POLITECNICO DI MILANO

Master of Science in Telecommunication Engineering

Study on propagation path loss in 28GHz and 39GHz and key parameters for 5G

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Abstract

The transmission rate and transmission quality of communication system are restricted by wireless channel. To solve the challenge of wireless communication, the problem of signal coverage must first be solved. Based on the requirement of next generation wireless communication , this paper studies on the propagation characteristics of fifth generation communication candidate band 28GHz and 39GHz channel, and analysis results are of great significance to the deployment of 5G network.

Astratto

La velocità di trasmissione e la qualità di trasmissione del sistema di comunicazione sono limitate dal canale wireless. Per risolvere la sfida della comunicazione wireless, è necessario innanzitutto risolvere il problema della copertura del segnale. Basandosi sul requisito della comunicazione wireless di prossima generazione, questo documento studia le caratteristiche di propagazione dei canali di comunicazione di quinta generazione a 28GHz e 39GHz e i risultati dell'analisi sono di grande importanza per l'implementazione della rete 5G.

contents

1 Introduction

1.1 Research background

With the rapid and steady progress of the economy and the rapid development of science and technology , we are urgently required to communicate with others at any time and place at any time , and this communication service needs a mobile communication system to achieve it . The mobile communication system is a system that covers both sides of the communication equipment. It includes cellular mobile communication system, wireless paging, cordless telephone system, cluster mobile communication system , satellite mobile communication system and mobile communication system center and so on . Cellular system is one of the most widely used systems in communication systems. The advantage of that are a lot of novelty relative to the past technology and huge network coverage.

The demand for information transmission is higher and higher. In the past ,the radio communication in the troposphere often uses low frequency bands ,which causes the problem of frequency congestion in the frequency band blow the millimeter wave. At the same time ,it is difficult to adapt to the the new requirements of the large capacity, low cost and portable communication needed by the internet age.

1.2 The introduction of 5G

5G refers to the fifth generation of mobile communication technology, which is the integration of wireless communication technology. Compared with the spectrum below 6GHz, millimeter wave bandwidth is very rich , its antennas tend to be miniaturized, antenna gain is higher ,and can be used as long authorized. So millimeter can be used by operators all over the world. At the present, the peak rate can reach 100Mbp/s,and the peak rate of 5G can reach 10Gbp/s, which is 100 times faster than that of 4G. 5G will introduce more advanced technology to solve these problems faced by 4G network communication ,improve the spectrum efficiency, enrich the spectrum resources , meet the requirements of social development and human progress, and build a network society with high efficiency , large capacity ,low delay , reliable and good user experience. For 5G communications , the International Telecommunication Union(ITU), and the Third Generation Partnership Program (3GPP) have jointly planned the two phase of the 5G standard.

From May 21st to 25th 2018 , the 3GPP working group of the International Mobile Communications Standardization Organization held the final meeting of the first phase of 5G standards development in Busan, South Korea. It is reported that this meeting will determine the full content of the 3GPP R15 standard. It is expected that 3GPP will announce the first phase of the 5G standard at the plenary meeting held in the United States next month.

1.3 Thesis outline

To solve the challenge of wireless communication, the problem of signal coverage should be solved. Based on the requirement of next generation wireless communication , this paper studies on the propagation characteristics of fifth generation communication candidate band 28GHz and 39GHz channel, and analysis results are of great significance to the deployment of 5G network.

2 Some characteristic introductions of 5g

2.1 Introduction of milliwave(millimeter wave)

Milliwave means the lower wave part which can avoid disturbing from other factors, but the disadvantage is the propagation distance no more than 50km.Milliwave has the advantage of large communication capacity, narrow beam, high resolution,strong anti-interference, good security, some weight , easy carrying and assemble, so it has a wide application prospect in civil and military fields.

The military applications mainly include space navigation and maritime navigation ,as well as location, detection and tracking of the research targets, such as monitoring , navigation, weather radar, measurement, and surveying and mapping in public. In the science area, it is applied to astronomy, cartography, imaging, precise distance measurement and remote sensing of natural resources.

The 4G technologies are quickly going to reach their limits to meet this demand of people. This has resulted in the search for technologies to help increase the available bandwidth. Millimeter wave (mm Wave) technology, wherein communication happens in the spectrum range of 3 – 30 GHz, appears to be one of the promising technologies. MilliWave communication technology has been around for a while.

The typical character of milliwave is that its short wavelength and milliwave part have considerable spectrum resources, which can effectively solve the difficult of shortage frequency resources. The short wavelength of the milliwave can get more available space dimension,which makes the transfer antenna more miniaturized,the small base stations will become one group and low frequency Acer station at the emitter to achieve seamless access. The multi antenna working in the milliwave is the character of high direction of narrow beam,which solves the problem of channel interference and low security. So milliwave is the best choice for the 5g system.

2.2 MIMO

MIMO(Multiple input multiple output), means there are amounts of transmit antennas and receiving antennas at the transmitter and receiver to transmit and receive signals through multiple antennas at the transmitter and receiver end, which can improve the quality of communication. It can make full use of space resources and multiply multiple antennas though multiple antenna, without increasing the spectrum resources and transmitting power of antenna, it can multiplied the capacity of the system channel, showing obvious advantages and being regarded as the core technology of the next generation mobile communication.

The MIMO technology has the advanced signal processing is a important part in the communication development history, and the MIMO technology can effectively overcome the problem of absorption and attenuation effect of milliwave by the atmosphere and the shielding effect of terrain and surface objects.[1]

2.2.1.Modulation

Figure 2.1 gives the frame of MIMO communication system which includes transmit antennas n and receive antennas m. The channel model of this framework can be expressed as :

$$y(t) = \int_{\tau} H(t,\tau)x(t-\tau)d\tau + n(t) \qquad (2\text{-}1)$$

X(t) is the vector of n1 dimension, which is the vector of the signal at the time of T, y(t) is the vector of M, which is a vector that receives the signal at the time t, H(t) is the matrix of m n .[2]

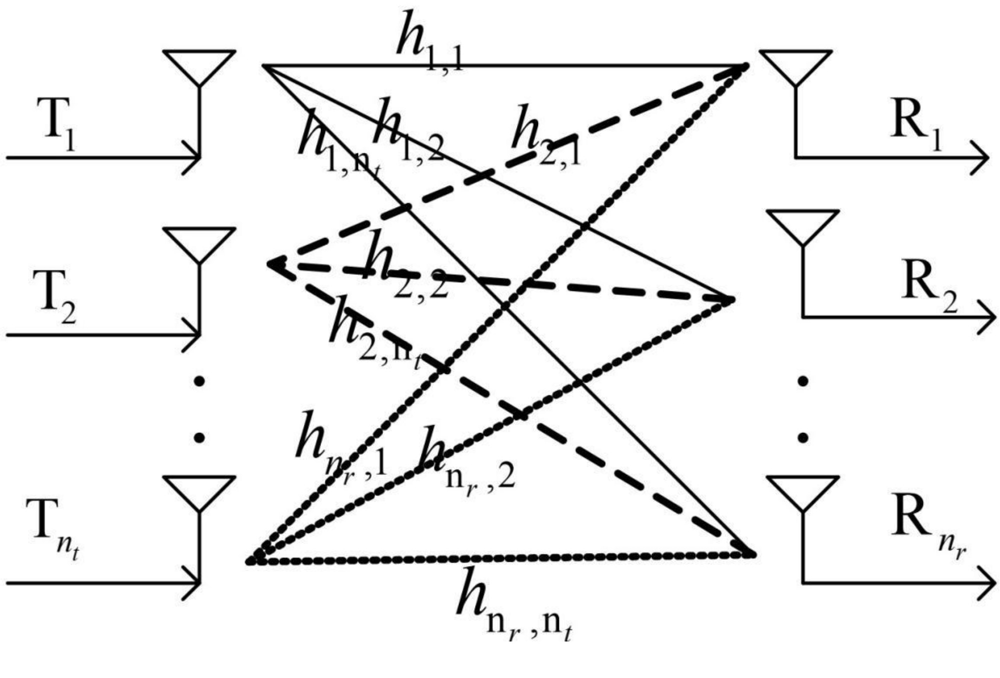


Fig.2.1. MIMO system

2.2.2 EQUALIZATION

Inter symbol Interference is introduced, When the bandwidth of modulated signal crosses the coherence bandwidth of the channel. To reduce and compete this influence, different type of equalization techniques are used at the receiver.

1. Zero Forcing Equalizer(performance of MIMO system under different fading channel with ZF and MRC , Aishwary jain, Pankaj Shukla , Lokesh Tharani ,2017 Recent development in control ,Automation, and Power engineering (RDCAPE))

For making the ISI part in the output reach the 0, ZF will use a Linear Time Invariant Filter of an appropriate transfer function. If F(t) is the channel frequency response, the zero forcing receiver C(f) can be expressed as :

$$C(f) = \frac{1}{F(f)} \quad (2\text{-}2)$$

The frequency response is a linear equalization algorithm:

$$y1 = h1{,}1x1 + h1.{,}2x2 + n1 = [\; h1{,}1 \quad h1{,}2 \;] \begin{bmatrix} x1 \\ x2 \end{bmatrix} + n1 \quad (2\text{-}3)$$

Then the second antenna will receive:

$$y2 = h2{,}1x1 + h2.{,}2x2 + n2 = [\; h2{,}1 \quad h2{,}2 \;] \begin{bmatrix} x1 \\ x2 \end{bmatrix} + n2 \quad (2\text{-}4)$$

y1 and y2 are the signals received in the first and second antenna, h1,1 is the channel from first antenna to first receive antenna; h1,2 is the channel from second antenna to the first receive antenna; h2,1 is the channel from first antenna transmits signal to second receive antenna; h2,2 is the second antenna transmits signal to the second receive antenna. X1 and X2 is the transmitted symbols. N1 and na2 are the noise on the first and second receive antenna .

We also can write it use the matrix notation :

Y=Hx+n

Fig2.2 is the matrix about the expand of h. The ZF needs meet the requirement that WH=I.

