Error Vector Magnitude Measurement To Characterize Tracking and Data Relay Satellite(TDRS) Channel Impairment

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Outline

I. Introduction
II. Background
III. System Model
IV. Measurement Analysis
V. Future Work
VI. Summary

Introduction(1/2)

What is Tracking and Data Relay Satellite (TDRS) ?

- A specialized communications satellites that orbit 22,300 miles above the Earth
- The satellites relay signals between spacecraft including the International Space Station and ground control stations on Earth.
- With the TDRS spacecraft in place, spacecraft including Earth-observing missions and NASA's Hubble Space Telescope have near-constant communication links to Earth.

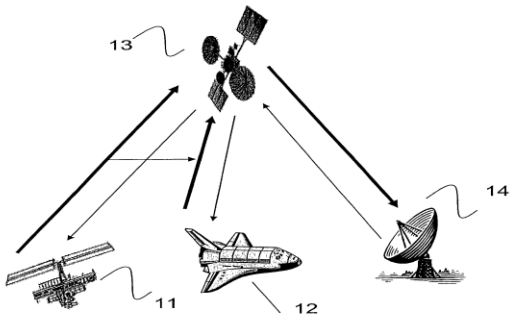
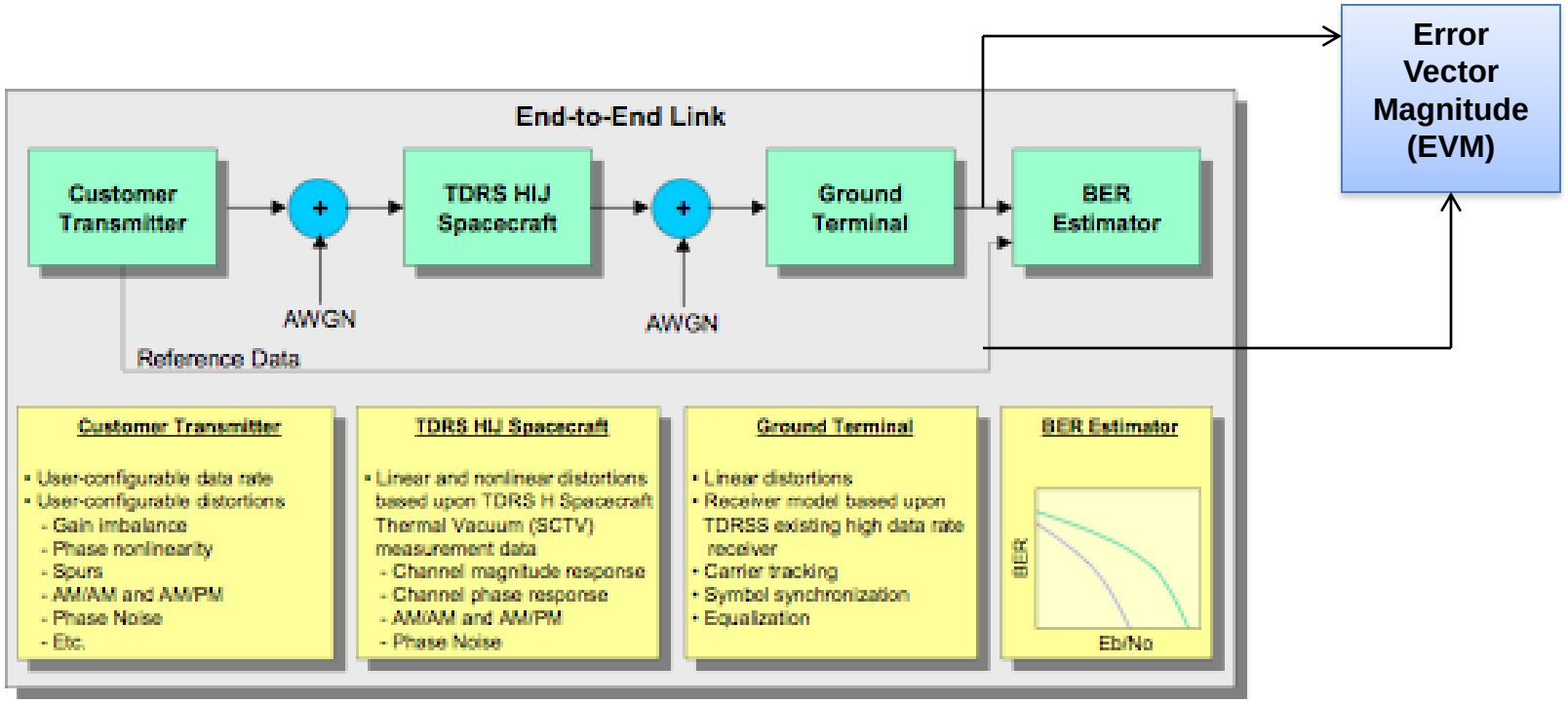


