# RTCA Special Committee 186, Working Group 5

# ADS-B UAT MOPS

# Meeting #7

## Transmitter Test Equipment, Tools, and Considerations

## (PRELIMINARY)

**Prepared by Dave Thomas**
**Presented by Tom Pagano**
**Titan Systems**
**Wm J Hughes FAA Technical Center**

| SUMMARY |
| --- |
| **Standard Spectrum Analyzers and Power Meters fall short of the requirements necessary for the testing of today's digitally modulated communications equipment. Current communication test equipments provide the features and accuracy needed in order to comprehensively test the UAT Transmitter.** |

Traditional swept spectrum analyzers are frequency selectivity, and they have excellent dynamic range, but when it comes to measuring noise power, they have distinct disadvantages.[1]

The structure of a Vector Signal Analyzer (VSA) has both similarities to, as well as differences with, an Analog Spectrum Analyzer (ASA). The VSA is similar to the ASA in that it has an analog front end, or down conversion stage, which converts the selected frequency range of the input RF to a baseband signal. At this point, the VSA differs. The VSA digitizes the baseband signal, and applies selectable digital processing, filtering, and corrections.

The VSA, either single or dual channel, possesses many features, which are useful, if not necessary, for the testing and evaluation of a modern communication transmitter.

There are many parameters which can be measured, and display presentations which are available, with a piece of equipment like a VSA. A sample listing of only some of them follows:

- Gated Modulation Envelope
- Spectrum
- Power (true RMS)
- Power Transients
- Frequency Transients
- Phase (unwrapped)
- Error Vector Magnitude (EVM)
- EVM Spectrum
- I-Eye Diagram

What follows is a series of captured screen graphics from a VSA. All screens of the HP89441A VSA can be saved (or plotted) into a file using a HP Graphics Language ".HGL" format. Again, these are only a sampling of what is available, but some of the major ones which would be used are shown.

1 Frequency and Time-Selective Power Measurements with the HP89410A and 89440A, Product Note 89440A-1

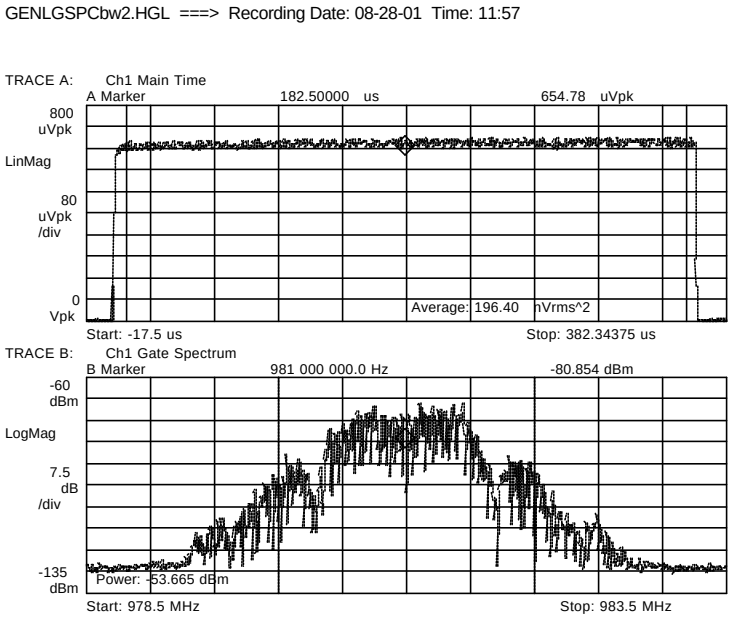
## Description of VSA Displays and Features

**Gated Modulation Envelope (upper)**
A time domain display showing the magnitude (envelope) of a modulated RF signal. Using "gate delay" and "gate length" parameters, a desired segment of a displayed time domain trace can be selected as a basis for computation. The thick vertical lines in the upper trace at right mark the desired segment.

**Power Transients**
With a magnitude time domain display, transients, droop, and other irregularities in the modulation envelope can readily be seen.

