APSK Signal evaluation in case of DVB-S2X using Error Vector Magnitude (EVM) and Bit Error Rate (BER)

Simar Mann Singh Chawala
University of Kiel
Electrical Engineering
Email: stu126538@mail.uni-kiel.de

***Abstract*—The Paper presents a brief evaluation of the performance of different higher order APSK modulations in the DVB-S2X system. Evaluation is done using Error Vector Magnitude (EVM) and Bit Error Rate (BER) as the performance characteristics. Also, already established performance results of different QAM modulations are shown to justify the correctness of EVM vs BER curve for various APSK signal modulations. Thereafter, Simulation results are presented to illustrate the error performance of the APSK modulations.**

***Index Terms*—Error Vector Magnitude (EVM), Bit Error Rate (BER), APSK, DVB-S2X, Satellite Communications, QAM**

I. INTRODUCTION

Digital Television (DTV) is the transmission of audio and video by digitally processed and multiplexed signal, in contrast to the totally analog and channel separated signals used by analog television. Digital TV can support more than one program in the same channel bandwidth.

Digital Video Broadcasting (DVB) is a set of standards designed to broadcast video and audio signals via various channels. DVB standard is maintained by an international industry consortium with more than 270 members and are published by European Telecommunications Standards Institute (ETSI). Data is distributed using variety of approaches in DVB which include DVB-C (DVB Cable), DVB-S (DVB Satellite), DVB-T (DVB Terrestrial) and DVB-M (DVB Microwave). Digital Video Broadcasting (DVB) uses coded orthogonal frequency-division multiplexing (OFDM) modulation and supports hierarchical transmission. This standard has been adopted in Europe, Singapore, Australia and New Zealand.

DVB-S was introduced in 1995 for the transmission of video signals over the satellite channel. In 2003, second generation of DVB-S was developed and was called DVB-S2 (DVB-S Second Generation). It had more bandwidth efficiency, higher data transmission rates and was more robust against transmission errors. It employed APSK modulations for the first time for transmission of video signals over satellite channel.

In 2014, DVB-S2X (stands for DVB-S2 extension) was introduced. It uses higher order APSK modulations which greatly increases the channel bandwidth efficiency allowing more data to be sent over the same Satellite channel.

In this paper, we evaluate the higher order APSK signal in case of DVB-S2X transmission by using error performance metrics like Error Vector Magnitude(EVM) and Bit Error Rate(BER) for accessing the quality of transmission. Often BER is synonymous to the other performance metrics, such as signal to noise ratio (SNR), since direct relationship exist between them. However, for BER measurements, it is incumbent that the signal must be demodulated first at the receiver side which is not required in case of EVM. The novelty in this paper lies in that both the performance metrics EVM and BER can be correlated, since BER is a direct consequence of EVM. [1]

In section 2, BER and EVM calculations for APSK modulation are explained. In section 3, simulation results are presented. In section 4, a short conclusion is derived from the simulation results.

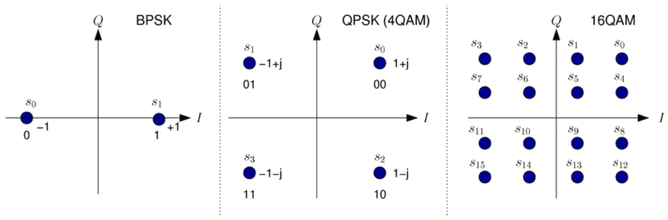

Fig. 1. QAM Constellation Diagram

II. SIGNAL CONSTELLATION FOR APSK AND QAM MODULATIONS

A signal constellation is a representation of signal modulation in the form of a two dimensional scatter diagram in the complex plane. Every symbol which is transmitted in digital communications occupy space in this complex plane as a point as shown in figure 1 for QAM modulation.

When the signal passes through a channel, interference causes distortion in the transmitted signal and hence the symbols end up in a changed position in the signal constellation. The distance of both the transmitted and received symbol in the constellation diagram is averaged over subsequent symbols and this average value is called EVM (Error Vector Magnitude).

