Synthesizing MIMO Antennas for Compact Devices

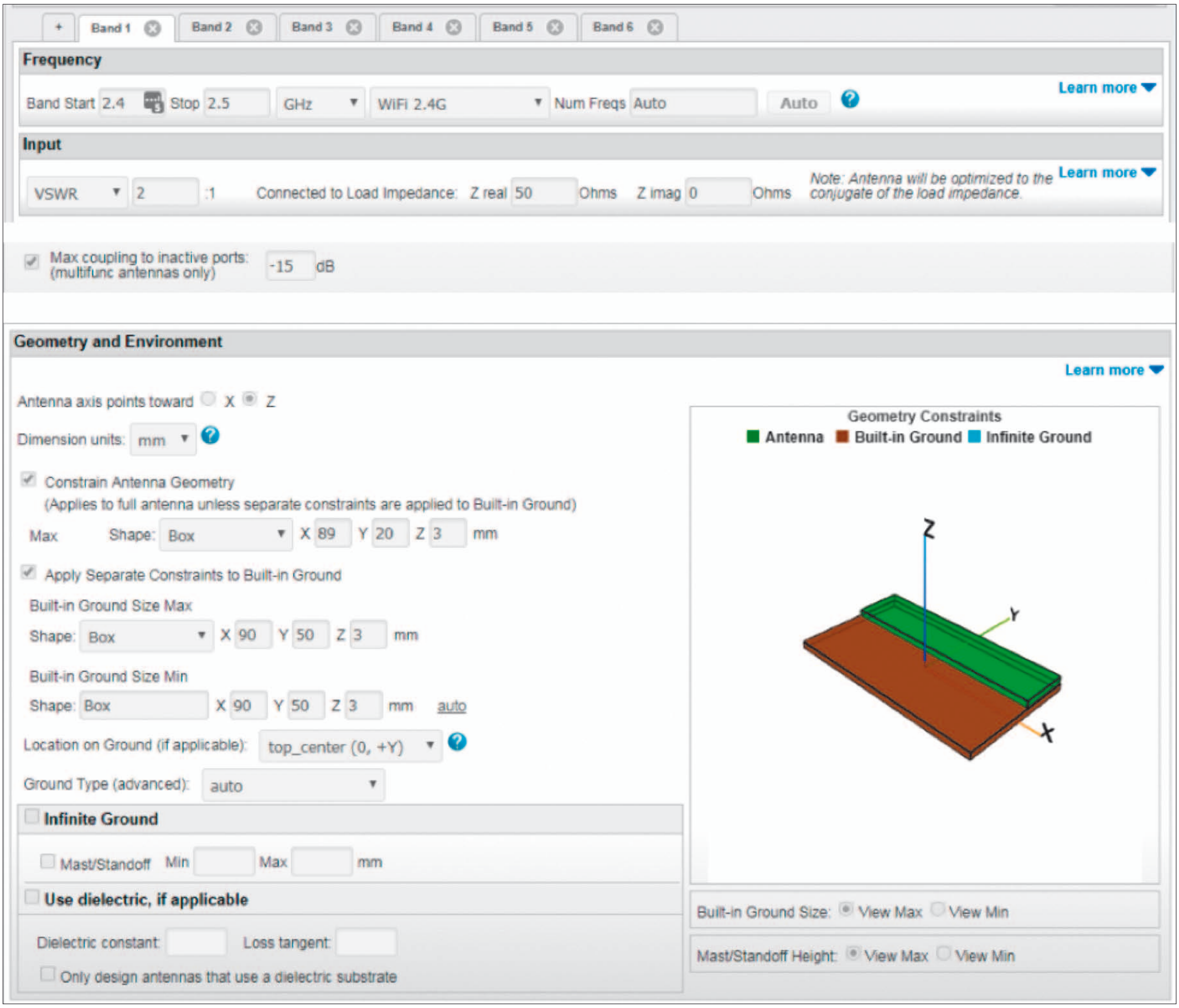

Figure 1: AntSyn spec sheet for MIMO

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Multiple-in-multiple-out (MIMO) is a technique that uses multiple antennas on a single device, thus providing greater throughput and performance reliability for wireless devices, however, this requires not only good antennas, but also high isolation between them.

