RF Soc. From 3932.16MHz to 491.52MHz.
- 256x decimation in our custom IP to achieve Fs of 1.92MHz at LTE Cell search IP.




## NCO (Numerically Controlled Oscillator)

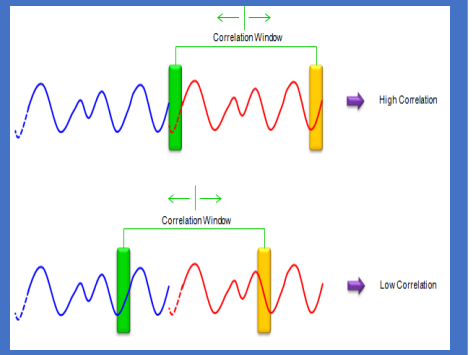
- NCO configured to down convert carrier frequency to DC.
- 48-bit NCO per RF-ADC.
- Mixer is programmed to fine mode.

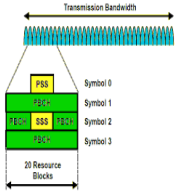
# Main LTE Blocks – For Cell Search




## CP

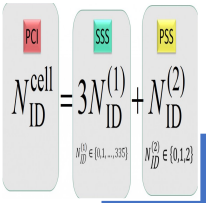
- Cyclic Prefix is an exact copy of the last part of OFDM symbol



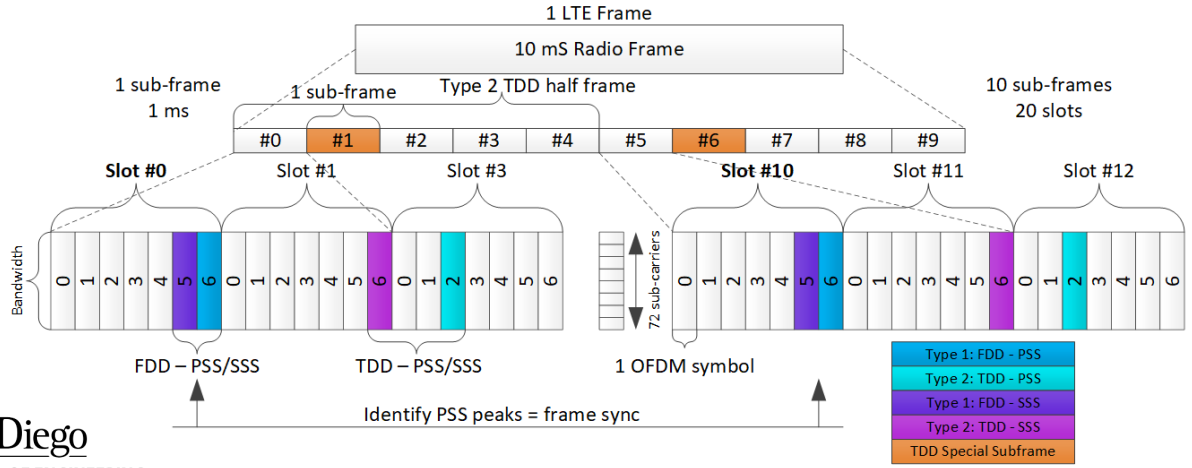

## PSS

- 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.




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

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

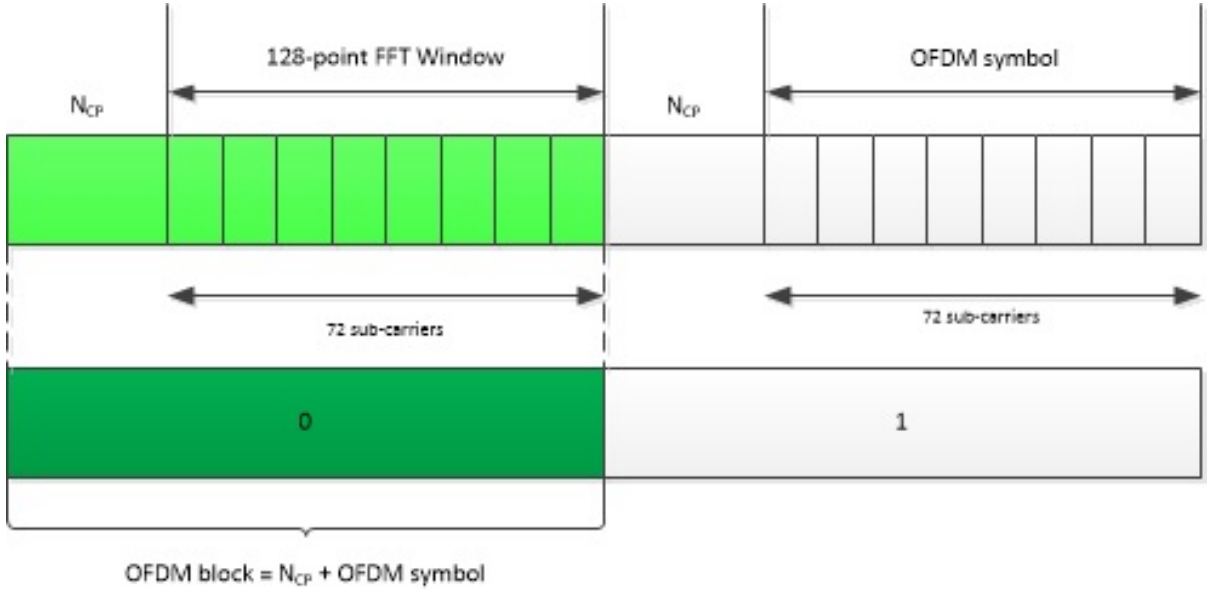
- $N_{ID}^{(1)}$ is the physical layer cell identity group (0 to 167).
- $N_{ID}^{(2)}$ is the identity within the group (0 to 2).

