Electromagnetic Compatibility: RFID and Medical Equipment in Hospitals

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Abstract – **The objective of this study is to evaluate if some life-supporting medical electrical equipment can be affected by electromagnetic waves emitted by sources for the remote identification (RFID). In particular, we assessed the occurrence of electromagnetic interference with an in-situ testing method specifically developed, based on standard ANSI C63.18, within an intensive care unit. Some serious faults were identified, both related to the RFID sources and to power sources.**

Keywords – **Electromagnetic Compatibility, Radio Frequency Identification, Essential Performance, Intensive Care, ME Equipment.**

I. Introduction

RFID (Radio Frequency Identification) remote identification techniques are widely used today in many fields of application. In recent years this technology has spread in the health sector. There are many applications: medication management, identification and tracking in surgery, blood transfusion, maxi-emergency situation, people/medical equipment tracking, and maintenance. [2] [3]

In literature there are many studies that address the problem of electromagnetic compatibility between life support electrical medical equipment and sources of radio frequency as mobile phones. [4] [5]

The introduction of a new wireless technology within a hospital environment, especially in an area where there are life-supporting electrical medical devices, makes the problem of electromagnetic interference (EMI) even more critical. Despite the spread of this technology, the literature provides conflicting results regarding the safety and reliability on the use of RFID in the healthcare environment. [6] [7] [9]

The purpose of this study is to evaluate the occurrence of electromagnetic interference between life-supporting medical electrical equipment (ME equipment) and RFID sources (active and passive). Starting with a standard protocol, the ANSI C63.18, suitably modified to adapt to our case, we made some tests for the evaluation of EMI. [8]

II. Material and methods

A. ME Equipment

This study was performed in collaboration with the Santa Maria Nuova Hospital in Florence. The tests were carried out in the resuscitation department of this hospital. All ME equipment used are in this category and are used in medical practice.

The units recruited for the test are 9 units in total: four ventilators, an infusion pump, two defibrillators, a multi-parameter monitor and an electroencephalograph (see Table 1).

For each unit we determined functions and alarms to be tested, within essential performance of the device itself. From a viewpoint of electromagnetic compatibility, "ME equipment and ME systems shall have adequate immunity to be able to provide its basic safety and essential performance in the presence of electromagnetic disturbances". [10]

Table 1 ME Equipment tested

Type	Manufacturer	Model
Ventilators	*Siemems*	*Servo 900*
	Siemens	*Servo i*
	Fraeger	*EVITA cap 2*
	Carefusion	*Avea Ventilator Sistem*
Infusion Pump	*Carefusion*	*Alaris GP*
Physiological Monitor	*Siemens*	*SC - 7000*
Defibrillators	*Medtronic*	*Lifepak 9*
	Medtronic	*Lifepak 12*
EEG	*EB Neuro*	*B.E. Light*

This was possible thanks to a documentary analysis on current regulations and manuals of the devices and through close collaboration with the medical and nursing staff, in accordance with the guidelines of ANSI 63.18 Protocol [9]

B. RFID System

To perform our tests we used two RFID sources operating at 868 MHz (passive RFID) and 2.45 GHz (active RFID). The passive source emits up to 1000 mW ERP (with an 8dBi antenna), while the active delivers 100 mW EIRP.

The passive system has a reader that also provides power to the antenna, while the active one needs an external power

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supply to operate. In the tests we used both a switching-mode power supply and a linear one.

Comparative tests were made in an anechoic chamber to compare the power levels declared by the manufacturer with real ones. Assuming that the power adaptors could be sources of interference, we made some measurements also on these devices in an anechoic chamber.

C. Test Method

The protocol used is based on ANSI C 63.18 international standard [8].

During the test it is determined the final distance to which interference will occur, and any errors encountered are classified into mild, intermediate, and fatal, using expert opinion of medical staff.

All tests were performed in the intensive care unit of the Hospital Santa Maria Nuova in Florence, on a total of 5 beds. The tests were performed near the patient bed with all the instruments mounted in the configuration of normal use (in-situ tests).

The tests are performed as follows.

