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Computer set for processing radio signals

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The work relates to digital signal processing of radio frequencies. Developed and implemented a computer program that allows to work with radio signals, ie. filtering, demodulation, strengthening and radio physical system whose task is to match the radio frequency range from 0 to 30 MHz for the possibility of processing them into discrete signal by the analog to digital which is standard equipment on every sound card of the PC. The use of the computer significantly expanded capabilities of the system and provided the ability to preview spectrum radio signal on the basis of which it is possible to assess the type and quality of the received signal.

KEYWORDS: software-defined radio, microcontrollers, programming, electronic design, object-oriented programming, digital signal processing

1. Introduction

The development of digital technology greatly expanded the capabilities of existing solutions in the field of telecommunications and gave rise to the creation of standards for radio competing with their wired counterparts. Initially, the analog signal was supplemented only by some digital components, mainly related control devices. There is a tendency to transmit all the information in the form of digital modulated signals. Evidenced by the introduction of DVB-T in the whole country and broadcasting standard DAB + running 1 October 2013. Also in wavelengths long, medium and short, which are mainly used analog modulation of amplitude, introduced international standard DRM, and other digital transmission technology. The range of frequencies is particularly interesting because of the ability to cover large areas of the signal from one transmitter. The use of digital transmission methods in this case gives interesting results both qualitative and economical. However, there was a sense that the introduction of new systems requires the existence of reception facilities to enable decoding of digital signals. Solution in the form of dedicated receivers are expensive and have many technological limitations. The use of a computer application, the flexible due to the possibility of development significantly decreases financial expenditures and allows the user to more easily propagate modern standards. On the basis of this assumption at work, a project of computer software processing radio signals in both analog and digital. A prerequisite for the application is to provide a radio signal of appropriate

frequency to the ADC, which is part of the computer's sound card. This was achieved using a specially designed radio-controlled from a computer application that can process signals in the range from 0 to 30 MHz fixed frequency with a value of 12 kHz.

2. Project of programmable radio application

2.1. Conceptual design and choice of development environment

The concept application project of the computer system processing radio signals was based on the following assumptions:

- application on a popular operating system,
- working with computer audio devices (read signals from the input and output signals generation)
- signal processing with a minimum of delay,
- visualization of the received signals,
- clear and intuitive user interface,
- ability to work with a physical system designed programmable radio.

The implementation of the guidelines began with the selection of the operating system, which will work application development platform, development environment and application model. A huge variety of available models gives a wide range of choice. However, to achieve high application compatibility selected the following configurations:

- development Platform NET Framework 4.0 from Microsoft,
- operating system capable of running .NET 4.0,
- development environment Visual Studio 2012 Express for Windows Desktop,
- object model created on the basis of high-level language C #,
- graphical interface program created in WPF (ang. Windows Presentation Foundation).

.NET Framework Development Platform is a powerful tool used to create and manage applications built on the basis of high-level languages. Its main feature is the use of runtime (CLR called. Common Language Runtime). This tool is a kind of virtual machine that allows the application to run on any system with an installed .NET. Code written in a supported platform high-level language during compilation is translated into a standardized CIL bytecode (called. Common Intermediate Language). When you run the application on the target machine, the CLR compiles the CIL code into a machine in an optimal way for the CPU installed on your device. In addition, the runtime ensures the correct operation of the application, occupied memory resources, and error handling. NET platform includes many ready-made libraries allow use of the hardware capabilities of the computer.

In the present project, due to the use .NET development environment using Visual Studio 2012 Express for Windows Desktop Microsoft. It is a full-featured suite of tools for creating window applications, console and in the form attached libraries using one of the three available programming languages. To create a program selected language C #, which is a modern, fully object-oriented, designed specifically for .NET high level programming language. The object is to use a hierarchical classes interconnected with each other, thanks to the structure of an application written in C # is more transparent and intuitive. The superior class of uniting all the other class is of type Object. The great advantage is that some processes are automated, for example. Releasing the unused memory objects, which facilitates the work of the programmer [4].

