Defense Technical Information Center Compilation Part Notice

ADP010979

TITLE: Software Radios for Maximum Flexibility and Interoperability

DISTRIBUTION: Approved for public release, distribution unlimited

This paper is part of the following report:

TITLE: Strategies to Mitigate Obsolescence in Defense Systems Using Commercial Components [Strategies visant a attenuer l'obsolescence des systemes par l'emploi de composants du commerce]

To order the complete compilation report, use: ADA394911

The component part is provided here to allow users access to individually authored sections of proceedings, annals, symposia, etc. However, the component should be considered within the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:
ADP010960 thru ADP010986

Software Radios
for Maximum Flexibility and Interoperability

Rüdiger Leschhorn, Karlheinz Pensel
Radiocommunications Systems Division
ROHDE & SCHWARZ GmbH & Co. KG
Mühldorfstraße 15 D-81671 Munich, GERMANY
Ruediger.Leschhorn@rsd.rohde-schwarz.com
Karlheinz.Pensel@rsd.rohde-schwarz.com

Abstract

The upcoming Software Radios will change the commercial as well as the military market of radio communications. Due to their programmability Software Radios offer an extreme flexibility falling into 3 main domains: Multirole, Multimode and Multiband operation. Multiband just means that the radio can cover the complete spectrum from HF to SHF, Multimode requests to cope with different air interfaces and Multirole addresses the question, which applications a software radio has to serve. Essential properties of a software radio architecture, particularly supporting the use of COTS components and mitigating parts obsolescence, are the strict decoupling of application software and platform hardware (forming APIs) together with a consequent modularization of the hardware. The decoupling allows hardware-independent development of the application software, whilst the hardware modularization supports a cyclic reengineering process in case components have to be replaced by new COTS parts. Savings in term of logistic and upgrades reduce the overall life-cycle costs by about 40 percent in comparison with conventional radios. In turn, these platforms are free to be scaled to manpack, airborne, naval or stationary deployment, simultaneously optimised for example in terms of power saving, size or flexibility, where the software layer guarantees interoperability among these radio families by common waveforms. An example of an existing military software radio is presented showing multiband, multimode and multirole features.

Introduction

In former days radios for military applications often have been supportable for 25 to 30 years. Components, once selected in the design process, have been available for many years and one could expect that there are suppliers for these components active on the market even after a long period of time. On the other hand waveforms and transmission methods in the military as well as in the civil world have been stable for years. The technical progress was low compared with today and military technology was regarded nearly always to be ahead of civil technology.

As we all know times have changed. Today components like microprocessors double their performance within a few years. As a consequence obsolete components tend to vanish from the market. But not only components are getting obsolete. Driven by civil communications technologies like GSM, TETRA, UMTS or Wireless LAN military people have to face the fact, that in many cases they do not have equipment comparable with civil equipment in performance any longer. The capabilities of military equipment are getting obsolete too. It has to be expected that this trend will speed up in the future.

The effects of this trend are that life cycle cost are increasing, lifetime is decreasing and there is a time lag of military technology compared with civil technology. On the other hand military logistics require equipment to be stable and to survive even if technology is setting the pace.

Means and concepts have to be found to fight these effects. One of these concepts is the Software Radio technology.

How can Software Radio Technology contribute to mitigate obsolescence and life cycle cost?

Paper presented at the RTO SCI Symposium on "Strategies to Mitigate Obsolescence in Defense Systems Using Commercial Components", held in Budapest, Hungary, 23-25 October 2000, and published in RTO MP-072.

The User's Need

In times of decreasing military budgets the cost factor is one of the most important issues for the user. Life Cycle Cost is a suitable figure to express the overall cost for the user.

Life Cycle Costs consist mainly of

- Purchasing costs
- Maintenance support costs (including spare parts)
- Test equipment costs
- Transportation and handling costs
- Training costs
- Facilities costs
- Documentation costs

Life Cycle Cost shall be optimised in sum.

Changing boundary conditions like altered military strategies and tasks (e.g. peace keeping operations) finance flow or upcoming new waveforms require the possibility to update or upgrade the equipment. Update means to improve the equipment maintaining the same functionality, whilst upgrade means to increase the functionality e.g. by adding new waveforms, options or interfaces. It is highly desirable to perform update and upgrade by software download means only. Changing the hardware or software configuration calls badly for an efficient configuration management. The user needs to know the actual status of the hardware or software implemented.

