"IoT" Antennas

The antenna conundrum

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Abstract

A well-designed wireless device, perhaps equipped with the most sophisticated sensors, can be compromised by the poor efficiency of the antenna system. As a result, the entire IoT network can become unstable and difficult to manage. Here we tackle the antenna problem, in particular for applications on sub-GHz frequencies and in particular with small 434 MHz wireless sensors made with "microSP" Technology.

"Antenna"

what the hell is this stuff?

The antenna is a very important part of any wireless device. It is generally believed that Marconi invented the radio and it is probably so: however in his first experiments, the main innovation was to use a true radiant system with an "Antenna" and a "Ground" reference (Fig.1).

• *Later I will clarify what is meant by "Ground".*

Some years earlier Heinrich Rudolf Hertz had experimentally verified Maxwell's prediction that electromagnetic waves exist. Hertz studied their propagation for a long time and practically invented the antenna (fig.2).
Interestingly, on the receiver side, Hertz used what is actually a "Loop" antenna. Just the type of antenna that in many cases should be used in small wireless devices, where "wire" antenna are not very efficient. The "Logo" chosen for the "microSP" Technology (Fig.3) reproduces, precisely in honor of Hertz, the design of the "Loop" magnetic antenna used in his experiments..

The "Antenna" !
Perhaps we can name it as a "Patch" antenna .....

And this is the "Ground".

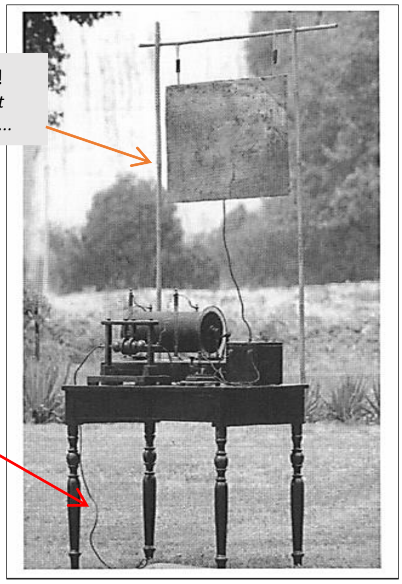


Fig.1 - Marconi Transmitter (1895)

Heinrich Rudolf Hertz

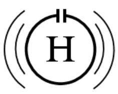
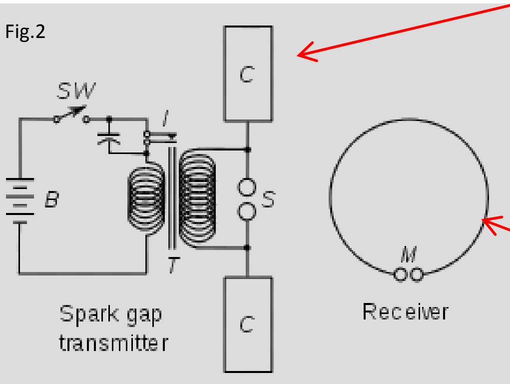


Fig.3 – The "microSP" Logo

Fig.2



Transmitter antenna
Practically a "Dipole".

Receiver antenna
A "Loop" antenna.
"Ground" is not required.

So that the "Conundrum" antenna does not turn into a "Nightmare", it will be good to pay attention to the radiant system and its tuning. Particular attention is needed in small wireless devices, which operate on sub-GHz frequencies and for which dimensions, costs, and the low energy problems are critical.

“Antenna” in a small Box .

In this Whitepaper, we will examine "Antenna" problem with specific reference to "IoT" applications on sub-GHz bands and in particular when the wireless "Device" must be housed in small plastic boxes. We can practically consider two types of antennas: the "Electric" and the "Magnetic" antenna. Undoubtedly this is a simplified way to describe antenna types, but it can be a good starting point for a discussion on "IoT" antennas (Note-1).
In the vast majority of cases, the classic quarter-wave antenna is used as a radiating element. Whether it's a "Trace" on the PCB, a "Helical" or "Ceramics" antenna is almost always a quarter wave. And the quarter-wave antenna needs a "Ground".
Now we will consider the problem of how to radiate all (or almost all) the power of an "IoT" transmitter when everything is contained in a *"small"* plastic casing (no connection or cable outside). As an example at a frequency of 434 MHz, the wavelength is 69 cm and the quarter-wave is 17 cm: *"small"* in this case means a size of the electronics and the enclosure less than about 5- 10 cm.

