Metallic Letter Identification Based on Radar Approach

***Arnaud Vena*[1], *Taranjeet Singh*[1], *Smail Tedjini*[1] and *Etienne Perret*[1]**

[1]Laboratoire de Conception et d'Intégration des Systèmes (LCIS) / Grenoble Institute of Technology, 50 rue Barthélémy de Laffemas, BP 26902 Cedex Valence, France
arnaud.vena@lcis.grenoble-inp.fr; taran.iitr@gmail.com, smail.tedjini@lcis.grenoble-inp.fr; etienne.perret@lcis.grenoble-inp.fr

Abstract

A new concept of letter identification by use of RF wave is presented in this paper. Since letters have various shapes, their Electromagnetic signature can be identified independently. Considering the Latin alphabet, its 26 letters can be identified for a given font size. To measure the electromagnetic signature of each letter, a wideband measurement set-up has been used with a frequency span until 10 GHz. It is based on a bi-static radar system with a pulse generator as source, compatible with UWB regulations, and a real time sampling oscilloscope as receiver. The Arial letters used in this work are 48 mm in height and were realized on a flexible Kapton substrate. The main application of metallic letters is in item identification. But the greatest interest of using metallic letters is based on combining the visual identification, with the remote Electro Magnetic identification, also possible outside the line of sight.

1. Introduction

There has been a growing interested in RFID applications since last few years. Basically, this technology allows identification of items by use of radio frequency waves. An RFID system [1] is composed of a reader and a tag which is associated with an item in order to identify it. A tag can be active, i.e. battery cell is embedded or be passive. In passive tag, the feeding power is extracted directly from the incident field emitted by the reader. A chip is embedded in the tag and powered via an antenna. The chip gets a special request command from the tag and produces a response in turn using backscattering modulation of continuous wave. Internal impedance of tag is modulated to produce a change in its radar cross section (RCS). Thus, the reader detects a power level change and samples the response of the tag. To address applications where very low cost is imperative, a novel family called chipless RFID has emerged to address this issue. This new technology differs from passive RFID as there is no chip embedded into the tag [2-4]. Since there is no protocol of transmission, the metallic shape of the tag embeds data and consequently is designed in order to produce a specific and unique electromagnetic signature, which is used to identify the tag.

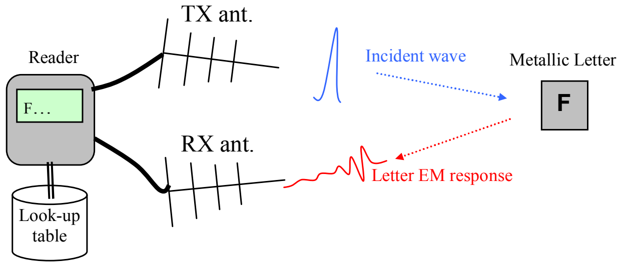

Fig. 1 : Principle of letter reading system

A chipless tag is designed to encode several bits of data to produce a large number of identifiers. Data can be encoded in time domain [2] using multiple pulse reflection or in frequency domain [3-4]. In this later case data is encoded as a function of presence / absence of resonance at specific frequency. The design presented in this paper can be classified into RFID chipless family since it can be seen as an object having a unique Electromagnetic footprint. The use of metallic words has been firstly introduced by M. Keskilammi [5]. He showed that metallic words can be used as radiating elements for transponder, in top of their visual identification. In this paper, metallic letters are use for the first time to combine classical visual identification with Electromagnetic identification. A look up table containing all recorded signatures can be defined and the reader can act as a radar recognition system which is able to recognize letters instead of aircraft, as a function of its RCS. Metallic alphabet cannot compete with conventional chipless tag, because the capacity of coding is much lower. But contrary to chipless tag, visual identification is still possible since letters

978-1-4244-6051-9/11/$26.00 ©2011 IEEE

make words and sentences and an entire text can be read. The measurement set-up proposed in this article is designed in respect to UWB regulation mainly in term of emitting power. So that it can be a base to develop a specific RF reader. This paper presents in Section 2, the physical description of few letters and their associated electromagnetic responses. Then in Section 3, measurement set up and concept of reading system will be discussed.

2. Characterization of letters

Letters of an alphabet have different shapes making their visual recognition simple for people. It was proven [6] in a previous work that the RF identification of all the letters is possible using both Vertical and Horizontal polarization of RF reading signal.

