An Optimized SAW Chirp -Z Transform for OFDM Systems

Takaya Watanabe
World Technology Instrument Co., Ltd. 533 Kamoshidacho, Aoba-Ku, Yokohama, 227-0033 Japan

Abstract The OFDM system that can use it combined to the Fourier transform to the OFDM signal for amount of wave of the inverse Fourier transform and received OFDM can have a definite advantage in power consumption, a super-high-speed operation processing performance be possessed, and the SAW Chirp-Z transform be applied to high-speed wireless LAN and WAN. As for the SAW Chirp-Z transform, operation speed 5.5GFLOPS is feasible in OFDM for 5GHz band high-speed wireless LAN. However, the following points exist as a problem to the OFDM system that consists of the SAW Chirp-Z transform.

1. In the SAW element, is not the temperature delay characteristic a problem?
2. There might be a limit in the adjustment of the chirp rate by the accuracy of the pattern of the SAW element.

This paper presents the solution of these various problems, and has achieved optimization SAW Chirp- Z transform for the OFDM system.

Keyword SAW Chirp-Z Transform, OFDM, Fourier Transform, High-speed Wireless LAN, Power Saving, Chirp Rate, Temperature Delay Characteristic

1. Introduction

The SAW Chirp-Z transform has the following points as a problem to the OFDM/OFDAMA system as the transformer multiplexer that can be used combinedly to Fourier transform (FFT) to the OFDM signal for amount of wave of reverse Fourier transform (IFFT) and received OFDM.[1]

1. In SAW Chirp Filter that composes the Chirp-Z transform, isn't the temperature property a problem?
2. There might be a limit in the correspondence of chirp rate by the accuracy of the pattern of SAW Chirp Filter.

In this paper, the solution of these various problems is presented, and optimization SAW Chirp- Z transform for the OFDM system is examined.

2. Problem of SAW Chirp-Z transform

2.1 Temperature characteristic of delay time of SAW Chirp Filter

The maximum problem is a temperature characteristic of the delay time of SAW Chirp Filter that achieves SAW Chirp-Z transform.

As for the piezoelectric substrate used for the SAW Chirp-Z transform, because the electromechanical coupling factor is small, only crystal is only unsuitable for SAW Chirp Filter though is zero the temperature coefficient of the delay time of the material.

As for SAW Chirp Filter that composes the SAW Chirp-Z transform, because 40 or more is demanded as for the BT product, $LiNbO_3$ or $Bi_{12}GeO_{20}$ is chiefly used.

The electrode separation that composes SAW Dispersive Delay Line comes to be arranged at inequitable intervals. In this case, the temperature property can derive rule from the temperature coefficient of the material chiefly by the frequency decentralization characteristic according to an easy analytical result. The temperature characteristic of the delay time of RAC type SAW Chirp Filter is considered here.

The temperature property of RAC type SAW Chirp filter is examined.

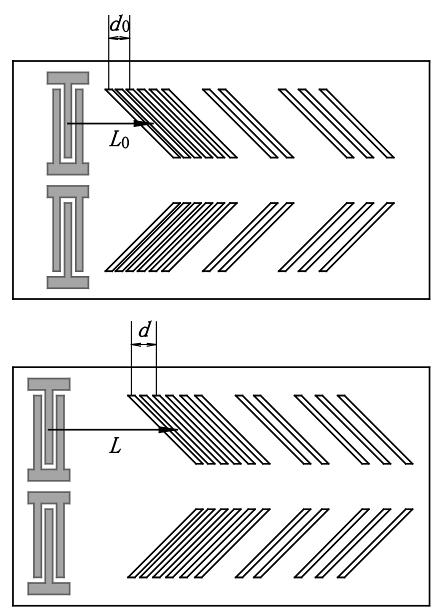

Figure 1. Structure of RAC type SAW Down Chirp Filter

The temperature is indicated T_0 and the frequency f_0 and delay time of τ_0 are indicated as follows.

$$f_0 = \frac{v_0}{d_0} \tag{1}$$

$$\tau_0 = \frac{L_0}{v_0} \tag{2}$$

Here, d_0 and L_0 are the electrode finger cycles and the spread distances.

