Efficient, Compact 868MHz Antenna for Retrofit of Electronic Appliance

A. Vorobyov[1], P. Dallemagne[1]

[1]CSEM (Center Suisse d'Electronique et de Microtechnique SA), Wireless Embedded Systems, Neuchatel, Switzerland, alexander.vorobyov@csem.ch

***Abstract*— This paper describes a wire loop antenna with a parasitic element, designed for use in smart smoke detector, acting as a wireless gateway. The antenna has been designed, prototyped and tuned to 868MHz band, then it was characterised and tested in real environment. The antenna can easily be tuned to the 2.45GHz ISM band, and then used by Bluetooth and WiFi devices.**

***Index Terms*—antenna, propagation, measurement, .**

I. INTRODUCTION

There are numerous antenna designs for RF communications in the UHF bands. Each presents various characteristics and properties. Some of them are resistant to environmental changes, others are compact, well integrated into the device or the printed circuit boards and some show good radiation efficiency. In some applications, the antenna must present all the above-mentioned properties. It is for example the case of the smart smoke detector in the LYNCEUS [3] application.

This paper describes the design of an efficient antenna, highly integrated into the plastic smoke detector shell without needing any physical modification of detector hardware. The original smoke detector (Fig.1) consists of a plastic shell, and internally fixed metallic parts: connectors, PCB and a metallic detector elements.

Fig. 1. AUTRONICA BS-100 smoke detector [17].

In addition to the integration requirements, the antenna must be resistant to the location environment such as metallic, concrete, wood, plastics surfaces, and provide uniform hemispherical radiation.

In Section II, we study the different designs that present one of these properties. Section III presents the use case for which the antenna is optimised. The concept of the gateway antenna is introduced in Section IV. Section V discusses the antenna prototyping. The measurement setup and characterization results of prototyped antenna are described in Section VI. Conclusions are drawn in Section VII.

II. COMPACT ANTENNAS OVERVIEW

Various types of antennas for example, loop, helical, and monopole have been considered to accomplish single frequency and multiband performance in a small volume [4]–[6]. In the paper [7] the proposed mobile headset antenna was folded to reduce the size of the antenna. Several types of planar inverted-F antennas (PIFAs) have been proposed in internal mobile handsets [8], [9].

Miniaturization and wideband characteristic for PIFAs in mobile terminals is also well described in the literature. There are several research works on PIFAs with coupling feed for the antenna bandwidth extension [10]–[13]. Example of the PIFA with coupling feed technique and parasitic elements that has very small volume and wideband characteristic is proposed in [14].

Antenna compactness can be reached by applying folded structures with dielectric materials. As an example of this combined structure, a miniature dielectric-loaded folded half-loop antenna is presented in [15].

Most of compact antennas integrated into small/portable devices are narrowband. A technique for enhancing bandwidth of a patch antenna is proposed in [16].

III. USE CASE DESCRIPTION

In the past few years, a large number of studies and research have been carried out following casualties involving ships [1], [2]. These studies have identified the need to improve evacuation, mustering and abandoning procedures. An important step in the above procedures is the counting and accounting for all persons onboard a passenger ship and controlling their movement for safe abandoning.

During the LYNCEUS project, the wireless infrastructure is developed through the deployment of a network of 'smart' fire and smoke detection sensors. In addition to its main role to detect fire and smoke, the smoke detector becomes a gateway between the wireless and a backbone media. All the information from and to wearable modules (life jacket node, bracelet) will be passed through the smoke detector/gateway system.

The antenna and radio must operate under difficult propagation conditions (various placements on the body, and movements of body parts). As a matter of fact, the wireless communication systems must be able to cope with particularly difficult propagation environments, such as the extreme multipath due to the ship's steel structure.

IV. ANTENNA CONCEPT

Taking into account LYNCEUS application requirements, recommendations for the manufacturing of the deployment of the smart smoke detector in cruise ships , the limited space, the 3D profile and the presence of many metallic objects in the smoke detector, we decided to use a combination of different antenna designs.

As result, the antenna is formed of several wire elements placed in parallel.

The proposed solution for the smoke detector antenna consists of a number of co-axial circular loop elements that are close to resonance at 868MHz (Fig.2).

