Development and Approach to Software-defined Radio Technology

NAGATA Kimitaka, SEKI Satoshi, MINAMI Kenji, OKA Makoto, ISHII Yasuo, SUGATA Masatoshi

Abstract

Software-defined radio (SDR) refers to radio equipment systems that can switch between multiple communication methods by changing the software. Specifically, multiple modulation and demodulation methods are realized by switching the processing and the circuits of the built-in digital signal processor (DSP) and the field programmable gate array (FPGA) with the central processing unit (CPU). This paper describes the Japan-U.S. joint research for two-way software-defined radios between Japan and the U.S., the prototype and mass production of a broadband multipurpose radio system for the Japan Ground Self-Defense Force (JGSDF) using the research results, and a program modification project that makes use of the characteristics of software-defined radios.

Keywords

software radio, Software Defined Radio (SDR), Software Communications Architecture (SCA), broadband multi-purpose radio system

1. Introduction

Software-defined radios have been the focus of attention as an application for military radios. The military has several types of radios with different modulation schemes, and they have found it necessary to carry several radios during operations.

The use of software-defined radios can reduce the number of radios to be carried during operations, and therefore, they have become required equipment.

2. Software standardization

The Joint Program Executive Office Joint Tactical Radio System (JPEO JTRS), then the U.S. Department of Defense Joint Program Executive Office, now the Joint Tactical Networking Center (JTNC), defined the software architecture for software reusability and portability. The SCA defines the mechanisms (OS, CORBA middleware, Core Framework, Application) needed to realize the software-defined radio (**Fig. 1**).

For the operating system (OS), the detailed operation of functions is specified to ensure mutual portability. For CORBA middleware, a software bus is implemented to provide a common interface for the waveform application or Application and the Core Framework. The Core Framework encapsulates the hardware dependencies and provides the same hardware resources for all appli-

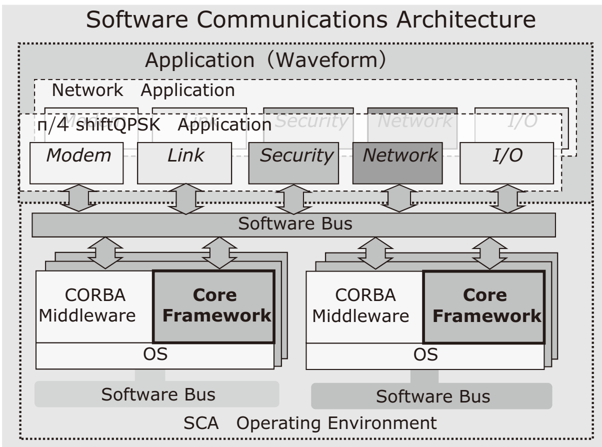

Fig. 1 Overview of the Software Communications Architecture.

cations.

The OS, CORBA middleware, and Core Framework are called the operating environment, and the Application is called the waveform (WF). By absorbing all the differences in hardware in the operating environment (OE), we have built a system that allows applications, once developed, to run on different hardware.

3. Japan-U.S. Joint Research

In the U.S., it was essential to improve intercommunication among the various armed forces (Army, Navy, Air Force, and Marines). However, due to a large number of radio types (25 to 30), the cost problem of owning multiple radios, and the need for new communication network functions, it was necessary to develop radios with architecture different from that of existing radios (hardware radios). Therefore, we started to develop software-defined radios, in which the communication method can be changed by software and the required hardware is the same for all. At that time, the United States asked its allies to participate in the development of these radios. Japan conducted joint research with the U.S. in the form of an information exchange based on a memorandum of understanding (MoU) signed between general governments (GG) with the Second Research Department of the National Institute for Defense Studies (NIDS) as the contact point. The contractor in the U.S. was the Raytheon Company (now transferred to BAE Systems), and NEC was the contractor in Japan. The development proceeded as an information exchange in accordance with a technical assistance agreement (TAA) between NEC and the Raytheon Company.

