KEYSIGHT

SatCom Systems Design

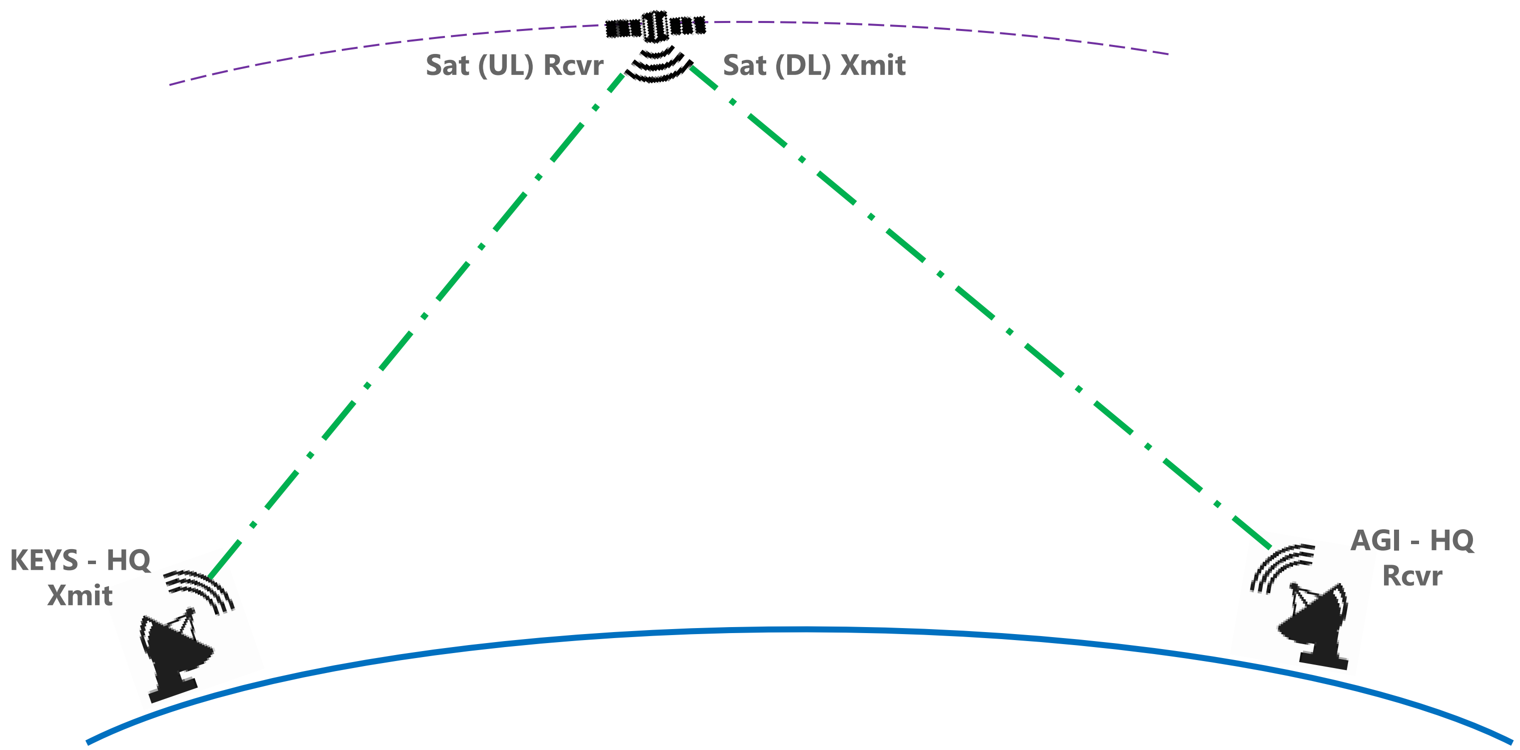
Wilfredo Rivas-Torres, Ph.D.

Agenda

- Introduction – Background and Story
- SatCom Link Budget
- PathWave System Design and System Toolkit (STK) Link
- Complete System Simulation – The Digital Twin

Digital Mission Engineering – The Digital Twin

Scenario Architecture/Story



SETUP

Two ground stations with Xmit/Rcvr Object communicating with a passing LEO satellite with applicable Xmit/Rcvr objects

Satellite Comms

The comm equipment modeled on the satellite is assuming a Tx/Rx phased array antennas with adaptive beamforming utilized to focus on the ground transmitter/receiver

Ground Comms

The comm equipment modeled at the ground stations are defined with parabolic dish tracking antennas.

RF Link Quality

The links can be explored separately, both the Uplink and Downlink path. Access has already been calculated and there are Reports within the Report & Graph Manager to explore the link metrics that are intended to be used within SystemVue

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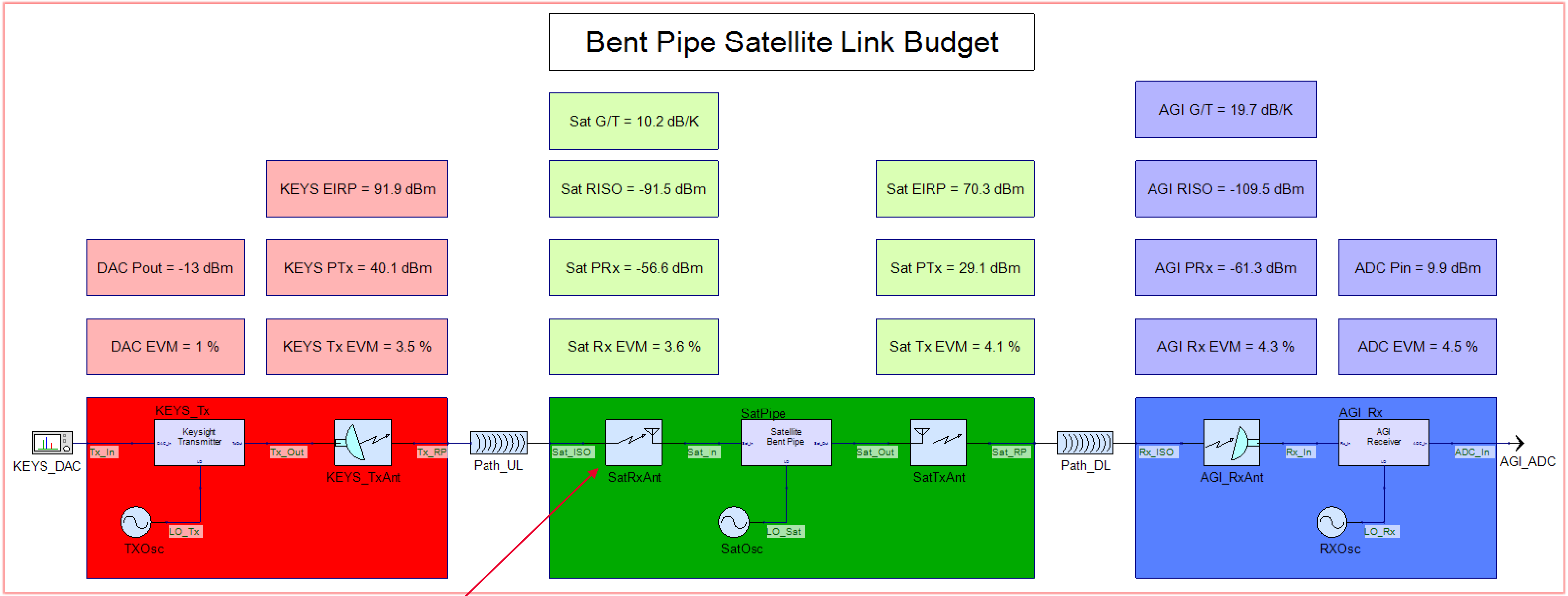
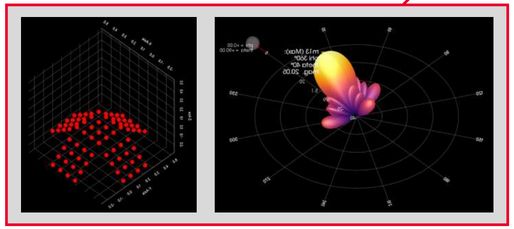
Link Analysis: Satellite – Bent Pipe Version 12/21/20

	A	B	C	D
1	**Bent Pipe Satellite Power and EVM Link Budget**			**SystemVue Nodes**
2				
3	DAC Frequency	2400.0	MHz	Tx_In
4	DAC Output Power	-13.0	dBm	
5	DAC SNR	40.0	dB	
6	**DAC Noise**	**-53.0**	**dBm**	
7	**DAC EVM**	**1.00**	**%**	Tx_Out
8	TX converter gain	53.0	dB	
9	**TX power**	**40.0**	**dBm**	
10	TX loss	1.0	dB	
11	TX antenna gain	51.8	dBi	
12	**TX EIRP**	**91.8**	**dBm**	Tx_RP
13	Tx Frequency	18545.0	MHz	
14	Bandwidth	10.0	MHz	
15	Slant distance (max)	1700.0	Km	
16	**Free Space Loss**	**182.4**	**dB**	
17				
18	**Sat Received Isotropic Power**	**-90.6**	**dBm**	Sat_ISO
19	**Sat Receiver Input Noise**	**-130.6**	**dBm**	
20	Sat RX antenna gain	35.8	dBi	
21	**Sat RX antenna G/T**	**7.8**	**dB**	
22	Sat RX loss	1.5	dB	
23	**Sat Noise**	**-96.3**	**dBm**	Sat_In
24	**Sat RX SNR**	**40.0**	**dB**	
25	**Sat EVM RX**	**1.00**	**%**	
26	Sat Bent Pipe conv gain	87.0	dB	
27	Sat Bent Pipe NF	2.5	dB	
28	Sat TX loss	1.0	dB	
29	Sat TX antenna gain	38.0	dBi	
30	**Sat EIRP**	**67.7**	**dBm**	Sat_RP
31	**Sat TX SNR**	**37.5**	**dB**	
32	**Sat EVM TX**	**1.33**	**%**	
33	Sat Tx Frequency	12200.0	MHz	
34	Slant distance (max)	1700.0	Km	
35	**Free Space Loss**	**178.8**	**dB**	
36				
37	**RX Isotropic Power**	**-111.1**	**dBm**	Rx_ISO
38	**RX Receiver Input Noise**	**-148.6**	**dBm**	
39	RX antenna gain	48.2	dBi	
40	RX antenna G/T	**38.2**	dB	
41	**RX Noise**	**-100.4**	**dBm**	Rx_In
42	**RX SNR**	**37.5**	**dB**	
43	**EVM RX**	**1.33**	**%**	
44	RX loss	1.0	dB	
45	RX conv gain	70.0	dB	
46	RX NF	2.4	dB	
47	**RX ADC Input Power**	**6.1**	**dBm**	ADC_In
48	**RX ADC Input Noise**	**-29.1**	**dBm**	
49	**RX ADC SNR**	**35.2**	**dB**	
50	**EVM ADC RX**	**1.75**	**%**	
51	ADC Frequency	2400.0	MHz	

- Home grown tools such as this one are:
  - Difficult to follow from a Management or Design perspective
  - Many engineering hours spent on customizing for each project, i.e., not easy to leverage for other projects
  - Prone to data entry and modelling mistakes
  - Can only handle anticipated impairments

PathWave System Design – Link Analysis





- Validated across Aerospace/Defense and wireless industries.
- Unique RF Modeling Excellence that provides faster operational confidence

