



Accounting for Antenna and MIMO Channel Effects Using Agilent SystemVue

Application Note

Introduction

The Multiple-Input-Multiple-Output (MIMO) technique was introduced to address the growing demand for higher data-rate applications in communication standards like 3G, WLAN, WiMAX™. In MIMO systems, both the radio channel propagation conditions and antenna characteristics influence the end user's quality-of-service (QoS). MIMO channel models, with the ability to simulate the multipath fading that incorporates antenna patterns, are therefore important. Agilent SystemVue offers a MIMO Channel Builder that provides just such a capability. This application note discusses two MIMO channel models, namely geometry-based and correlation-based models, which were realized using Agilent's W1715 MIMO Channel Builder, to show how antenna effects and channel characteristics are coupled in the channel models. It will also present some MIMO Channel Builder applications as a means of describing how to use the models step-by-step and apply them in system simulation and measurements.

MIMO Channel Modeling Approaches

Agilent SystemVue MIMO Channel Builder consists of a geometry-based WINNER II MIMO channel model that is standards compliant, and a correlation-based MIMO channel model that is flexible enough for user customization.



Approach 1

Geometry-based Stochastic Channel Modeling

The WINNER II channel model is a geometry-based stochastic model. [1] It also called a double directional channel model. The model does not explicitly specify the locations of the scatters, but rather the directions of the rays, like the well-known Spatial Channel Model (SCM). [2] Both IMT-advances and consequently, LTE-Advanced, apply this kind of model as the MIMO channel model for performance tests. Geometry-based modeling of the radio channel enables separation of propagation parameters and antennas. The time variant impulse response matrix of the UxS MIMO channel is given by

$$\mathbf{H}(t; \tau) = \sum_{n=1}^N \mathbf{H}_n(t; \tau)$$

where t is time, τ is delay, N is the number of paths, and n is path index. The impulse response matrix is composed of the antenna array response matrices F_{tx} and F_{rx} for the transmitter (Tx) and the receiver (Rx) respectively. The channel from the Tx antenna element s to the Rx element u , for cluster n , is expressed as

$$H_{u,s,n}(t; \tau) = \sum_{m=1}^M \begin{bmatrix} F_{rx,u,V}(\varphi_{n,m}) \\ F_{rx,u,H}(\varphi_{n,m}) \end{bmatrix}^T \begin{bmatrix} \alpha_{n,m,VV} & \alpha_{n,m,VH} \\ \alpha_{n,m,HV} & \alpha_{n,m,HH} \end{bmatrix} \begin{bmatrix} F_{tx,s,V}(\phi_{n,m}) \\ F_{tx,s,H}(\phi_{n,m}) \end{bmatrix} \\ \times \exp(j2\pi\lambda_0^{-1}(\bar{\varphi}_{n,m} \cdot \bar{r}_{rx,u})) \exp(j2\pi\lambda_0^{-1}(\bar{\varphi}_{n,m} \cdot \bar{r}_{tx,s})) \\ \times \exp(j2\pi\nu_{n,m}t) \delta(\tau - \tau_{n,m})$$

Where:

- $F_{rx,u,V}$ and $F_{rx,u,H}$ are the antenna element u field patterns for vertical and horizontal polarizations, respectively;
- $\alpha_{n,m,VV}$ and $\alpha_{n,m,VH}$ are the complex gains of vertical-to-vertical and horizontal-to-vertical polarizations of ray n,m , respectively;
- λ_0 is the wavelength of the carrier frequency;
- $\bar{\varphi}_{n,m}$ is the AoD unit vector;
- $\bar{\varphi}_{n,m}$ is the AoA unit vector;
- $\bar{r}_{tx,s}$ and $\bar{r}_{rx,u}$ are the location vectors of element s and u , respectively; and
- $\nu_{n,m}$ is the Doppler frequency component of ray n,m .

WINNER II inherits the 'drop' concept from the SCM. During a drop, the channel undergoes fast fading according to the motion of the user equipment (UE). However, parameters in the channel model, such as number of paths, number of sub-paths, mean angular spread at the base station (BS) and mobile station (MS), AoA/AoD distributions, delay spread, path loss, and shadowing are kept constant. Each drop reflects a short snapshot of the fading channel. Setting a longer drop time can lead to an intrinsically smooth channel model. Two consecutive drops are independent, which makes the channel model discontinuous. The system performance is usually evaluated over multiple drops. The simulation results for different drops may be quite different. In order to get a stable link-level simulation result, it is better to average the simulated results over tens of drops, with each drop lasting tens of channel-coherent time. This simulation condition can be guaranteed by setting the proper simulation time and drop interval.

WINNER II models cover a wide scope of propagation scenarios and environments. They are antenna independent and well suited for evaluating transceiver techniques (e.g., adaptive radio links, equalization techniques, coding, and modulation). [1] Additionally, WINNER II models provide both large-scale and small-scale fading parameters, which are useful for evaluating the performance of multiple cells and users. The models also provide a useful tool for link budget calculation and network planning.

Approach 2

Correlation- based Channel Modeling

Correlation-based modeling is another approach to spatial MIMO channel modeling. It is widely accepted for its elegant mathematical form and ease of modeling in WiMAX and WLAN. Unlike the WINNER model, in a Correlation-based model, the correlation matrices are explicit. Several comparisons have shown that correlation- and ray-based modeling are equivalent in terms of channel coefficients and Block Error Rate (BLER). [3]

For antennas with radiation patterns, the spatial correlation matrix can be expressed in [4] as

$$\rho_{Tx,mm} = \frac{\int_{-\pi}^{\pi} e^{-j2\pi \frac{d_{mm}}{\lambda} \sin(\theta)} PAS_{Tx}(\theta) \sqrt{G_{Tx,m}(\theta)G_{Tx,n}(\theta)} d\theta}{\sqrt{\int_{-\pi}^{\pi} PAS_{Tx}(\theta)G_{Tx,m}(\theta) d\theta} \sqrt{\int_{-\pi}^{\pi} PAS_{Tx}(\theta)G_{Tx,n}(\theta) d\theta}}$$

$$\rho_{Rx,mm} = \frac{\int_{-\pi}^{\pi} e^{-j2\pi \frac{d_{mm}}{\lambda} \sin(\theta)} PAS_{Rx}(\theta) \sqrt{G_{Rx,m}(\theta)G_{Rx,n}(\theta)} d\theta}{\sqrt{\int_{-\pi}^{\pi} PAS_{Rx}(\theta)G_{Rx,m}(\theta) d\theta} \sqrt{\int_{-\pi}^{\pi} PAS_{Rx}(\theta)G_{Rx,n}(\theta) d\theta}}$$

Under the Kronecker assumption that the transmitter and receiver side are uncorrelated, the spatial correlation matrix, R_s , can be calculated using the following equation

$$R_S = \frac{1}{tr\{R_{Rx}\}} R_{Tx} \otimes R_{Rx}$$

In the standard, the joint correlation matrix of spatial and polarization can be expressed by [5] as

$$R = R_S \bullet R_P$$

where R_s is the spatial correlation matrix and R_p is the polarization correlation matrix. The channel coefficients can be generated using $H_s = \sqrt{R}H_u$

where H_u is a spatially uncorrelated Rayleigh fading sample and temporal correlated by the Doppler spectrum.

