

# A FULLY SOFTWARE CONFIGURABLE RECEIVER FOR AUTOMOTIVE APPLICATIONS

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## ABSTRACT

### 1. INTRODUCTION

The demand for communication interfaces between a car and the environment increases following the number of stationary applications. In addition there exists a need for a worldwide uniform equipment of a car for cost reduction. All this leads to the need for a software configurable platform that is capable to handle standards like AM, FM, GSM, UMTS, digital broadcasting standards (DAB, Sirius, XM-Sat Radio), analog and digital television and other data links. This presentation describes a fully software reconfigurable multi-channel broadband sampling receiver for standards in the 100MHz band.

### 2. HARDWARE CONCEPT

The input signal is directly sampled with a sampling rate of about 80MS/s. This leads to a moderate downsampling ratio so that the input signal in the range of 85 to 115 MHz appears at 5 to 35MHz (see Fig. 1). In these frequencies we'll find standards like FM and IBOC. The receiver offers additionally the possibility to sample signals between 0-10MHz directly for the reception of

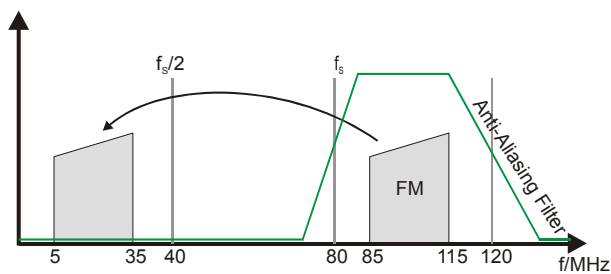


Fig. 1 frequency plan for downsampling

LW, MW and SW including their digital modulated derivatives. The downconversion, channel filtering and demodulation are realized in the digital domain. Fig. 2 shows the complete block diagram of the built up receiver [3],[4], [5].

The use of a broadband sampling architecture has a couple of advantages:

- The bandwidth of a new standard can be as large as the Nyquist frequency. Specially for future digital audio broadcasting standards becomes important because fading gaps can be avoided by using OFDM or other broadband modulation techniques.

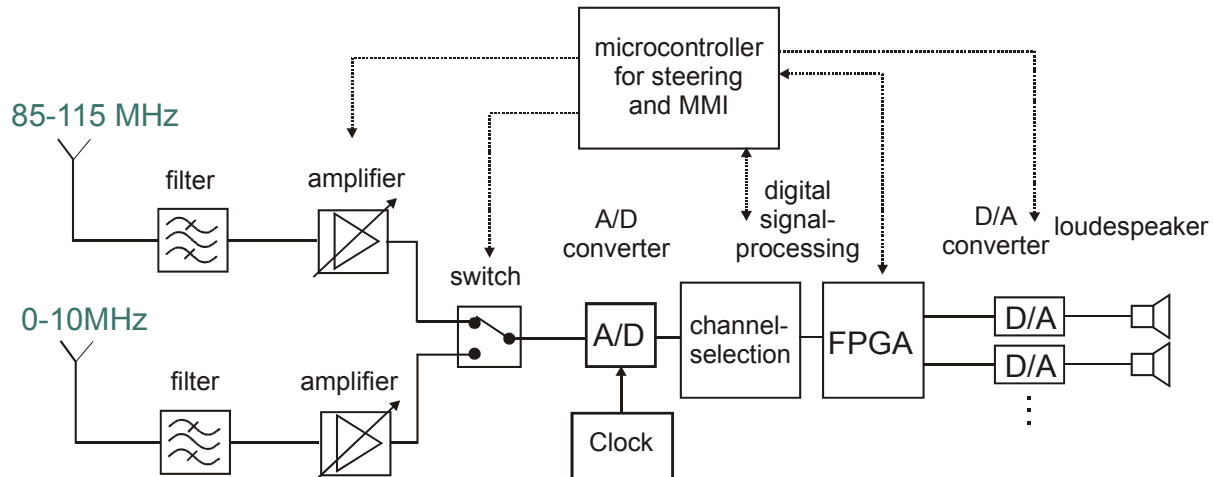
- all channels of the desired frequency band are available in the digital domain in the same time. This enables a cost effective reception of several channels in parallel e.g. for traffic messages or individual sound for each passenger. It also offers the possibility to improve the signal quality by superposition of different channels with the same content (Channeldiversity®) [7],[8].

- Developed processing algorithms can be directly reused when receivers are built with higher sampling rates.

The signal processing chain contains only a few analog input amplifiers and filters to adapt strong input fading and to suppress aliasing components. The steering of the input amplifiers will be performed by the microcontroller. The Analog to Digital Converter with a resolution of 12 Bit performs the discretisation of time and value [9]. The intermodulation characteristic of the ADC is the most important when receiving narrowband standards like FM. State of the art are about 100dBc spurious free dynamic range.

When sampling an RF signal the phase noise of the clock oscillator is critical because it is a main source for sampling jitter [1]. The jitter will result as amplitude- and phase noise of the sampled signal and therefore reduce the dynamic and the phase accuracy.