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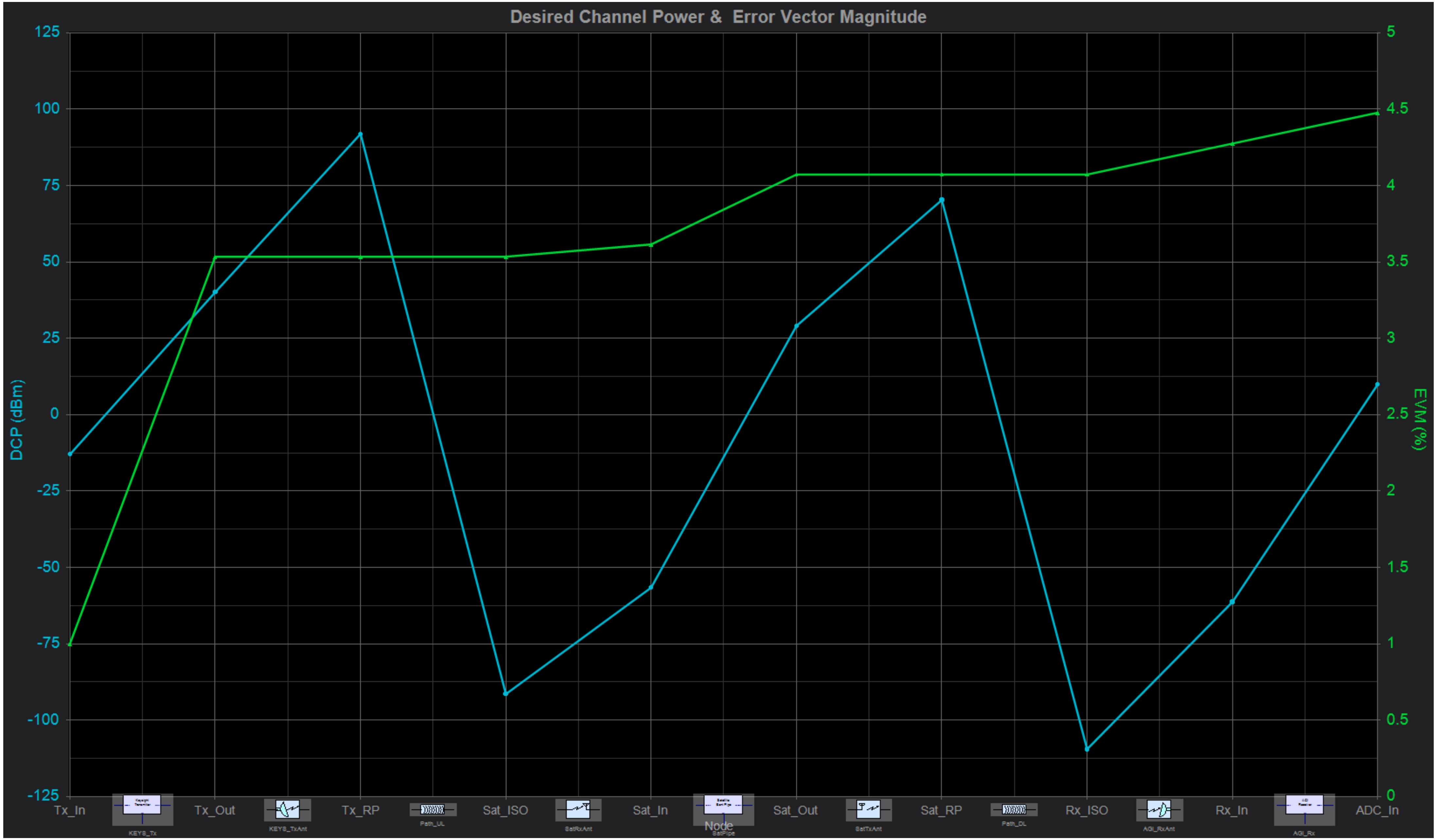
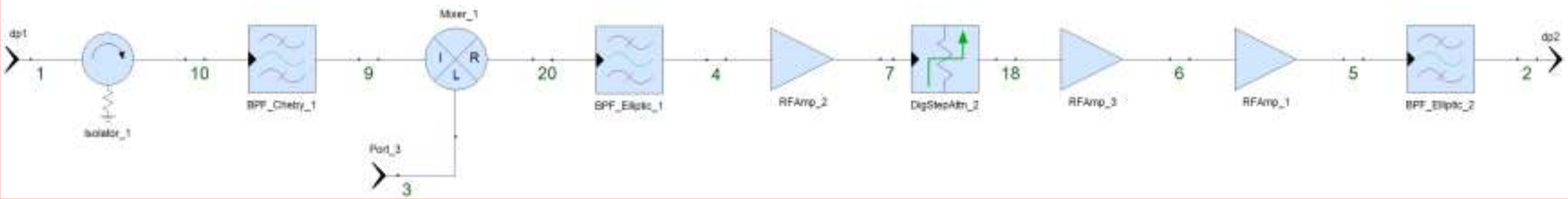


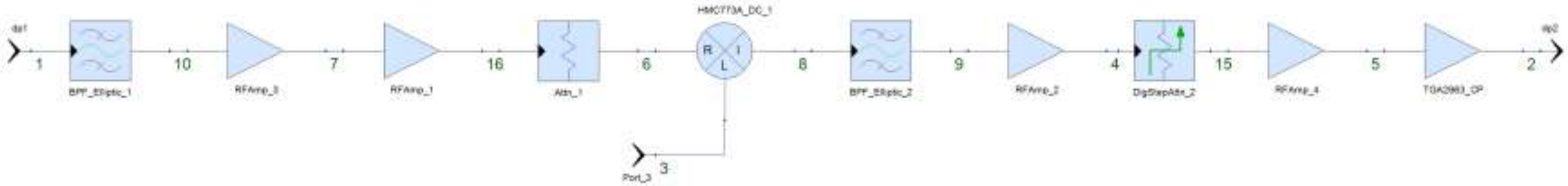
Desired Channel Power & Error Vector Magnitude
DCP (dBm)
EVM (%)
125
100
75
50
25
0
-25
-50
-75
-100
-125
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Tx_In
Tx_Out
Tx_RP
Sat_ISO
Sat_In
Sat_Out
Sat_RP
Rx_ISO
Rx_In
ADC_In
Node

