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SOFTWARE DEFINED RADIO CONCEPT IN DIFFERENT SYSTEMS

Abstract

Nowadays we are facing a continuous development of different technical systems using the frequency spectrum. People have more and more devices in their hands, the same ones used by the Defence Forces, as well. While developing them experts have to take into consideration not only the use of advanced technology, but also the ability to offer their products at low cost. In connection with the systems that are dependent on the frequency spectrum, the Software Defined Radio (SDR) concept offers a suitable solution.

Napjainkban a frekvenciaspektrumot használó különböző technikai eszközök folyamatos fejlődésének vagyunk tanúi. Az embereknek egyre több és több eszköz van a kezükben és természetesen a rendvédelmi erők is alkalmazzák azokat. Ezen eszközök fejlesztése során a fejlesztőknek nemcsak a fejlett technológiát kell figyelembe venni, de az alacsony költségszintet is. Ezen, a frekvenciatartomány alkalmazhatóságától függő eszközökkel kapcsolatban a szoftverrádiós koncepció megfelelő megoldást nyújt.

Keywords: *Software-Defined Radio, SDR, cognitive radio ~ szoftverrádió, SDR, kognitív rádió*

INTRODUCTION

Nowadays people use different electronical devices without any knowledge of their technical background. Walking on the streets we see people using smart phones, tablets, and we can also find a lot of innovations in our own households. Earlier these developments were used for military purposes, and they showed up only after a short time in civilian life. However, this tendency has recently changed.

In connection with communication systems, radar systems and navigation systems, there are several smaller and bigger innovations. In my article I examine the use of the Software Defined Radio and Cognitive Radio concepts. The SDR concept is applied in various new technical systems, and is used by the industry in new products.

These new equipments and innovations mean new challenges for electronic warfare experts, as well. They have to keep up with these innovations, and they also need to find new ways against them.

The aim of this article is to show some examples of the application of the SDR concept, and to analyze the possibilities of the SDR-based EW systems.

ELECTROMAGNETIC SPECTRUM

I think it is important to mention the environment where these platforms are used, before the actual analysis of the different systems. Generally, the electromagnetic spectrum is not known by many people, they only know some keywords, frequency and wavelength for instance, and most of them think it is more than enough for them. Naturally, for the experts it is not enough, and this is a very important issue in the military environment, as well.

For general users it is important to have a service on an acceptable level without any interference, and this question has recently become a very important issue. The problem is that because of the newer and newer systems the electromagnetic spectrum is full. There are different forums, national and international agencies for spectrum management to find the best solutions for communication and non-communication services. International agencies play a special role, because the waves are unaware of borders and it is needed to improve different standards for different systems. In the picture below you can see some typical examples of the devices used in various frequency bands.

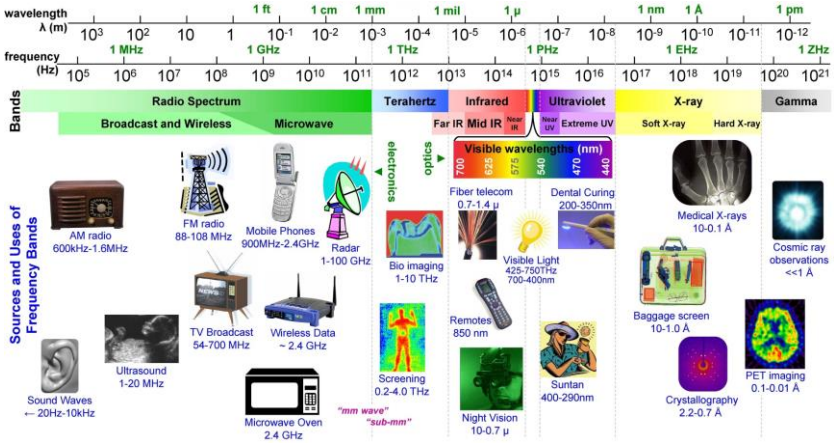

Figure 1. Use of the electronic spectrum [1]

In military life there are strict rules in connection with frequency management, because the emissions can give away details about forces, e.g. the type and position of emitters, or even the position of their own forces. One of the military fields that use the electromagnetic spectrum is the electronic warfare. Based on the new terminology the electronic warfare has three parts, electronic attack, electronic defence and electronic surveillance.

