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Antenna Evolution
From visible to invisible Antennas

Do you remember the days when mobile phones had large, protruding antennas? These eye-catching designs are almost unimaginable today, as modern smartphones seamlessly integrate their antennas into the casing. But how did this transformation happen?

Have the underlying physical principles fundamentally changed over the past decades?

The answer may surprise you: Although the fundamental laws of physics have remained the same, technological advancements have enabled impressive miniaturization and integration of antennas. However, this progress doesn't mean there are no challenges – quite the opposite. Integrating tiny antennas into compact devices requires a deep understanding of physics and innovative approaches to minimize inevitable trade-offs.

Small Antennas – Big Challenges

Space is a valuable commodity in modern electronics. Whether it's wearable devices, IoT sensors, or other compact systems, developers constantly face the challenge: How can an antenna be made as small as possible without sacrificing efficiency and bandwidth?

Unfortunately, physics imposes clear limits – reducing antenna size inevitably comes with trade-offs. The behavior of an antenna is governed by physical laws, particularly those described by the antenna equation:

Sine Dependence (sin θ): This describes how the signal radiates in different directions. Reducing the size of the antenna alters this angle, affecting the radiation pattern.

Exponential Component: This determines how rapidly the signal decays in space. Smaller antennas often result in higher attenuation and lower efficiency.

$$\sin(\Theta) * \int_{z=-\frac{L}{2}}^{z=\frac{L}{2}} I(z) e^{jkz\cos(\Theta)} dz$$

The mathematical models show that any reduction in antenna size directly affects the radiation efficiency..

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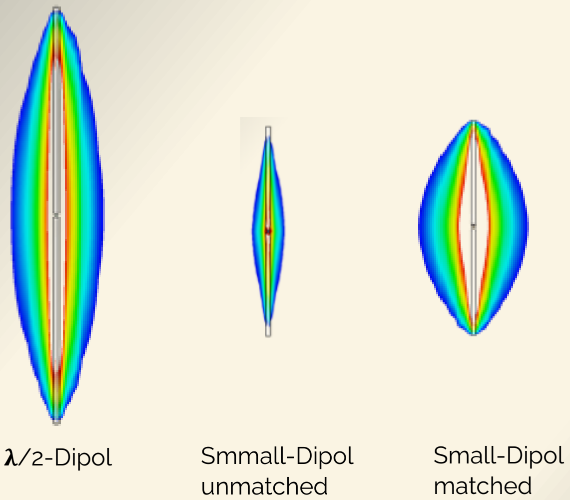
Why does miniaturization lead to efficiency losses?

The answer lies in the current distribution within the antenna. Resonant antennas generate standing waves, where the loss resistance increases relative to the radiation resistance as the antenna is miniaturized. The result: increased losses and reduced efficiency – even with low loss resistance.

The current distribution on small dipoles shows significant differences between matched and unmatched antennas. Without matching, substantial efficiency losses occur.

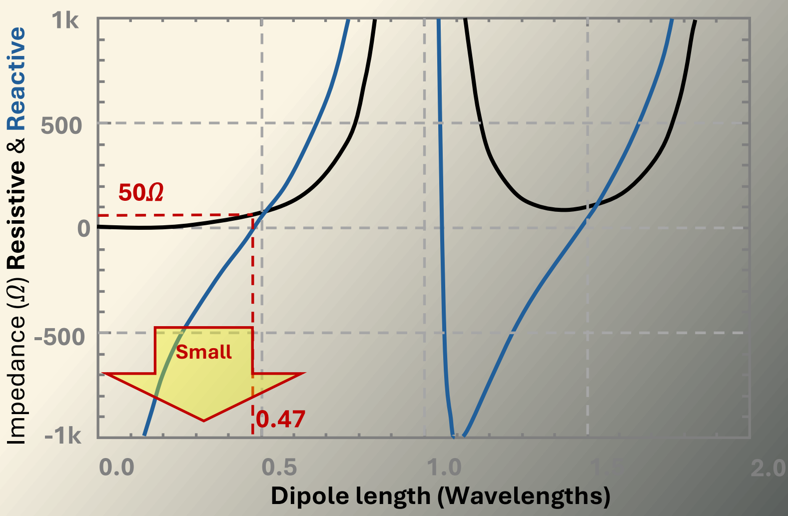


Additional Challenge: Impedance Matching

Another issue with small antennas is impedance matching. The smaller the antenna, the harder it becomes to achieve effective matching. This often results in severely limited bandwidth or significant efficiency losses. Impedance matching becomes particularly challenging for small antennas. The graphic illustrates how matching efficiency decreases as the size is reduced.

Are physical limits the obstacle for ultra-compact IoT devices?

The world of IoT technology demands increasingly smaller devices. From asset-tracking solutions to wearable electronics – the requirements for antennas in these systems are immense. Design limits are especially tested at sub-1 GHz frequencies.



The Challenge of Miniaturization

The challenges faced by IoT devices today are strikingly similar to those of the first smartphones: multiple antennas must deliver high performance in minimal space. The difference? While smartphones are getting larger to accommodate bigger displays, IoT devices must become smaller as they are worn on the body – think smartwatches or fitness trackers.

