System-on-Package Ultra Wideband Transmitter with Integrated Bandpass Filter and Broad Band Planar Antenna

Myunghoi Kim, Junwoo Lee, *Young-jin Park, and Joungho Kim
Terahertz Interconnection and Package Laboratory, Department of Electrical Engineering and Computer Science,
Korea Advanced Institute of Science and Technology, 373-1 Guseong-dong, Yuseong-gu, Daejon 305-701, Korea
Tel: +82-42-869-5458, Fax: +82-42-869-8058, E-mail: mhkim@eeinfo.kaist.ac.kr, Homepage: http://tera.kaist.ac.kr
*Korea Electrotechnology Research Institute (KERI), Naeson 2-dong, Euiwang-city, Kyunggi-do, Korea

Abstract

In this paper, the UWB transmitter module for System-on-Package (SOP) is presented, which contains the miniaturized bandpass filter. This module is designed to achieve low data rate, low cost applications for location and tracking system based on non-coherent architecture. The presented module contains Field Programmable Gate Array (FPGA), the crystal oscillator, RF amplifier, planar antenna and bandpass filter the role of which is to make the transmitted pulse from the transmitter module satisfy the FCC regulation. A conventional bandpass filter occupies large area and is the bottleneck of miniaturization of transmitter module. The size of proposed bandpass filter is greatly reduced and it is about 10% area of conventional bandpass filter for UWB system. This leads to miniaturization of UWB transmitter module for SOP.

1. Introduction

Ultra wideband (UWB) technology has become a major issue for Wireless Personal Area Networking (WPAN) since the Federal Communications Commission (FCC) has approved the commercial use of the UWB systems. The FCC defined the UWB system as wireless system, whose fractional bandwidth is more than 20% or absolute bandwidth is more than 500 MHz [1]. Thanks to its large bandwidth, the UWB system can transmit the ultra short pulse signal whose duration is less than 1 ns with very low power spectral density. The intrinsic properties of the UWB allow the high data rates, the high capacity, the small power consumption, and the high spatial resolution as well as co-existence with the conventional wireless systems.

One of the dominant technologies for the UWB system is the classic Impulse Radio (UWB-IR) technique. The implementation of the UWB-IR is relatively simple which enables the transmitter to be small, low power consumption, and low cost. The main focus of this paper is on the miniaturization of the UWB transmitter for the low power and the low cost applications such as the identification, the imaging, and the positioning system.

Generally, there are two ways to make UWB-IR signal. One is to use a base band signal generator, a RF mixer, and a local oscillator (LO) just like the conventional carrier modulation scheme. The cost and the power consumption of the broad band RF mixer and the high frequency LO (around 4 GHz) are not suitable to the low cost and low data rate applications. The other is to use a fast enough pulse generator to contain high frequency spectrum whose frequency range is from 3 GHz to 5 GHz and a RF band pass filter to meet the FCC spectral mask, which is adopted in this paper.

