Software defined radios – overview and hardware (1)

Software defined radios combine a broad scope of complex radio techniques in one instrument. You can expand them for future techniques, reconfigure them for modified application profiles, and switch them between different radio services. Are they the ready-made solution or merely the concept of things to come?

The changing world of radiocommunications

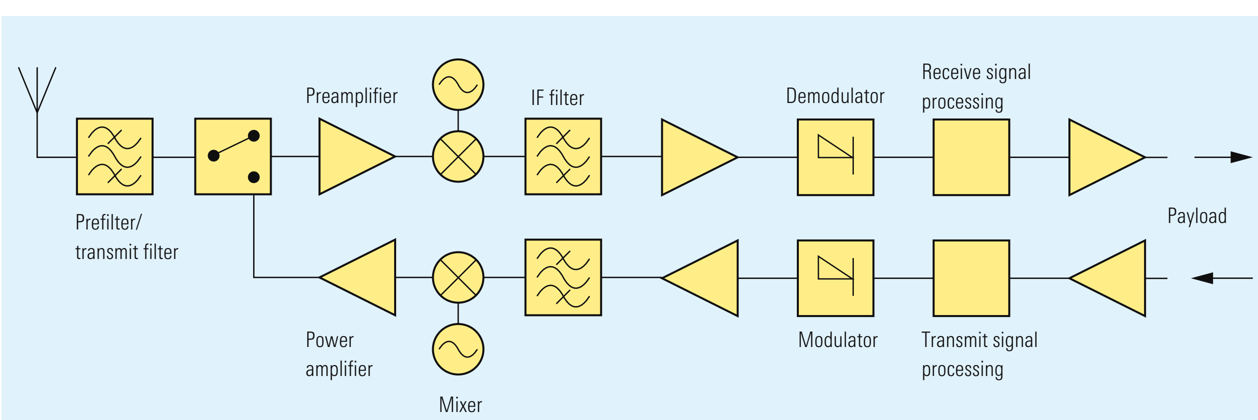
Radiocommunications and radios themselves have been around for more than 100 years. It all started with the trailblazing experiments of Marconi and others. Device architectures were developed soon thereafter, particularly the concept of the superheterodyne receiver. For decades, these architectures were considered optimal for most applications. Until just a few years ago, these analog-based architectures were state of the art (FIG 1).

Digital technology initially found its way into radiocommunications around 1980. The first components to be digitally controlled were primarily audio signal processing units, modulators, demodulators, filters and mixers. They were later implemented as digital. Today, the main functions of radios are controlled by software, which has led to the term "software defined radio" (or "software radio").

An ideal software radio does not have any analog stages for signal processing, except antenna, power amplifier and microphone/loudspeaker (FIG 2). In this model, the analog signals in the receive branch are converted to digital virtually right next to the antenna. These signals can then be modified as necessary in processors.

As the name "ideal software radio" implies, this device is not yet feasible – at least not with today's technology. However, software defined radios (SDRs) are feasible. In SDRs, analog components still handle important tasks. The definition of the Software Defined Radio Forum (SDRF) is useful here:

FIG 1 State-of-the-art architecture of traditional radios as it existed until a few years ago.



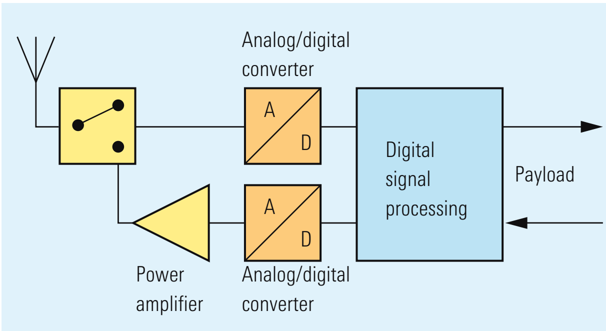


FIG 2
The "ideal" software defined radio does not have any analog components except antenna, power amplifier and microphone/loudspeaker.

