ISSN 1392 – 1215 ELECTRONICS AND ELECTRICAL ENGINEERING 2008. No. 4(84)
ELEKTRONIKA IR ELEKTROTECHNIKA

T180 TELECOMMUNICATIONS ENGINEERING
TELEKOMUNIKACIJŲ INŽINERIJA

Software Radar

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Introduction

History of radio communication begins with analog technology. First radio sets were built with tunable analogue components. Performance of device was defined by its structure, each different way of communication demanded totally different set of equipment. As price of digital IC decreased and their performance increased the digital radio became possibility. Although main operations were carried out digitally the performance of device was still fixed in hardware. Third generation of this evolution the software defined radio – SDR are means of wireless telecommunication which parameters are defined mostly by used software. SDR has many advantages over ordinary – hardware radio. Pending only by used software same device can execute many different functions. For example same physical device can be used for receiving AM, FM and SSB signals – by means of only changing software. A new communication solution doesn't need new hardware anymore – only changes in software are usually sufficient. This keeps updating costs low and makes whole process much faster. From negative side higher cost and complexity of SDR devices and also need for both hard- and software to build a radio, can be mentioned.

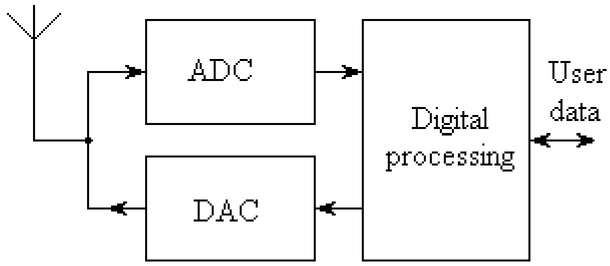

Fig. 1. Ideal software defined radio

In case of ideal SDR receiving antenna is directly connected to the input of analog-to-digital converter. All following processing of radio signal, like filtering, demodulating etc, are carried out fully digitally. Analogously at transmitting end would form signal fully digitally and transmitting antenna would be connected to the output of digital-to-analog converter. Structure of ideal software defined radio is shown on Fig. 1. Although this ideal concept can be theoretically used on some cases we still usually need some extra analog components for satisfactorily performance of SDR. To amplify input signal into demanded level for best ADC performance we need pre-amplifier. Also frequency of input signal must be converted into suitable diapason before we can digitalize signal. At transmitting end usually output power of DAC is not sufficient for transmitting and therefore we need power amplifier there. And again there can be often need for up conversion of DAC output frequency. Also some part of Digital processing may have to be carried out by fixed digital schematics like FPGA. Thus generally software defined radio looks like illustrated at Fig. 2.

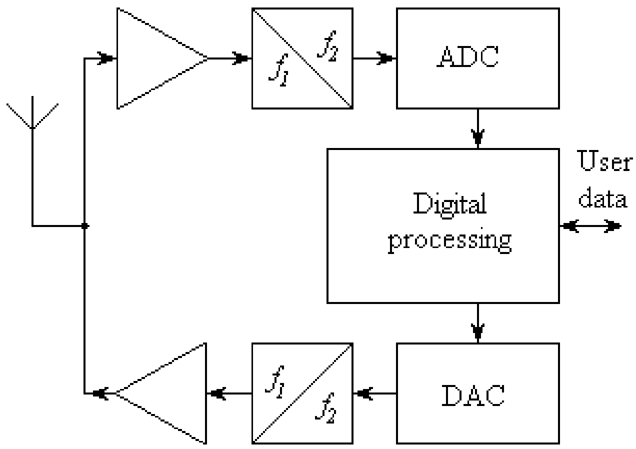

Fig. 2. Schematic of actual software defined radio

Main functionality of device is provided by digital processing module (at Fig. 1. and 2.). Digital processing module can be realized in many ways – usually by means of FPGA or digital signal processors. According to need it can be built on only single general purpose processor or also big multiprocessor system.

Conception of Software Radar

Conception of Software defined radio is not useful only for communication purposes but also at other fields of radio technology and science. Amongst them radio interferometry and astronomy, sonar and radar systems etc. Most radar devices used nowadays still using magnetron or other highs power-high frequency device as generator of probe signal. In case of probe signal with complex structure it is usually generated by help of delay elements or switches. Software radar can use fully digital probe signal generator instead. Thus we can generate practically infinite amount of different probe signals, with different shape, duration and inner-pulse modulation. When need arises we can use different probe signal for every new probe cycle. This opens us opportunity to use adaptive probe signal forming. By other words – radar can automatically change shape of probe signal to be optimal for detecting and tracking current target. To expand traceable diapason it is possible to generate two or more probe signals with different length in a row. Short pulses with low energy are suitable for short distance surveillance as long modulated pulses with high energy are suitable for long – distance surveillance. By combining those echoes from many pulses we can obtain simultaneously traceable area which would be impossible by use of only single type of probe signal.

