2.3.6 RF Design

2.3.6.1 General Description

The IN610 has an integrated BLE radio, a protocol stack and application profile. The SOC can support master and slave modes concurrently. The RF module is supplied through its integrated step-down (buck) DC-DC converter and two external inductors paired with a bypass capacitor.

Multiple design implementations (antenna type, antenna location and antenna matching components) were evaluated to determine the best and most cost-effective Bluetooth Low Energy RF transmitter.

The radio Tx power is software configurable between -35 to +3dBm.

The following parameters of the BLE radio have been examined: return loss, bandwidth, insertion loss and radiation pattern.

2.3.6.2 Antenna Type

A PCB trace antenna, which is a common antenna type for Bluetooth Low Energy RF radios, is used in the Atlas Pod BLE RF design. In PCB trace antennae, the antenna becomes a 2D structure that is on the same plane as the PCB. The PCB antenna has the advantages of cost reduction and easiness of manufacturing. The selected antenna deviates from gen 2's loop antenna by using an inverted-F style antenna. There are several advantages of this type: First, it can be placed on the PCB's edge, maximizing the amount of board area available to other components. Second, the inverted-F does not require any discrete capacitors or inductors to achieve the correct resonant frequency. This fully printed design is thus simpler and cheaper than the loop antenna option. Finally, the antenna has higher efficiency (leading to greater transmission and reception) because its physical size corresponds to the correct resonant length (approximately one-quarter wavelength), and so does not require the capacitive loading necessary with the loop antenna.

2.3.6.3 Antenna Pattern

The simulated Pod antenna gain pattern can be seen in *Figure 3: Radiation Pattern and Antenna Gain (dBi)* , and the measured patterns for the three principal planes are shown in *Figure 4: Measured Free-Space Antenna Pattern for Thee Principal Planes.* The peak effective gain was determined to be 1.7 dBi. This data was captured in free space, without the presence of a human analog. This data is new for Atlas because of the new antenna design.