The features of software-defined radios are as follows:

- Software standardization
- Support for various modulation schemes by respective software download
- Improved interoperability among U.S., Japan, and other relevant government agencies

NEC has launched a Japan-U.S. joint research project to standardize software (**Fig. 2**). The ultimate goal was to jointly develop hardware and software between Japan and the U.S., and then port the respective software to each other's hardware so that the two countries could communicate with each other. First, we aimed to pass the SCA compliance test, which consists of automated testing (using compliance verification tools made in the U.S.), manual testing (directly checking the source code), and documentation testing (referring to the OS and CORBA manuals to confirm contents). A total of about 1,000 test items were conducted. In FY2005, NEC passed the SCA compliance test for the operating environment and Waveform, and in FY2006, NEC installed both Japanese and U.S. Waveforms on their respective hardware and confirmed that they could communicate with each other.

4. Equipping Broadband Multipurpose Radio System

Japan's Ministry of Defense invited the public to apply

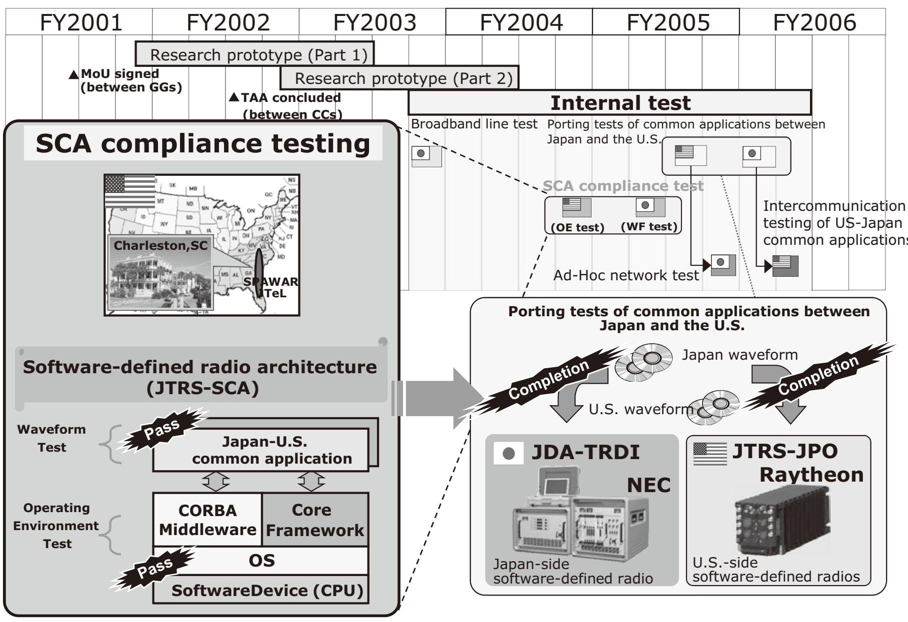

Fig. 2 Japan-U.S. joint research projects.

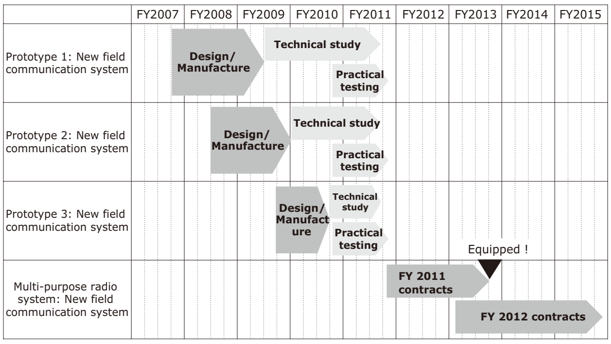

Fig. 3 Process for equipping the system.

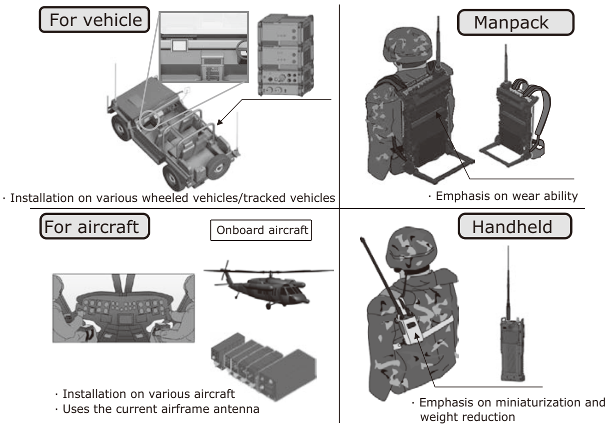

Fig. 4 Types of broadband multipurpose radio systems.

