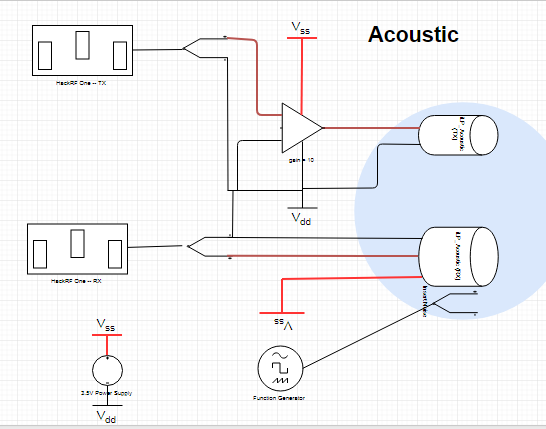
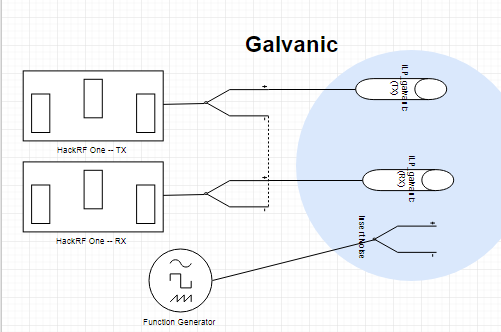
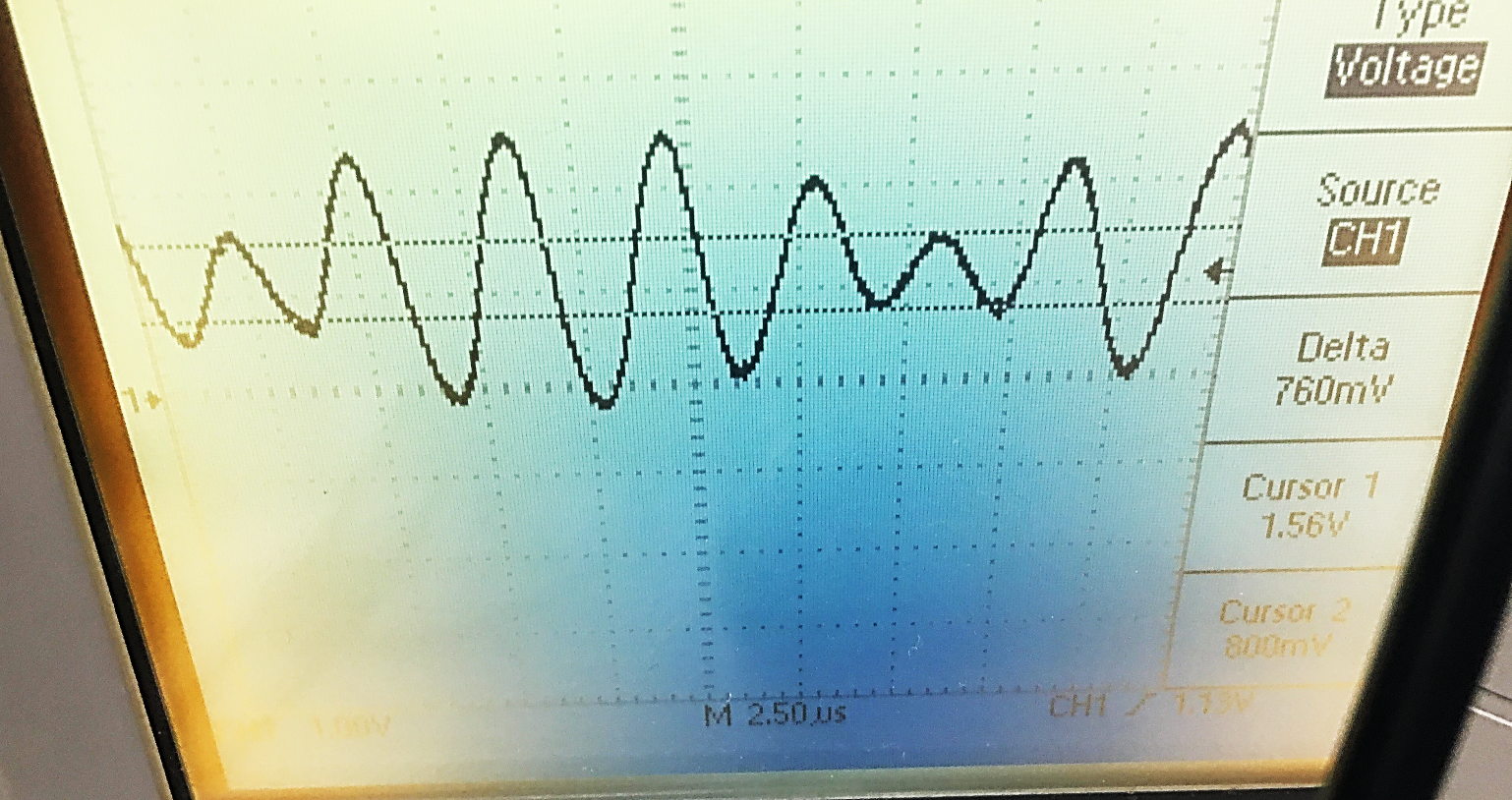
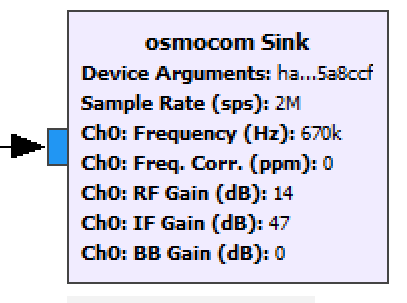
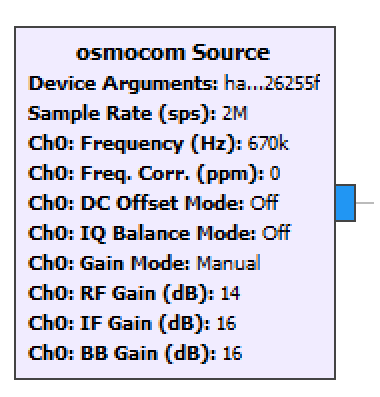
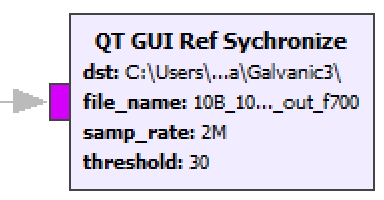
