Ubiquitous Wireless Communication
-Possibility of Software Defined Radio-

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Abstract

In this paper, concepts, background, and current status of software defined radio (SDR) are explained as a solution for ubiquitous wireless communication environments. The latest research results as well as the research issues for SDR are presented.

key words Ubiquitous Wireless Communication, Software Defined Radio

1 Introduction

The 3rd generation wireless cellular communication systems have already been launched in Japan and the configuration of wireless communication systems beyond 3G has been under investigation.

The evolution of wireless communication systems is shown in Fig. 1. In '80s the mobile communication service was developed. In '90s the digital cellular system replaces the analog system. In 2001 the 3rd generation wireless cellular communication system was implemented. It can supports not only voice but also video transmission.

On the other hand, wireless LAN (WLAN) systems had appeared in late '80s as the replacement of Ethernet. It had been mainly used in office environments. In late '90s WLAN systems started to be used at homes with personal computers.

Now, a new type of wireless communication network, called wireless personal area network (WPAN), has been implemented and its applications seem to be expanding.

Most of these evolution processes are based on the motivation of "High Quality" and "High Mobility". However, new key words may be required for the next generation wireless communication systems.

The important keyword for the next generation wireless communication systems is "ubiquitous". The image of ubiquitous wireless communication is shown in Fig. 2. The same terminal should be able to connect not only to the cellular system, but also to the WLAN system or the WPAN system [1]. The terminal can select the best communication link based on parameters such as accessibility, cost, bandwidth, power consumption, and so on. Or it may use multiple communication links depending on the requirements of the data to be transmitted . New applications such as an IP phone system over WLAN or WPAN may be realized.

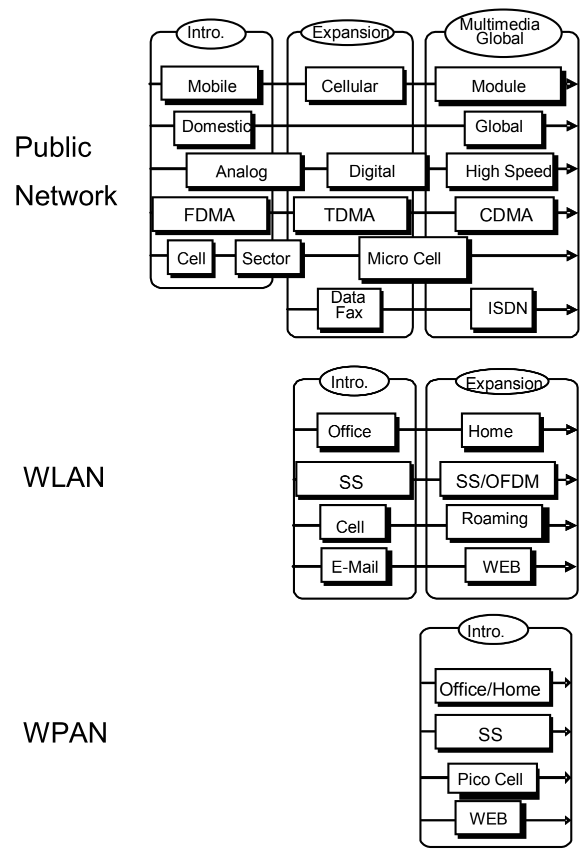

Figure 1 Evolution of Wireless Communication Systems.

Software defined radio (SDR) technology enables to satisfy those demands. The SDR terminal consists of reconfigurable devices for signal processing such as digital signal processors (DSP) and field programmable gate arrays (FPGA). The latest DSPs operate at speeds up to 1.1 GHz and offer performance of nearly 9 billion instructions per second. FPGAs can now provide densities of up to 2 million gates with low power consumption. These numbers are even improving [2, 3]. With those powerful devices the SDR terminals can support multiple wireless communication standards.

