WIRELESS NETWORKING

BREATH DETECTION
Radar Implementation on Software Defined Radio

April 27, 2017

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Introduction

The aim of the project is to detect breath in a non contact technique. We implement radar to achieve breath detection. There are several applications of wireless sensing the breath: baby monitoring, medical applications for old and for lung patients.

Figure 1.1: Doppler Radar Implementation

Radars exist in active and passive forms. An active Doppler radar consists of a transmitter that sends an EM signal at high frequency and at the same time one or more receivers receive, amongst other things, the reflected waveform from the object. We choose to design a radar using just 1 transmitting antenna and 1 receiving antenna.

1 Purpose

The analysis of breath plays a very important role in detection of various sleep-related disorders such as sleep apnea, sudden infant death syndrome, pulmonary disorders, lung disorders and other chronic or acute breathing problems [1].

Approach	**Hardware**
Non-contact	Infrared (IR) sensor, USB camera
Non-contact	Pressure sensor, Temperature sensor & Microphone
Non-contact	Mid-wave Infrared(IR) camera, piezo-strap transducer
Non-contact	Infrared (IR) illuminator, Infrared (IR) camera
Non-contact	Non-invasive hydraulic bed sensor i.e. pressure sensor
Non-contact	Microphones
Contact	Tracheal & ambient microphone
Contact	Omnidirectional microphone, aluminum conical bell

Table 1.1: Hardware used in different approaches [1]

Table 1.1 gives an overview of the successful methods used till now to implement the breath detection. The wearable contact sensors cause inconvenience and discomfort for the subject. Moreover some subjects may develop skin allergies if used for longer duration due to adhesives used for mounting the sensors. Wearing the sensor for a long duration might be uncomfortable for the subject. Moreover, non-contact approach requires minimal or no wiring and the subject can be monitored potentially at his/her home and not in lab [1].

2 HARDWARE SET UP

We can't discern the directions from which reflections are coming, we need to make sure we don't receive too many auxiliary reflections or the line of sight signal, either by encasing our antenna making it directional, or by putting the radar close enough to the user so that the primary reflection has the largest magnitude. The following section explains the ways by which the receiver antenna is made directional.

2.1 Construction of parabolic reflector

Parabolic antennas are used in satellite communication. This implies that they provide high directionality for the signal being transmitted/received at earth from space. Inspired by the design we implement it in our project. All the parallel lines entering the parabola, would get reflected by the parabola and get reflected to the focus. Parabolic reflector helps to attain a directional antenna from an omni directional telescopic antenna.

The parabola constructed on Mat-lab. It was printed on and stuck on a rigid cardboard. Another piece of cardboard of height more than the height of the antenna was pasted longitudinally along the figure. Metal tape was stuck on the inner side of the cardboard to act as reflector. We position the antenna at the focus such that we get axial or front feed. With the feed antenna located in front of the dish at the focus, on the beam axis, all incident rays on dish are focused [2].

