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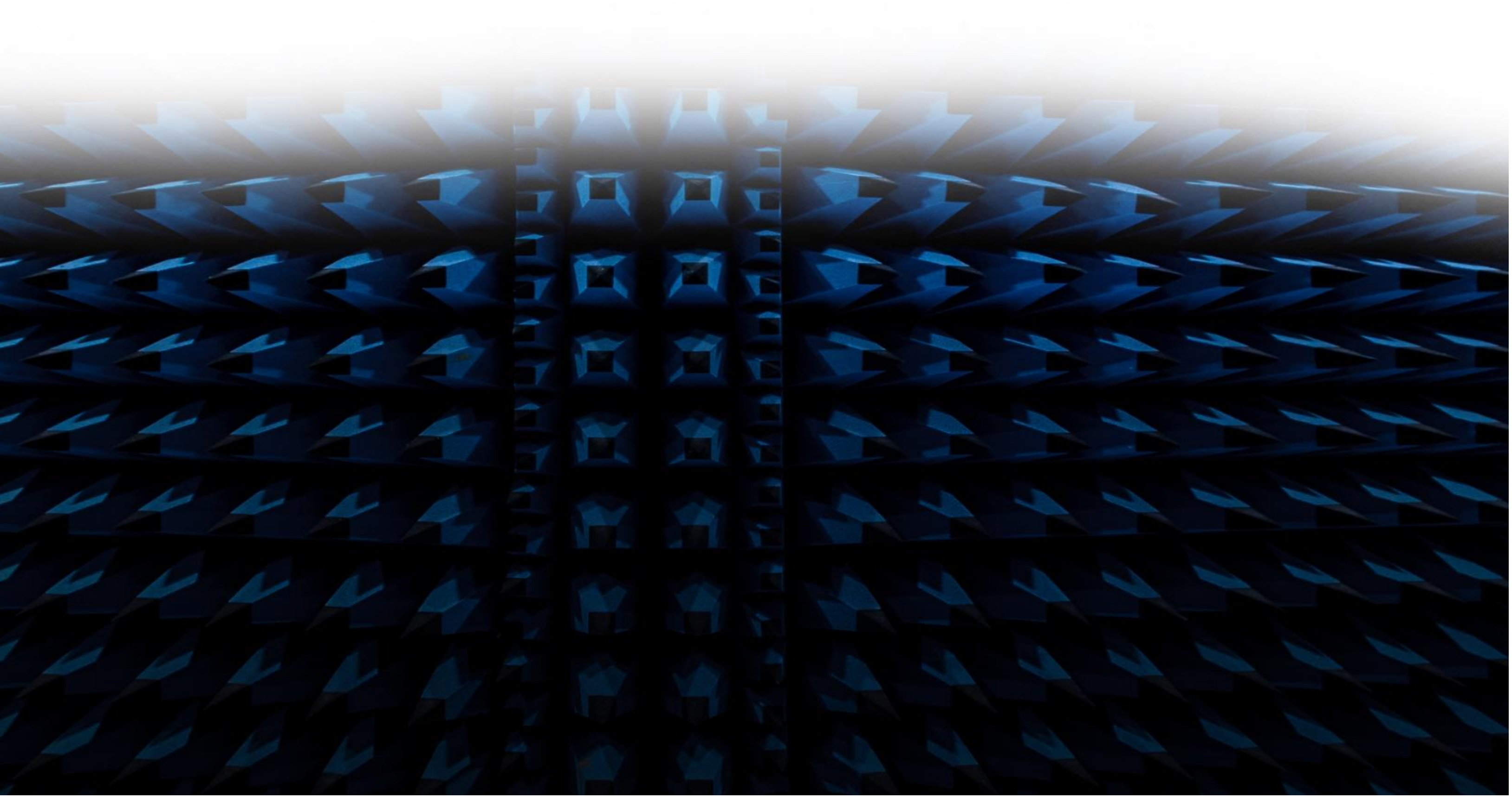
Choosing an Embedded Antenna



Introduction

When it comes to selecting an embedded antenna for your wireless product, the options can sometimes seem overwhelming. There are a myriad of antennas available with various shapes, sizes, performance and costs, so how do you select the best type for your product?

It's been my experience that the primary selection criteria for mobile and wearable products is usually size, with cost and performance being secondary considerations. For larger products, the emphasis is far more likely to be on cost and/or performance. There is certainly no one size fits all solution, however, with a little thought, it's possible to considerably narrow the options. In this article, I describe some of the most common embedded antenna types used in portable wireless products.

The Chip Antenna

At first glance, the chip antenna would appear to be the smallest and most simple antenna solution. However, first impressions aren't always accurate. Firstly, many chip antennae require much more 'free' board space than their mechanical dimensions suggest. Although there are some exceptions, many chip designs need significant ground clearance and careful PCB ground plane management to ensure optimum performance. The ground clearance requirements are often very specific and it's important to strictly adhere to the manufacturers layout rules.

