APPLICATION NOTE

Analyzing UXM IQ captures with the SJ001A WaveJudge Wireless Analyzer Toolset

Import, Decode and Troubleshoot UXM IQ Captures

Insightful Wireless Analysis to Diagnose and Adjudicate Root Cause of Problems

Troubleshooting functional and interoperability issues in 5G is not easy. We need to determine what Protocol messages were sent, relative to what PHY events occurred, and the timing of those messages and events. With Sanjole Solutions, Keysight can address new use cases moving forward.

This Application Note describes the process to import, decode and troubleshoot UXM IQ captures. This is really useful to complement the capabilities of Keysight Network Emulation Solutions, and to adjudicate disputes created when multiple vendors' products and analysis logs are contradictory, causing undue delays and increasing engineering expenses.

This paper demonstrates how to analyze
UXM 5G IQ captures using the
Keysight WaveJudge Wireless Analyzer Toolset

Testing 5G requires diagnosing the root causes of problems between layers, which often takes hours, days or even weeks.

The SJ001A WaveJudge Wireless Analyzer Toolset provides visibility into protocol and physical layer interaction in wireless transmissions, with the ability to record and review the conditions when performance is optimal and compare when the results are less than expected.

KEYSIGHT TECHNOLOGIES

Table of Contents

Preliminary Steps

1. Run WaveJudge (this step has to be done once only). The shortcut should be available on the desktop.

Figure 1. WaveJudge Icon, available on the desktop

2. If there is an error message observed about the license during WaveJudge launching, please check the following information:

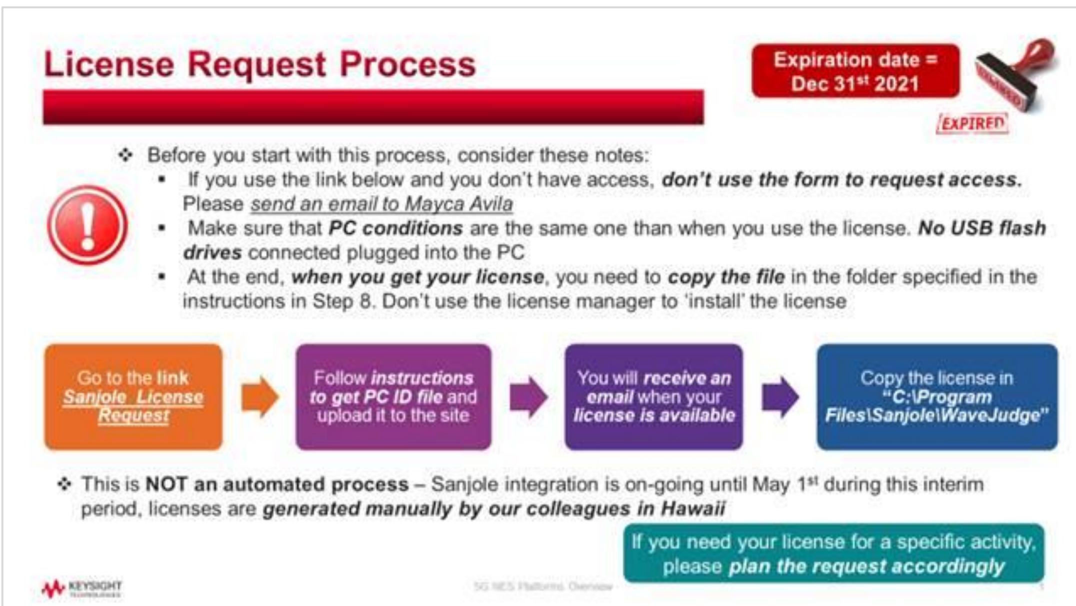


Figure 2. License Request Process

It may be also required to change the settings the first time that WaveJudge is opened under your profile. If so, click on OK and make sure that Cell is configured as below. Click on Apply to apply the changes. If you have already the default setting, you can just use it.

