A modern automated warehouse relies on many wireless links to ensure communication and data transfer for proper operation. The antenna patterns show the location of some of the wireless devices in the warehouse. The system must be designed to operate antennas simultaneously without interfering with each other.

Ensuring Antenna Performance in **Complex Wireless Environments**

As wireless systems proliferate in our increasingly connected world, the opportunities for interference and performance degradation expand. The results could range from merely inconvenient with regard to personal entertainment to catastrophic in the case of aircraft or defense equipment. By determining where interference is likely to occur early in the development cycle using specialized simulation software, companies can avoid interference issues, decrease the costs to remediate problems later and reduce risk.

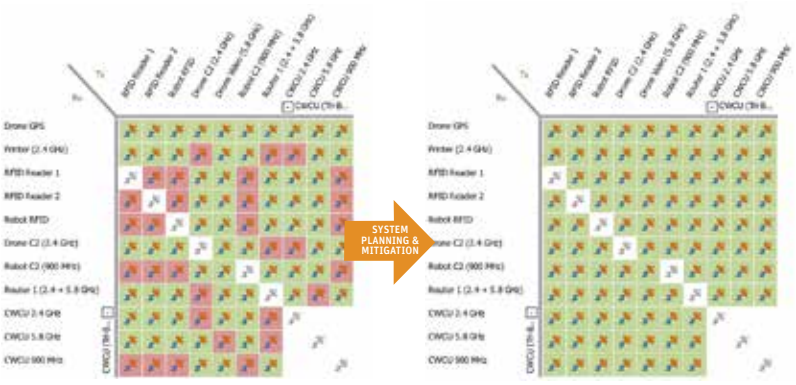
By **Fred German**, Senior Manager Research and Development, ANSYS

This widespread proliferation of wireless systems provides constant mobile communication, navigation and data services that extend across multiple industries and applications, including personal electronics, home automation, telecommunications, automotive, aerospace and defense. With the emergence of exciting new wireless technologies that include fifth-generation wireless systems (5G), the Internet of Things (IoT), autonomous vehicles with advanced driver-assist systems (ADAS), and rapid advances in expanding the application and performance of existing wireless technologies, the business opportunities have become enormous. Simultaneously, the challenges of designing and deploying so many wireless systems in complex environments have increased. Competition demands rapid design, evaluation and deployment of wireless systems that are capable of achieving superior performance in their intended operating environments. These systems must operate in the presence of other nearby wireless systems that have the potential to cause interference and performance degradation. Unintentional sources of radio frequency (RF) interference (RFI) present in the environment also must be considered to achieve a robust system design.

Simulating Wireless Systems

Simulation-driven product development of wireless systems to predict performance in complex environments must begin very early in the conceptual stage of the system design. By necessity, design needs to include the impact of other wireless devices and sources of RF signals in the environment that are not part of the system under design. Failure to design for the intended environment will likely lead to a system that works spectacularly in lab tests, but suffers performance degradation when deployed, leading to costly interference mitigation and possibly failed business strategies.

The simulation of wireless systems in complex environments spans multiple computational domains and solution methodologies. It requires a workflow created for design engineers, not just expert analysts. Design productivity and efficiency demands that these methods work together in a seamless engineering workflow that provides the necessary multifidelity model libraries so simulations can begin before complete and detailed device information is available. Simulation should produce results that drive performance requirements and component selection.

