Mini-Project for EG7023 Radio Communications

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Contents

Design of the Mobile Telephone System

Requirement for the Mobile Telephone System in Rome

1. Estimation of traffic. We have a license for up to 600 channels.
2. The blocking factor should be no more than 2%.
3. Co-channel interference should be considered.
4. We assume that in order for the mobile unit to receive a call the signal power should be higher than -85dBm.
5. We should investigate the effect of signal fading in the above calculation.
6. The height of mobile units may be taken as 1.5m.
7. The frequency of transmission is 1.8GHz.
8. We should minimise the base station power.
9. No base station antenna can be placed more than 4m above the skyline.
10. We just are responsible for a subarea with sides of between 1.5 and 2km.

Preparation for the Mobile Telephone System

After knowing the requirement for the system, firstly, we should consider the population and population density in Rome in order to provide the good service that keeps all the clients can use the system as well as possible.

Through some investigation, we find the population condition in Rome for 2006 on the website:

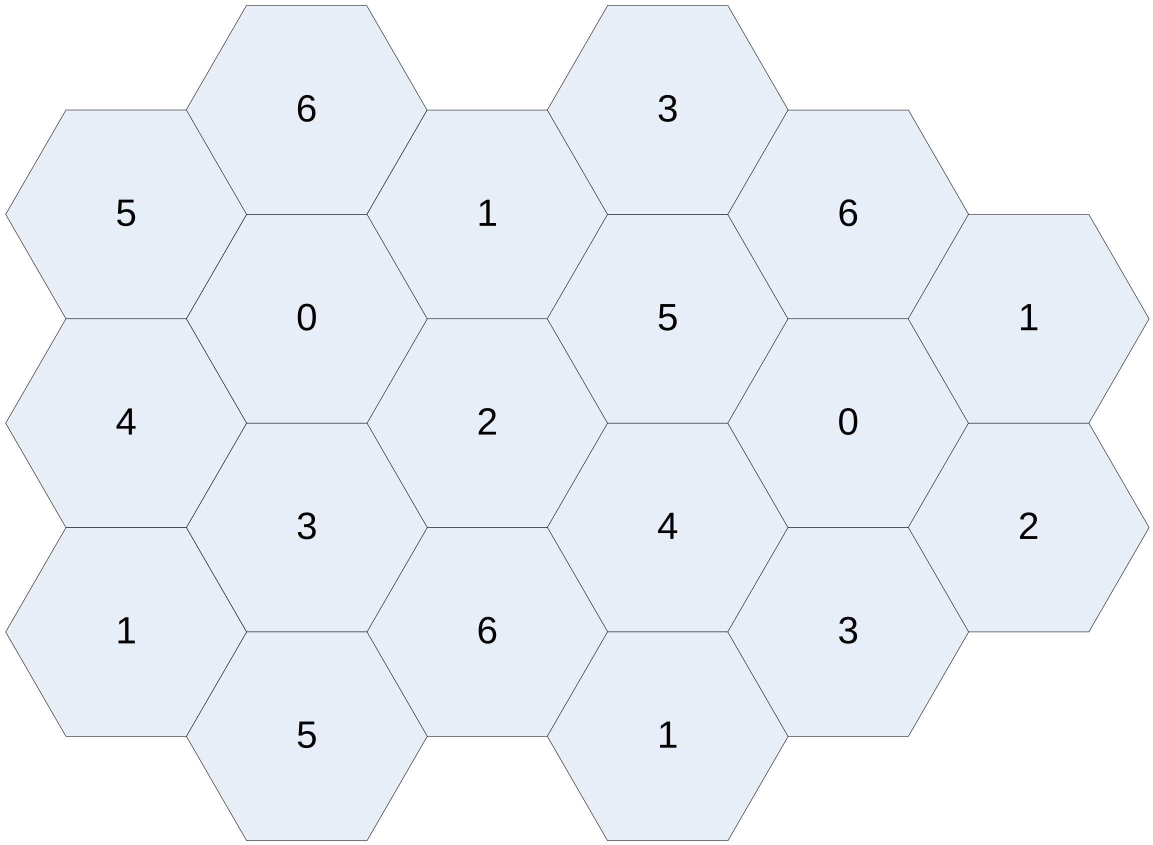
http://www.citymayors.com/statistics/largest-cities-density-125.html

Largest cities in the world ranked by population density

Rank	City / Urban area	Country	Population	Land area (in sqKm)	Density (people per sqKm)
77	**Goiania**	Brazil	1,475,000	479	**3,100**
78	**Munich**	Germany	1,600,000	518	**3,100**
79	**Stuttgart**	Germany	1,250,000	414	**3,000**
80	**Dublin**	Ireland	1,075,000	365	**2,950**
81	**Kuwait**	Kuwait	1,600,000	544	**2,950**
82	**Nizhni Novgorod**	Russia	1,500,000	505	**2,950**
83	**Rome**	Italy	2,500,000	842	**2,950**
84	**Phnom Phen**	Cambodia	1,500,000	518	**2,900**
85	**Beirut**	Lebanon	1,800,000	648	**2,800**
86	**Brasilia**	Brazil	1,625,000	583	**2,800**
87	**Essen/Düsseldorf**	Germany	7,350,000	2,642	**2,800**

Comparing with the data from other database, we think the population density 2950p/km^2 in Rome is the reasonable one. So we use this as the population density for the further calculation of the Mobile Telephone System.

In this system, I want to use the seven-cell cluster which can be described as the graph below:



The reason I use this frequency reuse-pattern is that for the fixed number of channels, population density and area, the size of the cell and the available channels in the cell is the most reasonable choice for the system. The 12-cell cluster which could reduce the co-channel interference (20.7dB) will reduce the available channels in each cell and the size of the cell. It means that we will need more base station in the area. That will increase our cost for the system.