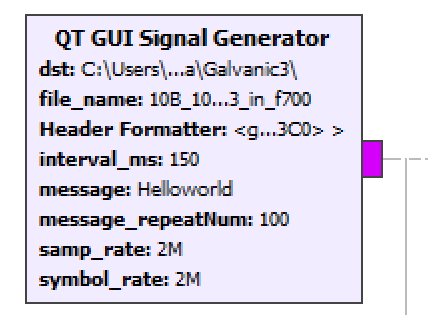
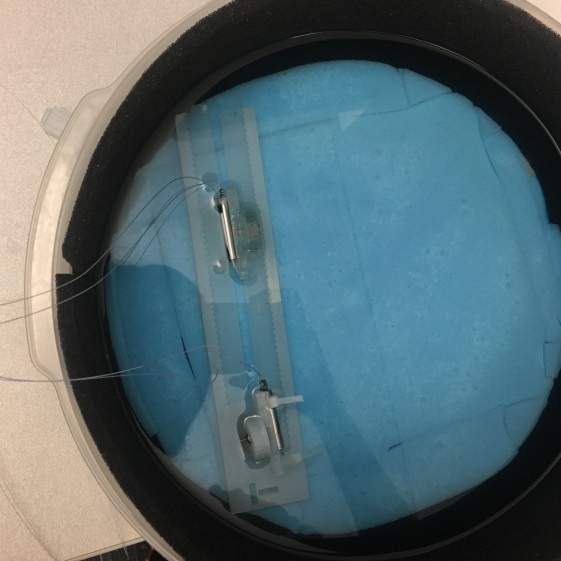
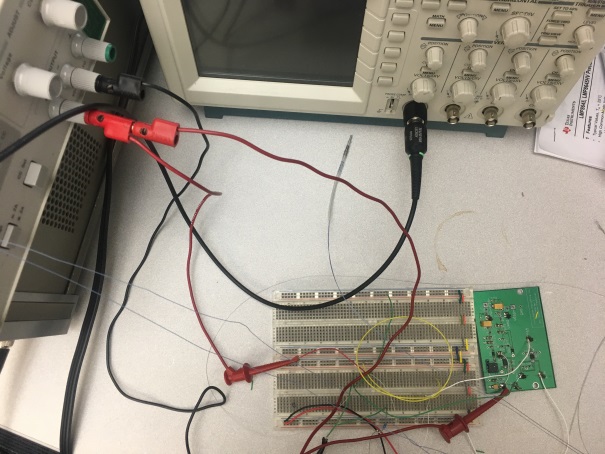
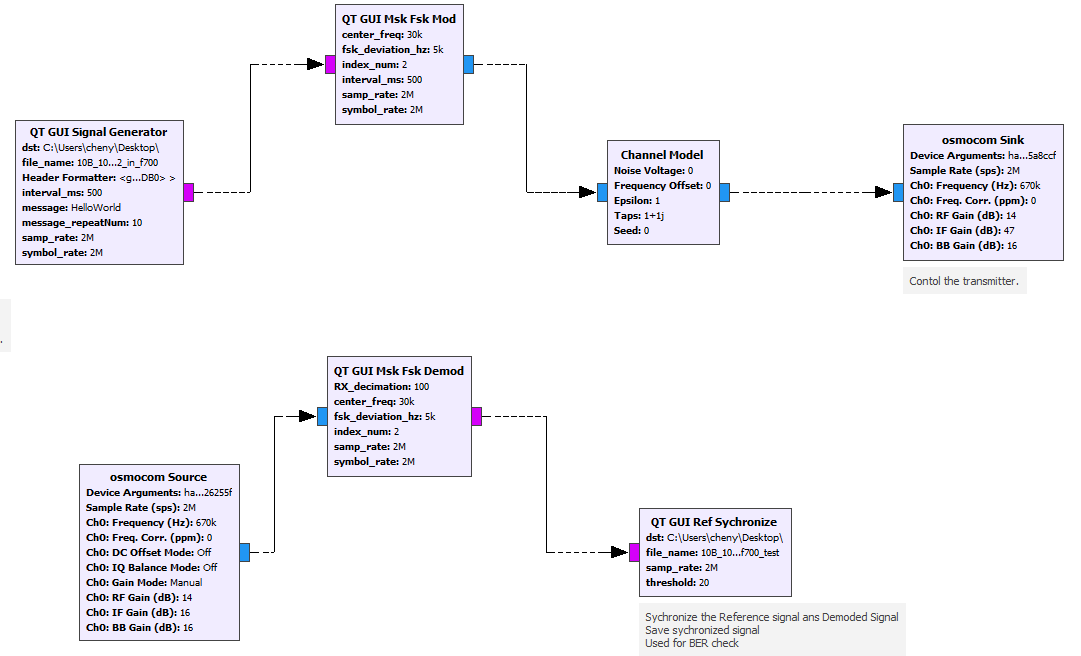
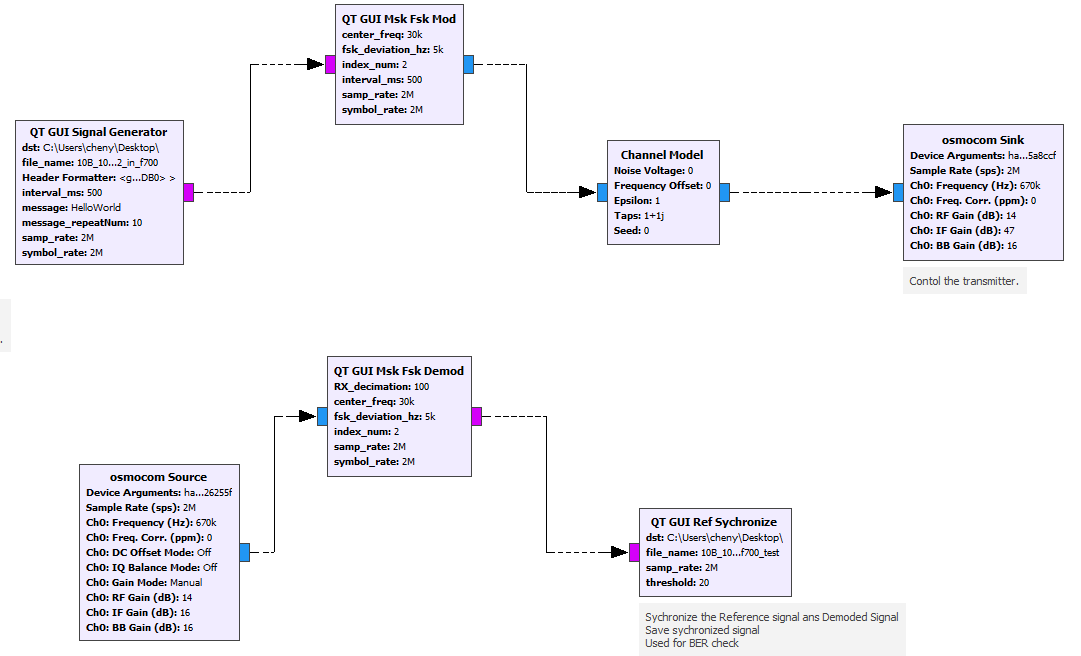
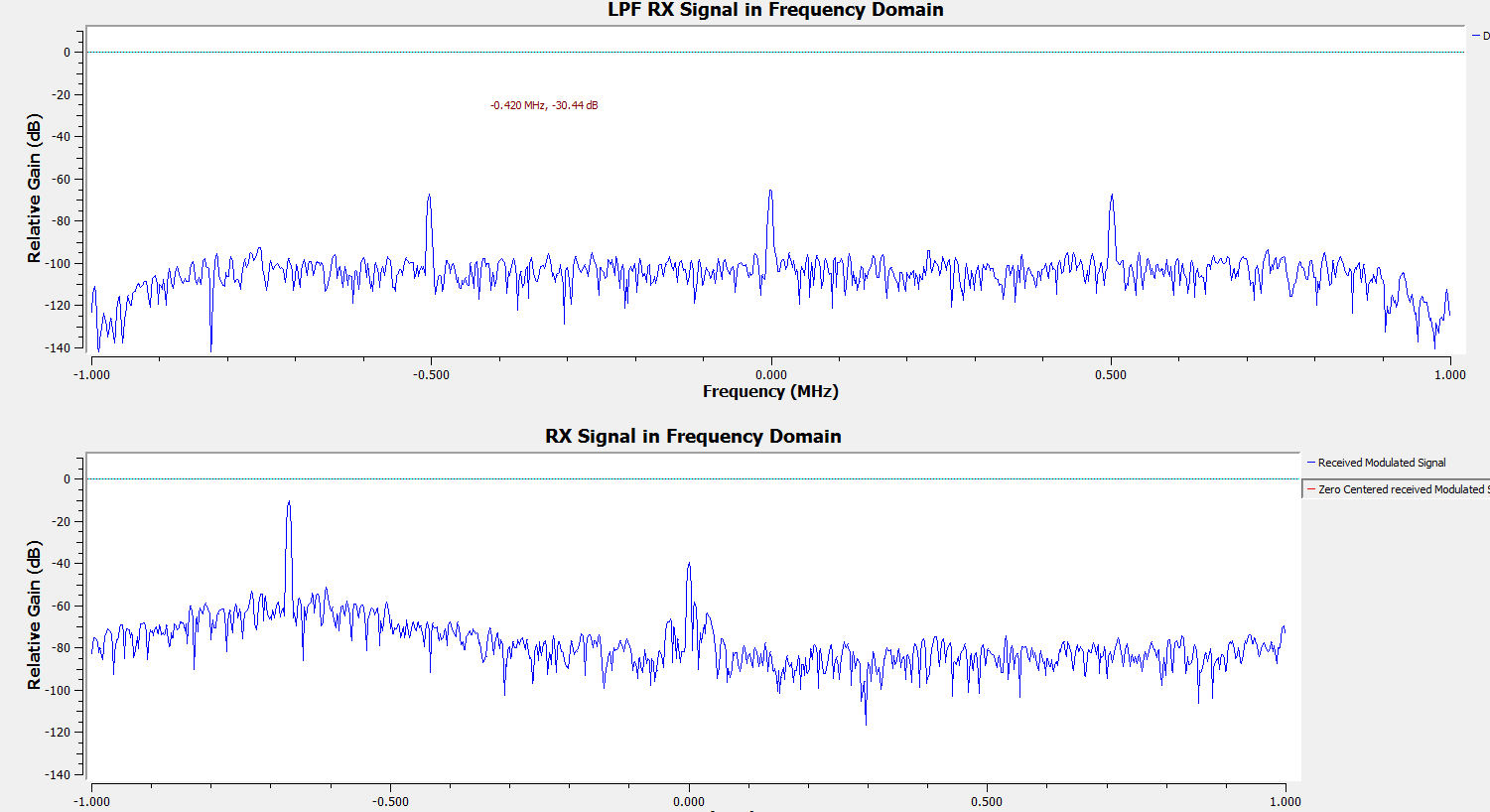
