Lumia Antenna Simulation

On 7/20/2024, Lumia Health emailed the FCC OET the following email

To whom it may concern,

We are a startup
manufacturing a tiny Bluetooth Low energy wearable earpiece. Our FRN is 0035698083, and our FCC Grantee ID is 2BHMV.

Following the guidance of Intertek, our compliance testing partner, I read the October 2022 Antenna Test guidance located here:
https://transition.fcc.gov/oet/ea/presentations/files/oct22/35-Part-15-Antenna-Updates-TCB_Oct_2022.pdf

On Slide 5, there is a carveout that "Simulated Antenna characterization may be considered with technical justification through a KDB inquiry."

I am messaging to verify that the simulated antenna characterization we have conducted is adequate. I am attaching the antenna design and simulation that F3 Wireless, a premier antenna design house, conducted on our behalf.

As you'll see, we simulated the antenna on our tiny earpiece by putting it inside of a realistic 3D human ear attached to a part of a head. As you'll see in the simulation, our antenna's peak gain is only -17.3dBi, with an average gain of -22dBi. The antenna performance is very poor because we are making quite
possibly the world's smallest wearable, so our antenna is only ~14mm long despite it being a 2.4GHz BLE antenna which corresponds to a 12.5cm wavelength. So our antenna is almost 1/10th of the wavelength due to the size of our earpiece, resulting in the very poor antenna gain. So from that fact alone, we hope that concern around needing the antenna to be fully characterized is not necessary due to the highly attenuating antenna gain. The gain is well below what is required to meet the SAR exclusion. The BLE EIRP can be up to +6dBm and meet the ISED and FCC exclusion with a 100% duty cycle, so we have ~24dB of margin. In addition, we are driving our conducted output power at 0dBm which gets an automatic exclusion for SAR testing if our antenna gain is negative, which our -17.3dBi peak gain antenna certainly is.

The other dynamic that makes conducting a typical radiation pattern test difficult is the very small battery in our very small earpiece. Unfortunately, our earpiece's battery when fully charged can only support ~2 seconds of constant transmit at 0 dBm. So in order to run a proper antenna radiation pattern test, we need to attach a larger battery with a couple of wires attached to it, which affects the radiation pattern. So our simulation's antenna radiation pattern is actually a better approximation than a larger battery with wires in any OTA test.

For the two above reasons 1) our antenna has extremely negative peak and average gain due to its tiny size, and 2) our earpiece's battery is too small to do continuous TX for proper radiation pattern testing, we would like to ask the FCC to waive the antenna test report requirement.

I am attaching the simulated antenna characterization to this inquiry.

Thank you!
Daniel

On 7/30/2024, the OET responded with the following email

FCC response on 07/30/2024

Dear Daniel,
Please see comments below:

- For an embedded antenna that is permanently integrated into a device, where compliance with FCC limits are established using radiated measurements, a statement stating that all measurements were performed radiated andtherefore additional antenna gain documentation is not required. Antenna information may be limited to antenna description, manufacturer data, electro mechanical specs, antenna photos, and relevant information if appropriate.
- For simulated antenna information, antenna report should should include antenna description, manufacturer data, electro mechanical specs, simulation software description if used, description of simulation method used, applicable standards and references, measurements if any, computations and conversions used for simulation, validation of results, and tabulated results. Antenna report needs to self supporting and detail for a reviewer to validate.

It is best to consult with a TCB to see which approach is applicable to your device. If simulated antenna information, please provide the detail information identified above.

All measurements were not performed radiated.
Additional antenna documentation is required, per the FCC OET response.

Below is the antenna related information that the OET requested:

- Antenna Description
- Manufacturer Data
- Electro-mechanical Specs
- Simulation Software Description if used
- Description of Simulation method used
- Applicable standards and references
- Measurements if any
- Computations and conversions used for simulation
- Validation of results
- Tabulated results

Antenna Description: The antenna is a single monopole micro-antenna that is 13.74mm long, which is about 1/10th of the length of the 2.4GHz resonant length (~12.5cm). In simulation, it has a peak gain of -17.3dBi, with an average gain of -22dBi, so it is a highly inefficient antenna due to its necessarily minuscule size. It is constructed as a Laser-Deposited Structure onto a PEEK plastic substrate that forms one of the plastic housing elements of the earpiece. The LDS process deposits 25-30um of composite metals, finished by a 0.1-0.2um layer of Gold. Finally, it is coated with multiple layers of Acrylic paint.