In general, the frequency f at an arbitrary temperature is shown by the next expression, considering the temperature coefficients up to the third.

$$f = \frac{v}{d} = f_0\left\{1 - \sum_{n-1}^{3}(Tl^{(n)} - Tv^{(n)})\Delta T^n\right\} = f_0\left\{1 - \sum_{n-1}^{3} TC^{(n)}\Delta T^n\right\} \tag{3}$$

However, it is $TC^{(n)} = Tl^{(n)} - Tv^{(n)}$. Here, $Tl^{(n)}$ and $Tv^{(n)}$ n are the following linear coefficient of expansions, and coefficients of the SAW speed temperature. Similarly, delay time τ at an arbitrary temperature is shown as follows.

$$\tau = \frac{L}{v} = \tau_0\left\{1 + \sum_{n-1}^{3}(Tl^{(n)} - Tv^{(n)})\Delta T^n\right\} = \tau_0\left\{1 - \sum_{n-1}^{3} TC^{(n)}\Delta T^n\right\} \tag{4}$$

The frequency decentralization characteristic of the decentralized delay line is put as follows at reference temperature T_0.

$$\tau_0 = G(f_0)$$

The distributed property at the arbitrary temperature is as follows from expression (3) and (4).

$$\tau \cdot (1 - \sum_{n-1}^{3} TC^{(n)}\Delta T^n) = G(f(1 + \sum_{n-1}^{3} TC^{(n)}\Delta T^n))$$

$$\tau \approx (1 + \sum_{n-1}^{3} TC^{(n)}\Delta T^n) G(f(1 + \sum_{n-1}^{3} TC^{(n)}\Delta T^n))$$

$$\approx (1 + \sum_{n-1}^{3} TC^{(n)}\Delta T^n)\left[G(f) + fG'(f)\sum_{n=1}^{3} TC^{(n)}\Delta T^n\right]$$

therefore,

$$\tau \approx G(f) + \left[G(f) + fG'(f)\right]\sum_{n=1}^{3} TC^{(n)}\Delta T^n \tag{5}$$

It is shown like this. Therefore, the temperature coefficient of delay time in the reference temperature T_0 can be requested as follows.

However, it is $C_T = TC^{(1)} = Tl^{(1)} - Tv^{(1)}$.

$$\frac{1}{\tau}\frac{\partial \tau}{\partial T} = \frac{G(f) + fG'(f)}{G(f)} C_T \tag{6}$$

In addition, it obtains from expression (3) as follows.

$$\frac{1}{f}\frac{\partial f}{\partial T} = -C_T \tag{7}$$

Temperature coefficient C_T and distributed property $G(f)$ of the substrate take part in the temperature coefficient of delay time. As for the distributed property of linear down chirp filter, delay time decreases monotonously as the frequency increases. The case where the $T_0 + \Delta T$ temperature changes from Figure 2 into reference temperature T_0 like clearness is shown in the short dashed line.

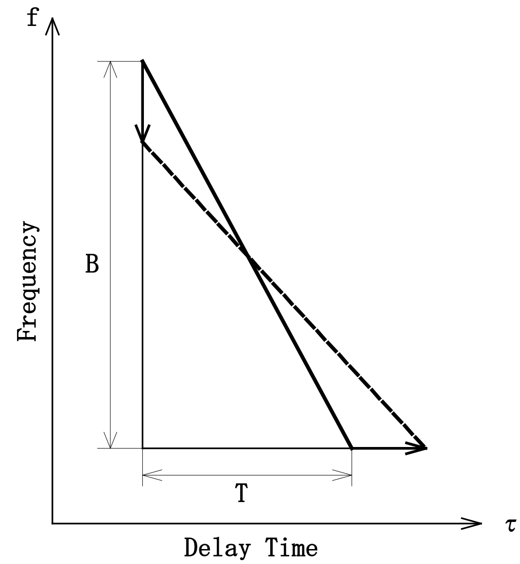

Figure 2. F-τ temperature property of SAW Down Chirp Filter

It approximates by the linear expression in reference temperature T_0 at delay time τ_0.

