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Design Ground Penetrating Radar

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Abstract

In this paper we developed ground penetrating radar (GPR) operating in megahertz region based on frequency modulating continuous wave technology (FMCW). We used bow-tie antenna, because it is the best option for satisfying the bandwidth requirement. We used two antennas, one for transmitting and other for reception. We analyzed the signal obtained.

1. INTRODUCTION

This paper follows from the initial proposal outlining the design of a Ground Penetrating Radar (GPR) system. The GPR system will employ a non-invasive method in helping detect sub-surface water features, metal detection, mines detection…etc. By having the GPR system a better resolution can be obtained. This paper looks at some of the work that has been accomplished and also contains the obstacles that were encountered. It also outlines future milestones to be performed in the up coming weeks along with some foreseeable problems that will have to be tackled.

GPR transmits powerful low frequency signal directly to the ground using narrow band beam to concentrate waves into a particular direction. Receiving antenna picked up reflected signal. Method used is frequency modulated continuous wave. So we transmit and receive at the same time using two separate antennas for transmission and another for reception. The time it takes the signal to penetrate in ground and return back measure the depth at which energy was reflected.

We need to investigate the structure and location of subsurface features which help us to better understand the environment. Also, sometimes we need to decide where to safely build a bridge and to know how ancient civilizations lived. All these are considered to be of the applications of GPR [1].

2. LITERATURE REVIEW

The task of detection and determining the location of underground utilities is a significant cost for constructing projects in areas with existing infrastructure. This cost is estimated to be 10% or more of the project budget.

In addition to the cost implications there are serious safety risks present to construction workers, plus the consequential costs and inconvenience in disruption of services for extended periods.

GPR is a perfect tool in terms of leaving the site 'untouched'. The main purpose of GPR is the detection of underground utilities such as water, sewer, gas, electricity, and communication cables. GPR has advantages in the following areas; detection of non-conducting materials (example: PVC, nylon, fiber optic cables), detection of isolated utilities (example: concrete encased) and detection of abandoned buried infrastructure [2]. An example of radar image is shown below in figure 1.

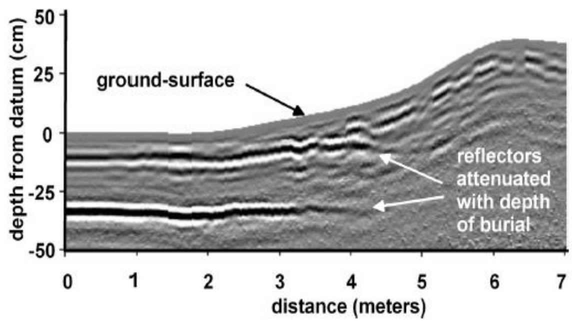

Figure 1. Radar Image

We discussed in this paper the design of (GPR).

The block diagram below shows final GPR design:

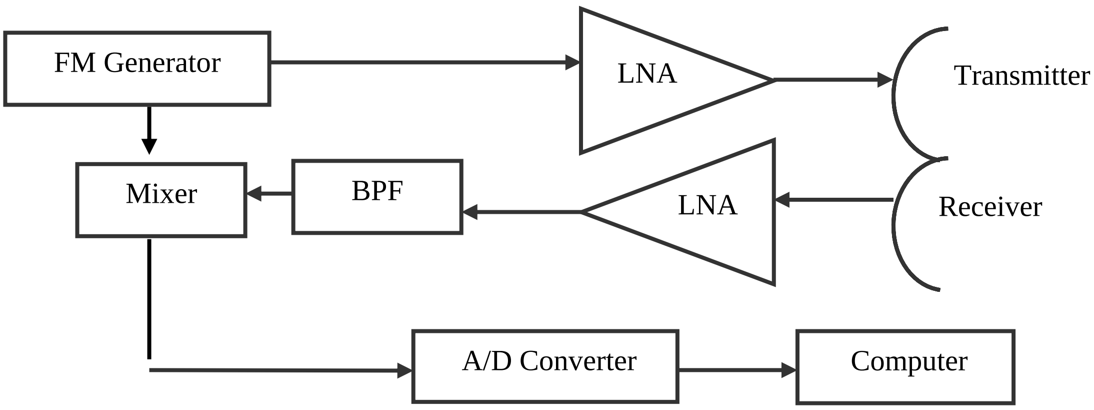

Figure 2. Block diagram of Final project design [3].