Ideally, in APSK modulation, symbols lie on concentric circles in the constellation diagram. The APSK modulation is more robust against distortions caused by channel nonlinearities which largely depend on the high-power amplifier (HPA) such as the Traveling Wave Tube Amplifier (TWTA).[2]

For 16-APSK, the symbol constellation consist of two concentric rings having one of the two configuration : 4 transmission symbol points uniformly distributed on the inner ring with radius R_1 and 12 transmission symbol points uniformly distributed points on the outer ring with radius R_2 (4+12) or with both the rings containing 8 uniformly distributed transmission symbol points (8+8) as shown in figure 2. Radius of both the concentric rings is optimized for different configurations. [3]

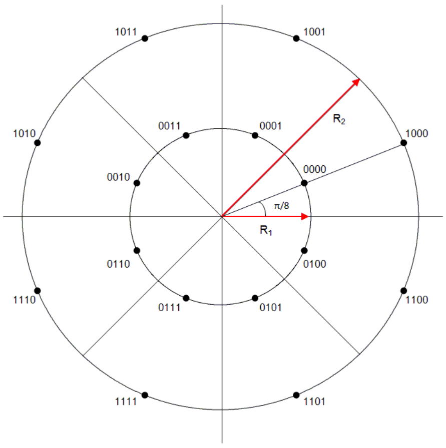

Fig. 2. Radius Ratio for 16-APSK

The ratio of the outer and inner radii is called Radius Ratio and is denoted by

$$\beta = \frac{R_2}{R_1}$$

Similarly, for 32-APSK, the constellation consist of either (4+12+16) or (4+8+4+16) symbols in each ring as shown in figure 3.

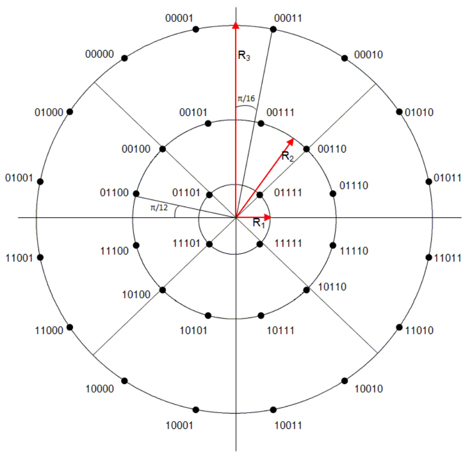

Fig. 3. Radius Ratio for 32-APSK (4+12+16)

For 64-APSK, the constellation ideally consist of (16+16+16+16), (8+16+20+20) or (4+12+20+28) symbol configuration in each ring as shown in figure 4. And likewise, 256-APSK, 512-APSK and 1024-APSK modulations have an ideal constellation description as given in [3].

When the Signal travels through the non-linear channel, distortion is introduced in the signal which results in displacement in the position of symbols in the constellation of APSK modulated signal. One type of distortion (AM/AM) causes the outer symbols to move inwards or towards the center of the constellation relative to inner symbols. Another type of distortion (AM/PM) will affect the phase of the outer states which causes the outer symbols to rotate around the origin relative to the inner states. This displacement of the symbol points from their ideal position in the constellation is measured in calculating the performance metric EVM.

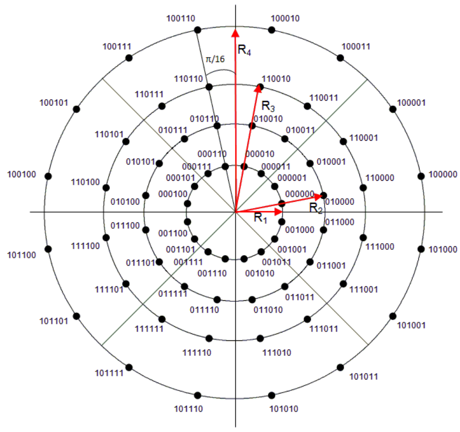

Fig. 4. Radius Ratio for 64-APSK (16+16+16+16)

III. BER FOR ASPK MODULATIONS

The setup used for calculation of BER is shown in the figure 5. Data generator is a memoryless discrete source block which generates a stream of data. To increase the transmitted data per unit time, source coding is done by the APSK Mapper block which maps the generated bit sequence into different symbols.

