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Design of Aeronautical Satellite Communication System Using Ray Tracing Modeling Technique

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ABSTRACT :

In aeronautical traffic system, reliable propagation simulation and modelling are absolutely necessary to achieve safe aeronautical communication. This paper applies the numerical ray-tracing method on propagation modelling to model satellite-to-aircraft communication in. The objective of this paper is to simulate importance ofdirect and diffusesignal power loss and time delay of received signal on the aircraft antenna. Ray-tracing models are designed for simulation results which showsthe carrier-to-noise ratio is less than 100dB below 17 degree of aircraft elevation angle. Further the differential time delay is less than 30µs below 20 degree aircraft elevation angle with maximum Doppler shift being220Hz for Boeing aircraft in aeronautical satellite communication system.

KEYWORDS:DOPPLERSHIFT,GEOCENTRIC-EQUATORIAl,COORDINATESYSTEM,FARADAYROTATION,IONOSPHERICSCINTILLATION,ELLIPSOID,
POLYDRON.

1 INTRODUCTION:

Ray-tracing model has been used for several decades propagation prediction for channel modelling in aeronautical communication. Inreliable propagation One of the severest constraints of aeronautical satellitecommunication 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 [2],[3].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. The amplitude of the reflected wave of the reflected components is measured by the reflection coefficient of the earth surface. The reflection coefficient includes reflectioncoefficient 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.

2.RAYTRACINGMODELLING TECHNIQUE:

Currently used models based on geometric optics employ simple propagation mechanisms such as smooth surface specular reflection, and wall transmission to estimate the phase and amplitude of an ensemble of rays arriving at the receiver from the transmitter, Using this prediction of mean signal level, in channel input response,RMS delay spread, time and spectrum signatures, and fading statistics. This information can be used to predict symbol rate of the transmitter must be constrained to prevent multi path fading and decreases potential blockage

Ray-tracing method is one of the numerical methods on propagation modelling [2] Under geometrical optic assumption, propagation takes place by "Rays". There are two general methods using the ray tracing techniques. The first method is called the "image method", and the second method is called the "ray shooting method". A new ray-tracing design method is developed in this paper by combining the above two Ray tracing methods to adapt to the special environment in aeronautical satellite communication system .

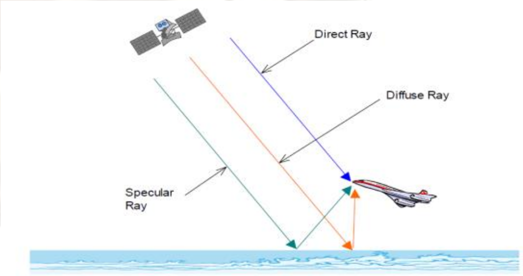


Fig.1.Satellite-to-Aircraft Ray-Tracing

A new ray-tracing design method is developed in this paper by combining the above two ray A new ray-tracing design method is developed in this paper by combining the above two ray tracing methods to adapt to the special environment in aeronautical satellite communication system .Ray tracing methods to adapt to the special environment in aeronautical satellite communication system .

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

The geodesic sphere transmitter model is modified so that the transmitter-model can transmit a maximum beamwidth of degrees from a portion of geodesic sphere transmitter model in thesis modifications to Icosahedrons Geodesic Sphere Ray launching mechanism and ray-shooting ray-tracing method. Firstly, the geodesic sphere transmitter model is modified such that the transmitter model transmit a maximum beamwidth of 127.12 degrees from a portionofthegeodesicsphere. Then applying the concept of image ray tracing method combined with transmitter and receiver theorems of ray-shooting ray-tracing to find out the specular reflection point of earth surface since earth surface is the only potential reflector. Then the transmitter model is rotated to point to the specular reflection point on earth surface, and the angular separate to between rays from the transmitted model is adjusted such that only the specular reflected ray's wavefront covers exact the area of the aircraft antenna. Finally, certain amount of rays is sent out from the transmitter model to take into account the diffuse reflected rays of the diffuse signal.

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.

The geodesic sphere transmitter is modified that in modelling can transit a maximum beamwidth of 127.12 degree from a portion.

