

Low-Probability of Intercept of Ultra-Low-Power, Near-Field Signals

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Introduction

Long considered a technical backwater, low-power, near-field systems are emerging as the preferred solution for a variety of useful applications. These applications include short-range communication, radio frequency identification (RFID), and real-time locating systems (RTLS). This paper explores the ultra-low-power and thus low-probability of intercept nature of near-field signals operating within the AM broadcast band under Part 15 constraints.

Regulatory Constraints

The performance of a near-field link depends in large part upon regulatory constraints. The FCC authorizes unlicensed operation in the AM broadcast band under a couple of provisions within Part 15. Part 15.209 allows operation in the band 0.490-1.705MHz provided the field strength does not exceed $24000/f(\text{kHz})^{\mu\text{V}}/\text{m}$ [1]. At a typical operating frequency of 1.295 MHz, the field strength limit is $18.5^{\mu\text{V}}/\text{m}$, measured at 30m. Alternatively, Part 15.219 allows a transmit power of 100mW (+20dBm) into an antenna smaller than 3m [2]. These two limits work out to be roughly equivalent in many cases.

The radiated power density (S) results from the transmitted power (P_{TX}) being distributed over the spherical surface at range r ($4\pi r^2$) as modified by the gain of the transmit antenna relative to an isotropic radiator (G_{TX}). Thus the radiated power density or power per unit area is given by:

$$S = \frac{P_{TX} G_{TX}}{4\pi r^2} = \frac{P_{EIRP}}{4\pi r^2} \quad (1)$$

where the Effective Isotropic Radiated Power (EIRP) is $P_{EIRP} = P_{TX} G_{TX}$. The EIRP is a good standard for comparing transmit power and antenna gain to regulatory limits. Consider a compact loopstick antenna with an antenna gain of about -75dBi connected to a $+20\text{dBm}$ transmitter. The EIRP ($P_{EIRP} = P_{TX} G_{TX}$) is thus -55dBm (about 3.2nW).

For a radiated field in free space, the electric (E) and magnetic field intensities (H) are directly proportional, and the proportionality constant is the wave impedance ($Z_S = 376.7 \Omega$). The radiated power density may be rewritten:

$$S = \frac{1}{2} |\mathbf{E} \times \mathbf{H}^*| = \frac{1}{2} EH = \frac{|\mathbf{E}|^2}{2\eta} = \frac{P_{TX} G_{TX}}{4\pi r^2} = \frac{P_{EIRP}}{4\pi r^2} \quad (2)$$

Solving for EIRP in terms of field strength, and substituting in the 15.209 limit of $18.5 \mu\text{V}/\text{m}$ at 1.295MHz yields:

$$P_{EIRP} = \frac{4\pi r^2 |E|^2}{2\eta} = \frac{4\pi(30\text{m})^2 (18.5 \frac{\mu\text{V}}{\text{m}})^2}{2(376.7\Omega)} = 5.14 \text{ nW} = -53 \text{ dBm}. \quad (3)$$

In other words, one has the option of complying with the 100mW (+20dBm) transmit power requirement of 15.219 or the $18.5 \mu\text{V}/\text{m}$ radiated field limit (EIRP = -53dBm) requirement of 15.209. In fact, the 15.219 standard is a regulatory idiosyncrasy found only in the US and Canada. Compliance with the 15.209 standard means that near-field systems are likely to be in line with typical international regulatory requirements. Figure 1 presents the generic 15.209 limits translated in terms of EIRP.