BASICS OF THE SOFTWARE DEFINED RADIO AND COGNITIVE RADIO CONCEPTS

Nowadays the Software Defined Radio (SDR) technology is generally used by manufacturers of civilian and military systems, mainly among radio systems, but we can also find more and more information about other applications, as well.

As for the definition of Software Defined Radio, I would recommend to use the following one: "Radio in which some or all of the physical layer functions are software defined." Numerous firms use the SDR technology, because there are a lot of benefits for manufacturers, radio service providers of the civilian market and users. Manufacturers can introduce new products more quickly into the market, they can decrease the development costs using the same software in the family of radio products. The main benefit for the radio service providers is that using the former infrastructure they can add new capabilities to their systems. Using the SDR technology enables users to get a reliable solution for communication. [2]

In the following picture you can see an overview of the basics of the SDR.

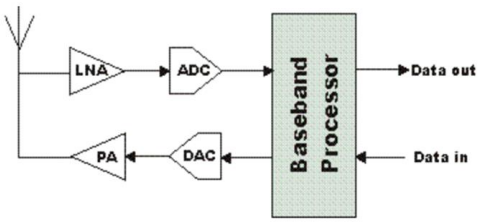

Figure 2. Block diagram of the SDR radio [3]

Former hardware based radios could be updated only through the change of the needed part. As a result, the production costs were higher and support was more difficult. To get a new upgrade, we had to buy a new element, a new radio or a new system. Instead of this solution with the Software Defined Radio technology we are able to simplify the upgrade and decrease the costs. This means that the key element that used to be the hardware in the past is now the software. [2]

Talking about the SDR concept we have to mention the cognitive radios, as well. This idea is the next step after the SDR. We can use the same basics, but with an additional part this radio system can check the spectrum and - e.g. in case of electronic jamming or interference caused by another system - is able to change to another unused frequency, which was observed during the continuous check of the frequency spectrum. [4]

The aim of the SDR solution in the signal processing is to replace the analogue RF front-end with modern digital signal processing. The core of this procedure is the use of FPGA (Field Programmable Gate Arrays) in the systems. The FPGA is a digital circuit in which the programmers can program to perform different kinds of tasks. "FPGAs are semiconductor devices that are based around a matrix of configurable logic blocks (CLBs) connected via programmable interconnects. FPGAs can be reprogrammed to desired application or functionality requirements after manufacturing. This feature distinguishes FPGAs from Application Specific Integrated Circuits (ASICs), which are custom manufactured for specific design tasks. Although one-time programmable (OTP) FPGAs are available, the dominant types are SRAM based which can be reprogrammed as the design evolves." [5]

In connection with the SDR concepts, we have to mention the advantages and disadvantages, as well. Advantages can be the better utilization of the frequency spectrum or the simple way of development. A major disadvantage is the new way of attack on the systems in which the SDR part is implemented. These attacks can be categorized in different

ways, the most known attack method is the electronic jamming, but because of the software defined parts, various malicious programs can be used against the SDR equipments, as well.

Generally, the civilian off-the-shelf solutions can also be used for military purposes, but we need to make some changes due to complex operational environments. The most important requirements for the military equipments are the operation on a wide frequency spectrum and under difficult weather conditions, use special military waveforms and special security rules.

SDR SOLUTIONS IN DIFFERENT SYSTEMS

Communication systems

In this part I am going to show some examples of communication systems. The German manufacturer Rohde & Schwarz GmbH & Co. KG is the partner of the German Armed Forces in the development of new software defined radio based communication systems. The firm has different types of radios for stationary, shipborne, airborne and ATC communications. In the names of their products they use the M3 abbreviation which means Multiband, Multimode and Multirole. This radio system is able to provide different services, not only radio services, but also GPS and satellite services. [6] [7]

Figure 3. A member of the M3TR family: the MR 3000 radio [8]

The Harris Corporation is another important player on the field of military communication. This firm has been awarded the Mid-Tier Networking Vehicular Radio (MNVR) contract from the U.S. Army in 2013. The two-channel MNVR solution is based on the Falcon III wideband networking technology. One of the newest radio types by Harris is the AN/PRC-152, which is based on the same Falcon III technology. This system is already in use by different users, e.g. by all branches of the U.S. Department of Defense or different countries. [9]

