A FMCW Radar as Electronic Travel Aid for Visually Impaired Subjects

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Abstract

In this paper design and test of a frequency modulated continuous wave (FMCW) radar to be used as electronic travel aid for visually impaired subjects are presented. The sensor is based on the Infineon BGT24MTR11 integrated circuit. Transmitting and receiving serial arrays of patch antennas have been suitably designed and tested. An amplifying circuit, with a shaped gain, has been used to enhance and filter the received signal. The radar range accuracy has been experimentally investigated with different modulation signals and targets, finding a worst-case uncertainty lower than 6 cm for all the distances of interest.

Index Terms – Digital Signal Processing (DSP), ETA device, FMCW radar, patch antennas.

I. INTRODUCTION

The mobility in unknown environments is one of the major problems for visually impaired people [1]. Currently, there are some electronic travel aids (ETAs) for visually impaired people mobility [2]. They are based on ultrasonic or optical systems. However, such systems have a limited range and have difficulty to operate in the presence of very reflective surfaces and with a low incidence angle. Recently, the possibility of using electromagnetic radiation for the detection of obstacles has been explored [3], [4]. Ultra-wideband radars can be used for realizing ETA devices. These radars have high resolution but require bulky antennas [5]. On the contrary, frequency modulated continuous wave (FMCW) radars use compact planar antennas and have the further remarkable advantage of being realized in integrated technology resulting in a very compact device. Finally, thanks to its small dimension the FMCW radar can be easily integrated in the white cane that is largely used by visually impaired subjects. In this paper, the design of a portable device for the mobility of visually impaired people, using an FMCW Radar, is addressed and some characterization tests are performed.
II. RADAER SYSTEM OVERVIEW

A radar system based on the BGT24MTR11 integrated circuit (IC) by Infineon has been designed. For preliminary tests a NI PXI 6251 DAQ card controlled by a graphical user interface developed in the LabVIEW environment for ramp generation and signal acquisition has been used (see Fig. 1a). The BGT24MTR11 IC is based on a voltage controlled oscillator (VCO in Fig. 1a). The VCO is driven by a ramp or a triangular wave signal with a repetition rate (RR) of 100 Hz and 50 Hz respectively and generates a chirp from 24 to 24.25 GHz (B=250 MHz). The power delivered by the power amplifier (PA) to the radiating antenna is about 11 dBm. The receiving channel is constituted by a low noise amplifier (LNA) and an I&Q demodulator. The collected signal is then amplified and filtered (AMP) in order to remove the DC component and reduce the noise. The output of the amplifier is acquired by the DAC and processed on a PC by a Matlab algorithm to extract the frequency component associated with the distance.

III. ANTENNA DESIGN

A serial patch array has been chosen both for the transmitting and receiving antennas to obtain a system compact enough to be put on a cane for visually impaired subjects. Fig. 1b shows a scheme of the radar on the white cane together with the position of possible obstacles. To design the array the Microwave Studio software by CST has been used. In order to guarantee a field of view between one and five meters, with an azimuthal resolution of about 10°, a serial array of 8 patches was necessary. In particular, since the radar output is differential, a balanced antenna has been realized for the TX section (see Fig. 2a bottom). The receiving antenna (RX) uses the same array attached to a Wilkinson power combiner whose two outputs have a phase difference of 180° with each other (see Fig. 2a top). Figs. 2b and 2c show the measured reflection coefficient for the RX and TX antennas, respectively. The figure shows the good matching of the antenna in the 24 GHz ISM band.
IV. SIGNAL PROCESSING

Both the generation of the ramp and the acquisition of the IF signal have been performed at a sample rate of 10 kHz. For each ramp 100 samples are acquired, the first and the last 10 samples are deleted since they are close to modulation signal discontinuities and the remaining are zero padded up to 256 samples. Because of the non-perfect isolation between the transmitting and the receiving channel, the received signal is affected by crosstalk and a triangular offset is superimposed to the IF signal. To reduce this effect the signal is filtered with a moving average filter using a window of 3 samples. Finally, FFT is applied to the signal and the spectrum peak frequency is extracted and converted into distance.

V. RESULTS

In order to test the performance of the system, a metallic reflecting panel (90 x 90 cm) and a water-filled plastic tank (30 x 20 x 10 cm) have been positioned in front of the radar at different distances from the antenna. The system has been calibrated to eliminate the residual time delay due to cables connecting the antenna to the radar. Fig. 3a shows the FFT of the received signal without any processing (red curve), with the application of the zero padding (green curve) and with the further application of the moving average (blue curve). Only in this last case the 480 Hz peak due to the panel located at a distance of 2.9 m far from the antenna is well evidenced. The complete set of measured results is reported in Fig. 3b. It is possible to notice a good agreement between the measured distances and the real ones with both targets. This conclusion is better evidenced by the error defined as the absolute value of the difference between the measured distance and the real one. The error reaches in the worst cases 5.21 cm and 5.99 cm using the panel and the water tank, respectively.
VI. CONCLUSIONS

In this paper, a FMCW radar system has been investigated. Transmitting and receiving antennas have been designed and realized. An analog filtering circuit has been developed to amplify the signal and select the frequency components of interest. A Graphical User Interface and a signal processing software have been realized. The entire system has been tested using a metallic reflecting object and a water tank. Measured distances are in good agreement with the real ones, confirming the possibility of using the proposed radar as travel aid for visually impaired subjects. As future developments, the radar will be implemented on a single board controlled by a Digital Signal Processor (DSP) and installed on a white cane.

VII. REFERENCES


