New Features in V93000 WCDMA Demodulation

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Abstract

This work presents an overview of some of the new features pertaining to WCDMA found in the Verigy Demodulation Library. These can improve test times and TTM (Time To Market) by allowing users to select demodulation results for either a specific, or multiple WCDMA slots. Code examples are also provided. It is assumed that the reader is somewhat familiar with the basics of coding demodulation procedures in the V93000 programming environment, as such, details on the structure of that implementation are not provided. For more general demodulation implementation details on the V93000 it is suggested to view the V93000 documentation.

Demodulation on the V93000

The Verigy Demodulation Library within the V93000 supports all of the modulation formats found in consumer wireless devices and is essential to finding TX (transmit) and RX (receive) EVM values. Many consider demodulation algorithms to be complex. However, the process can be broken down into a few key high-level pieces to make it better understood.

A flow chart of the algorithm is shown in Figure 1. To use the demodulation library, first an array, either from a digitized capture or from a file, is acquired. This sampled I/Q array of information is applied to the algorithm. Each waveform has its own properties such as sample rate, modulation type, encoded data, etc. and from them the appropriate EVM can be calculated. The user selects the demodulation type and required input parameters and from there, the EVM or other needed values are calculated.

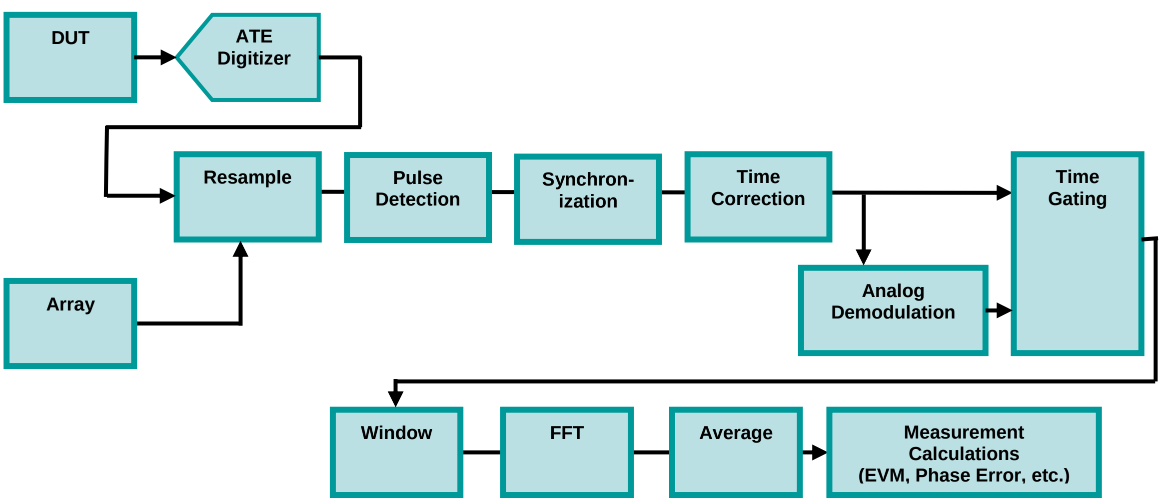

Figure 1 Flow chart of the algorithm used for the demodulation library on the V93000 [1].

The following outline of the key steps within the algorithm reference Figure 1 and how it handles an array of data (on the V93000, data is passed into the algorithm as an array of doubles, either ARRAY_D or ARRAY_COMPLEX). This is usually a capture of the signal coming from the DUT (Device Under Test) by the digitizer (DGT), but it can be achieved by reading digital bits as well and converting to equivalent analog levels. Alternatively, it can be a mathematically generated waveform or saved capture from a separate piece of hardware/ATE. Verigy's supported file formats are ASCII, Agilent Signal Studio encrypted, and Agilent 89600 recordings. The steps of the algorithm are:

- Resample - Data is internally resampled to a sampling rate where corrections can be made accurately and test times are minimized. The value is a function of each standard's symbol rate or chip rate for the code domain multiple access standard types.

- Pulse Detection - Many standards, to save test time, will detect whether a pulse is present or not prior to synchronization. Synchronization is a time consuming process when searching for the sync (synchronization) word and it is a lot less time intensive to first search if there is a valid pulse to begin with. With pulse detection a threshold level is set. This level defines what an on/off pulse is. To detect the burst there has to be an OFF/ON/OFF period. If a signal contains no OFF period pulse it is suggested to have the pulse detection set to off and only search for a synchronization word.

- Synchronization - Synchronization words have a known bit sequence that is defined by the standard. Synchronization words are made to be robust to avoid symbol errors and many standards will have this synchronization word be at the constellation where the least symbol errors will occur. An internally generated synchronization word is created and the signal is searched until a match with the synchronization word is found (or a best-fit correlation occurs). Once the sync word and the digitized signal are aligned and we know exactly how many samples in this peak happens at, we can overlay both signals and we will know exactly where we are in the received signal. The most commonly used input parameters in the demodulation library that are associated with controlling synchronization are syncMode and skipSynchronization.

