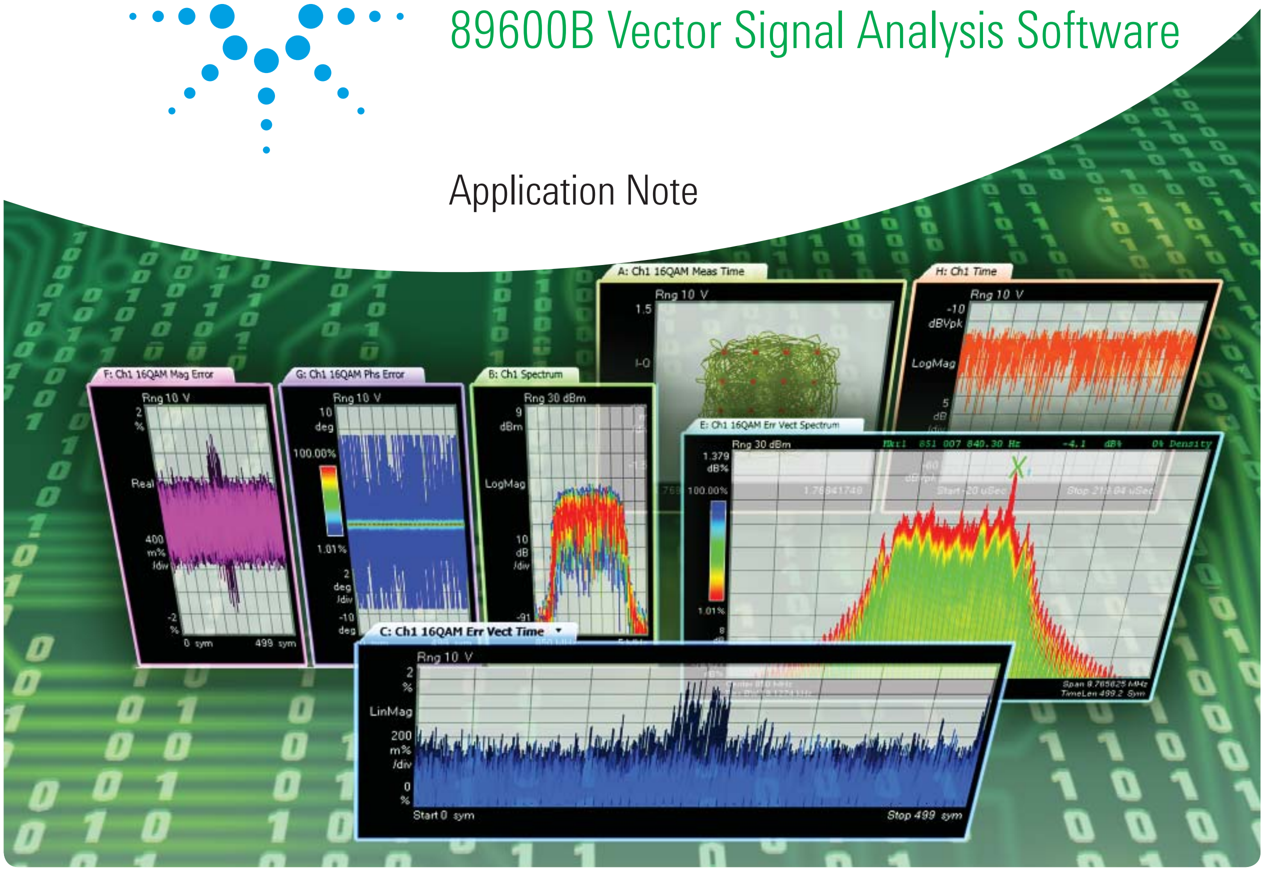
Successful Modulation Analysis in 3 Steps
89600B Vector Signal Analysis Software

Application Note



Agilent Technologies

Introduction: The Measurement and Troubleshooting Sequence

When measuring or troubleshooting digitally modulated systems, it is tempting to go directly to the digital demodulation tools. Making a random sequence of measurements on a system and watching for things that look wrong or questionable can produce useful results, but important things can be missed and a great deal of time wasted on unproductive or inefficient measurement approaches.

A planned measurement sequence is the most reliable way to find the cause of signal problems and reduces the chances that other important signal errors will be missed. This application note presents a planned measurement and troubleshooting sequence that consists of three steps:

Step 1 – Frequency, frequency and time measurements:
Verify signal center frequency, bandwidth, signal-to-noise ratio, and other important time and frequency domain parameters.

Step 2 – Basic digital modulation analysis:
Get a constellation displayed and examine the modulation quality numbers.

Step 3 – Advanced digital modulation analysis:
Use signal specific tools to dig deeper into the signal.

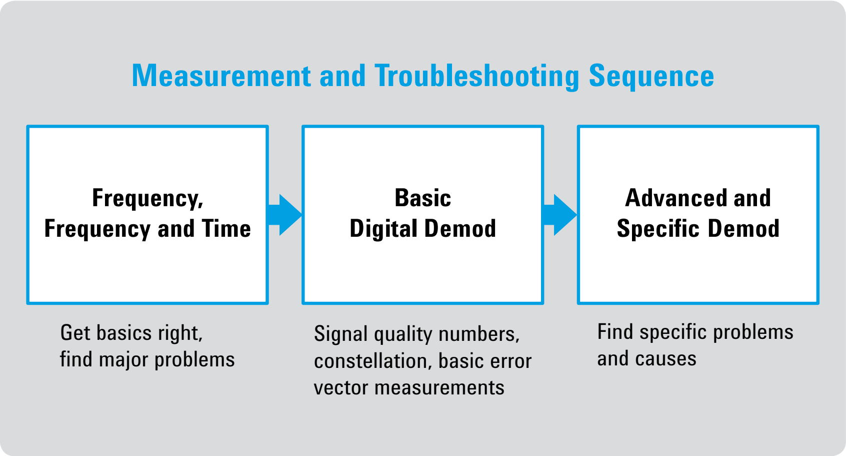


Figure 1. Measurement and troubleshooting sequence

Step 1: Frequency, Frequency and Time Measurements

The planned sequence begins with spectrum measurements and vector measurements that combine frequency and time domain analysis.

Most demodulators will not cleanly demodulate signals that are off frequency, have the wrong spans, or have poor signal-to-noise ratio. This can lead to elevated EVM results. Step #1 verifies these key parameters along with several others.

A great deal can be learned about digitally modulated signals before modulation analysis is employed. Examples include truncated training sequences, which can cause compatibility issues even if digital modulation is successful, and improper measurement ranging, which may disguise itself as a digital modulation problem such as timing error.

Even some problems which arise in the digital modulation process itself may be seen more readily in a vector measurement (frequency + time measurements) mode. Vector analysis also provides a good opportunity to set triggering and pulse search length to optimize values.