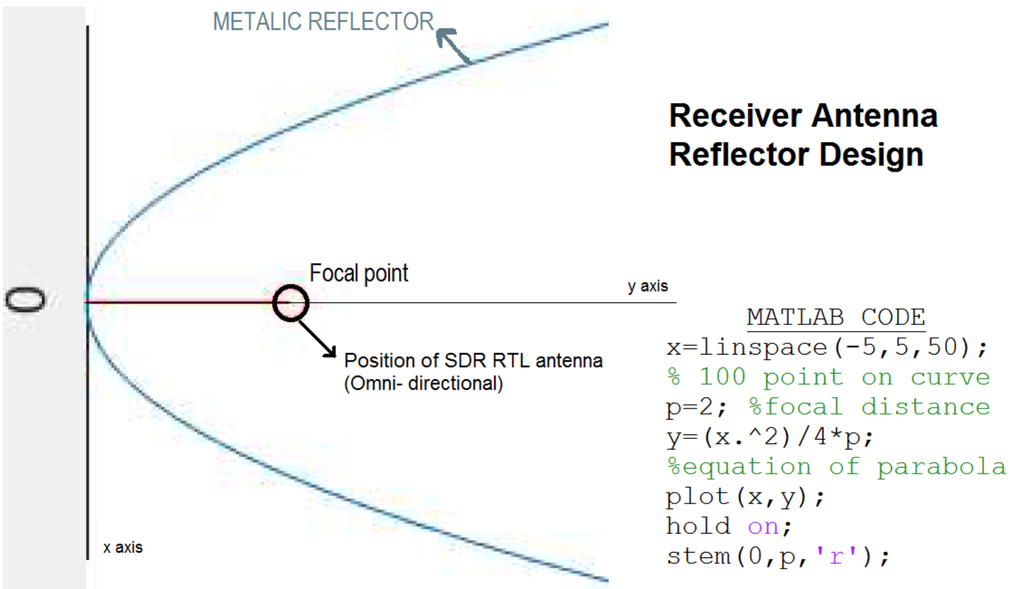

Figure 1.2

2.2 Setup layout detail

- The height of the transmitter and receiver must be the same to achieve the maximum radiation for the best transmitter and reception.
- The log periodic antenna has a maximum radiation pattern if kept vertical.
- The signals penetrates clothes and therefore we use a cardboard wrapped in a multi-layered aluminum foil which acts as reflector.
- The transmitter and the receiver should not be placed facing at each other directly. Line of sight will contour the amplitude of the reflected beam.

3 Digital Signal Processing - Matlab SDR RTL

3.1 Choice of spectrum

Since the speed of EM waves is very large, there will only be a small frequency deviation that we must measure. Therefore, we need to use a high frequency transmitter (1Ghz or more) and it must be very narrow band. This rules out FM transmitters and other low frequency devices.

The software defined radio will Rafael Micro R820T- 25-1750 MHz. Also, we need to choose frequency in alloted citizen band and a frequency that can be generated by signal generator. We choose a center frequency of 1 GHz.

3.2 Basic Principle

We inspect to parameters in the analysis of the breath detection using the frequency modulation continuous wave [3] concept and the radar range equation.

Frequency Modulation of Continuous Waves

RADAR is the system that uses radio waves to detect several parameter including distance. Here we implement FMCW radar. This is a frequency modulated radar whose operating frequency changes during measurement. The distance is measured by comparing the frequency of the received signal with respect to the reference. If the duration is greater that the required receiving time for installed distance measuring range than the distance has increased and can be calculated using the time difference.

FMCW is used because it capable of measuring very small range distances. It is immune to used indoor as well as outdoor. Also, it emits low power therefore doesn't pose any harm to human body. We however fail to completely implement FMCW radar, but can observe Δt influence on the received signal.

