An Application of Ray Tracing Modeling Technique to design Aeronautical Satellite Communication

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***Abstract :*In this paper , to achieve safe aeronautical communication, reliable propagation simulation and modeling are absolutely necessary in aeronautical traffic system. This paper mainly applies a ray-tracing method on propagation to model satellite-to-aircraft communication. The main aim of this paper is to reproduce data link power and time delay of direct and scatter signal power loss and time delay of received signal on the aircraft antenna. In aeronautical satellite communication system, Ray-tracing models are mainly designed for simulation results which show the carrier-to-noise ratio is less than 100dB below 17 degree of aircraft elevation angle. For Boeing aircraft , the maximum Doppler shift being 220Hz with a differential time delay is less than 30µs below 20 degree aircraft elevation angle.**

***Index Terms* : Air traffic control, Doppler shift,, Geocentric equatorial, Ionospheric Propagation, Power system modeling, Ray tracing**

I INTRODUCTION

Ray-tracing model has been used for several decades propagation prediction for channel modelling in aeronautical communication[1]. In reliable propagation One of the severest constraints of aeronautical satellite communication system is the severe limitation of available power on the satellite transmitter and small aircraft antenna. Other constraints are the large frequency offset due to Doppler effect, and the frequency selective fading due to differential time delay between the direct and the diffuse components of the received signal in [1][5].Early use of ray-tracing technique used for estimating the location and severity of ghosting in broadcasting TV. Current Ray tracing method required a number of assumptions. The numerical ray-tracing method is applied to model the propagation of three main signals (direct, specular, and diffuse signal) of satellite-to-Aircraft communication[4]. The amplitude of the reflected wave of the reflected components is measured by the reflection coefficient of the earth surface. The reflection coefficient includes reflection coefficient from smooth flat surface

The ray-tracing models use L-band frequency and circular polarisation antenna in the satellite transmitter to overcome the losses in the atmosphere (Faraday rotation and ionosphere scintillation.) Planet earth is modelled as an ellipsoid. A modified geocentric-equatorial coordinate system is applied as the ray-tracing coordinate system.

II.RAY TRACING MODELLING TECHNIQUE

Current ray-tracing [3]methods require a number of assumptions about the propagation environment, among them that the building walls are smooth and homogeneous. By using this prediction of mean signal level, in channel input response, RMS delay spread, time and spectrum signatures, and fading statistics. In the transmitter symbol rate,this information can be used to predict and must be constrained to prevent multi path fading and decreases potential blockage. Under geometrical optic assumption, propagation takes place by “Rays”. It is one of the numerical methods on propagation modeling[6]. There are two basic methods using the ray tracing techniques. The first one is image method and the second one is ray shooting method. In this paper, a new ray-tracing design method is developd by combining the above two Ray tracing methods to adapt to the special environment in aeronautical satellite communication system[2].

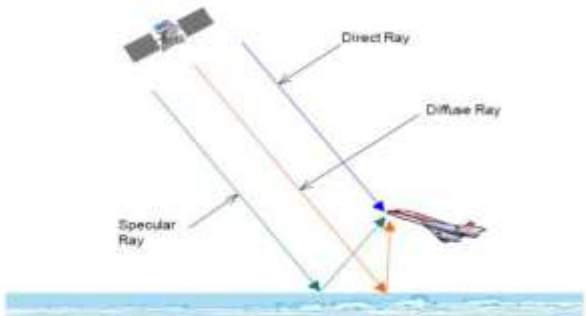
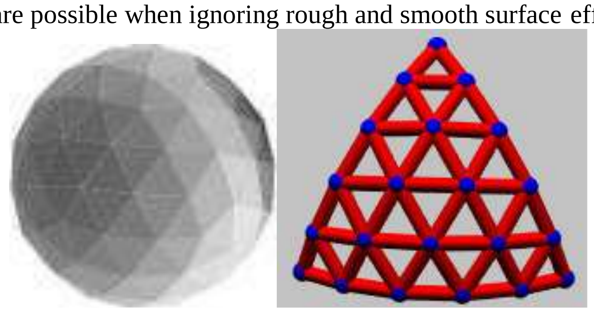


Fig.1.Satellite-to-Aircraft Ray-Tracing

The 2G ray tracing model used here includes several new features includes their heights and terrain on which they are located.Correct ray tracing method have a required number of assumptions about the propagation environment among them reflection and scattering.