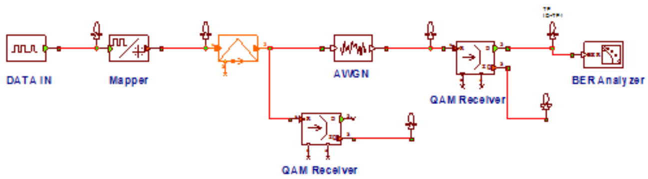

Fig. 5. System setup for BER calculation

To enable physical transmission of these symbols over the physical medium, the symbols is transformed into pulse using root raised cosine function with roll of factor of $\alpha = 0.35$. The choice of pulse shaper function determine the amount of Inter Symbol Interference (ISI), which the communication system can mitigate. Additive White Gaussian Noise (AWGN)

Channel is the simplest noise model, often used to simulate Satellite channel and deep space communication links. AWGN block performs linear addition of independent Gaussian noise samples to its input signal. QAM (Quadrature Amplitude Modulation) implements a QAM receiver with demodulation and detection functions. It operates on a noisy Complex Envelope (CE) sampled data waveform to produce estimates of the original transmitted bit stream. The BER analyzer block calculates the bit error rate (BER) from a digital signal. BER is defined as

$$BER = \frac{Number\ of\ Errors}{Total\ number\ of\ Transmitted\ Symbols} \tag{1}$$

The BER analyzer block automatically determines the reference signal. BER is capable of sweeping simulation, producing swept BER output. An optional variable to be swept along with the value of each sweep can be specified using the name of variable to sweep and the vector of values for that variable. BER block starts a new sweep when minimun number of errors per pass have been detected or when all the symbols contained in the maximum number of trial blocks per sweep have been processed.

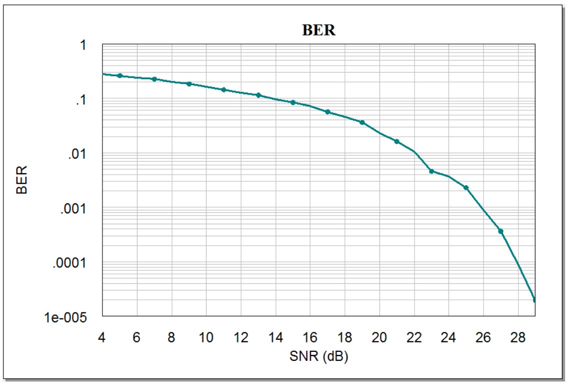

Fig. 6. BER curve for 64-APSK

IV. EVM FOR ASPK MODULATIONS

An ideal signal or the signal sent by transmitter would have all the constellation points precisely at the ideal location. However, due to distortion of signal in the channel, these constellation points end up at different position in the receiver. This shift in position of the constellation points is measured at the receiver. Error Vector Magnitude (EVM) is a measure of how far these constellation points are from their ideal location. The setup used for calculation of EVM is shown in the figure 7. The same setup with slight modification is used, for calculating the EVM. The different blocks used here are a splitter and a Vector Signal Analyzer. A splitter splits the incoming signal into n-connected output ports as :

$$V_{out} = \begin{cases} \frac{V_{in}}{n} & Voltage\ Splitting \\ \frac{V_{in}}{\sqrt{n}} & Power\ Splitting \end{cases} \tag{2}$$

where n indicates the number of connected output ports. A vector signal analyzer is an instrument that measures the magnitude and phase of the input signal at a single frequency within the Intermediate Frequency bandwidth of the instrument. It gathers the reference signal and measured signal, and acts as a sweep controller. The sprectrum analysis by a VSA consist of two stages - down-convert & digitze stage and Digital signal processing and display stage. A portion of the input signal spectrum is down-converted (using a voltage-controlled oscillator and a mixer) to the center frequency of a band-pass filter. The use of a voltage-controlled oscillator allows for consideration of different carrier frequencies.

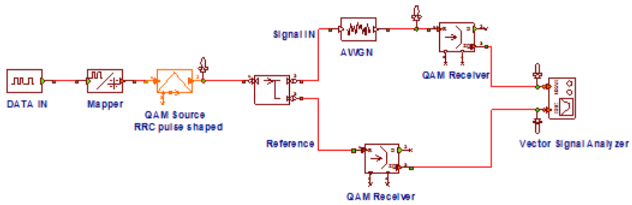

Fig. 7. Setup for EVM calculation

After the conversion to an intermediate frequency, the signal is filtered in order to band-limit the signal and prevent aliasing. The signal is then digitized using an analog-to-digital converter. Sampling rate is often varied in relation to the frequency span under consideration.