FIG. 2
Background Art

Introduction (2/2)

Block diagram customer, TDRS, and NASA's White Sands Complex



Bit Error Rate(BER) provides a conclusion stating a single bit has some error.

Why Error Vector Magnitude ?

Background(1/4)

What is Error Vector Magnitude (EVM)?

1) EVM is the measurement of modulator or demodulator performance in a communication system.

2) EVM is used to evaluate the quality of communication system with a single measurement.

3) EVM can offer insightful information on the various imperfections.

    a) Carrier leakage
    b) IQ mismatch
    c) Non-linearity
    d) Phase noise
    e) Thermal noise
    f) Frequency error

Background(2/4)

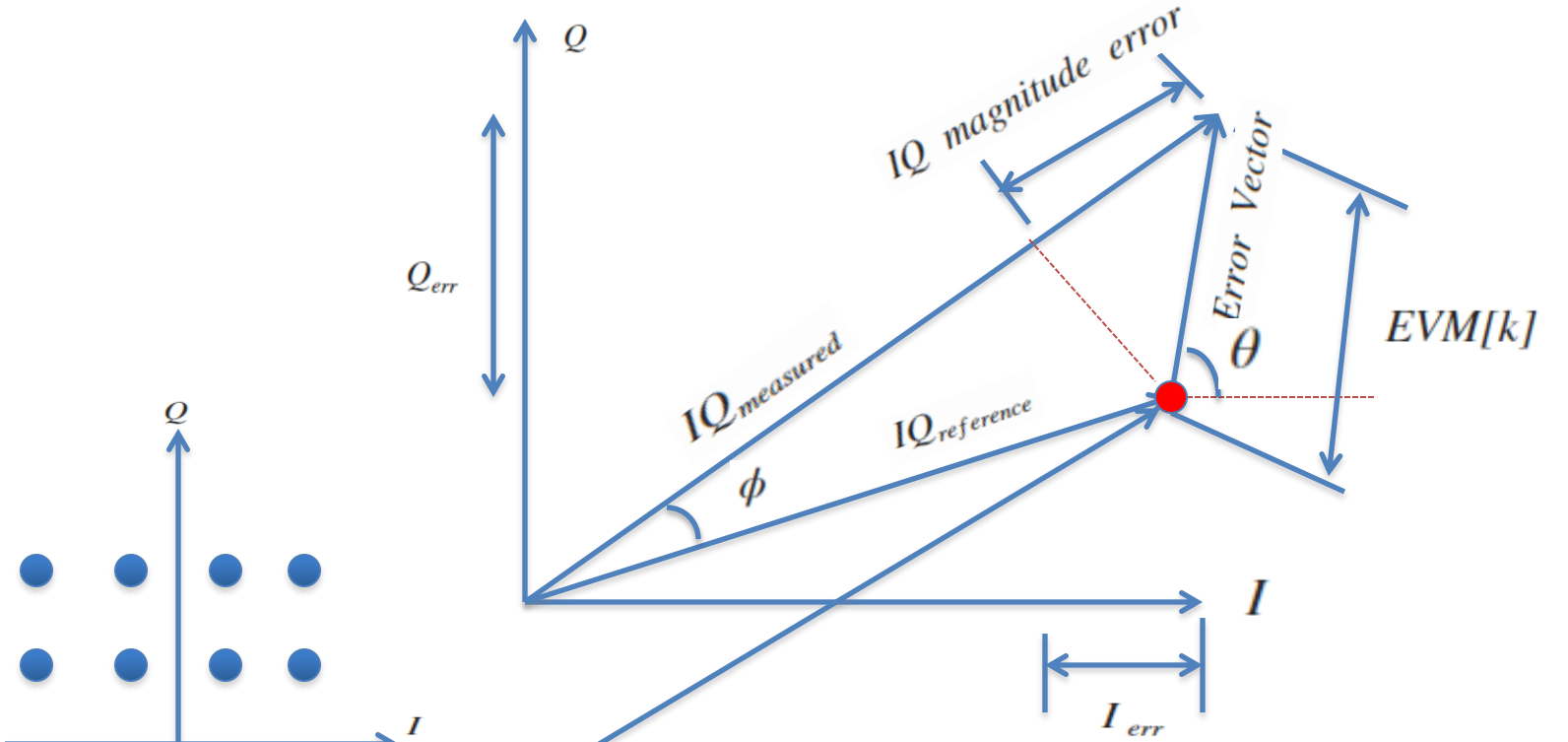
How can Error Vector Magnitude be applied to the Space Network?