A maximum beamwidth of 127.12 degrees is transmitted from a portion of the geodesicsphere in the modified geodesic sphere transmitter. Earth surface is the only potential reflector, to find out the specular reflection point of earth surface and are combined with transmitter and receiver theorems of ray-shooting ray-tracing by applying the concept of image ray tracing method. In order to adjust the angular separation between rays such that only the specular reflected ray's wavefront covers exact the area of the aircraft antenna. At the end, to take into account that diffuse reflected rays in diffuse signal have some amount of rays is sent out from the transmitter model.

In typical ray tracing model, rays from the transmitter to the receiver may undergo multiple reflections. Errors in calculating the magnitude of the reflection coefficient at each reflection will add up so that after4 to5 reflections ,ray amplitude error of 10 dBs or more are possible when ignoring rough and smooth surface effect



(a) (b)

Fig2.Transmitter models (a) geodesic sphere (b)one triangular face

The ray is transmitted in all directions uniformly that cover a sphere, which is certainly waste since the satellite's beamwidth is only 17degrees. Eventransmitting17degreesofbeamwidthfroma portion of geodesic sphere[5] transmitter model is still computation inefficient. Angular separation between rays is determined by the tessellation frequency of geodesic sphere[5]. All rays transmitted from the transmitter model have approximately the same angular separation between nearest neighbour rays to meet the two uniformity criteria in ray launching geometry. These two uniformity criteria are **1**) The small scale uniformity so the local pattern of ray impinging on a wavefront should be a predictable and **2)** The large scale uniformity so rays illuminate all regions of equal space.

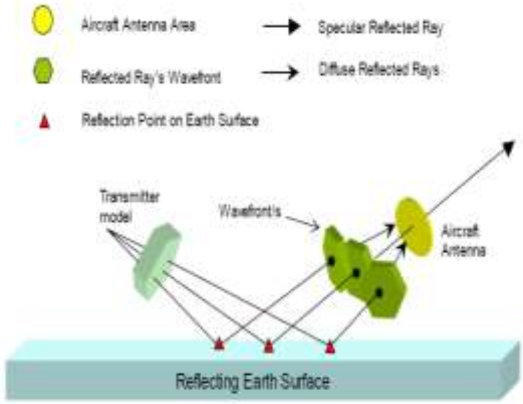


Fig.3.ray tracing transmitting model

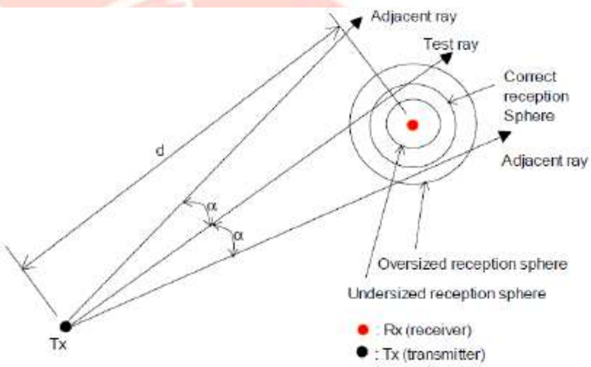


Fig 4:view of Reception sphere

To construct a reception sphere at the receiver, its size will depends on the characteristics of the incoming ray, and its radius is proportional to the unfolded path length and the angular spacing between neighbouring rays at the sources. The reception sphere must change the sphere radius in fig.4, because ray spread out so they leave the source.

Any ray will have more than two adjacent (nearest neighbour) rays In 3D space. The minimum radius for a reception sphere to guarantee the collection of at least one ray from a wavelength is 1/3 the distance between rays.A minimum radius specified above to intercept two wave fronts is still possible for a reception sphere in case of 3-dimensional. This error is called the double-counting error, it occurs with a probability of 20% in 3-D space regardless of tessellation frequency with additional voltage and power are introduced.

