

Exploiting the Harmonic Components

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1 Introduction

This package contains the code for reconstructing transient images and the data from a new prototype ToF camera. The prototype camera is not the one in the manuscript of 'Fourier Domain Transient Imaging', so their correlation functions are different.

In the 'code' path of the package,

1. The root contains the test code,
2. the 'calib' path contains the calibration data,
3. the 'data' path contains the raw data of a scene with mirrors, and
4. the 'functions' path containing our MATLAB code.

2 Calibration of the Camera

In the process of calibration we measure at frequencies from 1MHz to 180MHz in a step of 1MHz and 160 equally spaced phases from 0 to 4π . To reduce the measurement error, we take 8 measurements for each frequency. Thus the raw data is more than 17G bytes.

To visualize the raw calibration data, run '`show_calib_raw.m`' in the 'code' path to show the waveforms at a pixel (Fig.1). We can see that the waveforms at low frequencies are close to square waves which contain more harmonic components, whereas the waveforms at high frequencies are close to sine waves.

Then run '`show_calib_amp.m`' in the 'code' path to compare the fundamental component and the harmonic components at a pixel. The result in Fig. 2 shows that, although the amplitude of the fundamental component is dominant, the amplitude of the 3-order harmonic component is nontrivial at frequencies below 90MHz. Consequently, we can exploit the 3-order harmonic component to extend the frequency range of acquired data. Note that there is a flaw in the signal generator of the prototype camera such that the modulation frequencies around 95MHz is imperfect.

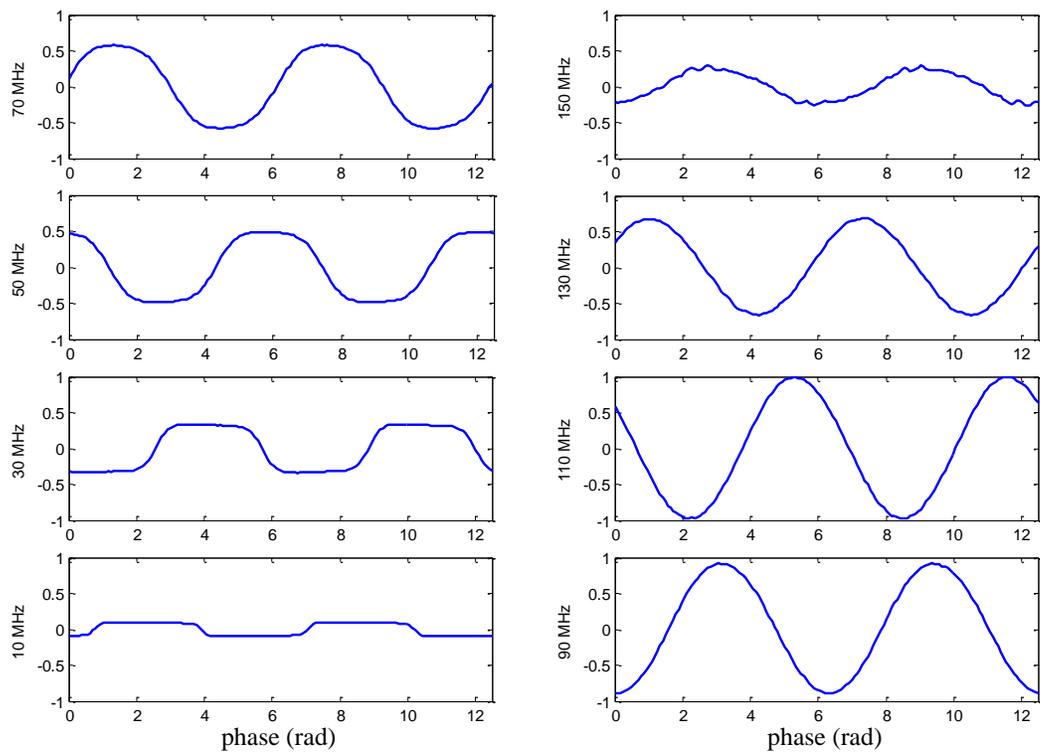


Fig. 1 Raw calibration data at (130,60). The waveforms at low frequencies contain more harmonic components, whereas the waveforms at high frequencies are close to sine waves.

