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PROJECT REPORT

CAPACITY ANALYSIS OF 5G SYSTEMS

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CERTIFICATE

This is to certify that the project entitled "**Capacity analysis of 5G systems**" submitted by Agrim Bari as part of Summer Internship-2018 at offered by the NYU Tandon School of Engineering, is a bonafide record of the work done by him under my guidance and supervision of Prof. Shivendra Panwar at the New York University, Tandon School of Engineering from 21st May 2018 to 15th July 2018

Prof. Shivendra Panwar

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ABSTRACT

Millimeter-wave (mmWave) propagation is known to be severely affected by the blockage of the line-of-sight (LOS) path. In contrast to microwave systems at shorter mmWave wavelengths, such blockages may be due to mobile blockers and the user's own body. This blockage results in the wireless channel to alternate between the blocked and non-blocked LOS states, which ultimately results in reduced data rates. For the same, Macro-diversity of base stations (BSs) has been considered a promising solution, where the user equipment (UE) can handover to other available BSs. However, any analytical model or simulation for blockage events in this setting is unknown. This is what we explore in this project, whereby using the Random Way-Point Mobility Model, the effect of mobile blockers can be understood. Since a single blocker can block multiple LOS links simultaneously, there is also a need to consider the correlation factor in the model. However, the gains in the capacity will come at the expense of increased handover (HO) rates which need to be modelled based on Received Signal Strength along with Hysteresis and threshold, and at the same time outage in such handoff scenarios will be modelled as the reception of low data rate at the UE end. To append, we have also included the effect of self-blockage in our study. As a result, we have tried to understand in the scenarios of low latency applications what will be a limiting factor in deciding the minimum density of BS.

INTRODUCTION

BLOCKING objects – blockages – in the form of moving cars, trucks, and people can severely impact the performance of cellular networks by reducing the signal strength and thus SNR. Blockage's effect is more severe at higher frequencies including mm-wave, due to higher penetration losses and reduced diffraction. Therefore, Los connections are highly desirable for mm-wave. In addition, a user can block the otherwise Los signals due to its own body, hurting the overall reliability of the communication links, and the effect is more pronounced when dynamic blockers with correlation are being considered along with the self blockage. To overcome blockage effects, macro-diversity can be leveraged whereby a user is connected to multiple BSs simultaneously, which clearly increases the chance for a Los connection.. m

This work presents a blockage model for Los using stochastic geometry. In particular, our contributions are as follows:

1. We developed a model based on random waypoint mobility for dynamic blockers, where the blockers can be simultaneously blocking more than one link at the same instance.
2. We incorporated the effect of path loss as the signal is transmitted, and then is being received by the UE, based on the 3GPP Technical Report.
3. We have made use of the shadow fading in the NLoS links based on the number of blockers, instead of making use of a log-normal distribution
4. We have inculcated the effect of handoffs which is based on the rule of Received Signal Strength with hysteresis and threshold
5. We have incorporated the effect of handoff delays by assuming that the UE is in an outage when such a handoff is being initiated.

A. *Background and Related Work:* The importance of dynamic blockage of the Los path in mmWave deployments has recently been shown to be one of the critical design factors that affect system performance [1]–[3]. Dynamic blockage by small mobile objects within the environment, such as moving people, cars, trucks, etc., introduces additional uncertainty in the channel, which may eventually result in sharp drops (up to 30 ~ 40 dB) in the received signal strength [5] The blockage frequency, duration, and the resultant degradation of signal strength affect the performance of a mmWave system.

Recent work has studied the impact of Los blockage in urban microwave systems [6]. However, the results do not directly apply to mmWave systems as the objects of interest in mmWave and microwave systems are of fundamentally different nature and hence would require different models for their accurate representation.

Indeed, in addition to self blockage by a dynamic blocker, one also needs to take into account the self blockage by the user itself.

The Los blockage by humans in mmWave systems has been evaluated through simulation studies in [7]. In [8], a Los blockage model where humans are represented as cylinders of random width and height was proposed. However, there the authors assumed that both the users and the blockers are stationary. In addition to academic work, the 3GPP community is currently exploring various options for modelling the impact of human blockage appropriately [6] as though in the current work we have assumed the signal to be completely blocked.

B. <u>*System Model:*</u> Our System Model consists of the following settings:

- BS Model: The mmWave BS locations are modelled as a homogeneous Poisson Point Process(PPP) with density λ_T. Consider a disc of Radius R with UE located at the center of the disc. Thus, the number of BSs M inside the disc follows a Poisson distribution with parameter $\lambda_T \pi R^2$

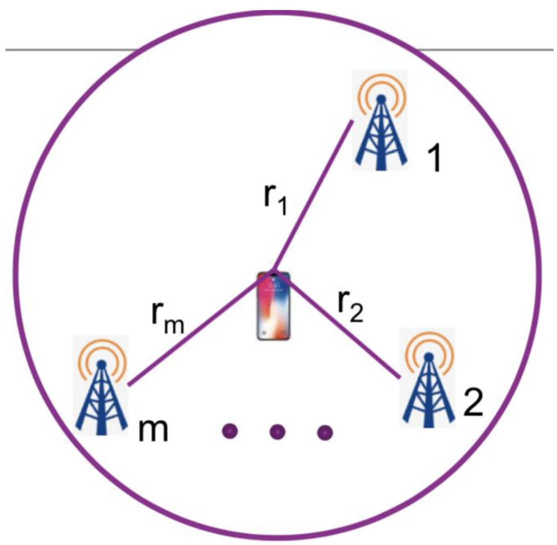


Fig-1: Ref: Limited by Capacity or Blockage? A millimetre-wave Blockage Analysis by Ish Kumar Jain et al.

Given the number of BSs M inside the disc, we have a uniform distribution of BS locations.

- Self Blockage Model: The user blocks a fraction of BSs due to his/her own body. The self Blockage Zone defined as a sector of the disc making an angle ω. Thus all the BSs in the self blockage zone are considered blocked.

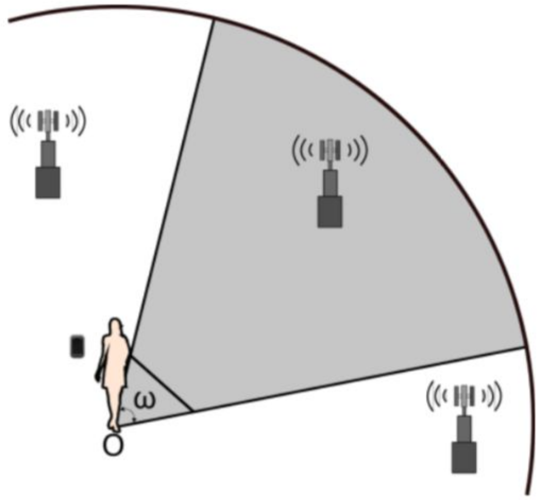


Fig-2: Self Blockage zone: Ref: Limited by Capacity or Blockage? A millimetre-wave Blockage Analysis by Ish Kumar Jain et al.

- Dynamic Blockage Model: The blockers are distributed according to a homogeneous PPP with parameter Λ_B, where they are assumed to follow a random waypoint mobility model, and it is assumed that they can simultaneously block more than one Los link.