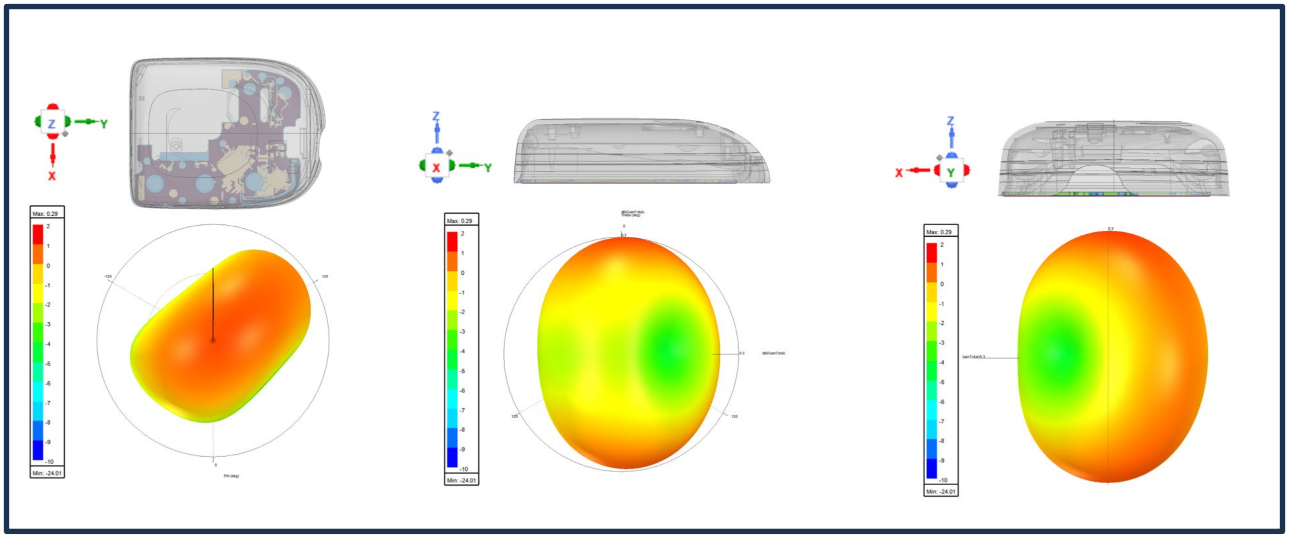

Figure 3: Radiation Pattern and Antenna Gain (dBi) in Three Orientations

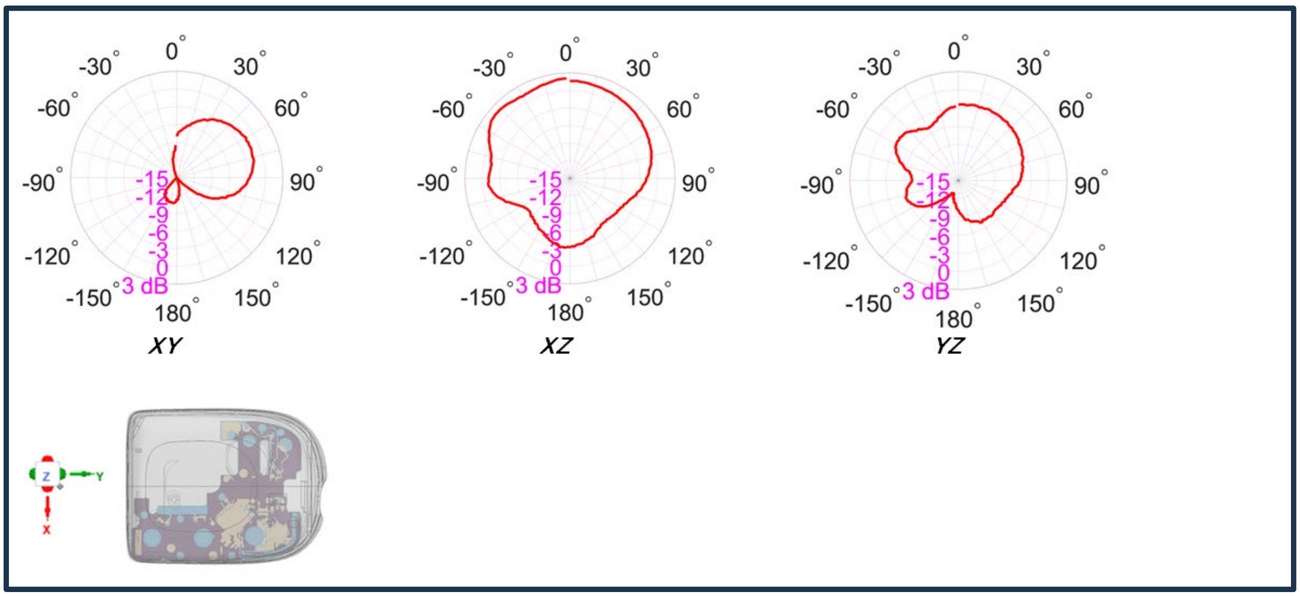

Figure 4: Measured Free-Space Antenna Pattern for Thee Principal Planes

2.3.6.4 Antenna Return Loss and Bandwidth

The return loss of an antenna is a measure of the effectiveness of matching to a 50Ω transmission line. The return loss is an indication of much incident power is reflected by the antenna due to mismatch and is calculated using the equation below.

$$Return\ Loss\ (dB) = -10\ log\ (\frac{Power_{Incident}}{Power_{Reflected}})$$

The measured antenna bandwidth is approximately 213MHz (2.3225GHz - 2.535GHz) next to the human body, given an -6dB return loss threshold. The measured S11 is shown in *Figure 5: Antenna Return Loss (S11)*

