# Application of the Method of Fresnel Zone Analysis in Base Station Location Survey

**Zhiyuan Song, Feng Gao, Kai He, and Wentao Zhu**
China Mobile Group Design Institute Co., Ltd., Beijing 100080, China

**Abstract**— Along with the LTE mobile communication network rapid demand in China, it appears more trouble and difficulties in network plan and needs a faster and relative accurate scientific method to support the BS (base station) location survey with a view to the weakness transmissibility of the radio wave above 2 GHz.

The BS location survey project is one of the important items in mobile communication network plan before construction; however there are less computation model methods and theoretical arithmetic based on measured data to be utilized. The conclusion of BS location survey projection is mainly depended on the experiences and subjective judgments of survey stuffs. In considering of objective factors of surroundings parameter collection, length of work time and etc. in location survey, the common methods including propagation model, ray tracing and etc. have such difficulties and incompetence to apply.

Huygens-Fresnel principle is one of most key point characters of radio wave. In the propagation of radio, every point on the surface of the wave is a secondary radiation wave of spherical wave. And space for a bit of radiation field is surrounded by the wave of each point on the arbitrary closed surface wave from the secondary waves in which the result of superposition of mutual interference Take advantage of Huygens-Fresnel principle it has greater possibility to adapt the ability range of BS location survey tools and the requirement of work time with the rapid computation method of Fresnel Zone in BS location survey project. In this paper, it is reported that Fresnel Zone method for the mobile communication will be studied in-depth and the application and the propagation criterion selection of this method will be analyzed concretely.

## 1. INTRODUCTION

Mobile communication network, especially LTE, is being planned and built in a rapidly increasing speed in China. There are many methods including Okumura model COST231-Hata model, VolcanoMini model used in the network plan and simulation software. However, these software are almost suitable for the large computer servers and long-time simulation indoor. They need hundreds of data from streets, buildings, rivers, forest, towers and the relative position difference between them to input. The BS location survey project is one of important items in network plan. It has many different characters to evaluate the propagation environment from the network plan and simulation software, such as much shorter time to collect building parameters, small computer equipment as laptop or PAD.

The Fresnel Zone is an application product of the Huygens-Fresnel principle used in the mobile communication system. It has greater possibility to adapt the ability range of BS location survey tools and the requirement of work time in BS location survey project. In Sections 2 and 3, the operation method of Fresnel Zone is described concretely. In Section 4, the conclusion and suggestion are given.

## 2. FRESNEL ZONE THEORY

According to Huygens-Fresnel principle, in the process of radio transmission, each point on the surface of the wave is the wave source of a spherical wave of secondary radiation, called secondary wave source And any point's radiation field in the space is surrounded by the wave of each point on the arbitrary closed surface wave from the secondary waves in which the result of superposition of mutual interference. Obviously, the closed surface on each point of the secondary waves reach the receiver system is different, which makes the receiver signal of the size of the field intensity change It is shown as Fig. 1.

Furthermore, the definition of Fresnel Zone can be given visually in Fig. 2. Point $Q$ is the wave source and point $P$ is the receive point in the free space. The space region which is contained in the rotation ellipsoid, point $Q$ and $P$ as the focal point, is called Fresnel Zone.

In Fig. 2, $S_1$ is one point in the radio propagation space. And the plane including $S_1$ perpendicular to line QP, gets a circle $C_1$ in Fresnel Zone. The distance between point $Q$ and $P$ is $d$, the

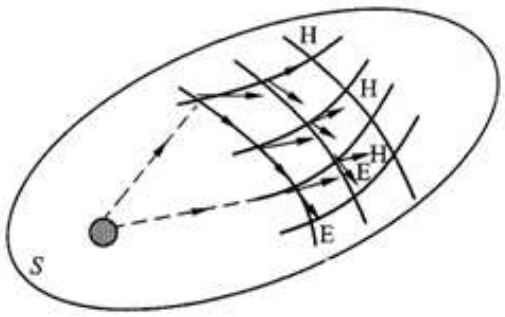


Figure 1: Tecondary wave source of Huygens-Fresnel principle.

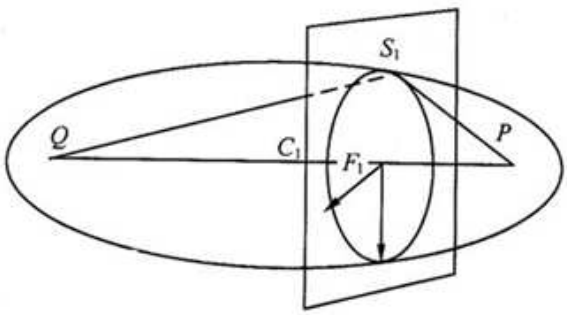


Figure 2: Fresnel zone.

distance between point $Q$ and $C_1$ is $d_1$, and the distance between point $P$ and $C_1$ is $d_2$. As the frequency of the radio is known, the radius of circle $C_1$ can be calculated by Eq. (1) as:

$$F_1 = \sqrt{\lambda d_1 d_2 / d} \tag{1}$$

In Fig. 2, the result of QS1+S1P-d, which could be named as $T$, is the distance different of the two different path of radio waves between transmitting antenna and receiving antenna. When $T$ is odd times of $\lambda/2$, the two path of electromagnetic wave are on the same role and the electric field of the receiving point is strengthened. And when $T$ is even times of $\lambda/2$, the two path of electromagnetic wave are on the contrary role and the electric field of the receiving point is offset. So we could obtain the division of Fresnel Zone.

$$\begin{aligned} T &= \lambda/2 \\ T &= 2 \times \lambda/2 \\ &\cdots \\ T &= n \times \lambda/2 \end{aligned}$$

These formulas define the first Fresnel Zone, the second Fresnel Zone and the $n$th Fresnel Zone, respectively.