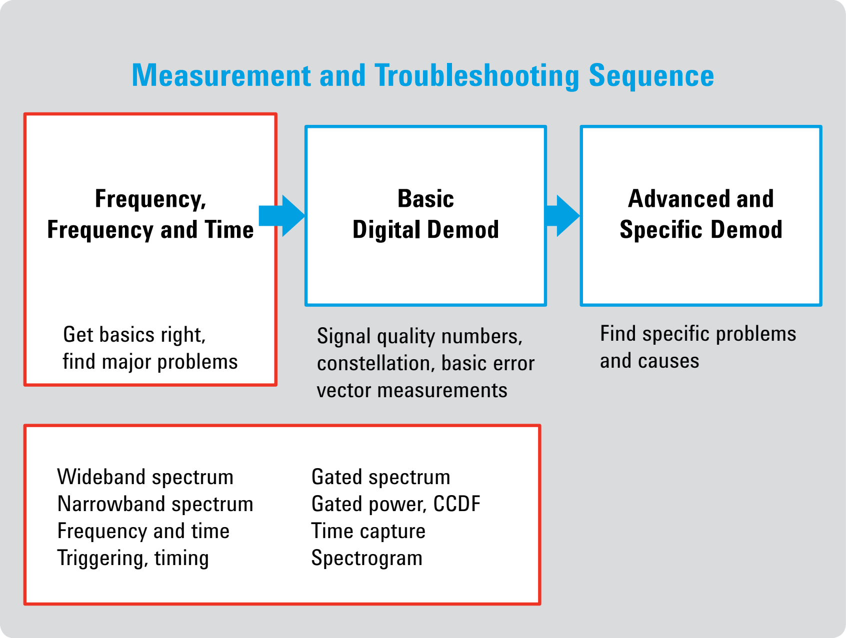


Figure 2. Planned measurement and troubleshooting sequence

Spectrum measurements

Begin with wideband spectrum analysis (Figure 3) and use tools such as peak hold (usually implemented as a type of averaging) to ensure that no significant signals are missed, either in-band or out-of-band. This is especially important for pulsed or burst signals, and where frequent channel changes or hops occur.

The spectrum measurements in Figure 3 progress from broadband to narrow-band signal analysis, and include efforts to avoid missing signals in the time domain as well.

During this step measure and verify:

- Center frequency
- Occupied bandwidth
- Amplitude – average and variations during the burst, looking for transients or drift
- Turn-on and turn-off behaviors including on/off ratio
- Burst length, duty cycle, unanticipated frequency/time variations

These may seem like relatively basic measurements but a significant number of system problems are traced to these behaviors. Such problems may arise from analog or digital circuits, or interactions between them.

Frequency Measurements

Frequency – Wideband Spectrum

- Approximate center frequency, occupied bandwidth, power level/range
- Other signals present, spurs & interference

Frequency – Narrowband Spectrum ~ 1.1 x (nominal bandwidth)

- More accurate center frequency
- Transition to frequency and time
- Spectrum alone (even with averaging) is inadequate for pulsed signals with AM
- Accurate spectrum requires triggering

Figure 3. Spectrum measurements

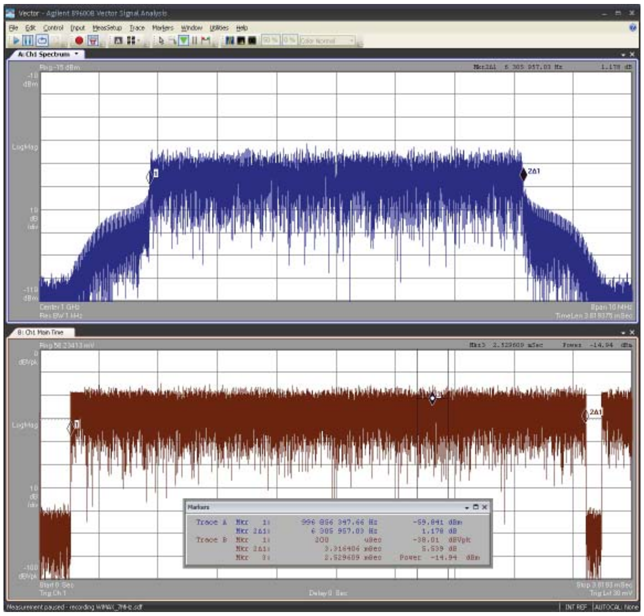
Simultaneous frequency and time measurements

The power of vector analysis is most evident when frequency and time domain measurements are linked. The most useful time domain display is the envelope or log magnitude data format type. For very long bursts, a very large number of time points (>10,000) may be required to obtain time record lengths long enough to see the entire burst while maintaining adequate bandwidth. The number of time points is likely to be much larger than would be needed for an adequate spectrum display.

Simultaneous Frequency and Time Measurements

- Set time to log magnitude (burst envelope)
  - Select IF triggering, pre-trigger delay, adjust trigger level, add holdoff (holdoff often essential for pulsed signals with AM)
  - Stabilize acquisition to make all other measurements reliable
  - Adjust time record length to see entire burst(s)
    - Increase frequency points if necessary (may need large number)
    - Leave “auto time resolution” off (otherwise span may be reduced below occupied BW)

Figure 4a. Simultaneous frequency and time measurements



```
Markers
  Trace A  Mkr    1:     996 856 347.66 Hz      -59.841 dBm
           Mkr 2Δ1:        6 305 957.03 Hz        1.178 dB
  Trace B  Mkr    1:         200       uSec      -38.01  dBVpk
           Mkr 2Δ1:          3.316406 mSec        5.539 dB
           Mkr    3:          2.529609 mSec   Power  -14.94  dBm
```

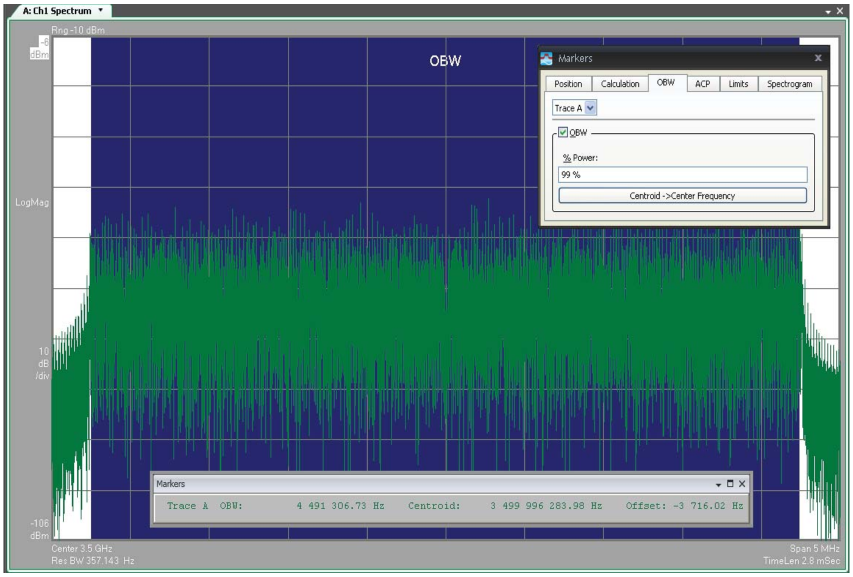
Figure 4b. Simultaneous frequency and time measurements

Vector mode measurements like the one in Figure 4 are valuable for verification of many basic signal parameters in both the frequency and time domains.