1) Characterize distortions that are listed in SNUG.

2) Establish EVM constraints for customer transmits platforms and Space Network ground receivers.

3) Use EVM as a cost effective test to validate modulator/demodulators and RF systems.

Background (3/4)



$$EVM = \sqrt{I\ err[K]^2 + Q\ err[K]^2}$$

K = Symbol index

$I\ err$ = $I\ Ref$ - $I\ measure$

$Q\ err$ = $Q\ Ref$ - $Q\ measure$

Background (4/4)

USS-CR modem

1)FPGA based modem
2)Narrowband (NB) modem and Wideband (WB)demodulator
3) NB modem is a single board computer with I/O signal distribution card
4) Can be controlled and monitored Via SNMP v3 protocol
5) Evaluate the quality of communication system
6) Support advanced modulation and coding techniques

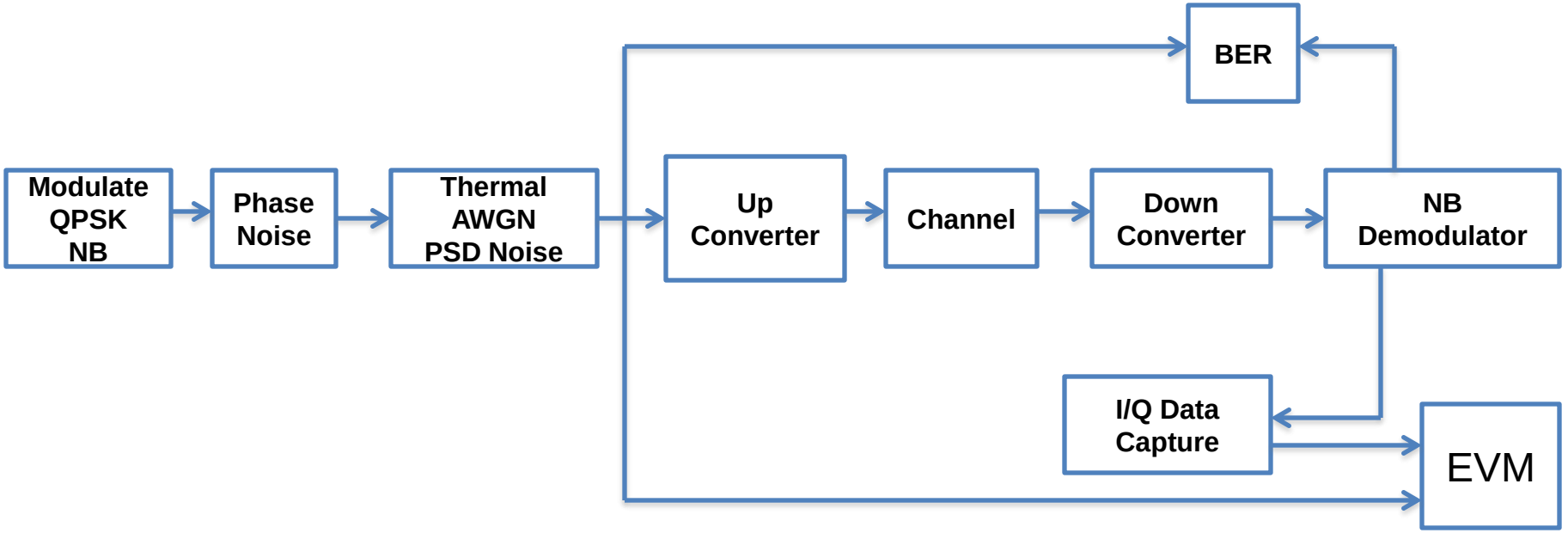
Matlab, Simulink and C++ Simulation

1) QPSK modulation and Demodulation Scheme
2) User define noise (SNUG's reference)

a) Thermal noise
b) White Gaussian Noise
c) Noise Spectral Density

System Model(1/2)

Preview EVM measurement

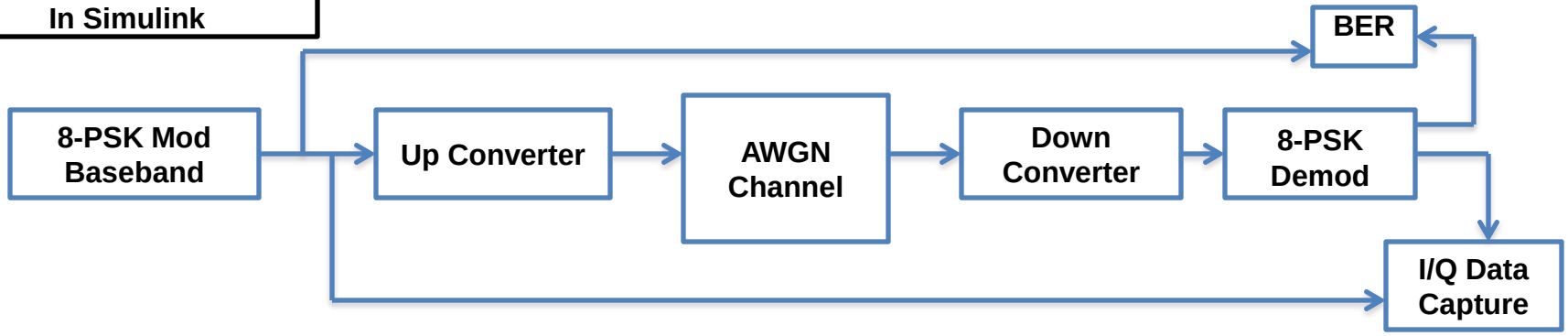


System Model(2/2)

