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# A Software-configurable Adaptive Array Antenna System for ISDB-T Reception

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## Abstract

*This paper presents an adaptive array antenna system for ISDB-T reception (Japan Digital TV Broadcasting) with the adaptive array algorithm is configurable by software. By exploiting the merits of Software-Defined Radio (SDR), a number of adaptive algorithms such as digital beam-forming and/or null-steering (i.e. Maximum Ratio Combining - MRC, Sample Matrix Inversion - SMI) are embedded in DSP board that is reconfigurable according to the radio propagation environment. The experiment results for MRC and SMI algorithms successfully improved BER performance for ISDB-T reception with an analog TV interference and inter-symbol interference by Over GI delay waves.*

## Introduction

For wideband broadcasting system, such as ISDB-T, multipath fading caused by many reflected signals seriously deteriorates the quality of digital communication. Software antenna as the particular aspect of Software-Defined Radio (SDR) is receiving enormous attention as the promising solution to realize high bandwidth wireless communication systems. By using SDR technology it may become possible to implement signal processing radio functions by software running in general-purpose micro-processor.

In this paper, the software antenna for ISDB-T reception system is presented. We have chosen digital beam-forming and/or null-steering algorithms in time domain in order to reduce the hardware costs. Moreover, since the ISDB-T receiving system has been developed and refined in past years, this method ensures the high flexibility and good compatibility in connecting with the existing systems. Those algorithms are implemented by C-function in the DSP board.

## Concept of Software Antenna

Figure 1 illustrates the time-domain beam-forming algorithm [1]. In ISDB-T reception system, the ISDB-T OFDM signal and other interference signals have to be distinguished. By exploiting the periodic property of the OFDM signal, i.e. the header of OFDM signal is copied of the tail OFDM signal itself, the header and tail of OFDM signal are used to calculating the coefficients of software antenna.

Suppose that array antenna is equipped with M element antenna. Then the received signal is expressed as followed

$$\mathbf{X}(t) = \left[x_1(t) \quad x_2(t) \ldots \ x_M(t)\right]^T \qquad (1)$$

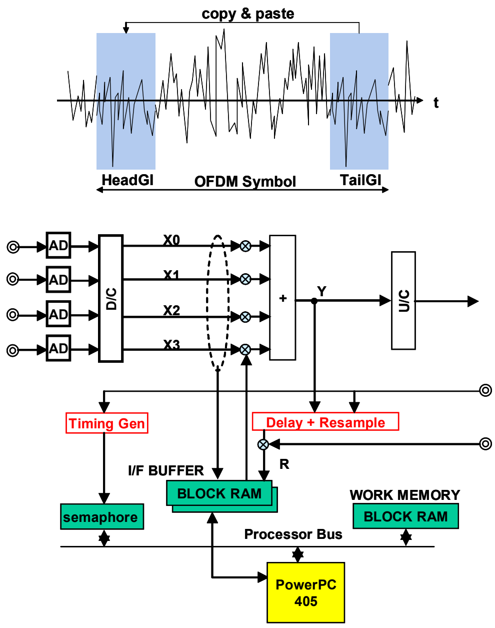


Fig. 1: Block diagram of Adaptive System

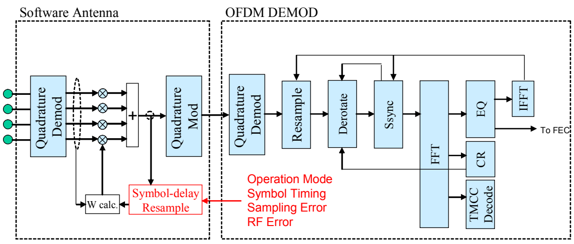


Fig.2: Block diagram of software antenna in concatenation with OFDM reception system.

where $^T$ and $^H$ denote the transpose and hermitian of the matrix. The output signal of software antenna is defined as

$$\mathbf{Y} = \mathbf{W}^H \mathbf{X} \qquad (2)$$

where $\mathbf{W} = \left[w_1 \quad w_2 \ldots \ w_M\right]^T$ is coefficient of array antenna. The coefficients of digital beam-forming is calculated by MRC algorithm as followed

$$\mathbf{W}_{MRC} = \mathrm{r}_{xy} = \mathrm{E}\left[\mathbf{X}\mathbf{Y}^H\right] \qquad (3)$$

In addition, the digital beam-forming/null-steering algorithm (SMI) is also supported in order to overcome the limitation of MRC algorithm in severe propagation environment in which the strong interference is dominant. The coefficients of SMI is calculated as follows

$$\mathbf{W}_{SMI} = \mathrm{R}_{xx}^{-1}\mathrm{r}_{xy} \qquad (4)$$

where $\mathrm{R}_{xx}$ is correlation matrix of received signals.