The Falcon III software-defined tactical radio family is a radio system which fulfills the U.S. military's Joint Tactical Radio System's (JTRS) requirements. The Joint Tactical Radio System (JTRS) is a Department of Defense program with the purpose of developing a family of software-defined tactical radios that enable networks to send and receive voice, data and video to make tactical communication on the battlefield possible. [10]

Figure 4. AN/VRC-110 vehicular system [11]

Naturally, there are a lot of other ones besides the two manufacturers I have mentioned. The main conclusion is that the manufacturers and the users have the same purpose. They would both like to find a solution which is sophisticated, cost-effective and is able to fulfill certain requirements (e.g. frequency, services, security, etc.), and can be upgraded easily.

RADAR systems

Nowadays different radars are in use, and based on the provided information by these systems, our life can be safer and easier. In civilian life we use them to track and control airplanes and ships, we have weather radars and also special radars (e.g. car speed radar, bird radar, fish radar).

In military life the use of the radars has the same purpose, but there are some further important tasks, as well. A possible classification of these military radars is the following:

- Air-defense Radars;
- Battlefield Radars;
- Air Traffic Control (ATC) radars. [12]

Fundamentally the main parts of radars are:

- Transmitter;
- Duplexer;
- Receiver;
- Radar antenna;
- Indicator. [13]

The frequency bands used by them are shown in the following picture.

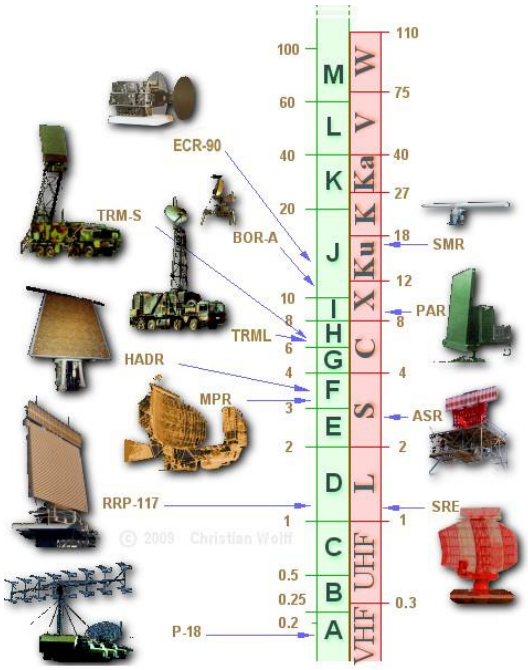

Figure 5. Examples of radars and frequency bands [12]

The early radar systems had mechanically-steered antennas. Nowadays we can find more and more phased-array radars where the radar beam is electronically steered. Software radio technology is used during the improvement of new radar systems as well. In these cases the acronym SDR stands for Software Defined Radar (SDR).

Global Navigation Satellite Systems

The next analyzed system is the Global Navigation Satellite Systems (GNSS). Generally we call it GPS (Global positioning system), this name comes from the name of the US improved positioning system, but the right name of these systems is Global Navigation Satellite Systems. We have to mention four important systems, the US NAVSTAR GPS system, the Russian GLONASS, the European Union's GALILEO and the Chinese BeiDou (COMPASS).

Generally we can tell that GNSS systems have three elements, the space segment, the control segment and the user segment. The GPS space segment consists of a constellation of satellites transmitting radio signals to users. The GPS control segment consists of a global network of ground facilities that track the GPS satellites, monitor their transmissions, perform analyses and send commands and data to the constellation. Just like the Internet GPS is an essential element of the global information infrastructure. The free, open, and dependable nature of GPS has led to the development of hundreds of applications affecting every aspect of modern life. GPS technology is now in everything from cell phones and wristwatches to bulldozers, shipping containers and even ATM's. [14]

NAVSTAR GPS (Navigation System with Timing and Ranging Global Positioning System): This system is an U.S development. The USA ensures at least 24 operational GPS satellites 95% of the time. To provide this capacity, the US Air Force has been flying 31 operational GPS satellites for the past few years. [15]