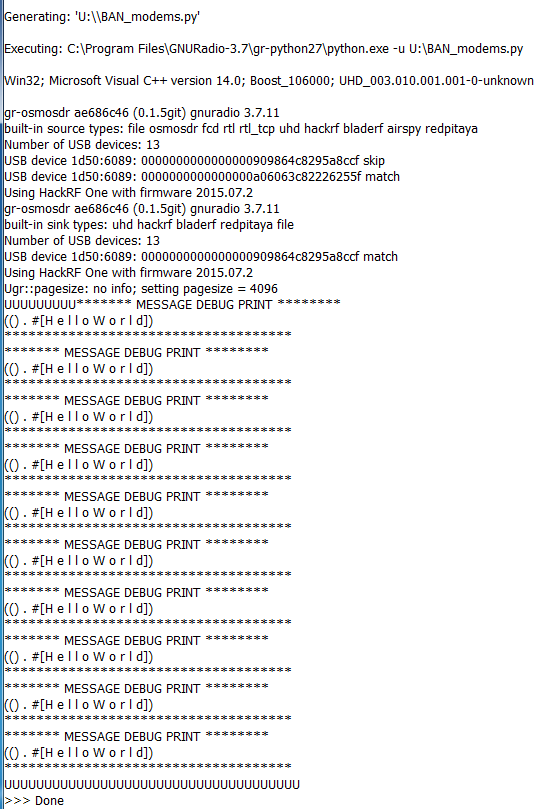
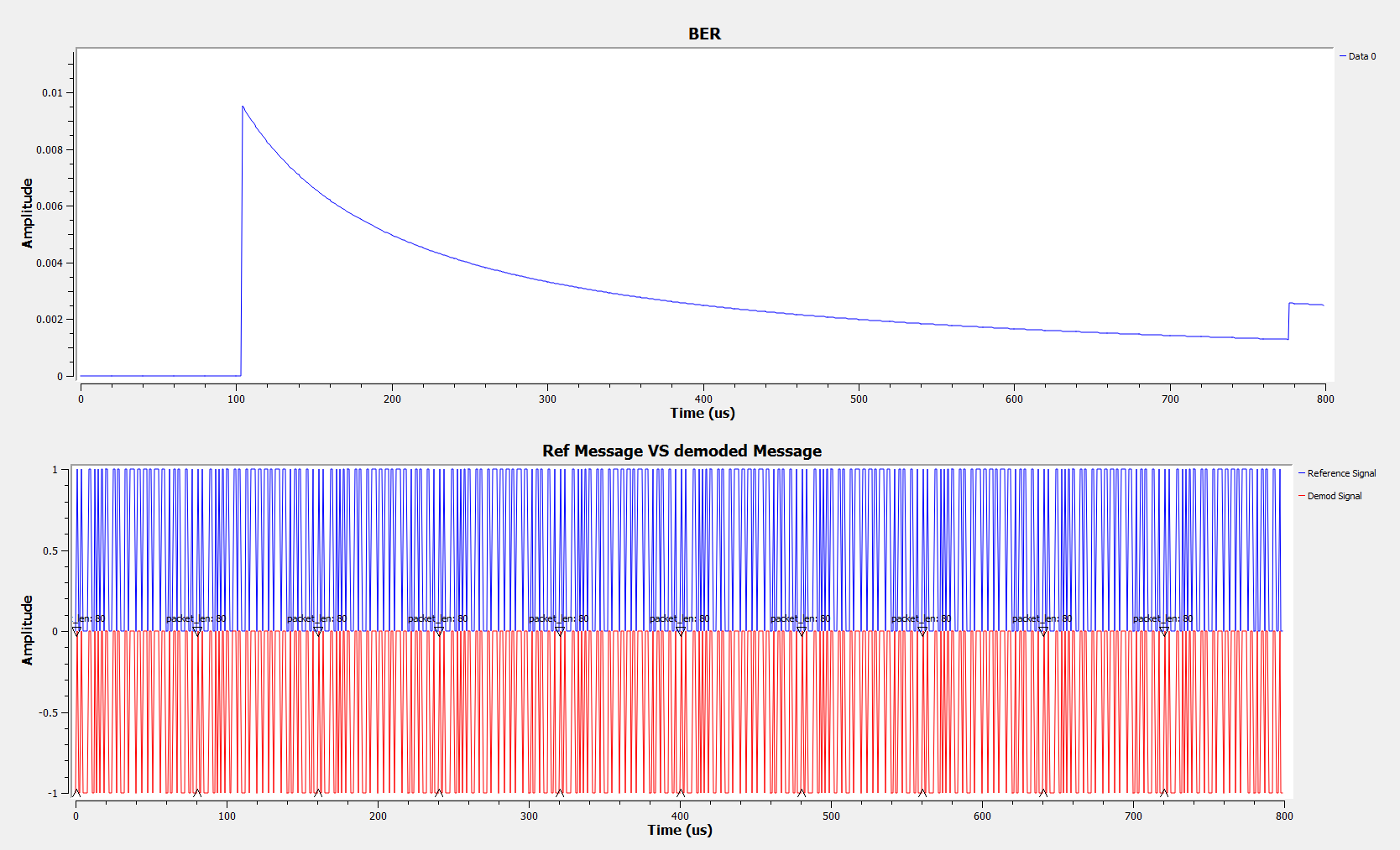
* Experiment Purpose:
* Test Preparation:
  1. Instrument Requirements:
     1. iLP\_Galvanic and iLP\_Acoustic
     2. Two Hackrf Ones (Used as SDR at TX/RX)
     3. Function Generator (Used as noise generator and debugging tool)
     4. Oscilloscope (Used as debugging tool)
     5. A container surrounded with acoustic-absorbing materials (foam)
     6. Salt and conductivity meter (Used to simulate the blood conductivity)
     7. iLP\_Acoustic special:
        + hydrophone (Use as debugging tool)
        + External amplifier XXX (Use to amply the input to TX)
        + DC Power supply (Use as power for external amplifier and build-in RX side amplifier)
  2. Schematic:



* 1. Check the settings:
     1. Make sure the Hackrf One to Hackrf One (connected by cable only) communication works, which means it can successfully do the whole modulation and de-modulation process.