The wide range of internet of things (IoT) applications in development today are made possible by smart devices operating across different network configurations, frequencies, power requirements, and protocols. Developing cost-effective IoT solutions requires a smart, organized approach to radio and antenna integration within a design flow that may have little to do with traditional RF product development.

Introduction

Many IoT designers are utilizing off-the-shelf, pre-certified modules to circumvent some of the technical challenges such as RF integration and emission compliance, as well as development costs associated with such a wide range of devices and networks.

Even with this modular approach, integrating a transceiver modem, RF front-end components, and antenna(s) within a size-restricted enclosure is a sensitive design effort that is increasingly being tackled

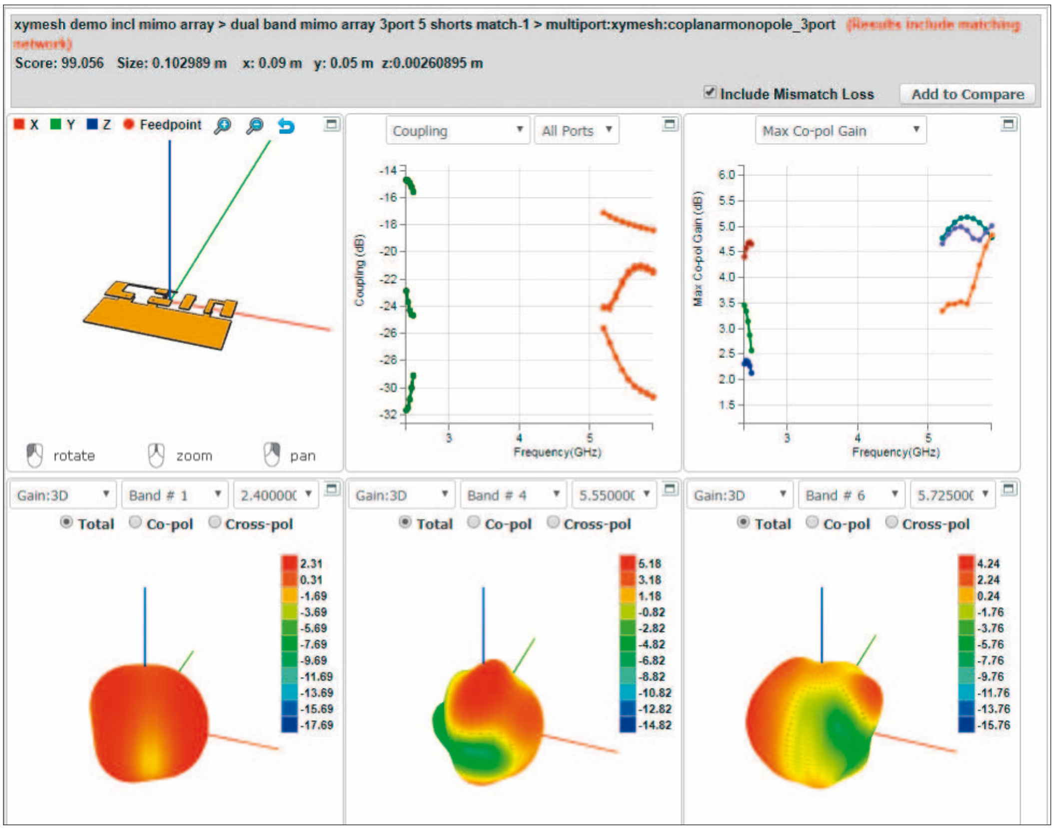

Figure 2: AntSyn software returns one or more optimized antenna designs

by engineers with little or no RF design experience.

NI AWR software provides engineers with the RF simulation, automation, and access to knowledge (through online training videos and tutorials) to tackle these challenges from a methodical and low-risk approach. Using a modular design approach, engineers can focus on combining all the relevant components in the RF signal path, including the supporting printed-circuit board (PCB) substrate and/or the device enclosure, into a hierarchical simulation network for analysis prior to manufacturing and test.

Integrated simulation technology and smart design automation are redefining the possibilities for companies at the forefront of IoT technology. To learn more about IoT trends and challenges, the companies developing the next generation of innovative IoT products, and the software enabling their success, visit ni.com/awr.

