MILITARY SOFTWARE DEFINED RADIOS – ROHDE & SCHWARZ STATUS AND PERSPECTIVES

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ABSTRACT

Rohde & Schwarz is one of the leading manufacturers of radios for the military market with an international presence in the fields of test and measurement, information technology and communications. Being among the first to have developed Software Defined Radios Rohde & Schwarz today has a family of SDRs in the market for airborne, tactical/mobile and stationary/shipborn applications. A review of the current status will be given in the second chapter of this article.

Germany and many other European nations have developed new military operational concepts to meet challenges yet to come. For their implementation they will require advanced communication capabilities. The European requirements for the next generation of Software Defined Radios are currently under development. Chapters three and four give insight into which requirements are to be expected and how these requirements can be fulfilled by the industry under the aspect of today's expertise and capabilities, and pointing out migration paths for existing SDRs and concepts for integrating the new features.

1. INTRODUCTION

The Software Defined Radio concept has been under consideration on a broader basis for more than 10 years. After a phase of experimentation and demonstrator programs SDRs have now finally reached the market (e.g. the R&S®M3xR family). The development programs behind these SDRs and the experience fielding large SDR-based communications systems have brought the expertise to industry required to develop the next generation of SDRs.

At the time the R&S®M3xR development project started, there were only few experts worldwide that had a clear notion of what Software Defined Radio would look like. In the mean time there are several definitions of Software Defined Radios covering different advantages of the SDR concept.

The FCC (Federal Communications Commission) and ITU (International Telecommunications Union) for instance define that SDRs are characterized by the possibility to change frequency, modulation and output power via software.

The SDR Forum, which today is the most important community to treat all technical, commercial and regulatory aspects of SDRs, gives a more stringent definition. In the essence the forum requires an SDR to provide software control of a variety of modulation techniques, wide-band or narrow-band operation, communications security functions (such as frequency hopping), and waveform requirements of current and evolving standards over a broad frequency range. An SDR shall be capable of storing a large number of waveforms and of adding new ones via software download.

A further approach is to define SDRs as radios having an architecture that is in alignment with the Software Communications Architecture (SCA). The SCA is a US DoD standard that is closely related to the US JTRS project.

All these different definitions are justified from their respective point of view. The Rohde & Schwarz M3xR family of Software Defined Radios is characterized by software control, wide operational frequency range, extensive digital signal processing, and the ability to store several waveforms and download new ones. Consequently they fulfill the SDR Forum's definition of an SDR.

2. SOFTWARE DEFINED RADIOS IN THE FIELD – THE R&S®M3XR FAMILY

2.1. Overview

The radios of the R&S®M3xR family are based on the same technology platform. It uses similar processor families for the respective tasks within the radio, e.g. human-machine interface (HMI), radio control, digital signal processing, and protection processing units as far as this is viable. The technology platform provides an architectural framework that is comparable to the Joint Tactical Radio System/Software Communications Architecture (JTRS/SCA) and eases the scalability of the radio and the portability of software functions across the different members of the family.

Fig. 1: R&S®M3AR (Multiband, Multimode, Multirole Airborne Radio)

The R&S®M3xR Technology Platform provides a sound basis for the three members of the Rohde & Schwarz SDR family, which are used for various applications and roles in the armed forces. As these applications put different emphasis on the operational requirements, e.g. wide temperature range, lowest possible power consumption, or high flexibility, the members of the family are optimized accordingly.

2.2. The Airborne Radio R&S®M3AR

The R&S®M3AR was designed focusing on two tenets: First, the radio should be able to replace the ARC-164, which is a device used onboard of many aircraft all over the world and which is of remarkably small size. Second, the radio should be able to download and provide modern EPM waveforms, both for the NATO market and the world market.

