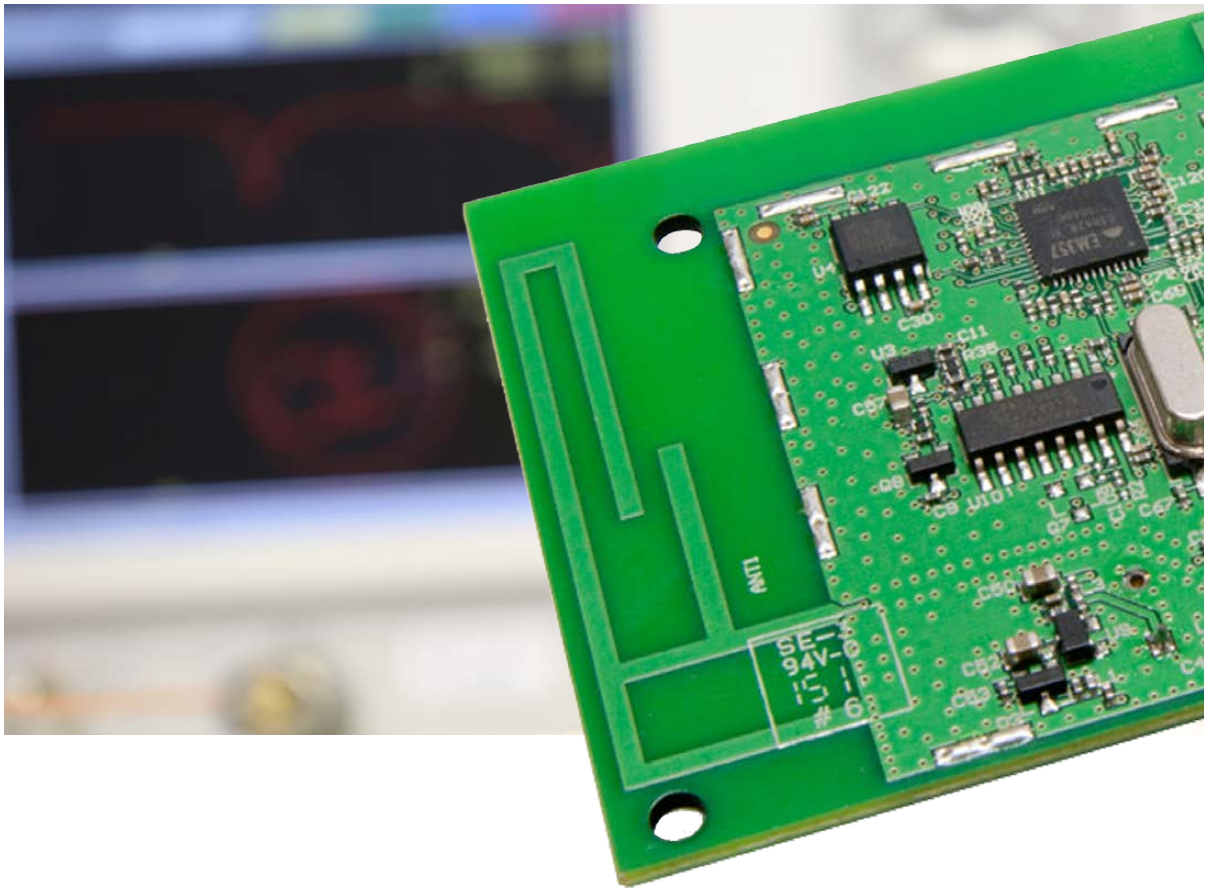


TOP 10 ANTENNA-DESIGN CONSIDERATIONS



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 is bringing sweeping change to almost every industry by connecting products that previously were never connected.

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 – so much so that they have largely disappeared from view and users take them for granted. But antennas are often the most confusing, overlooked component and a common failure point in wireless design.

1 Start Early

Antenna performance is heavily dependent on antenna size and frequently on the size of printed circuit board 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 is the most important component in your wireless device and should not be taken lightly.

2 PCB Size and Layout Will Affect Antenna Performance

Chip antenna performance is highly dependent 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 important to follow the datasheet or application note carefully and use a PCB size very similar to the antenna evaluation board.

3 How to Choose the Right Antenna (What's the difference between a dipole and monopole?)

Dipole antennas are balanced structures and thus have fewer 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 Balance Antenna Matching With Efficiency

Impedance matching is only half the antenna story. Total antenna efficiency is dependent on mismatch losses, matching network resistive losses, and radiation efficiency. A purely resistive match (e.g. 50Ω resistor) may provide very good return loss and low mismatch loss, but the resistive losses will dwarf the overall performance. It is 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 Options for an Impedance Matching Network

Matching networks provide a means to transform a non-50Ω antenna impedance to 50Ω, 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 50Ω. Bottom line: if you don't provide options for an impedance matching network, you may have a severely detuned antenna leading to additional PCB spins in order to add the required matching network or change the antenna.