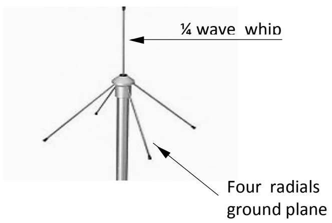


Fig.4 – A full size 434 MHz Ground Plane

Rubber antenna   Helical antenna   Ceramic antenna

Fig.5 – Example of shortened 434 MHz ¼ wave

“Electric” antenna

The basic “Electric” Antenna is the "Dipole" (Fig.6), it is half wavelength and it is not very convenient to be used because it requires a "balanced" output from the transmitter. The quarter-wave is more convenient, has half the length and is, in fact, the most used antenna, but it needs a ground reference (Fig.7).

There are antennas that need ground and antennas that do not need ground and, for example, the dipole is one of them.
The basic form of a quarter-wave antenna is the “GP antenna” (Ground Plane Antenna) where “Ground” is made by the four radials (Fig.4). The quarter-wave antenna is fine when the dimensions of the PCB (electronics, battery, etc.) are such as to guarantee an efficient "Ground" (fig.7). In this case, shortened antennas (Fig.5) can be used with excellent results.
If the transmitter and the antenna are all inside the *"small"* box (Fig.8), the lack of ground drastically reduces the radiation efficiency and the intensity of the signal sent to the receiver to levels that reduce the reliability of the radio link.

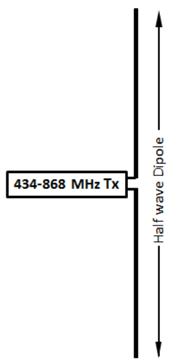


Fig.6 – Dipole antenna

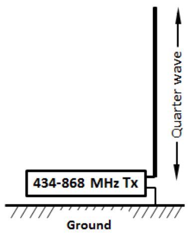


Fig.7 – 1/4 wave antenna

Fig.8–All inside a *“small”* box

Note-1 : "Antenna" is an electric charge that moves in the space. Then, according to Faraday's laws, a magnetic field is generated by a moving charge and vice versa. Maxwell thought about it (long before Hertz and Marconi) to mathematically explain the creation of the electromagnetic field. At a distance of about half the wavelength from the antenna (Near Field), the electric and magnetic fields are not yet correctly concatenated . The "Near Field" is the critical space in which if the antenna is "Electric" the electric field prevails, if the antenna is "Magnetic" the magnetic field prevails.

Practical implementation of a "Electric" antenna

Where dimensions are not so important, as in industrial applications, and where a metal housing can be used, a rubber or helical antenna is the best choice. The "Limit Switch" wireless sensor shown in Fig.9 has an aluminum housing and a helical antenna and a radiation efficiency of over 90%.

Fig.9 – A Limit Switch "microSP" wireless sensor

"Magnetic" antenna

The "Magnetic" antenna has some advantages over the classic quarter wave and this makes it interesting for its use in small wireless devices. Normally called "Magnetic Loop Antenna", it consists of a loop of wire with a capacitor that makes it resonate at the operating frequency. A smaller loop can be used to transfer the RF power of the Tx (Fig.10).
It is like a RF transformer that translates the RF power of the Tx into electromagnetic energy by practically converting the 50Ω output of the Tx to the free space impedance (377Ω).
The first advantage compared to the "Electric" antenna is that it does not need a "Ground" and therefore, for the reasons explained above during the description of the quarter-wave antenna, this is a requirement that can be decisive for the success of a wireless sensor in a *"small"* box.

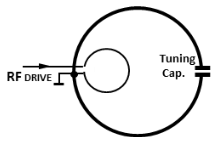


Fig.10 – "Magnetic Loop" antenna

In fig.11 the electronics and the antenna of a TPMS (Tire Pressure Monitoring System) sensor powered by a 9 mm lithium battery and which is therefore equipped with a "Magnetic Loop" antenna of the same diameter. Such a small device has practically no "Ground" and an electric antenna would have a radiation efficiency of less than 10%.
The "Loop" antenna, even with a diameter of just 9mm, has a radiation efficiency that exceeds 70%.

Fig.11 – Small loop "PCB antenna"

Another advantage of the magnetic antenna is that it is poorly affected by the plastic housing or by objects in the immediate vicinity, including metal.
In the version of fig.12 the "Loop" is realized in a different way and has the advantage of a lower resistivity, with therefore greater RF efficiency, and is also constructed so as to further reduce the negative influence on the resonant frequency and on the radiation efficiency deriving from the positioning of the device on walls or even on metal parts.

Fig.12 –High efficiency "Vertical Loop".

Note -2 : Going back to what was said in the description of the electric antenna and then in Note -1, the electromagnetic field and the "Near field" area, it was experimentally observed that the magnetic field in the area near the antenna is less influenced by external conductive parts than the electric field. An in-depth discussion on the design and construction of antenna systems, in particular for "IoT" wireless devices, is reported in the STE-Industries AN-905 Application Note .
In AN-905 Application Note, it is also discussed the part related to antenna employ in receive systems.