Implementation of the Spectral Analysis Module in a Radio Traffic Supervision and Monitoring System

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Abstract - **Spectral analysis is a powerful way to observe and analyze the signals characteristics, while DSP technique can be efficiently applied for that purpose. One method for performing the spectral analysis is presented in this paper. Given method is applied for the realization of modulation classification and spectrum monitoring operations, which are very important tasks of systems for radio traffic supervision and monitoring. One solution of a such system is described in the paper.**

Keywords - **spectral analysis, digital signal processing, modulation classification, spectrum monitoring.**

I. Introduction

Soon after the possibility of information transmission by electromagnetic waves was discovered, radio supervision and monitoring became necessary. This is particularly important in HF, VHF and UHF frequency bands, where current civilian and military radio systems mostly operate. Basic functions of systems for radio traffic supervision and monitoring (RTSM) are following [1]:

- desired frequency range searching,
- identification of active frequencies,
- measurements of signals characteristics,
- modulation classification,
- spectrum monitoring and
- radio traffic analysis.

Implementation fields of a RTSM system include radio diffusion systems and military radio surveillance systems. Radio diffusion systems main tasks include: supervision of the admitted wireless stations, whether they obey limits of their operation parameters, spectrum occupancy analysis, as well as detection of non-licensed transmitters. On the other hand, the key functions of military electronic surveillance systems are identifying, intercepting, locating and analyzing sources of hostile radiation. After searching for signal activities, their identification and extraction of signals intelligence, a decision about further activities that should be taken is made. Some potential actions are: continuing or ceasing of the surveillance procedure, supervision and monitoring of certain frequencies of particular interest, the use of electronic counter-measures (jamming) and so on.

During the radio traffic supervision procedure, large number of collected data about detected signals appear. In order to carry out an analysis, like the spectrum occupancy analysis, it is often required to monitor these data. The most suitable data monitoring method is the graphical presentation, since it enables users to visually survey the results. It was rather hard to achieve this task in the past. However, the appearance of advanced developing tools and new visual program languages provides the easy creation of graphically oriented user interfaces. Furthermore, when unknown radio signals are monitored, either for civilian or military purposes, the modulation type is one of significant transmission parameters. So, the automatic recognition of radio emissions type i.e. modulation classification, have to be carried out. Modulation classification and spectrum monitoring are important functions of a RTSM system. These functions can be realized with the use of spectral analysis.

A DSP-based method for spectral analysis is presented in this paper, applying a special DSP module. Suggested solution of the spectral analyzer is applied for the realization of modulation classification and spectrum monitoring operations. They are further used in a system for radio traffic supervision and monitoring, which is also described.

II. Basic principle of the spectral analysis

Spectral analysis of the signals generated by a physical system is a powerful way to analyze that system behavior. Many characteristics of one signal or system can be easily observed and analyzed in the frequency domain. Due to this fact, spectral analysis is often applied in telecommunications.

There are two main problems that have limited the use of spectrum analyzers: the requirement for real time analysis of signals and their high cost [2]. Namely, the analysis is performed by means of the Fourier transform that requires numerous time-consuming operations, so it is unusable for real time applications. Nowadays, the availability of digital signal processing (DSP) and signal processors overcome earlier problems. These powerful and cheap devices represent microprocessors specialized for digital processing of signals in real time. Thus, they are designed for fast and continual processing and memory access, which is indeed necessary for real time operating. Moreover, signal processors are characterized by high internal parallelism, allowing partial or full overlap of the instruction fetch and execution. These innovations result with extreme increase of their numerical features, in relation to conventional microprocessors that belong to the same technological generation.

One method for spectral analysis is suggested. For that purpose, a special DSP module is designed and realized [3]. Its main task is to generate the spectrum of detected signals, which is further applied for modulation classification and spectrum monitoring functions. The principle of spectrum generation is simple. At first, an analog signal, which is brought from the receiver must be converted to a digital form.

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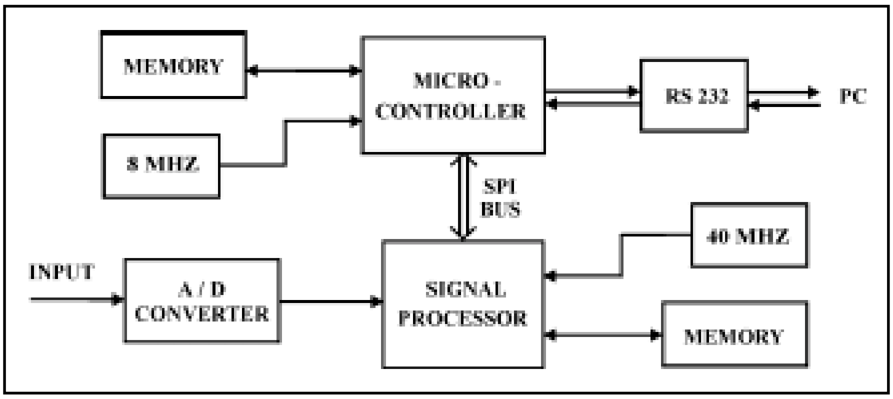

