Environmental Evaluation
of
RF Exposure
for the DM-25 Module

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1. Introduction

1.1. Purpose of the Report

This technical report is a detailed environmental evaluation of the radio frequency exposure expected from use of the DM25 transmitter. The following analysis demonstrates that the DM25 device is in compliance with the requirements for maximum permissible exposure (MPE) to radiofrequency exposure as defined in the FCC Rules, 47 CFR 2.1091, as amended.

1.2. Description of the DM25 Device

The DM25 Transceiver has been designed as an OEM module for use by various OEM integrators. For all applications, the radiating antenna is not provided with this product and must be supplied by the customer. All calculations related to MPE are made using antenna gain guidelines provided in the customer documentation such as the DM25 OEM Interface Manual.

The module has three functional modes of operation:

(1) AMPS mode – Burst Modem Transceiver Class I device
(2) AMPS & TDMA mode (cellular band) – Class II device
(3) TDMA mode (PCS band) – Class IV device

1. The CLASS 1 burst modem transceiver is designed to send a burst of data as a CLASS 1 AMPS cellular mobile, with 3 Watts of RF power at the antenna connector. Typical applications will trigger registrations of less than 120 ms in duration at most every 15 minutes. Once the DM25 determines that data is to be sent, the transceiver initiates a call and then transmits a 4.5-second data burst, which includes a training sequence and V.27 data. The entire transmitter burst duration varies depending on the cellular system network connection time. When the burst modem call is initiated, the DM25 transmits for 1.5 seconds and then powers down for 4 seconds, and then transmits for 1.5 seconds and then powers down for 4 seconds; this process continues until a tone is detected, up to a *maximum* of eight cycles of 1.5 seconds ON, 4 seconds OFF. The tone is normally detected between two to seven seconds (depending on the cellular system network connection time). Once the tone is detected, the 4.5 second data burst is sent, after which the burst transmitter is disabled by the software for 30 or 50 seconds in order to protect the hardware that has been designed to dissipate heat appropriately for this duty cycle. The disable time is 30 seconds for a sequence of two or less 1.5-second bursts, and 50 seconds for three to eight 1.5-second bursts.

2. The second mode of operation is as a dual mode (AMPS and DAMPS), CLASS 2 terminal operating in the cellular band (824 to 849 MHz) with nominally 1.5 Watts of RF power at the antenna connector. The usage would vary from a low duty cycle with a meter reading application, to a high duty cycle with a fixed telephony application.

3. The third mode of operation is as a CLASS 4 terminal operating in the PCS band (1850 to 1910 MHz) with nominally 0.6 Watts of RF power at the antenna connector. The usage would vary from a low duty cycle with a meter reading application, to a high duty cycle with a fixed telephony application.

The DM25 is capable of operating in either of the modes described above, and can “switch” between modes by re-registering with the cellular system (identifying its CLASS type and technology).

This transceiver is designed primarily for situations where the DM25 module is located within the application and an external antenna, connected to the module through a length of coaxial cable, is located a short distance away. The operator is always located a distance away from the application.

2. Classification of Device / Applicability of Rules

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2.1. Mobile devices

The DM25 module is properly defined as a mobile device per 47 CFR 2.1091 (b), which states that "mobile devices are defined as transmitters designed to be used in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimeters is normally maintained between radiating antennas and the body of the user or nearby persons."

For most applications of the DM25, there is typically a separation distance of greater than 27 centimeters. Some applications of the DM25 device will involve operation in a residential environment with examples including wireless local loop, security alarm and electrical meter reading applications. The discussion below should clearly demonstrate that the maximum likely exposures in these applications are significantly below the maximums permitted. However, whenever possible, the transmitter should be installed in such a manner as to make it unlikely that a human body can be maintained in close proximity (i.e. less than 27 centimeters) to the radiating antenna. A statement to this effect is included in the manual supplied to the Original-Equipment-Manufacturers (OEMs) developing applications using this device (DM25 FCC filing - exhibit 8 User's Manual). This statement should make it clear that Sony Ericsson does not mean to imply that proximities of less than 27 centimeters are unsafe. Rather, maintaining a separation of at least 27 centimeters simply ensures that the analysis below is valid and that the margins with respect to the maximum permissible exposures that are demonstrated below are maintained.

2.2. Excludability from routine environmental evaluation

47 CFR 2.1091 (c) states that "mobile devices that operate in the Cellular Radiotelephone Service...are subject to routine environmental evaluation for RF exposure prior to equipment authorization or use if…their effective radiated power (ERP) is 1.5 watts or more."