SDRs provide software control of a variety of modulation method, wideband or narrowband operation, communications security functions (such as frequency hopping), and waveform requirements of current and evolving standards over a broad frequency range. The frequency bands covered may still be constrained at the frontend requiring a switch in the antenna system.

FIG 3 shows one possible SDR design. In this example, the first frequency conversion on the receiving end is still analog, while all subsequent signal processing steps are digital. On the transmitting end, the digital-to-analog conversion is followed by another frequency conversion to the transmit frequency and power amplification.

Why are SDRs so appealing?

The main appeal of SDRs is that you can set or change a radio's properties (e.g. transmission method) without having to modify or replace the hardware.

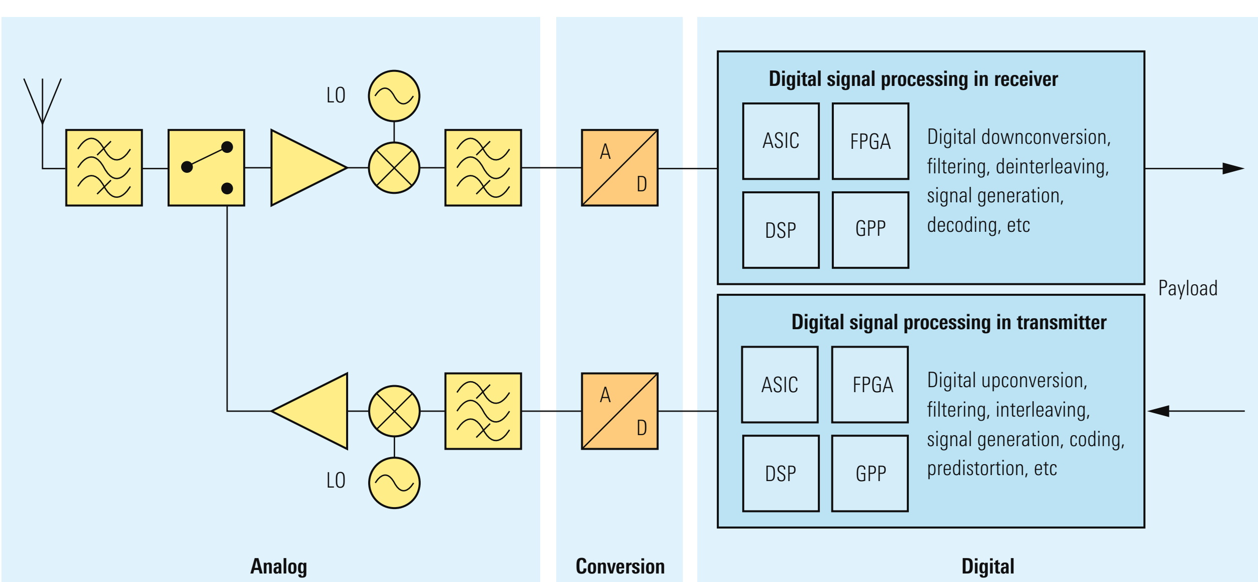
A good example is the use of SDRs by rescue services. Using just one radio, rescue services can access multiple transmission method in different frequency ranges simply by switching between them. This enables one rescue team to reach other rescue teams, the police, fire department, medical service teams or armed forces with just one radio unit. Furthermore, this applies even if these services use different radiocommunications techniques, which is usually the case.

In addition, you can easily modify radios that are already in use. For example, you can install bug-fixes, modify a protocol stack or download a complete, new transmission method. This flexibility means substantial economic benefits.

SDR components

SDR components can be divided into analog and digital (FIG 3). Even in the age of digital technology, the analog components in SDRs such as antennas, prefilters, switches, preamplifiers und power amplifiers play a critical role and determine a radio's technical properties. Compared with traditional radios, analog components in SDRs are usually subject to higher – not lower – requirements.

FIG 3 Possible design of a software defined radio.



This is because each SDR must offer the full scope of technical properties provided by the radios to be replaced, e.g. frequency range, sensitivity, dynamic range and adjacent channel separation.

