Research on Random Wireless Channel of Radio Indicator for Mariners

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Abstract— It is presented a random wireless channel model of marine emergence radio indicator in this paper, which describe the performance of telecommunications in difference typical ocean states. First, it is introduced a random rough ocean surface modeling method under typical ocean states which is the foundation for simulation of LOS and NLOS telecommunication channel. Second, massive data is calculated by running simulation code which is necessary for statistical analysis of linking properties. Last, the telecommunication performance is predicted by signal to noise ratio vs bit rate error in situation of typical ocean states and elevation angles which may provide key information for the design of next generation of marine indicators.

1. INTRODUCTION

Because the sea is rich in Marine products and mineral resources, it is very important to observe, research and reasonable use the the oceans. Thought a random rough ocean surface modeling under typical ocean states, we can get the background information of the sea-surface. The electromagnetic environment of the surface is very complicated. So, radio waves propagation on the surface of the time domain modeling theory and technology should be provided to research the target detection and recognition of sea surface. There is no doubt that the impact of sea clutter to the communication link is an important issue to evaluate and demonstrate [1].

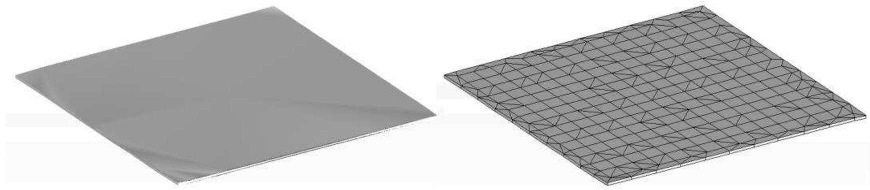
Radio waves propagation of free space is divided into Line-of-sight propagation (LOS) and Non-light-of-sight propagation (NLOS). LOS is that space wave can communicate between two points in direct. In other words, there is direct path between launch and receiver. The distance of LOS is similar with the distance as far as the eyes can see, and it is generally not more than 50 km. LOS can be divided into two types. One of them is direct wave propagation. Radio wave spread by transmitting antenna go the straight line like the light to reach the receiver directly. The other one is reflection wave propagation. Radio wave transmitted by the antenna, thought the reflection, reaches the receiver finally. The waves of LOS received at the receiver is synthesized from direct wave and reflected wave. NLOS has no direct wave. We research the LOS when the radio wave spread on the sea surface [2].

According to random rough ocean surface modeling and then electromagnetic simulation, we can obtain statistical analysis of linking properties and model wireless channel based on stochastic bridge. Combined with typical DSSS/BPSK modulation, we analyze and simulate the downstream communication link model and calculate the performance of communication system.

2. OCEAN SURFACE MODELING AND CHANNEL MODELING METHOD

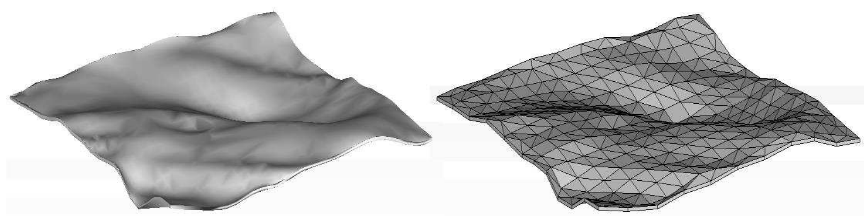
On the study of random waves, its model is divided into linear and nonlinear model. Linear wave model is more mature, and it take the waves as the superposition of a series of simple harmonic which have different amplitude, phase and frequency [3]. PM spectrum is fully growth state of the wave spectrum based on wind speed parameter, and it is detailed in the analysis of observational data and simple form. According to the PM spectrum and corresponding wind speed, using linear wave model method, we can generate the three-dimensional geometric model of sea surface [4–6]. The waves range from level 1 to level 6. The area of sea surface is $50\,\text{m} \times 50\,\text{m}$, and the direction of wind is crosswind. Then, the geometric model of sea surface is put into frequency domain electromagnetic simulation software which take electromagnetic waves as rays.

Before the electromagnetic simulation, the electromagnetic model of the surface should be generated, that can be done by taking the geometric model of sea surface into mesh generation and taking the triangle plane as the main way of fitting for the surface. We take wave model of level 1 and level 6 for example. From Figure 1 and Figure 2, we can find the sea surface is made up by large curved surface. We also can see that all of the electromagnetic model save the details of the geometric model of sea surface well.



