WCDMA EVM Testing Method on ATE

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1. Introduction

The diverse technologies that comprise today’s digital RF communications systems share in common one main goal: modulating digital bit-streams onto RF carriers and demodulating them with accuracy, reliability, and efficiency. Achieving this goal demands engineering time and expertise, coupled with keen insights into RF system performance.

EVM, using magnitude and phase measurements, is called out in several system standards including GSM, PHS, and CDMA. EVM measurements are growing rapidly in acceptance and now it becomes one of the most powerful methods for the analysis of RF communication system performance. In mass production testing, more and more customers prefer to testing EVM on ATE system for it can not only truly test the performance of device but also provide the opportunity to replace other RF tests so as to reduce test time.

This paper is organized in the following way. First a brief overview of EVM concept and EVM measurement process is introduced. Followed by ATE testing challenges analysis and the details of the adaptive equalization which used to eliminate the ATE test system interference. Then test results are compared with the bench equipment. Finally are the conclusion and references.

2. EVM Definition

Figure 1 defines EVM and several related terms. As shown, EVM is the scalar distance between the two phasor end points (the magnitude of the difference vector). Expressed another way, it is the residual noise and distortion remaining after an ideal version of the signal has been stripped away. By convention, EVM is reported as a percentage of the peak signal level, usually defined by the constellation’s corner states. While the error vector has a phase value associated with it, this angle generally turns out to be random, because it is a function of both the error itself (which may or may not be random) and the position of the data symbol on the constellation (which, for all practical purposes, is random). A more useful angle is measured between the actual and ideal phasors (I-Q phase error), which will be shown later to contain information useful in troubleshooting signal problems. Likewise, I-Q magnitude error shows the magnitude difference between the actual and ideal signals.

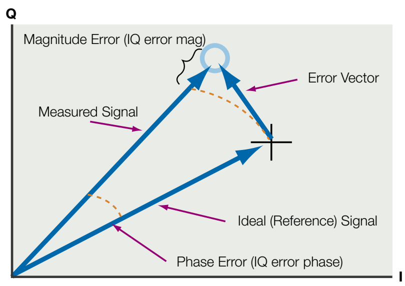


Fig.1 Error vector magnitude (EVM)

$$EVM_{rms}=\sqrt{\frac{\sum|Zn-Sn|^2}{\sum|Sn|^2}}$$

3. WCDMA EVM testing on ATE

W-CDMA is one of the leading wideband digital cellular technologies which used for the third generation (3G) cellular market. W-CDMA is designed to allow many users to efficiently share the same RF carrier by dynamically reassigning data rates and link budget to precisely match the demand of each user in the system. Unlike some 2G and 3G CDMA systems, W-CDMA does not require an external time synchronization source such as the Global Positioning System (GPS)[1]. WCDMA uplink modulator use HPSK ((Hybrid Phase Shift Keying) spreading technology which is a complex spreading scheme that is very different from the modulation formats commonly used until now. Figure 2 shows steps to generate base band HPSK I/Q signal to test WCDMA transmitter's EVM.

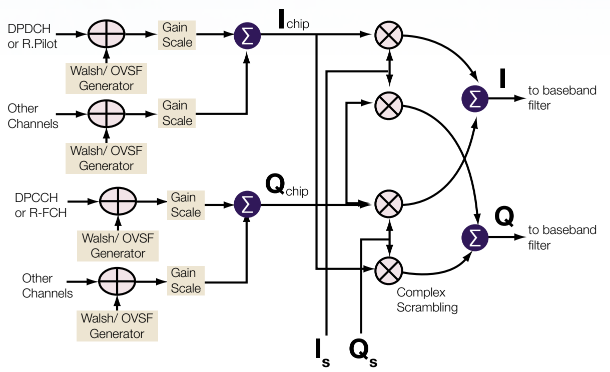


Figure 2. HPSK I/Q signal generate steps

Figure 3. shows constellation diagram of generated HPSK signal (1 DPDCH + 1DPCCH).

