

Small Terminal Antennas for Mobile Applications: Design Considerations and Specific Examples.

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1. Introduction

The need for small terminal antennas designed to fulfil the specific need of mobile communications started roughly 25 years ago with the apparition of the 1st generation of mobile phones. Indeed, the mobile phone service had new and stringent requirements for antennas, which differed from the portable radio link systems which were anterior to them, these new requirements being linked to the fact that this new communication service targeted a broad market. Thus, the handheld had to be small enough to be easily carried, of reasonable weight and low cost to manufacture. Initially, the low frequency used gave little degrees of freedom in the antenna design, the only practical solution being a whip where the handheld itself acted as the ground. The strong development of the second generation of mobile phones in the last decade induced an increase of the carrier frequency, giving thus a little more freedom in the antenna design.

New mobile services like high speed data transfer (WLAN), Bluetooth, ad hoc networks, mobile peer to peer transfer, as well as the competition for the available frequency spectrum have broadened the range of requirements that are made for the antennas which are used on the mobile terminals. These requirements include typical "user defined requirements" like 1) small dimensions; 2) low weight; 3) low induced SAR; 4) low cost. But also requirements that are defined by the service provider or by the network like 5) high efficiency; 6) capability to handle multiple frequency bands; 7) broadband; 8) robust to changes in the environment; and 9) optimized use of the available channel capacity.

Of course, depending on the considered service, the relative importance of all these requirements varies a lot. The size is for instance far less critical for WLAN system located in a laptop than for a DCS phone. The bandwidth and capacity however will be far more critical in the former example.

Considering this, the design of terminal antennas is more than ever an art of defining the right compromise between all the requirement for a specific application. In this paper, we will show some design examples for specific situations and propose some solutions to meet the design requirements listed above.

2. Classical multifrequency antennas

The venue of new generations of voice services (DCS and UMTS to GSM for instance), and the offer of new services incorporated in phone terminals (like Bluetooth, GPS) require antennas which provides multiband possibilities. Indeed, a multiband antenna solution is often smaller and less costly than a solution with a distinct antenna for each frequency band. Typically, a distinction can be established between single and multiple feed (port) antennas.

2.1 Multiband Single feed Antennas

The big advantage of having a common feed point for all the bands is that we do not need to care about mutual coupling problems. The drawback is that the radio front end has to discriminate the signal belonging to different services. Single feed is the usual choice for dualband mobile phone handset antennas. An example of this kind of antenna[1] is shown in figure 1.

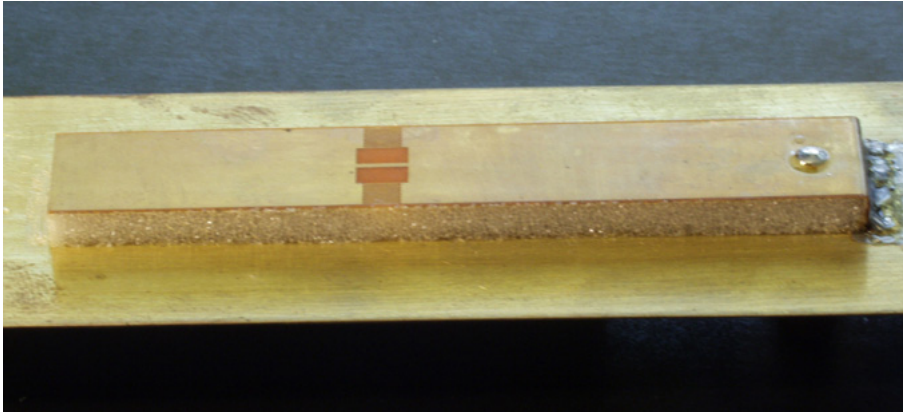
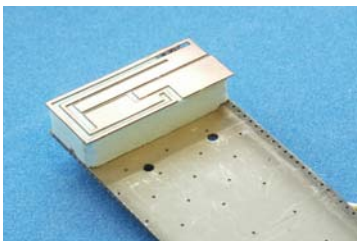


