Wideband RF Transceiver System with Adjustable RF Carrier

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Abstract

In this paper, a wideband RF transceiver system with adjustable bandwidths and center frequencies is presented. Because the proposed wideband RF carrier can control an RF spectral shape without changing the modulation scheme, the transmitting channel power can be adjusted by changing the channel bandwidth. From the experimental results, the proposed system has been evaluated from PER (Packet Error Rate) tests to measure a sensitivity level for each flexible channel spectrum. In addition, the OOK-modulated signals with 64 kbps data rate and 50 % duty-cycle have been successfully transmitted by flexible channel frequency and bandwidth. The proposed system has established the controllability of the emitting power by adjusting bandwidth instead of peak power on conventional systems.

Keywords : UWB, RF transceivers, emission power, channel bandwidth, personal area networks

1. Introduction

The UWB (Ultra Wideband) technology has been researched to be applied to commercial personal area networks (PANs) from military purposes, since the frequency and spectrum mask were released by US FCC (Federal Communication Commission) in February 2002. Thanks to its unique spectral characteristics such as low-level spectral power density (-41.3 dBm/MHz) and ultra wide channel bandwidth (about 500 MHz to 2 GHz), several applications have been tried in the RF/Microwave fields for NFC (Near Field Communication) services. However, the MBOA (Multi-Band OFDM Alliance) group suffered from the low-level spectral density, because peak power of the OFDM spectrum violates the FCC spectrum mask. Meanwhile, the UWB technology was applied to the low-power sensor networks in the IEEE 802.15.4a standard with various UWB carrier sources such as an impulse, a chirp, and a chaotic signal [1]. This low-power UWB technologies specifies emitting channel power as '*class x*' in the standard specification by controlling the gain of a power amplifier. This adjustment of amplification isn't only limited by the UWB spectral mark, but also requires inefficient front-end design because the system should be designed to be capable of maximum power emission [2-4].

In this paper, a wideband RF transceiver system is designed with adjustable wideband RF carrier (WRC) signal, which can control the emitting channel power by adjusting the channel bandwidth. The WRC is generated from non-conscious baseband noise signal, which cannot only produce wideband system, but also contribute to reduce the system power-consumption. Even though the bandwidth of the WRC is adjusted, the modulation schemes and transmission performances can be kept except emission channel power. The proposed system has a merit of constant spectral density, while the conventional ones vary the peak power for every power control.

2. Wideband Transceiver Design With Adjustable Channel BW

The wideband RF transceiver system is designed as shown in Fig. 1. The transmitter is composed of a WRC signal generator, a switching OOK modulator, an LPF, and a power amplifier. The WRC is generated by VCO output at a frequency range of 2 GHz - 3 GHz, which controls the center frequency by offset DC provided through a bias-tee and the bandwidth by variable amplitude of the baseband noisy signal through a variable attenuator. The baseband pseudo-noisy signal is implemented by a combination of three different signals of a sine, a triangular, and a sawtooth waves with different periods and shapes, respectively. The On-Off Keying (OOK) modulation scheme is adopted by a switching modulator. The receiver is designed by LNAs, an envelope detector, and a comparator (1-bit ADC). The WRC can control the carrier spectrum of a bandwidth from 20 to 100 MHz and a center frequency from 2 to 3 GHz. While the proposed system utilizes the WRC signal, low-rate modulated signal can maintain almost the same channel bandwidth. The proposed system is designed to keep the modulation performances in spite of changing the bandwidth of the WRC.