Environment Visual Studio allows you to create windowing applications in two different systems, Windows Forms (WF) and Windows Presentation Foundation (WPF). The project uses WPF system to create the structure of graphical user interface using XAML language (called. Extensible Application Markup Language) based on XML. In addition, the system of WPF user interface, operations are supported in hardware through the use of graphic card processor [7]. The general principle of the proposed application of the programmable radio is presented in Fig. 1.

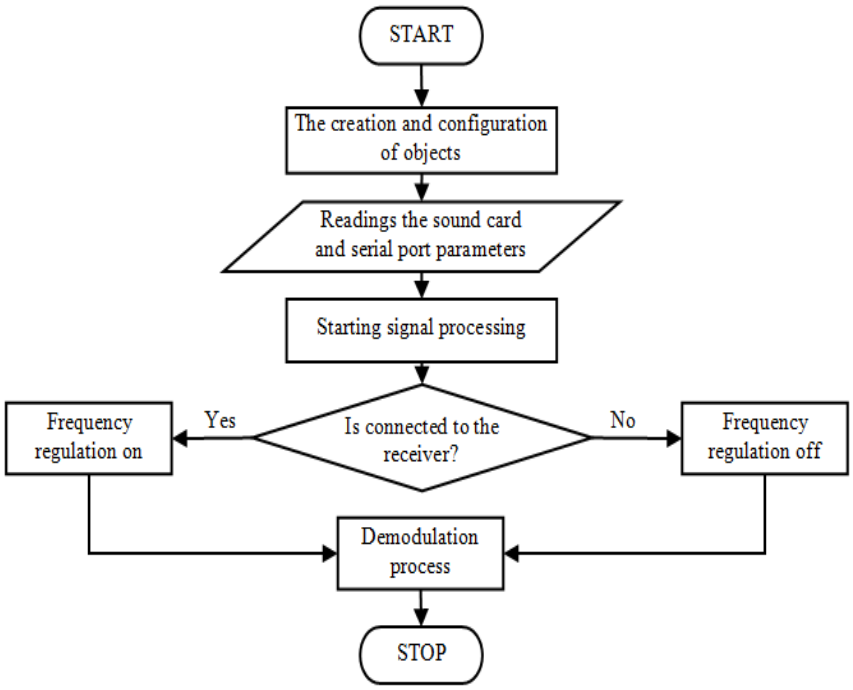

Fig. 1. Algorithm of the application of the programmable radio

2.2. Communication via serial port

One of the project application is the possibility of communication with the receiver. In .NET library responsible for communication via the serial port is System.dll. It includes a built-in SerialPort class that provides a complete co-operation with the serial port. The project uses a fixed baud rate of 9600 baud value. You can select the appropriate port and multiple networking and closing the connection while using the program. Also used to prevent connection security in the absence of the device in the computer where the application is running. Figure 2 shows the object creation portSzeregowy initiating operation.

```
portSzeregowy = new SerialPort(listaPortowCbx.SelectedItem.ToString(),
9600, Parity.None, 8, StopBits.One);
```

Fig. 2. Initiation object portSzeregowy

The transmission frame used in communication always consists of 8 bytes. The data are transmitted in the form of a single character occurring in the amount of one character per byte. Since the value of the transmitted frequency is not always made up of so many digits, hence the use of automatic replenishment of empty bytes zero value using the method PadLeft (). Figure 3 shows the command recording registry data to the serial port.

```
portSzeregowy.Write(czestotliwosc.ToString().PadLeft(8, '0'));
```

Fig. 3. Command that send data to a receiving device

The value of the frequency change is sent when an event occurs MouseWheelEventsArgs which is initiated rotation wheel mouse when the cursor is within the control czestotliwoscLbl Label class. Sent data are taken from the Content property of the control. One rotation changes the value up or down by a specified step, which is represented by the SelectedIndex property of the ComboBox control krokCbx class.

2.3. Computer process for detecting and demodulating

The main task of the proposed application is the ability to demodulate radio signals received by an external circuit. This requires the control of the sound device in your computer, which is equipped with the appropriate analog to digital converters. Standard components .NET do not fully support your sound card, hence the use of an external library Bass.NET greatly expanding the possibilities of collaborative software in this matter. It provides comprehensive support for audio streams, and thus their creation, capture, processing of the data contained within, and many others. A special collection of delegates gives

you complete control over the processed signals. Library Features making it possible for the signal processing methods in such a way that it was possible to obtain the original signal from the sender. In the process the following steps are performed:

- capturing the audio stream from the input analog-to-digital
- downloading data from the audio buffer,
- data processing (filtering, frequency conversion, demodulation)
- write processed data to the buffer,
- emit sound received by the DAC.

