Direction Finding of OFDM Signals

Kazuhiro SATOYOSHI Yoshihiko KUWAHARA

Graduate School of Science and Engineering, Shizuoka University 3-5-1
Johoku Hamamatsu, Shizuoka 432-8561, Japan
e-mail: f0830101@ipc.shizuoka.ac.jp

1. Introduction

Diversity antenna is essential for the mobile communication terminal to receive the ISDB (Integrated Services Digital Broadcasting). Mean Effective Gain (MEG) and spatial correlation are used for criterion of diversity antenna performance. To compute them, distributions of horizontal and vertical DOA (Direction Of Arrival) where signals are incident into diversity is needed.

We have measured DOA distributions of FM broadcasting to evaluate the FM diversity antenna mounted on the vehicle [1]. We already confirm that correlation between fading pattern achieved by the field test tends to correspond with numerical simulation results and experimental results using the scale model in anechoic chamber [2]. Based on these results, we try to analysis the characteristic of the diversity antenna quantitatively for receiving ISDB.

In this paper, we investigate a direction finder which estimates DOA of ISDB in the field. We design the antenna aperture based on the result of delay-profile measured in the field. And we present experiment results of DOA estimation by a Time Division Multiplex (TDM) receiver and a scaling model to confirm validities of our design.

2. Design of direction finding antenna aperture

2.1 Basic demands of the direction finder

Fig.1 shows delay-profile around the place where it is difficult to receive ISDB signal. This figure shows that there are 2 delayed waves (Desired and Undesired Ratio<20dB) well as a main wave. Based on the result, we decided maximum number of waves for DOA estimation is 3. Minimum separation angle is 45º from reference [3] on measurements of 900MHz cell phone. As for OFDM signals in the multi-path propagation, super resolution techniques such as Capon and MUSIC are applicable without the pre-processing like the spatial smoothing because of no correlation between main wave and delayed waves.

2.2 Simulation

2.2.1 Simulation conditions

We assume 3 64-QAM OFDM signals with successive 2-bit delay and the same average power. Minimum separation angle of DOA estimation are investigated under the condition that vertical incidence angle is 90˚ (boresight of the antenna element) while horizontal incident angles change. The antenna is a circular array composed of vertical half wavelength dipoles. The number of elements is evaluated by numerical simulation. Steering vector is calculated by the method of moment NEC2. The algorism of DOA estimation is MUSIC with MDL for decision of incident wave number.

2.2.2 Results of simulation

Minimum separation angle between 3 incident waves with the same amplitude is investigated. DOA of an incident wave is fixed at the 0° in the horizontal plane, and the others are approached gradually form ±120 °. SNR is set to 0～30dB, and radius is also changed from 0.7 to 1.2λ. This range equals band width of ISDB (470～770MHz). Fig.2(a) shows the relationship between minimum separation angle and number of elements. Fig.2(a) shows more than 6 elements are needed for our demand. Fig 2(b) shows the relationship between SNR and minimum separation angle under the condition that element number is 8. From Fig.2(b), more than 5dB of the SNR is needed. RMSE (Root Mean Square Error) of DOA estimation is less than 1° if separation angle will be larger than15° and SNR will be more than 20dB.

3. Experiments by TDM receiver

3.1 TDM receiver

Due to limitation of experiment equipments, we have experimented using scaling model in anechoic chamber. The frequency was 2.5 [GHz]. Fig.3 shows the experiment system. Base-band OFDM modulated signals (main and delayed) are generated by C6713DSK. And 2.5GHz signals are generated by 2 signal generators equipped with external IQ modulation terminals. Transmitting antennas are vertical polarized Microstrip Patch Antenna (MSPA). 8 λ/4 monopole antennas are mounted on the circle on the reflector (250mm by 350mm). In this equipment, 8 signals received by 8 element array antenna are input to a TDM receiver [4]. For simplicity, transmitter and receiver are synchronized by wire. The receiving signals are taken into PC after they are IQ demodulated. The correlation matrix is estimated using the TDM receiving signal. After wave number estimation by MDL, MUSIC spectrum is calculated and DOA is estimated.