Figure 1 - A 5 GHZ W-LAN antenna from TDK

The size reduction realised in a chip antenna is obtained by using a high-permittivity low-loss dielectric substrate, but this magical size reduction doesn't come for free. Fundamentally, the bandwidth of an antenna decreases as its size is reduced. Hence the smaller ceramic chip antennas tend to exhibit relatively narrow bandwidths and even when correctly tuned, the bandwidth is often just wide enough to maintain a reasonable performance across the frequency of operation. Matching or 'tuning' the antenna is therefore of upmost importance.

The antenna tuning circuit is essentially an impedance matching network that matches the antenna's impedance to the input/output impedance of the RF circuitry (usually 50 ohms) to ensure maximum power transfer. Obtaining a good match is a relatively complex task and should be done using a high-quality Vector Network Analyser.

It's difficult to provide radiation efficiency information for this type of antenna as it is not often quoted by the manufacturers, but typical efficiencies of between 40% and 80% are obtainable, depending on size and application. As with all antenna types, multiband antennas tend to be less efficient than signal frequency solutions. Cost is also highly variable, with some very simple devices costing just a few cents, whilst more complex offerings can be several dollars!

It's also worth noting that the chip is only half of the antenna, with the PCB ground plane forming the other half. Most manufacturers' data sheets will provide reference data for gain, bandwidth and radiation patterns for a specific size of 'ideal' ground plane, which may not be realisable within the constraints of your own product. Deviation from this ideal will impact performance and correctly tuning the antenna for the actual ground plane geometry is essential.

That's not to say that chip antennas don't have their place. When space is very limited or when complex multi-band solutions are required within a small volume, they are often the only choice. That said, in over thirty years of antenna design, I've only resorted to using a chip antenna in two products. In most situations, there is a lower cost, more efficient solution available.

It's safe to say that chip antennas cannot be treated like any other SMD device. Optimising the performance of a chip antenna is similar to that of any other antenna and to describe them as a 'drop in solution' as some literature would suggest, is somewhat misleading.

Primary chip antenna manufactures include Antenova, Ethertronics, Johanson Technology, Taiyo Yuden, TDK and Walsin.

The Monopole

The basic monopole is not the most obvious choice for an embedded design because of its physical size. You certainly wouldn't want to use a straight PCB trace monopole unless you had a significant amount of free PCB space available. However, the basic monopole structure can be varied to produce a more compact solution. For example, the monopole can be reshaped to produce a meander line antenna shown in figure 2

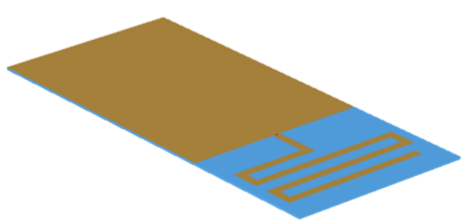


Figure 2 - Printed Meander-line monopole antenna

A monopole antenna can also be integrated with other wiring within a product and I've seen this technique used several times on wireless headsets, where the microphone boom wires have also been used to form a monopole. Obviously, care must be taken when combining the two signals and blocking techniques must be employed to prevent interference. However, if done correctly, the results can be extremely effective.

Because of their large physical volume, the radiation efficiencies are usually in the high 90%'s. If your product has the space, or lends itself to integrating the antenna with existing wiring, the monopole could be the optimum choice. Sometimes, simple is best.

The Inverted F (IFA)

So called because of its shape, the Inverted F Antenna (IFA) and variations of it, are probably the most common of the embedded antennas. The majority of smart phones and wireless devices sold today are likely to use one or more inverted F's, even though visually, the antennas sometimes have little resemblance to an F shape.

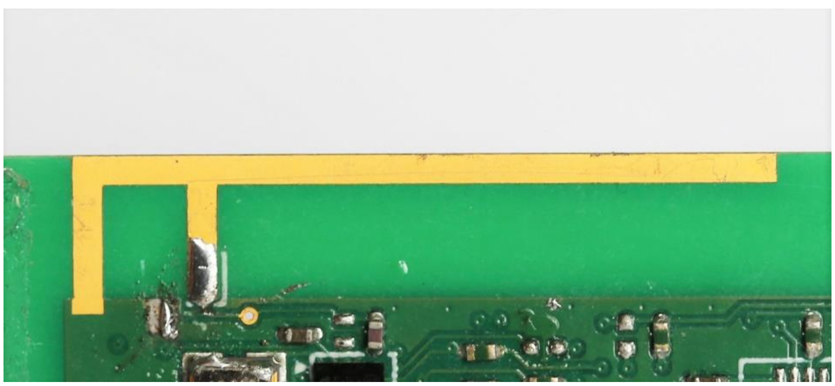


Figure 3 – The classic single frequency IFA antenna

The inverted F is essentially a folded monopole with an inductive stub added to offset the capacitance introduced by locating to antenna element closer to the ground.