Use of long probe signals with complex inner structure enables radar to use pulse compression technology. From viewpoint of energetic there is no difference between short probe signal with high power and long signal with low power. If product of probe signals power and duration are equal then both signals have equal energy, same maximal detection distance and minimal detectable radar cross section of target. Longer the probe signal is the poorer is radars capability to separate closely spaced targets. This is not a problem if we use inner pulse modulation. In case of long modulated pulse then we can compress received echo in such manner that separation of closely spaced targets are determined only by length of modulation element instead whole signal. And at same time we still retain long surveillance distance with low output power.

Due that fact software radar can have extremely low instantaneous output power. For example Saab Bofors radar PILOT Mk3 can detect targets up to 5 km with output power of 1mW. Low output power is economical, safe for radar crew and surrounding environment and also causes less interference with other electronic devices working at same frequency band. Most important feature with low output power and pseudo noise type modulation is low probability of intercept – which means that device is hard to detect by means of radio intelligence and also hard to intercept by enemy electronic warfare equipment. This kind of radar can detect and track enemy vessels from greater distance than enemy radar warning receiver is able to detect presence of our radar. It is also much harder do destroy such kind of radar device with an anti radiation missile. So by summing up we can claim that detection, tracing and destroying of enemy is possible without danger of being detected and destroyed. Such feature is especially desirable on vessels built by using stealth technology.

Physical dimensions, mass and power consumption of software radar device is basically defined only by analogue part of device. Practically only part witch size can not be reduced is antenna as its dimensions depend on used wavelength and necessary directional resolution. Modern digital circuitry is small, lightweight and energy efficient and thus do not take much space. Hence digital radar can be small, lightweight and flexible device. It can be mounted stationary, on vehicle or even can be carried by personnel.

Construction and Work Principles of Software Radar

Structure of software radar can be divided into two main modules. Analog module contains amplifiers, frequency converters, antenna and other needed equipment for amplification, transmitting and receiving probe signal. Analog module converts output signal of digital waveform generator into desired frequency band and amplifies its power up to needed level. Amplified probe signal will then emitted by antenna. Received echoes are amplified and their frequency is converted back into IF. In consequence analog module determines radars frequency, output power and initial sensitivity.

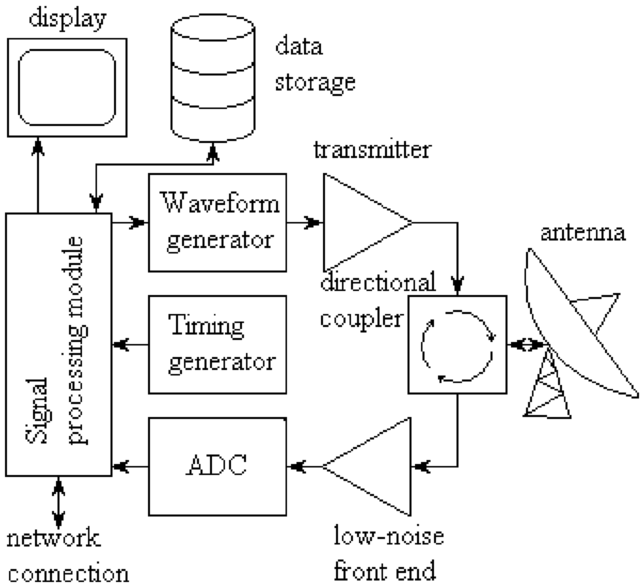

Fig. 3. Simplified structure of software radar

To decrease mutual interference between radar and other devices and increase radars low probability of intercept ability, frequency hopping can be used.

Digital module contains digital waveform generator for purpose of generating probe signals. Digital waveform generator can be realized on fast FIFO shift registers or other similar devices. Waveform generator must also contain digital to analogue converter to turn probe signal into analogue form. Such digital waveform generator architecture enables us to generate practically indefinite number of different probe signals and use adaptive probe signal forming when such a need arises.

Receiving end of digital module contains analog-to-digital converter and digital signal processing system, which can be realized in many different ways. As radar produces huge amount of raw data it is usually a multiprocessor system of fast DSPs. Analog Devices TigerSHARC® DSPs are often used product on such case. Exact amount of raw data depends mostly on duration of probe cycle, maximum and minimal distance of surveillance, demanded resolution and dynamical diapason of signal. As most of received raw data is useless, then preprocessing is usually reduces amount of data drastically.