Designed in the application algorithms allow demodulation analog signals AM, SSB and digital BPSK. In the first case, the data copied from the buffer are converted to form a complex, and then calculated the module from its value. This algorithm works in the same manner as an envelope detector classical [2, 5]. Piece of code performing this operation is shown in Fig. 4.

```
if (demodulator == TypDemodulatora.AM)
{
   for (int i = 0; i < length / 2; i++)
   {
      sygnalZespolony = Poziom*strumienDzwieku16bit[i];
      strumienDzwieku16bit[i] = (short)(sygnalZespolony.Magnitude);
   }
}
```

Fig. 4. Code showing the AM signal demodulation proces

Receipt of the original signal from the modulation of single side is a task more difficult, because the signal is devoid of the carrier wave to be generated in the receiver. For this purpose, a special class implements the oscillator, which allows you to generate sine waves with frequencies of acoustic. In a first step, the VFO signal is generated, by which the frequency of bringing down and producing composite components, which in the next step are multiplied by the composite carrier signal generator BFO frequency of 1.5 kHz. Depending on the type of the received sideband imaginary composite signal is subtracted (for LSB) or added (USB) to the actual value. In both methods of demodulating the received line input signal is first filtered using methods available in the library Bass.NET. Figure 5 shows the implementation of the LSB signal demodulating method [2, 5].

The application also uses a digital signal modulation decoder PSK31. It works by measuring the phase of the signal and on this basis to determine the logical value of the transmitted symbol. Since PSK31 signal is transmitted in the standard BPSK, there is a need to determine only two phase states. After the Fast Fourier Transform is defined sign of the real part obtained for the band, which corresponds to the frequency of the signal and on this basis a decision is made to assign an appropriate value to a variable logical.

```
if (demodulator == TypDemodulatora.LSB)
{
   for (int i = 0; i < length / 2; i++)
   {
      vfo.GenerujSygnal();
      bfo.GenerujSygnal();
      sygnalZespolony= new Complex(strumienDzwieku16bit[i]
      *(Poziom*vfo.WyjscieCosinus), strumienDzwieku16bit[i]
      *(Poziom*vfo.WyjscieSinus));
      strumienDzwieku16bit[i]=(short)(sygnalZespolony.Real*
      bfo.WyjscieCosinus - sygnalZespolony.Imaginary*bfo.WyjscieSinus);
   }
```

Fig. 5. Showing a code of SSB signal demodulation process

2.4. Program interface and visualization of the received data

Graphic design of the application was provided to work with the minimum screen resolution of 900 510 pixels. All program options are available in the main window, which is divided into three parts. In the first (upper part of the form) are options for configuring the application, choice of audio devices, gain control, selection of the COM port, with the help of which the application is to communicate with the receiver and the establishing the connection. In the central part of the form are set closely associated with radio function, that is, the choice of demodulator, the tuning and the main panel allows tuning the connected device. In the third section of the window is a graph of the frequency spectrum of a signal from the audio input. The functions that are implemented using the built-in Visuals class library structure Bass.NET. The frequency spectrum is generated cyclically as a bitmap and displayed in a reserved spot. The use of technology to create a WPF interface also allows you to create different patterns and skins for the appearance of the program. Figure 6 shows the main screen of the application developed.