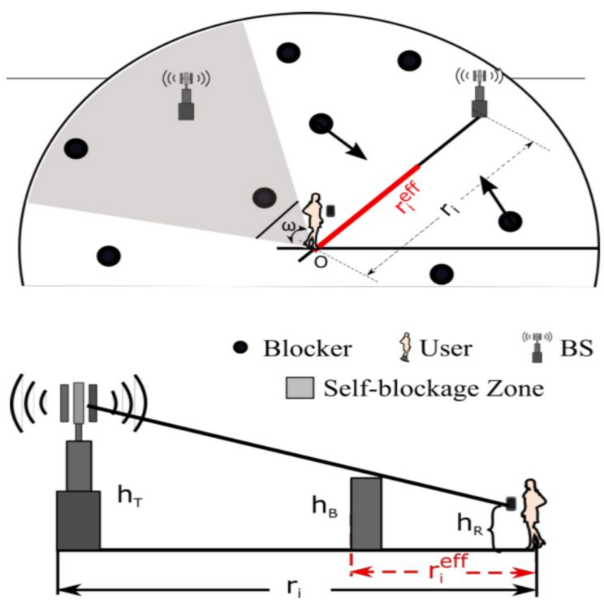


Fig-3: Dynamic Blockage: Ref: Limited by Capacity or Blockage? A millimetre-wave Blockage Analysis by Ish Kumar Jain et al.

SIMULATION SETUP

Capacity analysis of 5G systems

1. Matlab Simulations
2. Random Waypoint Mobility Model (blockers)
3. Random Number of Base Stations and random Locations

Parameters	Values
Radius R	100m
Velocity of Blockers	10m/s
Height of Blockers	1.8m
Height of User Equipment h_R	1.5m
Height of APs h_T	5m
Density of Blockers	0.05 bl/m^2
Density of AP	200*10^-6 AP/m^2
Frequency of operation	28Ghz
Self Blockage Angle	60 degrees

Table 1: Simulation Parameters

WORK DONE

Dynamic Blockage with the effect being correlated

We have implemented the effect of dynamic blockage by making use of the Random Waypoint Mobility model, for the blocker being modelled as a truck in motion with blocker parameters being:

Length of the Blocker(L): 13.6m
The velocity of the Blocker(V): 10m/s
Duration of Blockage: D = (L)/(V*cos(Ψ-Θ))

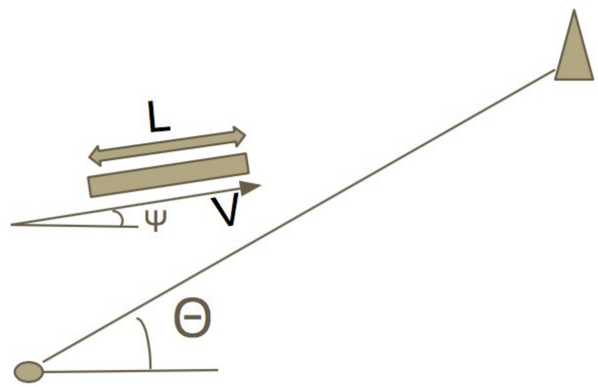


Fig- 4: Blockage Model for computing the duration of blockage

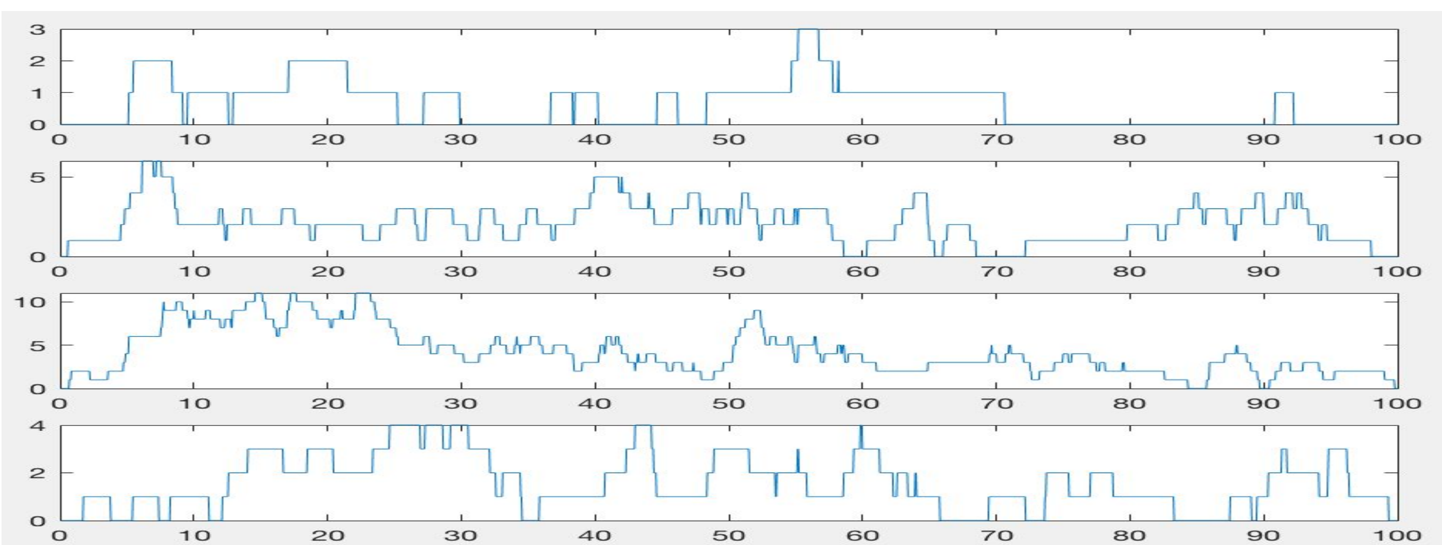


Fig:5: Typical Number of Blockages as time proceeds for each of the base station with the inclusion of Correlation

Incorporated a model for Path loss

Based on the 3GPP technical report, a channel model is being simulated in order to evaluate the path loss the signal suffers as it moves from the transmitter end to the UE end, but at the same time the shadowing effect for the NLoS path is based on the number of blockers[4]

$PL_{UMi-LOS} = PL_1 \quad 10m \le d_{2D} \le d'_{BP}$ and $\sigma_{SF} = 4$ for LOS

$PL_{UMi-LOS} = PL_2 \quad d'_{BP} \le d \le 5km$ where the parameter d'_{BP} *Is as explained in [6]*

With $PL_1 = 32.4 + 21 * \log_{10}(d_{3D}) + 20 * \log_{10}(f_c)$ and

$PL_2 = 32.4 + 40 * \log_{10}(d_{3D}) + 20 * \log_{10}(f_c) - 9.5 \log((d'_{BP})^2 + (h_{BS} - h_{UT})^2)$

$PL_{UMi-NLOS} = \max(PL_{UMi-LOS}, PL'_{UMi-NLOS})$ for $10m \le d_{2D} \le 5km$ and ***SF=P$_t$*uniform(0,1)*(No. Of Blockers)***

With $PL'_{UMi-NLOS} = 35.3 \log_{10}(d_{3D}) + 22.4 + 21.3 \log_{10}(f_c) - 0.3(h_{UT} - 1.5)$