6 Some Applications Are Better Off Without Matching Network Options

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 1-3 SMT components could save tens of thousands of dollars over the life of a product.

7 High-Q Wire-Wound Inductors Should Always Be Used in Matching Networks

High-Q inductors decrease loss when compared with their ceramic or thin-film counterparts and will provide lower transmission losses when matching networks are used. However, it is sometimes advantageous to use a more lossy inductor. For example, electrically small (where the longest dimension is less than $1/2\pi$ 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 as a result. 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, as a resistor will improve the match but has a direct impact on overall losses.

8 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 under-performing antenna. This helps explain why some products perform better than others.

9 The More Gain the Antenna Has, the More Directional It Is

Antenna gain is a measure of how much energy is radiated in any given direction. An omni-directional antenna with low gain (e.g. 0dBi) 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 30dBi, 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 36dBm, so if conducted output power is 30dBm or 1 Watt, the antenna gain must be under 6.0dBi 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 pass.

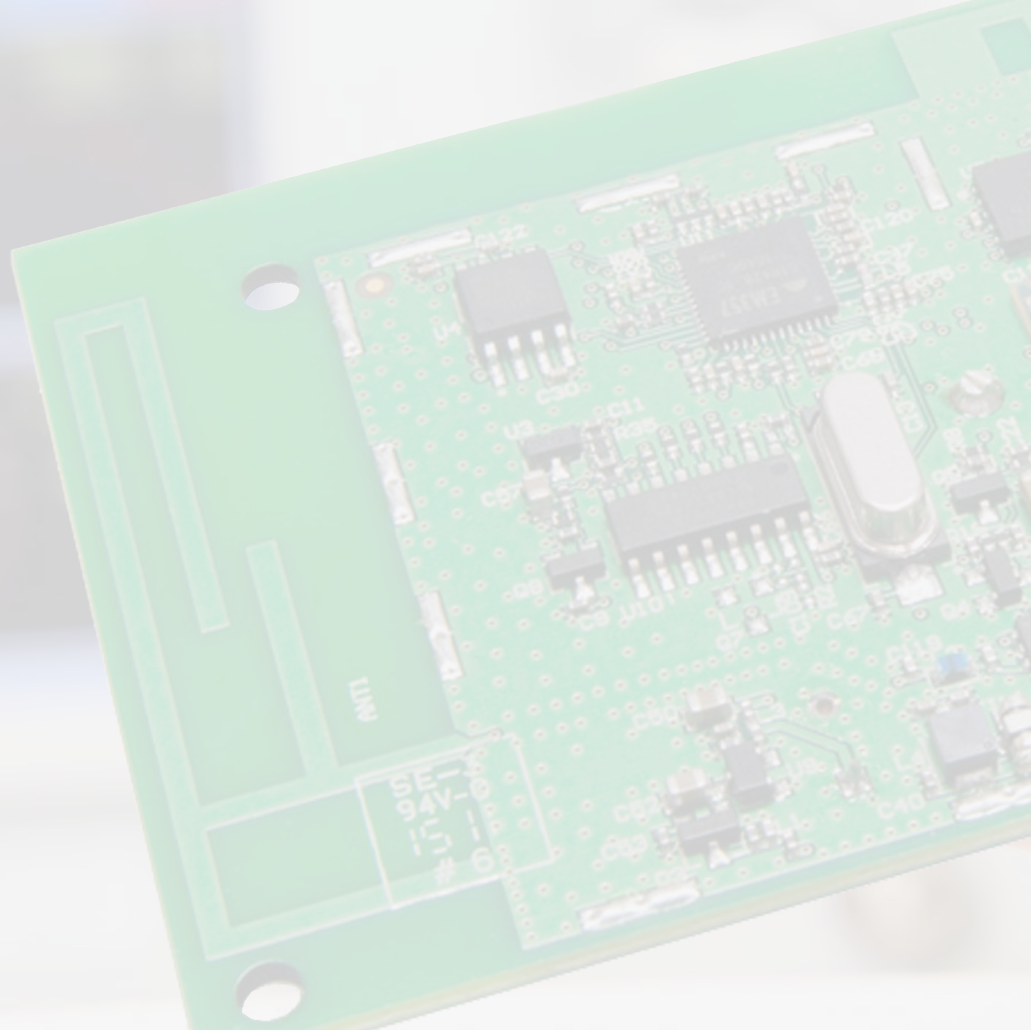
10 Lower Frequency Doesn't Necessarily Mean Less Path Loss

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 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 effective aperture of an antenna is defined as follows:

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

Where λ is wavelength and G is antenna gain. As frequency increases, wavelength decreases and so does effective aperture. However, as frequency increases, 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 around antenna design will have increasingly important implications for PCB and industrial designs. It is critical that antenna design is carefully considered early in the development cycle to avoid costly delays and design changes that may have a significant impact on time-to-market and development costs.



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