After the analyzing we can know some theory of MIMO and MIMO will be the key technology in the 5g.

$$\mathbf{H} = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1n_t} \\ h_{21} & h_{22} & \cdots & h_{2n_t} \\ \vdots & \vdots & \ddots & \vdots \\ h_{n_r1} & h_{n_r2} & \cdots & h_{n_rn_t} \end{bmatrix}$$

Fig.2.2 matrix about the expand of h

2.3 large scale and small scale model

Wireless channel fading mechanism can be divided into large scale model and small scale model, large scale fading model is divided into path loss and shadow fading and small scale fading model is divided into multipath frequency selective fading, flat fading), Doppler (fast fading and slow fading).Large scale propagation model in general will have a great distance scope changes, mainly small scale model between transmitter and receiver signal amplitude phase changes, such as time domain and frequency domain the airspace of the tiny change in signal change. Large scales are generally within a few hundred thousand meters, and the receiving signal decreases as the distance increases.

2.3.1 large scale path loss model

In wireless communication ,the path loss caused by distance and shadow fading caused by the gerontological shelter are called slow fading. The free space model obtained by the propagation principle of electromagnetic waves in free space is the most basic model.

If the transmitter power is p_T ,and the emission source will be surrounded by power, and is evenly distributed on the sphere of radius d, the power per unit area can be obtained:

$$p_d = \frac{p_T}{4\pi d^2} \qquad (2.3\text{-}1)$$

The power of receive antenna:

$$p_R = \frac{p_T G_T}{4\pi d^2} A_{eff} \qquad (2.3\text{-}2)$$

and for $A_{eff} = \frac{\lambda^2}{4\pi} G_R$ .which is active area ,substitute into (2.3-2),we can get :

$$p_R = A_{eff}\, p_T G_T G_R \left(\frac{\lambda}{4\pi d}\right)^2 \qquad (2.3\text{-}3)$$

Path loss is:

$$PL(dB) = 10\log\frac{p_T}{p_R} = -\log\left[\frac{G_T G_R \lambda^2}{(4\pi d)^2}\right] \qquad (2.3\text{-}4)$$

The formula (2.3-4) is called Fri is free space model. The applicable condition of this model is that the distance of the domain transmitting antenna which satisfies the long distance condition. That is the famous Bonhoeffer distance of the antenna design:

$$d > d_f = \frac{2D^2}{\lambda} \qquad (2.3\text{-}5)$$

d is the biggest effective size of the antenna , and λ is the wavelength of transmitting. The assumption that there is a ground reflection and only one reflection path, in fact,this is a good agreement with the actual results. When d>> $\sqrt{h_T h_R}$, the ground reflection model is :

$$p_R = p_T G_T G_R \left(\frac{h_T h_R}{d^2}\right)^2 \qquad (2.3\text{-}6)$$

Express the formula (2.3-6) use the dB:

$$PL(dB) = 40\lg d - (10\lg G_T + 10\lg G_R + 20\lg h_T + 20\lg h_R) \qquad (2.3\text{-}7)$$

The large scale outdoor propagation model is mainly based on the topography and the nature of electromagnetic waves and the actual measurement. Through actual measurement, it is found that in the same frequency band, the amplitude of the signal changes very fast even in a short time . Radio electromagnetic waves in mobile communication systems are usually transmitted under irregular geographical conditions. During the loss of the budget path , the geographical environment of a particular area should be fully considered, such as altitude ,vegetation cover or occlusion and the shelter of buildings should be considered. There are many propagation models that can predict irregular terrain path loss, but these methods differ greatly in terms of complexity, accuracy and the scope of application.

For another large scale model ,This model is made by the Euro Cost organization. Because of the Hata model, the propagation distance is more than LKM, but the use frequency is 2.0GHz, the macro cellular communication system , the base station antenna is 30m to

200m and the antenna of the mobile is 10m. compared with the Okumura, the Hata model, the frequency attenuation coefficient is different and increases the consideration of the center attenuation in the metropolitan area. The application frequency of these path loss models, the propagation distance and the height of the antenna are totally different. Any communication environment should be measured according to the specific science and select the appropriate parameters to play the role of there models, so as to provide a reliable reference for the link budget, coverage area and capacity evaluation.

2.3.2 small scale path loss model

Unlike large scale model, the small scale path loss model is a fast change of receiving level in the short time. This is due to the arrival of multiple signals from different paths to receiving antennas, and interference caused by different phase superposition. In short , small scale model is attributed to multipath propagation ,movement speed, speed of surrounding objects , and bandwidth of signal transmission. Because of the multipath of the wireless channel. In time domain: multipath delay spread of wideband signal will cause frequency selective fading. The time domain parameters of the channel are equalized with the average additional delay and RMS delay extension, in which the average additional delay τ is the first moment of the power delay distribution(PDP,Power Delay Profile).

Bibliography	situation	Frequency (Hz)	LOS/NLOS	Average additional delay(ns)	RMS delay spread(ns)
	Large building	850M	LOS		270
	Large building	1.7G	LOS		150
	Large building	4.0G	LOS		130
	Indoor hot-spot	2.4G	LOS	30.37	420.39
	Indoor hot spot	2.4G	NLOS	42.90	270.20
	Indoor hotspot	3.7G	LOS	224.3	47.79
	Indoor hotspot	3.7G	NLOS	303.8	64.66
	Indoor	3.7G	LOS	387	50.9

	hotspot				
	Indoor hotspot	3.7G	NLOS	416.2	80
	Indoor office	28G	LOS	17.2	16.4
	Indoor office	28G	NLOS	17.8	12.5
	Indoor office	28G	LOS-Best	4.1	1.6
	Indoor office	28G	NLOS-Best	13.4	13.1
	Indoor office	73G	LOS	12.1	17.2
	Indoor office	73G	NLOS	10.7	13.0
	Indoor office	73G	LOS-Best	3.6	1.5
	Indoor office	73G	NLOS-Best	11.3	14.4

table2.3.2-1 Small scale characteristic parameters of channel

3 Path loss model

3.1 introduction of CI ,FI and ABG model

This paper shows and compares the two candidate large-scale φ propagation path loss models, the close-in (CI) free space reference distance mode(1m) and the floating intercept(FI).

(1)The CI path loss model accounts for the frequency dependency of path loss by using a CI reference distance(1m) based on Friis' law as given by

$$PL^{CI}(f_c, d_{3D})[dB] = FSPL(f_c, 1m) + 10n\log_{10}(d_{3D}) + \chi_{\sigma}^{CI}$$

Where χ^{CI} is the shadow fading(SF) ,n denotes the single model parameter ,the path loss exponent(PLE), and the 10n describing path loss in dB in terms of decades of distances beginning at 1m , d is the distance of 3D T-R separation. For the FSPL(f,1m) means the free space path loss in dB at a T-R separation distance of 1m at the carrier frequency f :

$$FSPL(f, 1m)[dB] = 20\log_{10}(\frac{4\pi f}{c})$$

Where c is the speed of light .

The CI model is based on the basic principles of wireless propagation, dating back to the the Friis and Bullington, where the PLE offers insight into path loss according to the environment, having a value of 2 in free space as shown by Friis and a value of 4 for the asymptotic two-ray ground bounce propagation model.

2)For the FI PL model is :

$$PL[dB] = 10\alpha \log_{10}(d) + \beta + X_{\sigma}$$

α is the dependency coefficient with respect to the distance , β is the path loss offset determined typically by the measurement data.

3）ABG model ($\alpha\beta\gamma$ model)

The equation for the ABG model is :

$$PL^{ABG}(f,d)[dB] = 10\alpha \log_{10}(\frac{d}{1m}) + \beta + 10\gamma \log_{10}(\frac{f}{1GHZ}) + \chi_{\sigma}^{ABG}$$

Where $PL^{ABG}(f,d)[dB]$ means the path loss in dB over frequency and distance , α,γ are the parameters of path loss which shows the dependence about distance and frequency ,respectively. β is the optimized offset value for path loss in dB, f is the carrier frequency in GHz,d is the 3D T-R(transmitter to receiver) separation distance in meters, the χ_{σ}^{ABG} is the shadow fading standard deviation.

The CI model is the main model which is always selected to analyse in more papers and the FI and ABG model are similar but FI PL model is more convenient because less parameters. So in this essay we just focus CI path loss model and FI path loss model and make the simulations and analysis about this two models.

3.2 the introduction of some scenarios

For this paper we will choose the four major organizations in the past two years are reviewed and compared for analyzing the path loss . These organizations include:

1) The 3rd Generation Partnership Project (3GPP TR 38.901),which provides the 0.5-100GHz’s channel models.This organization works continually to serve as the international industry standard for fifth generation cellular.

2) 5G Channel Model(5GCM),this organization based on extensive measurement campaigns and helped seed 3Gpp understanding for TR 38.900

3) Mobile and wireless communication Enablers for the Twenty-twenty information society(METIS),which is laying the foundations of Fifth Generation (5G) mobile and wireless communication system. METIS envisions a fifth generation system main concept that efficiently integrates the new applications developed in the METIS horizontal topics .

4) Millimeter-wave Based Mobile Radio Access Network for 5G Integrated Communicants(mmMAGIC),The mmMAGIC project was co-funded by the European Commission ’ s 5G PPP program, bringing together the main company and organization (Samsung, Ericsson, Alcatel-Lucent, Huawei, Intel, Nokia), the major European operators

(Orange, Telefonica), which leads research institutes and universities (Fraunhofer HHI, CEA LETI, IMDEA Networks, Universities Aalto, Bristol, Chalmers and Dresden), measurement equipment vendors (Keysight Technologies, Rohde & Schwarz) and one SME (Qamcom)

Because the 5GCM has simple and clear statistics and parameters so this essay will focus on the data from 5GCM to compare the large-scale path loss of 28GHz and 38GHz in the UMa and UMi scenarios. And in 5GCM the FI and ABG have a same parameters and formulas.For the UMi scenario in the 5GCM UMi-street Canyon LOS ,5GCM UMi-street Canyon NLOS, 5GCM UMi-Open square LOS, UMi-Open square LOS .For the UMa scenario we have 5GCM UMa LOS , 5GCM UMa MLOS.

