UDC 621.391

DIGITAL SYNTHESIZER OF THE NONLINEAR FREQUENCY MODULATION SIGNALS ON SIMPLE FPGA

Khokhlov D. V.
e-mail: danylo.khokhlov@nure.ua
Scientific supervisor – Dr. Sci., Prof. Antipov I. E.
Kharkov National University of Radio Electronics, Dep. IRTIS,
Kharkiv, Ukraine

Features of the construction of tabular digital signal synthesizers using FPGA are considered. It is proposed to use a reversing adder for ROM addressing and install a controlled inverter before the DAC. This allows, on the basis of repeated use of the original signal recorded in ROM, to form a set of multi-segment signals with general nonlinear frequency modulation, a lower level of ACF side lobes and a large base value.

When processing linear frequency modulation (LFM) signals in radio engineering systems, ACF side lobes are an undesirable "byproduct" of compression. High side lobe levels (SLLs) complicate signal detection and separation. Therefore, much attention is currently being paid to nonlinear frequency modulation (NFM) signals, which provide significantly lower SLLs compared to traditional chirp signals.

Nonlinear frequency modulation generation is typically accomplished using direct digital synthesis (DDS). However, high-speed and high-precision generation of complex signals over a wide frequency range requires expensive microprocessors with large memory capacities and power consumption. Our work examines the possibility of creating a DDS device using a simple FPGA with minimal memory. The block diagram of such a device is shown in Fig. 1.

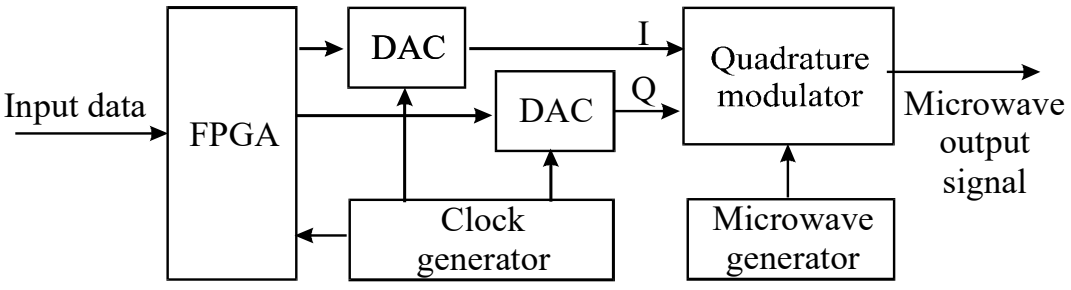

Fig.1

It based on a FPGA that generates digital samples of a synthesized NFM signal with a specified frequency, amplitude and initial phase. To minimize memory and resource requirements for the FPGA, we propose the following steps.

First, synthesis is implemented using a table of digital samples pre-stored in memory. These samples are sequentially extracted at a fixed clock rate and fed to the DAC. As shown in [1], this does not require complex processing and calculations. This approach allows the same data array to be used repeatedly. Changing the frequency and phase of the synthesized signal is achieved by changing the order of sample extraction.

Secondly, the FPGA incorporates a reversible adder (Fig. 2), which allows rapidly reverse of the sample extraction order. This makes it possible to generate inverse chirps and other types of chirps using the same sample table.

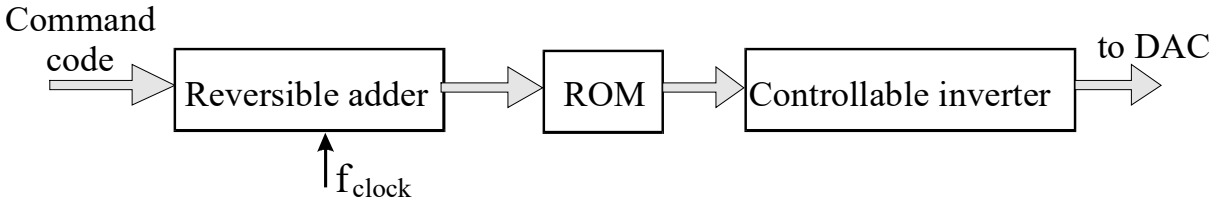

Fig. 2

Third, the FPGA incorporates a controlled inverter that allows for selective inversion some signal samples. In "spectral inversion" mode (only odd samples are inverted), this is equivalent to shifting the signal frequency by half the sampling frequency or mirroring the spectrum relative to a quarter of the sampling frequency.