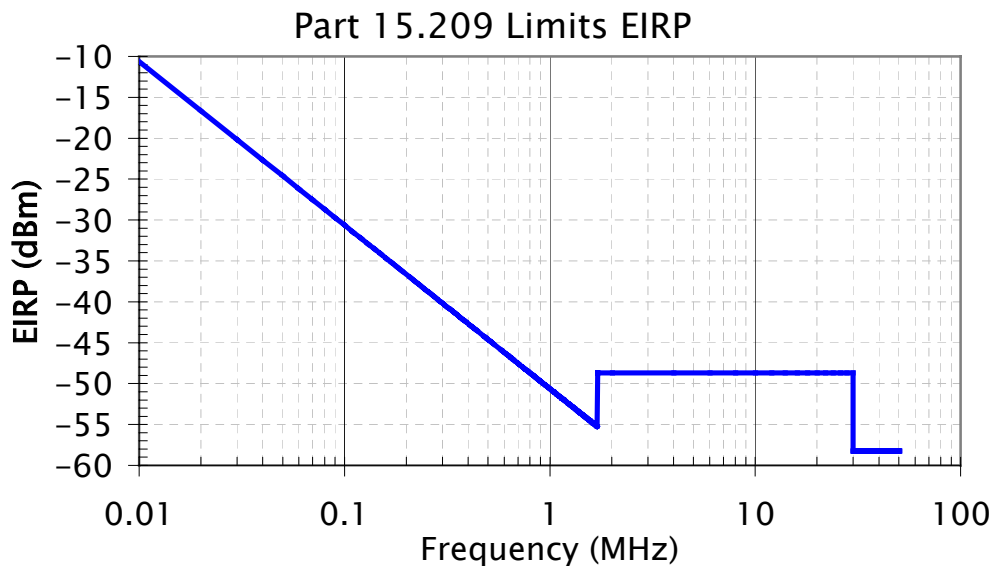


Figure 1: The FCC allows operation on an unlicensed basis in the AM broadcast band. Typical EIRPs are on the order of -45dBm to -55dBm [© 2006, Q-Track].

Detection and Interception of Near-Field Signals

Near-field signals remain largely coupled to an antenna. Only a very small fraction of this near-field energy decouples and radiates away. Thus, near-field signals are difficult to detect at significant ranges. A typical hand-held phone (FCC Category 5 Compliant) transmits a maximum of 800mW (+29dBm) into a nominally -5dBi gain antenna for an EIRP of +24dBm. A typical UWB system has a spectral density of -41.3dBm/MHz across 1GHz of spectrum for an EIRP of about $100 \mu\text{W}$ (-10dBm). A typical near-field transmitter uses +20dBm of transmit power into a -75dBi gain antenna for an EIRP of about 3.2nW (-55dBm). Outside the near field region, these ultra-low power emissions make near-field signals virtually undetectable. In fact, near-field transmitters are quieter

relative to a typical UWB signal than UWB signals are relative to a typical hand-held phone signal. Figure 2 summarizes these properties.