4 Simulation

4.1 the comparison of some specific scenarios

There are some group simulations including:

Group one :

5GCM UMi-street canyon LOS and 5GCM UMi-open square LOS、

5GCM UMi-street canyon LOS and 5GCM UMi-open square LOS 、

5GCM UMi-street canyon NLOS and 5GCM UMi-open square NLOS i、

5GCM UMi-street canyon NLOS and 5GCM UMi-open square NLOS in 28GHz and 39GHz

Group two:

5GCM UMi-street canyon LOS in 28GHz and 39GHz

5GCM UMi-open square LOS in 28GHz and 39GHz

5GCM UMi-street canyon NLOS in 28GHz and 39GHz

5GCM UMi-open square NLOS in 28GHz and 39GHz

5GCM UMa LOS in 28GHz and 39GHz

5GCM UMa NLOS in 28GHz and 39GHz

And in NLOS we also have the comparison between CI and FI

After the comparison we will also make the discuss with the model built by others.

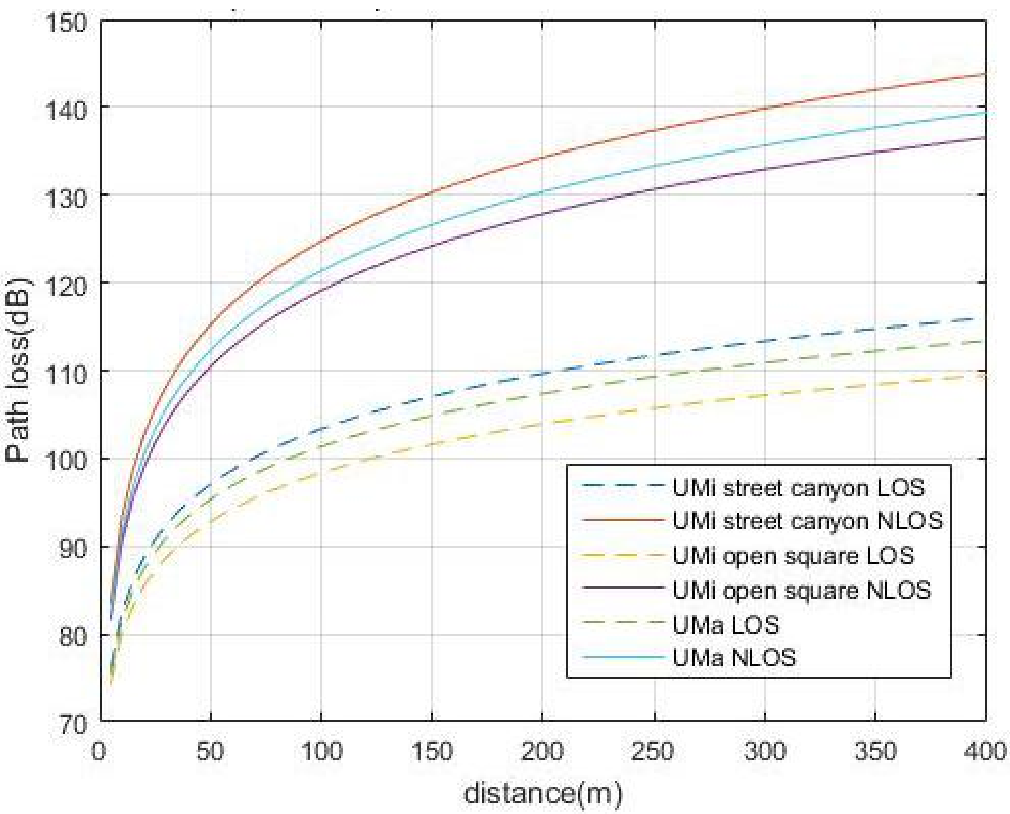
4.2 [3]simulation results and analysis

	PL [dB], f_c is in GHz and d_{3D} is in meters	Shadow fading std [dB]	Applicability range and Parameters
	5GCM [12]		
5GCM UMi-Street Canyon LOS	**CI model with 1 m reference distance:** $PL = 32.4 + 21\log_{10}(d_{3D}) + 20\log_{10}(f_c)$	$\sigma_{SF} = 3.76$	$6 < f_c < 100$ GHz
5GCM UMi-Street Canyon NLOS	**CI model with 1 m reference distance:** $PL = 32.4 + 31.7\log_{10}(d_{3D}) + 20\log_{10}(f_c)$ **ABG model:** $PL = 35.3\log_{10}(d_{3D}) + 22.4 + 21.3\log_{10}(f_c)$	$\sigma_{SF} = 8.09$ $\sigma_{SF} = 7.82$	$6 < f_c < 100$ GHz
5GCM UMi-Open Square LOS	**CI model with 1 m reference distance:** $PL = 32.4 + 18.5\log_{10}(d_{3D}) + 20\log_{10}(f_c)$	$\sigma_{SF} = 4.2$	$6 < f_c < 100$ GHz
5GCM UMi-Open Square NLOS	**CI model with 1 m reference distance:** $PL = 32.4 + 28.9\log_{10}(d_{3D}) + 20\log_{10}(f_c)$ **ABG model:** $PL = 41.4\log_{10}(d_{3D}) + 3.66 + 24.3\log_{10}(f_c)$	$\sigma_{SF} = 7.1$ $\sigma_{SF} = 7.0$	$6 < f_c < 100$ GHz

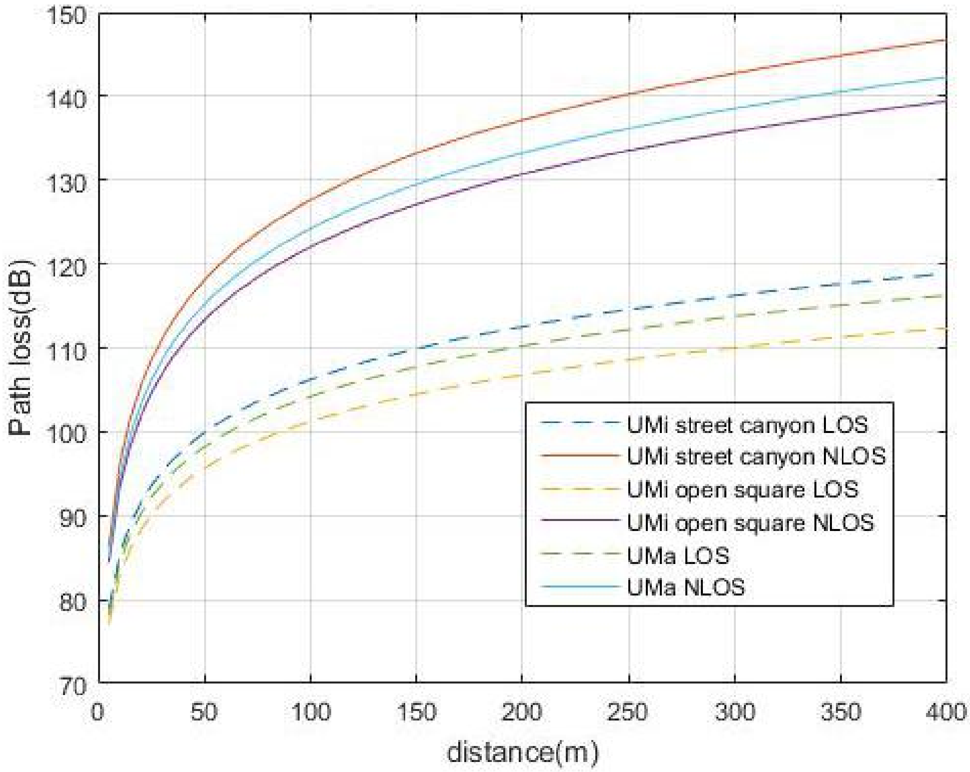
Fig 4.2-1 The statistic of CI model

	PL [dB], f_c is in GHz, d is in meters	Shadow fading std [dB]	Applicability range and Parameters
	5GCM [12]		
5GCM UMa LOS	**CI model with 1 m reference distance:** $PL = 32.4 + 20\log_{10}(d_{3D}) + 20\log_{10}(f_c)$	$\sigma_{SF} = 4.1$	$6 < f_c < 100$ GHz
5GCM UMa NLOS	**CI model with 1 m reference distance:** $PL = 32.4 + 30\log_{10}(d_{3D}) + 20\log_{10}(f_c)$ **ABG model:** $PL = 34\log_{10}(d_{3D}) + 19.2 + 23\log_{10}(f_c)$	$\sigma_{SF} = 6.8$ $\sigma_{SF} = 6.5$	$6 < f_c < 100$ GHz

