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Radionavigation field monitoring in the landing area using software-defined radio receiver

The model of the measuring receiver using SDR technologies for monitoring the radio navigational field in the landing area. The structure of the receiver and the result of the measurements are given.

The growth of aviation and the urgent need to reduce fuel consumption and emissions demand increased airspace and airport capacity and a focus on providing the preferred trajectory to each aircraft. Aircraft operators also require efficiency gains via approaches with the lowest possible minima and the significant safety benefits of vertical guidance. GNSS-based services can meet these goals and have already provided significant safety and efficiency benefits to many aircraft operators worldwide (USA, and EU-members mainly). Following this trend, Ukraine started GNSS implementation in aviation as well. Paper [1] addresses main aspects of Performance Based Navigation (PBN) implementation in Ukraine.

According the requirements and methodology provided in the Manual on Testing of Radio Navigation Aids [2,3], GNSS monitoring and testing should be performed, to confirm the ability of GNSS signals to support flight procedures in accordance with Annex 10 [4].

The safe operation of an aircraft landing based on GNSS signals depends on the performance of navigation receiver and accuracy of its coordinates determination, which depends on the accuracy of atmospheric parameters estimation [5] and surrounding electromagnetic environment [4]. Therefore, an important scientific and technical problem is monitoring and control of the radionavigation field and electromagnetic environment in the approach and landing area in order to increase the safety of aircrafts using GNSS technology [6-9].

Currently, multichannel scanning receivers are used for radio monitoring. They perform constant automatic control and radio signals search at predetermined frequencies. It should be noted that the efficiency of radio monitoring depends not only on the availability of expensive equipment (frequency meters, field indicators, spectrum analyzers, broadband antennas, band filters, low noise antenna amplifiers, high-frequency cables with small losses), proper installation, but also on the methods of data analysis, qualification and experience of radio operators. Radio broadcast monitoring is a constant and intense work of qualified specialists in identification, measurements of radio signals parameters, recording, storing and processing of the obtained information.

Radio monitoring is able to solve the following main tasks for providing information security of the object:

- detection of unauthorized radiation devices and their localization (jamming devices);

- control if communication discipline is respected, when employees use open radio communication channels;
- detection of side radiation arising from the operation of radio-electronic means;
- monitoring the location and state of the vehicles in real time using satellite navigation systems;
- accumulation of data on the electronic environment in the area of the object of interest location.

To estimate the level of electric field strength measuring receivers are used. The measuring receiver is a radio with normalized metrological characteristics of measuring the level and frequency of radio signals. The main purpose is a selective measurement of the voltage or power of weak signals. Many modern receivers also have additional functions, such as: analysis of the signal spectrum, modulation measurement, scanning according to the frequency range in order to identify the transmitting channels or to identify interferences. To determine the radio emission parameters in space, the measuring receiver is used in a coupling with the measuring antennas.

At the moment there is a wide variety of measuring equipment of such type from different manufacturers: series П5-хх (from USSR times) in the frequency modes from 9 kHz to 37.5 GHz; Narda STS ® PMM 9010Fast (10 GHz – 18 GHz); Rohde&Schwarz® ES(W/R/U) in the frequency modes from 10 GHz to 44 GHz; FCLE 1535 — 9 kHz … 3.25 GHz; РИАП 1.8 9 kHz … 1800 MHz; Willtek 8100 GPR 100 kHz … 2.5 GHz. However, despite of all their advantages, those equipment is intended (предназначен) mostly for stationary laboratory measurements due to their quite high price (tens of thousands of dollars) and weight (15 to 27 kg).

Therefore the development of a tactical, small, low weight and cost (up to 300 $) measuring receiver for estimation of power level of electric field in the GNSS frequency range is a relevant (actual) technical task.

After the analysis of current state of radio receiving and information processing technologies the choice was stopped at the Software Defined Radio (SDR), which refers to the radio communication systems, in which most of the functions are realized in the software using algorithms of digital signal processing (DPS) [10,11]. Processes performed by the SDR-receiver are depicted at the Fig. 1.

The radio receiver measures the signal strength at a given frequency or frequency range at the observation point, at a level not worse than -140 dBW [12].

