P-801T SAR Analysis

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Summary
This document will present an electromagnetic environmental evaluation for the P-801T portable radio. Emphasis will be placed on deriving a maximum likely exposure level. This analysis will show that, based on projected worst-case parameters, the P-801T does not present an excessive RF exposure risk and comfortably meets the FCC Human Exposure limits.

References:

- CFR 47, 2.1093 "Radiofrequency radiation exposure evaluation: portable devices."
- FCC OET Bulletin 65, Supplement C "Additional Information for Evaluating Compliance of Mobile and Portable Devices with FCC Limits for Human Exposure to Radiofrequency Emissions"

Exposure Limits:

Portable devices are subject to a routine environmental evaluation for RF exposure prior to equipment authorization or use. The P-801T radio will be sold exclusively to public safety / public service customers, and never to the general public. Therefore, the P-801T will be evaluated against the "Occupational / Controlled" exposure limits (reproduced below, emphasis added).

CFR 47, 2.1093 (d)

*(1) Limits for Occupational/Controlled exposure**: 0.4 W/kg as averaged over the whole-body and spatial peak SAR not exceeding 8 W/kg as averaged over any 1 gram of tissue** (defined as a tissue volume in the shape of a cube). Exceptions are the hands, wrists, feet and ankles where the spatial peak SAR shall not exceed 20 W/kg, as averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube). Occupational/Controlled limits apply when persons are exposed as a consequence of their employment provided these persons are fully aware of and exercise control over their exposure. Awareness of exposure can be accomplished by use of warning labels or by specific training or education through appropriate means, such as an RF safety program in a work environment.*

The P-801T user's manual (and training materials) will include discussion of electromagnetic exposure. Users will be warned to keep their transmit time limited and to hold the antenna at least 2 inches away from them at all times, in all configurations.

Analytical Parameters

The P-801T transmitter is designed for 3 Watts maximum power, in the 806-824 MHz frequency band. It is shipped with a 0dBi antenna. The user is cautioned not to hold the antenna closer than two (2) inches.

The P-801T operates in two modes: analog and digital. In the analog mode, the radio limits transmission times to 30 seconds, but the transmitter is on 100% of the transmit time. In the digital mode, the radio also limits transmission time to 30 seconds, and the waveform used is a 2-slot time-division-multiple-access (TDMA), so the transmitter is on only 50% of the transmit time. Since the analog mode produces more exposure, the analog mode will be used for this analysis.

In both modes, the P-801T is designed to be used in an industry-standard "90-5-5" usage model. Under this model, the radio is monitoring the channel 90% of the time, receiving (with active audio) 5% of the time, and transmitting for the final 5% of the time. For this analysis we will consider that a user might operate with a maximum 20% duty factor. This will represent a worst-case level of exposure. The FCC rules (reproduced below) allow us to make this assumption.

CFR 47, 2.1093 (d):

(4) For purposes of analyzing portable transmitting devices under the occupational/controlled criteria, the time-averaging provisions of

the MPE guidelines identified in §1.1310 of this chapter can be used in conjunction with typical maximum duty factors to determine maximum likely exposure levels.

Rather than use extensive computational modeling, this analysis will presume that the human body is not at all reflective to electromagnetic energy. In other words, this analysis will assume that the portion of the body under RF exposure will absorb all of the incident energy, and reflect none.

Also, for this analysis, the human body will be considered to have only three densities. The densities used are taken from OET Bulletin 65, Supplement C. We will use 1035 kg/m^3 (=1.035 g/cm^3) for flesh (brain / muscle) and we will use 1850 kg/m3 (=1.85 g/cm^3) for bone (skull).

Analysis

Consider the case of the user operating the transmitter with the antenna two (2) inches from his head. The transmitter maximum output power is radiated from the antenna in a spherical pattern (because the antenna has 0dBi gain). Consider a series of concentric spheres centered at the antenna. The first sphere which touches the users head will have the highest power density. The surface area of this sphere is:

$$Asphere = 4\pi r^2$$

Since the antenna is isotropic, we can assume that the power is spread evenly over the surface of this sphere. This means that:

$$PowerDensity = \frac{P}{4\pi r^2}$$

At a radius of 2 inches (r=5.1cm), the power density on the surface of the sphere is 9.2 mW/cm^2.

Now consider the flesh that the sphere is touching. The peak exposure limit is written in terms of W/kg, averaged over any 1 gram of tissue in the shape of a cube. To relate tissue mass (grams) to power absorption, we need to determine how much of the sphere is subtended by the tissue in question. Since we are assuming the tissue is in the head, it seems appropriate to use skull tissue (density=1.85 g/cm^3). 1 gram of skull tissue would then correspond to a 0.54 cm^3 sized cube. This cube of skull tissue would measure 0.81 cm on each side, and would cover approximately 0.66cm^2 of the radiation sphere's surface area.

Surprisingly, due to its lower density, it is more appropriate to assume that the users head is made of flesh (muscle or brain) rather than skull. The lower flesh density (=1.035 g/cm^3) leads to a 1 gram flesh cube measuring 0.99 cm on each side. This cube covers approximately 0.98cm^2 of the radiation sphere's surface area.

Since the tissue cube covers 0.98cm^2 of the radiation sphere, and since the sphere's power density is 9.2mW/cm^2, we can see that the tissue cube is absorbing 9mW of electromagnetic energy. This represents the peak SAR measurement, since all other points on the body are significantly further from the antenna.

Results

A 1 gram cube of tissue two inches from the P-801T antenna will absorb 9mW when the transmitter is on. We can multiply this exposure level by 20% (absolute worst-case duty factor as described above) to get a **spatial peak SAR exposure of 1.8W/kg. This is well within with the limit of 8 W/kg**.

Note that there is significant room in this analysis for different configurations. For example, assume the user holds the radio 1 inch from his body (this would represent a worst-case distance with a belt-mounted radio with external microphone). **The spatial peak SAR exposure for this case is 7.2 W/kg, which is still within the limit of 8 W/kg**.

Note also that this analysis includes the following conservative assumptions.

- the P-801T will be operating in analog mode (rather than in the preferred digital mode which reduces exposure by 50%).
- the P-801T has a 0dBi antenna. In reality, small handheld antennas at these frequencies are almost always significantly below unity gain, often as low as –3dBi. This will reduce exposure by 50%.
- The P-801T has a time-averaged duty factor of 20%. The industry standard for this type of radio is 5%, which would have reduced exposure levels by 75%