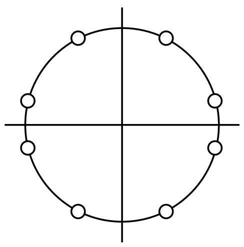


Figure 3. constellation diagram of generated HPSK signal

Figure 4 shows ATE setup to test device's EVM performance. Device used here is a WCDMA transceiver. Here use analog instrument to source HPSK I/Q base band signal and capture DUT's (Device-Under-Test) output RF signal with RF option.

This paper will focus on DSP algorithm which can help to eliminate the interference coming from whole ATE test system so as to get better bench mark result.

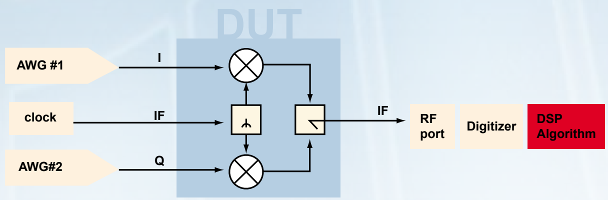


Figure 4. ATE setup for EVM testing

4. Key Algorithm in EVM calculation

4.1 symbol timing recovery

Digital modulation scenarios all rely on the idea of a signal traversing the IQ signal space and being at certain ideal locations at the periodic "decision_instants". EVM is calculated at symbol rate, to get the correct result, optimal measurement point ("decision_instants") must be found. This section will introduce a algorithm used to find such point. The key idea is to look at the eye diagram of the symbol sequence and find the maximum opening, which corresponds to the optimal sample position. The Steps are as follows [2]:

1.Get burst of K samples: Z(k), k=0,1,⋯,K-1.

2.Divide Z(k) in T vectors:

3.Obtain the magnitude of each element of the vectors vt:

4.Compute the variance of each magnitude vector

5.The optimal sample position is the one that leads to the lowest variance.

This method can only help to find the relative optimal sample position instead of truly "decision_point" for the limitation of sample points per symbol. It will cause EVM from ATE much worth than it from bench.

4.2 EVM testing challenge on ATE

When perform EVM testing on ATE equipment, several challenges may occur. The biggest one of them is that EVM is very sensitive to any signal impairment that affects the magnitude and phase of a demodulated signal. It will be very difficult when you try to correlate the EVM result from ATE equipment with it from bench result, ATE result may be much worse than the bench result.

It is reasonable because signal path in ATE test system is much more complicated than in bench system. In bench system, RF modulated signal comes out from DUT, through a short micro-strip and RF cable then captured by instrument directly. This short signal path will introduce little interference into RF signal. While in ATE testing system, things become complicate. Modulated signal comes out from the DUT, go through the socket and a quite long micro-strip on the top of the load board, then down to the bottom of the load board through a via and finally goes into the ATE system by a long RF cable. This is NOT the destination, in ATE system, it has to go through a LNA, mixer, several filter and finally be captured by a digitizer. Each component on the signal path may add interference into the signal and makes the test result much worse than bench. People have to spend a lot of time trying to optimize the result so as to correlate with bench result and it will greatly affect the time to market. EVM becomes the most challenge test item in production testing.

4.3 Optimization algorithm

In this section, a DSP based method is presented to eliminate the interference coming from whole ATE test system including DUT load board and ATE tester itself so as to get better correlation result with bench. After digitizing the IF signal from the mixer of the ATE tester, a pre-designed high pass digital filter is applied on the signal. Then an adaptive equalizer is presented with Least Mean Square (LMS) algorithm. Both of them are done in ATE tester's local DPS block with proper mathematics algorithm. This method can automatically adjust equalizer's tap coefficients so as to eliminate the interference from ATE test system. Although this algorithm will take some time but it only needs to do once in whole production testing. Because the test system does not change a lot from DUT to DUT during testing. When equalizer finds the optimized coefficients to compensate the whole test system, it does not change any more. So this method will affect little on device test time.

LMS adaptive equalizer

The most destructive source of interference coming from whole ATE test system and symbol timing recovery algorithm is Inter-Symbol Interference (ISI). Adaptive equalizer is a special category of equalizer that uses the input data stream to adjust the characteristics of filter. The commonly-used combination of Feed-Forward equalizer (FFE) and Decision-Feedback equalizer (DFE) has been extensively investigated in previous works [3][4].