Manufacturer Data: The original designer of the antenna was F3 Wireless, a leading US-based antenna design consultancy. Amphenol SAA is the manufacturer of our micro-antenna, using their well-validated and high-volume Laser-Deposited Structure (LDS) process. Amphenol is a leading supplier of LDS antennas and supplies many of the world's largest consumer electronic manufacturers with these antennas.

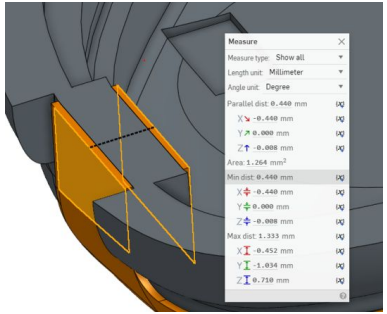
F3 Wireless

Amphenol

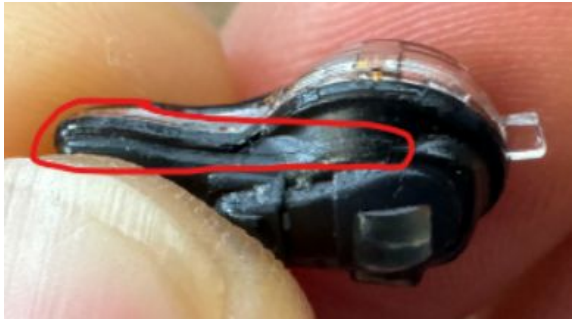
SAA

Shanghai Amphenol Airwave

Electro Mechanical Specs: The LDS antenna is etched to both the inside and the outside of the plastic housing, connected via laser-drilled vias that go through 0.44mm of plastic.



The LDS antenna conductor on the inside of the plastic housing is soldered directly to the PCBA to connect to the BLE chip.



After the antenna is successfully etched onto the plastic housing, it is then coated with a layer of acrylic resin based paint. See paint covering circled in red above, where raised antenna is still slightly visible under the paint.

The length of the antenna is 12.9mm on the short length, and 13.7mm on the long side, for an average length of 13.4mm:

After the paint layer, the device is wrapped in a soft silicone jacket that flexibly adapts the earpiece to differently shaped ears.

Simulation Software Description: The simulation was conducted within ANSYS 2022 R2 by F3 wireless, a highly regarded US-based antenna design house with vast experience in BLE antenna design.

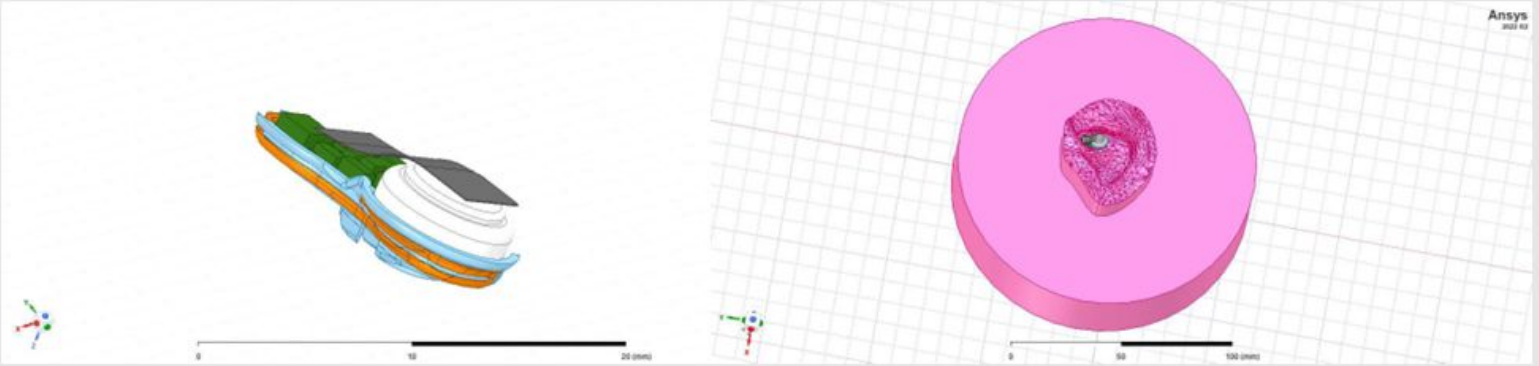
Computations and Conversions used for Simulation: A Finite-Element-Method Simulation was used to solve for the antenna gain, radiation pattern and efficiency. Simulations were conducted with the earpiece inside of a model of the human ear utilizing RF parameters for human tissue.