A. Configure 5G NR as scenario (Please perform this if you don't have a following setting)

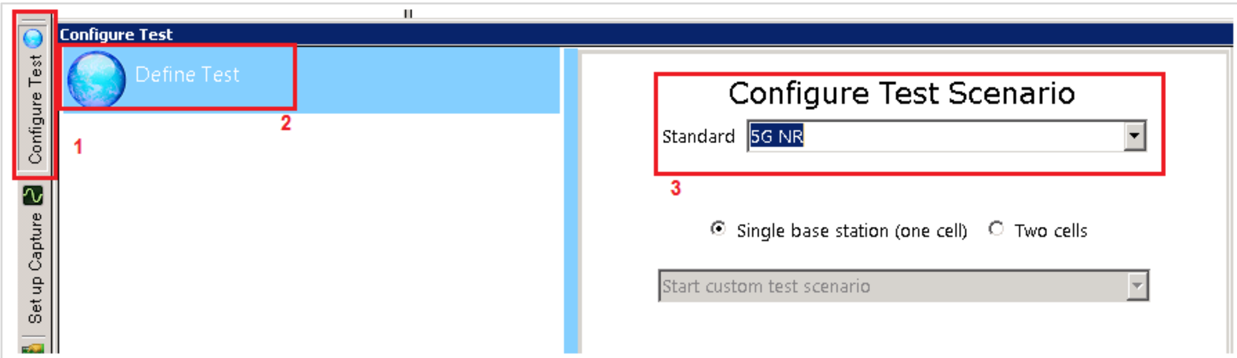


Figure 3. Configure 5G NR Test Scenario

B. Click on Add Cell → 5G NR Cell

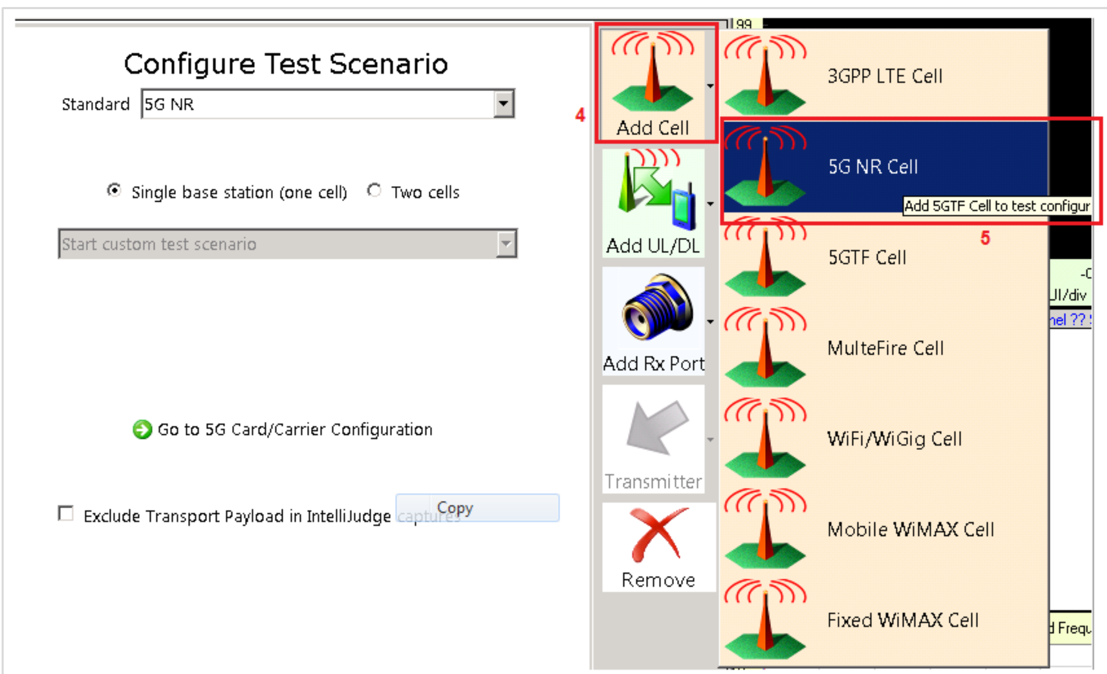


Figure 4. Add 5G NR Cell

C. Configure 5G NR cell with any valid configuration. Do not need to take care of the 5GNR configuration right now.

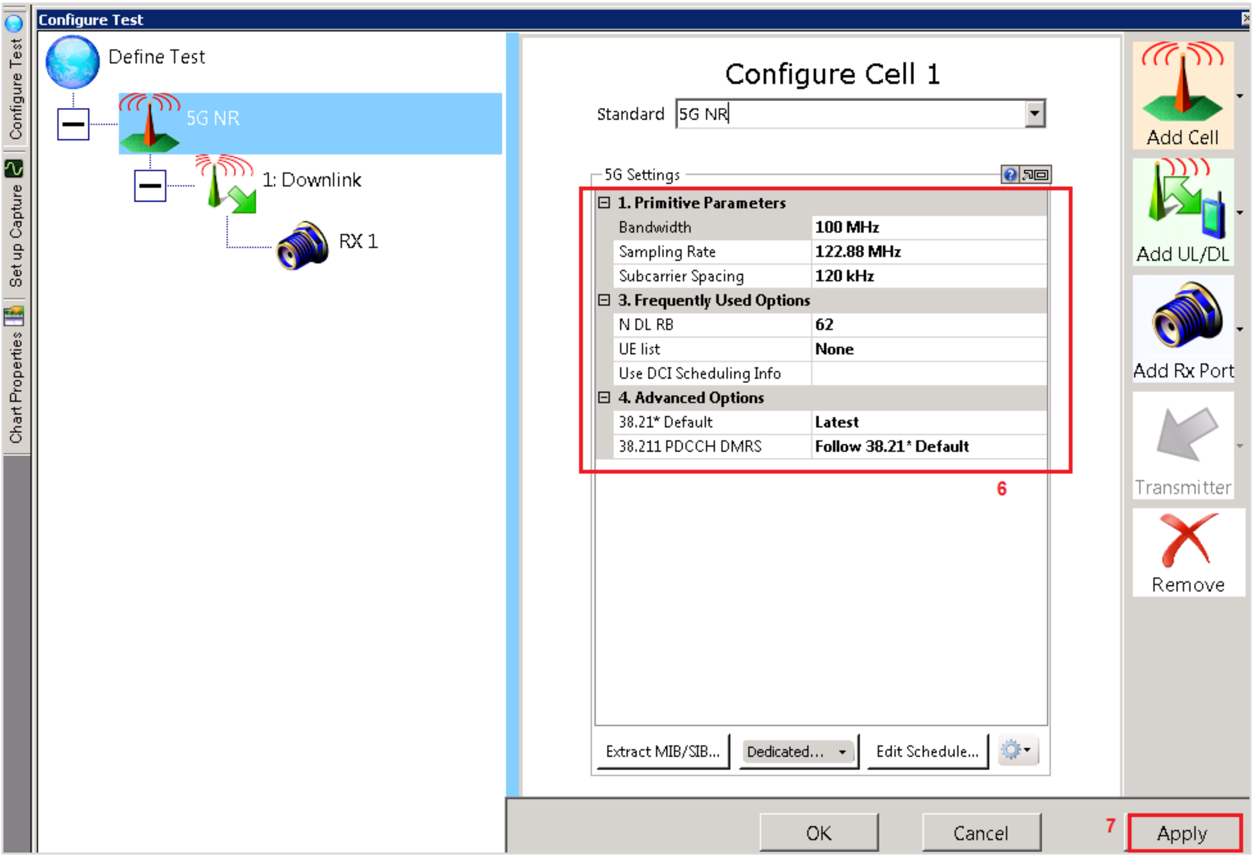


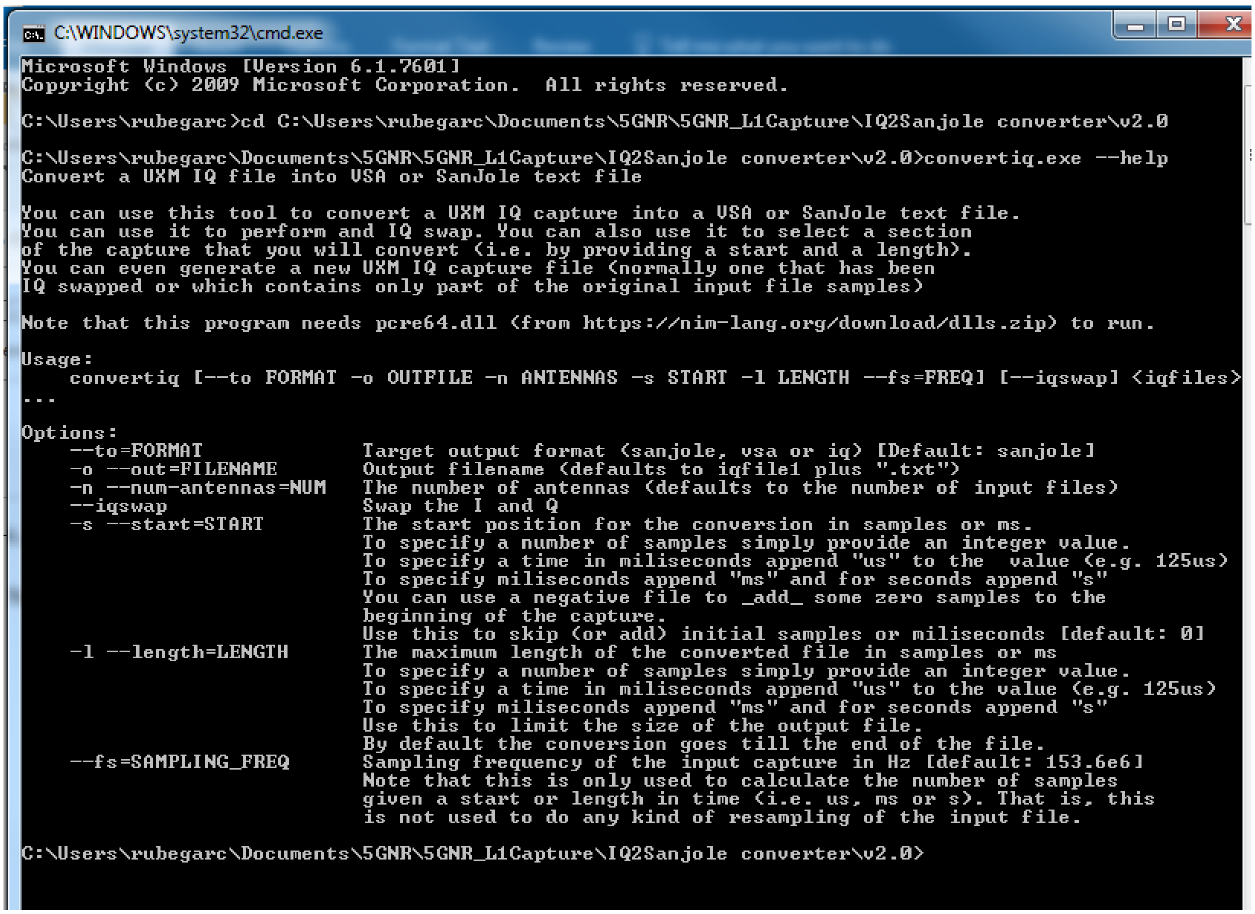
Figure 5. Configure 5G NR cell

How to Load an IQ Capture onto WaveJudge

1. Perform an IQ capture (either using TAP or L1 Capture tool) with the info to be analyzed.

2. Convert that IQ capture files to WaveJudge format. For that, you can use an iq2sanjole converter program or Matlab (e.g. fid = fopen(\'y1_DL1.iq\'); x = fread(fid, inf, \'int16\', 0, \'l\');).

Instructions to use this are simple. You can type convertiq.exe –help to get more details about the input/output allowed parameters. This tool allows converting .IQ files to Sanjole format, VSA format, or IQ format (if you desire to cut the capture, making it shorter or capturing only a part of the entire capture).



```
C:\WINDOWS\system32\cmd.exe
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Users\rubegarc>cd C:\Users\rubegarc\Documents\5GNR\5GNR_L1Capture\IQ2Sanjole converter\v2.0

C:\Users\rubegarc\Documents\5GNR\5GNR_L1Capture\IQ2Sanjole converter\v2.0>convertiq.exe --help
Convert a UXM IQ file into VSA or SanJole text file

You can use this tool to convert a UXM IQ capture into a VSA or SanJole text file.
You can use it to perform and IQ swap. You can also use it to select a section
of the capture that you will convert (i.e. by providing a start and a length).
You can even generate a new UXM IQ capture file (normally one that has been
IQ swapped or which contains only part of the original input file samples)

Note that this program needs pcre64.dll (from https://nim-lang.org/download/dlls.zip) to run.

Usage:
    convertiq [--to FORMAT -o OUTFILE -n ANTENNAS -s START -l LENGTH --fs=FREQ] [--iqswap] <iqfiles>
...

Options:
    --to=FORMAT             Target output format (sanjole, vsa or iq) [Default: sanjole]
    -o --out=FILENAME       Output filename (defaults to iqfile1 plus ".txt")
    -n --num-antennas=NUM   The number of antennas (defaults to the number of input files)
    --iqswap                Swap the I and Q
    -s --start=START        The start position for the conversion in samples or ms.
                            To specify a number of samples simply provide an integer value.
                            To specify a time in miliseconds append "us" to the  value (e.g. 125us)
