Cumhuriyet Üniversitesi Fen Fakültesi
Fen Bilimleri Dergisi (CFD), Cilt:36, No: 3 Özel Sayı (2015)
ISSN: 1300-1949

Cumhuriyet University Faculty of Science
Science Journal (CSJ), Vol. 36, No: 3 Special Issue (2015)
ISSN: 1300-1949

Power delay profile modeling for Multilateration system

Niloofar SOLEYMANİ ROUDİ[1,*], Bijan ABBASİ ARAND[1]

[1] *Tarbiat modares university, Tehran*

Received: 01.02.2015; Accepted: 05.05.2015

Abstract. Nowadays, multilateration systems are widely used for locating the aircrafts. One of the challenges in implementation of the system is placing receivers in appropriate locations which are dependent to several factors such as delay spread. By modeling power delay profile, delay spread can be obtained. In this article, two airports of Iran were considered and ray tracing method was applied to them for calculating delay in multiple paths. Then by using the results and LSE method, cost-207 model was modified for receivers in different areas of the airports. Ray tracing method and modified cost-207 can be used for specifying appropriate areas for multilateration receivers in those airports. The same algorithm can be used for the other airports with the similar structure.

Keywords: cost-207, distortion, multilateration, power delay profile

1. INTRODUCTİON

Multilateration is a proven technology to accurately locate aircraft by using a method known as TDOA[1]. It employs a number of ground stations which their locations have impact on propagation channel. Therefore, by placing receivers in appropriate locations, received signal power, accuracy and distortion will be improved. Several factors such as SNR, TDOA error and delay spread should be noticed for finding best places for receivers. Delay spread can be calculated from power delay profile. So by modelling power delay profile, delay properties of the channel can be studied.

Specific and statistics models can be used for modelling a channel. Specific models are more accurate but complex and take more calculation time. One of the most popular ways for specific modeling is ray tracing. Statistical methods are simple and easy to use, but approximate. For statistical modeling of power delay profile, cost-207 can be used.

2. POWER DELAY PROFİLE

Power delay profile[2] provides an indication of distribution or dispersion of the signal in a multipath propagation. A typical plot of the power-delay profile is shown if Figure 1.

[1] Time difference of arrival
[2] PDP

*Corresponding author. *Email address*: *niloofar_soleymani@yahoo.com*

Special Issue: The Second National Conference on Applied Research in Science and Technology

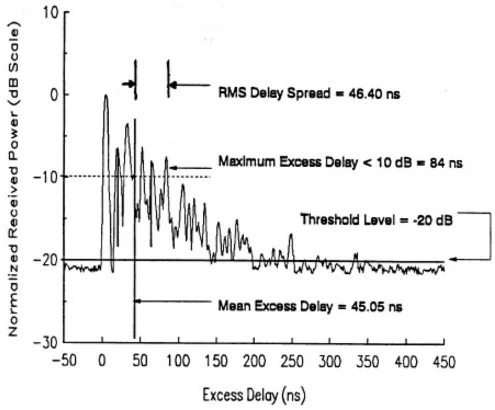


Figure 1. Power delay profile.

Multipath propagation causes severe dispersion of the transmitted signal. The expected degree of dispersion is determined through the measurement of the power-delay profile of the channel. Time dispersion varies widely in a mobile radio channel, due to the fact that reflections and scattering occur at seemingly random locations, and the resulting multipath channel response appears random, as well. Time dispersion is dependent on the geometrical position relationships among the transmitter, the receiver, and the surrounding physical environment [1].

In telecommunication, intersymbol interference[3] is a form of distortion of a signal in which one symbol interferes with subsequent symbols. This is an unwanted phenomenon as the previous symbols have similar effect as noise, thus making the communication less reliable. ISI is usually caused by multipath propagation or the inherent non-linear frequency response of a channel causing successive symbols to "blur" together. The presence of ISI in the system introduces errors in the decision device at the receiver output. Therefore, the objective is to minimize the effects of ISI [2].

There are several techniques to mitigate the distortion due to multipath delay spread, including equalization, multicarrier modulation, and spread spectrum. ISI mitigation is not necessary if $T>>T_m$ (T is the pulse duration and T_m is the multipath delay spread), but this can place significant constraints on data rate. Multicarrier modulation and spread spectrum actually change the characteristics of the transmitted signal to mostly avoid intersymbol interference; however they still experience multipath distortion due to frequency-selective fading [3].

