**WNR Testing Plan**

**Testing Spec 1: Transmission Rate of at least 128 kbps per WNR device**

The scope of this test is to ensure that the WNR devices are able to send neural data in real time with high enough throughput for our data requirement needs of 8 bit precision at 1KHz for 16 electrode contact points. This test will verify that the WNR system is working properly in real-time to gather all neural data from the electrodes and transmit data via Bluetooth Low Energy (BLE) to the central data recording device.

The equipment required for this test would be the:

* Completed WNR devices
* NRF52 development boards
* Computer

The final WNR devices would communicate to the computer connected with a central NRF52 development board.

In the prototyping stage, the peripheral NRF52 development boards will be communicating to a computer connected with a central NRF52 development board.

Steps:

1. Using the computer, load WNR devices / NRF52 peripheral boards and NRF52 central board with the Nordic SoftDevice BLE Drivers.
2. Compile and load the WNR devices / NRF52 peripheral boards with the BLE transmission code and sample neural signal data.
3. Compile and load the NRF52 central board with the data receiving and recording example.
4. Power on the WNR devices / NRF 52 peripheral boards such that they automatically advertise and connect to the NRF52 central board. Record transmission start time observed on laptop message.
5. Observe transmission data successfully being received on NRF52 central board connected to computer.
6. Stop transmission of data from WNR device/ NRF52 peripheral boards. Record transmission end time observed on laptop message.
7. Confirm continuous data rate of at least 128kbps from data transmitted over time by dividing total size of received data by difference in start and end transmission times.

The test will be confirmed to be successful if the WNR devices/ NRF52 peripheral boards were able to successfully connect and transmit data for at least 10 minutes at a constant calculated average throughput of at 128kbps. The test can be repeated for varying amounts of time from 1 minute to several hours to ensure consistent throughputs for varying amounts of time.

**Testing Spec 2: Sampling precision of at least 8 bits for 16 channels**

The scope of this test is to ensure that the WNR devices are able to sample analog data from the electrode’s 16 channels with at least 8 bit precision. This will ensure the data being transmitted and recorded will contain enough data resolution to be recompiled and displayed.

The equipment required for this test would be the:

* Completed WNR devices
* NRF52 development boards
* Intan RHD2132 A2D
* Function generator
* Computer

The final WNR devices would received analog data via the electrodes from the function generator and communicate the converted A2D data to the computer connected with a central NRF52 development board.

In the prototyping stage, the function generator will generate an analog signal for the intan chip to convert to a digital signal, which is then sent to the peripheral NRF52 development boards, which will be communicating to a computer connected with a central NRF52 development board.

Steps:

1. Turn on function generator to generate a triangular waveform of 1000 Hz or less
2. Connect function generator output to the WNR device electrode or directly to intan chip
3. Using the computer, load WNR devices / NRF52 peripheral boards and NRF52 central board with the Nordic SoftDevice BLE Drivers.
4. Compile and load the WNR devices / NRF52 peripheral boards with the A2D code & BLE transmission code.
5. Compile and load the NRF52 central board with the data receiving and recording example.
6. Power on the WNR devices / NRF 52 peripheral boards such that they automatically advertise and connect to the NRF52 central board.
7. Observe transmission data successfully being received on NRF52 central board connected to computer.
8. Stop transmission of data from WNR device/ NRF52 peripheral boards.
9. Confirm all received digital data contains at least 8 bits by opening data and checking if data type is uint8.
10. Reconstruct received data by plotting it and checking to see if waveform received is waveform generated by the function generator.

If the WNR devices/ NRF52 peripheral boards were able to successfully convert the analog data to digital and transmit that data, the test will be confirmed to be successful once the data received is checked to be of at least 8 bit precision by checking if the data type received is of unit8 and was reconstructed to be the signal generated by the function generator.

**Testing Spec 3: Sampling rate of at least 1 kHz**

The scope of this test is to ensure that the WNR devices are able to sample analog data from the electrode’s at a maximum of 1 kHz. This will ensure the data being transmitted and recorded will contain enough data to be recompiled and displayed.

The equipment required for this test would be the:

* Completed WNR devices
* NRF52 development boards
* Intan RHD2132 A2D
* Function generator
* Computer

The final WNR devices would received analog data via the electrodes from the function generator and communicate the converted A2D data to the computer connected with a central NRF52 development board.