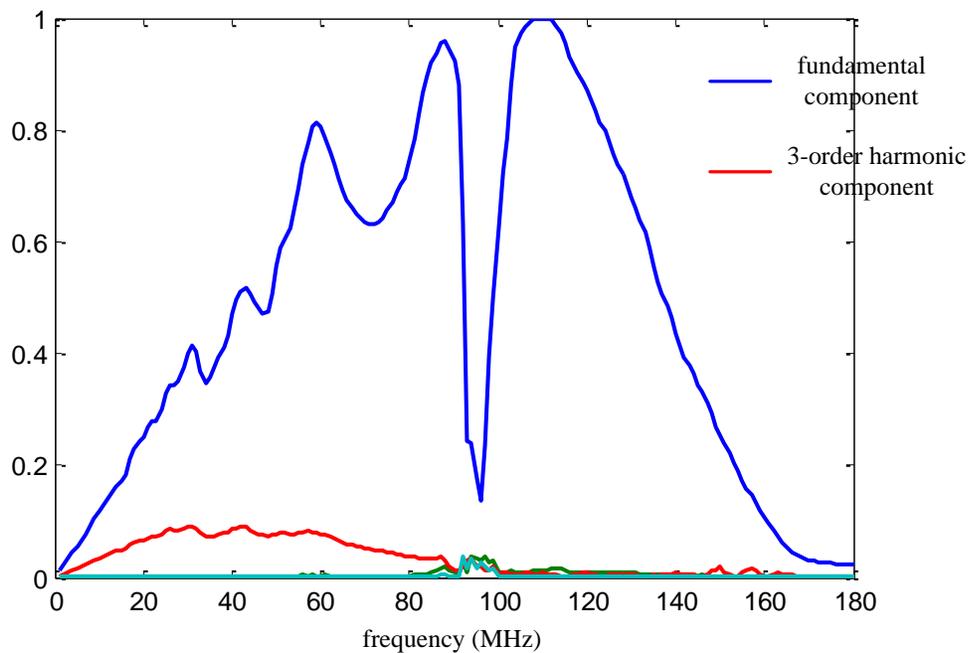


Fig. 2 Amplitude of each components at (130,60), the 3-order harmonic component is nontrivial at frequencies below 90MHz.

3 Reconstruction of a transient image

We set up a scene with two mirrors. Reflection of the light gives a second pulse in the transient image. One of the mirrors is attached with the letters of 'THU' and thus the letters will appear in the second pulse. The data is acquired at frequencies from 1MHz to 180MHz in a step of 1MHz and 10 equally spaced phases from 0 to 2π . The rectified data is composed of the fundamental component from 5MHz to 90MHz and the 3-order harmonic component from 20MHz to 85MHz. That is, the frequencies in [5, 90] MHz is from the fundamental component and [90, 255] MHz is from the 3-order harmonic component. The frequency range is then extended to $85*3=255$ MHz.

Run '`rec2_mirror.m`' in the 'code' path to reconstruct the transient image by exploiting the harmonic components. The images of the first pulse and the second pulse are shown in Fig. 3. Note that in a conventional image only the image of Fig. 3(a) is seen. Run '`rec1_mirror.m`' in the 'code' path to reconstruct the transient image without exploiting the harmonic components. Fig. 4 compares the time profiles of the transient images by the two methods. The former method is able to separate the two pulses.

