Designing IoT Antennas That Make the Connection

Figure 1: The Antenna Library screen in AntSyn software shows some of the many antenna models that can be used as starting points for design and simulation

Developing cost-effective IoT solutions requires a smart, organized approach to radio and antenna integration within a design flow that includes PCB (and enclosure) characterization, antenna and RF front-end component modeling, impedance-matching network design support, and proper interconnectivity between the design layout and simulation tools.

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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 by engineers with little or no RF design experience.

RF Simulation & EM Analysis

The IoT ecosystem consists of a vast and diverse network of sensors, gateways, and infrastructure operating across different configurations, frequencies, power requirements, and protocols.

NI AWR software provides the RF simulation, EM analysis, and automation to address these challenges from a methodical and low-risk approach. Using a modular design methodology, engineers can focus on combining all the relevant components in the RF signal path, including the supporting PCB substrate and/or the device enclosure, into a hierarchical simulation network for analysis prior to manufacturing and test.

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.

Overview

The many different mechanical and electrical requirements for IoT devices pose challenges for antenna designers seeking the best combination of price and performance. Sensors may one day be everywhere, providing remote monitoring and control of electronic devices by means of the IoT applications. But first, those millions of IoT devices that rely on wireless communications for internet access will need antennas. Among the challenges in designing those many antennas will be the classic tradeoffs of performance for size: since many IoT devices are meant to be completely unobtrusive as they communicate to the internet, antennas will need to be compact.

But such factors as the wireless frequency band, the required communication range of the IoT device, the data upload and download rates between the IoT device and the wireless access point, even the location of the IoT device can all determine the type of antenna that best suits a particular IoT application. To complicate matters, the antenna