In the past each waveform or transmission method had its own, dedicated equipment. The new global political context increases international operations like humanitarian aid, peace keeping and peace forcing tasks. Interoperability between different nations using different military waveforms will be mandatory in the future. Equipment must be able to be switched between different waveforms. Humanitarian aid requires also interoperation with civil authorities with their dedicated frequency bands and civil waveforms. This shall be performed without exchanging assets as far as possible.

Multiband, Multimode, Multirole

As for **multiband** operation, a Software Radio should cover a maximal frequency range starting from HF (about 1.5 MHz) up to several GHz because of various reasons: The increasing demand for information exchange and its involving broadband waveforms are facing sharply limited frequency resources and are shifting applications to higher currently not used frequency ranges. Secondly, each country has its individual frequency assignment scheme. Finally, ITU refarming procedures place civil, commercial communication in formerly military occupied frequencies. GSM or the security service system TETRA for example covers a broad range of frequencies. Therefore, multiband operation is of extremely importance to cope with mobility requirements across international borders.
Frontend modularity helps to extend frequency bands in the future. Experience shows that the broader the covered frequency band the more challenging it is to maintain performance over the whole band.

A software radio, however, must not place unrealistic demands on linearity, image rejection, dynamic range and interference reduction. From the current technology point of view some analog

Multiband	Multimode	Multirole
Multiple Frequency Bands	Multiple Air Interfaces	Multiple Applications
HF 1.5 - 30 MHz	Civil waveforms TETRA, GSM, UMTS, AM, FM, VDL ...	Radio Terminal, Relais, Base Station, Data Link, Civil, Military
VHF 30 - 174 MHz		
UHF 225 - 400 MHz	Military waveforms FSK, HQ, SATURN, L11, L22, JTIDS ...	Handheld, Mobile, Airborne, Stationary
UHF + 400 - 2000 MHz		
TETRA bands	High data rate waveforms	Point to Point, Point to Multipoint, Broadcast
Frontend modularity	COMSEC/TRANSEC	Voice, data, video
Colocation issues	TDMA, FDMA, CDMA	Different Interfaces, Protocols, Rem. Control
Pre**p**lanned **P**roduct **I**mpr.	**P**re**p**lanned **P**roduct **I**mpr.	**P**re**p**lanned **P**roduct **I**mpr.
PPPI	**PPPI**	**PPPI**

Figure 1: Multiband, Multimode, Multirole

pre-processing by mixing and filtering helps a lot to meet requirements in terms of power consumption, size and collocation performance.

Multimode operation requests the Software Radio to be compliant with various air interfaces. Throughout the civil world there exists a large number of different standards, e.g. GSM in Europe, IS-95 and AMPS in the US and there will be no convergence of wireless standards in the future due to political/commercial (see for UMTS) and technical reasons. Amplitude Modulation (AM), frequency modulation (FM) and frequency shift keying (FSK) are still widely used legacy waveforms. Digital modulation schemes like QPSK, GMSK and D8PSK are required by modern waveforms.
In the military area there are various NATO standards and proprietary waveforms in use. Often there is a requirement to switch from one waveform to another either due to tactical/operational or due to maintenance reasons (switch-in of a backup unit).

Multirole operation addresses the question, which applications a software radio has to serve. Besides the capability to handle voice, data and video transmission a Software Radio has to answer to different operational scenarios particularly placed by different roles. These operational scenarios influence the choice of line interfaces, line protocols and remote control concepts.

Combat Net Radio (CNR), Radio Access Point (RAP), Relay and Data Link are typical applications a military Software Radio must meet. It has to be scalable from handheld with stringent power consumption requirements over airborne equipment (optimised in size), manpack up to a base station with several communication lines in parallel. Besides typical hierarchical networks (between mobile and base) mobile radios should be able to establish links among themselves, like TETRA's direct mode. A Software Radio has to cope with lots of different access and network control schemes, introduced by advanced supplementary services (e.g. Access Priority, Dynamic Group Assignment, Late Entry, Remote Disable/Enable) or redundant, multi-hierarchy networks. That applies to fixed networks such as ISDN/PSTN, LAN, WAN and to moving networks on the air as well. A Software Radio should be able to establish point-to-point and point-to-multipoint links and to provide broadcast services. Consequently, there is a need to build radio families based on scalable platforms to meet the requirements in terms of size, weight power, functionality and performance.