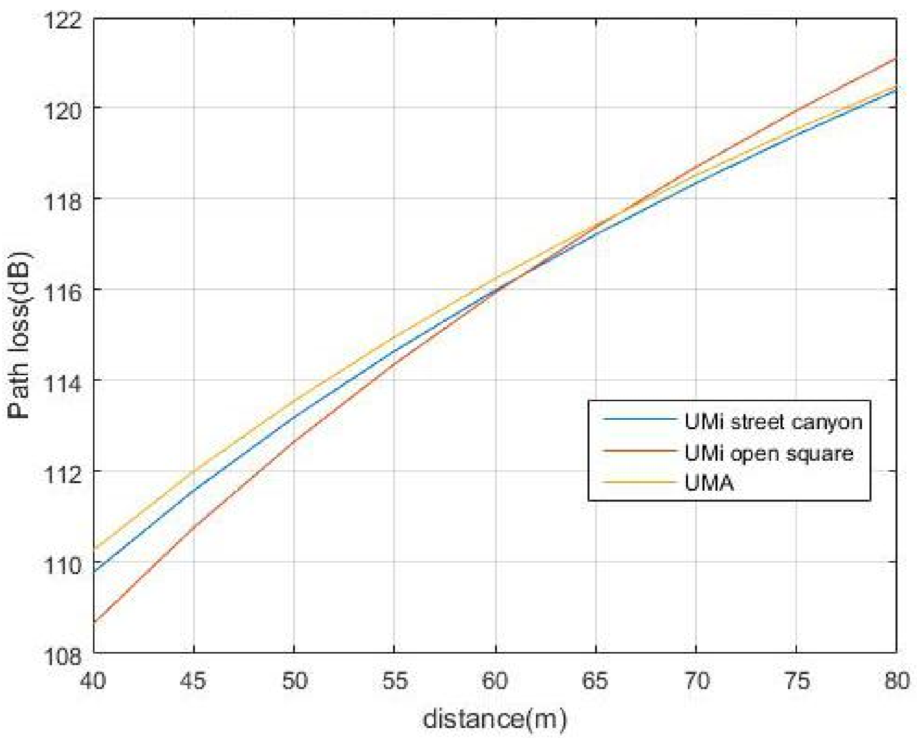
Fig 4.2-2 The statistic of FI model



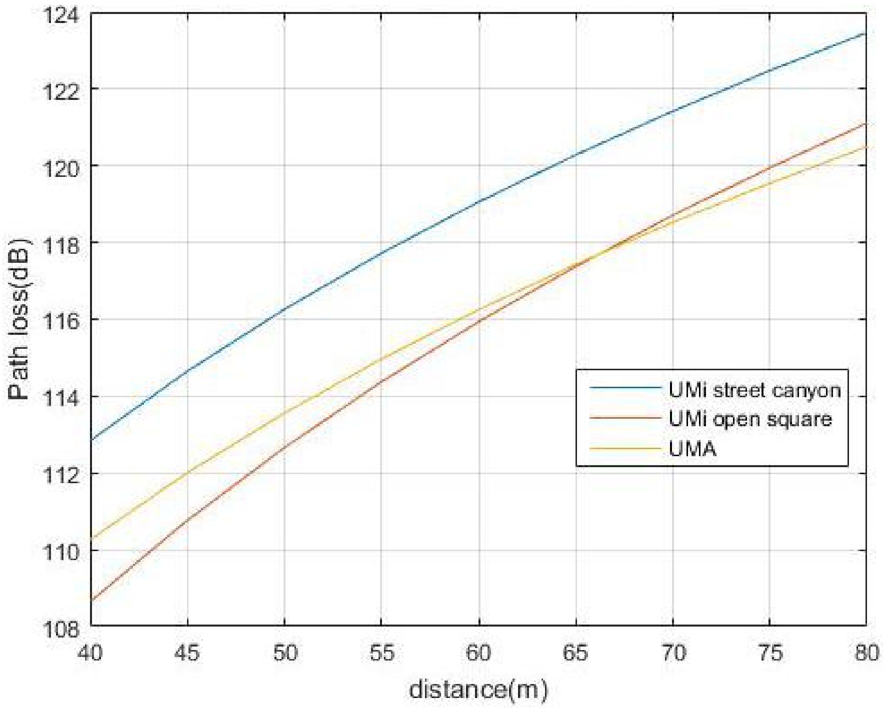
This picture shows the path loss in CI model among different situations including UMi street canyon LOS and NLOS, UMi open square LOS and NLOS, UMa LOS and NLOS. From this picture we can see the path loss in NLOS always higher than in LOS ,and in street will have a higher path loss in LOS and NLOS.



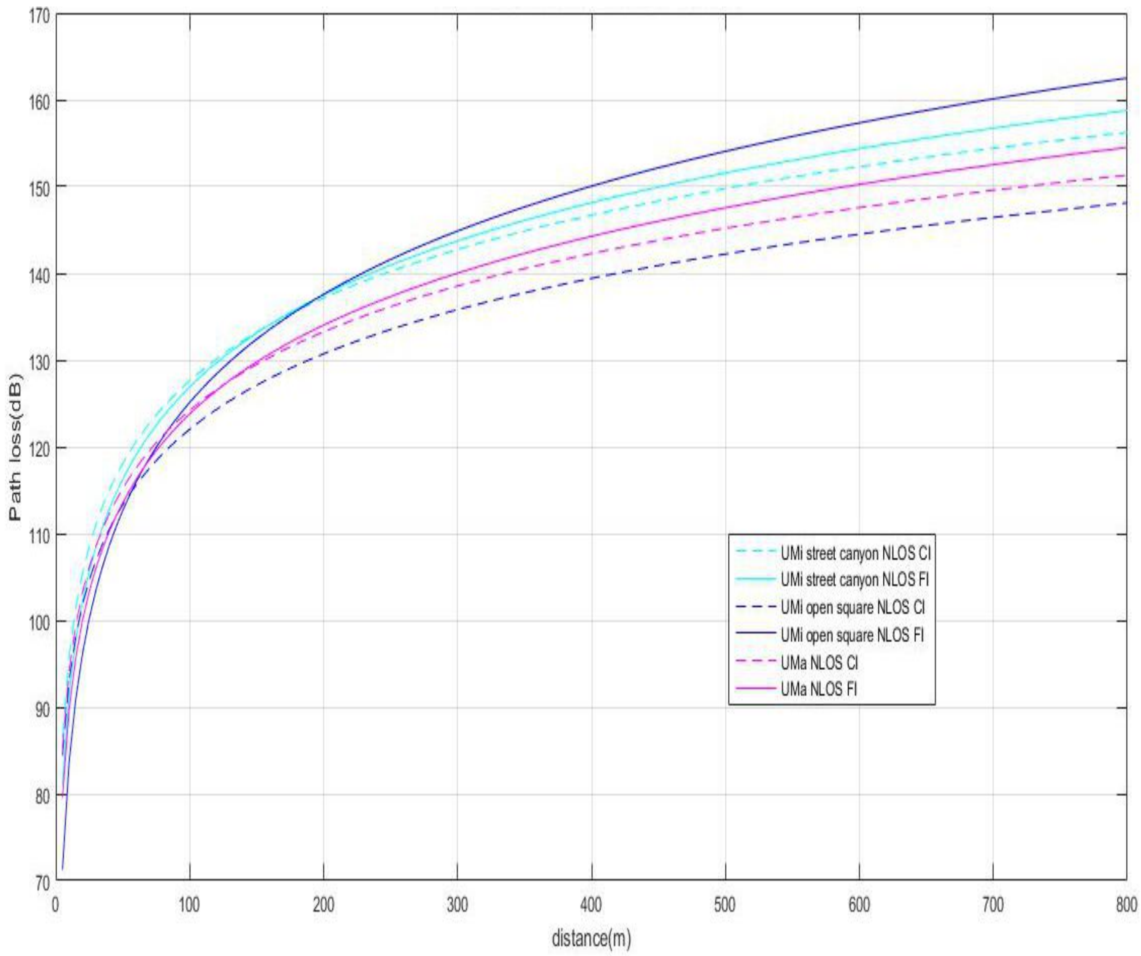
This picture shows the path loss in CI model in 39GHz among different situations including UMi street canyon LOS and NLOS, UMi open square LOS and NLOS, UMa LOS and NLOS. From this picture we can see the path loss in NLOS always higher than in LOS ,and in street will have a higher path loss in LOS and NLOS.



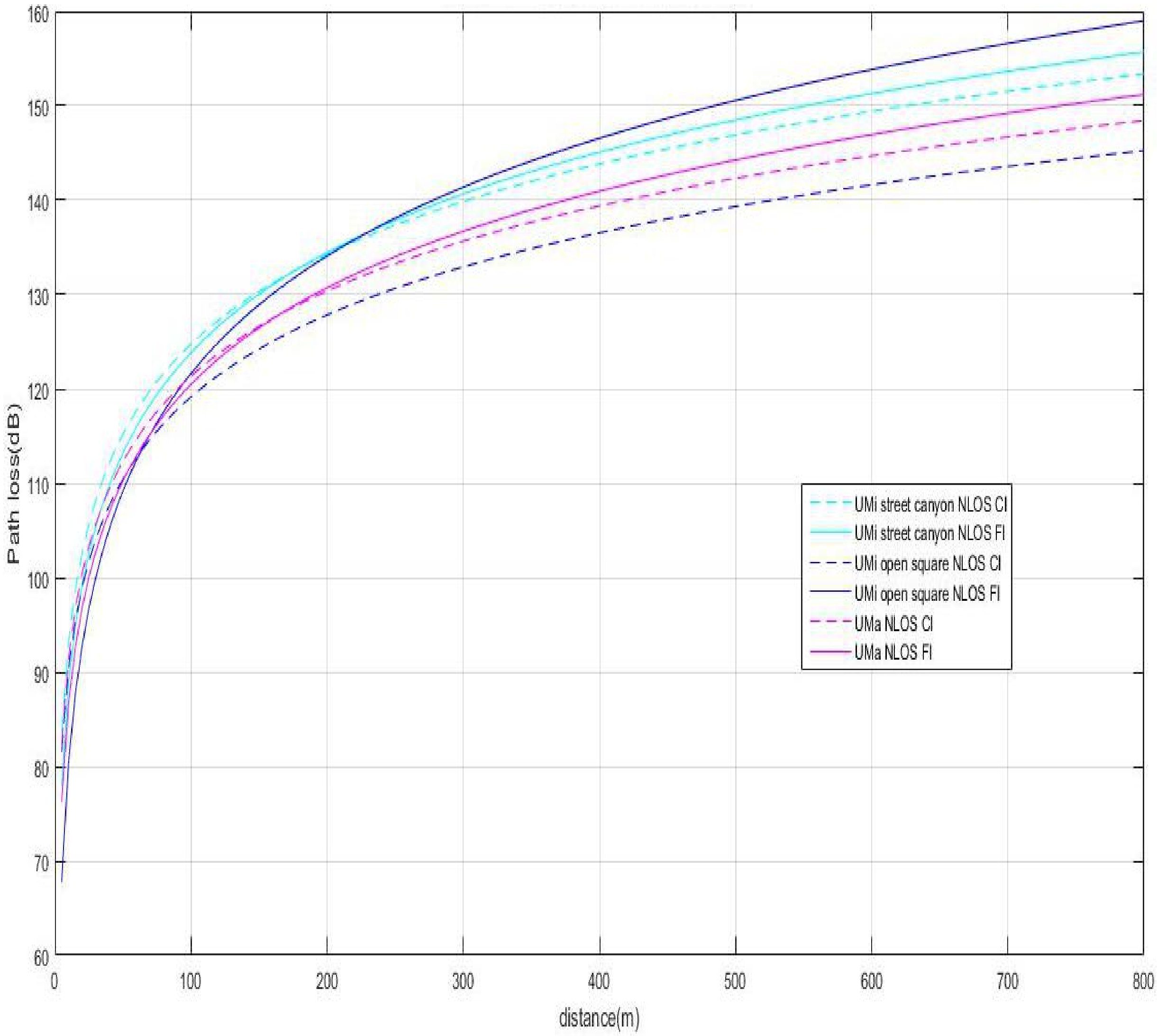
This picture shows the UMi street canyon ,UMi open square and UMA in NLOS FI model 28GHz. From this picture we can see in the short distance UMA will have a low path loss but after 67m it will have a largest path loss than another two.