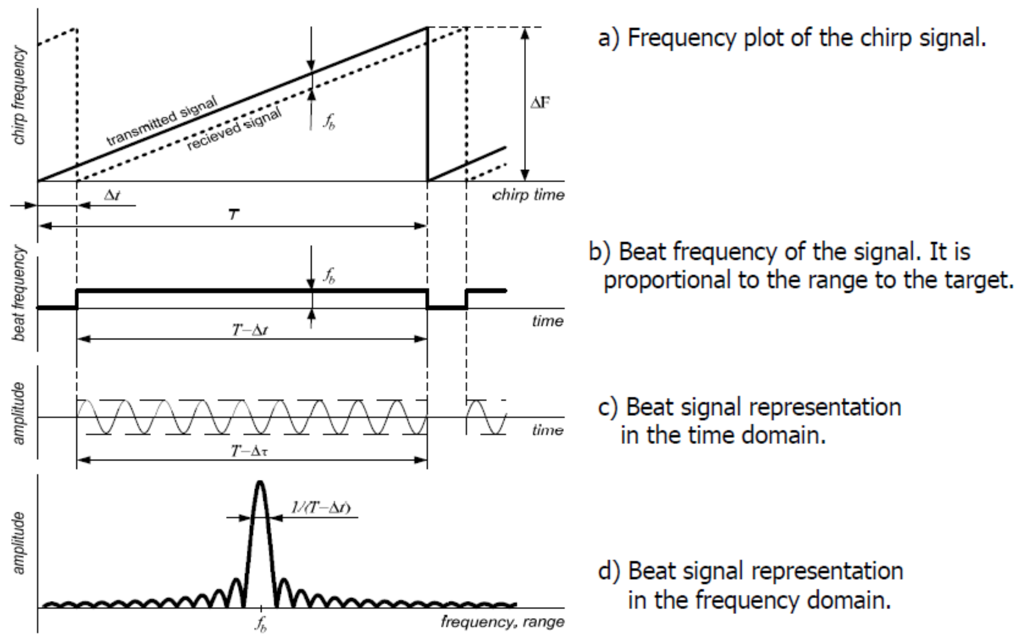

Figure 1.3: FMCW Radar implementation

Radar Range Equation

The radar range equation (RRE) gives the ratio of the transmitted power (fed to the transmitting antenna) to the received power, after it has been scattered (re-radiated) by a target of cross-section. In the general radar scattering problem, there is a transmitting and a receiving antenna, and they may be located at different positions as it is shown in the figure below. This is called bistatic scattering. The RCS of a target may vary considerably as the location of the transmitting and receiving antennas change. Therefore we keep the setup (receiver and the transmitter) static and only move the object from reference.

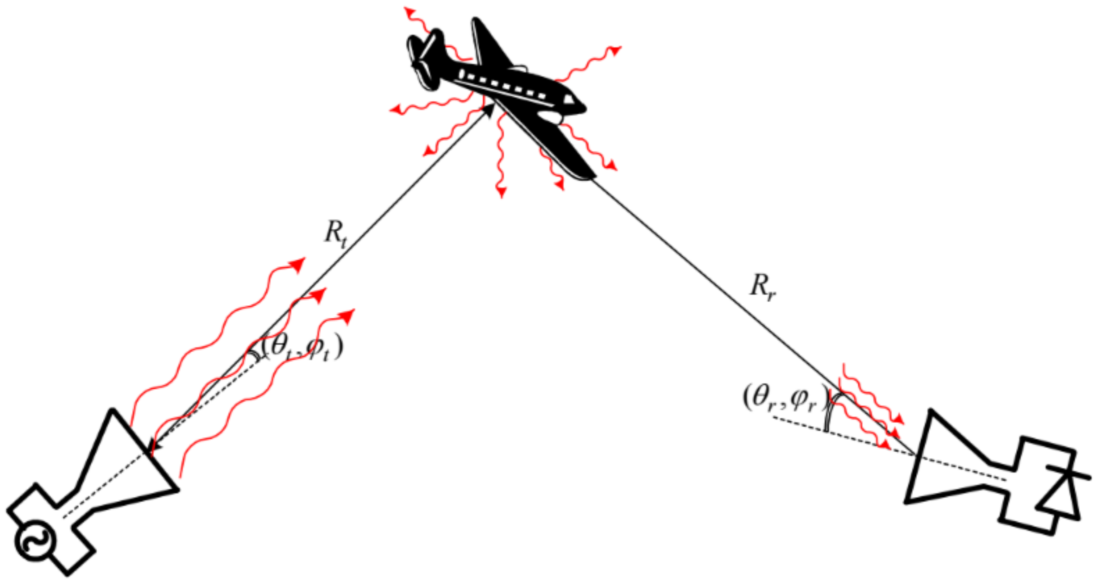

Figure 1.4: Matlab simulation

The following is the radar range equation. From the equation we can deduce that power transmitted is inversely proportional to the distance between reflector and the receiver. This equation gives us a very important deduction of the graphs obtained. The power received at the receiver is inversely proportional to the square of the distance between them. This implies that amplitude also holds an inverse proportionality with the distance. As we move the reflector away form the setup, the power received decreases and therefore the amplitude falls down. The inhale happens when the chest is away from setup, thereby the power is less compared to when the exhaling action when the chest is nearer to the setup. This principle is used to discriminated between the inhaling and the exhaling action. Comparing the speed of change in action gives us the respiratory rate.

$$\frac{P_r}{P_t} = e_t e_r (1 - |\Gamma_t|^2)(1 - |\Gamma_r|^2) \, |\hat{\boldsymbol{\rho}}_t^* \cdot \hat{\boldsymbol{\rho}}_r|^2 \, \sigma \left(\frac{\lambda}{4\pi R_t R_r} \right)^2 \frac{D_t(\theta_t, \varphi_t) D_r(\theta_r, \varphi_r)}{4\pi}$$

Figure 1.5: Matlab simulation

3.3 MATLAB Simulink

We implement frequency discriminator based frequency modulation. It processes the received signal and produces signals in time domain and frequency domain. The main purpose is to obtain a signal that is useful to analyse FMCW and radar range equation.