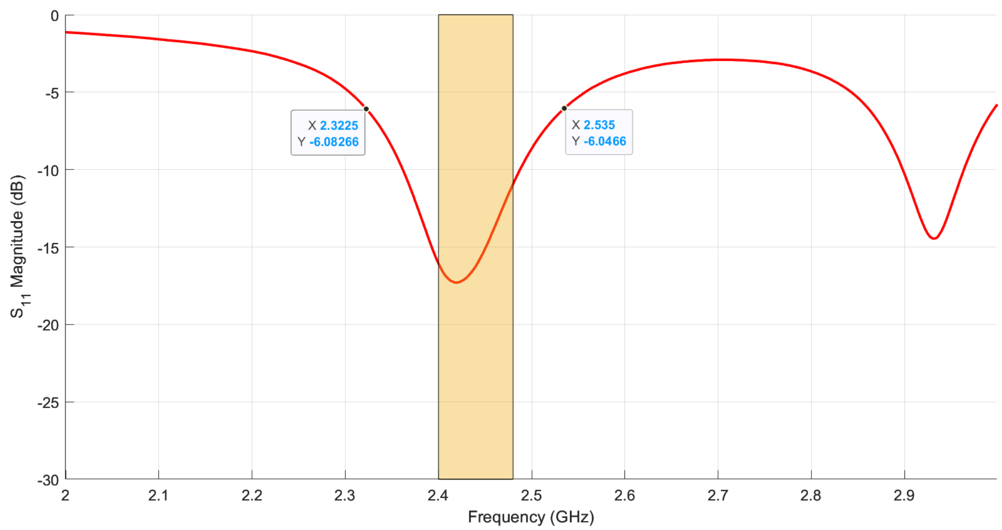

Figure 5: Antenna Return Loss (S11)

2.3.6.5 Harmonic Filter Insertion Loss

The harmonic filter is the same pi network as DASH Gen 2. L-C values have changed slightly from DASH Gen 2 to account for the new antenna. The insertion loss measured on the RF radio antenna at 2.48GHz is equal to 1dB. The measured insertion loss (S21) could be calculated using the equation below.

$$Insertion\ Loss\ (dB) = 10\ log\ (\frac{Power_{Transmitted}}{Power_{Received}})$$

The graph below, *Figure 5: Harmonic Filter Insertion Loss*, shows the insertion loss measurement and the harmonic filter frequency response from 1GHz to 9GHz.

