THE INSTITUTE OF ELECTRONICS,
INFORMATION AND COMMUNICATION ENGINEERS

IEICE Technical Report
PEM2015 FCB-1 (2015-11)

[Poster Presentation] Development of Log-scale Comb-generator for EMC Emission Measurement less than 30 MHz Using FPGA-based Arbitrary Waveform Generator

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Abstract In this paper, a log-scale comb-generator using FPGA-based arbitrary waveform generator are proposed. This comb-generator can be utilized for daily-checking of conducted and radiated emission measurement system. The proposed comb-generator can cover the frequency range of 9 kHz to 30 MHz and can generate almost-equal-space comb-like spectrum in frequency logarithmic scale. Additionally, the fine tuning of output level of each comb can be realized due to the use of FPGA architecture. After fine tuning for highly flatness of frequency response of comb spectrum, the output levels of 90 dBuV ±0.01 dB are achieved. The standard deviation of the output spectrum of the proposed comb-generator is less than 0.01 dB in the frequency less than 20 MHz, therefore the output spectrum of the proposed comb-generator is quite stable. By the use of this equipment, the amplitude of the electromagnetic fields radiated from this generator can be leveled off. Therefore, this signal generator can be used as a reference field generator. By the reference field generator, the RoF link system and the photonic electric field sensor system easily calibrated and realize more accurate electromagnetic field measurements. The measurement results by RoF link system will be presented in the poster session.

Keywords comb-generator, arbitrary waveform generator, FPGA, emission measurement.

1. Introduction

Recently, the needs for the emission measurement of electronic devices are increasing. Especially, in association with the development of RF-ID system, electromagnetic cooker, and the wireless power transmission for automobile, the conducted and radiated emission measurement in the frequency range of 9 kHz to 30 MHz become very important [1].

Comb-generators are generally used for daily checking for emission test equipment [2]. Conventional comb-generators are periodically generate the pulse waveform with a certain period, T. As a results, comb-like spectrum with the frequency-spacing of $1/T$ are generated from the comb-generator. The period of pulse generation and the output level of comb-generator have inverse relationship because longer period decrease the waveform energy per second. In addition, the frequency characteristics of the comb-generator and the pulse waveform are Fourier transformation pairs. Therefore, the fine control of the spectrum of the comb-generator is quite difficult.

Additionally, if the frequency-spacing of the generator is set to 1 kHz, the frequency spectrum is too thick around 30 MHz and the output level of the comb-generator are too low due to the inverse relationship of the period and the output level. On the other hand, if the frequency-spacing of the generator is set to 1 MHz, the spectrum of less than 1 MHz cannot be generated.

To solve these problems, a log-scale comb-generator using FPGA-based arbitrary waveform generator is proposed in this paper. This comb-generator can cover the frequency range of 9 kHz to 30 MHz, which correspond to CISPR Band A and B. The comb-generator can also generate almost-equally-spaced comb-like spectrum in the logarithmic frequency scale as shown in Fig.1. For emission test less than 30 MHz, the log-scale frequency scale are frequently used. Therefore, the log-scale comb-generator is very useful for full band measurement in the frequency range of 9 kHz to 30 MHz. Moreover, by the use of programmable devices, the fine tuning of the output level of each comb-spectrum can be realized. This makes highly flatness of frequency response of the comb spectrum in the frequency range of 9 kHz to 30 MHz.

In the next section, the configuration of the log-scale comb-generator and the hardware specifications are explained. In the 3rd section, the flatness of the frequency spectrum and the stability of the proposed log-scale comb-generator are experimentally verified.

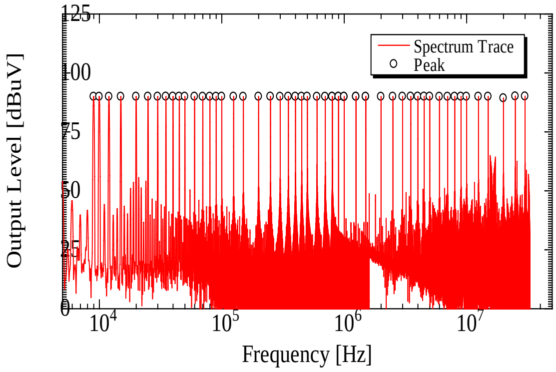

Fig. 1 Example of Output Spectrum from Log-scale Comb-generator.