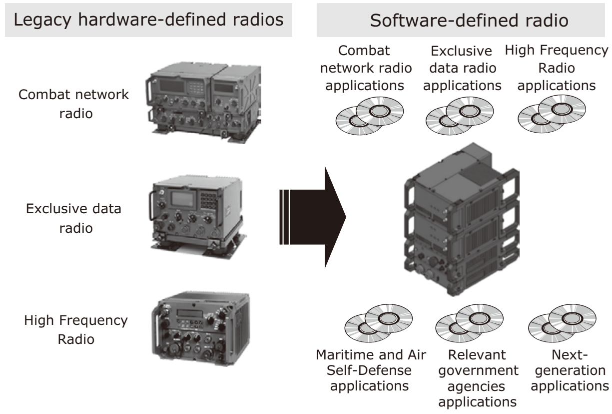

Fig. 5 Software-defined radio.

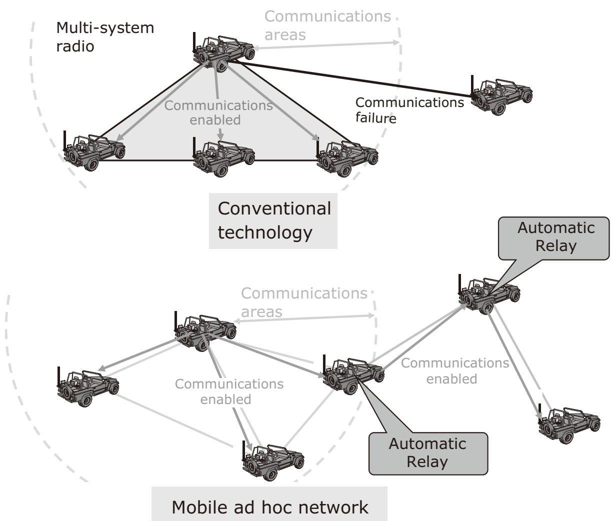

Fig. 6 Ad hoc networks.

for the prototype project of the broadband multipurpose radio system. As a result, NEC, after already passingd the SCA compliance test in the Japan-U.S. joint research project, was awarded the contract for this prototype project.

We delivered the first prototype in 2009, the second prototype in 2010, and the third prototype in 2011, and after technical and practical tests were conducted by Japan's Ministry of Defense, we were able to start mass production in 2013 (**Fig. 3**).

There are three types of broadband multipurpose radio systems in the series: one that can be mounted on motor vehicles, one that can be mounted on aircraft, and two different models of a portable one: a manpack(Type I) carried on one's back and a handheld one (Type II) (**Fig. 4**).

By replacing the software, which is a characteristic of software-defined radios, it is possible to realize a multi-purpose radio with a single unit and to use it as a successor to conventional radios in equipage (**Fig. 5**).

Compared to conventional radios, broadband multipurpose radio systems can be smaller and less expensive and they can make better use of installation space.

Currently, there are several newly developed broadband multipurpose radio systems in addition to Waveform, which is designed for intercommunication with conventional radio systems. Each of them is capable of simultaneous use of voice and data communications. In addition, an ad hoc network function has been added to enable IP communications among multiple units, allowing not only voice but also e-mail and video transmission. An ad hoc network enables a direct connection between a large number of terminals without the need for a base station and allows them to communicate with each other in an autonomous and decentralized manner, acting like a router (**Fig. 6**). Also, data communications is now possible using civilian communication networks as well as the JGSDF's own communications network. The functions can be easily improved by changing the software.