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Signal from FM generator applied to the LNA & mixer. The transmitted signal is amplified using LNA. The transmitted signal is detected by receiving antenna and amplified by LNA. Then the received signal is filtered to leave only the range of frequencies 500 – 1100MHZ [4].

The following figure shows the final circuit design of the GPR.

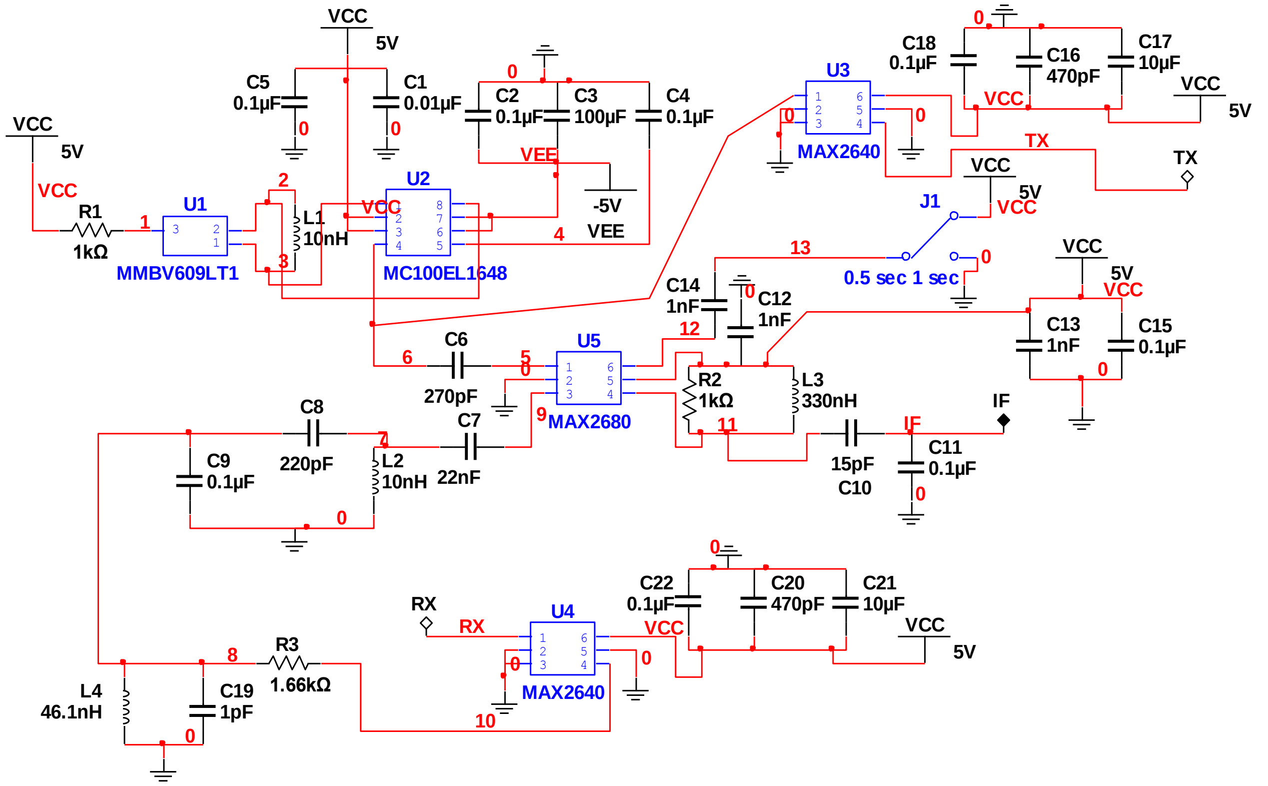

Figure 3. Final circuit of GPR.

4. FM GENERATOR

We used three devices to generate FM signal:

1- VCO (MC100EL1648–ON Semiconductors).