Overview

Upcoming IoT devices will rely heavily on customized antenna solutions optimized for performance, cost, and size. Multiple-in-multiple-out (MIMO) is a technique that uses multiple antennas on a single device, thus providing greater throughput and performance reliability for wireless devices, however, this requires not only good antennas, but also high isolation between them. This can be achieved by separating the antennas but doing so can make the device quite large and/or require external antennas. High isolation can also be achieved between closely-spaced internal antennas by using chokes, matching networks, and other techniques, each having their own advantages and drawbacks.

Optimizing antennas by hand to meet multiple performance metrics such as impedance matching, coupling, radiation efficiency, and operating bandwidth is a time-consuming process involving numerous iterative simulations and a significant amount of design knowledge. This application note presents an alternative method using NI AWR software's AntSyn antenna synthesis tool, which enables designers to synthesize compact MIMO antenna arrays automatically from user requirements, saving significant design time and allowing even inexperienced designers to design antennas that successfully meet size, cost, and performance requirements.

Antenna Design by Requirements

AntSyn software combines advanced optimization algorithms, expert systems, and electromagnetic (EM) simulation into a user-friendly tool that operates on a "what you want is what you get" principle, where the user inputs the antenna requirements rather than a (parameterized) physical design. For this application, the specifications are items like frequency band, target impedance match (return loss), size/form factor, and coupling. These requirements are input into the intuitive "spec sheet" user interface, which is automatically organized into a project file. A partial spec sheet, showing a sample of the relevant specifications for MIMO, is shown in Figure 1.

By running the spec sheet, AntSyn software returns one or more optimized antenna designs, the results of which are viewed using a customizable dashboard for rapid evaluation, as shown in Figure 2.