RF Engineering Designs

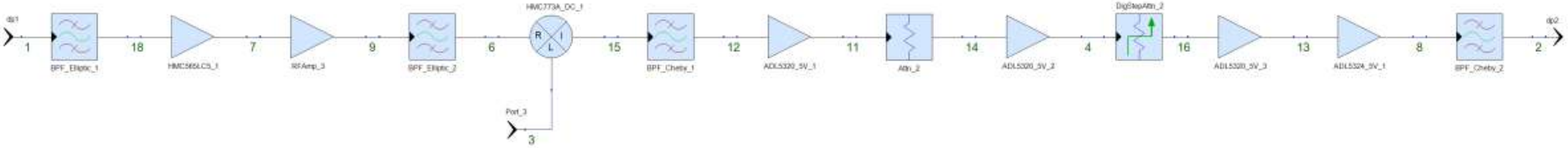
Ground Station RF Transmitter Design



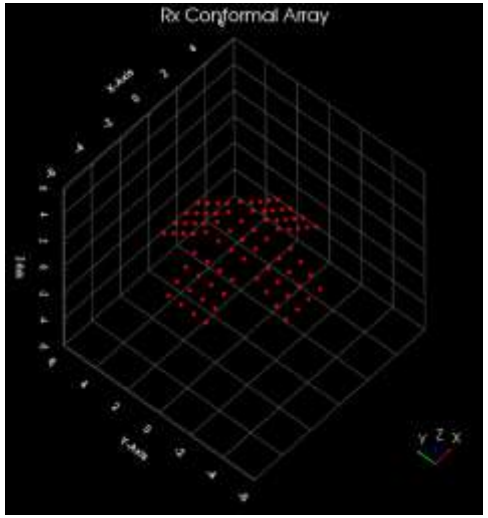
Bent Pipe Satellite RF Design

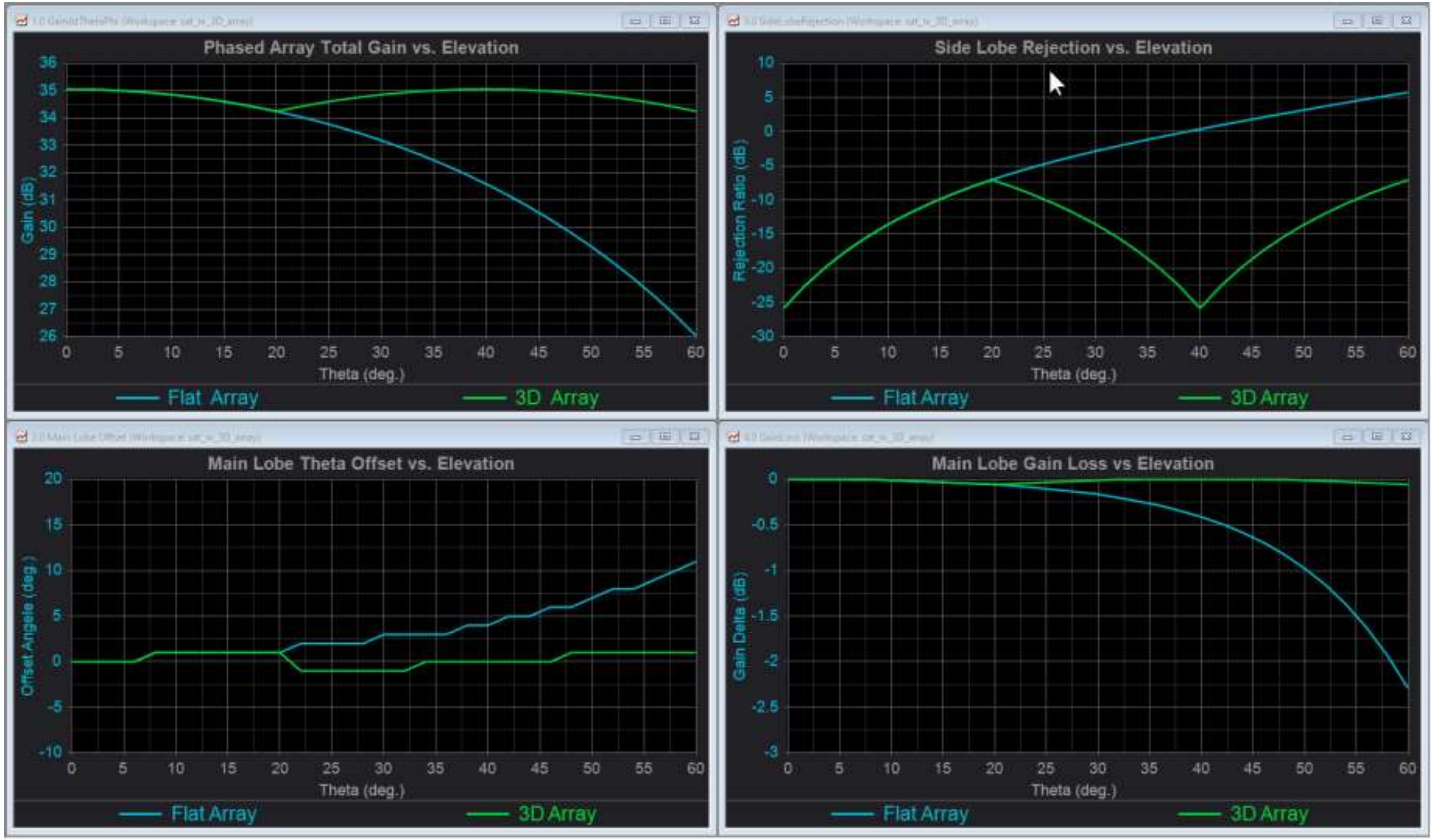


Ground Station RF Receiver Design

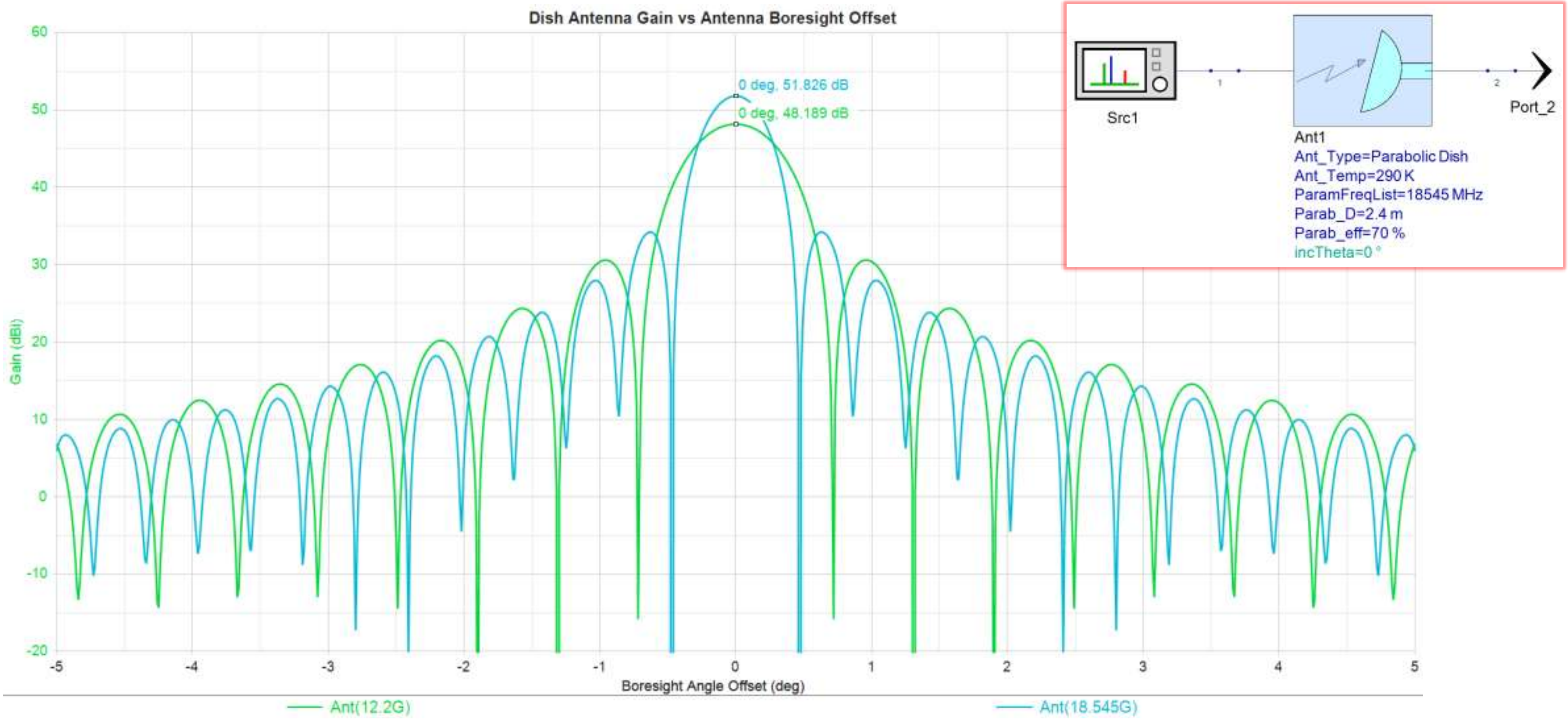


Phased Array Designs





Circular Dish Modeling



KEYSIGHT

* Spreadsheet table format results can be viewed and exported, see Appendix for an example.

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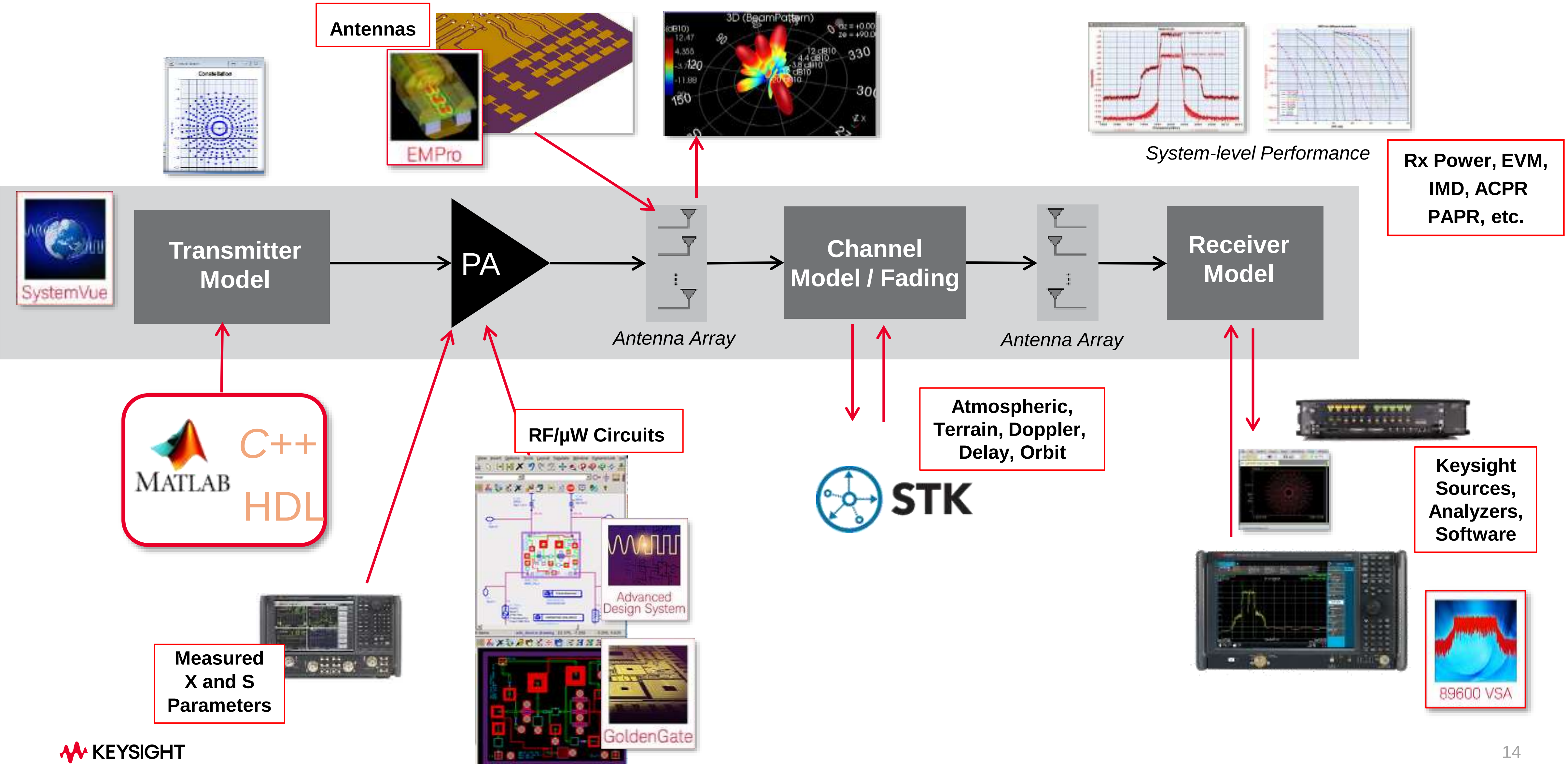
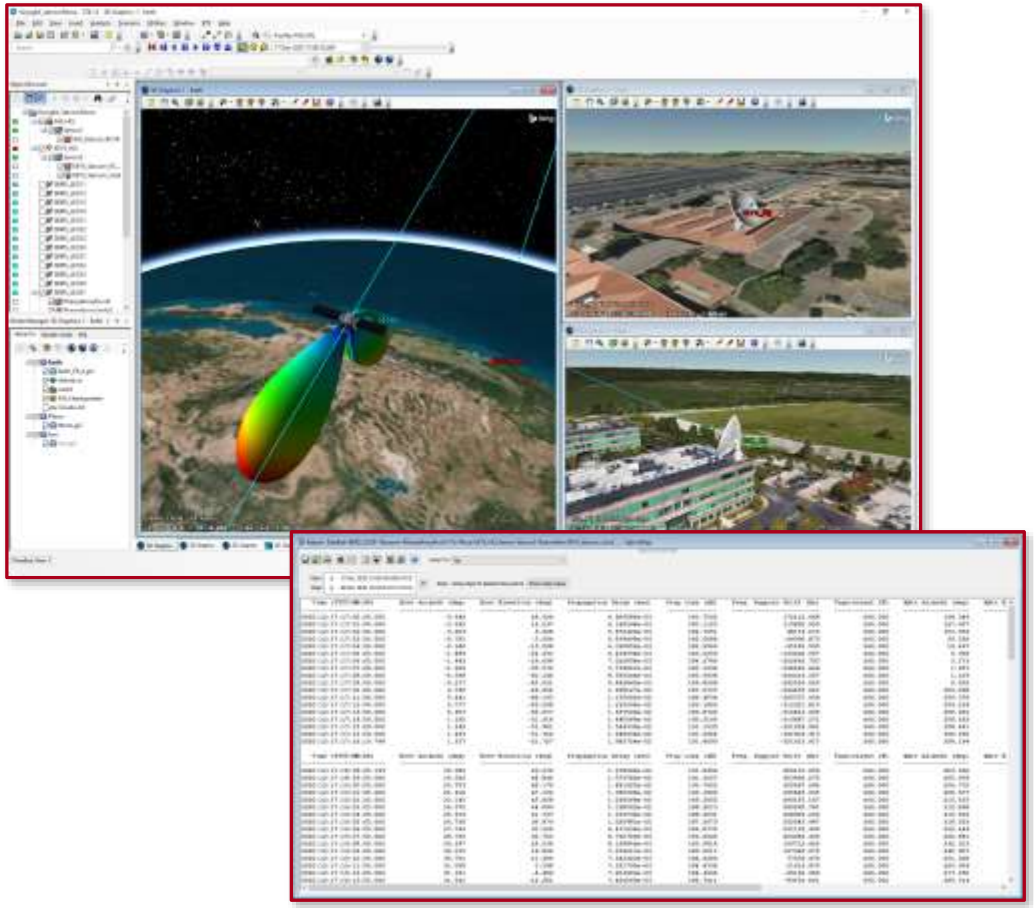
PathWave System Design: Your Digital Engineering Flow