The 89600B VSA software has several features available to facilitate vector mode measurements including:

- Linked frequency and time displays and measurements
- Triggering (both live signals and recordings) with trigger hold-off
- Variable overlap processing in playback
- Variable block size (51,200 points in this measurement) and time resolution
- Offset markers in time and frequency
- Band power markers
- Time-gated spectrum, CCDF, and others
- Multiple average types (exponential, time, peak hold)

In Figure 4, delta frequency markers are used in the upper display to show the approximate occupied bandwidth. In the lower display, delta time markers are used to measure the length of the "on" time of the burst, and band power markers are used to measure the power of a specific portion of the burst.



Trace A

☑ OBW

% Power: 99 %

```
Trace A  OBW:        4 491 306.73 Hz    Centroid:     3 499 996 283.98 Hz    Offset: -3 716.02 Hz
```

Figure 5. Occupied bandwidth marker function

A fast and simple check of basic signal parameters can be performed by using the occupied bandwidth marker function (Figure 5). This function quickly verifies bandwidth and center frequency.

Note that the frequency centroid (center frequency calculated from the power-weighted spectrum) is calculated, along with the difference between this frequency and the analyzer's center frequency. Also note that the power percentage used to calculate the occupied bandwidth can be set as appropriate.

Time-gated spectrum measurements

Time-Gated Measurement Setup

Time – Gating Setup

- Set main time length to approximately 5 symbol times (number of points does not need readjustment)
- Enable gating, set gate length for desired signal segment and RBW, then set gate to 1 x (“OFDM symbol time”) to see preamble symbols
- Set initial gate delay to match pre-trigger delay

Select Appropriate Gate Windows (RBW Shape)

- Flat Top for amplitude accuracy, uniform for frequency resolution

Time – Gating CCDF

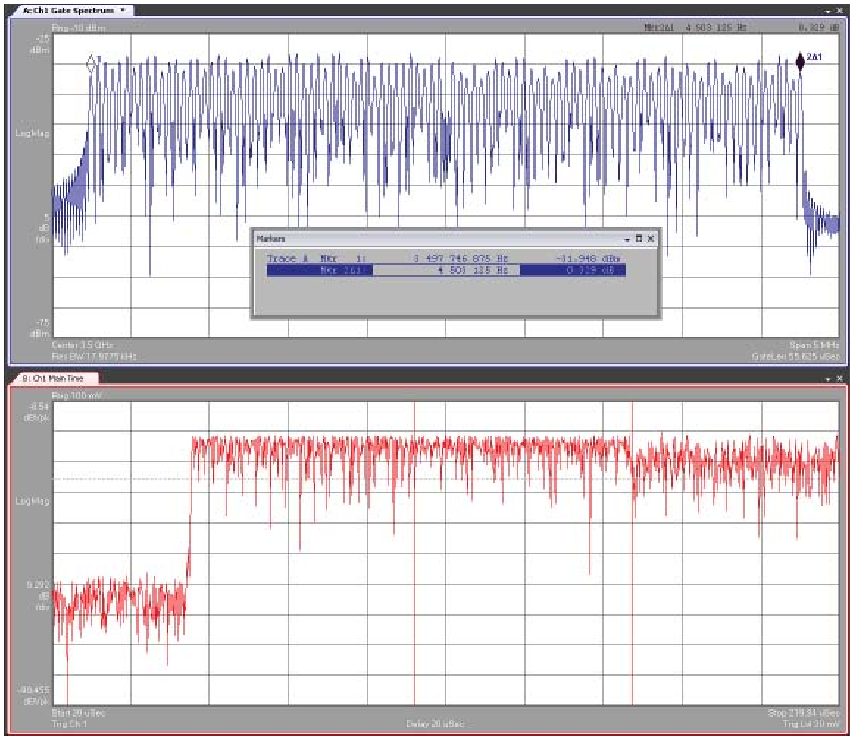
- Preamble vs. data

Averaging Types

Figure 6. Time-gated measurement setup

The flexible and precise time gating in vector signal analyzers is particularly useful for signals with training sequences. In some measurements, it is important that time gates be aligned with specific symbols in the preamble.

In many wireless signals, the frequency and amplitude behaviors of the signal change at different times during a burst or frame. Dynamic amplitude behavior (measured as peak/average power or CCDF) changes between the preamble and data portions of the signal, and even between different parts of the data portion of the transmission. Time-gated measurements, including power and CCDF, are essential for accurate measurements of individual portions of the signal.



Trace A Mkr 1: 3 497 746 875 Hz -11.948 dBm
Mkr 2Δ1: 4 503 125 Hz 0.329 dB

Figure 7. Time-gated spectrum measurement of a preamble

Figure 7 is a time-gated spectrum measurement of the second symbol of a preamble, which is composed of every 2nd OFDM carrier, QPSK modulation. The gate time is defined by the vertical gate markers in the lower (time envelope) trace. A uniform RBW filter shape is used to obtain maximum frequency resolution, which allows the individual carriers to be resolved. The delta markers in the upper (spectrum) trace measure the frequency difference between the “corner” OFDM carriers. This measurement is different from an occupied bandwidth measurement, and is useful in troubleshooting both analog and digital signal generation problems.

This example uses a recorded signal. The analyzer frequency span is reduced from the span at which the recording is made. This post-capture center frequency and zoom adjustment capability can be extremely useful in situations where the signal has frequency problems, or when the capture is made with sub-optimal settings, or if a different portion of the signal is analyzed.

Time-Gated Spectrum Measurements

- Spectrum vs. time, any spectrum artifacts
- Power changes during burst, CCDF variations
- Carrier structure, missing or extra carriers, energy at exact CF
- Side lobes (part of signal, not ACP), symmetry
- Frequency accuracy, carrier spacing
- Spurious, interference
- Flatness, tilt/ripple
- Preamble length, structure
- Confirm sampling factor, guard interval

Figure 8. Time-gated spectrum measurements

With time gating, many specific measurements can now be made.