The most recognisable version of the IFA is the single frequency PCB trace version shown in figure 3. There are however multiple variations on this theme. They can be situated off-board using Flex PCB technology, formed metal structures or created using selective metallization techniques to print the antenna trace directly onto the product case plastics or a separate internal plastic former. The IFA can also be designed to deliver multiband operation by stacking two or more F type structures or the trace can be meandered to reduce its size.

Selective metallization is extensively used in mobile phones and is often used to combine multiple antennas on to a single plastic substrate. Other antenna types such as loops, Inverted L's and monopoles can also be used side-by-side with the IFA to support the multiple radio technologies contained within today's mobile devices.

Selective metallization processes, such as Laser Direct Structuring (LDS) and two shot molding are not cheap however, and are probably only viable for relatively high-volume production. The ability to integrate the antenna into the product case plastics is a real plus, so when space is at a premium, the use of these techniques should not be ruled out.

Figure 4 - 3D LDS antennas from Molex

The basic PCB trace IFA is very popular with designers' due to its relative simplicity, large bandwidth, good efficiency, ease of tuning and of course cost. While not free, the cost of the extra PCB space required to incorporate an IFA is usually tiny when compared to the overall bill of materials for a wireless product. As mentioned previously, operational bandwidth of an antenna is a function of its physical volume, so the larger the structure can be made, the wider the bandwidth. Sufficient bandwidths for most radio systems can be achieved with the antenna trace positioned just a few mm from the PCB ground plane, so physical volume requirements aren't usually too onerous. Radiation efficiencies in the low to mid 90%'s can easily be achieved and the input impedance can be designed to ~50 Ohms, which removes the requirement for matching circuitry.

IFA's are usually custom designed to fit within the available PCB space or product geometry. The design costs are small once amortized over the product's life cycle and if a PCB trace based design is selected, the IFA can be a very effective and low-cost solution.

Planar Inverted F Antenna (PIFA)

Although it has a similar name to the IFA, the Planar Inverted F Antenna is in fact a very different animal. Where the IFA is related to the monopole, the PIFA is related to the Patch antenna.

As the name suggests, the PIFA structure is positioned planar to the PCB. This provides the antenna with an increased physical volume and hence a wider bandwidth than the IFA. In addition, as the PIFA can use air as it's dielectric rather than a lossy PCB material, it tends to be slightly more efficient.

Like the off-board IFA, PIFA's can be constructed from formed metal (usually Tin) or using Selective metallization techniques on a plastic former. The size can be reduced by replacing the air gap between the metal structure with a dialectic material, though at the expense of bandwidth and efficiency.

The PIFA also has less radiation through the ground plane, which if used in a mobile phone or wireless headset, can help reduce the amount of 'wasted' RF energy sent towards the users' head and hence help reduce the Specific Absorption Rate (SAR) of the device.

Figure 5 – A metal PCB Mounted PIFA antenna from San Jose Technology Inc.

Like the IFA, PIFA's are normally custom designed to fit within the product's geometry. If your product's antenna requires a small amount of directivity or you have sufficient planar space, a simple Tin based solution with an air dielectric can provide a very cost effective option.

Patch Antenna

The patch antenna is seldom used in portable equipment and is far more likely to be found inside a base stations or wireless access points. The two main exceptions being GPS and RFID applications.

Figure 6 - Galileo/GPS antenna from 2J Antenna

Ceramic patch antennas are often used in GPS location devices such as, trackers and Car Sat Navs and in portable RFID scanners primarily because of their directivity. As with all the other antennas, the lager they are the better the tend to perform, with typical directional gains ranging between 1dbi and 6dbi.

As with all antennas, correct tuning is essential, however, small ceramic patch antennas tend to have particularly narrow bandwidths, sometimes just a few MHz. This makes tuning critical and very careful attention should be paid to manufacturers' mounting and ground plane specifications.

Patch antennas can also come with either Left or Right Hand Circular Polarisation (LHCP or RHCP), so it's important to select the correct type for your application.

Cost range from around a dollar to serval tens of dollars for higher performance solutions.

Manufacturers include 2J Antenna, Abracon, Laird and Taoglas

Key Takeaways

This article was not intended to be a comprehensive review of all the possible embedded antenna choices, but hopefully it will provide guidance on some of the more popular options.

When it comes to embedded antenna design, there are no one size fits all solutions. Variations in product to product ground size and geometry mean that even the 'off the shelf' offerings require some level of tuning.

If your product has sufficient space for either a IFA or PIFA then this will almost certainly be the most efficient, lowest cost solution in the long term. If you are very limited on space, then a chip antenna may be the only option. However, careful positioning and tuning are still essential for optimum performance.

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