The core feature across the multiband, multimode and multirole properties is Preplanned Product Improvement (PPPI). The design target is to foresee prerequisites for future extension and improvement of the radio. A vast majority of improvements can then be performed my sole means of software download.

Software Radio Architecture

One of the key elements of Software Radio Architecture is the strict separation of the applications (software) from the hardware platform by horizontal architecture layering. This principle, which is well known from PC technology, offers a well defined, hardware independent interface (API) to the software (see Figure 2).

Typically, the Software Radio Architecture is functionally partitioned into different modules interconnected by Radio Control Buses (RCBs).

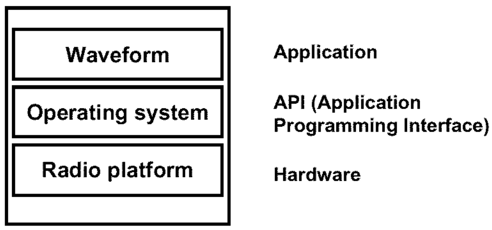

Figure 2: Separation of Applications from the Hardware Platform (Horizontal Approach)

Analog to the ISO/OSI-model we can distinguish between channel processing, modulation processing, bitstream processing and network processing (Figure 3).

Channel processing includes amplification, filtering on RF and IF level, RF switching, RF matching, mixing, AGC/ALC (automatic gain control/ automatic level control) etc. Processing is done on analog and digital levels.

Modulation processing (or waveform processing) is dealing with all kind of manipulation and managing of the signal like modulation and demodulation, equalisation, digitisation, symbol tracking.

The module **bitstream processing** performs operations on bit level. Those are e.g. forward error correction, interleaving and ciphering. In context with ciphering red/black separation has to be taken into account if necessary.

Network processing includes the Media Access Control (MAC) functionalities, routing, and network management.

The modules in Figure 3 show the horizontal layering as in Figure 1, separating hardware and

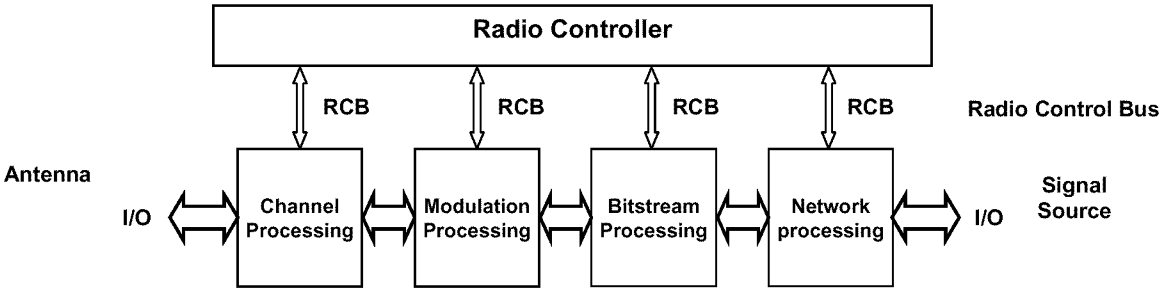

Figure 3: Typical Software Radio Architecture

software parts from each other. The software incarnated by DSPs and programmable FPGAs holds the control over the main operating parameters and offers an extreme flexibility with benefits in both commercial, security services and military applications. Moreover, due to well defined and standardised interfaces between the modules, which prepare some kind of "open architecture", modules can be simply plugged into or moved away from. As a result the radio platform is scalable to e.g. handheld, manpack or base station applications. This optimisation in terms of power saving, size or flexibility is of particular importance, since hardware components represent a bottleneck in terms of radio performance. The software driven hardware platform allows an easy implementation of advanced waveforms and functions.

A software radio must not place unrealistic demands on e.g. A/D and D/A converters by direct digitising at the RF stage (from the current technology point of view). Instead, some trade-offs are essential. Digitisation usually takes place on the first or second IF. This allows to relieve the A/D converter from excessive demands for the dynamic range.

Example of an Existing Software Radio

The M3TR (Multimode Multirole Multiband Tactical Radio) represents a completely new generation of high-performance Software radios. Contrary to conventional radios with fixed architecture the M3TR features maximum flexibility in terms of frequency bands, waveforms and functions satisfying the requirements of various user domains. M3TR is not restricted to military networks, but serves via loading the appropriate software also as a terminal in civilian PMR (Professional Mobile Radio) networks.

