APPLICATION NOTE

Application of 315-MHz Short Range Devices Under FCC Regulations

APPLICATION OF SHORT RANGE DEVICES

This application note reflects the FCC regulations for short range devices. The purpose of this document is to provide information about FCC regulations useful in the development of short range devices, especially for 315-MHz operation frequency. This document consists of a summary of some important paragraphs and the interpretation of the required limits as necessary for the design of a short range device. A couple of diagrams are plotted in order to give an overview of the required limits in the form of a graph.

Section 6. “Converting the Field Strength (dBµV/m) to Effective Isotropic Radiated Power (EIRP)” on page 11 contains information such as the formula for converting field strength into the effective isotropic radiated power (EIRP). The method of calculating a duty factor correction that is allowed in FCC is described in Section 5. “Correction of the Limit Values of the Emission by the Duty Factor (Section 15.35)” on page 10.

This information is provided in order to assist your design process. For the best recommendations, designers should get more information from their preferred test house.

This document is based on the Part 15 updated regulations which were released by the FCC on April 23, 2004. Complete information on the issue can be found at the FCC website, www.fcc.gov.

1. 15.205 - General Limited Frequency Ranges

Table 1-1 is the list of general limited frequency bands under FCC regulation. These frequency ranges may not be used as the operating frequency for any short range devices. Only spurious emissions with a field strength complying to Section 2. “15.209 - The General Requirements of the Radiated Emission Limits” are allowed in these bands.

Table 1-1. Limited Frequency Ranges for Transmitters

MHz	MHz	MHz	GHz
0.090 - 0.110	16.42 - 16.423	399.9 - 410	4.5 - 5.15
0.495 - 0.505	16.69475 - 16.69525	608 - 614	5.35 - 5.46
2.1735 - 2.1905	16.80425 - 16.80475	960 - 1240	7.25 - 7.75
4.125 - 4.128	25.5 - 25.67	1300 - 1427	8.025 - 8.5
4.17725 - 4.17775	37.5 - 38.25	1435 - 1626.5	9.0 - 9.2
4.20725 - 4.20775	73 - 74.6	1645.5 - 1646.5	9.3 - 9.5
6.215 - 6.218	74.8 - 75.2	1660 - 1710	10.6 - 12.7
6.26775 - 6.26825	108 - 121.94	1718.8 - 1722.2	13.25 - 13.4
6.31175 - 6.31225	123 - 138	2200 - 2300	14.47 - 14.5
8.291 - 8.294	149.9 - 150.05	2310 - 2390	15.35 - 16.2
8.362 - 8.366	156.52475 - 156.52525	2483.5 - 2500	17.7 - 21.4
8.37625 - 8.38675	156.7 - 156.9	2655 - 2900	22.01 - 23.12
8.41425 - 8.41475	162.0125 - 167.17	3260 - 3267	23.6 - 24.0
12.29 - 12.293	167.72 - 173.2	3332 - 3339	31.2 - 31.8
12.51975 - 12.52025	240 - 285	3345.8 - 3358	36.43 - 36.5
12.57675 - 12.57725	322 - 335.4	3600 - 4400	
13.36 - 13.41			

2. 15.209 - The General Requirements of the Radiated Emission Limits

Table 2-1 lists the general limits of the allowable radiated field strength in different frequency ranges. The measurement distance is defined in the table.

Table 2-1. General Requirement for the Radiated Emission Limit

Frequency [MHz]	Field Strength [µV/m]	Measurement Distance [m]
0.009 - 0.490	2400 / f [kHz]	300
0.490 - 1.705	2400 / f [kHz]	30
1.705 - 30.0	30	30
30 - 88	100	3
88 - 216	150	3
216 - 960	200	3
> 960	500	3

Example: A maximum field strength of 200µV/m (46.02dBµV/m) is the limit for the emission in the frequency range between 216MHz and 960MHz. For a frequency range higher than 960MHz, the radiated field strength may not exceed 500µV/m (53.98dBµV/m). Both field strengths must be measured at a distance of 3m from the device under test.

