Ray Tracing Based Marine Mobile Wireless Channel Modeling

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***Abstract*—This paper proposed an improved spatial partitioning ray tracing algorithm to model the marine broadband mobile wireless channel. In this paper, a communication scene between an unmanned aerial vehicle (UAV) and a boat is simulated, then, the marine wireless channel is studied.**

I. INTRODUCTION

Wireless channel modeling and analysis at sea surface is the basis of the construction of the over-sea wireless communication system, which is of considerable significance to the design of the system. The commonly used wireless channel model in terrestrial propagation models are Winner II [1], Okumura model[2], etc. Sea surface fluctuations and weather are changing over time, resulting in maritime wireless channels also show changing characteristics, and stable terrestrial wireless transmission model has a greater difference. The existing terrestrial channel model is not applicable to the open and varied sea environment. Therefore, it is necessary to conduct in-depth research on the over-sea wireless channel model.

II. DEVELOPMENT OF AN MARINE COMMUNICATIONS CHANNEL SIMULATOR

A. Modeling of Marine Surface Morphology

The commonly used sea waves spectrum is JS spectrum model [3] which is a joint observation project conducted by the relevant organizations in Germany, the United Kingdom, the United States and the Netherlands.

B. Development of Spatial Partitioning Ray Tracing Algorithm

The key to ray tracing algorithm is to calculate propagation path of the ray. The commonly used method to obtain the intersection of a ray with multiple finite planes is traversing which is very complicated. In order to reduce the computational complexity, we partitioning the sea surface into grids.

As shown in Fig. 1, for the two-dimensional plan, according to the direction of the ray forward direction of the ray is divided into multi-segment, identify the line may pass through the region, the ray and the whole plane to solve the problem of intersection, into a smaller plane to find the intersection point.

When the ray advances to the point T1, the next target position is T2 according to the linear parameter equation. It is then judged that the line segment T1T2 may have an intersection with the plane1 and the plane2.

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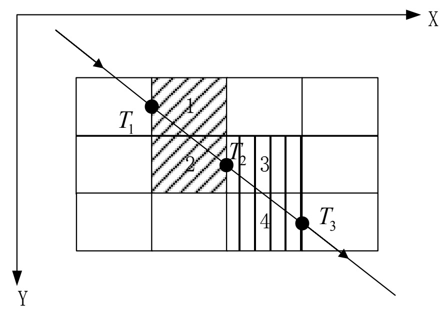

Fig. 1 Grid partition diagram

According to the advancing direction of the ray, whether there is an intersection between the ray and the plane1, and if necessary, the intersection position and the reflection vector are obtained. If there is no intersection with the plane1, it is judged whether the line segment T_1T_2 may have an intersection with the plane2, and if there is an intersection, the processing method is similar to that of the plane1.

If there is no intersection, the ray advances to point T_3, then it is judged that the line segment T_2T_3 may intersect the plane3 and the plane4. Judgment and processing are similar to before.

Through the partitioning method, greatly reduces the computational complexity, which is about $O(2N)$.

The intersection of a ray and a single finite plane can be solved by the following process:

1) find the normal vector of the plane $\vec{n}=(n_x,n_y,n_z)$*, and the plane can be express by (4)*

$$n_x(x-x_A)+n_y(y-y_A)+n_z(z-z_A)=0 \quad (1)$$

2) incident ray vector is $\vec{S}_{in}=(S_x,S_y,S_z)$ *, and the linear parameter equation of incident ray is given by (5)*

$$\begin{aligned} x &= T_x + s_x t \\ y &= T_y + s_y t \\ z &= T_z + s_z t \end{aligned} \quad (2)$$

3) solve of equations (1)(2), obtain the only intersection point's coordinates $P(x_p, y_p, z_p)$.

C. Calculation Method of channel parameters

The evaluation parameters of channel model can be calculated through the method proposed by [4].