Considering, the physical aspect, a letter's shape is a simple combination of several shapes such as square, dipole and circle. When an EM plane wave impinges the structure, free electrons start to move along the metallic surface and create current paths that in turn create a backscattered EM field. The net effect of all these individual contributions creates a specific radiation pattern and frequency spectrum. But it is very difficult to predict it analytically using Maxwell's equations. So, the classical way is to use numerical techniques to solve this kind of problem. Hence, the study on EM signature that follows has been driven using Time domain solver provided by CST Microwave. This solver gives quickly accurate results for design having a wide band response usually spread on one decade. The height of letter is chosen to be 48mm in order to cover a frequency band between 1GHz and 10GHz. But a previous work [6] showed that it was possible, using a Vector Network analyzer, to recognize smaller letters with a lower RCS. The simplest letter that can be produced is 'I', because it behaves as a shorted dipole. So with a height of 48mm, resonant frequency of 'I' is close to 3GHz. All the other 48mm height letters show resonances distributed around this frequency. The letters presented in the Fig. 2 a) have been realized on a flexible laminate called Kapton, of thickness 100µm having permittivity equal to 3.8. Copper metallic lines have been etched chemically. Line width is approximately 7mm and there is no ground plane below letters. Theses parameters were introduced into CST Microwave Studio and simulation results are shown in Fig. 2 b) and c) for letters 'C', 'G', 'A', 'E'. It can be seen that the EM response strongly depends on wave polarization. This behavior can help recognize some letters. Indeed in some special case, both vertical and horizontal polarization may be required in order to distinguish two different letters. Globally, letters can be classified into two families 1) letters having sharp resonances, showing a very narrow band response 2) letters with flattened resonances, showing a wide band response. Sharp resonances can be easily distinguished, as shown in Fig. 2 b) and c) for letters 'C' and 'E' in both polarizations, because of strong contrast between floor level and maximum level of backscattered response. Resonance frequency value can be determined accurately in this case. Wide band response is harder to distinguish. Indeed, usually it is necessary to use also the Horizontal polarization to determine a letter among many others as described in Fig. 2 c) for letters 'A' and 'G'.

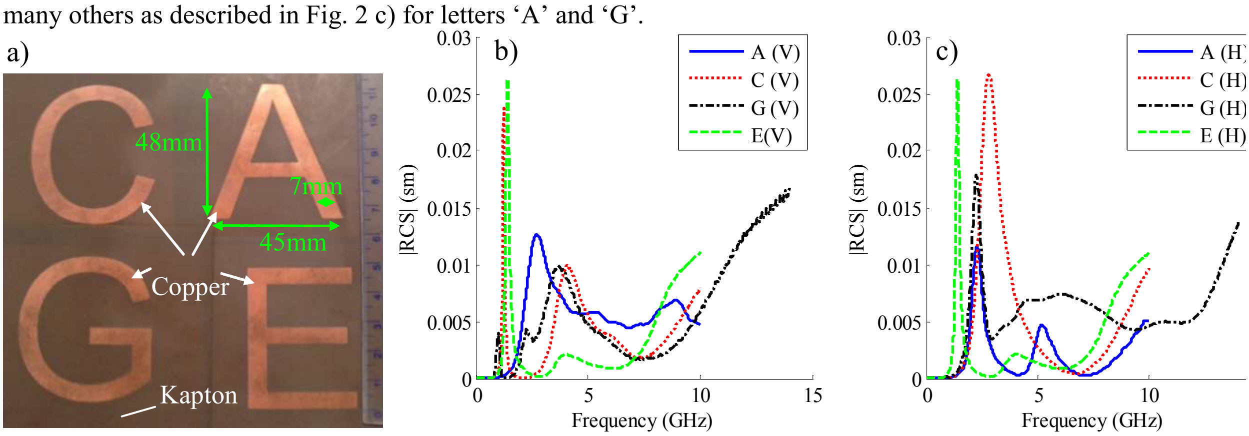

Fig. 2 : a) View of realized 48mm height letters, b) Simulation results for Vertical polarization, c) Simulation results for Horizontal polarization.

A correlation can be done between the shape of letter and its frequency spectrum presenting peaks more or less selective. It is explained in [6] that letters with bent conductors give resonance with a higher quality factor because of increase of parasitic capacity. Indeed when conductors are close each to other, the field lines are more concentrated and both equivalent capacitor and mutual inductance are increased. But selectivity is strongly dependant on current distribution in conductors because the generated EM field can be constructive or destructive. A letter having sharp resonance is due to a combination of constructive fields for a specific frequency. This is why even if letters 'C' and 'G' are visually, nearly similar, their behavior is very different from electromagnetic point of view.