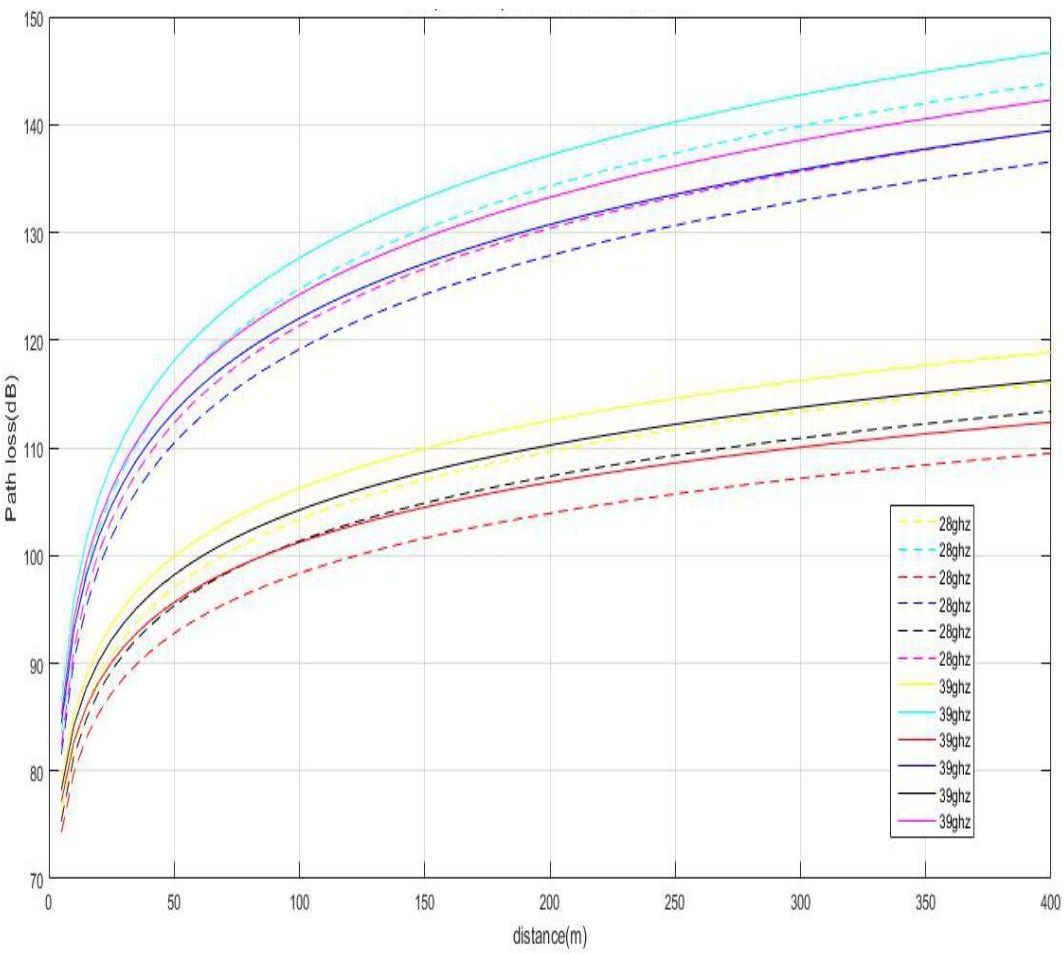
This picture shows the UMi street canyon ,UMi open square and UMA in NLOS FI model in 39GHz. From this picture we can see the UMi street canyon always has a largest path loss than another two situation from the short distance to long distance .



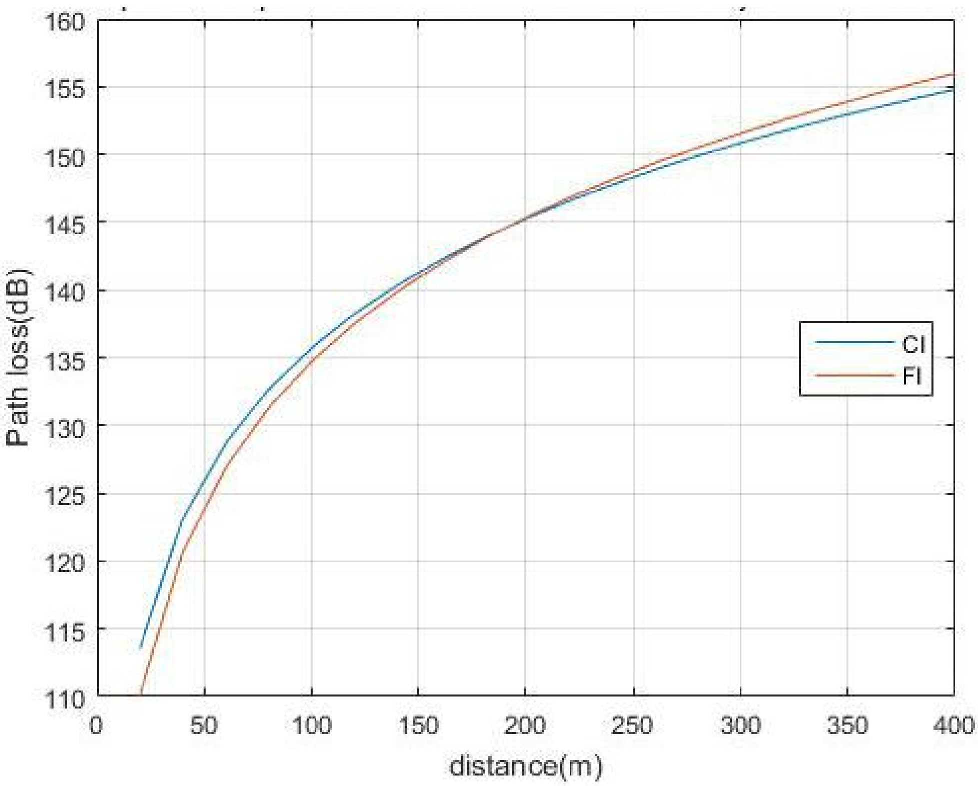
From this simulation we can get UMi open square NLOS FI will have largest path loss in 39GHz than others after 230m



From this simulation we can get UMi open square NLOS FI will have largest path loss in 28GHz than others after 270m.



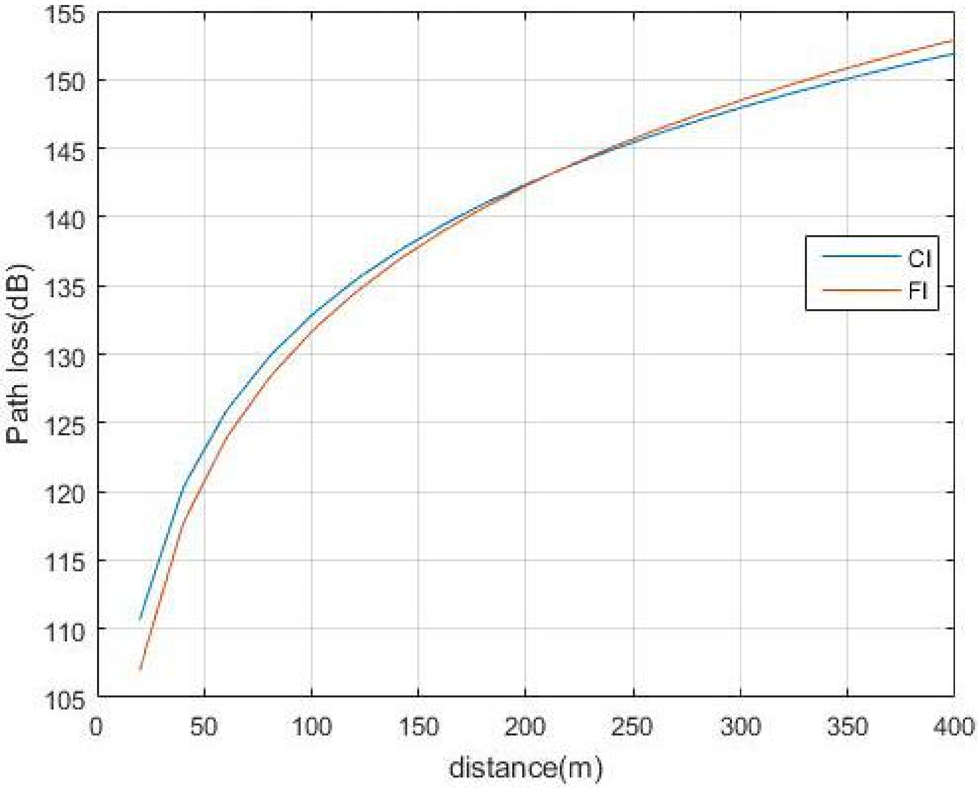
This simulation shows the comparison of 28GHz and 39GHz in some situations. From this simulation , we can see the situation in 28GHz will have a large path loss than in 39GHz .



	n/A	B	FSPL(f.1m) (dB) / G	σ_{SF} (dB)	F(dB)
CI	3.17		32.4+20lg(f)	8.09	39
FI	3.53	22.4	2.13	7.82	39

Table 4.2-3 parameters in the ABG and CI path loss models in UMI and UMA scenarios

