Development of Two Kinds of UWB Sources for Propagation, EMC and Other Experimental Studies: Impulse Radio and Direct-Sequence Spread Spectrum*

Takatoshi Ogawa*, Atsushi Tomiki, and Takehiko Kobayashi

Wireless Systems Laboratory, Tokyo Denki University
2-2-1201 Nishiki-cho, Kanda, Chiyoda-ku, Tokyo, 101-8457 Japan
Phone/Fax: +81-3-5280-3839 E-mail: ogawa@grace.c.dendai.ac.jp

I. INTRODUCTION

In February 2002, the Federal Communications Commission (FCC) conditionally waived unlicensed operation of unlicensed of personal ultra wideband (UWB) products in the United States. The UWB technologies have been exploited to be able to use for super-high-speed communication, highly-accurate sensing and geolocation, low-cost RF tagging, and so forth; and to pioneer a new spectrum resource substantially. Research areas, however, remain to be fully studied such as UWB propagation characteristics and interference effects from the UWB wireless systems to conventional narrow-band ones sharing the same frequency bands. Nonetheless, UWB sources have not been readily available for the experimented studies. This paper reports prototypes of impulse radio [1] and direct sequence spread spectrum (DS-SS) UWB sources [2] to serve for propagation, electromagnetic compatibility and other experimental studies.

II. CONSTRUCTION OF UWB SOURCES

The impulse radio UWB source consists of a square wave generator, an impulse waveform generator, and a bandpass filter, as shown in Fig. 1 (a). The 33-MHz square wave is randomly on-off-keying-modulated with a 8-stage M-sequence to avoid producing spectral lines. The impulse waveform generator, employing step recovery diodes (transition time = 70 ps and carrier lifetime = 15 ns) as shown in Fig. 1 (b), generates a short (typically 300 ps) bipolar impulse at every fall of the input square wave. The impulse is then bandpass-filtered to comply with a FCC spectral mask [3] (-41.3 dBm/MHz from DC to 960 MHz; -75.3 dBm/MHz from 960 MHz to 1610 MHz; -63.3 dBm/MHz from 1610 MHz to 1990 MHz; -61.3 dBm/MHz from 1990 MHz to 3100 MHz; -41.3 dBm/MHz from 3100 to 10600 MHz; and –61.3 dBm/MHz above 10600 MHz).

The DS-SS UWB sources comprises a 2-GHz square wave generator, a M-sequence generator, a lowpass filter, a mixer, a 5-GHz local oscillator, and a bandpass filter, as shown in Fig. 2. The 15-step, 2-Gchip/s M-sequence is generated with an emitter-coupled-logic (ECL) 15-bit shift register. The M-sequence signal is applied to a lowpass filter (cutoff frequency = 2 GHz) to suppress the harmonics, then up-converted with a 5-GHz continuous wave, and bandpass-filtered.

III. PERFORMANCE OF THE UWB SOURCES

Trains of impulses are generated and then bandpass-filtered, as observed in time domain with a 20-G sample/s digital oscilloscope in Fig. 3. The frequency spectra of the impulse trains are shown in Fig. 4. Although a part of the noise floor of the spectrum analyzer exceeds the FCC spectral mask in Fig. 4 (b), the output signal itself complies with the mask. The cumulative amplitude probabilities of the impulse signals (with and without the bandpass filter) are plotted on normal distribution paper in Fig. 5.

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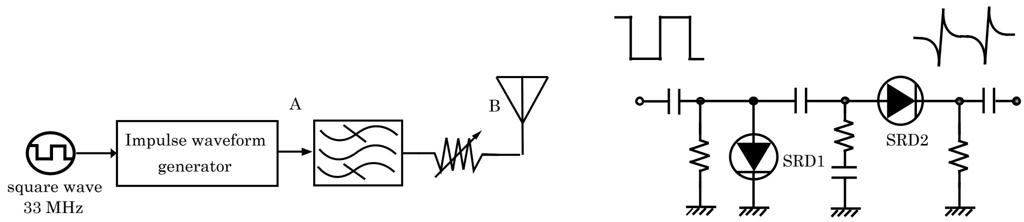


(a) (b)

Fig. 1. Impulse radio UWB sources: (a) block diagram and (b) impulse waveform generator using two step recovery diodes (SRD).

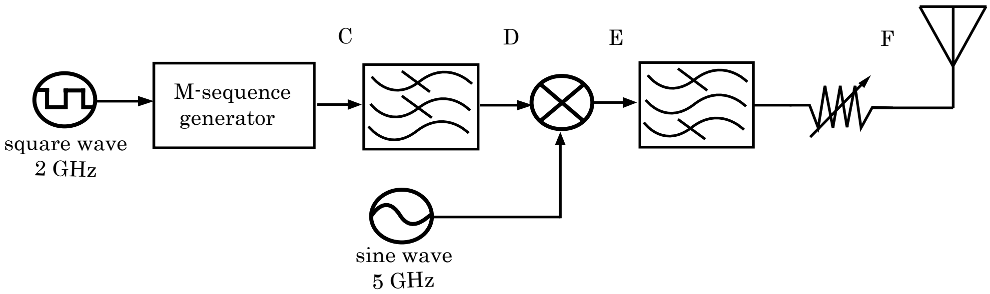


Fig. 2. Block diagram of the DS-SS UWB source.

