

POTENTIAL INTERFERENCE ISSUES BETWEEN FCC PART 15 COMPLIANT EMITTERS AND IMMUNITY COMPLIANT EQUIPMENT

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ABSTRACT

Transmitting equipment may interfere with sensitive electronic equipment even if both are in compliance with regulatory standards. This paper examines the potential for electromagnetic interference (EMI) between Federal Communications Commission (FCC) Part 15.247 for Ultra-High Frequency (UHF) emitters and immunity compliant sensitive equipment. At close ranges, the electromagnetic (EM) fields from these UHF emitters may exceed minimum standard immunity testing levels. This does not imply that interference will occur, but that the device may not be qualified to operate in the EM environment near the emitter. UHF Radio Frequency Identification (RFID) emitters are deployed regularly in locations where sensitive electronic equipment is in use. Recent studies have indicated that an interference potential can exist between some UHF emitters and medical, commercial and military systems. This paper estimates the range at which FCC compliant devices may pose a risk to industrial, consumer and medical devices and compares it to previously published data.

Keywords: FCC Part 15.247 devices, IEC 60601-1-2:2007 immunity levels, UHF RFID, 4W EIRP, sensitive electronic equipment

1.0 Introduction

This paper describes how interference could occur between an emitter operating within FCC Part 15 regulations and medical equipment that have passed required immunity tests. This could be a nuisance or have life threatening consequences.

Emitters of RF power must comply with regulations to mitigate interference with other devices. FCC Title 47 of the Code of Federal Regulations (CFR) Part 15 covers unlicensed radiators for Industrial, Scientific and Medical (ISM) equipment [1].

Transmit power limits are set in FCC Part 15 to balance between usable power for applications (telemetry, disturbance, communications, etc) and reasonable levels

to minimize noise and interference potential. Section 15.247, which sets guidelines for frequency hopping and digitally modulated intentional radiators, allows up to 1 W conductor power to the antenna. Part 15 section 15.247 was drafted for UHF RFID [2] and other devices such as wireless smoke detectors and security systems that use frequency/power/modulation allocations [3].

Most electronic equipment must pass immunity requirements specific to its application. For example medical equipment and devices must meet the RF immunity requirements defined in IEC 60601 series and IEC 61000 series standards [4].

The electromagnetic fields that emanates from Part 15.247 UHF devices at close distances have the potential to be more intense than the minimum RF immunity levels that many consumer, industrial, and medical devices must operate satisfactorily. This does not imply interference will happen, only that the device may not be qualified to operate in the EM environment around these emitters. There are many different applications for RFID systems which give rise to the potential deployment in an uncontrolled environment. RFID systems have a greater potential of being used in very close range to a multitude of systems other than most other 15.247 emitters. Studies on medical devices have shown other UHF RFID systems may induce electric upset and the risks should be studied in greater depth [5,6].

This paper focuses on the potential effect of RFID emitters operating in the in the United States UHF ISM band, from 902 to 928 MHz, on electronic medical equipment.

The results will also be compared to results from a recent study in Europe [7]. The European Union (EU) UHF communications frequency band is from 864-868 MHz. Though the frequency allocations, power levels, channel and bandwidths differ slightly the basic analysis is applicable to the EU UHF devices. Similar EMI effects are being studied in other areas such as the military [8].

2.0 Unlicensed Radiator Limits

Unlicensed UHF, digital, frequency-hopping radios operate in the United States under 47 CFR Part 15 section 15.247 [9] and are restricted to 902-928 MHz. Section 15.247(b)(2) allows a “maximum conducted output power” or the maximum power to the antenna, P_T , of up to 1 W. At an output power of 1 W, the gain of the antenna, G_T , is limited to 6 dBi (decibel relative to isotropic). If the gain of the antenna is greater than 6 dBi, the power must be reduced “by the amount in dB that the directional gain of the antenna exceeds 6 dBi” **Error! Reference source not found..** This sets the Effective Isotropic Radiated Power (*EIRP*) as defined below:

$$EIRP = P_T \cdot G_T \text{ (in Watts)}, \quad (1)$$

where the gain of the antenna is expressed in linear (non-dB) units,

$$G_T \text{ (linear units)} = 10^{\frac{G_T(\text{dBi})}{10}}. \quad (2)$$

The resulting maximum *EIRP* for UHF ISM is the often cited 4 W. This compares to EU limits of 2 W Effective Radiated Power (*ERP*). *ERP* and *EIRP* are related by a factor of 1.64 (the 2.15 dBi gain of a half-wavelength dipole):

$$EIRP = 1.64 \cdot ERP. \quad (3)$$

EU limits of 3.28 W *EIRP* are comparable to the US limits. The fields resulting from these radiators are discussed in Section IV of this paper.

3.0 Immunity Standards

Radiated RF immunity is a measure of the minimum RF field level at which a device must satisfactorily operate. Standards set immunity levels depending on product type, environment, and the requirements of the product to be in continuous operation. IEC 61000-6-1 sets immunity levels for general consumer devices, IEC 61000-4-3 sets immunity levels for general industrial devices and equipment, and IEC 60601-1-2 sets base radiated immunity for medical devices. Other product specific standards may set other radiated immunity standards as needed for specific classes of devices that have unique requirements [10]. These levels are summarized in Table 1.

Table 1. Minimum IEC RF Immunity Levels.

Standard	Radiated Immunity Levels
IEC 61000-6-1:2005 Consumer Devices	3 V/m
IEC 61000-4-3:2008 Industrial Devices and Equipment	1 V/m – Level 1 Devices 3 V/m – Level 2 Devices 10 V/m – Level 3 Devices 30 V/m – Level 4 Devices
IEC 60601-1-2:2007 3 rd Ed Medical Devices	3 V/m – Non Life-Critical Devices 10 V/m – Life-Critical Devices

Most critical, non-military devices must operate satisfactorily in the presence of a 3 or 10 V/m field. In reality, designers of critical products must make an assessment of worst-case levels and add an allowance for measurement uncertainty and test to that level [11]. The draft 4th Edition of IEC 60601-1-2 suggests that an actual analysis of the EM environment should be made and equipment designed and tested to that level. If the EM environment can't be assessed then the equipment should be tested to the 10 V/m level. Since this is still in draft most government agencies have not fully adopted the IEC 60601-1-2 4th Edition [11].

4.0 Radiated Field Levels

Using the Friis transmission equation, the far-field power density, P_D , in Watts/meter² from a radiator can be written as:

$$P_D = \frac{P_T G_T}{4\pi R^2} = \frac{EIRP}{4\pi R^2}, \quad (4)$$

where R is the distance from the transmitting antenna in meters. The far-field electric field amplitude, E , can be determined from the power density:

$$E = \sqrt{P_D \eta_0} = \sqrt{\frac{EIRP \cdot \eta_0}{4\pi R^2}} = \frac{\sqrt{EIRP \cdot 30}}{R}, \quad (5)$$

where η_0 is the impedance of free space. Equation 5 shows that the field halves every time distance is doubled. Near the antenna, less than a wavelength, the near-field effects may become significant and alter the field from Equation 5, and coupling between the antenna and the device may vary by other than $1/R$.

The calculated fields emanating from a 1 W source with a 6 dBi antenna (4 W *EIRP*) along with measured field levels are shown in Figure 1. The calculated and measured electric field levels are displayed as a function of distance from an RFID reader operating at 910 MHz.

These values are compared to the 3 and 10 V/m immunity test limits of 60601-1-2. Field levels greater than 10 V/m can be generated in the main beam of the emitter at distances less than 1 m. The less critical 3 V/m levels are experienced at 3.6 m from the antenna. This does not imply that the devices will be susceptible to interference closer than 1 or 3.6 m, respectively. It does show that the field levels illuminating a device may be higher than the immunity test levels.

