PCB Trace vs. Chip Antenna Design Considerations

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Introduction

The modern urban environment poses a challenge to high-speed designs involving Cellular, GNSS, WiFi/ Bluetooth/BLE/ZigBee and LPWA protocols: the reflection, refraction, scattering, diffraction, polarization and absorption of signals necessitates highly efficient RF chains. Of all components in the chain, the antenna has the key role in establishing wireless connectivity.

A PCB trace antenna is given serious consideration when attempting to reduce the overall system cost; however, chip antennas offer better overall performance in terms of size selectivity and efficiency in most cases. The following information outlines the attributes of both chip and PCB trace antennas. It also covers the design considerations required in selecting the right type of antenna to implement in your design.

Which structures are typically employed in PCB trace antennas?

Inverted-F (IFA), Planar Inverted-F (PIFA) and Meandered Inverted-F (MIFA) structures are commonly considered for trace antenna designs because they are ideally suited when board space is limited and are also low-cost solutions.

How is the trace antenna designed?

The above-mentioned antennas are monopole designs with a quarter wavelength (λ/4) at the resonant frequency. Monopoles require a ground plane, which forms the other quarter wavelength to radiate efficiently. The antenna should be designed with no ground plane beneath the trace structure. The electric performance depends on the dielectric substrate material (e.g., FR4), dielectric constant (εr) and substrate thickness (h). The radiation pattern is nearly omni-directional.

How can we reduce the size? What are the trade-offs?

In order to reduce the size of trace antennas, quarter wavelength designs are preferred with arms short to the ground plane. Figure 1 presents a typical PCB trace inverted-F antenna layout.

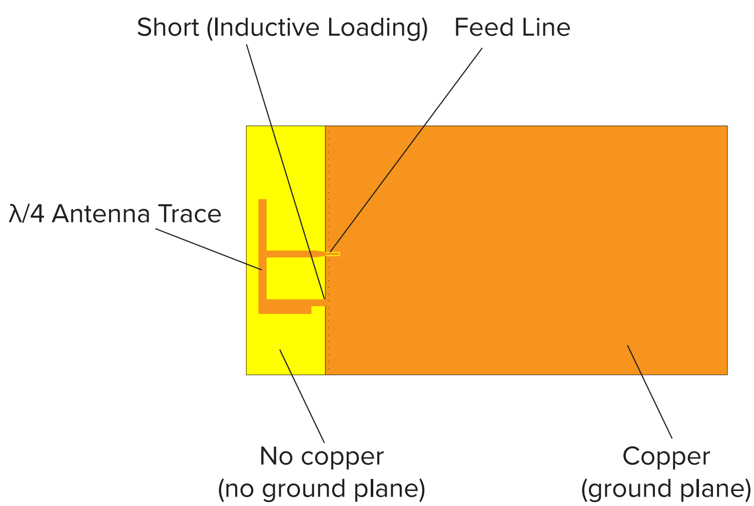

Figure 1

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It should be noted that loading increases the Q of the antenna, which consequently reduces the effective bandwidth.

$$Q = F/BW$$

Where Q = Quality Factor, F = Resonant/Center Frequency and BW = Antenna Bandwidth

Furthermore, the overall radiation efficiency decreases as the surface area shrinks.

What are the disadvantages of having a PCB trace antenna?

The two common disadvantages associated with designing antennas are lower frequencies and with wider bandwidths.

Lower-frequency trace antennas are challenging from a size perspective because the design demands quarter wavelength structures with ground plane to support effective radiation characteristics. For instance, the quarter wavelength (λ/4) of 433 MHz is 172.5 mm. PCB trace antennas at lower frequencies, such as 433 MHz, become physically large when directly designed onto the PCB, as opposed to utilizing a chip antenna.

For cellular designs, it is challenging to cover a wide frequency range of 698~960 MHz, 1710~2170 MHz, and 2500~2700 MHz and still match the lowest LTE bands (698 MHz) with a PCB design.
In such cases, chip antennas serve as the best alternative

How do you implement a chip antenna into a design?

Several factors contribute to the performance and radiation characteristics while designing a chip antenna onto a PCB: the PCB size, the PCB layout, the ground/clearance space dimensions, the tuned matching circuit, the RF shielding and the housing. When implementing an off-the-shelf chip into a design, closely follow the reference layout design to avoid any de-tuning or performance variation. Figure 2 illustrates a typical chip antenna layout.

