PULSE COMPRESSION WEATHER RADAR WITH IMPROVED SENSITIVITY, RANGE RESOLUTION, AND RANGE SIDELOBE

TOSHIBA Leading Innovation

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INTRODUCTION

In recent years, a solid-state weather radar (SSWR) has become mainstream.
The many advantages of SSWRs compared with klystron or magnetron radar include high-accuracy, small size, easy maintenance, low lifecycle cost and low spurious emission.
Pulse compression is a key technology for SSWR from the viewpoint of securing the desired transmission energy, range resolution, and range sidelobe level.
For a basic performance enhancement of SSWR, we consider application of non-linear frequency modulation (NLFM) in pulse compression, replacing the conventional linear frequency modulation (LFM).
Our work on the developed NLFM is described below.

PULSE COMPRESSION TECHNIQUE

Comparison of the Main Characteristics between LFM and NLFM

- LFM : A range sidelobe can be suppressed to a low level by applying a lossy window function. However, SNR is sacrificed for the loss of a window function
- NLFM: SNR can be improved, because a lossy window function is not required. However, it is more difficult to suppress a range sidelobe compared with LFM.

⇒ Suppression of a range sidelobe is an important issue to be resolved in NLFM.

Pulse compression output in the ideal loopback condition

LFM: $y(t) = \int_{-\infty}^{\infty} x(\tau) \cdot r^* (\tau - t) d\tau$, NLFM: $y(t) = \int_{-\infty}^{\infty} x(\tau) \cdot x^* (\tau - t) d\tau$

(Modulated signal: $x(t) = a(t) \cdot e^{j\phi(t)}$, Reference signal: $r(t) = w(t) \cdot e^{j\phi(t)}$)