3. 15.231 - Periodic Transmitting in Frequency Ranges 40.66MHz - 40.70MHz and > 70MHz

3.1 15.231(a)

Section 15.231(a) is valid for transmitters, for example, garage door openers, RF alarm systems, RKE, TPMS, etc. Continuous transmitting is not allowed in these frequency ranges.

The following rules must be met:

- A manually activated transmitter must be switched off within 5s after releasing the button.
- The data transmission for an automatic transmitter must be ceased within 5s of being activated.
- A periodic transmission in a regular interval is not allowed except for validating the integrity of a security and safety system.
- A transmitter that is used to indicate an emergency situation, such as fire, is permitted to send a signal continuously during the emergency condition.

3.2 15.231(b) - Field Strength of the Transmitter

The values in Table 3-1 must be measured at a distance of 3m from the device under test and are expressed in µm/V. The second column shows the field strength limits of the fundamental frequency, whereas the third column lists the limits of the allowed field strength of the spurious frequency.

Table 3-1. Limit of the Field Strength for Fundamental and Spurious Frequencies According to 15.231(b)

Frequency [MHz]	Field Strength [µV/m]	Measurement Distance [m]
40.66 - 40.70	2250	225
70 - 130	1250	125
130 - 174	1250 - 3750(1)	125 - 375(1)
174 - 260	3750	375
260 - 470	3750 - 12500(1)	375 - 1250(1)
> 470	12500	1250

Note: 1. Linear interpolation

Example:

The following calculation of a defined required limit shows the method using linear interpolation.

The maximum transmitting field strength at an operating frequency between 260MHz and 470MHz can be calculated as follows:

$$E_{[\mu V/m]@3m} = (41.67 \times f_{MHz}) - 7083.33$$

$$E_{[dB\mu V/m]@3m} = 20 \times \log(E_{[\mu V/m]@3m})$$

The following formula is used for calculating the spurious field strength in the frequency range of 260MHz to 470MHz:

$$E_{[\mu V/m]@3m} = (4.167 \times f_{MHz}) - 708.333$$

$$E_{[dB\mu V/m]@3m} = 20 \times \log(E_{[\mu V/m]@3m})$$

For a transmitter with an operating frequency of 315MHz, the following field strength limits must be fulfilled:

The limit for fundamental frequency (315MHz):

$$E_{[\mu V/m]@3m} = (41.67 \times 315) - 7083.33 = 6042.72 \mu V/m$$

$$E_{[dB\mu V/m]@3m} = 20 \times \log(6042.72) = 75.62\ dB\mu V/m \rightarrow P_{EIRP} = -19.61dBm$$

The limit for spurious frequencies within 260 MHz to 470MHz:

$$E_{[\mu V/m]@3m} = (4.167 \times 315) - 708.333 = 604.272 \mu V/m$$

$$E_{[dB\mu V/m]@3m} = 20 \times \log(6042.72) = 55.62 dB\mu V/m \rightarrow P_{EIRP} = -39.6dBm$$

The field strength limits for fundamental and spurious frequencies within the frequency range of 260MHz to 470MHz are listed in Table 3-2, expressed in µV/m and the calculated equivalent power for each field strength limit in Effective Isotopic Radiated Power (dBm). Figure 3-1 and Figure 3-2 on page 5 describe the limit values according to 15.231(a) in the frequency range of 260MHz to 470MHz in the form of a graph.