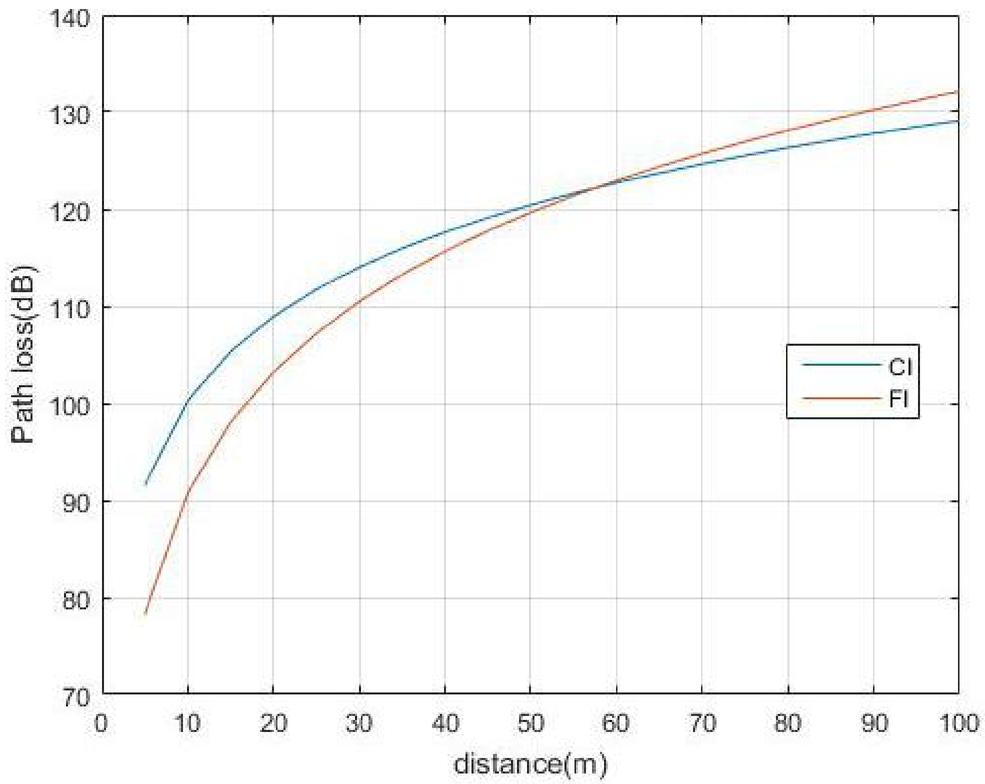
In this situation we compare the FI and CI in 39 GHz in street canyon ， the path loss of CI is more before 190m after that distance the FI will has more path loss(σ_{SF} this is the shadow fading)



	n/A	B	FSPL(f.1m) (dB) / G	σ_{SF} (dB)	F(dB)
CI	3.17		32.4+20lg(f)	8.09	28
FI	3.53	22.4	2.13	7.82	28

Table 4.2-4 parameters in the ABG and CI path loss models in UMI and UMA scenarios

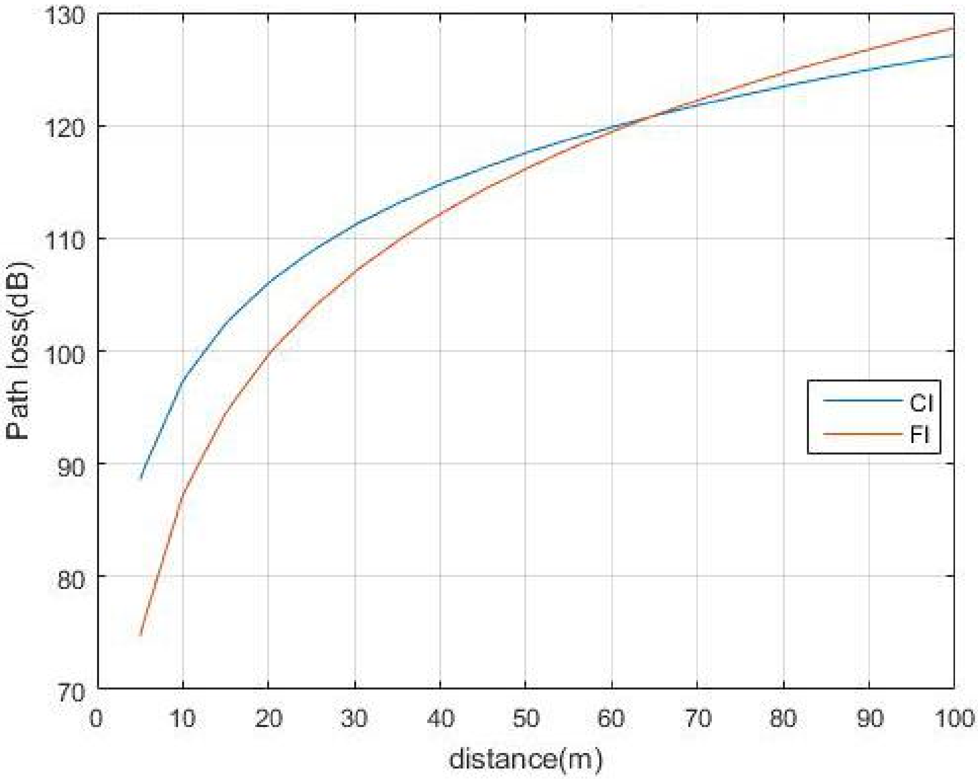
In this situation we compare the FI and CI in 28 GHz in street canyon , the path loss of CI is more before 230m after that distance the FI will has more path loss and compare with the fig5 we can know 28GHz will has less path loss.



	n/A	B	FSPL(f.1m) (dB) / G	σ_{SF} (dB)	F(dB)
CI	2.89		32.4+20lg(f)	7.1	39
FI	4.14	22.4	3.66	7.0	39

Table 4.2-5 parameters in the ABG and CI path loss models in UMI and UMA scenarios

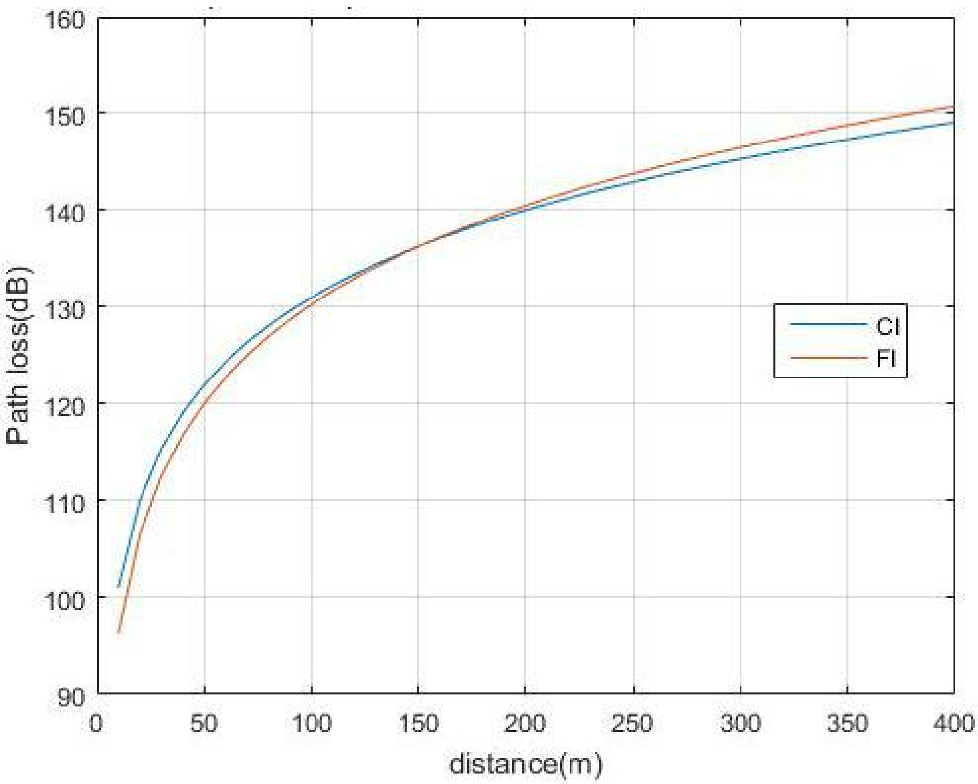
In this situation we compare the FI and CI in 28 GHz in open square , the path loss of CI is more before 56m after that distance the FI will has more path loss.



	n/A	B	FSPL(f.1m) (dB) / G	σ_{SF} (dB)	F(dB)
CI	2.89		32.4+20lg(f)	7.1	39
FI	4.14	22.4	3.66	7.0	39

Table 4.2-6 parameters in the ABG and CI path loss models in UMI and UMA scenarios

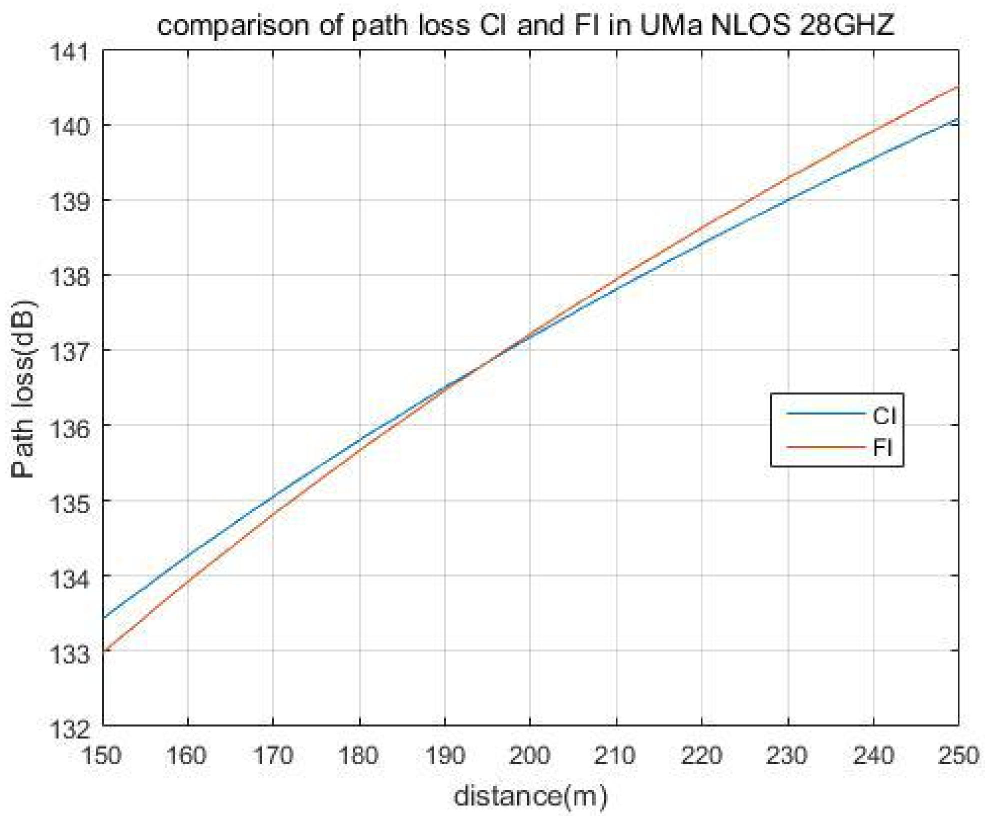
In this situation we compare the FI and CI in 39 GHz in open square , the path loss of CI is more before 56m after that distance the FI will has more path loss and compare with the fig8 we can know 28GHz will has less path loss.