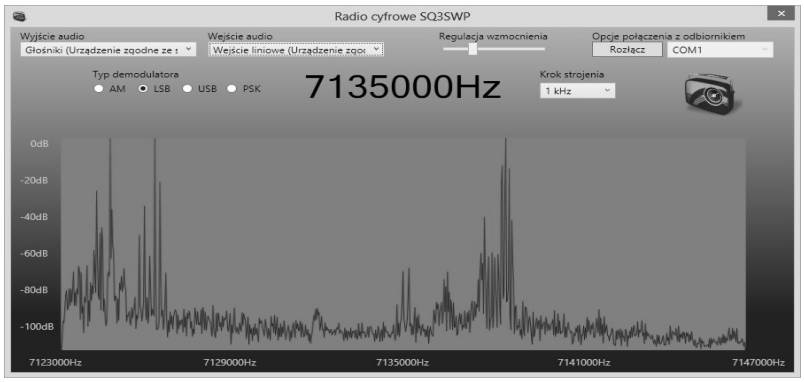

Fig. 6. Main window of the application

3. Receiving circuit

3.1. Properties of the circuit

Developed receiver has the following features:

- reception of radio signals in the range of 0 to 30 MHz,
- adjustment to the input line-in sound card PC (bandwidth, frequency, signal level),
- complete control system using a microcontroller (infinitely adjustable frequency control components and devices to communicate with a PC via a serial port emulation system RS-232),
- achieve high processing parameters (sensitivity of 2 μV, selectivity not exceeding 12 kHz, low noise to 6 dB) by choosing the right kind of systems,
- the use of the finished module of the programmable digital frequency synthesis as a tunable generator VFO with high stability and smooth adjustment of the frequency,
- mobility of the system.

These parameters were obtained using a super heterodyne receiver type Triple conversion. In order to attenuate the signal at the receiver input mirror using low-pass filters and the selected value of the first intermediate frequency of 5.5 MHz Subsequent conversions allow for an adequate signal filtering and matching it to the operating frequency of the analog-to-digital computer sound card. Figure 7 shows a block diagram of a receiver designed.

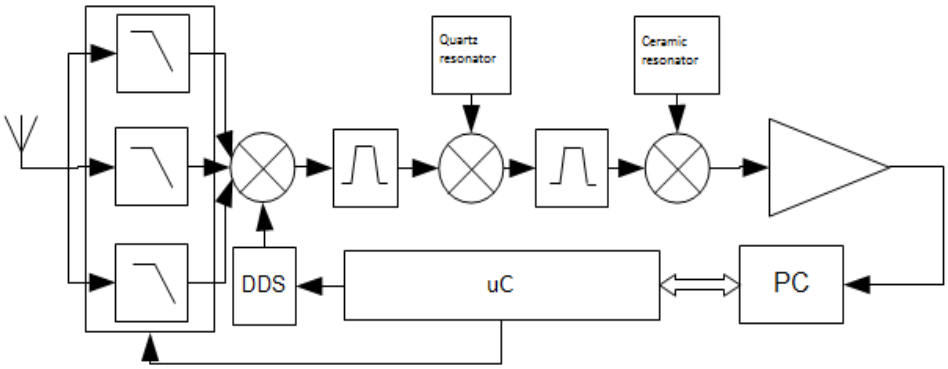

Fig. 7. Block scheme of the receiver

To develop a wiring diagram and PCB design environment used free KiCad available Open Source license. The application allows you to create fully-fledged set of files, including technical documentation and files enabling start of mass production using digital equipment to create printed circuit boards.

3.2. Local oscillator with adjustable frequency values

Design and construction of analog frequency generators for a wide range of jobs and stable parameters is difficult. The components of such systems in the form of capacitance and inductance change their properties depending on temperature, mechanical stress and other various types of anomalies. The generated frequency is changing and it is difficult to synchronize the receiver with digital modulation requires stable parameters. It becomes necessary, therefore use another generator providing wide operating band and high stability. To meet these requirements in the present draft system uses digital frequency synthesis (DDS. Direct Digital Synthesis) AD9850 from Analog Devices. Figure 8 shows the internal structure of the function blocks of the AD9850.