                            To specify miliseconds append "ms" and for seconds append "s"
                            You can use a negative file to _add_ some zero samples to the
                            beginning of the capture.
                            Use this to skip (or add) initial samples or miliseconds [default: 0]
    -l --length=LENGTH      The maximum length of the converted file in samples or ms
                            To specify a number of samples simply provide an integer value.
                            To specify a time in miliseconds append "us" to the value (e.g. 125us)
                            To specify miliseconds append "ms" and for seconds append "s"
                            Use this to limit the size of the output file.
                            By default the conversion goes till the end of the file.
    --fs=SAMPLING_FREQ      Sampling frequency of the input capture in Hz [default: 153.6e6]
                            Note that this is only used to calculate the number of samples
                            given a start or length in time (i.e. us, ms or s). That is, this
                            is not used to do any kind of resampling of the input file.

C:\Users\rubegarc\Documents\5GNR\5GNR_L1Capture\IQ2Sanjole converter\v2.0>
```

Figure 6. Convert IQ help details

Example:

IQ Captures named as → y1_DL1.iq, y2_DL1.iq

Command to execute: convertiq.exe --to sanjole -o capture.txt -s 0 y1_DL1.iq y2_DL1.iq

This command will generate a capture.txt file that can be opened by WaveJudge software. This file structure is 8 columns. The first four columns belong to 1st antenna port, and the other four columns belong to the 2nd antenna port.

- First column: I numerical values of 1st antenna port.
- Second column: Q numerical values of 1st antenna port.
- Third column: I numerical values of 2nd antenna port.
- Fourth column: Q numerical values of 2nd antenna port.

```
862137  -2041   -1328   0   0
862138  3337    2925    0   0
862139  4135    4060    0   0
862140  793 -2519   0   0
862141  -2592   -2087   0   0
862142  340 354 0   0
862143  4151    -1935   0   0
862144  -2719   112 0   0
862145  -3077   3324    0   0
862146  4026    1953    0   0
862147  953 1168    0   0
862148  -2454   866 0   0
862149  -2427   1367    0   0
```

Figure 7. Capture.txt columns format

3. Open WaveJudge and click on File → Import → I/Q Samples from text file.

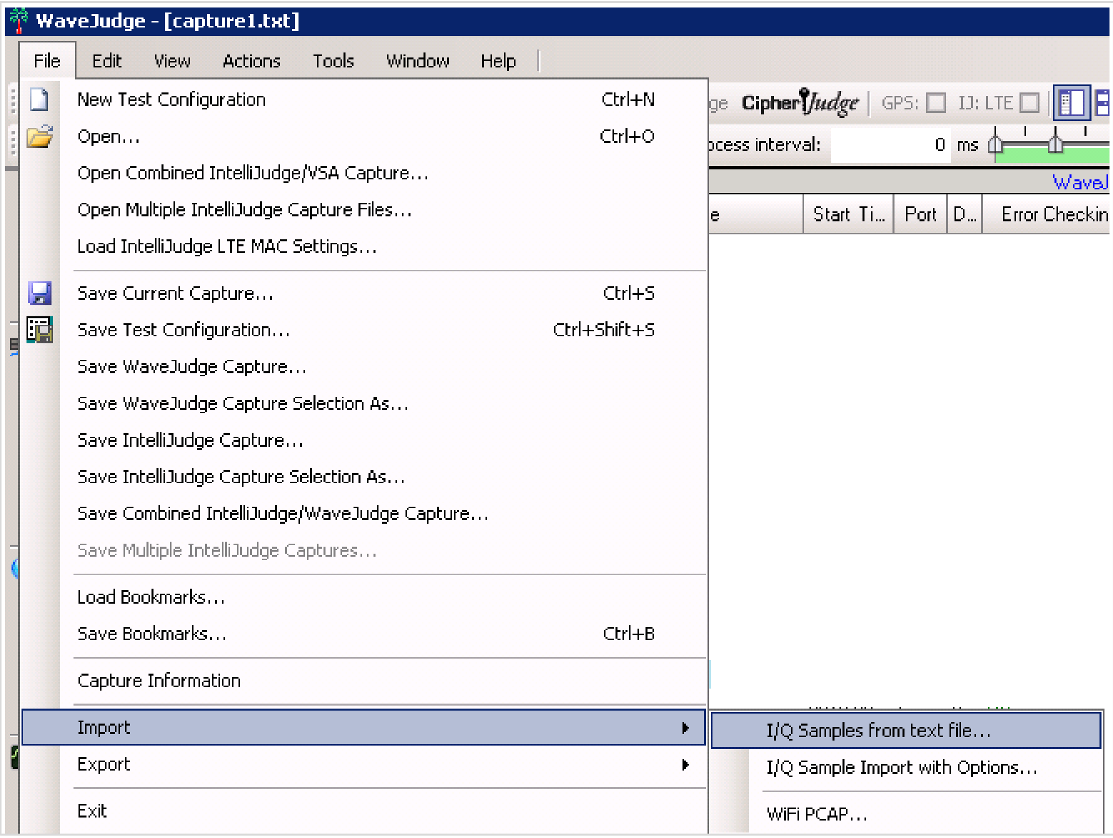


Figure 8. Selecting the .txt file

Select the .txt file generated in step #2 and wait until it is imported completely.

