A Chirp Spread Spectrum DPSK Modulator and Demodulator for a Time Shift Multiple Access Communication System by using SAW Devices

Yoshihiko Takeuchi* *and* **Kazuhiko Yamanouchi****

∗ Laboratory, Japan Radio Co., Ltd.
2-1-4 Fukuoka, Kamifukuoka, Saitama, 356-0011 Japan

∗∗ Research Institute of Electrical Communication, Tohoku University
2-1-1 Katahira, Sendai, 980-8577 Japan

ABSTRACT

We have developed a modulator and a demodulator for DPSK modulated chirp signals using a SAW dispersive delay line and a SAW matched filter. The SAW chirp modulator spreads the 100MHz spectrum between every 1 bit data interval of 1.5μsec and provides DPSK modulation, depending upon data. The SAW demodulator demodulates data using exclusive output pulses from two output ports of a newly designed SAW matched filter. By employing nonlinear chirp modulation, the modulator generates a frequency–weighted chirp signal that keeps a flat amplitude in the time domain. The demodulator has a 19dB process gain, and it has good correlation characteristics of less than −30dB time sidelobe. By using these modulator and demodulator, we have examined a multiple access of the chirp spread spectrum(SS) system. The multiplexity is achieved by the time shift of chirp SS signals, which are easily produced by the SAW modulator. We have confirmed 20 multiplex accesses experimentally, and have measured the bit error rate up to 9 multiplexity. In the case of one chirp signal, the bit error rate degrades 2dB from the theoretical level, and the degradation of multiplexity up to 9 was only 1dB.

INTRODUCTION

Wireless communications have become a significant area of growth within the latest few years. In this area, wireless computing is a rapidly emerging technology providing users with network connectivity without being tethered off a wired network. In these consumer applications, high data transmission rate within a limited bandwidth is emphasized instead of the need of confidentiality at the physical layer of the communication. Therefore the DS(Direct Sequence) spread spectrum system with short spreading sequence is of interest[1]∼[4]. But in the case of short code, so much DS signals cannot be piled up without decrease of bit error rate.

Chirp signals can overcome this piling up problem. The phase relation between summing DS signals does not change between one chip duration, on the other hand, the phase relation of piled up chirp signals is gradually changing between one chip duration. therefore the summing chirp signal does not keep in a fatal phase relation anytime. We have developed a modulator and a demodulator of the chirp spreading signals using a SAW Dispersive Delay Line(SAW DDL) and a SAW Matched Filter(SAW MF). In this paper we describe a configuration of these modulator and demodulator, and we also show good experimental results of the multiplex data transmission.

Table 1: Design parameters of the SAW modulator and demodulator

Item	Specifications
Center Frequency	300MHz
Spreading Bandwidth	100MHz
Time Duration(1data bit)	1.5μs
Spreading Method	Chirp(Nonlinear, Up)
Data Modulation	DBPSK

SAW CHIRP DPSK MODULATOR and DEMODULATOR

We have developed a modulator and a demodulator for DPSK modulated chirp signals using a SAW DDL and a SAW MF[5]. In the modulator, one sweep of chirp signal is generated by one input RF pulse injected into the SAW DDL, and the repetition of chirp signals are produced by the periodic input RF pulses into SAW DDL. Our SAW DDL is characterized by a specialized nonlinear group delay characteristics. Using nonlinear group delay, the excited chirp signal has a fixed amplitude in the time domain, which is an advantage for nonlinear amplification, and has a weighted amplitude in the frequency domain for good correlation characteristics. The design parameters are shown in Table 1.

The SAW chirp modulator spreads the 100MHz spectrum between every 1 bit data interval of 1.5μsec. The frequency and impulse responses of this nonlinear SAW DDL are shown in Figure 1 and Figure 2, respectively. As shown in figures, frequency weight is achieved under the flat impulse response.

The deferential data modulation of DPSK is executed by the relative time shift of continuous 2 input RF pulses. The 0° deferential modulation is performed in case the time duration of pulses is just 1.5μs. The 180° deferential modulation is performed in case the time duration is 1.5μs plus half cycle of the center

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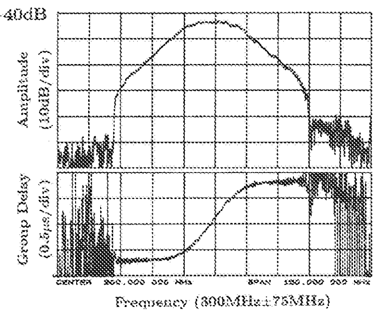

Figure 1: Frequency responses of SAW DDL in the modulator.