The driven antenna loop element is placed in between two additional loops (Fig. 2). The bottom loop, which is closely placed to the metallic disk is playing a reflector role, and the top loop element is a director.

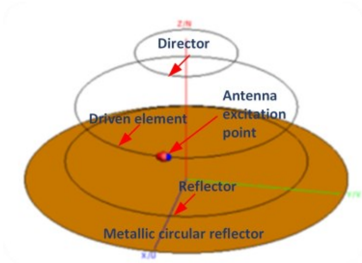


Fig. 2. Proposed smoke detector antenna: 3D theoretical model.

When an array of loops with the correct dimensions is used, a directive beam in the axial direction can be obtained. One of the loop elements is driven directly and the other ones have currents induced in them by mutual coupling. Correctly spaced elements have similar currents with an equally progressive phase shift, making the array essentially a structure supporting a travelling wave.

The smoke detector is usually placed on a ceiling. The ceiling can be made of different materials, like metal, plastic, wood or concrete. Care must be taken so that the material behind the smoke detector does not detune the antenna and degrade the antenna radiation performance.

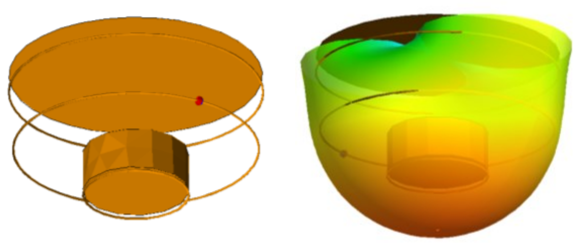


Fig. 3. Smoke detector antenna model with metal element and its 3D radiation pattern.

The role of the bottom metallic circular reflector (Fig. 2) is precisely this: this additional reflector allows keeping the antenna performance constant for whatever material is present behind the smoke detector surfaces.

Taking into account the model detector element, the theoretical model of the gateway antenna is presented in Fig. 3.

Optimized antenna dimensions and the antenna theoretical performance are given in, Table 1, Fig.4 and Table 2 respectively.

TABLE 1. ANTENNA THEORETICAL RESULTS SUMMARY

Polarisation	Antenna size [mm2]	Frequency [MHz]	BW [MHz]	Gain [dBi]	HPBW
Linear	120(D)×62(h)	868	100	3.5	78°

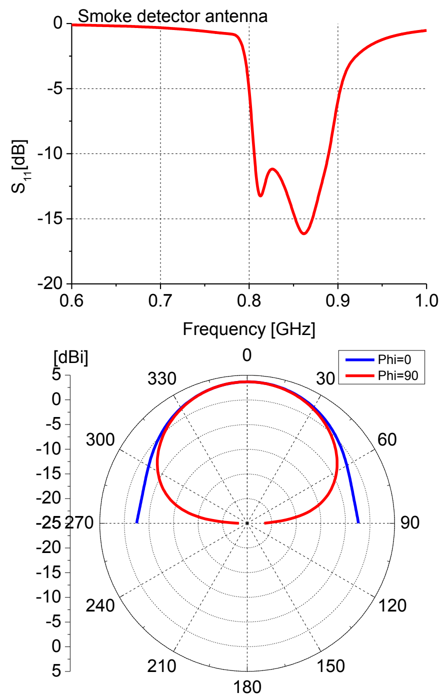


Fig. 4. Smoke detector antenna theoretical performance.

TABLE 2. SMOKE DETECTOR ANTENNA DIMENSIONS.

Antenna element	Dimensions [mm]
Wire diameter	1
Metallic circular reflector diameter	120
Antenna loop reflector diameter	100
Antenna loop driven element diameter	100
Antenna loop director diameter	50
Distance between metallic reflector and loop reflector	9
Distance between loop reflector and loop driven element	30
Distance between loop driven element and loop director	23

The designed antenna demonstrates good matching over 868MHz. The antenna is linear polarised and provides an almost uniform radiation pattern in the E-plane and the H-plane.

V. Antenna Prototyping

The proposed theoretical antenna model has been prototyped and integrated into the AUTRONICA [17] smoke detector plastic shell. The antenna parts assembly is presented in Fig.5.