Digital modulation or DSP-related measurements, such as carrier spacing on OFDM signals, can easily be made in vector rather than modulation analysis mode. Modulation errors such as carrier spacing may in some instances be easier to spot at this point rather than later, when they may prevent digital modulation from succeeding at all.

Time-gated Complementary Cumulative Distribution Function (CCDF) measurements can be made to evaluate gain compression effects when the signal level and modulation type change. CCDF measurements can be made in a relative fashion and do not require a perfect stimulus signal. For example, in Figure 7, the amplitude of the preamble in this signal is 3 dB above the rest of the sub-frame and is likely to change CCDF.

The gray curves in the traces of Figure 9 represent additive white Gaussian noise (AWGN) and are common reference points for CCDF measurements. AWGN is a challenging signal for amplifiers and many OFDM signals behave similarly to AWGN.

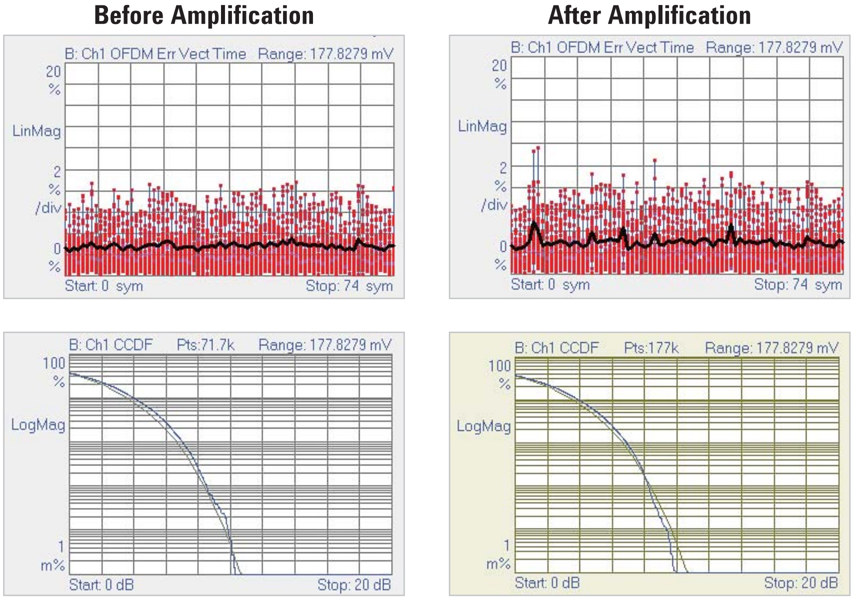


Figure 9. CCDF measurements – gain compression changes

Additional measurements before digital demodulation

Gain Drift and Transients

Gain Drift
- ADC reference changes with thermal
- Amplifier gain change with temperature
- Power supply

Transients
(usually occurs at start of burst)
- Fast thermal
- Short-term power supply instability
- Oscillator instability (PS/other coupling)

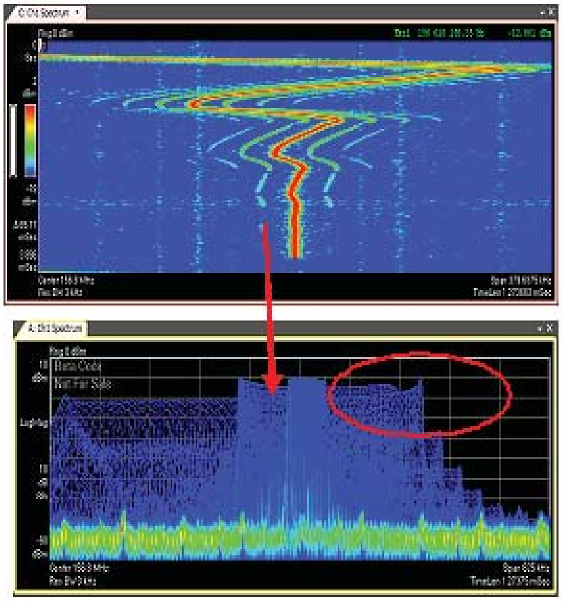
Figure 10. Gain drift and transients

Additional measurements can be made (though in slightly different ways) in both vector and digital demodulation modes. Vector mode measurements correlate these behaviors with RF burst timing, while digital demodulation correlate these measurements with symbols or carriers.

Transients and drift are common with pulsed systems and are often seen in microwave systems, where physical device geometries are small and thermal time constants are short. In many cases, the information produced by the tracking algorithms is itself useful as a diagnostic tool. We will demonstrate this in the advanced digital demodulation portion of this presentation.

Always consider making, using and saving a time capture of signals, particularly if they pulse or change during the measurement period. Analysis of captured signals is gap-free for the length of the capture. It is especially useful when teamed with spectrogram and digital persistence or cumulative history displays. Spectrograms provide a detailed view of signal frequency dynamics and digital persistence provides a detailed view of signal amplitude dynamics.

Extremely long time captures are possible but usually unnecessary. Capturing 2 to 10 signal bursts is usually sufficient. One benefit of starting with a good set of vector measurements is the ability to choose a time capture length that is long enough, but not so long as to cause slow analysis due to excessively large capture files.



Spectrum with overlap processing

Cumulative history with overlap processing. Note details of the amplitude dynamics.

Figure 11. Spectrogram

STEP 2: Basic Digital Modulation Analysis

Starting the planned troubleshooting sequence with frequency and vector measurements increases the chances for successful modulation analysis measurements. If problems are encountered in the Step #2 signal, you can eliminate spectrum and time problems as a cause and concentrate the investigation on the modulation itself.

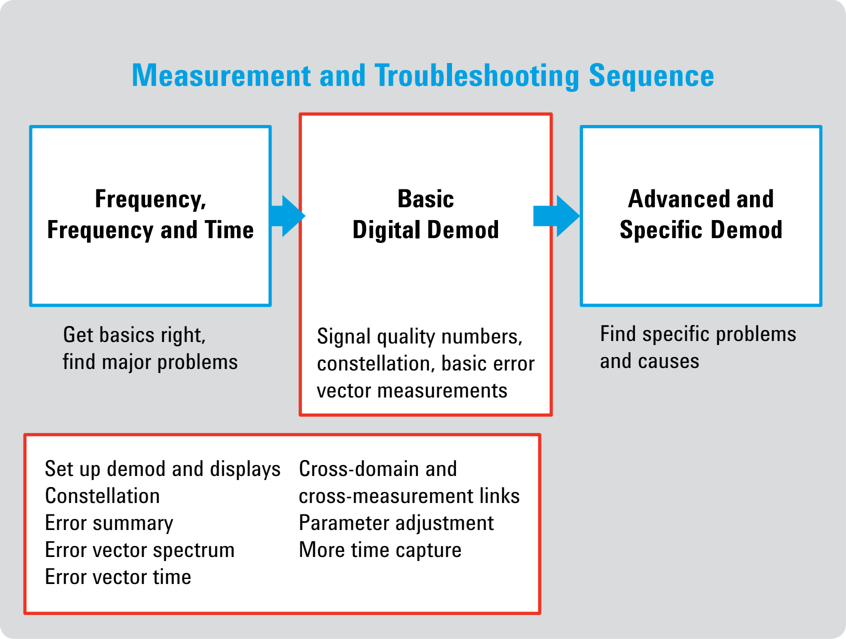


Figure 12. Digital demodulation sequence

For some measurement tasks, especially design verification, basic modulation analysis will be sufficient. The error summary table in the 89600B VSA software provides a complete numeric summary of signal quality and the magnitude of major error types. A large amount of measurement data is available at this stage, and significant troubleshooting can be performed as well.