STK & PathWave System Design Integration

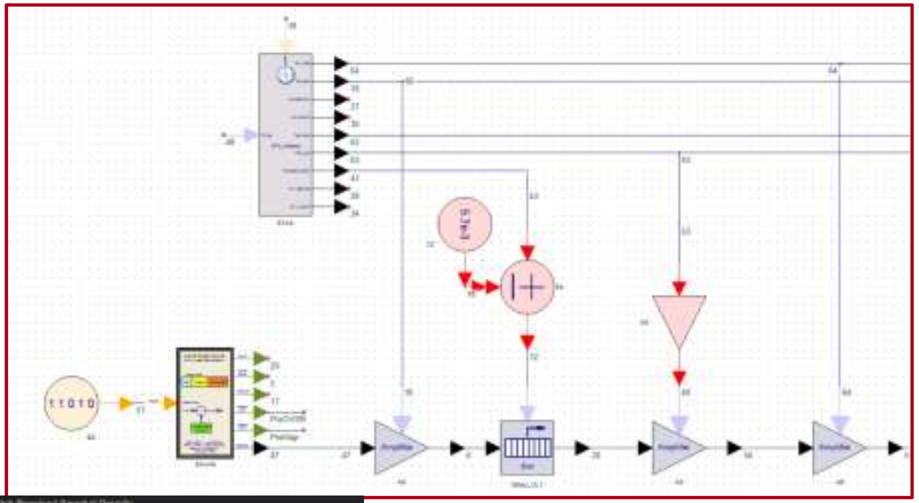
Reference Mission

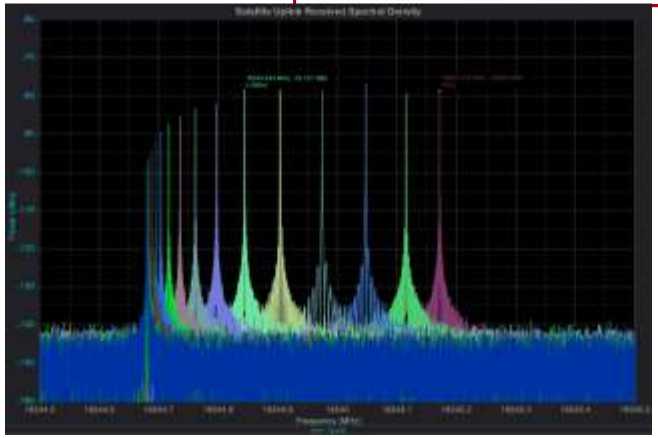
STK

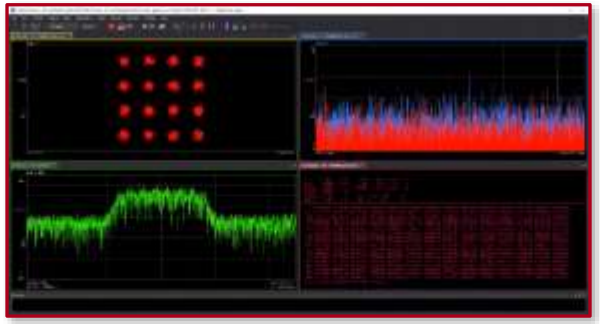


Design Reference Platform

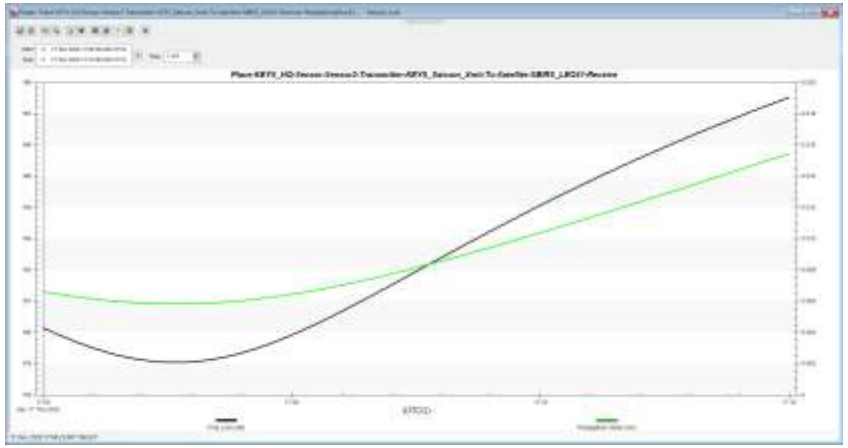
PATHWAVE System Design (SystemVue)

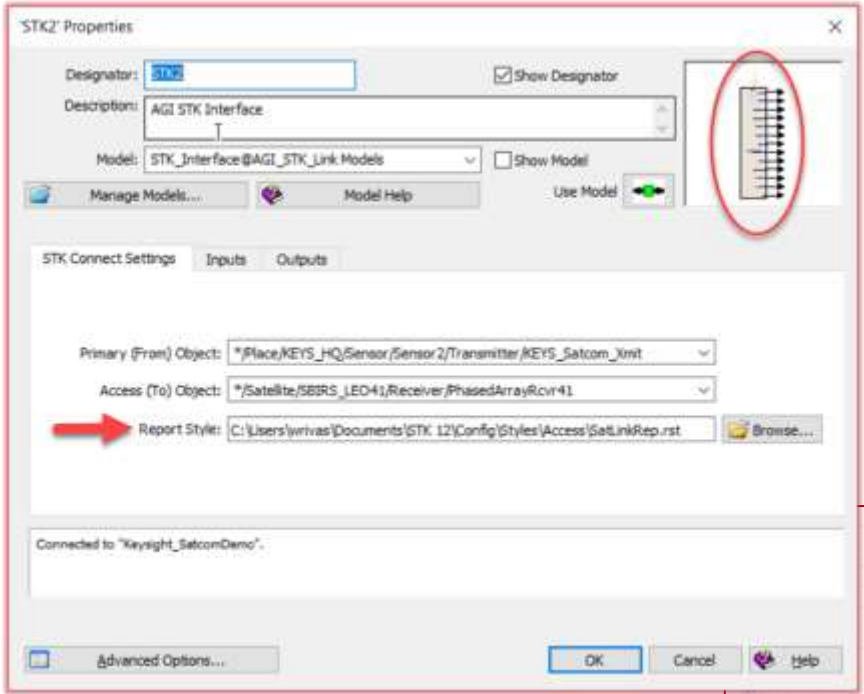


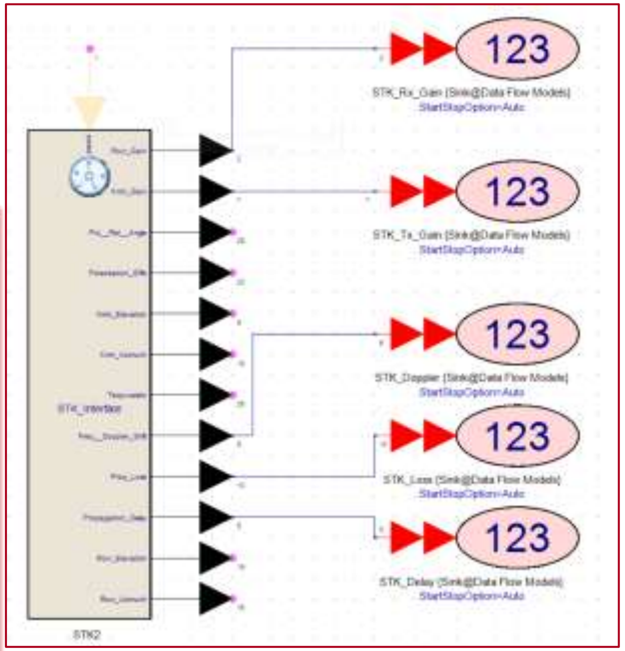


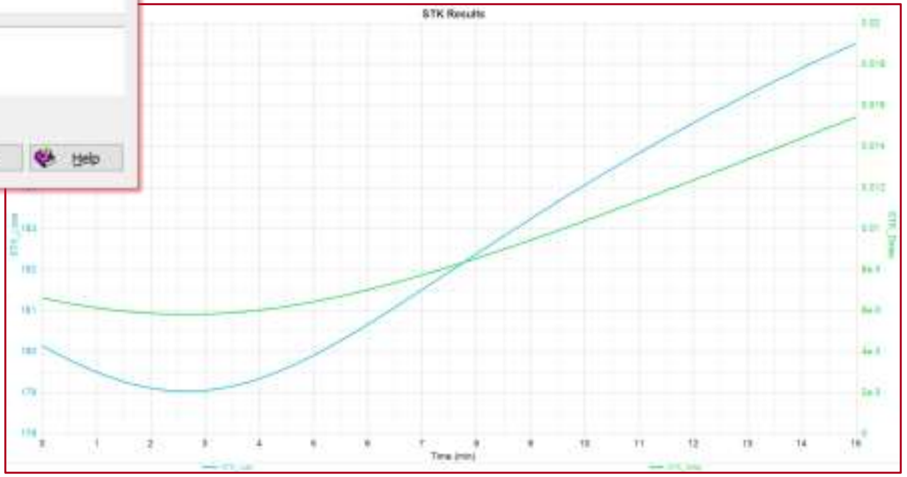


Connection to STK Scenario



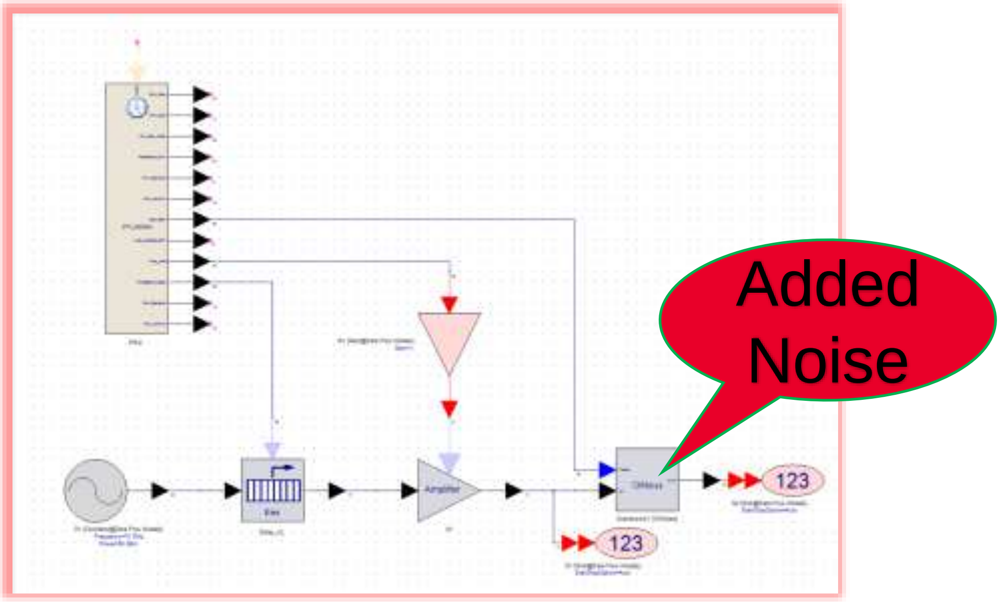


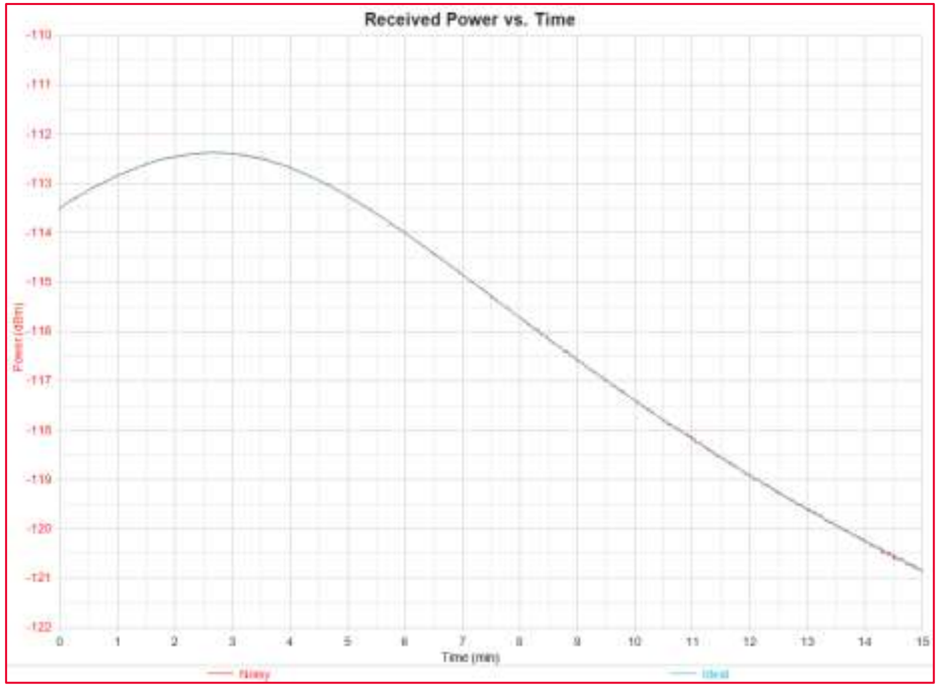




- The connection to STK is via the SystemVue STK_Interface component.
- SystemVue will recognize the STK scenario and objects in this scenario.

