

Wideband RF Signal Generator Implementation for Demodulator/Receiver Testing in Systems of SDR

Predrag Jovanović, Predrag Petrović, Ninoslav Remenski and Branislav Pavić

Department of Radio communication

IRITEL A.D.

Belgrade, Serbia

pesccia@iritel.com

Abstract — In this paper, the design of a wideband RF signal generator for demodulator/receiver testing is presented. The design of test generator is based on direct digital synthesizer (DDS) and voltage-controlled oscillator (VCO), controlled by microprocessor. It provides generation of arbitrary waveform signal up to 4.5 GHz. Output signal level is adjustable with precision of 0.5 dB. Dynamic range of RF test signal generator is 130 dB. Generation of octal frequency shift keying, quadrature phase shift keying and amplitude modulation is described in this work. Results of spectrum measurements are presented.

Keywords — RF signal testing, Direct digital synthesis, Up-conversion, Software defined radio (SDR), Octal frequency shift keying, Quadrature phase shift keying, Amplitude modulation.

I. INTRODUCTION

Software defined radio (SDR) is radio system implemented by means of the software on some embedded platform [2]. This approach is quite opposite to classic hardware realization approach. Larger capabilities of digital processing provided ground base for rapid expansion of software defined radio systems. Software defined radio is multidisciplinary field of radio technique. It integrates system design with analog (RF) technique, digital design and software development. Signal generators are common devices in the field of software defined radio. RF test signal generator is a device that provides arbitrary waveform signal at its output. Demodulator/Receiver testing is the main aim of development of presented device [1]. Maximum frequency of signal generated by test generator is about 4.5 GHz. This upper limit frequency is determined by voltage-controlled oscillator of up-converter's module in signal generator. By means of user interface, all parameters for signal generation are entered. This way, great flexibility is provided to the user in terms of v of modulating signal shape. There are three signal control parameters which determine type of modulation: amplitude, frequency and phase. Hence, amplitude, frequency or phase shift keying is obtained. Many other modulation schemes are possible, such as linear FM, GMSK, AM noise etc. Also, combination of two control parameters is possible. Therefore, polar modulation can be generated by combining amplitude and phase parameter.

II. DIRECT DIGITAL SYNTHESIS

Wideband RF test signal generator is based on direct digital synthesis. Direct digital synthesis is frequency synthesis that produces arbitrary signal waveforms from fixed-frequency reference clock. Block scheme of direct digital synthesizer is shown on figure 1.

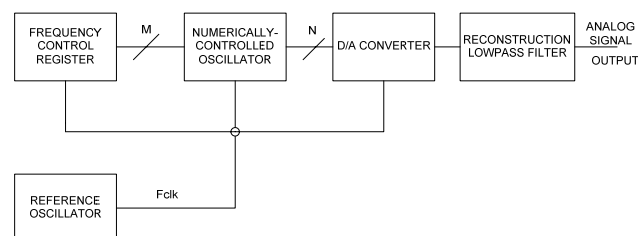


Fig.1 Block scheme of the direct digital synthesizer

Basic elements of direct digital synthesizer are: Numerically-controlled oscillator, reference oscillator and digital-to-analog converter. Reference oscillator provides reference clock for complete system. Resolution of direct digital synthesizer is determined by this clock. It also provides clock for numerically-controlled oscillator, which generates discrete-time, quantized version of desired signal waveform whose period is defined by digital word written to frequency control register. Sampled signal is then passed through digital-to-analog converter and filtered by lowpass reconstruction filter. At the output of direct digital synthesizer, analog signal appears.

For purpose of designing wideband RF signal generator, there are some basic conditions that ought to be satisfied. Direct digital synthesizer with high sampling rate is needed. Sampling rates close to 1 GS/s would be satisfying for purpose of building wideband, agile synthesizer. Important criterion is ability of direct digital synthesizer to generate frequency agile analog sinusoidal signal. For fine tuning, frequency resolution of RF synthesizer should be better than 0.5 Hz. Compatibility with other components on the board, in terms of communication, has to be provided. Also power consumption and compact dimension of chip shouldn't be neglected.

III. WIDEBAND RF TEST SIGNAL GENERATOR DESIGN

RF test signal generator uses direct digital synthesizer to generate various types of signal. Choice of direct digital synthesizer is determined by Need for high resolution, high output frequency and compact dimensions. AD9910 synthesizer satisfies all of these demands [8]. Block schematic of direct digital synthesizer AD9910 is shown on figure 2.