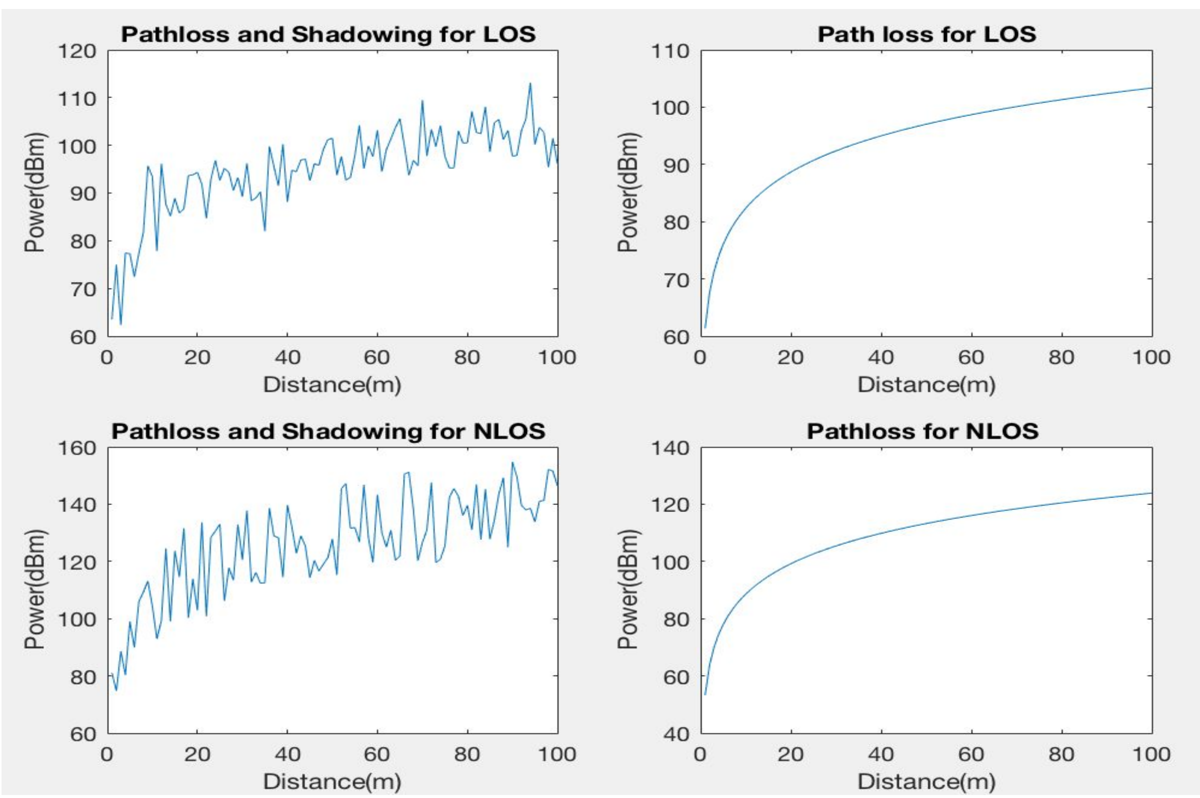


Fig6::The channel Model

<u>Effect of Handoffs is being considered</u>

The Handoffs between different base station is made on the basis of Received Signal Strength(RSS) and hysteresis with threshold[7] and a delay of 50 ms(25ms{for beam training}+25ms{for control plane })[10]-[11] is being added to the system as handover delay, and user is assumed to be in outage in such scenarios.

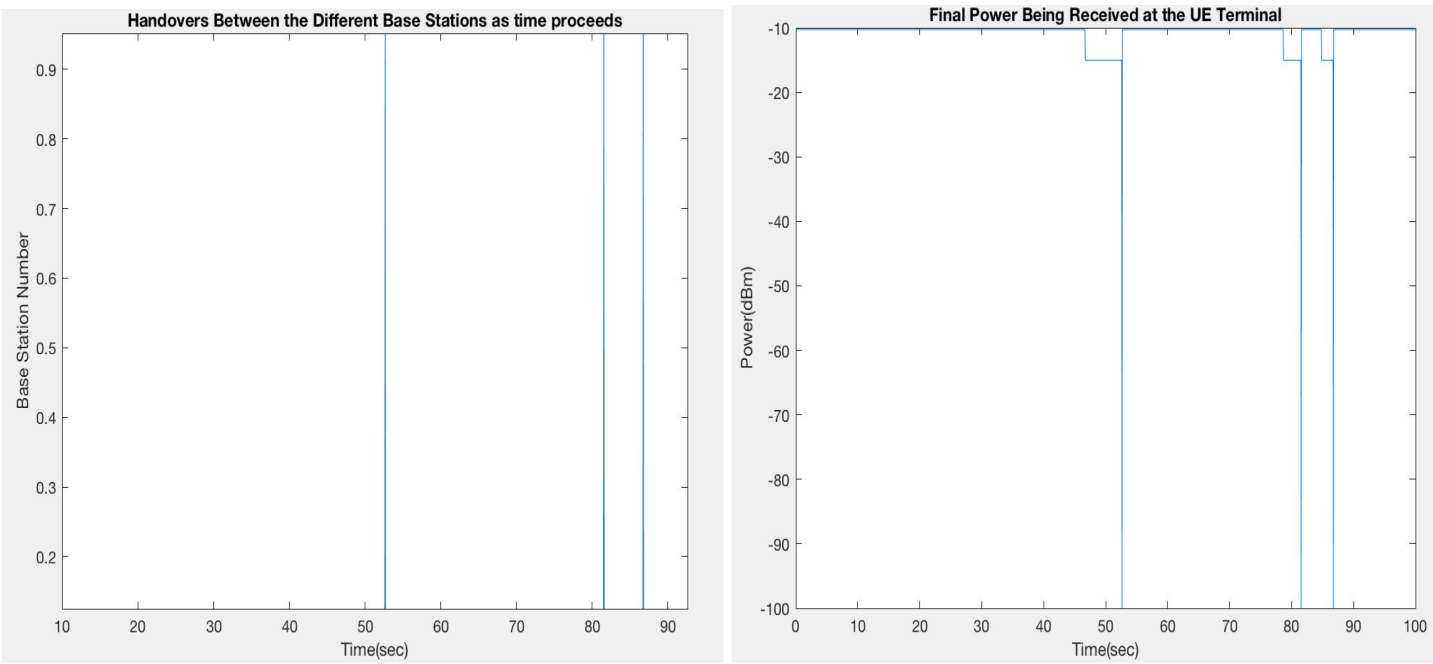


Fig-7: A Typical Scenario of Handover when the effect of shadow fading is not included(***RSS+Hysteresis+Threshold[12]***)