For the generic antenna array, the Kronecker assumption may not hold. Agilent Technologies has therefore developed a proprietary algorithm that calculates the spatial-polarization and joint correlation properties as a means of improving the correlation model based on the basic concept detailed above. Experimental validation has shown that this algorithm is an excellent fit for realistic antennas. [6]

This method is compatible with the well-known Kronecker model, and escalates it to include the effect of different types of antenna elements. It provides a flexible way of evaluating the performance of antenna and channel effects. Moreover, since the correlation model allows users to customize all parameters, including: Power Delay Profile (PDP), AoA and AoD, Angular Spread, different power angular spectrums and antenna patterns, it is a useful tool for users evaluating the system performance of their designs and antenna performance under different channels environments.

System Simulation Using SystemVue

Agilent SystemVue provides a convenient system-level communications design platform. To better understand how to set the channel models in SystemVue, let's examine an example that demonstrates swept throughput versus Signal-to-Noise Ratio (SNR) measurements for the LTE downlink in WINNER II channel- and correlation-based channel environments.

Example 1: WINNER II Channel Model

Simulate the system throughput using `<SYSTEMVUE INSTALL DIR>\EXAMPLES\MIMO CHANNEL MODEL\CHANNELTHROUGHPUT_LTE.WSV`.

Step 1 | Set the Channel Simulation Environment

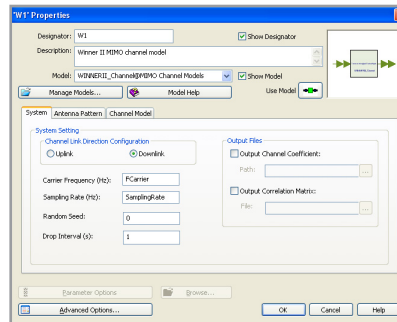


Figure 1. System setting profile in WINNER

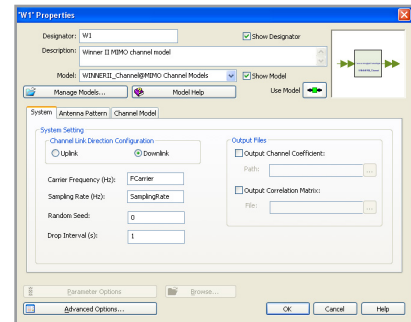


Figure 2. Channel model setting profile in WINNER

First, set the system parameters, which are consistent with the system simulation conditions (e.g., carrier frequency and sampling rate (Figure 1)). Random Seed is the seed of random integer number generator. For each non-zero setting, the Channel Impulse Response (CIR) can be repeated. Otherwise, the CIR is generated randomly for each simulation run. Output files can be applied for further analysis.

Second, set the channel model parameters (Figure 2). In a WINNER II MIMO-channel model, the channel scenario decides the path parameters. Ten scenarios can be selected, from the indoor to the outdoor environment. The WINNER II channel model is fully consistent with the LTE specification. More complex channel simulation environments can be set by choosing different options, such as UseFixedCdlPar, UseDualPolarise, UseIntraClusterDelays, UseManualPropCond, UseShadowModel, and UseLOS. A detailed explanation of the parameters is found in reference [1].

Step 2 | Antenna Setting

Antenna patterns that include orthogonal polarizations (typically linear theta (θ) and phi (ϕ) polarizations) can be measured in an anechoic chamber. They can also be simulated using Agilent's 3D electromagnetic (EM)-solver EMPro software or some other EM simulation tool. Of course, ideal antenna patterns like the omni-directional pattern, 3-sector pattern and 6-sector pattern are options as well. While Agilent's algorithm supports 2D and 3D MIMO channel models, the Channel Model Builder only considers 2D antennas. Approximate EM wave propagation is regarded as in one panel, a practice which is widely accepted in channel simulation. 3D radiation patterns can be sliced into a 2D pattern according to the assigned parameters TxPhiRotation and TxElevationAngle in Antenna Pattern profile. A detailed description regarding antenna file format can be found in the model help menu.

In this step, numbers, positions and radiation patterns of Tx and Rx antennas should be assigned separately (Figure 3). When antenna patterns are loaded from data files, it is assumed that the calibration was completed when measuring or simulating the antenna patterns. As a consequence, the positions of the antennas are unnecessary.

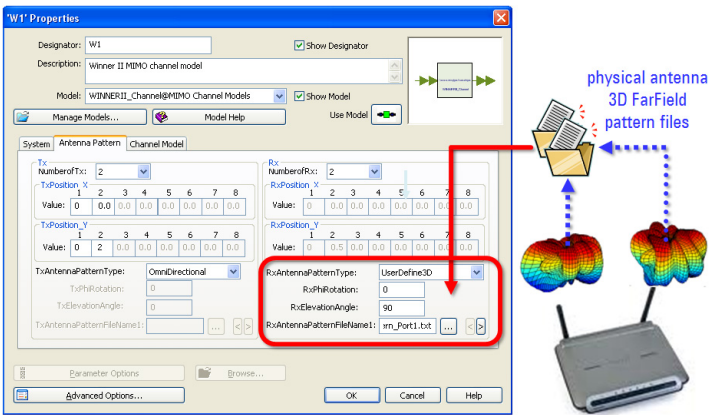


Figure 3. Load antenna patterns in a WINNER channel model

Importing 3D Radiation Pattern Data from Agilent EMPro

Two advantages of using Agilent’s EMPro software to predict antenna pattern data are 1) earlier R&D access to physical performance data, and 2) precise control. EMPro models the antenna directionality using preliminary mechanical CAD and industrial designs. It adds earlier physical degradations into the overall link-level system performance, well before any of the baseband signal processing, RF transceiver or mechanical hardware designs have been integrated into a hardware prototype. This early validation allows diagnostics and some system-level performance to be “measured” at the algorithmic stage, where architectural changes and system re-partitioning are still easy to adjust. Using EMPro with the SystemVue MIMO-channel models and LTE library makes it possible to achieve much higher confidence when verifying full, working hardware prototypes on the test bench, or in Over-the-Air (OTA) real-time testing.

EMPro can also model antennas in various positions and loadings, such as SAM reference head positions, or left versus right hand-held positions. Due to environmental factors, as well as the differences between the physical antenna elements themselves, it is recommended that each radiating element be exported individually. The Correlation and WINNER-II models in SystemVue are able to accommodate up to 8 unique patterns, for either transmit or receive arrays.