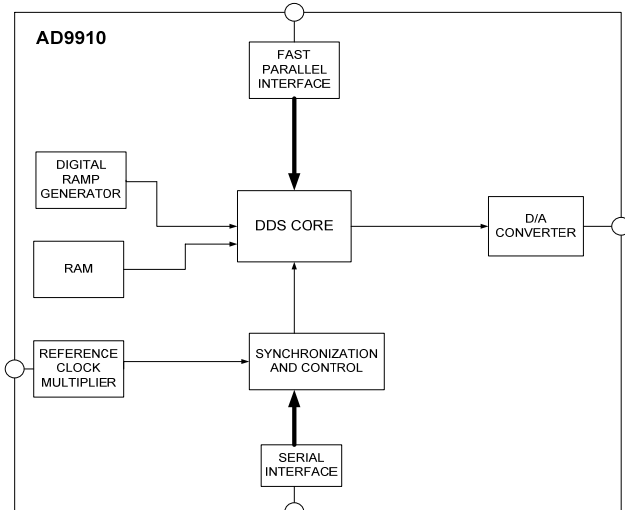


Fig.2 General block scheme of AD9910

As it can be seen from figure 2, basic blocks of direct digital synthesizer AD9910 are: DDS core, RAM, digital ramp generator and high resolution D/A converter. Direct digital synthesizer communicates with its surroundings by means of two interfaces: serial and parallel. Parallel interface allows higher rate modulations to be performed. This chip supports sample rates up to 1 GS/s. Hence, AD9910 is capable of generating frequency agile analog sinusoidal waveform up to 400 MHz. In order to obtain various waveforms, three control parameters are available: amplitude, phase and frequency. Control of AD9910 is achieved by programming its internal control registers via serial I/O port. AD9910 has an integrated static RAM, which is used to support various amplitude, phase and frequency modulations. Direct digital synthesizer is controlled by general purpose microprocessor. Microprocessor LPC2148 by Philips is used [9]. It's based on 16/32 bit ARM7TDMI-S™ CPU and has 512 kB on-chip flash memory and 32 kB on-chip static RAM. Maximum CPU clock available is about 60 MHz. LPC2148 communicates with AD9910 by SPI bus (serial communication). AD9910 is double buffered chip. Bytes sent by LPC2148 are loaded to serial I/O buffer of AD9910. Data contained in serial buffer are inactive. Therefore, LPC2148 sends strobe signal to transfer data from serial buffer to active registers of AD9910. To generate signal at high frequencies (above 400 MHz), up-conversion block is needed [3]. Up-converter is based on wideband frequency synthesizer with an integrated VCO. ADF4350 by Analog Devices is used [10]. Its output

frequency range is from 137.5 MHz to 4400 MHz. It has programmable output power level. This chip is very convenient because of its low power consumption and compact dimension. General block scheme of RF test generator is shown on figure 3.

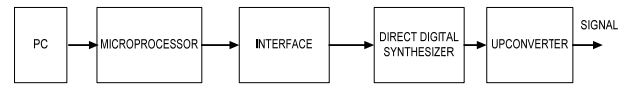


Fig.3 General block scheme of RF test signal generator

RF test signal generator is controlled by user interface software on PC. The great advantage of this device is compact dimension which allows high mobility and easily attained field testing. Power supply is provided by Ni-Cd batteries (aggregates). Power supply of RF test signal generator is 5 V. Power consumption of the system is about 700 mA. More detailed block scheme is shown on figure 4.

