A Miniaturized Clock Generator for a Time-Domain Microwave Breast Health Monitoring Device

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***Abstract*—This work presents the use of a compact and cost-effective clock generator to be incorporated in a time-domain microwave medical device. We demonstrate the ability of the Adafruit Si5351 development board as an alternative to the currently used table-top Tektronix gigaBERT 1400. We demonstrate the ability to produce low-noise clock signals from the development board that allows for the proper triggering of both the impulse generator and high-speed oscilloscope in our system. The choice of the Adafruit Si5351 as a replacement clock is validated by the analysis of the resulting pulse stability. The paper also compares the shape of the waveforms produced by the system to verify that they remain unchanged.**

I. Introduction

Biomedical applications of microwave systems has garnered much attention in recent years. Particularly for breast imaging, microwave based techniques offer a promising complementary to the screening methods currently used for detecting malignant tissue [1]. This combination of techniques will lead to better detection accuracy rates and earlier detection. Unlike x-ray mammography and magnetic resonance imaging (MRI), microwave imaging systems can be more comfortable to the patient and devoid of ionizing radiation which makes them a useful tool for frequent scanning.

Microwave based imaging can be performed in both the time-domain and the frequency-domain. Many research groups have focused on taking measurements in the frequency-domain, notably [2] and [3]. Alternatively, time-domain measurements offer the possibilities of lower hardware costs and faster scan times, which makes them suitable for rapid and frequent scans [4]. This improvement however comes at the cost of a lower signal-to-noise ratio [4]. The development of better signal measurement techniques and computer algorithms for diagnostics has led to the possibility of using time-domain based microwave imaging for frequent periodic scans of the breast. By making advancements in the capabilities of imaging systems, the hope is to detect potentially malignant tissue at its earliest onset for ease of treatment.

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II. Time-Domain Breast Imaging System

The current system requires the patient to lie in the prone position on top of a medical table. A bra containing a 16-element broadband antenna array is placed underneath the table in a hole that coincides with the patient's breast. The system is composed of a clock generator, pulse generator, a switching-matrix, a pulse-shaping circuit, and an oscilloscope. A complete description of the system without the antennas is provided in [5].

The aim of this project is to develop a system that can be used with ease by patients to perform frequent periodic scans. The system must thus be comfortable, compact and easy-to-use for the user. This requires that the aforementioned components of the system to be miniaturized and made affordable.

The clock generator that is currently driving the system is the Tektronix gigaBERT 1400. This is an expensive and table-top clock generator with a multitude of functions that are not utilized for this project. In this paper we investigate the use of the Adafruit Si5351 Clock Generator as a low-cost and small form replacement to the Tektronix gigaBERT 1400 clock generator. We quantify the equivalence of the two clock generators by comparing their horizontal time jitter and frequency spectrum.

A. *Adafruit Si5351 Clock Generator Breakout*

The Adafruit Si5351 Clock Generator provides three independent clocks that have a frequency range between approximately 8KHz and 150MHz with a reported high stability [6]. The component is based on the Silicon Labs Si5351 integrated circuit. This project utilizes a 25MHz clock to drive the system, thus it is within the operating region of the Adafruit Si5351 Clock Generator. The development board's small dimensions of 1.2 inches by 0.85 inches and an approximate cost of 10$ makes it a suitable replacement [6]. Figure 1 shows the Adafruit component; the image is reproduced from the specification sheet [6].

III. Results

Testing of the Adafruit Si5351 Clock Generator was performed for the system's operating frequency of 25MHz. Each test was performed using 240 clock signals coinciding with the

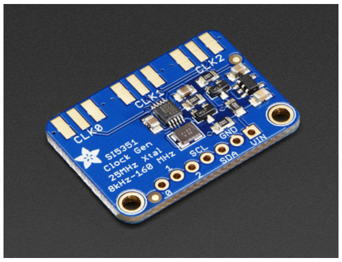

Fig. 1. A photograph of the Adafruit Si5351 Clock Generator Breakout component (reproduced from [6]).