- Time Correction – Corrections are applied. For example, once synchronization occurs the demodulator knows exactly how off the received signal is in phase, magnitude, equalization, etc. (phase due to transmission line length and local oscillator phase, magnitude due to gains or losses in the path and timing due to the start time of sampler and transmission line length).

- Analog Demodulation (Optional) – This provides AM, FM, and PM analog demodulation for analysis of either intentional or unintentional modulation contained within a signal.

- Time Gating – Time Gating is implemented when the user is interested in a specific part of the received signal or packet. For example, time gating would be if the signal received is composed of several different types of waveforms (maybe first half is a 1KHz sine wave and second half is a 2KHz sine wave). If the user wants to analyze the first half of this combined waveform only they would use time gating to ensure that only the 1KHz part of the received waveform is analyzed. For waveforms that are standard compliant, this is used to look at certain parts of the received packet (automatically done in standard compliant waveforms for measuring EVM).

- Window - Windowing is performed prior to obtaining an FFT (Fast Fourier Transform) on a signal. The true frequency domain response of a certain signal is obtained if the signal is infinitely long. Any truncation of this signal in time will convolve the frequency response of a rectangular window that is multiplying the signal. This truncation is calculated by the RBW (resolution bandwidth) set in the frequency domain measurement. A rectangular window (or no windowing) has a lot of power in its sidelobes so windowing with a different shape helps obtain the best frequency response representation of the true signal. The number of samples used for the FFT for a certain RBW depends on the ENB (Eqivalent Noise Bandwidth) of the specific window being used. This is, $RBW = ENB*Fs/N$, where Fs is the sampling frequency, N is the number of samples and ENB is the Equivalent Noise Bandwidth.

- FFT – Fast Fourier Transform. This is implemented to look at the energy content of a signal in the frequency domain. For demodulation FFTs are performed to equalize the signal or to extract the received symbols (such as in an OFDM type of signal).

- Average – Averaging is a way to compute the mean of a measurement (mean = $\Sigma x(n)/N$). Averaging of FFTs is a great way to lower white noise since white noise has a phase that is randomly uniformly distributed. Due to this property, if enough averages are implemented, the white noise will sum up to a very small amount of power due to the random nature of the phase.

- Measurement Calculations – – Mathematical derivations on a signal in order to extract certain signal properties (or parameters). This could be something as simple as signal power or as complex as EVM.

WCDMA Demodulation

The V93000 has two available WCDMA demodulation formats that support all of the variations of WCDMA modulation. They are:

- WCDMA_HSDPA_UPLINK – Uplink is handset to tower, used with TX measurements on handset chips
- WCDMA_HSDPA_DOWNLINK – Downlink is tower to handset, used with RX measurements on handset chips

Two key new features found within the WCDMA_HSDPA_UPLINK/DOWNLINK modulation formats are:

- Desired Slot Demodulation
- Multi-Slot Demodulation

These two features can improve flexibility as well as speed and throughput when performing demodulation analysis. The following sections contain descriptions and some code examples which exemplify these new features.

Desired Slot Demodulation

When a user wants to obtain some of the demodulation parameters (EVM, phase error, frequency error, etc.) for a specific slot within the WCDMA frame, the Desired Slot mode can be used. The key parameters that are used within this mode are `analysisMode` and `desiredSlotIndex`. The returned rms EVM result, for example, is the rms EVM over the entire slot (2560 chips by default, but an optionally be changed via `evmLengthInChips`). The following code example shows how this can be implemented.

```
double evm;
double sampleRate;        // User must provide a value for this
ARRAY_COMPLEX iqData;     // User must populate this array

DEMODULATION demod("WCDMA_HSDPA_UPLINK");
demod.setInputParameter("analysisMode", 1);
demod.setInputParameter("desiredSlotIndex", 4);

demod.execute(iqData, sampleRate);

demod.getResult(“globalRmsEVM”, evm);
```

Multi-Slot Demodulation

In production testing it may be desirable to test multiple slots or multiple frames of data. This can be done using the Multi-Slot mode. There are two ways to achieve this, but only the one-shot method is recommended for production.

Multi-Slot Demodulation – Iterative Implementation

One way is to iteratively use the Desired Slot mode, each time advancing the value of `desiredSlotIndex`. This is a very "brute force" means and does consume excess test time. It is essentially the same as performing the entire demodulation algorithm N times to demodulate N slots. It is not recommended for production, but may be useful during test program development. An example of the implementation follows.

```
double evm;
double sampleRate;       // User must provide a value for this
ARRAY_COMPLEX iqData;    // User must populate this array

DEMODULATION demod("WCDMA_HSDPA_UPLINK");
demod.setInputParameter("analysisMode", 1);
demod.setInputParameter("totalNumSlots", 1);

for(int i=0; i<7; i++)
{
 if(i>0) demod.setInputParameter("skipSynchronization", true);
 demod.setInputParameter("desiredSlotIndex", i);

 if(i==0) demod.execute(iqData, sampleRate);
 else demod.execute();

 demod.getResult("globalRmsEVM", evm);
}
```

Notice, in this code, that the parameter `skipSynchronization` was used and set to true on the second and subsequent iterations. This provides a significant test time savings by eliminating the synchronization step (that is done the first time through).