$$\tau_0 = af_0 + b \tag{8}$$

The delay time τ is shown from the expression (5) by the next expression at arbitrary temperature T.

$$\tau = af + b + (2af + b)\sum_{n=1}^{3} TC^{(n)}\Delta T^n \tag{9}$$

In addition, the temperature coefficient of the frequency is shown by expression (6) and (7) at delay time.

$$\frac{1}{\tau}\frac{\partial \tau}{\partial T} = \frac{2af + b}{af + b} C_T \tag{10}$$

$$\frac{1}{f}\frac{\partial f}{\partial T} = -C_T \tag{11}$$

When expression (10) is transformed, it becomes (12).

$$\frac{1}{\tau}\frac{\partial \tau}{\partial T} = \frac{2f/f_0 - 1}{f/f_0 - 1} C_T \tag{12}$$

Figure 3 is a relation of the expression (12). The molecule is in f, and the temperature coefficient of almost zero and zero, in a word, delay time is and there are zero and a frequency that vanishes almost. By the way, the electrode is usually used as for the temperature coefficient of the metal film that composes the substrate and the reflecting grating. As for the speed of the surface wave of $Bi_{12}GeO_{20}$, the length of the substrate of SAW Chirp Filter becomes below the half of $LiNbO_3$, and becomes upper big advantage to design the device below the half of $LiNbO_3$. The temperature characteristic of the delay time of this $Bi_{12}GeO_{20}$ substrate is a monotone increasing. The temperature characteristic of the electrode delay time is a monotone decreasing on the other hand, and the temperature inclination at delay time is brought close by the film thickness and the value the electrode is used for the reflecting grating by finishing changeability can be unlimitedly brought close to zero.

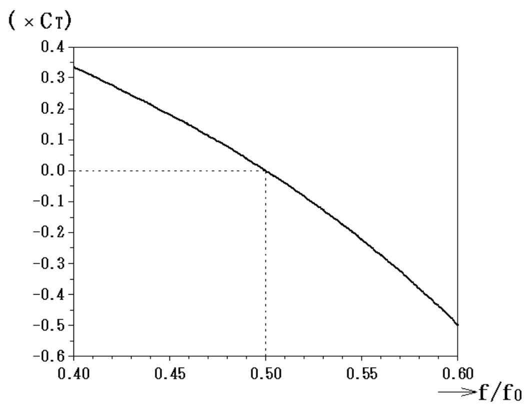

Figure 3. Temperature property of SAW Chirp-Z transform

2.2 Accuracy of chirp rate of SAW Chirp Filter

SAW Chirp Filter system of Figure 4 solves this problem for the problem of the adjustment of the chirp rate by the accuracy of the pattern of SAW Chirp Filter that composes the SAW Chirp-Z transform. Photo-mask in the alternate finger electrode (Inter-digital Transducer Electrode) part where a transversal electrode is composed is designed by LSI rule. The frequency response obtained from the IDT electrode pattern formed with the photolithography technology includes the material difference of the piezoelectric substrate and the processing accuracy of submicron of IDT. It can be adjusted to desired chirp rate by producing it with photo-mask that corrects the obtained characteristic first time again. The SAW characteristic is decided single meaning by the size accuracy of IDT. In this, the surface acoustic wave is analog wave motion, and as for the SAW element produced by using the same manufacturing process, reproducibility is good, and the performance is guaranteed. Figure is showing of the relation between the wafer material and the Electron Beam(EB) drawing as for the design design of SAW Chirp Filter. It is necessary to put the frequency accuracy that can be achieved by the size accuracy of the SAW device in center frequency 100MHz within 100ppm though reproducibility becomes important though the computation simulation is one important tool for the SAW system design. 10ppm accuracy of the 1/10 is at least demanded. Because the transmitting velocity of SAW is 4,000m/s for $LiNbO_3$, the width of the electrode finger of the IDT electrode becomes the 1/4 1μm from wavelength λ=4μm. Therefore, 0.1μm will be demanded as for the electrode finger accuracy. It is because the demand of such high accuracy can be verified by the measuring method in which frequency.

