An Adaptive Array Direction Control LSI For Mobile Digital HDTV Receivers

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ABSTRACT

This paper presents a multi-antenna diversity LSI that enables the mobile reception of Digital HDTV. A unique algorithm of four-branch combination with three-band division method drastically improves the performance of mobile reception, especially in high-speed environment. The rate of reception is achieved 97% field-testing result in Japan.

INTRODUCTION

The terrestrial digital TV broadcast has started since 1998 in the U.S. and Europe, and 2003 in Japan, where the HDTV is the main service in the U.S. and Japan. However, this service is not popular to home using, and also mobile reception is not realized yet because of technical difficulties. Low antenna height drops the electrical field of the received signal. Reflection of radio wave by buildings as shown in Fig.1 degrades the signal quality due to Doppler shift and fading of the radio wave.

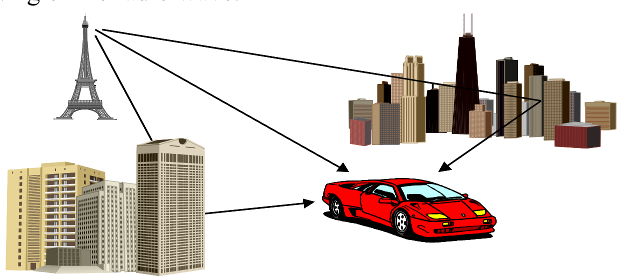

Fig. 1 Mobile Reception of the Digital HDTV

A diversity system with two to four antennas is necessary for the mobile reception of the HDTV. In Japan or Europe, the diversity receiver using the Orthogonal Frequency Division Multiplexing (OFDM) demodulator outputs have been researched [1]. However, the hardware size increases in proportional to the number of antennas because each antenna needs an OFDM demodulator.

This paper reports an Adaptive Array Direction Control (AADC) LSI. The LSI is placed prior to the demodulator and digitally combines the received signals from at most four antennas. The direction of the four antennas is adaptively controlled using a beam forming method, so that the diversity operation improves the performance dramatically in the high-speed environment. The rate of reception is achieved 97% field-testing result under the Japanese OFDM HDTV system.

CHIP ARCHITECTURE

Fig.2 shows the four-antenna diversity system using the AADC LSI. First, the received radio wave signals are down converted to IF signals by tuners. The IF signals are digitally combined into one signal in the AADC LSI and transferred to the demodulator and an MPEG-2 decoder. Then picture and sound are played on an HDTV monitor.

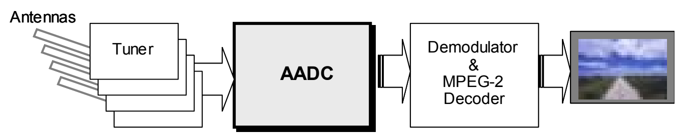

Fig. 2 Four-Antenna Diversity System with the AADC LSI

Fig.3 shows the block diagram of the AADC LSI. Four AD converters are implemented in order to digitize the four tuner outputs (branches). The digitized signals are down converted to base-band signals. The 6-MHz bandwidth is divided into three bands (Low, Middle, and High). The combination of the four branches is done in each band [2]. The performance improves because the combined results are optimized in each band. The four-branch combination consists of weight calculation, multiplication of the weight to the input signals, and summation [3]. The combined signals of the three bands are added to rebuild a 6-MHz signal. Finally, the up-converted IF signal is output and transferred to the demodulator.

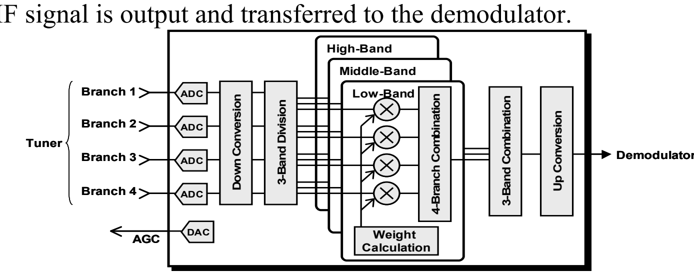

Fig. 3 Block Diagram of the AADC LSI

ALGORITHMS

The four-branch combination is based on the Maximum Ratio Combination (MRC) algorithm [3]. In the MRC algorithm, the weights are calculated so as the multiplication results to have the same phase value. The weight of k-th branch W_k is expressed as

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

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

In the three-band division, the signal is divided into three 2-MHz bands, and the equation (1) is calculated in each band.

SIMULATIONS

To confirm the effect of the algorithm, Bit Error Rate (BER) of the demodulator output is simulated using the Japan OFDM model (64 QAM, no FEC). A two-path Rayleigh fading model with a delay spread of 0.4us is used. Fig.4 shows the Doppler Shift Frequency dependency. The BER improves as the number of the branches increase. In the fast fading environment, the BER performance is deteriorated due to the degradation of the cross-correlation estimation.