The table presents the parameters of one-, two-, and three-segment NFM signals synthesized using the proposed hardware and software solution. Fig. 3 – 5 show the synthesis results – the amplitude spectrum and ACF of the signal.

Table

T1, μs	T2, μs	T3, μs	Δf1, MHz	Δf2, MHz	Δf3, MHz	max. SLL, dB	Main lobe width, rel. un. (level 0.707)	Fig №
40			6			-13,35	1.867	3
32	8	-	4	2	-	-17.16	2.054	4
8	32	8	2	2	2	-18.07(sec)	2.188	5

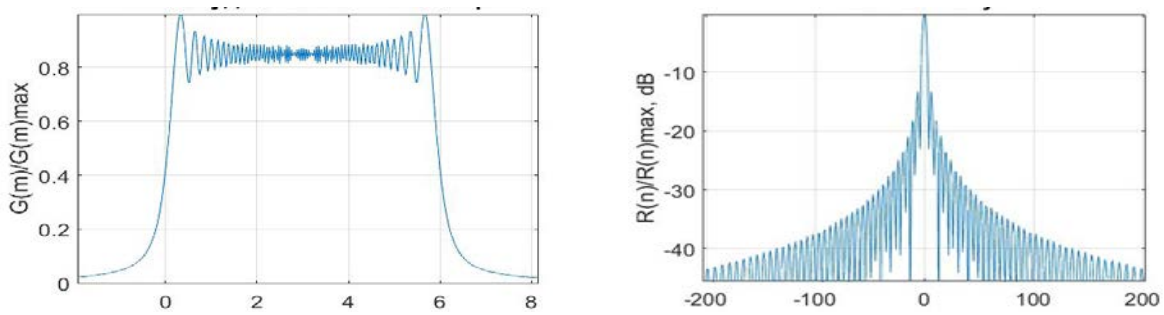

Fig. 3

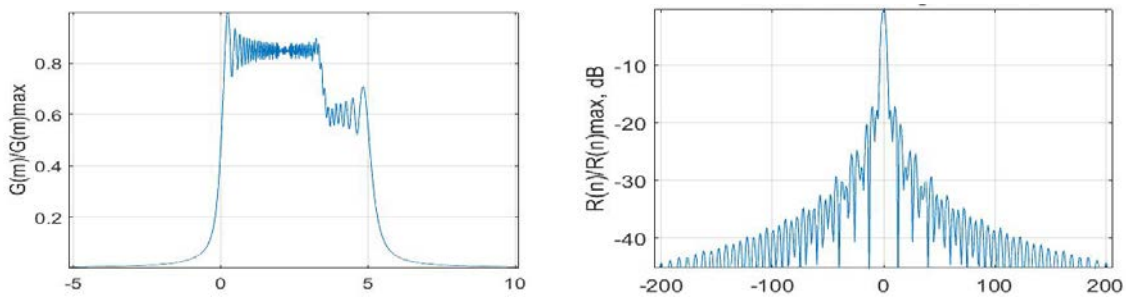

Fig. 4

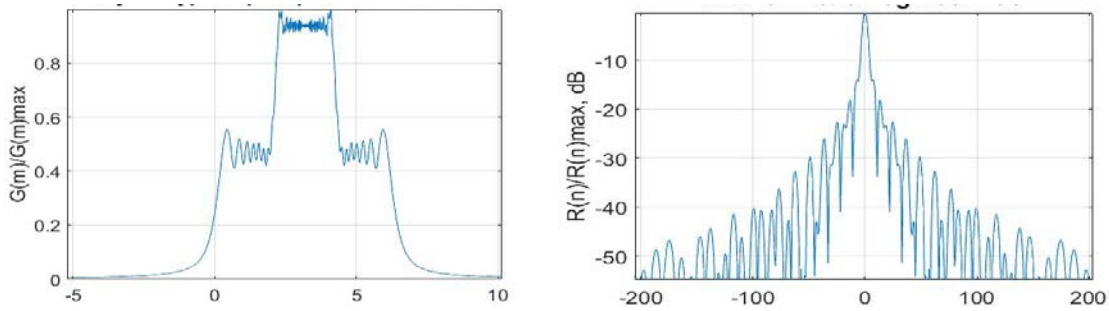

Fig. 5

Using a two- or three-segment NFM signal only slightly reduces the SLL. A significant reduction (up to –24 dB) is achieved using a two-segment reference signal, the spectrum and ACF of which are shown in Fig. 6. The spectrum and ACF of the converted five-segment NFM signal are shown in Fig. 7.