Calculation for the Mobile Telephone System

The last thing we should do before implementing the system is that we should calculate the size of the cell through the preparations above.

$$p(B) = GOS = 0.02$$

From the Erlang B values table the offered traffic with 85 available channels (cell) for a blocking probability of 0.02 is

$$A = 73.490\ Erl/cell$$

The carried traffic is

$$A_C = A[1 - p(B)] = 73.490 \times 0.98 = 72.0202\ Erl/cell$$

We assume that the each user makes an average of 3 calls/hour, each call lasts an average of 3 minutes. So the traffic intensity by each user is

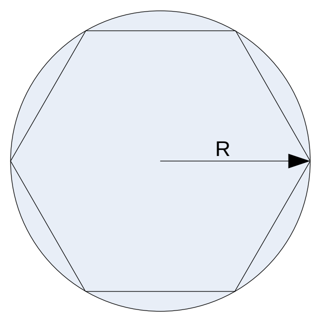
$$A_I = \frac{call}{hour} \times call\ duration = 3 \times \frac{3}{60} = 0.15\ Erl$$

Therefore, the maximum number of users that can be supported by this cell is:

$$\frac{A_C}{A_I} = \frac{72.0202}{0.15} \approx 480.1347$$

Because the population density is about 3000p/km^2, the cell size will be

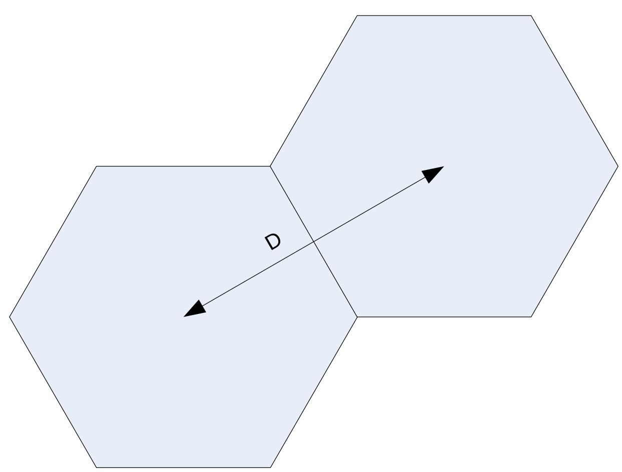
$$S_{cell} = \frac{480.1347}{3000} \approx 0.16\ km^2$$



$$\pi \times R^2 = 0.16$$

So the radius is

$$R = 0.2257\ km$$



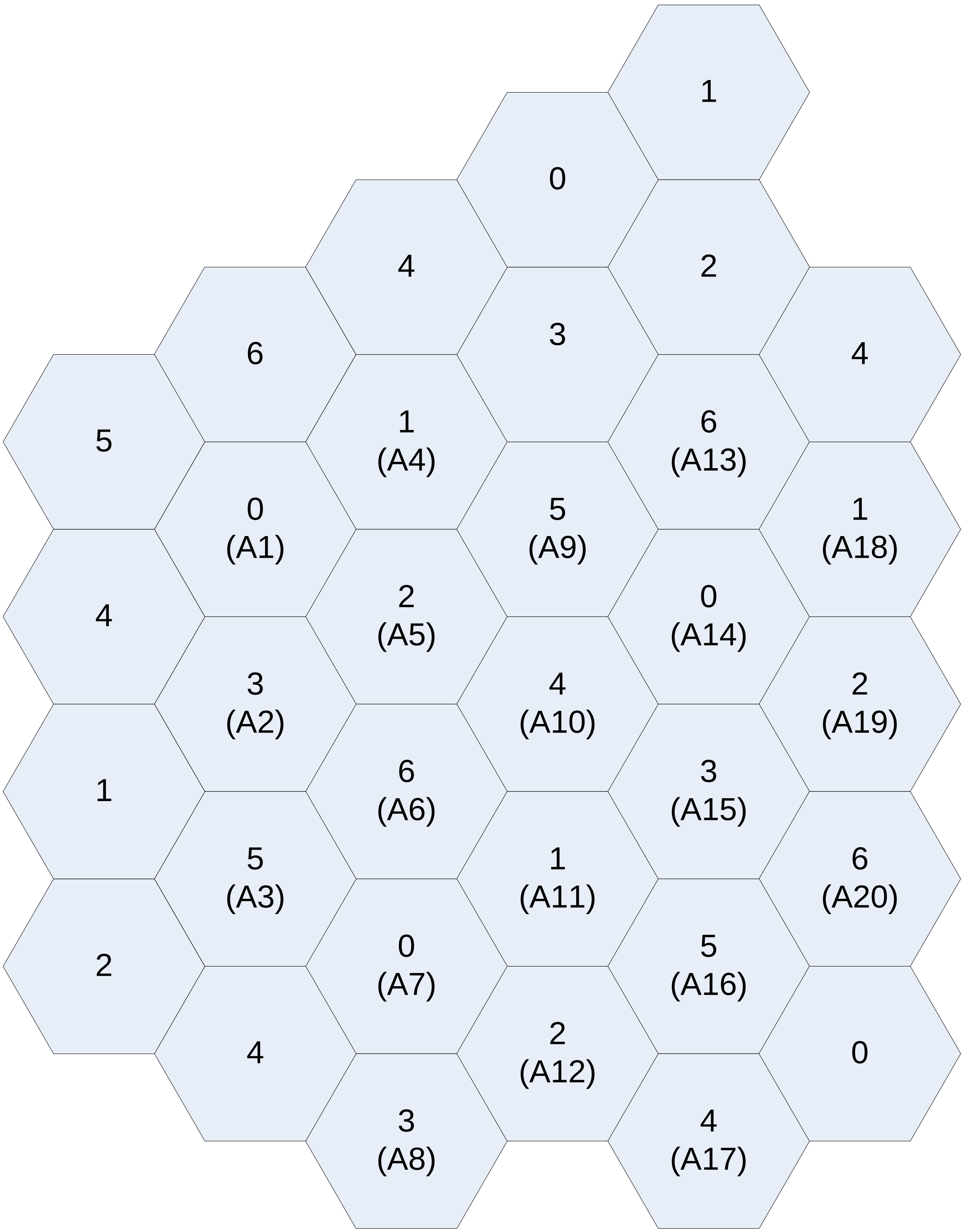
The distance between two cells is

$$D = \sqrt{3 \times R} \approx 0.3909\ km = 390.9\ m$$

Distribution of the Antennas

I choose the region (51420<x<51600, 5033800<y<5035800) as the area where I should allocate the antennas in.

Firstly, I allocate the antennas and channels as following graph:



We can see that there are 20 antennas in this area which use 7-cell cluster frequency reuse pattern.