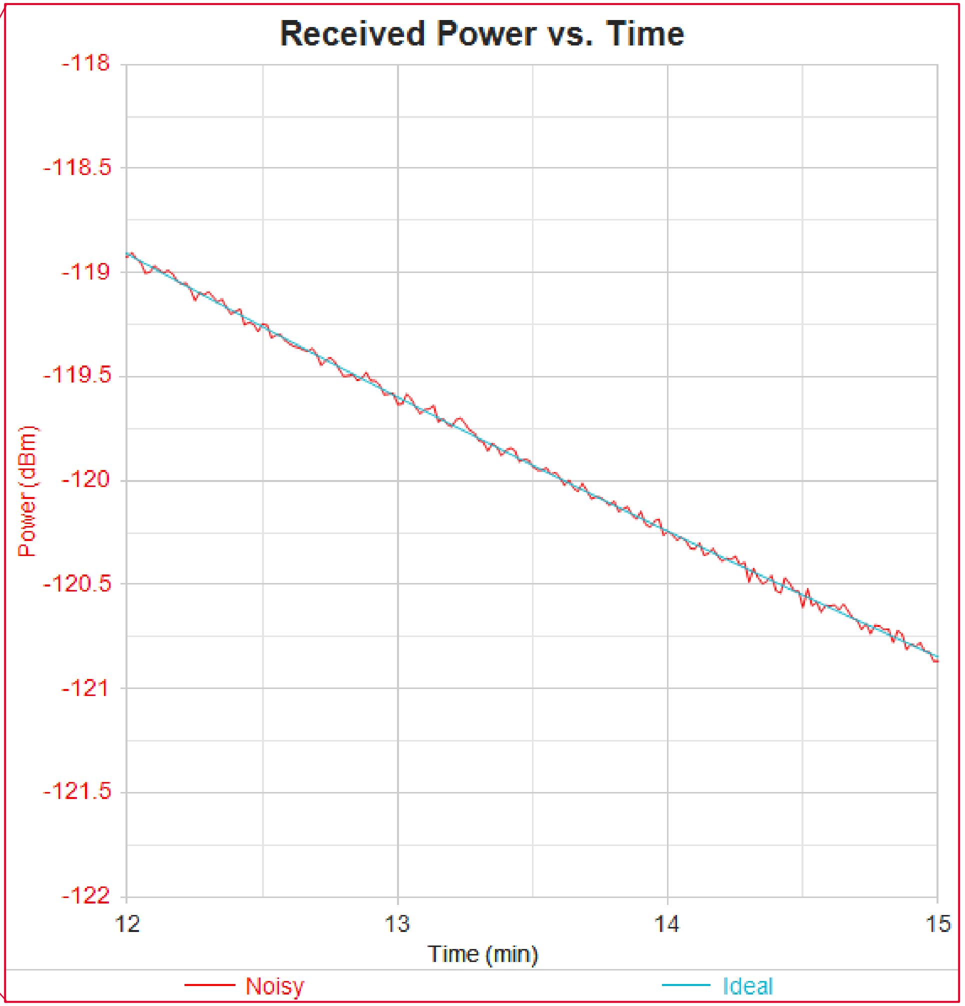
Utilizing STK Scenario Dynamic Channel in SystemVue



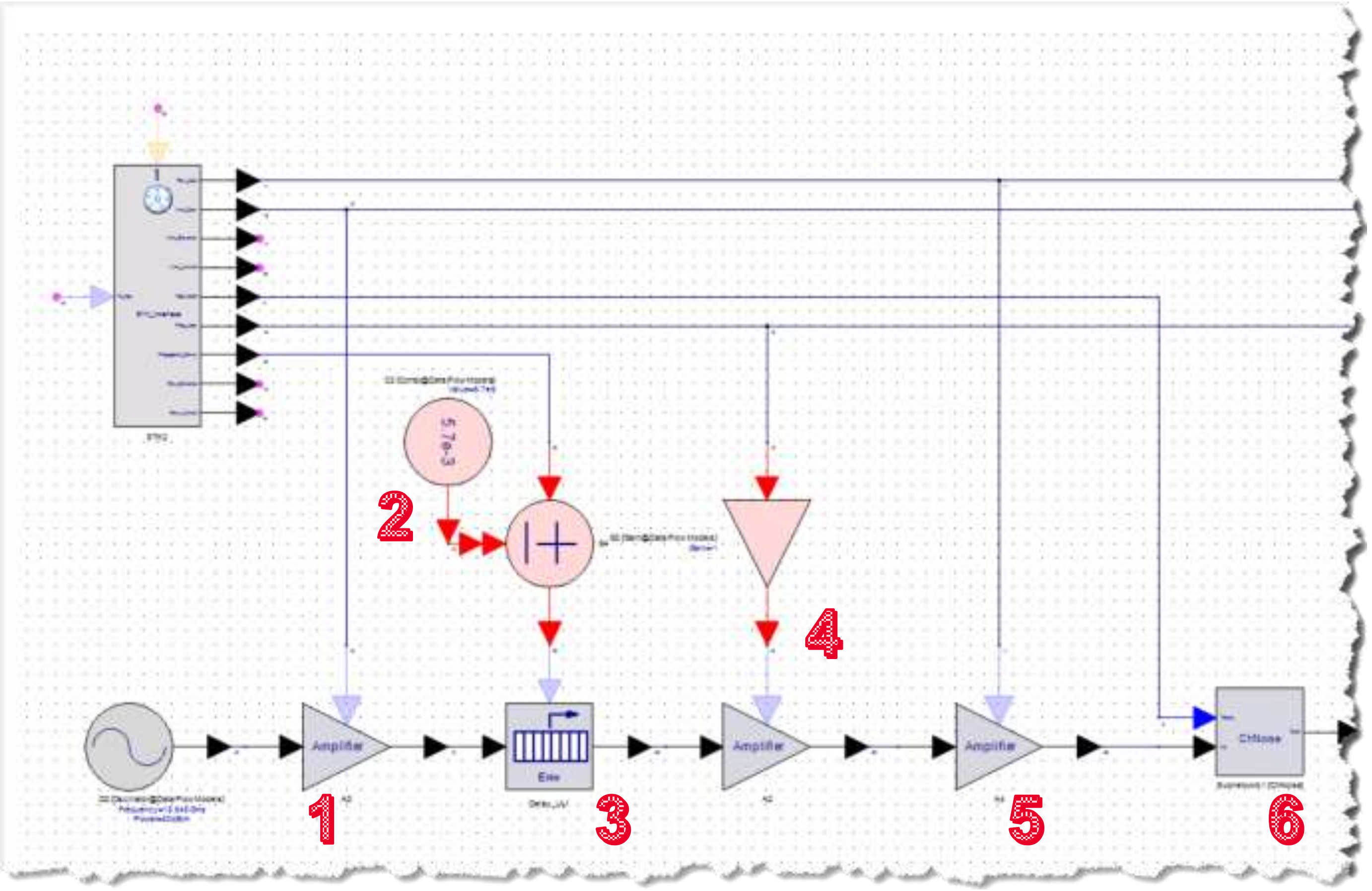


- The STK_Interface output can then be used in SystemVue to form a dynamic channel (i.e., one that includes Kinematics)
- This schematic utilizes the propagation delay, propagation loss and equivalent temperature to form a time variant noisy channel with fading and doppler effects
- In SystemVue the waveform is then perturb by this dynamic channel

Utilizing STK Scenario Dynamic Channel in SystemVue – cont.



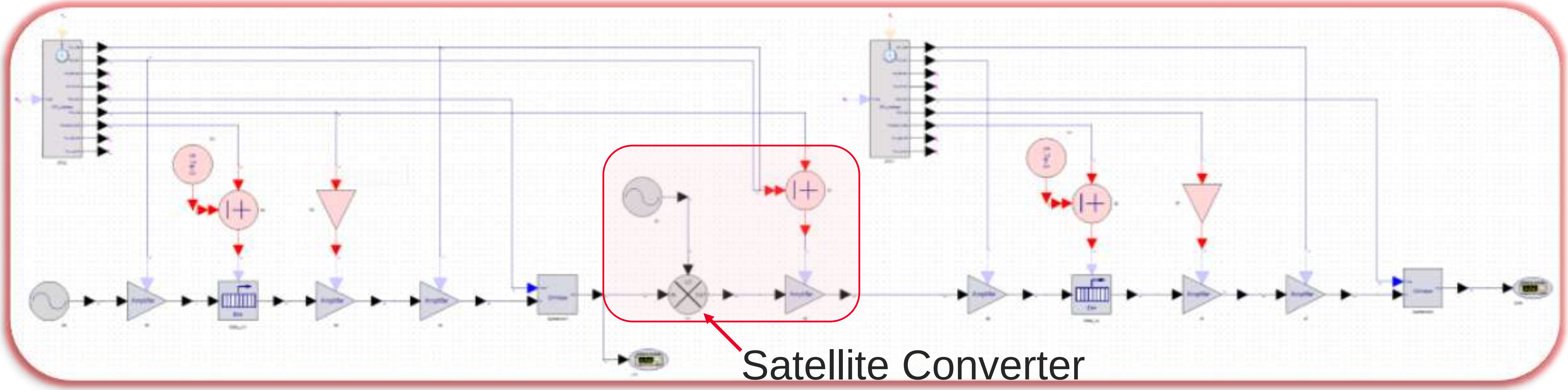
Channel Model



Time Varying Channel Setup

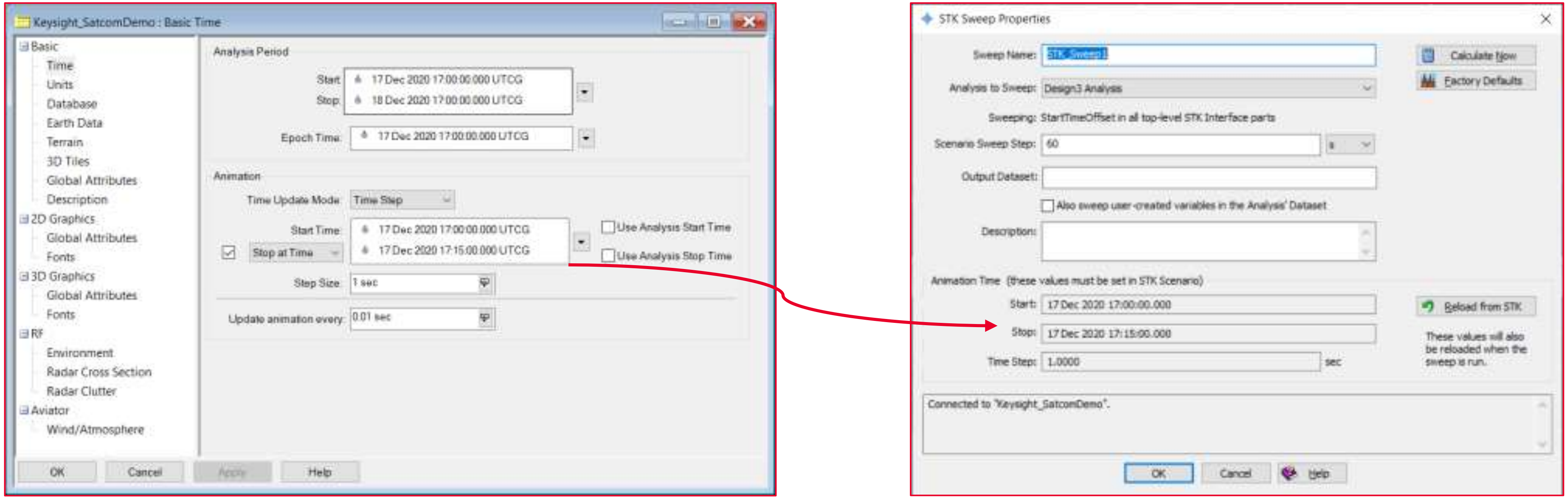
1. Transmit Antenna Gain
2. Delay Bias cancelation, helps speed simulation (optional)
3. Time varying delay
4. Propagation loss, multiply by -1 to convert STK value to negative dB value
5. Receive Antenna Gain
6. Temperature dependent noise source