Because the input bandwidth can not be the complete frequency range from zero to 120MHz it is necessary to



**Fig. 2** block diagram of the RF sampling receiver

define two frequency bands, each with a bandwidth below the nyquist bandwidth of 40MHz. An analog switch that selects the input path will switch between these to modes. Each path has to contain its own input filtering to reject aliasing products.

After the signal processing the signal is Digital to Analog converted, amplified and sent to a loudspeaker.

### DIGITAL ARCHITECTURE

The digital architecture can be divided into four main tasks:

- downconversion and channel filtering
- demodulation
- source decoding and output formatting
- system steering tasks

In our actual design the downconversion and a rough channel filtering are performed in a dedicated integrated circuit from GrayChip. The decimation rate is reconfigurable so we obtain full reconfigurability. The output of the chip is the complex baseband data with a reduced sample rate.

Steep channel filtering and demodulation are performed in an FPGA. The channel filtering is done by a 80 tap FIR filter which ensures a linear phase (constant group delay). A nonlinear phase would result in disturbance of the signal after demodulation. The filter coefficients are freely programmable via the microcontroller. This enables to suppress neighbor channel interferers dependent on the necessary blocking.

The complete baseband processing including the demodulation and output formatting is performed in an FPGA. This enables complete reconfigurability to adapt new standards after the radio is assembled and built in.

The programming data of the microcontroller and FPGA are stored in Flash-ROMs. If the receiver has to be updated because of changes of the standard or probably the modified modulation scheme of the same standard in another country “has to be understood” the Flash ROM can be updated by a higher level controlling unit in the car.

A disadvantage of using an FPGA to perform digital signal processing is that the costs specially for high volume products are higher than those of an ASIC.

The microcontroller has to perform the steering of the input stages, the programming of the downconverter to select the channel, the programming of the filter coefficients to obtain an optimum signal to noise ratio after demodulation and it should provide a rudimental human machine interface. The realized prototype is programmable via a RS232 interface and during runtime all important machine parameters can be requested for development purpose.

Some of these tasks are time critical so a simple real time operation system has to be implemented. Specially the power measurement of the input signal, which will be used to ensure not to have too many overdrives of the analog to digital converter has to be done periodically. In parallel the power of the filtered baseband signal has to be measured to compensate the dynamic of the broadband input signal and not to result in quantisation noise after the decimation process.

The receiver is designed in a way that a connection to an optical car network is well possible.

### RESULTS

The receiver is actually designed for the reception of FM signals. Although the work is going on the reception

quality is comparable to that of standard receivers. It has to be realized that in mobile environments the steering of the analog part is very important and sensitivity will decrease dramatically if it is not performed correctly.

The full software reconfigurability shows that new standards can be received by the change of software. The receiver architecture is realized in a way that the new software can be implemented during runtime.

An important topic for future work will be the automatic implementation of new standards based on parametric or algorithm based standard definitions.

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- [1] T. Müller, S. Herter, „Clock Generator Phase Noise in RF Sampling Receivers“, 2nd Karlsruhe Workshop on Software Radio, March 20/21 2002, Karlsruhe, Germany
- [2] T. Müller, K. Böhm, T. Hentschel: „A GSM / GPS Receiver With a Bandpass Sigma-Delta Analog to Digital Converter“, Conference Proceedings European Wireless, S. 27-30, München, Oktober 1999
- [3] J.-F. Luy, T. Müller: „Front-End Architectures in Millimeter-Wave Systems: From Analogue to Digital Concepts, Conference Proceedings European Microwave Week, Vol. 2, S. 295-298, München, Oktober 1999
- [4] T. Müller, H. Schnepf, J.-F. Luy, “A Software Autoradio”1. Karlsruhe Workshop on Software Radios, Univ. Karlsruhe, 29.-30 März 2000, Proc. S. 13-18, Deutschland
- [5] T. Müller, „Architectures for Multimode Receivers“, RF & Hyper europe Microwave, Wireless & Optical Technologies for Communications Convergence, 17. Januar 2001
- [6] T. Müller, H. Schnepf: „Hardware Architectures for Multimode Receivers“, ITG Fachausschußsitzung 7.2, Funksysteme, Diskussionssitzung Software Defined Radio, 29. März 2001, Gerhard-Mercator-Universität Duisburg
- [7] H. Schnepf, T. Müller: „Digital Signal Processing of a Software Defined Car-Radio“, ITG Fachausschußsitzung 7.2, Funksysteme, Diskussionssitzung Software Defined Radio, 29. März 2001, Gerhard-Mercator-Universität Duisburg
- [8] H. Schnepf, T. Müller, J. Luy, „Channel Diversity in a Software Autoradio“, IEEE VTS 53<sup>rd</sup> Vehicular Technology Conference, Spring, 2001, 6.-9. Mai 2001, Rhodos, Griechenland
- [9] R. H. Walden “Performance trends for Analog to Digital converters”, IEEE communications magazine, feb. 1999, vol. 37, no. 8. pp. 96-101

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