[3] ISI

Distortion of the channel can be derived from power delay profile. So by modeling the power delay profile, appropriate areas for receivers can be specified. Modeling can be done by ray tracing or cost-207.

Image ray tracing technique is a suitable method for modeling the channel. It takes into account propagation effects like reflection, refraction, dispersion and scattering. It distinguishes the wave paths and therefore delay of each path can be calculated from the distance. Ray tracing needs information about building properties and locations in the airport.

Cost-207 model [4] is an empirical method for modelling power delay profile. Cost-207 model assumes UHF-frequencies around 900 MHz. It gives normalized scattering functions, as well as amplitude statistics, for four classes of environments: Rural Area, Typical Urban, Bad Urban, and Hilly Terrain. The following PDFs are used:

- Rural area

$$P_h(\tau) = \begin{cases} \exp(-9.2\frac{\tau}{\mu s}) & for \quad 0 < \tau < 0.7\mu s \\ 0 & elsewhere \end{cases} \tag{1}$$

- Typical urban area

$$P_h(\tau) = \begin{cases} \exp(-\frac{\tau}{\mu s}) & for \quad 0 < \tau < 7\mu s \\ 0 & elsewhere \end{cases} \tag{2}$$

- Bad urban area

$$P_h(\tau) = \begin{cases} \exp(-\frac{\tau}{\mu s}) \, for \quad 0 < \tau < 7\mu s \\ 0.5\exp(5-\frac{\tau}{\mu s}) \quad for \quad 5 < \tau < 10\mu s \\ 0 \quad elsewhere \end{cases} \tag{3}$$

- Hilly terrain

$$P_h(\tau) = \begin{cases} \exp(-3.5\dfrac{\tau}{\mu s})\ for \quad 0 < \tau < 2\mu s \\ 0.5\exp(15 - \dfrac{\tau}{\mu s}) \quad for \quad 15 < \tau < 20\mu s \\ 0 \qquad elsewhere \end{cases} \tag{4}$$

Where $P_h(\tau)$ and τ are power delay profile and delay respectively.

3. MODİFİED COST-207

Characterizing the aeronautical channel is a difficult, non-unique task due to different scenarios happens in the airport like parking, taxi, en-route, landing and take-off. Therefore, a channel model should be as flexible and general as possible.

By definition, τ=0 refers to the LOS path and for other paths $\tau \geq 0$. Hence, τ is called excess delay, and is related to the distance via $\tau = \Delta d/c$, where c is the speed of light and equal to 3.10^8 m/s[5].

Delay power spectrum for parking, taxi and en-route (Air-Ground and Air-Air) scenarios are plotted in Figure 2. the spectra and its parameters were specified by COS-207.