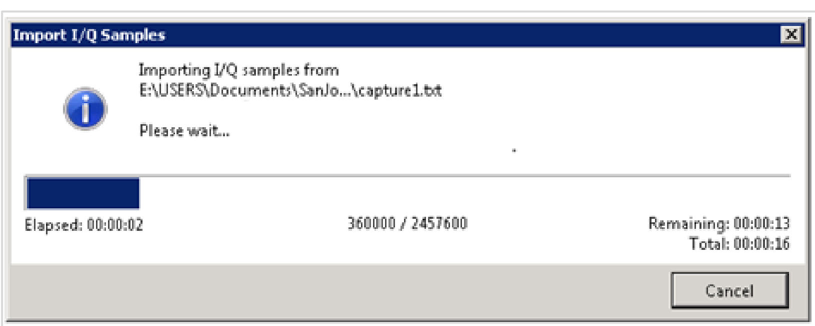


Figure 9. Importing the .txt file

4. Once imported, click on the Reprocess button.

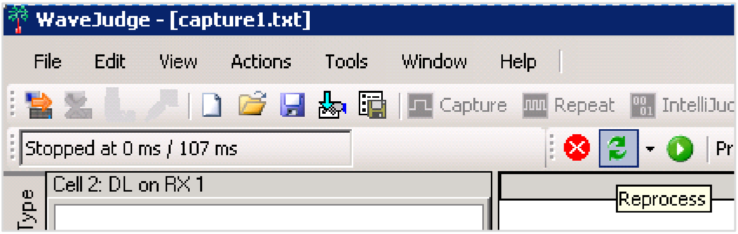


Figure 10. Reprocessing (after importing)

5. Once completed, you should be able to see the signal on WaveJudge (at least, on time domain).

6. Start to configure the **5G NR parameters and/or Scheduling elements** to properly decode the signal. If it already exists, you may load an existing WaveJudge configuration file and apply it to the current I/Q capture. This will make the analysis easier and faster.

To do this:

a. In WaveJudge, File → Open

b. Select the WaveJudge Configuration file.

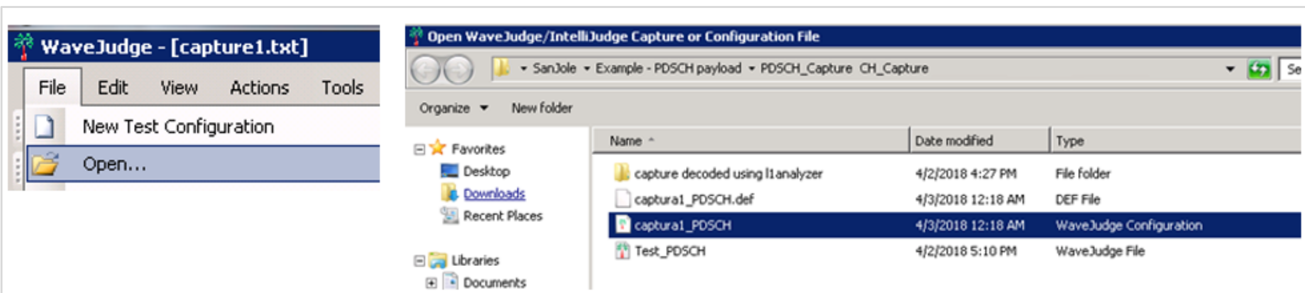
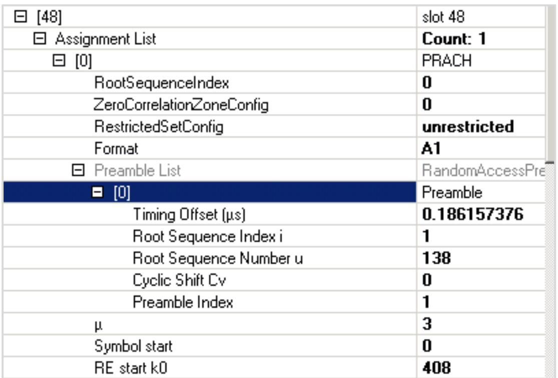


Figure 11. Opening and selecting an existing WaveJudge configuration file

PRACH Analysis

Parameters



[48]	slot 48
Assignment List	**Count: 1**
[0]	PRACH
RootSequenceIndex	**0**
ZeroCorrelationZoneConfig	**0**
RestrictedSetConfig	**unrestricted**
Format	**A1**
Preamble List	RandomAccessPre
[0]	Preamble
Timing Offset (µs)	**0.186157376**
Root Sequence Index i	**1**
Root Sequence Number u	**138**
Cyclic Shift Cv	**0**
Preamble Index	**1**
µ	**3**
Symbol start	**0**
RE start k0	**408**

Figure 12. PRACH Analysis Parameters

WaveJudge Verification

1. Time domain power → OK

Format		N_{SEQ}	T_{CP}	T_{SEQ}	T_{GP}	Use case
A	1	2	288 • T_S	2048 • T_S	0 • T_S	Small cell

$T_s = {}^{1}/_{8\cdot 30720}\ ms$ *for 120 kHz subcarrier spacing*

PRACH Format A1 = $288\cdot T_s + 2\cdot 2048\cdot T_s + 0\cdot T_s \approx$ **18 µs**

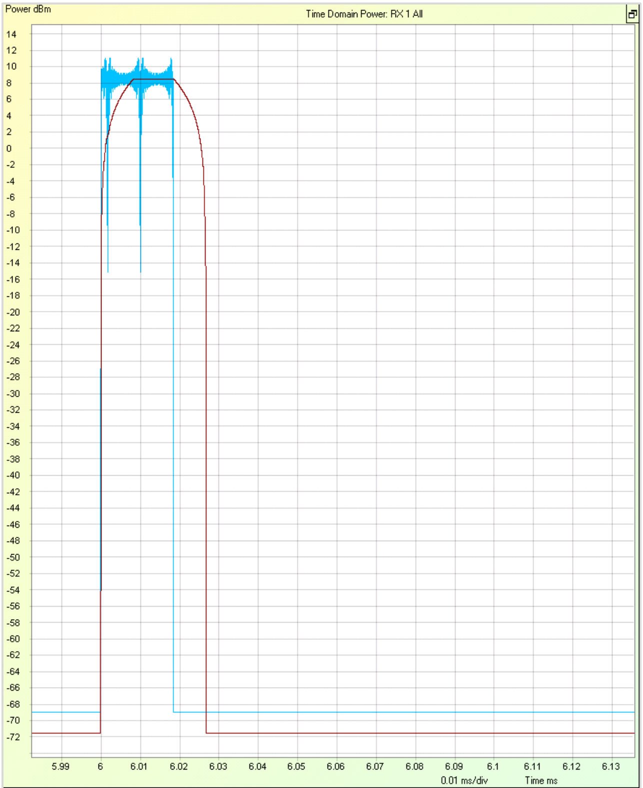


Figure 13. PRACH in time domain

2. Mapping location → OK (2 OFDM symbols (1st and 2nd) in Format A1)

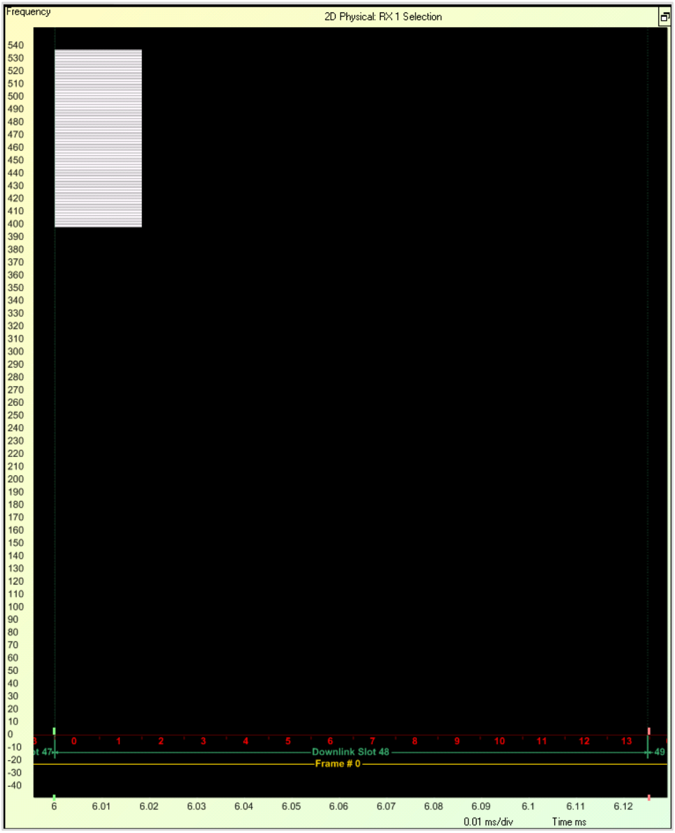


Figure 14. PRACH mapping location

3. Number of subcarriers → OK

144 subcarriers = 12 PRBs.