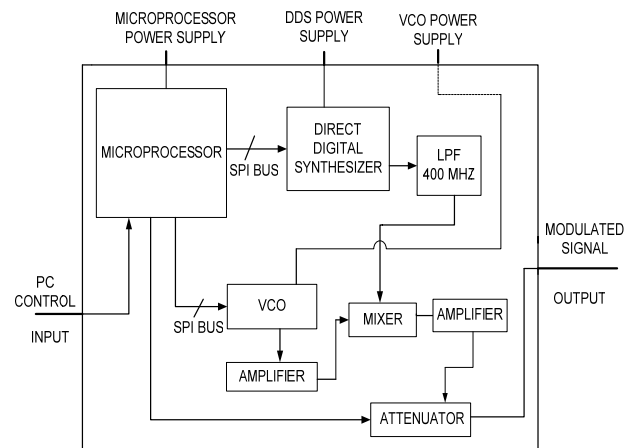


Fig.4 Detailed block scheme of RF test signal generator

During mixing process, a lot of unwanted spectral components are generated. In other words, spectrum is very polluted. Filtering is needed to extract useful signal. Bandpass filters are used for extraction of spectrum of useful signal. Filtered analog signals are then passed through digital attenuator controlled by microprocessor. It's used 4-bit digital attenuator HMC629LP4 by Hittite [11]. It covers frequency range DC-6 GHz. It allows 3 dB step attenuation. Maximum attenuation is 45 dB. Also, two RF amplifiers with 15 dB gain are used (HMC636ST89 by Hittite) [12]. Power supply of both amplifiers is 5 V. First amplifier adjusts signal power level that goes to the mixer. Second amplifier is used to compensate conversion loss in mixing process. Signal level at the output of RF test signal generator ranges from -125 dBm to 5 dBm. Therefore, 130 dB dynamic Range is obtained. Filtration of output signal is performed by means of analog filters. Depending of frequency of signal to the output of the RF test generator, different filter's topology has been implemented. For frequencies up to 1 GHz, LC ladder filters are applied.

Above 1 GHz, parallel coupled half-wave resonator filters in microstrip technology are in use. Layout of bandpass filter above 1GHz in implemented in microstrip technology is shown in figure 5.

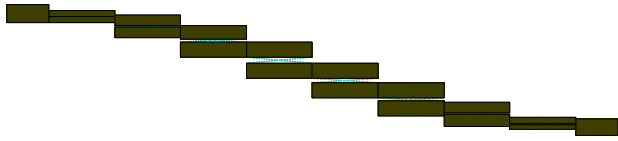


Fig.5 Layout of analog filter above 1GHz

Modulation based on amplitude, frequency and phase signal control parameters variation is possible. Carrier can be modulated by random signal programmed into flash memory of microprocessor. This provides great flexibility of generating various modulation schemes. In this paper, octal frequency shift keying, quadrate phase shift keying and amplitude modulation are presented. User application on PC controls selection of wanted modulation. Communication between PC and RF test signal generator is based on RS232 interface. Baud rate used for communication is 19.2 kB/s.

Presented RF test generator consists of software and hardware parts, which had to be designed separately. Substrate used for PCB is *Rogers4003*. Its height is 0,813mm, metallization thickness is $t=0,017\text{mm}$ and its dielectric constant is $\epsilon_r=3.55$. Decision for choice of this material is based upon its acceptable losses ($\tan\delta=0.0021$) at higher frequencies. Also, *Rogers4003* PCB substrate is used very often for high speed, high frequency PC boards. RF signal test generator is one of these high frequency applications.

Various software tools are used in design process of wideband RF test signal generator. For hardware design (PCB), Design Explorer DXP (Altium Limited) is used [5]. For software development, IAR Embedded Workbench 4.0 is used [4]. Downloading hex file into memory of microprocessor is provided by Flash Magic software (NXP Semiconductors) [7]. User interface is fully developed in Microsoft Visual Basic 6.0 program package. For analog filter design AWR Design Environment 2006 is used [6].

IV. MEASUREMENTS RESULTS

In this section, measurements results of three types of modulations are shown. All measurements have been performed on spectrum analyzer (10 GHz upper limit frequency). Various types of modulations are generating with carrier frequencies below 4.5 GHz. First, octal frequency shift keying is obtained. Carrier frequency is 2900 MHz. Basically, octal frequency shift keying is generated at central frequency 100 MHz with spectrum width 500 KHz, and then, using carrier frequency at 2900 MHz, frequency modulated signal is

shifted to 2800 MHz (lower sideband). Higher sideband is filtrated with analog bandpass filter. Spectrum of octal frequency shift keying signal is measured on spectrum analyzer. This spectrum is shown on figure 6.