(a) (b)

Figure 1: Sea surface model of level 1. (a) CAD model. (b) Electromagnetic model.



(a) (b)

Figure 2: Sea surface model of level 6. (a) CAD model. (b) Electromagnetic model.

The height of sea surface model of level 1 is about 0–0.1 m. The surface is flat, and approximate plane; The height of level 2 is about 0.1–0.5 m. There are some ups and downs low ripple on the sea surface; the height of level 3 is about 0.5–1.25 m. The sea surface produce smaller waves; The height of level 4 is about 1.25–2.5 m. The waves get bigger, and sea surface produce obvious peaks; The height of level 5 is about 2.5–4.0 m. The wavelengths stretch, form a large wave crest, and the distance of peak valley get bigger; The height of level 6 is about 4.0–6.0 m. Towering peaks appear more, and wave breaking appear at the top of the peaks [7].

According to electromagnetic simulation, we can obtain direct ray, and the rays hop once, twice, triple at viewpoint, that is the length and number of rays. The rays path is random propagation. According to the simulation parameter, we can model wireless channel based on stochastic bridge. The stochastic bridge can be described as follows: the transmitter and the receiver are respectively taken as the starting point and the destination of a stochastic bridge process; Electromagnetic waves are considered as rays; Every ray path can be regarded as a sample of a stochastic bridge process, and all the numerical characteristics of which is determined by electromagnetic simulation. According to the length of rays, we can get the time delay of multipath components. If we want to get the impulse response of electromagnetic waves propagating on the sea, we also should know the the amplitude of multipath components.

3. THE CHARACTERISTICS OF RADIO WAVE PROPAGATION

When the electromagnetic wave propagate, the scattering loss must be considered except for path loss. The scattering coefficient can be calculated, based on the sea surface mentioned above, as well. Kirchhoff approximation (KA) and small perturbation method (SPM) are two basic approaches to calculate the scattering problem of rough surfaces which hold for the large-scale rough surface and the small scale one, respectively [8, 9]. SPM will be adopted here as the sea condition is from level 1 to level 6, under which the roughness is considered to be relative small. For a two dimensional (2D) sea surface realization, a directional function $f(k,\phi)$ is necessary. The 2D sea spectrum can be written as in terms of directional function as follows:

$$S(k,\phi) = S(k) f(k,\phi) \tag{1}$$

where $S(k)$ is the PM spectrum. The scattering coefficient developed by SPM is formulated as follows:

$$\sigma_{SPM} = 8k^4 \cos^2(\theta_i)\cos^2(\theta_s)\left|\alpha_{pp}\right|^2 S(\left|K_1\right|,\phi) \tag{2}$$

$$K_1 = \begin{bmatrix} k\sin(\theta_s)\cos(\phi_s-\phi_i) - k\sin(\theta_i) \\ k\sin(\theta_s)\sin(\phi_s-\phi_i) \end{bmatrix} \tag{3}$$

α_{pp} is polarimetric coefficient expressed as:

$$\alpha_{hh} = -\frac{(\varepsilon_r - 1)\cos\phi_s}{\left[\cos\theta_i + \left(\varepsilon_r - \sin^2\theta_i\right)^{1/2}\right]\left[\cos\theta_s + \left(\varepsilon_r - \sin^2\theta_s\right)^{1/2}\right]} \tag{4}$$

$$\alpha_{vv} = \frac{(\varepsilon_r - 1)\left[\varepsilon_r\sin\theta_i\sin\theta_s - \cos\phi_s\left(\varepsilon_r - \sin^2\theta_i\right)^{1/2}\left(\varepsilon_r - \sin^2\theta_s\right)^{1/2}\right]}{\left[\varepsilon_r\cos\theta_i + \left(\varepsilon_r - \sin^2\theta_i\right)^{1/2}\right]\left[\varepsilon_r\cos\theta_s + \left(\varepsilon_r - \sin^2\theta_s\right)^{1/2}\right]} \tag{5}$$

where θ_i, θ_s, ϕ_i, ϕ_s, ε_r are the incidence angle, scattered angle, incidence azimuth, scattered azimuth and relative permittivity of sea water respectively. Incidence azimuth is general set as 0°.

According to scattering coefficient, scattering loss can be obtained. The amplitude of multipath components can be calculated based on ray scattering loss and paths loss. Finally, the impulse response of electromagnetic waves propagating on the sea can be obtained. We can get the output signal thought the convolution of impulse response and the input signal, and then predict telecommunication performance by signal to noise ratio vs bit rate error.