To export 3D radiation data from Agilent EMPro, go to its “Results” post-processing tab, choose the “Gain” from one of the “Far Zone Sensors,” and right-click to export the data. Export the “.uan” ASCII type file for each MIMO radiating element (Figure 4). Then, from either the Correlation or WINNER-II MIMO-channel models in SystemVue, assign the pattern files to each NxN MIMO element (Figure 3).

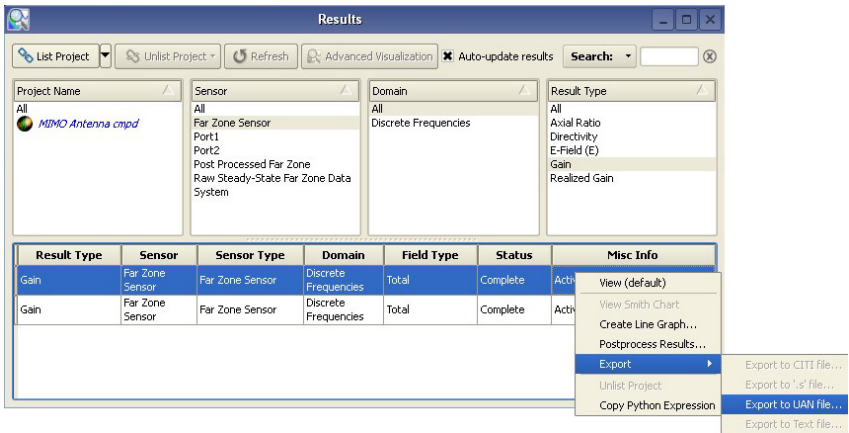
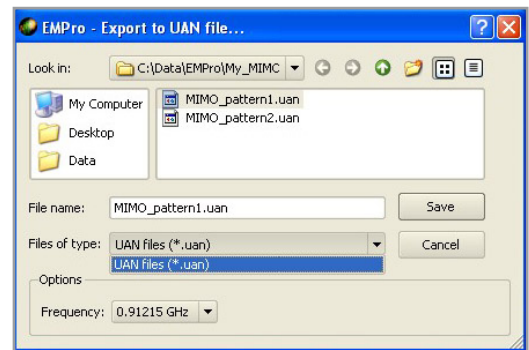


Figure 4. Using Agilent EMPro to export MIMO antenna pattern files for each radiating element. These files add antenna directionality due to physical degradations and loading, and replace the ideal patterns built into the SystemVue MIMO Channel models.



Step 3 | System Simulation

The ability to evaluate the antennas' influence in different MIMO-channel scenarios is a unique value provided by the SystemVue LTE simulation library plus MIMO channel model. Now, SystemVue provides a flexible platform that can be used throughout the complete baseband design flow for baseband modeling, debugging and verification.

The top-level system platform structure is shown in Figure 5. The main models in the block diagram include LTE MIMO signal source, channel model and downlink baseband receiver. Designers can substitute the models with their own to easily verify the algorithm using SystemVue.

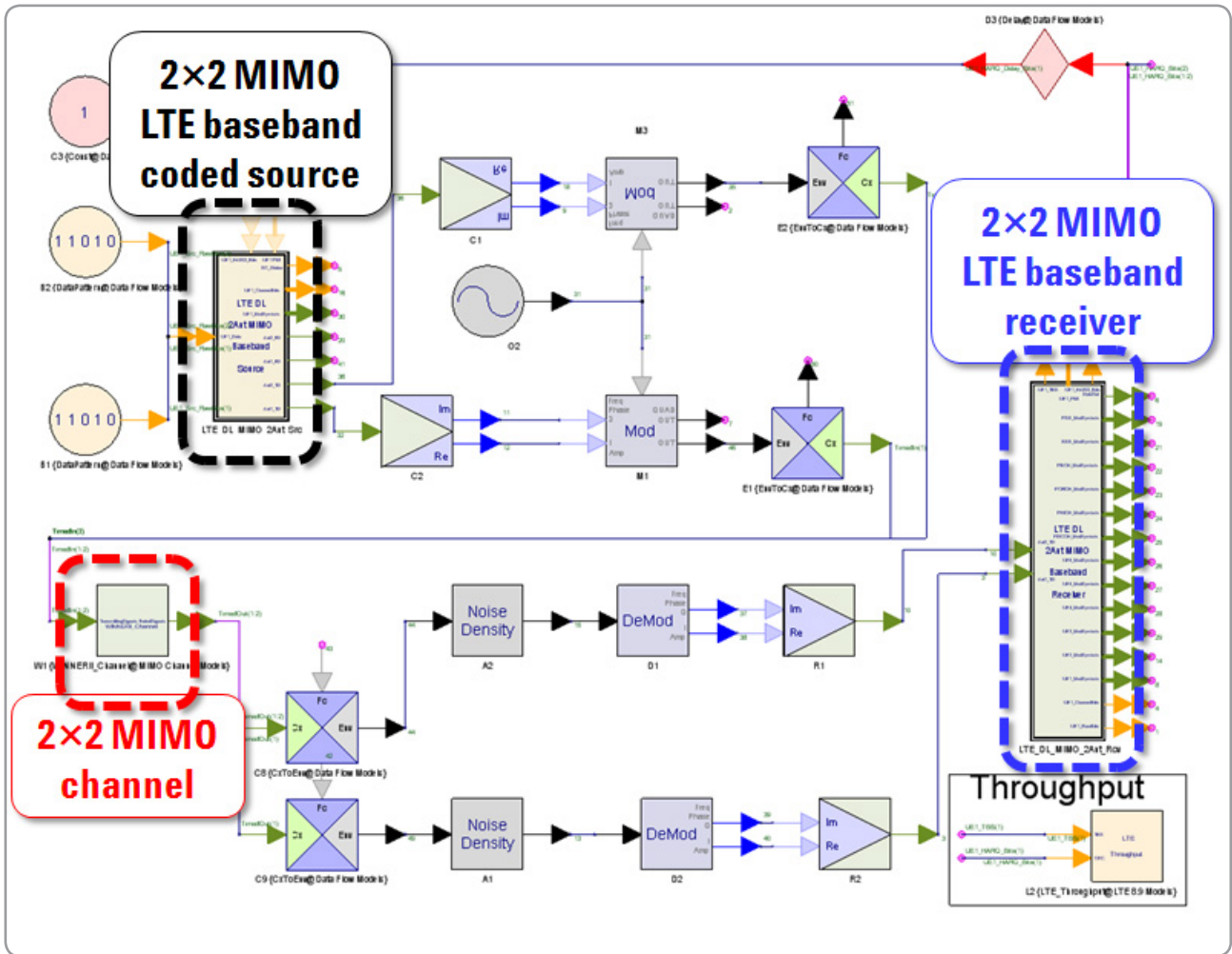


Figure 5. Design of LTE downlink coded 2x2 MIMO with throughput versus noise/fading

Correlation-based Channel Model

Step 1 | Set Channel Simulation Environment

1. Set the system parameters (Figure 6).
2. Set the channel model parameters (Figure 7).
3. Set the path parameters (Figure 8). Because the Correlation-based channel model is a user defined model, the path profile (including path PDP, Doppler shape, type of PAS, angular information (e.g., angle of arrival, angle of departure and angular spread), and cross polarization ratio, should be set by the users' requirements.

