Technical E-Paper

INTEGRATED ANTENNAS

11

engineering and industrialization

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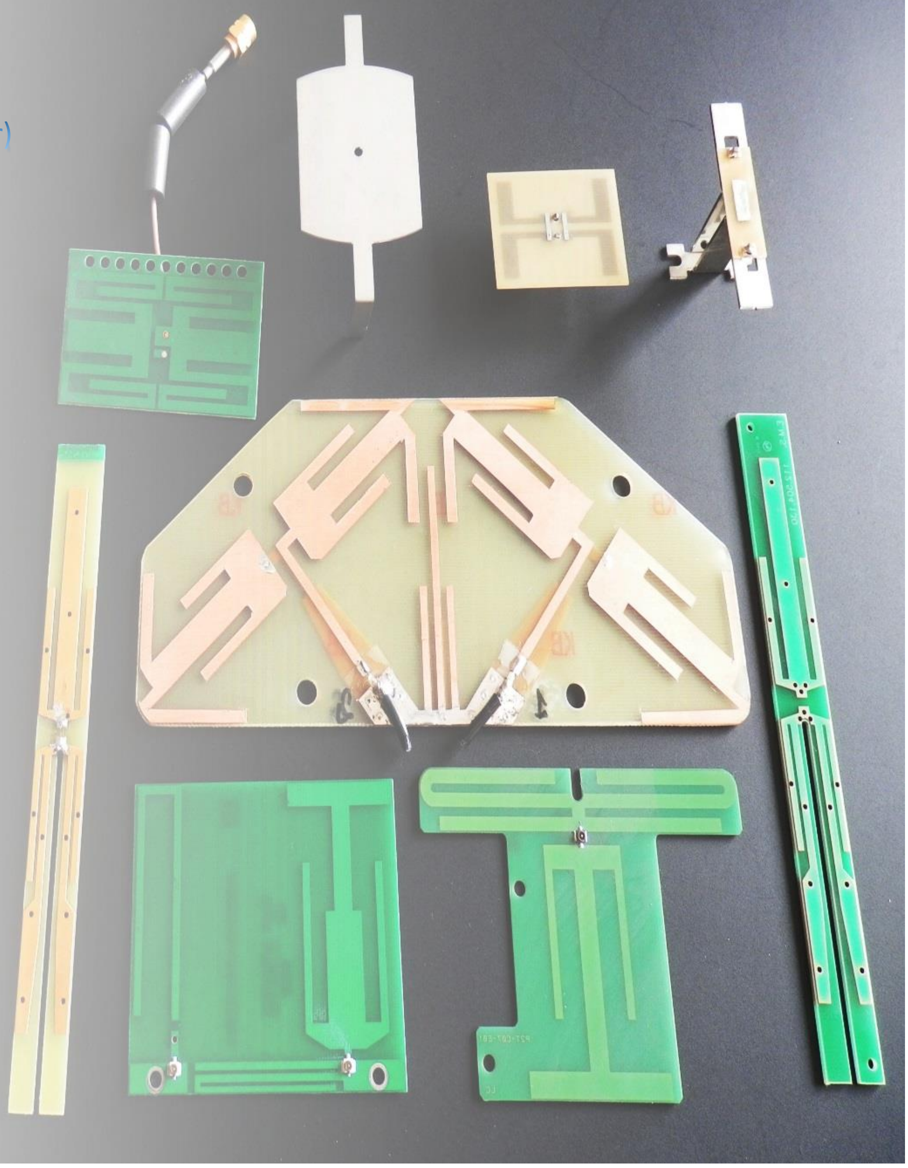

Another important aspect of integrated antennas is their engineering.

What should be taken into account in the product engineering stage?

And, above all, what problems are most commonly encountered with prototypes?

Here are some insights that we hope will be useful when developing an integrated antenna for your wireless product.