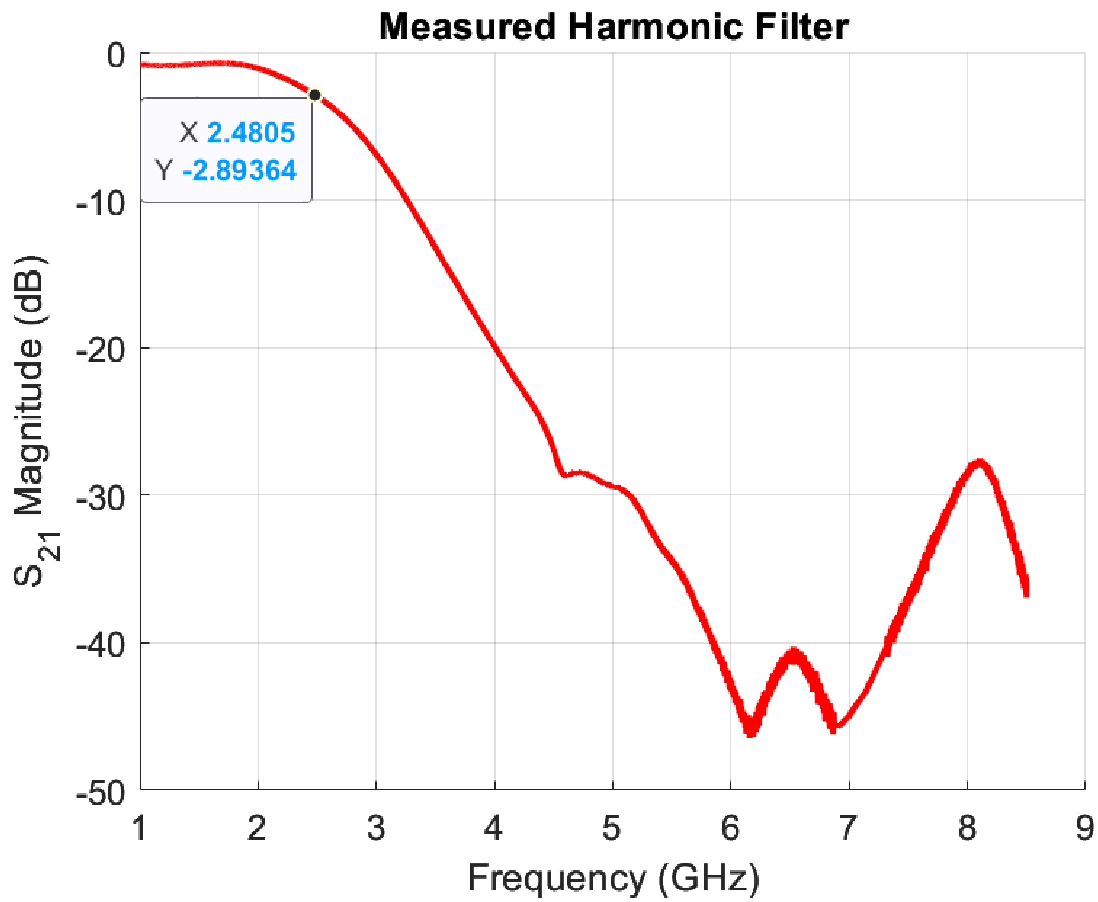

Figure 6: Harmonic Filter Insertion Loss

The table, *Table 6: Matching Network Loss Measurements*, below summarizes some of the key measurements performed on the antenna matching network of the Atlas Pod PCBA Assembly rev 02 (**TBD confirm**). The previous graphs and table below show that the antenna impedance matching has been tuned to minimize the loss at the 2.45GHz nominal frequency.

Table 6: Matching Network Loss Measurements

Frequency (GHz)	Harmonic Filter Loss (dB)	Return Loss (dB)	Mismatch Loss (dB)	Attenuation (dB)
2.3	~0.92	7.3	0.89	2.1
2.4	~0.97	6.2	1.19	2.6
2.485	~1	5.5	1.46	2.9
2.57	~1	4.7	1.75	3.4

2.3.6.6 Antenna Geometry and Location

Various designs of the PCB layout were explored as possible options for the PCB trace antenna. The illustrations below, *Figure 6. Shorter Antenna Geometry* and *Figure 7. Longer Antenna Geometry*, show examples of antenna variations tested to achieve the correct resonant frequency. The top of the PCB was selected as the antenna location because it is close to the BLE chip's RF output, and farthest away from the other large metal components; thus, it avoids detuning from the batteries, and from any potential impact of SMA wire noise during its operating and idle states.