There are three smoke detector plastic parts: top (consist of metallic contacts for the wire connection), middle (holds the RF board) and bottom (plastic cover of the detector sensor). The antenna driven element is wire loop fixed around the RF board placed in the smoke detector middle part. The antenna loop driven element is fed through the coaxial cable with a miniature uFL connector. Due to the small size of the connector (3×3mm^2), the antenna can be easily connected to the integrated PCB with the radio components. The assembled antenna is presented in Fig.5.

Fig. 5. Antenna parts integration in the smoke detector plastic shell.

The director or parasitic antenna element is a wire ring, which is integrated into the inner bottom plastic part of the smoke detector and glued for a better fixation.

Finally the reflector wire ring antenna element is fixed on the outer of the top detector plastic shell, which is covered with a metallic circular disc.

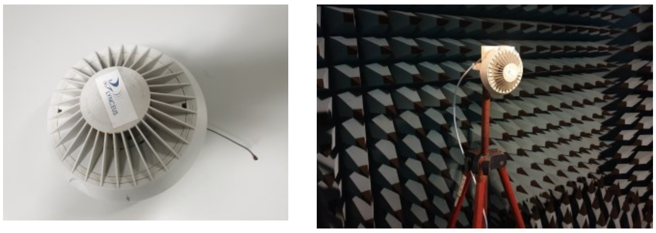
As we can see, the antenna reflector loop element and the metallic reflector is located outside of the smoke detector shell, and the driven together with the director loop antenna elements are placed inside the plastic shell. The driven antenna loop element is placed around the PCB with radio.

It is important, that the integrated antenna does not require any physical modification of the detector and does not affect the detector functionality.

VI. Antenna Characterisation

The prototyped and assembled smoke detector antenna (as shown in Fig.6) was characterised in laboratory environment and anechoic chamber.

The antenna measurement results are presented in Fig.7. During the S-parameter measurement, the antenna was connected to the HP8753D network analyser. To prevent common mode current influence during the measurements a ferrite flexible layer has been used along the coaxial cable and near the uFL connector which are attached to the AUT (antenna under test).



Top view *Radiation pattern measurements*

Fig. 6. Assembled antenna.

The antenna is well matched at the desired frequency (868MHz). However, the vicinity of the radio PCB to the antenna driven loop element affect the antenna resonant frequency, which explains slight difference with simulated results. This can be tuned by increasing or decreasing the driven loop diameter, or applying PI-matching circuit.

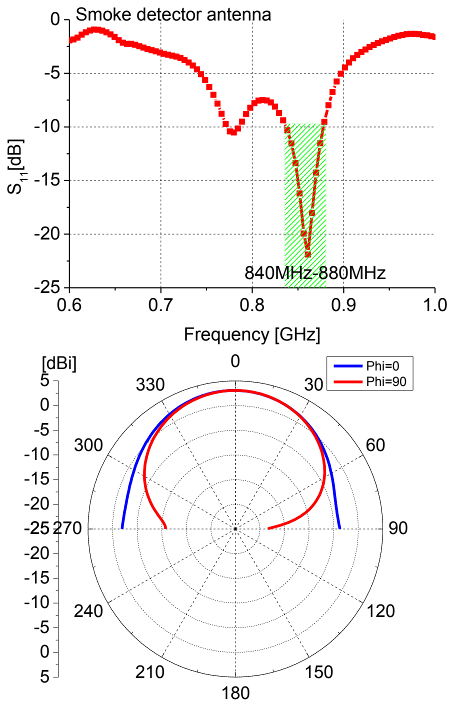


Fig. 7. Smoke detector antenna measurement results: S-parameter (left) and radiation pattern (right).

Antenna radiation performance measurements have been performed in the CSEM anechoic chamber. As reference antenna we used a log periodic antenna (868MHz). The antenna demonstrated a radiation performance similar to the theoretical model. However, the maximum measured antenna gain (~2dBi) is a slightly lower than the theoretical one. This can be explained by assembly of the antenna and by antenna matching difficulties when the radio PCB is close to the antenna director element.

The smoke detectors with the integrated antennas have been tested in real environment on a cruise ship. The smart smoke detectors have demonstrated good performance in various conditions (e.g. attached to a plastic surfaces, attached to a metallic surfaces).