GLONASS (Globalnaya navigatsionnaya sputnikovaya sistema): The GLONASS system was started in October 1982, and until 1993 24 satellites were launched. Because of the financial problem there was a short break, but the system is now supported by the Russian President and government. The purpose of the current developments is to improve accuracy, reliability and reduce the operating costs. [16]

GALILEO: The European Navigation Satellite System, called Galileo consists of 30 satellites and ground infrastructures. It was developed by the European Union and the European Space Agency (ESA). The aim of its development is to provide independence for Europe from the other GNSS systems, and it is also important to be interoperable with them. [17]

BeiDou (COMPASS): The goal of BeiDou Navigation Satellite System is to provide independence for China. Based on the current plans this system will be able provide full coverage in the Asia-Pacific region. [18]

GNSS system	First satellite	Operational from	Active satellites
GPS (USA)	1978	1993	31
GLONASS (RUS)	1982	1993/2011	24
COMPASS (CHI)	2007	2011	14
GALILEO (EU)	2011	2011	4

Figure 6. GNSS systems [14] [19] [20] [21]

These systems are used in the whole world and in so many fields of the life, that it is very difficult to enumerate them. I am going to mention only a few of them: mapping for different purposes (e.g. agriculture or site-specific farming, tracking animals to help their preservation, etc.), tracking and guiding different types of vehicles (emergency vehicles, ships in the ports, airplanes, trucks, etc.). I would like to mention the Automatic Identification System (AIS) transmission, which is endorsed by the International Maritime Organization, and it is used for vessel traffic control around busy seaways. The other example is from the industry, in some types of new cars the GPS and crash sensors are in contact, and the system is able to inform the emergency services in case of an accident.

The GNSS is used widely in the military, as well. We can find it in different weapon systems, and it is used for tracking cars, tracks, units. There are some states where the GNSS

is embedded into soldiers' vests and uniforms, so that it will be easier to find them in case of emergency.

The SDR technology is already used in various GPS products, and there are further researches in order to find better and better solutions. The SDR element is used in receivers which is the user segment of the GNSS. The use of SDR element can be a solution for jamming, and can also provide joint receivers which is able to handle the signals of two or more different GNSS systems and makes using of both civil and military GPS signals possible. For example the NASA had a program - until the end of 2013 - to improve a low-power, modernized, advanced anti-jam GNSS SDR positioning platform, which allows the use of both civil and military GPS signals. [22] [23]

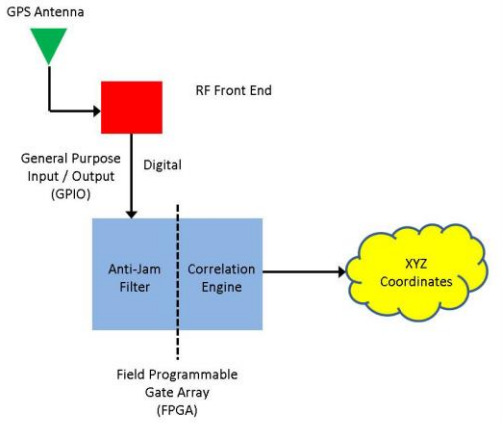

Figure 7. GNSS SDR System Integration Diagram [23]

In the different articles there are some news in connection with a Secure Software Defined Radio (S-SDR) GNSS receiver capability. The aim of this development was – by utilizing available satellite signals – to ensure a high level signal availability to reach the maximum accuracy in positioning. [24]

To prove the need for this kind of new technology I would like to mention an incident that happened in 2009 at the Newark Airport in New Jersey. A truck driver with his GPS jammer temporarily battered the airport satellite-positioning receivers, while he was driving in the vicinity of the airport. [25]

GSM systems

Since the early 1980s we have seen an unbelievable development of cellular telephone systems. In order to have a usable mobile system in Europe, the participating nations started working together for financial and technical reasons. To unite various self-developed systems they formed a study group called the Groupe Spécial Mobile (GSM) to study and develop a pan-European public land mobile system. The phase I of the GSM specifications was published in 1990. The commercial service was started in mid-1991. [26]

Nowadays, as I have mentioned in the previous paragraph, the frequency spectrum is very busy. We have more and more instruments and more and more users. The experts have to find different solutions for providing a higher and higher level of service for the end-users, and also have to be able to keep the readiness on a minimum level of service. In the next figure you can see examples for different standards for the mobile telecommunication.