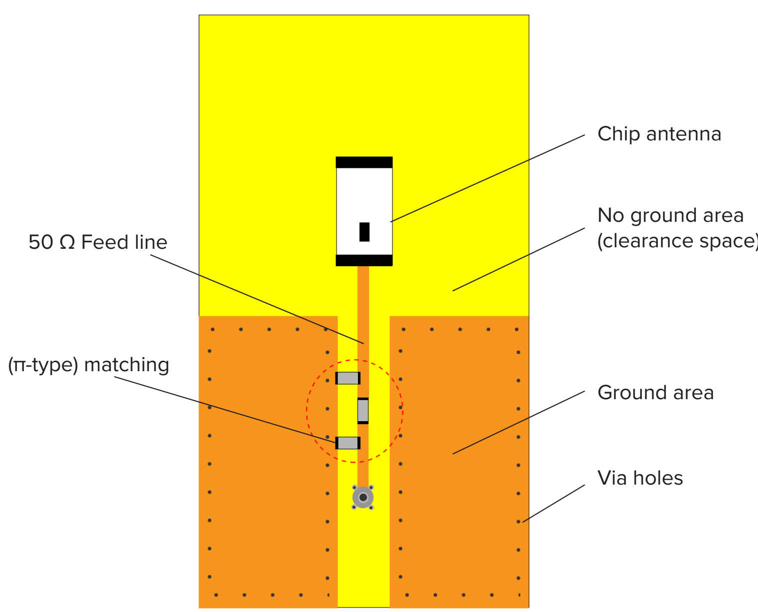
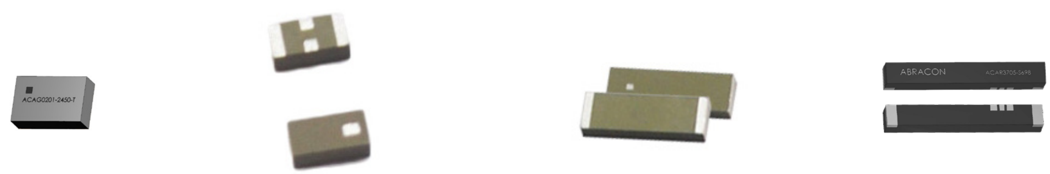


Figure 2 (Top View)

Abracon's chip antennas utilize dielectric and LTCC multilayer technology, creating quarter-wave monopole structures to serve as compact and lightweight solutions. The chip antennas provide an optimal convergence in size, cost and performance. The range of form factors vary as a function of gain and operating bandwidth. The Abracon chip antennas identified in Table 1 are designed to yield desired range, optimal gain and suitable bandwidth, resulting in unsurpassed system-level sensitivity and efficiency when compared to typical PCB trace antennas.

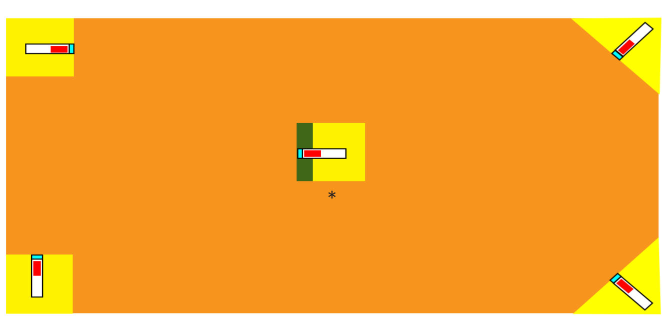


PART NUMBER	ACAG0201-2450-T	ACAG0301-15752450-T	ACAG1204-433/868/915-T	ACAR3705-S698
FREQUENCY (MHz)	2450	1575, 2450	433, 868, 915	700~960, 1710~2170, 2500~2700
SIZE (mm)	2 x 1.25	3.2 x 1.6	12 x 4	37 x 5
BW (MHz)	-65	20, 100	10, 20, 15	260, 460, 200
EFFICIENCY (%)	72.7	57, 73	35, 52, 59	55, 70, 50
PEAK GAIN (dBi)	2.7	1.21, 3.18	-1.72, 2.63, 3.42	-1.13
GROUND PLANE SIZE (mm)	90 x 50	90 x 50	90 x 50	107 x 45

Table 1

Where are the ideal chip placements?

Antenna orientation plays a primary role in defining the radiation characteristics. The suitable placement for orienting a monopole design is on a corner of the PCB, as demonstrated in Figure 3. Avoid placements near metals or other electronic components because coupling between the antenna and the surrounding elements may degrade the chip antenna performance. Use the above guidelines and ground clearance area dimension, as provided in the datasheet, when designing the chip onto a PCB design that is unable to follow the overall reference design layout.



* Indicates bad antenna placement

Figure 3

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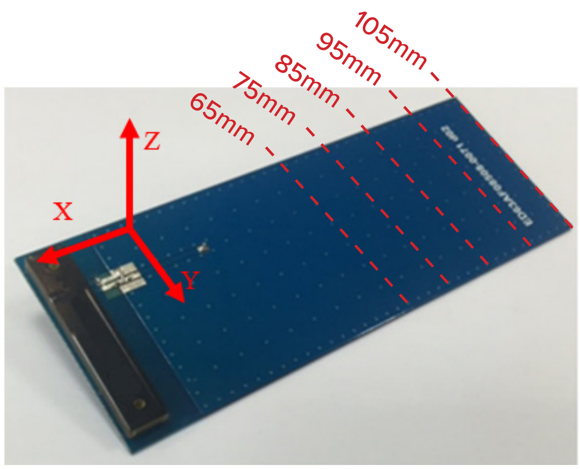
How critical is the ground plane?

