Professor Jun-ichi TAKADA

was born in Tokyo, Japan, in 1964. He received the B.E., M.E., and D.E. degrees from the Tokyo Institute of Technology, Tokyo, Japan, in 1987, 1989, and 1992 respectively. From 1992 to 1994, he was a Research Associate at Chiba University, Chiba, Japan. From 1994 to 2006, he was an Associate Professor at the Tokyo Institute of Technology before becoming a Professor. He has been participating in European COST action 2100 “Toward mobile broadband multimedia networks.” His current research interests are wireless propagation and channel modeling, array signal processing, Cognitive radio, and application of wireless communication and information technology for regional/rural development. Dr. Takada is a member of IEEE, IEICE, Applied Computational Electromagnetics Society (ACES), and ECTI Association, Thailand.

Assistant Professor Minseok Kim

Asst. Prof. Kim was born in Seoul, Republic of Korea. He received the B.S. degree in Electrical Engineering from Hanyang University, Seoul, Korea, M.E. and Ph.D. degrees in Division of Electrical and Computer Engineering, Yokohama National University (YNU), Japan in 1999, 2002 and 2005, respectively. He was with a startup company from 2005 and has experienced H/W and S/W development of various embedded system. He was also with YNU as a postdoctoral research fellow shortly in 2006. He joined Tokyo Institute of Technology (Tokyo Tech) as an assistant professor from July 2007. His research interests include digital signal processor implementation, radio propagation measurement, array signal processing, smart antenna system, software defined radio / cognitive radio. He is a member of IEEE and IEICE.
Paper Awards of Takada Laboratory

Gilbert won First Prize for Best Student Scientific Paper at World Congress on ITS

Panarat won Student Paper Award at APMC 2007

Member of Takada Laboratory
Real-Time Propagation Measurement System for Electric Toll Collecting (ETC) System

Introduction

In the early deployment of electric toll collecting (ETC) system, multipath interference has caused the malfunction of the system. Therefore, radio absorbers are installed in the toll gate to suppress the scattering. This paper presents a novel radio propagation measurement system to identify the individual scattering object and the power intensity of the ETC gate in real time.

Table 1: System specification

<table>
<thead>
<tr>
<th>Signal</th>
<th>ARIB-T75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulation</td>
<td>ASK split phase coding, 1024 k symbol/s</td>
</tr>
<tr>
<td>Carrier frequency</td>
<td>D1: 5.765 GHz, D2: 5.805 GHz, BW = 4.4 MHz</td>
</tr>
<tr>
<td>Rx power range</td>
<td>-30.6 ~ -60.5 dBm, -70.5 dBm (threshold)</td>
</tr>
<tr>
<td>Array geometry</td>
<td>8 element uniform linear array</td>
</tr>
<tr>
<td>Element spacing</td>
<td>25.77 mm (0.5 wavelength)</td>
</tr>
<tr>
<td>Antenna element</td>
<td>Circularly polarized MSA</td>
</tr>
<tr>
<td>RF frequency</td>
<td>5.470 ~ 5.875 GHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>40 MHz</td>
</tr>
<tr>
<td>Sampling frequency</td>
<td>80 MHz</td>
</tr>
<tr>
<td>Quantization bit</td>
<td>14 bit</td>
</tr>
<tr>
<td>FPGA</td>
<td>Xilinx Virtex-II 2 M gate x 5</td>
</tr>
<tr>
<td>FPGA memory</td>
<td>about 28 k sample/ch</td>
</tr>
</tbody>
</table>

Measurement System

The signal and system specifications are presented in Table 1. The measurement system captures the data in burst-wise manner at each time frame in a moving vehicle. The vehicle loading this system usually passes through the toll gate at constant speed of 20 km/h. In the measurement, the laser sensor is used to trigger for the start and end positions of the measurement and the system captures the data at every equi-time interval along the running path until the end-trigger is detected.

In this system, DOAs are estimated with a linear antenna array with cone ambiguity. To overcome this, this paper proposes the scattering object identification method using 3-D visualization of beamforming results that include the signal power intensity at any direction along the observation points. The beamforming results is applied to a spherical beampatterns that express the corresponding power intensity by its transparency in a cone shape on its surface. It means making any parts of the surface transparent when the power is higher than a threshold value and making them colored otherwise. When producing the spherical beampattern, the threshold level should be appropriately selected. The spherical beampatterns is converted to VRML (virtual reality modeling language) with the 3-D model of the toll gate.
Results and Discussion

Figure 1 presents the measurement results on the adjacent lane in case of water sprinkler exits in ETC lane. The length of the measurement area was 13m and the transmitter antenna location in the ETC lane was x=8m from the start point of the measurement. As shown in Fig.1(a), the vehicle with this system carries out the measurement passing through the toll gates. Fig.(b) shows the contour plot of the beamforming pattern that provides the power intensity distribution. From this results, we can find large leak power about -55 dBm to the adjacent lane caused by the reflection of the water sprinkler at around x=2m and $\theta_0=140^\text{deg}$. It means that the malfunction can occur by this leaked signal because the threshold power level in the ETC receiver operation is prescribed by -70.5dBm. The results of the scattering object identification using 3-D beampatterns are shown in Fig.(c). The threshold level in producing the spherical beampattern was set by the lower bound of the ordinary receiving power, -60.5dBm. It can be seen that the water sprinkler is identified as a scattering object and the power intensity is also easily found.