The frequency domain signal uses the concept of frequency modulated continuous waves. We try to see the change in the width of the signal at the center frequency. One can deduce that this change is directly proportional to the time difference (Δt). This Δt is one the most important parameter when we have to calculate the distance between the setup and the object. However, because of overlapping of long pulses we do not receive signal that is not the implementation of FMCW, in fact all the frequency waves add up and produce a different result than expected. If pulse compression was implemented than the overlap could be avoided and the signal would be used to efficiently demonstrate FMCW. Also, we see the width at the center frequency has a behavior resembling to the expected. The change is very minute and hard to harness, since the amplitude of the frequency introduced is similar to noise amplitude.

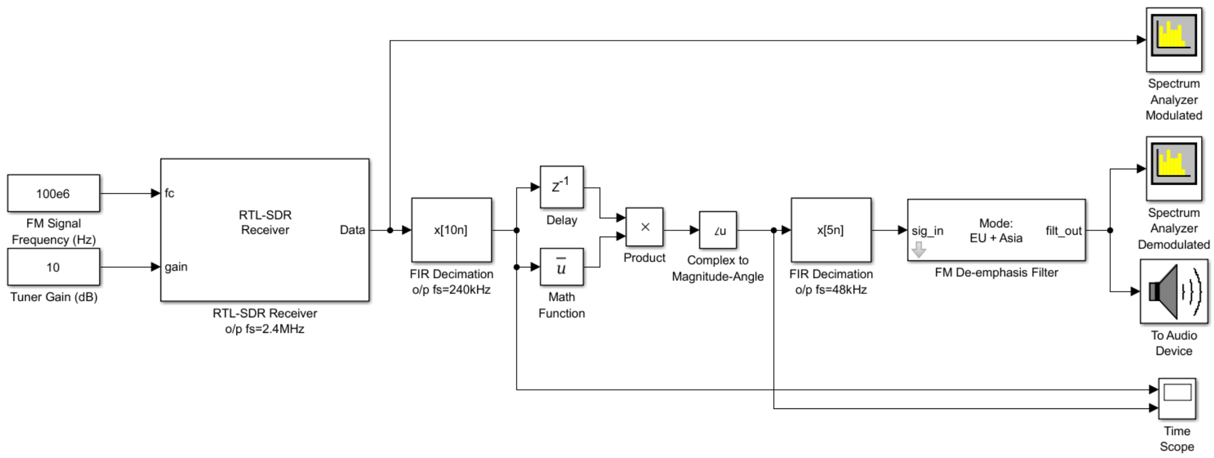

Figure 1.6: Matlab simulation

To observe the change in the amplitude of the power received, we observe the time domain. The time scope gives us the graph of the time versus amplitude of received signal, observing it one can very easily realise the breathing pattern.

Further in code, we could have implemented which compares the human less room and compares it with a breathing person sitting infront of the setup. Also, improving the code logic by implementing pulse compression would improve the frequency domain signal, thereby improving the quality of analysis of the received signal.

4 RESULT

The optimization of the implementation is figured out by changing various parameters and analyzing the respective change in detection of breath. The parameters being changed were the distance between the setup and human being, the angle between transmitter and receiver and the speed of breath. The results give a brief and which position and angle are best for optimum breath detection with the given hard ware. Also, we find out that changing the speed of the breath can be detected by the setup. This property enables us to use the setup in non contact vital signal monitoring in hospitals.

4.1 Distance between set up and Human being

The amplitude at the received signal decreases as you go farther from the setup. According to Friis's equation we derive that the power is received is directl This is because the power decreases as the distance increases.