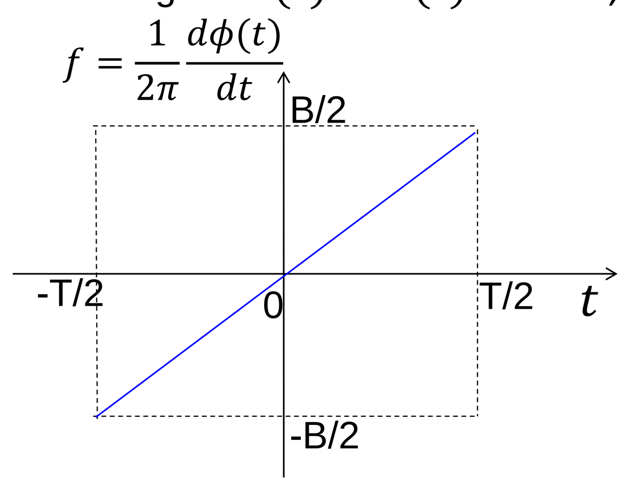

Figure 1. Linear Frequency Modulation

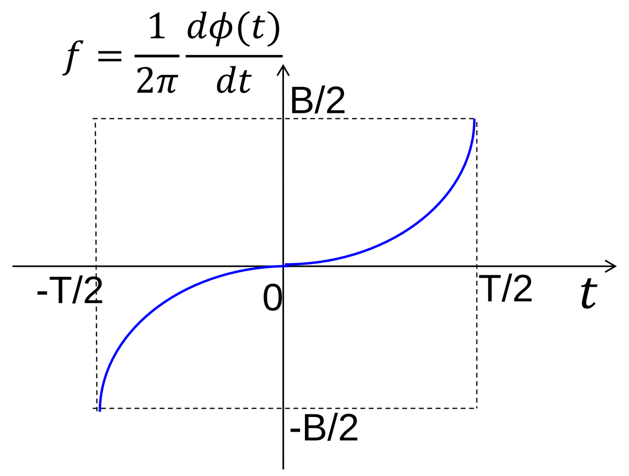

Figure 2. Non-Linear Frequency Modulation

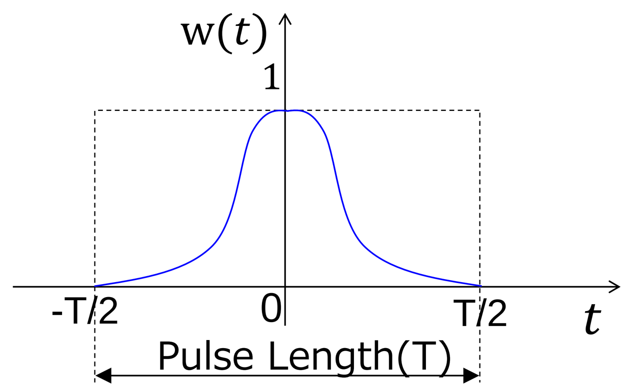

Figure 3. Window Function ($w(t)$)

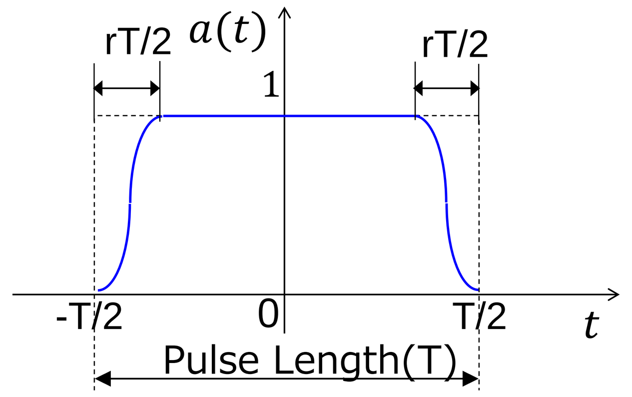

Figure 4. Amplitude Taper ($a(t)$)

RESULTS OF LOOPBACK TEST

Our Approaches for Suppression of Range Sidelobe in NLFM

- High-precision corrections for the distortion properties in the transmitter.
- Optimization of signal waveform by use of genetic algorithm.
- Application of our unique amplitude taper model.
- Including the characteristic of a digital filter in the optimization cycle.

⇒ We suppressed a range sidelobe in NLFM to a lower level than that in current LFM, not only in the ideal simulation, but also in the real implementation.

Table 1. Waveform Parameters

Parameter	LFM (current)	NLFM (developed)
Frequency Bandwidth (B)	1.63 MHz	←
Chirp Type	Down Chirp	←
Pulse Length (T)	36μs, 72μs, 108μs	←
Amplitude Taper ($a(t)$)	Tukey Window (r=0.16)	Unique Waveform (r=0.16)
Window Function ($w(t)$)	Blackman-Harris Window	Same as Amplitude Taper
Digital Filter	Included (Bandwidth =1.4MHz)	←
Sampling Frequency	2MHz(Ref)、 80MHz(Drive)	←
Center Frequency	0MHz(Ref)、 20MHz(Drive)	←

