SPACEX SERVICES REQUEST FOR MODIFICATION

The Commission recently granted SpaceX Services, Inc. ("SpaceX Services") a blanket license authorizing operation of next-generation end-user earth stations ("UTs") for use at fixed locations.[1] In support of that application, SpaceX Services provided an analysis of the non-ionizing radiation levels for its UTs in compliance with the methods described in FCC Office of Engineering and Technology Bulletin Number 65 (Edition 97-01) ("Bulletin 65") as adjusted to account for an updated IEEE standard that Bulletin 65 had relied upon in part.[2] Those calculations demonstrated that the UTs will not result in exposure levels exceeding the applicable radiation hazard limits so long as they observe a maximum transmit duty cycle of 10.3 percent.[3]

Bulletin 65 states that it "is not intended to establish mandatory procedures, and other methods and procedures may be acceptable if based on sound engineering."[4] Moreover, the bulletin recognizes that "[i]n some cases, . . . measurements or a more detailed analysis may be required."[5] In this case, a fundamental assumption of the IEEE analysis may not apply to the flat planar nature of the SpaceX Services UT.[6] Accordingly, SpaceX Services has undertaken to directly measure power density emitted in the near field region—rather than calculate predicted values—to determine whether the UT would comply with the Commission's radiation limits at a higher duty cycle. As demonstrated below, these measurements show that the UT will comply so long as it observes a maximum transmit duty cycle of 17.5 percent. Accordingly, SpaceX Services requests that its authorization be modified to allow operations up to that duty cycle.

Test Procedure

In order to determine power density in the near field region, the UT was positioned in a horizontal orientation on a remote-controlled turn table within an anechoic chamber. The chamber was manufactured by MVG (Microwave Vision Group) and rated to cover 700 MHz to 40 GHz. The turntable allowed the vertical and horizontal axes to be controlled remotely. A calibrated AR RF/Microwave Instrumentation FL7040 Isotropic Electric Field Probe was used for all measurements (with an operating dynamic range of 2 to 1000 V/m), with a FL7000 probe interface.

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1 *See* Radio Station Authorization, IBFS File No. SES-LIC-20210708-01019, Call Sign E210127 (granted Nov. 10, 2021).

2 *See* IEEE Std C95.3-2021, *IEEE Recommended Practice for Measurements and Computations of Electric, Magnetic, and Electromagnetic Fields with Respect to Human Exposure to Such Fields, 0 Hz to 300 GHz*, IEEE Standards Association (approved Mar. 25, 2021) ("Updated IEEE Standard"). Among other things, that update revised its recommended methodology for calculating power density in the near field region.

3 *See* Letter from David Goldman to Marlene H. Dortch, IBFS File No. SES-LIC-20210708-01019 (Nov. 8, 2021); letter from David Goldman to Marlene H. Dortch, IBFS File No. SES-LIC-20210708-01019 (Nov. 9, 2021) (erratum).

4 Bulletin 65 at 1.

5 *Id.*

6 The SpaceX Services phased array UT consists of a large number of identical radiating elements (over 1000 small patch antennas) distributed uniformly over the physical aperture, and each antenna element is excited with the same RF power. As a result, the aperture illumination is uniform and the illumination efficiency is 100% (i.e., illumination efficiency is 1). By contrast, the antennas discussed in the new IEEE Standard assume a circular aperture with non-uniform illumination (i.e., illumination efficiency less than 1), which reduces the effective area of the antenna and thereby increases power density in the near field. *See* Updated IEEE Standard, Section D.4.4.

The probe was placed on a vertically oriented fiberglass mast, at the proper angular tilt suggested by the datasheet of the probe. The composite electric field component was the result used for all data presented in this report.

The measurements were made with the UT operating at its maximum transmit power of 2.44 W. During operation, the UT transmits bursts of energy towards the target satellite only at designated times assigned by the network (a TDMA system). As a result, SpaceX Services UTs will operate only at a specified, limited duty cycle. Nonetheless, our testing assumed the extreme case of a 100% duty cycle—i.e., with the UT transmitting continuously.

RF power density measurements were taken at a height above the face of the antenna beginning at 6 cm and increasing to approximately 340 cm, with a radial distance from the center of the antenna that ranged from -20 cm to 20 cm at the maximum height, as illustrated in Figure 1 below. The peak value of these measurements was used to identify the boresight vector of the UT. The electric field strength along the boresight vector is plotted in the test results below. This guarantees the measurements against z are in the main beam of the UT and produces the worst case electric field strength.

