

11.2-3

A Robust Two-Antenna Digital TV Receiver for Portable Handsets with Ultra-High Interference Cancellation

Yoshitomo Kaneda, Hajime Toma, Michiru Hori, Sadanori Sakaguchi, Sho Tamaki,
Takayoshi Tomoyose, Kunio Morimoto, Shuji Murakami
Magna Design Net Inc, Naha Okinawa, Japan

ABSTRACT

This paper presents a robust two-antenna digital TV receiver optimized for portable handsets with ultra-high interference cancellation capability. An adaptive array direction control system drastically enhances desired OFDM signals, and it compensates undesired interference signals. An FPGA prototype of the Japanese ISDB-T 1-segment receiver demonstrates the improvement of D/U ratio by maximally 13 dB. Thus, any interference, e.g. analog TV signal, can be completely eliminated.

INTRODUCTION

Digital Television (TV) broadcasting service for portable handsets, mainly targeting cellular phones, is one of the major emerging markets in the world.

For example, Japan may start the 1-segment version of integrated services digital broadcasting-terrestrial (ISDB-T) [1] in 2006, while High Definition TV (HDTV) started in 2003. Since it uses Quadrature Phase Shift Keying (QPSK) and convolutional code of 1/2, the Carrier-to-Noise (C/N) ratio limit is reduced as low as 5 dB. However, the actual C/N ratio becomes less than the value because cellular phones are often used indoors. They also suffer from interferences caused by electronic appliances such as personal computers as shown in Fig. 1.

This paper presents a two-antenna adaptive array mobile digital TV receiver with strong interference cancellation capability. The algorithm is optimized for the portable handsets from the 4-antenna adaptive array direction control LSI presented in the ICCE 2004 focused on the HDTV reception in high-speed environment [2]. Both digital beam-forming and/or null-steering algorithms in time domain are applied. An FPGA prototype of ISDB-T 1-segment receiver is implemented to demonstrate the capability. The ratio of OFDM signal to interference signal (D/U ratio) is improved by maximally 13 dB, and the C/N ratio is improved by 3 dB compared to the one-antenna receivers.

Robust receiver architecture

Figure 2 illustrates the time-domain two-antenna adaptive array architecture. The 2-antenna combination is based on the beam-forming algorithm Maximum Ratio Combination (MRC) beam-forming algorithm [2]. In the MRC algorithm, the weights are calculated so as the multiplication results to have the same phase value. The weight of k-th antenna W_k is expressed as

$$W_k = E[X_k^* \cdot y] \quad (1),$$

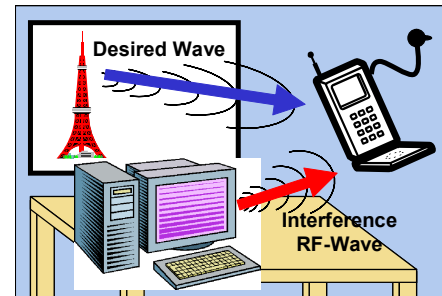


Fig. 1: Severe co-channel interference at indoor from electronic appliances

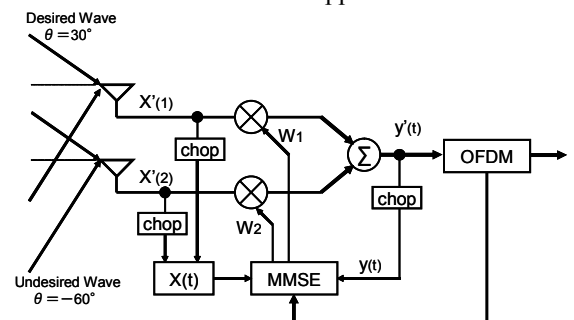


Fig.2 Block diagram of 2-antenna adaptive array with OFDM receiver

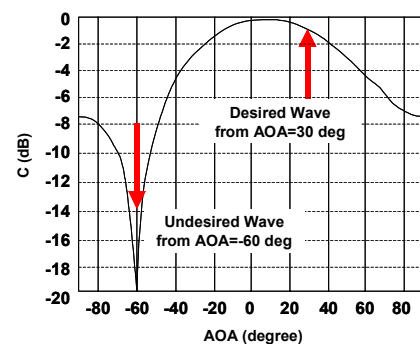


Fig. 3: Simulated gain vs. angle-of-arrival (AOA) with co-channel interference

where X_k^* is the complex conjugate of the input signal of k-th antenna, y is the combined output.

In this receiver, another sophisticated algorithm is introduced. The weight W_k is calculated by exploiting the periodic property of the OFDM signal, i.e. guard interval (GI) is a copy of the tail of the OFDM symbol. According to the property, adoption of a Minimum Mean Square Error (MMSE) null-steering algorithm becomes possible.

Figure 3 shows a simulated gain of 2-antenna adaptive array vs. angle-of-arrival (AOA) using the MMSE algorithm, assuming the desired OFDM signal and undesired interference signal arrive from 30 degree and -60 degree, respectively. The interference signal is completely suppressed, and the OFDM signal is enhanced to almost highest gain.

