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Published in:
Proceedings of the 2012 IEEE International Symposium on Antennas and Propagation (APSURSI)

DOI (link to publication from Publisher):
10.1109/APS.2012.6348851

Publication date:
2012

Document Version
Accepted author manuscript, peer reviewed version

Radio channel sounding using a circular horn antenna array in the horizontal plane in the 2.3 GHz band

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***Abstract*— This paper presents results from an outdoor radio propagation experiment at 2.35 GHz using a channel sounder and a spherical horn antenna array. The propagation test was performed in Aalborg city in Denmark. Comparing the ray-tracing results and the results obtained with the proposed method on the measured data shows a good match in both the spatial and time domains.**

I. INTRODUCTION

There have been a significant number of investigations on radio channel soundings applicable for cellular mobile radios [1]. Almost all channel soundings can be demonstrated using high-resolution estimation algorithms, such as SAGE or ESPRIT [2]. Unfortunately, these algorithms require a large amount of calculation power. The purpose of this work is to evaluate the accuracy with which the wave path can be determined using a horn antenna array together with a simple algorithm. This paper presents an experimental investigation of radio channel sounding measurements in an urban area in Aalborg city in Denmark in the 2.3 GHz band. Estimation of the wave path is done utilizing the radiation pattern of the horn antenna. A comparison between the measured results and calculations by a ray-tracing method demonstrate the effectiveness of the channel sounding algorithm presented here.

II. CHANNEL SOUNDING ALGORITHM AND EXPERIMENTAL CONDITIONS

A simple algorithm for estimating the radio path, utilizing the radiation pattern, is presented. Fig. 1 illustrates the radiation patterns of the three antennas #(i-1), #i and #(i+1) of the receiving array, which overlap each other. In this paper, estimates are made of the azimuthal angle from which the waves arrive at the array. As seen in Fig. 1, the received power at the i-th antenna for an incoming wave at an angle, ϕ_0, is greater than that of the adjacent antenna according to the difference between the antenna gains. This indicates that we can predict the direction of the radio path from the power difference between the two signals received by adjoining antennas. The difference, $\Delta D(\phi)$, between the gains of the two antennas gradually reduces with increasing ϕ, as shown in Fig. 1, so, we can obtain a one-to-one correspondence between ΔD and ϕ for directly predicting ϕ from $\Delta D(\phi)$.

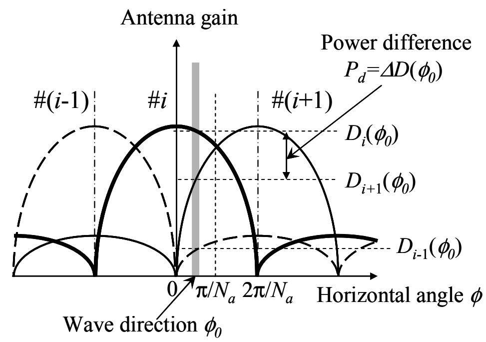


Figure 1. Three overlapping radiation patterns of the array.

Fig. 2 show photographs of a horn antenna array and a horn antenna probe. Seven probes were used for receiving waves in the horizontal plane. Figs 3(a) and 3(b) show the radiation patterns in the horizontal plane and the gain difference between adjacent antennas at 2.35 GHz. It was found that the gain difference decreases as the horizontal angle increases, indicating that this horn probe has a radiation pattern suitable for estimating the angle of arrival.

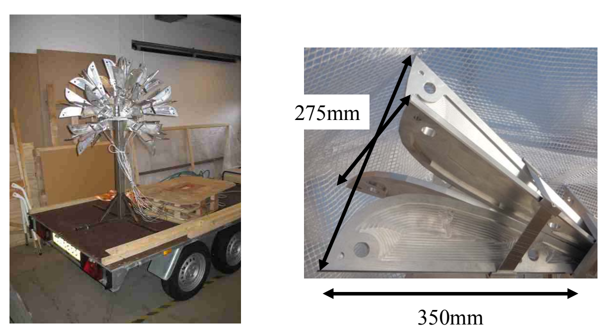
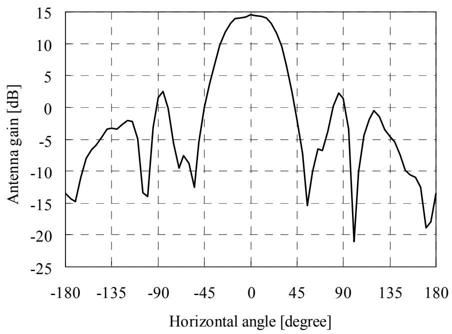


Figure 2. Horn antenna array and antenna probe.