In this paper, concepts, background, and current status of software defined radio (SDR) are explained as a

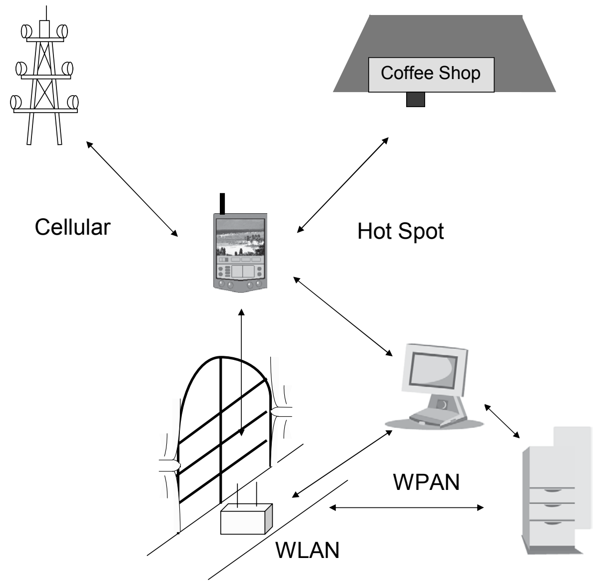

Figure 2 Image of Ubiquitous Wireless Communication.

solution for ubiquitous wireless communication environments. This paper is organized as follows. In Section 2, the background and the current status of SDR is clarified. Key technologies for SDR is presented in Section 3. The research issues for implementation of SDR is described in Section 4. Section 5 presents our conclusions.

2 Background and Current Status of SDR

One of the original research program of SDR is called SPEAKeasy conducted in US [16, 5]. The purpose of this system was to communicate with multiple wireless platforms which had been employed in US military. This project had continued from 1992 to 1997. In 1996, MMITS (Modular Multifunctional Information Transfer System) Forum was established for standardization of SDR. It is now called SDR Forum and still continues the standardization process [6].

In Europe many research program related to SDR has been conducted in ACTS and ESPRIT programs [7, 8]. The followings are the part of those programs.

- FIRST:Flexible Integrated Radio Systems Technology(Sept. 1995-Dec.1998, ACTS Project)
  - Demonstration of dual mode terminal (DCS1800 and TD-CDMA)
- SORT:Software Radio Technology(ACTS Project)
  - Demonstration of dual mode terminal (GSM and UMTS-DCS1800)
- PROMURA:Programmable RF chipset in SiGe BICMOS(Jan. 1998- Dec. 1999, ESPRIT Project)
  - Development of chip sets with a wideband power amplifier, a reconfigurable analog filter, a wideband synthesizer, and a wideband mixer
- SLATS:Algorithm development for software radio's(Jan. 1998-Jan.2000, ESPRIT Project)
  - Development of software libraries for SDR

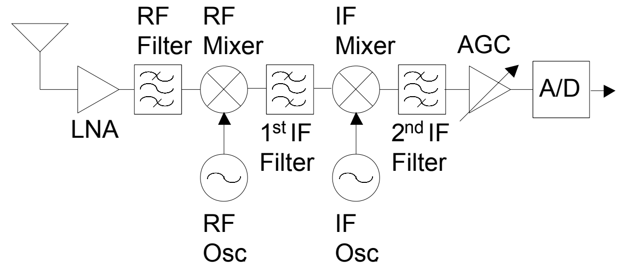

Figure 3 Block diagram of the Heterodyne Receiver.

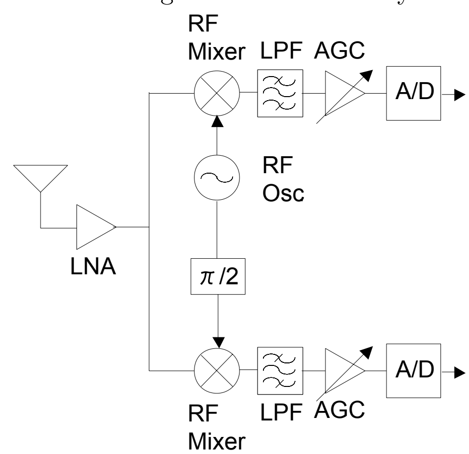

Figure 4 Block diagram of the Direct Conversion Receiver.