After this, I set the first antenna with the location(x=514465.52, y=5035398.64) and carrier as 0.Then I can calculate all the locations of other antennas and carriers. The data is as below:

Antenna	X	Y	Carrier
A1	514465.52	5035398.64	0
A2	514465.52	5035007.74	3
A3	514465.52	5034616.84	5
A4	514803.04	5035593.87	1
A5	514803.04	5035203.07	2
A6	514803.04	5034812.17	6
A7	514803.04	5034421.27	0
A8	514803.04	5034030.37	3
A9	515142.62	5035398.64	5
A10	515142.62	5035008.54	4
A11	515142.64	5034618.44	1
A12	515142.64	5034227.54	2
A13	515480.14	5035593.94	6
A14	515480.14	5035203.04	0
A15	515480.14	5034812.14	3
A16	515480.14	5034421.24	5
A17	515480.14	5034030.34	4
A18	515819.72	5035398.64	1
A19	515819.72	5035007.74	2
A20	515819.72	5034616.84	5

Hereto, we have finished the calculation for the mobile telephone system. Then we will use winprop software to test this system we design.

Implement for the Mobile Telephone System

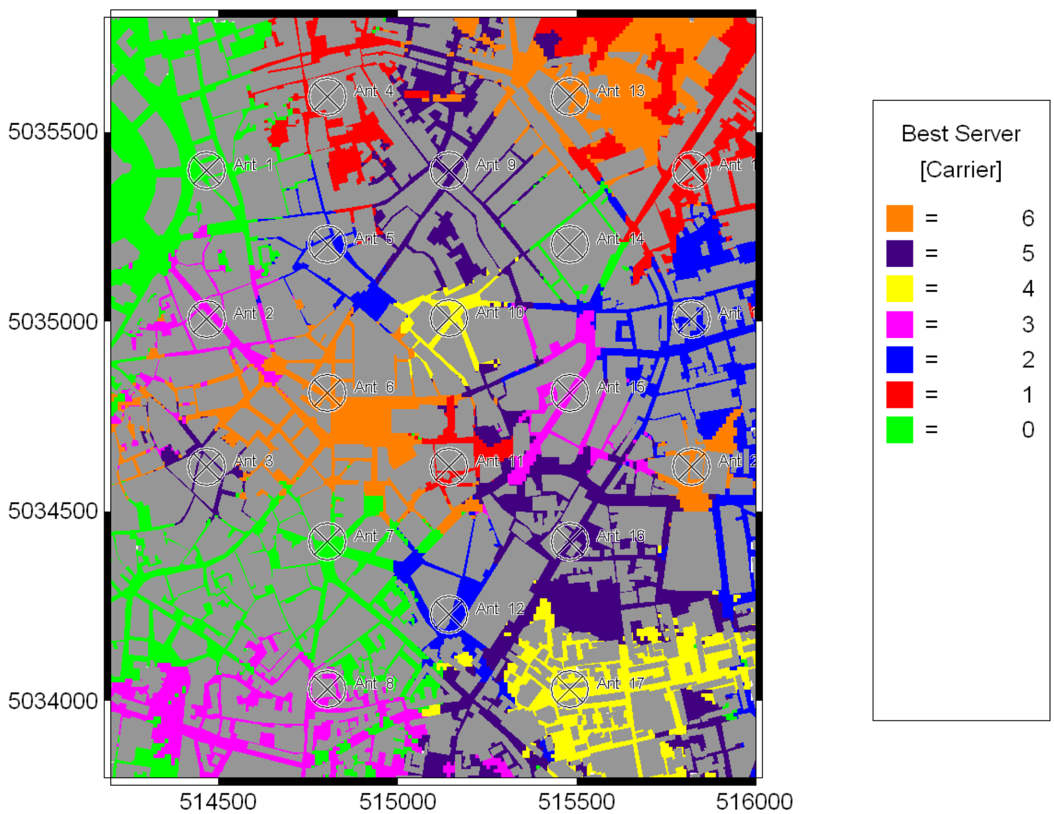
The Mobile Telephone System for Original Design

Setting Parameters

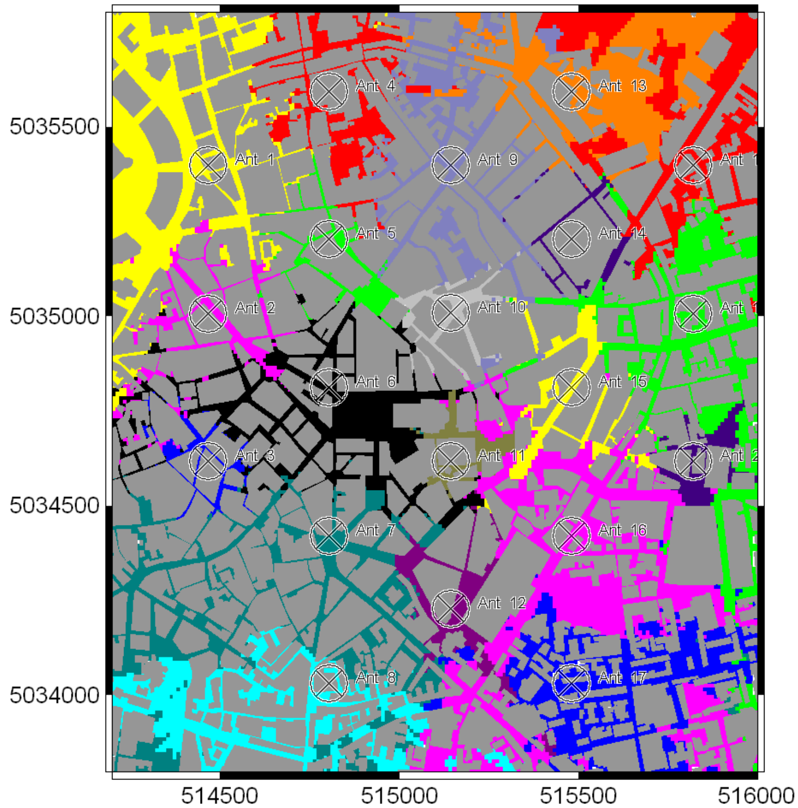
In the winprop, we use the default antenna power 10w. The prediction height is 1.5m and frequency is 1800MHz. All the heights of the antennas are set up as the tallest buildings nearby with 4m high. Because in this step, we just set all the parameter as the data we calculate above, there may be something unsuitable, and we will improve it later.