System Path Antenna Pattern Channel Model

System Setting

Channel Link Direction Configuration

Uplink Downlink

Carrier Frequency (Hz): FCarrier

Sampling Rate (Hz): SamplingRate

Random Seed: 0

Output Files

Output Channel Coefficient:

Path:

Output Correlation Matrix:

File:

Figure 6. System setting profile in correlation channel model

System Path Antenna Pattern Channel Model

Channel Model Setting

General Configurations

ThetaBs (deg): 0 MsVelocity (km/h): 60

ThetaMs (deg): 0 MsDirection (deg): 120

BsHeight (m): MsBsDistance (m): StreetWidth (m): PathLossOptions:

MsHeight (m): NumWalls: Perpendicular Dist (m): NumPenetratedFloor:

Figure 7. Channel model setting profile in correlation channel model

System Path Antenna Pattern Channel Model

Path

NumberofPath: 18 RayleighSpectrumShape: 0: Classical6db XPRindB: -4

PASType: 0: Lap CorrSource: 1: From Antenna Pat

PathIndex	PathPowerindB	PathDelay	PathAoA	PathAoD
1	-3.0	0	0	0
2	-5.2	5e-9	0	0
3	-7.0	10e-9	0	0
4	-7.5	25e-9	-71	13
5	-10.5	35e-9	-84	-15
6	-3.2	35e-9	46	-8
7	-6.1	45e-9	-66	12
8	-8.3	50e-9	-66	12

Figure 8. Path profile in correlation-based model

Step 2 | Antenna Setting

In the Correlation-based model, there are two ways to get the correlation matrices: either assigned by the user or calculated by considering antenna effects. In order to enable the antenna pattern effects, the CorrSource should be set from Antenna Pattern, otherwise, the correlation matrix must assigned by the user path-by-path (Figures 9 and 10).

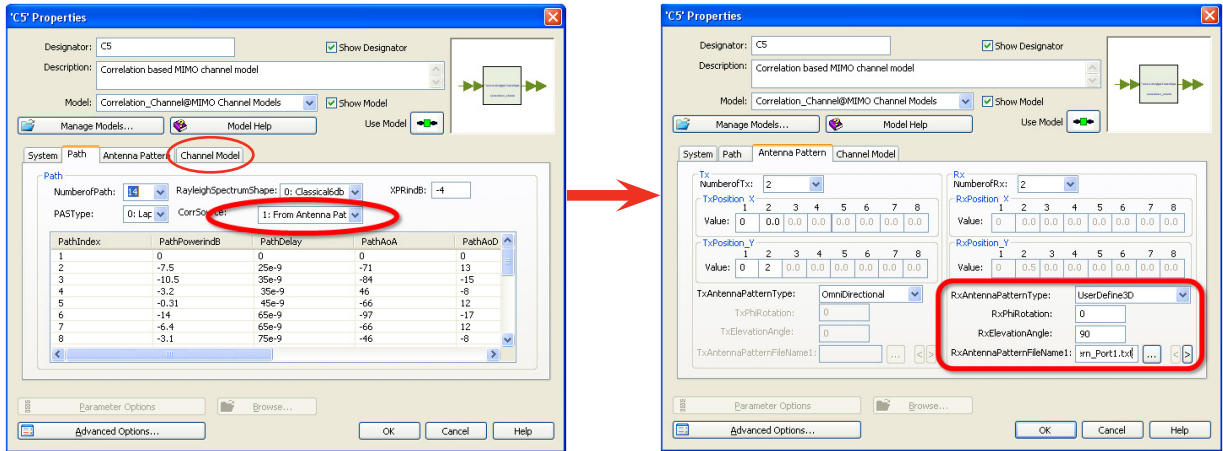


Figure 9. Load antenna pattern in a correlation-based channel model

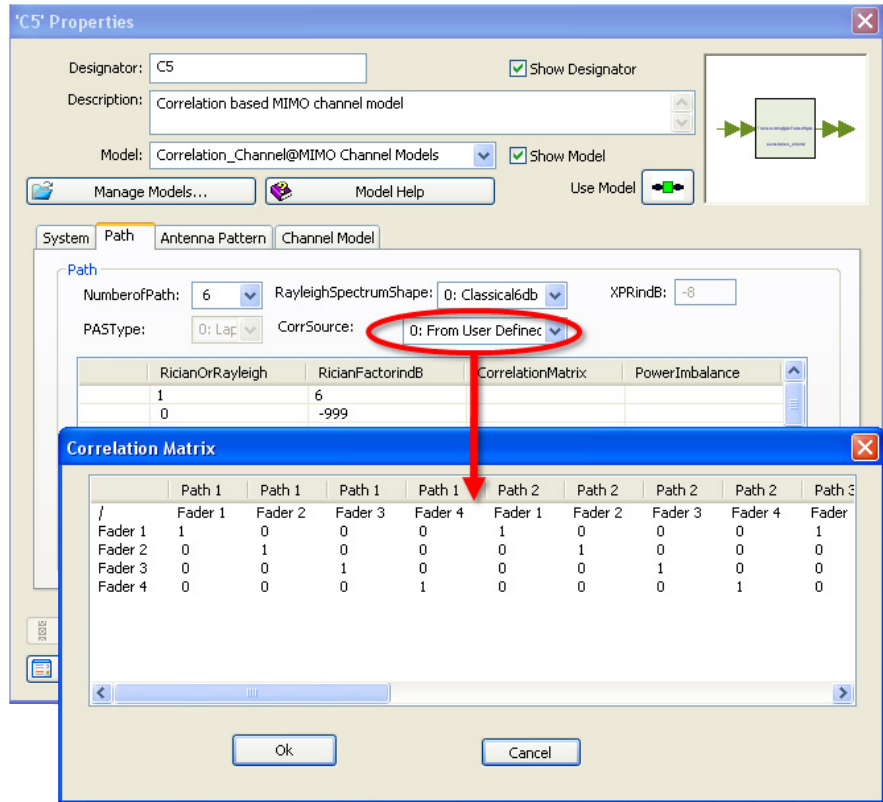


Figure 10. Correlation matrix setting

Step 3 | System Simulation—LTE System Performance Evaluation

Both simulations use the same LTE-FDD configuration with the same propagation condition—a 2×2 MIMO configuration for transmit diversity with a targeted maximum throughput of 12.96 Mbps.