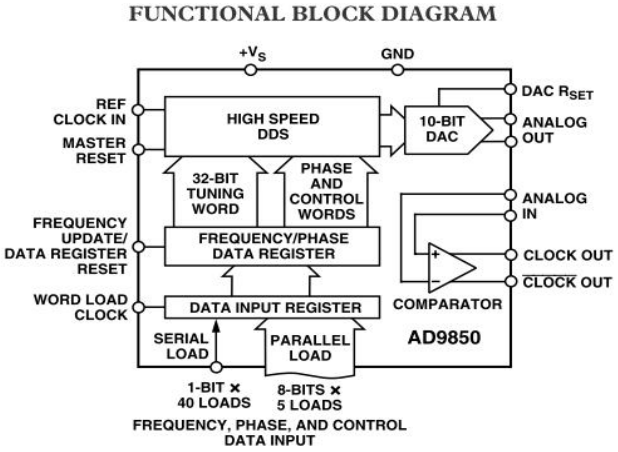

Fig. 8. Function blocks of the AD9850 [1]

The selected system following parameters [1]:

- maximum frequency of the reference signal generator 125 MHz,
- maximum output frequency of 62.5 MHz for sine wave and 1 MHz for rectangular,
- output level of about 1 Vpp (peak to peak voltage)
- supply voltage from 3.3 to 5 V,
- power consumption of 155 to 380 mW,
- control frequency value by 40 bit word (32-bit refer to the frequency which gives a resolution of 0.03 Hz for the 125 MHz reference clock, 8 bits is responsible for the phase and configurations)
- the ability to adjust the phase of the output signal,
- possibility of programming using one serial input or eight parallel inputs.

Use of the system as a local oscillator in a radio communication equipment is possible by adapting the output sound to the possibility of mixing processing by the system. These requirements meet the finished module HC-SR08 shown in Fig. 9.

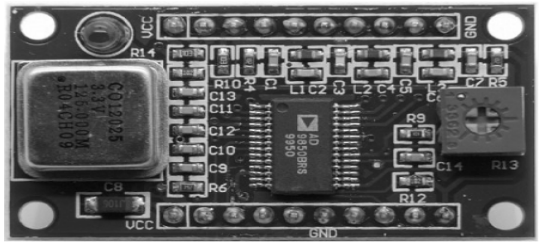

Fig. 9. Module HC-SR08 generator

The module has an integrated 125 MHz generator and a built-in low-pass filter limiting the frequency of the sinusoidal output signal to 40 MHz. An additional advantage is the output pins of the module, which greatly facilitates the assembly of printed circuit board. Power is indicated by the lit LED. The system uses a combination of the snap, which in the future is also able to use the generator in other devices. Sinusoidal output signal is applied to the input 6 NE612 mixer. The frequency of the output signal is set by the microcontroller, which on the basis of information from the PC generates the appropriate word bit fixing the frequency of the digital generator.

3.4. Circuit board design

Designed plate has a rectangular shape with dimensions of 17 to 7 cm and a thickness of 1.4 mm. Signal path width is 0.3 mm while the feed of 0.38 mm to 0.5 mm. The aperture size depends on the element used. In the areas left unused conductive layer connected to the ground. Throw the connections shown in Fig. 10.

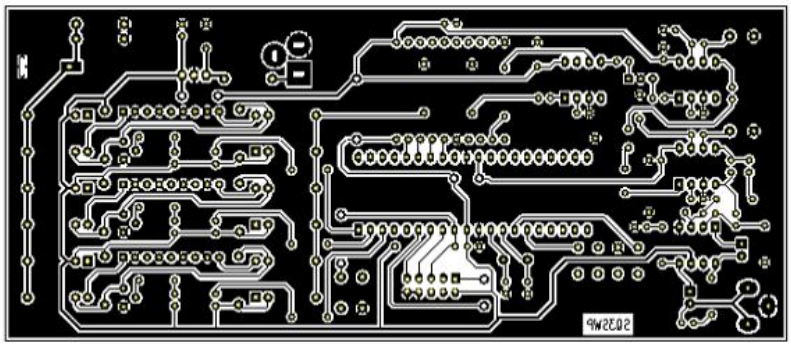

Fig. 10. View of a printed circuit board connections

KiCad software after installing additional plugin allows you to preview the view three-dimensional model of the proposed system. With this function it is possible to present the real look of the future system. The Figure 11 shows a three-dimensional model of the programmable radio receiver.