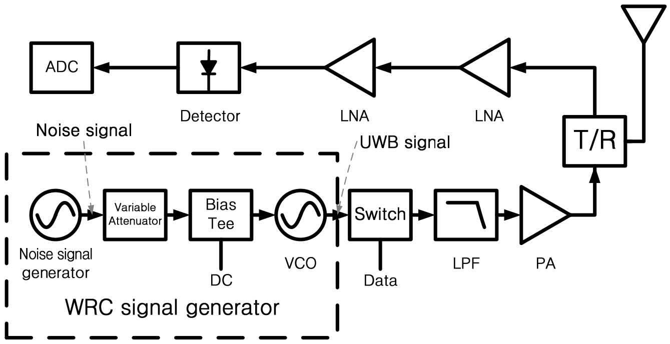


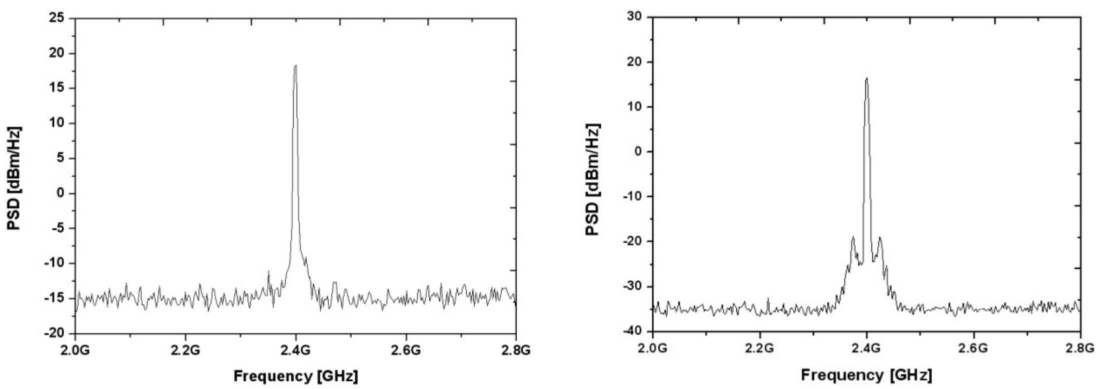
Figure 1: Block diagram of the RF transceiver system.

3. Performance Evaluation of the Proposed System

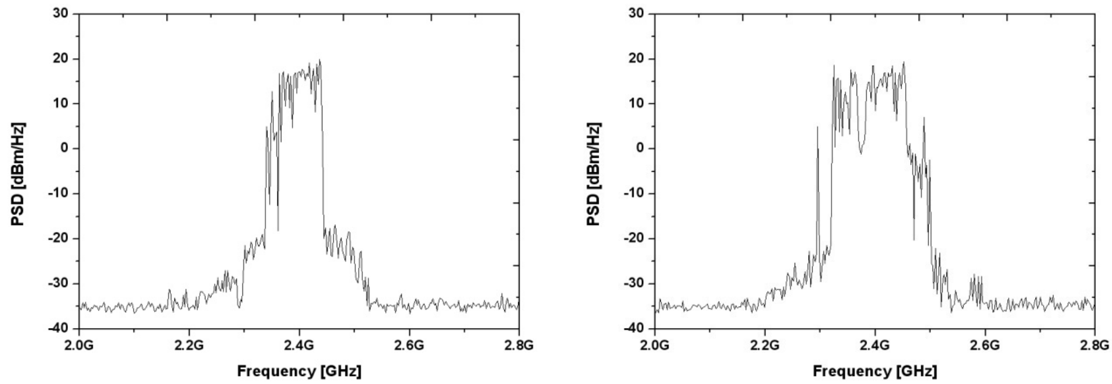
For the purpose of testing the proposed system, two kinds of experiments are conducted. The adjustability of the WRC signal and the possibility of the Tx. power control through adjusting the channel bandwidth are tested.

3.1 Adjustable WRC Signal Test

To evaluate the transmitter, the message signal with a clock rate of 64 kbps, a cycle of 15.625 μsec, and a duty cycle of 50 % was modulated with the WRC signal. The bandwidth and the center frequency control of the OOK modulated WRC signal was measured by a spectrum analyzer. For the bandwidth control, a variable attenuator at the WRC signal generator is controlled to change noise signal amplitude on a VCO. While high amplitude varies RF spectrum widely at VCO output, low amplitude makes small spectrum deviation. Fig. 2 shows the measured spectrum with 0, 10, 100, and 200 MHz bandwidths at 2.4GHz. Fig. 3 presents a set for WRC signal at center frequencies of 2.2GHz, 2.4 GHz, 2.6 GHz, and 2.8 GHz with a bandwidth of 100MHz. The dotted line shows self-oscillating output power of the VCO, which is the reason why the peak powers are a little different.



(a) 0 MHz (single tone) (b) 10 MHz



(c) 100 MHz (d) 200 MHz

Figure 2: Channel bandwidth control of the WRC signal.

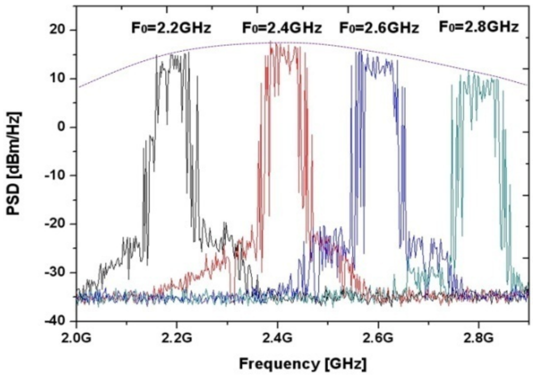


Figure 3: Adjustable center frequencies of the WRC signal.