Conclusion

This paper proposes a novel radio propagation measurement system useful for the ETC gates without closing the gate. The measurement can be made on the vehicle passing through the gates using real ETC signal transmitted by ETC base station. This system can identify the individual scattering object and the power intensity of the ETC gate as well as the spatial power intensity distribution in real time. Moreover, the validity of the system was verified by the field experiment.
Identification of Relatively Strong Clusters in an NLOS Scenario at a Small Urban-Macrocell Mobile Station

Introduction

The need to model the collection of multipaths (MPCs) that lie in the same angle-delay domain, or clusters, is also one of the things needed to approach the full performance advantage of Multiple-Input Multiple-Output (MIMO) systems for future cellular communications.

- Researchers have various ways of defining a cluster.
  ⇒ Cluster size & location highly depends on the physical environment.
- Current research focuses on microcells & picocells but not much on macrocells.

We present a procedure for identifying clusters around the mobile station in a small macrocell. It is based on the parameters of stronger clusters, which serve as the initial centroids. Using this method, most of the clusters were identified in an NLOS scenario. Employing this approach may aid in the identification of clusters when relatively strong paths below the path power of the centroids are included.

Channel Sounding Setup

<table>
<thead>
<tr>
<th>Table 1: Medav RUSK-Fujitsu MIMO Channel Sounder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier frequency</td>
</tr>
<tr>
<td>Bandwidth</td>
</tr>
<tr>
<td>BS Antenna</td>
</tr>
<tr>
<td>MS Antenna</td>
</tr>
<tr>
<td>V- &amp; H-polarized 4-by-2 Patch Elements</td>
</tr>
<tr>
<td>V- &amp; H-polarized 24-by-2 Patch Elements</td>
</tr>
<tr>
<td>Tx Signal</td>
</tr>
<tr>
<td>Tx Power</td>
</tr>
<tr>
<td>Maximum path delay</td>
</tr>
</tbody>
</table>

- Conducted dynamic measurements after midnight
- Offline maximum likelihood multidimensional parameter estimation.
  ⇒ Estimated parameters: azimuth & elevation AoA, azimuth & elevation AoD, time delay, & the amplitude of the 4 polarimetric MPCs.
- Results are independent of the antennas used.
  ⇒ Double-directional channel concept based measurement & estimation system.

<table>
<thead>
<tr>
<th>Table 2: Environment Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>NLOS Measurement Route</td>
</tr>
<tr>
<td>Coverage</td>
</tr>
<tr>
<td>BS Height</td>
</tr>
<tr>
<td>MS Height</td>
</tr>
<tr>
<td>BS-MS Separation</td>
</tr>
</tbody>
</table>
Results and Discussions

• Paths considered: until 20dB below the normalized strongest path (0dB) ⇒ Scenario length: 2m (frame containing five snapshots) the paths within it did not change considerably.
• More clusters can be seen after we included the paths below −6dB. See Fig. 2.
• As can be seen in Fig. 1, C1 in Fig. 2 had the largest concentrations of MPCs.
• The results also show that each cluster is unique ⇒ Traditional uniform distribution of scatterers around the MS is not always appropriate.
• Overall, the identified clusters accounted about 68% of the path power with respect to the total power (including the diffuse components).

Fig. 1: Initial clusters defined with their parameters. Order of the arrow label: the mean azimuthal AoA, the mean time delay, & the mean elevation AoA of the centroids.

Fig. 2: Time delay against the azimuthal AoA. C1 refers to cluster 1 while U1 refers to unclustered path 1.

Conclusion

• Using the stronger path centroids enabled us to identify clusters when all the considered paths were included.
• But there remains some unclustered paths that may not easily be identified by the procedure.
• This work may augment the initial selection of cluster centroids in automatic clustering.
Introduction

For any wireless systems, ray tracing can be used to simulate the multipath propagation environment. But due to its geometrical optics (GO) approximation and computational limitation, error occurs depending on the environment. In this work, we first survey the range in a microcell environment where the GO can be calculated. Next we introduce the complex radar cross section for ranges that are impossible to calculate by GO. We then perform the correct simulation by simple expansion of the ray tracing simulator.