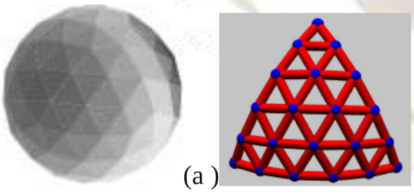

(a) (b)

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

The transmitter transmits ray in all directions that uniformly cover a sphere ,which is certainly waste since the satellite's beamwidth is only17degrees. Eventransmitting17degreesofbeamwidthfroma portion of geodesic sphere transmitter model is still computation inefficient. Angular separation between rays is determined by thetessellation frequency of geodesic sphere[3]. 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 large scale uniformity so rays illuminate all regions of space equally and 2) The small scale uniformity so the local pattern of ray impinging on a wavefront should be a predictable, uniform pattern.

The concept of image ray-tracing method combined with ray-shooting ray-tracing method to find out the specular reflection point on earth surface since earth surface is the only potential reflector in aeronautical satellite communication system

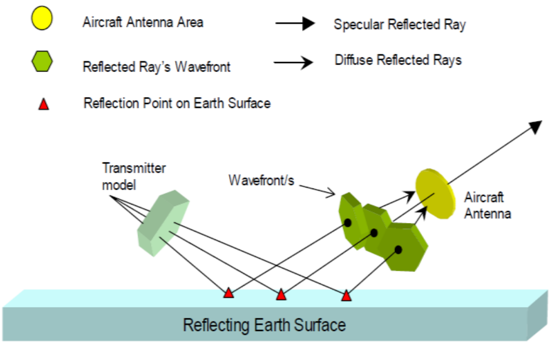


Fig.3.ray tracing transmitting model

A reception sphere is constructed around the receiver. The size of reception sphere 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. Because ray spread out so they leave the source ,the reception sphere must change the sphere radius fig 4.

In 3D space any ray will have more than two adjacent (nearest neighbour) rays. 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

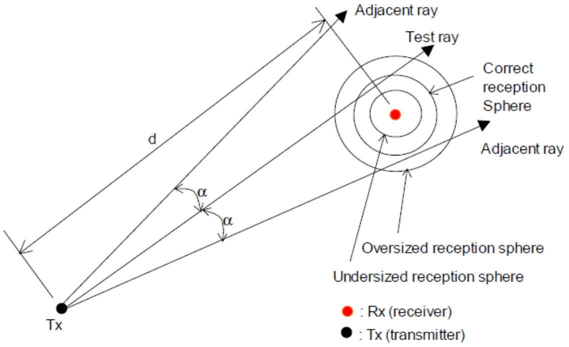


Fig 4:view of Reception sphere

In 3-dimensional case, it is still possible for a reception sphere with minimum radius specified above to intercept two wave fronts This error is called the double-counting error ,which introduce s additional voltage and power it occurs with a probability of 20% in 3-D space regardless of tessellation frequency.

The transmitter model is then rotated to point to the specular reflection point on earth surface for which the angular separation between rays transmitted from the transmitter model is adjusted so that the wavefront of the specular reflected ray exactly covers the area of aircraft antenna (Fig 1).

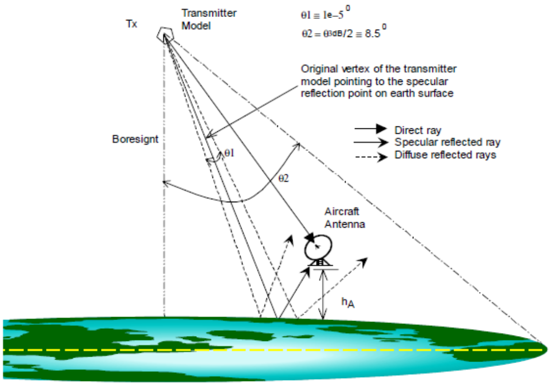


FIG.4.Satellite to aircraft ray tracing model

Ray tracing technique is then applied to compute all the relevant points and vectors of rays along the signal's propagation path. In Fig[4] 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. The powers of direct ray, specular reflected ray and diffuse reflected rays are thencomputed with all the specific parameters of signals along propagation paths derived using ray-tracing technique[4],[5].