By forecasting technology trends the platform is designed in advance to cope with future applications, frequency ranges, additional functions and future COTS products. Evolutionary updating of modules fully exploits the technological advance of semiconductors and keeps the radio up-to-date, an implementation of the ETSI standard TETRA for example is planned. In fact, software configurability and upgradability by Pre-Planned Product Improvement (PPPI) is a key asset of a modular hardware and software architecture in order to reduce technology refresh insertion time and to lower costs.

The two manpack transceivers MR3000H and

Figure 4: Example of an Existing Software Radio (M3TR)

MR3000U providing seamless coverage of the transmission range from 1.5 MHz up to 108 MHz (model H) and from 25 MHz up to 512 MHz (model U) form the core of the M3TR transceiver family. In total, both units are designed for transmission and reception from 1.5 MHz to 512 MHz. So, with just two transceivers (MR3000H and MR3000U), the M3TR transceiver family covers the whole spectrum from short wave through to the UHF band.

Thanks to optimised protocols and waveforms M3TR attains high data rates for digital voice, real-time video and visual display data. Beyond Line of Sight (BLOS), e.g. HF offers up to 5.4 kbps user rate per 3 kHz channel, while in the Line of Sight (LOS) case VHF/UHF provides up to 64 kbps per 25 kHz channel suited for real-time data, video and Internet / Intranet access via the radios integrated Ethernet interface. In command systems this ensures among other things automated data exchange, for example for online position display and data distribution. PPPI (Pre-Planned Product Improvement) ensures to subsequently integrate planned and future methods in the equipment through simple software upgrades.

Different communications standards exist even within NATO and new ones are still being prepared. Examples are HAVE QUICK I and II, SATURN for UHF or STANAG 4444 for the shortwave band. Export waveforms like the Rohde & Schwarz proprietary waveforms SECOM and SECOS can easily be implemented. As a software-defined radio, M3TR can be made compatible with almost all existing EPM (Electronic Protection Measure) radios. It is interoperable with legacy communication systems and supports growth for new requirements.

Multiband	Multimode	Multirole
HF/VHF 1.5 - 108 MHz	Classic waveforms AM, FM, SSB ...	Radio Access Point
VHF/UHF 25 - 512 MHz	Civil waveforms TETRA	Combat Net Radio
Seamless coverage	Military Waveforms HQ, SATURN, SECOS, SECOM, 4444	Packet Radio Services
Civil bands	High Data Rate waveforms	Relais, Crossband Relais
Military bands	COMSEC/TRANSEC embeded	Selective links
	Digital voice	Gateway/Interface
	Future extensions	WAN/LAN
		Interfaces Standard, TCP/IP, UDP, EUROCOM
		Future extensions

Figure 5: Multiband, Multimode, Multirole Properties of the M3TR

The use of open system standards, like TCP, Ethernet, and well defined interfaces within the radio makes M3TR scaleable to match the communication requirements of different users and furthermore extendible to support further growth and changes.

Comprehensive multirole features allow its easy integration into communication networks, e.g. as a functional terminal in a subnet, e.g. CNR (Combat Net Radio: voice and data semi-duplex transmission in combat networks) or PRN (Packet Radio Net: multi-hop functionality for packet data transmission, adaptive routing of messages in case of jamming or relocation). But M3TR can also act as an interface between the subnets, REN (Range Extension Node: for user voice and data services established among radios out of range). Playing the role of a RAP (Radio Access Point) M3TR establishes the interface to fixed networks, e.g. ISDN/PSTN, LAN, WAN, and standardised bus systems, e.g. RS485, and to data interfaces, e.g. RS232, RS422 and MIL-STD-188-114A. It also offers intelligent gateway and relay functions.

Commercial off the Shelf (COTS)

In the past there were good reasons for military people to buy special Mil-equipment instead of civil products. Today there are no doubts that the trend to make greater use of COTS products does make sense particularly as user budgets are limited. However a careful analysis is necessary to optimise the user's benefit arising from this trend.

"Just buying COTS" does not necessarily secure all of the benefits they might bring to the development, maintenance and cost of systems. There arise some problems and sources of risk by the use of COTS products. First, COTS products may commit the user to proprietary interfaces and solutions that are not common with any other product, component, or system. Secondly, many security service systems have a 25- to 35-year lifetime, while the average COTS component today may be upgraded every 6 to 12 months. Thus any money that is saved by procuring a COTS product with proprietary interfaces will quickly be lost in maintenance and logistics as products and interfaces change without the ability to migrate cost-effectively to other products and other technologies in the future. This situation becomes even worse when the vendor stops supporting the product without any substitutes.