2- Tuning diode (MMBV609LT1. This device is designed for FM tuning, general frequency control and tuning).

3- Constant Inductor (10nH).

Our frequency range dictates the capacitance values that are needed for the L – C tank, the Inductance remains constant. The voltage input to the tuning diode varied the capacitance of the tuning diode [3]. Frequency output and Voltage input for Capacitance Values are shown below in table 1.

Table 1. Frequency output and Voltage input for Capacitance Values.

Capacitance (pF)	Frequency (MHz)	Voltage Input (V)
3.0	918.9	15
7.0	601.5	10

The modulated continuous wave signal is within the range of 600 to 1000MHz. This signal is shown below in figure 4.

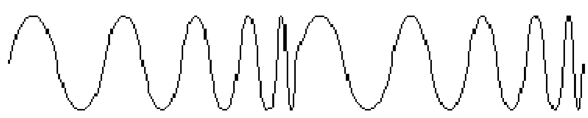

Figure 4. Modulated Signal

4.2 Power Divider

Power divider was used to make match impedance for all circuit components.

That produces maximum power transfer in RX, which makes circuit receive weak signal.

We didn't use power divider. We solved the problem of mismatch by using another amplifier before the antenna of the transmitter, then the signal amplified twice first time in VCO (The MC100EL1648 is a voltage controlled oscillator

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amplifier [16]) & second time in LNA before the transmitting antenna, that solves power loss in Rx.

4.3 Low Noise Amplifier (LNA)

→ We used LNA (MAX2640, From Maxim Semiconductors IC) that operate in the region (400 - 1500) MHz.

→ We used LNA in two places:

1- Before transmitting antenna (to amplify the TX signal to solve mismatch).

2- After RX antenna and before BPF to amplify the weak received signal and that give high response to BPF.

Table specifications of MAX2640 is shown below in table 2.

Table 2. MAX2640 Highlighted Specifications [3].

	Operating Frequency (MHz)	Noise Figure	Gain	Reverse Isolation
MAX2640	400 to 1500	.9 dB	15.1 dB	40 dB

MAX2640 circuit is shown below in figure 5.

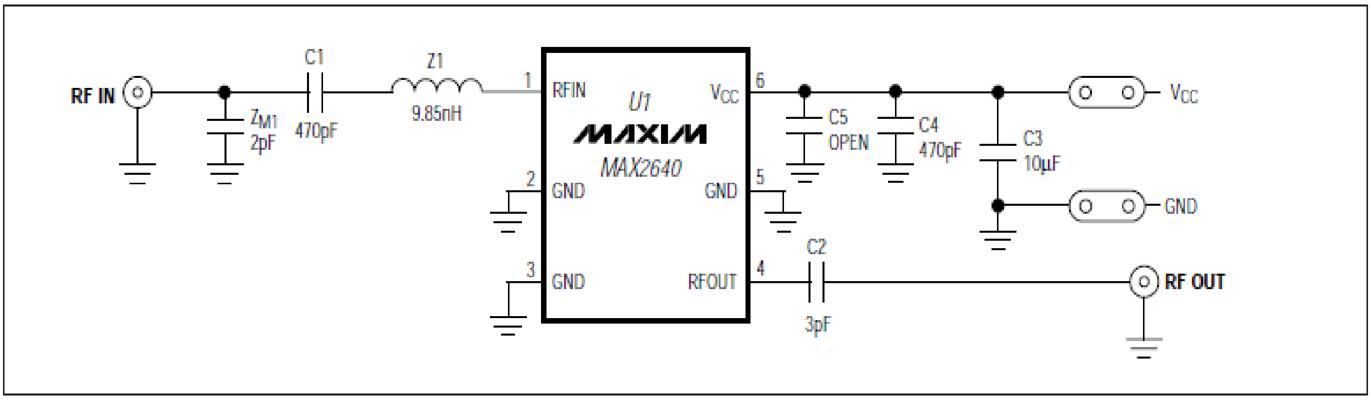

Figure 5. Circuit for Max2640 [5].

4.4 Band Pass Filter (BPF) :

Circuit design of the BPF is shown below in figure 6.