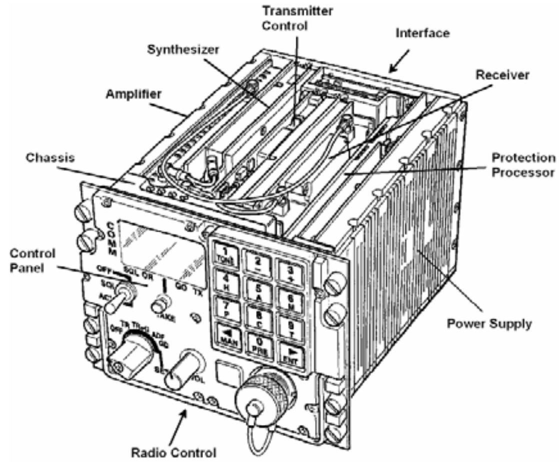

Fig. 2: Modularity of the R&S®M3AR

Airborne radios have stringent requirements in terms of environmental conditions, size and technical performance. To meet these high demands airborne radios have to be optimized with the Technology Platform as a basis. The main design goals for the development of the R&S®M3AR have therefore been:

- Retrofit of the type ARC 164 radios (form, fit and function)
- Minimum size and lowest weight
- Housing ARINC ATR 600 as an option
- Operational performance temperature range -54°C to +71°C
- High reliability
- Software reprogrammable

The VHF/UHF Transceiver features a modular design based on the following modules (see also Fig. 2):

- Chassis compatible to ARC- 164
- Control Panel
- Protection Processor to perform advanced waveforms (TRANSEC and COMSEC)
- Synthesizer
- Receiver including guard receivers
- Transmitter Control
- Amplifier
- Power Supply
- Interface
- Radio Control

The frequency ranges covered are the UHF range (225 – 400 MHz), the upper VHF range from 108 MHz to 174 MHz as well as the lower VHF range from 30 MHz to 88 MHz.

Today several waveforms are provided e.g. R&S®SECOS (a fast frequency hopping system with

Fig. 3: R&S®M3SR (Multiband, Multimode, Multirole Stationary Radio)

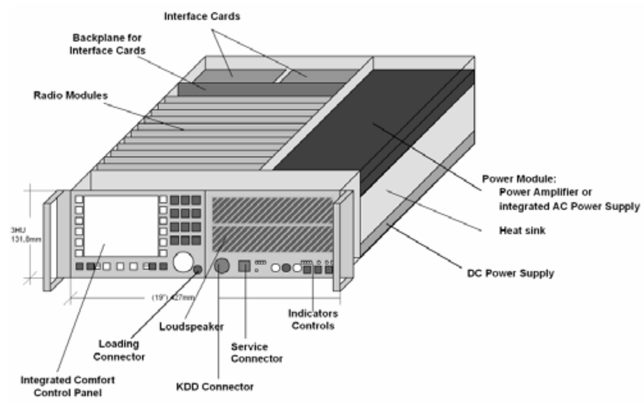

Fig. 4: R&S®M3SR outline

embedded COMSEC functionality), NATO-Have Quick I/II and NATO-SATURN.

2.3. The Stationary/Shipborne Radio R&S®M3SR

The R&S®M3SR, Fig. 3, is a modular, multimode and multirole radio, developed for civil/military ATC, air defense and naval operations. Applicable platforms are ships, ground stations, shelters and special aircraft like AEW (Airborne Early Warning). Different variants are available by using a basic radio equipped with selected options. Potential military applications include navy, air defense, military air traffic control and land mobile. Today it is available for the VHF/UHF frequency range 100 MHz to 512 MHz.

Air defense typically requires secure and electronically protected communication. Usually frequency hopping methods are used as Electronic Protection Measures (EPM). There are EPM-modes with slow, medium and fast hop rates, depending on frequency range and standard used.

Naval forces today are using the UHF range with EPM and various link methods for ship-ship and ship-shore communications.

During the definition and design of the R&S®M3SR emphasis was set on high modularity, flexibility, extensibility and performance. These are the prerequisites for true multiband, multimode and multirole capabilities and can realistically only be implemented using the software defined radio approach.

The R&S®M3SR has a well structured extremely flexible modular design. It consists of a powerful radio basis (comparable to the motherboard in the PC-world) which can accommodate several modules. To keep maintenance to a minimum, the individual radio modules are fully independent of each other. If an individual module is replaced, no hardware adjustments of the radio basis are required.