Additionally, network operators are increasing pressure to transition to 4G, especially in the U.S., where 3G products are rarely approved anymore. Although 4G is essential for smartphones, most IoT devices transmit only small data packets, utilizing just a fraction of 4G's capacity. However, these lower frequencies pose significant challenges for antenna and PCB designs.

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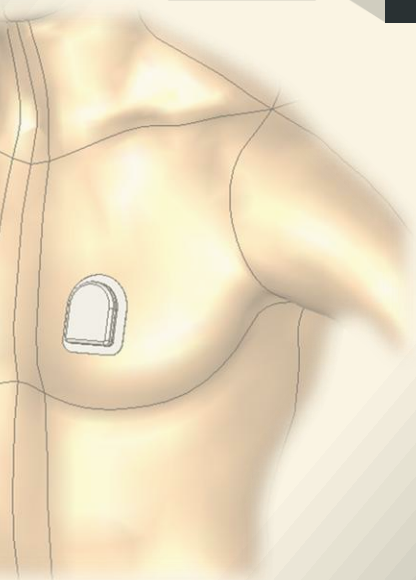
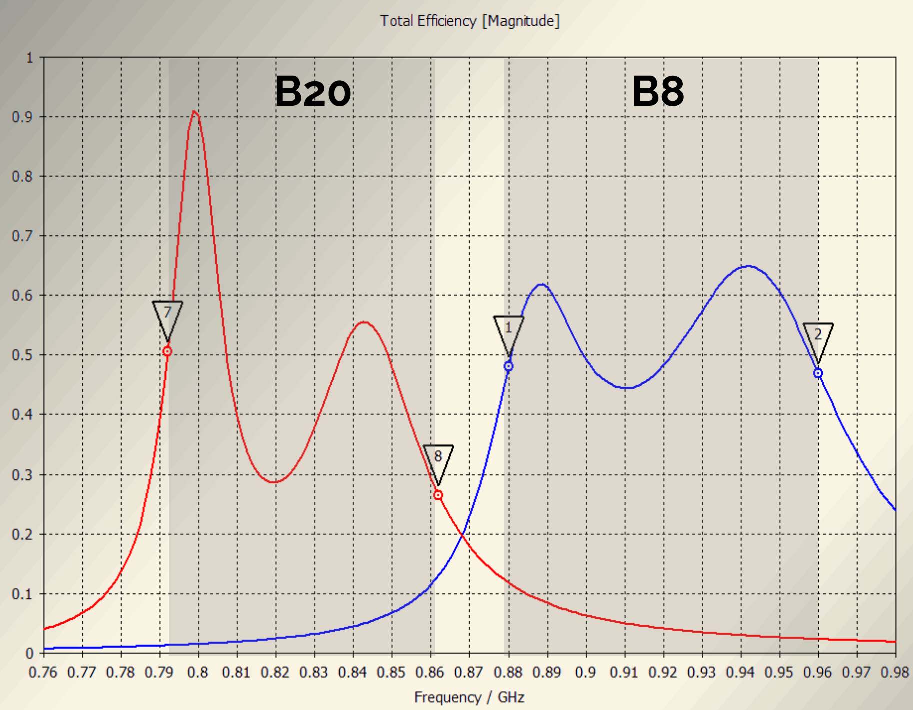
Advanced Antenna Solutions for Ultra-Compact Wearable Medical Devices

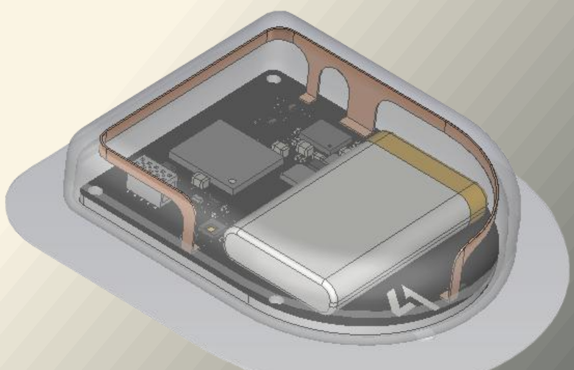


Modern wearable medical devices for health monitoring are small, lightweight, and discreet – but their performance heavily relies on the efficiency of the built-in antenna technology. Whether continuously tracking vital signs or wirelessly transmitting body sounds, these devices must deliver reliable, real-time data from various body positions.

For cellular technologies like NB-IoT and LTE-M – particularly in the demanding primary bands B20 and B8 – we develop highly innovative antenna solutions that excel even in devices as small as 40 mm x 45 mm. While conventional designs often achieve efficiencies below 15%, our technologies enable antenna efficiencies exceeding 30%.

This ensures that even the smallest medical devices communicate reliably, even in frequency ranges that challenge compact designs – enabling precise, continuous health monitoring without compromise.





Conclusion: High Performance despite Miniaturization

Designing embedded antennas is a challenging art, especially with the difficulties of sub-gigahertz frequencies. Balancing compact form with excellent performance requires precise design and innovative approaches. This is where Quarterwave comes in: We provide customized solutions that not only guarantee maximum physical performance but also successfully pass all stringent network certifications.

Trust Quarterwave to bring your visions to life with no costly delays and with the highest efficiency. Together, we'll elevate your antenna designs to the next level – ready to shape the future of connected technologies.

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