4.2 Angle between the transmitter and receiver

Varying the angle between transmitter and receiver doesn't have any effect unless the signal is received as line of sight i.e., without being reflected from human body. In case of line of sight, it doesn't solve the purpose at hand. As the line of sight signal will be the strongest. The reflected pulse will have lesser power compared to the direct signal and there will not be of any use. This is one of the reasons why the line of sight signal is completely eliminated.

4.3 Speed of breath

The amplitude change increases with speed of movement of chest. With the increase in the speed i.e., making more prominent movement of chest (breathing) one can detect breath more properly. As, one makes the gestures of breath more distinguished, it becomes easier to detect breath. The speed of breath signifies a major factor in the health of a human being.

Age	Respiratory Rate
birth to 6 weeks	30–40 breaths per minute
6 months	25–40 breaths per minute
3 years	20–30 breaths per minute
6 years	18–25 breaths per minute
10 years	17–23 breaths per minute
Adults	12-18-breaths per minute
Elderly >= 65 years old	12-28 breaths per minute
Elderly >= 80 years old	10-30 breaths per minute

Table 1.2: Average resting respiratory rates by age; Source:Wikipedia

There are two phenomenons namely Bradypnea (abnormally slow breath) and Hyperventilation (elevated breath) which may be caused due to medical reasons including asthma, blood clot in an artery in the lung, choking, chronic obstructive pulmonary disease (COPD) and other chronic lung diseases heart failure; requiring immediate medical attention. A patient with a respiratory rate greater than 27 breaths/minute should receive immediate medical review; and patients with a respiratory rate greater than 24 breaths/minute, in combination with other evidence of physiological instability, should also receive immediate medical review.

5 Limitations of the approach

The SDR RTL is a radio software which hardware limitations. It can't precisely process the breath of a human being. Using a frequency of 1 GHz provides us with a wavelength of 15 cm, implying that it can detect a movement of 7.5cm. However, a very prominent breath of person is in the range of 1-2 cm. This requires the need to implement higher frequency for the purpose.

Implementing the pulse compression is needed to avoid overlapping of long pulse or the a four times bigger antenna use might help. One more possible solution will be implementing sliding window protocol to handle the samples in sustained rate.

In future, the device can be coded to sense the rhythm of the breath and therefore can be used in hospitals for non contact analyses of the breath. The device is used for baby sleep monitoring, since the children move a lot during their sleep, their clothes need to be changes and they are wet a contact device due to urine or saliva; wireless monitoring is a good way out [4]. Also, there is a lot research being done in the making wireless health monitoring as a part of smart homes. The project in the report is a start to many wide applications. In fact, since it is very feasible, it would be very efficient if this was developed to be implemented in hospitals.

POSTSCRIPT

The result obtained was not possible before making some unsuccessful attempts. Following section gives a concise through the attempts made.

- **Doppler effect doesn't work**- The frequency shift around the center frequency of 1GHz we expect the change of frequency from 999.999.999,97 Hz to 1000.000.000,03 Hz which is very small. Apparently, this change is visible. It is visible in the width of the

  However, the noise is of the same amplitude, so if one tries to remove noise using a low pass filter or amplify the noise using low noise amplifier, you loose the minute frequency change.

- **Directionality attempt using kitchen strainer**- A kitchen pasta strainer was used to make the omni directional antenna directional. This however worked in some orientations and did not work in others. It was tough to point out the pattern of shielding. Later it was realized that if it was a hemisphere or a hemisphere cut and if the centre of the hemisphere was known or the

- **Experimentation with WiFi Signal** We upload a file on the on Internet to check the frequency of operation of the signal which denoted by the uploading signal.

  We create a transmission signal in from the wifi antenna of the laptop to be received by the wifi router at the university. This signal is detected by SDR RTL antenna. We do this by uploading a file on drive from laptop. The following is the screenshot of the signal detected by the dongle.

- **Why can't we use WiFi signal as transmitted signals?** The SDR RTL is not capable of detecting the frequency above 1766 MHz. Also, there will be need of channel estimation to check which frequency slots are available at the given time. As the frequency allocation of WiFi will change with time.

Bibliography

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