	ASIC	FPGA	DSP	GPP
Power consumption	+ +	–	❍	❍
Cost for large quantities	+ +	–	❍	❍
Computing power for signal processing	+ +	+	❍	❍
Cost for small quantities	– –	–	❍	❍
Flexibility	– –	+	+ +	+ +
Reusability of programs	❍	❍	+	+ +

FIG 4 Comparison of the various categories of signal processing components.

The main digital hardware components are the following:

- GPPs (general-purpose processors)
- DSPs (digital signal processors)
- FPGAs (field-programmable gate arrays)
- ASICs (application-specific integrated circuits)

These computational and control components are used to implement the various functions in the radio, e.g. modulation, demodulation, filtering and coding. The specific requirements determine which types of components are used. FIG 4 provides a comparison of the basic properties of the various categories of signal processing chips.

ASICs merit a special note because they are not programmable, which in principle contradicts the basic concept of SDRs. However, their special characteristics have made them a standard part even of the newest generation of SDRs. ASICS must be specially developed for each application, after which they can be manufactured economically in large numbers. They are highly valued because they offer high computing power, low manufacturing costs when produced in large numbers and low power consumption. This makes them ideal for products such as mobile phones.

FPGAs are useful in applications in which you need high computing power and flexibility at relatively low unit production quantities. The computing power of FPGAs is very high in comparison to

Software Defined Radio Forum (SDRF)

The SDRF was founded in 1996 to promote SDR technology and use. Today, this international forum has approx. 120 members from industry, research institutes and government offices. In conjunction with the Object Management Group (OMG), the SDRF is the most important international organization that focuses on software defined radios.

The SDRF handles market, regulation and technology issues for software defined radios in civil and military applications. One of its current objectives is to define radio-internal interfaces that allow software to be kept independent of the computational hardware (e.g. processor type).

Software-Based Communication Domain Task Force of the OMG

The OMG is the world's largest software consortium. It consists of members from the software industry and end users. In the past, it defined software standards such as UML (unified modelling language) and CORBA (common object request broker architecture).

The Software-Based Communication Domain Task Force was formed by the OMG to develop specifications that support development, deployment, operation and maintenance. One of its tasks is to define software interfaces (APIs) for SDR applications.

DSPs and GPPs because they permit quasi-parallel processing. In contrast, DSP and GPPs are essentially serial in operation, and, in some cases, iterative.

The main strengths of DSPs and GPPs are their flexibility and easy configurability. One of their most important benefits is that they allow better reuse of existing programs for other purposes.

The art of implementation

In comparison to radios with traditional architecture, software defined radios present special challenges for developers:

- The significantly greater complexity of SDRs is comparable to that found in computer technology. Compared to the development of traditional radios, this places especially high requirements on a structured approach.
- Like in PCs, software has a longer lifespan than hardware. To ensure portability, the software to be developed must be kept decoupled from the hardware as far as possible.
- Analog/digital conversion is still a technical bottleneck. The requirements for higher bandwidths (e. g. for UMTS) and higher dynamic range (to eliminate effort-consuming analog prefiltering) are diametrically opposed. Achieving both at the same time is difficult.
- The analog frontend, which includes the antenna and is still required, must meet high RF requirements, since state-of-the-art digital signal processing still has a long way to go before it can ensure a high performance radio.
- Many multifunction radios require particularly low power consumption and low weight combined with high performance and flexibility. This can be achieved only through intelligent architecture and carefully selected computational components.

More information at www.rohde-schwarz.com (search term: M3AR / M3SR / M3TR)

REFERENCES

[*] Series 4400 (R&S®M3SR): Software-based radios for professional use. News from Rohde & Schwarz (2000) No. 166, pp 8–9

Rohde & Schwarz is one of the first companies that has developed software defined radios. One example is the R&S®M3SR [*], which covers a number of different communications standards and waveforms in different frequency ranges (FIG 5).

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(Part 2 in next issue)

FIG 5 The Software Defined Radio R&S®M3SR from Rohde & Schwarz covers a number of different communications standards and waveforms in different frequency ranges.