The RTL-SDR RTL2832U module has been chosen. It has the following characteristics: sensitivity 0.22 μV; frequency range 27 – 1800 MHz; amplification gain of RF signal 0 – 49.2 dB; sampling rate ADC 200 – 3200 kHz.

The structural scheme of the receiver measuring signal strength is presented at the Fig. 2.

The receiver RTL2832U requires the following input parameters:
- frequency of the signal to be obtained;
- sampling frequency for ADC;
- amplification gain;
- buffer size;

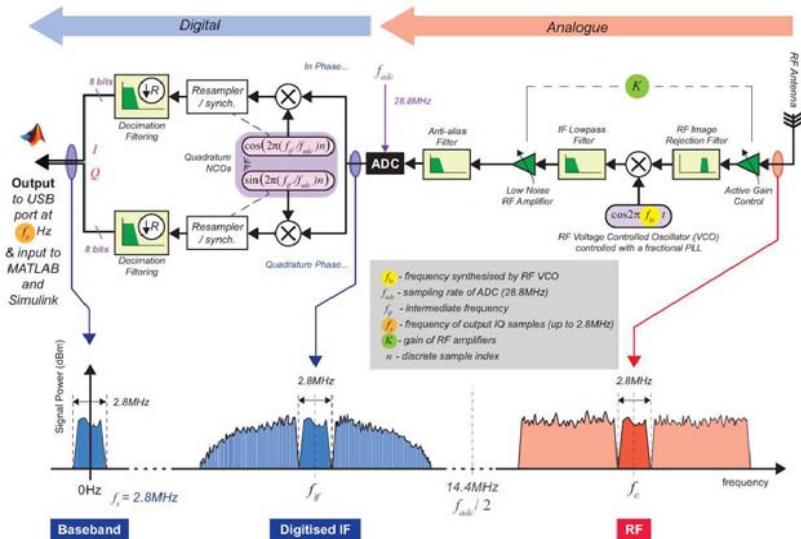- initial and final scanning frequency;
- scanning step.

Fig. 1. The process carried out by the R820T/RTL2832U RTL-SDRs: downconverting an RF signal to an IF, then digitizing the baseband. (Note that block diagram runs right to left). The parameters of baseband sampling rate, f_s, the tunable gain, K, and the RF centre frequency, f_c are set in the Simulink RTL-SDR *Receiver block* or MATLAB comm.SDRRTLReceiver system object
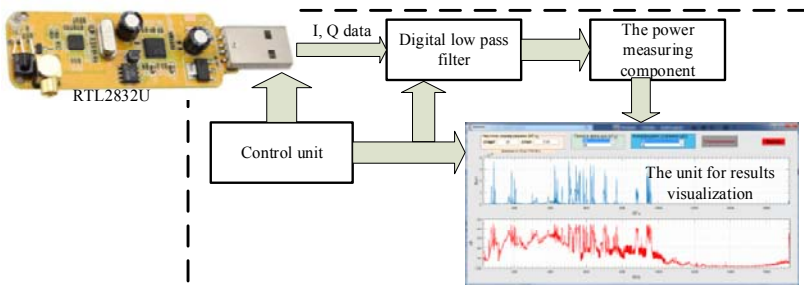

Fig. 2. The structural scheme of the receiver measuring signal strength

Those parameters are fed from the control unit.

According to the requirements, the signal strength must be measured at the signal frequency, but the receiver has some defined bandwidth, which depends on the sampling rate (f_s = 200 kHz to 3.2 MHz). That is, the receiver bandwidth can be

within Δf = ±100 kHz to ±1.6 MHz, which means the signal must be limited by the frequency that can be realized by the low pass filter with a low bandwidth. Based on the technical characteristics of scanning receivers, the minimum scan step is 10 kHz. Therefore, we can choose a bandwidth of a digital filter 10 kHz or less, thereby increasing the frequency resolution.

The control unit for the digital low pass filter provides a sampling rate and filter bandwidth.

The power measuring component of the received signal operates according to the following principle: the received signal can be considered random at some time interval. As it is known, the power of a random process is reflected by its dispersion. Therefore, the power measuring component will calculate the dispersion of the received signal.

The unit for results visualization reflects the results of signal power measuring at the received frequency as a plot "power-frequency". All necessary for receiver parameters are specified through the unit interface.

All units inside the dashed area at the Fig. 2 will be implemented as a software using MATLAB package.