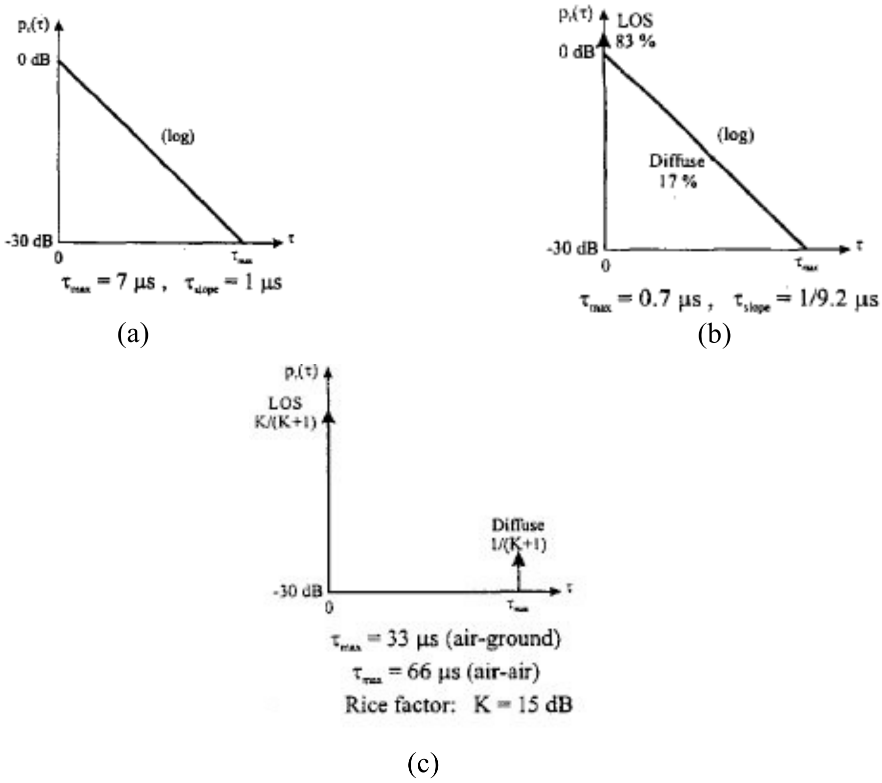
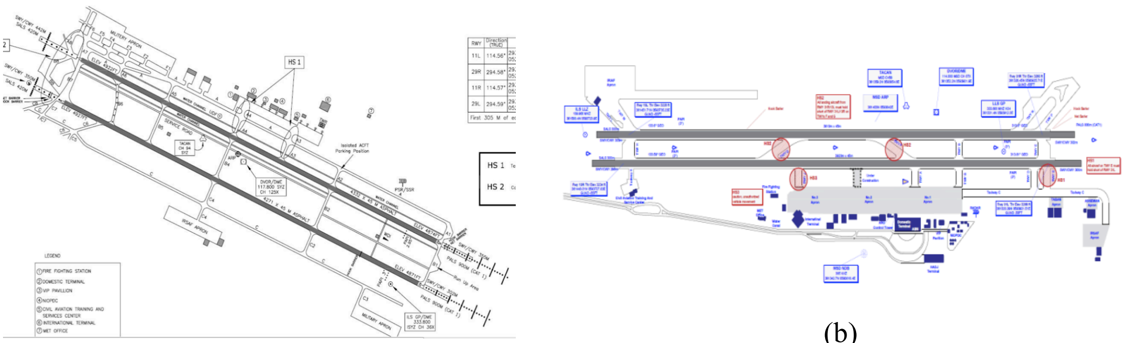


Figure 2. Delay power spectrum for a) parking b) taxi c) en-route scenarios[5].

A typical urban environment and a rural area are proposed for the parking and taxi scenario respectively. Although cost-207 can be used for these scenarios, it needs modifying for take-off and landing scenarios. To modify Cost-207 parameters for these scenarios, Ray tracing technique was applied to two airports: Shiraz Shahid Dastgheib International airport and Mashhad Shahid Hashemi Nejad International airport. The structures of the airports are necessary for ray tracing and are plotted in Figure 3.



(a) (b)

Figure 3. a) Shiraz Shahid Dastgheib International airport b) Mashhad Shahid Hashemi Nejad International airport.

After deriving buildings locations from the maps, ray tracing was applied to them. The algorithm used for first order reflection is demonstrated in Figure 4. Flowcharts for higher order reflections are plotted on Figure 5. Algorithm used for finding reflection point and obstacles is illustrated in Figure 6.