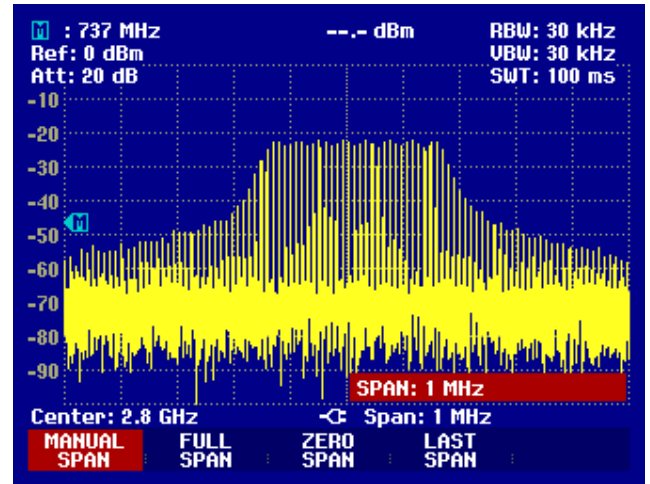


Fig.6 Octal frequency shift keying

Second, quadrate phase shift keying (QPSK) is obtained and measured. Carrier at 500 MHz is modulated by four-phase (level) quadrate pulse train at 100 MHz. Used phase levels are: 0° , 90° , 180° and 270° . Upper-side band at 600 MHz is used. Lower side band is rejected by means of analog filter. Spectrum is observed on spectrum analyzer. Result is shown on figure 6.

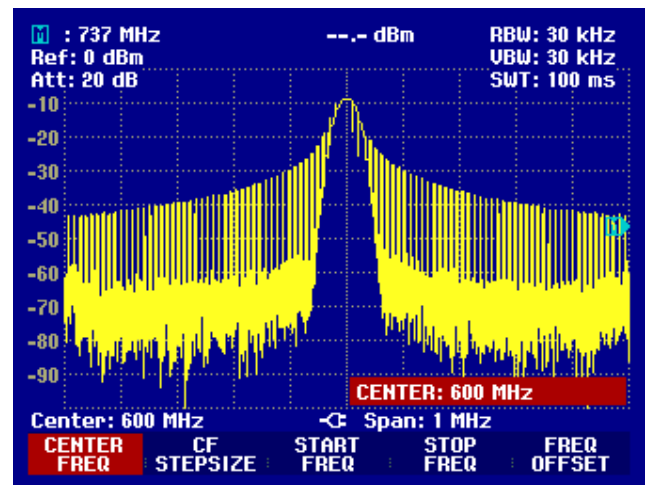


Fig.7 Spectrum of QPSK signal

Third, AM signal is generated and measured. AM signal is generated at 100 MHz and then shifted to 1100 MHz (lower-side band) with carrier at 1200 MHz. Higher side band is rejected by bandpass filter. Hence, this spectrum is shown on figure 8.

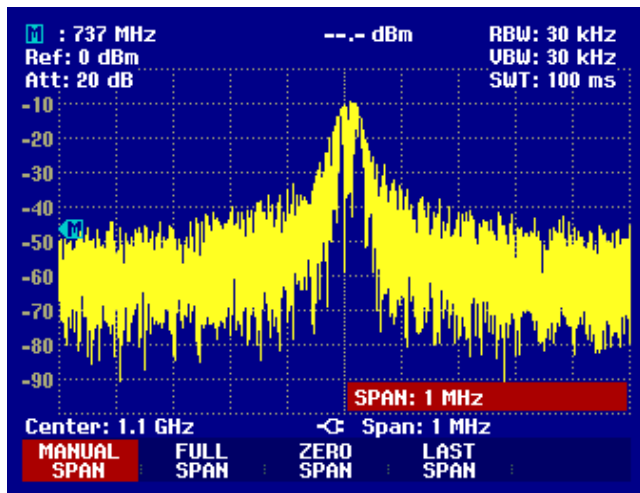


Fig.8 Spectrum of AM signal

V. CONCLUSION

In this paper, the design of wideband RF test signal generator was presented. Signal generation was based on direct digital synthesis. AD9910 direct digital synthesizer was used, controlled by LPC2214 microprocessor. Up-conversion was performed by ADF4350 wideband frequency synthesizer with integrated VCO. With this generator, arbitrary signal waveforms were provided. Upper limit frequency was 4.5 GHz and dynamic range was 130 dB. Octal frequency shift keying, quadrature phase shift keying and amplitude modulation were obtained and described. Measurements have been performed on spectrum analyzer, where spectrums of signals have been observed. Versatile modulations could be generated using this RF signal test generator. One of the most important applications of RF test signal generator is for testing demodulators in radio receivers. Due to its compact dimensions and low weight, RF test generator is highly mobile. Field testing is also very conveniently performed by this device. Further improvements in terms of broadening frequency and dynamic range are part of current research.

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