Fig. 1. Basic configuration of the DSP module

After that, the signal should be translated in frequency domain, calculating its Discrete Fourier Transform. Finally, obtained spectrum samples are stored in a memory. The whole procedure is performed applying the mentioned DSP module. It contains: a signal processor, a microcontroller, an A/D converter, clock generators (8 and 40 MHz), changeable (RAM) and fixed (PROM) memories, the RS232 interface, an address decoder and required control logic. The DSP module basic configuration is given on figure 1.

For digitalization of input analog signals, the AD7891 converter is used. It is an 8-channel, 12-bit analog-to-digital (A/D) converter, with 454 kHz maximal sampling rate. All algorithms related to DSP technique, performs the signal processor TMS320C50. It is fixed-point, 16-bit processor, running at 40 MHz, with 20 MIPS processing power. Required clock is externally generated. The processor's external memory includes 32K bytes of the erasable programmable ROM (EPROM) and 32K words of the RAM. User programs are stored in the EPROM, while the RAM is used to store processed data. For the spectrum generation, the complex Fast Fourier Transform (FFT) algorithm is realized, representing a modified version of the well-known 1024-point ($1K \times 1K$) complex FFT software package [4].

The module control and supervision is carried out by the MC68HC11 microcontroller, advanced 8-bit microprocessor. The required 8 MHz clock is externally generated, while external memory includes 16K bytes of the EPROM and 8K bytes of the RAM. The DSP module is connected with a personal computer (PC), as the input/output unit, by the RS232 interface. It is common, serial asynchronous interface. When the transfer of generated spectrum samples from the DSP module to a PC is required due to monitoring, the microcontroller controls this job. The communication between it and the signal processor is carried out over the SPI (Serial Peripheral Interface) bus, serial synchronous interface.

III. THE RTSM SYSTEM DESCRIPTION

One solution for a RTSM system is proposed. It should perform several tasks, such as: detection of radio emissions in wide frequency range, recognition of their modulation type, spectrum monitoring, recording of certain signals on a tape recorder, creation and updating of data bases etc. Its basic configuration is shown on figure 2.

For signal detection, the AR5000 radio receiver is used. It is a wide band all mode receiver, with wide range of search or scan facilities and remote control capabilities. The receiver covers 0.1 - 2600 MHz frequency range in AM, FM, USB, LSB and CW modes. More of them can be involved in the given system (up to 4). When the surveillance procedure is concerned, 4 operating modes exist. Surveillance on single frequency represents the manual operating mode (required channel parameters are manually set). Surveillance over the given list of channels is the operating mode where the receiver scans a list of frequencies, previously defined. Similarly, surveillance over the bank of memorized channels is the operating mode where the receiver scans a bank of memorized channels. Surveillance into given range is the operating mode in which the receiver tunes through all frequencies into a given range, previously specified.

The antenna block consists of antennae set, which has to cover required frequency range, and an antenna splitter and commutator (ASC). Its task is to connect each of receivers with all antennae. For the choice of desired antenna, software control from a PC is used.

Due to recording certain emissions of particular interest, a double cassette deck is used. Remote control of the cassette deck is available via the RC-5 protocol. It is a common remote control protocol between an infra-red remote control unit and an user device [5]. The RC-5 protocol is modified, so that software control from a PC can be applied.

A signal commutator (SIGCOM) enables the commutation of all input signals to all outputs. The input signals include demodulated low frequency (LF) signals from the receivers and signals from the cassette deck. They can be brought to the cassette deck, due to recording or to the audio output. The signal commutation is performed with analog switchs, circuits for audio signals selection and passing, while a keyboard on the device front panel is used for their control.

The spectral analyzer main function is to generate the spectrum of detected signals. Obtained spectrum is further used for spectrum monitoring and modulation classification. Proceeded data are transferred to a PC and stored in its memory. In order to later radio traffic analysis, corresponding data base should be created. It contains many useful information about detected radio emissions: date and time of detection, frequency, field level, operating mode, bandwidth, modulation type, signal spectrum etc.