3.2 Experiment

Fig.4 shows the TDM receiver and antenna aperture, generated OFDM signal and its spectrum. Fig.5 shows MUSIC spectrum under the condition that, DOA of second wave is set to either (φ,θ)=(30°,90°) or (90°,90°) while DOA of first wave is set to (0°,90°). Range of spectrum search is 45～90° in vertical , 0～360° in horizontal plane. SNR is 25dB. 2 incident waves are isolated completely.

4. Conclusion

Based on the delay profile measurement in the field of ISDB and reference on DOA measurements of 900MHz mobile cell phone, antenna aperture of the direction finder for ISDB has been investigated by numerical simulation. And DOA of 2 OFDM waves (main and delayed) has been estimated by the TDM receiver and 2.5GHz scaling model. In the future, we are to evaluate the DOA distribution of

ISDB in the field.

Reference

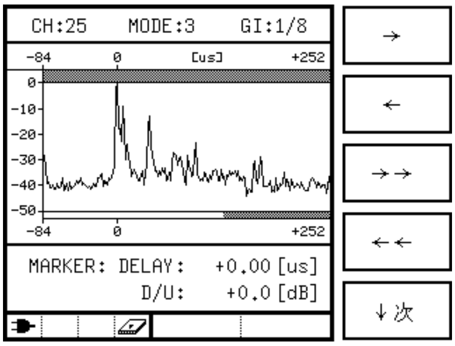
[1] T. Ikeda, Y. Suzuki and Y. Kuwahara, DOA Estimation for the FM Radio, IEICE General Conference, B-1-28, 2006.

[2] C. Shimizu and Y. Kuwahara, Analysis of a Diversity Antenna Mounted on the Vehicle for FM Radio, Proceedings of the 2007 international symposium on antennas and propagation pp.1068-1071, 2007.

[3] T. Taga, Analysis for Correlation Characteristics of Antenna Diversity in Land Mobile Environments, IEICE Trans. VolJ73B, pp.833-895, 1990.

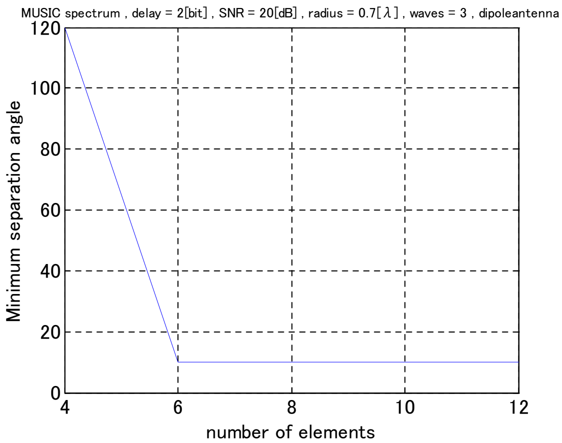
[4] T. Maruyama and Y. Kuwahara, Digital Beamforming Equipment by Time Division Multiple Receiving for the Direction Finder, Proceedings of the 2002 international symposium on antennas and propagation, pp9-12, 2002.