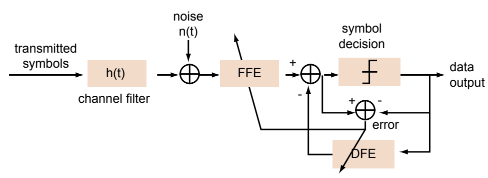


Fig. 5 adaptive Equalizer

A general block diagram is presented in Figure 5, showing the relationships between the equalizer, adaptive block and the slicer. The FFE is a generic linear filter, with its input stream coming directly from an digitizer. The DFE has a similar internal structure to the FFE, but is used in a feedback arrangement, with its input being the hard decision of the slicer block. The purpose of FFE is to deal with precursor ISI, while of DFE is to deal with post-cursor ISI. The outputs of two adaptive filter are summed with result being the soft decision. When the equalizer's coefficients have fully adapted to the channel, the soft decision should be very close the hard decision outputs. The difference between them is the error sequence, and is used to adapted the coefficients of the filters.

The operation of the adaptive equalizer can be summarized by following equations, the first describing filtering operation, and the second describing LMS coefficient update:

$y(n)=\sum_{j=0}^{N-1} Cjx(n-j)$

$Cj(n+1)=Cj(n)+\mu e(n) \mid x(n-k) \mid$

where x(n) is filter input at time n, y(n) is filter output, Cj(n) is the value of the jth. filter tap coefficient, e(n) is the slicer error sequence, and u is the adaptation step-size. To ensure the convergence, the step size should be : $0 < u < 2/\lambda_{max}$

This adaptive equalizer can be implemented in ATE's DSP block to deal with demodulated I/Q signal. When this equalizer get convergence, it can help to cancel the interference from both whole ATE test system and missing of truly "decision point" from symbol timing recovery algorithm in section 4.1.

5. Test result from ATE system

We implement this optimized algorithm on a WCDMA transceiver device. Figure 6 shows device's output signal spectrum:

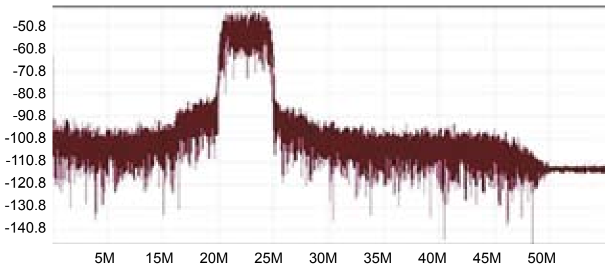
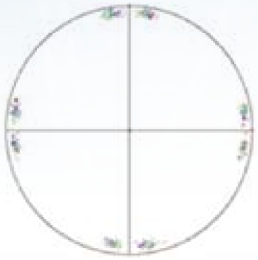


Figure 6, WCDMA output spectrum

The EVM result from bench system is around 6.6%. Without this method, the EVM result from ATE is 7.88% , with this optimized method, the EVM result is around 6.68% which agree pretty well with bench result.

左：Figure 7 ATE result with method (6.68%)
右：Figure 8 ATE result without method (7.88%)

6. Conclusion

In this paper, a DSP based method is presented to eliminate the interference coming from whole ATE test system. We tested this method on a WCDMA transceiver device. Without this method, the EVM result from ATE system is around 7.88% which is far away from the bench result (6.6%). After applying this method, a better result achieved, that is around 6.68% which agree pretty well with bench result.

7. Reference

[1] JaeRyong Shim and SeungChan Bang, Spectrally Efficient Modulation and Spreading Scheme for CDMA Systems, IEE, August 19, 1998.

[2] Osvaldo Mendoza, "Measurement of EVM (Error Vector Magnitude) for 3G Receivers", Ericsson Microwave systems AB, Molndal, Sweden, February 2002

[3] J.G.Proakis, "Digital Communications", 3rd. Edition, McGraw-Hill Education.

[4] S.Haykin, "Adaptive Filter Theory", 4th. Edition, Pearson