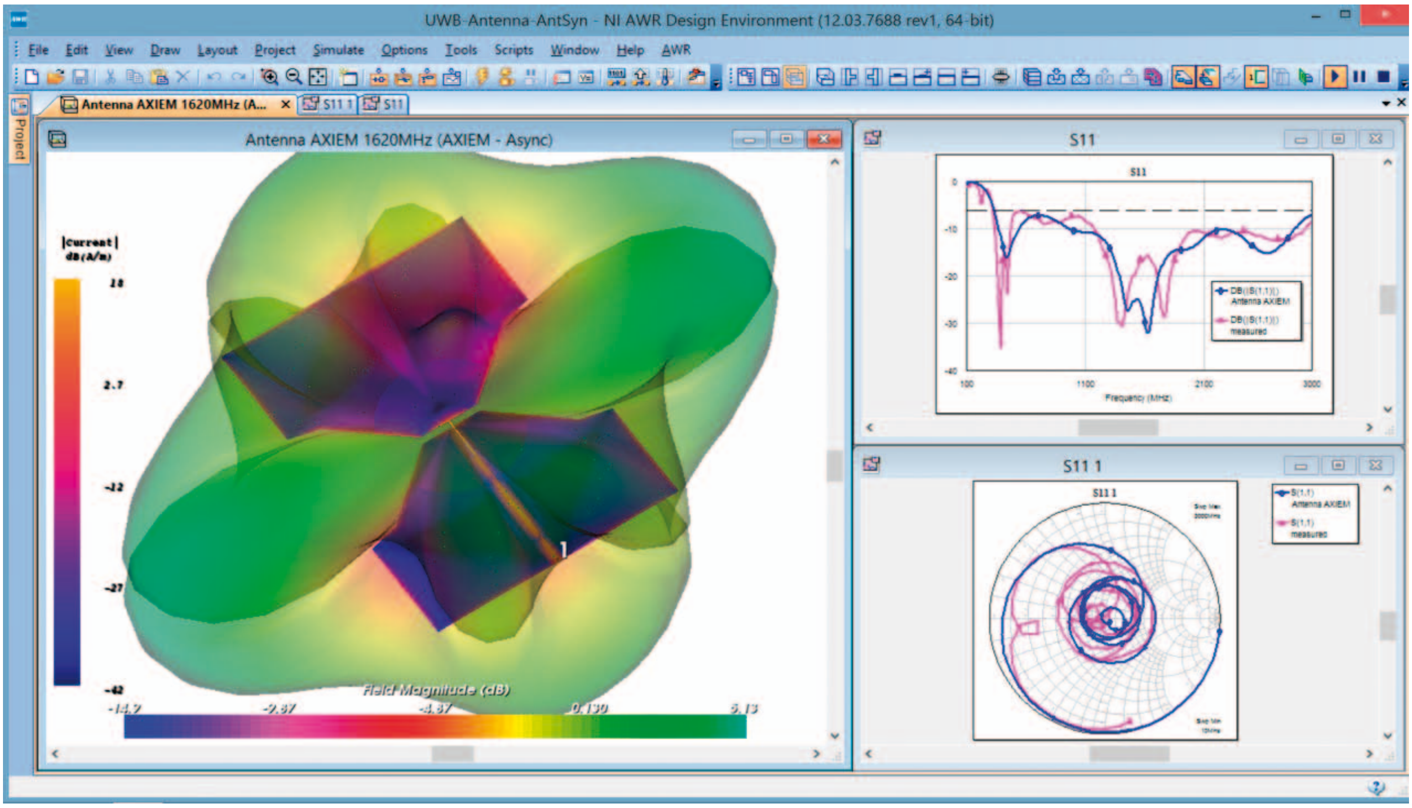

Figure 2: By exporting data from AntSyn software to an EM simulator, detailed 3D field studies can be performed on an antenna design

may have to fit into an IoT device that is small enough to essentially remain invisible.

Market forecasts are predicting millions if not billions of IoT products to be sold during the next half decade, with applications spanning commercial, industrial, and military areas. Devices may be as simple as temperature sensors for remote-control thermostats to more complex security systems in warehouses. Some IoT devices may gain access to the internet using electrical wired or optical connections, but many will rely on wireless communications for Internet access, and the antenna will be a key part of that link.

Wireless internet access for IoT devices will be achieved via existing standards, such as wireless local area network (WLAN) channels (per IEEE 802.11), WiFi, standard Bluetooth, Bluetooth Low Energy (BLE), radio-frequency identification (RFID) channels, even cellular radio signals, using Third Generation (3G) and Fourth Generation (4G) Long Term Evolution (LTE) wireless networks. The choice of wireless access will play a role in the functionality of any IoT device. A wireless standard such as BLE, for example, can provide short-distance wireless communications with extremely low power consumption, remaining active for extended periods on battery power.

Any IoT antenna design must be optimized for the wireless band or bands of interest. Additional capability, such as a BLE-enabled IoT product that operates with energy scavenged from co-located radio signals, can further complicate the antenna design. The various wireless standards offer different capabilities, requiring IoT antennas that support different frequencies, bandwidths, and polarization schemes, resulting in different design strategies. An IoT device, for example, may require access to multiple wireless standards, such as 4G and WLAN/WiFi. Factors such as cost and IoT device package size will help a designer determine if such a case can be handled with a single antenna or if it requires multiple antennas. In addition, the advanced antenna technologies used in some wireless standards, such as 4G's multiple-input-multiple-output (MIMO) technology, used to minimize the impact of interference from surrounding radio waves, can further complicate the design of IoT antennas. Typically, MIMO signals are typically handled by means of multiple antennas or a number of antenna resonant elements in an array pattern.

Narrowband frequency coverage for a single antenna may be sufficient for an IoT design meant to work within a single wireless band. For an IoT device designed to function across multiple wireless standards, such factors as size and cost will help determine the optimum antenna solution. A single wideband or ultrawideband (UWB) antenna may provide the performance required for multiple wireless standards, including reception of global positioning system (GPS) signals for precision location, while multiple more narrowband antennas may be needed to provide the performance needed for all bands.

In some cases, even a single wireless standard may require multiple antennas. For example, an IoT device based on 3G can work with a single antenna while an IoT device using 4G for internet access may need at least two antennas in support of that standard's MIMO technology. Antenna solutions for IoT devices must be small enough to be unobtrusive.

Many IoT devices are meant to be invisible, such as healthcare monitoring units built into USB housings. Internal antennas for such devices must be small, typically with bandwidth optimized for 2.4-GHz WLAN/Wi-Fi use. Some IoT applications are better served by an externally mounted antenna, such as an IoT device that must connect to an access point through a wall. An IoT device's housing can also influence an antenna's mounting point, with a plastic housing resulting in minimal loss for an internally mounted antenna while a metal housing and its shielding characteristics inviting the use of an external antenna.

Sizing Up IoT Antennas

No single antenna is a best fit for all wireless IoT devices. As noted, in some cases it makes more sense to locate an IoT antenna (or antennas) outside of a product's housing, and a simple monopole or dipole antenna may provide the frequency and bandwidth needed to cover multiple wireless bands and standards. But when an antenna must be mounted internally, and size is a concern, a number of miniature antenna types are candidates for single or multiple-band frequency coverage. These include wire antennas, whip antennas, chip antennas, PCB antennas, and integrated-circuit (IC) antennas. Each approach has advantages, disadvantages, and cost differences that may guide the choice of antenna for a particular IoT product design. How do the different miniature antennas for IoT devices compare?

