# Radio wave propagation characteristics measurement and modeling over the sea

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## Abstract

Radio wave propagation test is introduced in this paper. It was held in the sea area near Qingdao city, and involved different band including L band ,S band, C band and X band. Using the path loss model given in the International Telecommunication Union (ITU) recommendation propagation 1411, we derived the characteristic parameters such as path loss exponent and shadow fading for different frequencies. The statistic propagation model can be used for providing a reference for ship information communication.

**Keywords:** Radio wave propagation; Transmission loss; Recommendation ITU-R P.1411；Path loss exponent; Standard deviation

## 1. Introduction

The mobile communications environment on the sea between the ship and vessel is complicated. because both the sea surface and the climate are diversiform. And the roughness of the sea surface and different heights of the airplane are so large that the receive signal amplitude ranged large. These characteristics determine that this communications is depended on the channel model and we must model it effectively so that the communications system is reliable.

There are two ways in deriving the communications channel model. One way is based on the measurement which can acquire channel's statistics parameters or fitting parameters. So we can acquire the empirical model or the statistics model. The other way is based on the radio wave propagation mechanism including direct and reflecting and diffraction and scattering. And if we use the primary propagation path then we can calculate the path loss and other channel parameters. Finally we can establish the deterministic model.

The existed channel models are always primarily aimed to the land mobile communications or the land broadcast systems. But channel model which can be used for the sea mobile communications is few[1,2]. The paper [1] presents the simulation results of the sea propagation models. And the authors add two-ray method in one kilometer and combination calculation method beyond 10 kilometers to empirical Longly-Rice model. The paper [2] gave Experiment study of electromagnetic wave propagation loss in oceanic evaporation duct and compared the path loss between the actual measurement and computed result using parabolic equation method . What we need to point out is that the simulation model must be validated in the experiment. But the experiment result in paper [2] was done in the limited distance point and it demonstrated that the actual path loss is larger than parabolic equation method. The main objective of this paper is to perform a detailed study of an experiment at different frequency bands (L band ,S band , C band and X band) . and the channel model is fitted for the distance between 1 and 20 kilometers. And using the rich experiment data and ITU-R P.1411 path loss model, we derived the path loss exponent and standard deviation parameter. At last we established the channel model at different frequency bands for the ship information communication. These results can give reference in the communication system on the sea.

## 2. Radio wave propagation experiment over the sea

This experiment was held at the Jiaozhou sea area. The measurement system is comprised of two components called transmitter and receiver respectively. The transmitter antenna is placed on the poop and the transmitter antenna is placed on a flat which is near the seashore. Based on this measurement platform we did the experiment in L, S, C and X frequency bands. The transmitter is composed by transmitter antenna and signal generator and the receiver is composed by receiver antenna and low noise amplifier and spectrum analyzer. The signal generator generates continuous wave signal of different frequencies at different time. And the receiver receives the signal simultaneously and recorded the time and the frequency and the power level. Also GPS instrument is used to record the time and location including longitude and latitude. Both the transmitter antenna and the receiver antenna are horn antenna and their frequency range is between 1 to 18 GHz. The height of antenna was four meters and three meters for transmitter and receiver respectively. The measurement system is as figure 1.

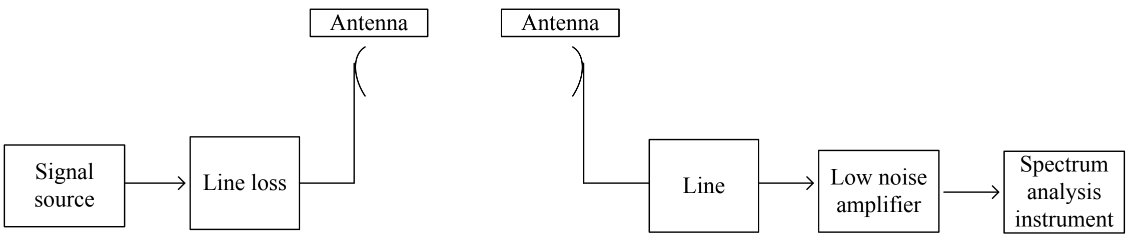


**Fig 1 Measurement system**

Then we can calculate the path loss using the following formula:

$$L_b = P_t - L_t + G_t + G_r - L_r - P_r \tag{1}$$

Where $L_b$ is the path loss in dB and $P_t$ is the transmit power in dBm and $L_t$ is the loss of feeder line in transmitter in dB and $G_t$ 、 $G_r$ is the gain of the transmitter antenna and receiver antenna respectively in dB； $L_r$ is the loss of feeder line in receiver in dB； $P_r$ is the receiver power in dBm.