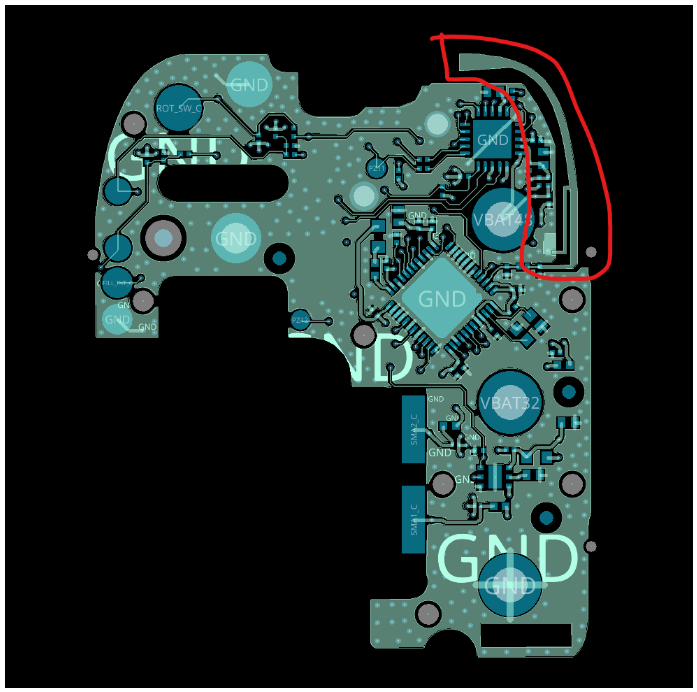

Figure 7. Shorter Antenna Geometry

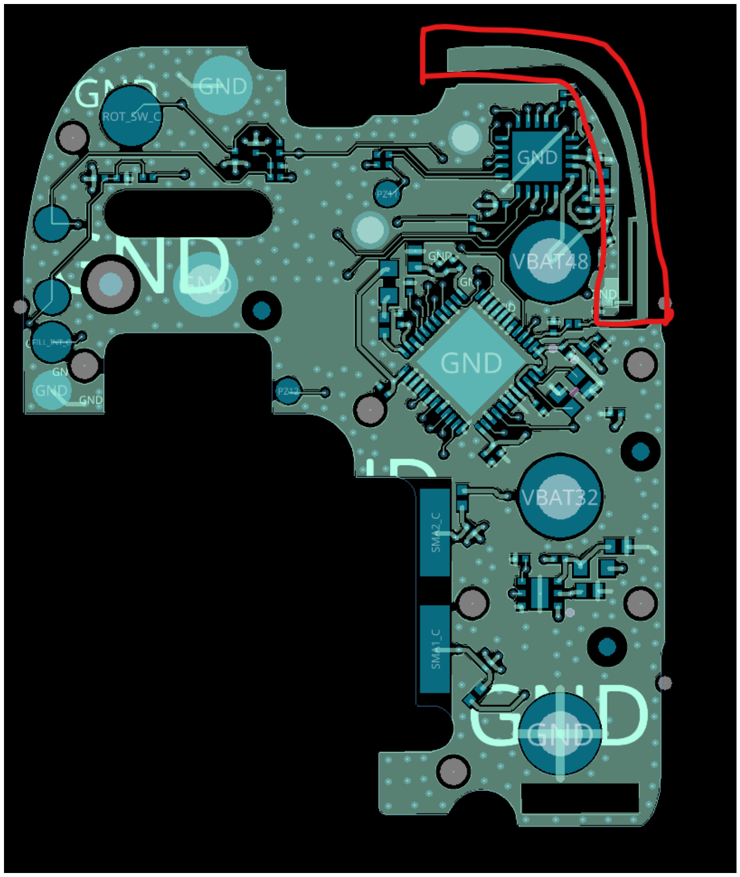

Figure 8. Longer Antenna Geometry

2.3.7 IN610 SOC Brown out Detection (BOD) Configuration

The IN610 supports Brown Out Detection BOD with four programmable thresholds refer to section 17.2 in the IN610 Reference Manual. The BOD monitors the VMCU voltage, if the voltage drops below the minimum threshold voltage of 1.71V, the BOD can trigger an interrupt.

Since Atlas does not have a boost circuit to help maintain VMAIN during wire-drives software has a solution to disable the BLE transceiver within the IN610 during wire drive to maintain VMCU above the minimum operating threshold of 1.65V.

2.3.8 IN610 SOC CHIP PACKAGING

The IN610 package selected for Atlas is a 6x6mm thermal enhanced Very-thin Quad Flat-pack No-leads (QFN48). Refer to the IN610 Datasheet, section 6.2 Fig 25 for details on chip marking.