Satellite Uplink and Downlink – First System Test



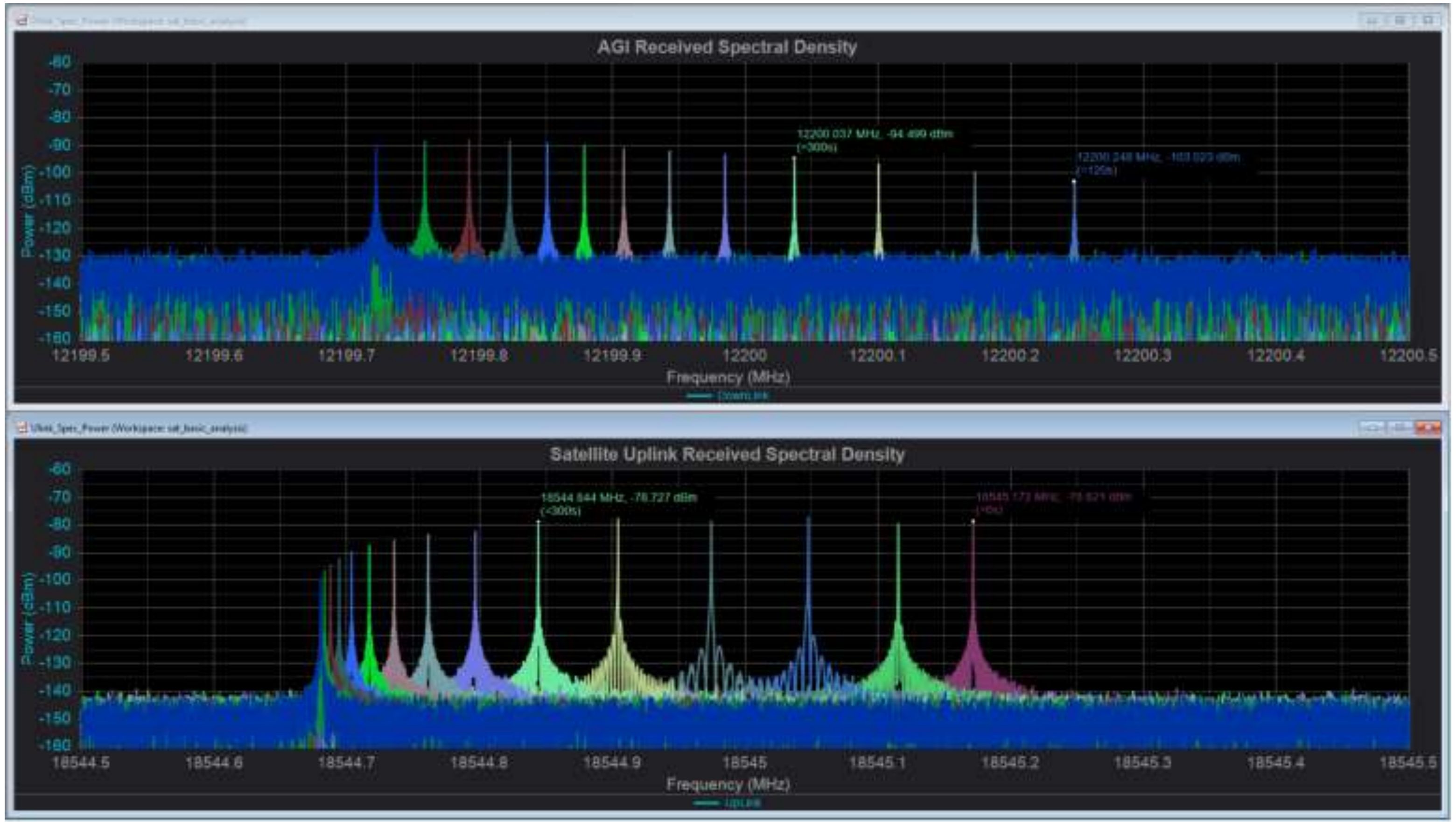
- Simulation can have more than one STK_Interface component
- In this example two dynamic channels are formed, uplink and downlink
- Initial assessment such as this one can be done to verify mission parameters are as expected and that a successful and accurate link is being modeled with high fidelity

SystemVue Scenario Time Sweep



- Scenario Time is controlled from STK scenario properties
- SystemVue controls Sampling Time and the Number of Samples used to characterize the waveforms.
- SystemVue has a dedicated STK Sweep controller.

Received Satellite & Ground Station Spectrum Over Time



- The orbital Kinematics effects are visible from the reduction in power (fading) over time and the frequency shift (doppler) effects noticeable on this plot
- Spectrum over time data that matches actual satellite flight performance

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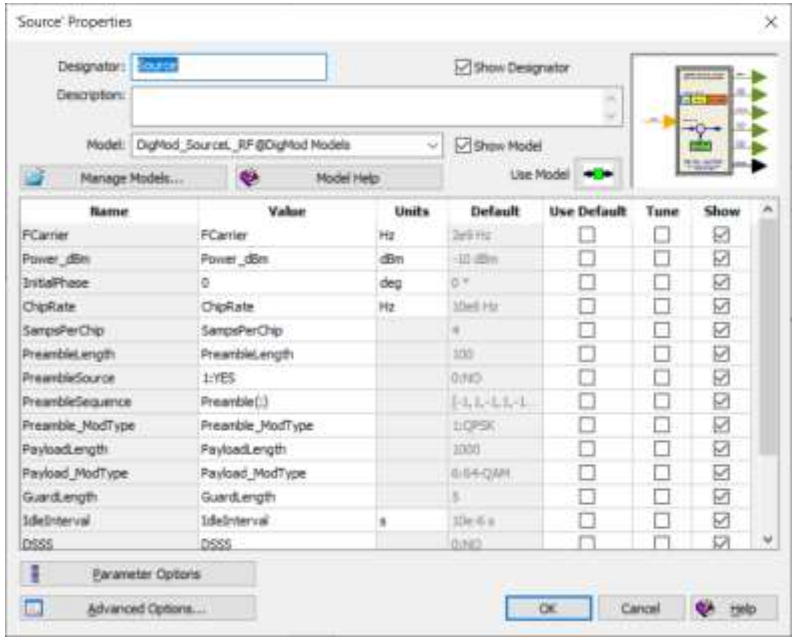
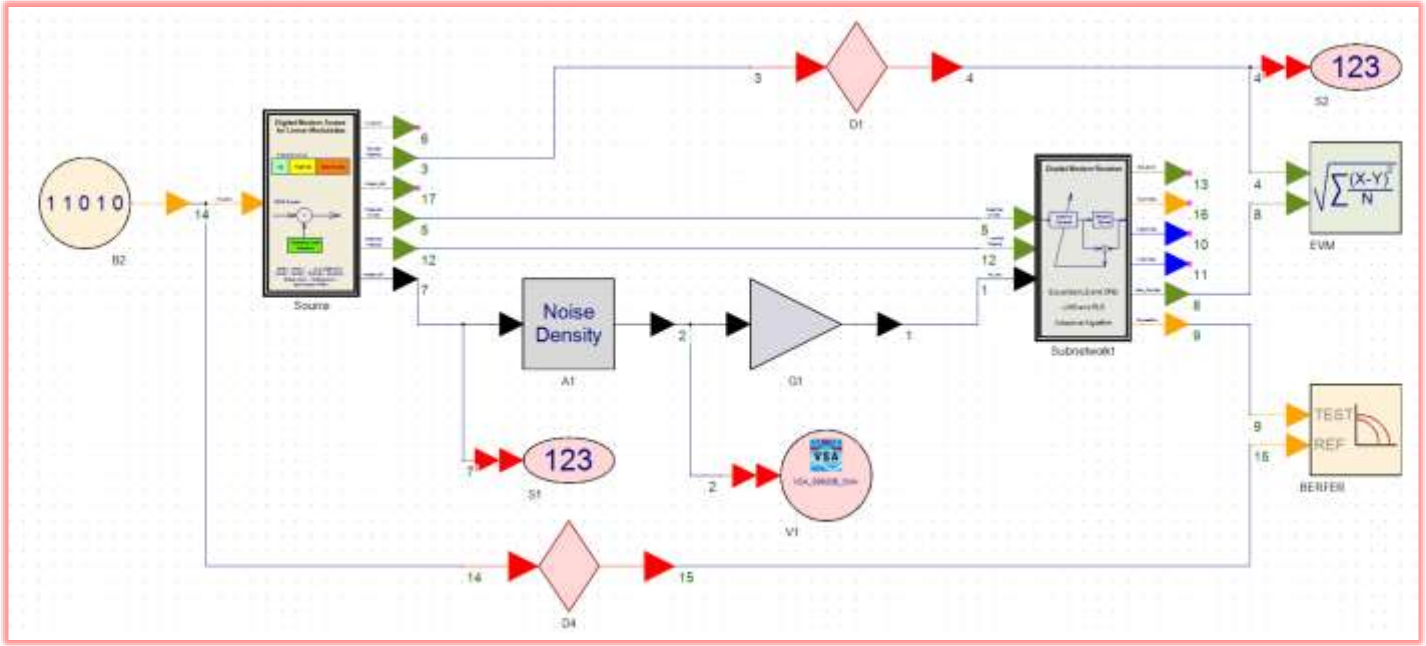
Flexible Modulated Waveforms Emulating Digital Modem

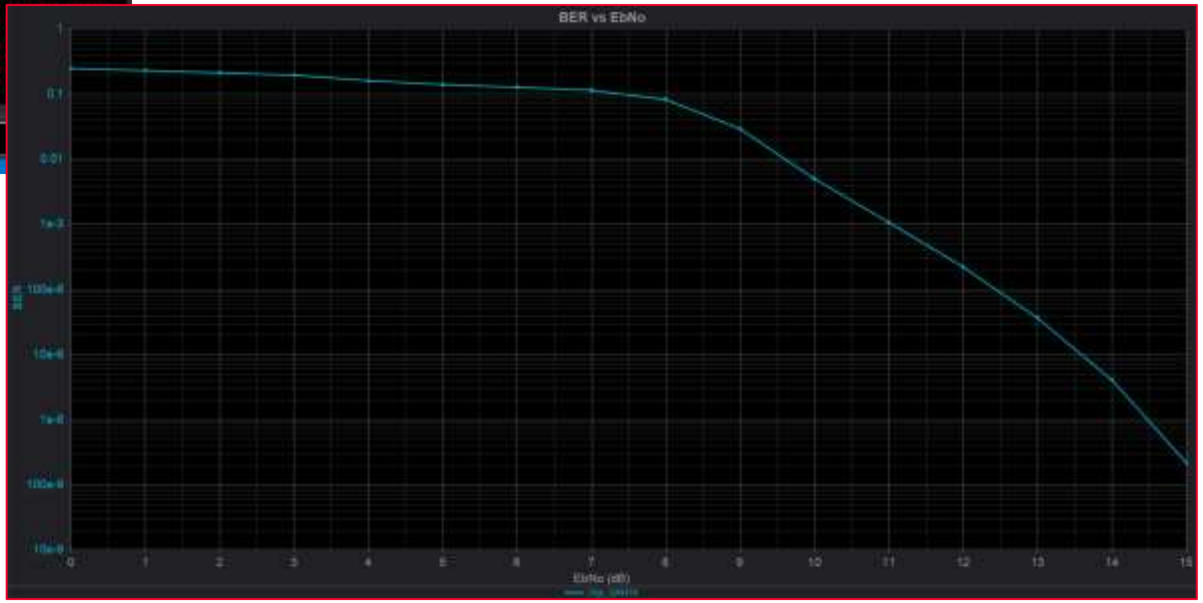




- The DigiMod Source and Receiver in SystemVue provide a flexible digital modem
- Frame structures with Idle Time, Preamble and Data Payload can be specified
- Large selection of digital modulations from BPSK, QAM (thru 4096 levels) and APSK are available for Preamble and Data Payload
- Addition of Noise Density component determines Signal to Noise Ratio (SNR)

