Extraction of an Overlapped Second Harmonic Chirp Component using the Fractional Fourier Transform

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***Abstract*—In ultrasound harmonic imaging with chirp coded excitation, the axial resolution can be improved by increasing the excitation signal bandwidth. However increasing the bandwidth will cause overlap between the received nonlinear second harmonic chirp component (SHCC) and the fundamental component. In the spectral overlap harmonic condition, signal decoding using the second harmonic matched filter (SHMF) typically produces higher range sidelobes level (RSLL) which reduce the contrast resolution. A multi-pulse excitation scheme such as pulse inversion can be used to extract the overlapped SHCC; however it is susceptible to motion artifacts and reduced system frame-rate. In this paper, fractional Fourier transform (FrFT) is proposed with chirp coded excitation for the extraction of the overlapped SHCC. The experimental results indicate at least a 13 dB improvement in the RSLL of the FrFT filtered compressed SHCC when compared with the unfiltered compressed SHCC.**

***Index Terms*—ultrasound imaging, superharmonic, linear frequency modulation, harmonic pulse compression.**

I. INTRODUCTION

[1]

II. EXPERIMENTAL INVESTIGATION

A. Excitation Signals

The LFM chirp signal, $x(t)$, can be expressed as [2],

$$x(t)=W(t)\cdot\left\{P\cdot\exp\left[j2\pi\left(\frac{B}{2T}t^2+(f_c-\frac{B}{2})t\right)\right]\right\},\ 0\leq t\leq T \tag{1}$$

where $W(t)$ is the windowing function, P is the peak excitation pressure, B is the bandwidth, T is the duration, and f_c is the centre frequency of the chirp signal.

In the experiments, chirp and tone-burst are used as an excitation signals. Chirp signals have a centre frequency of 2.25 MHz, duration of 10 μsec, and a -6 dB fractional bandwidths (FBW) of 20% and 40%. For comparison, a 2.25 MHz tone-burst signal of same duration is used as an excitation. The ripple artifacts in the signals' power spectra are reduced using a Hann window. The excitation signals and their power spectra are shown in Fig. 1.

B. Experimental Setup and Procedure

In order to validate the proposed method, experiments are performed to measure the harmonic components generated due to the nonlinear propagation of ultrasound waves through water. The experimental setup is shown in Fig. II-B. The experiments are performed in a tank containing deionised, degassed water. The transducer and hydrophone are mounted coaxially in a pitch-catch configuration. An axial scan is performed between the depths of 1-10 cm using a custom built motion control system. A programmable function generator (33250A Agilent, 80 MHz, Santa Clara, CA, USA) is set to generate excitation signals. The signals are amplified by an RF power amplifier (A150 E&I, 55 dB, Rochester, NY, USA). The amplified chirp signals are transmitted by a 56% fractional bandwidth 2.25 MHz single element immersion transducer (V323-SM, Panametrics, Waltham, MA, USA). The nonlinear signals are detected using a needle-type Polyvinylidene Fluoride (PVDF) hydrophone with an active element diameter of 0.2 mm (calibrated from 1 to 20 MHz, Precision Acoustics Ltd., Dorchester, UK). The pressure level of each waveform is calibrated and the mechanical index (MI) of 0.75 (peak negative pressure of 1.125 MPa at 2.25 MHz) is set at the focus of the transducer. The pulse repetition frequency of the excitation is 100 Hz. The received signals are acquired at 1 GHz sampling rate using a digital oscilloscope (44Xi LeCroy, 400 MHz, Chestnut Ridge, NY, USA) with 32-times averaging. The captured data is stored in a computer and processed offline using MATLAB software (The MathWorks Inc., Natick, MA, USA). All received signals are corrected using an inverse filter designed in Matlab according to the frequency response of the hydrophone.

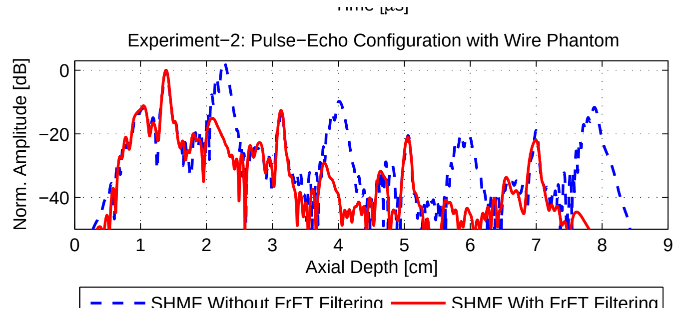

Fig. 1. Illustration of the power spectra of 20% FBW chirp, 40% FBW chirp and 2.25 MHz tone-burst excitation signals.

TABLE I
DESIGNED PARAMETERS OF HARMONIC MATCHED FILTERS

	Centre Frequency [MHz]	Chirp 20% Bandwidth [MHz]	Chirp 40% Bandwidth [MHz]
Fundamental	2.25	0.45	0.90
Second	4.50	0.90	1.80
Third	6.75	1.35	2.70
Fourth	9.00	1.80	3.60
Fifth	11.25	2.25	4.50

C. Design of Harmonic Matched Filters

III. EXPERIMENTAL RESULTS AND DISCUSSION

IV. CONCLUSION

The FrFT can be used as a filtering tool with a wide bandwidth chirp excitation in order to extract the overlapped SHCC without reducing the system frame-rate. Using the FrFT filtering, the RSLL in the compressed SHCC can be reduced which potentially improve the contrast resolution.

REFERENCES

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