Figure 1 : dual band PIFA antenna (GSM/DCS). (EPFL [1])

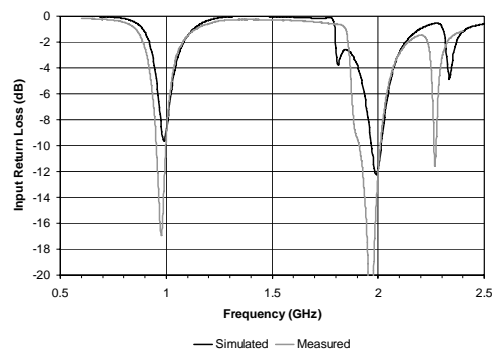
In printed antennas, multiband design usually start combining several resonant structures in a single antenna, with a common feeding point. Typically, slots and patches resonance are combined to obtain several bands. Optimisation combining an accurate analysis technique (for instance IE-MoM or FDTD) with a fast optimizer (genetic algorithm) is essential here. With proper tuning, four or even five bands can be obtained, keeping essentially the same surface and volume needed for a single band patch and achieving good performances in terms of matching and efficiency.

Figure 2 shows a quad-band antenna for mobile phone applications (GSM 900/1800/1900 +UMTS) combining a parasitic element and a $\lambda/2$ slot (at the UMTS frequency) etched in the main patch [2].

Figure 2: Quadband patch antenna for mobile telephones (IMST, [2])



(a) implementation



(b) matching

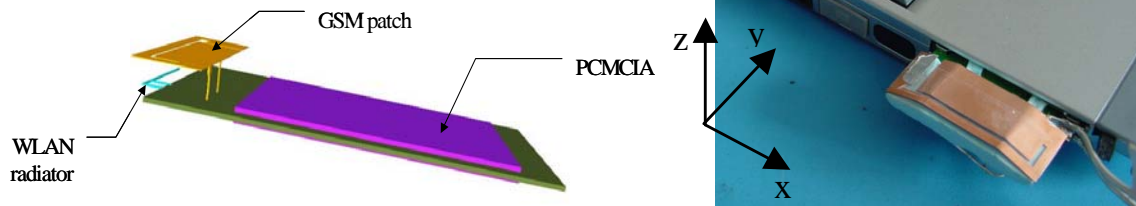
2.2 Multiband Multiple feed Antennas

In some applications, multifeed antennas with a feed per frequency band are needed. The drawback is that the mutual coupling between the feed points can be high. This can degrade the overall performances in certain circumstances. However, each service is decoupled already at the antenna stage. This scenario is usually chosen when the two offered services are uncorrelated (voice and GSM for instance). This can also be a good choice for frequency bands which are far apart.

For instance, to implement a multi-standard PCMCIA antenna system that covers simultaneously the frequency bands of the GSM family (namely, GSM 900, GSM 1800 and GSM 1900) and WLAN, two feeding ports are usually necessary, in order to comply with the current requirements of hardware manufacturers, who can thus use cost-performant circuitry. An example of multiband antenna for PCMCIA [3] is presented in figure 3. Two separate radiating structures were integrated into the available volume. A PIFA was chosen to cover the GSM bands. It provides two separate resonances for the GSM 900 and the GSM 1800/1900, respectively. In this case, a single mode was enough to cover these two overlapping bands. Also, an Inverted-F antenna (IFA) was added, to ensure the access to WLAN. It consists of a shorted wire printed onto a non-metallised area of the PCB board. The overall size of the PCMCIA board is 54mm x 110mm. For this kind of antenna,

computer optimization is needed to only for achieve a good matching but also to obtain a good decoupling between ports.

Figure 3: Multiband antenna for PCMCIA



2.3 Multiband Antennas with reduced feeds

Using less feeds than bands is a solution often introduced to cope with the evolution of one type of service [4]. For mobile voice in Europe for instance, one could use a multi band antenna with two feed points, one for the GSM/DCS bands and a second for UMTS. An example covering GSM/DCS on one port and UMTS on the other is shown in figure 4.