Table 1. LTE transmit diversity system configuration

Parameter	Unit	Value
Channel bandwidth	MHz	10
Allocated resource blocks		50
Modulation		16 QAM
Target coding rate		1 / 2

The channel configuration parameters are listed in Table 2.

Table 2. Channel configuration

NumberofTx=2	NumberofRx=2
DistanceofTx=2λ	
TxAntennaPatternType=OmniDir ectional	Rx Antenna Files: RadiationPattern2D_Port1.txt; RadiationPattern2D_Port2.txt
Scenario=C1; NLOS; UseFixedCdlPar=1; UseDualPolarise=1; ThetaBs=0; ThetaMs=0; MsVelocity=60km/h; MsDirection=120; Drop Interval=1s; simulation time=40s	

As the MIMO channels are correlated, the measured signal power at the receiver side may be dependent on the correlation of the channels. This correlation dependency prevents a channel emulator from accurately configuring the MIMO system for a desired SNR, using power measurements at the receiver. To overcome this difficulty, the system simulation uses measurements of the signal power at the transmitter to appropriately set the required SNR. [7]

When the simulation time is long enough, the simulation results are quite close for both channel models (Figure 11).

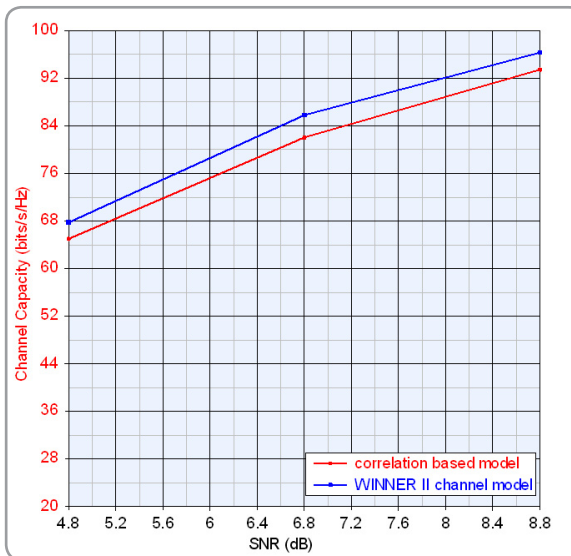


Figure 11. Simulated throughput fractions versus SNR

Example 2: Channel Analysis Using SystemVue

Understanding MIMO channel characteristics is important in a MIMO communication system. SystemVue MIMO channel Builder provides not only the channel models used in the system simulation, but also the CIR and correlation matrix, which customers can post-process for further analysis and verification of the system simulation results.

To simulate the channel capacity using `<SYSTEMVUE INSTALL DIR>\EXAMPLES\MIMO CHANNEL MODEL\CHANNELCAPACITY_MEASUREMENTS.WSV`, follow these steps:

1. Set a simple design with channel model (Figure 12).
2. Enable Output Correlation Matrix in channel models.
3. Set the channel capacity calculation design. Load the correlation matrix generated in Step 2.

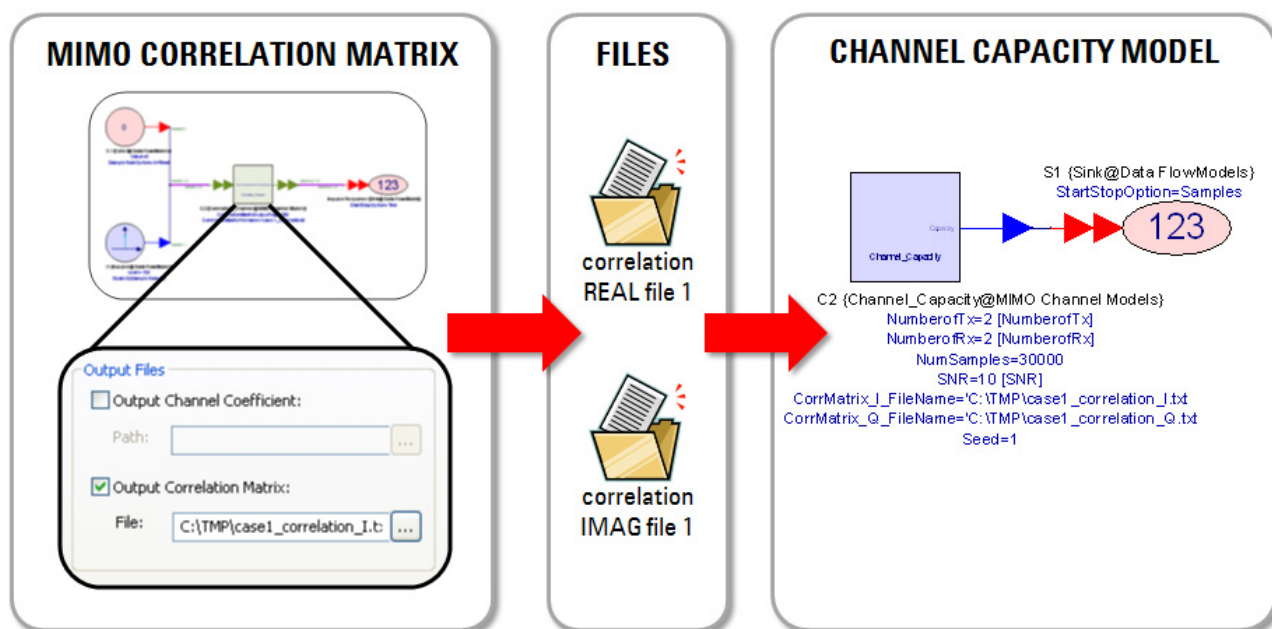


Figure 12. A simulation using the MIMO Channel model can choose to save the correlation matrix for later use. This reduces simulation times in subsequent simulations.