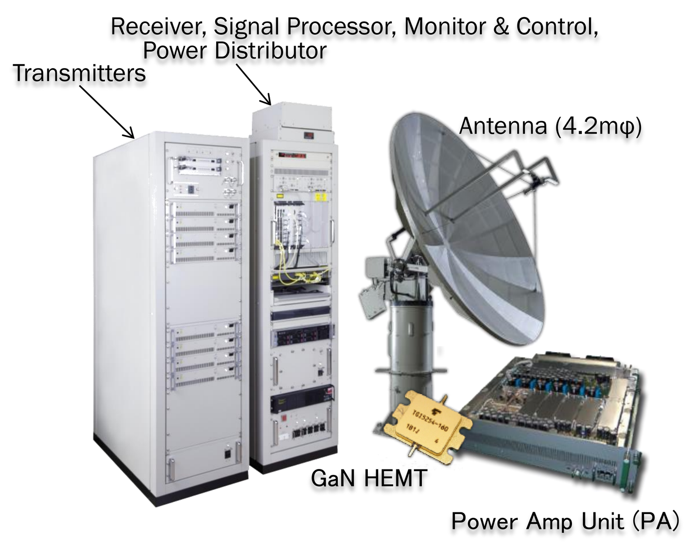

Figure 5. C-Band SSWR System

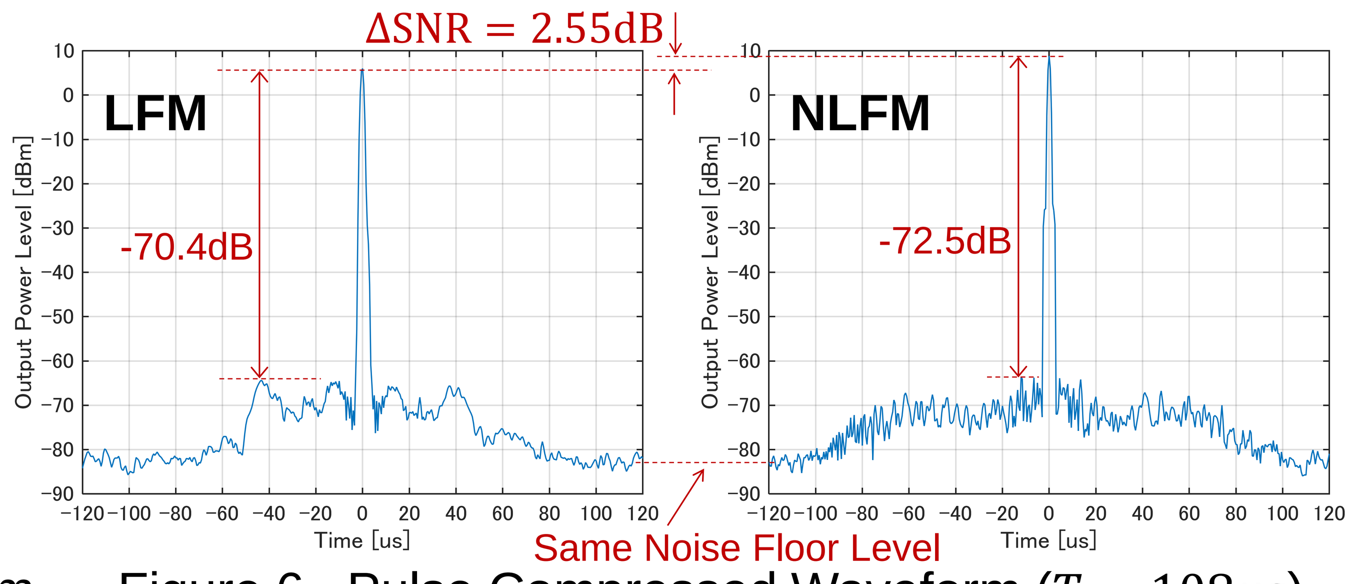

Figure 6. Pulse Compressed Waveform ($T = 108\mu s$)

Table 2. Summary of Loopback Test Results

	LFM $T = 36\mu s$	NLFM $T = 36\mu s$	LFM $T = 72\mu s$	NLFM $T = 72\mu s$	LFM $T = 108\mu s$	NLFM $T = 108\mu s$
Peak Range Sidelobe Level (dB)	-43.5	-56.3	-61.1	-65.7	-70.4	-72.5
Range Resolution 3dB (m)	180	148	179	145	178	149
Mainlobe Width (m)	1,050	1,050	1,200	1,200	1,200	900
Peak Power Level (dBm)	+1.73 (=P_1)	P_1 + 2.52	+4.62 (=P_2)	P_2 + 2.52	+6.29 (=P_3)	P_3 + 2.55

RESULTS OF WEATHER OBSERVATION

Comparison of Weather Observation Results

- Weather observation results of LFM and NLFM are compared in terms of an area integral calculus level of the reception strength.
- More than 2.5 dB improvement of SNR is confirmed in developed NLFM compared with current LFM using the Blackman-Harris window function.