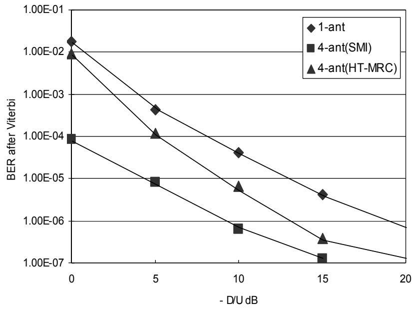


Fig. 3: BER performance with Analog co-channel interference

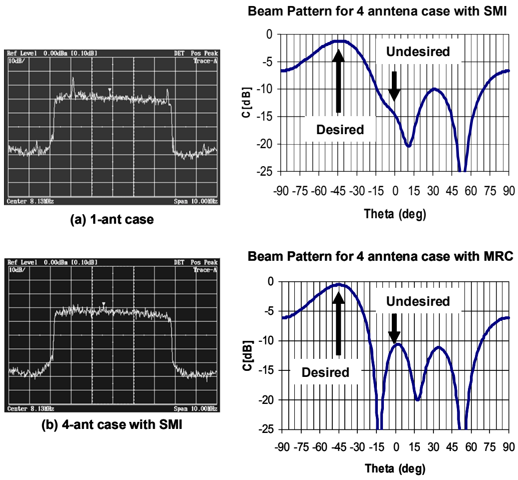


Fig.4: Power spectrum and beam pattern of digital beam forming/null-steering

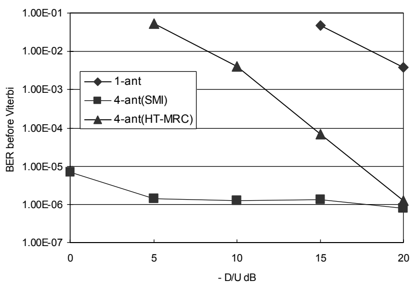


Fig.5: BER performance with delay exceeding the GI length

The block diagram of software antenna in concatenation with the OFDM demodulation system is given in Fig. 2.

## Experimental Results

In the measurement, the Mode 3 (8KFFT) and the 64-QAM modulation is used. OFDM signal comes to array antenna with angle of arrival $\theta = -45^0$, while analog TV co-channel interference has angle of arrival $\theta = 0^0$. Fig.3 and 4 show the BER performance of our software antenna with SMI and MRC algorithm in case of the co-channel analog interference and equivalent beam-patterns. The power spectrums of output signal of software

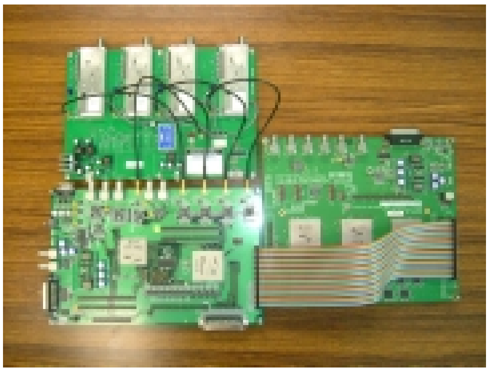

Fig.6: Implementation Software antenna for ISDB-T reception system.

antenna are also illustrated in Fig.4. It is shows that SMI algorithm is suitable for radio environment in which the co-channel interference is dominant. Otherwise, in the region of small co-channel interference, performance of MRC algorithm matches with that of SMI algorithm.

OFDM signal coming with delay exceeding the Guard Interval length will be treated as co-channel interference. Therefore, we can expect that Inter-symbol Interference (ISI) is also reduced by using software antenna. Fig.5 shows the BER performance for this case. It is showed that software antenna can distinguish the large delay signal and improve the performance of system. Fig.6 shows the implementation of software antenna in concatenation with our OFDM demodulation. The demodulation system is implemented by FPGA board, while software antenna is embedded in DSP board operating by PowerPC micro-processor in FPGA.

## Conclusions

In this paper, the software antenna for ISDB-T reception system is presented. Two types of array antenna algorithms are supported in order to overcome limitation of each algorithm in different type of propagation environment.

Experiment results show that the strong Analog co-channel interference is suppressed by software antenna. Moreover OFDM signal with delay exceeding GI length causing ISI effect is also treated as co-channel interference.

Our software antenna solution is implemented in DSP board in concatenation with OFDM demodulation system.

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## References

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