ElettroMagnetic Services SRL

1. Introduction.

Nowadays, the development of any industrial product is a multidisciplinary process that involves different actors, both inside or outside the company, each of whom bring their specific know-how in a given technological field.

Modern CAD and rapid prototyping technologies have helped expedite some of the development stages and allow definition at a very early stage of how the final product will look, from both an aesthetic and functional point of view.

The increased complexity of the products (just think of the number of components they comprise) has led to the risk of having a blurred vision of the project as a whole and to the division of skills into watertight compartments, that communicate with each other solely through official channels, in accordance with modern project management techniques.

Also integrated antennas, incorporated in a device or apparatus designed and developed for a specific purpose, benefit and suffer from these business realities during their development process.

While in a multidisciplinary activity it is easy for everyone to gain awareness of the evident aspects of the project, such as mechanical criticalities, it is more difficult to make the whole project team aware of the electromagnetic aspect of the new product.

In fact, experience shows that, not infrequently, final modifications are made to the product that may appear insignificant, but which can lead to a serious deterioration of the antenna's electrical performance.

Without wishing to seem presumptuous, here we will try to give some insights on the engineering of this type of product, which involves not only the antenna itself (more properly identified as *a radiant element*) but also the final product as a whole.

Looking at the various possible ways of dealing with the subject, we have taken inspiration from a typical problem that, unfortunately quite frequently, companies encounter during the development of its wireless device.

2. *A frequently recurring story*.

The company *Joe-Schmoe Ltd.* begins to develop a wireless product for an innovative application: of course, the project involves many technicians who begin to design the mechanical structure, the electronic part, the software and so on.

Immediately following the kick-off meeting, a 3-D drawing of the object is prepared which, of course, will be as small as possible and with really attractive aesthetics: this is approved by the client, in the case of an external customer or by the board of directors of the company.

As regards the integrated antenna, indispensable for the device to function, there are no particular problems and either a pre-prepared drawing or commercial antennas (*SMD chip* or *PCB antennas*) are used. Indeed, their electrical performances are known and reported on the respective datasheets attached by the manufacturers. This is very reassuring at a systemic level.

After completing the mechanics, sorted out the circuit, defined the layout according to the various electronic components, wiring, miscellaneous connectors, displays, etc., the antenna is inserted in the remaining space, like any other electronic component soldered to the PCB, reassured by the specifications in the Application Notes issued by the manufacturer.

In a more advanced stage of the project, often a little bit *too* advanced, you realize that the integrated antenna does not achieve the declared performance. Then you see tests in the field failing and / or non-conformity of the certifications or, in the best case scenario, the need to revolutionize a project whose basic characteristics had already been defined and approved by the client.

If this imaginary story of the *Joe-Schmoe company* can make us reflect, we will now try to provide some ideas for further reflection on products that use an integrated antenna.

3. The evaluation board

Commercial integrated antennas (ceramic SMD chip or other technology) can certainly be valid but it must be remembered that they are certainly not a plug & play component: the problem usually arises from the misinterpretation of the specifications and / or the Application Notes provided with them.

On this point we could open a separate chapter but, for obvious reasons, it is not possible for us to take any real reference as an example.

It must always be borne in mind that the electrical specifications of commercial integrated antennas, in particular the gain and efficiency, refer to the antenna mounted on an evaluation board, i.e. a reference PCB that the manufacturer uses to characterize the antenna.

If, on the one hand, it is logical and correct for an integrated radiant element to be characterized in well-defined reference conditions, on the other hand, most of the time an evaluation board with an appropriate shape and rather generous dimensions is cunningly chosen: indeed, it is in the manufacturer's interest to define the specifications of its product by placing it in the best possible operating conditions, so as to be able to draw up very attractive datasheets.

This reference board is also devoid of any other component or container, obviously present in a real product. A similar argument can be made when incorporating a standard radiant element in a printed circuit.

So, the first question to ask and to think about is:

how different is the object I am developing from the evaluation board of the antenna I would like to use?