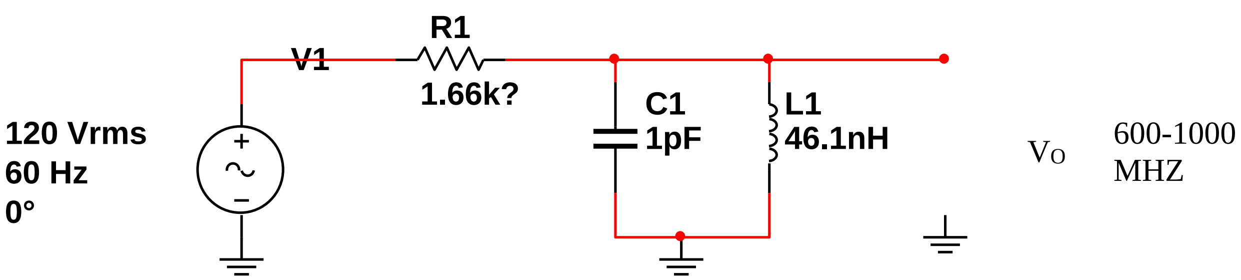

Figure 6. Circuit of BPF.

→ BPF operates in the region (500-1100) MHz. First we need to solve equations, then take values of (L,C,R), we assumed (C = 1pF)

$$f = \frac{1}{2\pi\sqrt{CL}} \qquad (1)$$

$$750M = \frac{1}{2\pi\sqrt{1p \times L}} --> L = 45nH \qquad (2)$$

$$Q = \omega o RC = \frac{\omega o}{BW} = \frac{2\pi \times 750M}{600M} = \frac{5}{2}\pi \qquad (3)$$

$$\frac{5}{2}\pi = 2\pi \times 750M \times R \times 1p --> R = 1.66k\Omega \qquad (4)$$

→ Practical there isn't value of L = 45nH, so we used L = 46nH.

Finally
R = 1.66 KΩ
C = 1 pF
L = 46.1 nH

4.5 Mixer:

→ We used down converter Mixer (MAX2682, From Maxim Semiconductors IC) , RF frequencies from 400MHz to 2.5GHz and IF frequencies from 10MHz to 500MHz.

Table 3 shows MAX2682 specifications.

Table 3. MAX2682 Highlighted Specifications [6].

	Input (MHz)	LO (MHz)	IF (MHz)	Noise Figure (at 900 MHz)
MAX2682	400 to 2500	400 to 2500	10 to 500	6.3 dB

Figure 7 demonstrates the circuit design for MAX2682.

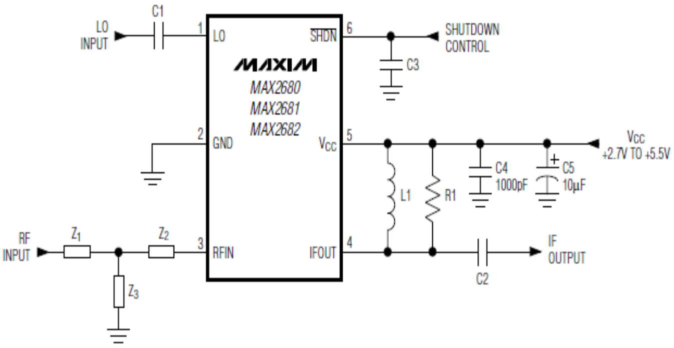

Figure7. Circuit for MAX2682 [6].

→ Capacitor C6, placed near the VCC connection, and capacitor C4, placed near the device, help to reduce any high-frequency crosstalk. Capacitor C3, placed near the SHDN pin on the device, helps to filter out any noise [6].

4.6 Antenna Design:

In order to design our system, it's necessary to select the suitable antenna for our applications. We need to work in a wide bandwidth from 600MHz to 1000MHz.The suitable antenna for our design is the bow – tie [3].

The length of the antenna is:

$$\text{Length} = \lambda/4 = \frac{3 \times 10^8}{4 \times 750 \times 10^6} = 0.1m = 10cm \qquad (5)$$

→ Length can be changed to get best impedance match using the Smith Chart.

→ Final Length = 128 mm.

Tem horn antenna design is shown below in figure 8.