Figure 13 compares the results of the channel capacity of the WINNER and correlation-based channel models under the conditions used in Example 1. The simulated results are quite close, which agrees with the conclusion that the two models are equivalent in terms of their channel coefficients and BLER. [3]

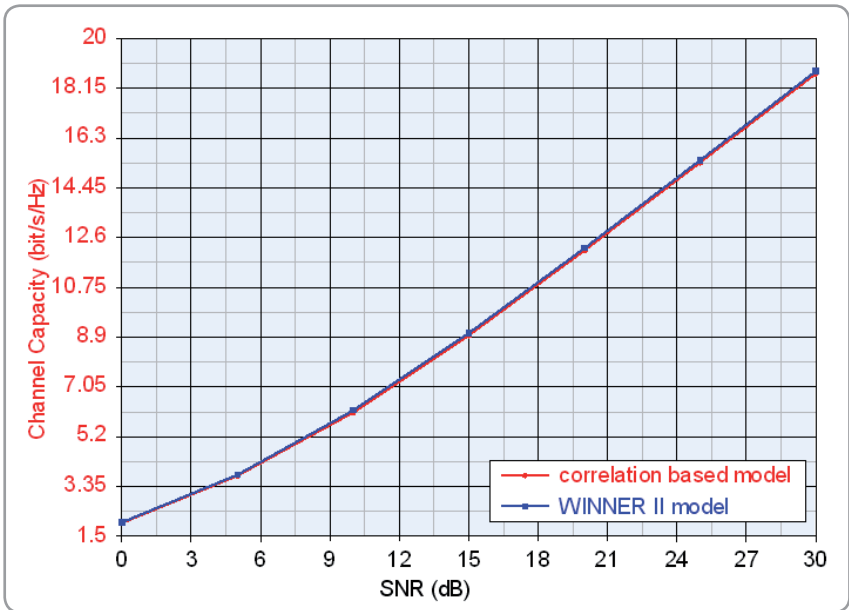


Figure 13. Channel capacity comparison of WINNER- and correlation-based models

Similarly, channel coefficients can be saved in data files. The channel coefficient is saved with a 100 KHz sample rate, regardless of the system's sample rate setting. This SystemVue feature is quite useful for users interested in the channel statistical characteristics. The channel information is used, for example, to investigate things like the Level-Cross-Rate (LCR), Average Duration of Fades (ADF), correlation factor, and capacity of the channel—all of which can be extremely helpful in understanding channel properties and improving algorithms.

MIMO Antenna OTA Performance Evaluation Using SystemVue

MIMO OTA testing is a new test method that may allow engineers to test the true performance of mobile terminals. Different approaches to this task are being discussed in COST 2100, 3GPP RAN WG4 and the CTIA. Currently, several major test methodologies exist to address MIMO OTA test. They include the:

- Reverberation chamber method—A reverberation chamber generates echoes to mimic multipath propagation. [8]
- Emulator + anechoic chamber method—Several wireless channel emulators in an anechoic chamber provide a realistic propagation environment. [9, 10]
- Two-stage method—MIMO antenna radiation patterns are measured within the anechoic chamber and combined with the measured antenna radiation pattern with the multipath fading emulation. This data is then used to perform the OTA performance test. [6]

SystemVue's MIMO Channel Builder simulates the multi-channel fading, which incorporates realistic antenna patterns. As an alternative to the OTA test, it is based on a two-stage method that is both economic and repeatable (Figure 14). The stages in this method include:

Stage 1: Test multiple antenna systems in a traditional anechoic chamber or simulate antenna radiation patterns using the Agilent EMPro software or some other EM simulation tool.

Stage 2: Load the antenna patterns into SystemVue MIMO channel models and emulate the MIMO channel model with incorporated patterns. Two different approaches exist in the SystemVue Channel Model Builder to add the antenna patterns to the MIMO channel model. One method is to use the WINNER II channel model. The other method is to use a correlation-based model.

This two-stage OTA method can be used to measure the following figures of merit in SystemVue: throughput, CQI, BLER, antenna correlation, and MIMO channel capacity. [11] This method also has the capability to measure TRP, TRS, antenna efficiency, and MEG.

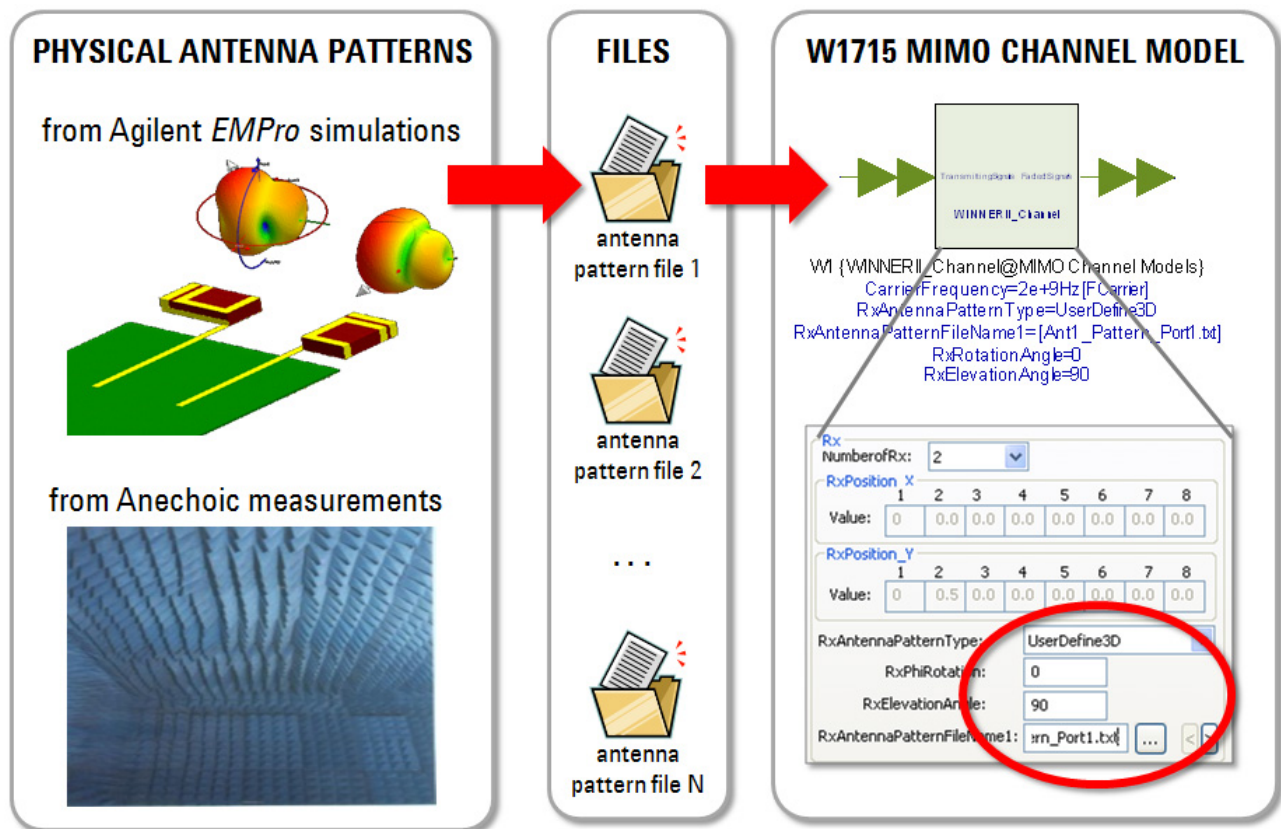


Figure 14. Antenna patterns for each MIMO radiating element can be simulated in 3DEM software, or measured directly, then added to the propagation and fading models in the MIMO Channel models. The overall result is similar to live hardware over-the-air (OTA) testing, but predictive and much earlier in the overall design process.