Analysing Results

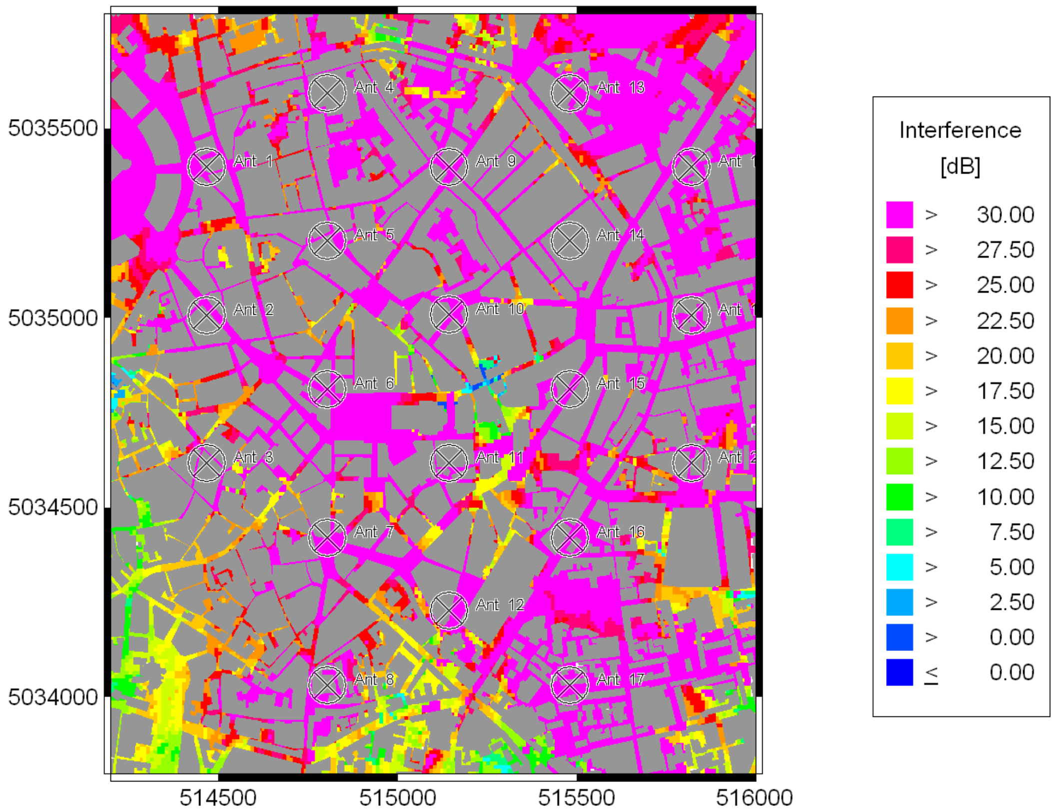
Through the propagation project, we calculate the data from each of the 20 antennas and put the data into the network project. Then we get the output result of Best Server, Cell Area, CoChannel Interference, Maximum Power and Nr Received Channels from the original design.



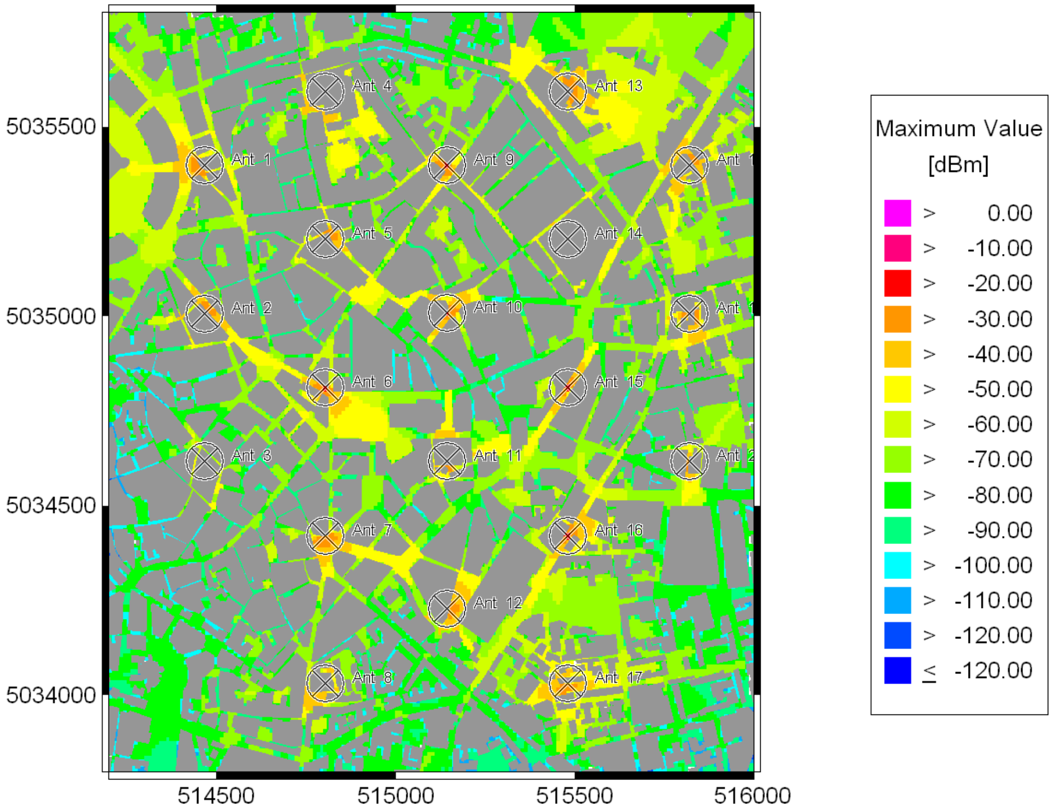
We can see that the best carrier for each pixel in the graph is almost as the carrier of the closest antenna. The areas with same carriers are separated by the areas which use different carriers. That will reduce the co-channel interference.