240 antenna pairs in the bra. The aim of the test performed is to confirm that the Adafruit Si5351 Clock Generator is a suitable replacement for the Tektronix gigaBERT 1400.

For analysis of the clock's time jitter the 240 clock signals recorded with the Tektronix gigaBERT 1400 and the Adafruit Si5351 Clock Generator were compared using their average frequency across the multiple samples and their respective standard deviations. The standard deviation is used as a metric for comparing the horizontal uncertainty of the components.

TABLE I
COMPARISON OF THE FREQUENCY STABILITY OF THE TEKTRONIX GIGABERT 1400 AND THE ADAFRUIT SI5351 CLOCK GENERATOR

	Mean Frequency	Standard Deviation
gigaBERT	25.00743 MHz	0.013315 MHz
Adafruit	25.01134 MHz	0.015041 MHz

The Tektronix gigaBERT 1400 being a table-top device has 8.618μs less measured horizontal uncertainty than the Adafruit Si5351 Clock Generator. A comparison of a period produced with both clock generators is shown in Fig. 2.

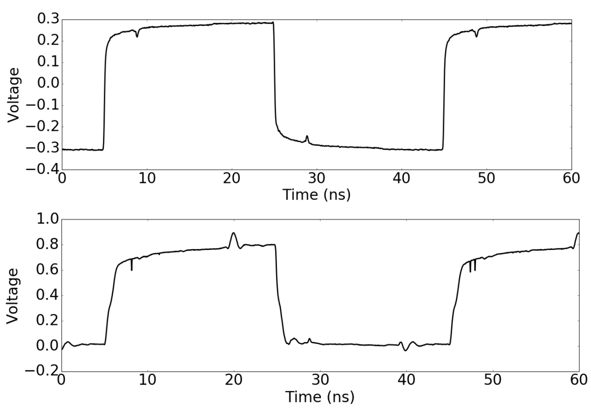

Fig. 2. The clock signals generated with the Tektronix gigaBERT 1400 (top) and the Adafruit Si5351 Clock Generator (bottom).

The system was tested using both the Tektronix gigaBERT 1400 and the Adafruit Si5351 Clock Generator. The system produces a pulse that is fed through the antenna array at every rising edge of the clock. As can be seen in Figure 3, the small difference in the measured horizontal uncertainty between the two clock generators did not affect the waveform or the desired frequency content as described in [7].

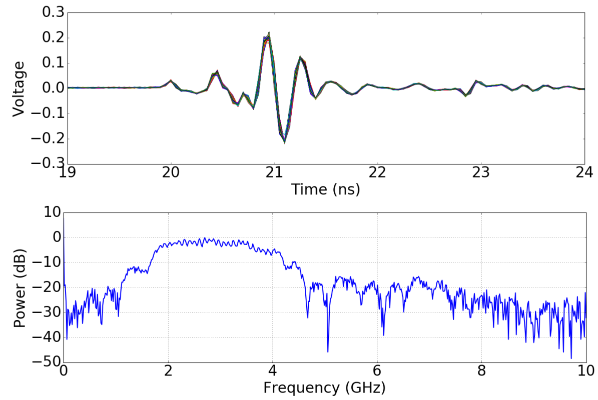

Fig. 3. The 240 overlaid pulses generated using the Adafruit Si5351 (top) and the frequency content of the pulses generated (bottom).

IV. CONCLUSION

It was determined that the system's response was unchanged when replacing the Tektronix gigaBERT 1400 with the much cheaper and smaller Adafruit Si5351 Clock Generator. This change does introduce 8.618μs more horizontal uncertainty in the system. This did not affect the waveforms that are fed into the antenna array on the bra. Moreover, this change brings the system closer to being able to be integrated in an easy to use product for breast cancer detection.

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