

# SDR Based Wideband Frequency Transceiver for UWB Medical Imaging

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**Abstract**— **Abnormalities in the human body have a noticeable dielectric contrast when compared with normal biological tissue. If signals of a wide frequency range were to be transmitted to biological tissue, it would be possible to receive the reflected signals from the many layers of this tissue and determine the electrical properties (i.e. dielectric) of this tissue to detect and classify abnormalities. It is possible to create a software defined radio (SDR) based transceiver system to be used for imaging biological tissue. The proposed system consists of a computer controlling a SDR operating in the lower frequency bands (below 4GHz) and a transverter system which can up-convert and down-convert the signals to and from a higher frequency band (4-12GHz). Using the developed hardware, algorithms can be developed to utilize this wideband transceiver system for medical imaging.**

**Index Terms**—**Medical Imaging, Software Defined Radio, Transceiver Design**

## I. INTRODUCTION

RF transceivers are common devices which are used extensively in many industries. In particular, an ultra-wideband (UWB) transceiver/radio system can operate over a very large frequency range. It is possible to utilize this wide frequency range for medical imaging.

Ultra-wideband (UWB) medical imaging devices are used to detect abnormal biological tissue. In UWB medical imaging, a UWB radar sends electromagnetic pulses to the human body and upon analyzing the reflections from the body layers (skin and fat), the electrical properties and composition of the body structure can be characterized [1]. This technique can be used to detect tumors and other medical conditions as the electrical parameters of tissue affected by these conditions have a large contrast to regular/normal tissue[2]. In particular, the frequency range of interest is 4-12GHz which will allow for surface imaging.

Previous works (e.g. [3] [4] and [5]) utilize imaging systems consisting of commercial equipment in the forms of signal generators and vector network analyzers which can be large, expensive and have a limited frequency ranges. The proposed solution is to create an imaging system which consists of a SDR which is able to transmit and process signals at a low frequency range (below 4GHz) and a transverter board which is able to up-convert and down-convert signals to and from a range of frequencies between 4GHz to 12GHz. Achieving this

effectively extends the range of the SDR and by doing this, it is possible to eliminate the need for commercial equipment which could be a benefit because some SDR's have much lower costs (e.g. BladeRF SDR). It is also possible to use the developed transverter board to extend the frequency range of existing commercial devices.

## II. TRANSVERTER BOARD DESIGN

In order to design the developed system, the main design specifications were for the transverter system to have:

- A high dynamic tuning range
- Fast scanning speed
- Phase consistency between up and down conversion

The transverter system (see Fig 1&2) consists of a PCB which contains mixers, multiplier and a frequency synthesizer allowing it to interface with an SDR and up/down convert signals to and from the SDR. This system can also interface with circulators to create a radar system. The idea behind achieving the large dynamic tuning range lies within transmitting/receiving narrowband signals from an SDR and scanning by tuning the synthesizer on the transverter system which mixes with the signals to and from the SDR and up/down converts them to the suitable frequencies.

A single stage heterodyne mixing topology was used for up and down conversion. The particular synthesizer chosen for the system utilized one phase locked loop (PLL) for two outputs (the ADF4351). Because of this, it was possible to achieve a consistent phase between up conversion and down conversion making this system suitable for medical imaging.

Frequency triplers were utilized in the design in order to increase the synthesizer's scanning range. The ADF4351 is capable of creating signals of single frequencies configurable via SPI and its scanning speed is only limited by its software controller. The ADF4351's frequency range is 0.035GHz to 4.4GHz and when its signals tripled, it has allowed for the desired frequency range to be reached after mixing.

## III. RESULTS

By following the design proposed in Section II, an up-converted signal can be found by selecting either the sum or difference component after mixing (by filtering) to generate a 4GHz-12GHz signal. The device used to create an input signal was the Agilent EXG N5178. Fig 3 shows a power vs output frequency plot of the up-converter on the transverter board.