In free space, the radiation electromagnetic energy from the wave source point $Q$ to point $P$ is primarily spread by the first Fresnel Zone As long as the first Fresnel Zone is not blocked, the free space propagation condition could be approximately obtained. So the blocks area between the transmitter and the receiver is asked to less than a certain ratio of the Fresnel Zone, which means the antenna can be raised to suitable height.

Including the first Fresnel Zone, the Minimum Fresnel Zone possesses important significance. The Minimum Fresnel Zone is in the first Fresnel Zone. And when the radio wave passes through the whole Minimum Fresnel Zone, the signal of different paths are added in the same phase at the receiving point, so the signal is strengthened.

$$F_0 = 0.577 \times \sqrt{\lambda d_1 d_2 / d} \tag{2}$$

It can be inferred that when the distance between the transmitting antenna and the receiving antenna is a fixed value, the shorter of the wave length, the smaller of the Fresnel radius of the main spread area, the more slender of the Fresnel ellipsoid area, and the Fresnel ellipsoid area degrades to be a straight line as one spread path of light.

## 3. APPLICATION OF THE METHOD OF FRESNEL ZONE

According to the theory of Fresnel Zone, a practical application method can be used in the BS location survey for the evaluation of the propagation environment. The BS location survey stuff can utilize the survey tools to obtain the block's area relative to the Fresnel Zone of the propagation environment of the survey building, and then can evaluate the kind, height, pitch angle of the antenna and that the planned scheme is feasible or not.

The application software can run on the Android system mobile phone and PAD. The key parameters of the application software include the Fresnel radius, the downtilt and the overlap area of the block and the Fresnel ellipsoid. Each parameter can be inferred from the normal survey tools, such as laser rangefinder, downtilt measuring instrument. These parameters would be introduced.

### 3.1. The Fresnel Radius

As the description in Section 2, the Fresnel radius $F_1$ can be deduced by Eq. (1) after the radio frequency, the distance between the transmitting point and the receiving point $d$, and. Before the BS location survey, the mobile network plan has already done. So the radio frequency is known. And the coverage radius which has been planned in the network plan could be regarded as $d$. Depended on the utilization of laser rangefinder, $d_1$ and $d_2$ can be obtained.

### 3.2. The Downtilt

The downtilt is the inclination of the antenna and the receiving point. It can be obtained by the downtilt measuring instrument.

### 3.3. The Overlap Area

The overlap area of the block and the Fresnel ellipsoid is the most difficult and important parameter in this software algorithm. There are nearly ten cases to consider.

Figure 3 shows the main relationship of Fresnel Zone and the block. $A$ is middle point of the top side and $C$ is the center of the Fresnel Circle. Then it is defined that angle $\alpha$ is the inclination of $Q$ to $A$ and $\alpha'$ is the inclination of $Q$ to $C$, $r$ is the radius of the Fresnel Circle. Then $H = QA \times \sin\alpha - \frac{\cos 3^\circ \times \sin 3^\circ}{\cos\alpha - OA}$, $H$ is the relative height of $A$ to $C$ and $h$ is $QA \times \sin\alpha$.

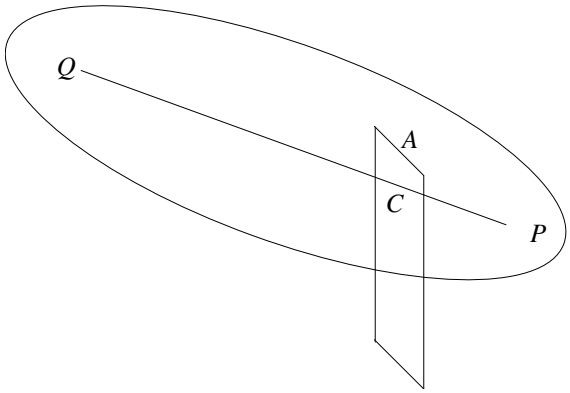


Figure 3: Judgment of the overlap area.

When $C$ is out of the block:

(1) $r < h$. It means that the Fresnel Circle and the block have no overlap area.
(2) $r > h$. The overlap area can be computed by

$$\frac{2\arccos\frac{h}{r} \cdot \pi r^2}{360} - \sin\left(\arccos\frac{h}{r}\right) \cdot r \cdot h \tag{3}$$

When $C$ is in the block:

(1) $r < h$. It means that the Fresnel Circle and the block have no overlap area.
(2) $r > h$ and the vertical side is more than the value of $r$ plus $h$ and the horizontal side is more than the value of twice of $r$. It means that the Fresnel Circle and the block have no overlap area.
(3) $r > h$ and the vertical side is more than the value of $r$ plus $h$ and the horizontal side is less than the value of twice of $r$. The overlap area is $(r + h) \cdot y$.

We had chosen a roof of dense urban building. Depend on distance meter and laptop, this method gives the result of different pitch angle of the antenna. When the pitch angle is 3 degree, the radio wave can bypass the block. When the pitch angle is 10 degree, the radio wave is blocked.

## 4. CONCLUSION AND SUGGESTION

The application of the method of Fresnel Zone provides a scientific way and a quick calculation model to evaluate the propagation environment compared to depending on the experiences and subjective judgments of survey stuffs in BS location survey, especially in the dense urban. However, how to simulate the accurate propagation way of radio in a sustainable time is still a difficulty problem. The work in this paper makes some helpful explore to solve the problem.

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