For Class 1 operation, the DM25 transceiver is rated at 3 Watts of output power in AMPS mode. The module is shipped without an antenna so the actual ERP in the field will vary somewhat with different antennas and different applications. The User's Manual supplied to customers specifies the use of an antenna with maximum system gain of 1 dBi (2.5 dBi antenna gain and 1.5 dB cable loss). For the purposes of calculating the maximum exposure below, an ERP of 6 watts is assumed (3W + 2dB variation + 1 dB antenna gain). Although the peak ERP for the DM25 exceeds 1.5 watts, the device has an operational duty factor of 18.1% for the CLASS 1 burst modem, over a 41.5-second period. Applying this duty factor to a maximum ERP of 6 watts yields an average ERP of 1.08 Watts, which is below the 1.5-watt threshold for excludability. The nature of the application (short bursts of data) makes it extremely improbable that this duty factor is maintained at this high a level for any 30-minute period (FCC rules indicate an averaging time of 30 minutes is appropriate for use in analyzing this device). Furthermore, due to hardware limitations of the burst modem (continuous transmission is not permitted to prevent overheating of the burst power amplifier), MPE or SAR evaluation is not feasible because the power amplifier device does not have a normal operating mode that would support the duration of an RF exposure evaluation.

For Class 2 operation, the DM25 transceiver is rated at 1.5 Watts of output power in AMPS and DAMPS mode. The same assumptions as to the application and antenna can be made. For the purposes of calculating the maximum exposure, an ERP of 3 watts is assumed (1.5W + 2dB variation + 1 dB antenna gain). Although the peak ERP for the DM25 exceeds 1.5 watts, the device has an operational duty factor of 33% for the CLASS 2 TDMA operation. Applying this duty factor to a maximum ERP of 3 watts yields an average ERP of 1.0 Watts, which is below the 1.5-watt threshold for excludability. Since the AMPS mode is continuous operation, maximum exposure calculations must be used to determine a minimum separation distance. The antenna is customer supplied so SAR evaluation is not feasible. The following sections analyze the maximum RF radiation exposures from a DM25 transmitter under maximum and typical conditions.

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2.3. Applicable limits for exposure to radio frequency exposure

The following paragraphs analyze the maximum RF radiation exposures from a DM25 transmitter under extreme and typical conditions. This analysis will clearly demonstrate compliance with the amended FCC rules.

The table below is excerpted from Table 1B of 47 CFR 1.1310 titled Limits for Maximum Permissible Exposure (MPE), Limits for General Population/Uncontrolled Exposure:

Frequency Range (MHz)	Power Density (mW/cm^2)	Averaging Time (minutes)
300 – 1500	f/1500	30

where f = frequency in MHz

The highest frequency of operation in the cellular band is 850 MHz, so the MPE limit is f/1500 = 850/1500 = **0.567 mW/cm^2.**

In all systems calculations for the DM25 module the following assumptions are made:

Customer supplied antenna gain = 2.5dBi = 1.78
Antenna gain of standard dipole = 2.14dBi = 1.64
Insertion loss through connecting cable = 1.5 dB
Total directive gain of antenna system = 1dBi

Given power density $\mathbf{S = P_{out} \times D / 4\pi R^2}$, where: P_{out} = transmitter output power from connector (Watts)
D = directive gain of antenna relative to std. dipole
R = spherical surface distance from origin

The effective radiated power (ERP) is defined as the product of the measured transmitter output power and the specified antenna system gain, relative to a half-wave dipole, in the direction of interest. To provide extra margin, if a distance of R = 27 cm is selected, then the ERP can be found as follows:

$$\mathbf{ERP = P_{out} \times D = S \times 4\pi R^2}$$
$$\mathbf{= .567 \times 4\pi \times 27^2}$$
$$\mathbf{= 5.19\ Watts}$$

The maximum radiated power of 5.19 W represents the maximum average power that produces MPE limit levels at 27 cm over a 30 minute period. It should be noted that this power density equation is only accurate in the far-field and that at 27 cm distance, the MPE will be overestimated.

3. Maximum Exposure Analysis

3.1. Maximum exposure

To complete the calculations, the peak ERP delivered by the device must be determined. In AMPS Burst Mode, the DM25 is a CLASS 1 device calibrated to deliver 3 Watts to the antenna connector. The DM25 can also operate in a Class 2 mode for both AMPS and TDMA (cellular band). In all cases of operation, it is assumed that the application uses an antenna with 2.5dBi gain and 1.5dB cable loss between the module and the antenna. In extreme cases of temperature and voltage, the transmitter output tolerance is ±2.0dB.

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3.2. Transmission duration

The CLASS 1 AMPS Burst Mode has a variable duration dependent on the system response. The maximum duty cycle corresponds to the occurrence of tone detect immediately after the second Tx burst of 1.5 seconds. The sequence is 1.5 seconds Tx on, 4 seconds Tx off, 1.5 seconds Tx on, 4.5 seconds Tx on for data burst, 30 seconds Tx off. As outlined in the introduction, typical applications will trigger registrations of less than 120 ms in duration at most every 15 minutes. The typical situation results in an extremely low duty factor. For purposes of the calculation, the extreme case scenario has a maximum transmission duration of 7.5 seconds over a 41.5-second period.

The CLASS 2 dual mode transceiver transmission duration has a 33% duty cycle in DAMPS mode and 100% duty cycle in AMPS mode. Clearly, for the CLASS 2 mode, the maximum exposure occurs for continuous transmission in AMPS mode.

