POTENTIAL INTERFERENCE GENERATED BY UHF RFID SYSTEMS ON MILITARY TELECOMMUNICATION DEVICES

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Abstract: The Commission Decision 2006/804/EC of 23 November 2006 *on harmonisation of the radio spectrum for radio frequency identification (RFID) devices operating in the UHF band* offers big expectations of market developing for RFID systems but, on the other hand, creates some concerns for possible interference on defence telecommunication equipment operating in the same UHF frequency bands (865-868 MHz).
This paper intends to analyse the military electromagnetic compatibility standards (MIL-STD-461E), and to evaluate possible interference on defence telecommunication equipment, with the intention of stimulating a constructive discussion between military and industrial stakeholders on how to overcome interference problems.

Introduction - Opportunities and fears arising from the EC Decision 2006/804/EC:

Some characteristics of RFID systems operating in the UHF band, such as the possibility of working at a distance of a few meters using passive – therefore cheap – tags, or the fact that UHF RFID readers can scan hundreds of tags simultaneously, make UHF RFIDs suitable for logistics applications and for object tracking, with a strong potential impact on industry and the service sector. Therefore, there is a strong demand from European Industry to obtain more UHF RFID spectrum and for a RFID standardization to ensure interoperability, to facilitate wider RFID applications deployment and to bring down tag costs due to economies of scale.

In order to meet these requests, on 23 November 2006 the European Commission issued the Decision 2006/804/EC *on harmonisation of the radio spectrum for Radio Frequency Identification (RFID) devices operating in the ultra high frequency (UHF) band* [1]. The RFID operational frequencies harmonised by the Commission Decision are the UHF bands ranging from 865 to 868 MHz. These bands are covered for use by RFID by harmonised standard EN 302 208 [2] and ruled by the Recommendation CEPT/ERC/REC 70-03 (RFIDs are classified as Short Range Devices) [3].

While industrial RFID stakeholders are welcoming this Decision, in some European Defence environments (which we will call generically "*military*") there is a big concern for its possible consequences. In fact these RFID UHF frequencies, in some EU countries, are handled by the ministries of Defence for security purposes (telecommunication services of Army, State police, penitentiary police, fire brigades).

The Commission Decision 2006/804/EC imposes "*to make available, within six months after the entry into force of this Decision and on a non-exclusive, non-interference and non-protected basis, the frequency bands for RFID devices*." Without interference and without protection means that RFID civil users may not cause interference to the military ones and that they cannot ask for an exclusive use of the frequencies, with consequent legal protection. So, between civil RFID and military telecommunications it is not a frequency sharing on equal terms, because telecommunication services have the priority over RFIDs, but some military environments are however concerned about the risk of harmful interference.
Therefore, some EU Countries have asked for a *derogation* to the RFID Commission Decision, requesting a reduction in UHF RFID transmitting power or a limitation on UHF RFID use only to indoor environments [4], [5].

Some industrial stakeholders consider these fears exaggerated, arguing that the use of the frequencies in question is only for RFID systems using passive tags, classified as short range devices, that it's not in RFID users' interest to aim RFID antennas (intrinsically directive) at military installations, and that the power of 2W is not sufficient to disturb telecommunication systems.

In order to understand if UHF RFID devices can cause interference to military equipments operating in the same frequency range some simple electromagnetic considerations should be undertaken, but first it is necessary to briefly analyse the military standard involving Electro Magnetic Compatibility issues.

Electromagnetic compatibility – The MIL-STD-461E Radiated Emission limits and Immunity levels:

Electro Magnetic Compatibility (EMC) issues have a dual nature of considering both *emissions* and *immunity (or susceptibility)* of a device, and are evaluated by executing tests or analyses on an apparatus such that: "*the electromagnetic disturbance it generates does not exceed a level allowing radio and telecommunications equipment and other apparatus to operate as intended*" (emissions) and "*the apparatus has an adequate level of intrinsic immunity of electromagnetic disturbances to enable it to operate as intended*" (immunity) [6]. Moreover: "*The motivation behind the development of military and commercial requirements is similar. Both are concerned with controlling emissions from equipment that may couple to electronics with very sensitive interfaces – particularly antenna ports –* (emissions) *and with providing adequate immunity of other electronic equipment to similar electromagnetic disturbances present in the environment" (immunity)* [7]. Figure 1 shows these EMC principles applied to the specific study of this paper.