3. Elements that worsen the antenna's performance.

When an integrated antenna, whether commercial or developed ad hoc, has to coexist with other electronic and mechanical components necessarily present in a given device, there are always elements that affect and deteriorate the antenna's performance.

If in a traditional antenna the mechanical structure and the related components are designed to obtain optimal electrical performance from the antenna itself, in the case of an integrated radiant element this is generally not true.

In fact, in this case it is the device that is optimized for its specific application or installation and certainly not the antenna contained in it, even if the latter is vital for its correct functioning.

There are therefore some elements that affect, and often worsen, the performance of an integrated antenna and which in fact represent the potential problems to be taken into account, to minimize their effects from an electromagnetic point of view.

These elements, always present in a real device, are:

- *Batteries;*
- *Wiring;*
- *Sensors, connectors;*
- *Large electronic components (electrolytic capacitors, transformers, etc.);*
- *Metallic masses very close to the radiant element;*
- *Dielectrics with high loss factor;*
- *Ground planes (one or more) of various shapes and sizes.*

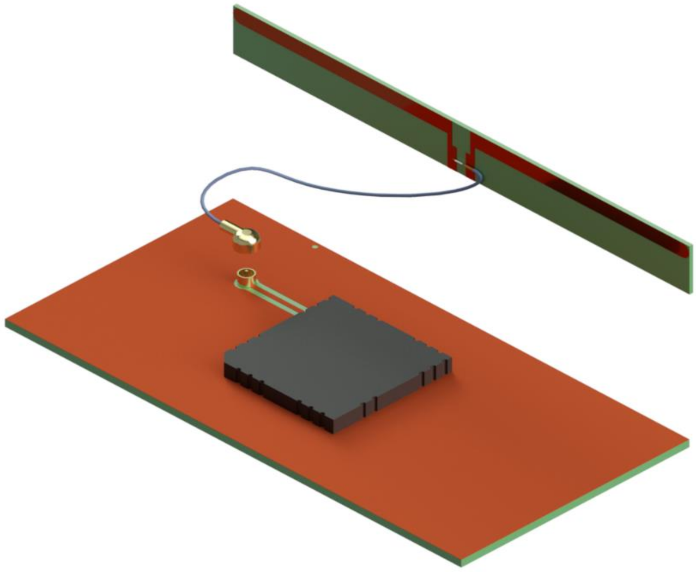

Figure 1
Dipole on PCB connected to the *radio module with a coaxial wire and U.FL. connector*

Batteries, especially larger ones (about $\lambda/4$), often present in telemetering devices or wireless sensors, can appreciably reduce the efficiency of the antenna and their effect is difficult to estimate even with modern electromagnetic simulation software.

If there is wiring in the device whose path is not well defined and repeatable, this can introduce maladjustments in the antenna which vary according to their position inside the container.

There are some radiating elements, such as for example a simple dipole on PCB similar to the one depicted in *Figure 1*, which should not be placed less than $0.1\ \lambda$ from any metal surface parallel to them: for distances of less than 0.1λ, the radiant element is in fact increasingly "short-circuited" by the underlying metal, resulting in a rapid reduction in efficiency.

Also the plastic material used for the container can introduce loss factors, especially if it is of the dissipative type, that is, loaded with resistant pigments for purely aesthetic reasons (color) or also for regulatory reasons (explosive environments subject to ATEX regulations).

All those components of a certain size (always with respect to λ and/or to the size of the radiant element located close to them), such as connectors, sensors, encoders, electrolytic capacitors or transformers can be critical elements for the functioning of the antenna and their lay-out must be studied with care.

Last but not least, the size and shape of the ground plane (or layer) plays a fundamental role in the performance of an integrated antenna, as already mentioned when talking about the evaluation board.

Sometimes, not being able to count on an adequate RF mass on which to place the antenna, it is possible to take advantage of the way in which the device is installed: for example, if the device is mounted on a metal object (e.g. a gas meter), it is possible to indirectly use the latter as a layer for the antenna, significantly improving its efficiency.