Based on an embedded real-time operating system, the radio basis handles internal communication, the interfaces to the outside world and takes care of audio signal processing as well as radio control. Waveform modifications or additional data radio protocols can be implemented by software downloads. The user can thus create flexible radio systems from hardware and software building blocks.

Besides the radio basis the R&S®M3SR consists of various modules to establish different radio configurations (see Fig. 4): e.g. receiver and guard receiver modules, synthesizer and filter modules, waveform processor modules and interface cards.

For software download a TCP/IP interface is used. A protocol for the download process has been developed to cope with critical download issues like error-free and secure code transfer, configuration management and authorization.

2.4. The Tactical Radio R&S®M3TR

The R&S®M3TR is designed for use with military and civil waveforms, both legacy and new ones.

The multirole features of a Software Defined Radio are determined by its ease of integration into tactical communication networks.

The radio can be used for different applications either as a manpack, in vehicular mount or in stationary installations. With its functionality the radio can perform the tasks of the participating units in a Mobile Sub-System such as Combat Net Radio (CNR), Packet Radio Net (PRN), Repeater (Range Extension Node, REN), Radio Access Point (RAP) or gateway between different nets in different frequency bands.

Fig. 5: R&S®M3TR (Multiband, Multimode, Multirole Tactical Radio)

The R&S®M3TR offers high data rates of up to 72 kbps for real-time data and video transfer as well as an Internet/Intranet access via the integrated Ethernet interface.

Especially when used as a manpack tactical radio, extremely high demands exist in terms of power consumption and weight. Other design considerations are miniaturization, flexibility and system capability.

In order to optimize the radio in RF performance the R&S®M3TR manpack was designed in two versions. One version covers the HF and the lower VHF frequency range (1.5 MHz up to 108 MHz), the other the VHF and the UHF range (25 MHz up to 512 MHz). The two versions differ only in the TX amplification capabilities. So, with just two manpack versions, the R&S®M3TR transceiver covers the whole spectrum from short wave through to the UHF band. On top of this with the vehicle version only one R&S®M3TR with external power amplifiers is necessary for the frequency range 1.5 MHz up to 512 MHz.

Besides this outstanding multiband capability the power consumption and versatility are among the most important features for a tactical radio product. The architecture of the R&S®M3TR was designed to meet these requirements.

The Tactical Radio R&S®M3TR consists of the following main modules:

- Radio Controller
- Protection Processor (optional)
- Power Amplifier VHF/UHF or HF/VHF-FM with integrated Antenna Tuning Unit
- RF Unit
- Power Supply

The Radio Controller is the central control module of the R&S®M3TR. It controls the entire radio and handles all user voice and data services supported by several links interfaces to the radio components.

The computing devices of the R&S®M3TR include one central general purpose processor, several DSPs and a security processor, interlinked and initialized by FPGAs. The storage capacity allows up to 99 default settings (preset pages), including several Electronic Protection Measure (EPM) methods, to be stored simultaneously. The preset pages contain all the variable parameters of the selected waveform, such as hopsets, modulation modes and addressing.

The Power Amplifier amplifies the transmit signal and filters out unwanted harmonics. The internal Antenna Tuning Unit as a part of the power amplifier is responsible for antenna matching. In receive mode the harmonic filters increase the image rejection and improve the preselection performance.

The Radio Frequency Unit (RFU) is divided into two main sections: the Front-end and the Synthesizer rejection mixers. The front-end is mainly composed of input image and IF rejection filters, mixers, channel filters, amplifiers, and the automatic gain control, AGC. In receive mode the incoming signal is low pass filtered for HF (1.5 to 30 MHz) or tuned band pass filtered for VHF/UHF and digitally mixed down to IF.

The synthesizer, controlled by means of a reference clock oscillator, supplies all local oscillator signals of the radio, e.g. all mixer frequencies.

The Power Supply Module has to deliver the required voltages with very high efficiency, since this determines significantly the power dissipated in the radio and thus the operational lifetime between two battery charges. It consists of synchronized low distortion-DC/DC-converters to deliver the supply voltages, the high-side-switch for power-on and filters for the supply voltages. EMC-filters are provided for all power and control lines to the rear power supply connector.