**Spectrum (lower)**
A frequency domain display showing the spectrum of the time domain trace segment selected as the Gated Modulation Envelope. Using "band center" and "band width" parameters, a desired segment of a displayed spectrum trace can be selected as a basis for RMS power computation. The thick vertical dotted lines in the lower trace at right mark the desired spectrum segment.

**Power (true RMS)**
Near the lower left of the spectrum display, a measure of true RMS power of the selected frequency band segment can be displayed.




**ADS-B Long Message: Signal Generator @ » -53.5 dBm**
Time Measurement: 350 usec between extra vertical lines, and averaged over 50 traces.
Spectrum Power: calculated in 2 MHz bandwidth.

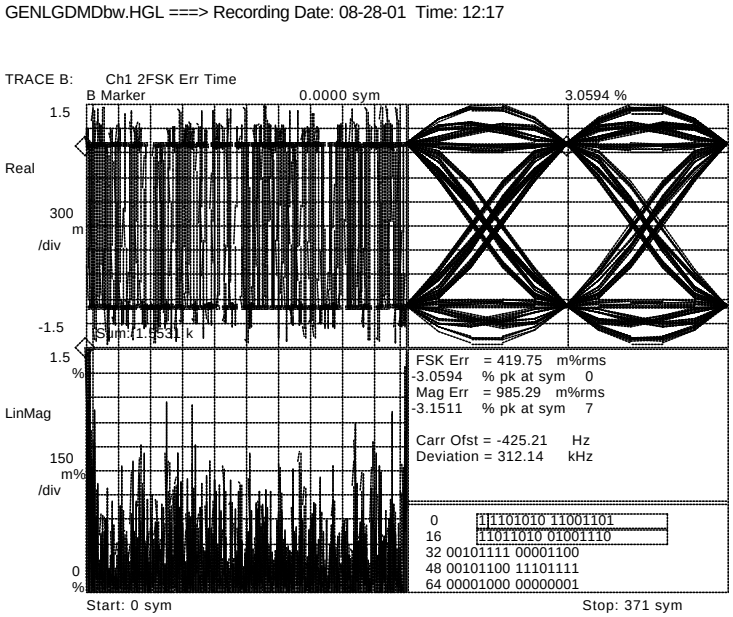
**Demodulated FSK (upper-left)**
Detection decision points (small square symbols) indicate "1" or "0" data bit decisions. The two rows of square symbols should be mostly aligned in straight lines.

**Error Vector Magnitude (EVM) (lower left)**
EVM is a time-based display of error magnitude computed using the magnitude and phase of both measured and reference signals. It can detect signal transmission errors, and it is easily measured and displayed with a VSA.

By changing the display to the spectrum of the EVM, problems can be shown, such as a close in spur, which are not evident in even the EVM display.

**Measured FSK I Eye Diagram (upper right)**
This display shows the path of the frequency shifts, and how well they are aligned with the detection decision points. Notice small spread at the crossover points.

**Symbol Table/Error Summary (lower right)**
Displays decoded symbols, several computed errors, and at which symbols the worst FSK and Magnitude errors occur.