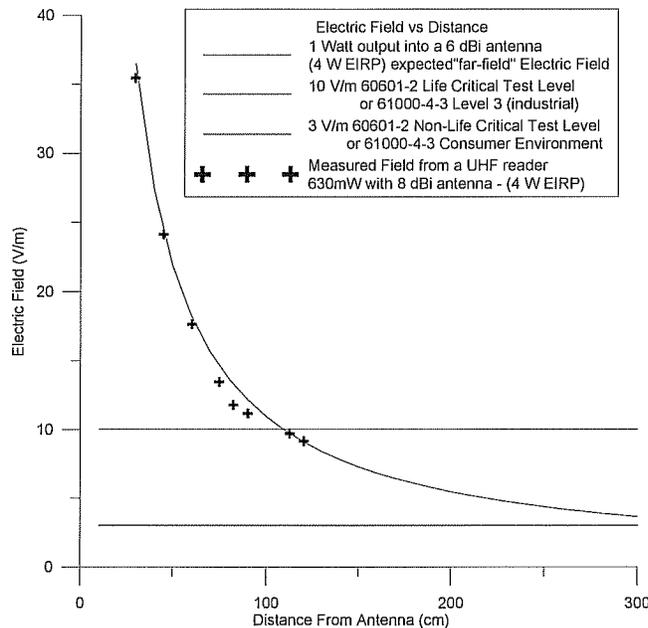


Figure 1. FCC Part 15.247 maximum allowable field level vs IEC 60601-1-2 minimum immunity field levels.

The predicted values in Figure 1 were confirmed using a commercial RFID reader set at 0.63 W conducted into the antenna port connected to a 8 dBi antenna (4 W EIRP). The RMS field level measured during RF carrier-on using a 15 cm field sensor is shown at various distances from the antenna taken inside a partially lined anechoic facility. There are slight variations between measured and calculated field levels. One possible explanation is that Equation 5 does not account for near-field effects and coupling between the source and probe.

5.0 Analysis of Interference

The gap between the emission and immunity standards revealed in the previous section could explain the inconsistent results in recent studies [5, 6, 7, 8]. Some testing and analysis in similar EU bands (865-868 MHz)

have shown significant potential for interference [7, 8]. While testing of interference potential using some Section 15.247 equipment has shown only isolated effects on IEC 60601-1-2 compliant equipment [5, 6]. In both studies, the effects were most prominent in devices with voltage feedback or voltage detectors with moderate to high input impedances [5, 12]. Devices such as electrocardiogram (EKG) monitors could be more susceptible to stray signal interference as they have long high-impedance pickup devices and are measuring signals at the millivolt level.

Interference potential can also be affected by signal duty cycle, the rate of frequency change, and the range of the frequency hopping. FCC rules allows for essentially 100% carrier on time as long as all 50 channels are used equally. Duty cycle and rate of frequency hop vary between manufacturers and system usage. For example, some RFID devices interrogate with carrier-on duty cycles varying from under 25% to 100% depending on manufacturer, system complexity, and tag population. This variation in duty cycle can change the energy incident on a victim unit by a factor of 4:1. The interpretation of FCC frequency occupancy of 0.4 s for any 20 s period (consistent dwell for 0.4 s versus several shorter operations at a specific frequency) can have varying effects on frequency sensitive systems or the ability of fault detection routines to adapt. The smaller EU frequency band for UHF RFID and the listen before talk (LBT) frequency occupancy rule may also account for some of the differences between EU and US based immunity studies.

Modulated RF signals may cause interference at lower field levels if modulation correlates to the data rate of a victim device. Other tests have shown system vulnerabilities of equipment when systems are exposed to carriers modulated at frequencies near the data rate of the equipment [13]. In very rare cases, it is possible to interfere with equipment at much lower power levels than immunity standards dictate, especially if a modulation scheme affects a particular victim device. This can have the practical effect of increasing the range at which EM incidents occur. Standards have started to address the issues of modulated signal interference and some typical testing specifications to address this issue have been proposed [14]. However, they tend to be limited to the frequency bands and modulation schemes of the telecommunications industry.