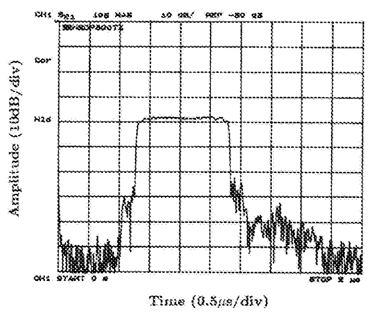

Figure 2: Impulse response of SAW DDL in the modulator.

frequency. therefore the DPSK data modulation is achieved by only $\pm\frac{1}{2}$cycle–shift of RF input pulses. The block diagram of the chirp modulation is shown in Figure 3(Case $k = 1$).

The SAW demodulator demodulates data using exclusive output pulses from two output ports of a newly designed SAW matched filter. Figure 4 shows a schematic of SAW matched filter for the chirp DPSK demodulation.

The DPSK data modulation is sensed by 2 output transducers, which are arranged 1.5μs SAW propagation delay or 1.5μs plus half cycle delay of center frequency, depending upon Output No.1 or Output No.2, respectively. One input transducer and one output transducer make together the matched filter characteristics of designed nonlinear chirp signal. Two output transducers are connected electrically. therefore continuous 2 matched pulses are added or subtracted depending upon input DPSK chirp signals. Frequency and impulse responses of this SAW matched filter is shown in Figure 5 and Figure 6, respectively. The SAW devices for DDL and MF are fabricated on the ST–cut quartz for the purpose of temperature stability($-20°$C $\sim +80°$C).

By employing nonlinear chirp modulation, this demodulator has a 19dB process gain and less than a 0.4dB receiving power loss in a 56MHz receiving bandwidth. In addition, it has good correlation character-

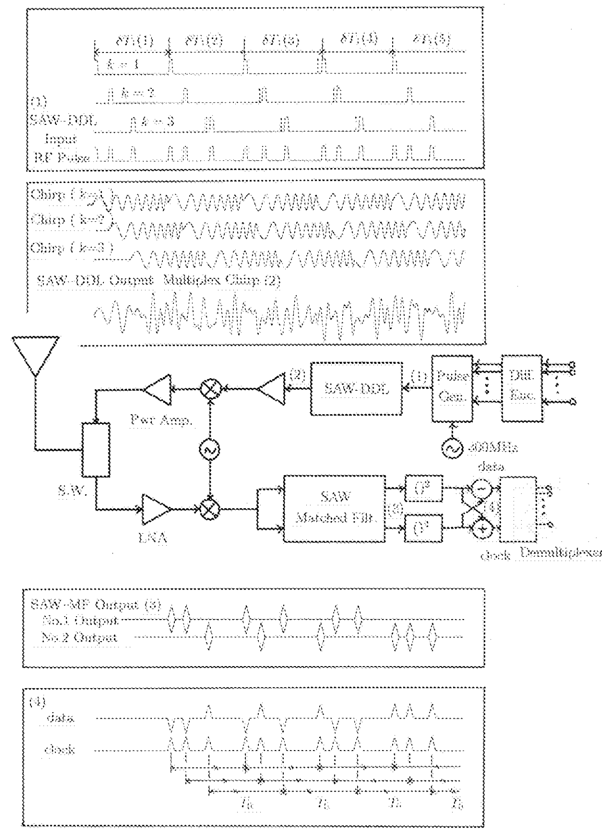

Figure 3: A block diagram of the SAW chirp DPSK modulator and demodulator.

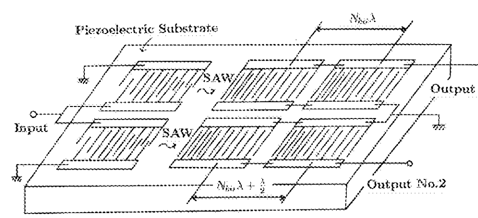

Figure 4: A schematic of the SAW matched filter for Chirp DPSK demodulation.

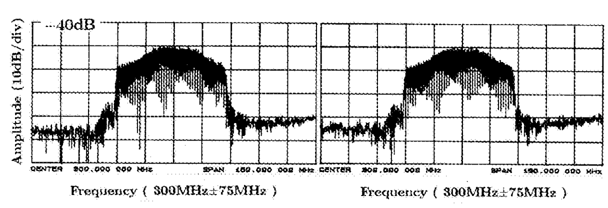

Figure 5: Frequency response of SAW matched filter.

