Multi-hop HF Radio Propagation Model Based on Multi-Paths Attenuation

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Abstract – In this paper, we mainly solve the multi hop frequency radio propagation problem for radio propagation on the sea surface and establish model to solve. In high frequency radio communication, two paths are mainly considered. One is the reflection path, the other is the direct path. Reflection on the sea surface is a complex problem. Therefore, we introduce the concept of the sea wave series first to simplify the problem. Meanwhile, we analysis the energy loss, such as to establish attenuation model through sea considered multi paths. At the same time, we establish the model of atmospheric noise and analyze, and then we can obtain the number of radio hops before the SNR falls below 10db.

Keywords – Multi-Paths Attenuation; Multi-Hop Frequency; Reflection Path; SNR.

I. INTRODUCTION

Short-wave communication is a long distance communication method that uses the radio waves emitted from the ground to be realized by one or more reflections between the ionosphere or between the ionosphere and the ground and its communication frequency range is 3MHz~30MHz. The complexity of Marine environment’s influence on radio wave propagation and the particularity of communication between multiple fishing vessels are important factors to be considered when designing maritime wireless communication systems. Among other factors, the characteristics of the reflecting surface determine the strength of the reflected wave and how far the signal will ultimately travel while maintaining useful signal integrity. Also, the MUF varies with the season, time of day, and solar conditions. Frequencies above the MUF are not reflected/refracted, but pass through the ionosphere into space. In this problem, the focus is particularly on reflections off the ocean surface.

Therefore, in this paper, we established the multi-paths attenuation model to calculate the radio hops before the SNR falls below 10db. The wind and waves in the ocean can cause the fluctuation of the ship in the sea, resulting in the change of the antenna height in the communication process, which is an important factor affecting the communication at sea. The sea-earth waves are usually described internationally in terms of sea state, which we show in table 1.

Table 1. The sea condition level of Douglas.

<table>
<thead>
<tr>
<th>Sea level series</th>
<th>Douglas</th>
<th>Root mean square wave height(m)</th>
<th>Sea surface roughness</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Clam</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>&lt;0.3</td>
<td>Smooth</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.3–0.9</td>
<td>Light</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.9–1.5</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1.5–2.4</td>
<td>Rough</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2.4–3.7</td>
<td>Very rough</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3.7–6.1</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>6.1–12.2</td>
<td>Very high</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>&gt;12.2</td>
<td>Steep</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>

III. MODELS OF THE MULTIPATH FADEING CHANNEL ON THE OCEAN

1. Loss of Direct Path

If the signal passes through the free space to the receiver at the distance $l$, there is no obstacle between the transmitter and the receiver, and the signal travels in a straight line, which is called a stadia channel.

The ratio of receiving signal power and transmitting signal power is as follow. [1]

$$\frac{P_r}{P_t} = \frac{\sqrt{G_t}}{4\pi l}$$

Where $\sqrt{G_t}$ is the gain of the transmitting antenna and receiving antenna.

2. Spherical Reflection Dual Diameter Model

In order to better observe the geometrical relationship, first consider the plane reflection dual diameter model as shown in figure 1. The receiving power of the signal under the double path model is as follow. [2]

$$P_r = P_t \left[ \frac{\lambda}{4\pi l} \sqrt{G_t} + \frac{\Gamma G t e^{-i\phi}}{x + x'} \right]^2$$

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Where $P_t$ is the transmitting power, $\lambda$ is wave length, $\sqrt{G_t} = \sqrt{G_a G_b}$ is the direct path emission and total gain of receiving antenna: $\sqrt{G_r} = \sqrt{G_a G_r}$ is the reflection path emission and total gain of receiving antenna, $\Gamma$ is plane reflection coefficient, $\Delta \varphi$ is the phase difference between direct and reflected signals.

\[
\Delta \varphi = 2\pi \left( x + x' - l \right) / \lambda, \quad x = h_t / \sin(\theta), \quad x' = h_r / \sin(\theta)
\]

\[
\vartheta = \arctan \left( \frac{h_t + h_r}{d} \right), \quad d = \sqrt{d^2 + (h_t - h_r)^2}
\]

Where $h_t$ is the height of the ionosphere, $h_r$ is the height of the receiving antenna, because of $h_t \gg h_r$, so $\vartheta = \arctan \left( \frac{h_t}{d} \right)$, $d$ is the distance between the transmitter and the receiver.

The geometric model of Spherical reflection dual diameter model as shown in figure 2.

