SOFTWARE DEFINED RECEIVER FOR BROADCASTING SYSTEMS FOR AUTOMOTIVE APPLICATIONS

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ABSTRACT

Based on software defined radio technology, automotive receiver for three broadcasting systems has been developed. In this paper, an overview of the receiver architecture is given, and performance improvement achieved through utilization of digital signal processing methods is discussed. Two RF paths are implemented, which enables us to implement and test different diversity techniques. The mode of operation is programmable, and can be set through a control interface.

The signal is converted into digital domain at IF level and digital signal processing algorithms are used for further processing. Utilizing programmable and software reconfigurable hardware, receiver for multiple standards and different standard variations worldwide can be implemented on the single hardware platform.

Receivers for AM, FM and weather band broadcasting systems have been developed, and work on receivers for further waveforms is in progress.

1. INTRODUCTION

An important property of software defined radio is a possibility to implement a multistandard and multimode radio. To change the radio mode or broadcasting standard currently being demodulated, hardware is reconfigured per software control, and new waveform processing routines are loaded into a programmable processing unit. The advantage of software receiver approach is especially emphasized in the systems for which all or majority of hardware components can be reused for implementation of different modes and/or different standards. When two or more systems operate in the same frequency range and with the same or similar bandwidth, reconfiguration of RF hardware can be done in a relatively simple way. In the broadcasting world, these systems are e.g. analog AM broadcasting system and Digital Radio Mondiale (DRM), [1]. Such scenario enables optimal use of resource sharing methods, and thereby reduction of number of components in a multistandard and multimode radio receiver.

We have developed full-featured state of the art automotive software receiver for three broadcasting systems. The work described in this paper is a part of the effort announced in [2]. Receivers for AM, FM and weather band broadcasting standards have been implemented. Receivers for further waveforms are in development.

By using advanced digital signal processing techniques, significant performance improvement in comparison with analog receivers has been achieved. The performance gain is particularly important for automotive receivers, since they have to fulfil very stringent criteria in a fast changing mobile environment.

Modular hardware architecture and well defined software interfaces enable us to use the same hardware platform for development of receivers for further broadcasting systems.

2. HARDWARE

Principal hardware architecture is illustrated in Figure 1. It includes RF part with conversion to IF, sampling at IF level, and digital part consisting of a microcontroller and a general purpose digital signal processor.

Two RF paths are implemented, which enables either concurrent reception of two independent standards, or reception of the same standard on two different carrier frequencies, or utilization of diversity techniques to improve receiver performance. Mode of operation is programmable and can be controlled by the user.

The signal is converted into digital domain at IF level and the sampled signal is being further processed in the digital signal processor.

To reduce effort for calibration process and to minimize receiver sensitivity to temperature drifts, a few considerations in the hardware design had to be done. The same low jitter clock generator is used as master clock for both analog-to-digital converters (ADC). Coherence between both paths is an important issue if the receiver operates in a combining diversity mode. In combining mode, it is particularly important to have same conditions on both receiver paths. This significantly reduces complexity of digital signal processing part.

Figure 1: Principal hardware architecture

Digital signal processor (DSP) is used for demodulation tasks, and microcontroller is used to configure front end and to control the DSP. Computationally intensive conversion from IF to baseband and a part of channel selection filtering are implemented in a configurable hardware. The parameters are controlled by the DSP.

Demodulated signal can be fed either to local loudspeaker interface, or to network interface.

3. SOFTWARE ARCHITECTURE

In Figure 2, structure of DSP software is illustrated. Baseband processing is implemented on a general purpose DSP in a high level language, with well defined interfaces between the processing modules. Receivers for different standards can use the same signal processing sub-routines, which can be classified into two groups: basic and advanced signal processing functions. Basic signal processing functions are mainly available as a library function optimized for a specific processor architecture. Advanced DSP functions include other signal processing routines which can be re-used by different modules, like e.g. AM demodulation.

This approach enables both portability and good utilization of advantages offered by a specific processor architecture. For critical parts, which consume a lot of processing power, functions from signal processing library for a specific processor are used. When the code is ported to some other processor, only these parts of code have to be replaced. Signal processing functions are designed to support standardized interfaces and parameters. In this way, optional use of hardware accelerator with the same standardized interface is possible.