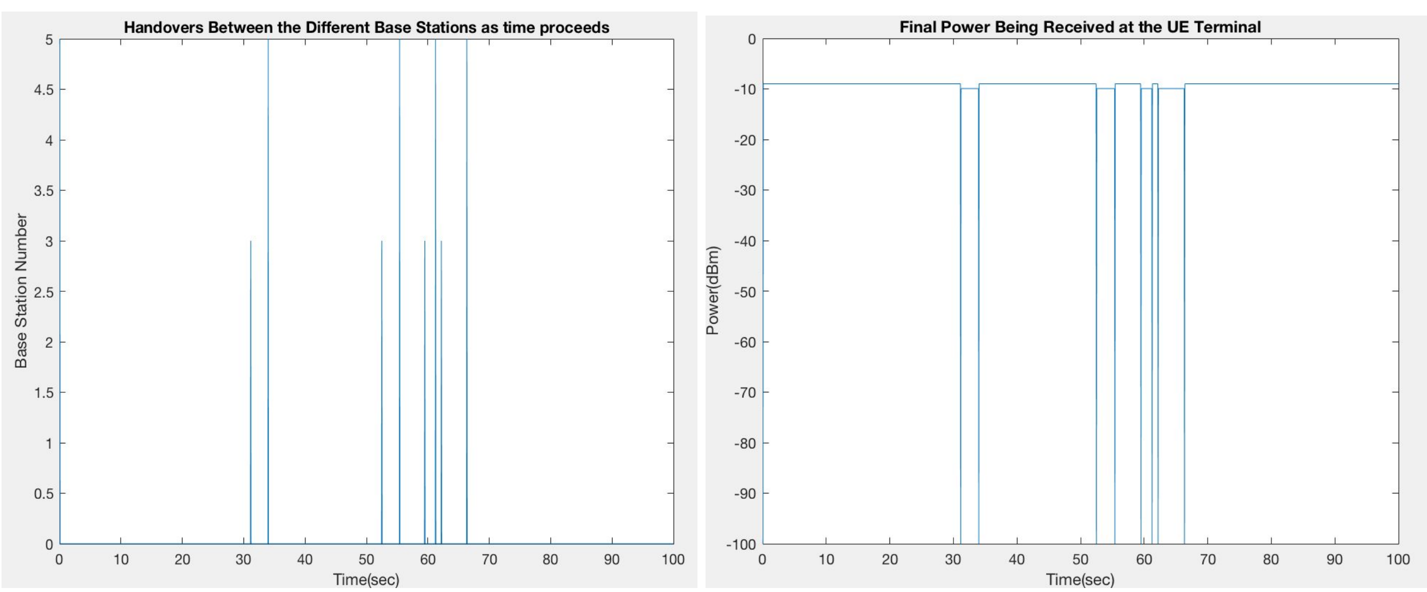


Fig-8: A Typical Scenario of Handover when the effect of shadow fading is not included(***RSS***)

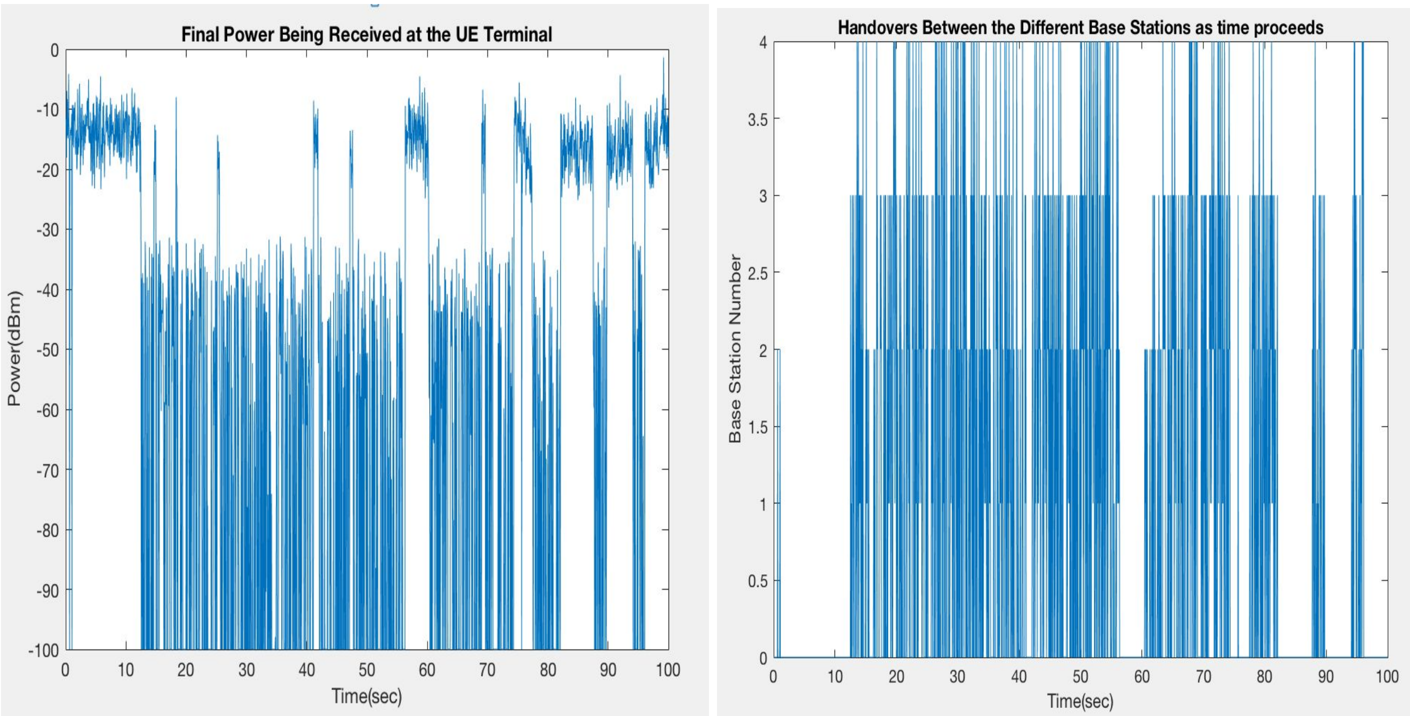


Fig-9: A Typical Scenario of Handover when the effect of shadow fading is included(***<u>RSS+Hysteresis+Threshold</u>***)