In the prototyping stage, the function generator will generate an analog signal for the intan chip to convert to a digital signal, which is then sent to the peripheral NRF52 development boards, which will be communicating to a computer connected with a central NRF52 development board.

Steps:

1. Turn on function generator to generate a triangular waveform of 1000 Hz or less
2. Connect function generator output to the WNR device electrode or directly to intan chip
3. Using the computer, load WNR devices / NRF52 peripheral boards and NRF52 central board with the Nordic SoftDevice BLE Drivers.
4. Compile and load the WNR devices / NRF52 peripheral boards with the A2D code & BLE transmission code.
5. Compile and load the NRF52 central board with the data receiving and recording example.
6. Power on the WNR devices / NRF 52 peripheral boards such that they automatically advertise and connect to the NRF52 central board.
7. Observe transmission data successfully being received on NRF52 central board connected to computer.
8. Stop transmission of data from WNR device/ NRF52 peripheral boards.
9. Reconstruct received data by plotting it and checking to see if waveform received is waveform generated by the function generator and is of the operating frequency of up to 1000 Hz and is the same frequency that was generated by the function generator.

If the WNR devices/ NRF52 peripheral boards were able to successfully convert the analog data to digital and transmit that data, the test will be confirmed to be successful once the data received was reconstructed to be the same frequency signal generated by the function generator. The test will be repeated for signals from 0 Hz to 1000 Hz in 50 Hz steps to ensure that the entire frequency spectrum is able to be sampled and transmitted.

**Testing Spec 4: Skin temperature change of less than 2 degree C**

The scope of this test is to ensure that the WNR devices is safe for human use as a change of more than 2 degree C can cause discomfort and skin cells to start dying.

The equipment required for this test would be the:

* Completed WNR devices
* Infrared thermometer
* Piece of silicone rubber
* Computer

The room temperature of a piece of silicone rubber will be measured with the infrared thermometer. The WNR device will be running at full throughput when placed on the silicone rubber. The temperature of the rubber will be measured every 10-20 minutes.

Steps:

1. Take temperature of silicone rubber with infrared thermometer. Record baseline starting temperature
2. Run WNR device under full load with steps from Testing Spec 1.
3. Place WNR device on silicone rubber
4. Record temperature of silicone rubber every 10-20 minutes

The test will be conducted over the course of 3-4 hours with temperatures of the silicone rubber being taken at 10-20 minute intervals. If there was never a change of more than 2 degree celsius in the silicone rubber, the WNR test will pass this safety specification requirement.

However, this test depends on a few variables such as a airflow and room temperature. The test will have to be repeated in rooms of varying temperatures from 15.5 to 26.6 degrees Celsius. The ventilation of the room will also affect the airflow and cooling of the skin and device, so a well ventilated room and a not-so ventilated room will be used for testing. This will ensure the device operates in various standard environments and ensure it meets the specification requirements.

**Testing Spec 5: Module size of 10mm diameter**

The scope of this test is to ensure that the WNR devices is small enough to be placed on a patient’s head without interfering with other WNR devices. The form factor ensures that the WNR device is competitive in the market with its tiny form factor.

The equipment required for this test would be the:

* Completed WNR devices
* Calipers

Both the completed WNR PCBs that will be placed into the WNR device housing and the housing will be measured with calipers to ensure it meets the 10mm diameter requirement.

Steps:

1. Take PCB from WNR device
2. Measure PCB diameter with calipers along 3 major axes
3. Place PCB back into WNR device
4. Measure entire WNR device with calipers along 3 major axes

The test will be considered a success if the PCB diameter is no more than 10mm. We will have the diameter and height of both the PCB and completed WNR device for documentation purposes.

**Testing Spec 6: Battery life of at least 6 hours**

The scope of this test is to ensure that the WNR devices is able to be installed in a patient and send data for at least 6 hours.

The equipment required for this test would be the:

* Completed WNR devices
* NRF52 development boards
* Intan RHD2132 A2D
* Function generator
* Computer

The WNR devices will be transmitting at their full data rate while on battery power. When the device drains the battery completely., the signal to the NRF52 central device will be terminated and the timestamp of the connection lost will tell us how long the WNR devices have been running.