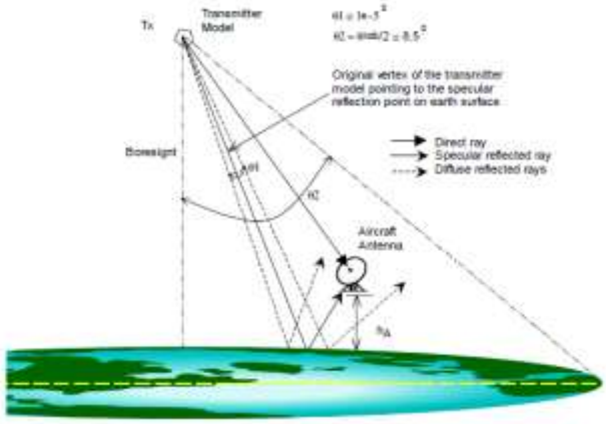


Fig.5 Satellite to aircraft ray tracing model

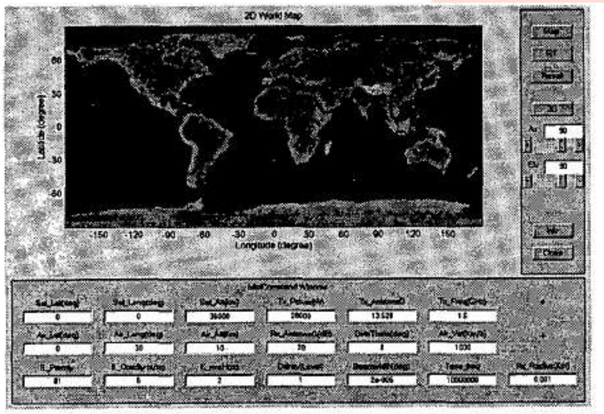
To compute all the relevant points and vectors of rays along the signal's propagation path is then applied by Ray tracing technique. In Fig 5. The propagation mechanisms such as free space propagation loss, and reflection coefficient are then applied to the rays that area sent out from the transmitter model accordingly. By using ray-tracing technique the powers of direct ray, specular reflected ray and diffuse reflected rays are then computed with all the specific parameters of signals along propagation paths derived [6],[7].

III.APPLICATIONS OF MODELS

Based on three models, this paper present to simulate results for different applications. The 1st model is the most common one, incorporates matlab GUIs (matlab graphical user interface) (Fig 6(a) &(b) &(c)).. The 2nd model investigates the power distribution and time delay of the received signal along the aircraft path. The results of Doppler shift and differential time delay are shown in Fig 6(d),fig 6(e) and Fig 6(f) The 3rd model is the carrier-to-noise ratio *(CM* ratio) versus aircraft elevation angle at different aircraft altitude on different earth terrain. A very calm seawater surface is presented in the *CM* ratio simulation result as shown Fig 6(g) &(h) &(i) &(j) &(k) &fig.6(L))

IV.RESULTS AND CONCLUSIONS

It increase the carrier-to-noise ratio significantly as elevation angle increases with surface RMS irregularity height. Due to scattering as shown in result . Due to scattering Less power are reflected on the rougher surface. Free space loss for direct ray is decreasing and for diffuse reflected rays are increasing with an increase of aircraft altitude.In aeronautical satellite communication environment, The differential time delay is less than 30ps below 20 degrees elevation angle. Maximum Doppler shift is about less than 220 **Hz** for flying at 1000km/hr. In this paper the ray tracing models developed in terms of power distribution and time delay within the specific assumptions are very close to the real world situation.