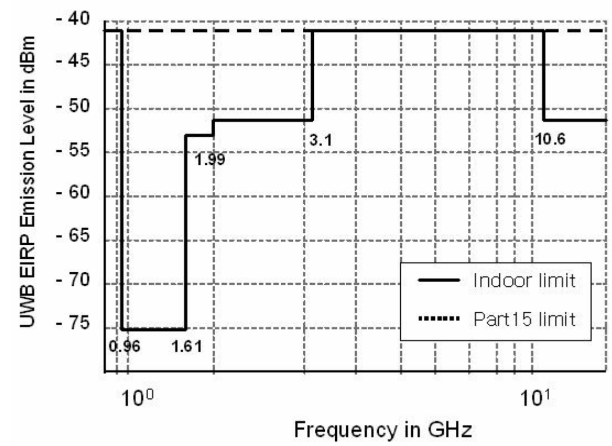

Figure 1 FCC spectral mask

Figure 1 shows the FCC spectral mask for indoor UWB systems [1]. As shown in figure 1, the transmission power of UWB systems is restricted below -41.25dBm/MHz between 3.1 and 10.6 [GHz], especially the transmission power is strictly limited from 0.96 to 1.61 [GHz] in order to prevent the frequency interference between UWB systems and the cellular systems or GPS. Therefore, UWB transmitter should contain the filtering components. In many UWB transmitters, bandpass filter fabricated on printed circuit board (PCB) is used as filtering components and also there have been many studies on bandpass filter for UWB systems [2][3]. Previous filter designer just considered filter performance like insertion loss, rejection and bandwidth while the filter size is not significant design parameter [4][5][6]. However, these days the miniaturization of UWB transmitter is needed strongly and filter size becomes more considerable design parameter as the applications of UWB system for Body Area Networking (BAN) or tracking system are required to portability. In this paper, the bandpass filter for UWB systems is designed considering the filter size as a significant parameter. This paper is organized as follows. In section 2, we present the newly designed UWB filter and simulation results, in section 3 the method to generate UWB pulse is described and then section 4, 5 give the measured results and conclusions respectively.

2. Design of miniaturized filter for UWB systems

Figure 2 and 3 show the structure of designed UWB filter. To reduce the filter size, we adopt the broad side edge coupled line filter with tapered short stub. The broad side edge coupled line is a half wavelength transmission line resonator and the transmission characteristic of coupled line is similar to that of bandpass filter [7]. However, it is hardly possible for a single section of coupled line filter to enable the transmission characteristic satisfy the FCC regulation. Therefore, the tapered short stub is connected in the middle of coupled line. It acts as an equivalent line resonator enabling the high rejection in the broad band. Since the stub length determines the location of attenuation pole, we can easily obtain the stub length to make an attenuation pole between 0.96GHz and 1.61GHz. The location of attenuation poles is evaluated using reduced S parameter and phase characteristics [4].

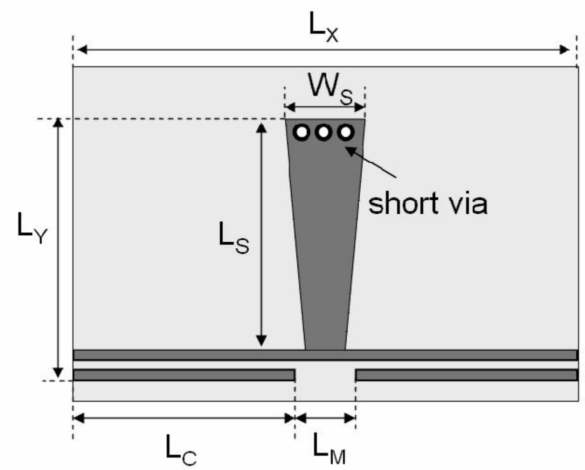

Figure 2 Schematic diagram of signal layer

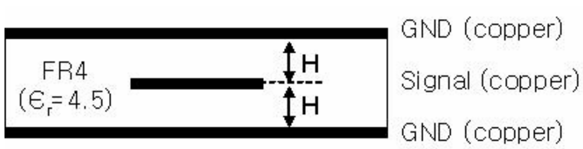

Figure 3 Stack up of UWB filter

Designing the UWB filter, the embedded type filter is considered to prevent the radiation from stub or coupled line interfering with the radiated signal from antenna. Since on package the filter is located near by antenna, the interference with filter and antenna can easily happen.

Table 1 shows values for design of UWB filter. The size of filter is 6.5mm x 13mm x 1.2mm which is 10% area of conventional UWB filter[4][5][6]. The size of this filter is so small that it is integrated on package.

Table 1 Dimensions of UWB filter

(units: mm)

L_X	L_Y	L_C	L_M	L_S	W_S	H
13	6.5	5.5	2	6.2	3.4	0.6

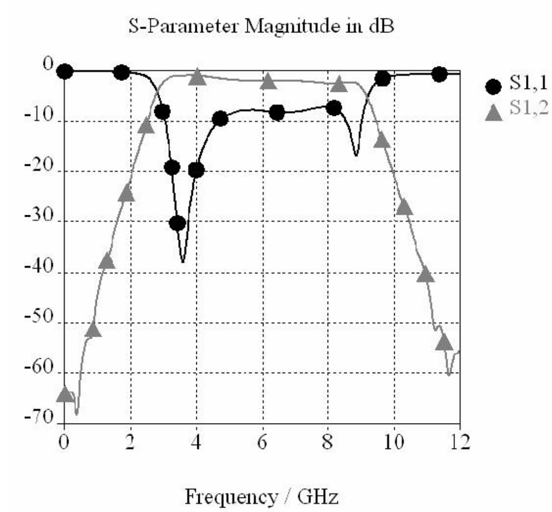

Figure 4 S parameters (simulated results)

Figure 4 shows simulated results of transmission and reflection characteristics. As shown in this figure, the filter has a 3 GHz to 9GHz pass band and the center frequency is 6GHz. Insertion loss is better than 2.3dB and suppression in lower band (0.96GHz to 1.61GHz) is more than 30dB.

