Influences of Scattered Field Caused by Buildings to ILS Localizer in Airport

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***Abstract*—This paper is concerned with influences of scattered field caused by buildings to instrument landing system (ILS). The localizer (LOC) which is one of ILS subsystem, plays an important role to provide guidance in the horizontal position of aircraft. The LOC emits signals with a varying modulation. The performance of the LOC is obtained by the difference of depth of modulation (DDM) whose values are distorted by the multipath caused by scattering objects, such as building and aircraft. In this paper, we provide a solution for analyzing electromagnetic fields in airport. Firstly, we review the principle of the LOC system. Then, we propose a numerical method based on the ray tracing method (RTM) in three dimensional propagation environment. In the numerical simulation, we show field distribution and the value of DDM. Finally, we discuss the influences of scattered field caused by buildings in an airport.**

I. Introduction

An Instrument Landing System (ILS) plays an important role in safety aircraft landing to an airport. It consists of Localizer (LOC), Glide Path (GP) and Maker (MK) [1]. The LOC provides guidance in the horizontal position of the aircraft [1]. The LOC emits two types signals, that is, carrier wave and sideband waves modulated by 90 Hz and 150 Hz. If the aircraft moves along runway center line, the difference of depth of the modulation (DDM) becomes zero, resulting in no movement of the pilot's LOC cross pointer indicator [2]. The value of DDM is regulated by International Civil Aviation Organization (ICAO) [1].

With increasing the demand of aircraft, building remodeling and relocation of buildings in an airport have been carried out. The LOC signals are much influenced by multipath which is caused by surrounding architecture [3]. Therefore, it is very important to analyze the multipath interferences and to estimate DDM in advance. However, as long as we know, study reports using many three dimensional obstacles have not been seen a lots [3], [4]. In addition, study on the effect of scattered waves from terrain profile has discussed especially for the ILS GP [5], [6], [7].

In this paper, we discuss influences of multipath interferences to ILS LOC. Firstly, we review the basic principle of LOC. Next, we propose a numerical method for rapidly computing electromagnetic (EM) fields. The method is based on the ray tracing method (RTM). In order to reduce computation time, we simplify the procedure of ray searching. The idea is based on the discrete ray tracing method (DRTM) which was used for analyzing EM field along random rough surface [8]. However, in this paper, we neglect the effects of scattered waves from the inhomogeneous ground. Focusing on the multipath from obstacles, we compute electromagnetic fields. Finally, we show some numerical examples. It will be shown that the proposed method is a useful numerical technique for the analysis of ILS LOC. We discuss how multipath interferences caused by obstacles influence on the LOC system.

II. Numerical Method of ILS Radiation Field

A. LOC Beam Pattern

The LOC which is one of ILS subsystem, gives the horizontal position of aircraft to pilots. There are two types of LOC with1 frequency and 2 frequencies. The LOC with 2 frequencies has better multipath immunity in comparison with the LOC with 1 frequency. One of LOC beam with 2 frequencies is called directional beam, and the other is called clearance beam. The details of two systems are omitted here.

The LOC beam consists of carrier wave and sideband waves [1]. The sideband waves are modulated by 90 Hz and 150 Hz. The LOC antenna is composed by several antenna components that have the different power feed. Those signals are given by

[Carrier wave]

$$\begin{aligned} E_c &= \sum_{n=1}^{N} E_n D(\theta)(e^{jdnsin\theta} + e^{-jdnsin\theta}) \\ &= 2\sum_{n=1}^{N} E_n D(\theta) cos(dnsin\theta) \end{aligned} \tag{1}$$

[Sideband waves]

$$\begin{aligned} E_{sb} &= \sum_{n=1}^{N} E_n D(\theta)(e^{jdnsin\theta+\pi/2} - e^{-jdnsin\theta-\pi/2}) \\ &= 2\sum_{n=1}^{N} E_n D(\theta) sin(dnsin\theta) \end{aligned} \tag{2}$$

where E_n is radiated electric field of each antenna element, and $D(\theta)$ is the directivity of each antenna. The directivity is generally given by the log-periodic diode antenna (LPDA). dn is the length between antennas. In the most of cases, the number of antenna elements is 14 or 24. The LOC beam are

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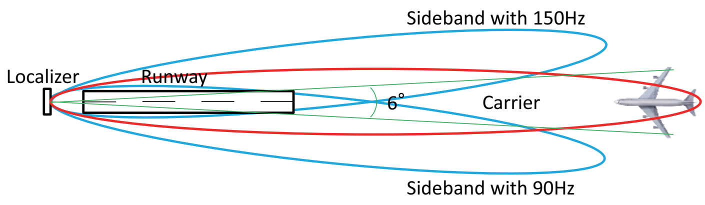


Fig. 1. Image figure of LOC beam pattern.

arbitrary generated by the ratio of the supplying power of each antenna.