Validation of Results: The BLE EIRP must be < 3mW at frequency 2450 MHz at a separation distance of <5mm for the SAR exemption. Intertek 3rd party testing lab validated that the max peak conducted power was 0.993mW. Further validation was determined to not be required as any negative antenna gain would keep the earpiece under the EIRP limit.

Tabulated Results: See Antenna Simulation results in subsequent slides.

Updated Simulation Model

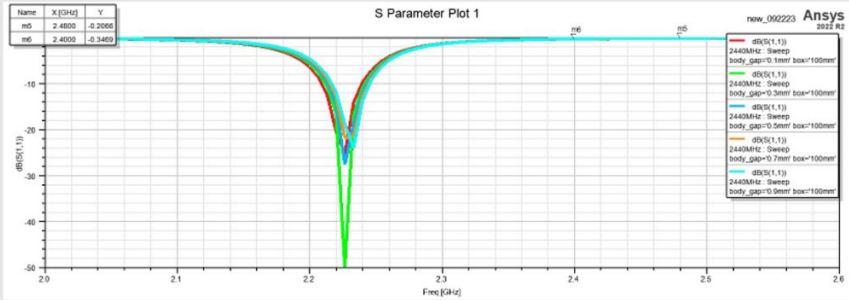
- Main changes to the simulation model were the antenna, solar cell and PCB.
- Battery is shorted to PCB ground near the middle of the PCB.
- Average muscle tissue was used for the ear/head (Dk = 54, σ = 1.8S/m) (previously used Dk = 43, σ = 2S/m, which is too conservative for the ear).

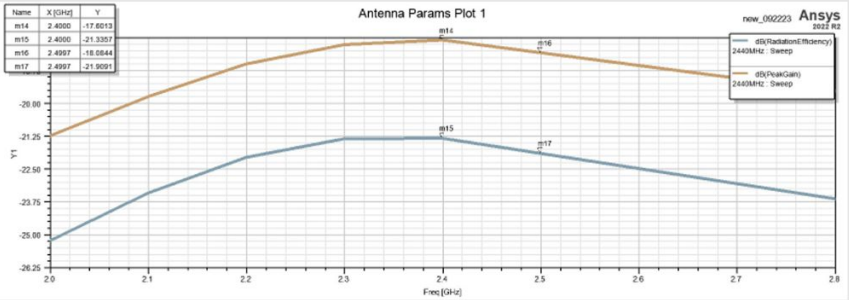


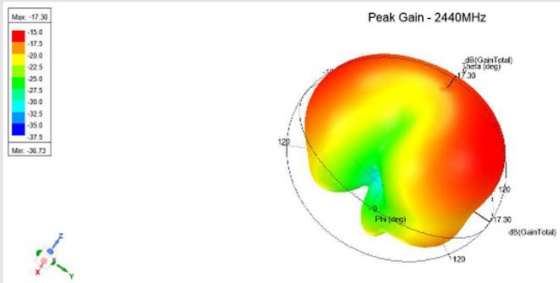
Antenna Simulation

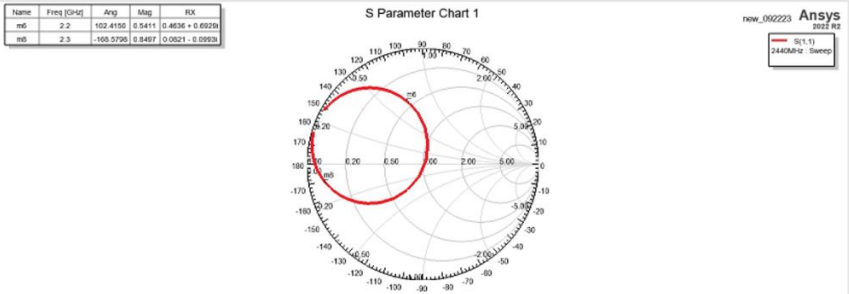
F3 Wireless

Results









F3 Wireless

Summary

- The antenna simulated peak gain is -17.3dBi. Average gain is -22dBi.
- This gives us ~13dB fade margin with a transmit power level of -10dBm at the peak of the radiation pattern.
- Ideally, we'd have ~20dB of fade margin for a more reliable system due to movement and nulls in the radiation pattern.
- The antenna is resonant at 2.2GHz, which is well below the 2.44GHz center; however, by designing the antenna to be too long one can easily cut the antenna to achieve the proper resonance.
- The simulation model includes a 1nH 0201 shunt inductor next to the antenna feed, which is absolutely required to achieve an impedance close to 50Ω.