Table 3-2. Field Strength for Fundamental and Spurious Frequencies in the Range of 260MHz to 470MHz as Specified in 15.231(b)

Frequency	Field Strength, Fundamental		Field Strength, Spurs	
f [MHz]	E [µV/m]	P_{EIRP} [dBm]	E [µV/m]	P_{EIRP} [dBm]
260	3750.00	–23.75	375.00	–43.75
270	4166.67	–22.83	416.67	–42.83
280	4583.33	–22.01	458.33	–42.01
290	5000.00	–21.25	500.00	–41.25
300	5416.67	–20.56	541.67	–40.56
310	5833.33	–19.91	583.33	–39.91
320	6250.00	–19.31	625.00	–39.31
330	6666.67	–18.75	666.67	–38.75
340	7083.33	–18.23	708.33	–38.23
350	7500.00	–17.73	750.00	–37.73
360	7916.67	–17.26	791.67	–37.26
370	8333.33	–16.81	833.33	–36.81
380	8750.00	–16.39	875.00	–36.39
390	9166.67	–15.99	916.67	–35.99
400	9583.33	–15.60	958.33	–35.60
410	10000.00	–15.23	1000.00	–35.23
420	10416.67	–14.88	1041.67	–34.88
430	10833.33	–14.53	1083.33	–34.53
440	11250.00	–14.21	1125.00	–34.21
450	11666.67	–13.89	1166.67	–33.89
460	12083.33	–13.59	1208.33	–33.59
470	12500.00	–13.29	1250.00	–33.29

Figure 3-1. Field Strength Limits in the Frequency Range Between 260MHz and 470MHz, Measured at 3m (15.231(a))

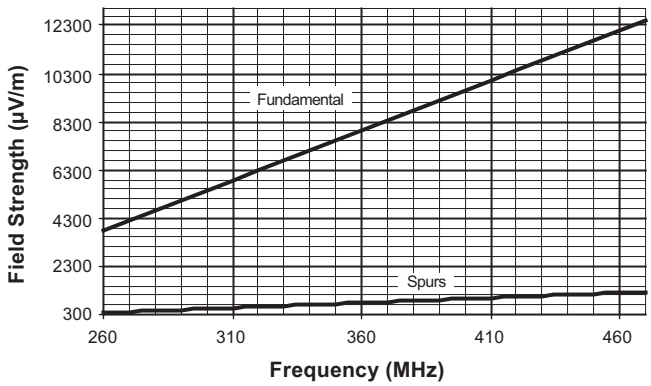
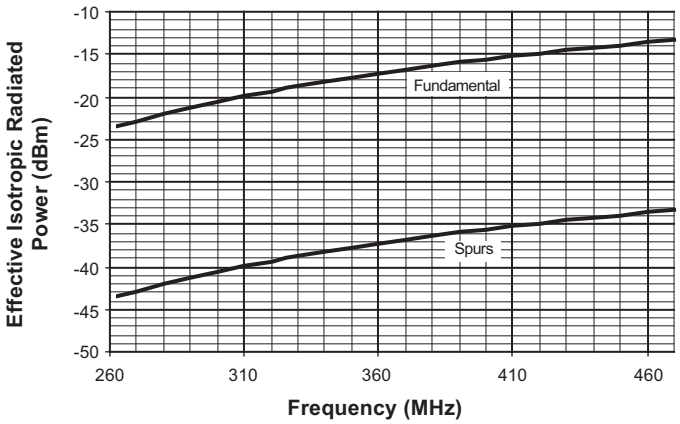


Figure 3-2. The Equivalent Power Limits in dBm (EIRP) Measured at 3m for the Frequency Range Between 260MHz and 470MHz (15.231(a))



3.3 15.231(c) - Occupation Bandwidth

The occupied bandwidth for the transmitter in the operating frequency range between 70MHz and 900MHz may not be wider than 0.25%, related to the fundamental frequency. For operating frequencies higher than 900MHz, the occupied bandwidth may not exceed 0.5% relating to the fundamental frequency. The bandwidth is measured 20dB down from the peak level of the fundamental modulated carrier frequency.

Example: For transmitters with an operating frequency of 315MHz:
Bandwidth (BW) = 0.0025 × 315MHz = 787.5kHz
Figure 3-3 and Figure 3-4 show the allowed occupation bandwidth for the application at 315MHz.