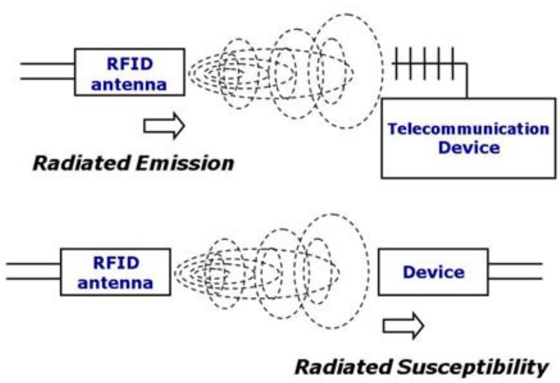

Figure 1 – Possible interference generated by a RFID antenna

The standards ruling electromagnetic compatibility requirements for military equipments are the MIL-STD, issued by the Department of Defence of the U.S.A. but used worldwide for military applications even in the European countries involved by the decision 2006/804/EC.

The most recent military EMC standard is the MIL-STD 461E [8]. Older versions of this standard are still in use but, in the UHF frequency range under examination, there is no substantial difference in limits and test procedures, so we will refer to the MIL-STD 461E issued on 20 August 1999.

The section of the MIL-STD 461E ruling Radiated Emission requirements in the frequency range of interest (865-868 MHz) is named RE102. RE102 details test procedures and emission limits according to the types of equipment or subsystems and their intended installations: limits are similar but different for naval, aircraft or ground applications. UHF RFID devices may cause interference mainly to ground military installations, so we will consider the *ground applications* limits reported in Figure 2 below (named Figure RE102-4 in the MIL-STD-461E).

Once the place of installation is decided on (ground), there can be two different limits according to the military force and the portability of the device (as seen in Figure 2): electric field emissions shall not be radiated in excess of the upper curve for Navy fixed devices and Air Force devices, while they may not exceed the lowest curve for Navy mobile devices and Army devices. Both for precautionary and logical reasons it is the lowest curve that must be taken into account.

We can find the value of the maximum allowed electric field (or emission limit) at the frequency range of interest analytically, by interpolation of the limit curve in the semi-logarithmic graphic reported in Figure 2, obtaining $E_{Limit} = 42.7$ dBμV.

Converting the dBμV value in the corresponding SI measure unit we have a Radiated Emission limit equal to: $E_{Limit} = 1.36 \cdot 10^{-4}$ V/m.