# Frequency Estimation

Test Bench: Verified HLS code with Matlab Simulated results

cp_corr_csim.log

```
555.542602539062500 555.533203125000000
572.667480468750000 572.657836914062500
575.054260253906250 575.044494628906250
576.773376464843750 576.763488769531250
574.544860839843750 574.534851074218750
566.088073730468750 566.077758789062500
580.017028808593750 580.006408691406250
587.009460449218750 586.998352050781250
590.618041992187500 590.606750488281250
612.359985351562500 612.349243164062500
------------------------------------------------
   RMSE(R)
0.005147035699338
------------------------------------------------
************************************************
PASS: The output matches the golden output!
************************************************
The maximum depth reached by any of the 3 hls::stream() instances in the design is 96000
INFO: [SIM 1] CSim done with 0 errors.
INFO: [SIM 3] *************** CSIM finish ***************
```




## 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)

# Synchronization

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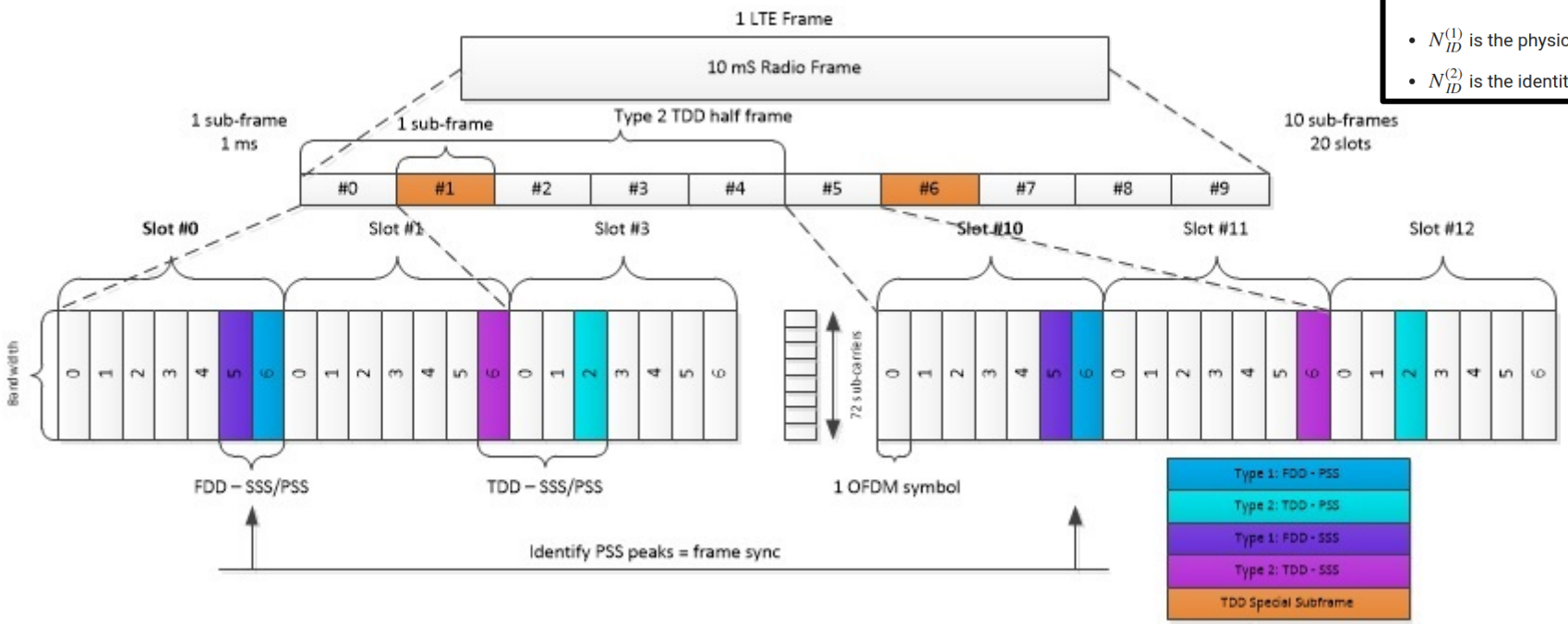