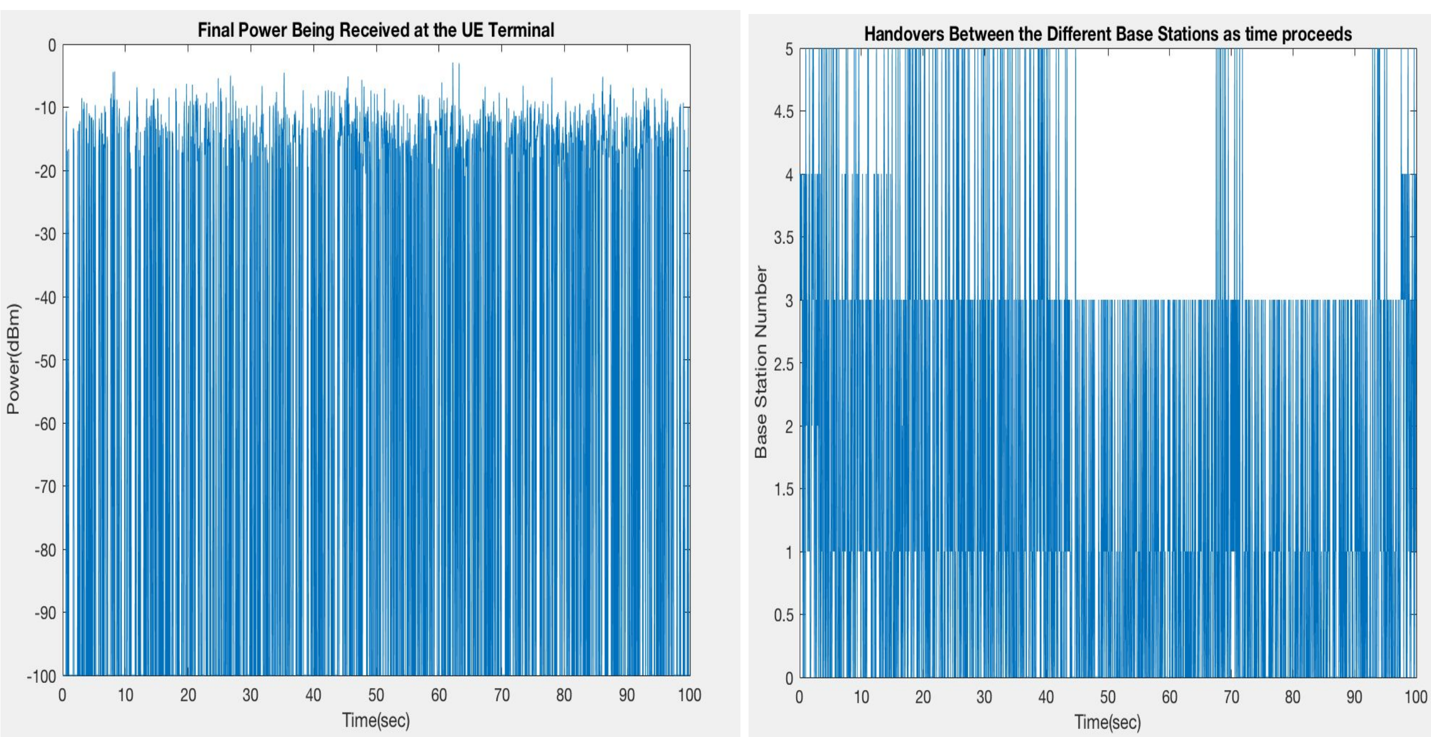
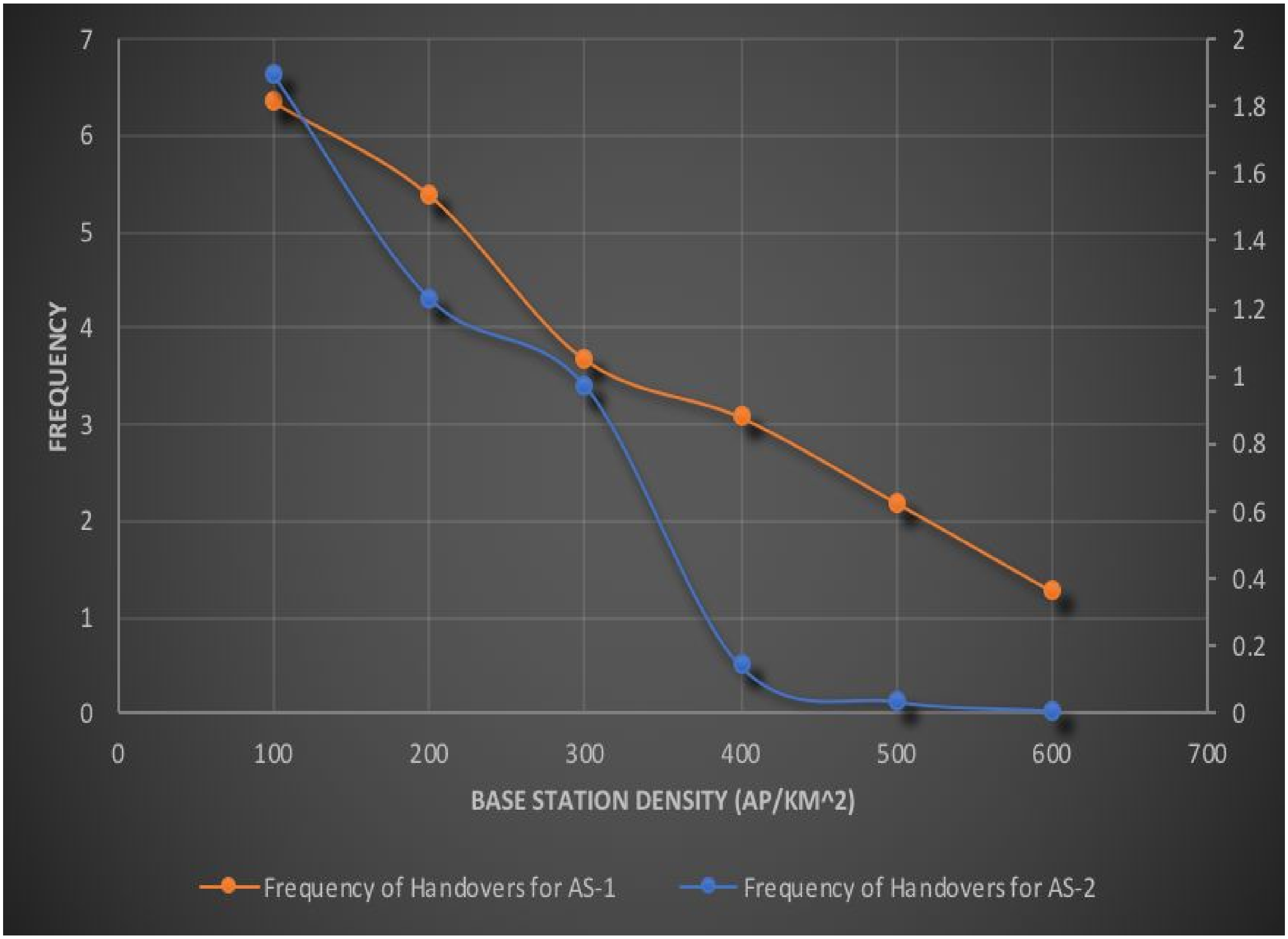
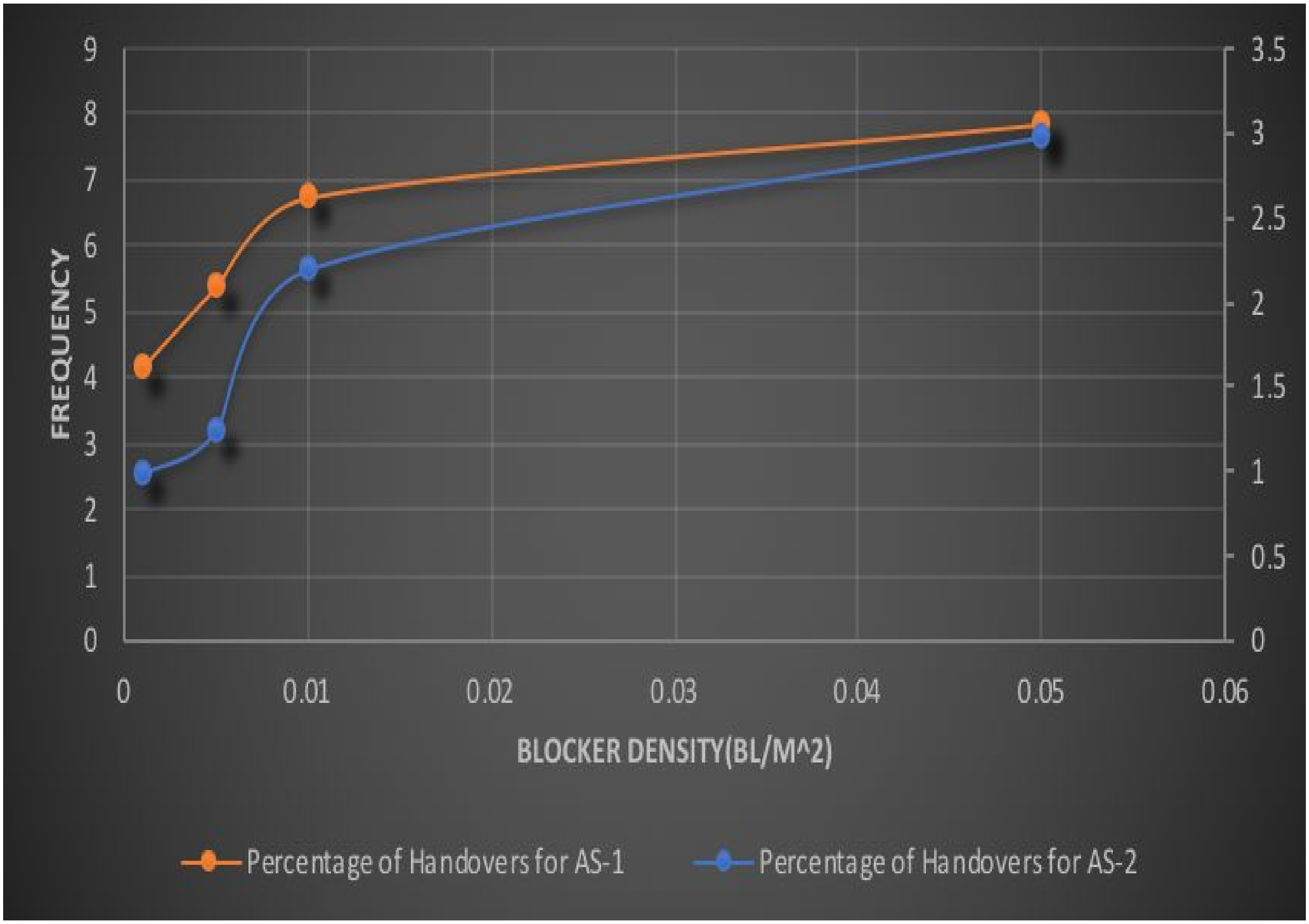