EVM measurement in USCCR modem

EVM measurement in simulation

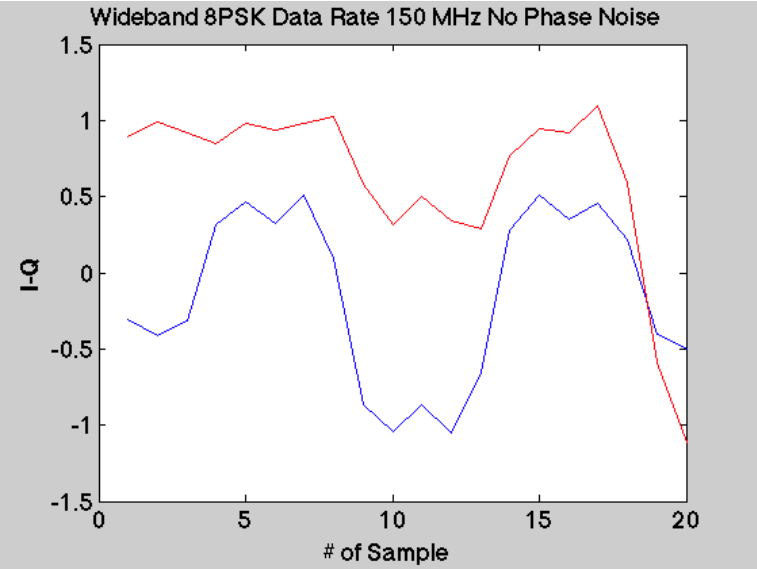
EVM measurement In Simulink

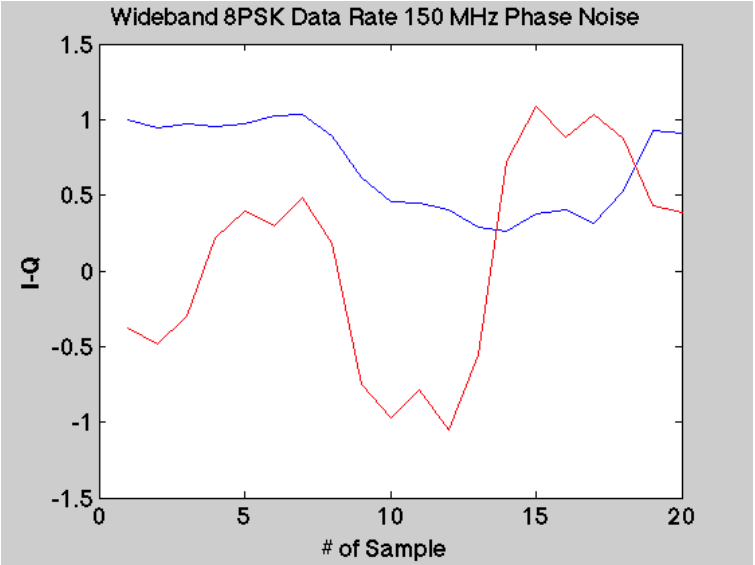


Measurement Analysis in USS-CR modem(1/4)

$$S_{phi}(f) = 180/\pi \sqrt{2\int L(f)df} \qquad \int L(f)df \qquad \textit{Integrated single sideband phase noise}$$