Map of Sagamihara

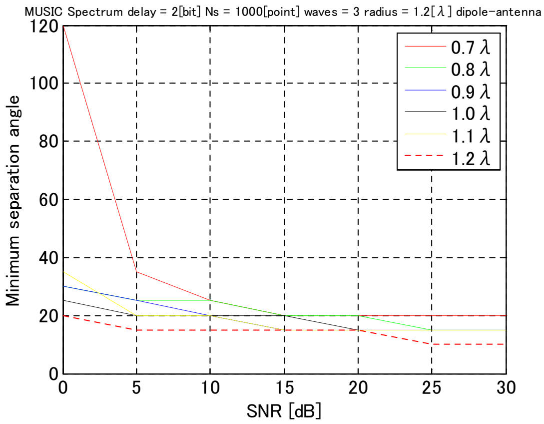


Delay-profile around Sagamihara

Fig.1 Delay Profile of ISDB around Sagamihara area



(a) elements number



(b) SNR

Fig 2　Minimum separation angle

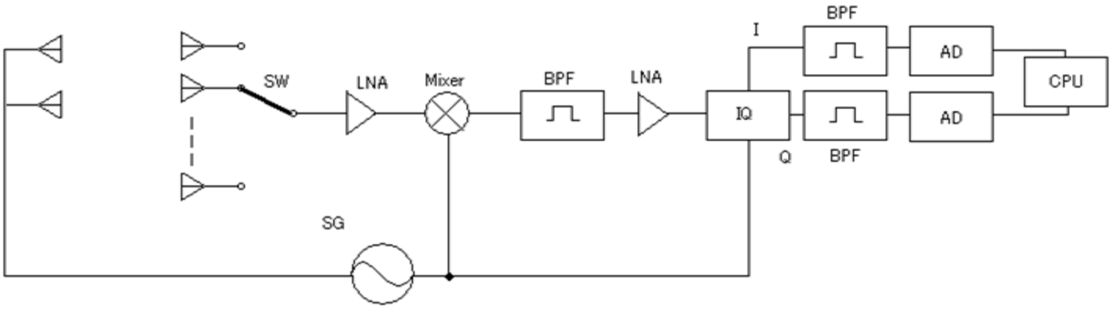
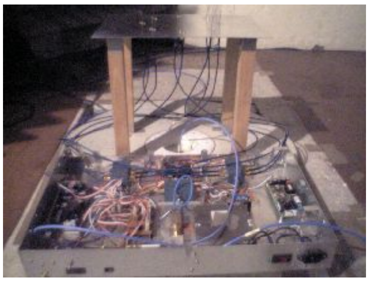
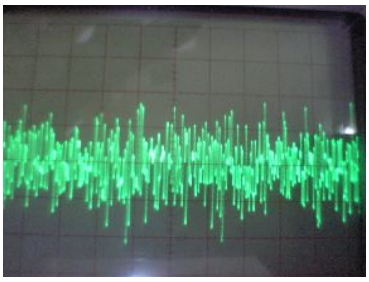
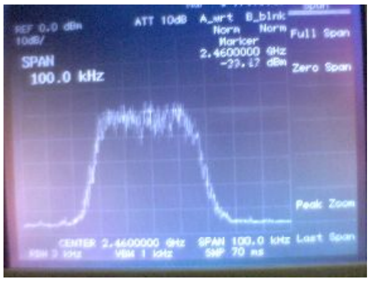


Fig3 TDM Receiver system







antenna and TDM receiver　　baseband OFDM signal　　spectrum of OFDM signal

Fig.4 Appearance of experiment

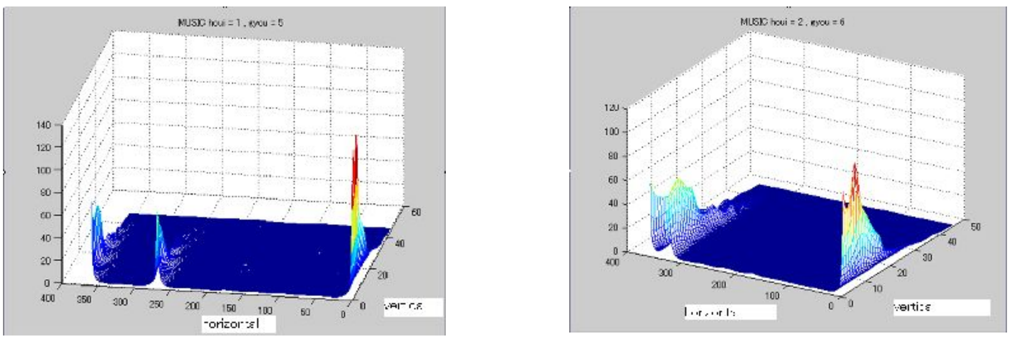


Fig.5 MUSIC spectrum of the experiment