Simulation and Analysis of Interference Avoidance Using Fractional Frequency Reuse (FFR) Method in LTE femtocell

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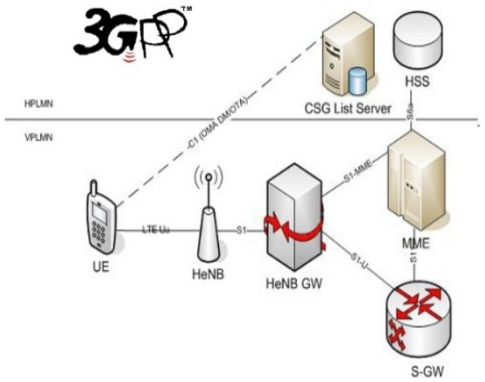
ABSTRACT- ***There for another way is needed to keep LTE reliable when use in indoor. Femtocell is the solution of the problem. But femtocell uses the same frequency spectrum as any other broadband services. The more femtocell used in an area, overall networks capacity will be disturbed by co-channel interference.***
There are two scenarios that were examined in this research experiment about femtocell LTE interference. That is between MBS – FUE and FBS – MUE. And then to both scenarios applied FFR method using 4 reuse frequencies, 1 frequency use in center cell and the other 3 is use in the edge cell, where the power transmit of the center cell is greater than edge cell. The using of FFR method is to decrease the interference. Parameter that being use to analyze is SINR value that observed from the user side.
FFR algorithm simulated with Matlab 7.11.0 simulator to determine SINR value and to create Layout Position Model of FBS, MBS, and MUE/FUE. Simulation result shows that FFR method is able to increase SINR value in each scenarios. In Scenario 1 with random distance, where the distance between MBS – FBS is 572.503 meters, the distance between FBS – FUE is 33.8378 meters, and the distance between MBS – FUE is 541.288 meters. SINR value increased by 124.4194 dB, that is from 57.8716 dB to 182.291 dB. In scenario 2, where the distance between MBS – FBS is 604 meters, the distance between FBS – MUE is 37.5366 meters, and the distance between MBS – MUE is 641.291 meters. SINR value increased by 104.6943 dB, that is from 78.5277 dB to 183.222 dB. It shows the improvement of quality or the decrease of interference to both Macrocell User and Femtocell User after FFR method being applied.

Keywords: Femtocell, Interference Avoidance, Fractional Frequency Reuse, LTE

1. LTE Femtocell [2]

Femtocells are an alternative way to deliver the benefits of fixed-mobile convergence (FMC). The distinction is that most FMC architectures require a new (dual-mode) handset which works with existing unlicensed spectrum home/enterprise wireless access points, while a femtocell-based deployment will work with existing handsets but requires installation of a new access point that uses licensed spectrum.

In 3GPP terminology, a Home NodeB (HNB) is a 3G femtocell. A Home eNodeB (HeNB) is an LTE femtocell at see Fig.1 :



2. Interference Avoidance

Interference avoidance is a method applied to a network to avoid interference, both between the subscriber station, and between the base station. In improving performance on the femtocell network is placed in a place it is necessary to the proper method or algorithm to manage interference. This project uses Fractional Frequency Reuse method

$$PL_{out} = 20\log10\left(\frac{4\pi do}{\lambda}\right) + 10\,\gamma\log10\left(\frac{d}{do}\right) + s + \Delta PL_f + \Delta PL_h \qquad (2)$$

(FFR) to avoid interference as interference avoidance. This research will be proved by the FFR method is the interference that occurs in each scenario can be reduced

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2. Fractional Frequensi Reuse (FFR)

Fractional Frequency Reuse (FFR) is a technique to correct the interference (interference avoidance), which is used in OFDM-based systems. FFR is the frequency reuse scheme in which the coverage area is divided into two areas of the cell center and cell edge. Center cell is the cell coverage area with your fingers - fingers Ro cells, using a frequency reuse and the use of transmit power Po. Cell edge is the coverage area of cells with cell radius R, using a frequency reuse scheme is greater than one and use a transmit power P, where P is greater than Po. Advantages FFR scheme is able to provide good performance on the users in cell edge, at see fig.2