     2. Acoustic:
        + **Check the input signal:** Connect the Hackrf One TX to the amplifier first, make sure the amplified signal is around 2V peak-to-peak amplitude. And the output is a clear cosine wave (or maybe a little triangle wave which is also ok because the capacitor connected to the iLP TX will filter out the high frequency and turn it back to cosine wave again) with desired frequency. 
        + **Check if the transmitter transmit the acoustic signal:**
          - Use the function generator as input to TX (no external amplifier connected). Set it to the burst mode with N=10, interval time = 2ms, f = 270KHz, voltage = 2V.
          - Use the hydrophone connected to oscilloscope as RX. You should see the burst signal around 5-15mV. If it is hard to see you can use trigger to capture that. The reason we use hydrophone is that it can only capture the acoustic signal. So we get rid of the electrical signal intervene.
        + **Check if the receiver with build-in amplifier works:**
          - Now replace the hydrophone with iLP receiver (don’t forget to power it). You should see the similar pattern with much larger amplitude. Make sure do not coupling the RX wires with TX wires!
          - In order to let Hackrf One RX recognize the signal. The output from iLP receiver should be …..
     3. Galvanic: The set for galvanic is quite easy so you can directly step into experiment first. I didn’t meet any issues by now.
  2. Requirements and limitation during testing:
     1. Software Modems (for FSK):
        + Recommended gain for Hackrf One build in amplifier is TX\_RF = 14, TX\_IF = 47, TX\_BB (doesn’t matter); RX\_RF = 14, RX\_IF = 16, RX\_BB = 16. This is the maximum gain you could get without much distortion for FSK. Further increase for RX\_IF and RX\_BB will fail to get target frequency. ASK and PSK not been tested yet. For more details on amp gain adjustment please refer to **Software modem instruction <Interface to receiver>/<Interface to transmitter>**  
        + Recommended for synchronize threshold, which used to synchronize the generated signal and demodulated signal to do BER assessment is 30. Higher threshold will fail in synchronizing, causing high BER in received signal. Lower threshold may be two strict that not easy for us to see the BER changes. For more details on amp gain adjustment please refer to **Software modem instruction <Packet Decoder>.**
        + Recommended sample rate and symbol rate for narrow down the testing scope purpose is 2M. Change in sample rate may lead to more deep adjustment to the SDR system. Please refer to **Software modem instruction** for more deeper change.
        + Recommended repeat time for message is >= 100 times. This is used to better assess the BER, avoiding some random interrupt. For more details on amp gain adjustment please refer to **Software modem instruction <Packet Encoder>.**
     2. Galvanic:
        + Recommended testing range for carrier wave frequency generated by Hackrf One is 700KHz (pkp\_amp=94-751mV) – 1990KHz. Any f < 500KHz will not work. f between 500KHz and 600KHz only works without noise. The reason might due to the insufficient pkp-amplitude. Frequency between 1990KHz and 2000KHz also not work, probably due to hackrf’s own limitation. f > 2000KHz is not tested yet.
     3. Acoustic:
        + The driven voltage (pkp-amp) for TX need to be >= 2V
        + The DC power required by RX is around 3V. DO NOT go to high, this may cause amplifier saturation which may destroy the build-in amplifier.
        + Recommended testing range for carrier wave frequency generated by Hackrf One is 270KHz – 310KHz.
     4. Other requirements:
        + Do not couple the wires.
        + Try to avoid other EM source besides the signal from wires.