3. UWB transmitter

Figure 5 shows the block diagram of the UWB transmitter. The rectangular pulses from FPGA which includes base-band circuit are generated and input to the proposed UWB filter. The UWB signal out from bandpass filter is radiated through the planar antenna.

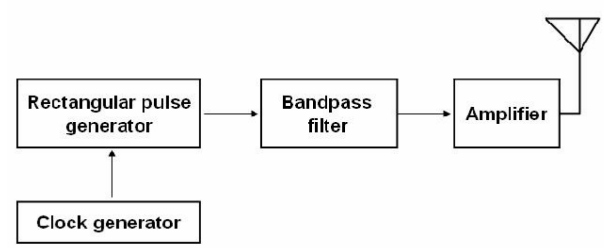

Figure 5 Block diagram of UWB transmitter

In order to generate clock pulses, 100MHz crystal oscillator is used. These pulses input to PLL of FPGA. One of the reasons why we used PLL of FPGA is to need high-speed buffer. The output of crystal oscillator can't cover the UWB band even if the lower band from 3.1GHz to 5.1GHz. However, the frequency spectrum of pulses from FPGA cover the lower band because the output pulses of PLL has small rise time in the order of hundreds of ps. Figure 6 shows the relationship between time domain waveform and frequency spectrum of rectangular pulses.

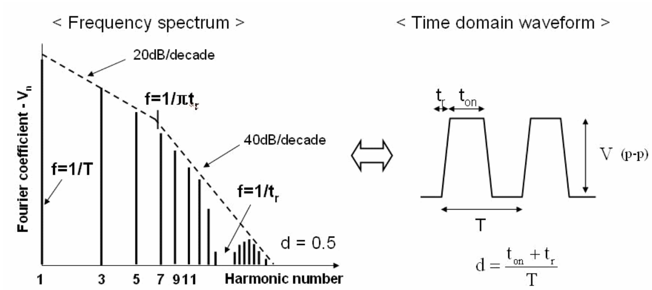

Figure 6 the relationship between frequency spectrum and time domain waveform of rectangular pulses

The period of rectangular pulses determines the fundamental frequency and harmonic frequencies. The harmonics fall off with frequency at a 20dB per decade rate up to a frequency of $1/\pi t_r$; beyond that they fall off at a rate of 40dB per decade [8]. The period and rise time of rectangular pulses are significant to guarantee the high frequency spectrum. The period determines the number of harmonics and rise time determines the magnitude of harmonics in designated band. In our case, the rectangular pulses having 10ns period and 400ps rise time are selected.

To radiate the UWB signal, antenna has both the broadband characteristics in frequency domain and non-dispersive characteristics in time domain. Conventional broad band antennas such as spiral and log periodic antenna are not suitable to UWB system for their time dispersive characteristics [9]. However, the characteristic of monopole antenna is non-dispersive in time and monopole antenna has broadband characteristics. In this paper, monopole antenna is implemented in UWB transmitter. Figure 7 shows the reflection characteristics of implemented antenna.

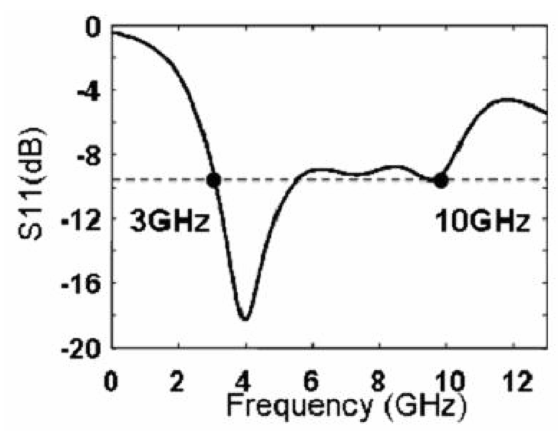

Figure 7 reflection characteristics of planar antenna

Figure 8 shows the implemented UWB transmitter module. Its size is 4cm x 7cm. All components are integrated on single substrate and module is miniaturized for SOP by miniaturization of UWB filter.