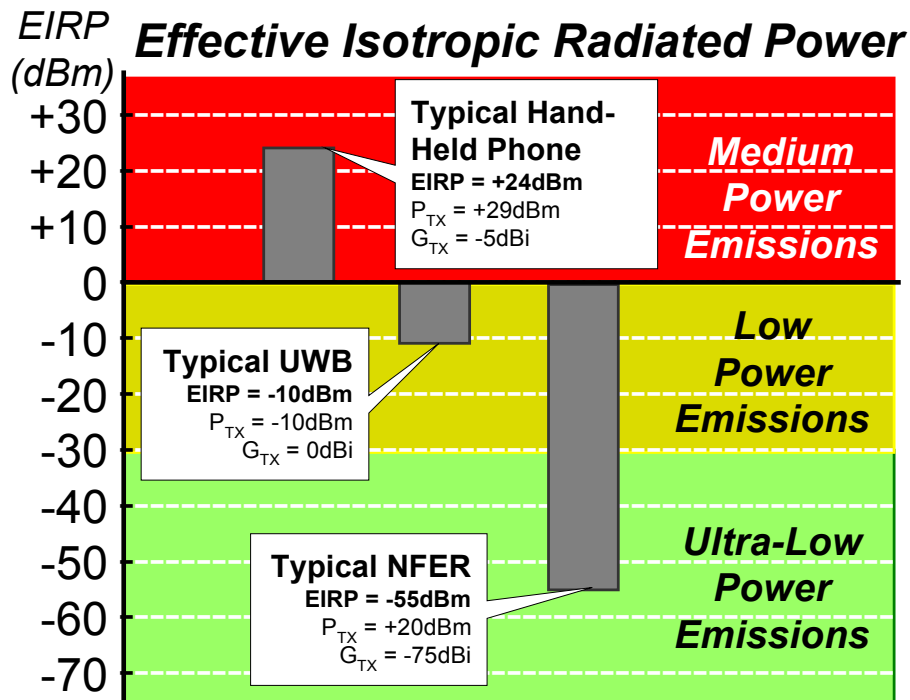


Figure 2: Because most of the energy conveyed by a near-field signal remains coupled to the transmit antenna, only a small fraction of the energy is radiated away for possible detection outside the near-field region. In fact, the ultra-low power emissions of a typical near-field transmitter are quieter relative to a typical UWB transmitter than a UWB transmitter is relative to a typical hand-held phone [© 2006, Q-Track].

By operating with narrow bandwidths on the order of 100s of Hertz, near-field systems can be further hidden well below the noise floor of wider bandwidth eavesdroppers. This approach is not suitable for links requiring large data bandwidths. However for inherently narrowband applications, like precision location and tracking, near-field signals are a credible option. The ultra-low power emissions of near-field systems like those used in near-field electromagnetic ranging (or NFER) systems are well-suited for applications where low-probability of intercept signals are desirable [3].

Conclusions

Near-field systems can operate on an unlicensed basis under a variety of regulatory standards within the US, including Part 15.209 and 15.219. These two regulations offer roughly comparable performance. Because near-field signals remain largely coupled to an antenna, very little power radiates away to be available for detection in the far field. The ultra-low power emissions of a typical near-field system are significantly quieter than a low power UWB system, for instance.

References:

[1] **Section 15.209 Radiated emission limits; general requirements.**

- (a) Except as provided elsewhere in this subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

Frequency (MHz)	Field strength ($\mu\text{V/m}$)	Measurement distance(m)
0.009-0.490	2400	300
0.490-1.705	24000	30
1.705-30.0	30	30
30-88	100 **	3
88-216	150 **	3
216-960	200 **	3
Above 960	500	3

** Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this section shall not be located in the frequency bands 54-72 MHz, 76-88 MHz, 174-216 MHz or 470-806 MHz. However, operation within these frequency bands is permitted under other sections of this part, e.g., §§ 15.231 and 15.241.

- (b) In the emission table above, the tighter limit applies at the band edges.
(c) The level of any unwanted emissions from an intentional radiator operating under these general provisions shall not exceed the level of the fundamental emission. For intentional radiators which operate under the provisions of other sections within this part and which are required to reduce their unwanted emissions to the limits specified in this table, the limits in this table are based on the frequency of the unwanted emission and not the fundamental frequency. However, the level of any unwanted emissions shall not exceed the level of the fundamental frequency.

(d) – (g) omitted

[2] **Section 15.219 Operation in the band 510-1705 kHz**

- (a) The total input power to the final radio frequency stage (exclusive of filament or heater power) shall not exceed 100 mW.
(b) The total length of the transmission line, antenna, and ground lead (if used) shall not exceed 3 meters.
(c) All emissions below 510 kHz or above 1705 kHz shall be attenuated at least 20 dB below the level of the unmodulated carrier. Determination of compliance with the 20 dB attenuation specification may be based on measurements at the intentional radiator's antenna output terminal unless the intentional radiator uses a permanently attached antenna, in which case compliance shall be demonstrated by measuring the radiated emissions.

- [3] “*NFER*” is a registered trademark of the Q-Track Corporation. For additional information on Q-Track's NFER technology, please see www.q-track.com.