EVM is the Root-mean-square (RMS) value of the difference between a collection of measured symbols and ideal symbols. It is calculated as follows

$$EVM_{RMS} = \frac{\frac{1}{N}\sum_{n=1}^{N}|S_n - S_{0,n}|^2}{\frac{1}{N}\sum_{n=1}^{N}|S_{0,n}|^2} \tag{3}$$

where S_n is the Normalized n^{th} Symbol in the stream of measured symbols. $S_{0,n}$ is ideal normalized Constellation point of n^{th} symbol N is the Number of unique symbols in constellation

V. EVM VS BER FOR APSK MODULATION

After plotting the EVM values against BER, we get an EVM-BER curve which is shown below in figure . The figure 9 below shows the EVM-BER curves for the APSK modulations like APSK-16, APSK-64, APSK-256 and APSK-512 along with QAM modulations (QAM-16 and QAM-64). The EVM-BER curve for the 16-QAM and 64-QAM are already established results which have been reconstructed to justify the correctness of the APSK plots.

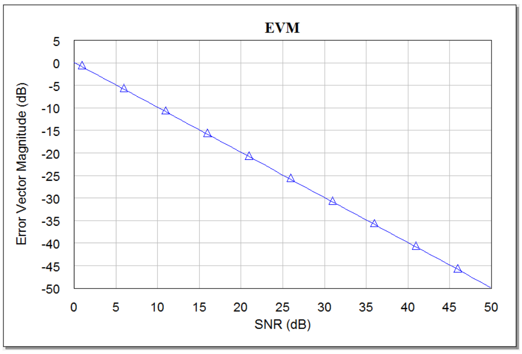

Fig. 8. EVM curve for 64-APSK

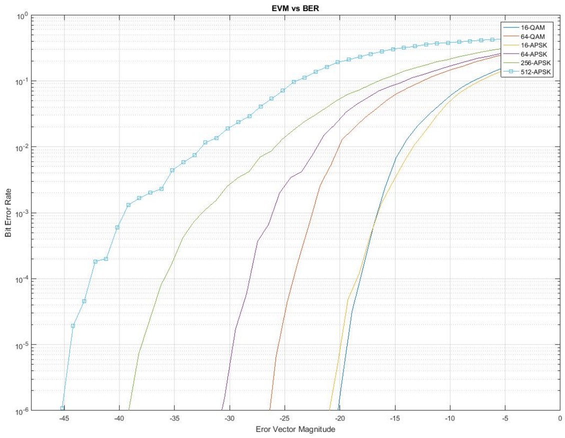

Fig. 9. EVM vs BER curve

Minimum EVM required corresponding to a given value of BER can be easily determined from the figure above. While BER(10^{-5}) is used by many engineers as a standard signal performance metric, it takes time to measure the signal performance. In case of a communication system that employs Automatic repeat request (ARQ) system, retransmissions causes delay in taking BER measurement. In such cases, EVM can be helpful as it quickly sweeps through the signal and determines the quality of the signal transmission. This saves a lot of cycles which decreases the latency.

Taking EVM measurements requires only a Vector signal analyzer which also measures a lot other parameters. Hence, EVM measurement doesn't require any special instrument which makes it cost effective.

References

[1] R. A. Shafik, M. S. Rahman, A. R. Islam, and N. S. Ashraf, "On the error vector magnitude as a performance metric and comparative analysis," in *Emerging Technologies, 2006. ICET'06. International Conference on*. IEEE, 2006, pp. 27–31.

[2] W. Sung, S. Kang, P. Kim, D.-I. Chang, and D.-J. Shin, "Performance analysis of apsk modulation for dvb-s2 transmission over nonlinear channels," *International Journal of Satellite Communications and Networking*, vol. 27, no. 6, pp. 295–311, 2009.

[3] ETSI, "Digital video broadcasting," European Telecommunications Standards Institute, 650 Route des Lucioles F-06921 Sophia Antipolis Cedex - FRANCE, ETSI ETSI EN 302 307-2 V1.1.1 (2015-02), 2015.