Set up modulation analysis

Once input range, center frequency and span are set, the modulation analysis measurement must be configured. Most off-the-shelf vector signal analysis software or hardware that tests commercial standards comes with presets to speed initial measurement setup. These presets usually require the user to identify signal type, bandwidth, uplink/downlink, and number of antennas if MIMO is involved. For simpler signals, modulation type, symbol rate, filter type and alpha need to be provided before a constellation can be displayed.

A solid constellation with identifiable symbol locations and without rotation indicates the demodulator is properly set-up.

Setting Pulse Search and Length

Use Pulse Search, Set Search Length

- Minimum: 2 x (on time) + 1 x (off time)
- Reliable indicator of inconsistent burst length or burst problems

Select Default Quad Display

- Default is a good starting point
- Select new 6-trace display if desired
- Constellation, error vector time, error vector frequency, symbols/errors

Figure 13. Setting pulse search and length

For pulsed signals, the demodulation must be aligned with the pulses, which requires triggering. A good "rule of thumb" for setting the 89600B's pulse search length (for bursts of equal length) is shown in Figure 13; this minimum search length will ensure that a complete pulse is always available in the acquisition time record.

Switching to a 4-trace or 6-trace display is a good idea at this stage to help verify proper setup and to reveal any problems.

Basic demodulation results

Constellation Diagram and Error Summary Table

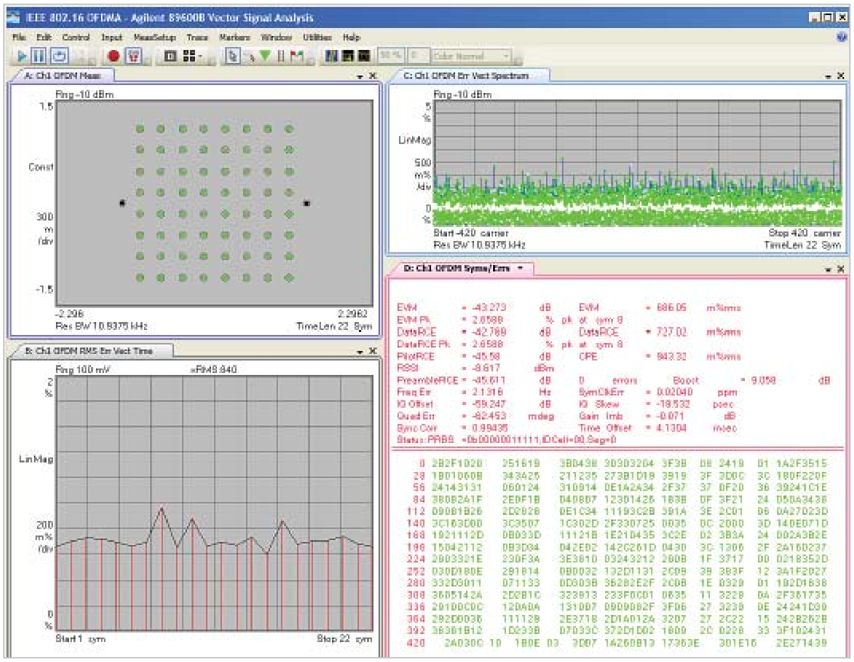
Constellation

- Successful demodulation?
- Modulation type(s)?
- Indications of error?

Symbol/Errors Table

- Relative constellation error (RCE) = EVM
- Pilot & common pilot errors (CPE)
- I/Q errors including gain imbalance, quadrature error,
- delay mismatch
  Preamble type identified (short, long, etc.) only when sym/error table large enough

Figure 14. Constellation diagram and error summary table



```
EVM          = -43.273   dB      EVM          = 686.05   m%rms
EVM Pk       = 2.6588    %  pk  at  sym 8
DataRCE      = -42.769   dB      DataRCE      = 727.02   m%rms
DataRCE Pk   = 2.6588    %  pk  at  sym 8
PilotRCE     = -45.58    dB      CPE          = 943.32   m%rms
RSSI         = -9.617    dBm
PreambleRCE  = -45.611   dB      0    errors      Boost       = 9.058      dB
Freq Err     = 2.1316    Hz      SymClkErr    = 0.02040   ppm
IQ Offset    = -59.247   dB      IQ  Skew     = -18.532   psec
Quad Err     = -82.453   mdeg    Gain  Imb    = -0.071     dB
Sync Corr    = 0.99435           Time  Offset = 4.1304    msec
Status:PRBS  =0b00000011111,IDCell=00,Seg=0

   0 2B2F1020   251619   3B0438 30303204 3F3B  0B 2419  01 1A2F3515
  28 1B01060B   343A25   211235 273B1D18 3919  3F 3D0C  3C 180F220F
  56 24143131   060124   310914 0E1A2A34 2F37  37 0F20  36 39241C1E
  84 3B0B2A1F   2E0F1B   040807 12301426 1B3B  0F 3F21  24 050A3438
 112 09081B26   2D2828   0E1C34 11193C2B 391A  3E 2C01  06 0427023D
 140 3C163D00   3C3507   1C302D 2F330725 0035  0C 2000  3D 140E071D
 168 1921112D   0B033D   11121B 1E210435 3C2E  02 3B3A  24 002A3B2E
 196 15042112   0B3D34   042E02 142C261D 0430  3C 1306  2F 2A160237
 224 2803321E   230F3A   3E3810 03243212 280B  1F 3717  00 0218352D
 252 030D180E   281814   0B0032 132D1131 2C09  39 383F  12 3A1F2027
 280 332D3011   071133   0D303B 36282E2F 2C08  1E 0328  01 182D1838
 308 3605142A   2D2B1C   323813 233F0C01 0635  11 3228  0A 2F361735
 336 2910DC0C   120A0A   131007 0909082F 3F06  27 3239  0E 24241D39
 364 292D0036   111128   2E3718 2D1A012A 3207  27 2C22  15 2428262B
 392 36381B12   1D233B   07033C 372D1D02 1809  20 0228  33 3F102431
 420    2A030C 10   180E 03   3D07 14260813 17363E    301E16    2E271439
```

Figure 15. Basic demodulation results

Figure 14 represents a typical basic demodulation result. This OFDM-based WiMAX™ mobile signal has considerable complexity even in the basic demodulation results. Understanding and using the relationships between these measurements and displays is powerful in terms of understanding signal characteristics and impairments, and ultimately in optimizing the factors that lead to commercial success.