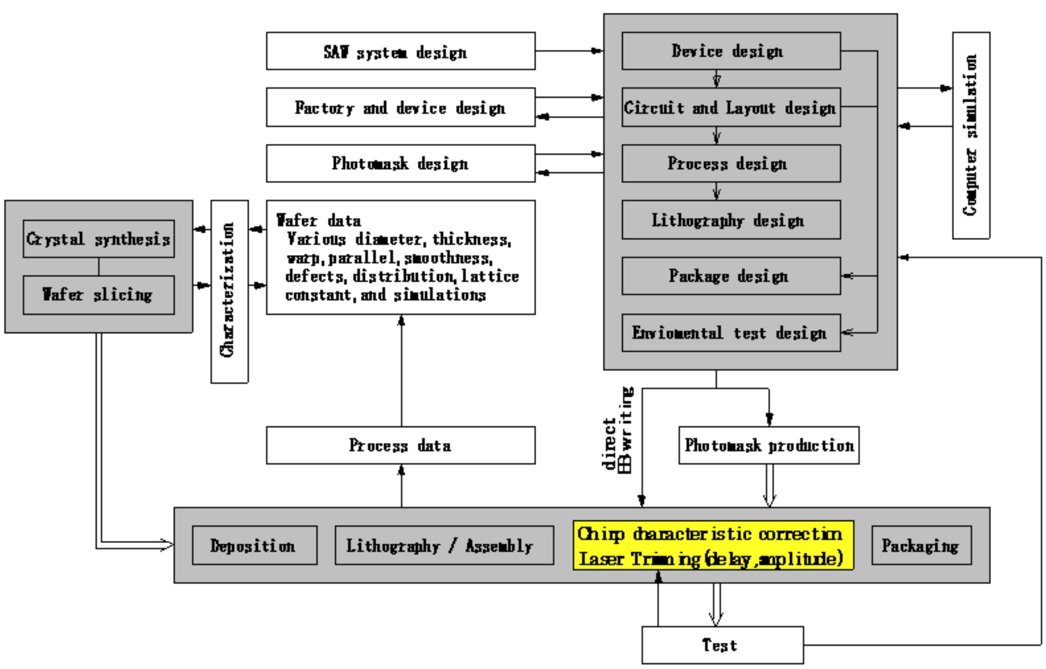

Figure 4. SAW Chirp Filter System

3. Improvement of RAC type SAW Chirp Filter overshot

As for SAW Chirp Filter for the SAW Chirp-Z conversion that can be applied to the OFDM system, the BT product becomes 1000 or more. SAW Down Chirp Filter like figure becomes several thousand the number of metallic reflection lattices, happens on the band edge the overshoot phenomenon, and causes the characteristic degradation. The amount of the correction of an initial frequency response exceeds the limit according to the mask design of Figure 1 and it is not possible to do. The proposal, and the BT product is used and only the one of about 40 can use this technique though well, it is the use of the structure named Slanted RAC that diagonally arranges the direction where SAW is propagated the use as the structure like the electrode finger in inclination type Chirp IDT to avoid this of the reflector. It has been understood to oppress the over shot phenomenon in confirming the position with flash SEM on the substrate and irradiating the YAG laser to the focus of the SAW wave surface. Procedure of characteristic improvement of SAW Chirp Filter

1. SAW Chirp Filter of the mask first time is made for trial purposes.
2. The overshoot part on a piezoelectric substrate is irradiated by the YAG laser in the YAG laser, and it matches and is YAG laser and is frequency response data accumulation.
3. Electrode film removal of piezoelectric substrate
4. Correction mask making.
5. The thin film is formed on a piezoelectric substrate, and it is a photolithography and a pattern formation according to the marker for the photo-mask.

It did not separately reach the former in the method of simulation the overshoot characteristic after the pattern was formed and making the correction mask with this method in the strict sense of the word.