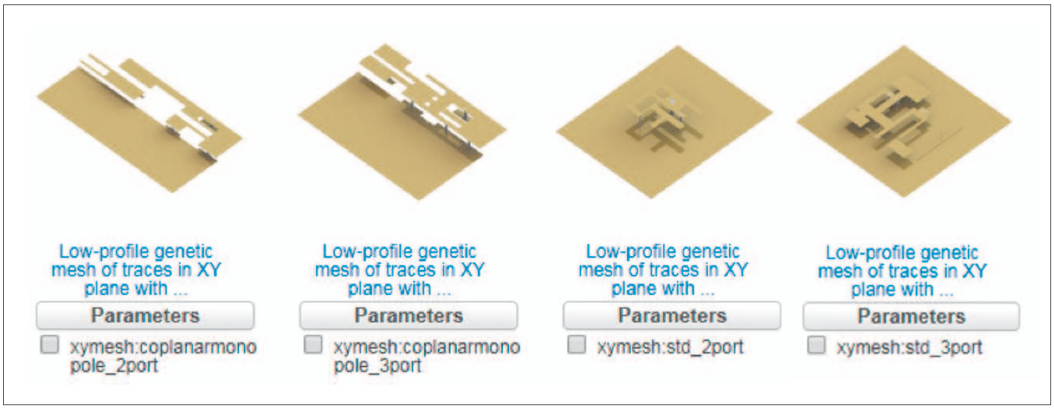

Figure 3: Sample mesh antennas

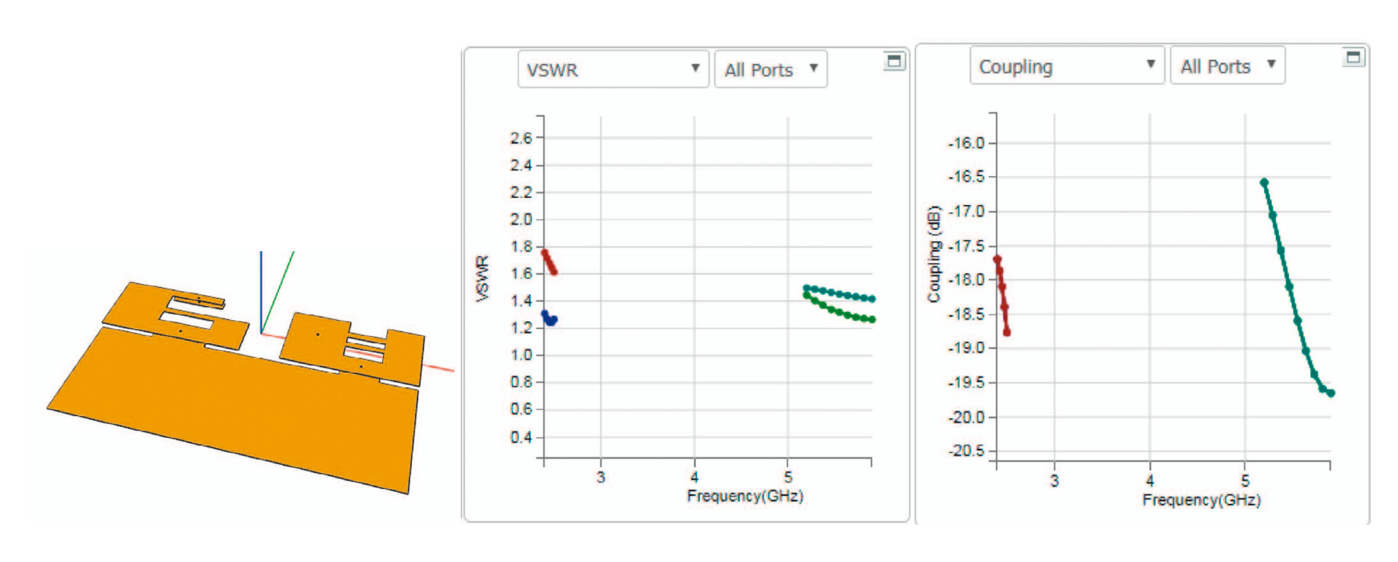

Figure 4: Two-port MIMO antenna with VSWR and coupling performance predicted by AntSyn software

The user-specified dashboard can be set to view the proposed 3D model, input impedance (match) versus frequency in several formats, maximum gain versus frequency, radiation pattern cuts, and qualitative star rating, all of which help identify good performers quickly. AntSyn software has been used to develop a wide range of antenna types such as single band, dual band, multiband, broadband/ultra-wideband (>100:1), high efficiency, loaded, electrically small, phased array, wire, patch, conformal, handset, horn, dual-polarized, and multifunction.

AntSyn software offers over 29 antennas and provides features that are made specifically to generate compact MIMO designs, including new multi-function computer-generated mesh antennas with multiple ports, augmented matching network optimization that allows each port to be separately matched and optimized, and improved accuracy and features for ground planes.

The new mesh antennas are particularly unique and flexible. They are a set of four new antenna types, with either two or three ports (more ports to be supported in the future). These ports can be independently assigned to different bands, which can have very diverse RF requirements such as different polarization, gain patterns, and frequencies. The antenna mesh is optimized by AntSyn software for the specifications given and it is sufficiently flexible to enable the software to essentially invent new antennas.

Images of these antennas are shown in Figure 3. The two standard versions of the mesh antenna can be placed on any corner or edge on the ground, or they can be placed in the center as shown. The ground can be solid beneath these antennas or it can be an optimized mesh as well. The coplanar monopole version does not have a ground beneath the mesh but is expected to project over one edge of the ground, which can be useful in many device applications.

The following examples use the coplanar monopole, which is known to have excellent bandwidth and flexibility for this application. The examples demonstrate how AntSyn software is able to use these antennas to synthesize high-performance MIMO arrays with good isolation and impedance matches.

Examples

The AntSyn tool was used to create both a two-port and a three-port MIMO antenna on a notional compact device using the new features in its latest release.

This notional device had the following characteristics and requirements:

- Dual-band WiFi
- 2.4 and 5 GHz bands
- IoT device package
- Compact, planar geometry
- Approximate size of a standard business card, 90 mm x 50 mm