Fig-10: A Typical Scenario of Handover when the effect of shadow fading is included(***<u>RSS</u>***)

The plot of Frequency of Handovers for varied values of Base Station Density and a fixed blocker density(0.005bl/m^2) including the shadow fading effect for AS-1(RSS) and AS-2(RSS+Hysteresis+Threshold)

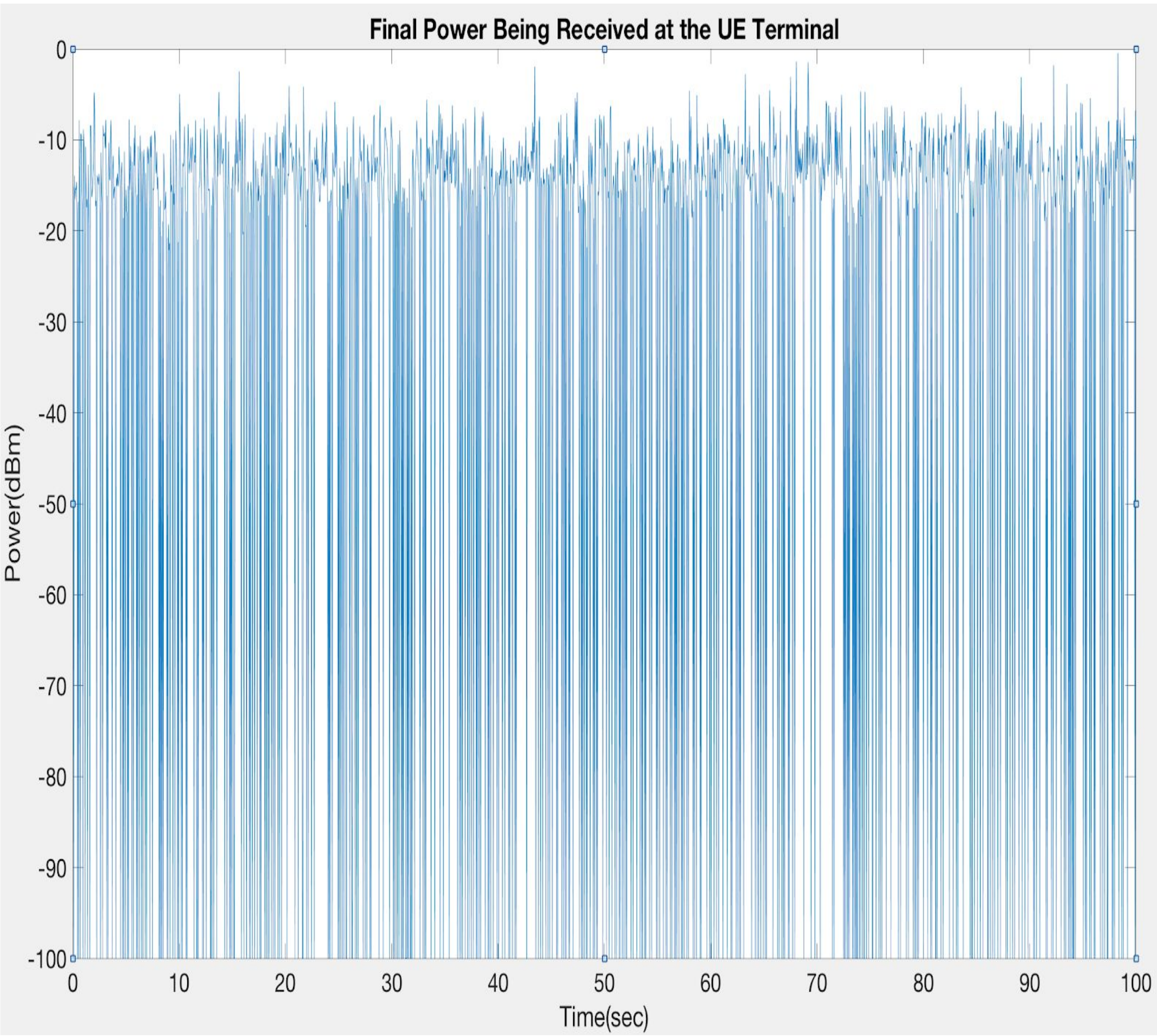


The plot of Percentage of Handovers for varied values of Blocker Density and a fixed base station density including the shadow fading effect for AS-1(RSS) and AS-2(RSS+Hysteresis+Threshold)

