Study on Sea Surface Reflection of High Frequency Radio Signals

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Abstract: We set up ocean reflection models to study the effects of different ocean surfaces on signal reflections. For a 100 W HF constant carrier signal with a transmission frequency less than MUF, the field strength, after the calm sea surface reflection, is always higher than the field strength after the turbulent sea surface.

Keywords: Signal propagation; Multi hop; HF radio; MUF

1. Introduction

Sky-wave is the most dominant form of HF radio transmission, which propagates the signal through multiple reflections between the Earth's surface and the ionosphere. Since the ocean accounts for 71.8% of the Earth's surface, reflections on the surface of the ocean are important when considering sky-wave reflection.

The researches on the sea surface reflection model are not much, especially on the ocean surface roughness. Thus, we study the effects of different ocean surfaces on signal reflections.

2. Ocean Reflection Models

2.1. Reflection on a still ocean

Assume that the sea is a perfectly smooth interface, which is an ideal situation. At this time, surface reflection coefficient r equals to Fresnel reflection coefficient , namely, $\rho = \rho_0$. The formula of Fresnel reflection coefficient[1] is shown below.

Reflection coefficient in the case of vertically polarized waves, that is, the electric field vector is parallel to the ground.

$$r_0 = \frac{e\,sin\mathbf{V}\sqrt{e - cos^2\mathbf{V}}}{e\,sin\mathbf{V} + \sqrt{e - cos^2\mathbf{V}}} \tag{1}$$

Reflection coefficient in case of horizontal polarized waves, that is, the electric field vector is perpendicular to the ground

$$r_0 = \frac{sin\mathbf{V} - \sqrt{e - cos^2\mathbf{V}}}{sin\mathbf{V} + \sqrt{e - cos^2\mathbf{V}}} \tag{2}$$

Where, refers to sea surface dielectric constant, which is a function of carrier wave length λ , sea surface conductivity s_e and dielectric constant ε_r . Here, . $\varepsilon = e_r - j60s_e$

Where, λ can be calculated by $c = lf$ .f refers to radio frequency.

2.2. Reflection on a calm ocean

It is impossible for the sea surface to fluctuate completely and smoothly. If the reflective surface has a certain degree of roughness, but relatively flat, in other words, it meets the Rayleigh criterion, the reflection coefficient can be expressed as:

$$r = r_0 r_s \tag{3}$$

Where, refers to mirror scattering factor.

$$r_s = \begin{cases} \exp\left[-2(2pt)^2\right] & 0 < t < 0.1 \\ \dfrac{0.812537}{1 + 2(2pt)^2} & t > 0.1 \end{cases} \tag{4}$$

This formula shows that the roughness of the reflecting surface attenuates the amplitude of the specular reflection [2] . is the rough surface roughness factor, described as

$$t = \frac{r_h sin\mathbf{V}}{l} \tag{5}$$

2.3. Reflection on a turbulent ocean surface

Rayleigh's criterion cannot be met when the surface of the ocean is rough. Specular reflection de-creases, while diffuse reflection increases with increasing roughness. The theory of geometrical optics does not satisfy diffuse reflection. Thus, the diffuse reflectance of a rough surface β needs to be multiplied by a diffuse reflectance.

$$b = r_0 r_d \tag{6}$$

r_d denotes diffuse reflectance. It is formed by the launch elevation angle $\mathbf{V}$, square wave height r_h and the impact of electromagnetic wavelength . Through theoretical research, we get the diffuse reflection coefficient expressed as following[3].

$$r_d = \begin{cases} \sqrt{2}\left|r_0\right| 3.68t & 0 < t < 0.1 \\ \sqrt{2}\left|r_0\right|(0.454 - 0.858t) & 0.1 < t < 0.5 \\ \sqrt{2}\left|r_0\right| 0.025 & t \geq 0.5 \end{cases} \quad (7)$$

3. Simulation

We fire a number of HF constant carrier signals with frequencies below MUF and a power of 100 W.
Draw the relationship between the frequency of the signal and the field intensity after the first reflection at different emission angles.

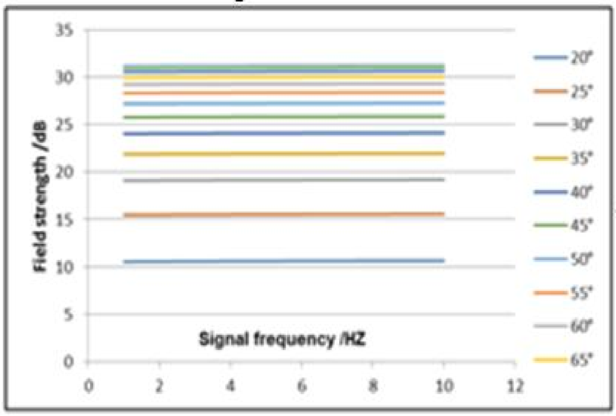

Figure 1. Calm Sea Surface

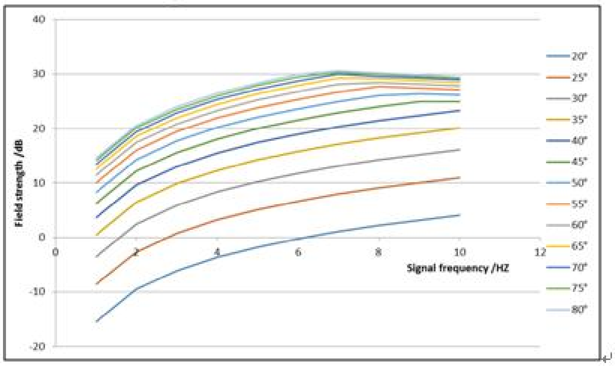

Figure 2. Turbulent ocean surface

It can be seen from the Figure 1 and Figure 2, in a calm sea, the signal strength is greatly influenced by the emission angle rather than the frequency. The greater the angle, the greater the field strength is. However, in the turbulent ocean surface, with the same frequency, the greater the angle, the greater the field strength is.
The signal strength of calm sea surface reflection is always higher than that of the turbulent one. The signal is less intense and less affected by its own frequency in calm surface. However, the turbulent one is less intense at low frequencies. As the signal frequency increases, the intensity becomes larger. The influence of signal frequency is obvious when the frequency is low, then the influence is getting smaller.

4 . Conclusions

In this paper, we set up ocean reflection models to study the effects of different ocean surfaces on signal reflections. We simulated the relationship between the frequency of the signal and the field intensity after the first reflection at different emission angles.

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