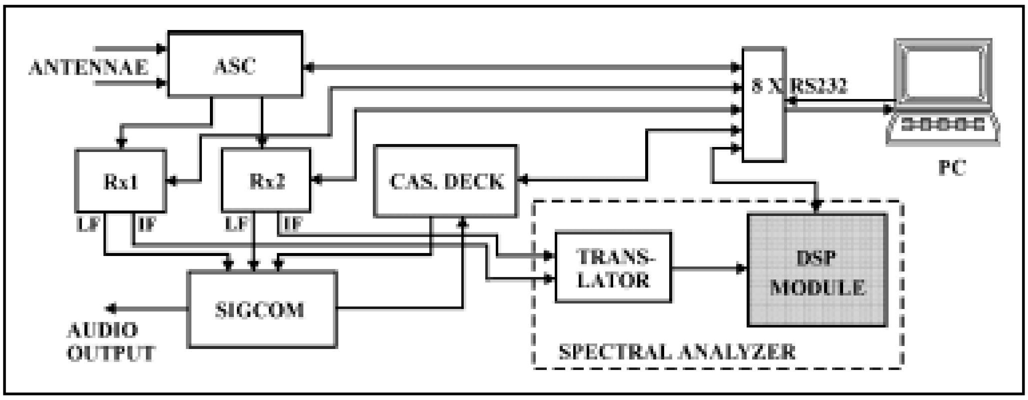

Fig. 2. Basic configuration of the RTSM system

The common PC platform is used as a central control unit of the system. If specific exploitation conditions are required (the system has to be embedded in a vehicle representing a mobile system or it should operate in very hard ambient conditions), the industrial PC can be used. It has strengthened tower, boards which are resistant to shocks and vibrations and components that satisfied the military standard. The Windows NT is chosen as the operating system, while the Visual Basic program language is applied for control procedures, data base creation and spectrum monitoring, since it is suitable for the graphical user interface creation. The PC controls the job of individual devices. All of them are connected to the PC through the RS-232 connection box, enabling simultaneous work of 8 devices. The communication between them is carried out by the intelligent interface card PCL-844 (it is put into the PC) and corresponding software routines.

IV. Implementation of the Spectral Analysis

Modulation classification and spectrum monitoring of detected signals are very important tasks of the RTSM system. They are performed on the basis of generated signal spectrum. Implementation of the DSP–based method for spectral analysis and the DSP module (previously described), provides simultaneous performing of these functions. Modulation classification is carried out together with the spectrum generation in the spectral analyzer, while the signal spectrum samples are transferred to the PC due to monitoring.

Besides the DSP module, the spectral analyzer contains a translator. Namely, before digital processing, the received signal has to be translated from the receiver intermediate frequency (IF) 455 kHz to the 0 - 50 kHz base band. The given bandwidth is sufficient for all desired signals that should be classified. Thus, selected IF signal is lead from the receiver to the translator. There, the signal is filtered (a band pass filter, central frequency 455 kHz, pass band 50 kHz) and amplified. The translation is realized with a local oscillator (480 kHz) and a low-pass filter (50 kHz), which separates the lower band. After that, the signal is brought to a compression amplifier to adjust the signal level (±5 V) for A/D conversion. Obtained signal remains modulated and it is brought to the DSP module. The FFT algorithm is then applied and as a result of proceeding, the spectrum samples are generated. They are stored in the memory.

Since the spectrum has generated, the modulation type of received signal can be recognized. Proposed classification procedure is carried out in frequency domain, while it is achieved using the pattern-recognition approach [6]. In this method, some useful information (named features), which can indicate modulation type of incoming signal, are extracted from it. The power spectrum is chosen as a feature in the suggested solution. It is computed on the basis of given magnitude spectrum samples. As the 1024-point FFT algorithm is applied, there is 1024 power spectrum samples. They should be processed to obtain parameters that are suitable for classification of required modulation types. So, several parameters are calculated (such as the mean value, the dispersion, the peak value etc.) and few thresholds are set, enabling the distinction of various signal spectral shapes. On the basis of many predetermined criteria, the final decision about modulation type is made. The especial algorithm is developed and the software DSP-based routine is realized, for this purpose. In such a way, it is possible to classify most AM and FM signals that are usually met in HF, VHF and UHF bands. Obtained result is transferred to the PC.

The function of spectrum monitoring is achieved using the Visual Basic program language. For this purpose, generated spectrum samples, transferred from the DSP module, are graphically presented on the monitor. Two display modes of spectra are available: the wideband and narrowband display. In the first case, the signal spectrum is displayed in whole required range (5 MHz), while in the second case, only its narrow part (50 kHz) is shown, which is specially important for the analysis. Independently from its width, the spectrum can be presented in different forms, that improved the analysis. The following display forms are available to users: the spectrum of instantaneous values, the spectrum of averaging values, the spectrum of max-hold values, , the spectrum occupancy (time dependency), the spectrum of new values after certain time and the three-dimensional "waterfall" spectrum. In addition, for any display form there are few setting parameters that can be seen on the PC monitor: the start frequency, the stop frequency, the detection threshold (it denotes minimum signal level that is shown), the signal frequency and its field level of marked position. The zoom possibility is enabled using the marker. The marked signal can be either directed to audio monitoring (a speaker) or the narrowband analysis of this signal can be carried out.