Figure 3-3. Occupation Bandwidth Expressed in Field Strength for a 315-MHz Application (15.231(c))

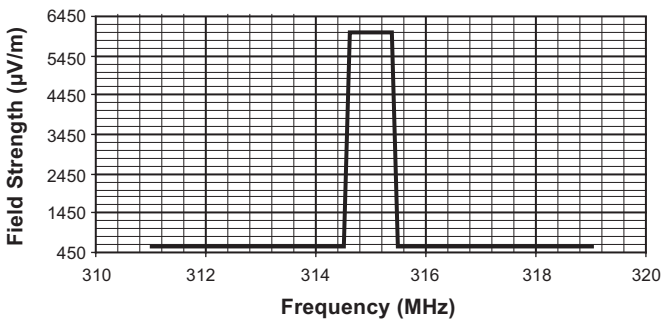
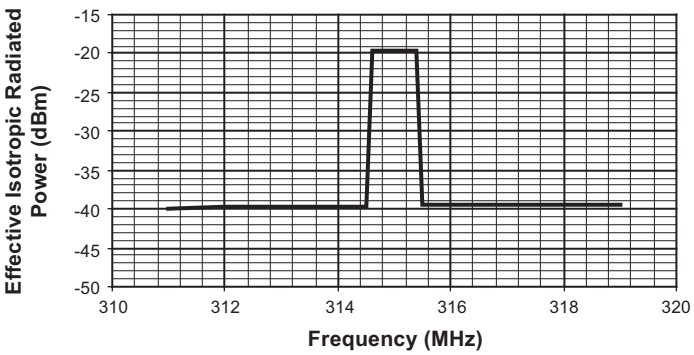


Figure 3-4. Occupation Bandwidth Expressed in Equivalent Power (dBm, EIRP) for a 315-MHz Application (15.231(c))



3.4 15.231(e)

For the transmitting devices whose periodic rates don't meet the defined conditions of Section 15.231(a), Section 15.231(e) must be applied to the design.

Requirements in this section:

- A possibility to switch off the transmitter must be guaranteed, so that the duration of the transmission will be limited to less than 1s.
- The pause between transmit sequences must be at minimum 30 times the duration of the transmit sequence. Also, the pause may not be shorter than 10s.

Table 3-3 lists the limit values of the field strength for the fundamental and the spurious frequencies. The values have to be measured at a distance of 3m from the device under test, and are expressed in µV/m.

Table 3-3. Limit of the Field Strength for Fundamental and Spurious Frequencies According to 15.231(e)

Fundamental Frequency [MHz]	Field Strength of Fundamental [µV/m]	Field Strength of Spurious Emissions [µV/m]
40.66 - 40.70	1000	100
70 - 130	500	50
130 - 174	500 - 1500(1)	50 - 150(1)
174 - 260	1500	150
260 - 470	1500 - 5000(1)	150 - 500(1)
> 470	5000	500

Note: 1. Linear interpolation

Example: The maximum transmitted field strength of the operating frequency range between 260MHz and 470MHz can be calculated using the equations below:

$E_{[\mu V/m]@3m} = (16.67 \times f_{MHz}) - 2833.33$

$E_{[dB\mu V/m]@3m} = 20 \times \log(E_{[\mu V/m]@3m})$

The field strength of the spurious frequencies in the range between 260 MHz and 470 MHz can be expressed as follows:

$E_{[\mu V/m]@3m} = (1.667 \times f_{MHz}) - 283.33$

$E_{[dB\mu V/m]@3m} = 20 \times \log(E_{[\mu V/m]@3m})$

Specifically for transmitting devices with operating frequency of 315MHz:

Field strength in the fundamental frequency (315MHz):

$E_{[\mu V/m]@3m} = (16.67 \times 315) - 2833.33 = 2417.72\ \mu V/m$

$E_{[dB\mu V/m]@3m} = 20 \times \log(2417.72) = 67.67\ dB\mu V/m \rightarrow P_{EIRP} = -27.56dBm$