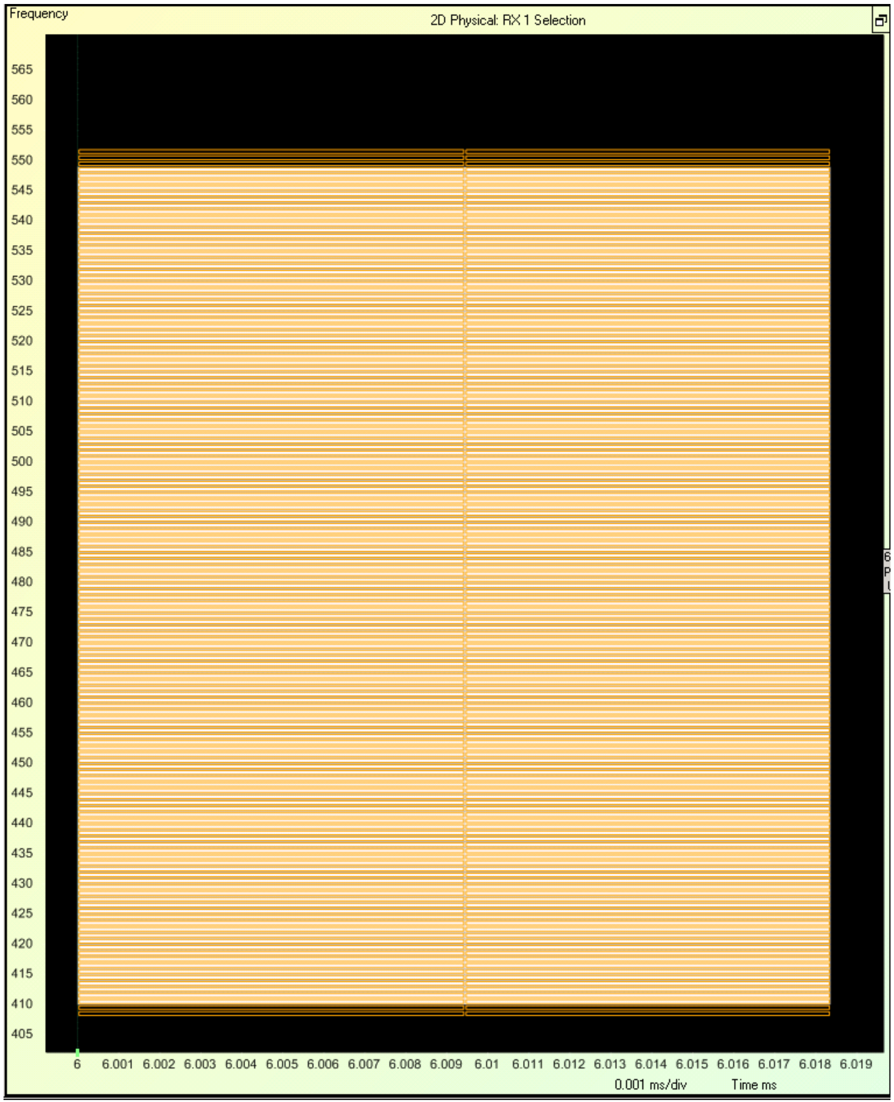


Figure 15. PRACH subcarriers

4. Cell ID = 0 → OK

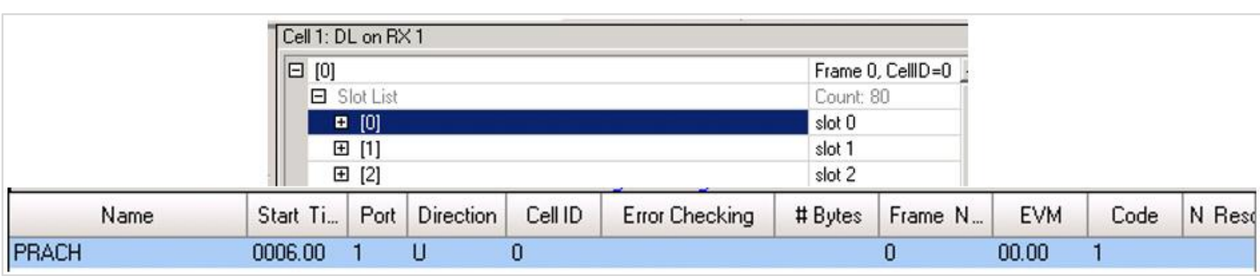


Figure 16. Cell ID in PRACH

SSB Analysis

Parameters

```
% General Parameters
f0              = 0;                % RF frequency in Hz (set to 0 to skip phase pre-compensation)
n_cell_id       = 28;               % Cell ID                              [0 : 1007]
sfn             = 0;                % System frame number                  [0 1023]
n_hf            = 0;                % Half-frame number                    [0, 1]
mu              = 3;                % Subcarrier scaling (2 ^ mu) * 15 kHz [0, 1, 3]
n_fft           = 1024;             % FFT size                             [512 : 4096] n_fft * (2 ^ mu) * 15 kHz = 122.88 Msps
k_0             = 0;                % Subcarrier offset in OFDM signal transmission [-6, 0, +6]
n_rb            = 66;               % Number of resource blocks            [20 : 275]    n_rb * 12 * (2 ^ mu) * 15 kHz <= 100 MHz
n_bwp_start     = 0;                % Bandwidth part start [0:274].
dc_notch        = false;            % DC notch
n_ant           = 2;                % Number of antennas                   [1 : 2]
periodicity     = 20;                % Periodicity of generated signal (in ms) [5, 10, 15, 20]

% SSB Parameters
mu_ssb          = 3;                % Subcarrier scaling for SSB (2 ^ mu) * 15 kHz [0, 1, 3, 4]
n_fft_ssb       = 1024;             % FFT size for SSB                     [512 : 4096] n_fft * (2 ^ mu) * 15 kHz = 122.88 Msps
k_0_ssb         = 0;                % Subcarrier offset in OFDM signal transmission for SSB [-6, 0, +6]
n_rb_ssb        = 66;               % Number of resource blocks for SSB    [20 : 275]    n_rb_ssb * 12 * (2 ^ mu_ssb) * 15 kHz <= 100 MHz
pss_gain        = 1;                % Gain for PSS                         (< 2.0) - linear maginitude
sss_gain        = 1;                % Gain for PSS                         (< 2.0) - linear maginitude
pbch_tbs        = 24;               % Number of bits for PBCH
pbch_payload    = zeros(1, pbch_tbs);% High layer payload for PBCH (must be 24 bits)
pbch_trch_en    = true;             % Enables channel encoding             [true, false]
pbch_data_gain  = 1;                % Gain for PBCH data                   (< 2.0) - linear maginitude
pbch_dmrs_gain  = 1;                % Gain for PBCH DMRS                   (< 2.0) - linear maginitude
ssb_l           = 64;               % Number of SSB in a SSB Burst Set     (<= 30 kHz: 4 or 8; 120 kHz: 64)
ssb_map30       = 0;                % Mapping alternative for SSB at 30 kHz [0, 1]
ssb_re          = 0;                % First RE of SSB                      [0 : (n_rb_ssb - 20) * 12]
ssb_p1_id       = [1 1];            % P1 index for 2 antennas for all SSBs  (index starts at 0)
ssb_p2_id       = ones([1 64]);     % P2 index for all SSBs in a SSB Burst Set (index starts at 0)
```

