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Software Defined Radio: Enabling technologies and Applications

A Mini-Literature Survey

Abstract The survey paper identifies the enabling technologies and research areas in radio frequency engineering that may facilitate the development of Software Defined Radios (SDR). Receiver architectures are also discussed and their viability for a reconfigurable radio application is investigated. The paper also reviews several important techniques based on Software Defined Radios.

I INTRODUCTION

SDR, software defined radio, also known as software based radio (SBR) or just software radio, is a technological innovation that is coming of age for wireless communications of many types. There is no one single agreed definition of SBR/SDR/SR terminology, since there are several different perspectives for the technology. An SDR is defined as a radio in which the receiver digitization is performed at some stage downstream from the antenna, typically after wideband filtering, low noise amplification, and down conversion to a lower frequency in subsequent stages - with a reverse process occurring for the transmit digitization.

Digital signal processing in flexible and reconfigurable functional blocks defines the characteristics of the radio. Software Defined Radio (SDR) concept is considered as the future of mobile communications. The number of mobile communication standards is rapidly growing to offer new services to the users. Conventional multimode radios use an auxiliary radio frequency (RF) front-end module for each supported communication standard. Therefore, the complexity and cost of these handsets are increasing. Using fixed RF front-end modules makes the radio inflexible and incapable of accommodating communication standards that may be introduced in the future.

In an idea world, a software defined radio (SDR) would be able to transmit and receive signals of any frequency, power level, bandwidth, and modulation techniques. Current analog receiver and transmitter hardware sections are still a long way from being able to achieve this ideal behavior.

The objective of SDR is to provide a reconfigurable radio platform that is capable of accommodating both current and future communication standards [1]. In order to realize a SDR terminal, flexibility at both the RF front-end and the baseband module is required. The reconfiguration of the latter can be achieved by reprogramming the Digital Signal Processors (DSP) and Field Programmable Gate Arrays (FPGA), but the operation of analogue front-end module is not defined in software and thus designing reconfigurable RF components definitely requires a new approach.

In this survey paper, receiver architectures are explained and their suitability to a reconfigurable radio is discussed. The paper also discuss about several techniques based on Software Defined Radio. The bottlenecks in the RF technology in realizing a SDR are identified to promote long-term research areas in order to accelerate SDR development.

II RECEIVER DESIGN OF SDR

As the work of Reference [2], the author notes that a receiver should transform a low-power RF input signal into a complex baseband signal. The designer has to consider all the performance parameters; dynamic range, third order intercept point (TOI), noise figure (NF), gain (G), image rejection, filtering, signal to noise ratio (SNR) and Spurious- Free Dynamic Range (SFDR) as a whole since a subset of them may not give a clear indication of the true performance of the receiver. However, for a reconfigurable radio, the input power level, frequency, bandwidth, and modulation scheme is variable, and this is not the case. An ideal SDR must cover following parameters: a general range of center frequencies, possess a flexible bandwidth, transmit and receive signals within a wide dynamic range, while maintaining spurious free operation. In addition, the receiver ought to be simple enough to be manufactured as an integrated circuit (IC). The power consumption should be low to be attractive for mobile handset applications.

III TRANSCIEVER DESIGN OF SDR

In transceiver design suitable devices need to be chosen to meet the required performance. In SDR applications, this is crucial because the limits of current RF technology will be met in the design of a reconfigurable receiver.

a. Analogue to Digital Converters

In the ideal SDR, the received signal is digitized after the antenna at RF, while it is currently unachievable to perform direct digitization at microwave frequencies. Meanwhile, the power consumption of an ADC increases dramatically when the resolution and sampling rate get higher. At the present rate of advance in ADC technology, it is possible if it will be some time before digitization at RF.

b. Antennas

Antennas are usually designed for a single frequency band of operation. Having a wideband antenna will decrease the sensitivity of a receiver. Filtering will be more demanding since more interfering signals will reach the Low Noise Amplifier (LNA) and mixer, and thus high linearity will be required from these devices. Tunable antennas will be an advantage for rejecting the unwanted frequency bands and add some selectivity to the receiver at an early stage. These antennas can be realized by utilizing an emerging technology, such as Micro Electro Mechanical Systems (MEMS). Electronic tuning of the antennas is a subject that has been investigated by a number of researchers and promising results have been obtained [3].