⇒ We confirmed SNR improvement not only for the point target but also for the distributed weather target.

Figure 7. C-Band SSWR Installed at MRI Facility

2016-8-23 18:04 EL=0.5 deg. MRI, Tsukuba, Japan

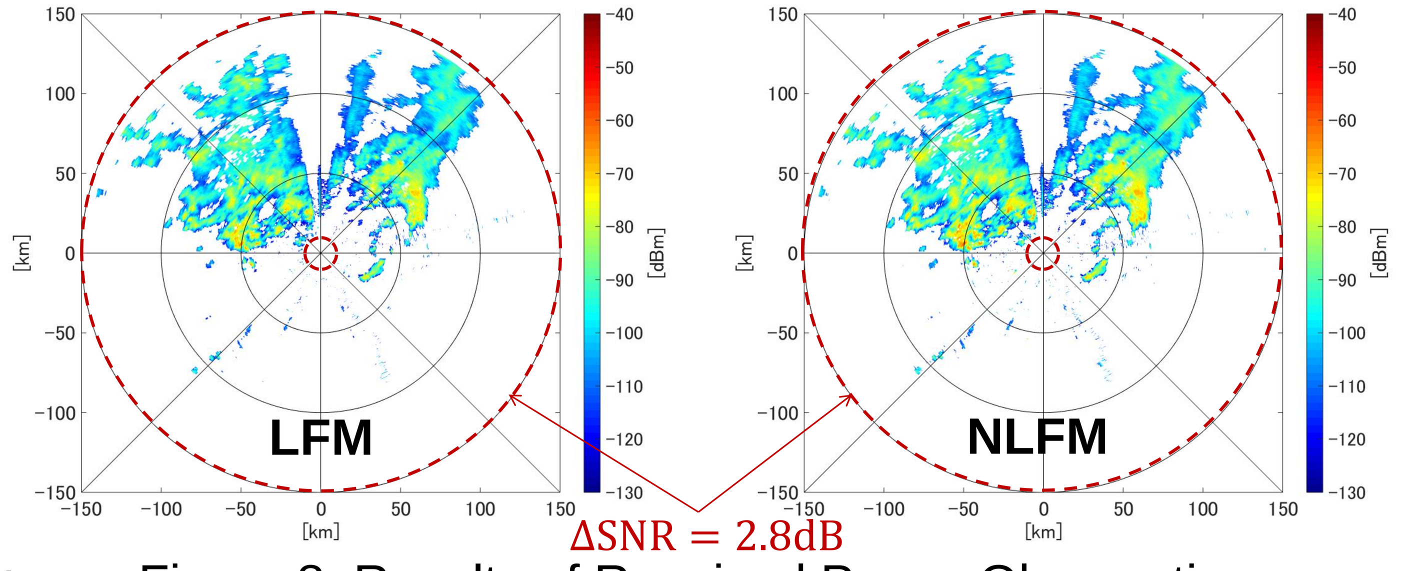

Figure 8. Results of Received Power Observation

CONCLUSION AND FUTURE WORK

We developed a pulse compression weather radar with improved sensitivity, range resolution, and range sidelobe by use of proposed NLFM.

Compared with current LFM using the Blackman-Harris window function,

- More than 2.5 dB improvement of SNR is confirmed from the results of the loopback test and the actual weather observation.
- Range resolution is approximately 1.2 times lower because of the optimization of NLFM signal by use of genetic algorithm.
- Peak range sidelobe level is about 2.1 dB to 12.8 dB lower as a result of our above-mentioned approaches. Peak range sidelobe level is suppressed to a very low level. (-65.7 dB @ T=72 us, -72.5 dB @ T=108 us)

We are conducting further evaluation of the developed NLFM in weather observations and plan to make practical use of NLFM in SSWR within the next few years.

ACKOWLEDGEMENT

The authors are grateful to the Advanced Radar Research Center of the University of Oklahoma for support of the adaptive waveform optimization framework of NLFM.