Multi-Slot Demodulation – One-Shot Implementation

The most efficient implementation of multi-slot demodulation is done by setting `totalNumSlots` to the required number of slots to be demodulated. This will perform demodulation on `totalNumSlots` slots starting at the beginning of the frame. The following code exhibits this implementation.

```
DOUBLE_VECTOR perSlotEVM;
double sampleRate;       // User must provide a value for this
ARRAY_COMPLEX iqData;    // User must populate this array

DEMODULATION demod("WCDMA_HSDPA_UPLINK");
demod.setInputParameter("analysisMode", 1);
demod.setInputParameter("desiredSlotIndex", 4);
demod.setInputParameter("totalNumSlots", 7);
demod.setInputParameter("enableBySlotOutputs", true);

demod.execute(iqData, sampleRate);

demod.getResult("rmsEVMPerSlotV", perSlotEVM);
```

An enhancement on this is that the user can set `analysisMode`=1 (Desired Slot) and then specify `totalNumSlots`. This will perform the analysis on `totNumSlots` starting with the `desiredSlotIndex` instead of the beginning of the frame.

Useful Input and Result Parameters

There are numerous input and result parameters. Verigy attempts to make as many as possible to default to standard-specific values, so unless the signal being analyzed deviates quite a bit from standard format, not too many parameters should need to be changed. It is recommended to only add parameter settings that deviate from default to test program code. That way, it is easy to observe and debug settings. Table 1 describes some of the more commonly used input and result parameters with their descriptions and default values.

Parameter	Description
Input Parameter	
analysisMode	Selects whether synchronized signal is aligned to the head (+delay) of the captured signal or specific slot index regard to radio frame. If set to 'Desired Slot', then specify slot index using desiredSlotIndex. Valid values: 0-Free Run, 1-Desired Slot
desiredSlotIndex	When analysisMode is set to 'Desired Slot', specify which slot (with regard to radio frame) you want to align synchronized signal with
enableBySlotOutputs	Per-slot results: TRUE = Enabled, FALSE = Disabled
skipSynchronization	Determines whether synchronization is done. Use only when performing multiple sequential execute() commands and the initial one is performed WITH synchronization AND the initial desiredSlotIndex is 0.
totalNumSlots	Specify the number of slots for which synchronized output are desired Global EVM, Symbol EVM, Peak CDE and other measurements can only be performed within the slots specified by this parameter.
Result Parameter	
globalRmsEVM	rms EVM [%]
globalPeakEVM	Peak EVM [%]
rmsEVMPerSlotV	EVM per slot [%]. Array size is totalNumSlots.
peakEVMPerSlotV	Peak EVM per slot [%]. Array size is totalNumSlots.

Table 1 Common input and result parameters used with the WCDMA_HSDPA_UPLINK and DOWNLINK formats in the Verigy Demodulation Library.

Available WCDMA Demodulation Graphs

The Verigy Demodulation Library has graphs available for each demodulation standard. These can be used for debugging as well as within the Signal Analyzer Tool. The generateGraph() function can be used with any of the many available graphs listed in Table 2. Using an IQ constellation plot as an example, a graph can be displayed in the Signal Analyzer Tool via the following code.

```
double sampleRate;        // User must provide a value for this
ARRAY_COMPLEX iqData;     // User must populate this array

DEMODULATION demod("WCDMA_HSDPA_UPLINK");

demod.execute(iqData, sampleRate);

demod.generateGraph("TestSuite", 1, 1, "PinName", "Label",
TM::CONSTELLATION);
```

More details on the generateGraph() function can be found in the V93000 documentation.

Parameter	Description
COMPOSITE	Displays the composite EVM results, this often has a very irregular shape to the plot
CONSTELLATION	Displays the I/Q constellation
EVM_VS_CHIP	Displays the rms EVM value on a per-chip basis
EVM_VS_SLOT	Displays the rms EVM value that was calculated for each slot (same values found in the corresponding per-slot result vector)
PEAK_PHASE_VS_SLOT	Displays the peak phase error value that was calculated for each slot (same values found in the corresponding per-slot result vector)
POWER_VS_TIME	Displays the uncalibrated power as a function of time, useful for observing the shape of the waveform in the time domain, also displays an overlay and values showing the beginning and end of the analysis region
RMS_PHASE_VS_SLOT	Displays the rms phase error value that was calculated for each slot (same values found in the corresponding per-slot result vector)
SPECTRUM	Displays the uncalibrated power as a function of frequency

Table 2 Available graphs in the WCDMA_HSDPA_UPLINK and DOWNLINK formats in the Verigy Demodulation Library.

Summary

A description of the algorithms used within the Verigy Demodulation Library is presented. A few key use models when using the library format, WCDMA_HSDPA_UPLINK and DOWNLINK, were shown along with the associated test method code so that the reader has a place to begin writing their code for demodulating WCDMA.

References

[1] Agilent Technologies, "Agilent 89600 Vector Signal Analysis Software," Technical Overview 5989-1679EN (2010).