In most applications, both chip and PCB trace antenna performances are sensitive to ground plane length. Abracon recommends to keep the lowest frequency of the operating band(s) in mind while considering the ground plane size.

PCB trace antennas' susceptibility to various factors creates a high probability of compromise on efficiency, especially with minimized ground plane sizes. On the other hand, both single and wide-band chip antennas can still meet efficiency requirements with minimized impact from external factors.

Figure 4 displays the performance variation of Abracon's ACAR4008-S698 chip antenna on various ground plane lengths. The chart shows a significant impact of ground plane size on the antenna's efficiency. Excluding antenna designs involving an extremely small PCB area, such as wearable applications, the reference ground plane dimensions should closely follow the datasheet to achieve maximum efficiency.



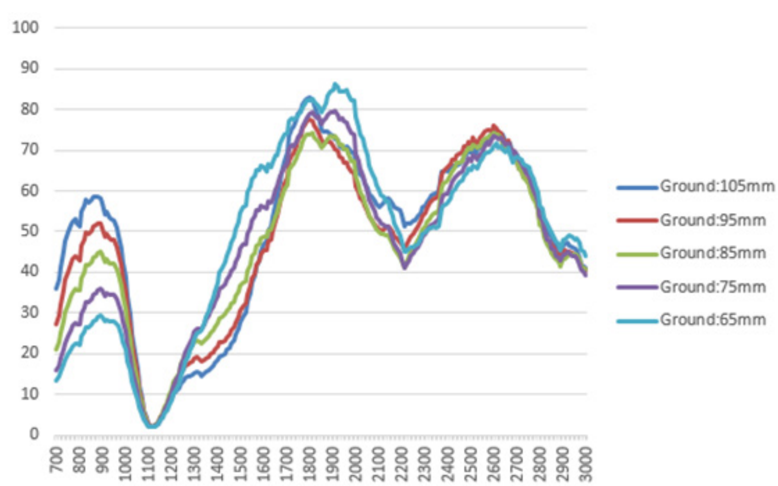


Figure 4

What challenges are related to antenna frequency detuning during system implementation or testing?

As the PCB layout greatly affects antenna performance, tuning is required to match the antenna for optimal performance. Accurate impedance matching yields maximum power transfer in the desired band.

With PCB traces, as the antenna design is susceptible to the overall PCB design, it is difficult to perform tuning and achieve the desired performance. Additionally, low dielectric permittivity of the PCB makes the antenna highly sensitive to design changes and tolerance variations. In such scenarios, re-spinning the PCB is required to achieve the desired antenna performance.

With chip antennas, matching elements can be varied to accommodate the in-system detuning. π-type is the most preferred technique because it offers maximum flexibility in terms of tuning the operational bandwidth. Other matching techniques include T-type, L-type and single series/shunt element. (See Figure 5.)