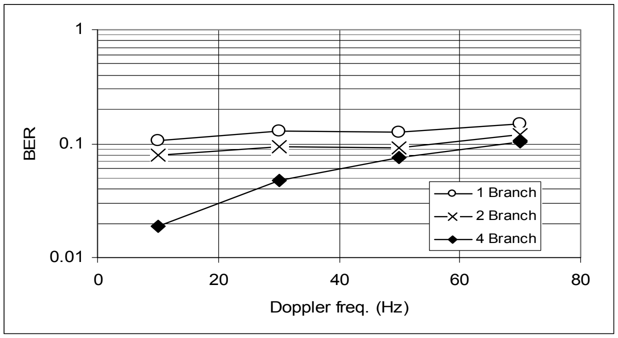

Fig. 4 Simulation of Doppler Shift Frequency Dependency

Fig.5 shows the Carrier-to-Noise ratio (C/N) dependency in a Doppler frequency of 30 Hz. Compared to the one-branch (no AADC) system, the BER is improved by 5 dB and 11 dB for two-branch and four-branch systems, respectively.

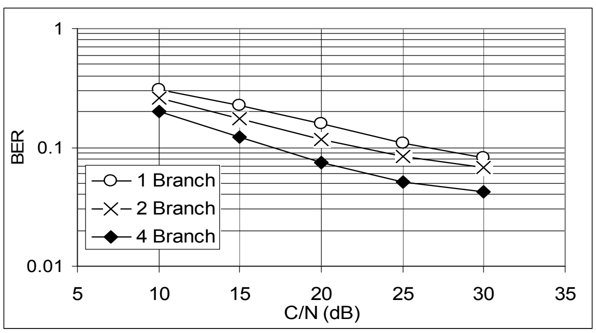

Fig. 5 Simulation of Carrier-to-Noise Ratio Dependency

CHIP CHARACTERISTICS

Fig. 6 shows a microphotograph of the LSI. The die size is 25 mm^2, and fabricated with 0.18-um CMOS 6-metal process, including four AD converters and 700-k gate logic. Power consumption is 600mW at supply voltages of 1.8 V for logic and 3.3 V for I/O.

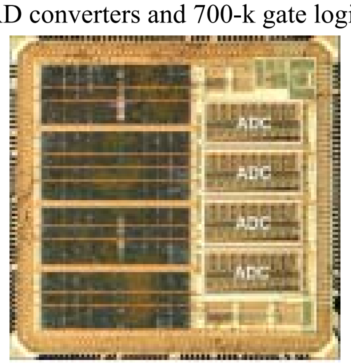

Fig. 6 Chip Micro Photograph

FIELD-TESTING RESULTS

Field-testing results are shown in Fig.7. The test was conducted in Nagoya City, Aichi Prefecture in Japan. The rate of reception (RR) is measured on Highways running through buildings. Average velocity of the vehicle is 80km per hour. The transmission parameters are as follows,

Mode 3, Guard Interval 1/8, 64 QAM, Code Rate 3/4, Interleave Length 2

Compared to the one-branch system without AADC, the RR increases by 15% and becomes to 90% with the four-branch system without band division. With the three-band division architecture the RR of 97% is achieved, which is sufficient to the commercial usage.

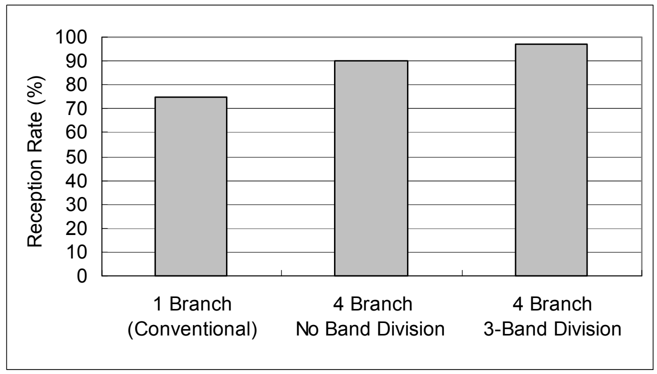

Fig. 7 Field-Testing Results

CONCLUSION

We succeeded in developing an Adaptive Array Direction Control LSI for the mobile digital HDTV receivers. The LSI realizes a single chip diversity system up to four antennas for terrestrial broadcasting. The rate of reception is achieved 97% field-testing result under the Japanese OFDM HDTV system.

This is the first LSI in the world providing a four-antenna diversity solution for the HDTV service. This LSI is available for all of the broadcasting systems in the world.

ACKNOWLEDGEMENT

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