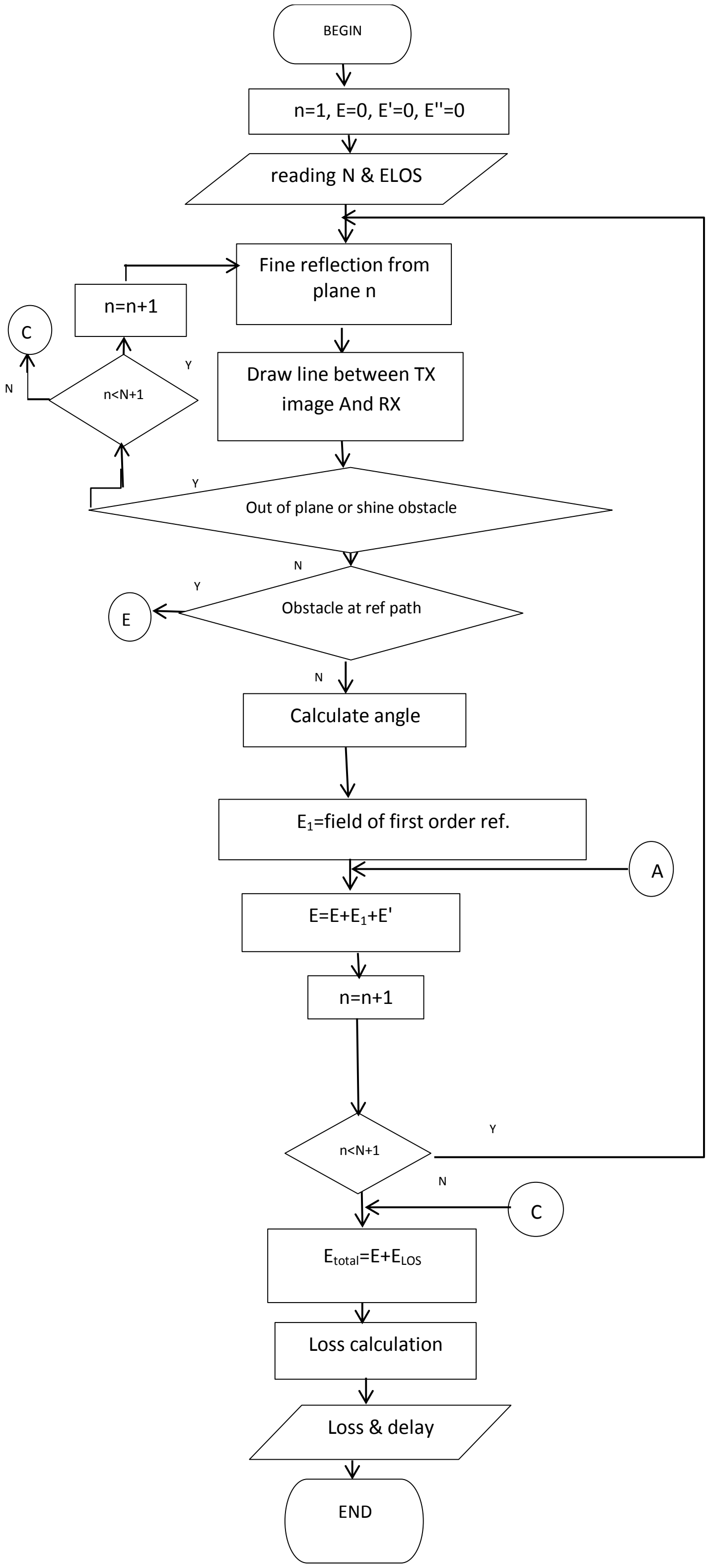
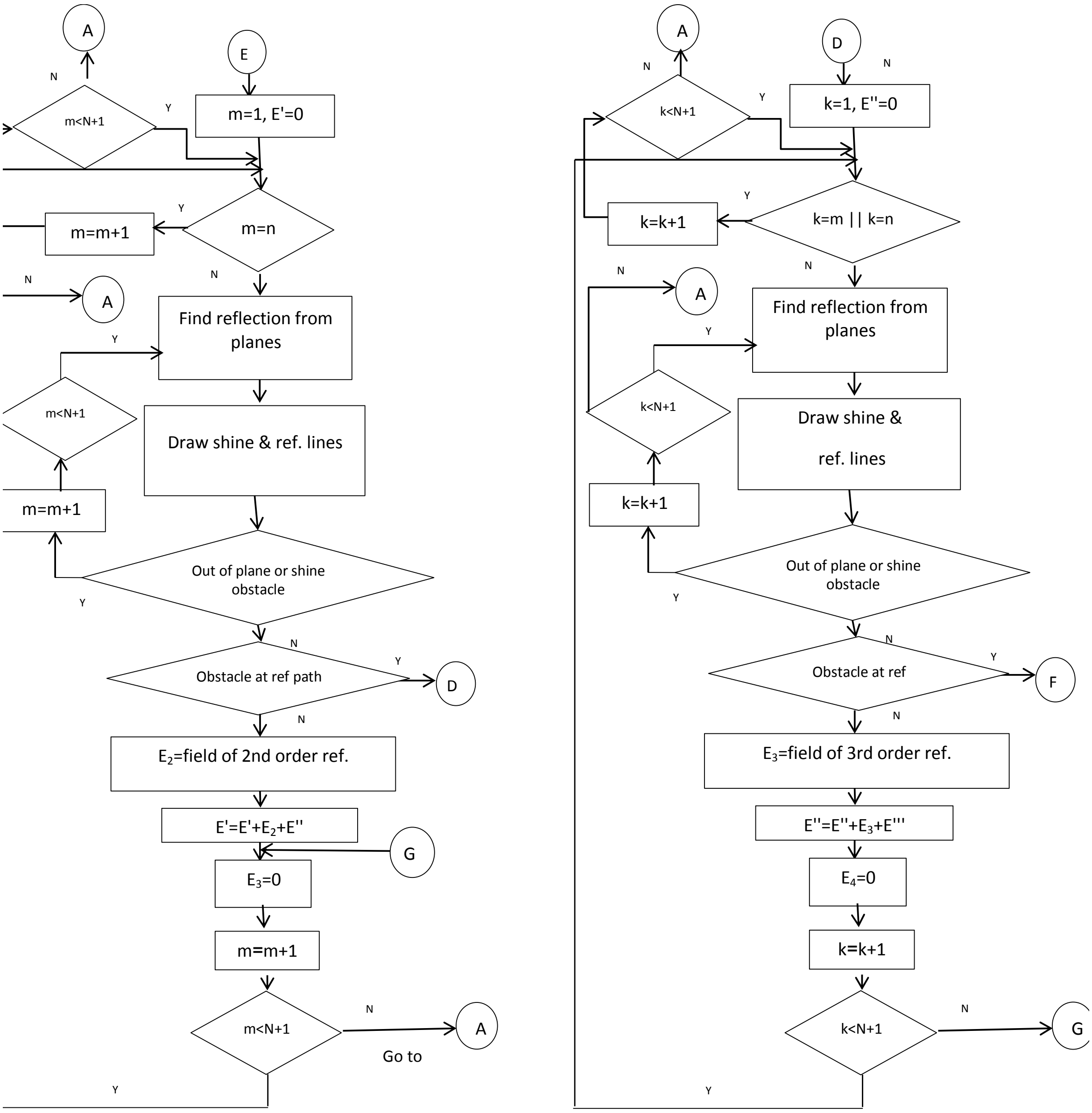
