# Antenna in Package (AiP) examples
- 2.4 GHz ISM band LTCC Antenna
- Organic Substrate AiP

**The SiP approach to RF system integration has become essential to the miniaturization road-map for nomadic devices.**

Two different examples of AiP are presented using Insight SiP design methodology:
- The first example uses a multilayer ceramic substrate,
- Whilst the second uses a 2 layer organic laminate substrate.

The AiPs presented in this paper are based on systems that function in the 2.4 to 2.5 GHz ISM band.

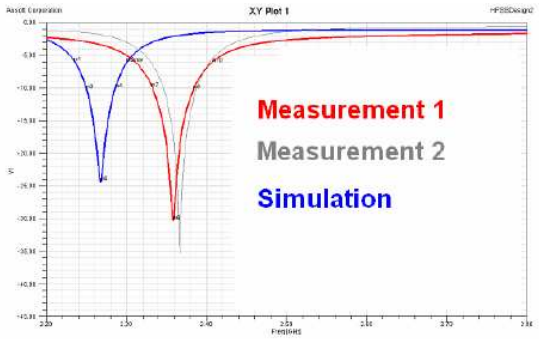
**Applications:**
- Wireless Connectivity

**LTCC Antenna 2.4 GHz**

The first antenna is a 2.4 GHz antenna for the ISM band. The AiP antenna is intended to be integrated with an existing WiFi module (the WiFi module uses LTCC and is 8 x 8 x 1.4mm).
The complete AiP based on this antenna is 8 x 12 mm.

A large range of potential meander type structures were evaluated to ascertain tradeoffs in terms of size, efficiency and operating bandwidth.

An initial batch of prototypes based on a 2 x 8 mm antenna size was manufactured. The best performance obtained is shown below.




Measurements and simulations are compared in Figure 1.

**Figure 1:** Measurement (red and grey) versus simulation (blue) for 2 x 8 mm LTCC antenna.

The operating bandwidth at 6dB points is less than the ISM band. Consequently this antenna version has not been productized.



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Further development of the antenna LTCC structure has been carried out with satisfactory results. New topologies with varying surface areas have been designed and the results for a 4 x 8 mm antenna size are shown in Figure 2.

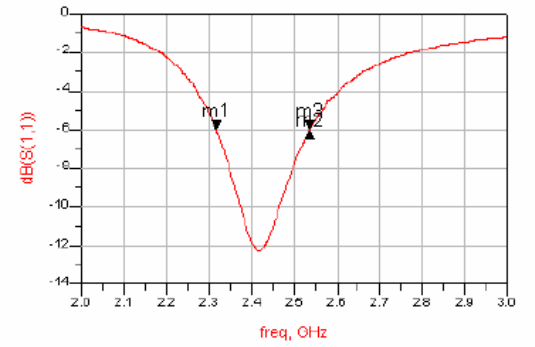


**Figure 2:** LTCC AiP Antenna Return Loss for optimum topology 4 x 8 x 0.6 mm

This antenna has adequate performance to meet ground plane size variations and manufacturing tolerances over the full ISM band:

| Parameter | Units | Characteristics |
|---|---|---|
| 6dB Bandwidth | MHz | 220 |
| Radiation efficiency over 6dB Bandwidth | % | > 50.0 |
| Min Gain over 6dB Bandwidth | dBi | -0.4 |
| Antenna Dimensions | mm | 4 x 8 x 0.6 |

During the development of this antenna, novel structures that optimize bandwidth and size simultaneously have been used. A European patent application has been filed to protect these structures[1].

## Organic Substrate AiP

A second AiP is presented below based on the use of a 2 layer organic substrate. The overall module size is 8 x 12 x 1.4 mm and includes a proprietary 2.4GHz ISM band USB radio and base-band, a crystal clock and a number of SMD devices together with an integrated antenna. The RF module includes electrical shielding within the case of the module.

Figure 3 shows a 3D view of the complete AiP structure mounted on a PCB.
Figure 4 shows a photo of the complete module.

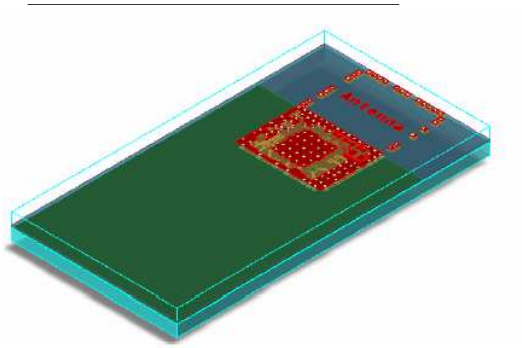

**Figure 3:** 3D view of organic laminate based AiP

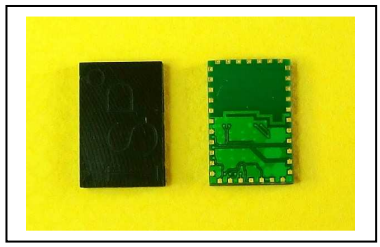

**Figure 4:** Photograph of AiP module 8 x 12 mm with QFN style LGA interface

The AiP module has the same functionality as the IC supplier's reference design, including Crystal, Transceiver, Matching circuit and Antenna.