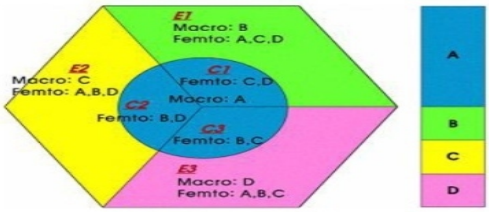

Figure 2. Example of Division of Frequency Allocations for Macro-Femto[12]

3. Interference Model System

The scenario designed is interference scenarios between Macrocell Base Stations (MBS) – Femtocell User Equiptment (FUE) and Femtocell Base Station (FBS) – Macrocell User Equiptment (MUE).with **parameters**

Table 1. Macrocell Base Station (MBS)Parameters[3]

Parameter	Value
Frequency operation	2100 MHz
Power Transmit	41 - 43 dBm
Bandwidth	15 MHz
Transmit antenna height	30 m
Coverage	1000 m

Table 1. contains the values of the parameters used in the Macro Base Station (MBS) in the scenario of this project.

Table 2 Macrocell User Equipment (MUE) and Femtocell User Equipment (FUE) Parameters[3]

Parameter	Value	
Receiver antenna height	1,5 m	
Thermal Noise	-104,5 dBm	
Noise Figure	7 dB	
Model Pathloss	FUE: P.1238	MUE: COST 231

Table 2. contains the values of the parameters used in both Macrocell User Equipment (MUE) and Femtocell User Equipment (FUE) in this project scenario.

Tabel 3. Femtocell Base Station (FBS) Parameters[3]

Parameter	Value
Frequency Operation	2100 MHz
Power Transmit	13 dBm
Bandwidth	1,4 MHz
Transmit Antenna Height	3 m
Coverage	25 m

Table 3 contains the values of the parameters used in femtocell is used in the experiment.

4. Design Interference Scenarios Models

Scenario 1: MBS – FUE Interference

In this scenario, the distance between FBS – MBS is made random, where the entire range of FBS still in the coverage range of MBS. Range FBS and MBS is in accordance with that written on tables 1 and 3. The existing user is a single user, namely Femtocell User Equipment (FUE) as the user which experiencing the interference, and MBS as interferer, at see Fig.3

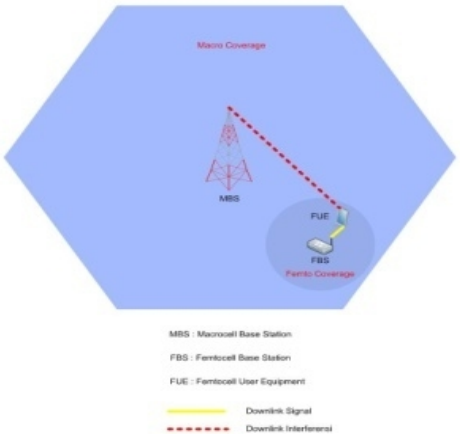

Figure 3. Interference of FUE by MBS

The purpose of Scenario 1 is to know the influence of Macrocell Base Station (MBS) to Femtocell User Equipment (FUE) that in the range of its coverage.

Scenario 2: FBS –MUE Interference

This scenario is the opposite of the scenario above, where there MUE located at some distance from the MBS, where the distance is made random which is still in the range of parameter values according to the FBS and MBS coverage on tables 1 and 2. In this scenario there is a single-user that is Macrocell User Equipment (MUE) that are susceptible to interference, where the FUE act as interferer, at see Fig.4

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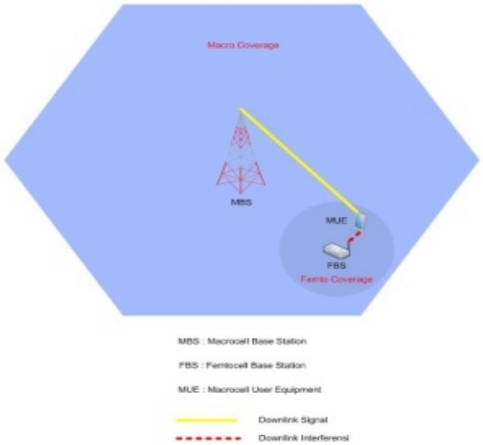