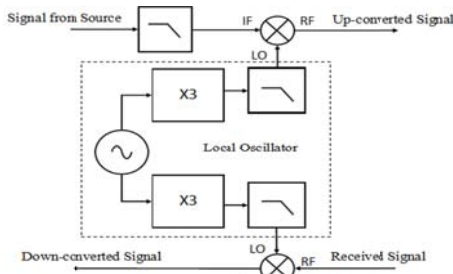


Fig 1 Block Diagram of System

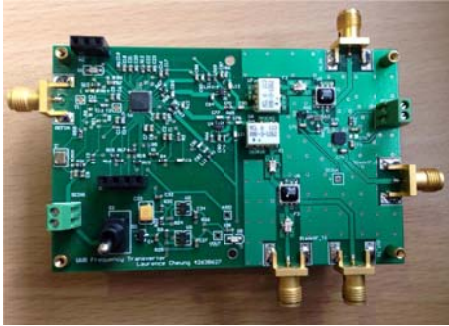


Fig 2 Completed Transverter Board

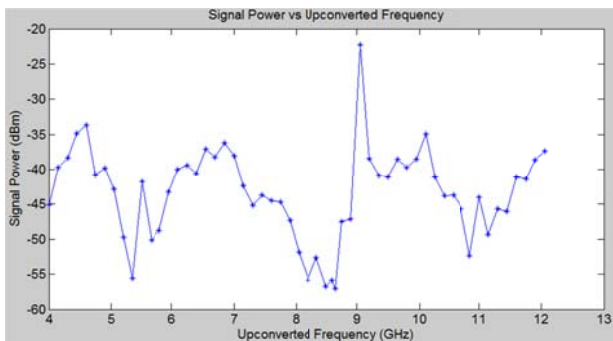


Fig 3 Power of upconverted signal vs signal frequency

From Fig 3, it can be seen that it is possible to scan and achieve the desired frequency range with the exception of a few frequencies where the amplitude spikes occur (e.g. at 5.5GHz and 9.05GHz). These peaks occur due to the overlap of the desired signal with strong signals which leak through the mixers or with the harmonics created by non-linear devices. When disregarding the frequencies where unwanted signals overlap, the power is relatively stable and is centered at around -45dBm. Furthermore, in these initial tests amplifiers before and after up-conversion were not used which could make the up-converted signal much stronger if required

To test the down conversion, a signal generator (Agilent EXG N5178) was used to produce a signal above 4GHz. By using a signal above 4GHz from a signal generator, it was possible to down convert this signal to 2.75GHz. A measure of the down-converted signal power vs input signal frequency is seen in Fig 4. This particular signal generator could only transmit up to 6GHz and hence the circuit could only be verified for 4-6GHz. However because the up- and down-conversion circuits are follow the same architecture, it is expected that down-conversion is also possible at higher frequencies. Issues with harmonics are also expected in the receiver.

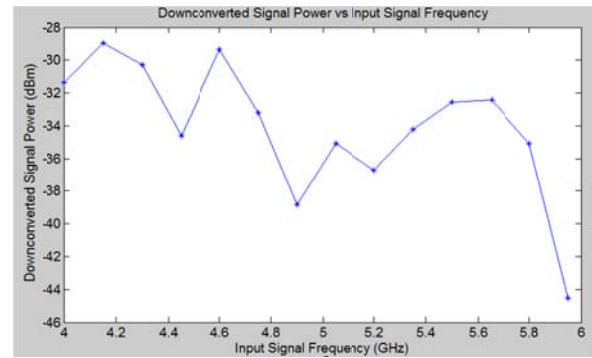


Fig 4 Power of received signal vs received signal frequency

#### IV. CONCLUSION AND FUTURE IMPROVEMENTS

The project's goals were to create a SDR based transceiver system which would be suitable for medical imaging. Although the designed system had its faults due to unwanted frequencies, it is possible to analyze the characteristics of the developed transceiver system and avoid problematic frequencies when scanning. In doing this, it is possible to see that a quick tuning transceiver with a very large tuning range was achieved. Furthermore, the transceiver was low in cost (compared to commercial equipment) and had phase consistency. The improvement of the developed system is currently ongoing with the aim to reduce unwanted frequency components and to utilize this system for imaging.

#### V. PERSONAL STATEMENT

I have recently graduated from the University of Queensland with a Bachelor's degree and I am currently working while continuing on with my thesis project with the intention to submit a paper to a conference or journal. My aim that I will complete my paper as preparation for higher level study which I am currently considering and seeking.

The MTT scholarship has had a large impact on my career plans as it exposed me to the academic community which has encouraged me to seek for a higher level of education. The major factor in this was the opportunity to attend IMS 2015. Attending IMS 2015 has allowed me to look into various research areas, industries and the current demands and trends of society. It was an amazing experience to listen to many of the presentations and to network at IMS 2015 and I will remember it fondly as I plan for the future.

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