The presented radios have been already delivered in larger quantities to international customers. Among others there are customers in Europe, America (e.g. Brazil), Near East and Far East.

3. UPCOMING EUROPEAN REQUIREMENTS

Even though Software Defined Radios are by far more versatile than radios of previous generations, differences in design will be required to be able to meet the specific needs of each customer.

One example is the US JTRS program, where the US military users have laid down their requirements in great detail and are constantly refining them. These requirements meet the demands of the US defense strategy and its goal to transform the US forces transformation into the information age. The underlying concept is known as

Network-Centric Warfare. The key focus is to provide the US forces with a significant advantage by robustly networking them. This task requires upgradeable high-performance network radios providing joint and combined interoperability.

What is called Network-Centric Warfare in the US has its counterparts in European countries like the United Kingdom, France, Sweden, Finland and Germany. Among the designations used are “Network Enabled Capabilities” (United Kingdom), “Network Based Defence” (Sweden) and “Vernetzte Operationsführung” (Germany). The concepts and their implementation are similar but not identical.

Concerning the radio part of the concepts there are many common requirements. The among the most important are multimode, multirole and multiband capability, interoperability with all services, partners and security forces, the need for multiple channels and high data-rates and extensive network capabilities based on IP (IPv6).

The main differences between the European and US requirements are for one the waveforms selected for implementation. The reasons for the different waveform priorities are evident: On the one hand there are a number of national and proprietary waveform solutions like PR4G, SEM93 and SECOS fielded in many thousands of units. Interoperability with this legacy equipment is essential as a large amount of it will remain in service for many years to come. On the other hand the US government and a number of companies have intellectual property rights on the waveforms selected for implementation in the US JTRS program – both a hindrance on the path to multi-national interoperability.

Further important differences concern transmission security, crypto and crypto policy. Nearly every nation has its own solutions and a large portion of the fielded units are not capable of additionally supporting an interoperable NATO standard. As national security is an important issue it seems unlikely that the requirements for national solutions will be dropped.

These are by far not the only relevant security issues for nations formulating their SDR requirements: The high flexibility of SDRs, which is a desirable feature as far as waveforms are concerned, in principal opens the possibility to compromise the radio by modifying its functionality – much the same way as a virus modifies the behavior of a personal computers. To counter this possibility, stringent supervision of the software and its status are indispensable. This includes the protection against unauthorized access to the software installed and thorough investigation (e.g. by code inspection) of third party software.

Apart from these differences most of the European programs have requirement similar to those of the US JTRS program. Examples for such similarities are multiband functionality, switching between waveforms during operation and software download. These requirements – as well as many others – are already covered by the fielded R&S®M3xR SDR-family.

4. MIGRATION TO FUTURE ARCHITECTURES

Though Software Defined Radio still is a new and exciting technology there is an industry history behind. Demonstrators like SpeakEasy, PDR, and MMR/ADM as well as early products with software-defined functionalities started this history. The current generation of Software Defined Radios has left the experimentation phase, is now fielded in military and commercial systems, and provides full SDR functionality. An example is the R&S®M3xR family. This is where industry is today.

The next generation of SDRs is being developed right now in different countries on both sides of the Atlantic. The salient characteristics of this new generation will be their harmonized radio architecture includes a Hardware Abstraction Layer (HAL). The transition from the today’s SDRs to the next generation can be a graceful one in many respects, since the majority of mechanisms of the common architecture of the next generation have already been foreseen and integrated into the current generation.

One example is the Hardware Abstraction Layer. During the development of the R&S®M3xR SDR-family the importance of having such a layer became obvious. Thus abstraction mechanisms were included, similar to those defined in the current US JTRS program.

The Migration to this third generation will include the implementation of further advanced waveforms providing high data rates and networking capabilities. This will require significantly higher processing power and an adapted front-end, as the carrier frequency and the bandwidth will increase significantly.

Rohde & Schwarz with its proven experience in SDR technology, mobile communications systems networks and high data rate transmission has the ideal prerequisites to tackle tomorrow’s challenges.