Example 3: MIMO Performance With and Without SAM Head

Evaluate the MIMO system performance, with and without the Specific Anthropomorphic Mannequin (SAM) head influence, using <SYSTEMVUE2010.07 INSTALL DIR>\EXAMPLES\MIMO CHANNEL MODEL\CHANNELTHROUGHPUT_LTE.WSV.

In real-world situations, the effects of the human body can be complicated. Never the less, the head is a critical aspect of successful implementation. Here, we try to evaluate the impacts caused by the interaction of the head and the real antenna. Two antenna gain patterns released with SystemVue are shown in Figure 15. One of the antenna gain patterns is without the influence of the head. The other is an antenna gain pattern with SAM head, which mimics the real scenario. As is evident, the SAM head will significantly change the antenna pattern.

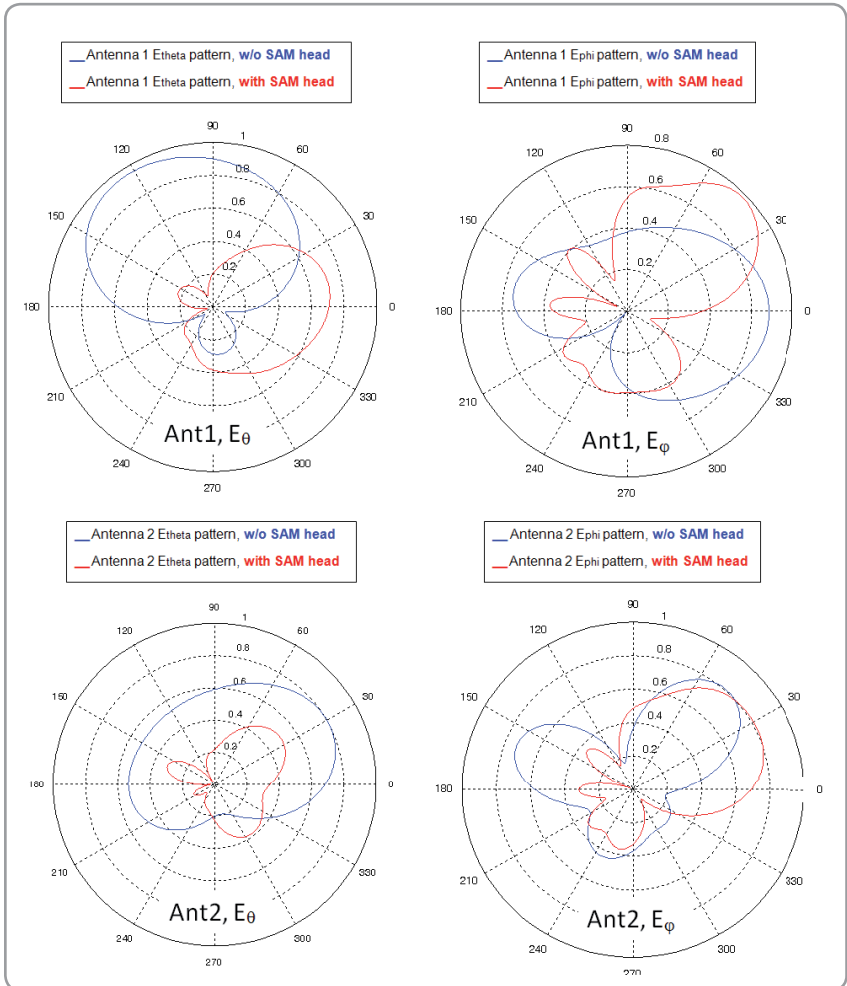


Figure 15. The farfield directionality of each individual MIMO antenna element changes with proximity to body parts and other environmental loadings, thus degrading the throughput performance of the MIMO array. Shown above is the effect of a SAM head.

Figure 16 is the simulated throughput fraction using the different antenna patterns shown in Figure 15 under the 2×2 MIMO LTE-FDD spatial multiplexing configuration with a targeted maximum throughput of 25.92 Mbps. The LTE system configurations are the same as that in Table 1. The channel configuration is shown in Table 3. The results demonstrate that for the designed antenna array, regardless of whether or not there is head influence, the rotation of the antenna will cause throughput fluctuation. When there is head influence, however, the fluctuation range will be much greater compared to the case with no head influence. In this way, the influence of the human body can be conveniently evaluated and the antenna performance easily investigated. The user simply changes the orientation or multipath scenarios to observe the antenna's robustness under different cases.

Table 3. Channel configuration

PathIndex	PathPowerindB	PathDelay	PathAoA	PathAoD	ASofAoA	ASofAoD
1	-3	0	-2.3	6.6	35	5
2	-5.2	5.00E-9	-2.3	6.6	35	5
3	-7	1.00E-8	-2.3	6.6	35	5
4	-4.3	2.85E-7	42.6	14.1	35	5
5	-6.5	2.90E-7	42.6	14.1	35	5
6	-8.3	2.95E-7	42.6	14.1	35	5

NumberofTx=2; NumberofRx=2; DistanceofTx=4λ; TxAntennaPatternType=OmniDirect
 ional; XPR=-9; NLOS; ThetaBs=0; ThetaMs=0; MsVelocity=10km/h; MsDirection=30;
 SNR=23dB

In the same simulation conditions, channel capacity is simulated in different rotation angles. The change trend of channel capacity is consistent with that of the throughput seen from the results (Figure 17).

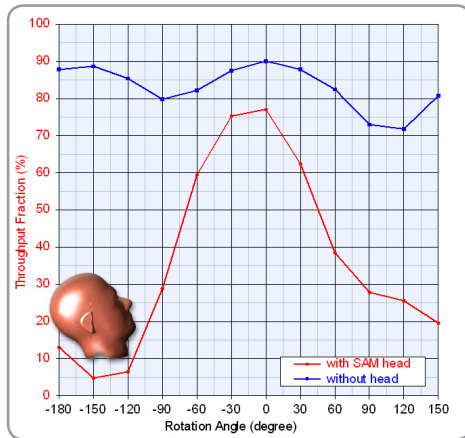


Figure 16. Throughput comparisons of antenna patterns with/without SAM head influence