For this reason, when designing an antenna, we must never lose sight of the final application of the wireless product to be developed.

Figure 2
In a wireless device there are numerous components that can affect *and impair the electrical performance of the integrated antenna.*

4. Assembly tolerances.

For the correct functioning of an integrated antenna, the tolerances of the various components of the device must be stricter than those required for the mechanical integrity of the product alone.

For example, if the radiant element must be at a certain distance from the plastic material cover of the product, appropriate mechanical measures must be adopted so that this shell of dielectric material can always be mounted in the exact same position.

The same goes for any wiring or ribbons that connect the PCBs inside the device (if there is more than one) or connect the PCB to elements outside it (for example connectors, transducers, displays).

5. Degrees of freedom.

The industrialization of an integrated antenna must be carried out from the very first steps of the development of the wireless product. Only in this way, in fact, is it possible to plan the correct position of the radiating element, often giving rise to modifications that, at the start of the development activities, are easy to implement.

It should be remembered that an integrated antenna needs some degrees of freedom to be able to size and design it optimally. It is not always necessary to carry out complicated electromagnetic simulations or laboratory tests at the start of the project, but it is certainly indispensable to have a preliminary evaluation of how the antenna can be incorporated in the end product performed by an expert technician.

In this way it is possible to avoid the greatest risk, that of having a fully defined object, in which the antenna provided does not work properly and there are no degrees of freedom on which to act to improve its performance.

In other words, we find ourselves in a condition that we could call "checkmate".

6. The mock-up to use in the development stage.

We have already mentioned how the development of a wireless product is a complex activity that creates a synergy of different skills and multidisciplinary technologies. Also as regards the antenna, the design stage is carried out in parallel with the other activities involved in defining the various parts or subsystems which, once assembled, produce the final result.

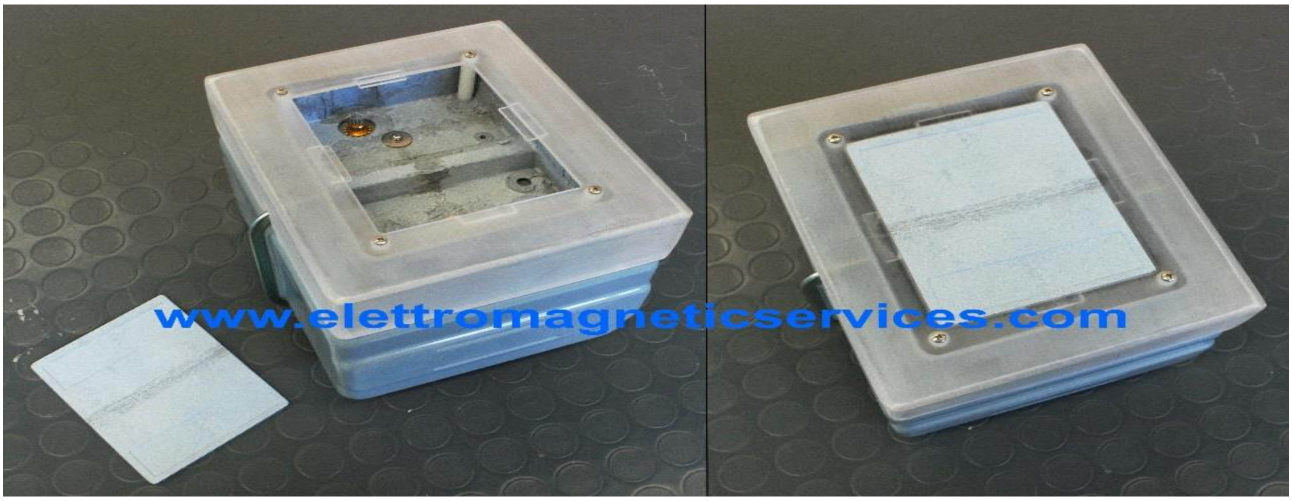

Figure 3

Example of a mock-up made for the development of an integrated antenna for a gas *meter telemetering system, here without the antenna and electronics.*

Although sophisticated simulation tools are available, it is still essential to supplement and validate the results of these with laboratory tests, which must necessarily be conducted on a mock-up of the device, or on a prototype of the finished product (or part of it) which, although not operational, resembles the real object as closely as possible, reproducing as faithfully as possible all the parts or components that interact with the radiant element from an electromagnetic point of view.