In Japan, Software Radio study group was established in Dec. 1998 [9]. In this study group the issues such as

- Research on the theory of SDR
- Research on the hardware and software issues of SDR
- Liaison issues with foreign groups such as SDR Forum

have been discussed.

3 Analog Digital Signal Processing for SDR

3.1 Direct Conversion Receiver

In order to realize a multimode multiband SDR, the RF front-end should be able to support a wide range of frequencies and bandwides. This task may be difficult with conventional RF front-end architectures [10].

The block diagram of a conventional heterodyne receiver is shown in Fig. 3. This architecture requires frequency-dependent passive components such as dielectric filters in the RF stage and surface acoustic wave

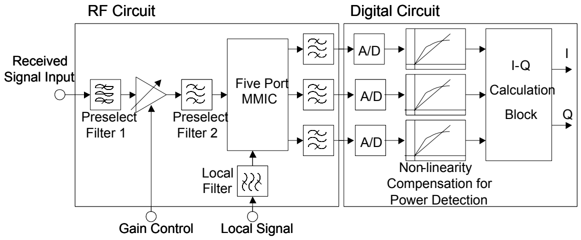

Figure 5 Block diagram of the Direct Conversion Receiver with Six-port Technology.

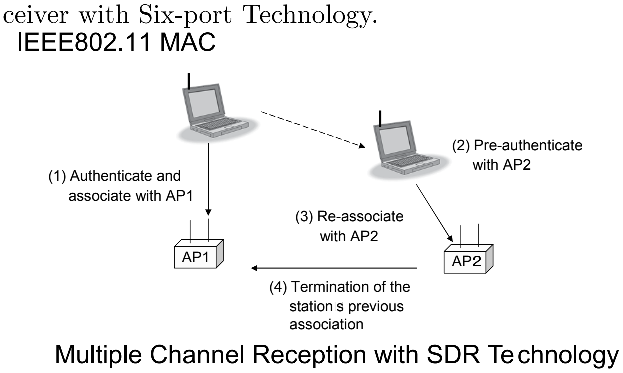

Figure 6 Multiple Channel Reception for WLAN.

(SAW) filters in the first IF stage. A ceramic or crystal filter is also needed in the first IF stage. The center frequencies and bandwidth of these filters are not flexible and not wide enough to support a multiband radio receiver.

Thus, the candidate for the RF front-end for SDR is the direct conversion (DC) principle. The block diagram of a conventional direct conversion receiver is shown in Fig. 4. The received signal is down converted directly to baseband by the quadrature mixer. The downconverted in-phase and quadrature (IQ) signals are prefiltered by the anti-aliasing low-pass filters (LPFs) with variable cutoff frequency. They are converted to digital signals by IQ analog-to-digital converters (ADCs) and fed to the digital stage. The desired signal is selected by the software-defined filter with programmable cutoff frequency.

We have also proposed a different type of direct conversion receiver [11] which is shown in Fig. 5. In order to achieve very wideband RF performance, resistive network and power detectors are used. Unlike the conventional direct conversion approach, this architecture can support both 2.4 and 5.2 GHz band. In addition, the power level of the local oscillator (LO) is smaller compared to the classical approach. Low local power can bring reduction of power consumption of the receiver.

3.2 Analog/Digital Conversion

The direct conversion receiver architecture gives flexibility to the wireless communication system. One of the possible function is the fast roaming capability be-

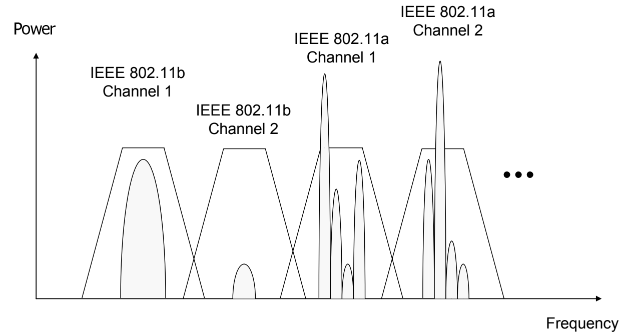

Figure 7 Multiple Channel Receiver for WLAN.

