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A Review on Recent Trends in Software Defined Radio Design and Applications

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Abstract **-** Software Defined Radio is an all new technology being developed in the 21st century. Over a past couple of decades many Mobile communication standards have evolved and even today researches are going to develop new standards. Different standards of Mobile communication use different type of hardware circuitry. The existing mobile communication standards are primarily regional and not global. So efforts are going on to develop systems which can support multiple mobile communication standards using same hardware but swapping the software. A software-defined radio is a radio in which some or all of the physical layer functions are software defined. The ideal SDR hardware should support any waveform at any carrier frequency and any bandwidth. An SDR can be adapted for use in multiple markets and for multiple applications.

Index Terms **-** Software-controlled radio, Radio frequency, bandwidth, security, and waveform

I. INTRODUCTION

The software defined radio, SDR, sometimes called a software radio has been the aim of many radio developments for a number of years. The roots of software defined radios can be traced back to the days when software was first used within radios and radio technology. The basic concept of the SDR software radio is that the radio can be totally configured or defined by the software so that a common platform can be used across a number of areas and the software used to change the configuration of the radio for the function required at a given time. There is also the possibility that it can then be re-configured as upgrades to standards arrive, or if it is required to meet another role, or if the scope of its operation is changed. Most radios are not software defined but rather software controlled.[2]

For example, a modern cellular phone may support both GSM (2G) and WCDMA (3G) standards. Since the user is not required to flip a switch or plug in a separate module to access each network, the standard selection is controlled by software running on the phone. This defines the phone as a software-controlled radio. A conceptual block diagram of such a radio is shown in Fig.1

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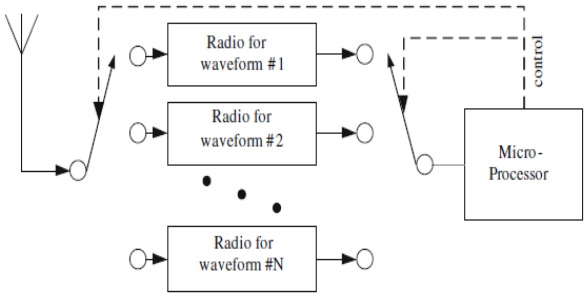

Fig 1: Basic software-controlled radio[2]

One major initiative that uses the SDR, defined radio, is a military venture known as the Joint Tactical Radio System, JTRS. Using this single hardware platform could be used and it could communicate using one of a variety of waveforms simply by reloading or reconfiguring the software for the particular application required. This is a particularly attractive proposition, especially for coalition style operations where forces from different countries may operate together. Radios could be re-configured to enable communications to occur between troops from different countries, etc.

The SDR software radio concept is equally applicable for the commercial world as well. One application may be for cellular base stations where standard upgrades frequently occur. By having a generic hardware platform, upgrades of standards can easily be incorporated. Migrations for example from UMTS to HSPA and on to LTE could be accommodated simply by uploading new software and reconfiguring it without any hardware changes, despite the fact that different modulation schemes and frequencies may be used.

There are many opportunities for considering the use of the software defined radio, SDR, concept. As time progresses and the technology moves forward, it will be possible to use the concept in new areas.

A. Software Defined Radio

The SDR Forum themselves have defined the two main types of radio containing software in the following fashion :

- **Software Controlled Radio**: Radio in which some or all of the physical layer functions are Software Controlled. In other words this type of radio only uses software to provide control of the various functions that are fixed within the radio.

- **Software Defined Radio**: Radio in which some or all of the physical layer functions are Software Defined. In other words, the software is used to determine the specification of the radio and what it does. If the software within the radio is changed, its performance and function may change.

Another definition that seems to encompass the essence of the Software Defined radio, SDR is that it has a generic hardware platform on which software runs to provide functions including modulation and demodulation, filtering (including bandwidth changes), and other functions such as frequency selection and if required frequency hopping. By reconfiguring of changing the software, then the performance of the radio is changed. To achieve this the software defined radio technology uses software modules that run on a generic hardware platform consisting of digital signal processing (DSP) processors as well as general purpose processors to implement the radio functions to transmit and receive signals.