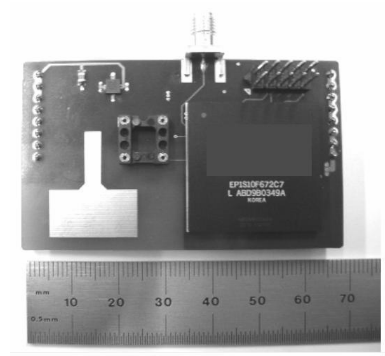

Figure 8 UWB transmitter module

4. Measurements

Time domain waveform and frequency spectrum are measured with sampling oscilloscope and spectrum analyzer, respectively. The antenna which is used for receiving is the same as TX antenna. Figure 9 shows the setup for measurements.

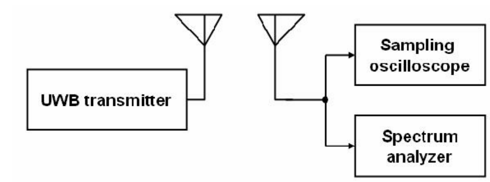

Figure 9 measurement setup

The measured UWB pulse waveform is shown in figure 10. Measured results are the following:

- Magnitude : 23mVp-p, 18mVp-p
- Pulse width : 1.5ns
- Pulse repetition rate : 200MHz

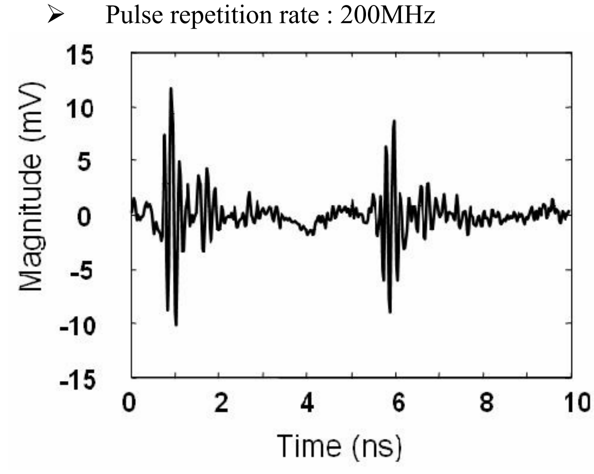

Figure 10 output waveform radiated from transmitter

Figure 11 shows the measured frequency spectrum of UWB transmitter. Peak power is -47dBm/MHz at 3.7GHz. The lower frequency below 10dB of peak frequency is 2.5GHz and the upper frequency is 3.8GHz. Fractional bandwidth is 0.41 which is more than 0.2 of UWB definition.

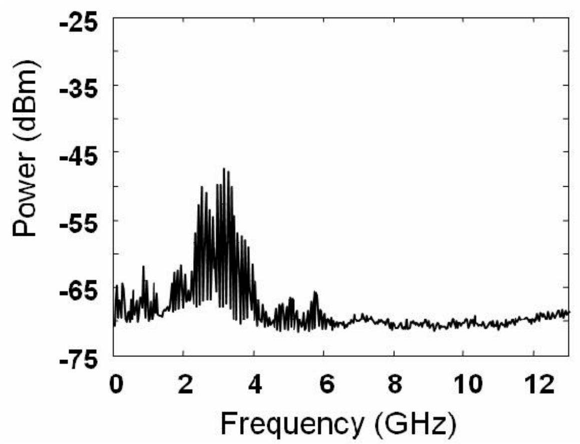

Figure 11 measured frequency spectrum of radiated output

5. Conclusions

In this paper, the miniaturized UWB filter for SOP has been presented and also the demonstration module of UWB transmitter for SOP is implemented. While the size of conventional UWB filter is too large to be integrated on single package, the proposed UWB filter the size of which is 10% area can be integrated. The UWB transmitter with integrated UWB filter and antenna on single substrate has been implemented and its radiated output waveform and frequency spectrum are measured in time domain and frequency domain respectively.

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