c. LNAs

There are a large number of components available from a number of semiconductors. For SDR, a LNA operating up to 6 GHz is sufficient. There are broadband devices available with a NF as low as 1.5 dB and a TOI up to 41 dBm, offering 15-20 dB gain. Our application requires a device with a good compromise between NF, TOI, gain as well as current consumption.

d. RF Preselect Filters

The most demanding filtering at the RF stage is required around 2 GHz frequency band. To achieve a better selectivity and rejection of interference, a tunable RF filter with variable bandwidth and center frequency would be ideal. According to on-going research, this may be achieved in the coming years by utilizing MEMS technology, but tunable RF filters are not yet available off-the-shelf.

e. Mixers

There are a very limited number of high-TOI mixers that can operate from 900 MHz to 6 GHz. Although they are regarded as “high-TOI” mixers, the TOI of these devices are considerably lower than the narrower band versions. One solution to this problem is the use of external circuitry to improve linearity, but these techniques require a significant number of additional components. For broadband receiver applications, the linearity of RF mixers will continue to be a bottleneck in the coming years.

IV TYPICAL TECHNIQUES BASED ON SOFTWARE DEFINED RADIO

a. Cognitive Radio

In the work of Reference [5], the author views cognitive radio as a novel approach for improving the utilization of a precious natural resource: the radio electromagnetic spectrum. He addresses the task of radio-scene analysis, and introduces the notion of interference temperature as a new metric for the quantification and management of interference in a radio environment. The paper also reviews nonparametric spectrum analysis with emphasis on the multitaper method for spectral estimation, then emphasis on application of the multitaper method to noise-floor estimation. The paper discusses the related issue of spectrum-hole detection and channel-state estimation and predictive modeling. The paper highlights the processes of cooperation and competition that characterize multiuser networks. Following the discussion of interference temperature as a new metric for the quantification and management of interference, the paper addresses three fundamental cognitive tasks: radio-scene analysis, channel-state estimation and predictive modeling, transmit-power control and dynamic spectrum management.

b. Smart Antennas

Another techniques based on Software defined radio is Smart Antennas. In reference [6], this work presents a new technique, called the Instantaneous Air Interface (IAI). Its method is useful for future convergent systems based on software-defined radio (SDR) with smart antennas. The paper compares the frequency of arrival performance as a function of the number of users for CAPON, ESPRIT and Music. He also points out the angle-of-arrival ambiguity and it happens in all of the proposed DFOA methods, the author uses the joint frequency and direction of arrival, which is an improvement to the direction of arrival (DOA), then the author's IAI modifies the traditional methods of obtaining the DFOA. This is an approach that allows interface estimation.

c. Linearized Transmitters

In the work of Peter [7], the paper proposes that Transmitter linearization is a key enabling technology in the successful realization of software defined radio systems, in particular for the base station. The author makes uses of advantages in terms of efficiency and cost, and they are keys to the widespread adoption of SDR topologies in the marketplace. The author removes one of the final hurdles to the adoption of this long-discussed concept by use of techniques such as digital predistortion. Once this format has been accepted for a base station, there are a number of new network deployment topologies enabled by this type of architecture. The concept of an orphaned RF black box being the only item at a tower site, with the remainder of the base station hardware being deployed at a central location, has been described. It has been shown to have a number of fundamental advantages for both the base station manufacturer and network operator, primarily in the areas of cost and efficiency.

V Summary

Through all examples and introduction, we see that in the long term, software defined radios are expected to become the dominant technology in radio communications. A software defined radio can be flexible enough to avoid the limited spectrum by cognitive radio and software defined antennas, etc. SDR along with software defined antennas are the enablers of the cognitive radio. In addition, software defined radio designing tunable RF/IF filters will greatly simplify reconfigurable radio design. On the other hand, implementing tunable antennas will improve the frequency selectivity of the receiver and soften the linearity requirements of the RF front-end. Although the IF frequencies can be digitized with the current ADC technology, power consumption and sampling frequency of these devices should be reduced for mobile applications. Rejecting high level interference is crucial for reconfigurable radio design. Introducing interference rejection mechanisms will provide important benefits by lowering filtering and linearity requirements. As well as amplifier and mixer linearization, interference rejection techniques should also be investigated by the research community and industry.

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