In an ideal world the signal at the final frequency and at the correct level would emanate, and similarly for reception, the signal from the antenna would be directly converted to digits and all the processing be undertaken under software control. In this way there are no limitations introduced by the hardware. To achieve this, the Digital to Analogue conversion for transmission would need to have a relatively high power, dependent upon the application and it would also need to have very low noise for receive. As a result full software definition is not normally possible.

The ideal software-defined radio [2] is shown in Fig. 2. The user data is mapped to the desired waveform in the microprocessor. The digital samples are then converted directly into an RF signal and sent to the antenna. The transmitted signal enters the receiver at the antenna, is sampled and digitized, and finally processed in real time by a general purpose processor.

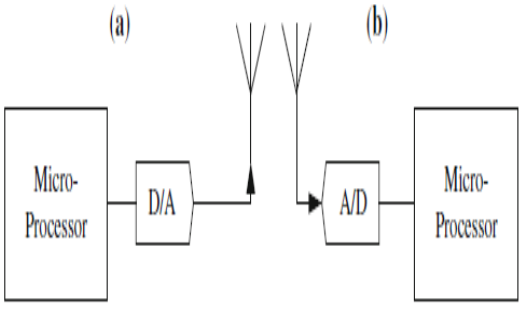

Fig. 2 Ideal software-defined radio: (a) transmitter, (b) receiver

B. Levels of SDR

In order to give a broad appreciation of the level at which a radio may sit, the SDR Forum (now called the Forum, WINNF) has defined a number of tiers. These tiers can be explained in terms of what is configurable.

- Tier 0: A non-configurable hardware radio, i.e. one that cannot be changed by software.
- Tier 1: A software controlled radio where limited functions are controllable. These may be power levels, interconnections, etc. but not mode or frequency.
- Tier 2: In this tier of software defined radio there is significant proportion of the radio is software configurable. Often the term software controlled radio, SCR may be used. There is software control of parameters including frequency, modulation and waveform generation / detection, wide/narrow band operation, etc. The RF front end still remains hardware based and non-reconfigurable.
- Tier 3: The ideal software radio or ISR where the boundary between configurable and non-configurable elements exists very to the antenna and the "front end" is configurable. It could be said to have full programmability
- Tier 4: The ultimate software radio or USR is a stage further on from the Ideal Software Radio, ISR. Not only does this form of software defined radio have full programmability, but it is also able to support a broad range of functions and frequencies at the same time. With many electronic items such as cell-phones having many different radios and standards a software definable multifunction phone would fall into this category.

Although these SDR tiers are not binding in any way, they give a way of broadly summarising the different levels of software defined radios that may exist. SDR waveform portability Apart from the fact that the software defined radio can reconfigure itself; another major advantage is that of waveform portability. There are several reasons for the need for SDR waveform portability:

- Cost savings: With the waveforms for various transmissions, military and commercial, costing huge sums to develop, there is a real need to be able to re-use waveforms on different projects and this is likely to involve very different platforms
- Obsolescence mitigation: A similar requirement comes as hardware technology develops and it is necessary to transfer existing waveforms onto newer platforms
- Interoperability To provide complete interoperability a customer may request the use of a particular waveform being used across the equipment from several manufacturers.

Complete SDR waveform portability is not always easy to achieve. However it is necessary to incorporate measures at the earliest stages of the design to ensure the optimum level portability. Elements such as the use of SCA - Software Communications Architecture, and CORBA, a form of middleware associated with SCA..In addition to the use of SCA and CORBA general good structured programming techniques are needed - short-cuts that may work on one platform are certainly not likely to work on another. It is often necessary to be able to re-compile the code for use the different platforms, so all code should be in a format that can be compiled on the foreseeable platforms.

II. SDR SECURITY

Another area of growing importance is that of SDR security. Many military radios, and often many commercial radio systems will need to ensure the transmissions remain secure, and this is an issue that is important for all types of radio. However, when using a software defined radio, SDR, there is another element of security, namely that of ensuring that the software within the radio is securely upgraded. With the growing use of the, many SDRs will use this to medium to deliver their updates. This presents an opportunity for malicious software to be delivered that could modify the operation of the radio or prevent its operation altogether. Accordingly SDR software security needs to be considered, if the Internet is used for software delivery or where there could be security weaknesses that could be employed maliciously.