4. SIMULATION AND ANALYZE THE COMMUNICATION LINK PERFORMANCE

The electromagnetic simulation conditions is as followed: The source is the dipole antenna; The elevation direction and height of source respectively are location 45 degrees and 40 km above the sea surface; The receiver is set on the sea surface, and the height of it is 10 m; The frequency of incident wave is 1.5 GHz; We just consider the vertical polarization, and the emulational sea level is ranging from 1 to 6. Based on the channel modeling, taking wave model of level 3 for example, the probability distribution of time delay is shown in Figure 3. Its units is ns, and each value of probability distribution correspond to 10 ns time delay. The time delays have direct impact on waveform distortion, then affect the bit error rate.

For the input signal, transmitter includes the generating of original data, the generating of the C/A code, spread spectrum, BPSK modulation [10, 11]. C/A code is a 1023 bit Gold code, which consists of two m-sequences of length 10. the number of randomly generated binary sequences is

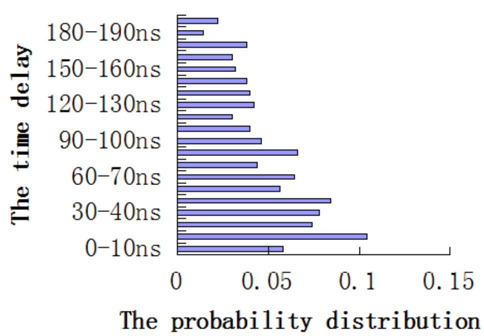


Figure 3: The probability distribution of time delay.

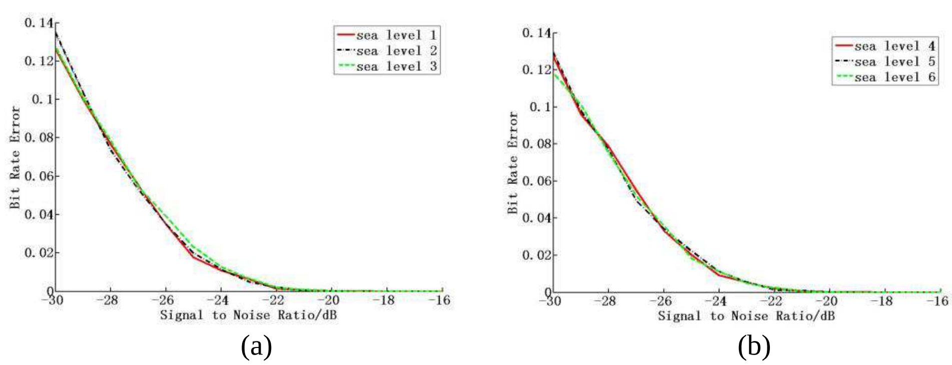


Figure 4: Performance of communication link. (a) Simulation result of BER of sea level 1–3. (b) Simulation result of BER of sea level 4–6.

10^5. The rate is 10 kbit/s, and the spreading code rate is 10.23 Mbit/s. Select 10 step balanced Gold sequences as the pseudo-code pattern. Carrier frequency is 1.5 GHz, and the sampling frequency is 6 GHz. For the output signal, receiver has the following function: finishing demodulation and dispreading the local carrier and code, restoring the original data and calculating the BER. BER is an important index to evaluate the performance of a communication link. Figure 4 is performance of communication link under typical sea level 1–6.

From Figure 4 we can see that when the SNR is greater than -22 dB, BER under different sea conditions are less than 10^{-4}. The BER is basically in the same order of magnitude when the typical grazing angle is small. Sea clutter did not contribute to the BER of the communication system significantly.

5. CONCLUSION

In this paper, we presented a random wireless channel model of marine emergence radio indicator which describe the performance of telecommunications in difference typical ocean states. At first, modeling random rough ocean surface provide the foundation for simulation of LOS and NLOS telecommunication channel. For the radio wave spreading on the sea surface, We research the LOS. Then, electromagnetic simulation and telecommunication channel modeling based on random bridge theory analyze linking properties. Last, we analyze and simulate the downstream communication link model, and calculate the performance of communication systems and the noise ratio vs bit rate error of signal in situation of typical ocean states and elevation angles.

By the finally simulation, we can obtain the preliminary conclusions of multipath channel transmission performance under the typical ocean states and elevation angles, which may provide key information for the design of next generation of marine indicators.

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