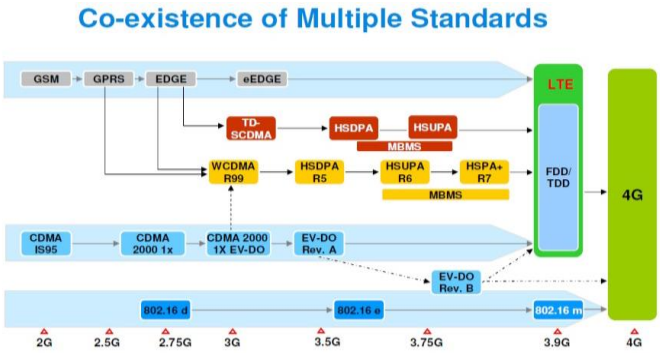

Figure 8. Applying SDR in Mobile Base Stations [27]

The SDR concept is used on base stations. "SDR base station resources need to be highly scalable to meet application and operator needs, as is already the case with existing GSM and UMTS base stations. Once the hardware can support different Radio Access Technologies, the base station will be able to run several Radio Access Technologies in parallel and even dynamically scale the performance assigned to the different Radio Access Technologies up or down." [28]

Electronic warfare (EW) systems

From the point of view of the EW systems the fast and precise control of the electromagnetic spectrum is a very important and basic requirement. The SDR and cognitive radio concepts are already in use in the EW and the connected fields, e.g. in SIGINT[1]. Being able to find the different emitters is basic for the SIGINT activity, which is an important element of the military intelligence. SIGINT is responsible for providing the Electronic Order of Battle (EOB) before different operations, and is useful to raise Situational Awareness.

Based on the shown examples in the previous paragraphs we can see that the different fields are prepared to fight electronic surveillance and electronic jamming. E.g. the communication equipments use different jam-resistant digital waveforms with different hopping methods. The transmitted data is highly coded, and even if we are lucky enough to intercept them, we would need lots of time and energy to decode them. Nevertheless, we need to note that this situation is valid only for armies equipped with state-of-the-art technology. Recently there have been several local conflicts and peacekeeping missions, where the counterparts did not have such sophisticated equipments. In these cases we can carry out the interception, analyses and geolocation of the emitters. In some places we have enough time to decode them, and in case of communication systems to translate the messages, as well.

FUTURE OF THE SOFTWARE DEFINED RADIO CONCEPT

To improve the effectiveness of our SDR assets, we have to coordinate the stand-alone assets and use central units. We also need to increase the speed of information exchange, so that we will be able to provide proper double-check of the received information and Situational Awareness. To increase the level of cooperation of our systems we also have to implement other tools, e.g. Geographic Information Systems (GIS). In most cases human resources have less importance, but we can not forget to provide suitable training for them.

We should not forget that there are some researches, in which the vulnerability of SDR based systems is under investigation. The main conclusion of these articles is that the SDR based assets are in danger due to the use of IT technology. It means, that the SDR based systems can be attacked using the common IT attack methods, e.g malwares, Denial-of-Service Attacks, etc.

[1] Signals Intelligence, SIGINT

CONCLUSION

In this article I have given some examples of the use of the SDR concept in both civilian and military equipments. We could continue the enumeration e.g. with other wireless systems, or with military systems (sensors, etc.), as well. I have to emphasize that we have just started using the SDR technology, and now we have a newer idea, the cognitive radio. The development will never stop, there will be always newer and newer solutions. The effective use of the new assets depends on the cost of the development and also the necessary time from the desk of the engineer to the end-user.

Using the SDR based devices, the use of the frequency spectrum is more effective and we can use more electronic devices simultaneously. To avoid interference and other anomalies, the developers and end-users need to have a very strong cooperation. Due to the complexity of the systems observed, electronic warfare activities are becoming more and more difficult. In order to be able to keep pace with technological advancement, we need stronger, faster and centralized EW systems that use the newest technology.

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