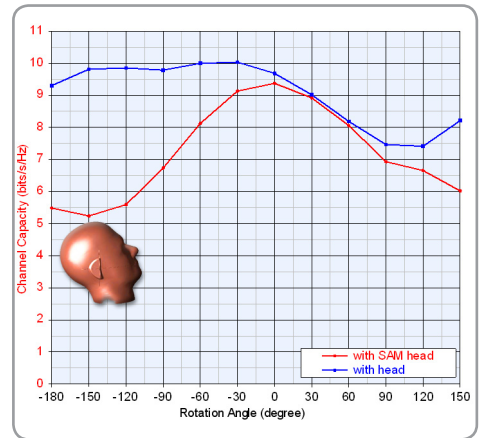


Figure 17. Channel capacity with/without SAM head influence at reference SNR=23 dB

We also find that the channel capacity at -60 degree is close to that at 60 degrees for the antenna with SAM head influence, but the throughputs at -60 and 60 degrees have a more than 20% total throughput difference. Comparing the channel statistical properties from the output files, it is apparent that while there is severe power imbalance at 60 degrees, there is very little power imbalance at -60 degrees. The channel capacity for the two channels are the same, but since the simulation does not adjust the transmitter power according to the channel, the channel capacity at 60 degrees is hard to achieve and results in a big throughput drop. The output of the channel statistical properties can be very useful tools in locating performance issues and helping to explain throughput simulation results.

The benefits of using the SystemVue LTE library and MIMO channel model to evaluate the MIMO antenna performance are as follows:

- evaluates MIMO antenna performance under the customized channel;
- evaluates MIMO antenna performance under different MIMO working modes and can evaluate both open-loop and closed-loop performance; and
- helps antenna designers optimize the antenna design even before the antenna is manufactured.

Real-World Verification Using SystemVue

SystemVue provides strong instrument connectivity support. With the SystemVue LTE simulation library and the MIMO channel model, designers can evaluate the MIMO antennas' performance using simulation, as well as a real-world measurement method. The SystemVue LTE simulation library generates and downloads the signal into the instrument and then sends it out with Agilent signal generators. The RF analyzer captures the received signal and sends it back to SystemVue for analysis. With this approach, the antenna influence through simulation can be further compared with the real-world measurement results.

Figure 18 shows an example of the connections between SystemVue and various instruments.

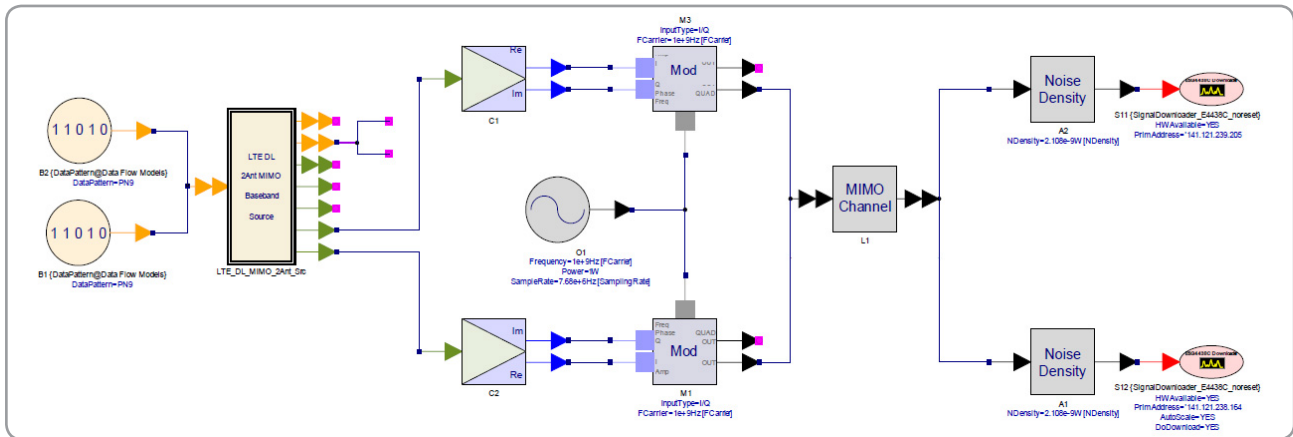


Figure 18. A 2x2 MIMO LTE downlink signal is coded in SystemVue, then faded using the MIMO Channel simulation models, and downloaded to two RF signal generators for hardware testing. If the decoded data bits are the recovered and compared to the original bit sequence, a fully coded BER/FER test can be made with only partially-implemented algorithms.

Figure 19 depicts an integrated test system that is used to conduct the throughput test in MIMO OTA. The advantages of system-level verification are:

- automates tests using integrated hardware and software;
- generates specific waveforms that are not available using regular hardware instruments; and
- allows the designer to use a software receiver before a hardware receiver prototype has been built, especially during the developing phase of a new product.

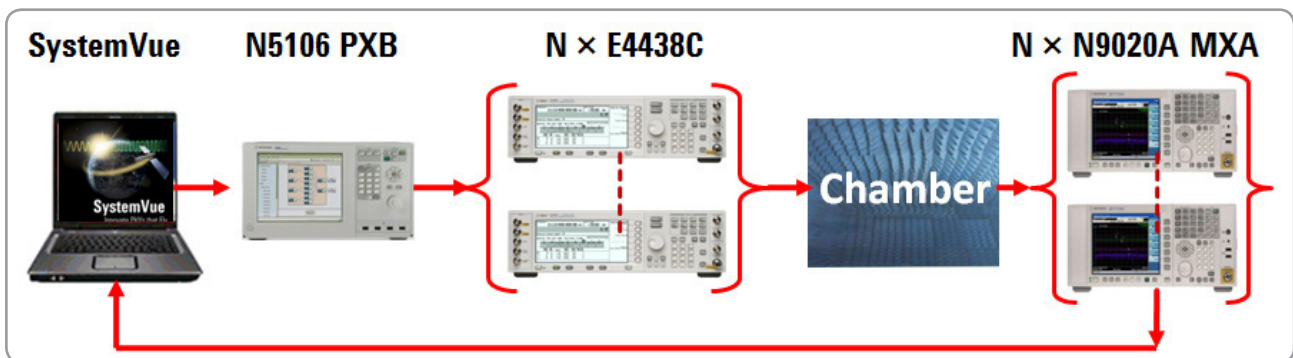


Figure 19. SystemVue simulation models can be used to fill gaps in either a link-level PHY, or in the MIMO test equipment, helping to facilitate inexpensive, multi-channel functional verification in early stages of R&D.

Summary

The W1715 MIMO channel builder in Agilent SystemVue provides a flexible platform for wireless MIMO systems design. Some of its key design and test benefits are:

- combines both antenna and channel effects in simulation;
- provides standard-compliant channel models and universal channel models to satisfy different application requirements; and
- provides R&D and manufacturing engineers with an inexpensive alternative to OTA evaluation.

Reference

- [1] IST-WINNER II Deliverable 1.1.2 v.1.2, "WINNER II Channel Models," IST-WINNER2, Tech. Report, 2008.
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