Figure 5 shows the AiP alongside the reference design as an indication of the miniaturization that has been achieved.

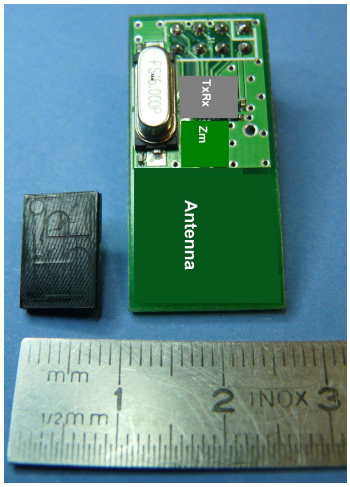


**Figure 5:** ISM band AiP compared to reference design.

Measurement results for the antenna structure used in this design are shown in Figure 6.
The antenna size is 6 x 8mm, corresponding to half the module surface area.

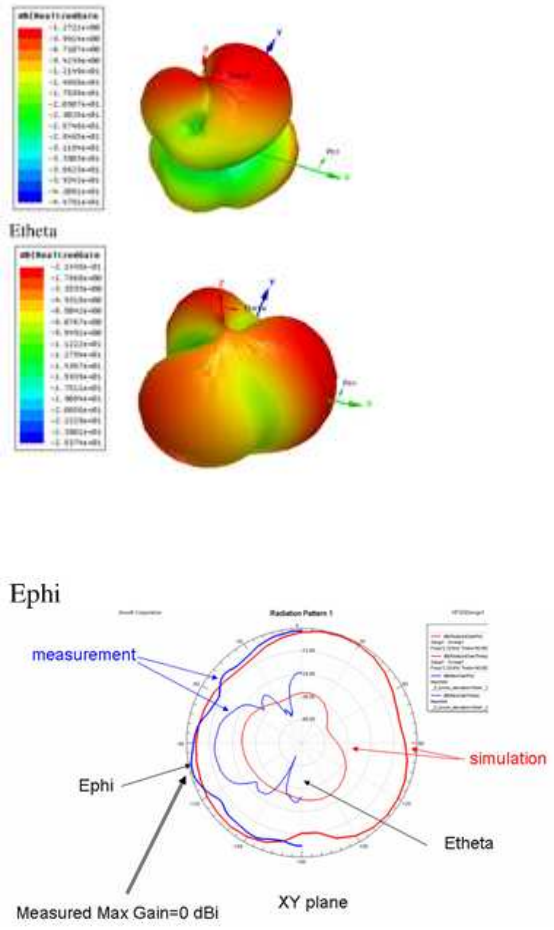


**Figure 6:** 3D and 2D antenna simulations and measurements for organic laminate antenna 6 x 8mm

Prior to building any SiP or AiP structure the tolerance to manufacturing and material tolerances is evaluated using a "Corner" analysis method.

The results shown in Figure 7 indicate the relatively small de-tuning effect should the dielectric constant of the substrate vary from 4 to 5.5.

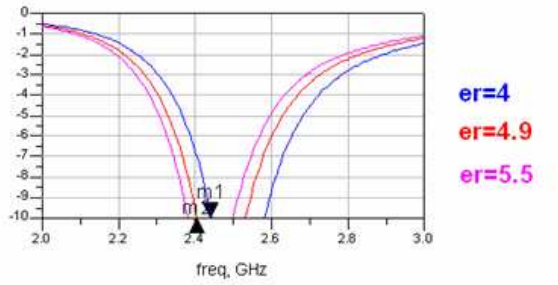


**Figure 7:** Performance variations as a function of substrate dielectric constant

The complete AiP described above has been tested in full operating mode using a link budget analysis.

The receive sensitivity of the AiP is within 1dB of that measured using a matched dipole antenna (6 cm long) and the same chipset mounted on the manufacturer's reference design. The sensitivity is approximately 1.5 dB better than that obtained by the manufacturer's reference system using a printed wiggle antenna.

This paper has described a new type of System in Package that includes not only the RF and Baseband functions but also the RF antenna. This Antenna in Package approach offers a simple solution path for system integrators that eliminates the need for costly and time-consuming detail RF design at the application level.

[1] European Patent Application 09305581.2
"Efficient integrated miniature antenna structure for multi-GHz wireless applications, M. Jeangeorges, C El Hassani, R Staraj, C Luxey, P Le Thuc.

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