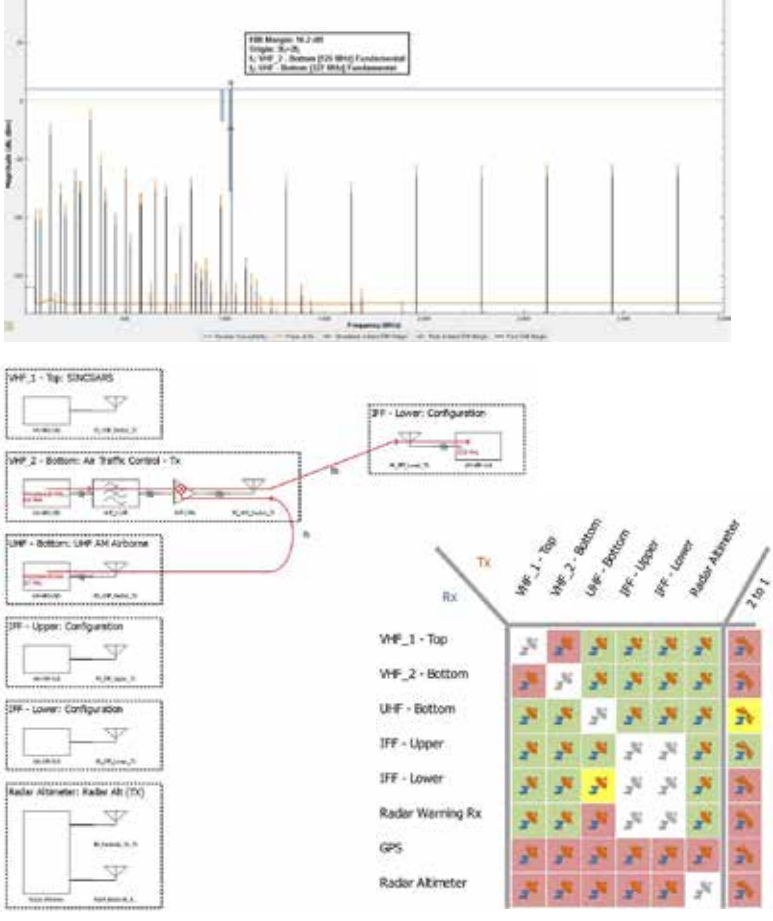


The scenario matrix simulation result view shows a color-coded systems-level summary of potential performance issues. Red squares indicate problematic interference between the affected systems and warrant further attention to mitigate the issue. After implementation of proper frequency planning, interference mitigation and operational procedures, the completely green scenario matrix shows that all systems operate properly in the warehouse environment.

Simulating Complex Environments

ANSYS provides world-class simulation solutions that cover all the required disciplines, including electromagnetic analysis using ANSYS HFSS for antenna design and placement, and circuit and system simulators employing the ANSYS RF Option to predict the performance of wireless sensors when connected to the antennas. ANSYS RF Option now includes ANSYS EMIT, which integrates all the technologies from the electromagnetic and circuit/system worlds to completely simulate the performance of all the wireless systems in complex environments. ANSYS EMIT provides model libraries based on industry standards for many types of wireless systems. Its unique multifidelity modeling approach provides useful simulations capable of driving early design decisions even when only an incomplete set of design and performance parameters is available.

For example, a modern automated warehouse might receive orders and dispatch them via delivery drones. The warehouse relies on numerous radio devices to wirelessly link the different parts of this order and delivery process. Wireless systems in the warehouse include radio frequency identification (RFID) tags and readers for inventory control, wireless links operating in various



Automatic diagnostics, signal traceback and tagged spectrum displays rapidly identify the root cause of wireless system performance issues so mitigation measures can be designed and evaluated.

Predicting Radio Frequency Interference with ANSYS EMIT
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unlicensed frequency bands to send and receive commands to the robots and drones, GPS for position information, and Wi-Fi and Bluetooth® connectivity between devices. Additionally, other sources of RF signals, such as handheld radios used for communication between workers in the warehouse, will affect the performance of the wireless links employed to keep the warehouse running. In such a complex wireless environment, there are many opportunities for interference to occur and degrade system performance. Using simulation during the early design of the warehouse's wireless systems can identify and prevent costly downtime before the system has been deployed.

An analyst can leverage ANSYS HFSS and ANSYS RF Option to model the performance of all antennas and wireless devices operating within the warehouse environment before the structure is even built. The top-level results can be summarized in a scenario matrix where each square in the matrix represents the interactions between the wireless systems. A color-coded scheme will identify any performance issues with a red square. Green entries indicate that performance requirements are being achieved. The detailed results from the simulation will drive proper frequency planning, define operational parameters and suggest mitigation measures necessary to ensure proper operation for simultaneous functioning of all wireless systems as evidenced by a completely green scenario matrix.

Avoiding Interference

Another typical challenge for system integration in complex environments is ensuring proper operation of all radio transmitters and receivers on an aircraft, such as a helicopter. All antennas must operate simultaneously without degrading the others' performance.

The integration of multiple RF systems onto an aircraft platform, such as a helicopter, is a common challenge for system integrators who need to ensure that all systems can operate in the crowded environment without interfering with each other. The radiation patterns indicate the positions of the nine antennas on the aircraft.

To appreciate the complexity that must be addressed, a typical aircraft environment can have tens of millions (or more) ways that interference, which leads to performance degradation, can occur. The scenario matrix provides a high-level overview to quickly identify problems in systems interactions, but it yields little insight into the root cause of the problem or the paths of the interfering signals. Automated diagnostics and results visualization available in ANSYS EMIT provide designers with the tools needed to rapidly identify problems and design mitigation measures.

For example, if one of the radios on a helicopter suffers from interference caused by simultaneous operation of other co-located transmitters, the diagnostic tool shows the signal traceback display along with interference tags that are placed on the wideband spectral plots. Designers can immediately identify that the issue is caused by a high-order intermodulation product arising from the nonlinearity of a power amplifier that occurs due to coupling between two of the transmitter systems. This sort of interaction can be incredibly difficult to predict and diagnose without automated diagnostics. Relying on test and measurement approaches to identify these problems is a very costly process exacerbated by the need to test the entire environment with all RF equipment operational. Recently, a system integration program manager at a major aerospace contractor estimated achieving a savings of over $1,000,000 by identifying and addressing aircraft RFI issues, similar to the one discussed here, early in the conceptual design phase for a new unmanned platform.

Integrated Workflow

These examples demonstrate the necessity of using simulation to drive wireless system design in complex environments. As the number of wireless devices proliferates, it becomes even more critical to assess the impact of co-located devices on the performance of the system being designed if proper performance is to be expected in installed locations.

Efficient and accurate simulation of wireless system performance in complex environments requires a tightly integrated workflow focused on system designers. It must leverage best-in-class solver technologies across multiple domains and provide automated diagnostics to support the rapid evaluation of design decisions throughout the design and integration of wireless systems.