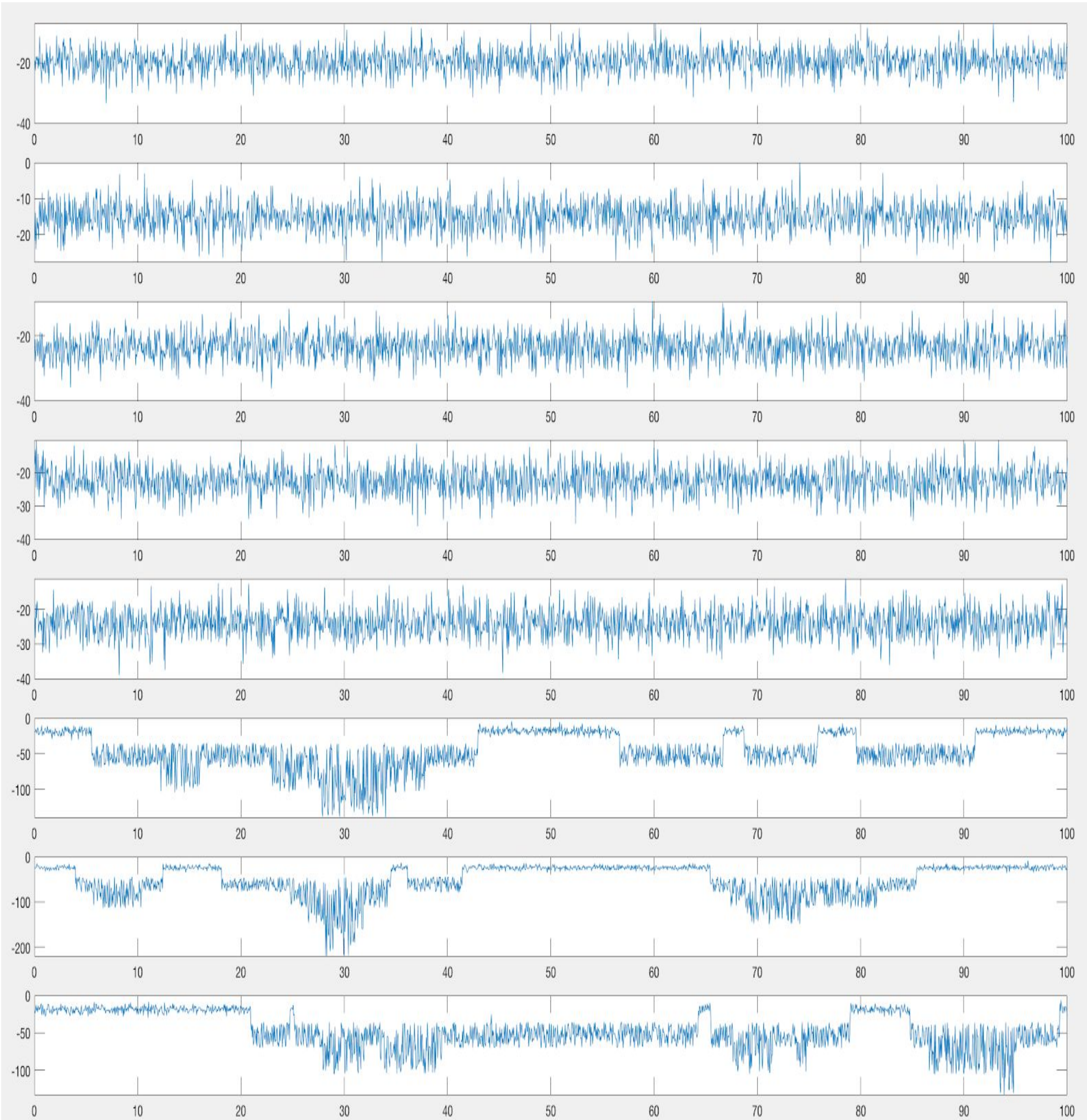


Simulation Results

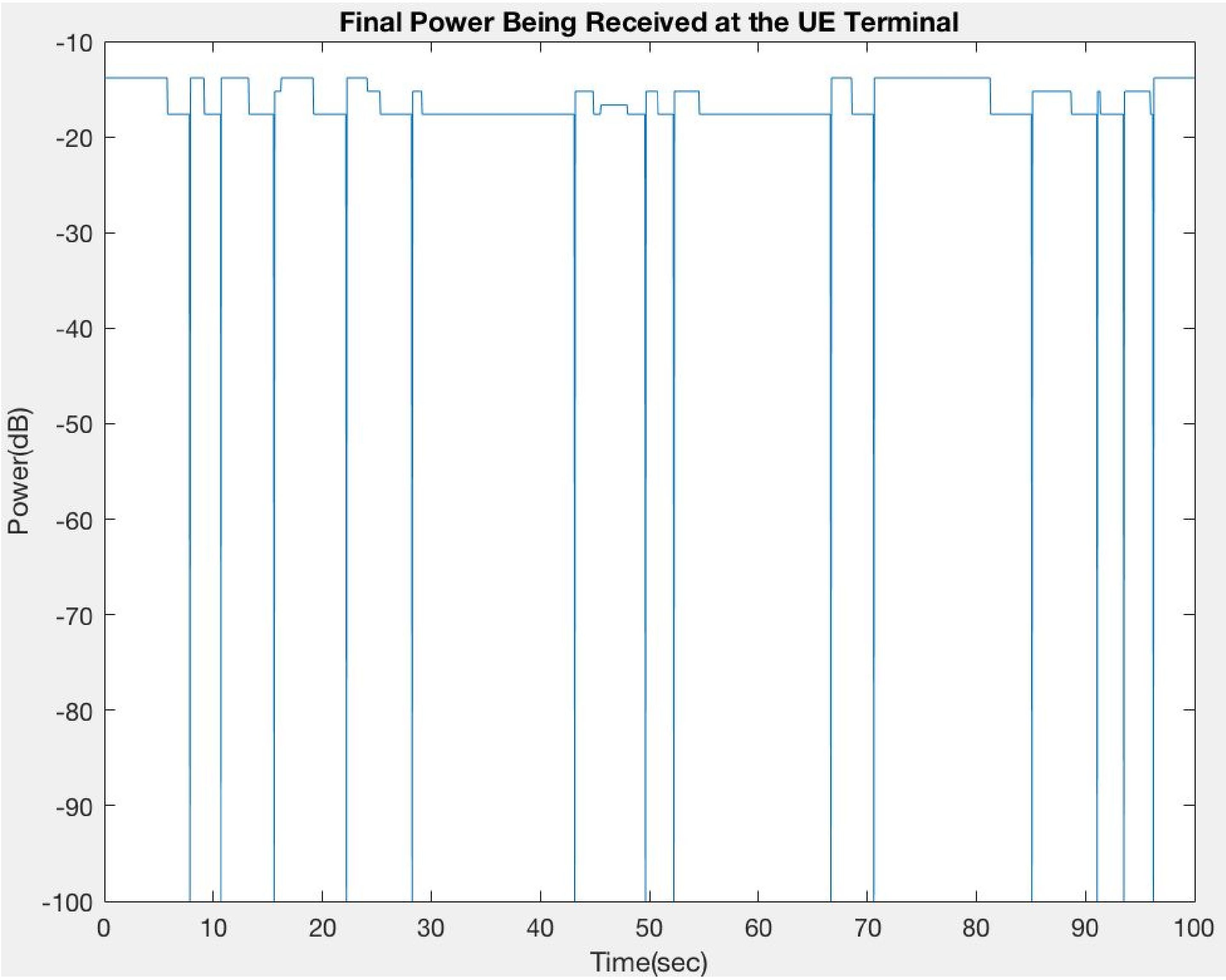
1. Final Power being Received including the effect of Shadow Fading