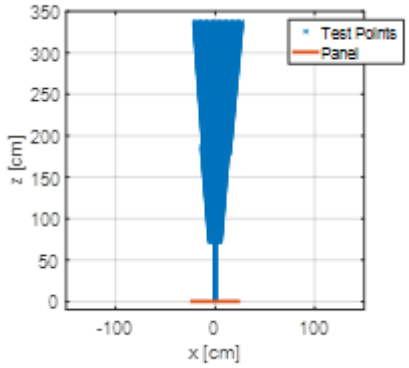

Figure 1. RF Measurement Test Points

In addition, consistent with the requirement for testing of mobile devices, another set of RF power density measurements were taken across the face of the antenna at a consistent height of 20 cm.

Test Results

Under the Commission's rules, at the Ku-band frequencies used by these UTs, the Maximum Permissible Exposure for general population/uncontrolled exposure situations is a power density equal to 1 mW/cm^2 averaged over a thirty-minute period.[7] As detailed below, SpaceX Service's measurement results confirm that the UT will comply with this limit when transmitting at duty cycles of up to 17.5 percent.

Figure 2 shows the results of the z-axis measurements of the SpaceX Services UT. The solid blue line indicates the power density at various distances above the aperture assuming a 100% duty cycle. As this figure shows, the maximum power density as measured is 41.4 W/m^2 after

[7] *See* 47 C.F.R. § 1.1310(e).

applying the appropriate correction factor recommended by the Electronic Field Probe manufacturer. To ensure that these measurements capture the potential worst-case power density, SpaceX Services has applied the ±1.4 dB measurement uncertainty that the test equipment manufacturer advises will achieve a 95% confidence interval for measurements in the 1-40 GHz frequency range.[8] That confidence interval, indicated in the blue shaded area, indicates a maximum power density of 57.15 W/m^2 at 100% transmit duty cycle. Because real-world UTs operate at far lower duty cycles, we provide these results only as a baseline against which to compare power density levels at lower, more realistic duty cycles.

In particular, from our measurements we calculate that if instead we enforce a 17.5% maximum duty cycle, the maximum power density would be 10.00 W/m^2 (57.15 W/m^2 * 0.175), as shown in the beige shaded area. This translates to 1.00 mW/cm^2. Accordingly, at or below that duty cycle, the UT will comply with the Commission's 1 mW/cm^2 Maximum Permissible Exposure for general population/uncontrolled exposure even in a worst case.

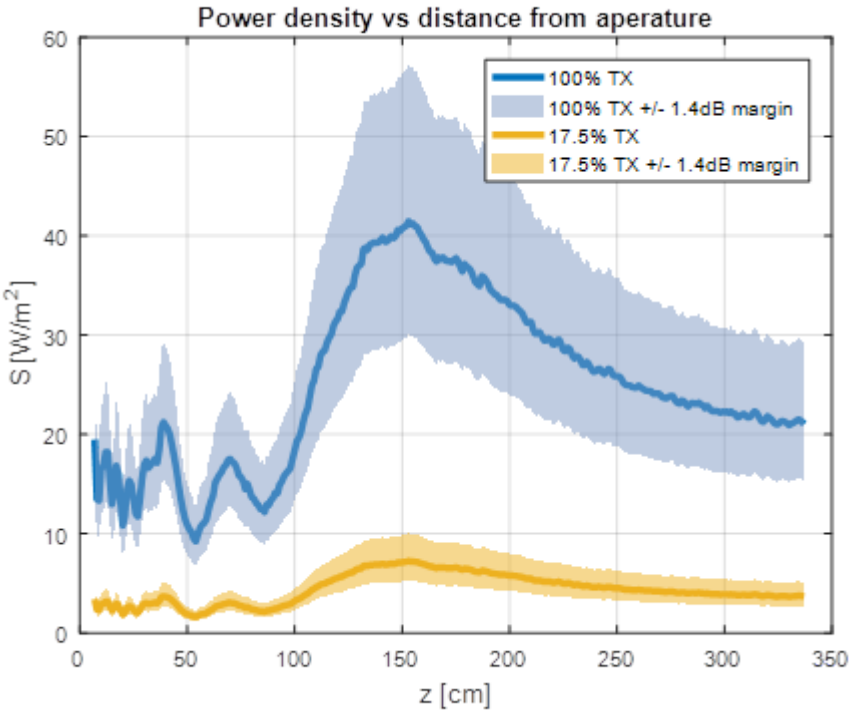

Figure 2. Test Results for Z-Axis Measurements

Figure 3 shows the physical aperture of the SpaceX Services UT as a black outline and the results of the planar measurements across the aperture at a constant offset of 20 cm and a 17.5% duty cycle. Power densities are indicated by the color of the circles indicating measurement locations, with those less than 0.1 mW/cm^2 shown as blue circles at the lowest power and those above 1 mW/cm^2 shown as red circles at the highest power. However, because the power densities for operation of the UT do not exceed 1 mW/cm^2, there are no red circles in the graphs below.