So the question is not “Shall we buy COTS?” but instead:
“How can we make use of COTS to optimise our Life Cycle Management?”

It makes sense to subdivide the COTS question into four areas:

COTS equipment, COTS modules, COTS components and COTS communication protocols.

Buying **COTS Equipment** only is useful in special cases, where the services provided by civil technology fit well the user’s need concerning the type of service, availability, maintainability and security. Examples may be GSM, TETRA, UMTS and SATCOM. Problem areas can be proprietary interfaces and logistic aspects.

COTS Modules (or subsystems) providing special functions can be integrated e.g. into a radio unit. This appears to be a useful approach for wireless LANs, modems or chip sets for dedicated waveforms like TETRA or GSM. TETRA for example represents a typical system developed for professional users. These COTS products are available at reasonable costs. The chip sets are optimised in terms of size and power, simultaneously making re-engineering for software dispensable and cutting down the required development effort. The main challenge is that COTS modules very often have proprietary interfaces, which cannot be influenced without loosing the cost advantage.

The most efficient area of use of COTS in military applications is that of **COTS Components**. Semiconductor elements like A/D- converters (often said to determine the bottleneck of a software radio) and DSPs are roughly doubling its performance every 2 years. Keeping up Third-Party DSP-libraries are available at reasonable costs. Radio suppliers have been analysing part samples in terms of reliability, performance and critical parameters. Industry programs have shown the rightness of this approach. COTS parts reduced material cost by up to 50 %, increased part availability by tenfold and achieved reliability equivalent to military parts.

Another important aspect is to make use of **COTS Communication Protocols** like TCP/IP, UDP and X.25. This addresses the question of infrastructure, often underestimated in terms of complexity and cost. If commercial available protocols are used possibilities arise to stick on commercial available equipment like TCP/IP routers, switches, multiplexers etc. This will reduce system cost considerably.

The requisite to use COTS components is an essential part of the Software Radio concept. In advance the platform is designed to cope with future applications, frequency ranges, additional functions and COTS products in the future. An internally "open" architecture with stable interfaces between the modules makes it possible to cope with the frequent fluctuations in COTS products and keep the radio adaptable to advances in technology and changes in the marketplace.

The ´plug-and-play´ idea let an update be accomplished through replacing old components with new products the marketplace supplies. In fact, this idea introduces an **evolutionary, cyclic process** with a constant system change (Figure 6). In a cyclic process the products from the COTS market are evaluated with respect to their technological advances e.g. in terms of signal processing power and power consumption and then integrated into the system (module update). Evolutionary and cyclic updating of modules fully exploits the technological advance of semi-conductors and keeps the evolvable system up-to-date. There will be no unexpected “vendor lock”.

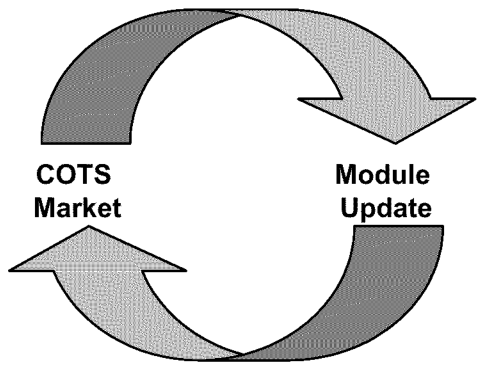

Figure 6: Evolutionary Cyclic Development Process

Typical examples for this cyclic process arise from the permanent improvement of A/D converters and Digital Signal Processors (DSPs). In more or less periodic intervals, determined by the user or market needs, a re-engineering of the modules containing the A/D converter or the DSPs is performed.

Conclusion

The increasing speed of technology progress especially on semiconductor component level and the drastically reduced product cycle will cause a severe obsolescence problem of military radios. Life Cycle Management is getting more and more difficult.
To mitigate this problem the Software Radio approach is an appropriate solution.

Key is first to provide a horizontal approach, which means to establish a sharp separation between application (software), and hardware (radio platform), This property of the radio architecture allows development of application software running independently from the hardware configuration. The second key point is consequent and transparent hardware modularization which enables to replace functional hardware modules in a cyclic, ongoing process:

Whenever components are obsolete a reengineering of a particular module can be done which replaces the existing module by a new module, which makes use of newer, more powerful and eventually cheaper components.

This page has been deliberately left blank

Page intentionnellement blanche