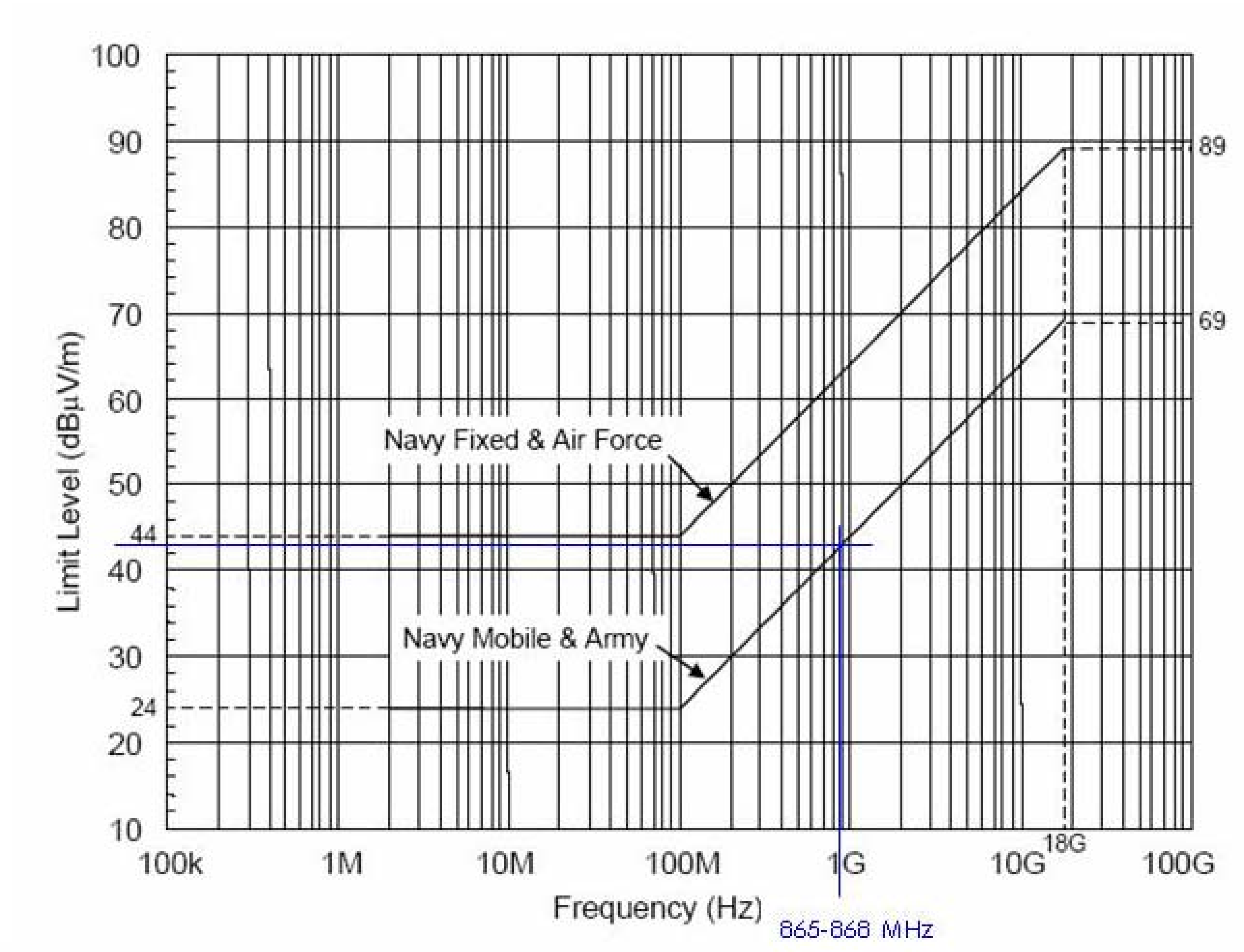

Figure 2 - MIL-STD-461E Radiated Emission RE102 limits for ground applications

The section of the MIL-STD 461E ruling on Radiated Susceptibility (or immunity) in the frequency range of 865-868 MHz is named RS103. According to its requirements electronic, electrical, and electromechanical equipment and subsystems under test "*shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to the radiated electric fields listed in Table VII and modulated with a 1 kHz pulse modulation, 50% duty cycle.*" ([8], chap. 5.19.2).
The kind of modulation used in the RS103 test is similar to the simple amplitude modulations adopted in the communication between UHF RFID readers and passive tags (e.g. the ASK modulation [9]). It therefore makes sense to compare the signal amplitude generated by a RFID with the RS103 immunity level not only from a normative point of view but also from a theoretical point of view.

Considering (as above) the immunity of a ground installation we can report the RS103 Radiated Susceptibility limits of interest in Table I.

Table I - MIL-STD-461E Radiated Susceptibility RS103 Limits for ground applications

Frequency range	Platform	Immunity level [Volts/meter]
From 30 MHz to 1 GHz	Army	50
	Navy	10
	Air Force	10

Evaluation of RFID potential interference with military telecommunication devices:

The Listen Before Talk technique protects RFID systems from disturbing each other and could safeguard RFID readers from interfering military transmissions, but it cannot protect military telecommunication receiving antennas from interference generated by RFID interrogators.

A complete analysis of real interference problems on a receiving telecommunication system would require EMC tests and measurements on the specific device, because the specific receiver sensitivity threshold varies according to electric field levels and modulation techniques.

But the intent of this paper is precautionary, so we aim at calculating an **interference range** defined as: "*the distance outside which no harmful interference will occur*" [10] and below which an interference may occur.

Assuming this principle conservative calculations must be done, considering, as worst case:

- A military telecommunication equipment with an interference threshold equal to the MIL-STD-461E RE102 emission limit. This is coherent with the EMC emission limit motivation that we have cited above: "*a level allowing radio and telecommunications equipment and other apparatus to operate as intended*".
- The disturbing equipment is a RFID interrogator (not a tag: the interrogator transmits with a power at least 4 orders of magnitude greater than a tag), transmitting at the maximum Effective Radiated Power (ERP or e.r.p.) allowed by the Commission Decision 2006/804/EC and reported in Table II.
- The transmitting RFID antenna is placed outdoor and radiates in line of sight exactly towards the military radio receiver antenna, positioned in the maximum gain direction.
- The electric field generated by the RFID system propagates towards the military radio receiver in free space, without any obstacle. However, some evaluations of wall attenuation are made (see Table IV).