A. SDR Interoperability Testing

With the need to transfer waveforms from one radio or platform to another it is necessary to undertake full interoperability testing. [2] This needs to assure that the code can be transported from one platform to another and provides the correct functionality for the particular waveform in case. To achieve these waveforms generally need to be certified and accredited. The SDR, software defined radio is a reality today, and it is being used in many areas. However there are a number of limitations that prevent them being used in as many applications as some would like. One is the sheer processing power that is required, and the resulting power consumption. It is necessary to undertake power consumption / processing power trade-off, and this is one of the core decisions that needs to be made at the outset. As a result of this it is not feasible to use SDR for cell-phone designs, but cell-phone base-stations are using them as power consumption and space are normally not issues and the software can be upgraded to enable the moving standards to be tracked.

Also software defined radios are being used by the military, and already some handheld designs are appearing. As technology progresses software defined radios will be used in applications, yet there will always be a decision to be made as the SDR is not the right decision for all radios. For small cheap radios where changes will be few, the SDR is definitely not right. But for more complicated systems where length of service is an issue and where change is likely, then the SDR is definitely a good option to be considered

III. LITERATURE SURVEY

Software Defined Radio (SDR) may provide flexible, upgradeable and longer lifetime radio equipment for the military and for civilian wireless communications infrastructure [11]. SDR may also provide more flexible and possibly cheaper multi standard- terminals for end users. It is also important as a convenient base technology for the future context-sensitive, adaptive and learning radio units referred to as cognitive radios. SDR also poses many challenges, however, some of them causing SDR to evolve slower than otherwise anticipated. Transceiver development challenges include size, weight and power issues such as the required computing capacity, but also SW architectural challenges such as waveform application portability. SDR has demanding implications for regulators, security organizations and business developers (Tore Ulversøy - 2010).

Radios have been designed to process a specific waveform. Single function, application-specific radios that operate in a known, fixed environment are easy to optimize for performance, size, and power consumption. At first glance most radios appear to be single function—a first-generation cellular phone sends your voice, while a Wi-Fi base station connects you to the Internet. Upon closer inspection, both of these devices are actually quite flexible and support different waveforms. Looking at all the radio devices in my house, only the garage door opener and the car key fob seem to be truly fixed. A software-defined radio is a radio in which some or the entire physical layer functions are software defined (Eugene Grayver - 2013).

The role of firmware and digital signal processing in radio transceiver design has increased to meet the global coverage requirement and to cover extra features in the mobile telephony. The Software-Defined Radio (SDR) is the practical approach for this. The paper reviews the SDR concepts, the benefits, the design steps involved in SDR, some emerging concepts, technological solutions and challenges, applications and economy. (Mehul R. Naik, C. H. Vithalani-2013)

This paper proposes a field-programmable gate array (FPGA)-based software defined radio (SDR) implemented flight termination system (FTS). This is purely a new kind of implementation of digital FTS in SDR platform. The applied design procedure replaces a multiple platform-based system with a single platform. It also guarantees reconfigurable, interoperable, portable, and handy FTS, and maintains errorless, bug free, and reliable implementation. Real-time flight termination operation demands a very highly reliable and ruggedized platform. Hence, the FTS is implemented in FPGA. In order to minimize hardware resources and to enable future up gradation, efficient optimization technique has been applied. LabVIEW, a high-level programming language is used to simulate and implement the system in real time and enables rapid prototyping. The system was validated at subsystems level by measurements of different parameters in various intermediate stages of processing, and further was validated as an integrated system at real-time telecommunication operation environment (Amiya Ranjan Panda et. al.-2015)

SDR has increasingly become an invaluable research, development, and educational tool within the telecommunications sector with respect to rapidly prototyping new algorithms and paradigms in actual radio hardware and evaluating them in real-world over-the-air conditions. Due to advances in microprocessor technology, radio frequency hardware, and software, SDR has matured into a reliable tool that is now part of almost every communication engineer's toolbox, and it has changed the way the telecommunication sector produces innovative solutions to technical challenges.(A. M. Wyglinski, D. P. Orofino, M. N. Ettus and T. W. Rondeau - 2016)