More study is needed on the immunity of critical systems, especially as the emissions allowance seems to conflict with immunity testing levels. IEC 61000-4-3 has testing requirements specific to cell phone and portable radio modulation types. The addition of a Part 15.247 emissions profile may be considered.

6.0 Recommendations

There are several ways to address the immunity versus emission issue. Detailed information of real interference potential is needed through EM environmental assessment and additional immunity studies. If the trends, as seen in [7], are borne out by additional studies, several possible actions could be considered. While the EMC community can wait to see if interference does arise in practical settings, other options can be taken to proactively address the potential immunity concerns.

Increase Immunity Requirements

60601-1-2:2007 already states the importance of immunity testing:

"[T]he existence of ELECTROMAGNETIC IMMUNITY standards is essential to assure safety of MEDICAL ELECTRICAL EQUIPMENT and MEDICAL ELECTRICAL SYSTEMS. ELECTROMAGNETIC COMPATIBILITY ... differs from other aspects of safety covered by IEC 60601-1 because the electromagnetic phenomena exist, with varying degrees of severity, in the normal use environment of all MEDICAL ELECTRICAL EQUIPMENT and MEDICAL ELECTRICAL SYSTEMS and by definition the equipment must "perform satisfactorily" within its intended environment in order to establish ELECTROMAGNETIC COMPATIBILITY. This means that the conventional single fault approach to safety is not appropriate for application to ELECTROMAGNETIC COMPATIBILITY standards [15]."

After analysis of the EM environment is made for Section 15.427 devices and if a realistic concern is found, immunity standards for IEC 60601-1-2 and IEC 61000-4-3 might be upgraded to reflect the new conformance standards. It is reasonable to assume that the use of Section 15.247 compliant systems will increase (with some industry groups predicting the ubiquitous consumer portable RFID reader) but many other devices using the same allocation may become more prevalent.

Studies of early implantable devices highlighted immunity issues when exposed to UHF frequency RF emitters [16]. The realization of the existence of a UHF threat by telecommunications equipment may have resulted in implanted devices with improved signal line filtering. The EM hardening against UHF interference now used in many implantable devices may be part of the reason why recent studies showed much less vulnerability to UHF Section 15.247 based RFID compared to other conventional RFID frequencies [6].

In general, it is difficult to control the RF environment that any device experiences. Increased immunity standards in the IEC 60601-1-2: 2nd edition addressed this uncertainty and the 3rd edition of IEC 60601-1-2 goes further:

"This collateral standard also recognizes that for certain environments, higher IMMUNITY LEVELS may be required. Research necessary to determine how to identify the environments that may require higher IMMUNITY LEVELS, as well as what the levels should be, is in progress." [15]

The negative aspect of changing the standard is that it takes time to write and accept standards. The US is currently using the 2nd Edition of IEC 60601-1-2 with the 2004 Amendment; the EU is using the 2nd Edition of IEC 60601-1-2 and will require compliance to the 2004 Amendment in 2009. Neither the US nor the EU has adopted the 3rd edition of 60601-1-2 (2007) [11]. Drafts for the 4th Edition of IEC 60601-1-2 are currently underway. In any new standard, the immunity of legacy devices needs to be considered.

Reduce UHF ISM 15.247 Power Allowances

UHF ISM designers and manufacturers, especially RFID system manufacturers, could work towards lower power requirements or regulation could be set to reduce radiated power levels. Researchers are proposing new designs for UHF RFID tags that require lower power [17, 18] that could be used at the same range with lower radiated power. Battery powered or battery-assisted tags may also reduce the required power levels – though tag lifetime becomes an issue. For a given antenna, reducing the power by a factor of four will reduce the electric field by a factor of 2 and the interference distance by a factor of 2, shown in Figure 2. It may not be practical to limit the power and range for an entire industry when some industry specific applications fall into this standards gap.