3.2.1. Class 1 Operation – 3 W AMPS Burst Mode

For the purposes of this analysis, a transmission of 7.5 seconds duration over a 41.5 second period is assumed, even though the probability of repetitive transmissions over a 30 minute period is virtually zero due to the nature of the transmission (small amounts of data).

Using a separation of 27 centimeters (per the definition of mobile device as discussed in section 2.1), a duration of 7.5 seconds, an averaging time of 41.5 seconds, and a maximum ERP of 6 Watts we come up with the following expression for the average field strength density in a maximum exposure scenario:

For Class 1 AMPS Burst Mode operation, the unit is calibrated to deliver 3.0W (34.8dBm) to the antenna connector but after tolerances and the antenna system gain are included, the field strength density becomes:

$S = P_{out} \times D / 4\pi R^2$ * duration/time where **Pout = 34.8 + 2 (tolerance) – 1.5 (cable loss) = 3400 mW**
D = 1.78/1.64 = 1.08 (antenna gain relative to dipole)
R = 27 cm

$= (3400 \times 1.08)/(4 \times \pi \times 27^2) * (7.5/41.5)$
$= .072$ mW/cm^2

Note that this maximum exposure is well below the MPE limit of 0.567 mW/cm^2 derived in section 2.3.

3.2.2. Class 2 Operation – 1.5 W AMPS Mode

For Class 2 AMPS operation (continuous), the unit is calibrated to deliver 1.5 W (31.8dBm) to the antenna connector but after tolerances and the antenna system gain are included, the field strength becomes:

$S = P_{out} \times D / 4\pi R^2$ where **Pout = 31.8 + 2 (tolerance) – 1.5 (cable loss) = 1700 mW**
D = 1.78/1.64 = 1.08 (antenna gain relative to dipole)
R = 27 cm

$= (1700 \times 1.08)/(4 \times \pi \times 27^2)$
$= .200$ mW/cm^2

Note that this maximum exposure is well below the MPE limit of 0.567 mW/cm^2 derived in section 2.3.

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Since the DM25 can independently operate in either CLASS 1 or CLASS 2 mode. When considering a combination of consecutive operational modes, the maximum exposure would occur in CLASS 2 operation when operating continuously in AMPS mode.

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4. Typical exposure analysis

The calculations shown in the analysis below use typical maximum power levels but it should be noted that cellular systems across the country have been optimized for portable use. The typical application will not be transmitting at full power except in rural areas or in the fringe areas of cellular systems which represents a small fraction of usage. Since the antenna is completely determined by the customer application, assumptions must be made as to the antenna system gain as shown in Section 2.3. With this information, a typical exposure can be calculated.

4.1. Class 1 Operation – 3 W Burst Mode

For Class 1 AMPS burst mode operation, the device is calibrated in the factory to deliver a maximum of 3.0 Watts to the antenna connector. Typically, the transmitter output tolerance is ±0.25 dB so the greatest output power seen at the antenna connector is 3.2 Watts. With the 1dBi (-1.14dBd) antenna system gain, the maximum ERP is 2.46 Watts (34.8dBm + 0.25dB - 1.14dBm). The field strength density in this scenario is:

$$S = ERP / 4\pi R^2 * duration/time \quad \text{where} \quad R = 27\ cm$$
$$= 2460 / (4 \times \pi \times 27^2) * (7.5/41.5)$$
$$= .048\ mW/cm^2$$

Note that this exposure is well below the MPE limit of 0.567 mW/cm^2 derived in section 2.3.

4.2. Class 2 Operation – 1.5 W AMPS Mode

For Class 2 AMPS operation (continuous), the device is calibrated in the factory to deliver a maximum of 1.5 Watts to the antenna connector. Typically, the transmitter output tolerance is ±0.25 dB so the greatest output power seen at the antenna connector is 1.6 Watts. With the 1dBi (-1.14dBd) antenna system gain, the maximum ERP is 1.23 Watts (31.8dBm + 0.25dB - 1.14dBm). The field strength density in this scenario is:

$$S = ERP / 4\pi R^2 \quad \text{where} \quad R = 27\ cm$$
$$= 1230 / (4 \times \pi \times 27^2)$$
$$= .134\ mW/cm^2$$

Note that this exposure is well below the MPE limit of 0.567 mW/cm^2 derived in section 2.3.

5. Conclusions

The preceding analysis makes it clear that any exposure to RF from the DM25 device is below the limits imposed by FCC regulations as long as a minimum separation distance of 27 centimeters is maintained. Due to the nature of telemetry and telematics applications using this device, close proximity of humans to the antenna during transmission is highly unlikely and the minimum separation distance is much greater than 27cm. In order to provide an even greater margin of comfort, applications developers (i.e. Sony Ericsson customers) will receive guidelines for use and installation of the DM25 device to ensure exposures do not exceed MPE limits.

Sony Ericsson requests an exclusion from routine RF exposure evaluation based on the calculations presented in this report. The results clearly demonstrate compliance with the amended FCC rules.

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