$$EVM \approx 100\% S_{phi}(f).\ {}^{\pi}/_{180}$$





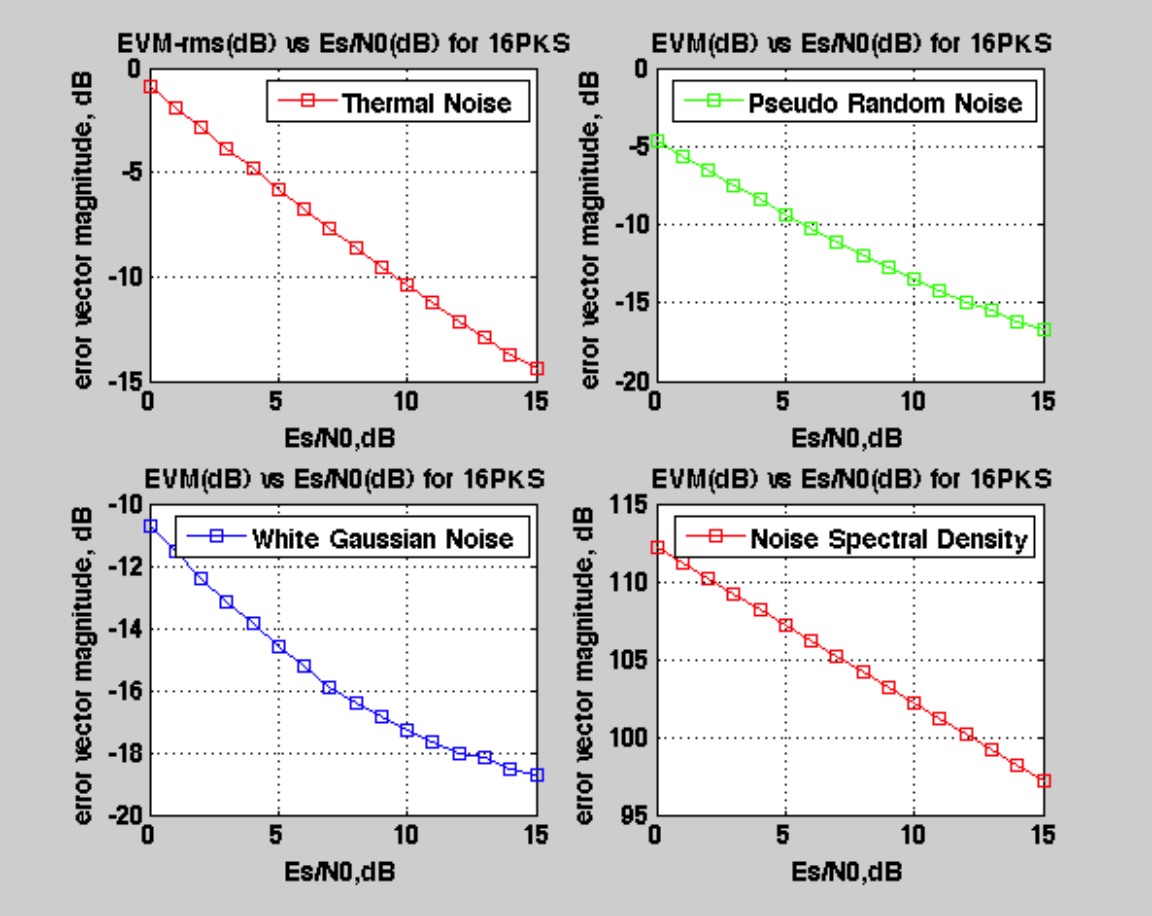
	dB	% rms	Max(degree)	Min(degree)
EVM	51.9	189		
Magnitude Error	46.709	183		
Phase Error	12.968		-22	22
IQ Offset	-25			
Quadrature Error	270			

Measurement Analysis in Simulation(2/4)