Table II – Maximum effective radiated power allowed for UHF RFID system by the Commission Decision 2006/804/EC

Frequency band	Maximum Power allowed (ERP)
865-865.6 MHz	100 mW
865.6-867.6 MHz	2 W
867.6-868 MHz	500 mW

Considering the direct free space propagation formula :

$$\frac{P_T \cdot G}{4 \cdot \Pi \cdot d^2} = \frac{E^2}{Z_0}$$

where:

P_T is the transmitted (RFID) power,

G is the gain of the transmitting RFID antenna,

The product of $P_T \cdot G$ is also called Effective Radiated Power (ERP) of the transmitter (see Table II)

E is the maximum allowed electric field (for the MIL-STD-461E RE102 limit emissions $E_{Limit} = 1.36 \cdot 10^{-4}$ V/m)

d is the interference range

Z_0 is the characteristic impedance of the air ($=120 \cdot \pi$),

substituting the values and reversing the formula it's possible to obtain the interference range for several values of ERP as reported in Table III:

Table III – Interference range [km] between a transmitting RFID system and a receiving military telecommunication device placed in line of sight.

RFID system ERP	Interference range [km]
2 W	57
500 mW	28
100 mW	13

It is possible to estimate how the interference range would change, for example, just positioning the RFID systems indoor, considering the free space propagation formula used above corrected with a wall attenuation factor. The attenuation produced by a wall structure is highly variable, depending on the wall material composition and on the angle of incidence of the electromagnetic radiation beam [11]. Considering an attenuation of 10 dB we can try to estimate the order of magnitude of the interference distance for an indoor RFID system. It is noted that even this is a precautionary estimation, because we still consider a direct propagation, with the only attenuation caused by an infinite homogeneous wall placed perpendicularly to the path.

Table IV – Interference range – RFID system indoor (10 dB attenuation)

RFID system ERP	Interference range [km]
2 W	18
500 mW	9
100 mW	4

Evaluation of immunity of generic military devices from RFID potential interference:
Another Electro Magnetic Compatibility analysis could be done in order to evaluate if a RFID system may cause interference to a generic military device (not a telecommunication one), causing malfunctioning that can be very harmful, especially for devices controlling weapons.

Hypotheses (direct line of sight) and calculations (free space propagation) are similar to those executed in the case of interference with military telecommunication devices, but in this case the maximum electric field allowed is not the MIL-STD-461E emission limit but the MIL-STD-461E immunity level limit (see Table I)
Even doing the most conservative assumption of a 10 V/m immunity level the calculations (reported in Table V) reveal no harm of electromagnetic interference between RFID systems and military generic devices.

Table V – Interference range between RFID systems and generic military devices

RFID system ERP	Interference range
2 W	< 1 m (0.8 m)
500 mW	< 1 m (0.4 m)
100 mW	< 1 m (0.2 m)

Indeed, the electromagnetic Immunity test MIL-STD-461E RE103 requires the device under test to withstand the immunity levels reported in Table I irradiated at a distance of one meter while in all the considered cases the calculated interference range is smaller than one meter. Note that the interference range values reported between brackets in Table V shall be considered just as an indication because inside the near field zone.

Conclusions:
There is a strong risk that UHF RFID systems may cause interference on military telecommunication devices operating in the 865-868 MHz UHF band as outlined in Table III and Table IV, while there is no risk that a RFID system cause harmful interference to a generic military device as shown in Table V.

RFID industrial operators should consider the prevention of possible interference on military telecommunication devices as a fundamental issue. In fact, in the case of heavy interference with military telecommunication equipments, the Commission Decision 2006/804/EC declares that "*radio communications services (…) have priority over such RFID devices*". Moreover, the CEPT/ERC/REC 70-03 states that Short Range Devices operating in shared bands "*are not permitted to cause harmful interference to other radio services*" and that "*manufacturers should advise users on the risks of potential interference and its consequences*".

It is therefore necessary to increase the electromagnetic compatibility culture amongst RFID system installers. For example, interference can be easily solved by placing RFID interrogator antennas in a slightly different position, or by setting the working frequency of RFID systems on a different channel.

On the other hand, even military operators should be interested in the wide spreading of UHF RFID system standards due to UHF RFID's ability in allowing quicker and safer object and vehicle identifications, particularly useful for security purposes. The American Department of Defence strongly supports UHF RFID implementation and from 2005 consider passive RFID mandatory for delivery of material [12].

The fostering of dialogue between military telecommunications operators and UHF RFID systems stakeholders could help to foresee possible electromagnetic interference, or contribute to the solution of eventual interference problems.

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