In the DS-SS UWB source, the M-sequence is observed in time and frequency domains as depicted in Fig. 6. The M-sequence signal is then up-converted (Fig. 7 (a)) and bandpass-filtered (Fig. 7 (b)). The output spectra of both the impulse radio and the DS-SS sources are widely spread over a few GHz. The cumulative amplitude probabilities of the two sources, however, are quite different, as shown in Fig. 8, since the amplitude of the DS-SS signal is essentially limited within ECL operating voltages.

IV. Conclusion

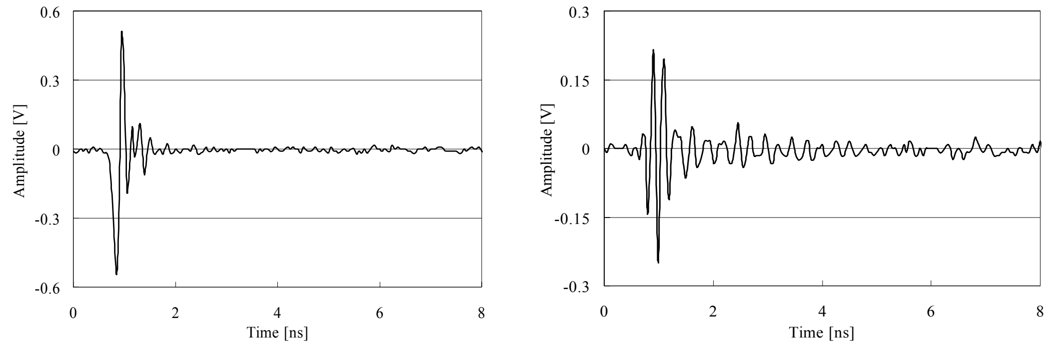
We have developed two kinds of UWB transmitting sources: impulse radio and DS-SS. They produce ultra wide spectrum and comply with FCC spectral mask, but differ in amplitude distribution.

References

[1] G. F. Ross, "A time domain criterion for the design of wideband radiating elements," IEEE Trans. Antennas Propagat., vol. 16, no. 3, pp. 355-356 (1968)

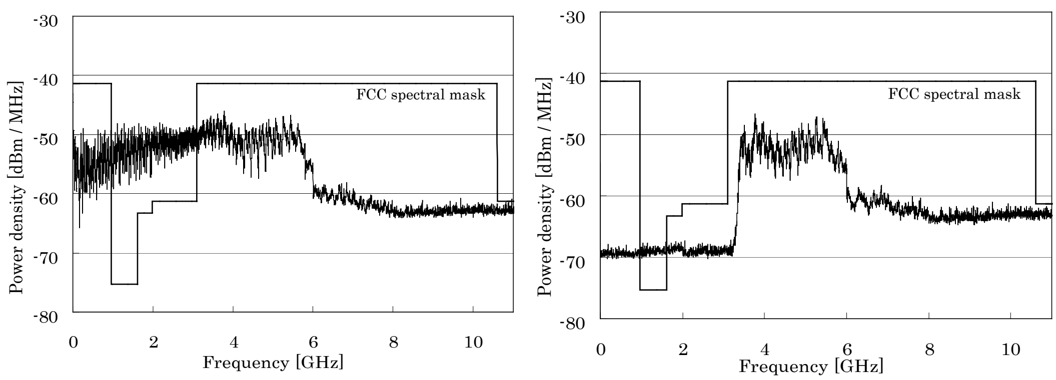
[2] J. Foerster, "The performance of a direct-sequence spread ultra-wideband system in the presence of multipath, narrowband interference, and multiuser interference," 2002 IEEE Conf. on Ultra Wideband Systems and Tech., pp. 87-91, Baltimore, MA, USA, June 2002.

[3] Federal Communications Commission, "Revision of part 15 of the commission's rules regarding ultra wideband transmission system," FCC 02-48, April 2002.



(a) (b)

Fig. 3. Time domain waveform of the impulse radio UWB sources at (a) the output of the impulse waveform shaper (point A in Fig. 1(a)) and (b) the output of the bandpass filter (point B in Fig. 1(a))



(a) (b)

Fig. 4. Frequency spectra of (a) the output of the impulse waveform shaper (point A in Fig. 1 (a)) and (b) the output of the bandpass filter (point B in Fig. 1(a)). Resolution bandwidth = 1 MHz, video bandwidth = 1 MHz, and 10 dB/div.