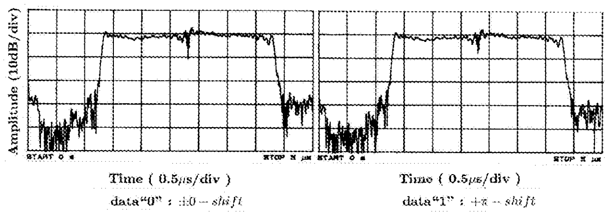

Figure 6: Impulse response of SAW matched filter.

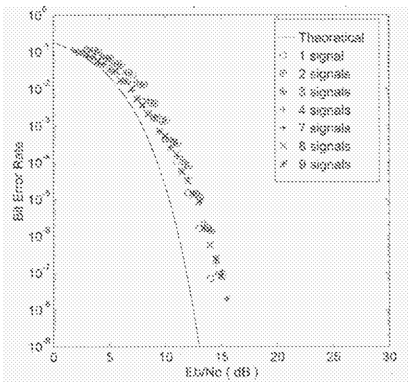

Figure 7: Bit error rates of the multiplex chirp signal communication.

istics of less than −30dB time sidelobe. Repetitive chirp signals are shown in Figure 8(a), and exclusive output pulses are shown in Figure 8(b).

CHIRP SIGNAL MULTIPLEXITY

We have examined a time shift multiple access of the chirp SS system[6]. The multiplexity is achieved by the time shift of chirp signal series. These multiplex chirp signals are generated by pulse series supplemented upon the trigger pulse series of the chirp SS modulator(Figure 3), and in the demodulator, piled up chirp signals are separeted into pulses. The groups of 1.5μs time–interval pulses are the same channels of multiplexity. The time responses and the frequency signal power densities of multiplex chirp signals are shown in Figure 9(a) and Figure 9(b)(In case of multiplex number $K = 1, 2, 3, 5, 10$), and the demodulator data output pulses are shown in Figure 9(c).

By using frequency weighting, good time sidelobe characteristics of the demodulator is achieved, and on the low time sidelobe, it is possible to make 42 multiple accesses theoretically(in case of the Hamming weighting). We have confirmed 20 multiplex accesses experimentally, and have measured the bit error rate up to 9 multiplexity. The results of the bit error rates of multiplex chirp signals are shown in Figure 7. In the case of one chirp signal, the bit error rate degrades 2dB from the theoretical level, and the degradation of multiplexity up to 9 was only 1dB.

CONCLUSIONS

We have developed a modulator and a demodulator for DPSK modulated chirp signals using a SAW dispersive delay line and a SAW matched filter. The SAW chirp modulator spreads the 100MHz spectrum between every 1 bit data interval of 1.5μsec and provides DPSK modulation, depending upon data. By using nonlinear chirp modulation, the chirp signal series has a fixed amplitude in the time domain, which is an advantage for nonlinear amplification, and has a weighted amplitude in the frequency domain for good correlation characteristics. The SAW demodulator demodulates data using exclusive output pulses from two output ports of a newly designed SAW matched filter. By employing nonlinear chirp modulation, this demodulator has a 19dB process gain and less than a 0.4dB receiving power loss in a 56MHz receiving bandwidth. In addition, it has good correlation characteristics of less than −30dB time sidelobe.

We have examined a time shift multiple access of the chirp spread spectrum system. The multiplexity is achieved by the time shift of chirp SS signals. These multiplex chirp signals are produced by pulse series supplemented upon the trigger pulse series of the chirp SS modulator. By nonlinear chirp weighting for getting good correlation characteristics of the demodulator, it is possible to make 42 multiple accesses theoretically, and have confirmed 20 multiplex accesses experimentally. We have measured the bit error rate up to 9 multiplexity. In the case of one chirp signal, the bit error rate degrades 2dB from the theoretical level, and the degradation of multiplexity up to 9 was only 1dB.