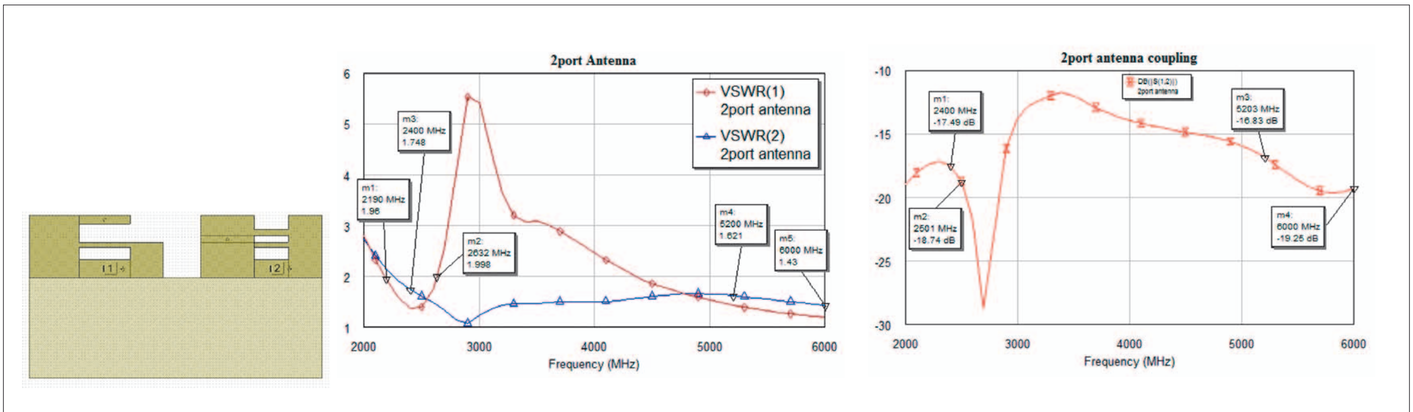

Figure 5: AXIEM simulation results

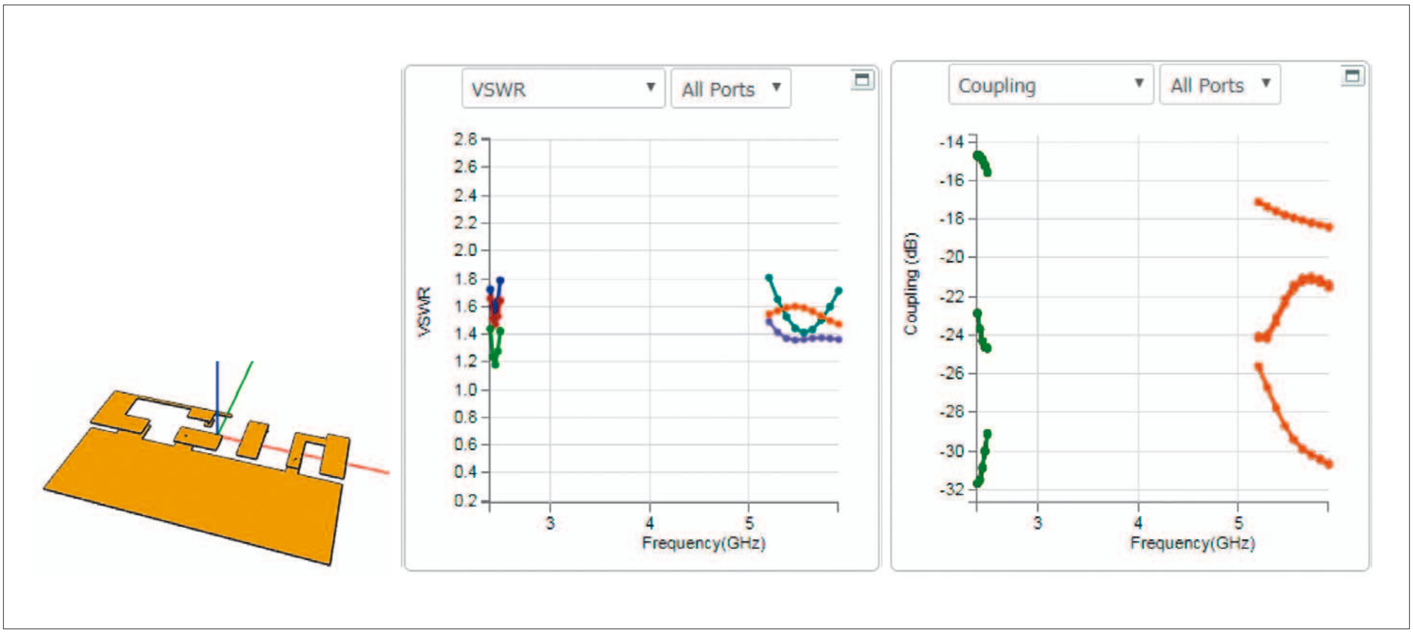

Figure 6: Three-port MIMO antenna performance as predicted by AntSyn software

- Antenna integrated with electronics
- Antennas placed along long edge
- MIMO
- Two or three ports/antennas for transmit and receive on each device
- Maximized isolation between ports to create de-coupled channels