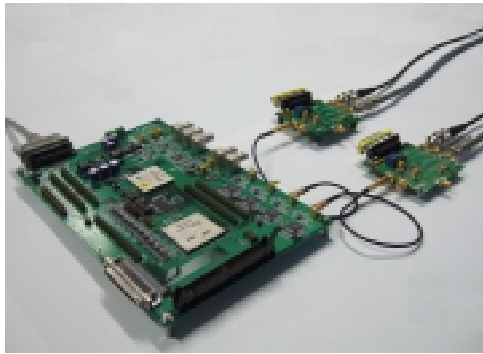


Fig.4: Photograph of two-antenna receiver prototype

Measurements

A prototype of the 2-antenna ISDB-T 1-segment digital TV receiver is implemented as shown in Fig. 4. The Xilinx Vertex II-Pro FPGAs are used.

Several basic performances are measured with the MRC algorithm. Figure 5 shows the Bit Error Rate (BER) at the Viterbi decoder output against the C/N ratio. 3-dB improvement is obtained compared to 1-antenna receiver. The Quasi-Error Free (QEF) point, i.e. the C/N ratio at the BER of $2e-4$, is as low as 2 dB. A fading characteristic is measured in Fig. 6. In the condition of three-wave Rayleigh fading model, the Doppler frequency immunity improved by 40 Hz.

The interference cancellation capability is evaluated in Fig. 7. The critical (or lowest) D/U ratio of OFDM signal to interference signal is plotted against the AOA of the OFDM signal, with the AOA of the interference fixed to 0 degree. With 1 antenna, the critical D/U ratio does not depend on the AOA. When the MRC algorithm is used in 2-antenna adaptive array, 3-dB improvement is observed at large AOAs. Drastic improvement is measured by utilizing the MMSE algorithm. The critical D/U ratio drops down by 13 dB at the AOA larger than 70 degree. Even though the improvement is not as much as the value in small AOA values, it is quite sufficient for the actual usage.

Conclusions

A robust two-antenna adaptive array digital TV receiver is successfully developed for the portable handset applications. The performance is proved by the FPGA prototype of the ISDB-T 1-segment digital TV receiver. Due to the MMSE algorithm utilizing the periodic property of the OFDM, the D/U ratio for demodulation is drastically improved by maximally 13 dB compared to one-antenna receivers. Thus, any interference, e.g. analog TV signal, can be completely eliminated.

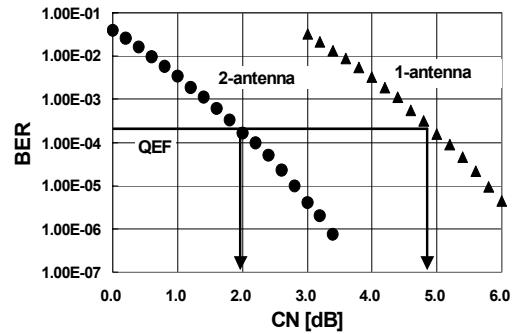


Fig. 5: C/N vs. Bit Error Rate (MRC, after Viterbi decode)

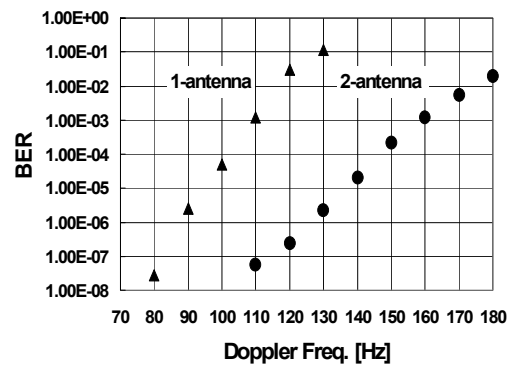


Fig.6: BER performance at fading condition (MRC, 3-wave Rayleigh model)

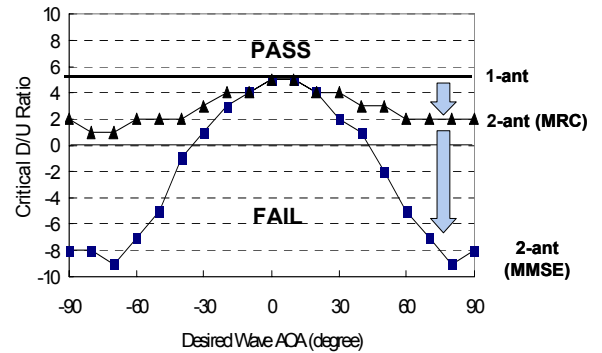


Fig.7: Interference cancellation performance by number of antenna and algorithms

The adaptive array system is applicable to all OFDM digital TV systems such as DVB-H and T-DMB.

References

- [1] "Channel coding, frame structure and modulation scheme for terrestrial integrated services digital broadcasting (ISDB-T)," ITU-R WP11A, May 1999.
- [2] S.Sakaguchi, M.Hori, H.Asato, K.Morimoto, S.Murakami, T.Wada, K.Sanda, and N.Itoh, "An Adaptive Array Direction Control LSI for Mobile Digital HDTV Receivers", 2005 Digest of Technical Papers, International Conference of Consumer Electronics, No.7.4.3, Jan., 2005.