## Structure of LTE frame

- 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

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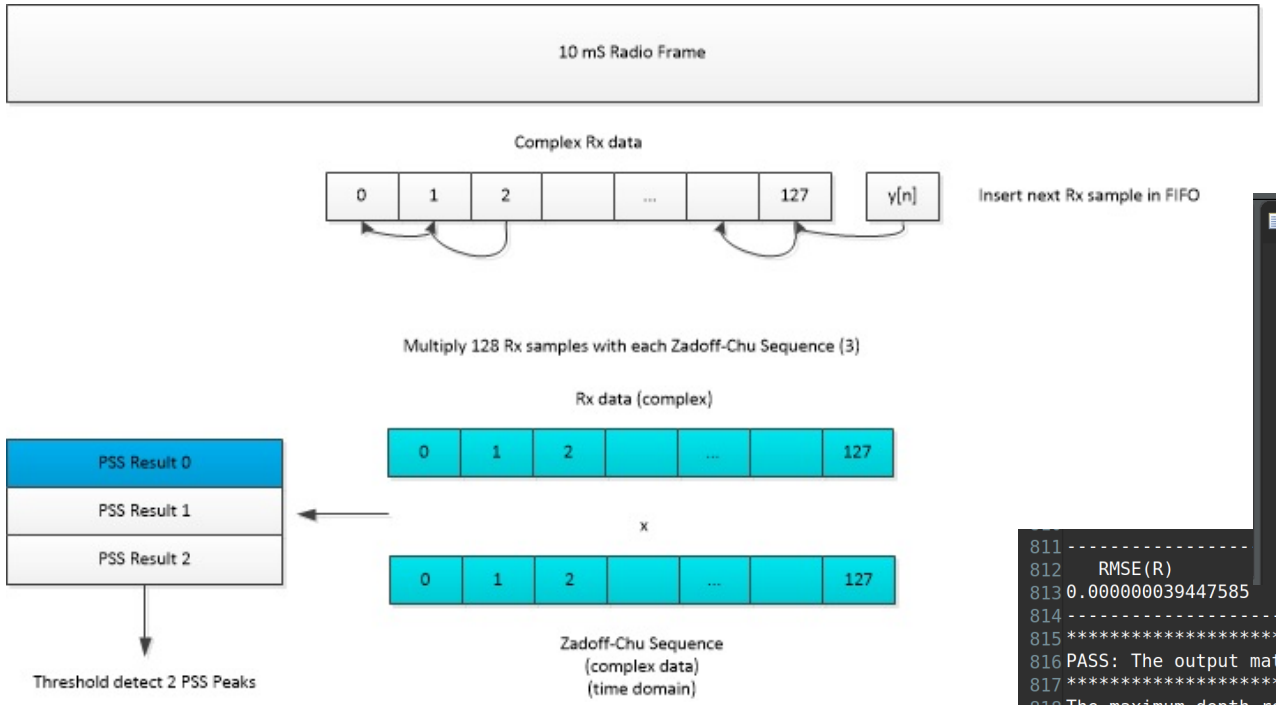