The medical unit sets the tested ME equipment as for normal operation. In some cases for the verification of essential performance is necessary to use a patient simulator. For example, for ventilators we used lung simulators, for the infusion pump bowls containing distilled water. For the ECG function of defibrillators and for the electroencephalograph we connected the devices to a healthy volunteer.

Then the RF transmitter is turned on and it is approached to the ME equipment through three intermediate distances until you get in contact. The initial distance depends on the power source in accordance with the ANSI protocol.

The tests were repeated three times; to make them independent we performed a power cycle to the ME unit for each test.

Each ME equipment has been tested along the spatial axes, Front, Rear, Left, Right, and - where possible – Up and Bottom (Fig. 1).

The number of functions and alarms depends on the type of device: the infusion pump has 1 function and 4 alarms; each tested ventilator has 2 functions and 4 alarms; each tested defibrillator has 2 functions and 3 alarms; the multi-parametric monitor has 1 function and 2 alarms, while the EEG has only one function, but the test was performed on two different parts of the appliance, the amplifiers and the PCMCIA external board.

To carry out the measures it has been necessary to create a movable wheeled cart on which we mounted all the measurement tools and the RF transmitter. The cart we designed meets the specifications of mobility and strength in order to be used on the field. To prevent reflections in the testing environment, the cart is made of wood.

When a failure occurs on the ME equipment tested, the test is repeated three times in order to verify that the cause is the presence of the RFID transmitter. Then, the procedure is carried out to determine the final distance at which the error occurs. If the malfunction ends after turning off the RF source, the error is defined as unstable. Then we turn away the RF transmitter at a constant rate until there is no more interference, according to the medical staff. If the interference does not end, the error is classified as stable.

Finally, the error is classified the error according to its criticality in collaboration with the medical staff.

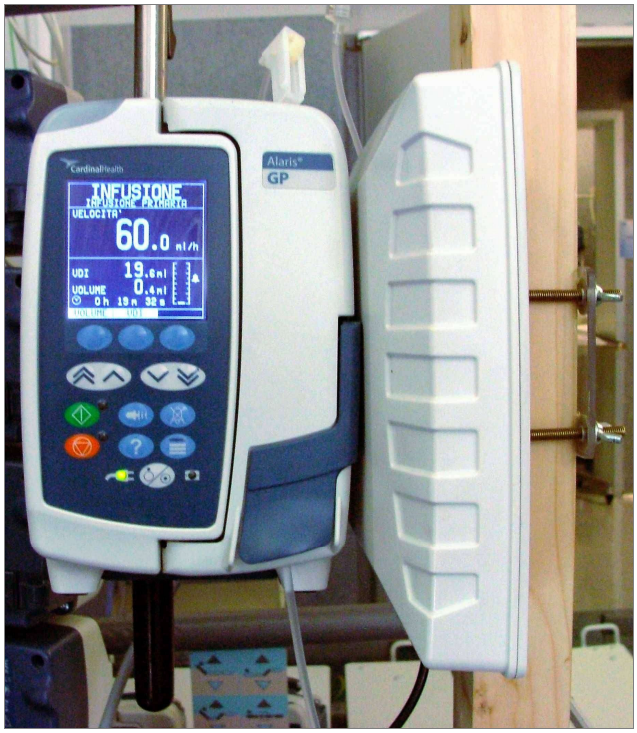

Fig. 1 868MHz passive RFID transmitter – Infusion pump test a right face test in contact.

III. Results

All 9 ME devices were subjected to the method of evaluation for both RF sources. The results are in Table 2. For two devices it was only possible to test the passive RFID source, as a result of a subsequent failure of the ME equipment (not related to the test). For the purposes of numerical analysis are considered only those tested with both sources.

Table 2 Test results: interferences.

Type	Model	Interference	
		868 MHz	2,4 GHz
Ventilators	*Servo 900*	**YES**	**-**
	Servo i	**NO**	**-**
	EVITA cap 2	**NO**	**NO**
	Avea Ventilator Sistem	**NO**	**NO**
Infusion Pump	*Alaris GP*	**NO**	**NO**
Physiological Monitor	*SC - 7000*	**NO**	**NO**
Defibrillators	*Lifepak 9*	**YES**	**NO**
	Lifepak 12	**NO**	**NO**
EEG	*B.E. Light*	**YES**	**YES**

As shown in Table 2, two devices have undergone interference by the passive RFID source, while just one device showed malfunctions when we used the active RFID source. The 21% test of interference, in relation to each ME unit, was positive.