2. Configuration of Log-scale Comb-generator

2.1 Circuit Configuration

The circuit diagram of the log-scale comb-generator is shown in Fig.2. Two DACs (Digital-to-Analog Converters) and two ADCs (Analog-to-Digital Converters) are controlled by a CPU (Central Processing Unit) implemented in FPGA (Field-Programmable Gate Array). The arbitrary waveform data preliminarily written in SD card can be generated from these DAC. Available output level from the DAC is ± 1 Vpp. The outputs from two DACs are combined by an RF combiner because only one DAC cannot cover the all frequency range of 9 kHz to 30 MHz. For monitoring the output level from the combiner, we use a directional coupler connected to the ADC.

In this configuration, Ch1 DAC cover the frequency range of 9 kHz to 800 kHz and Ch2 DAC cover the frequency range of 900 kHz to 30 MHz. The frequency list of comb spectrum are shown in Table 1.

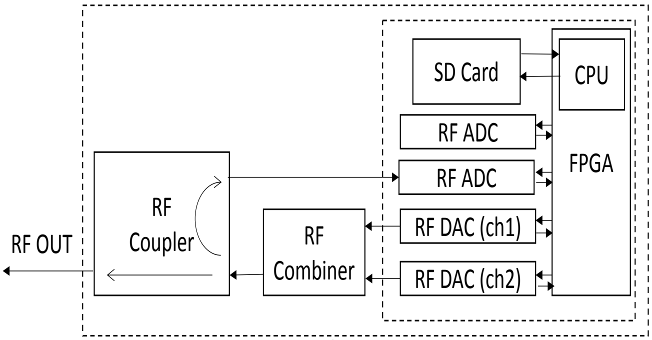

Fig. 2 Circuit Diagram of Log-scale Comb-generator

Table 1 Output Frequency List.

DAC	Frequency List	Number of Frequencies
Ch1	9 kHz, 10 kHz, 12 kHz, 15 kHz, 20 kHz, 25 kHz, 30 kHz, 35 kHz, 40 kHz, 45 kHz, 50 kHz, 60 kHz, 70 kHz, 80 kHz, 90 kHz, 100 kHz, 125 kHz, 150 kHz, 200 kHz, 250 kHz, 300 kHz, 350 kHz, 400 kHz, 450 kHz, 500 kHz, 600 kHz, 700 kHz, 800 kHz	28
Ch2	900 kHz, 1 MHz, 1.25 MHz, 1.5 MHz, 2 MHz, 2.5 MHz, 3 MHz, 3.5 MHz, 4 MHz, 4.5 MHz, 5 MHz, 6 MHz, 7 MHz, 8 MHz, 9 MHz, 10 MHz, 12.5 MHz, 15 MHz, 20 MHz, 25 MHz, 30 MHz	21

2.2 Hardware Specifications

Specification of hardware utilized in the proposed log-scale comb-generator are shown in Table 2.

Table 2 Hardware Specification.

FPGA[3]	
Model	Xilinx Zynq 7010 SoC
CPU	Dual ARM® Cortex™-A9 MPCore™
I/O	2x USB2.0, Gigabit Ethernet
Logic Cell	28k Logic Cells
DSP Slice	80
ADC[4]	
Model	Linear Technology, LTC2145-14
Resolution	14 bits
Sampling Rate	125 Msps
Analog Input Range	1Vpp or 2Vpp
SNR	73 dB (typ.)
DAC[5]	
Model	NXP, DAC1401D125HL
Resolution	14 bits
Sampling Rate	125 Msps
SFDR	69 dBc (fo = 20.1 MHz, 125 Msps, 0 dBFS)
Output Voltage	1 Vpp
RF Combiner[6]	
Model	Mini-Circuits, ZFSC-2-6-S+
Frequency range	2 kHz to 60 MHz
Insertion Loss	0.3 dB (typ.)
Isolation	30 dB (typ.)
Amplitude unbalance	0.1 dB (typ.)
Phase unbalance	0.2 deg. (type.)
RF Coupler[7]	
Model	ZFDC-10-6-S+
Frequency range	5 kHz to 20 MHz
Directivity	40 dB (typ.)
Mainline loss	0.4 dB (typ.)
Coupling	11 dB (typ.)