	n/A	B	FSPL(f.1m) (dB) / G	σ_{SF} (dB)	F(dB)
CI	3		32.4+20lg(f)	6.8	39
FI	3.4	19.2	2.3	6.5	39

Table 4.2-7 parameters in the ABG and CI path loss models in UMI and UMA scenarios

In this situation we compare the FI and CI in 39 GHz in open square , the path loss of CI has bigger path loss before 160m after that distance the FI will has more path loss.



	n/A	B	FSPL(f.1m) (dB) / G	σ_{SF} (dB)	F(dB)
CI	3		32.4+20lg(f)	6.8	28
FI	3.4	19.2	2.3	6.5	28

Table 4.2-8 parameters in the ABG and CI path loss models in UMI and UMA scenarios

In this situation we compare the FI model and CI model in 28 GHz in open square , and the range of x axis and y axis become small ,the path loss of CI has bigger path loss before 195m after that distance the FI will has more path loss. In the 195m the path loss of CI and FI almost same.

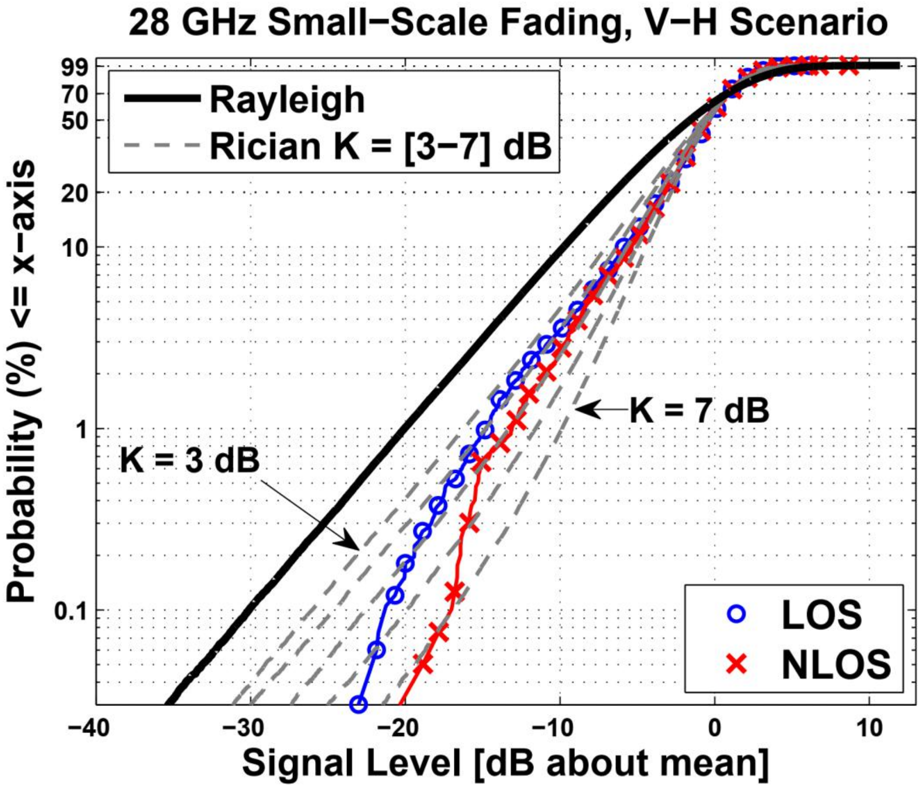
4.3 Comparison with some outcomes

Then we make the comparison with the some outcomes (IEEE ,28GHz Millimeter Wave ultra wide band Small-Scale Fading Models in Wireless Channels), which use the ultrawidedband measurements investigated spatial and temporal fading and autocorrelations of the received multipath signal amplitudes over a local area for vertical to vertical (V-V),

and vertical to horizontal (V-H),antenna polarization scenarios.

For the first figure is about probability and signal level of V-V scenario from which we can see at first the probability of the path loss is increasing when signal becomes strong then becomes gentle finally even horizontal. This outcome is coincident with the fig...

For the second figure it is the V-H scenario which has the same situation with the V-V scenario.



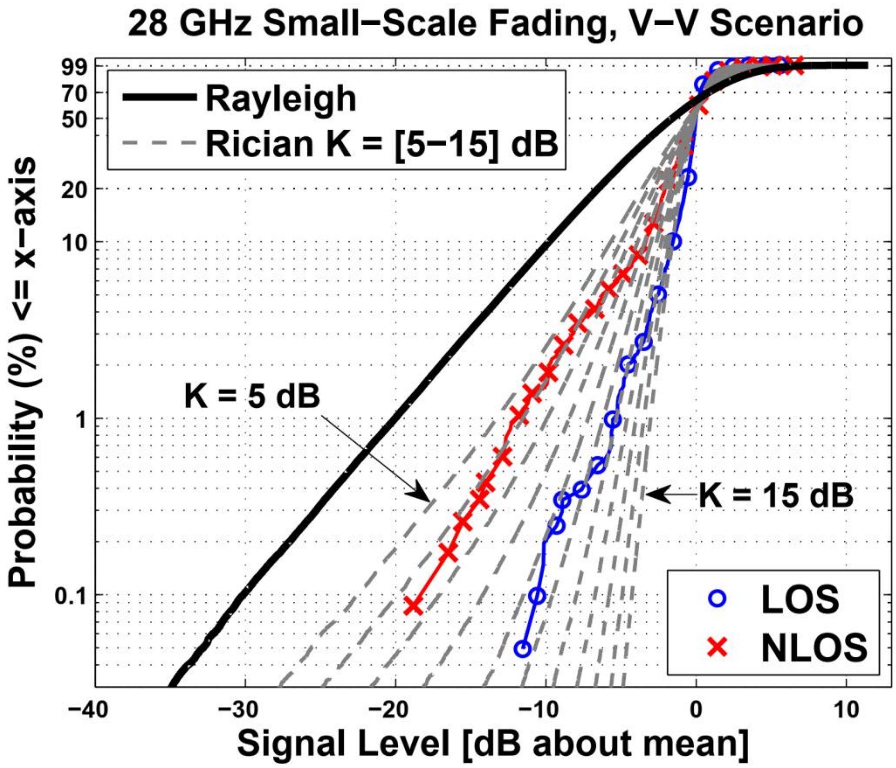


Fig 4.3-1 4.3-2 [4]vertical to horizontal(V-H) vertical to vertical (V-V)

[5]This picture shows the situation of 28GHz , which confirms some points then chooses one line to replace these points. The experience has consistent tendency with this paper made before.

