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FMCW RADAR based Level Gauge

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Abstract: ***The work mainly focuses on increasing the accuracy of FMCW RADAR based level gauge. The device uses FMCW (Frequency Modulated Continuous Wave) along with Changes in the antenna parameters like gain and beam-width, are some basic ways of increasing accuracy. Phase evaluation along with beat frequency evaluation is a way in which we can ensure a more accurate measurement of the distance to be calculated. Pulse wave radar eliminates the option of phase evaluation and hence we cannot calculate the distance with utmost accuracy. So FMCW is the best option to calculate the depth of tank. This project has intense research in the initial stage. We have chosen LAB-View software as best operational software that is compatible with high frequency ADC-DAC.***

Keywords: FMCW (Frequency Modulated Continuous Wave), Phase evaluation, Beat Frequency Evaluation, Frequency shift, LAB View

1. Introduction

24 GHz frequency is deployed by us for the highest precision of the level measurement. Currently available products in the market give accuracy of about 3mm-10mm which causes large loss in mass storage tanks (40m in height x 40m in radius). The project focuses only on minimizing the error of about 1 or less then 1mm. The simulation of the same is been done and in simulation we were able to achieve the accuracy of 0.05mm. The work is now speeding into hardware implementation of the simulation. A lot of intense research is being done to find out the best hardware components that could be used to such accurate implementation. Due to hardware and environmental constraints we are targeting the expected hardware accuracy between 0.5mm -1mm which will be far better than the current available products. The ultimate idea is to productize a device which gives accuracy less than or equal to 1mm and save the losses of the fuels due to inaccurate measurement. The idea inspired from a technical paper based on an experiment of FMCW RADAR in structural health monitoring.

2. Description

Following are the stages in which the work till now has been done:

Stage 1: The inspired idea from the structural health monitoring was altered according to our requirement.

Stage 2: The block diagram for the same was designed finalizing the blocks required in the implementation of the system. (Refer Fig. 1.1)

Stage 3: After the finalizing the blocks the simulation process of the proposed changes was tested in the LAB View software.

Stage 4: The entire simulation process took place and the outcomes was of 0.05mm of accuracy.

Stage 5: Currently we are researching for employment of various hardware component (that can support 24 GHz of Frequency) for the actual implementation of the product.

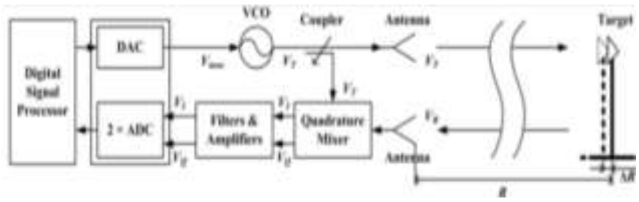

Figure 1.1: Block Diagram of the project.

3. Working Principle

A radar signal is emitted via an antenna, reflected on the product surface and received after a time t, t=2d/c. For further signal processing the difference Δf is calculated. The difference is directly proportional to the distance. A large frequency difference corresponds to a large distance and vice versa. The frequency difference Δf is transformed via a Fourier transformation (FFT) into a frequency spectrum and then the distance is calculated from the spectrum. The level results from the difference between tank height and measuring distance. The distance *D* to the reflecting object can be determined by the following relations:

$$D = c.|\Delta t| / 2$$
$$= c.|\Delta t| / 2.(df/dt)$$

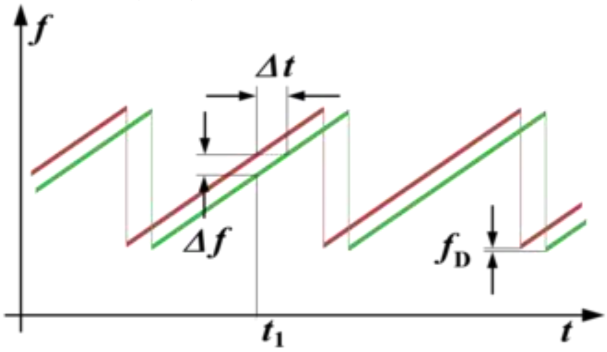

Figure 1.2: Shows the transmitted and received waves

Where,

c_0 = speed of light = $3 \cdot 10^8$ m/s

Δt = delay time [s]

Δf = measured frequency difference [Hz]