![Fig. 1. Plane reflection double path model](image1)

![Figure 2. Spherical reflection double path model](image2)

When the height and size of the receiving antenna are much smaller than the radius of the earth, the surface distance between the receiving antenna and the reflection point can be obtained by using the equation below [3].

\[
2r_1^3 - 3rr_2^2 + \left[ r^2 + 2R(h_1 + h_2) \right]r_2 + 2Rr_2h_2 = 0
\]

According to Figure 2, the equivalent height of receiving antenna is deduced as follow. [4]

\[
h_2' \approx h_2 - \frac{r_2^2}{2R}
\]

Similarly, the equivalent height of the launcher is as follows:

\[
h_1' = h_1 - \frac{(r - r_2)^2}{2R}
\]

According to table 1, when the sea state is 0-3, the surface specular reflection signal takes an absolute advantage, and the diffuse reflection can be ignored. We calculate the receiving signal power of a calm ocean, replace the spherical reflectance $\Gamma$ with a specular reflection coefficient $\rho'$, replace $h_t, h_r$ with $h_t', h_r'$. So the power of the reflected receiving signal on the calm sea surface of earth curvature is calculated using the plane reflection dual diameter model. [5], [6].

\[
P_r = P_t \left[ \frac{\lambda}{4 \pi} \right] \sqrt{G_t} \sqrt{G_r} e^{-i \Delta \varphi} \left[ \frac{l}{x + x'} \right]^2
\]

3. MATLAB Simulation Results Consider the Double Path Channel Model of the Calm Ocean Surface of Curvature of the Earth.

We assume that the height of the ionosphere is 100 km, Antenna height is 10 m, the range of the direct path. $l \in 150 - 300$, $\lambda = 60 m$, the range of high frequency carrier signal is $3 - 30 MHz$, we carrier frequency is 5 MHz, vertical polarization, antenna gain $G_a, G_b, G_r, G_l$ is all 1. First, we calculate the signal power received by the signal from the point source on land through the direct path to the ionosphere. Next, we calculate the signal power received by the receiving antenna when the high-frequency carrier signal is reflected for the first time by the calm sea surface. The simulation results are shown in the figure 3.

![Fig. 3. Relationship between signal power received by the receiving end and direct path distance.](image3)

4. Atmospheric Noise Model

In order to calculate the radio hops before the SNR falls below 10db, we find the main noise of sea shortwave communication is atmospheric noise, and the atmospheric noise is mainly caused by thunder and lightning. With the change of frequency, time, season, weather and so on, Geographical location and climate change.

According to the CCIR322 report, a global atmospheric noise profile is provided and is calculated using the following formula: [7].

\[
E_n = F_\alpha + 10\log B + 20\log f - 96.8
\]

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Where $E_{na}$ is the atmospheric radio noise intensity, $B$ is the effective noise bandwidth of the receiver, $f$ is the working frequency, $F_{a}$ is the atmospheric radio effective noise figure. In the meantime, calculate the power of noise generally adopt the following formula: [8]

$$P_{a} = F_{a} + 10\log B - 204$$

Where the unit of $P_{a}$ is $\text{dBw}$.

To simplify the model, let us assume that the atmospheric noise is white noise, which is a constant value. According to the CCIR332 report, taking the waters near South China Sea, 20 degrees north latitude and 115 degrees longitude as an example, the effective noise bandwidth is $25\text{KHz}$, calculating $P_{a}, P_{a} = -60.021\text{dBw}$

### 5. Analysis Based on MATLAB Simulation

When the sea level ranges from 0-3 level, the sea mainly specular reflection. In ionospheric reflection, since the ionosphere E located in the area of $90 - 150\text{km}$, it can radiate a few megahertz of radio waves, therefore, we assume that the height of the ionosphere is $100\text{km}$. Assuming that the height of the antenna is $17\text{m}$, the distance from the point of emission of the signal from the ionosphere to the receiving end of the received signal is $r \in 1 - 316\text{km}$, the high-frequency carrier is $3 - 30\text{MHz}$, we take the carrier frequency as $5\text{MHz}$, its wavelength is $\lambda = \frac{c}{f}$, $c \approx 3 \times 10^8 \text{ m/s}$, the wavelength is $60\text{m}$, Vertical polarization, antenna gain $G_a, G_v, G_h, G_d$ are 1. The simulation results from the point source to the ionosphere are shown in the Figure 4.

![Fig. 4. The power of the signal after reflection](image)

### IV. Conclusion

In this paper, we established the multi-paths attenuation model and combined with the analysis of atmospheric noise model to calculate the radio hop before he SNR falls below 10db. Meanwhile, we use the matlab to simulate our model and get the result. The model is specific, and easy to calculate this problem. The model and result we obtained simplified many results [9-12] in this problem.

### REFERENCES

[7] CCIR332 report

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