To create the receiver it is necessary to proceed the following steps:
- to create the user interface;
- to create the program of receiver control and power measuring.

The user interface is created using standard MATLAB application for graphic user interface creation, GUIDE. The work is started by typing in a command window "guide". More detailed information could be seen in [13]. At the main panel (Fig. 3) the following object are placed: three dialogue windows to enter the scanning range, low pass filter bandwidth (allows scanning according to frequency), receiver amplification gain; two buttons "Scanning" and "Output" and two graphic objects to output the results.

The mean value of measured power of electric field is depicted in windows between graphs.

To control the receiver the library of functions for RTL_SDR radio should be installed preliminary [10], and parameters to be specified: the frequency of the begin and end of scanning range, the receiver identifier, sampling frequency, amplification gain, the quantity of data in frame, type of data and correcting frequency for heterodyne.

```
% read_data(handles);
start_freq = str2double(get(handles.edit1,'String'))*1e6;
stop_freq = str2double(get(handles.edit2,'String'))*1e6;
rtlsdr_id = '0';          % RTL-SDR identifier or address
rtlsdr_fs = 2.8e6;        % RTL-SDR sampling frequency, Hz
% rtlsdr_gain = 40;       % RTL-SDR tuner gain in dB
rtlsdr_frmlen = 4096;     % RTL-SDR output data frame size
rtlsdr_datatype = 'double';   % RTL-SDR output data type
rtlsdr_ppm = 0;           % RTL-SDR tuner parts per million correction
```

The signal from SDR-receiver are obtained by MATLAB by means of object "receiver" with specified name.

```
% creating an object of RTL-SDR receiver
```

```
hSDR = comm.SDRRTLReceiver(...
        rtlsdr_id,...
        'CenterFrequency',      start_freq,...
        'EnableTunerAGC',       false,...
        'TunerGain',            rtlsdr_gain,...
        'SampleRate',           rtlsdr_fs, ...
        'SamplesPerFrame',      rtlsdr_frmlen,...
        'OutputDataType',       rtlsdr_datatype ,...
        'FrequencyCorrection',  rtlsdr_ppm );
```

The developed prototype of measuring receiver was used in NAU to measure the electric field strength in the L1 GPS range. The result of measurements is shown in the Fig. 3.
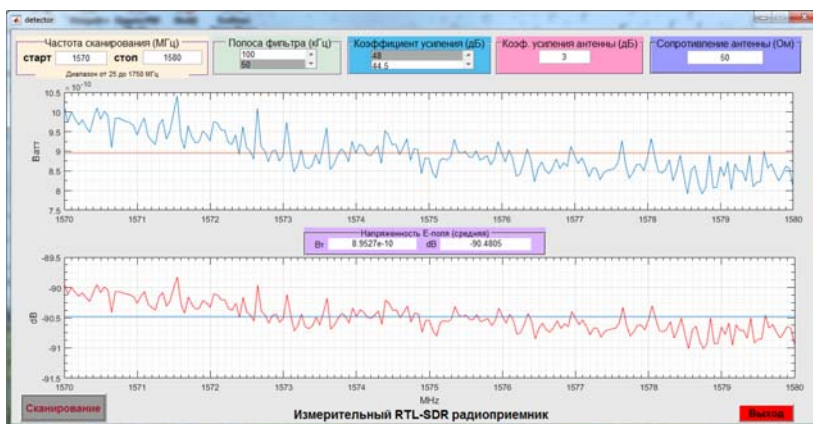

Fig. 3. Result of measuring receiver work in GPS L1 frequency range

With the help of the created receiver, it is possible to carry out operative monitoring and control of the radionavigation field. Under the presence of a method for assessing the level of hazard signals to GNSS receivers, the results of measurements can be used to make a decision on the GNSS availability, as well as the use of electronic warfare means (interferences) to GNSS [9].

Such a receiver can be used in stand-alone systems for monitoring and control the availability of the GNSS radionavigation field.

Conclusions

The implementation of a tactical measuring receiver for monitoring the radio navigation field for the safe landing of an aircraft using GNSS is presented. The receiver is implemented on the basis of SDR technologies in the Matlab software environment. The receiver was tested on the basis of the National Aviation University in the laboratory of satellite navigation.

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