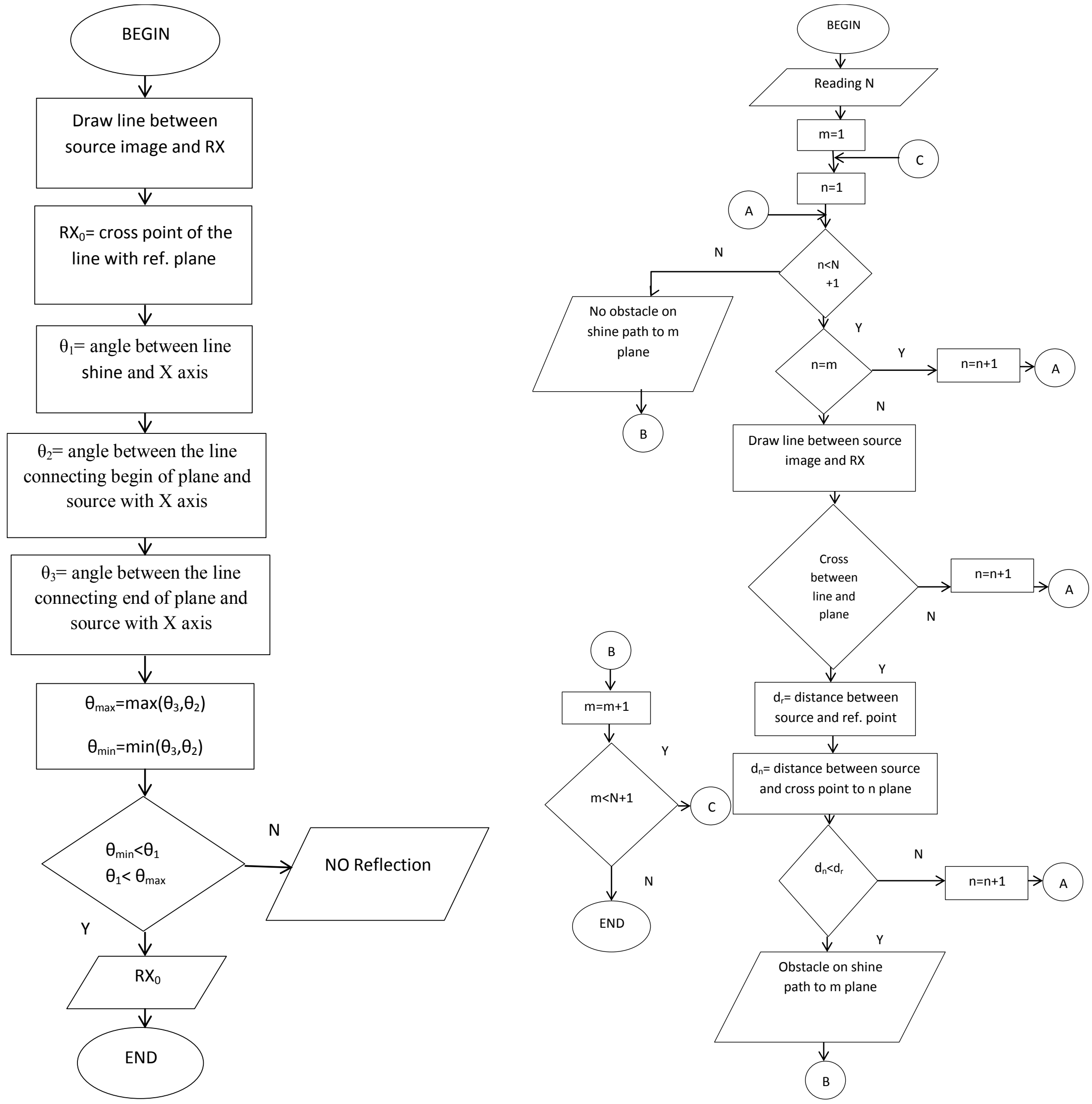