Waveform Demodulation and BER

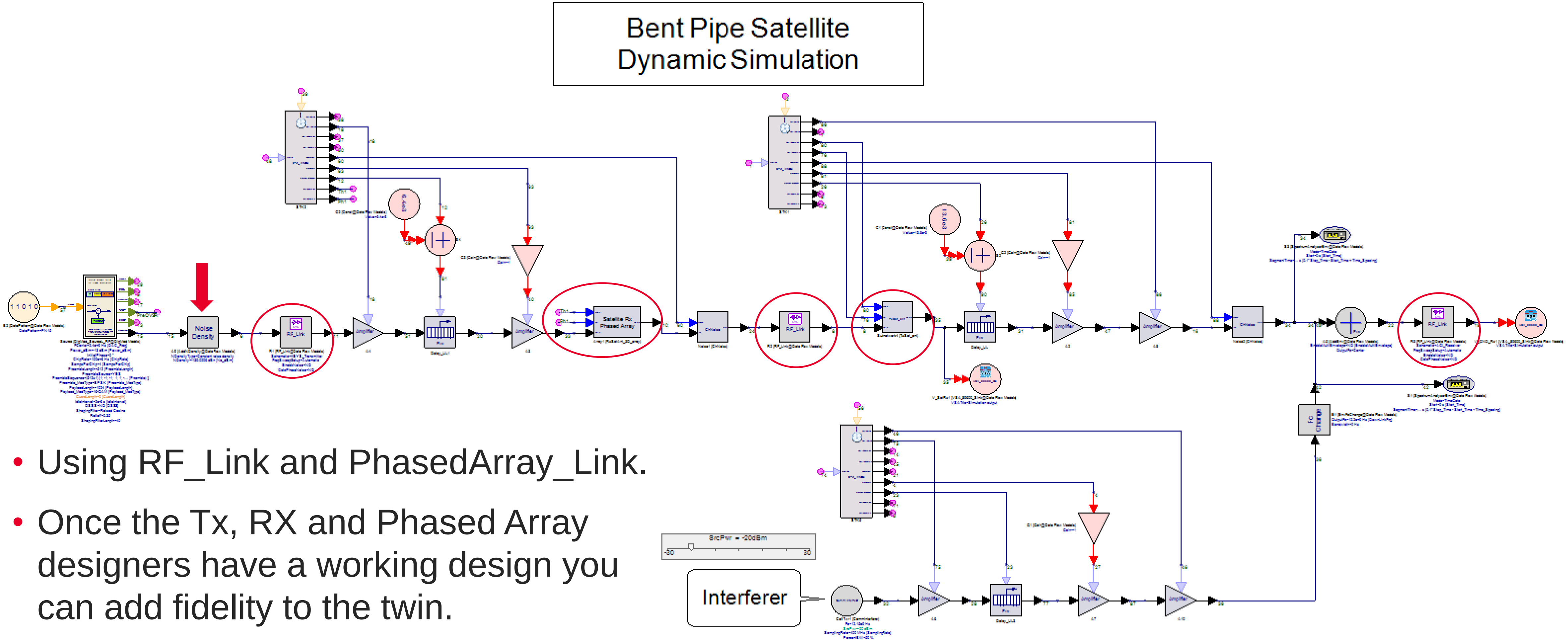
- VSA demodulates and analyzes our custom waveform
- Connectivity with the VSA SW allows the users to perform demodulation of practically any waveform
- The VSA sink can be connected to any node in your schematic



- Combining the BER sink with a SNR parameter sweep shows BER vs EbNo
- BER can be lengthy simulations
- Doing BER at this stage before kinematics and impairments are added, provides insight that helps with complete system simulation

Complete System Simulation

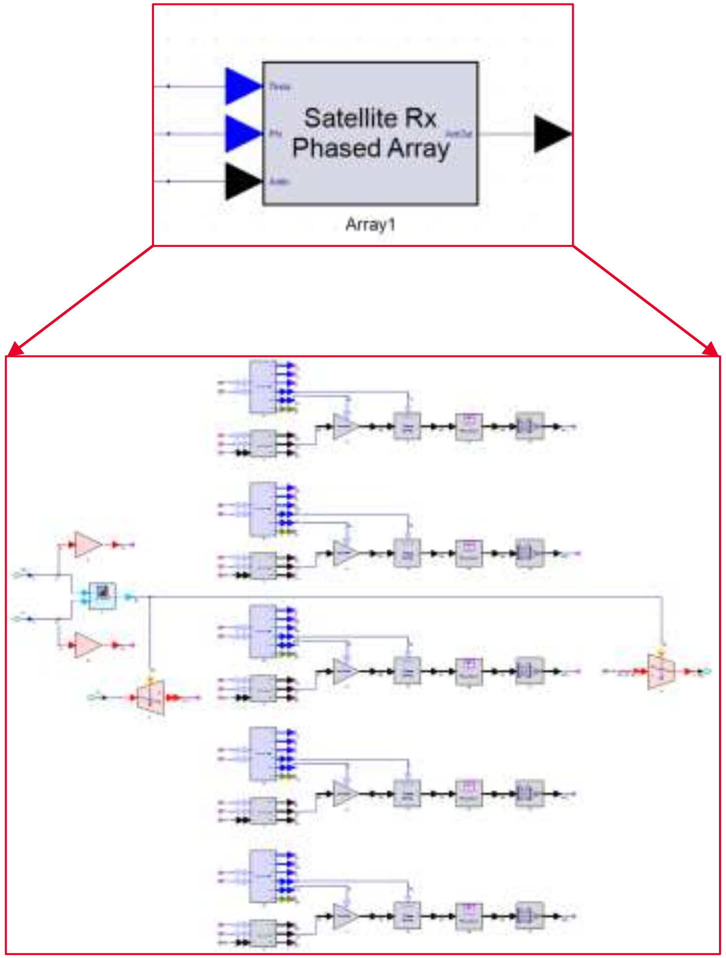
- Including RF Tx, RX, Bent pipe RF and Phased Array Designs

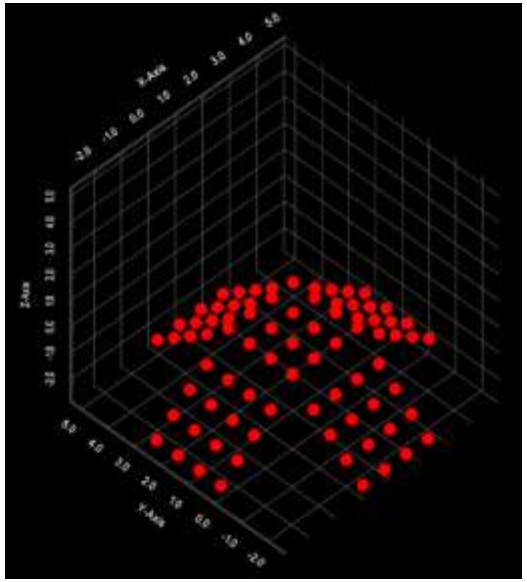


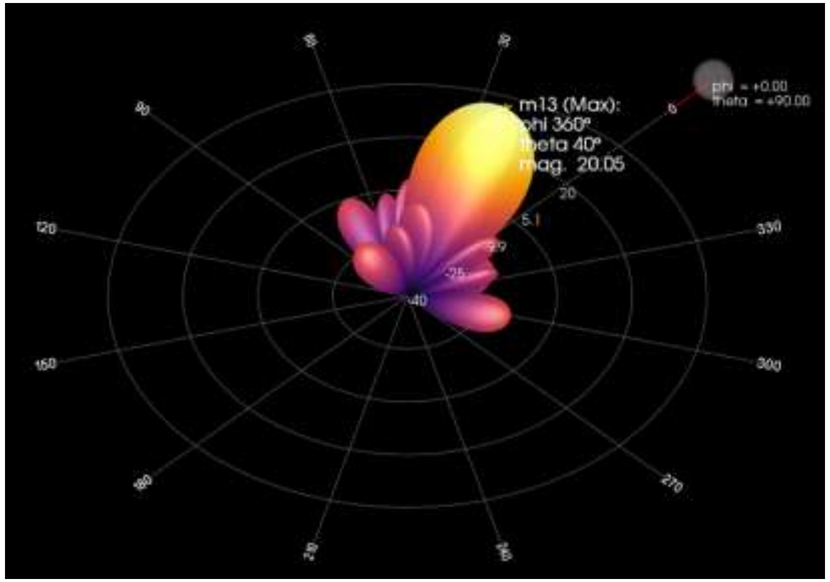
- Using RF_Link and PhasedArray_Link.
- Once the Tx, RX and Phased Array designers have a working design you can add fidelity to the twin.

You can also add other twins (evil twin?).
In STK added a cell tower near Ekton Mall

