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24th May 2019

Dear Sir / Madam,

Per KDB inquiry consultation with FCC, we have prepared answers to the reviewer's questions (their list item #3), in order to develop an exposure exclusion analysis for the 6.5GHz transmitter of the UBIMOD31 device:

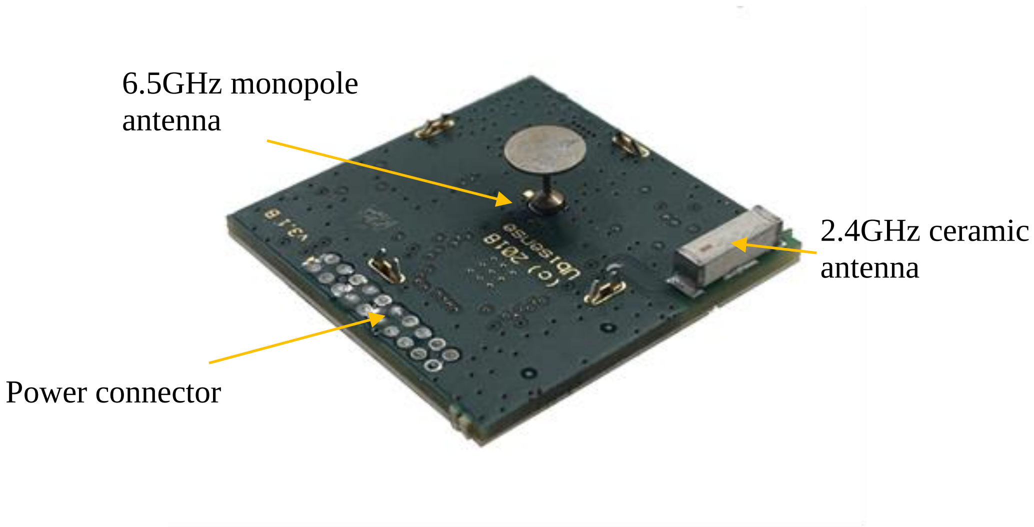
> *3) Considerations for exclusion from MPE evaluation measurements and simulations were mentioned at e.g. pg 16 of Nov. 2017 FCC-TCB conference notes*
>
> *One approach to start with might be per said pg 16:*
> *For certain products with simple antenna configurations that transmit uncorrelated signals and low exposure is justified*
> *– due to low power or certain inherent operating conditions*
> *– the power density at close proximity to users may be estimated according to the maximum power available at the antenna aperture and applicable beam width*
>
> *In reply herein please provide details about device design and operating configurations, features if any providing inherent spacing to persons, and antenna element(s) layout, feed power, etc.*

Summary statement:

- The 6.5GHz transmitter of the UBIMOD31 device has an extremely low measured average antenna feed power of 2.6 microwatts (-25.9dBm)
- The transmitter has a simple single monopole antenna configuration
- The device does not incorporate features providing significant inherent spacing to persons (although typical integrations are likely to result in some antenna-person separation)
- However, by virtue of the extremely low power output, even with zero separation to the person the estimated power density at the antenna is far below the 1mW/cm^2 limit for any relevant spatial averaging area.

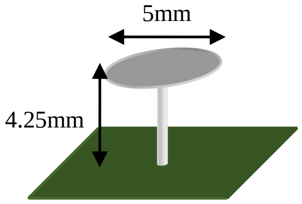
Device design

The device is a small (1” x 1”) module intended to be integrated into host equipment for the purpose of location tracking of that equipment. It is shown below:



The device has two low-power transmitters – a 6.5GHz Part 15.250 transmitter which is the primary subject of our KDB enquiry, and a 2.4GHz Part 15.249 transmitter[1]. Note that the two transmitters are never active simultaneously.

The 6.5GHz transmitter has a single top-loaded monopole quarter-wavelength antenna, as shown in the diagram below – it is a traditional monopole antenna with additional capacitive loading disc in order to widen its operating bandwidth:



The transmitter does **not** use multi-antenna, beam-forming or coherent transmission methods.

Operating configurations and output power

The average output power of the 6.5GHz transmitter is directly proportional to the rate of transmissions (i.e. the number of location-determining packets it

[1] As explained in our initial KDB enquiry, SAR exemption calculations for the Part 15.249 2.4GHz transmitter are straightforward (its maximum peak radiated output power after tune-up is only 0.56mW)

transmits per second). That transmission rate cannot in any circumstance be higher than 167 location packets per second due to limitations in the device's microcontroller.