3. Measurement Results of Log-scale Comb-generator

3.1 Frequency Characteristics and Spectrum Flatness

The frequency characteristics of the proposed comb-generator are shown in Fig.3. The only peak levels are shown in this figure. The black, red and blue lines indicate the case of both channel ON, the case of only ch1 ON and the case of only ch2 ON. Each frequency peak is adjusted to 90 dBuV after fine tuning. In the case that only one channel is active, the frequency response of the peak shows high-flatness of the output level of 90 dBuV±0.002 dB in the frequency less than 20 MHz. In the case that the both channel are active, the flatness of the frequency response of the peaks are degraded to 90 dBuV ±0.01 dB. The reason of the degradation of flatness is the influence of spurious noise generated from ch2 on the ch1 frequency range. The output level of 25 MHz and 30 MHz peaks are relatively higher than other output levels by approximately 0.1 dB. This is because the signal stability at 25 MHz and 30 MHz is worse than the stability of the lower frequency range.

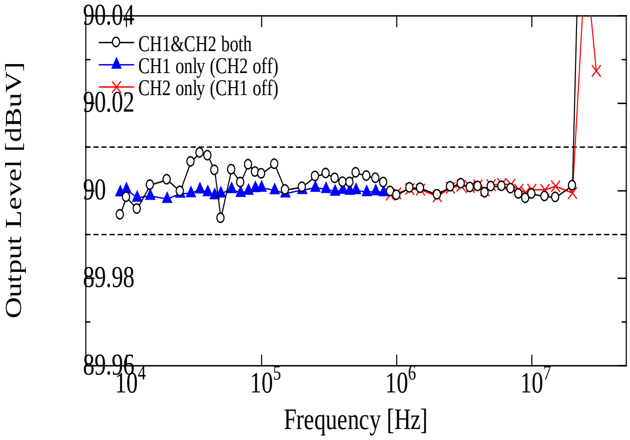

Fig. 3 Flatness of Peak Spectrum of Log-scale Comb-generator

3.2 Short-term Stability

The stability of the comb peak level is derived from the measurement of the standard deviation of the 10 times level measurements. The measurement results of standard deviation are shown in Fig.4. The line color in the figure shows the same situation as in the Fig. 4.

For the case of only one channel ON, the standard deviation is less than 0.003 dB in the frequency less than 20 MHz. For the case of both channel ON, although the standard deviation in the frequency range of 100 kHz to 1 MHz are increased, the maximum standard deviation is less than 0.01 dB in the frequency less than 20 MHz. This results show the good stability of the proposed comb-generator. The spectrum of 25 MHz and 30 MHz are slightly unstable and the standard deviation of the spectrum exceeds 0.02 dB.

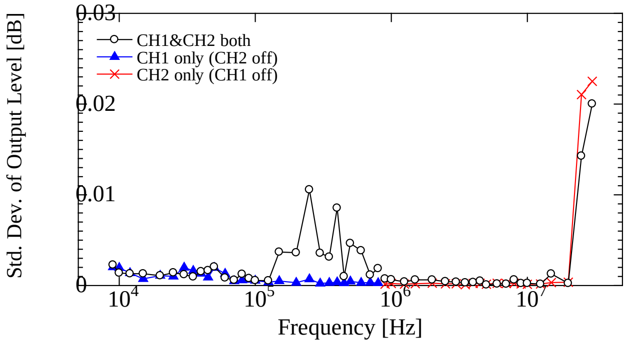

Fig. 4 Standard Deviation of Peak Spectrum of Log-scale Comb-generator.

4. Conclusions

In this paper, the log-scale comb-generator using FPGA-based arbitrary waveform generator are proposed. The proposed comb-generator can cover the frequency band of 9 kHz to 30 MHz and can generate the almost-equal-space comb spectrum in the frequency logarithmic scale. Additionally, the fine tuning of output level of each comb can be realized due to the use of FPGA architecture. After fine tuning for highly flatness of frequency response of comb spectrum, the output level of 90 dBuV ±0.01 dB is achieved. The standard deviation of the output level of the comb-generator is less than 0.01 dB in the frequency range less than 20 MHz, therefore the output spectrum of the proposed comb-generator is quite stable.

In the next step, we will try to make a limit-line comb-generator which proposed in the reference [8] using our FPGA-based arbitrary waveform generation architecture. By the use of this equipment, the amplitude of the electromagnetic fields radiated from this generator can be leveled off. Therefore, this signal generator can be used as a reference field generator. By the reference field generator, the RoF link system and the photonic electric field sensor system are easily calibrated and realize more accurate electromagnetic field measurements. The measurement results by RoF link system will be presented in the poster session.

Acknowledgments

This research is supported by the National Institute of Advanced Industrial Science and Technology (AIST), "2015 SANGIREN technical upgrade support grant".

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