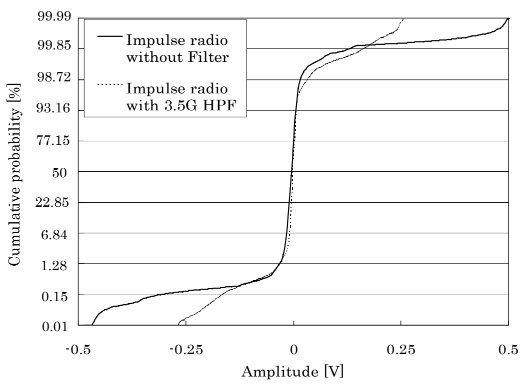
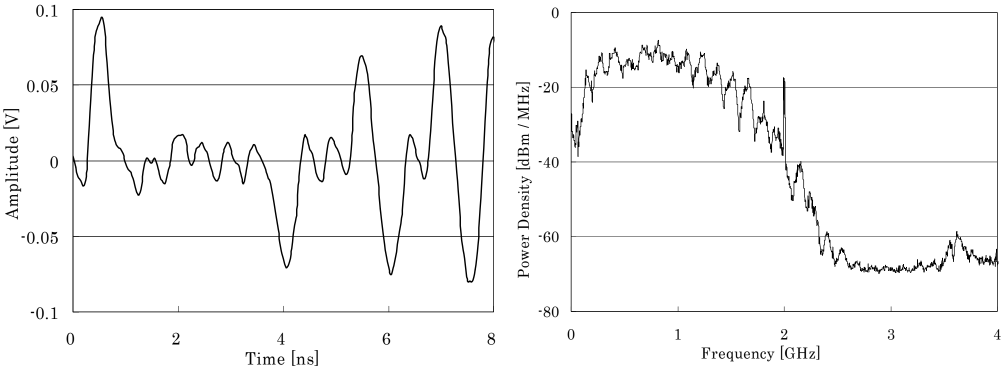
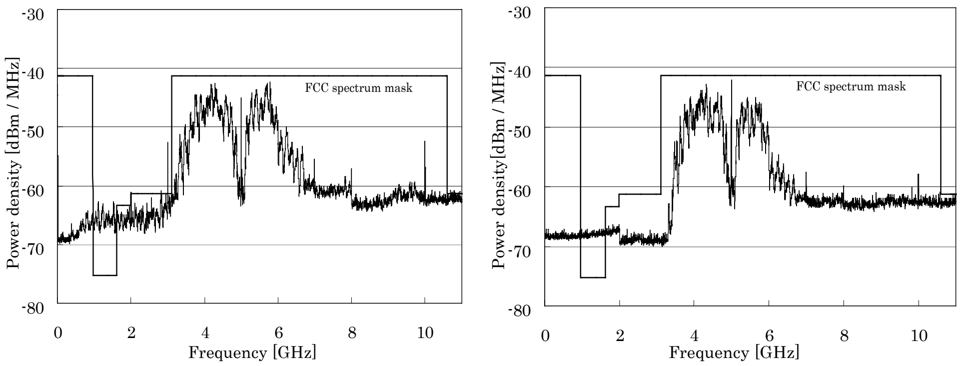


Fig. 5. Cumulative amplitude distribution plotted on normal distribution paper of the (a) the output of the impulse waveform shaper (point A in Fig. 1(a)) and (b) the output of the bandpass filter (point B in Fig. 1(a)).



(a) (b)

Fig. 6. A 15-stage, 2-Gchips/s M-sequence: (a) time domain waveform (point C in Fig. 2) and (b) frequency spectrum (point D in Fig. 2)



(a) (b)

Fig. 7. Frequency spectra at (a) the output of the mixer (point E in Fig. 2) and (b) at the output of the bandpass filter (point F in Fig. 2). Resolution bandwidth = 1 MHz, video bandwidth = 1 MHz, and 10dB/div.

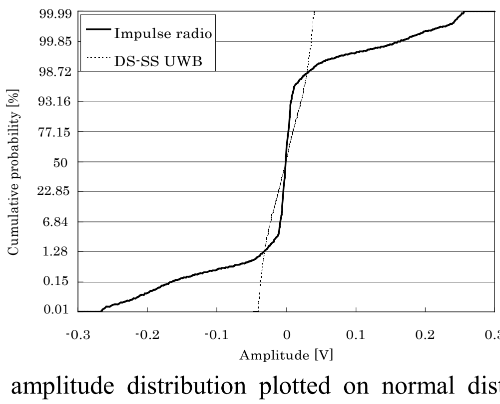


Fig. 8. Cumulative amplitude distribution plotted on normal distribution paper of the impulse radio (point B in Fig. 1(a)) and the DS-SS (point F in Fig. 2) UWB sources.