The most-used displays in basic digital demodulation are constellation diagrams and the error summary table. The use of OFDM and the potential for multiple modulation types makes the composite constellation diagram more difficult to interpret. Nonetheless it remains an essential display and one that engineers frequently consult first. Note that the constellation display and symbol table in the 89600B are color-coded according to modulation type. WiMAX uses the term relative constellation error (RCE) rather than EVM, but the two terms are equivalent and expressed in percentage terms and in dB.

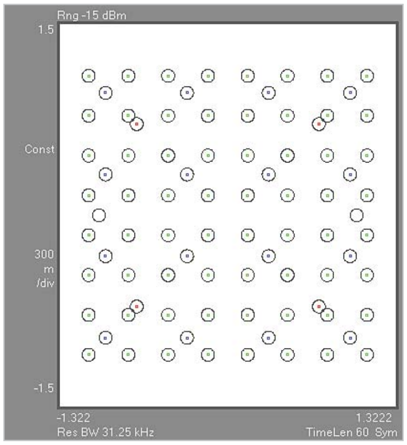


Figure 16. WiMAX constellation containing all possible modulation types

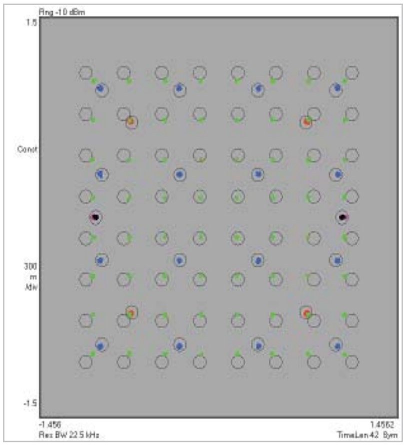


Figure 17. WiMAX constellation with gain compression errors

Figure 16 is an example of a WiMAX constellation containing all possible modulation types: BPSK, QPSK, 16QAM and 64QAM. As always, this is both an I/Q and a polar representation of the signal, where RF power is shown by the radial distance from the center of the diagram to a constellation point. The constellation points for the different modulation types (QPSK and 16QAM, for example) do not overlay exactly due to the effort to keep average signal power constant between different modulation types. Therefore, the nominal (outer state) constellation points are not the same magnitude.

While average power should remain relatively constant, peak power and peak/average power (CCDF statistics) will vary significantly, and can contribute to different error behaviors.

The 89600B VSA software color codes the WiMAX constellation (Figure 17) by modulation type and signal element (preamble vs. data vs. Frame Control Header (FCH) vs. pilots) to distinguish between them. The signal shows some amplitude compression and signal scaling errors, so some elements/colors fall on top of each other when they should be separate. Other elements such as the BPSK pilots and the BPSK in the FCH fall on top of each other because they are supposed to (in a display such as this, for example) and are separated by color. The 89600B software can zoom in close to view these individual signal elements.

Color coding:
FCH = Pink (BPSK, hard to see behind the pilots)
Pilots = Black (BPSK)
Data-QPSK = Red
Data-16QAM = Blue
Data-64QAM = Green

Color coding is adjustable – color coding has been added to bits in the symbol table and match accordingly.

Initial Demodulation Results

Error Vector Spectrum

- All symbols shown on Y-axis for each carrier on X-axis
- All-symbol average for each carrier is shown
- Examine for patterns/trends by carrier, differences between carriers and pilots
- Spurs will affect individual carrier or few carriers, for all symbols

Error Vector Time

- All carriers shown on Y-axis for each symbol on X-axis
- All-carrier average for each symbol is shown
- Examine for patterns or changes according to symbol (time)
- Impulsive errors (DSP, interference, clocks, power) will affect all carriers for an individual symbol or group of symbols

Figure 18. Demodulation results

As with all multi-carrier modulation types, error vector spectrum and error vector time measurements are valuable and complimentary. It is often useful to look at these two types of measurement results at the same time and couple markers between them.

The error vector time trace (lower left, Figure 14) shows EVM vs. symbol time. This signal has 200 OFDM carriers so there are 200 EVM values (shown as a column of dots) at each symbol time. Examine these traces for patterns/trends by carrier and differences between data carriers and pilot carriers. Spurs will affect individual carriers, or a few carriers, for all symbols.

The error vector spectrum trace (upper right, Figure 14) shows EVM vs. carrier. Each carrier has an EVM dot for every symbol time measured. Examine these traces for patterns changes by symbol time. Impulsive errors (DSP, interference, clocks, and power) will affect all the carriers for an individual symbol or group of symbols.

Initial Demodulation Results

Coupled Markers

- Identify a symbol by time, frequency, or error magnitude
- Link a symbol across time and frequency domains, and between different display types
- Link error peaks to constellation points, amplitude values, specific carriers, time points in a burst, as a way to pinpoint error mechanism
- Identify specific time instant or frequency to examine with specific advanced and specific demodulation techniques (next)

Change Measurement and Display Parameters Without Taking New Data

Use Time Capture to Provide Consistent Error Behavior

Figure 19. Demodulation results

Marker coupling is a powerful feature for troubleshooting and is often overlooked. It is helpful in relating error results displayed in different domains (such as error vector time vs. error vector spectrum) or when using different display types and scaling.

An important benefit of the 89600B software is the ability to change measurement (including demodulation) and display parameters and obtain updated displays without taking new data (whether from live measurements or a time capture file). This improves ease of use and measurement insight by removing possible sources of measurement variation.

