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11 Myths About Antenna Design

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Dustin Moore Kyle Sporre
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Antennas are mandatory for a product to connect via radio frequency. Obvious examples are cell phones, satellite communications, and even our garage-door openers. But the Internet of Things is connecting less-obvious devices, such as thermostats, parking meters, wearable devices, even dog collars, and in turn bringing sweeping change to almost every industry by connecting products that previously were never connected. And it's all done wirelessly, untethered to any wire or cable.

When it comes to these modern connected devices, industrial designers and device manufacturers such as Apple have made an art form of hiding a critical component—antennas—to the point where they've largely disappeared from view. As a result, the majority of users simply take them for granted. But antennas are perhaps often the most confusing, overlooked component and a common failure point in wireless design.

The following are 11 common myths about antenna design:

1. Antenna design can be put off until after the industrial/mechanical design.

Antenna performance relies heavily on antenna size and frequently on the size of printed-circuit-board (PCB) ground planes. All too often, a wireless product with subpar performance may even fail network operator approvals due to a poor-performing antenna.

Usually, the only option for improving antenna performance is to create more space for the antenna and/or ground plane, meaning the industrial design must change. To avoid industrial or mechanical redesign, extra PCB spins, and project delays, and to keep your boss happy, think of the antenna implementation from the very beginning of a project. It's the most important component in your wireless device and should not be taken lightly.

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2. Chip antennas perform well regardless of PCB size.

Chip-antenna performance depends a lot on ground-plane size. As ground-plane size differs vastly from the antenna evaluation board, antenna efficiency and bandwidth will suffer. When using a chip antenna, it's

›ortant to follow the datasheet or application note carefully and use a PCB size very similar to the antenna luation board.

3. Dipole antennas are always better than monopole antennas.

Dipole antennas are balanced structures and thus have less radiating currents on coaxial-cable shields. This results in more consistent performance than monopoles that don't have a significant ground plane to keep currents off the cable shield. However, monopoles can be smaller than dipoles, since they can utilize a PCB ground plane or metal chassis as the other half of the antenna without compromising performance.

4. A well-matched antenna will perform well.

Impedance matching represents only half the antenna story. Total antenna efficiency depends on mismatch losses, matching network resistive losses, and radiation efficiency. A purely resistive match (e.g., 50-Ω resistor) may provide very good return loss and low mismatch loss, but the resistive losses will dwarf the overall performance. It's very important to perform far-field testing at a calibrated antenna range in order to determine total antenna efficiency and ensure good radiation characteristics.

5. Matching networks should be avoided.

Matching networks provide a means to transform a non-50-Ω antenna impedance to 50 Ω, or any other impedance for that matter. Yes, matching networks have losses due to finite Q values of inductors/capacitors, but they provide a good contingency plan for antenna implementations that don't work out to be the ideal impedance of 50 Ω. Bottom line: If you don't provide options for an impedance-matching network, you may have a severely detuned antenna, which leads to additional PCB spins in order to add the required matching network or change the antenna.

6. Matching networks should always be used.

Matching networks offer a contingency plan for mismatched antennas; however, some applications are better off without matching-network options. When the number of devices sold is expected to be in the hundreds of thousands or even millions, removing a single surface-mount component from the assembly process may save a considerable amount of money.

A typical scenario is a Bluetooth printed antenna that can be tuned instead of impedance-matched with surface-mount components. Yes, an additional board spin may be necessary to tune the antenna; however, eliminating the need for one to three surface-mount components could save tens of thousands of dollars over the life of a product.

7. High-Q wirewound inductors should always be used in matching networks.

High-Q inductors do have less loss than their ceramic or thin-film counterparts, and will provide lower transmission losses when using matching networks. However, it's sometimes better to use a more lossy inductor. For example, electrically small (longest dimension is less than 1/2π of wavelength) antennas have a very high Q and narrow bandwidth. A small change in antenna dimensions, the materials surrounding the antenna, or the inductance value of a matching network could significantly detune the antenna.

For more consistent performance, use a ceramic or thin-film inductor to help increase the impedance bandwidth at the expense of additional loss. While peak performing devices may be slightly compromised, the variability in device performance will be much lower in this scenario. The other option would be to use a resistor in the matching network to reduce the overall Q. It's important to be cautious with this option, since a resistor will improve the match but directly affect overall losses.

Antenna efficiency is paramount regardless of the application or technology.

Some technologies such as cellular require high antenna efficiencies to get network-operator (VZW, AT&T, Sprint, etc.) approval. Other technologies using unlicensed spectrum like LORA, 802.15.4, or Wi-Fi don't have antenna requirements but still need regulatory approval such as FCC. However, the FCC doesn't impose antenna efficiency requirements. This means that it's possible to sell a FCC-certified LORA, 802.15.4, or Wi-Fi product that meets the application requirements with an underperforming antenna. This helps explain why some products perform better than others.

9. More gain equals less pain.

Antenna gain is a measure of how much energy is radiated in any given direction. An antenna with higher gain will be more directional. An omnidirectional antenna with low gain (e.g., 0 dBi) is a well-performing antenna that radiates in all directions (in at least one plane). A directional antenna like that of a satellite dish, might have a gain of 30 dBi, which means most of the energy is radiated in a single direction.

High-gain antennas may actually cause FCC and other regulatory failures. For example, FCC part 15.247 allows a maximum EIRP of 36 dBm. Therefore, if conducted output power is 30 dBm or 1 W, the antenna gain must be under 6.0 dBi for compliance. With 15.247, it's possible to simply reduce the output power to comply with a higher gain antenna; however, FCC part 22 or part 24 (licensed cellular bands) would not be as easy to comply with.

10. Wearable applications should use loop antennas.

Loop antennas are inherently less susceptible to dielectric losses or detuning than dipoles or monopoles due to the near fields being predominantly magnetic instead of electric. Since the body consists of mostly salt water, which is a lossy dielectric, it will absorb RF energy and attenuate electric fields. However, the amount of absorption really depends on frequency of operation. As frequency decreases, water becomes less lossy. And with some applications, a monopole antenna may prove worthy. Also, loop antennas typically require more space than monopoles, which translates into size/performance tradeoffs.

11. Lower frequency means more range.

Lower-frequency waves will generally propagate through materials more easily than higher-frequency waves. Yet, lower frequency doesn't necessarily mean less path loss. It just means that lower antenna gain is required to capture the same amount of power. The amount of power received is directly proportional to the effective aperture. The formula below represents the effective aperture of an antenna:

$$A_e = \frac{\lambda^2}{4\pi} G$$

where λ is wavelength and G is antenna gain. As frequency increases, wavelength decreases and so too does effective aperture. However, increasing frequency also means more antenna gain can be realized for a given antenna volume. For line-of-sight wireless links, higher frequencies can be used to communicate over great distances with one caveat: The antenna designer must create enough antenna gain to close the link.

As more and more products become wirelessly enabled, decisions surrounding antenna design will have increasingly important implications for PCB and industrial designs. Not being aware of the most common myths surrounding antenna design may delay design decisions and significantly impact time-to-market and elopment costs.

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