Steps:

1. Turn on function generator to generate a triangular waveform of 1000 Hz or less
2. Connect function generator output to the WNR device electrode or directly to intan chip
3. Using the computer, load WNR devices / NRF52 peripheral boards and NRF52 central board with the Nordic SoftDevice BLE Drivers.
4. Compile and load the WNR devices / NRF52 peripheral boards with the BLE transmission code and sample neural signal data.
5. Compile and load the NRF52 central board with the data receiving and recording example.
6. Power on the WNR devices / NRF 52 peripheral boards such that they automatically advertise and connect to the NRF52 central board. Record transmission start time observed on laptop message.
7. Observe transmission data successfully being received on NRF52 central board connected to computer.
8. Allow transmission of data from WNR device/ NRF52 peripheral boards until battery is drained. Record transmission end time observed on laptop message when battery is drained and disconnected from laptop.
9. Calculate operating time by taking difference of the start and end transmission times

This test will be considered a success if the WNR device is able to convert analog signals to digital signals and send it over BLE for an extended period of time lasting over 6 hours using batteries. For testing, we will have at least 4 WNR devices communicating at once to the computer, so we will have 4 data points to average and to see the minimum and maximum running times.

However due to the slight variance in capacity levels of batteries and the change in efficiency of energy transfer due to operating temperatures, we will need to repeat the test in rooms of varying temperatures from 15.5 to 26.6 degrees Celsius. This will allow us to understand the operating time of the WNR device is various standard environments and ensure it meets the specification requirements.

**Testing Spec 7: Operable range of at least 2 meters**

The scope of this test is to ensure that the WNR devices is able to transmit data wirelessly over a distance of at least 2 meters such that the patient is allowed to move about his or her room and ensure there is no loss in neural data transmission.

The equipment required for this test would be the:

* Completed WNR devices
* NRF52 development boards
* Intan RHD2132 A2D
* Function generator
* Computer

The WNR devices will be transmitting at their full data rate while the central device is moved to various locations around the room of varying distance.

Steps:

1. Measure out distance of 2m from placement of WNR device in all directions
2. Turn on function generator to generate a triangular waveform of 1000 Hz or less
3. Connect function generator output to the WNR device electrode or directly to intan chip
4. Using the computer, load WNR devices / NRF52 peripheral boards and NRF52 central board with the Nordic SoftDevice BLE Drivers.
5. Compile and load the WNR devices / NRF52 peripheral boards with the BLE transmission code and sample neural signal data.
6. Compile and load the NRF52 central board with the data receiving and recording example.
7. Power on the WNR devices / NRF 52 peripheral boards such that they automatically advertise and connect to the NRF52 central board. Record transmission start time observed on laptop message.
8. Observe transmission data successfully being received on NRF52 central board connected to computer.
9. Allow transmission of data from WNR device/ NRF52 peripheral boards until battery is drained. Record transmission end time observed on laptop message when battery is drained and disconnected from laptop.
10. Confirm continuous data rate of at least 128kbps from data transmitted over time by dividing total size of received data by difference in start and end transmission times.
11. Repeat step 6-9 for various distances up to 2 meters in various directions

This test will be considered a success if the WNR device is able to convert analog signals to digital signals and send it over BLE for a 10 minute period of time at its full data rate when the central laptop recording device is in various locations around the room. The laptop will be moved 2m in various spots from the transmitting peripherals and the data throughput test from specification 1 will be run to get the throughput. If the throughput received by the computer at 2m from the transmitting WNR device is sufficient, then we will be sure the WNR device is able to perform within the 2m requirements.

**Testing Spec 8: DC offset of RHD2132 < 2V**

The scope of this test is to ensure that the WNR devices is feeding less than 2 voltages back into the brain when it is recording brain signal.

The equipment required for this test would be the:

* Completed WNR devices
* NRF52 development boards
* Intan RHD2132 A2D
* Function generator
* Computer

Steps:

1. Setup WNR system to be operating as normal without providing an input to the RHD2132 chip. Configure input pin 1 to RHD2132 to be converting (Note that this pin can be any of the 32 analog input pins).
2. Connect Pin1 of RHD2132 to an oscilloscope.
3. Read DC offset coming from the analog input pin. This is the current that will potentially be injected into patient’s brain.
4. Repeat step 1 to 3 for other analog input pins.

This test will be considered a success if the feedback voltage is less than 2 Volts.