Detailed Phased Array Designs using COTS Parts



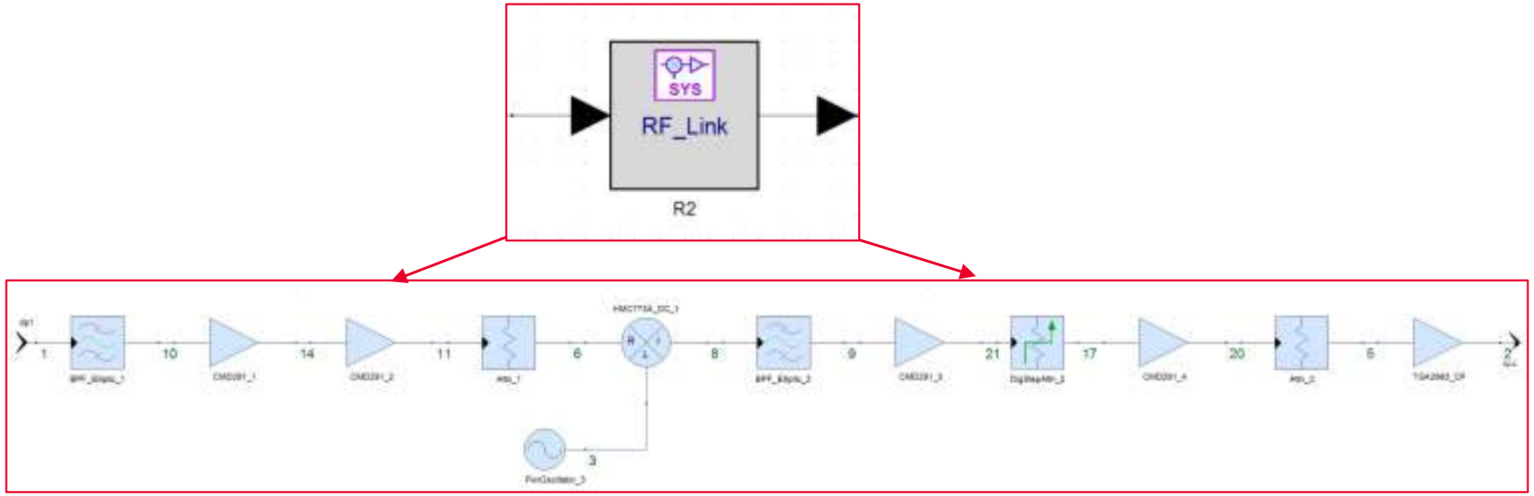




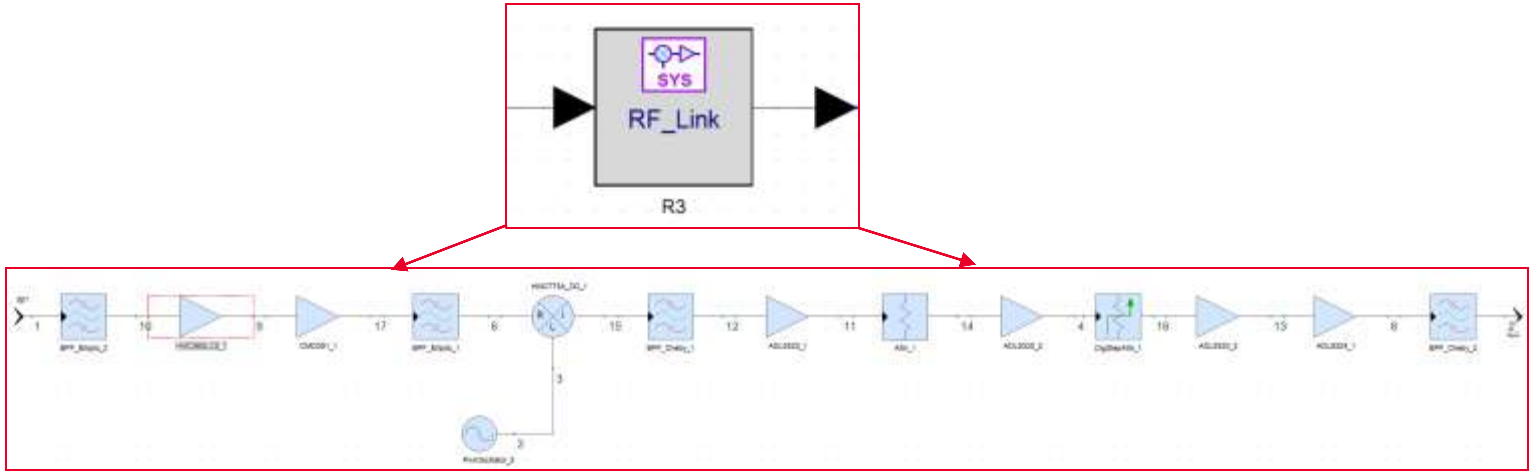
- Satellite has two Phased Arrays, Tx & Rx.
- This is the Rx Phased Array
- 3D/Conformal Array with RF COTS parts

Detailed RF Designs using COTS Parts

- RF Circuits are a mixture of COTS parts and basic SystemVue parts
- The point here is you can start evaluation even if you have not identified all the actual parts needed

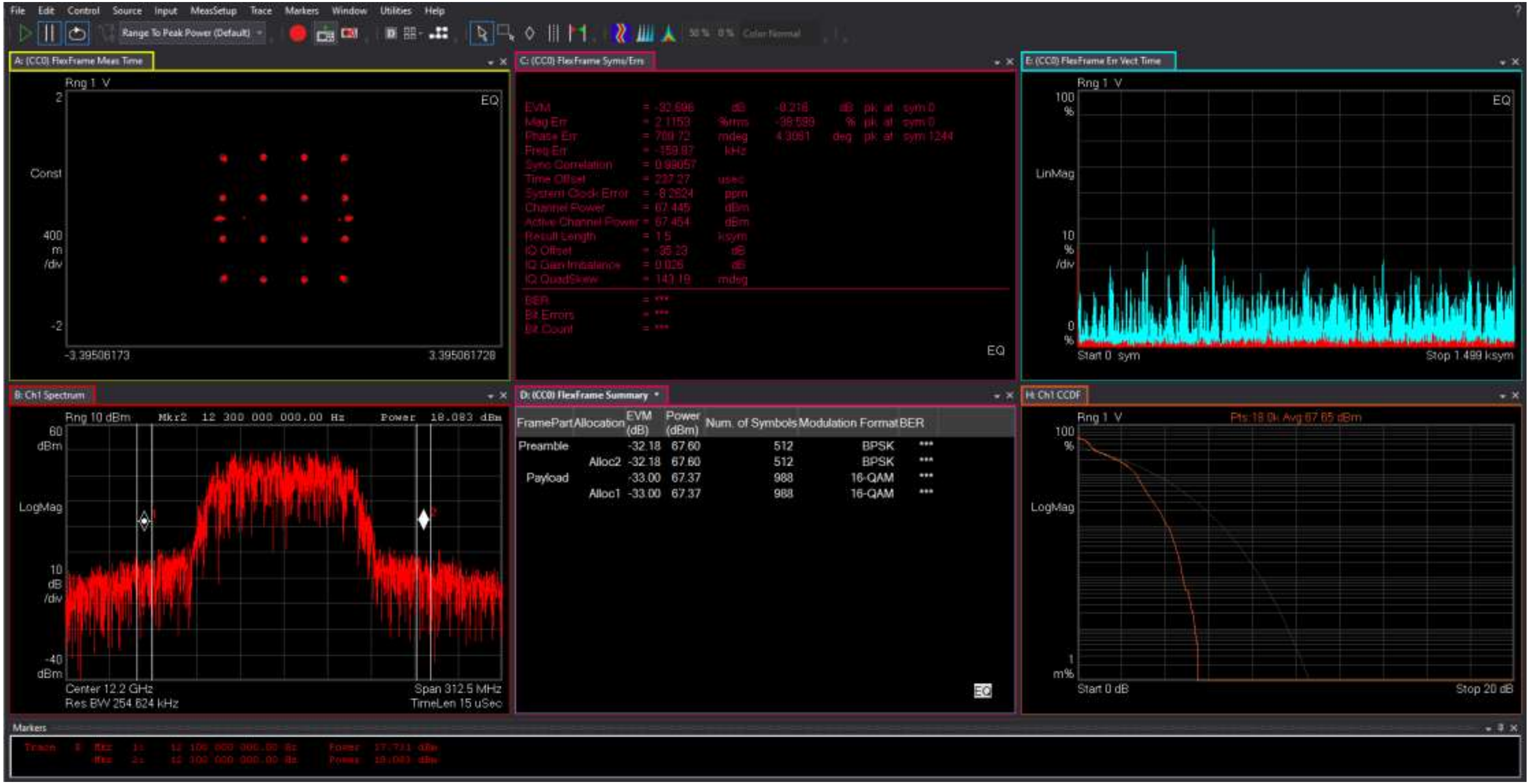


Satellite Bent Pipe RF Transceiver



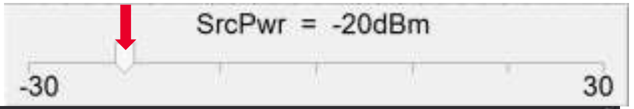
Ground Station RF Receiver

Results – Satellite Transmitter

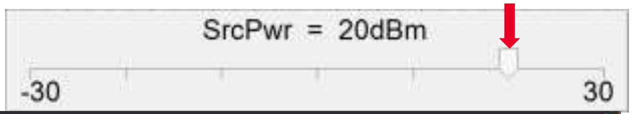


Communications Transmitter Location

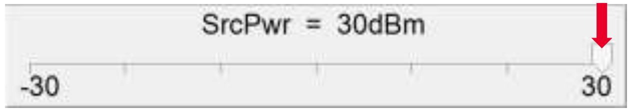
Results - Interferer Level Sensitive 1



Results - Interferer Level Sensitive 2



Results - Interferer Level Sensitive 3



Thank You!

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Appendix A

PathWave System Design - Detailed Analysis

NodeNames	Parts	CF (MHz)	DCP (dBm)	GAIN (dB10)	EVM (%)
Tx_In	KEYS_DAC	2400	-13	0	1
KEYS_Tx!10	KEYS_Tx\Isolator_1	2400	-13.522	-0.522	1
KEYS_Tx!9	KEYS_Tx\BPF_Cheby_1	2400	-13.93	-0.408	1
KEYS_Tx!20	KEYS_Tx\Mixer_1	18545	-22.378	-8.448	1.414
KEYS_Tx!4	KEYS_Tx\BPF_Elliptic_1	18545	-23.468	-1.09	1.414
KEYS_Tx!7	KEYS_Tx\RFAmp_2	18545	-0.566	22.902	1.415
KEYS_Tx!18	KEYS_Tx\DigStepAttn_2	18545	-11.566	-11	1.415
KEYS_Tx!11	KEYS_Tx\RFAmp_3	18545	11.275	22.841	2.276
KEYS_Tx!5	KEYS_Tx\RFAmp_1	18545	41.187	29.912	3.534
Tx_Out	KEYS_Tx\BPF_Elliptic_2	18545	40.097	-1.09	3.534
Tx_RP	KEYS_TxAnt\RFAmp_1	18545	91.924	51.826	3.534
Path_UL!4	Path_UL\Attn_1	18545	-91.456	-183.38	3.534
Path_UL!3	Path_UL\Attn_2	18545	-91.456	0	3.534
Sat_ISO	Path_UL\RFAmp	18545	-91.456	0	3.534
SatRxAnt!8	SatRxAnt\RFAmp_1	18545	-56.597	34.859	3.534
SatRxAnt!13	SatRxAnt\Split2_1	18545	-59.617	-3.02	3.615
Sat_In	SatRxAnt\RFAmp_3	18545	-56.605	3.012	3.615
SatPipe!10	SatPipe\BPF_Elliptic_1	18545	-57.695	-1.09	3.637
SatPipe!7	SatPipe\RFAmp_3	18545	-34.789	22.907	3.853
SatPipe!16	SatPipe\RFAmp_1	18545	-11.885	22.904	3.854
SatPipe!6	SatPipe\Attn_1	18545	-14.192	-2.307	3.854
SatPipe!8	SatPipe\HMC773A_DC_1	12200	-23.644	-9.452	3.858
SatPipe!9	SatPipe\BPF_Elliptic_2	12200	-24.736	-1.092	3.858
SatPipe!4	SatPipe\RFAmp_2	12200	-6.539	18.197	3.858
SatPipe!15	SatPipe\DigStepAttn_2	12200	-13.039	-6.5	3.858
SatPipe!12	SatPipe\RFAmp_4	12200	5.139	18.178	3.883
Sat_Out	SatPipe\TGA2963_CP	12200	29.076	23.937	4.072
Sat_RP	SatTxAnt\RFAmp_1	12200	70.264	41.187	4.072

Path_DL!4	Path_DL\Attn_1	12200	-109.479	-179.743	4.072
Path_DL!3	Path_DL\Attn_2	12200	-109.479	0	4.072
Rx_ISO	Path_DL\RFAmp	12200	-109.479	0	4.072
AGI_RxAnt!8	AGI_RxAnt\RFAmp_1	12200	-61.29	48.189	4.072
AGI_RxAnt!13	AGI_RxAnt\Split2_1	12200	-64.31	-3.02	4.275
Rx_In	AGI_RxAnt\RFAmp_3	12200	-61.306	3.004	4.275
AGI_Rx!10	AGI_Rx\BPF_Elliptic_2	12200	-62.144	-0.838	4.314
AGI_Rx!7	AGI_Rx\HMC565LC5_Sys...	12200	-41.751	20.393	4.495
AGI_Rx!5	AGI_Rx\RFAmp_3	12200	-23.606	18.145	4.502
AGI_Rx!6	AGI_Rx\BPF_Elliptic_1	12200	-23.462	0.144	4.502
AGI_Rx!15	AGI_Rx\HMC773A_DC_1	2400	-33.209	-9.746	4.525
AGI_Rx!12	AGI_Rx\BPF_Cheby_1	2400	-33.828	-0.619	4.527
AGI_Rx!11	AGI_Rx\ADL5320_5V_Sys...	2400	-19.39	14.438	4.509
AGI_Rx!14	AGI_Rx\Attn_2	2400	-22.333	-2.943	4.508
AGI_Rx!4	AGI_Rx\ADL5320_5V_Sys...	2400	-8.897	13.436	4.504
AGI_Rx!16	AGI_Rx\DigStepAttn_2	2400	-19.73	-10.833	4.494
AGI_Rx!13	AGI_Rx\ADL5320_5V_Sys...	2400	-6.609	13.121	4.468
AGI_Rx!8	AGI_Rx\ADL5324_5V_Sys...	2400	10.343	16.952	4.478
ADC_In	AGI_Rx\BPF_Cheby_2	2400	9.935	-0.408	4.477