R = distance between antenna and the reflecting object

df/dt = frequency shift per unit of time

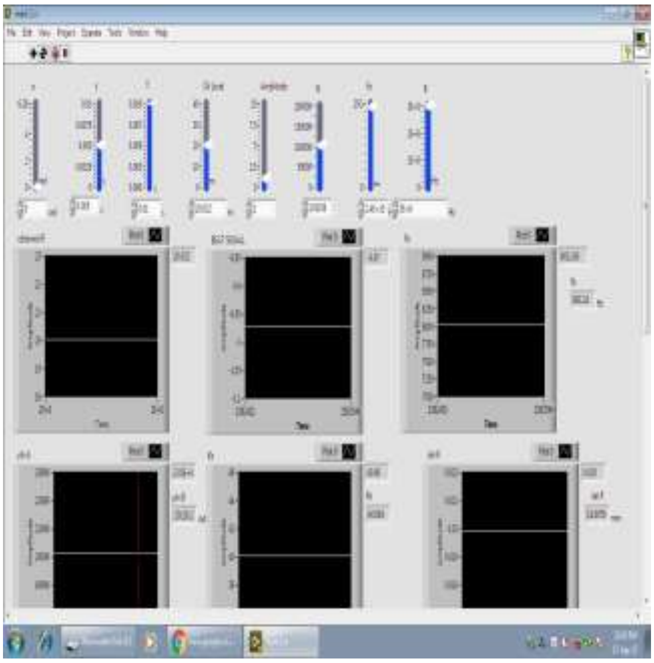

Figure 1.3: Calculation of various parameters displayed on an instant.

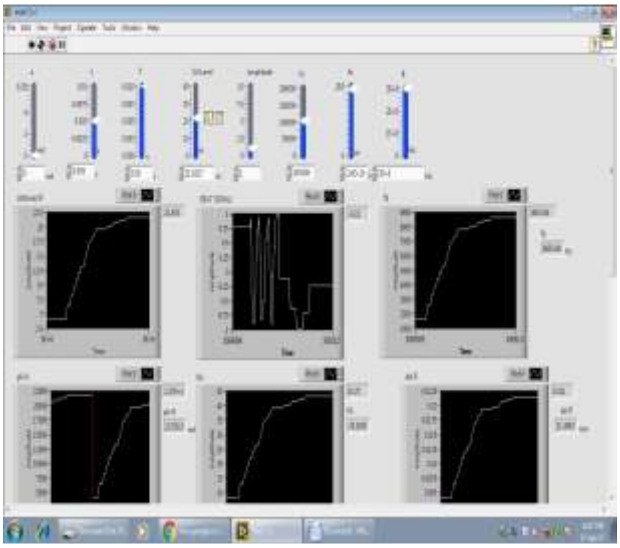

Figure 1.4: Varying levels of oil levels

The delay (delta t) is proportional to difference between the transmitted and received wave (delta f).

4. Output

The following are the simulation outcomes of the idea. The software used for the simulation was LAB View. In the simulation we were able to achieve in the accuracy of 0.05 mm. The screenshots of the outcomes are been added in the paper for references.

1) Calculation of various parameters displayed on an instant: (Refer Fig. 1.3)
2) Varying values in the oil levels(Refer Fig. 1.4)
3) Varying Bandwidth (Refer Fig. 1.5)
4) Varying number of samples(Refer Fig. 1.6)
5) Varying time(Refer Fig. 1.7)
6) Sub millimeter displacement measured(Refer Fig. 1.8)
7) Circuit diagram for evaluation of the signals(Refer Fig. 1.9)

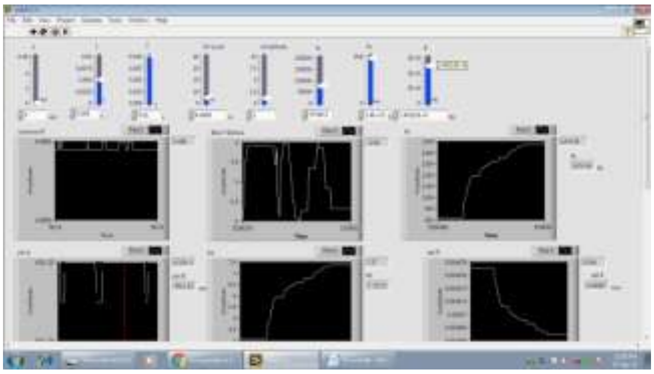

Figure 1.5: Varying Bandwidth

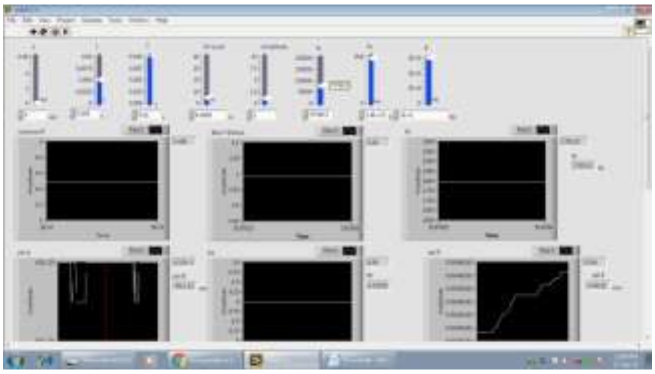

Figure 1.6: Varying number of samples.

Hardware Implementation

The hardware implementation of this project is the biggest task. Following constraints of hardware implementation we are majorly facing are:

(1) Substrates and other materials that can handle 24 GHz of frequency.
(2) The environmental effects on the materials.
(3) Availability and cost cutting of overall hardware implementation.