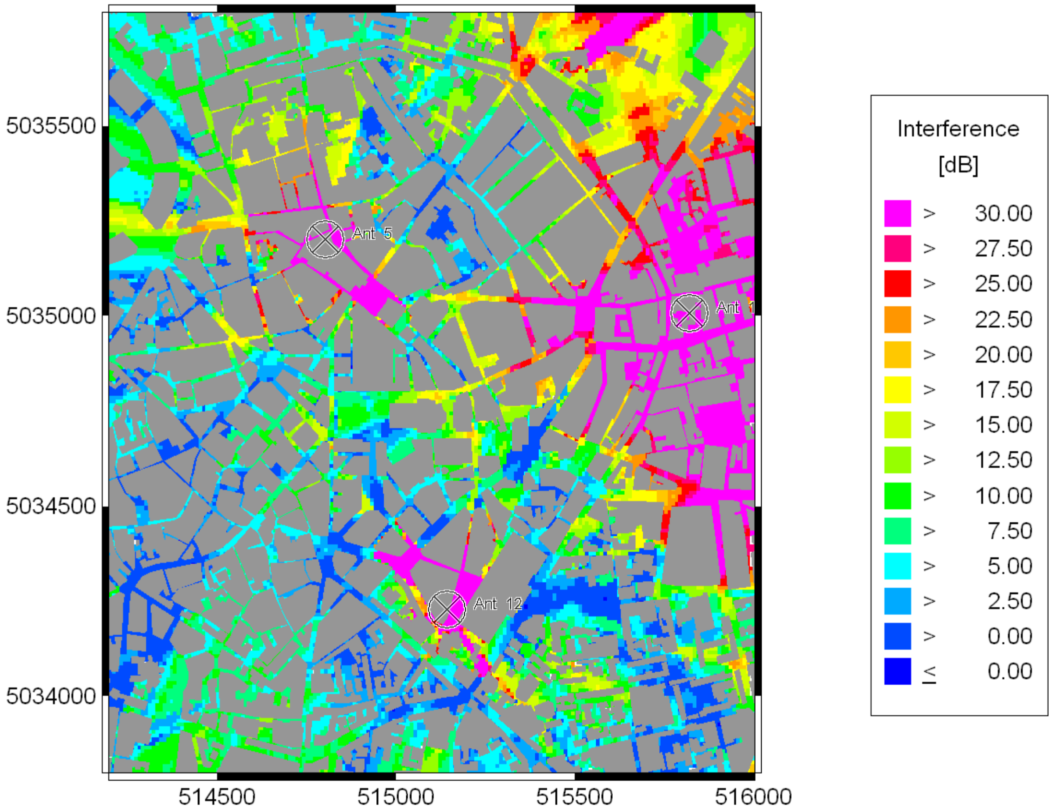
This is the cell area graph which indicates coverage of each cell. This picture is similar to the best server graph. We can see that each cell cover different areas with different sizes.



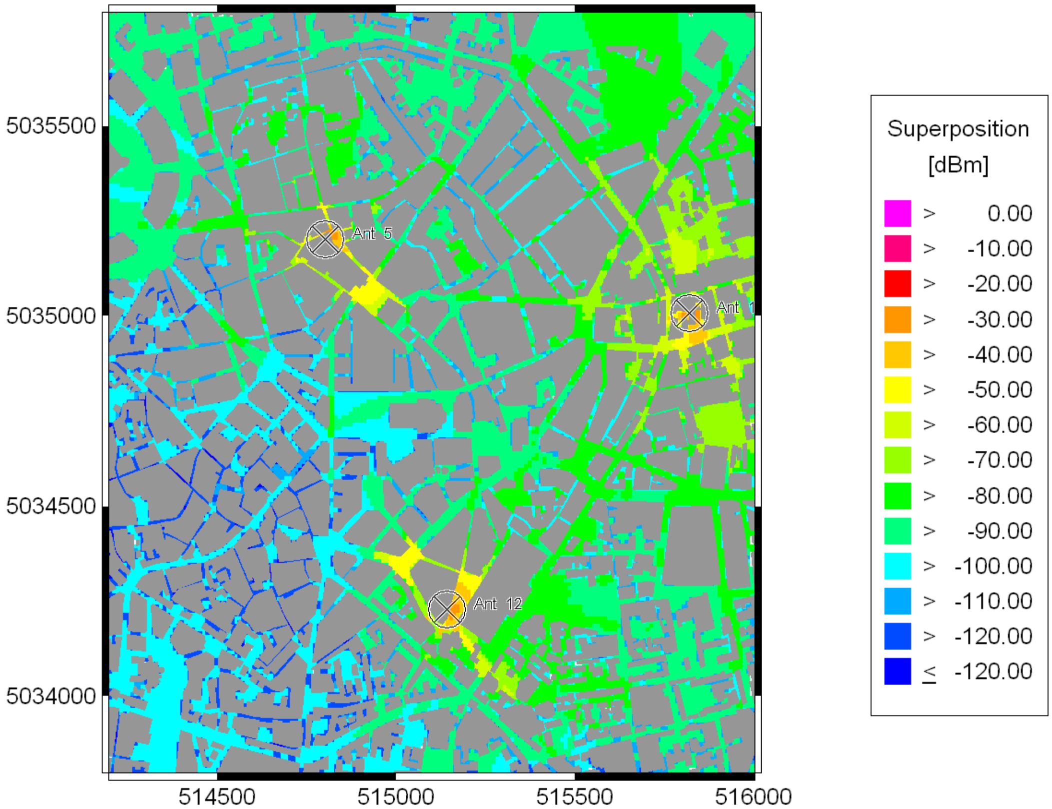
This is the output data of co-channel interference. From the figure above, we can see that the interference of every location is almost above the threshold and most of them overpass 30dB. There just a small area in the centre of the graph with serious interference. So we will improve it later.