Figure 4. Flowchart of ray tracing for first order reflection.



(a) (b)

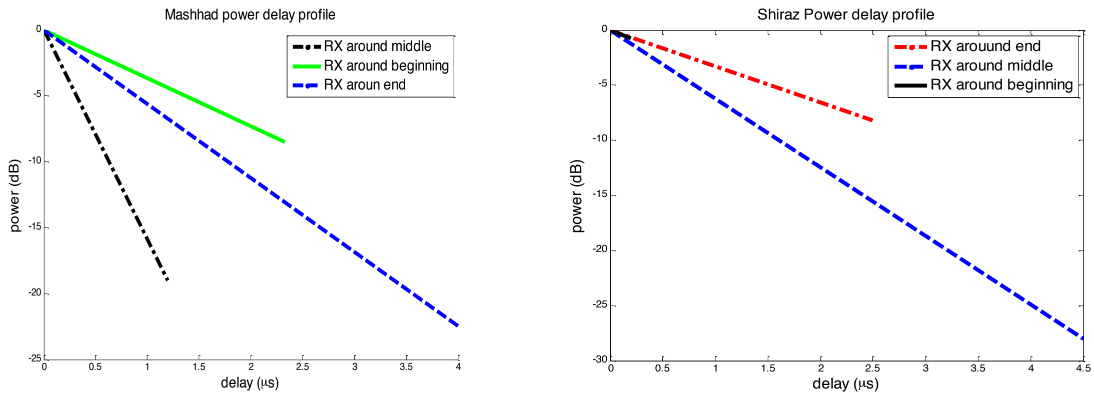
Figure 5. Flowchart of ray tracing for a) second order ref. b) third order ref.



(a) (b)

Figure 6. Flowchart of a) finding RX_0 b) finding obstacles

For simulating, RX locations were supposed to place in 3 regions: around the beginning, middle and ending of the band. Then, by considering the airplane approaching the band, delay of multipath propagation was calculated. At last, delay power spectrums in Figure 5 were obtained by averaging the results in each region.