Figure 1 shows an image figure of LOC beam. The quality value DDM is computed by the received signals, and it must be less than 0.155 which is regulated by ICAO [1]. The value of DDM is computed by

$$DDM = M90 - M150 \quad . \tag{3}$$

In general, the value of DDM becomes zero when the aircraft move along the straight line on runway center line. However, in an airport, there are many obstacles, such as terminal, buildings and large aircraft. Scattered waves are caused by the surrounding obstacles, resulting in the fluctuations of DDM.

B. Application of RTM

We employ the RTM to compute scattered fields because it treats relatively large analytical field in comparison with other methods [9]. There are two steps to compute EM fields: first one is to search rays between a source and a receiver, and second one is to compute EM field based on the ray data. However, it requires much computation time in complicated propagation environments. Therefore, we simplify the procedure of ray searching [8], [10].

The proposed method has two steps. Firstly, we discretize obstacles in terms of representative points as follows:

$$\begin{aligned} &\boldsymbol{p}^i_{mn} = (x^i_{mn}, y^i_{mn}, z^i_{mn}) \\ &(i = 1, 2, \cdots, I, \quad m = 1, 2, \cdots, M, \quad n = 1, 2, \cdots, N) \end{aligned} \tag{4}$$

where i is the number of obstacles, m is the number of faces and n is the number of representative points constituting the face. This is very important to rapidly compute EM fields and to maintain the field accuracy. It should be noted that the length between representative points must be larger than the wavelength [9].

Secondly, we simplify the procedure of ray searching. This is based on the DRTM [8], [9]. First, we select a representative point at each face of the generated obstacle. In this paper, we select one representative point at the center of each face. Next, we determine whether each representative point and source/receiver are in LOS with each other. If the representative point is in line of sight (LOS) for both source and receiver, we generate rays by connecting from the source to the receiver via representative points. However, they are approximate rays. In order to obtain more accurate rays, we can modify those rays by using the imaging method [8]. Diffraction is divided into two parts, that is, source diffraction and image diffraction [8]. They are given for the field continuity. Details are discussed in reference [9].

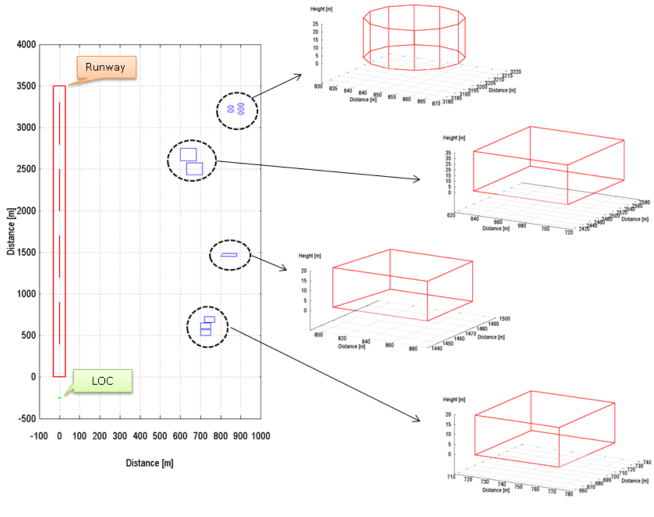


Fig. 2. Geometry of the problem.

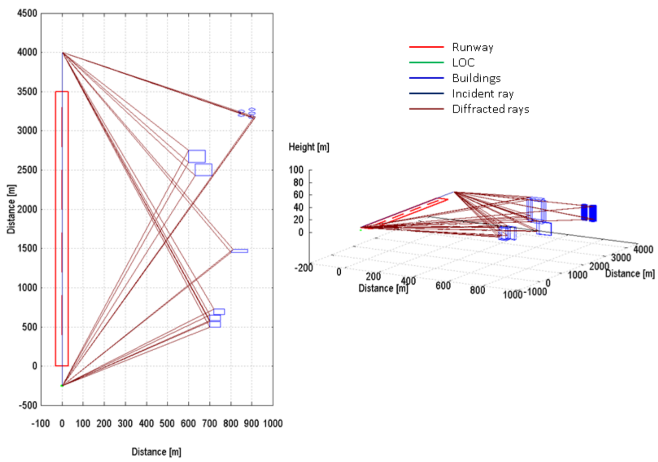


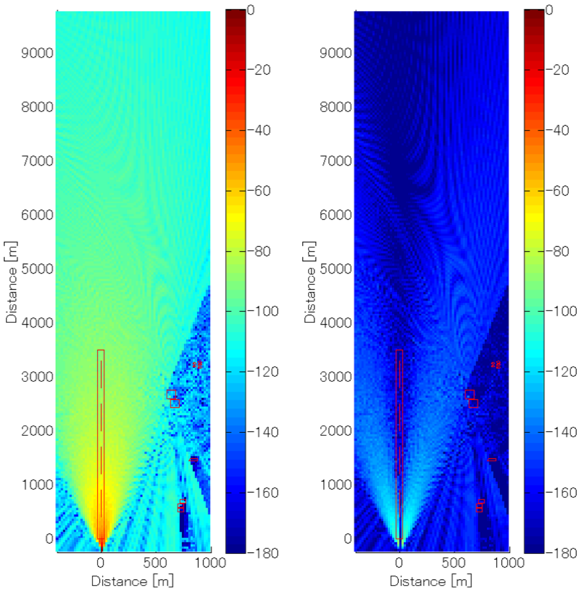
Fig. 3. Ray distribution.