Field strength of the spurious frequencies within 260MHz to 470MHz:

$E_{[\mu V/m]@3m} = (1.667 \times 315) - 283.33 = 241.77\mu V/m$

$E_{[dB\mu V/m]@3m} = 20 \times \log(241.77) = 47.67dB\mu V/m \rightarrow P_{EIRP} = -47.56dBm$

The limit values of 15.231(e) for the frequency range between 260MHz and 470MHz are listed in Table 3-4, with the corresponding equivalent power in dBm (EIRP). Figure 3-5 and Figure 3-6 on page 8 show the limit values of Section 15.231(e) for the listed frequency range in Table 3-4 graphically.

Table 3-4. Field Strength for Fundamental and Spurious Frequencies in the Range of 260MHz to 470MHz according to 15.231(e)

Frequency	Field Strength, Fundamental		Field Strength, Spurs	
f [MHz]	E [µV/m]	P_{EIRP} [dBm]	E [µV/m]	P_{EIRP} [dBm]
260	1500.00	–31.71	150.00	–51.71
270	1666.67	–30.79	166.67	–50.79
280	1833.33	–29.97	183.33	–49.97
290	2000.00	–29.21	200.00	–49.21
300	2166.67	–28.51	216.67	–48.51
310	2333.33	–27.87	233.33	–47.87
320	2500.00	–27.27	250.00	–47.27
330	2666.67	–26.71	266.67	–46.71
340	2833.33	–26.18	283.33	–46.18
350	3000.00	–25.69	300.00	–45.69
360	3166.67	–25.22	316.67	–45.22
370	3333.33	–24.77	333.33	–44.77
380	3500.00	–24.35	350.00	–44.35
390	3666.67	–23.94	366.67	–43.94
400	3833.33	–23.56	383.33	–43.56
410	4000.00	–23.19	400.00	–43.19
420	4166.67	–22.83	416.67	–42.83
430	4333.33	–22.49	433.33	–42.49
440	4500.00	–22.17	450.00	–42.17
450	4666.67	–21.85	466.67	–41.85
460	4833.33	–21.55	483.33	–41.55
470	5000.00	–21.25	500.00	–41.25

Figure 3-5. Field Strength Limits in the Frequency Range Between 260MHz and 470MHz, Measured at 3m (15.231(e))

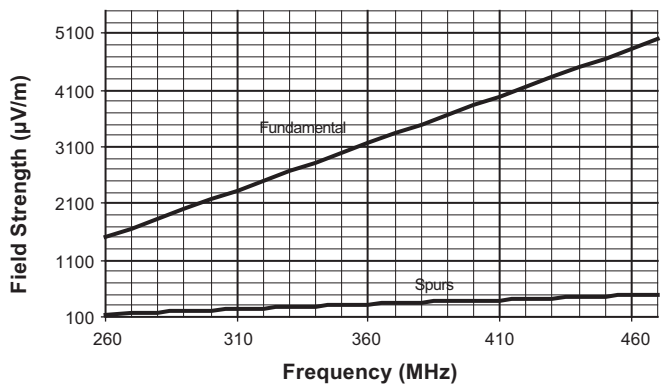
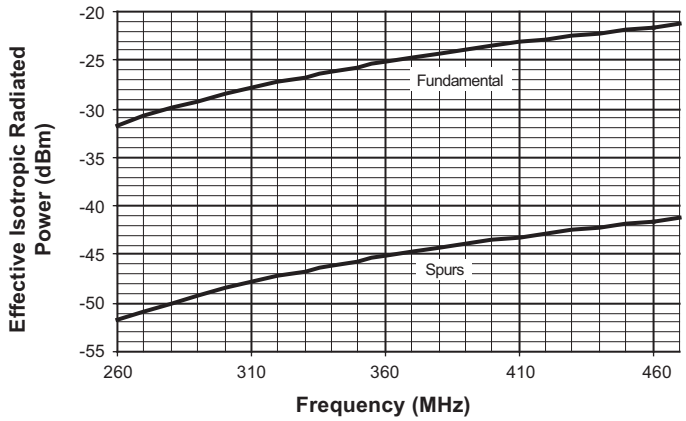