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(a) (b)

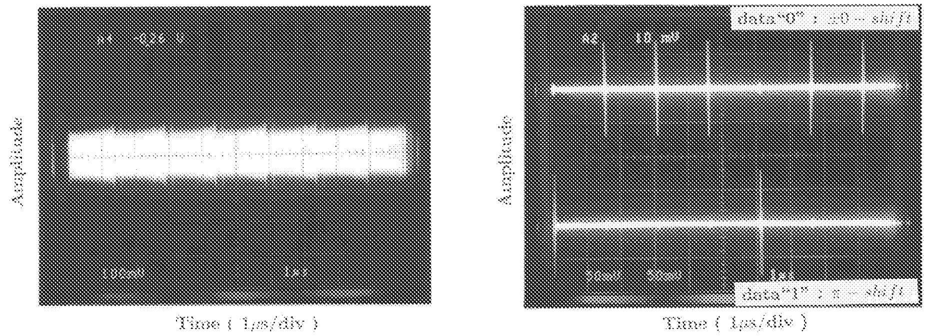
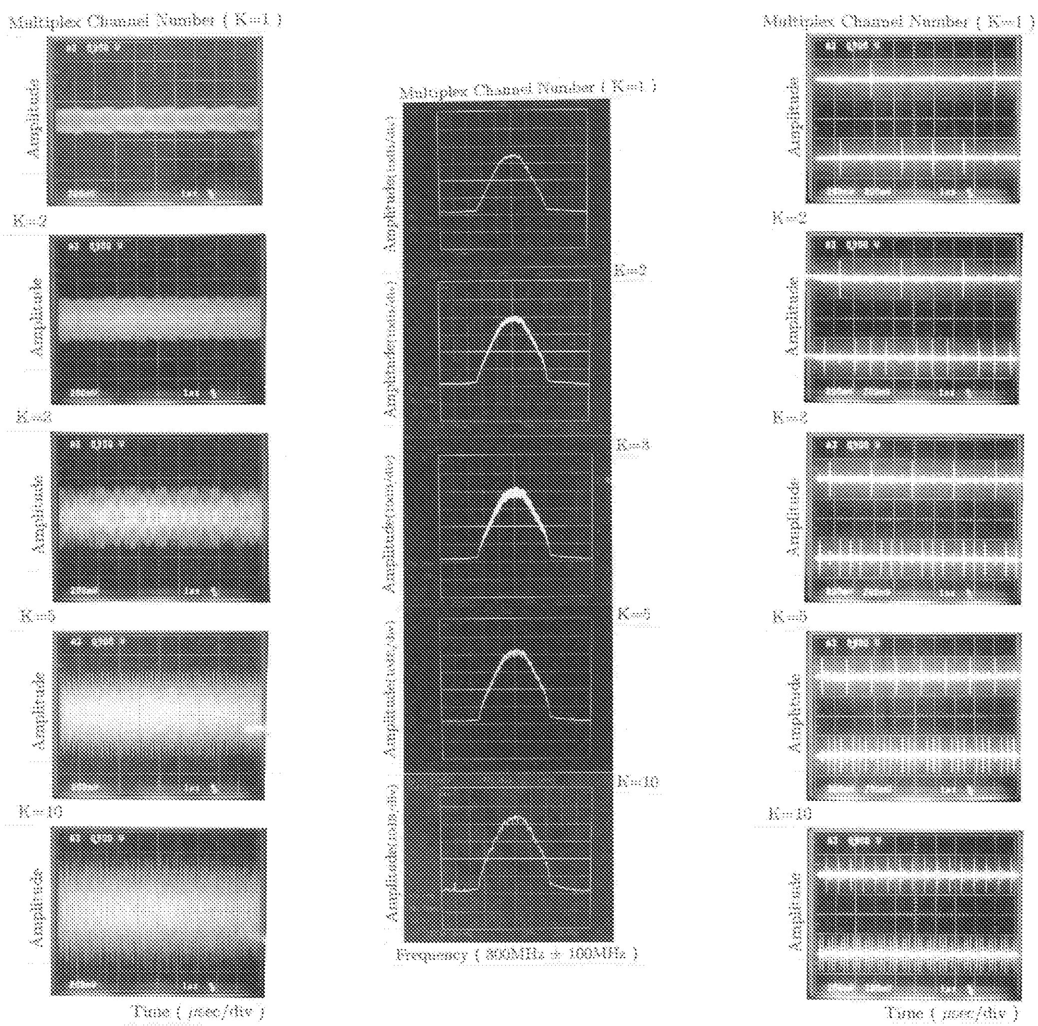


Figure 8: (a) Time response of one channel chirp signal, (b) Demodulator data pulses of one channel chirp signal.



(a) (b) (c)

Figure 9: (a) Time responses of multiplex chirp signals, (b) Frequency power density responses of multiplex chirp signals, (c) Demodulator data pulses of multiplex chirp signals.