Figure 4. Interference of MUE by FBS

5. Fractional Frequency Reuse (FFR) Design

Here is the Bandwidth and Power division table for each antenna of FFR scenario:

Table 4. Division of Power and Bandwidth Per-FFR Sector[3]

Number of Antennas	Edge Cell	3 antennas directional
	Center Cell	1 antenna omni-directional
Power Transmit [dBm]	Edge Cell	43
		43
		43
	Center Cell	41
Bandwidth [Mhz]	Edge Cell	3
		3
		3
	Center Cell	5

After the assignment of parameters as shown in Table 4, then the project obtained the territorial division between the macrocell and femtocell frequency as follows:

Table 5..Sub-carrier Allocation of FFR[3]

Location of the Cell	Sector	Frequency Operation	
		Macrocell	Femtocell
Center Cell	C1	A	Random (B/C/D)
Edge Cell	E1	D	Random (A/B/C)
	E2	C	Random (A/B/D)
	E3	B	Random (A/C/D)

After the FFR method is applied to both scenarios of the project, then the scenario becomes as shown in Fig 5 - .6 :

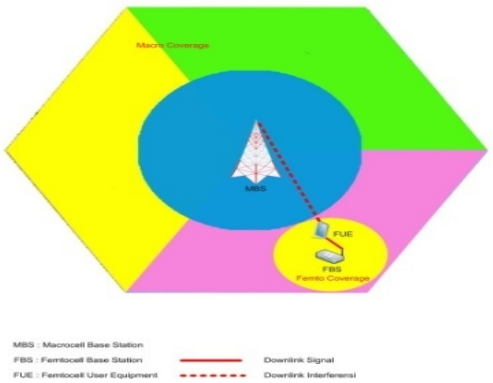

Figure 5. Scenario 1 after the FFR method is applied

Figure 6. Scenario 2 after the FFR method is applied

Project Flowchart

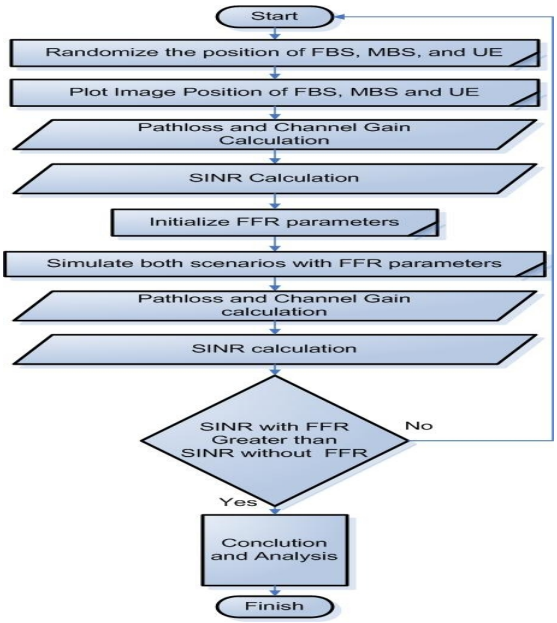

Figure 7. Project Flowchart

6. SIMULATION RESULTS AND ANALYSIS

6.a. Scenario 1 Analysis

In scenario 1,the interference that occurred in Scenario 1 is between Macrocell Base Station (MBS) – Femtocell User Equiptment (FUE). In this scenario FUE supposedly only receives the signals

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from Femtocell Base Station (FBS), but it turns out that it also receives signals from MBS as an interferer. The distance between FUE and FBS are made random in Matlab (0-30 meters), as well as the distance between FUE and MBS (0-1000 meters). The clear design of Scenario 1 can be seen in Figure 3.2 in the previous chapter.

Once the distance between FUE – FBS and FUE – MBS is randomized, then the value of SINR on FUE is calculated before and after the FFR method is applied. The scenario 1 design after the application of FFR method can be seen in Figure 3.5