3.APPLICATIONS OF MODELS:

This paper presents three models to simulate results for different applications. The first model, which is the most general one, incorporates matlab GUIs (matlab graphical user interface) such that it is user friendly (Fig 5(a) &(b) &(c)). The second 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 5(d),fig 5(e) and Fig 5(f).. The third model studies the carrier-to-noise ratio *(CM* ratio) versus aircraft elevation angle at different aircraft altitude on different earth terrain. The *CM* ratio simulation result on a very calm seawater surface is presented in(Fig 5(g) &(h) &(i) &(j) &(k) &fig.5(L)).

RESULTS AND CONCLUSIONS:

The simulation results show that the carrier-to-noise ratio is increase significantly as elevation angle increases with surface RMS irregularity height. This is due to rougher the surface ,less power are reflected due to scattering. Aircraft altitude increase free space loss for direct ray is decreasing and the free space losses for diffuse reflected rays are increasing. 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 aeronautical satellite communication environment. It concludes that the ray tracing models developed in this paper are very close to the real world situation in terms of power distribution and time delay within the specific assumptions. The software model is entirely developed by the author, and if any readers find it interesting, or like to discuss the features of the software model in more detail, please contact the author by e-mail.

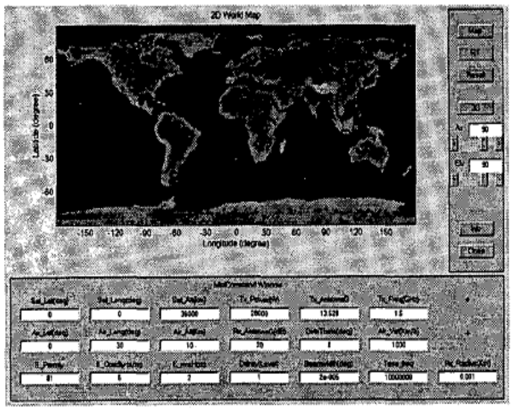
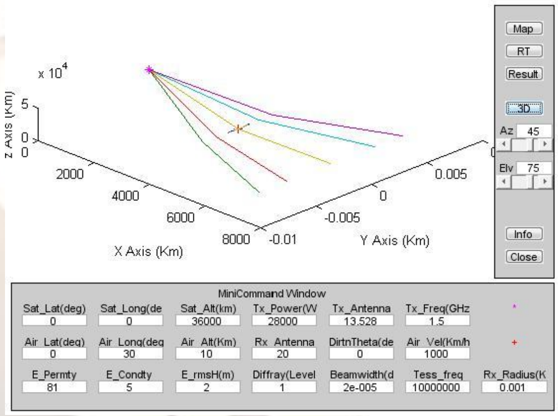


Fig.5(a):"map''3D push button(shape)



MiniCommand Window

Sat_Lat(deg	Sat_Long(de	Sat_Alt(km)	Tx_Power(W	Tx_Antenna	Tx_Freq(GHz	
0	0	36000	28000	13.528	1.5	
Air_Lat(deg)	Air_Long(deg	Air_Alt(Km)	Rx_Antenna	DirtnTheta(de	Air_Vel(Km/h	
0	30	10	20	0	1000	
E_Permty	E_Condty	E_rmsH(m)	Diffray(Level	Beamwidth(d	Tess_freq	Rx_Radius(K
81	5	2	1	2e-005	10000000	0.001