Direct measurements were made of the full-bandwidth power delivered to the antenna using a wide-bandwidth thermocouple-based average RF power meter (Agilent E4416A+8481A), which is modulation-independent. The average power measurements were made with the device set to beacon continuously at its highest possible transmission rate (167 maximum-payload location packets per second), and were taken over a signal averaging period of 20s (to comply with the interim guidance on MPE time averaging in the "RF Exposure: Order/NPRM Issues" TCB Workshop notes).

After correction for cable losses, the source-based, time-averaged feed power in the worst-case configuration (167 maximum-payload packets/sec.) was found to be -25.9dBm = **2.6µW**.

Note that this extremely low average power level is inherent to the source because of:

1) The low signal power spectral density levels and limited bandwidth permitted by Part 15.250
2) The extremely short (<=384 pulses) and sparse (~1ns pulses transmitted at 1µs intervals) nature of the individual location packets
3) The relatively low packet transmission rate, which is at most 167 packets/sec. (Of course, when lower packet rates are used, the source-based, time-averaged feed power will fall commensurately further from this worst-case value)

The worst-case average power level is not in any way dependent on the pattern of exposure to the bystander, thus justifying the use of source-based time averaging.

Features providing inherent spacing to persons

The 6.5GHz antenna is exposed on the top surface of the device. Therefore, in principle it would be possible to use the device with the antenna in extremely close proximity to persons, and therefore we **cannot** rely on the physical nature of the device alone to assure separation.

In practice, however, typical host installations will provide some separation from nearby persons. The 6.5GHz antenna is fragile and host integrators will place it behind a protective enclosure (typically made of plastic) to avoid damage. For reference, two proposed integrations for this device are shown below, together with the distances (measured from the centre of the 6.5GHz antenna) to the closest exterior point on the enclosure:

Example proposed host integration #1

(minimum distance from mid-point of antenna to external surface = 7.5mm)

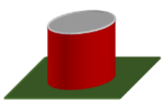
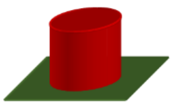

Example proposed host integration #2

(minimum distance from mid-point of antenna to external surface = 4.4mm)

Both examples place the UBIMOD31 device inside a plastic enclosure with a battery power supply to form a location tracking tag which can be attached to objects or carried by a person – other similar integrations are possible.

Estimation of power density in close proximity to persons

Assuming **zero** separation between the 6.5GHz antenna and the person, then we can use the physical area of the antenna components to determine the maximum possible power density next to the antenna, assuming that the whole feed power is distributed over the whole (or even only a subset) of the antenna bounding surface. We have computed power densities from the antenna feed power and antenna geometry for three scenarios below:

Scenario	**Diagram** (entire feed power radiated over red surface**)**	**Area over which antenna feed power is distributed**	**Power density over area**	**Comments**
1		5mm x π x 4.25mm = 67mm^2 = 0.67cm^2	2.6µW / 0.67cm^2 = 4µW/cm^2 = **0.004mW/cm²**	Most realistic, given standard far-field radiation pattern of monopole – effective antenna aperture is cylindrical
2		π x (5mm)^2 / 4 = 20mm^2 = 0.2cm^2	2.6µW / 0.2cm^2 = 13µW/cm^2 = **0.013mW/cm²**	Represents region which might typically be closest to a person, but unrealistic given that the disc lies in the null of the far-field radiation pattern
3		0.67cm^2 + 0.2cm^2 = 0.87cm^2	2.6µW / 0.87cm^2 = 3µW/cm^2 = **0.003mW/cm²**	Power density calculated over entire antenna bounding surface

As can be seen, by virtue of the very low average antenna feed power, the power density at the (bounding) surface of the antenna is very far below the 1mW/cm^2 power density limit for general exposure in each case.[2]

We would be grateful if the OET would consider this exposure exclusion analysis for the UBIMOD31 device.

Regards,

Dr Andy Ward
Chief Technology Officer, Ubisense
24th May 2019

[2] In fact, because the antenna input feed power is only 2.6 microwatts, and because power density cannot be negative in any area, it is impossible even in principle for the power density to exceed 1mW/cm^2 over any circular area with diameter greater than 0.6mm. Since field probes which might plausibly be used for direct power density measurements (e.g. https://speag.swiss/products/dasy6/probes/new-eummwvx-vector-e-probe/?pdf=view) have sensor elements which are physically larger than this diameter, and would therefore effectively average the power density over a larger area, it seems that measurements using these probes could never result in a reading which exceeded the 1mW/cm^2 limit