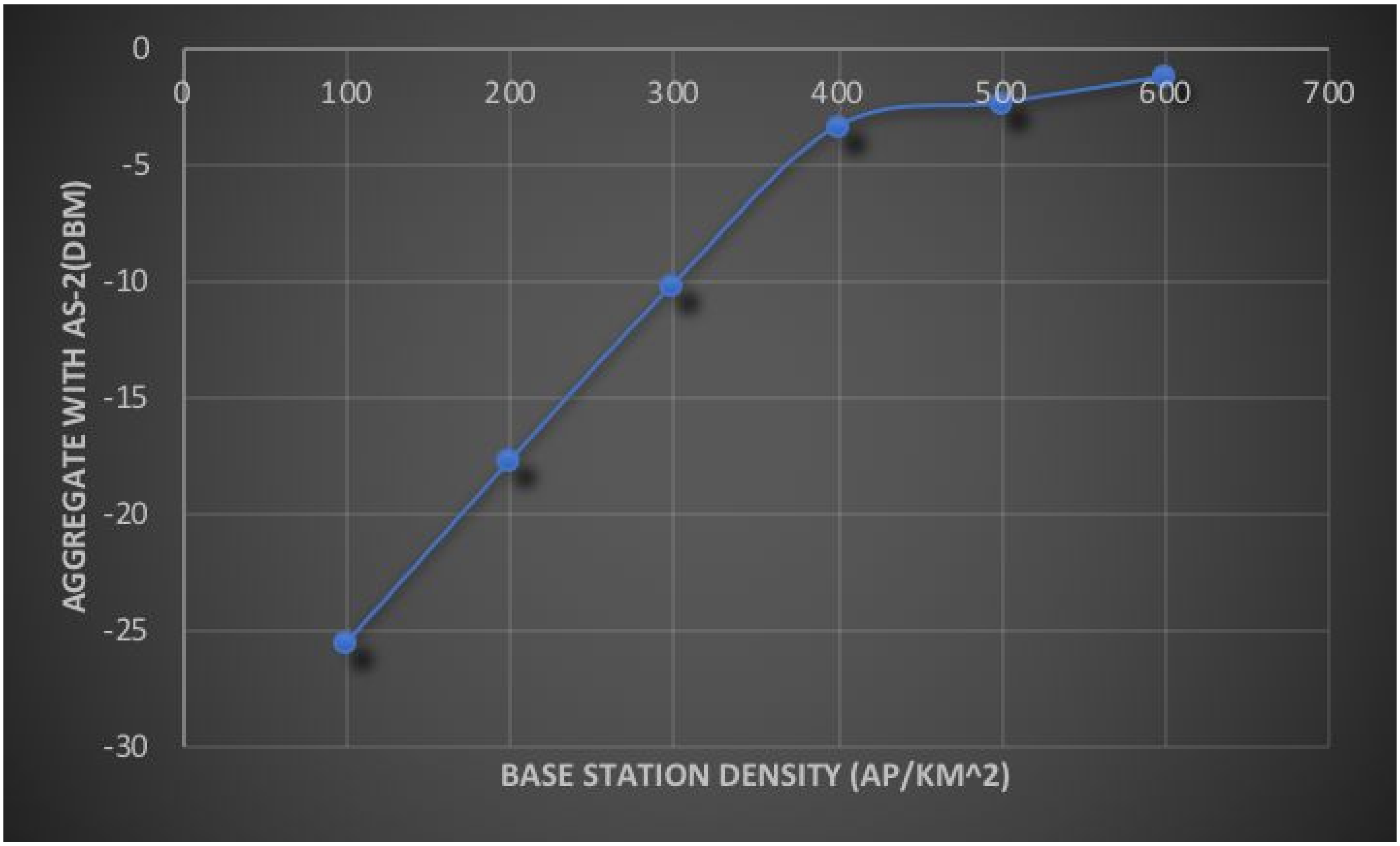
2. Power Received by virtue of any of the base station as time proceeds



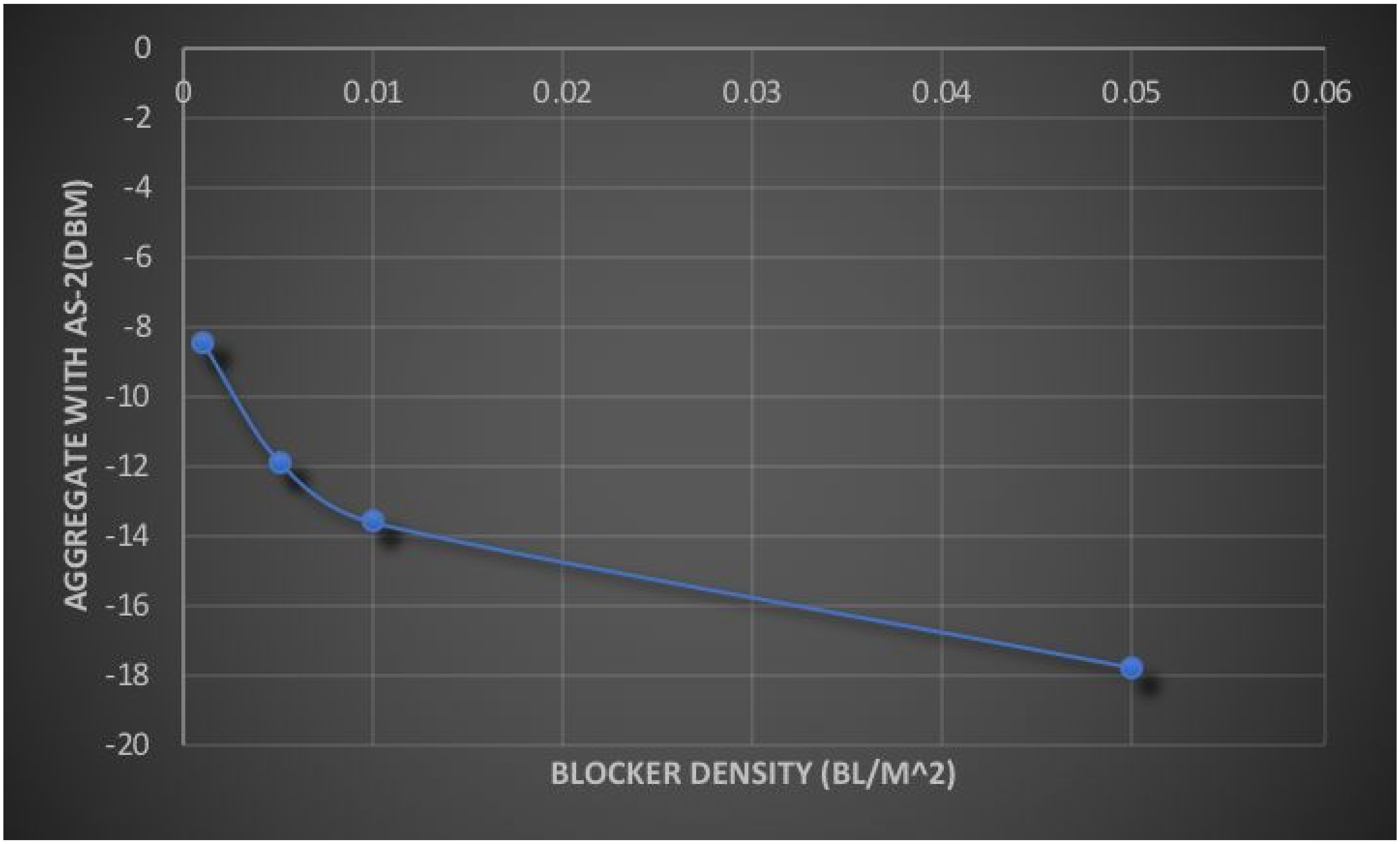
3. Final Power being Received without including the effect of Shadow Fading



The plot of Aggregate Power for varied values of Base Station Density and a fixed blocker density including the shadow fading effect for AS-2(RSS+Hysteresis+Threshold)



The plot of Aggregate Power for varied values of Blocker Density and a fixed base station density including the shadow fading effect for AS-2(RSS+Hysteresis+Threshold)



FUTURE WORKS

- All the base stations are assumed to be of the same efficiency
- User is assumed to be fixed thus not inculcating any frequency change, thus not affecting our channel model
- No consideration is being made for a time-varying channel
- Multiple UE's and how they will affect the whole system
- Effects of Interference are not included in the study so far
- Developing the theory behind it
- Making the NLoS paths more descriptive

CONCLUSION

- Developed a **dynamic blockage model** for the UE-BS LOS link considering mobile blockers with the effect being correlated.
- Considered **BS macro-diversity** (Cooperation among multiple BSs to serve the UE)
- We need to have **high antenna gains** along with other technologies to have significant capacity for the case considered
- Average power received **decreases** as a result of **an increase** in the blocker density, **increase** in the mean blockage duration and with an **increase** in the self blockage angle
- **Increasing** the access point density **increases** the average power received
- **Increasing** the height of the access point also results in an **increase** in the average power being received
- We need to include other technologies like Small cell, MIMO, Beam Training and Full-Duplex to have a significant because of the 5G system

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