In a case of the wideband display mode, the display range amounts to 5 MHz. The 16-point complex FFT algorithm is used for the spectrum generation. In respect of the received signal bandwidth (50 kHz), defined with the bandwidth of used filter (in the translator), the resolution of obtained spectrum is 6.25 kHz, what is entirely enough according to the given display range. Simultaneously, great speed of the FFT algorithm execution is enabled, which is very important because of necessity of its multiple repetitions. Namely, on account of the required display range there are 100 channels and hence, the FFT algorithm have to be repeated 100 times.

If more detailed spectrum analysis is required, the narrowband display mode is used. It can be applied for those signals which are selected (marked) during the wideband display, or for certain assigned signals, when their presence is expected in advance. In this case, the 50 kHz bandwidth is considered, while the complex 1024-point FFT algorithm is applied for the spectrum generation. In consequence, the spectrum resolution is much better, it amounts about 100 Hz. The same data is used for modulation classification i.e. on account of these spectrum samples, a decision about the signal modulation type is made. As an example, the spectrum of a FM radio signal at 98.2 MHz is shown on figure 3.

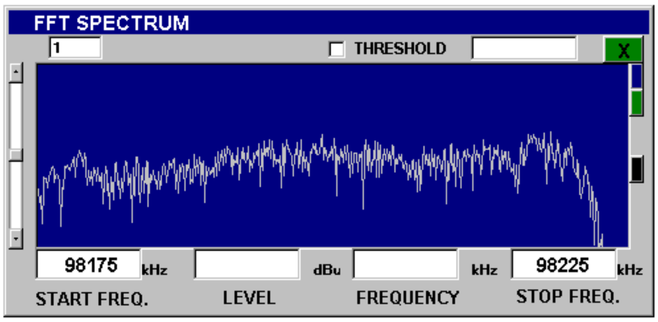

Fig. 3. Narrowband display mode

The spectral analyzer control is performed on a software manner, using the Visual Basic language. The PC is applied as a remote control unit, while the control window is shown on figure 4. It consists of 4 fields. The classification field provides the classifier control. The *run* button is used to set the start command, while the result is written into the text box. The auto option is available, where the operation is automatically repeated after each 1 or 2 sec. The choice of required receiver i.e. the signal that should be analyzed, is performed by option buttons from the receiver selection field. The spectrum monitoring field provides the appearance of classified signal spectrums on the monitor. The *IF signal* button is used to obtain the spectrum of IF modulated signal. In fact, it is the narrowband display mode from figure 3. On the other side, the *LF signal* button is used to obtain the spectrum of LF demodulated signal. For this purpose, the LF signal is brought directly from the receiver audio output to the A/D converter second channel. The receiver mode must be correctly set in that case. The communication state field indicates the classifier state (if it is connected with the PC) and also the state of spectrum display procedure (if the PC is ready for this job).

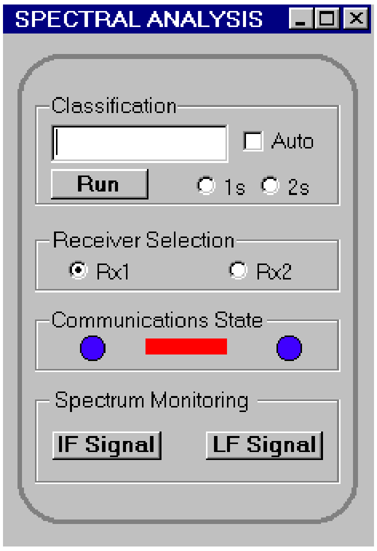

Fig. 4. Control window

V. CONCLUSION

Spectral analysis of signals is a powerful way to observe and analyze their characteristics. DSP technique can be efficiently applied for that purpose. Presented method for spectral analysis is based on the implementation of the DSP module. It is further applied for the realization of modulation classification and spectrum monitoring operations, important tasks of RTSM systems. One solution of the RTSM system, where these functions are carried out simultaneously, is described too. Modulation classification is based on the pattern-recognition approach and the power spectrum is applied as a signal feature that can be used to distinguish different modulation types. It is completely digital solution, while analog components are used only for translation of received signals to the desired frequency range. Generated samples of the spectrum are used for monitoring. The wideband and narrowband display modes and several display forms are available.

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