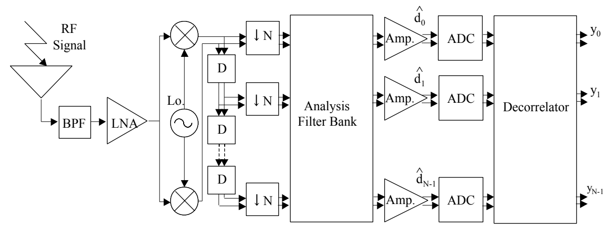

Figure 8 Filter Bank Parallel A/D Conversion.

tween WLAN access points.

The roaming protocol in IEEE802.11 is shown in Fig. 6. It does not allow simultaneous connection with multiple access points. The direct conversion architecture allows the flexibility in demodulation bandwidth. Thus, the mobile terminal may be able to demodulate the signals transmitted through multiple channels and fast handoff between the access points may be possible. Multiple signals from different WLAN systems may also be demodulated at the same time as shown in Fig. 7

To realize such capability, high speed A/D converters are required. However, improvement of A/D converters has been quite slow compared to that of digital signal processing devices [12, 13].

In order to improve the performance of A/D converters, we have proposed a parallel A/D signal processing technique [14]. The receiver structure with the proposed parallel A/D conversion scheme is shown in Fig. 8. With this architectures it is possible to increase the total speed of A/D conversion and reduce the required resolution of each A/D converter for each subband. It is also possible to reduce power consumption in terms of the normalized sampling rate [15].

4 Research Issues in SDR

There are many research issues to be solved to realize SDR. The followings are only the part of them.

OS and API

Development of OSs and APIs for SDR is a quite significant issue. SDR forum has been working on the reference architecture and APIs for SDR[16]. This ar-

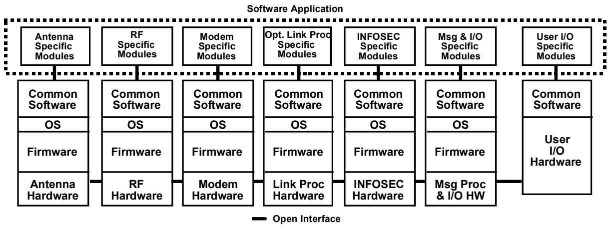

Figure 9 SDRF Open Architecture.

chitecture assumes multiple function modules and the interfaces between modules are defined as APIs. The reference architecture employs CORBA (Common Object Request Broker Architecture) for communications between software modules.

One of the problems in this architecture is that CORBA is not designed for SDR. It does not include any specification of real-time signal processing [17]. It is desirable to develop a software architecture suitable for SDR.

Security

In Sept. 2001, FCC announced a new policy that allows the authorization for SDR terminals [18]. In this policy 3rd party can make a software for SDR terminal.

Security is then the important issue since the SDR terminals are reconfigurable with replacing their softwares. If the software is modified by a malicious user, the SDR terminal can transmit the signal in illegal frequency band with unacceptable power.

Antenna and RF Circuits

In order to realize ubiquitous wireless communication, the SDR terminal has to be able to demodulate signals in multiple frequency bands such as 2.4 and 5.2 GHz bands. Antennas and RF circuits which can support multiple frequency bands are required. This is one of the key issues to be solved.

5 Conclusions

In this paper, concepts, background, and current status of software defined radio (SDR) has been reviewed. To realize ubiquitous wireless communication environments the SDR technologies are required. The example of the latest SDR technologies have been presented and the research issues to be solved have been described.

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