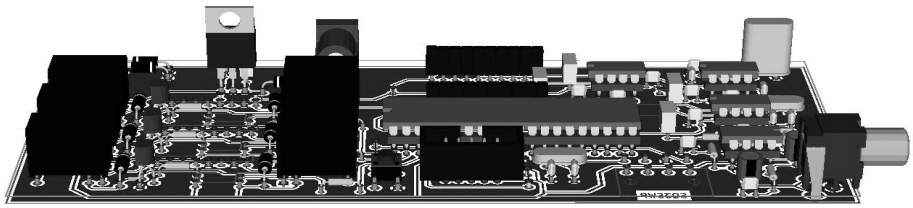

Fig. 11. Dimensional model of the receiver

3.5. Microcontroller software

Microcontrollers offer very broad ability to configure and are able to implement complex functions. Achieving the desired effect requires a program on the basis of which the system will perform the following tasks:

- during the launch adjust reference start frequency, which is also a function of controlling the operation of the generator frequency
- creation and calculation of variables for the selected frequency parameters of the serial communication interface UART and its initiation, as well as launching function interrupt the main program loop when receive the data,
- during an interrupt receiving adequate amounts of data,
- data conversion from ASCII characters received on the numeric format,
- setting the bits of Port responsible for the control circuit filters, start calculating methods of word bits required to set the frequency of the generator, send the information to the module generator
- ability to restore all variables to the initial state and restart from the first step, using for this purpose an external reset button.

Program runs in a loop. If the system registry data receiving display information about the start of the loop transmission is interrupted and the transition of the program to the function implementing the downloading of program memory. When the buffer is completely filled with the conversion of the received data from ASCII format integers, which is required to calculate the frequency control word bit and drive the appropriate input circuit high frequency. Then, based on the available data generation takes over the bits sent serially to the module generator. After performing these operations, the microcontroller goes into an infinite loop and waits for the next interrupt from the receiver UART port. In the event of malfunction of the program it is possible to set all the variables and outputs to the initial value by pressing the reset button.

4. Example of signal reception

In order to assess the performance of the receiving module attempts were made to radio. Figure 12 shows a strong signal station north-Korean working in the system of amplitude modulation, giving the city Kujang located about 7600 km from the receiver.

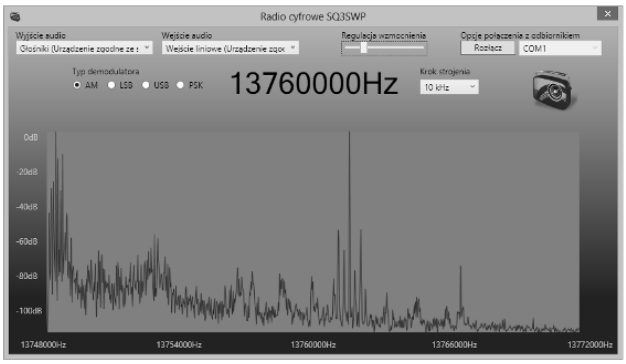

Fig. 12. Signal station Voice of Korea

Figure 13 shows the received transmission amateur band 40m. Station RA3GT worked with single-sideband modulation LSB and is at a distance of about 1300 km from the receiver.

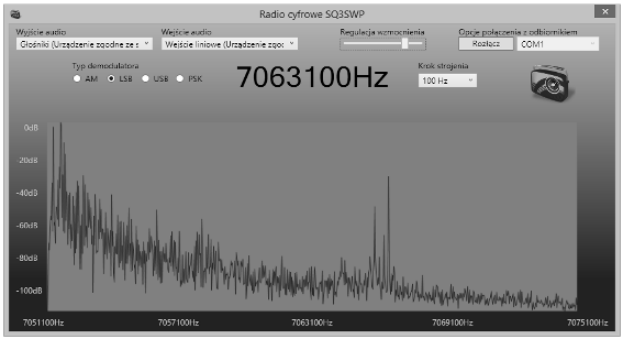

Fig. 13. Amateur station RA3GT working with LSB modulation

Also carried out the test signal receiving commercial stations broadcast in digital standard DRM. To decode the data stream used Dream program. Achieved excellent results taking a digital signal in the short wave band with excellent quality (SNR of 19.6 dB) at a distance of about 1500 km. Figure 14 shows the window Dream during reception of this signal.