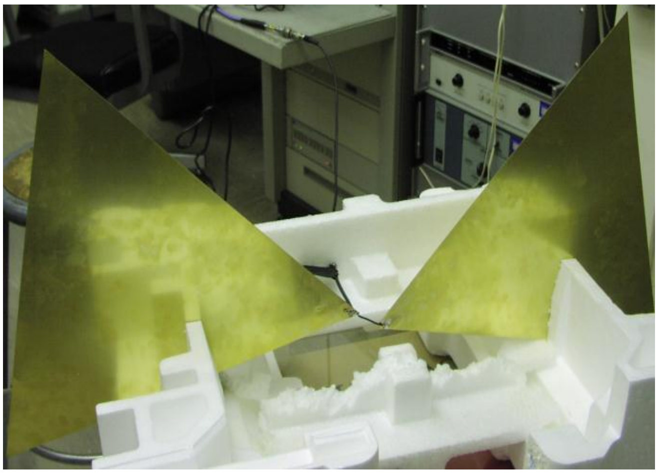

Figure 8. Tem horn antenna.

→We used one antenna for transmitting and another for receiving.

→ More control over directivity, but the size would be big as shown in figure 8.

4.7 A/D converter:

→ We used A/D (AD7992-1 all specifications apply for Frequency up to 3.4 MHz) as shown below in figure 9.

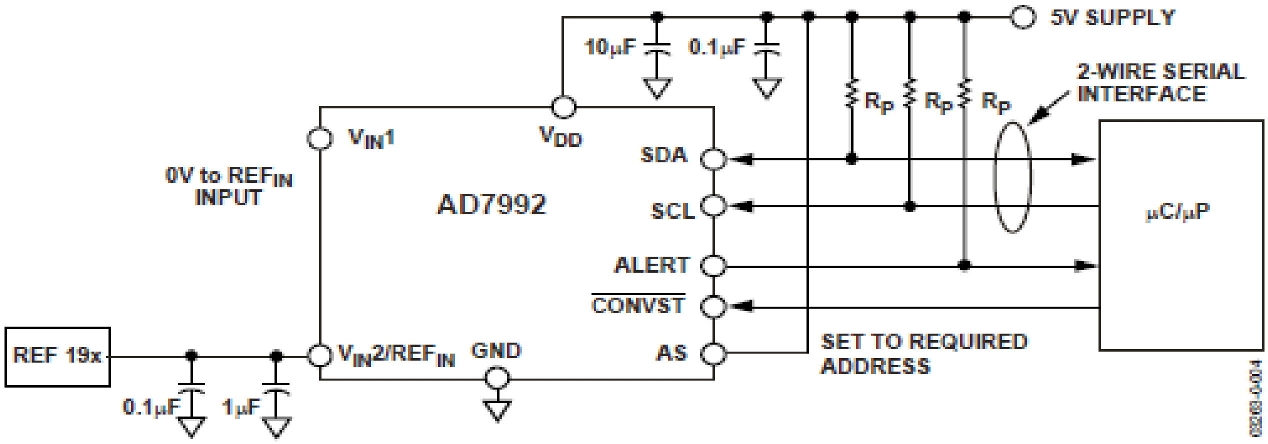

Figure 9. Connection of ADC 7992-1.

→ We used A/D converter before computer card to convert analog signal to digital in order to input it to computer.

→ We used A/D 12-bit to increase resolution output.

4.8 Computer Card:

→ We used PCMCIA card.

→ We took output of A/D as input to the card and Connect the PCMCIA cable (which is already inside the circuit) to the socket in the computer, power on the system, and the small light will turn red. Then start the software for measurement. See next section for detailed software operation.

4.9 Computer Software:

4.9.1 Interface description:

Figure 10 shows the interface of the GPR View software on the laptop computer for the measurement.