Fig.5(b):3D push Button

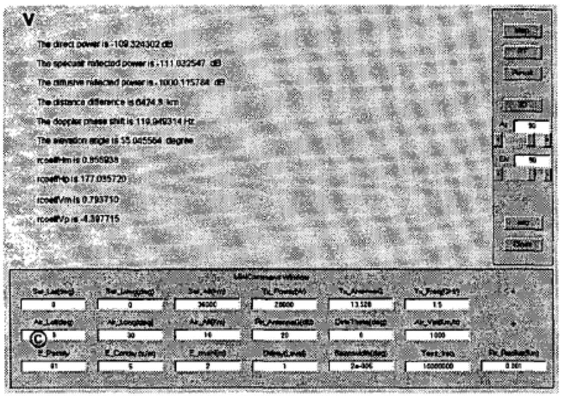

```
The direct power is -109.324302 dB
The specular reflected power is -111.032547 dB
The diffusive reflected power is -1000.115784 dB
The distance difference is 6474.5 km
The doppler phase shift is 119.949314 Hz
The elevation angle is 55.045564 degree
rcoeffHm is 0.855938
rcoeffHp is 177.035720
rcoeffVm is 0.793710
rcoeffVp is -4.397715
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Fig.5(c):Ray tracing information

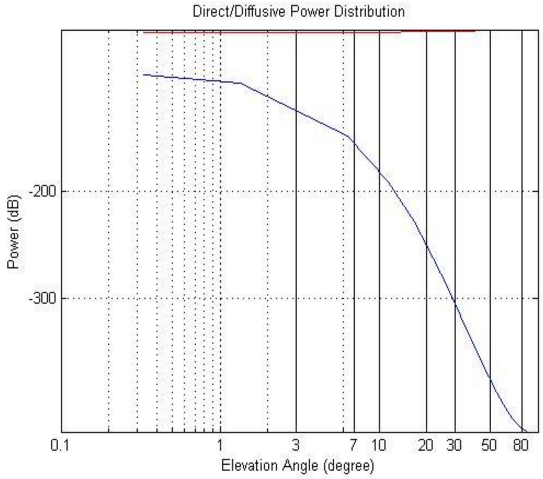


Fig 5(d): Direct/Diffuse Signal Power Distribution

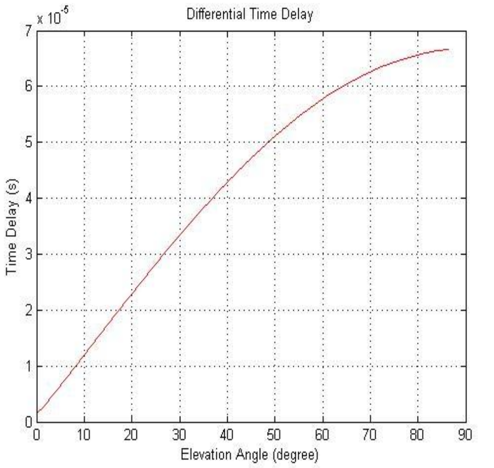


fig 5(e): Direct/Specular Signal Time Delay

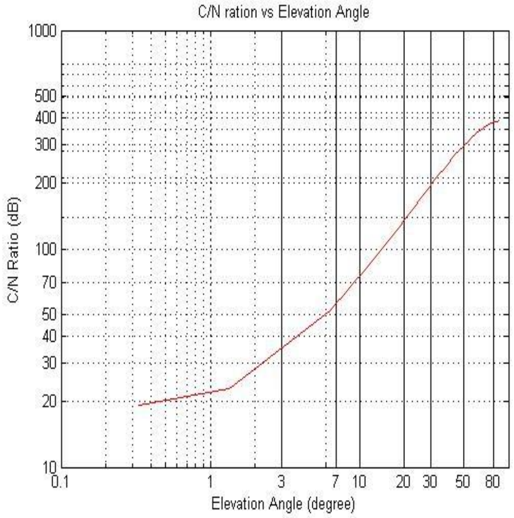