After the Matlab simulation obtained, the results are shown bellow in Fig.8

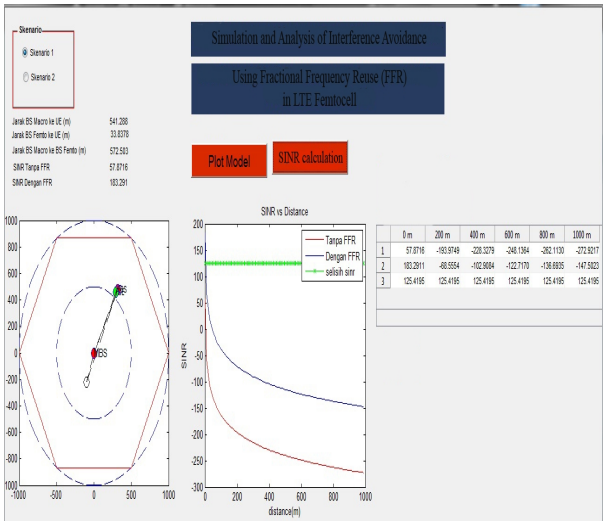

Figure 8. Matlab Simulation Results of Scenario 1

Simulation result shows the Position Layout of FBS, MBS and FUE after the random placement with Matlab. More details can be seen in Fig.9

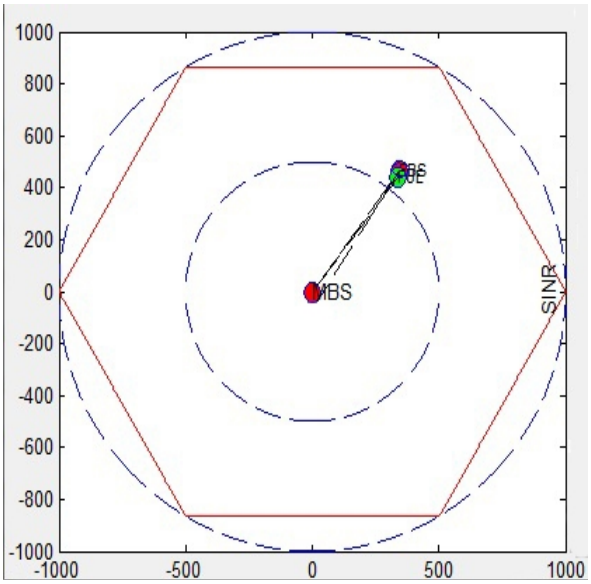

Figure 9. Layout Positions of FBS, MBS, and FUE

It can be seen in figure 9, a distance between MBS – FBS is 572.503 meters, distance between FBS – FUE is 33.8378 meters. And with the position as such in Figure 4.2, it can be obtained the distance between MBS – FUE is 541.288 meters. At such distances, we can obtained the SINR values before the implementation of FFR method is 57.8716 dB and the SINR value after the implementation of FFR method is 182.291 dB. It shows that after the FFR method is applied, there is an increase of SINR value by 124.4194 dB, that is from 57.8716 dB to 182.291 dB.

For more details, here is a Graphic Comparison of the SINR value with and without the implementation of FFR method, where the value of SINR compared to the distance between MBS – FBS at see Fig. 10.

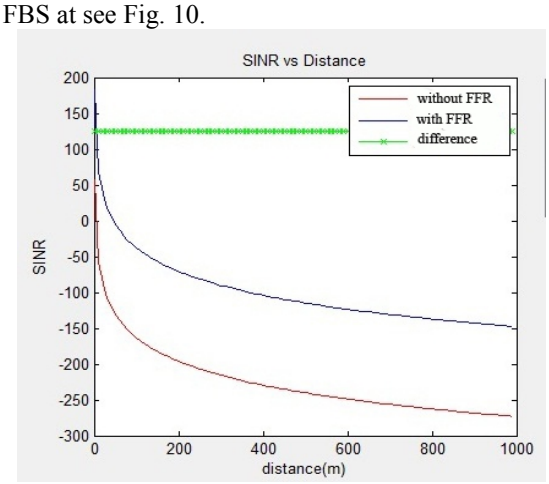

Figure 10. Comparison of SINR Values With and Without FFR to MBS – FBS Distance

The red line is the graph of SINR value without the application of FFR method. The blue line is the graph of SINR value after the application of FFR method. And the green line is the graph that shows the deviation between the red and the blue line. In the graphic, it can be seen that the SINR value of user after the FFR method applied is constantly higher than the value of SINR without the application of FFR method.