Figure 4 : double PIFA for GSM/DCS (feed point to the left) and UMTS bands

3. Multifrequency antennas for applications beyond 3G

Mobile services beyond 3rd generation will imply the use of much higher frequency bands. In an initial stage, these new service will have to appear along the existing ones. This means that there will be a market for antennas being able to work both in the actual wireless frequencies (1-5 GHz) and in the Ku band. The size of the low band antenna will be much large that the size of the high band antenna, and will set the overall size of the radiating part of the system. The discrepancy between the required sizes for both bands can be used to add some "smart" features to the high band part of the antenna. An example is sketched in figure 5. The radiating structures (in this case patches) is made of an array of elements resonating in the higher band, connected by filters, switches, or other circuit elements. For the lower frequency band , the entire structure will be considered as one single radiating element. For the higher frequency band, the structure can be considered as an array antenna, which features (beam steurability, tunability of the matching, etc.) will be determined by the nature of the connecting circuit elements, and by the feeding network

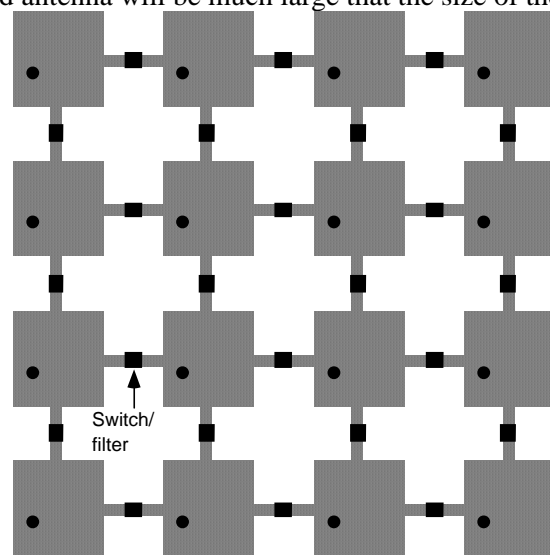
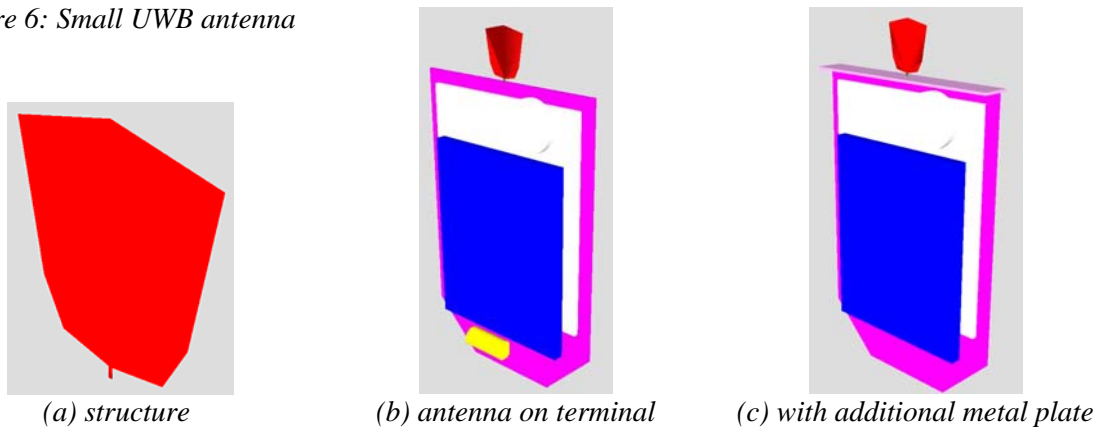