First, a two-port MIMO antenna using the multi-function mesh coplanar monopole type was optimized using AntSyn software. The specifications shown in Figure 1 were used to define the desired performance of the MIMO antenna in this example (note with the exception that a matching network was not used). This particular antenna used air as its dielectric. The resulting antenna and its predicted performance is shown in Figure 4.

This antenna has reasonably good voltage standing wave ratio (SWR) and isolation performance for the dual-band WiFi frequencies for both ports, with a maximum SWR of about 1.8 and a maximum coupling of about -16.5 dB. At the lowest frequency, the antenna edges are separated by less than 0.093 wavelengths and the ports themselves are only 0.41 wavelengths apart. As can be seen, the shapes of these two elements have some similarities, but are not identical. This is expected and helps improve the isolation.

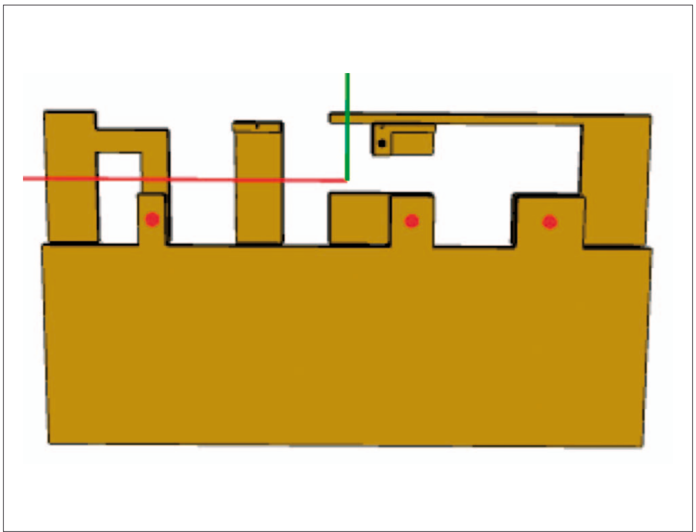

Figure 7: Bottom view of three-port MIMO antenna

This antenna was imported into NI AWR Design Environment, specifically Microwave Office circuit design software, and further simulated using AXIEM 3D planar EM solver across the full range of frequencies from 2 to 6 GHz. The results, shown in Figure 5, match well with the AntSyn predictions, with worst-case coupling of -16.8 dB. Note that although coupling and VSWR do rise in between the Wi-Fi bands, in-band performance is very good.

AntSyn software was also used to optimize a three-port antenna using the specifications and size limitations shown in Figure 1. This time, a matching network was used to help improve performance with the tighter spacing.

The maximum SWR was about 1.8, while the maximum coupling was -14.7 dB, which occurs between the two ports that are closest together, shown in Figure 6 as the right and center ports. Note that the spacing is only 0.163 wavelengths (at 2.4 GHz) between these ports, with a minimum spacing of 0.048 wavelengths between the elements. The distance from the center to the left port in Figure 7 is also only 0.31 wavelengths.

The shapes of these antennas are even more diverse than the two-port antenna. Essentially, AntSyn software created a different antenna for each port and a parasitic fence was placed between the center and left ports. All this complexity was created automatically by the software, demonstrating the inherent strength and robustness of the genetic algorithm to fully explore more of the design space and produce optimal performance MIMO antennas.

Conclusion

Demand is escalating for high-performance, low-cost antennas to provide reliable connectivity for upcoming 5G and IoT wireless devices. AntSyn software automated antenna design, synthesis, and optimization enables designers of antennas, including compact MIMO arrays, to address the challenges of next-generation antenna design and integration within mobile devices and IoT components. ◄