III. Numerical Example

We compute the EM field and DDM. The simulation model is shown in Fig.2. The runway length is 3,500 m, and the LOC is placed at 250 m from runway end. We generate 11 obstacles with 4 types shape. It should be noted that this is an image figure for numerical computation.

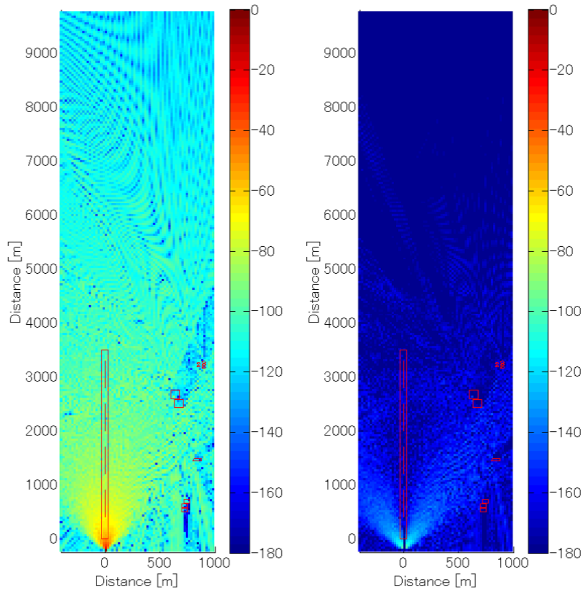
We select following parameters: frequency f=110.0 MHz, input power of directional beam Pd=10.0 W and input power of clearance beam Pc=10.0 W. We also use dielectric constant as relative permittivity ϵ_r=5.0 and conductivity σ=0.0023 S/m. We assume the obstacles to be a dry condition. The source height is 4.0 m. Figure 3 shows ray distribution. It is shown that the radiated EM waves are diffracted by obstacles. In this figure, incident wave and image diffracted waves are only shown.

Based on the ray information, we can compute EM field. Figure 4 shows EM field distribution of directional beam. The



(a) Carrier signal. (b) Sideband signal.

Fig. 4. Field distribution (directional beam).



(a) Carrier signal. (b) Sideband signal.

Fig. 5. Field distribution (clearance beam).

receiver height is 4.0 m. The unit of EM field intensity is expressed in dBm. It is shown that both waves are scattered by obstacles. Especially, sideband waves are influenced by obstacles. Figure 5 shows EM field distribution of clearance beam. The beam width of clearance pattern is broader than that of directional beam. Therefore, larger reflected and diffracted waves arrives at the straight line along runway center line. Their signals results in the DDM error.

Figure 6 shows the value of DDM. The receiver is located along landing course. The landing course becomes 3 degree from the touch down point. There are three categories of landing standard as CAT I, CAT II and CAT III. The value of DDM along runway center line is regulated by the ICAO. It is shown in the numerical simulation that the values at a few measurement points become larger than the regulated value. However, in this numerical condition, the values are almost satisfied with CAT I and II.

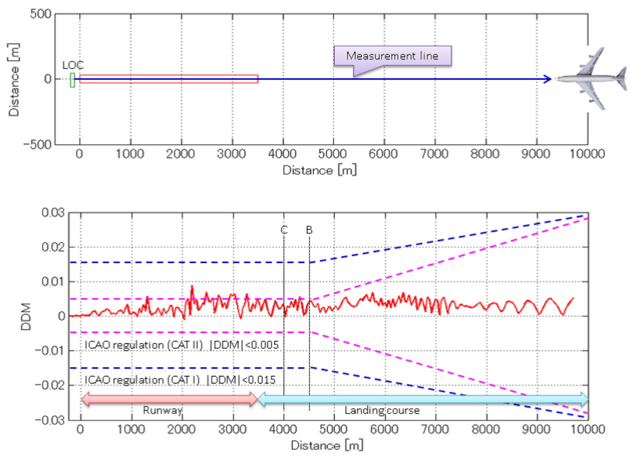


Fig. 6. Numerical result of DDM.

IV. Conclusion

In this paper, we discussed the influences of multipath interferences caused by buildings to ILS LOC. Firstly, we reviewed the principle of LOC. Next, we proposed the numerical method based on the RTM so that we treat the large analytical region. The characteristics of the proposed method is to reduce computation time by simplifying ray searching. Finally, we showed numerical results of EM field distribution and the DDM. It has been shown that scattered waves are occurred by surrounding obstacles. It has been found that scattered waves sometimes influence on the performance of LOC.

In this paper, we just applied the numerical method to the analysis of LOC. We need to check the accuracy of EM field. We would like to compare the numerical result with experimental result. They will be our future works.

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