Test Bench: Verified HLS code with Matlab Simulated results

cp_corr_pss_sss_csim.log

```
INFO: [SIM 2] *************** CSIM start ***************
INFO: [SIM 4] CSIM will launch GCC as the compiler.
   Compiling ../../../../cp_corr_pss_sss_test.cpp in debug mode
   Compiling ../../../../cp_corr_pss_sss.cpp in debug mode
   Compiling ../../../../matmul_partition.cpp in debug mode
   Generating csim.exe

n=0

Index    Description      Calculated           Gold
000      pss_rslts_0      0.011211848817766    0.011211834847927
000      pss_rslts_1      0.007450049743056    0.007450057193637
000      pss_rslts_2      0.008478664793074    0.008478645235300

001      pss_rslts_0      0.002562189241871    0.002562147332355
001      pss_rslts_1      0.005705999676138    0.005705954041332
001      pss_rslts_2      0.007109185680747    0.007109189871699

----------
   RMSE(R)
0.000000039447585
-----------------------------------------
*****************************************
PASS: The output matches the golden output!
*****************************************
The maximum depth reached by any of the 1188 hls::stream() instances in the des
INFO: [SIM 1] CSim done with 0 errors.
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

# Synchronization - SSS

Test Bench: Verified HLS code with Matlab Simulated results

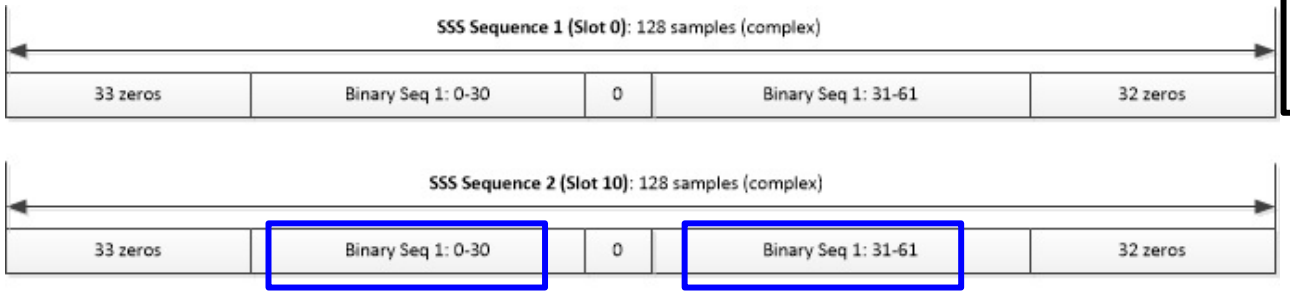
cp_corr_pss_sss_csim.log

```
INFO: [SIM 2] *************** CSIM start ***************
INFO: [SIM 4] CSIM will launch GCC as the compiler.
   Compiling ../../../../cp_corr_pss_sss_test.cpp in debug mode
   Compiling ../../../../cp_corr_pss_sss.cpp in debug mode
   Compiling ../../../../matmul_partition.cpp in debug mode
   Generating csim.exe
Start Read
Calling sss_sync

 n=0

Index  Description  Calculated            Gold
0      Out_11r      -0.247550204396248    -0.247584104537964
0      Out_11i      0.003370870836079     0.003370859427378
0      Out_12r      -0.250740051269531    -0.251053690910339
0      Out_12i      0.000468272890430     0.002253722399473
0      Out_21r      0.749129891395569     0.749139189720154
0      Out_21i      -0.001893163658679    -0.001893070875667
0      Out_22r      0.749780058860779     0.749722421169281
0      Out_22i      -0.000135826820042    -0.000306707486743
...
167      Out_11r      -0.258170008659363    -0.258163273334503
167      Out_11i      0.003966394811869     0.003966243937612
167      Out_12r      0.750460088253021     0.748103439807892
167      Out_12i      0.000252946862020     -0.000963220431004
167      Out_21r      -0.252290070056915    -0.252318084239960
167      Out_21i      0.001886585028842     0.001886588521302
167      Out_22r      0.749579966068268     0.749049842357635
167      Out_22i      0.000177846755832     0.000045595592383

------------------------------------------------
   RMSE(R)
0.001652569510043
------------------------------------------------
************************************************
PASS: The output matches the golden output!
************************************************
The maximum depth reached by any of the 1188 hls::stream() insta
INFO: [SIM 1] CSim done with 0 errors.
INFO: [SIM 3] *************** CSIM finish ***************
```

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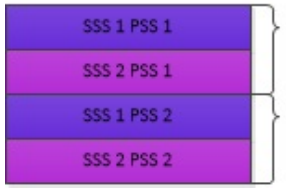
Even and odd Binary Seq values calculated differently, using Binary Scrambling Codes



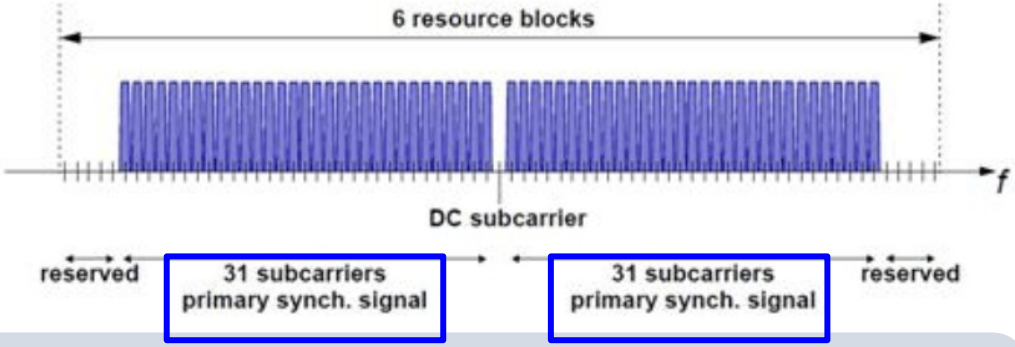

SSS Slot #1

SSS Slot #11

SSS correlation peak location in each slot should match

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

1 symbol: 128 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