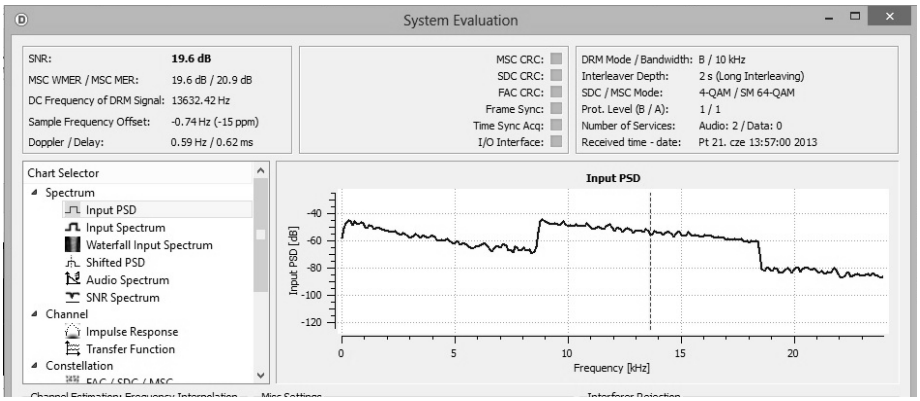

Fig. 14. Dream application window while receiving station on DRM

5. Final remarks

Development of the overall radio strives to continuously improve the quality and reliability of transmitted signals, as well as environmental reasons achieve the highest efficiency rate. of the programmable digital radio systems greatly facilitate these activities because their creation and use is highly desirable. It is possible that in the future any PC computer will be standard equipped with a module for working with radio signals in a wide frequency range.

Presented in this paper is a versatile receiver radio device. When its use has been made clear radio reception from a distance of over 10,000 km. The stable local oscillator is also possible for the synchronization of digital signals, which is difficult to achieve when using analog generators. Digital control with a PC significantly easier to work with the device, which increases comfort. The current design also allows the extension capabilities of the device, eg., by increasing the scope of the receiver to a maximum of 500 MHz. It is also possible conversion circuit in such a way that it fulfills the function of the transmitter. These benefits are available through the transfer function of modulation and demodulation for computer application.

Presented work proposes the use of a computer program having the following characteristics:

- electronic control unit receiving,
- demodulation of analog amplitude modulation AM, SSB,
- detection of digital signals PSK31,
- working with different types of sound cards,
- the ability to expand with new features without the need for intervention in the electronics of the receiver,

- demodulation of signals from different receivers (provided the corresponding frequency of the signal),
- display of the frequency spectrum of the input signal,
- gain control signal
- support for serial port.

It seems that the use of the project and .NET C # language allows you to create interesting programming constructs with advanced handling characteristics, as well as aesthetic. It creates an application can be used successfully in many operating systems. In the future, it is possible after applying some modifications, for example. Putting it through ASP.NET page managed network and providing global access to a receiver located in a specific location.

The use of digital radio standards also gives ample opportunities in the power control. Taking into account the economic factor, the method of communication may be particularly advantageous.

References

[1] AD9850, datasheet, [Access: 28.04.2013], Access in World Wide Web: <http://www.analog.com/static/imported-files/data_sheets/AD9850.pdf>

[2] Haykin S., Systemy Telekomunikacyjne Tom I i II, Wydawnictwa Komunikacji i Łączności, Warszawa, 1998.

[3] Hosking R. H., Software Defined Radio Handbook Eight Edition, Wydawnictwo Pentek, Inc. 2010.

[4] Sharp J., Microsoft Visual C# 2010 Step by Step, Microsoft Press, USA, 2010.

[5] Szabatin J., Podstawy teorii sygnałów, Wydawnictwa Komunikacji i Łączności, Warszawa, 2003.

[6] Wprowadzenie – Platforma.NET [w:] MSDN, [Access: 10.06.2013], Access in World Wide Web: <http://msdn.microsoft.com/pl-pl/library/wprowadzenie--platforma--net-framework.aspx>

[7] Wprowadzenie do WPF [w:] MSDN, [Access: 14.04.2013], Access in World Wide Web: http://msdn.microsoft.com/pl-pl/library/ms754130.aspx

[8] Youngblood G., A Software Defined Radio for the Masses, Part 1, [Access: 17.03.2013], Access in World Wide Web: <http://www.flex-radio.com/Data/Doc/qex1.pdf>