(a) (b)

Figure 7. Delay power spectrum of a) Mashhad b) Shiraz airports

By modifying the Cost-207 model with ray tracing results, power delay profile equations at the beginning, middle and ending of the band are obtained as the following equations.

Mashhad airport:

- Beginning

$$P_h(\tau) = \begin{cases} \exp(-0.96\frac{\tau}{\mu s}), 0 < \tau < 5.5\mu s \\ 0, elsewhere \end{cases} \tag{5}$$

- Middle

$$P_h(\tau) = \begin{cases} \exp(-4.3\frac{\tau}{\mu s}), 0 < \tau < 1.5\mu s \\ 0, elsewhere \end{cases} \tag{6}$$

- End

$$P_h(\tau) = \begin{cases} \exp(-1.28\frac{\tau}{\mu s}), 0 < \tau < 4.5\mu s \\ 0, elsewhere \end{cases} \tag{7}$$

Shiraz airport:

- Beginning

$$P_h(\tau) = \begin{cases} \exp(-0.75\frac{\tau}{\mu s}), 0 < \tau < 6.5\mu s \\ 0, elsewhere \end{cases} \tag{8}$$

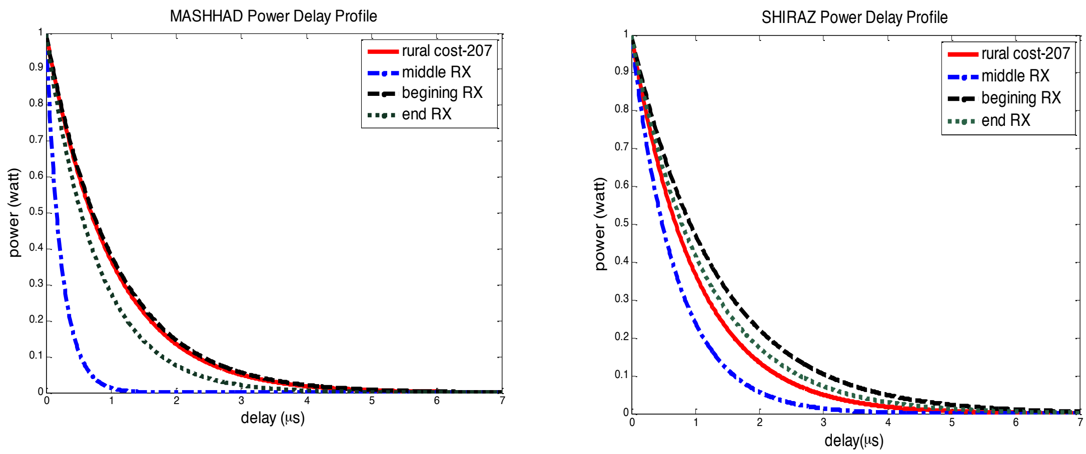
- Middle

$$P_h(\tau) = \begin{cases} \exp(-1.43\frac{\tau}{\mu s}), 0 < \tau < 4\mu s \\ 0, elsewhere \end{cases} \tag{9}$$

- End

$$P_h(\tau) = \begin{cases} \exp(-0.87\frac{\tau}{\mu s}), 0 < \tau < 5.5\mu s \\ 0, elsewhere \end{cases} \quad (10)$$

The modified Cost-207 model is plotted in Figure 6.



(a)

(b)

Figure 8. Modified cost-207 a) Mashhad b) Shiraz airports

4. CONCLUSIONS

In a multilateration system, finding the appropriate sites for the receivers is important. One of the effective elements in specifying the appropriate areas for placing receivers is delay spread. To study delay spread, power delay profile should be obtained for the airports. By using proposed ray tracing algorithm in the article, power delay profiles can be plotted. To illustrate this, two airports of Iran were selected and ray tracing was applied to them. Then, power delay profiles were obtained and cost-207 models for take-off and landing scenarios were modified. Ray tracing results and modified models can be used in order to distinguish maximum delay spread in different areas of the airports while airplane is approaching the band. Other parameters like SNR, LOS and TDOA error also should be noticed in order to find appropriate locations. The same algorithm can be used for finding power delay profile in other airports with similar structure.

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