STEP 3: Advanced and Specific Modulation Analysis

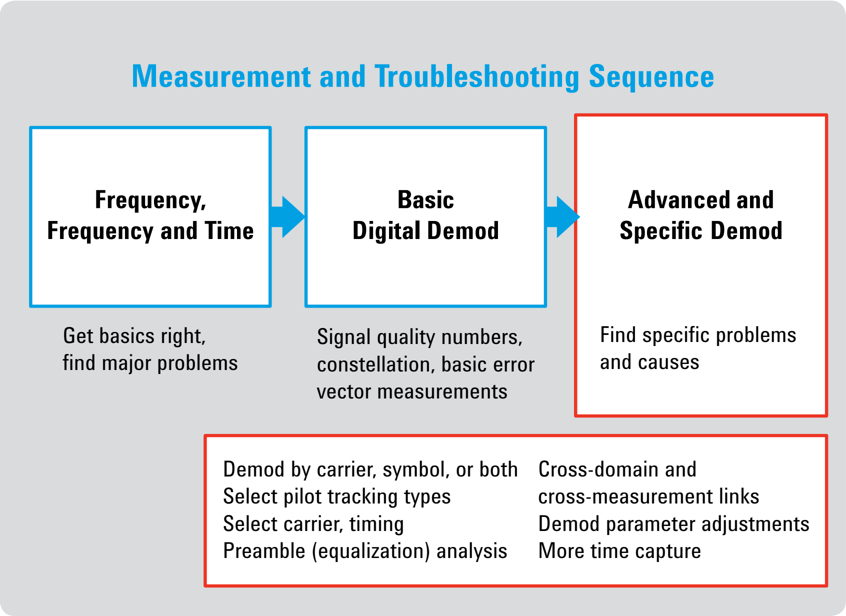


Figure 20. Advanced and specific modulation analysis sequence

The last step in the measurement and troubleshooting sequence is the most powerful for finding and measuring subtle or more complex problems.

A variety of modulation analysis techniques are available, including analysis of specific portions of the signal and adjustment of demodulation parameters. Many of the tools that support these techniques are modulation specific. The examples in this section take advantage of specific characteristics of the WiMAX signal, including the built-in equalization training sequences and pilot carriers.

Advanced and Specific Digital Demodulation

Demod By Specific Carriers
Demod by Specific Symbols
Enable/Disable Pilot Tracking Amplitude, Phase, Timing
Data Sub-Carrier Manual Select
Symbol Timing Adjust
Equalizer Training Select
Preamble Error Measurements (preamble only, preamble + data)
X & Y-Axis Scaling (display zoom)

Figure 21. Advanced and specific digital demodulation summary

Figure 21 summarizes some of the more advanced measurement techniques supported by the 89600B software for OFDM signals. If the source of a problem is in doubt, it is often useful to employ each of these techniques in turn, and consider using them together to isolate specific error behavior.

Carrier- and symbol-specific analysis

Analysis of specific elements of a subframe is a powerful troubleshooting technique. It allows clearer isolation of errors and impairments, and therefore a clearer view of their causes.

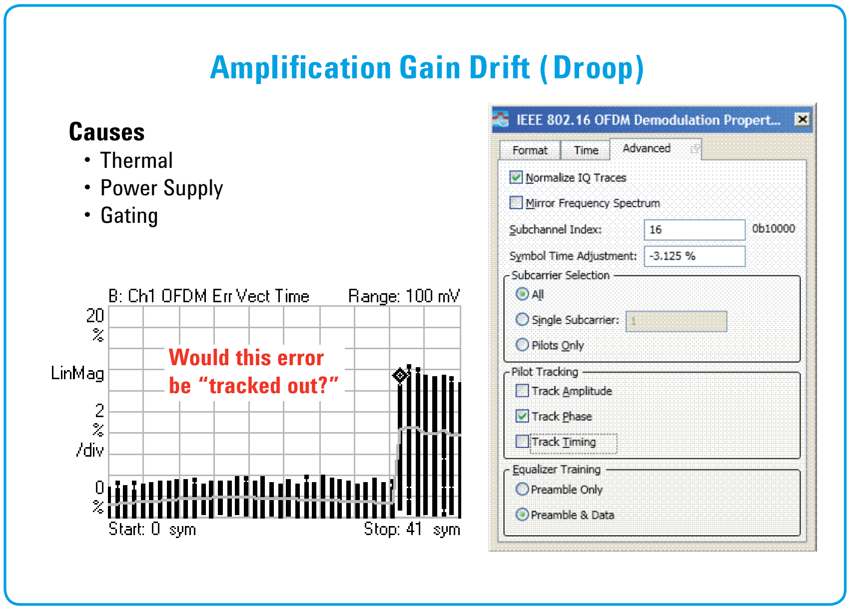
Focusing on specific carriers, or groups of carriers, isolates frequency-specific problems at the band edge and facilitates comparing the pilot carriers to data carriers.

Symbol-specific analysis helps isolate possible errors with intentional changes in modulation types between symbols and impulsive, intermittent or periodic error sources, along with turn on/off, power supply, settling or thermal effects.

Pilot analysis

Similar to 802.11a OFDM, WiMAX performs demodulation relative to the data in pilot carriers that are embedded in the signal. These pilot carriers replace data-carrying elements of the signal and allow certain types of impairments to be removed or "tracked out." The pilot carriers are transmitted continuously throughout the data portion of the sub-frames. Many signal impairments are common to all pilot carriers, and can be measured and displayed as "common pilot error."

In addition, the specific tracking functions can be individually switched on and off in the demodulation performed by the 89600B software. This is a very useful troubleshooting approach, since modulation errors can be examined with and without the benefit of particular types of pilot tracking.


Amplification Gain Drift (Droop)

Causes
- Thermal
- Power Supply
- Gating

Would this error be "tracked out?"

IEEE 802.16 OFDM Demodulation Propert...

☑ Normalize IQ Traces
☐ Mirror Frequency Spectrum
Subchannel Index: 16 0b10000
Symbol Time Adjustment: -3.125 %

Subcarrier Selection
● All
○ Single Subcarrier: 1
○ Pilots Only

Pilot Tracking
☐ Track Amplitude
☑ Track Phase
☐ Track Timing

Equalizer Training
○ Preamble Only
● Preamble & Data

Figure 22. Amplitude errors

A common type of signal impairment is non-constant amplitude error during a subframe. Circuit temperature and gain may change during an RF burst, and the combination of transmit and DSP power may cause amplitude droop.

The amplitude behavior of a circuit may also change due to the modulation type of the signal being used. In this example, the modulation type changes to 64QAM about three quarters of the way through the subframe. This change affects the scaling and peak power of the signal, causing a dramatic increase in the amplitude component of the error. This error can be isolated by comparing the peak error symbols with their location in the constellation.

In this case, we do not expect the amplitude problems to be removed by pilot amplitude tracking since the tracking operates on the pilot carriers, which do not use (and therefore do not correct for the effects of) the troublesome 64QAM modulation type.