$$EVM(dB) = 10\ log_{10}\left(\frac{P_{error}}{P_{reference}}\right)$$

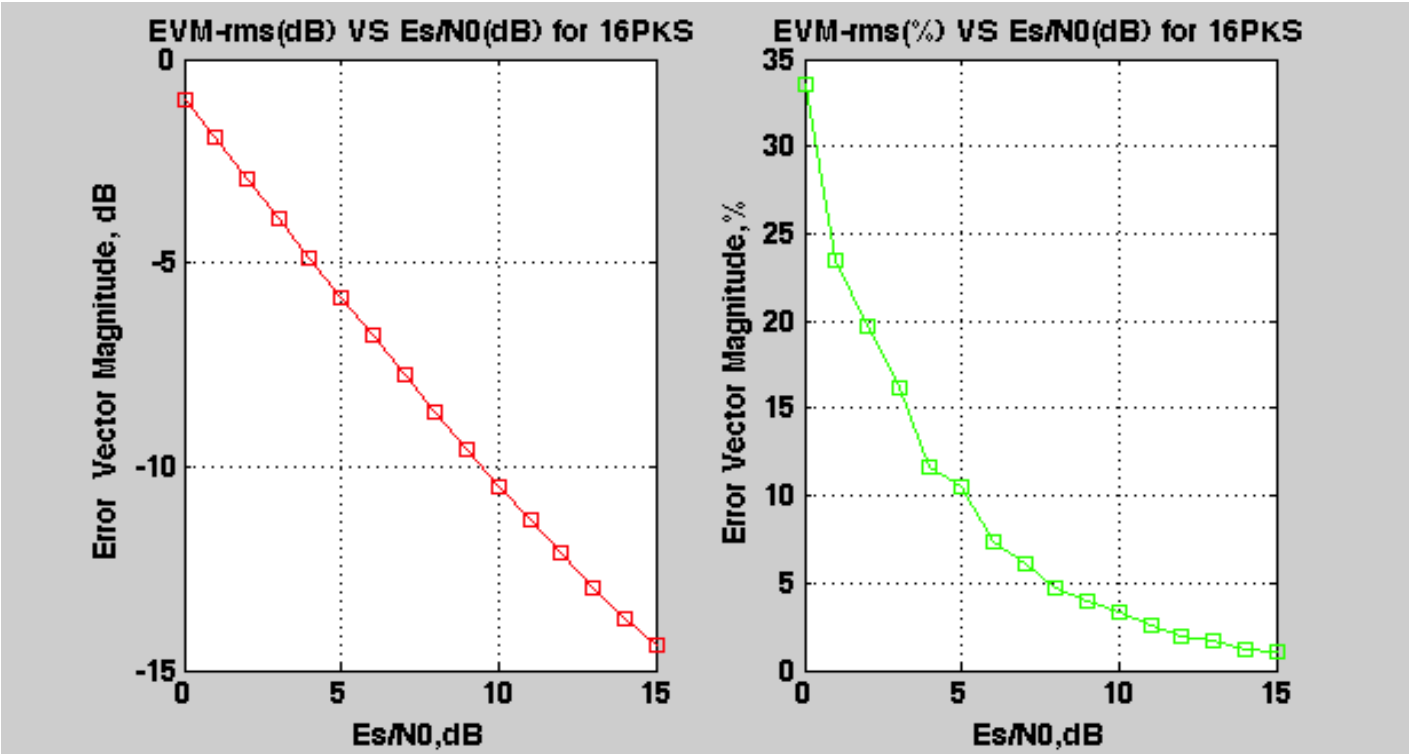
EVM(dB) Vs Noise

Thermal noise	Pseudo Random Noise	AWGN	Noise Spectral Density	Total Noise
1.3265	5.6564	1.4054	1.0182	1.0182
1.0579	4.5154	1.1581	0.8088	0.8088
0.8429	3.6271	0.9534	0.6424	0.6424
0.6754	2.9265	0.8119	0.5103	0.5103
0.5386	2.3578	0.6692	0.4054	0.4054
0.433	1.9166	0.5801	0.322	0.322
0.3468	1.5548	0.4915	0.2558	0.2558
0.2785	1.2624	0.4216	0.2032	0.2032
0.2261	1.0488	0.3834	0.1614	0.1614
0.1829	0.873	0.3365	0.1282	0.1282
0.1501	0.7346	0.3128	0.1018	0.1018
0.1226	0.6177	0.2811	0.0809	0.0809
0.1011	0.5326	0.2629	0.0642	0.0642
0.0849	0.4602	0.2495	0.051	0.051
0.0703	0.4046	0.2324	0.0405	0.0405
0.0595	0.3537	0.2209	0.0322	0.0322