Timing generator is responsible for synchronization on all parts of radar device and in case of radar network also for synchronization of data between different devices. GPS synchronized clock is often used solution for such purpose.

PC or some specialized computer device carries out control of system, displaying and storing results and connection between radar device and network usually.

Probe cycle of radar starts with start signal from PC. This signal starts digital waveform generator. At same moment also receivers ADC starts converting its input signal into digital form and storing results into cache memory. Duration of receiving process is determined by surveillance distance. Amount of received data depends on distance measuring resolution and dynamic diapason of receiver. It is also possible to start storing of received only after end of generated probe signal and thus decrease amount of raw data. But it is usually recommended to have also data about shape of radiated probe signal – for automatic control and measurement purposes. Along with received echoes also data about used probe signal, exact time and direction of antenna main lobe are stored.

Main task of finding peaks of signal corresponding to detected targets and measuring their distances are carried out by Digital Signal Processing module. Results of input data processing are then loaded into PC where they are further processed, stored and displayed on screen.

Software Radar Networks

While taking advantage of latest digital- and signal processing technology we should not stop there. Exponential growth of network, storage and computational capabilities allows software radars, as any other digital device to be connected to communication network in order to increase performance of whole system. Good example of such system is The Open Radar Initiative network of scientific software radars. To illustrate advantages of such network an example configuration of one such network is presented on Fig. 4. Our radar network contains three radar devices, two data storages, one processing and one control unit. Although elements of this network can be physically placed thousands of km from each other they can function as one system due to network connection between them. Modern global positioning systems work as worldwide time reference making possible synchronous work of devices spread on large areas. Share of common network connected storage and computational resources enable to share signal processing tasks between network nodes. Multicasting allows many different software agents on a variety of computing platforms to share access to system data. High speed data recorders allow storage of command, and status signals and radar output products.

For example radar devices from Fig. 4 can be only able to collect and preprocess data. Collected information is stored on data storages (RAID) and data processing cluster carries out final signal processing. Results are transmitted to control center where they are displayed. Failure of some elements or parts of network is not fatal as others still continue work.

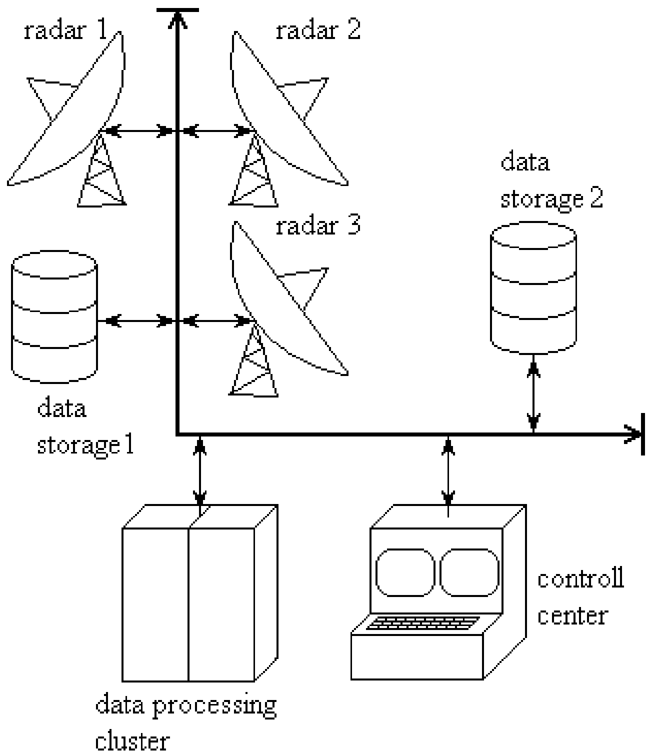

Fig. 4. Example Software Radar network

Whole system is easily configurable to work as one metainstrument. For example on bi- or multistatic regime. As reconfiguration is carried out only by means of software it can be done easily and fast. Some radar devices can work on monostatic regime, as two or more others can work on multistatic one. Witch radar is transmitter and which ones work as receivers can also be changed even after every single probe cycle if such a need arises. Also some or all radar devices can be used as passive radar.

Such adaptive synchronous multistatic configuration has many advantages. At first it makes possible to reduce mutual interference and further increase LPI properties. Because one can use as transmitter only radar that is at furthest distance from sensitive device or radar warning receiver. Second main advantage is that stealth vehicles are not invisible to multistatic radar. After detecting such a device radar network can be configured to obtain best surveillance performance for given stealth vehicle.

Also other measurement instruments can be connected to Software Radar Network if it helps to complete needed tasks. For example direction finder system can detect position of source of electromagnetic radiation indicating some kind of moving platform at given area. This kind of a priori information can help detect objects that could remain undetected else way.