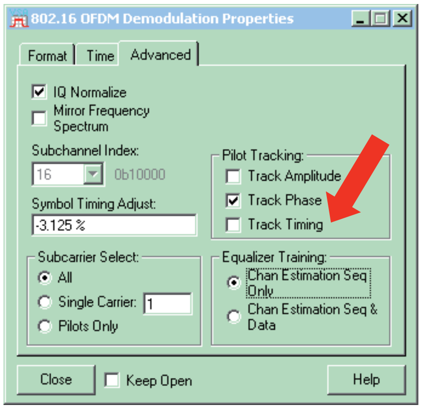
Timing Errors

Caused by:

- Frequency error in oscillators
- Wrong number of samples in Guard Interval

Troubleshooting

- Observe CPE when timing tracking is enabled



802.16 OFDM Demodulation Properties

Format | Time | Advanced

☑ IQ Normalize
☐ Mirror Frequency Spectrum
Subchannel Index: 16 0b10000
Symbol Timing Adjust: -3.125 %
Pilot Tracking:
☐ Track Amplitude
☑ Track Phase
☐ Track Timing
Subcarrier Select:
● All
○ Single Carrier: 1
○ Pilots Only
Equalizer Training:
● Chan Estimation Seq Only
○ Chan Estimation Seq & Data
Close ☐ Keep Open Help

Figure 23. Timing errors

Other pilot tracking types compensate for phase and timing problems. Phase errors, for example, may be caused by phase noise. Close-in phase noise can be removed or tracked out by phase tracking. Timing errors may be caused by oscillator frequency errors or DSP errors, such as an improper number of samples in the guard interval. Both analog and digital sources can cause timing problems. DSP defects, such as an improper sample rate, can also affect timing in the subframe.

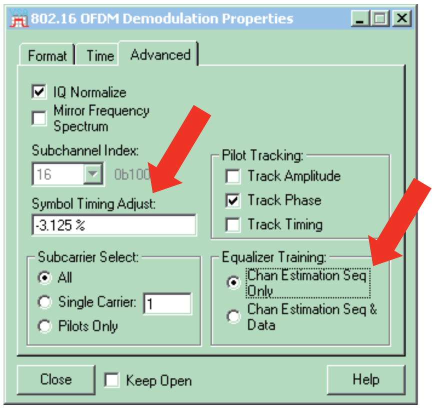
Linear Distortion and Equalization

Causes

- IF Filtering
- DSP Filtering
- ADC Sin(x)/X compensation

Troubleshooting

- Reposition FFT, observe RCE
- Use Data Driven EQ to improve EQ training



802.16 OFDM Demodulation Properties

Format | Time | Advanced

☑ IQ Normalize
☐ Mirror Frequency Spectrum
Subchannel Index: 16 0b100
Symbol Timing Adjust: -3.125 %
Pilot Tracking:
☐ Track Amplitude
☑ Track Phase
☐ Track Timing
Subcarrier Select:
● All
○ Single Carrier: 1
○ Pilots Only
Equalizer Training:
● Chan Estimation Seq Only
○ Chan Estimation Seq & Data
Close ☐ Keep Open Help

Figure 24. Linear distortion and equalization

Adaptive equalization

A sophisticated equalization facility (Figure 24) is essential when using broadband signals (because of possible frequency response problems) and when significant multi-path distortion is anticipated. The adaptive equalization in WiMAX is similar to that used in 802.11a, but unlike 802.11a, WiMAX may use a midamble as well. This equalization and its results (filter coefficients) are very useful for troubleshooting. The 89600B software allows the adaptive equalizer to be trained on the preamble or on the entire subframe, including the preamble.

Adaptive equalization can compensate for linear errors such as amplitude and phase flatness. These errors may be caused by multipath distortion, tilt, or ripple in the frequency response of a system. Noise, intermodulation, and the effects of amplifier compression are nonlinear forms of distortion and are not corrected by adaptive equalization.

Note also the ability to adjust the symbol timing used for demodulation, which positions in time the FFT used for demodulation. No specific time position is called out in the standard, and different timing settings will affect measured modulation quality. In particular, if filter ISI or multipath distortion affects the guard interval, certain symbol timing settings will provide much better demodulation results than others.

X- and Y-axis scaling is not actually an advanced demodulation technique, but it is a measurement refinement that is powerful and frequently overlooked. This capability zooms in the display to examine error peaks, for example, to determine the specific symbols or carriers or signal amplitudes, or even with specific modulation types the error occurs with.

Summary

A planned measurement sequence is the most reliable way to find the cause of signal problems. It reduces the time to find the root cause of a signal error. Figure 25 summarizes many of the measurements described in this presentation. These measurements are organized around the measurement and troubleshooting sequence presented in this application note.

For more information about the 89600B vector signal analysis software, go to **www.agilent.com/find/89600B**

Measurement and Troubleshooting Sequence

Frequency, Frequency and Time

Get basics right, find major problems

Frequency and Time Measurements
- Center frequency, occupied bandwidth
- Spurious, interference (all types)
- Amplitude – average and variations during burst (transients, drift)
- Turn-on and turn-off behaviors, on/off ratio
- Burst length, duty cycle, unanticipated frequency/time variations
- Band power measurements

Time-Gated Spectrum Measurements
- Spectrum vs. time, any spectrum artifacts
- Power changes during burst, CCDF variations
- Carrier structure, missing or extra carriers, energy at exact CF
- Side lobes (part of signal, not ACP), symmetry
- Frequency accuracy, carrier spacing
- Spurious, interference
- Flatness, tilt/ripple
- Preamble length, structure
- Confirm sampling factor, guard interval

Basic Digital Demod

Signal quality numbers, constellation, basic error vector measurements

Constellation
- Successful demodulation?
- Correct modulation type(s)?
- Indications of error?

Symbols/Errors Table
- Relative constellation error (RCE)
- Pilot and common pilot errors (CPE)
- I/Q errors including gain imbalance, quadrature error, delay mismatch

Error Vector Spectrum
- Average vs. spread, data vs. pilots
- Patterns/trends by carrier
- Spurs (will affect individual carrier or few carriers, for all symbols)

Error Vector Time
- Average vs. spread vs. mod types
- Look for impulsive errors such as DSP, interference, clocks, power (will affect all carriers for an individual symbol or group of symbols)

Marker Coupling
- Relation of error peaks (power, symbol value or location, carrier, time)
- Other relations discovered

Advanced and Specific Demod

Find specific problems and causes

Carrier-Specific Problems and Insights
- Individual carriers or groups, band-edge problems, pilots vs. data carriers

Time-Specific Problems and Insights
- Time interval or modulation type is cause of error
- Identify impulsive, intermittent, or periodic error sources
- Turn on/off, power supply, settling, or thermal effects

Simultaneous Freq and Time-Specific Demod Impairments Fixed by Pilot Tracking
- Amplitude droop, variations
- Phase noise, jitter, clock problems
- Timing uncertainties

Impairments Not Fixed by Pilot Tracking
- Modulation-related compression or clipping
- Non-narrowband phase noise

Linear Errors and Equalization
- IF and modulation filtering errors sin(x) x compensation
- Multipath
- Preamble (training sequence) problems--preamble vs. data-driven EQ

Figure 25. Planned measurement sequence summary

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