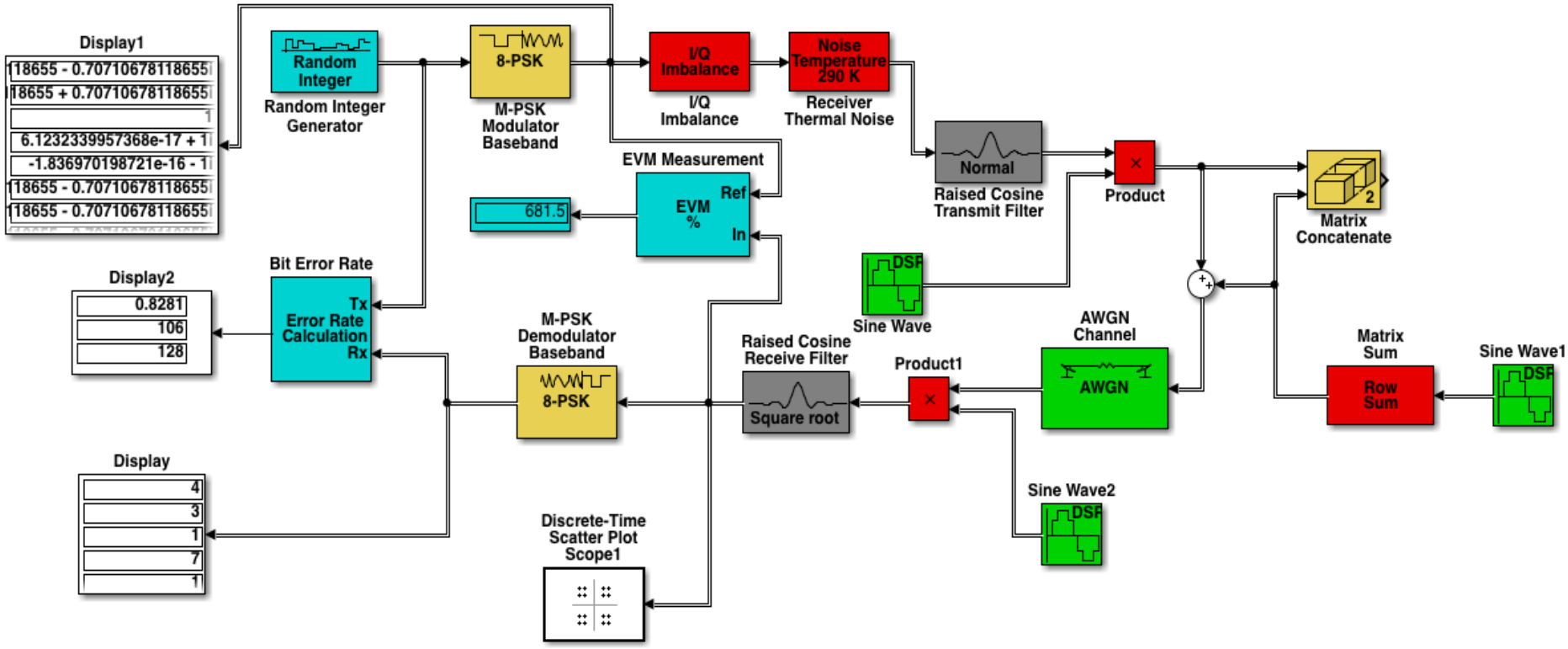


Measurement analysis in Simulation(3/4)

$$EVM(\%rms) = \frac{\frac{1}{N}\sum_{K=0}^{N-1} EVM[K]^2}{\sqrt{\frac{1}{N}\sum_{k=0}^{N-1} I\ Ref[K]^2 + Q\ Ref[K]^2}}, \qquad N=Number\ of\ sample\ points$$

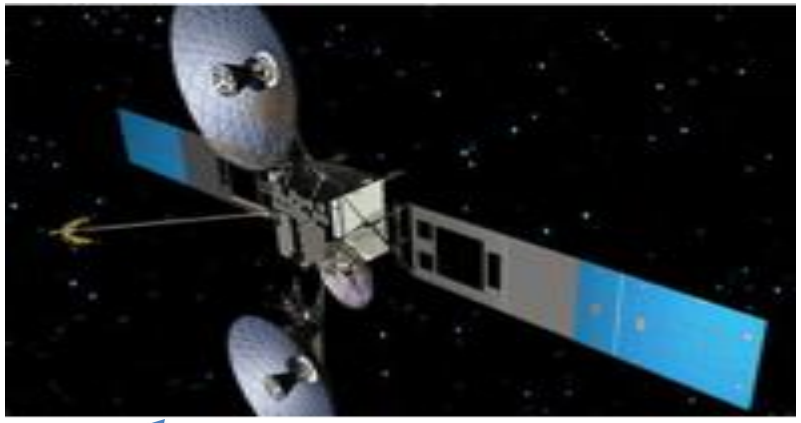


Measurement Analysis in Simulink(4/4)



Error Vector Magnitude measurement on modulated and demodulated baseband

Future Work



TDRS

EVM measures the performance of receiver to assess phase and magnitude error.

EVM measures the performance of a transmitter to evaluate phase and magnitude error

Customer can measure EVM on the ground

NASA's White Sand Complex

Summary

1) Error Vector Magnitude measures the communication system performance with a single metric.

2) EVM assesses noise distortion in a communication system

3) EVM guarantees a performance envelope prior to the demodulation process.

Question and answer

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