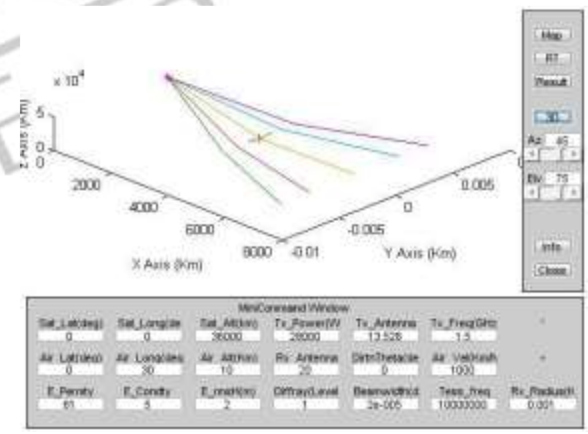


Fig.6(a):"map''3D push button(shape) Fi

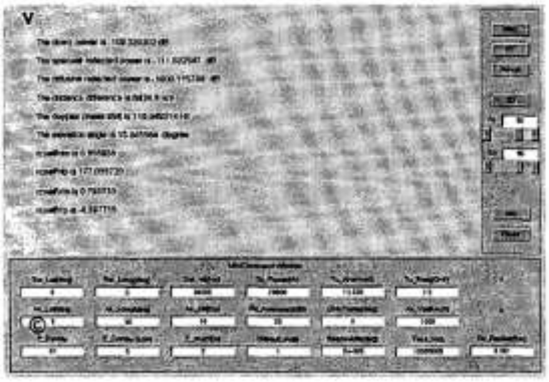


Fig.6(c):Ray tracing information

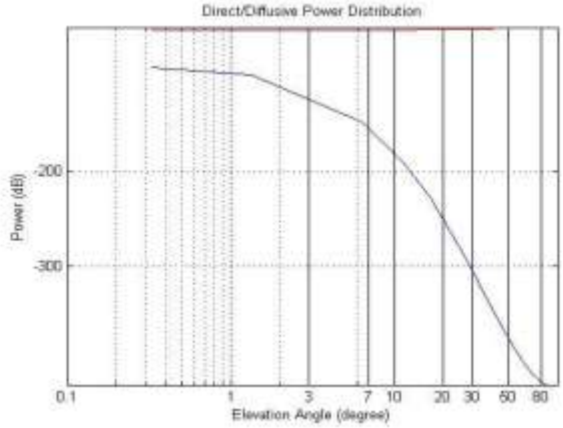


Fig 6(d): Direct/Diffuse Signal Power Distribution

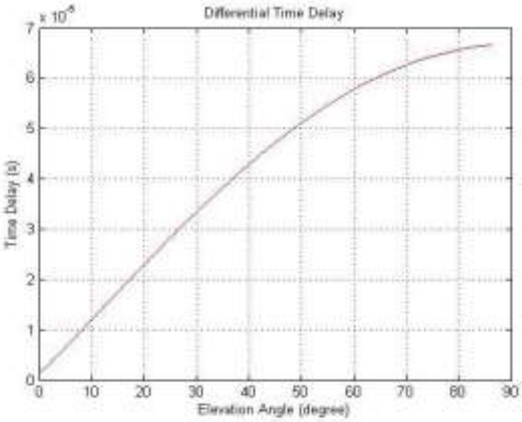


Fig 6(e): Direct/Specular Signal Time Delay

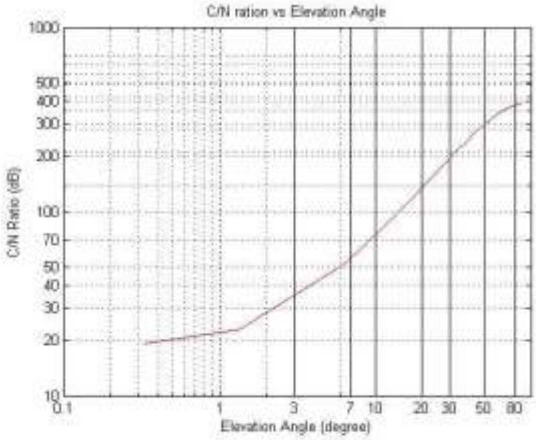
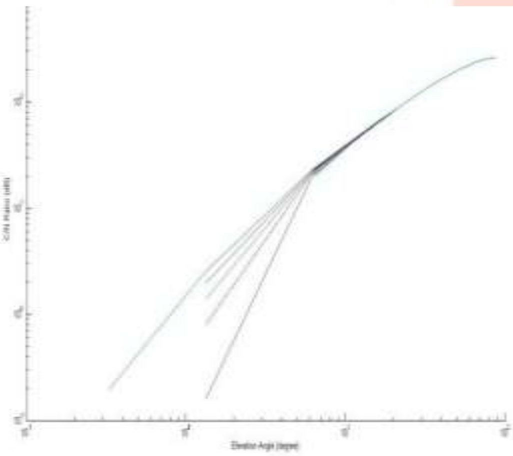