Figure 3-6. The Equivalent Power Limits in dBm (EIRP) in the Frequency Range Between 260MHz and 470MHz, Measured at 3m from the Device Under Test (15.231(e))

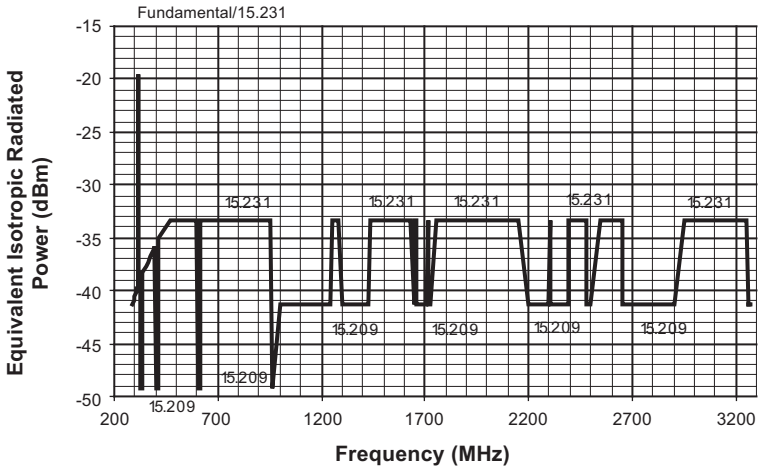


4. Summary, Especially for Transmitting Devices With an Operating Frequency of 315MHz

Periodically transmitting devices must fulfill the requirements in Section 15.231. Depending on the transmitting period, either Section 15.231(a) or 15.231(e) will be in force. The general requirements under Section 15.205, as well as under Section 15.209, must be fulfilled. This means, the device under test may not transmit in the frequency ranges prescribed in Section 15.205, whereas the spurious emissions are allowed under the radiated emission limits in Section 15.209.

Figure 4-1 illustrates the limit values of the radiation power in dBm (EIRP) over the frequency range between 290MHz and 3267MHz, from a transmitting device with an operating frequency of 315MHz. In Figure 4-1 the different limit values under 15.231(a) or 15.209 are signed as far as possible.

Figure 4-1. The Limit Power Spectrum of the Fundamental and the Spurious Frequencies for a 315-MHz Application Over the Frequency Range from 290MHz to 3267MHz



5. Correction of the Limit Values of the Emission by the Duty Factor (Section 15.35)

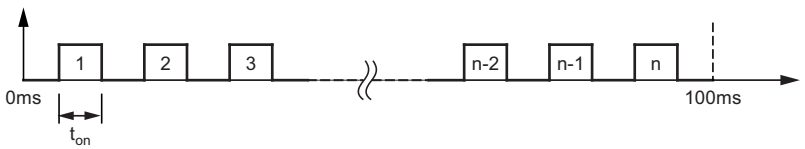
The measurement of the transmitted power in FCC regulations is generally based on the average measurement. So, depending on the transmitting sequences over a defined time range, the transmitted power to be measured in case of continuous mode can be corrected.

Duty factor (k_d) is a correcting factor based on the averaging of the measured power of the device under test over 100ms transmit time. The duty factor is defined using the following equation:

$$K_d = 20\log\left(\frac{n \times t_{on}}{100ms}\right)$$

Figure 5-1 shows, as an example, a timing diagram over 100ms from a transmitter with a periodical transmitting sequence (t_{on}).