3. Measurements set-up and reading system

A In a previous work [6] we presented the characteristics of many letters using a Vector Network Analyzer because of its good dynamic for very weak reflected signals. The present work considers regulation aspect mainly in terms of authorized emitting power. Wide band response of letters (from 1 to 10GHz) makes the use of classical reading system for their detection rather difficult. However, UWB technology involving wide band communication operating between 3.1GHz and 10.6GHz can be harnessed. Basically, UWB reading system uses very short pulse in time domain having wide band response with a very low duty cycle. The limit given by FCC rules is set to a power spectral density of -41.3dBm/MHz i.e. a transmitting power of -2.5dBm in the entire band. Using a Continuous Wave as for frequency domain method, the reading range will be extremely limited (< 1m). For time domain, the problem is different. Indeed, rules on UWB define a limited energy value for a given time of 1ms [7]. But this energy can be used on a very short pulse so that instantaneous power can reach value as high as 40dBm. In this case reading range will increase significantly.

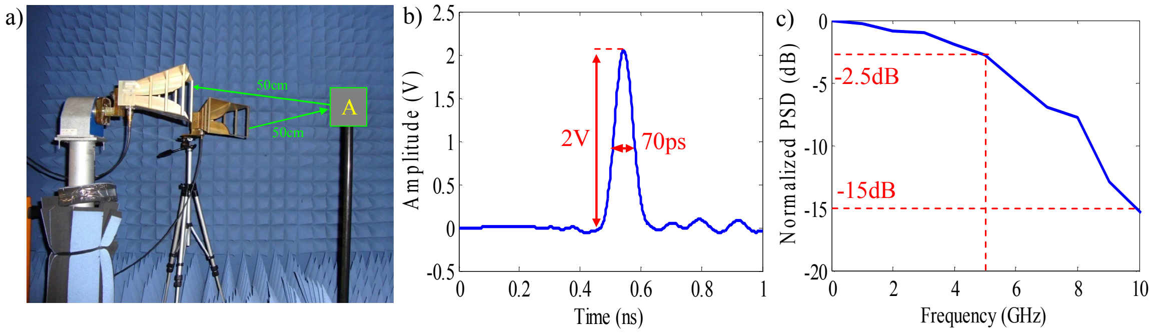

Fig. 3 : a) Measurement Set-up, b) shape of radar pulse, c) normalized power spectral density of pulse.

The measurement set-up is based on a bi-static radar approach. It uses as a receiver, the DSO Agilent DSO91304A having a bandwidth of 13 GHz and a sampling rate of 40 Gs/s. The source is the generator Picosecond 10060A generating a short pulse close to 100 ps of duration. Its maximum amplitude is 2 V into a 50 Ω load. A simple conversion to power value gives a maximum instantaneous power of 19 dBm. The pulse repetition period is set to 1µs so that maximum power spectral density respects FCC rules. Both source and DSO are connected to two identical horn antennas having 12dBi gain as shown in Fig. 3 a). The actual configuration doesn't use any amplifier but a reading range of 50cm is still reachable. Before measurement of the letter's EM signature, a reference measurement, also called isolation is done to remove static environment effect (reflection from various objects). This reference is then systematically subtracted from further measurements. An averaging based on 64 records is also used in order to increase the signal to noise ratio (SNR). The short pulse sent by the Picosecond generator is shown in Fig. 3 b) and its corresponding normalized power spectrum density is plotted in Fig. 3 c). The frequency response of pulse is wideband but a decrease in spectral density can be seen when frequency increases. At 5GHz; attenuation is -2.5 dB below maximum level and at 10 GHz, -15 dB. Since the source pulse is well defined and doesn't change during measurement, it can be compensated by dividing each letter measurement by frequency response of pulse.

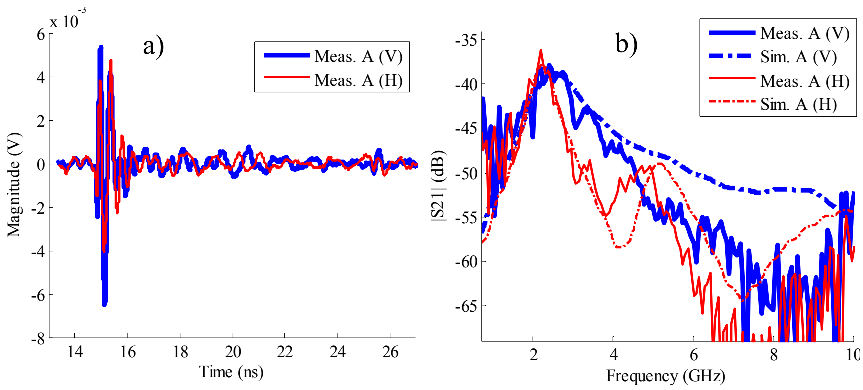

Fig. 4 : Letter 'A's measured response a) in time domain b) in frequency domain.