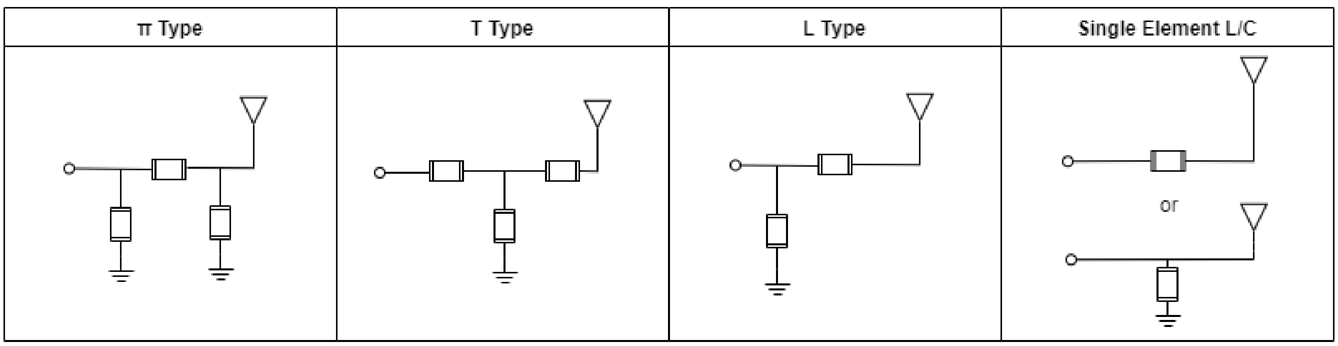
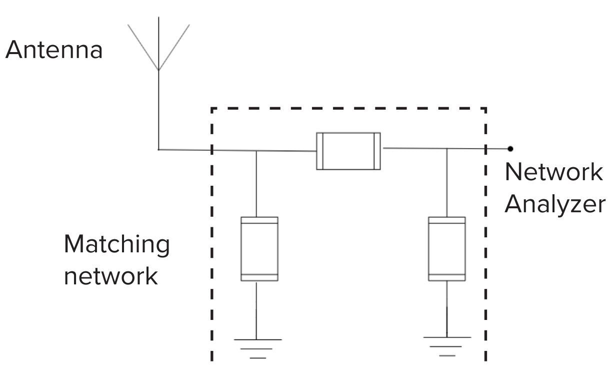
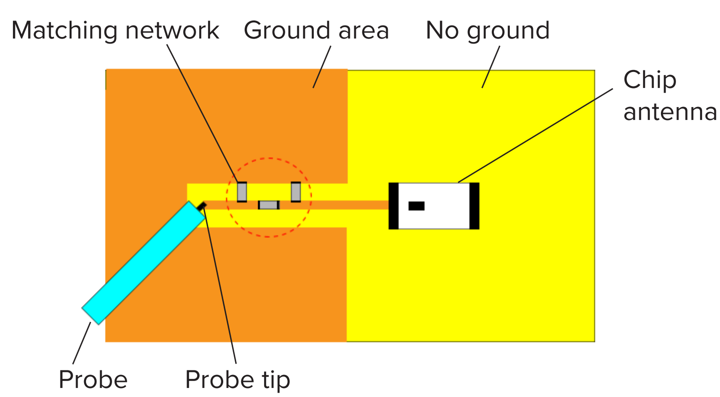


Figure 5

When designing the suitable matching network, a Vector Network Analyzer (VNA) can probe the test circuit on the board and determine the impedance at the antenna input. (See Figure 6.) Measuring the S-parameter and VSWR bandwidth analyzes the on-board chip antenna performance. Tuning can further improve antenna performance. Abracon's "Antenna Impedance Matching – Simplified" white paper offers additional information.



Test Measurement Using Network Analyzer



Section of Evaluation Board

Figure 6

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Abracon offers chip antenna optimization services in which RF engineers tune the matching network to 50-ohm real impedance using lumped elements for maximum efficiency. Matching helps optimize the antenna performance for the desired band in the actual device environment. Abracon engineers also review design layouts for effective usage of board space. The test requires shipping a fully functional system to Abracon and typically takes 4 weeks to complete.

Cost-Benefit Analysis: PCB trace or chip antenna?

Table 2 summarizes the above discussed ideas and weighs the PCB design considerations for PCB trace antennas versus chip antennas. Based on design requirements, you can choose the antenna type that best fits the application.

PARAMETER	PCB TRACE ANTENNA	CHIP ANTENNA
IN-HOUSE RF EXPERTISE	Required	Not Required
DESIGN CHANGES	Difficult	Different design configurations possible
SENSITIVITY	Highly sensitive to PCB changes	Less sensitive
SYSTEM LEVEL DE-TUNING	Requires a PCB re-spin (cost)	Can be achieved with input/output matching optimization (change L & C values)
EFFICIENCY	Poor	Good
SELECTIVITY	Poor	Good
SYSTEM COST	Cheapest	Moderate
SYSTEM LEVEL OPTIMIZATION SERVICE	Not available	Available from Abracon (see details below)

Table 2

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12/19/2019

ANTENNA OPTIMIZATION SERVICE BY ABRACON™ LLC

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Antenna's performance is affected by the environment such as its proximity to other components or to the enclosure. In most cases, tuning is required after the patch antenna is mounted in the end-application, especially if the antenna operating bandwidth is narrow.

There are several methods to tune the patch antenna such as moving the feed point, changing the shape of the top silver electrode, and removing the corners or sides of the top silver plate.

For chip antennas, the efficiency of the antenna depends mainly on the size and shape of the ground plane to which it is mounted as well the impedance matching of the antenna to the feed line. The antenna has to be tuned to center resonant frequency by matching the impedance to the antenna using inductors and capacitors. Higher efficiency guarantees more radiated power and increased operating range for the antennas.

Abracon offers in-system tuning services for patch and chip antennas. By characterizing the antenna performance in the end system or product, this service takes the guess work out of RF verification while offering corrective measures that re-tune the system for center frequency and impedance mismatch.

This provides maximum system efficiency delivering many benefits including, extended RF range, improved sensitivity and can reduce the required power consumption for a given level of transmit range.

Orderable Part Number: ABAOS-5WK

To view a complete list of applicable part numbers, visit our website at www.abracon.com/antenna-optimization-service

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