[8] *See* AR RF/Microwave Instrumentation, *Field Monitoring Products – FL 7040 Electronic Field Probe*, at 2, https://www.arworld.us/post/FL7040.pdf.

Indeed, there are not even any orange circles indicating power densities above 0.75 mW/cm^2. Accordingly, this analysis confirms that at this duty cycle the UT will comply with the Commission's Maximum Permissible Exposure for general population/uncontrolled exposure in all cases.

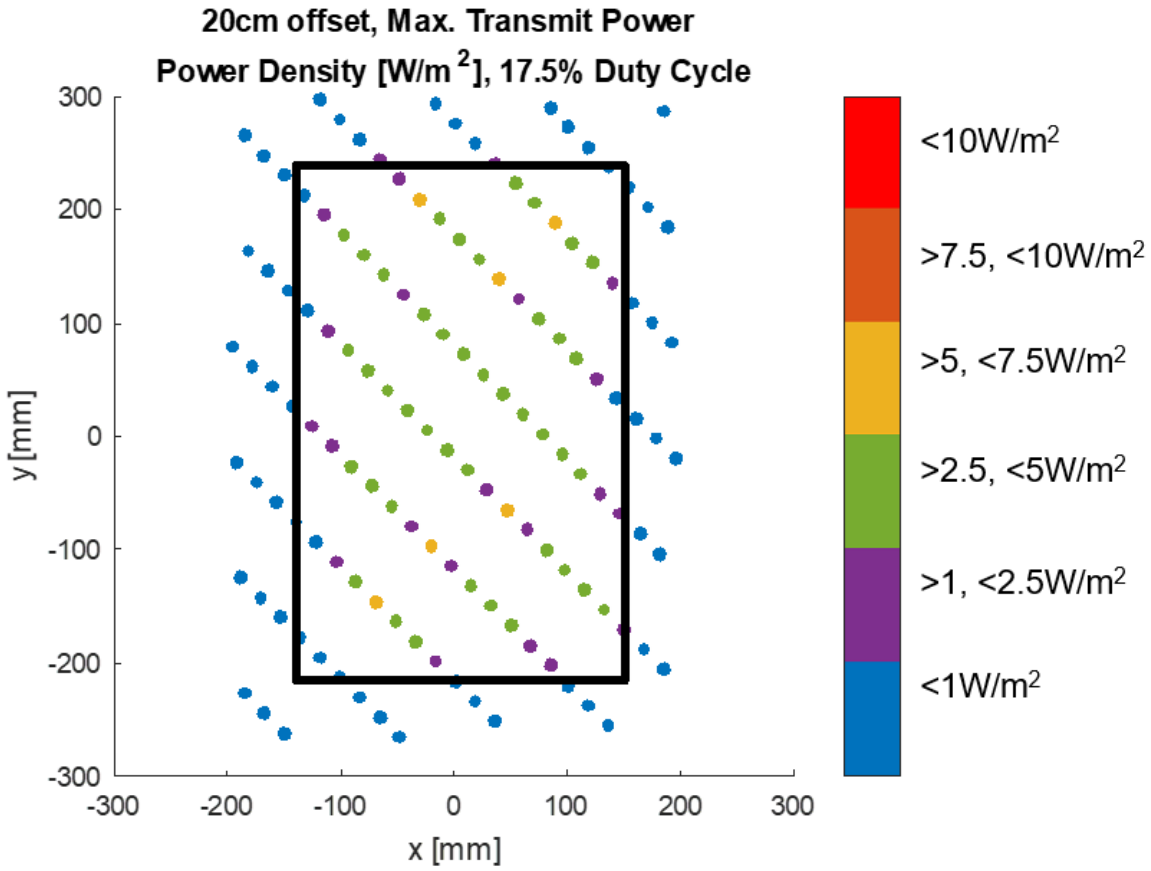

Figure 3. Test Results for Planar Measurements at 20 cm Offset