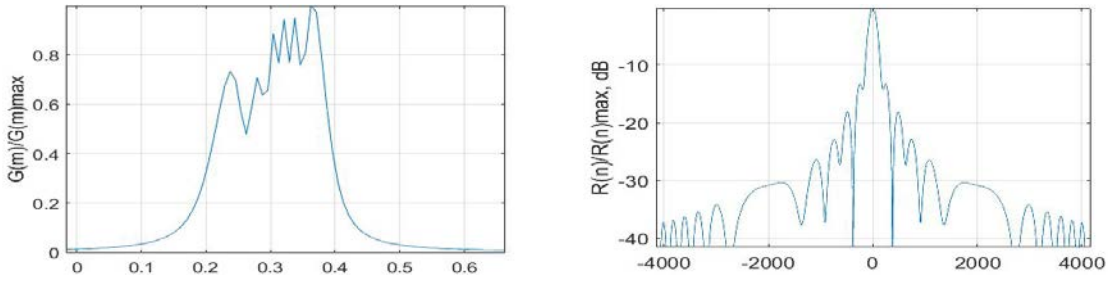

Fig. 6

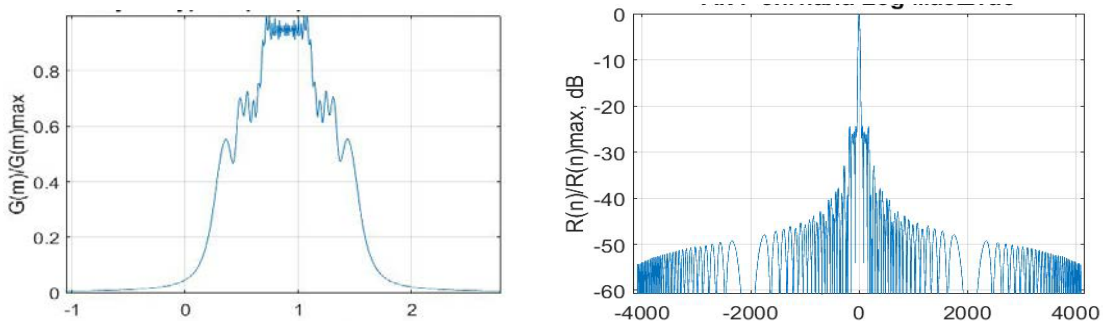

Fig. 7

Multiple using of signal samples in ROM allows to increase the duration and deviation (bandwidth) of the resulting NFM signal, thereby increasing the signal base. Thus, using table-based DDS with a multi-stage procedure for generating LFM signals based on their piecewise linear approximation significantly reduces the bandwidth with a single fixed reference signal in the FPGA ROM.

Reference

1. Хохлов Д. В., Никитюк О. Розширення функціональних можливостей табличних цифрових синтезаторів ЛЧМ сигналів // Матеріали 28-го Міжнародного молодіжного форуму «Радіоелектроніка та молодь у XXI столітті». Конференція «Інформаційні радіотехнології та технічний захист інформації». − 2024. – с. 481 – 484.