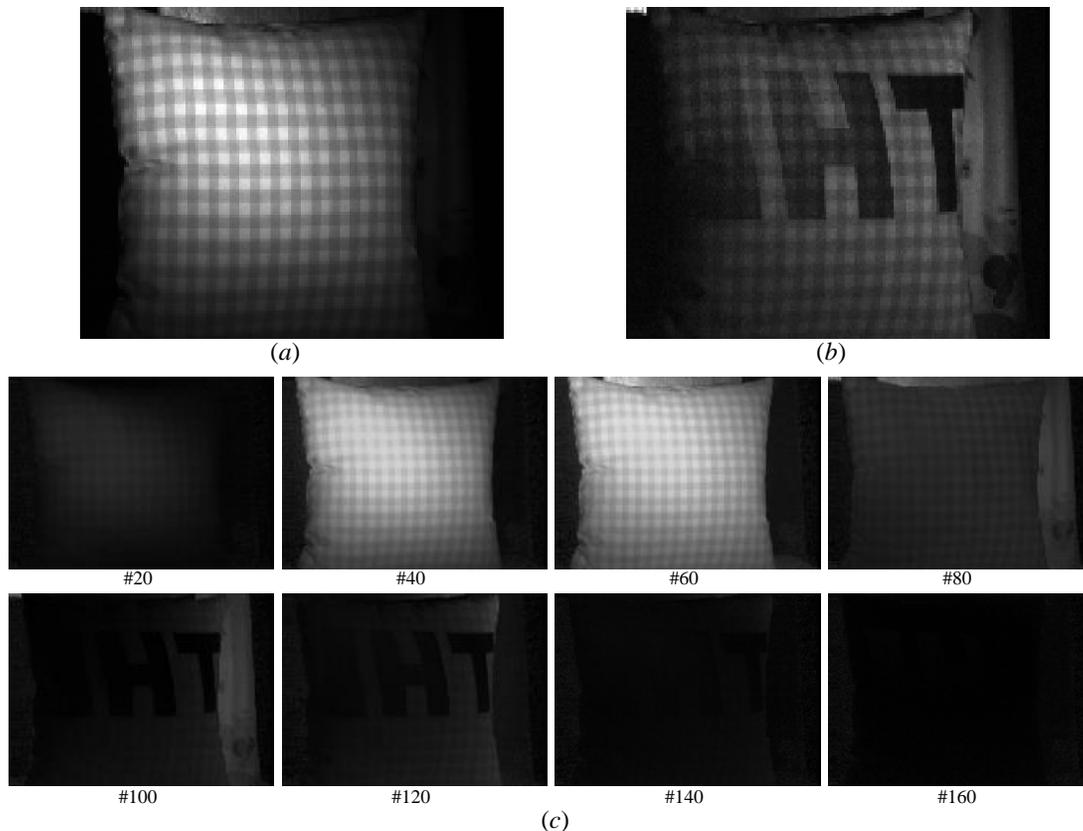


Fig. 3 The reconstructed transient image. (a) Image of the first pulse. (b) Image of the second pulse. (c) Image sequence of the transient image.

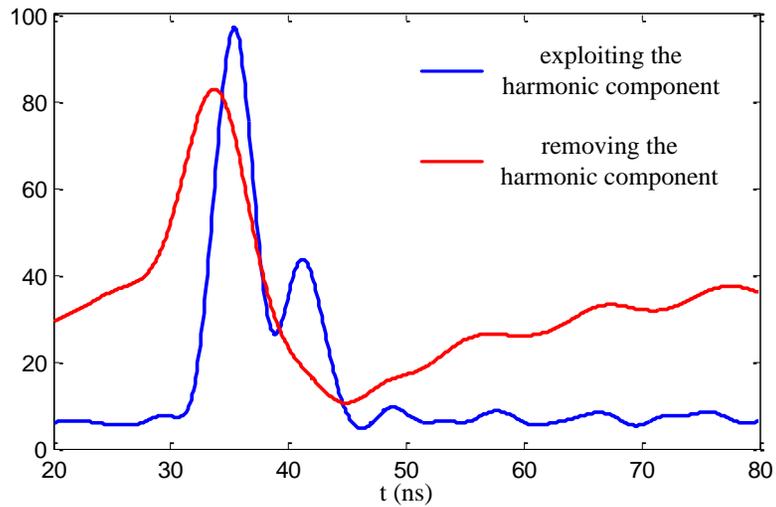


Fig. 4 Time profiles of the reconstructed transient image at (130,60). The two pulses can be separated by exploiting the harmonic component.

4 Conclusion

The square waves generated by the signal generator of a ToF camera get sinusoid as the modulation frequency increases. However, some of the harmonic components are nontrivial and thus they can be used to extend the modulation frequency. Consequently, the temporal resolution of a ToF camera can be increased by the order of the nontrivial harmonic component.