~~The prophesied ubiquitous reader in every store and in every cell phone may need to be examined more closely for allowed field levels in light of immunity concerns. However, it is very difficult to take back spectrum or power allowances once systems have been developed and deployed. Large investments have already been made by organizations with great lobbying power. Legacy devices will probably be exempt those systems will continue to use higher emitting devices.~~

Implement Usage Protocols for 15.247 Based Systems

A third option could be to implement regulations or "best practices". It may be reasonable to limit reader power in critical or susceptible environments. This would require documented administrative control or possibly engineering controls in the form of RF monitoring devices.

7.0 Conclusions

It is difficult to predict the interference potential of regulated emitters on immunity compliant devices.

FCC Part 15.247 regulates UHF emitters to operate at less than 4W EIRP. At distances of less than 1 m these regulated devices will emit field levels greater than 10 V/m.

The highest immunity levels set by IEC 60601-1-2:2007 for life critical devices are 10 V/m. This suggests that an interference potential exists within 1 m of Part 15.247 devices. The IEC 61000 series sets immunity levels for consumer and industrial devices. For Level 1, 2 and 3 devices the immunity field strengths are 1, 3, and 10 V/m, respectively. Only Level 4 devices are tested to 30 V/m. At distance less than 1 m to Part 15.247 emitters there exists a potential for interference.

It is recognized within IEC 60601-1-2 that these issues are the responsibility of the victim unit, the operator, and the interfering device.

While much of the current research is focused on RFID implementations [20], the same potential may exist for many other Part 15.247 devices. Wireless communication systems, wireless smoke detector systems and a multitude of other wireless systems have similar interference potential to immunity compliant devices. These other wireless systems have the potential to interfere with an RFID system also.

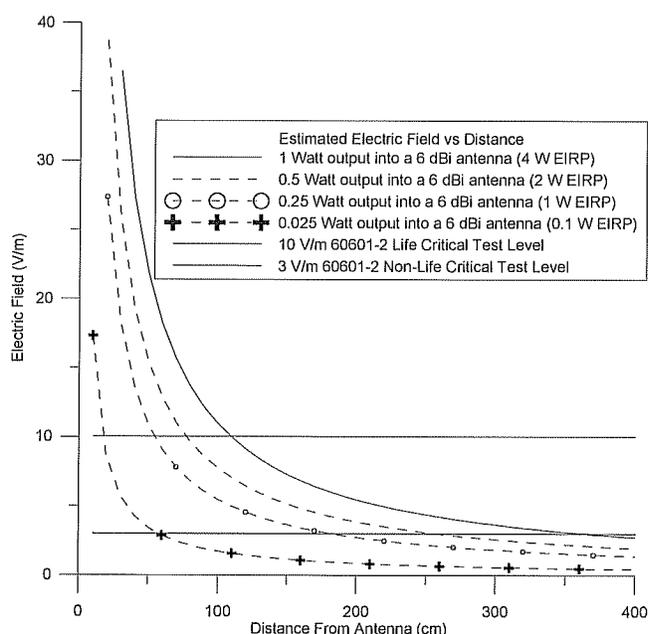


Figure 2. Estimation field levels vs. distance at different radiated power levels compared to IEC 60601-1-2 minimum immunity levels.

Operator Education

Operator implementations must to be considered. Many Section 15.247 authorized systems will allow for more than 1 W out of the source to account for losses in cable runs (allowable by FCC testing guidelines [19]). If used with lower loss or shorter cable, power at the antenna may exceed regulation. Manufacturer specified antennas may be replaced with higher gain models. This may also result in a higher radiated power. Combined, these effects can greatly increase EIRP, which could increase the interference potential, not to mention violating FCC regulations.

An unfamiliar operator may increase the output power of the reader if the desired communication performance is not met. Engineering controls limiting the power output of the reader could help mitigate this problem. Well documented usage and deployment guidelines along with regulation enforcement may help reduce interference potential. The responsibility lies with the employer and operator to ensure that the equipment is operating within limits set by regulation.

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