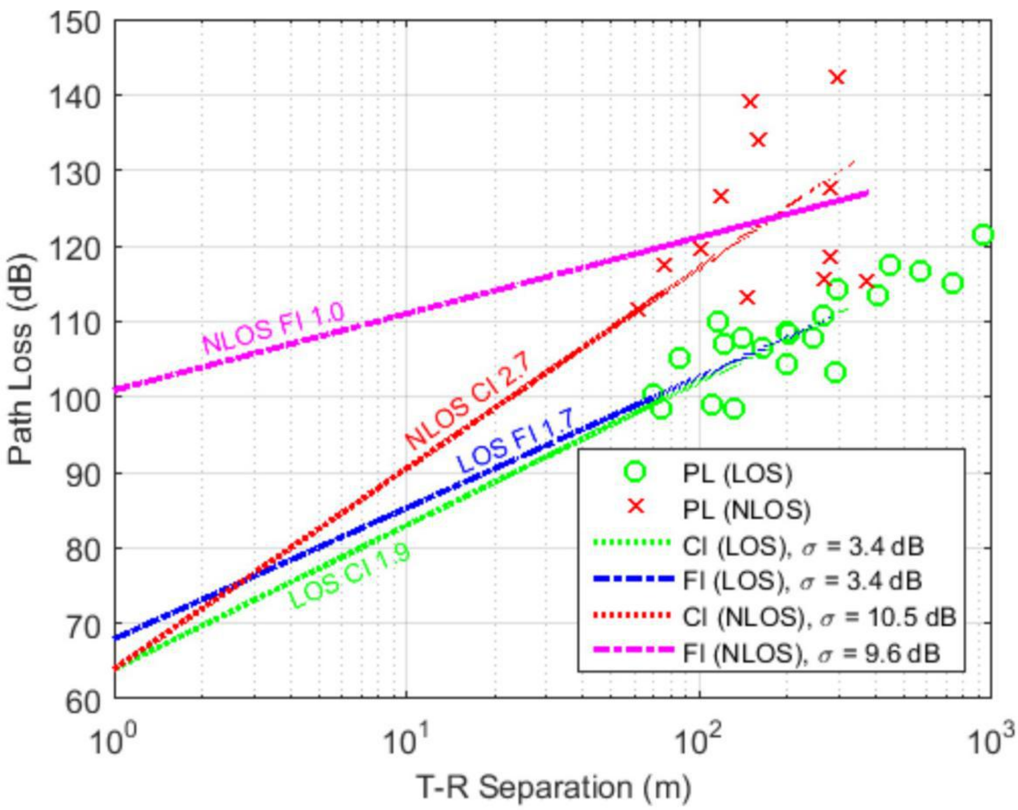


Fig 4.3-3 path loss of NLOS and LOS

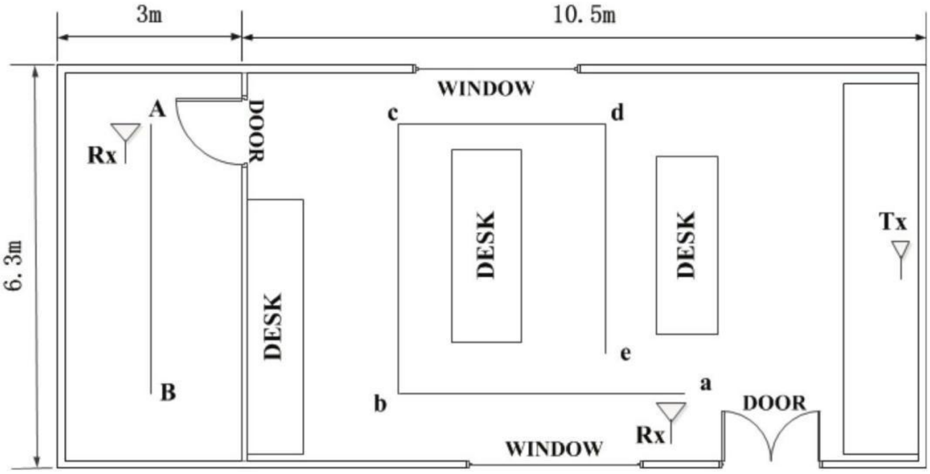


Fig 4.3-4 room model

BUILDINGS	$\sigma(s/m)$	ε_r
Wall	0.015	7
Door/Desk	0.001	5
Window	0.001	2.4
Floor	0.001	4.44
ceiling	0.015	3

Fig 4.3-4 parameter changes in different situation

[6]In this experience , comparisons of path loss in an indoor environment ,presented the simulated results of path loss at 2.4GHz which is the frequency of wireless local area networks and 38GHz which the 5G cellular network is considering on the both line of sight (LOS) and

non line of sight (NLOS)

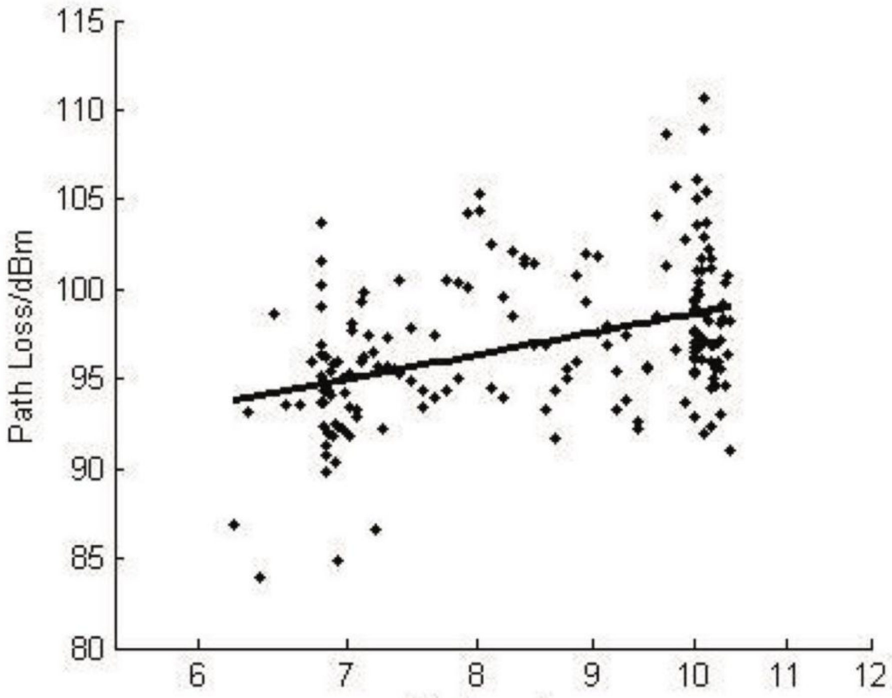


Fig 4.3-5 statistics of all measured points

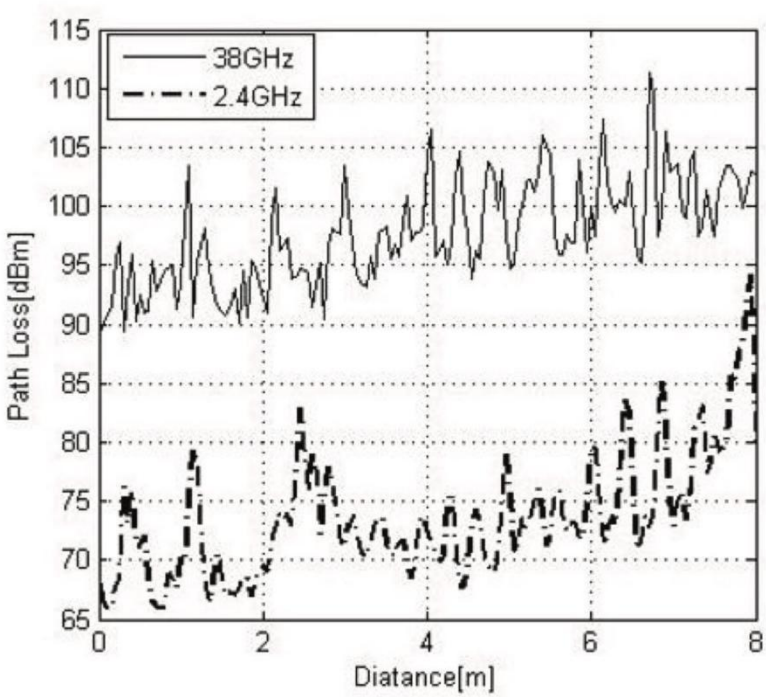


Fig 4.3-6 path loss in the measurement

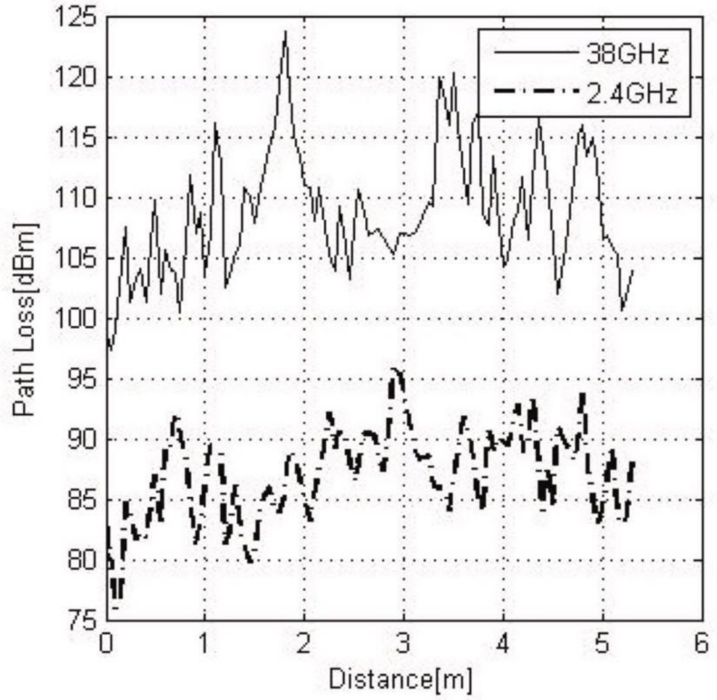


Fig 4.3-7 path loss in the simulation

During the measurement, some points are chosen as the line a-b-c-d-e as shown Figure(4.3-4), every point will have eight data were measured every ten seconds. Then we can see the Figure(4.3-5) which shows the statistics of all points. The Figure (4.3-6) and Figure(4.3-7) show the path loss in the measurement and simulation respectively. From the two pictures we can see the range of path loss is roughly same. So we can confirm the validity.

4.4 Simulation Conclusion

From the analysis above ,we can get that street canyon has more path loss than open square , and the 39GHz has large path loss than 28Ghz. We can predict that the path loss will increase as the frequency increasing.And for the comparison between CI model and FI model , at the short distance CI will has more path loss but when the distance becomes longer, the FI model will have larger path loss than CI model in this simulation process..

5 conclusions and expectation

5.1 conclusion

In this paper mainly studies the problem of wave propagation in 5G ground mobile communication system. The results of this paper have some theoretical significance and practical value for development and research of 5G.

Chapter 1: the introduction of background and the meaning of this paper. Then analysis of the 5G advantages and the outline of this paper.

Chapter 2: in this chapter , the advantages of millimeter wave MIMO system in the development of 5G mobile communication are introduced, and the corresponding problems to be faced are pointed out. And also briefly introduces the prospects and research topics of the fifth generation communication technology ,and analyzes the opportunity position of millimeter wave technology in the fifth generation communication technology. Then the large scale and small scale path loss model are discussed.

Chapter 3: introduction of the three path loss model (FI CI and ABG) also discuss why we choose the CI and FI model to make the simulation. Then we introduce some scenarios which will be used to make the simulation.

Chapter 4: make some simulations and some comparisons among these situations. Finally the simulation outcomes are compared with some previous experiences.

Chapter 5: the conclusion and the expectation in the future.

5.2 expectation

This paper mainly studies the propagation model of 28GHz and 39GHz channel. The paper has a large and real database. For the next generation of wireless mobile communication is developing towards broadband high frequency. This paper is mainly aimed at a series of analysis of monosyllabic signals. The analysis is mainly about the linear fitting of distance and loss, so there are some main aspects of the following research .

(1) Study the propagation model of wide band signal and increase the frequency. Study variables. From the free space path loss model, it can be seen that the path loss is directly related to the wavelength, so the loss of the broadband signal can not be calculated simply by the center frequency , but the loss model should be more complex.

(2) This study is mainly based on linear fitting of distance and path loss without considering break point and multi line loss model. Subsequent studies can use complex slopes to study complex propagation models

(3) For data with different frequencies at the same test site, multiple frequency loss models can be used , such as the FI loss model , CI loss model , and so on. The path loss model based on the measured data from different frequency bands will be more practical.

(4) The 5G communication path loss model in this paper is only proposed for several special frequencies , and the model that can be used in the millimeter wave segment needs to be studies.

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