Figure 5-1. Timing Diagram of a Transmitting Sequence Within 100ms



Example: For continuous transmission of an on-off keying (OOK) modulated signal with a data rate of 10kHz, the correcting factor can be calculated as follows:

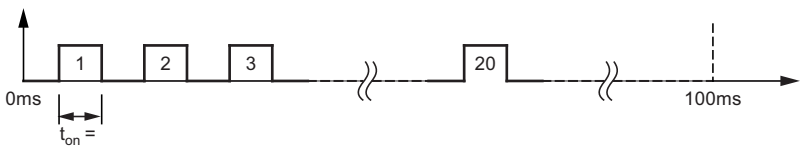
$$K_d = 20\log\left(\frac{1000 \times 50\mu s}{100ms}\right) = -6dB \text{ (correction for the power)}$$

This method of correction can only be applied to the fundamental frequency, which must fulfill the requirements under Section 15.231.

Note:
- The peak value of the transmitted signal power on the nominal frequency may not exceed 20dB over the maximum average value of the power requested in Section 15.231.
- As a theoretical example for the max allowed correction:
  A transmitter sends a 2-ms long OOK modulated signal with a data rate of 10kHz. The duration of the signal pause is 98ms. Figure 5-2 on page 10 shows the principal timing diagram of this example. The correcting factor will be calculated as follows:

$$K_d = 20\log\left(\frac{200 \times 50\mu s}{100ms}\right) = -20dB$$

Figure 5-2. Timing Diagram of a Transmitting Sequence Within 100ms (t_{on} = 50µs)



6. Converting the Field Strength (dBµV/m) to Effective Isotropic Radiated Power (EIRP)

In converting the field strength to effective isotropic radiated power, it is assumed that the antenna is an isotropic antenna. An isotropic antenna is a hypothetical antenna with an identical or equal performance in all directions while radiating or receiving. Please note, this kind of antenna does not exist physically, but it is a convenient reference when defining the directional properties of a physical antenna.

Field strength in V/m:

$$E_{[dB\mu V/m]} = 20\log(E_{[\mu V/m]}) \rightarrow E_{[\mu V/m]} = 10^{\left(\frac{E_{[dB\mu V/m]}}{20}\right)} \rightarrow E = 10^{\left(\frac{E_{[dB\mu V/m]}}{20}\right)} \times 10^{-6} = 10^{\left(\frac{E_{[dB\mu V/m]}}{20} - 6\right)} \frac{V}{m}$$

$$\text{Power density: } P_D = \frac{E^2}{120\pi} = P_{D\_EIRP} \times A$$

The power can be calculated as $P_{EIRP} = P_{D\_EIRP} \times A$ because the surface of a sphere is $4\pi r^2$.

Hence, the power can be expressed as:

$$P_{EIRP} = P_{D\_EIRP} \times A = \frac{E^2}{120\pi} \times 4\pi r^2 = \frac{r^2}{30} E^2 [\text{Watt}]$$

$$P_{EIRP\_dBm} = 10\log\left(\frac{\frac{r^2}{30}E^2}{1mW}\right) = 10\log E^2 + 10\log\left(\frac{r^2}{30 \times 1mW}\right) = 20\log\left(10^{\left(\frac{E_{[dB\mu V/m]}}{20} - 6\right)}\right) + 10\log\left(\frac{r^2}{30mW}\right)$$

$$P_{EIRP\_dBm} = E_{[dB\mu V/m]} - 120 + 10\log\left(\frac{r^2}{30mW}\right)$$

Specifically for the measurement range of r = 3m, the conversion from field strength to the effective isotropic radiated power can be performed by:

$$P_{EIRP\_dBm} = E_{[dB\mu V/m]} - 120 + 10\log\left(\frac{9}{30mW}\right) = E_{[dB\mu V/m]} - 95.233$$

7. Revision History

Please note that the following page numbers referred to in this section refer to the specific revision mentioned, not to this document.

Revision No.	History
4907C-AUTO-07/15	• Put document in the latest template

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