For a better understanding of the results we performed a more in-depth numerical analysis, trying to analyse the interference in relation to the functions and alarms tested.

118 EMI tests were performed. We obtained a total of 27 EMI positive tests (22% of the total), i.e. cases where interference was observed in the tested functions of the ME equipment.

Test results are summarized in Table 3.

Table 3 Test results: EMI.

	RFID source	
	868 MHz	**2,4 GHz**
Total tests	58	60
Low EMI	12	0
Significant EMI	5	10
Fatal EMI	0	0
Total EMI	**17**	**10**
EMI/tests	29%	16%

Particularly serious is the failure of the alarm for Medtronic Lifepack 9 tested with passive source: 3 EMI produced were classified by medical personnel classified as fatal. The device does not report cardiac arrest (alarm failure) after disconnecting the electrodes from the patient. The device's monitor shows a "cardiac signal" due to the sync pulse from the RF source (Fig. 2) erroneously interpreted as a heart signal in the frequency range between 30 bpm and 50 bpm. The distances at which these interferences have occurred are between 55 and 170 cm.

With regard to the electroencephalograph BE Light, the 868MHz passive RFID source produces interference on the EEG already at 150 cm, classified as "mild". The 2.45GHz RF source produces interferences classified as "significant" at a distance of 40 cm. This is because the noise produced by the active source may be confused with the EEG of the patient, leading to diagnostic errors (see Fig.3).

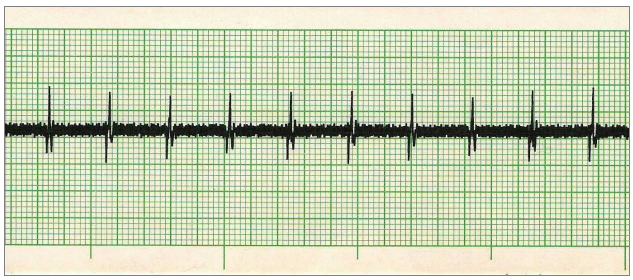

Fig. 2 Alarm failure: pulsed noise signal erroneously interpreted as cardiac signal!

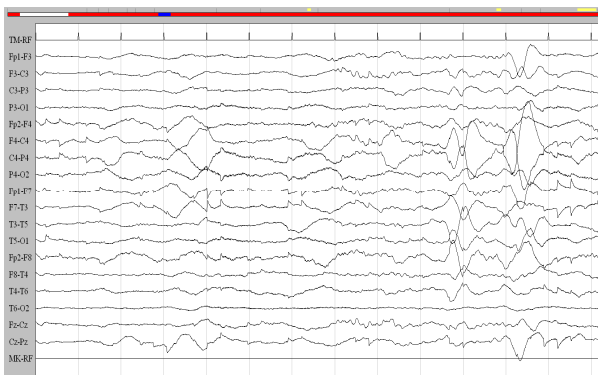

Fig. 3 Interference on EEG signal: possible diagnostic error.

IV. Discussion and Conclusions

During the tests for interference evaluation we verified through the application of a simplified protocol, that the power adaptors, particularly switching-mode power supplies, produces radiated interference, especially in the diagnostic ME equipment *(*ECG-monitoring defibrillators, and EEG*)*. The results of these tests show that a critical part for defibrillators are the plates, as they act as antennas and "capture" the waves in the environment.

The results obtained in this study are aligned to what is reported in the literature under similar conditions.

The interference affecting equipment that comply with the newest standards are not to be considered as critical

because they are obtained by approaching the source at a distance less than the minimum recommended by the standard. [10] [13]

Our results have still some limitations related to the reduced number of ME devices and RFID sources used, but are particularly interesting as obtained in an electro-magnetically noisy environment such as a fully operative resuscitation department.

In conclusion, the adoption of RFID technologies in healthcare settings full of medical electrical equipment must be performed paying attention to the following aspects:

- most appropriate technology (lower power RF sources, offering the needed reading distance, are to be preferred)
- attention to the characteristics of the whole chosen RFID system (with particular reference to power sources used)

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