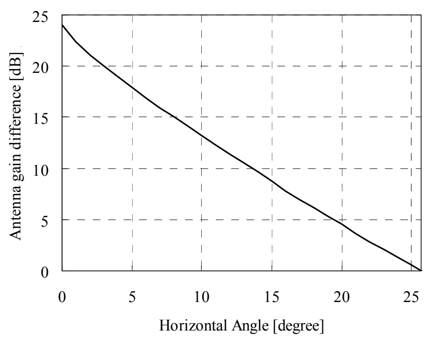
Fig. 4 depicts the test site of the MIMO propagation test [4] in an urban area of Aalborg city, Denmark. Almost all the buildings have a height of more than 15 m. The height of the base-station array was set at 14.5 m. Thus, all the sub routes

Presented at The 2012 IEEE International Symposium on Antennas and Propagation (APSURSI).
DOI: 10.1109/APS.2012.6348851

were in a non-line of sight (NLOS) condition. The horn array was set on a car trailer at a height of 1.75 m above ground level. In this paper, we evaluated the experimental data from the center of the test route, which has buildings along both sides. In the propagation experiment, a vertically polarized wave at a center frequency of 2.35 GHz with a bandwidth of 200 MHz was emitted from the transmitting antenna.



(a)



(b)

Figure 3 (a) Radiation pattern in the horizontal plane, and (b) gain difference between adjacent antennas at 2.35 GHz.

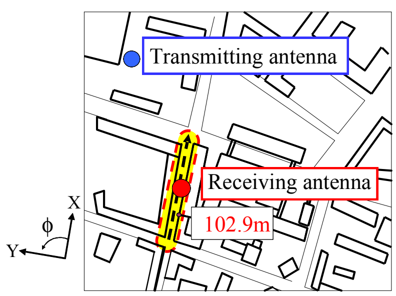


Figure 4 Test site of MIMO propagation test.

III. MEASURED RESULTS AND RAY-TRACING CALCULATIONS

The ray-tracing calculations were done using an imaging method. The calculation conditions are listed in Table 1. Fig. 5 shows the spatial distribution of the radio waves measured by the channel sounder and the results of the ray-tracing. It can be seen in Fig. 5 that two large clusters of radio waves at -60 and 35 degrees were obtained both by measurement and by calculation. This indicates that the most significant paths were reflections from the buildings on each side of the test route. Moreover, the good agreement between the measurements and the calculations reveals that wave detection using the proposed method was successfully accomplished in this outdoor channel sounding experiment.

TABLE I. CALCULATION CONDITIONS.

The number of reflection times		4	
The number of diffraction times		1	
Electric constant of concrete		5.99e-11 [F/m]	2.3e-3 [S/m]
Electric constant of asphalt		2.66e-11 [F/m]	1e-3 [S/m]
Frequency		2.35 GHz	
Tx antenna	Height	14.4m	
	Peak gain	16.5dBi	
	Radiation pattern	Directional	
Rx antenna	Height	1.75m	
	Peak gain	14dBi	
	Radiation pattern	Omni	

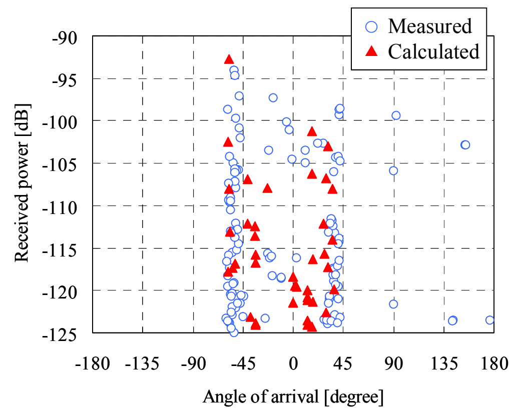


Figure 5 Received power of radio waves at 2.35 GHz measured and calculated using ray-tracing simulation.

IV. CONCLUSION

Radio channel sounding using a circular horn antenna array in the horizontal plane at 2.35 GHz was conducted in an outdoor urban radio environment. A simple wave detection method, utilizing the gain difference between radiation patterns, for detecting radio waves in the spatial domain was demonstrated. It was concluded from the agreement between measurements and calculations that the channel sounding experiment using our simple detection method is an effective means of obtaining the spatial distribution of radio waves.

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Presented at The 2012 IEEE International Symposium on Antennas and Propagation (APSURSI).
DOI: 10.1109/APS.2012.6348851