Experimental Software Radar

An experimental device is built according to principles of software radar. Aim is to test principle of software radar at practice. First experiments has shown that targets can be detected at range of 5 km with output power of 5W. Bigger test area is needed for further experiments in order to find maximal working distance and specify other parameters. Estimated and measured main parameters of experimental digital radar device are shown at Table 1.

Table 1. Parameters of experimental radar

Symbol	Quantity	Value
P	Maximum output power	5 W
D	Dynamic diapason	125 dB
l	Working distance	100 m-50 km
l_{min}	Separation distance	25 m
f	Frequency diapason	X-band
$\Delta\varphi$	Angle measurement precision	1.8º
Δl	Distance measurement precision	1.5 m
M	Mass	50 kg
P_o	Power consumption	200 W

Conclusion

Modern digital technology enables us to build such devices and systems that would be impossible to build by means of analog technology. Computer control and fast digital signal processing makes modern communication and data acquiring systems flexible and adaptive to environment. Connecting them together to software radar network can drastically increase performance of single devices. There is practically indefinite number of possible configurations of such radar networks.

References

1. **Bose V.** A Software Driven Approach to SDR Design, COTS journal. - January 2004.
2. **Steinheider J.** Software Defined Radio Comes of Age, - 1st March 2003**.** available: http://rfdesign.com/mag/radio_software_defined_radio/
3. **Skolnik M. I.**. Radar handbook, McGraw-Hill. -1990.
4. **Mingxin Z., Jun T., Yingning P.** A Dataflow Mechanism for High Speed Radar Signal Processing // Proceedings of IEEE TENCON´02. -2002.
5. **Bartenev V.G.** Software Radar: New Reality // IEEE -2006.
6. **Wojdołowicz G., Misiurewicz J., Piątek A.** COTS Hardware for Software Radar
7. **Grydeland T., Lind F. D., Erickson P. J., Holt J. M.** Software Radar signal processing // Eleventh International EISCAT Workshop. - 31 January 2005.

Submitted for publication 2008 02 03

I. Müürsepp. Software Radar // Electronics and Electrical Engineering. – Kaunas: Technologija, 2008. – No. 4(84). – P. 59–62.

Current article gives overview about use of software defined radio concept in the field of radar technology. Software defined radio is shortly introduced. Mainly is described buildup and work principles of software radar device and as a next level network of Software Radars. Rapid development in signal processing technology allows totally new approach to data acquisition systems. Performance of radar devices no longer depend only on analogue or even digital part of their structure. Reprogrammable and powerful data processing devices together with fast and reliable networks opens a huge number of totally new possibilities on a field of radar technology. Experimental radar device, built for testing Software Radar theory is also briefly introduced. Ill. 4, tabl. 1, bibl. 7 (in English; summaries in English, Russian and Lithuanian).

И. Мурсепп. Радар программного обеспечения // Электроника и электротехника. – Каунас: Технология, 2008. – № 4(84). – С. 59–62.

Дан краткий обзор об использовании определенного радио-понятия программного обеспечения в области радарной технологии. Определенное радио программного обеспечения коротко введено. Главным образом - описанное наращивание и принципы работы устройства радара программного обеспечения и как следующая сеть уровня Радаров Программного обеспечения. Быстрое развитие в сигнале, обрабатывающем технологию позволяет полностью новый подход к системам получения и накопления данных. Работа радарных устройств больше не зависит только от аналога или даже цифровой части их структуры. Перепрограммируемые и мощные устройства обработки данных вместе с быстрыми и надежными сетями открывают огромное число полностью новых возможностей на области радарной технологии. Экспериментальное радарное устройство, построенное для того, чтобы проверять теорию Радара Программного обеспечения также кратко введено. Ил. 4, табл. 1, библ. 7 (на английском языке; рефераты на английском, русском и литовском яз.).

I. Müürsepp. Programinės įrangos radaras // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2008. – Nr. 4(84). – P. 59–62.

Išanalizuotos radijo programinės įrangos sąvokos, kuri naudojama radiolokacinėje technologijoje. Programinė įranga, charakterizuojanti radiją, yra trumpai apibūdinta. Išanalizuoti radiolokacinio programinės įrangos prietaiso darbo principai. Atlikti bandymai su programuojamais ir galingais duomenų apdorojimo prietaisais kartu su greitais ir patikimais tinklais. Minėti tyrimai suteikia didžiulį skaičių visiškai naujų galimybių radiolokacinėje technologijoje. Il. 4, lent. 1, bibl. 7 (anglų k.; santraukos anglų, rusų ir lietuvių k.).

DOI: 10.5755/j02.eie.11134