DeskJet 995ck Bluetooth Printer MPE Analysis

As an intentional radio transmitter, the 995ck printer must meet the maximum permissible exposure (MPE) limits specified by the FCC and the European Union (EU) to ensure that people using or near the printer transmitter are not exposed to harmful levels of radiated electromagnetic energy.

In the US the applicable MPE limits are the general population uncontrolled exposure limits specified by the FCC in 47 CFR Ch. 1 (10-01-2001 Edition) Part 1 Sections 1.1307 and 1.1310, Table I (B), Part 2 Section 2.1091, and Part 15 Section 15.247. The limits are a hybrid combination of the recommended exposure guidelines published in ANSI/IEEE C95.1-1992, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, and in NCRP Report No. 86, Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields, National Council on Radiation Protection and Measurement, 1986.

The applicable limits in the European Union and in many other parts of the world are those published in the "Guidelines on Limits of Exposure to Radiofrequency Electromagnetic Fields in the Frequency Range from 100 kHz to 300 GHz," in IRPA Guidelines on Protection Against Non-Ionizing Radiation, International Radiation Protection Association (under the auspices of the UN's World Health Organization), Pergammon Press, 1991.

For radio transmitters operating within the 2400-2500 MHz ISM band, as Bluetooth does, the MPE limit in both the US and EU is defined to be a radiated power density of 1.0 mW/cm^2 (or 10 W/m^2). No special separation distance precautions are necessary for the 995ck printer to comply with this US and EU MPE limit, since the distance from the transmitter where the power density equals or exceeds that power density limit is wholly within the interior of the printer. This is due to the location of the transmitter approx. 1.0 inch from the surface of the printer's plastic housing and the low level of radiated power from the Bluetooth transmitter.

This is illustrated in the following calculations, using a nominal calculated EIRP value of 1.1 dBm, (based on a maximum measured radiated power density of -19.5 $dBmW/m^2$ at a distance of 3.0 meters from the printer), with the Radio module transmitting at full power midband (2441 MHz) with frequency hopping disabled. The transmit power density measurements and EIRP calculations include the effects of the printer housing and the chassis' metal parts on the Jeeni Bluetooth transmitter antenna pattern.

Maximum Far Field Radiated Power for Bluetooth Transmitter in DeskJet 995ck Printer

$$P_d = E_{\max}^2 / (120 * \pi) = EIRP / (4 * \pi * r^2)$$

$$EIRP = E_{\max}^2 * (4 * \pi * r^2) / (120 * \pi) = E_{\max}^2 * (r^2 / 30)$$

$$EIRP = 1.1\ dBm = 1.3\ mW$$

$$P_d = \frac{EIRP}{4*\pi*r^2} \geq P_d\ Limit = 1.0\,mW/cm^2$$

$$r \geq \sqrt{\frac{1.3}{4*\pi*1.0}} = 0.32\ cm$$

$\frac{\lambda_M}{2\pi} = 2.0\ cm$, Far Field Breakpoint for Elemental Dipole at 2400 MHz (Maximum Wavelength)

$\frac{2D^2}{\lambda_m} = 0.37\ cm$, Far Field breakpoint for Finite Antenna at 2483.5 MHz (Minimum Wavelength)

Where:

E_{max} = E-Field Intensity in Direction of Max. Radiation
$EIRP$ = Effective Isotropic Radiated Power
P_d = Power Density
r = Radial Distance from Antenna
D = Maximum Antenna Dimension = 1.5 cm
λ_M = Wavelength at 2400 MHz = 12.5 cm
λ_m = Wavelength at 2483.5 MHz = 12.1 cm

The above far field MPE power density calculations are strictly valid only in the far field, at distances from the antenna which exceed the far field breakpoint. For conservatism, we use the dipole approximation and conclude that the minimum allowable separation distance during transmissions is 2.0 cm (0.8 inches).

We also note that although the effects of a proximate reflective surface outside of the printer housing will be small at distances from the antenna which are much less than the distance to the reflector (e.g. the 20 cm distance to the surface beneath the printer), applying an upper bound reflected field correction factor of 2 (multiplying the nominal EIRP by a factor of 4) in the above calculations, would yield a calculated minimum separation distance of 1.28 cm, and again the far field distance limit value of 2 cm (within the confines of the printer housing) is seen to be conservative.