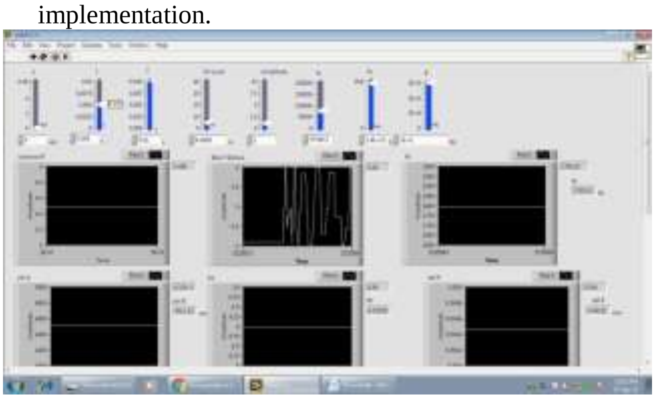

Figure 1.7: Varying time

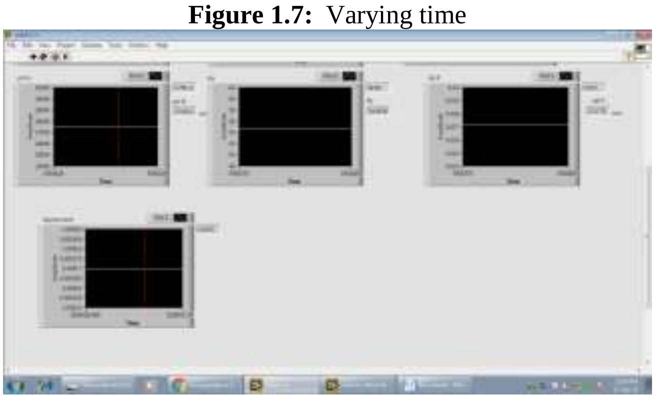

Figure 1.8: Sub millimeter displacement measured.

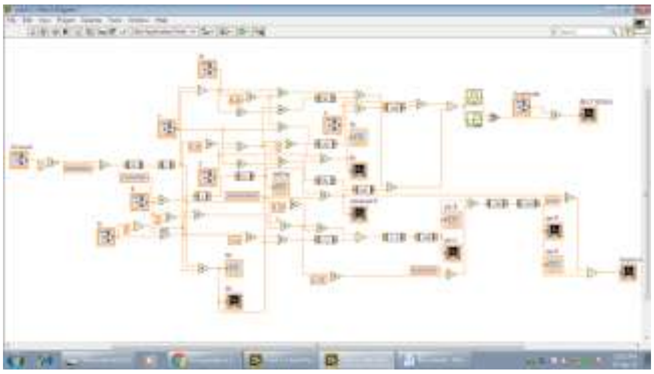

Figure 1.9: Circuit diagram for evaluation of signals.

Work done in hardware implementation is the substrate that we have finalized is RT/Duroid 5880 (Rogers Corp.). The substrate has lowest electrical loss, low moisture absorption, isotropic, excellent chemical resistant at high frequencies. Further we will be using here is a horn antenna which is also under designing. And lastly we are also currently on designing stage of Low Noise Amplifier (LNA). The LNA is designed for 24 GHz using p-HEMT.

5. Summary and General Assessment

The principles of high-accuracy displacement measurement and target identification using FMCW radar are discussed specifically. To verify the feasibility of the proposed measuring method, a FMCW radar prototype will be fabricated utilizing off-the-shelf devices, and the phase asynchronism induced by the hardware limitation will be analyzed. Finally, outdoor experiments will be carried out with one target and three targets, respectively.

Accuracy can be easily improved in case of oil level gauge. Using an idea from structural health monitoring system distance measurement we can implement the same idea in our project.

We have concluded that present market scenario can be drastically improved if we have high accuracy measurement devices in market. The market economic fluctuation due to error in measurement of oil level needs an immediate improvement. Economical fluctuation due to error= 5003.65 USD per tank. This results into millions of dollar at stake across the global market.

The hardware constraints will be soon overcome with lot of research of materials, design and simulation, finally implementation is likely to be completed within a year with expected accuracy being in the range of 0.05mm-1mm range.

6. Future Scope

The major scope for this project lies in simplifying the design of the project and overall cost cutting of the final product.

References

[1] A Non-Contact FMCW Radar Sensor for Displacement Measurement in Structural Health Monitoring System, Cunlong Li Weimin Chen,Gang Liu, Rong Yan, 2015.
[2] Richards, M.A. Fundamental of Radar Signal Processing, 2nd ed.; McGraw-Hill: New York, NY, USA, 2014. 27
[3] Oppenheim, A.V.; Chafer, R.W. Discrete-Time Signal Processing, 3rd ed.; Prentice Hall: Upper Saddle River, NJ, USA, 2009.
[4] A Dual-Stage Low-Noise Amplifier for 24 GHz Using Packaged p-HEMTs, Jeffrey Keyzer, Anthony Long.
[5] Rogers Corp. spreadsheet RT/Duroid 5880.