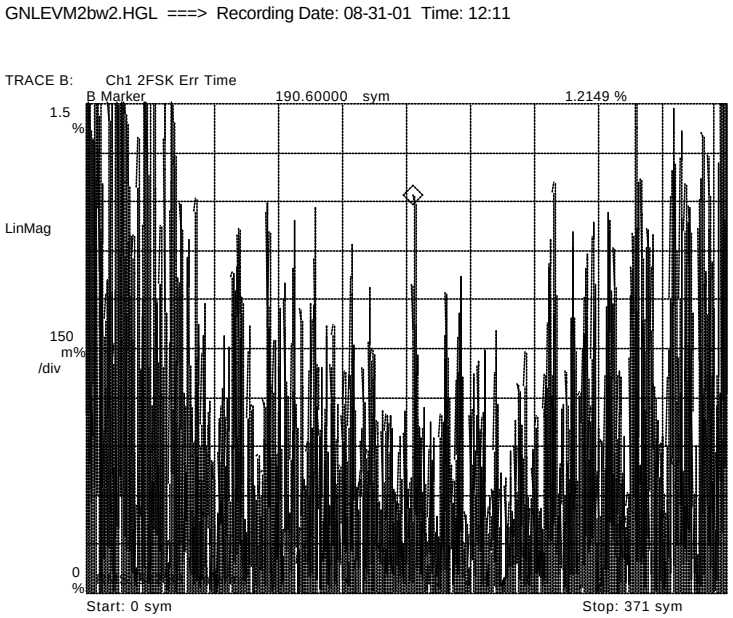



**Demodulated ADS-B Long Message: Signal Generator @ » -53.5 dBm Showing Error Vector Magnitude (2FSK Err Time) Display**
Demodulated FSK (upper-left): Decision points are mostly level.
EVM (lower-left): Rms error < 0.4% rms; Peak error @ symbol 0 ≈ 3%.
Eye Diagram (upper-right): Small crossover spread
Symbol Table / Error Summary (lower-right):

- Rms errors < 1% rms; Peak errors ≈ 3%
- FSK Deviation Low: ˜ 312.5 kHz

**EVM Example**
An example of an error, which is visibly evident in the EVM display. While the signal generator source for this display has otherwise low errors, the "V" shape of the EVM display illustrates the effect resulting from a message bit rate error of only 30 Hz.

The computed FSK EVM (blacked out by the trace in this example) is located near the lower left corner of the display.



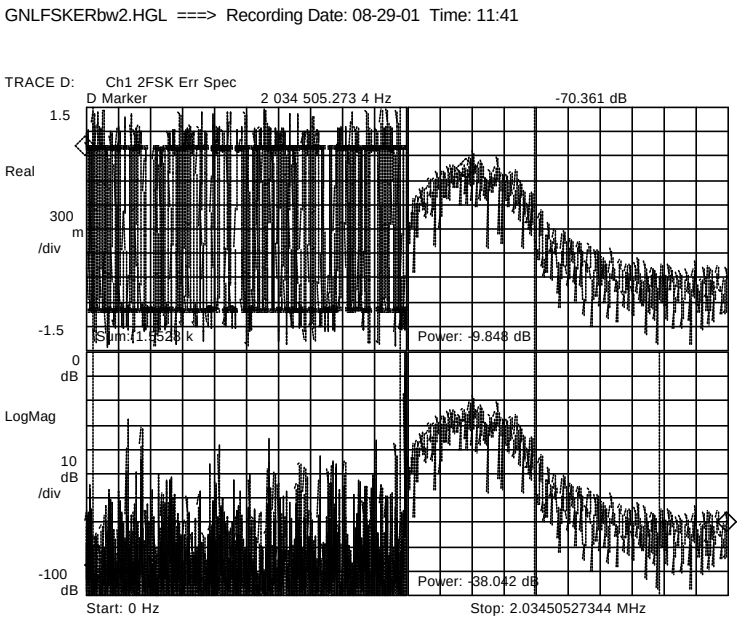

**Demodulated ADS-B Long Message from Rohde&Schwarz Signal Generator at » -53.5 dBm Showing FSK Error Vector Magnitude – Generator At 1.041697 MHz Bit Rate**

FSK Error Vector Magnitude: RMS FSK Error < 0.6%.

**FSK Error Spectrum**
By computing the spectrum of the FSK Error, this frequency domain display can detect errors not evident with even the EVM display. An example might be a close in spur, the indication of which cannot be seen in the EVM display.

(upper-right): Power < -9 dB
The bulk of the FSK Error Spectrum power is concentrated below 800 kHz.