Wire antennas are relatively simple and straightforward to design, as the name suggests, and they are capable of wide bandwidths using a single device. However, the physical size of a wire antenna is wavelength dependent, meaning that, as wavelengths increase with decreasing frequencies, the size of the antenna must also increase. Wire antennas are well-suited for external placement with an IoT module, although they can also be mounted internally given adequate package size. In manufacturing, it can be challenging to achieve good performance repeatability with wire antennas, making them a better match for lower-volume applications.

Whip antennas tend to be the most expensive and largest of the IoT antenna types, although they are capable of excellent performance. As with wire antennas, they typically require a coaxial cable, coaxial connector, and a coaxial launch to connect with IoT PCB-based transceiver circuitry, although the external antenna provides mounting flexibility when installing an IoT module.

Chip antennas are formed by means of metallization on a ceramic substrate, such as low-temperature-cofired-ceramic (LTCC) substrate. These antennas can be made extremely small and treated in IoT circuit assembly much like any SMT component. On the downside, they are limited in bandwidth and efficiency, and sensitive to ground-plane variations.

PCB-based antennas, such as the patch antennas commonly used in mobile telephones, are capable of wideband frequency coverage and relatively low in cost, since they are formed by etching patterns on the same PCB that holds the IoT transceiver. However, a planar antenna can occupy a large area on a PCB and increase the size of an IoT module.

IC antennas are perhaps the smallest but most complex of the IoT antenna options, although such active antenna designs are capable of wide bandwidths and multiple wireless bands. They can be integrated with additional functionality, such as voltage regulation and temperature sensing for stable performance over wide temperature ranges. Like passive chip antennas, they can be mounted like SMT components on a PCB, although they require a power supply and the associated bias circuitry. IC antennas are ideal for high-volume applications, but fabricating such antennas, which requires time at a commercial semiconductor foundry, can be expensive.

Antennas mounted internally in an IoT device, particularly PCB-type antennas, will contribute to that EM environment and will impact the overall circuitry. While the performance of a PCB antenna alone can be known, that performance is never totally independent of an IoT's associated wireless transceiver circuitry, and the combined performance can vary from the measured performance levels of the separate circuit portions.

For this reason, it is useful to take advantage of design help from proven antenna models and computer-aided-engineering (CAE) simulation software before committing to a prototype IoT circuit and antenna design. Such simulation software makes it possible to change input parameters for different design scenarios to better understand the results of the parameters on antenna and IoT system performance. As an example, the software could be used to weigh the performance tradeoffs between a patch antenna fabricated on low-cost FR-4 circuit-board material versus a more expensive PCB material with more tightly controlled dielectric properties.

AntSyn synthesis software within the NI AWR Design Environment platform provides design support beyond standard simulation software. This cloud-based (available online through any standard browser) software-as-a-service (SaaS) provides antenna design, synthesis, and an optimization tool that allows users to see the effects of their requirements on output antenna performance, for many different types of RF/microwave antennas. The flexible and easy-to-use software can design single- and multiple-band, broadband, patch, wire, horn, phased-array, even multi-function and dual-polarization antennas.

AntSyn software uses powerful EM optimization based on proprietary genetic algorithms to explore more design space and accelerate the early phases of the antenna design process (Figure 1). The software features a browser-based interface with intuitive operation. It includes a diverse database of proven antenna design "seeds" with geometries that are effectively modified to meet the desired performance and size requirements entered by the user. If the user does not select an antenna template as a starting point for optimization, AntSyn software will select antenna templates automatically based on the specifications entered.

Performance requirements include frequency, bandwidth, impedance, antenna gain pattern, polarization, and return loss or VSWR, in the form of a blank data sheet for each antenna design. Maximum antenna size can also be specified, along with some basic geometric layout parameters, which is very important for IoT devices. Once AntSyn software is run, it provides completed designs, CAD files such as STEP that can be downloaded, and simulated results in familiar formats, such as gain versus frequency and return loss versus frequency, for ease of comparison with measured results (when building that prototype).

For those who need further analysis, AntSyn software can export design data to commercially available EM simulation software (Figure 2). For higher-level simulations, the tool can export data to full-featured circuit/system simulation software tools within NI AWR Design Environment software, where EM simulations of an antenna design such as a PCB antenna can be combined with simulations of the active circuitry of an IoT module to gain insights into the interactions between the antenna and the IoT transceiver circuitry.

Conclusion

Antennas are often one of the last components considered in the design of an IoT product, although the choice of antenna can have an impact on the size and performance of the IoT device. Fortunately, software design tools such as the AntSyn antenna synthesis and optimization tool provide designers with an efficient tool to quickly explore different antenna types, different layout/geometry choices, and design parameters prior to committing to a physical prototype. The software makes it possible to try different antenna types when searching for the best match for the target IoT system performance parameters and wireless bandwidths. ◄