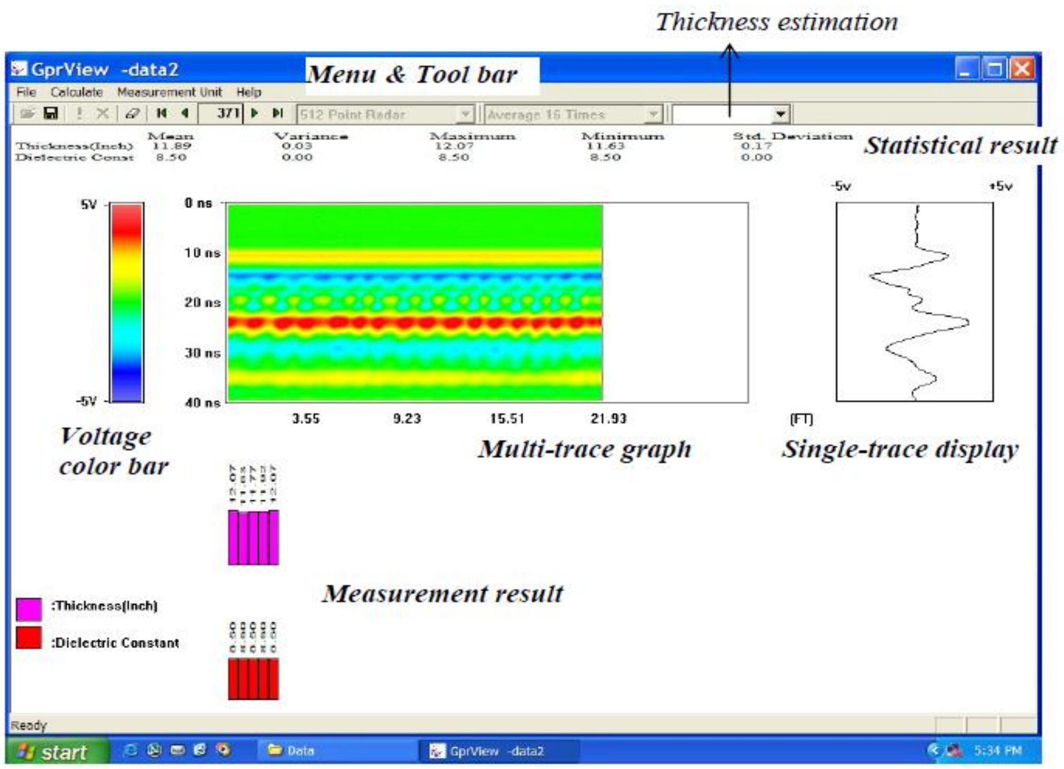

Figure 10. The interface for the GPR View software.

4.9.2 Statistical result:

→ Color bar: relationship between the color and signal value for the Multi-trace bar.

→ Multi-trace graph: a three-dimensional chart. The x-axis means moving distance. When you move the radar on the ground, the traces and their distances are displayed from left to right. The y-axis actually means the propagation time, the same meaning as y-axis in the single-trace chart. The color means value indicated in the color bar.

→ Single-trace display: also current trace chart (the trace index is shown on the current trace index display of the toolbar). The x-axis means signal value, the y-axis means propagation time. Measurement result: the thickness and dielectric constant information. Each bar provides the result of one measurement cycle, not of one trace, because the algorithm needs several traces (one measurement cycle) to locate the rebar location and cancel its effect. Since several traces cover at least one time distance between adjacent rebar's.

5. CONCLUSION:

The GPR method records microwave radiation that passes through the ground and is returned to the surface. A transmitter sends a microwave signal into the subsurface, and the radar waves propagate at velocities that are dependent upon the dielectric constant of the subsurface medium. Changes in the dielectric constant that are due to changes in the subsurface materials cause the radar waves to reflect, and the time it takes energy to return to the surface relates to the depth at which the energy was reflected. Thus, interpretation of this reflected energy yields information on structural variation of the near subsurface.

Detailed structural interpretation can be important for hydrological and geotechnical applications such as determining soil and bedrock characteristics in the shallow subsurface. In addition, high-resolution imaging is important for monitoring structural integrity of buildings, mine walls and roadways and bridges. Ground penetrating radar (GPR) is the only geophysical technique that can offer the horizontal and vertical resolution necessary for many of these applications. The GPR method can be used for reconnaissance (anomaly location) as well as for the more detailed studies.

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