Figure 5 : KU band array working as a single element in 2G or 3G bands

4. UWB antennas for handheld terminals

To put into service an UWB communications system, different kind of devices, both desktop and handheld, must be considered. Some standard antenna solutions, like Vivaldi or bowtie antennas, show a good behaviour for common household devices such as TV-sets or DVD players, they are however too cumbersome to be integrated into smaller, portable terminals. In this case, smaller and higher-performance solutions are needed. Figure 6a shows a small UWB antenna for handheld terminals. The design is based on a planar version of the monocone antenna, with a size of 20mm x 18mm . The handset was modelled as a 120mm-in-length, 80mm-in-width PCB, which is a normal size for multimedia devices to be used in an UWB environment. Some components of the device have also been considered, namely the RF-shielding, the battery, the display, the vibration motor and the loudspeaker. They all were modelled as metallic elements connected to the PCB. The final structure is displayed in Figure 6b. In order to improve the performance of the antenna, a horizontal metallic strip can be added, as shown in Figure 6c, which will act as a small ground plane for the antenna. The size of this strip is 11mm x 80mm. The simulated input return loss results of the antenna are depicted in Figure 7.

Figure 6: Small UWB antenna



Three cases were considered: the antenna over an ideal infinite ground plane, or integrated in both handset models

The antenna shows good matching performances from 3 to 10 GHz when an infinite ground plane is considered. Once the antenna is integrated into the handset, the matching is shifted to lower frequencies, whereas the overall level is deteriorated. Adding the thin metal strip at the top of the device allows a 2 to 4dB improvement of the input return loss, as the strip acts as a small ground plane, especially for the higher frequencies.

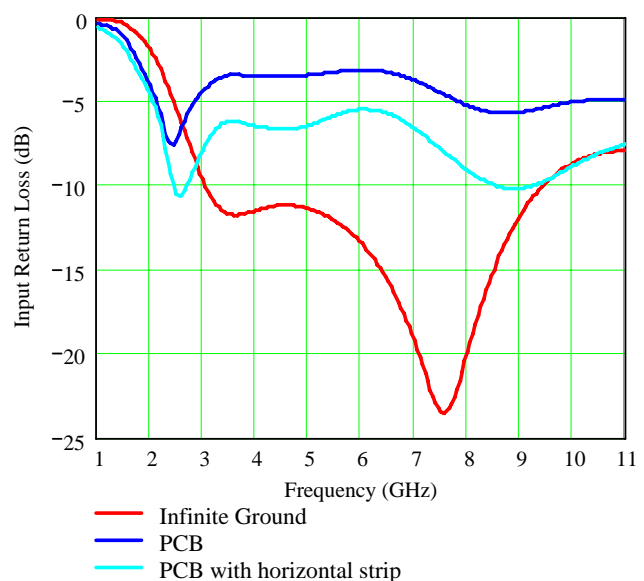


Figure 7: Simulated input return loss of the UWB antenna with infinite ground plane, and integrated into the terminal

4. Conclusion

There is still a lot of work to do in the novel field of small terminal antennas. Besides traditional fields of research, like the development of efficient full wave simulation tools and traditional design, new challenges appear in the form of transdisciplinary research. Indeed, beside antenna and electromagnetic theory, the designer of efficient future terminal antennas will have to develop skills in areas like MEMS technology, signal processing and MIMO channels, probability & statistics and optimization theory, as terminal antennas will migrate more and more from a component to a system, or at least a subsystem.

Acknowledgements

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The network ACE (see <http://www.antennasvce.org> and <http://www.ist-ace.org>) started 1 January 2004 as a Network of Excellence within the European Community 6th Framework Program in the Information Society Technologies thematic priority. It was proposed from the COST 284 group, based on the identified need for a more European approach to antenna research.

The project has a duration of four years (2004-2007). Currently 51 participating Institutions from 17 European countries, 323 researchers and 130 PhD students are involved. The ACE total budget is 13.5 M€ with EC Contribution up to 10.5 M€

The European Network of Excellence on Antennas "ACE" (2004-2007) has been very successful in structuring the antenna research in Europe. Several strategic lines have been covered by specific activities and partners issued from Academy and Industry have worked together towards common R&D goals.

This paper authors wish to acknowledge the ACE Network, which provided the adequate framework for this research and, more specifically, all the ACE members and partners involved in the "Small Antennas" and "Dissemination" activities.

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