The implemented software receiver supports different modes of operation. Some of these modes require that the DSP controls which signal (from which antenna) is fed to an ADC. For this purpose, antenna control interface is used (see Figure 2).

Through front end control interface, DSP can control a programmable gain, with the goal to optimally utilize ADC dynamic range. The amplitude of the signal being fed to ADC can be controlled in a limited range.

As already mentioned in Section 2, our current design employs digital down-converter (DDC) implemented in hardware. DSP controls downconversion frequency and filter coefficients via ADC/DDC control interface.

Baseband interface is used to receive baseband I and Q samples from the DDC. The clock on this interface is derived from ADC sampling clock.

Output from the software receiver is demodulated data and audio signal, which are made available to external components through data interface and audio interface, respectively.

The rules followed by the software design enable not only portability to other processor architectures, but also very simple extension of number of simultaneously demodulated waveforms through re-usability of signal processing functions. The number and type of simultaneously available services is limited by hardware resources. Our current implementation supports demodulation of two independent services, or reception of one service in diversity mode.

Control/status interface is used to communicate with the microcontroller. Microcontroller initializes receiver parameters and sets mode of operation.
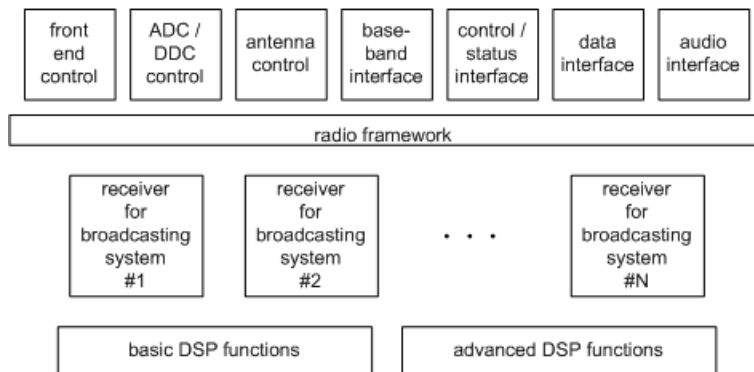

Figure 2: Software architecture. Waveform processing modules do not contain hardware dependent components.

4. PERFORMANCE GAIN

Because of inherent modulation gain and relatively large bandwidth used for signal transmission, FM broadcasting system provides relatively good audio quality in comparison to AM broadcasting system. However, there are some propagation scenarios which can significantly degrade quality of the demodulated FM signal. These scenarios include multipath propagation, adjacent channel interference, co-channel interference and weak signal reception.

The software defined FM receiver uses adaptive interference cancellation algorithms to suppress these types of interferences. The developed receiver uses interference detection algorithms to continuously distinguish between different types of interferences, and to process the signal accordingly, Figure 3. Adjustment of reception parameters is based on changes in signal quality, and smooth transitions between the processing states are achieved by adaptive control algorithm.

In multipath propagation scenario, transmitted RF wave propagates to the receiving antenna on different paths, each path having different delay time and different attenuation. The result is a linear combination of FM waveforms with different delays and therefore different instantaneous frequencies. As a result, demodulated audio signal can be severely distorted, [3].

The developed software receiver can be configured to use interference suppression techniques on the signal received from a single antenna, or to make use of antenna diversity techniques.

Two different approaches can be used to make use of advantages provided by multiple antenna systems. Both of them exploit spatial dimension to obtain independently faded replicas of the same signal. In antenna scan diversity, [3], signal from an antenna which is estimated to offer good reception conditions is fed to the receiver for further processing. Distortion has to be detected in a short time, and when distortion is detected, system switches to the next available antenna. In combining diversity, Figure 4, signals from two or more antennas are adaptively combined with the goal to maximize signal to interference ratio. Since propagation parameters change as the vehicle moves, combining parameters are constantly being updated. Adaptation algorithm is based on variations in signal envelope.