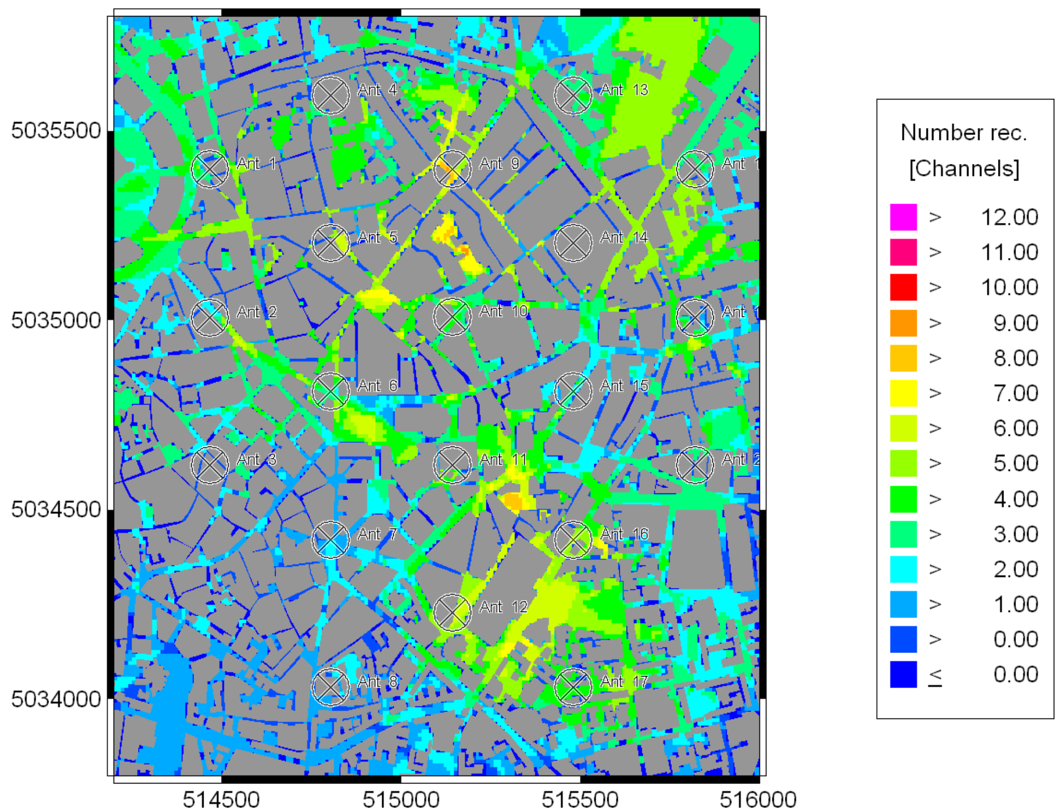
From this figure, we can see that the signal power in most area is bigger than the -85dB.It means that the clients can get the signal and make a call in most area within this region. So the power 10w we use in antennas is enough for this system.



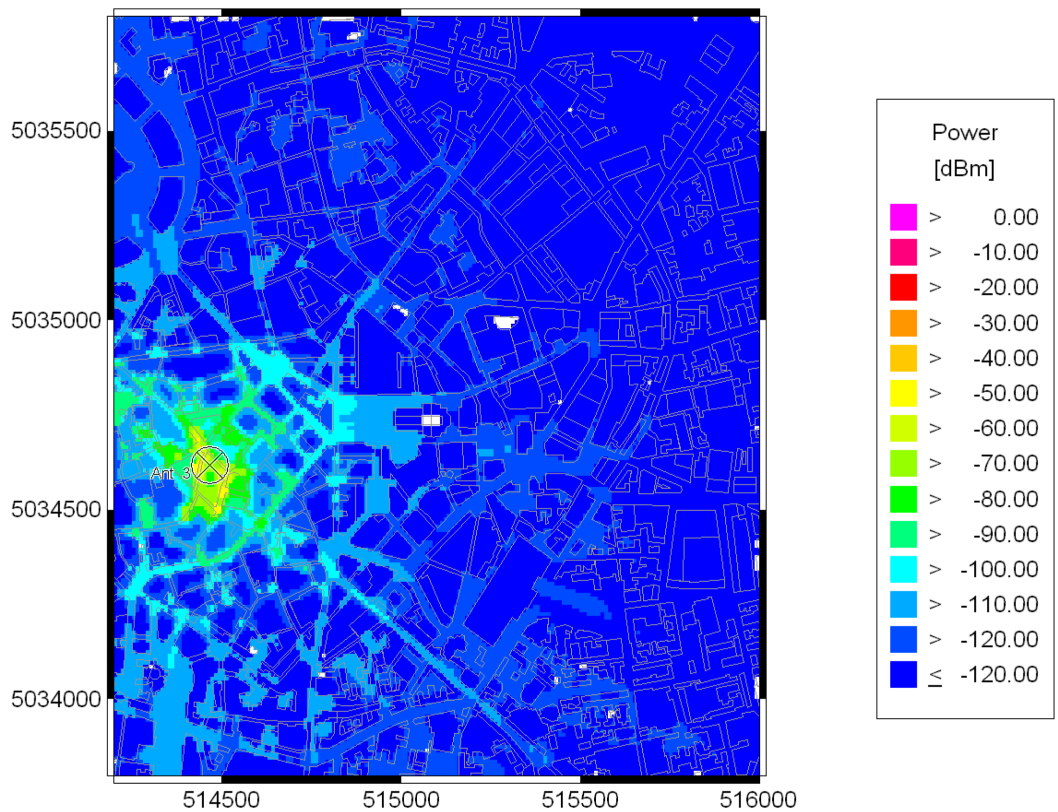
The picture shows that the co-channel interference of same carrier (2) with antenna 5, 12 and 19. We can see that the interference condition is much good due to the 7-sell cluster for frequency reuse pattern.



This figure illustrates the power distributions for the antenna 5, 12 and 19. We can see that the power condition is good under these antennas with the carrier 2.



This figure shows that how many channels are available in each pixel. We have set the threshold as -85dB. We can see that there are some areas can receive more than one channel. That means the signal power with different carriers from different antennas is higher in these regions. So clients in these areas will have more channels to choose. For instance, if the signal quality is decreased by people's move, the system can switch the client to use other channels which have better signal quality. This will avoid the disconnection of the call. There also some areas which cannot get channels at all, but these areas are not too large and we can improve it by some methods which we will do later. Some specific areas which still cannot get the channels could be neglected.



This is the picture showing the power distribution of the antenna 3, which we want to use to compare the power condition between outdoor and indoor. We can see that the areas closer to the antenna have good power condition and the outdoor power is 30-50dB higher than indoor's.