Figure 17. General and SSB Parameters

WaveJudge Verification

5. Time domain power → OK

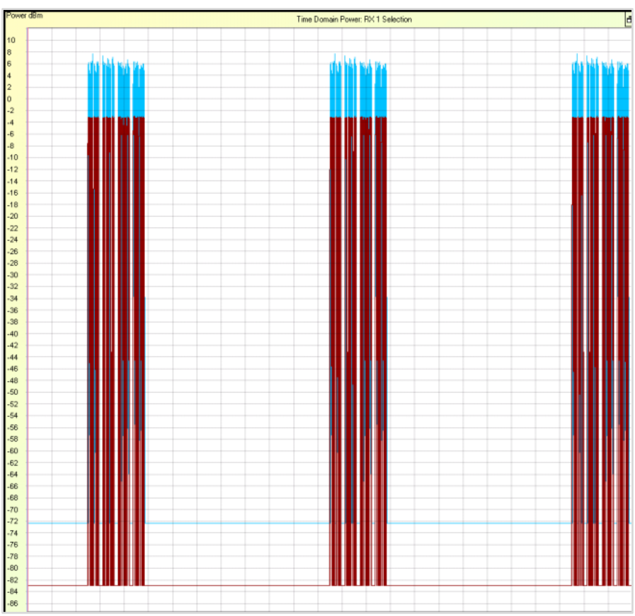


Figure 18. SSB Time Domain Power

6. Mapping location → OK

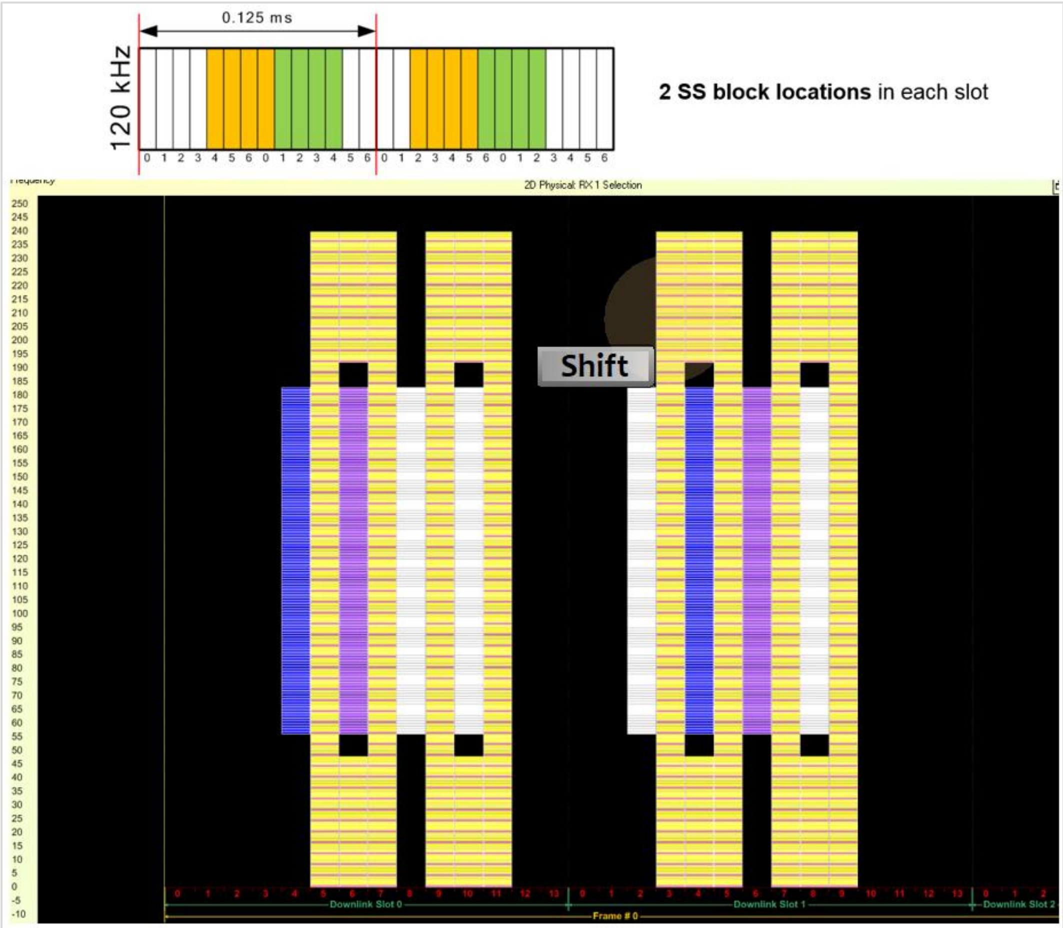


Figure 19. SSB Mapping Location

7. Number of subcarriers → OK

240 subcarriers = 20 PRBs

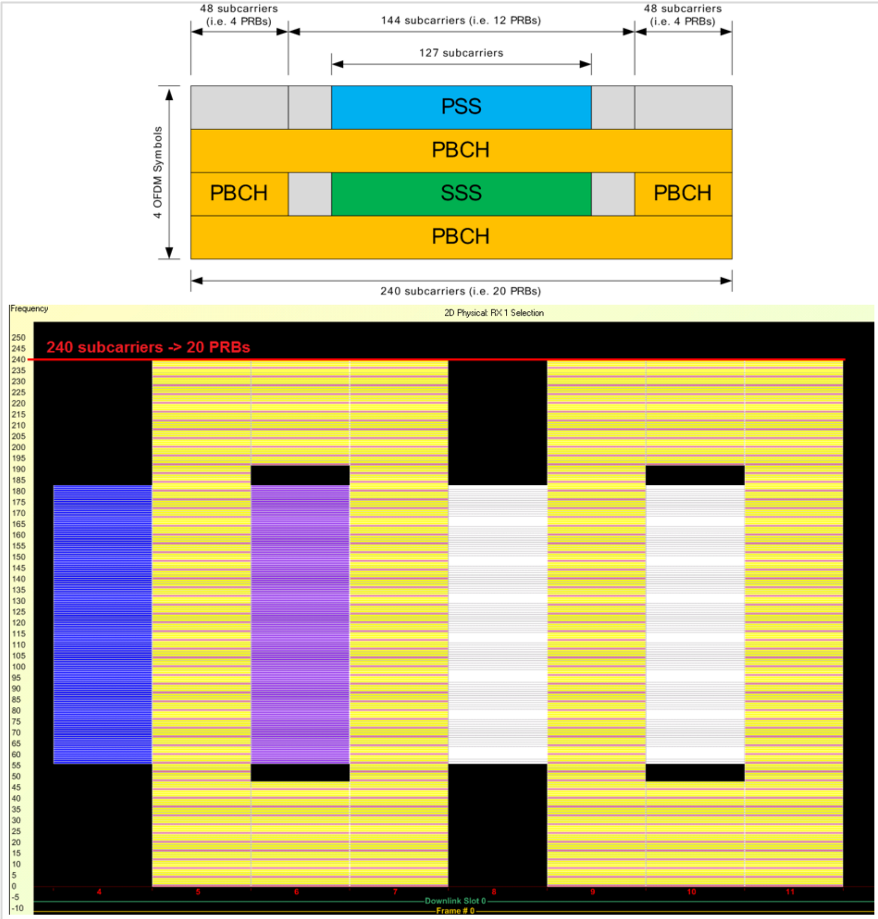


Figure 20. Number of Subcarriers

8. Cell ID = 28 → OK

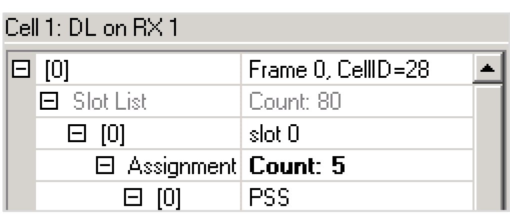


Figure 21. Cell ID in SSB

9. SSB Burst composition → OK

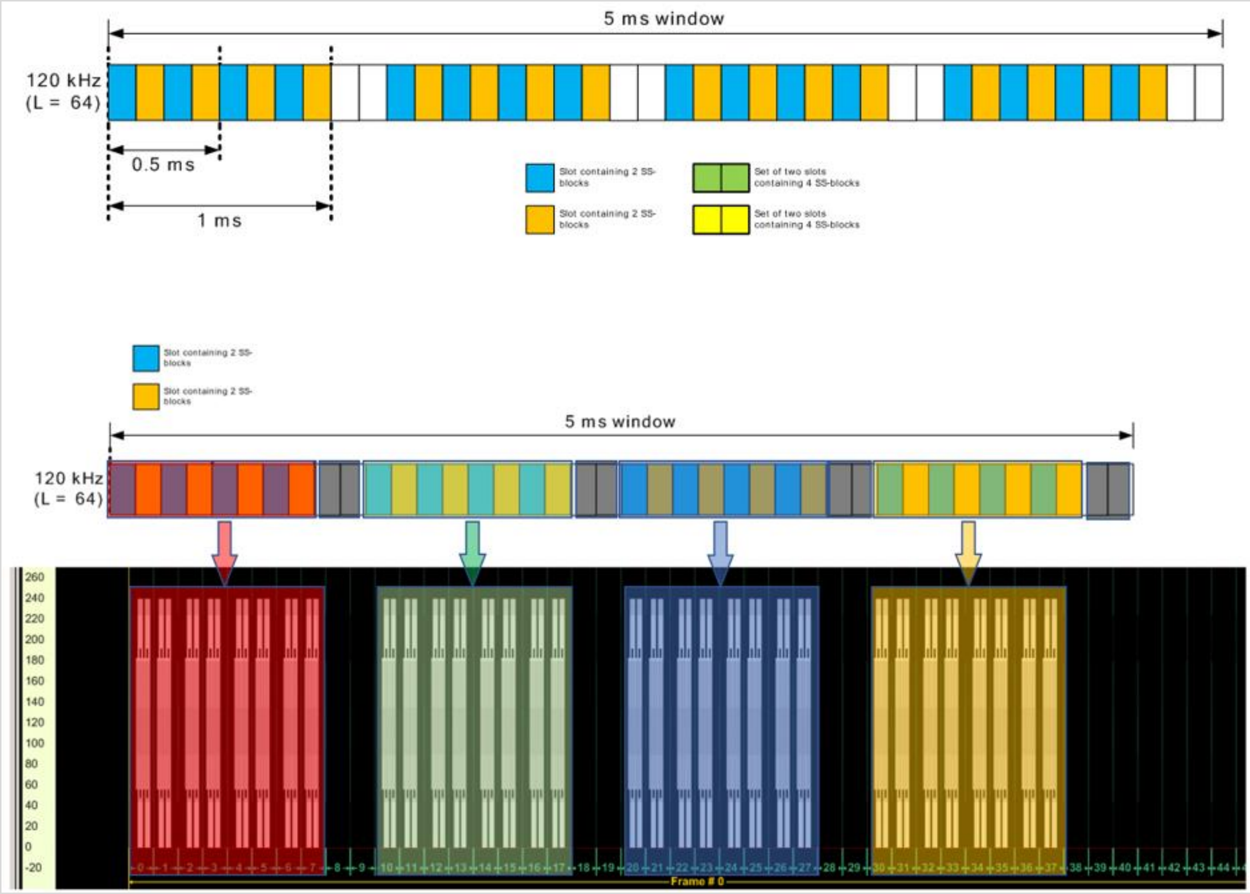


Figure 22. SSB Burst Composition

10. Periodicity (20 ms) → OK

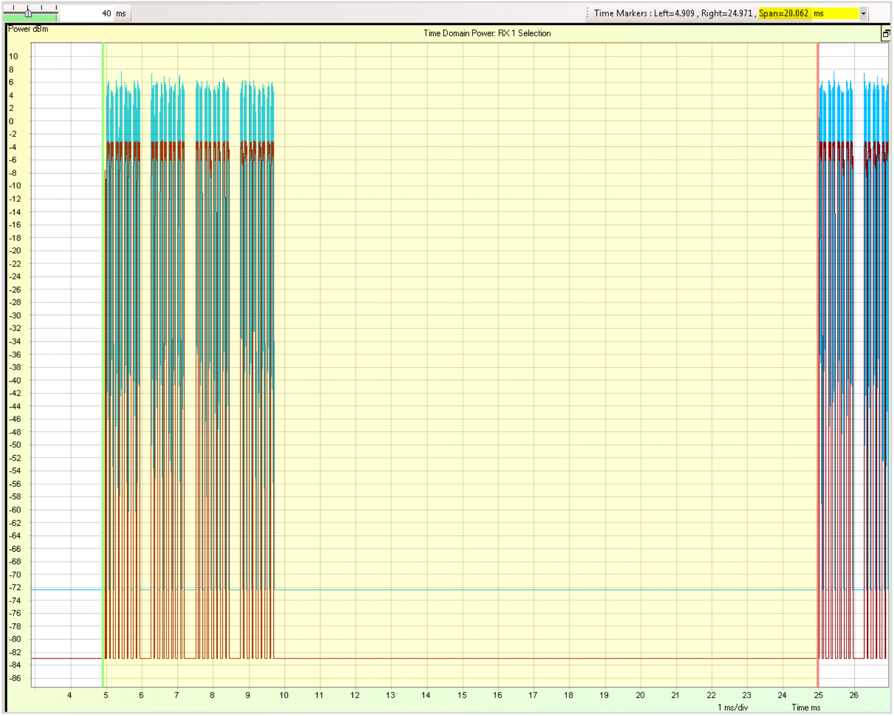


Figure 23. SSB 20 ms periodicity

11. Error checking → OK

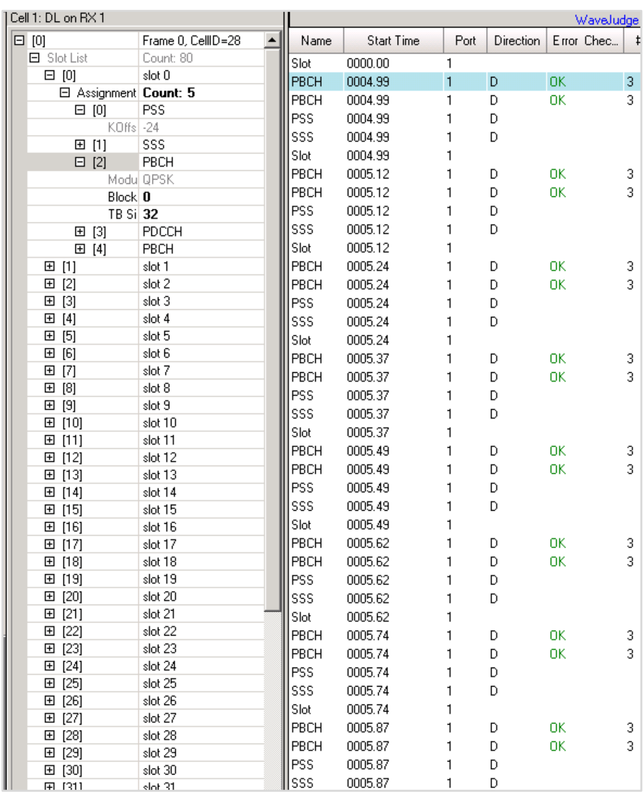


Figure 24. SSB Error Checking

12. EVM and constellation → OK

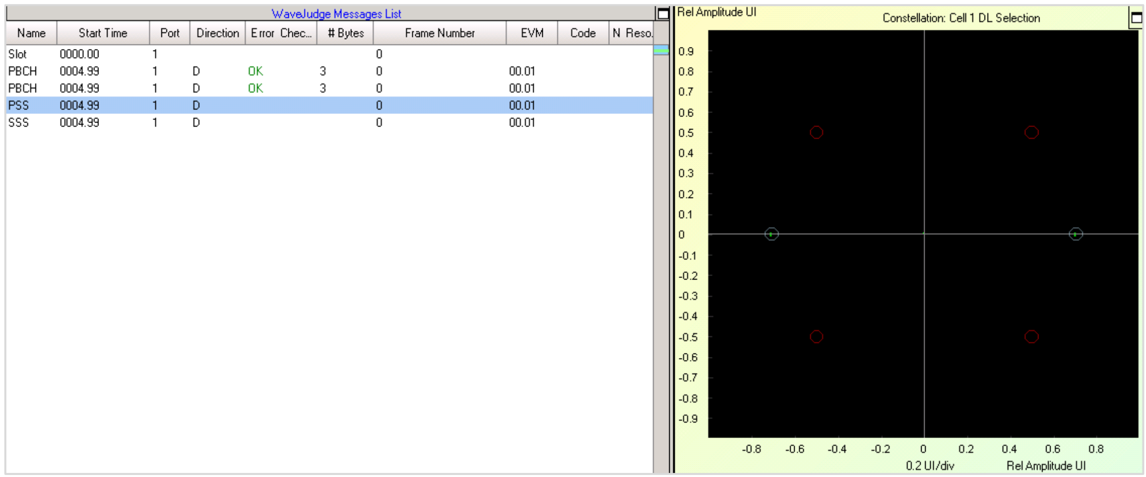


Figure 25. PSS EVM and Constellation

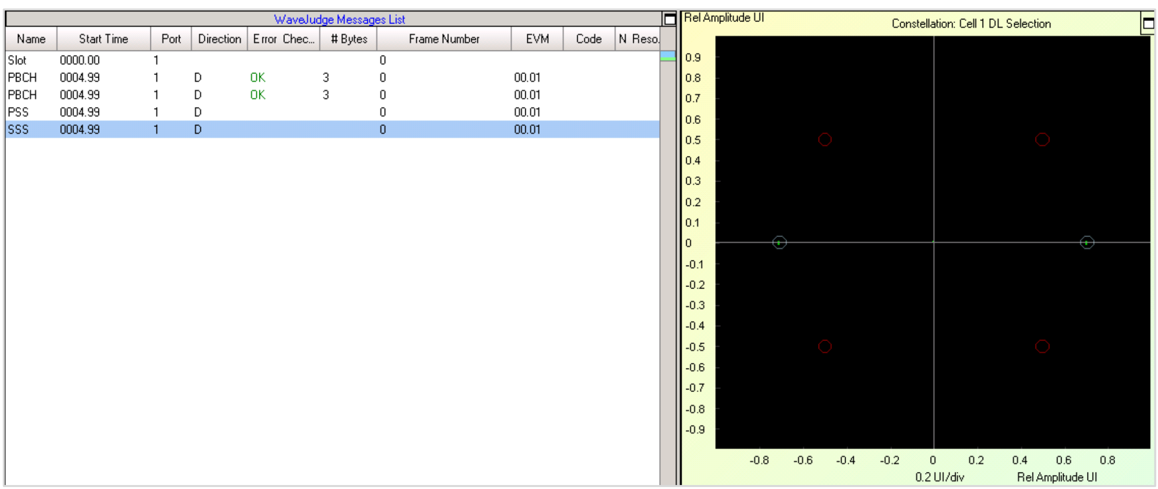


Figure 26. SSS EVM and Constellation

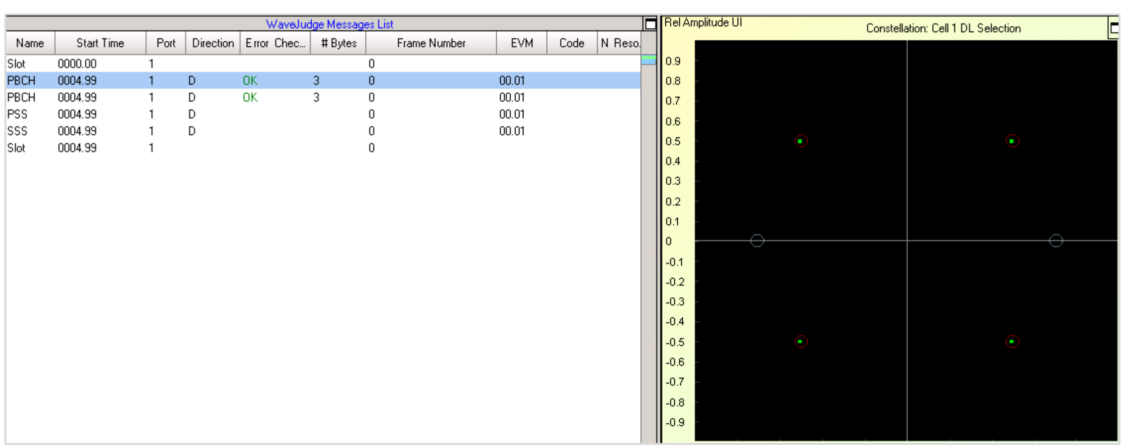


Figure 27. PBCH EVM and Constellation

13. Spectral power (RB Offset) → OK

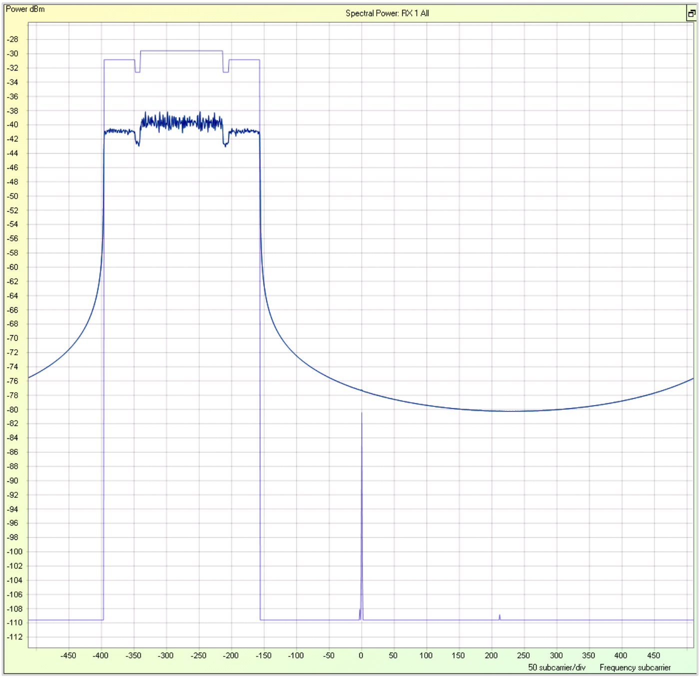


Figure 28. SSB Spectral Power

VSA Verification

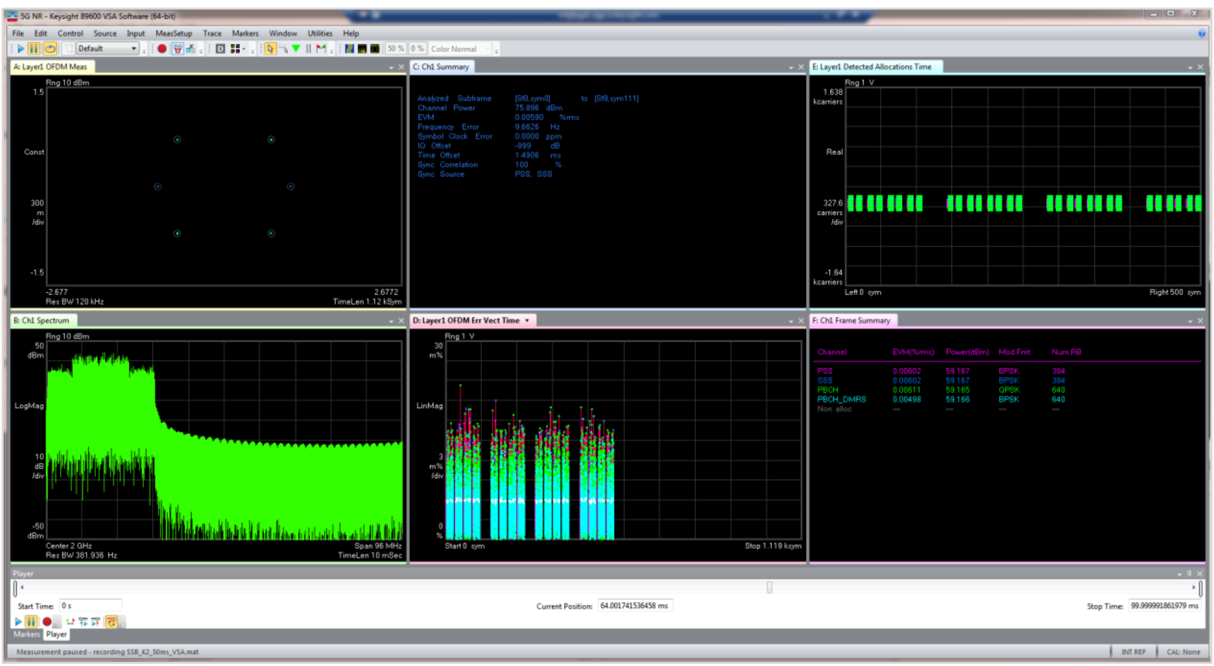


Figure 29. SSB VSA Verification

PDCCH+PDSCH Analysis

Parameters

- PDCCH parameters (kma missed)
- CCE Start = 0
- CCE Length = 1
- TB Size = 56
- RNTI = 1
- Data n ID = 28
- DMRS n ID = 30
- Symbol Length = 1
- PDSCH parameters (extracted from.kma)

```
%% This is an example of a PDSCH configuration file

%% SIGNAL TYPE
standard = 'nr' % Only supported standard is NR
signal_type = 'PDSCH'

%% LOG MODE
mode_interactive = true             % If false then the console is closed inmediately

%% CAPTURE FILES
y0_file = 'C:\LocalTemp\TestTBPDSCH\y5_DL1.iq'           % File containing samples for antenna 0 at Fs_capt
y1_file = 'C:\LocalTemp\TestTBPDSCH\y6_DL1.iq'           % File containing samples for antenna at Fs_capt
Fs_capt = 122.88e6                  % Sampling frequency of the capture expressed in samples per second

% Slot info
ns                  = 52             % Slot number within a frame
sample_offset       = 798720      % offset to start cutting the slot (at Fs_capt)
cfo                 = 0             % CFO to apply in Hz
soft_en             = true          % Soft decoding enable                [true: soft-decoding, false: hard-decoding]
llr_fix             = false         % Indicates if fixed-point representation for LLR is used
snr_value           = 40            % SNR

% General Parameters
n_cell_id       = 28                % Cell ID                                [0 : 1007]
mu              = 3                 % Subcarrier scaling (2 ^ mu) * 15 kHz    [0, 1, 3]