Applicable Range of Geometrical Optics

Propagation path loss at long distances decreases on the street model (Fig.1) which is usually well observed in an urban area. The reason is that there are a lot of diffraction rays with large energy near the specular reflection. The reflection and diffraction coefficients in GO are used on the assumption that the size of reflection and diffraction edge are infinite. We therefore survey the condition of applicable range where GO can be used, by comparing GO and the physical optics (PO), which gives better accuracy but longer simulation time. In this work, we compare PO and the stationary phase method (SP) which is a good approximation of PO and is equal to GO. Note that while the computation of GO can be separated into a reflection and diffraction component, the result of PO in this model combines already both components. In this section, multiple objects are designed on the assumption that only one plane connecting the multiple objects is allocated, and its center is the reflection point. PO diffraction is calculated as the difference between PO and SP's reflection component. The diffraction of GO is SP's diffraction. We note that PO's diffraction and SP's diffraction are different within the 1st Fresnel zone. It is therefore not applicable to use GO in this range.
Introduction of Complex Radar Cross Section

The radar cross section (RCS) is introduced for the range where GO is not applicable. The scattering rays are designed using RCS instead of specular reflection and diffraction in the 1st Fresnel zone for specular reflection (Fig.3). In this work, the complex RCS is introduced in order to calculate the scattering of multiple objects. The complex RCS is based on the 3-D plane model which is not a perfect conductor.

Simulation Result

Simulation result (Fig.4) is calculated based on Fig.1. Measurement data [1] with model similar to Fig.1 is also included. In the conventional technique the received level increases at long distances. In the proposed technique, the received level decreases, and is close to the measurement data.

Conclusion

In this work, we point out the problems of the geometrical optics approximation and examine the range that geometrical optics cannot apply. Next we introduce the complex RCS in ray tracing, and verified that the proposed technique is closer to measurement data than the conventional technique.

References

Performance Evaluation of Cyclostationary Detector for Cognitive Radio System

Introduction

Spectrum sensing is one of the most important techniques for cognitive radio systems because it can recognize the presence or absence of the primary signals. In this report, two modified generalized likelihood ratio tests (GLRT) for the spectrum sensing based on cyclostationarity are presented. One is based on sensing at multiple cyclic frequencies and the other is based on cooperation sensing among cognitive users.

Cyclostationarity Detector

To detect whether or not a primary signal $x(t)$ is present, a row vector $\hat{R}_{xx}^\alpha(\tau) = [\text{Re}\{\hat{R}_{xx}^\alpha(\tau)\}, \text{Im}\{\hat{R}_{xx}^\alpha(\tau)\}]$ is examined. In this case, $\hat{R}_{xx}^\alpha(\tau)$ the estimation of cyclic autocorrelation function (CAF) which is defined by $\hat{R}_{xx}^\alpha(\tau) = \frac{1}{T} \sum_{t=0}^{T-1} x(t)x^*(t + \tau)e^{-j\alpha t}$

For a given cyclic frequency $\alpha$ and delay $\tau$, the signal detection can be based on hypothesis testing problem which is stated as follows

$H_0 : \hat{R}_{xx}^\alpha(\tau) = \psi_{xx}^\alpha(\tau), \quad \text{signal is absent}$

$H_1 : \hat{R}_{xx}^\alpha(\tau) = \psi_{xx}^\alpha(\tau) + \psi_{xx}^\alpha(\tau), \quad \text{signal is present}$

where $\psi_{xx}^\alpha(\tau)$ is an estimation error. For $T$ is large, it is known that $\sqrt{T}\psi_{xx}^\alpha(\tau)$ is Gaussian with probability density function (pdf) $N(0, \Sigma_{xx}^\alpha(\tau))$, where $\Sigma_{xx}^\alpha(\tau)$ is the estimated covariance matrix.

Based on generalized likelihood ratio test (GLRT) the statistical cyclic test can be defined as follows

$T^\alpha(\tau) = T \sum_{\tau=0}^{T-1} \Sigma_{xx}^{-1}(\tau)\hat{R}_{xx}^\alpha(\tau)$

- Under $H_0$, $T^\alpha(\tau)$ converges to a central Chi-square distribution $\chi^2$
- Under $H_1$, $T^\alpha(\tau)$ converge to Gaussian distribution with pdf $N(T\psi_{xx}^\alpha(\tau), 4T\Sigma_{xx}^{-1}(\tau)\psi_{xx}^\alpha(\tau))$

For a given false alarm rate, the threshold $\gamma$ can be determined. Next, the detection can be performed as follows

$H_0 : T^\alpha(\tau) < \gamma, \quad \text{signal is absent}$

$H_1 : T^\alpha(\tau) \geq \gamma, \quad \text{signal is present}$
Results and Discussions

The conventional cyclostationary detector detects the presence or absence of the primary signal based on a single user at a single cyclic frequency. Therefore, the performance of this detector cannot be obtained significant improvement over other existing detectors such as energy detector. In this report, the detection based on multiple cyclic frequencies and based on multiple cognitive users are presented. The detection performances are evaluated in a noisy observation while an orthogonal frequency division multiplexing (OFDM) is considered as the primary user. Each cognitive user shares the information about the cyclic test $T^\infty(\tau)$ in order to find the vacant spectrum. Fig. 1 confirms that the detection performance can be improved as the number of cooperative users is increased. Fig. 2 shows that the probability of detection increases as the probability of false alarm is increased.

Conclusion

The cyclostationary detector outperforms the detection performance in low SNR and has the desirable receiver operating characteristics. The detection performance can be improved by sensing at multiple cyclic frequencies and it has also indicated the significant gains of performance via the cooperative sensing.