Conclusion

Through the result above, we can see the system we design is fairly good for use. However, we can see that there are some areas which can not fit for the situation for mobile communications. Thus, we will try to improve the system by adding more antennas, moving the location of the antenna, increasing the height of the antenna to increase the signal power and reduce the co-channel interference.

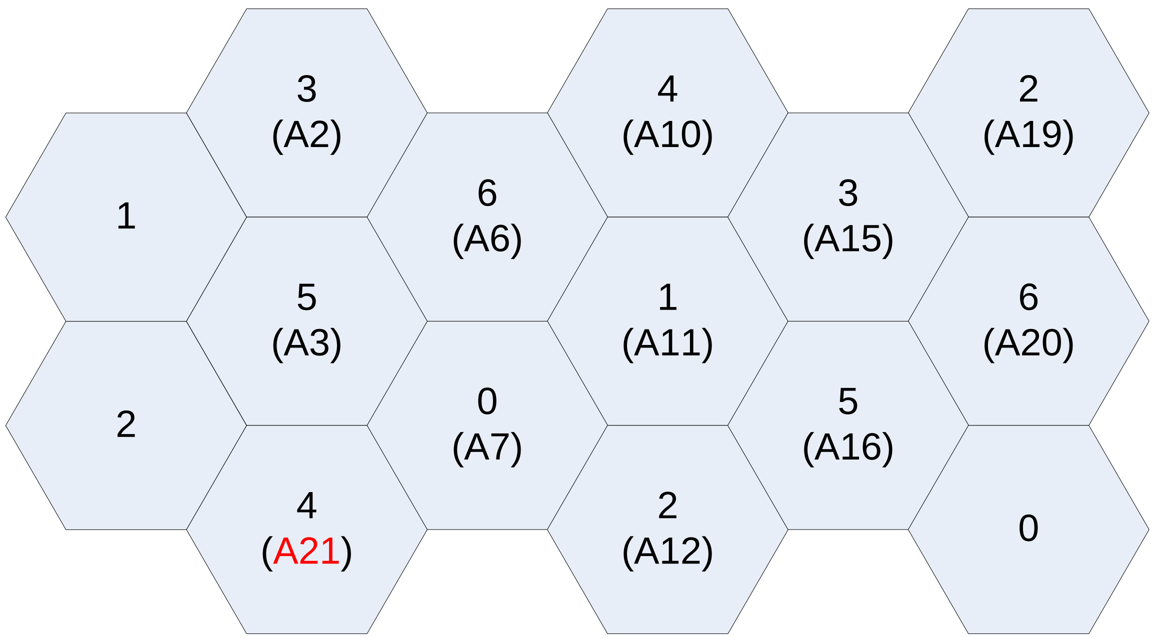
Improving the Signal Power by Changing the Location, Height of Antenna and Adding More Antennas

Setting Parameters

In this improving procedure, we try to improve signal power distribution by moving the antenna, increasing the height of the antenna and adding one antenna.

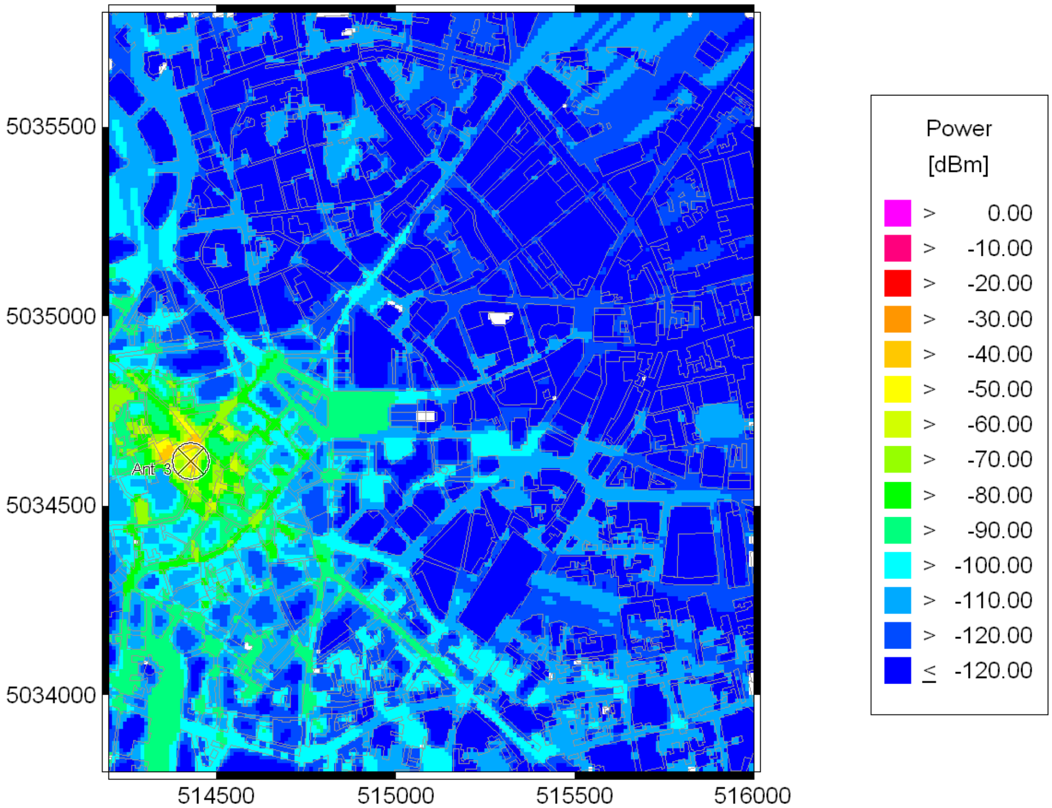
I find the power distribution of antenna 3 is not good, so I move the antenna 3 to the location (x=514426.71, y=5034616.55) and increase the height of it from 16m to 24m.

Because the signal quality is poor in the left down area, I decide to add one antenna to improve it.