Analysis has shown that other types of interferences, e.g. adjacent channel interference, will cause variations in signal envelope, too (Figure 5). Therefore, all interference cancellation functions had to be designed in a way to minimize possible negative influence on other adaptive algorithms. This is particularly important for functional blocks whose adaptation is performed using signal at the output from some interference suppression algorithm. In this way, performance improvement in both adjacent channel interference environment and multipath propagation environment could be achieved.

Unlike the scan antenna diversity which chooses the better of two or more antennas, combining diversity system can improve receiver performance even when both antennas suffer under severe multipath. Performance of combining diversity algorithm could be further improved by dynamically controlling not only combining parameters, but also the adaptation function itself.
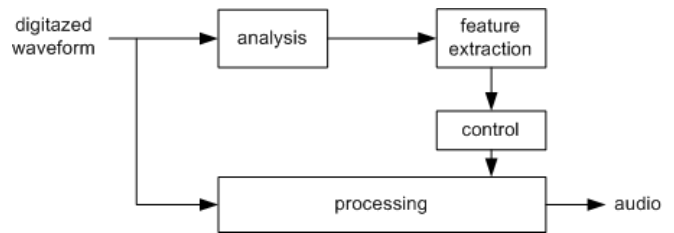

Figure 3: Adaptive signal processing based on interference analysis
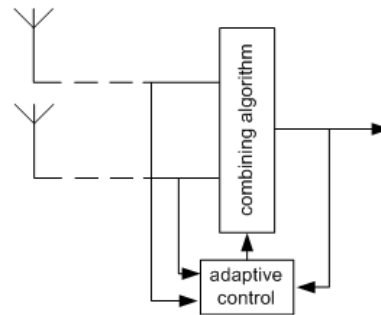
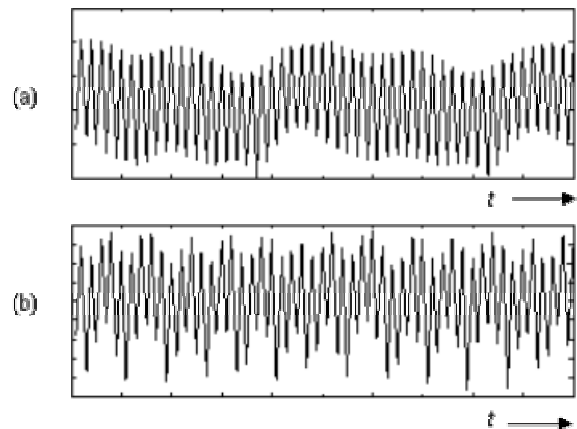

Figure 4: Combining antenna diversity

Figure 5: FM signal envelope under different interference conditions. (a) is envelope of signal suffering under multipath propagation. (b) is envelope of signal with adjacent channel interferer. Both signals are recorded in actual test drives.

5. FIELD TESTS

Extensive field tests of developed software receiver with integrated interference suppression methods have been done. In actual test drives, significant performance gain in multipath and adjacent channel interference conditions has been observed.

Analysis of performance in weak signal conditions has been done both in lab and through field tests. Performance improvement of FM receiver operating in combining diversity mode has been confirmed both by measurements and by field tests. Signal with very low level could be more clearly received in combining antenna diversity mode than in single antenna mode.

Optimization of receiver parameters was based both on results from actual test drives and standardized measurement methods.

6. SUMMARY

Software defined receiver for three broadcasting standards has been developed. Performance improvement in typical interference conditions has been achieved by utilizing adaptive digital signal processing methods and antenna diversity techniques.

Future work will include implementation and integration of software receivers for further broadcasting systems.

7. REFERENCES

[1] ETSI ES 201 980 V2.2.1, "Digital Radio Mondiale (DRM); System Specification", 10.2005.
[2] M. Sliskovic, H. Schöpp, "Software Radio Concept of the Receiver for Digital Broadcasting Services", 2nd Karlsruhe Workshop on Software Radio, Karlsruhe, Germany, 2002.
[3] H. K. Lindenmeier, "Multi antenna scanning", IEEE Potentials, Vol. 11, Issue 1, Feb. 1992.