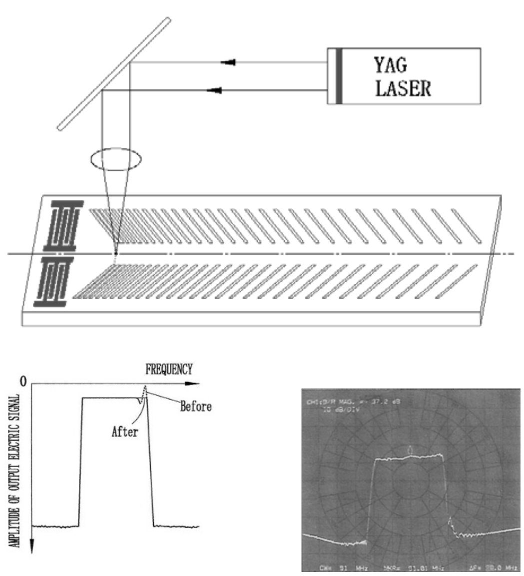

Figure 5. Improvement of SAW Chirp Filter by YAG Laser

4. Application of SAW Chirp-Z transform to OFDM

The OFDM signal transmits the high-speed data separately for FDM (Frequency Division Multiplex and frequency division multiplex) channel of a low-speed modulation of N bases separately for a lot of (assume it) parallel signals. The source signal is reproduced by recovering one's each FDM channels and converting it into the serial signal on the receiving part. The influence of the delay decentralization caused by dividing the transmission line into a lot of narrowband channels on the multiple propagation path can be decreased. In general, the digital signal processing done by FFT is used by reverse-fast Fourier transform (IFFT) on the receiving side as for division into the FDM channel at the transmitting end. In one difficult point of the digital signal processing, the amount of the operation is a huge thing. Generator 1 and Generator 2 are composed, and in the circuit of Figure 6, the Up Chirp signal is generated with VCO, and the circuit of the sending and receiving circuit using together can be composed of the SAW Chirp-Z transform with one SAW Chirp filter. If the I/O relation is reversed, IFFT is obtained. That is, the TDM pulse row is input and FDM multiple signal is output. SAW Chirp Filter used for the inversion uses the one used for positive conversion and the one of the same characteristic. Same SAW Chirp Filter can be used when communicating by the TDD (Time Division De-multiplex) method. In IFFT/FFT, the unnecessary alias signal removal filter caused at the digital-to-analog conversion is needed. However, the surface acoustic wave is unnecessary the processing because of an analog Fourier transform.

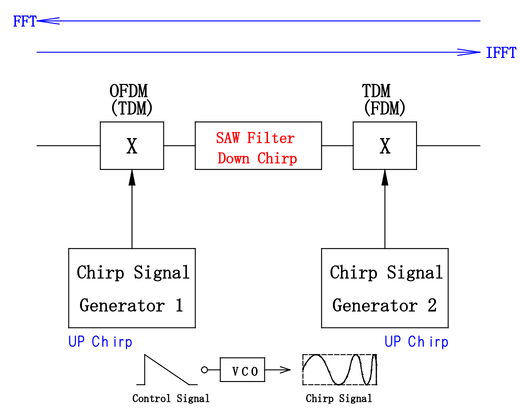

Figure 6. OMDM Transmitter (Receiver) Circuit

5. Summary

The solution of the critical point of the correspondence of the temperature property and Chirp rate when the SAW Chirp-Z transform is applied to the OFDM system is presented. It had a definite advantage in transform into the OFDM signal and the Fourier transform for amount of wave in power consumption and SAW Chirp-Z transform OFDM system that have a super-high-speed operation processing performance is examined. It has been understood to be able to show the condition that the temperature coefficient of the delay time of SAW Down Chirp Filter becomes zero.

Reference

[1]. Takaya Watanabe," An Optimized SAW Chirp-Z Transform for OFDM Systems," , IEICE Technical Report, pp.31-38, WBS2008-51(2008-12) (in Japanese)