Results obtained for various letters are shown in Fig. 4 and Fig. 5. Simulation results are also shown and confirm the good prediction of measurement in the overall bandwidth. Even if antennas and cables effect are not considered in simulation, a good agreement with measurements can be seen. Transient responses in Fig. 4 and Fig. 5 have been windowed in order to remove early time and late time environment noise. Frequency responses have been generated using an FFT of time response and dividing it by the frequency response of source pulse. In order to enable comparison with simulation results obtained from CST, a scaling has been applied on measurement results. A very good agreement of measurement and simulation for letter 'C' can be seen. For letter 'A', the Horizontal polarization measurement presents a good agreement with simulation but it is not really the case in Vertical polarization. As a conclusion, sharp resonances are much better distinguishable than smooth resonances and fit very well as per simulation results. Hence, EM responses presenting strong contrast are easily recognizable.

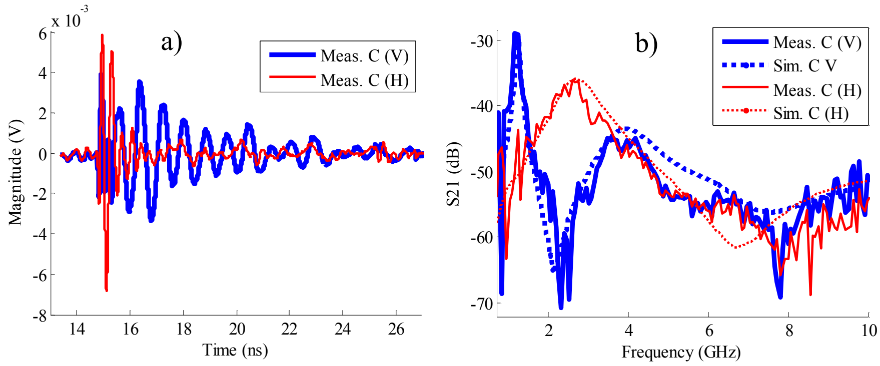

Fig. 5 : Letter 'C' measured response a) in time domain b) in frequency domain.

5. Conclusion

In this paper it was shown that metallic letters can be identified by use of EM wave. To compare with a chipless tag, metallic letters combine both electromagnetic and visual identification capability. The various shapes of letters makes it possible to recognize an entire Latin alphabet composed of 26 letters. A measurement set-up operating in time domain has been experimented and gives some good results for letter of 48mm height. A reading range of 50cm is reachable without any amplifier before the receiver, keeping the emitting power lower than limit set by FCC rules for UWB communication. So, that, this measurement set-up using a pulse generator and an oscilloscope can be adapted to develop a dedicated reader, which is FCC rule compliant. In a future work, association of letters enabling their independent detection inside a word would be studied. The use of specific designed antennas should help to read words and even complete sentences in a text.

6. Acknowledgments

The authors are grateful to Grenoble-Inp for supporting the project via the BQR programme.

7. References

1. K. Finkenzeller, "RFID Handbook: Radio-Frequency Identification Fundamentals and Applications", Wiley, 2004.

2. Clinton S. Hartmann, "A Global SAW ID Tag with Large Data Capacity," *IEEE Ultrasonics Symposium*, 2002.

3. S. Preradovic, N. C. Karmakar,"Multiresonator based chipless RFID tag and dedicated RFID reader," *IEEE MTT-S Digest*, May 2010.

4. I. Jalaly, D. Robertson, "RF Barcodes Using Multiple Frequency Bands," *IEEE MTT-S Digest*, June 2005.

5. M. Keskilammi, M. Kivikoski, "Using Text as a Meander Line for RFID Transponder Antennas," *IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS*, VOL. 3, pp 372-374, 2004.

6. T. Singh, S. Tedjini, E. Perret, A. Vena, "A Frequency Signature Based Method for the RF Identification of Letters," *IEEE RFID 2011*, Orlando, Florida, (USA), April 12-14, 2011.

7. S. Härmä, V. P. Plessky, X. Li, and P. Hartogh, "Feasibility of Ultra-Wideband SAW RFID Tags Meeting FCC Rules," *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 56, no. 4, April 2009.