Difference in the value of SINR with and without the FFR can be seen in the following table 6:

Table 6. Comparison and the Deviation of SINR Value Between With and Without of FFR

	0 m	200 m	400 m	600 m	800 m	1000 m
With FFR	57.8716	-193.9749	-228.3279	-248.1364	-262.1130	-272.9217
Without FFR	183.2911	-68.5554	-102.9084	-122.7170	-136.6935	-147.5023
Difference	125.4195	125.4195	125.4195	125.4195	125.4195	125.4195

It can be seen that the average increase of SINR is equal to 104.6944 dB. This is because after the application of FFR method, the FBS is no longer become an interferer. There for we can conclude that the application of the FFR method can reduce the interference of Macrocell User.

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6.b.Scenario 2 Analysis

In scenario 2, the interference that occurred in Scenario 2 is between Femtocell Base Station (FBS) – Macrocell User Equiptment (FUE). In this scenario MUE supposedly only receives the signals from Macrocell Base Station (FBS), but it turns out that it also receives signals from FBS as an interferer. The distance between MUE and FBS are made random in Matlab (0-30 meters), as well as the distance between MUE and MBS (0-1000 meters).

After the Matlab simulation obtained, the results are shown bellow in Fig.11 :

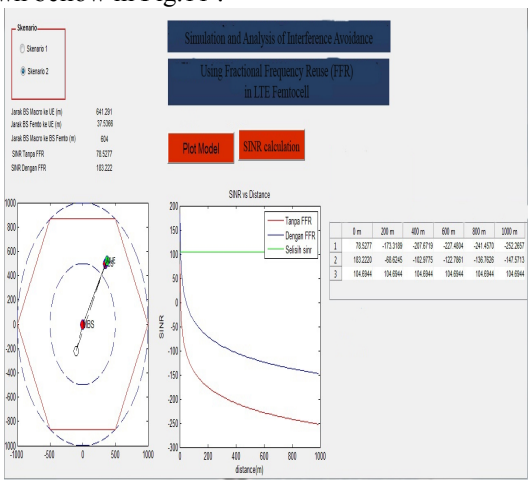

Figure 11. Matlab Simulation Results of Scenario 2

Simulation result shows the Position Layout of FBS, MBS and MUE after the random placement with Matlab. More details can be seen in Fig.12 bellow.

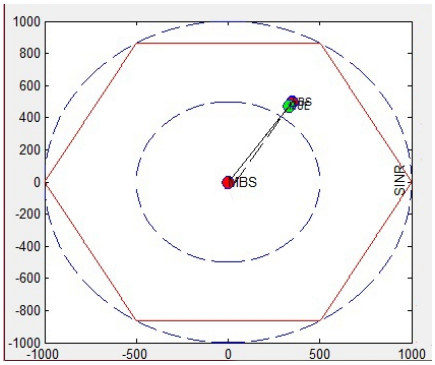

Figure 12. Random Distance FBS – MBS – MUE and the Result of SINR Value

In the fig.12, the MBS is placed in the center of the cell with diameter of 1000 meters, where the location of FBS and MUE randomized refer to the center dot of MBS inside the macrocell coverage. A red dot is FBS that already randomized in the range of 0-1000 meter distance from the MBS. The green dot is the MUE, which randomized in a distance of 0-30 meters from the FBS.

It can be seen in fig.12, a distance between MBS – FBS is 604 meters, distance between FBS – MUE is 37.5366 meters. And with the position as such in Figure 4.5, it can be obtained the distance between MBS – MUE is 641.291 meters. At such distances, we can obtained the SINR values before the implementation of FFR method is 78.5277 dB and the SINR value after the implementation of FFR method is 183.222 dB. It shows that after the FFR method is applied, there is an increase of SINR value by 104.6943 dB, that is from 78.5277 dB to 183.222 dB.

For more details, here is a Graphic Comparison of the SINR value with and without the implementation of FFR method, where the value of SINR compared to the distance between MBS – FBS, at can see fig.13.