f0              = 0                 % RF frequency in Hz (set to 0 if no pre-compensation is needed)
n_fft           = 1024              % FFT size                               [512 : 4096] Fs = n_fft * (2 ^ mu) * 15 kHz
n_rb            = 66                % Number of resource blocks              [1 : 275]    BW = n_rb * 12 * (2 ^ mu) * 15 kHz
k_0             = 0                 % Subcarrier offset in OFDM signal reception [-6, 0, +6]
n_bwp_start     = 0                 % Bandwidth part start [0:274].
dc_notch        = false             % DC notch


n_rnti              = 1             % UE RNTI
n_id                = 28            % PDSCH N_ID for scrambling
n_ant               = 1             % Number of antennas                     [1, 2]
n_layers            = 1             % Number of PDSCH layers                 [1, 2]
imcs                = 0            % IMCS for PDSCH                         (0 : 27) if 256QAM is enabled; (0 : 28) otherwise
en_256qam           = false         % Enables 256QAM
n_oh_prb            = 0             % PDSCH N_OH parameter
first_prb           = 0             % First PDSCH PRB                        [0 : (n_rb - 1)]
last_prb            = 65            % Last PDSCH PRB                         [0 : (n_rb - 1)]
first_symb          = 1             % First PDSCH symbol                     ([0 : 3] for mapping type A, [0 : 12] for mapping type B)
last_symb           = 11            % Last PDSCH symbol                      [first_symb : 13]
dmrs_l0             = 2             % First DMRS OFDM symbol                 ({2, 3}: Mapping type A; 0: Mapping type B)
dmrs_len            = 1             % Select between single and double-symbol DMRS (1: Single-symbol; 2: Double-symbol)
dmrs_add_pos        = 0             % DMRS additional positions              [0 : 3]
dmrs_type           = 1             % DMRS type                              [1, 2]
dmrs_boosting       = 0             % Boosting applied to DMRS               (dB)
dmrs_n_scid         = 0             % DMRS NSCID                             [0 : 1]
dmrs_n_id           = 28            % N_ID to use for DMRS                   [0 : 65535]
dmrs_p              = 0             % Antenna port indexes used for DMRS  p = 1000 + X
dmrs_cdm_no_data    = 1             % Number of DMRS CDM groups without data
ptrs_en             = false         % Enable PTRS
ptrs_l              = 1             % Parameter L_PTRS                                               [1, 2, 4]
ptrs_k              = 2             % Parameter K_PTRS                                               [2, 4]
ptrs_re_offset      = 0             % Parameter DL-PTRS-RE-offset                                    [0 : 3]
ptrs_p              = 0             % Association between PT-RS port and DMRS port dmrs_p(ptrs_p)
```