III. MODELING RESULT

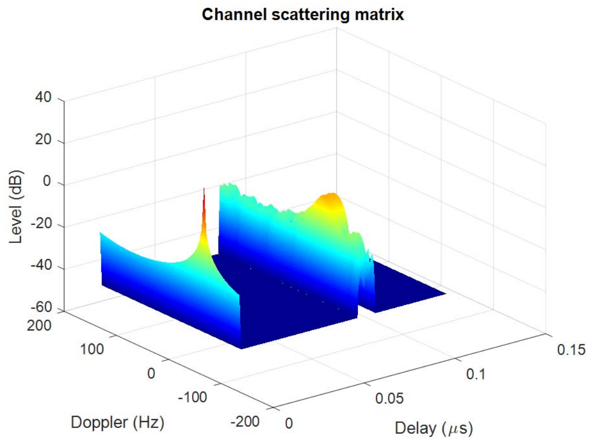

Fig. 2 Channel scattering matrix

The channel scattering function $S(\tau,v)$ is shown in Fig. 2, which can be seen that the Doppler frequency offset caused by the multipath channel is mainly concentrated in two locations. One is the Doppler shift caused by the direct path, and the other is the reflection path. Doppler frequency deviation caused. Since the wave path difference does not change significantly with time, the corresponding time-varying Doppler spectrum does not change significantly with time.

From Fig. 3 for the APDP(averaged power delay profile), the simulation result shows that the delay propagation of the over-sea radio channel is concentrated on the direct path and the single reflection path.

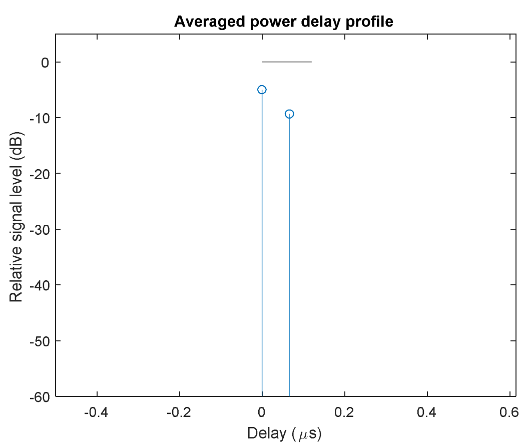

Fig. 3 APDP simulation result

Fig. 4 is the frequency response of the channel in 1997.5 ~ 2003.5MHz, which shown that the channel changes regularly with time. Fig. 5 is result of impulse response at the first sampling point, that is $h(\tau,t=0)$. Since the wave difference between the reflected signal and the direct signal is small, the impulse response is approximately a impulse function, which is similar to the measured conclusion in [5][6].

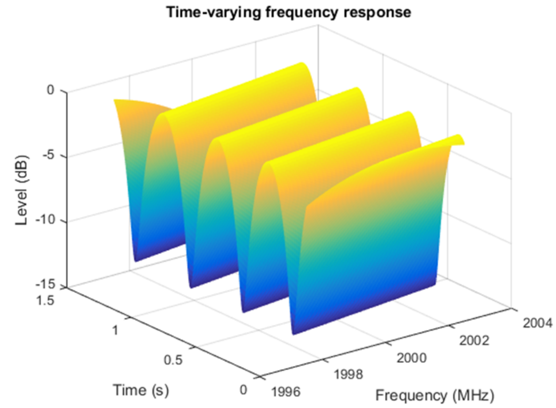

Fig. 4 Time-varying frequency response

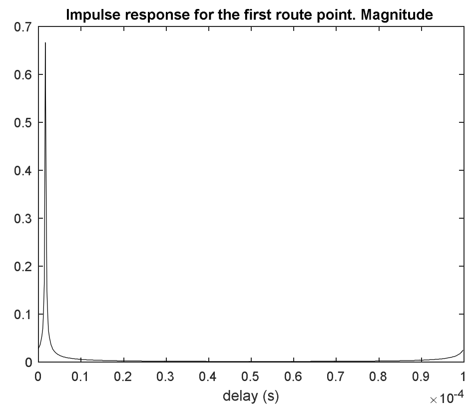

Fig. 5 Impulse response for the first route point

IV. CONCLUSION

The measurement of the over-sea radio channel requires a lot of financial and human resources. Through reliable and effective simulation, it can also study the propagation characteristics of the over-sea radio channel, which can reduce the cost of channel measurement. In our work, the marine broadband mobile wireless channel is obtained by an improved spatial partitioning ray tracing algorithm, which shows that the data-driven approache is efficacious.

EXAMPLES OF REFERENCE STYLES

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