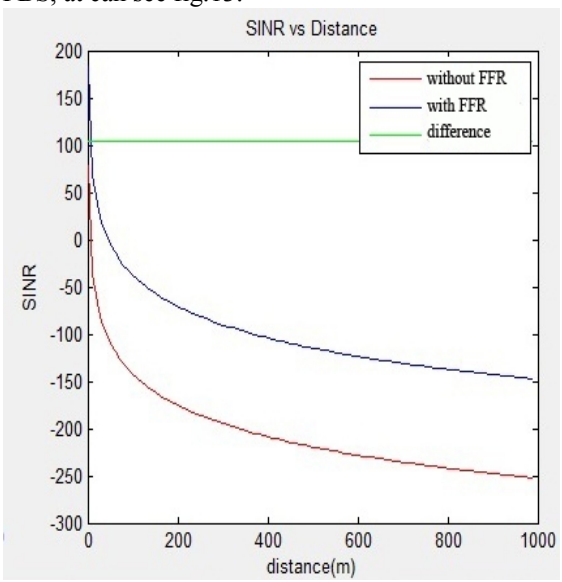

Figure 13. Comparison of SINR Values With and Without FFR to MBS – FBS Distance

The red line is the graph Fig.13 of SINR value without the application of FFR method. The blue line is the graph of SINR value after the application of FFR method. And the green line is the graph that shows the deviation between the red and the blue line. In the graphic, it can be seen that the SINR value of user after the FFR method applied is constantly higher than the value of SINR without the application of FFR method.

Difference in the value of SINR with and without the FFR can be seen in the following table 7:

Table 7. Comparison and the Deviation of SINR Value Between With and Without of FFR

	0 m	200 m	400 m	600 m	800 m	1000 m
With FFR	78.5277	-173.3189	-207.6719	-227.4804	-241.4570	-252.2657
Without FFR	183.2220	-68.6245	-102.9775	-122.7861	-136.7626	-147.5713
Difference	104.6944	104.6944	104.6944	104.6944	104.6944	104.6944

It can be seen that the average increase of SINR is equal to 104.6944 dB. This is because after

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the application of FFR method, the FBS is no longer become an interferer. There for we can conclude that the application of the FFR method can reduce the interference of Macrocell User.

7. Overall Results of Simulation

Of the whole experiment, all of the results of experiments in each scenario are following table 8 shows the results of simulation of Scenarios 1 and 2, which contains a comparison of the value of SINR with and without FFR, where the value of SINR compared to the distance.

Table 8. Comparison of the SINR With and Without FFR to MBS – FBS Distance

	Distance [m]	0	200	400	600	800	1000	SINR Difference [dB]
Scenario 1	- FFR	57.872	-193.975	-228.328	-248.136	-262.113	-272.923	125.4195
	+ FFR	183.291	-68.555	-102.908	-122.717	-136.694	-147.502	
Scenario 2	- FFR	78.528	-173.319	-207.672	-227.480	-241.4570	-252.2657	104.6944
	+ FFR	183.694	-68.625	-102.978	-122.786	-136.763	-147.5713	

In the table 8 above, it can be seen the difference between SINR value with and without the FFR method. On Scenario 1, the SINR after the FFR method is applied are increasing up to 125.4195 dB. And in Scenario 2, the increasing of SINR value is up to 104.6944 dB after FFR method is applied. It can be concluded that the application of FFR method in the macrocell can reduce the interference indicates by the increasing of the SINR value both to Macrocell User and Femtocell Users that happen to be in the range Femtocell coverage.

8. CONCLUSIONS

The conclusions to be drawn from this research are as follows:

[1] In scenario 1, where there are FUE and FBS, with MBS as interferer, the distance between MBS – FBS is 572.503 meters, distance between FBS – FUE is 33.8378 meters, and distance between MBS - FUE is 541.288 meters. SINR value increased by 124.4194 dB, that is from 57.8716 dB to 182.291 dB.. This indicates a decrease in interference to femtocell user after the FFR method is applied to the macrocell.

[2] In scenario 2, where there are MBS and MUE with FBS as a interferer, the distance between MBS – FBS is 604 meters, distance between FBS – MUE is 37.5366 meters, and distance between MBS – MUE is 641.291 meters. SINR value increased by 104.6943 dB, that is from 78.5277 dB to 183.222 dB. This indicates a decrease in interference in macrocell user after the FFR method is applied to the macrocell.

[3] SINR value comparison of user equiptment, both MUE and FUE, constantly have a value greater SINR after applying FFR method. Which means the application of FFR is able to reduce co-channel interference between the macrocell and femtocell.

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