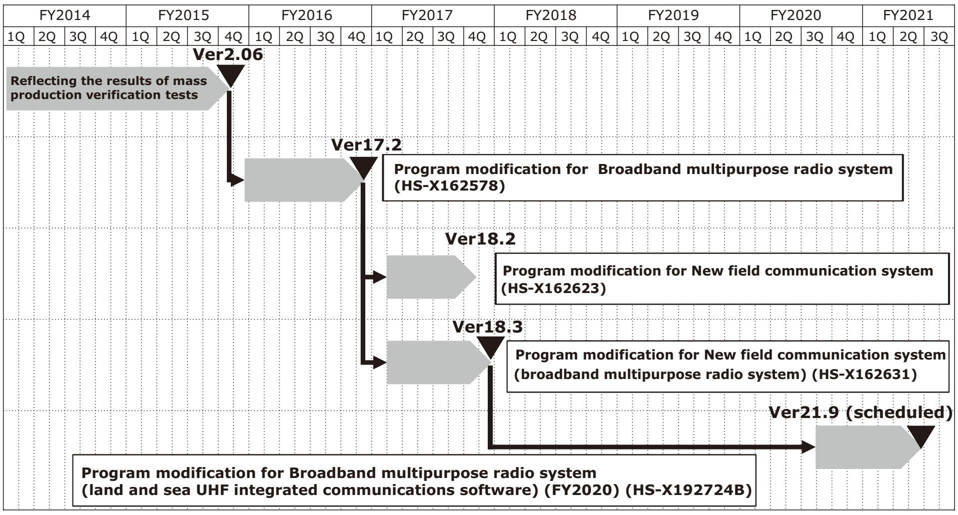

Fig. 7 Program modification project process after mass production.

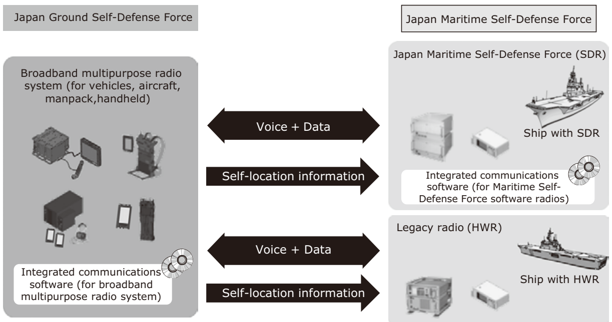

Fig. 8 Details of the fourth program renovation project.

5. Post Mass-Production Efforts

Taking advantage of the characteristics of software-defined radio, the broadband multipurpose radio system underwent a total of three program modification projects after mass production started.

In 2016, the first program modification of the broadband multipurpose radio system was carried out, mainly to improve the operability of the radio system for vehicles and manpack and handheld models and also to upgrade functions to support manual operations. In 2017, a second program modification was made, mainly to improve the usability of the onboard radios and to change the user interface. Almost at the same time with the second modification, a third program upgrade was conducted (**Fig. 7**). The command and control equipment of the JGSDF used to be only wired connections, but by using the upgraded broadband multipurpose radio system, secure wireless communications are now possible, helping troops act quickly.

Currently, we are under contract for the fourth program refurbishment project. The modification includes the application of Waveform, which enables two-way communications between the Ground Self-Defense Force and the Maritime Self-Defense Force using ultra-high frequency (UHF) software for land and sea (**Fig. 8**).

6. Conclusion

NEC will continue to improve the performance of its radios through various program modification projects that take advantage of the flexibility and expandability characteristics of software-defined radios. NEC will continue to develop the performance of software-defined radios in this way and contribute to a safe and secure social infrastructure.

Authors' Profiles

NAGATA Kimitaka
Manager
National Security Solutions Division

SEKI Satoshi
Assistant Manager
National Security Solutions Division

MINAMI Kenji
Assistant Manager
National Security Solutions Division

OKA Makoto
Assistant Manager
National Security Solutions Division

ISHII Yasuo
Manager
Defense and Aeronautic Systems Division
NEC Aerospace Systems

SUGATA Masatoshi
Assistant Manager
Defense and Aeronautic Systems Division
NEC Aerospace Systems

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