An example of an ad hoc mock-up, without the electronics and the antenna, is shown in **Figure 3**.

Nowadays, through 3D printing, it is possible to realize many of the components of the mechanical structure in a fairly detailed way even if, from an electromagnetic point of view, in this stage it is much more important to reproduce with precision the electrical characteristics of the materials that will be used in future production, leaving out the aesthetic aspect of the product.

It is therefore essential that a large part of the development of an integrated antenna is in fact devoted to the creation of a suitable mock-up, which is usually not provided by the customer in a complete or definitive form as this is an early stage of the development process.

The more precise the mock-up based on which the integrated antenna is defined, the better the result of the project and optimization of the antenna in the finished product will be.

7. The mock-up to use in the certification phase.

So, let's continue with the story of the company *Joe-Schmoe Ltd.* We can assume that the development of an integrated antenna for their innovative *IoT* device has been successful.

Figure 4

Preliminary measurements on an integrated antenna before the certification stage.

Regardless of the antenna that has been built, the first field tests provided good results and now the time has come for certification at an accredited laboratory, as requested by the client.

Much to their surprise, the EIRP (Effective Isotropic Radiated Power) and TRP (Total Radiated Power) measurements give poor results, measuring 8 to 10 dB less than the radiated signal level that would be expected from the design specifications.

But what happened?

Joe-Schmoe Ltd. clearly made mistakes, not evident to the layman in the preparation of the mock-up used for the certification.

For the test of the IoT device in question, the connection of an external power cable, a USB control cable and an external SIM card was required, all elements which significantly alter the electrical configuration of the object and which, even if necessary for laboratory tests, they have nothing to do with its actual conditions of use.

In fact, often, the development mock-up of the integrated antenna must necessarily be different from the test mock-up of the same wireless device, and it therefore becomes essential to prepare the device so as to be able to carry out certification measures that are as representative as possible of the actual operating condition of the product.

It is important to specify that the preparation of a test mock-up is not straightforward, and it is important that the people who make it have good experience of measurements in the field of electromagnetism.

Besides the technical point of view, this question is also complex from the commercial point of view: in fact, it can be difficult for the Customer to understand the time and experience it takes to prepare a valid setup for certification.

In this regard, two questions have to be asked.

First.

How much does the failure of a certification test weigh in terms of time, wasted resources and damage to image?

Second.

Will the supplier of the integrated antenna, whether chip -type or custom-made, at the end of the project be able to provide further and necessary specialized technical assistance of this type?

8. Conclusions.

Nowadays, with all the products and services that rely on wireless connectivity, integrated antennas have become extremely important, even if they remain hidden from the eyes of ordinary people and, sometimes, even of the same technicians who deal with complementary disciplines, such as electronics and information technology.

Without fear of contradiction, we can say that there are still some sectors in which the importance of the electromagnetic part of the system has not yet been fully understood and digested: the debugging efforts and optimization of the product are directed exclusively at other aspects of the technologies involved and not at improving the antennas, which therefore become the weak link in the chain and, consequently, limit the achievable results.

In this third Technical E-Paper dedicated to integrated antennas, we have provided a brief review of the world of integrated antennas, in the hope of having at least given a rapid overview of the topic and the problems related to it.

This with the aim of providing elements for reflection for developers and manufacturers of electronic devices in the world of wireless and IoT.

For further information or insights, write to bollini@elettromagneticservices.com

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