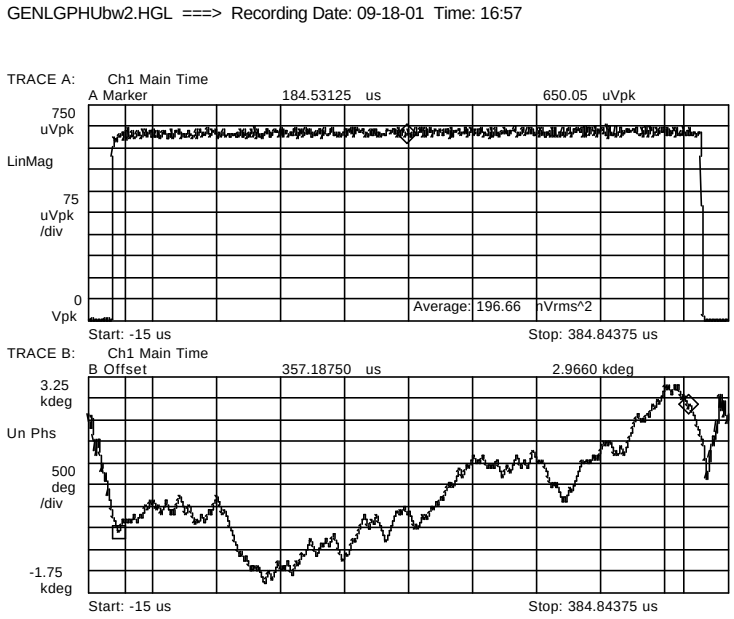
(lower-right): Power < -30 dB
The segment above 800 kHz is below – 30 dB.




**Demodulated ADS-B Long Message from Rohde&Schwarz Signal Generator at » -53.5 dBm Showing Spectrum of FSK Error**

Demodulated FSK (upper-left): Decision points are mostly level.
EVM (lower-left): Rms error < 0.4% rms; Peak error @ symbol 0 ≈ 3%.
FSK Error Spectrum – 0 to 800 KHz (upper-right): Power < -9 dB.
FSK Error Spectrum – 800 to 1.6 KHz (lower-right): Power < -30 dB

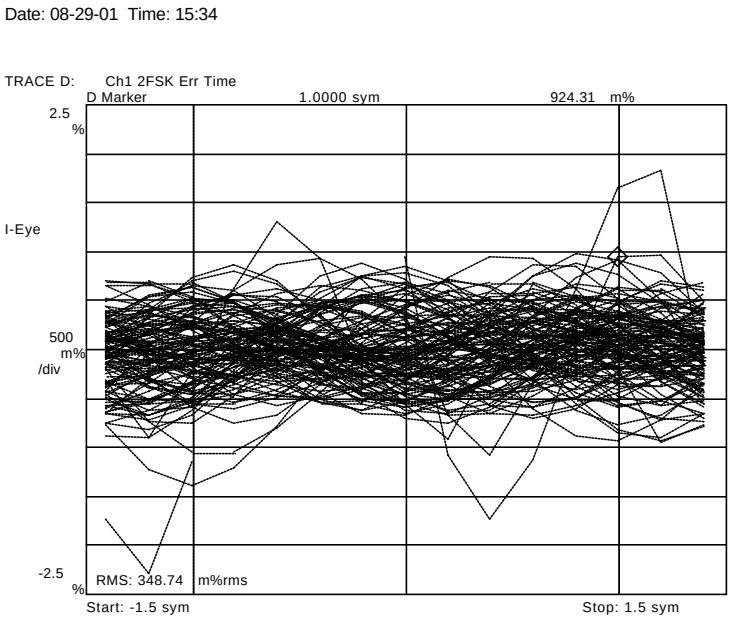
**Phase (unwrapped) (lower)**
Another time domain display available is Unwrapped Phase. For a fixed test message this phase display should appear stable, and will visibly indicate any bit detections, which change state unexpectedly. Using split markers, a "square" and a "diamond," the cumulative phase difference (from the beginning to the end of a message) is shown near the top right corner of the display.




**Demodulated ADS-B Long Message from Rohde&Schwarz Signal Generator at » -53.5 dBm Showing Unwrapped Phase of the Message**

Demodulated FSK (upper-left): Decision points are mostly level.

**FSK Error Eye Diagram**
This display is an Eye Diagram, similar to what was describe above. But instead of displaying Measured FSK versus Time, this displays FSK Error versus Time.




**Demodulated ADS-B Long Message from Rohde&Schwarz Signal Generator at » -53.5 dBm Showing FSK Error Eye Diagram**

FSK Error Eye Diagram (using same data as EVM diagram):

- RMS FSK Error < 0.4%.