Software Defined Radio (SDR) or Software Radio is one of the most important technologies for the modern

wireless communication system. SDR is a radio which can tune to any frequency band, implement different modulation and demodulation schemes and different standards in the same device by using reconfigurable hardware and powerful software. SDR provides flexible, upgradeable, multi-standard and longer lifetime radio equipment for both the military and for civilian wireless communications infrastructure. A detailed analysis of SDR hardware and its operation focusing on analog front end and digital front end was done. (D. Sinha, A. K. Verma and S. Kumar- 2016). The term reconfigure is nothing but use of the same hardware for different function for different time. The Software Defined Radio is the radio whose physical layer is significantly defined in software. The Hardware Defined Radios are fixed mode radios which consist of active filters, oscillators, mixer, and amplifiers. The Hardware Radio cannot be reconfigured easily at significant capacity (FM radio). In short SDR is the shift from the fixed mode Hardware Radios towards the Flexible, low cost Software Defined Radios.(Priyanka S. Kamble, Bhalchandra B Godbole- 2016).

Software Defined Radio (SDR) is a technology which makes it possible to implement the radio communication process simply with software. Comparing to the traditional radio communication systems, SDR omits all the hardware and replaces them by pure software. This solution also gives a great advantage in flexibility because a SDR receiver is able to decode all the signals. Past decades deals with many communication standards and even today also many researches are going on. A major problem in these is different communication standards use different hardware circuitry which causes these communication standards regional. Indoor to mitigate this problem, many developments are occurred in mobile communication to develop a communication system which works by swapping the software with a single hardware circuitry (Archa Sundar, Dhanya S- 2016).

IV. CURRENT TRENDS AND CHALLENGES

The Software Defined Radio (SDR) industry has been revitalized and creating a lot of buzz. The main reason for its recent growth and popularity is the result of communications devices needing to be more flexible, configurable, cost-effective, and interoperable. The increase in demand is directly linked to industries such as defence, public safety, and commercial research and development, finding more requirements for interoperability. As SDR technology is compatible with various networking standards, this technology will continue to be a hot commodity for years to come.

At present, there are several applications for SDR and these are being quickly adopted by mainstream RF designers. These days, one system can be designed and manufactured for an array of applications in order to gain economies of scale. RF designers are now challenged to develop wide band and high bandwidth RF front ends while digital engineers need platforms for developing unique DSP for unique applications. Software defined radio brings together both RF and DSP to appeal to both markets. When compared to dedicated hardware solutions, this technology provides several benefits. There is little need for changes in hardware when using SDRs as you are able to reprogram the device for different functionalities. Not only does this keep pace with the advancement of technology, it also keeps the systems cost-effective.

SDR users are typically divided into four groups: Academic Commercial Defence Public Safety Because of reduced number of hardware parts and software reusability, the academic SDR users will be able to continue to further their research efforts even with constraining or limited research budgets. Further, the commercial market is expected to continue to grow as companies innovate and build SDR technology into existing wireless products and solutions. In the defence market, all wireless solutions will be combined into one SDR device for communications, electronic warfare, and signal intelligence. For the defence applications, there has been significant development in signals intelligence applications for spread spectrum monitoring, emanation reconstruction, (counter) electronic warfare, and signal jamming. SDR in the public safety market will focus on interoperability among first responders. As it is currently limited by incompatible radio systems that operate on different frequency bands and/or use different protocols, requiring ad-hoc bridges between networks. As the demand grows for increased mobility with the need for information, it is expected to drive market growth as well. Further, as SDR technology provides a platform for next generation systems and terminals, the forecast for the industry is extremely positive.

There are many challenges inherent in the design of SDR terminals. This goes for transmitters as well as receivers. The task of designing a SDR is a relatively complex problem. Even though much of the required technology is available, it is often a matter of trade-off to find the best solution for a given application. In terms of a software defined radio, the most flexible solution is most likely the most expensive in terms of money or power dissipation. This trade-off calls for methods to optimize several parameters simultaneously. Furthermore, the problem is even more complex, as an SDR will contain both an analog and a digital.

V. CONCLUSION

As the document has described, the area of software defined radios is multi-disciplinary. The successful integration of SDRs requires knowledge about antennas, RF hardware design, reconfigurable computing, algorithm development and design methods that provides an efficient design. It has also been described that there are many challenges left, and a significant amount of research is to be done. However, the technology is mature enough to start employing software radio technology in existing products. Later, cognitive radio is expected to be the key application that requires SDR. Cognitive radio has also attracted focus from the SDR Forum as well as the European Telecommunications Standards Institute (ETSI).

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