Before the experiment was held, we have connected the transmitter and receiver equipment directly. Then we calculated the total effect of the feeder line's loss and the gain of low power amplifier. In the laboratory we set the power of signal generator is -20dBm and the frequency offset of the receive signal varied with the frequency is listed as table 1.

Table 1 the loss of line and the gain of low noise amplifier

| Transmitter frequency（GHz） | Frequency shift（Hz） | Received level（dBm） | Total gain（dB） |
|---|---|---|---|
| 1 | 280 | 12.5 | 32.5 |
| 2.5 | 400 | -0.17 | 20.17 |
| 3 | 830 | 7.67 | 27.67 |
| 5 | 1380 | -8.5 | 12.5 |
| 10.5 | 2930 | -7 | 13 |

The gain of the used antenna called double-ridged waveguide horn is listed in the figure 2 . Corresponding to the frequencies listed in table 2, the value are 8.6, 9.4, 11.5, 12.9, 13 dB.

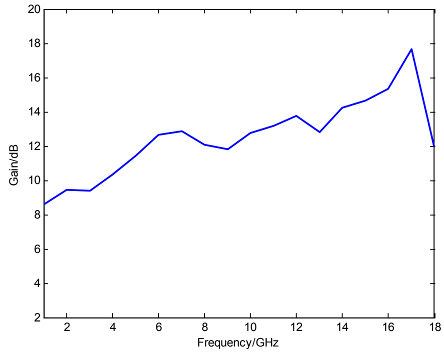


Fig 2 Gain of horn antenna

## 3. Path loss model

The path loss model in ITU-R P.1411 recommendation [3]is given by:

$$PL = PL_0 + 10n\lg d + S \tag{2}$$

$$PL_0 = 20\lg f + 32.4 \tag{3}$$

Where $n$ is the path loss exponent and $S$ is a random variable representing the random component around the regression line with normal distribution, and the standard deviation of $S$ is denoted as $\sigma_S$. The units of $f$ and $d$ are MHz and km, respectively.

## 4. Data fitting results

Least square method is used to fit the measured data $PL(d)$ and distance $d$ in the path loss model. Then we extracted the fading parameters such as path loss exponent and standard deviation value. According to the theory of least square, if the square sum of the difference of measured data and the expected value is the least, then this theory line is the regress line which nearly reflects the measured data. The fitting figures are not listed here. And the path loss exponent and standard deviation value for all frequencies is as table 2.

We can find that the path loss exponents are between 3 and 6 and the standard deviation values are between 7and 19 from the table 2. The value in C band is the least in the all data but the path loss exponent is much more than that in the free space. And it is 2 in the free space. The path loss exponents in different frequency bands can provide a reference for ship information communication. And we can choose the frequency with a smaller value to increase the operation area when the power of transmitter is fixed.

The typical path loss exponent in the city is between 2 and 5 in the reference [4]. The path loss exponent is 4.1 and the standard deviation is 8.55 dB at frequency of 3.5GHz which is derived from the measurement at the hot area in Changning area of Shanghai. So the results we derived is at a proper range but these are a little difference.

Table 2 the fitting value of path loss exponents and standard deviation

| Frequency | Path loss | Standard |
|---|---|---|

| （GHz） | exponents n | deviation S |
|---|---|---|
| 1 | 5.513 | 18.69 |
| 2.5 | 3.645 | 10.03 |
| 3 | 4.194 | 10.97 |
| 5 | 3.238 | 7.19 |
| 10.5 | 3.395 | 7.46 |

## 5. Conclusion

An experiment of radio wave propagation near the sea was introduced in this paper. We established some path loss channel models for different frequency bands using the general transmission loss model. The path loss exponents are between three and six and the standard deviations are between seven and nineteen. If we use the value of path loss exponent and standard deviation for different frequency bands above in the formula, we can compute the transmission loss fading in different frequency bands. These results can provide a reference in the communication application of ship information.

## 6. Reference

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