Fig.5(f):C/N Ratio vs Elevation Angle

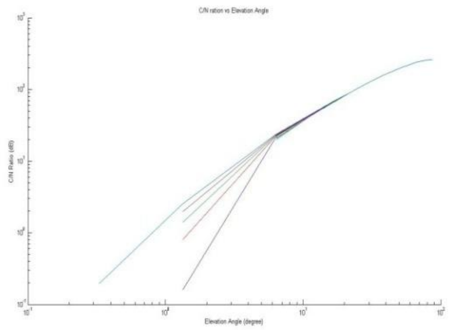


Fig.5(g):c/n ratio vs elevation angle with rms height 0.5m

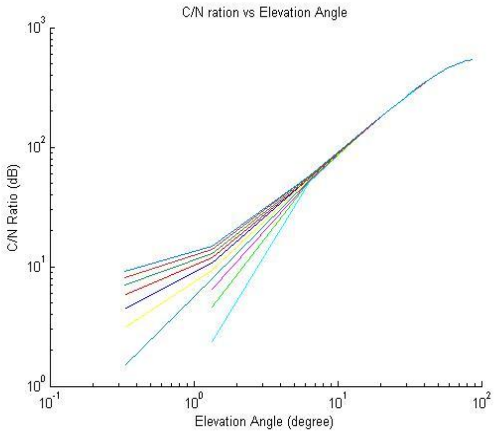


Fig.5(i):):c/n ratio vs elevation angle with rms height1m in sea-water

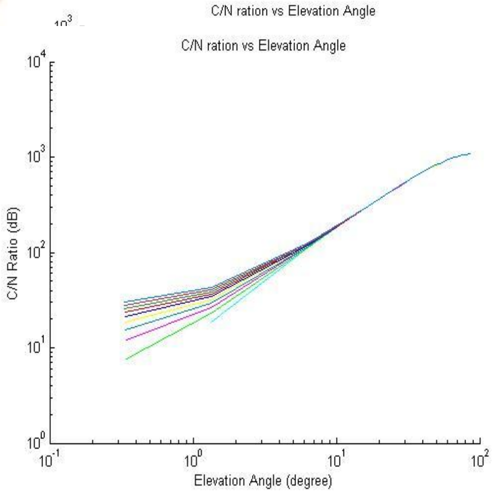


Fig.5(h):):c/n ratio vs elevation angle with rms height 2m

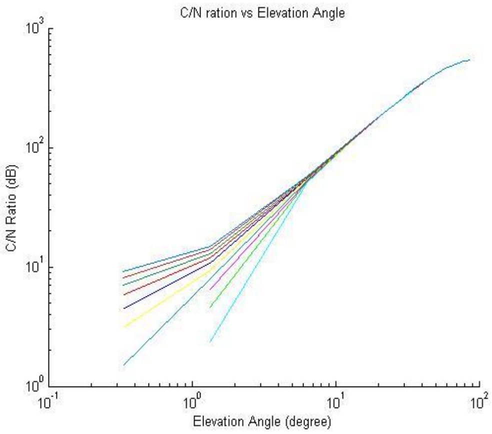


Fig.5(j):c/n ratio vs elevation angle with rms height 1m

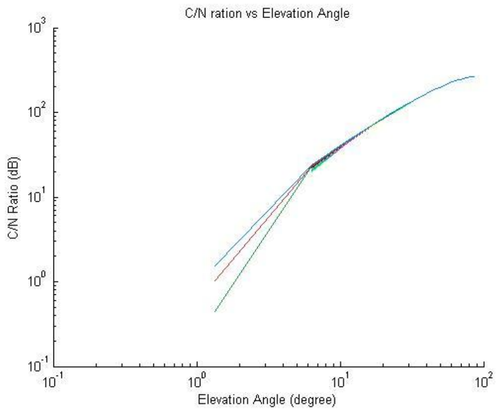
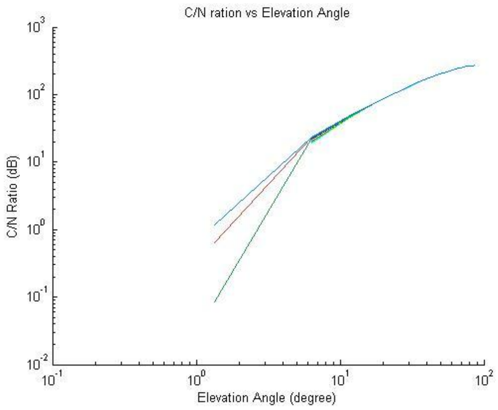


Fig.5(k):):c/n ratio vs elevation angle with rms height 5m



height 2m in typical -water

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