  3. Setting examples:



* Parameter Explanation:
  1. Message Related:
     1. Message Length: 1 byte (1 character) ; 10 byte : 1 byte (1 character)
        + Here I use ‘H’ as 1B message and ‘Helloworld’ as 10B message.
     2. Message Interval: The interval time between two messages, range from 150 ms to 500 ms. This parameter might related to human heart rate.
        + Here I test 150ms
  2. Physical Setting related:
     1. iLP\_device: Acoustic and galvanic. Please refer to **<Test preparation: Requirements and limitation during testing>** for detail requirement.
     2. Orientation: Each iLP can be freely rotated along y-axis or x-axis for any degree.
        + Below is the three most typical one I choose in this experiment
     3. Distance: the distance between two middle of iLP, can varies between 40mm – 250mm. In this experiment I choose 100 mm as the most usual distance.
     4. Transmission Media: In this experiment I only use water as media.
        + Water (conductivity = 0.45)
        + Air (in the balloon)
  3. Environment related:
     1. Noise:
        + The algorithm is theoretically designed as a Low pass filter to reject noise with frequency out of range carrier\_wave+- Total\_Bandwidth/2.
          - So test the out-of-range noise first, if BER incease a lot, this might due to build-in amplifier for Hackrf.
          - If the Low pass filter works, then you can test noise at or slightly within the boundary. The closer the noise is to the carrier wave, the harder it can be filtered out.
        + In this experiment I choose noise amplitude with 0V (no noise) and 0.6V
  4. Software algorithm related:
     1. Modulation Algorithm: In this experiment, FSK is the primary choice.
        + FSK: Theoretically this is the most preferable algorithm.
        + PSK: This one take longer time to process and maybe more power consumption. But can still try.
        + OOK: This one is very subjective to noise. So I not recommended trying this on.
     2. Total Bandwidth (= Minimum required sample rate): Suppose we are able to do all frequency down-converting in the analog device, which means after A to D converting, signal in the frequency domain will be zero – centered. This is the total Bandwidth that contains the targeted message information.
        + Total Bandwidth < RX\_sample\_rate <= TX\_sample\_rate
        + Total Bandwidth = BW + EBW
        + This parameter depends on other parameters. Please refer to the comprehensive excel sheet for more reference.
* Targeted Result:
  1. Bit Error Rate (Error Bits/ Total Received Bits)
  2. Relative power-consumption (could be roughly estimated from following parameters):
     1. Amplify gain (the lower the better)
     2. Total Bandwidth (= Minimum required sample rate): (the lower the better)
* Testing examples:
  1. Settings
     1. Message Length: 10 bytes (‘Helloworld’), sent 10 times
     2. Device: galvanic to galvanic
     3. Orientation: face-to-face
     4. Distance: 100mm
     5. Noise Amplitude: 0V (no noise)
     6. Modulation Algorithm: FSK
     7. Total Required bandwidth (=Minimum required sample rate): 20KHz
  2. Software Modem
  3. Top: Received signal; Bottom: signal after eliminating DC offset and Down-sampling (Low Pass Filter)
  4. Received Message printout in the console
  5. Check bit error rate and the result: I assess the BER using moving average, so when pool is small, BER will begin with a larger value but wil finally converge towards 0.2%. (P.S. the end of BER curve always jump to high I think it may due to some Hackrd One problem when turn 0ff the signal. I would recommended ignore that when do assessment)



* Debug Suggestions:
  1. Check if Hackrf One is working: the 3V3,1V8,RF and USB LEDs should all be on. During transmission RX/TX should be on.
  2. Check if all the cable connected works
  3. Check if amplifier works (If you smell something burned or the power supply to amplifier failed to provide 3.5V power, then some components in amplifier may be short)
  4. When using oscilloscope and function generator to debug: If you see the RX signal from oscilloscope but is very weak, that signal may not from the Receiver but from the EM field generated by Function Generator!