Fig.6(f):C/N Ratio vs Elevation Angle



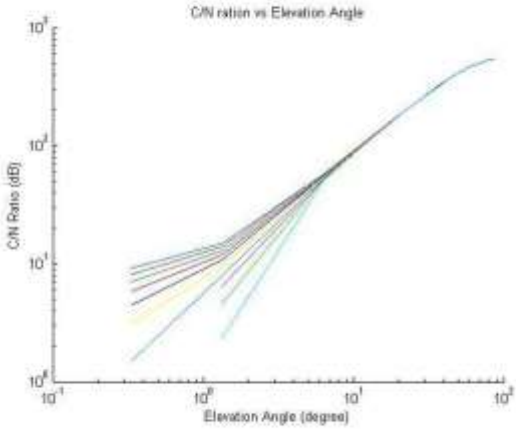
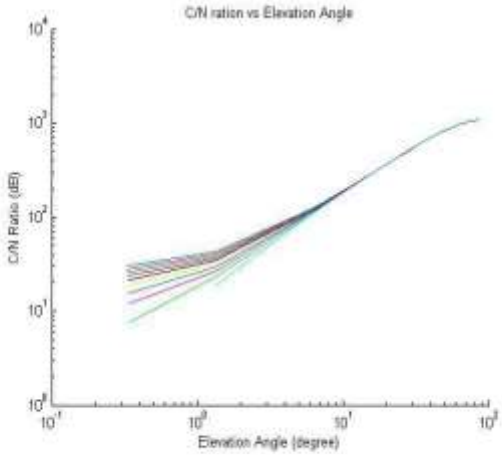


Fig.6(g):c/n ratio vs elevation angle with rms height 0.5m

Fig.5(h):):c/n ratio vs elevation angle with rms



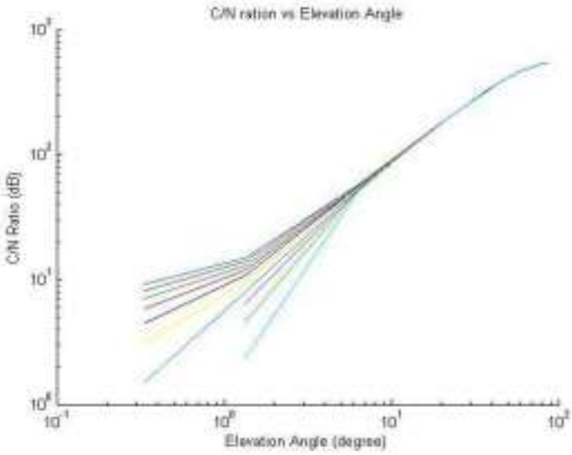
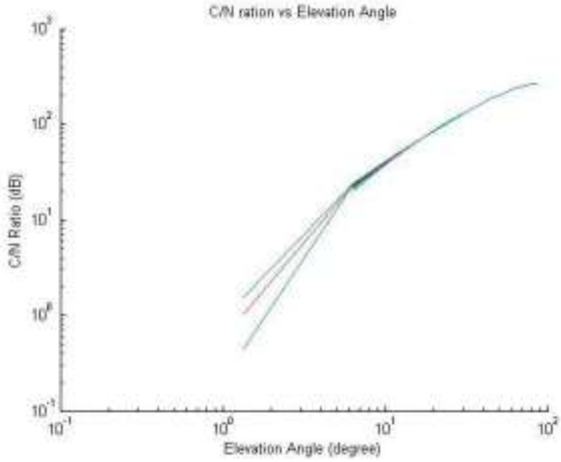


Fig.6(i):):c/n ratio vs elevation angle with rms height 2m

Fig.6(j):c/n ratio vs elevation angle with rms height



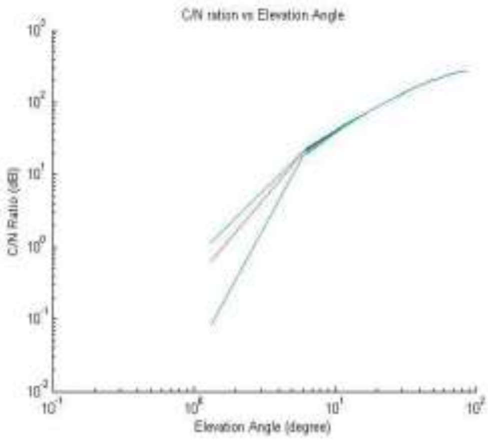


Fig.6(k):):c/n ratio vs elevation angle with rms height 5m

Fig.6(l): height 2m in typical -water

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