VII. CONCLUSION

In this paper, a highly integrated, inexpensive, effective antenna for smart smoke detector is proposed. As required, the antenna does not affect the initial design of the smoke detector and its performance. The proposed antenna is made of cheap copper wires, which can be replaced by metallised surface applied on the plastic detector shell.

The smoke detector with integrated antenna can be attached to any surfaces without any influence on the antenna performance which is important in many wireless applications.

Thanks to its simple and efficient design, the antenna can be integrated in a smaller size detectors, and can be easily tuned to operate at other frequencies e.g. some GSM and ISM bands.

ACKNOWLEDGMENT

The research leading to these results has received funding from the European Community's H2020 Framework Programme (H2020-MG-4.2-2014) under grant agreement no. 636286 and was carried out in the frame of Lynceus2Market project (An innovative people localisation system for safe evacuation of large passenger ships).

REFERENCES

[1] Kristiansen, S., 2005. Maritime Transportation – Safety Management and Risk Analysis. Elsevier Butterworth–Heinemann, London.

[2] Striking and Subsequent Sinking, Passenger and Vehicle Ferry Queen of the North, Gil Island, Wright Sound, British Columbia. Marine Investigation Report M06W0052.Minister of Public Works and Government Services Canada.

[3] https://cordis.europa.eu/project/rcn/193392_en.html

[4] M. Tzortzakakis and R. Langley, "Quad-band internal mobile phone antenna," *IEEE Trans. Antennas Propag.*, vol. 55, no. 7, pp. 2097–2103, Jul. 2007.

[5] K. Wong and C. Huang, "Printed loop antenna with a perpendicular feed for penta-band mobile phone application," *IEEE Trans. Antennas Propag.*, vol. 56, no. 7, pp. 2138–2141, Jul. 2008.

[6] S. Lee, K. Kim, B. Kim, J. Oh, and Y. Yoon, "Multi-band coupled feed loop antenna for mobile handset," in *Proc. Asia–Pacific Microw. Conf.*, Dec. 2009, vol. 4, pp. 2703–2706.

[7] Y. Chi and K. Wong, "Compact multiband folded loop chip antenna for small-size mobile phone," *IEEE Trans. Antennas Propag.*, vol. 56, no. 12, pp. 3797–3803, Dec. 2008.

[8] K. Fujimoto, A. Henderson, K. Hirasawa, and J. James, *Small Antennas*. London, U.K.: Research Studies Press & Wiley, 1987, sec.2.4.1.

[9] B. Kim, S. Park, Y. Yoon, J. Oh, K. Lee, and G. Koo, "Hexaband planar inverted-F antenna with novel feed structure for wireless terminals," *IEEE Antenna Wireless Propag. Lett.*, vol. 6, pp. 66–69, 2007.

[10] J. Ollikainen, M. Fischer, and P. Vainikainen, "Thin dual-resonant stacked shorted patch antenna for mobile communications," *Electron. Lett.*, vol. 35, no. 6, pp. 437–438, Mar. 1999.

[11] K. Wong and C. Huang, "Bandwidth-enhanced internal PIFA with a coupling feed for quad-band operation in the mobile phone," *Microw. Opt. Technol. Lett.*, vol. 50, no. 3, pp. 683–687, Mar. 2008.

[12] C. Chang and K. Wong, "Printed l/8-PIFA for penta-band WWAN operation in the mobile phone," *IEEE Trans. Antennas Propag.*, vol. 57, no. 5, pp. 1373–1381, May 2009.

[13] K. Wong and C. Huang, "Compact multiband PIFA with a coupling feed for internal mobile phone antenna," *Microw. Opt. Technol. Lett.*, vol. 50, no. 10, pp. 2487–2491, Oct. 2008.

[14] Ki-Joon Kim, SangHeun Lee and Young Joong Yoon, Small Antenna With a Coupling Feed and Parasitic Elements for Multiband Mobile Applications, *IEEE* Antennas and wireless propagation letters, VOL. 10, 2011.

[15] C. C. Chiau, "Miniature Dielectric-Loaded Folded Half-Loop Antenna and Ground Plane Effects", IEEE antennas and wireless propagation letters, vol. 4, 2005

[16] Pramod Kumar.M, "Novel Structural Design for Compact and Broadband Patch Antenna",2010 IEEE.

[17] https://www.autronica.nl/smoke-detectors.html