Figure 30. PDSCH Parameters

WaveJudge Verification

1. Time domain power → OK

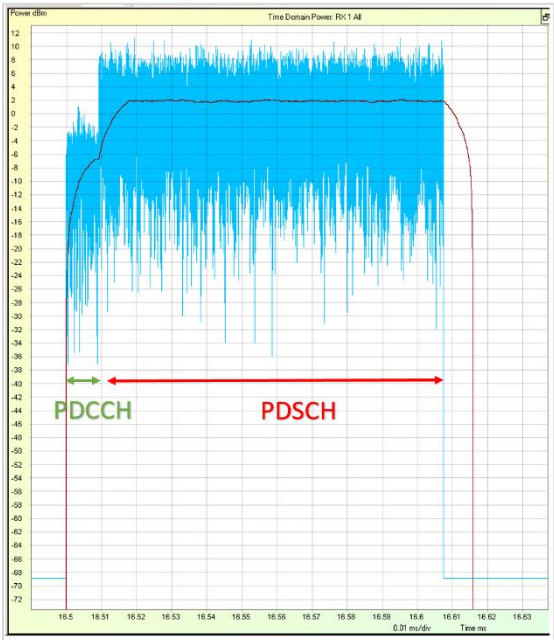


Figure 31. PDCCH+PDSCH Time Domain Power

2. Mapping location and number of subcarriers → OK

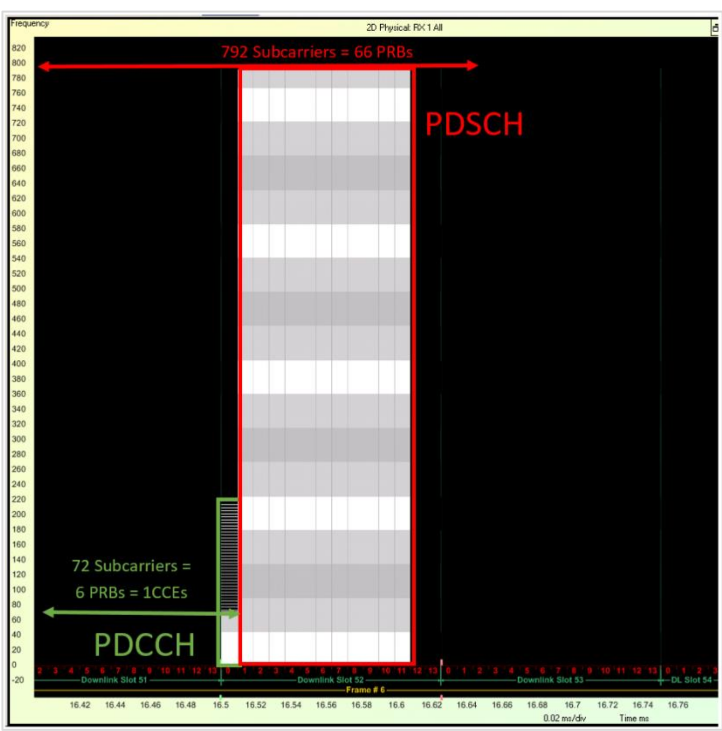


Figure 32. PDCCH+PDSCH Mapping Location

3. Cell ID = 28 → OK

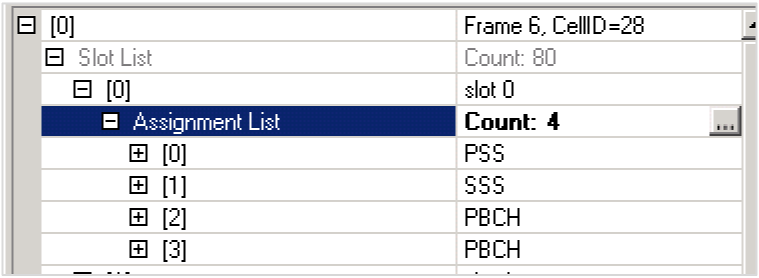


Figure 33. PDCCH+PDSCH Cell ID

4.- Error checking → OK

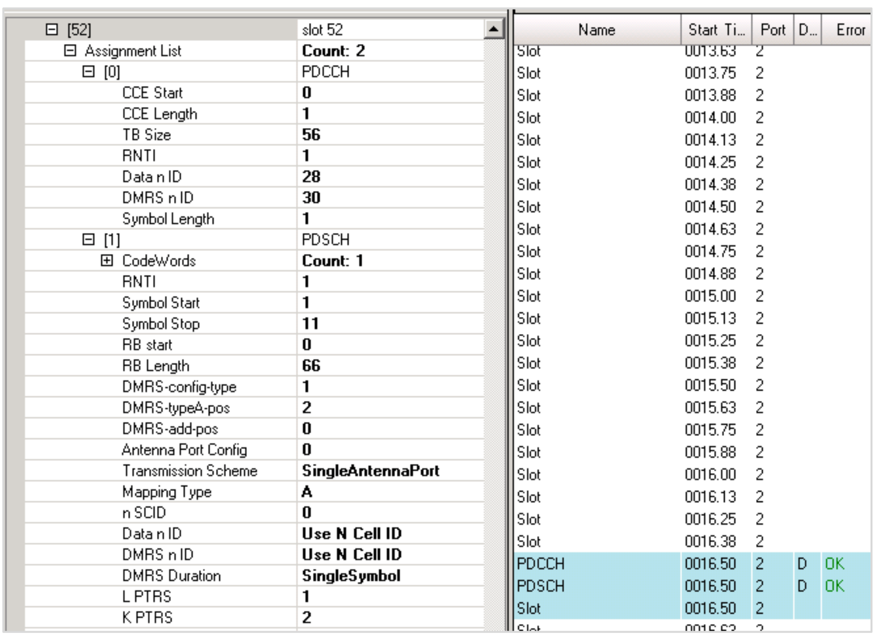


Figure 34. PDCCH+PDSCH Error Checking

5. EVM and constellation → OK

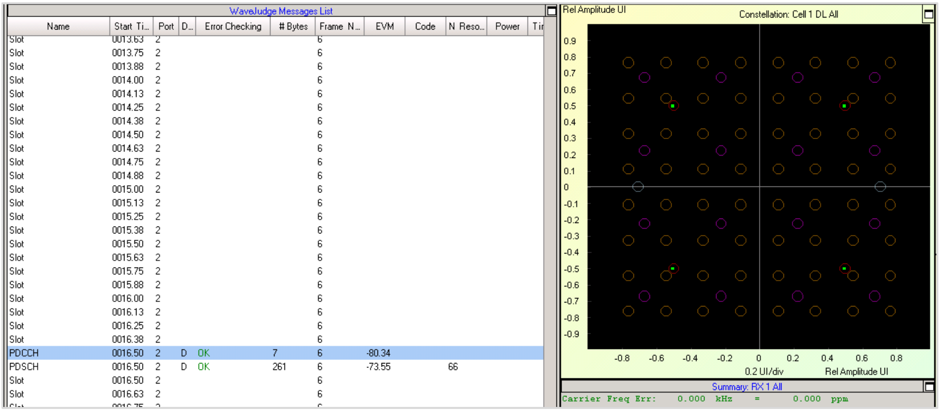


Figure 35. PDCCH+PDSCH EVM and Constellation

6. Spectral power (RB Offset) → OK

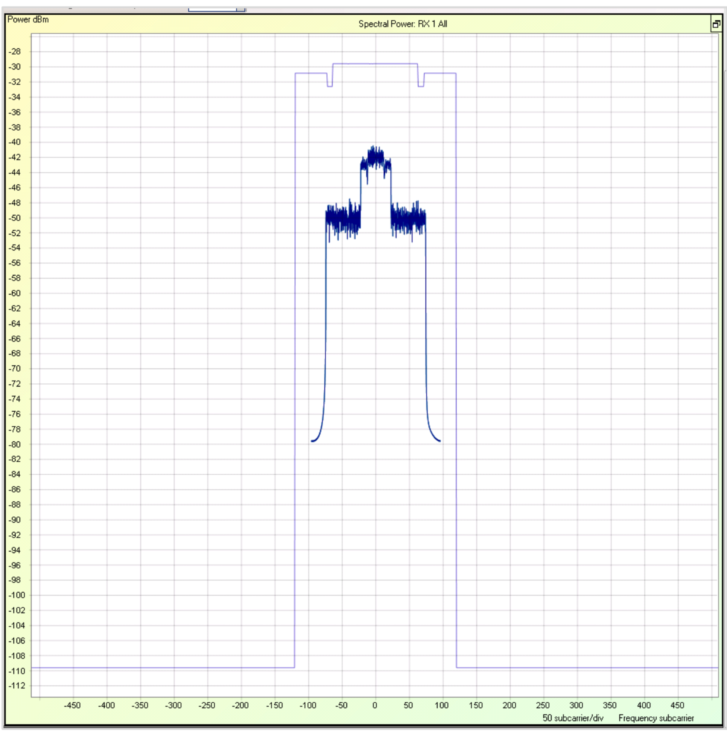


Figure 36. PDCCH+PDSCH Spectral Power

Troubleshooting

1. If the following error message appears during WaveJudge launching, click on OK and operate as usual. Root cause of this problem has not been identified yet.

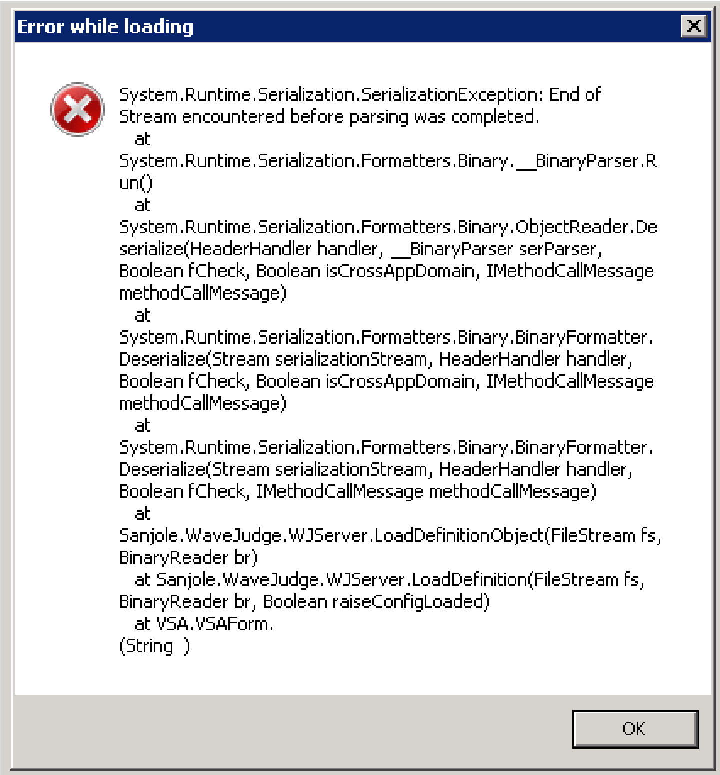


Figure 37. Error Message during WaveJudge Launch

2. The following steps describe how to face errors shown in below figure:

Name	Start Ti...	Port	D...	Error Checking	# Bytes	Frame N...	EVM	Code
Slot	0000.00	2				6		
PBCH	0010.00	2	D	OK	3	6	-69.44	
PBCH	0010.00	2	D	OK	3	6	-67.97	
PSS	0010.00	2	D			6	-72.35	
SSS	0010.00	2	D			6	-71.19	
BCCH-RRC	0010.00		D	Data Underflow	3			
BCCH-RRC	0010.00		D	Data Underflow	3			
Slot	0010.00	2				6		
PBCH	0010.13	2	D	OK	3	6	-68.95	
PBCH	0010.13	2	D	OK	3	6	-69.02	
PSS	0010.13	2	D			6	-00.49	
SSS	0010.13	2	D			6	-00.49	
BCCH-RRC	0010.13		D	Data Underflow	3			
BCCH-RRC	0010.13		D	Data Underflow	3			
Slot	0010.13	2				6		
PBCH	0010.25	2	D	OK	3	6	-69.37	
PBCH	0010.25	2	D	OK	3	6	-69.62	
PSS	0010.25	2	D			6	-72.35	
SSS	0010.25	2	D			6	-71.15	
BCCH-RRC	0010.25		D	Data Underflow	3			
BCCH-RRC	0010.25		D	Data Underflow	3			

Figure 38. Data Underflow Errors

Disable RRC messages doing:

2. Right click over Message List area -> Click on Chart Properties

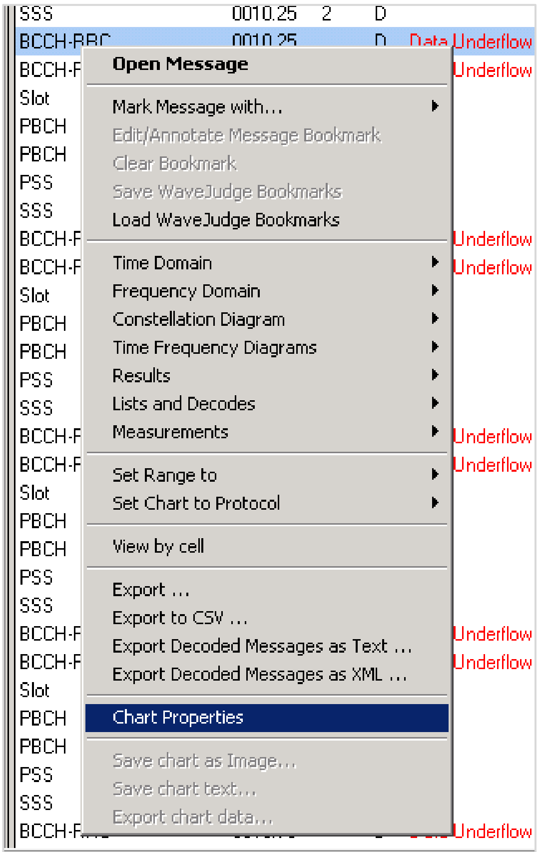


Figure 39. Disabling RRC Messages – Chart Properties

Disable RRC, NAS, IP, & Other

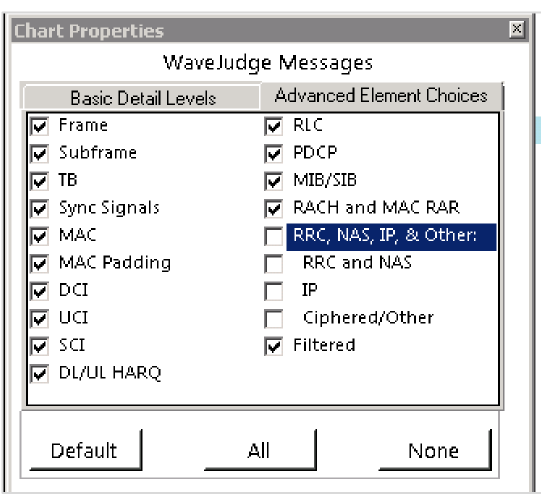


Figure 40. Disabling RRC Messages – Disabling Options

3. After the previous steps the View should look like the figure below:

Name	Start Ti...	Port	D...	Error Checking	# Bytes	Frame N...	EVM	Co
Slot	0000.00	2				6		
PBCH	0010.00	2	D	OK	3	6	-69.44	
PBCH	0010.00	2	D	OK	3	6	-67.97	
PSS	0010.00	2	D			6	-72.35	
SSS	0010.00	2	D			6	-71.19	
Slot	0010.00	2				6		
PBCH	0010.13	2	D	OK	3	6	-68.95	
PBCH	0010.13	2	D	OK	3	6	-69.02	
PSS	0010.13	2	D			6	-00.49	
SSS	0010.13	2	D			6	-00.49	
Slot	0010.13	2				6		
PBCH	0010.25	2	D	OK	3	6	-69.37	
PBCH	0010.25	2	D	OK	3	6	-69.62	
PSS	0010.25	2	D			6	-72.35	
SSS	0010.25	2	D			6	-71.15	
Slot	0010.25	2				6		
PBCH	0010.38	2	D	OK	3	6	-69.40	
PBCH	0010.38	2	D	OK	3	6	-69.21	
PSS	0010.38	2	D			6	-00.49	
SSS	0010.38	2	D			6	-00.49	

Figure 41. View after correcting the errors

Sanjole Wireless Analyzers

Sanjole Wireless Analyzers are industry-leading over-the-air communication sniffers, trusted as undisputed “source of truth” to find anomalies, uncover issues and quickly identify root cause in complex wireless systems.

With the addition of the Sanjole solutions, Keysight portfolio enhances its capabilities to provide industry-leading, end-to-end 5G solutions across the entire wireless ecosystem. Sanjole's software offerings will enhance Keysight's 5G solutions for modem, chipset, and radio access network (RAN) customers. Together, Keysight and Sanjole will be able to provide communications standards-validated interoperability testing, enable fast debugging, and accelerate time to deployment for customers.

To learn more about Sanjole Wireless Analyzers, please visit www.keysight.com/find/sanjole.