3.2 Transmitting Power Control

To evaluate the channel power control of the propose system, the system sensitivity levels have been measured for each channel bandwidth and each channel peak power of a conventional CW OOK transceiver system. The measurement set-up is presented in Fig. 4. To avoid exterior interferers, communication link is replaced by coaxial cables and a variable attenuator. Two PERTs (Packet Error Rate Testers) are connected to measured sensitivity level for TRx. At the sensitivity level of -53 dBm, the transmission distances are calculated from the measured link loss. The Furri's Formula is calculated to convert to the distance as presented in in eq. (1).

$$Loss = 10log\left(\frac{4\pi r}{\lambda}\right)^2 \quad (1)$$

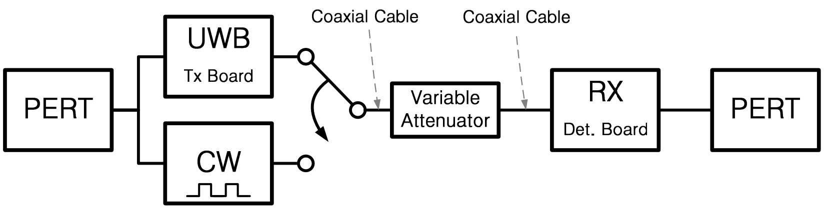
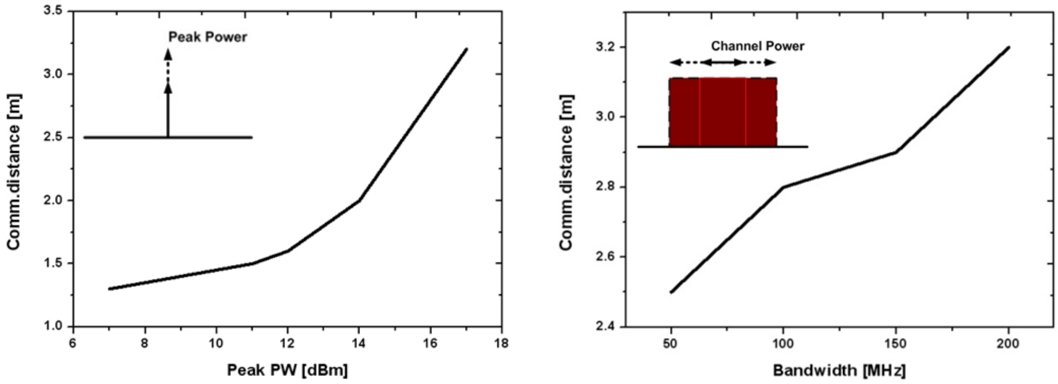


Figure 4: Measurement set-up for emission power comparison.

The possibility of controlling the transmission distance by the bandwidth instead of the peak power is proven by the experiments. The experimental results are presented in Fig. 5. As the peak power is raised for a conventional OOK-modulated signal with a CW carrier, a communication distance is increased as shown in Fig. 5 (a). Similarly, when the channel bandwidth of the signal with a WRC is increased from 50 MHz to 200MHz, the communication distance is also increased from 2.5m to 3.2m in Fig. 5 (b). Two power control systems show almost the same patterns, when each measured channel power is compared. Fig. 6 presents the photograph of the proposed wideband RF system with a WRC module.



(a) CW carrier. (b) Wideband RF carrier.

Figure 5: Channel power controls by the peak power and the channel bandwidth.

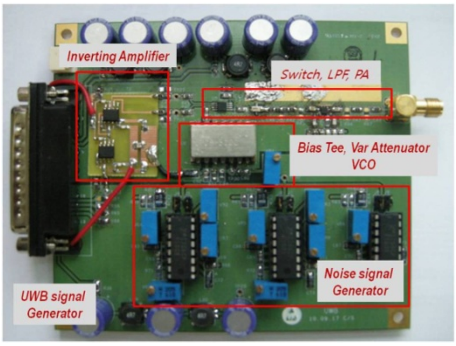


Figure 6: Photograph of the transmitter

4. Conclusion

In this paper, a wideband RF transceiver system with adjustable channel bandwidths is designed. Thanks to the WRC has controllable center frequencies and bandwidths, the system can control the transmitting power without violating power emission regulations. Moreover, because the controllability is almost linearly matched to the conventional peak power control, it can be applicable to the commercial UWB services based on the current standards. Furthermore, since the proposed system has various system flexibilities, it can be applicable for low-power Near Field Communications (NFCs).

References

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