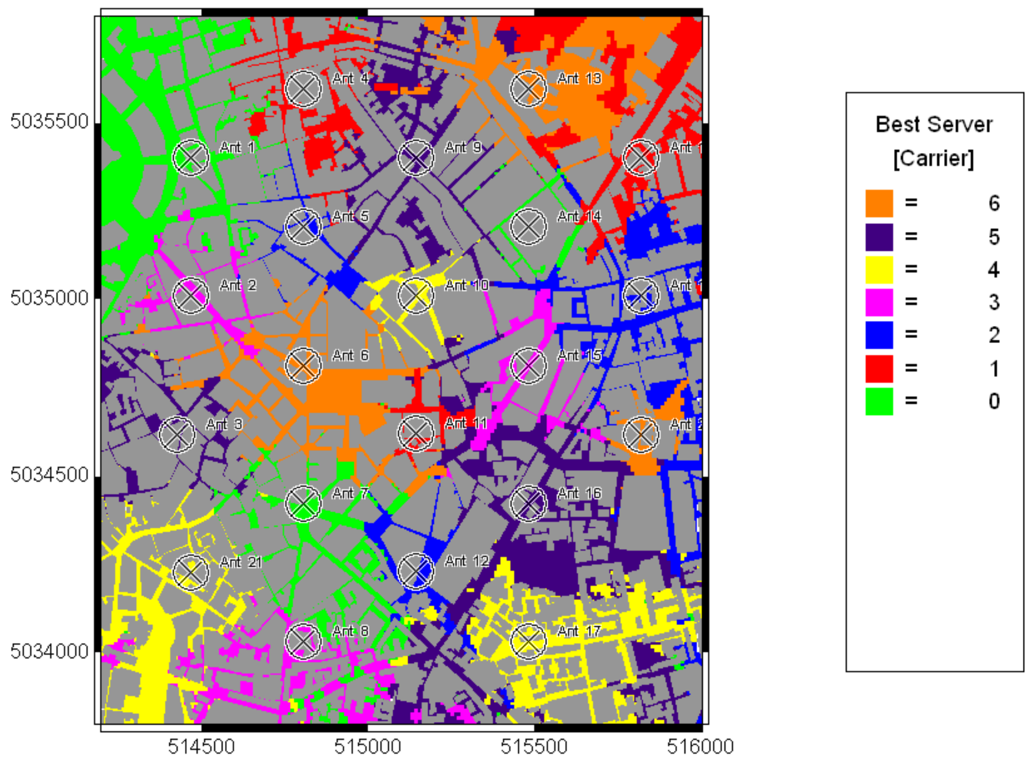


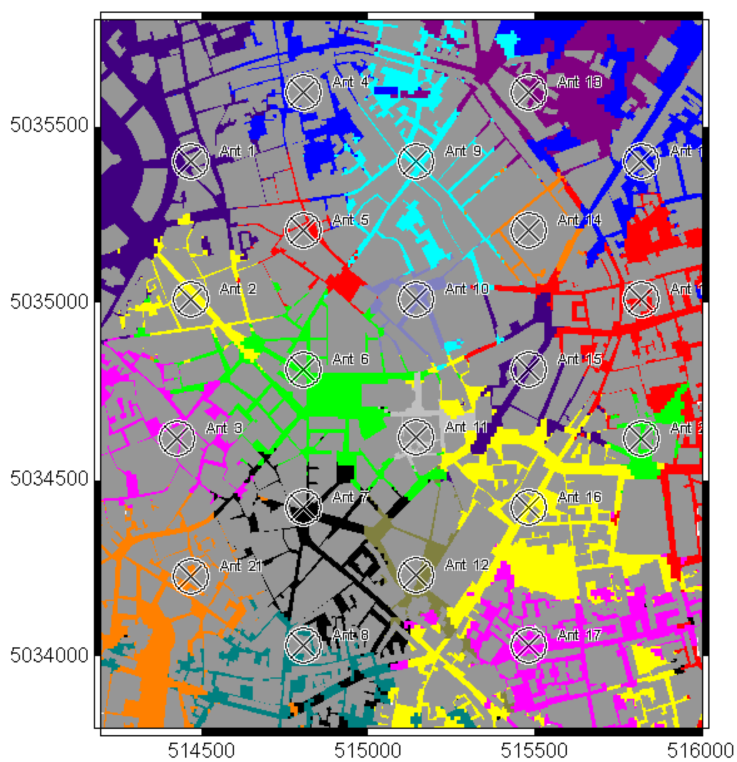
Antenna	X	Y	Carrier
A21	514465.52	5034225.94	4

Analysing Results

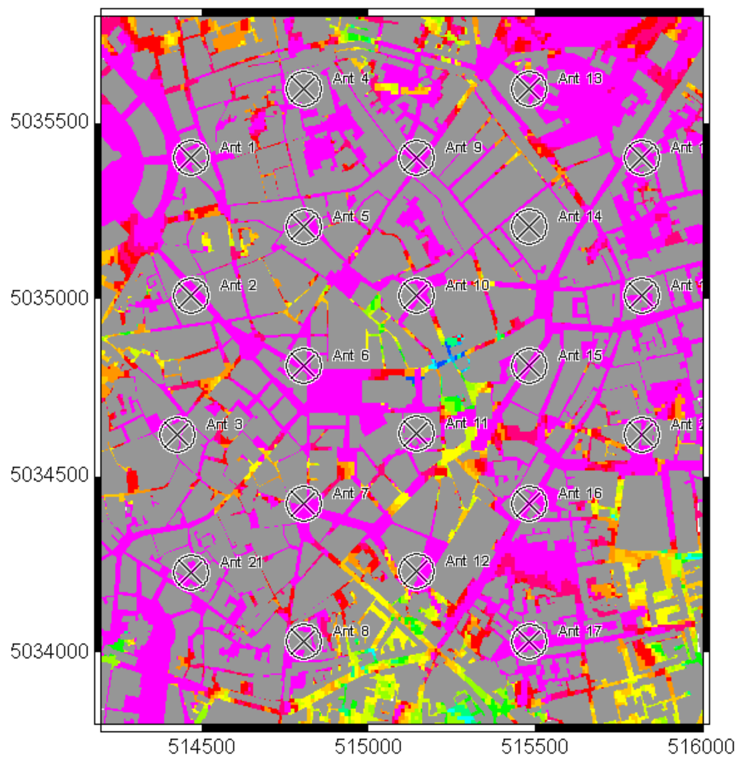


This is the graph showing the power distribution of antenna 3, which is better than that before.

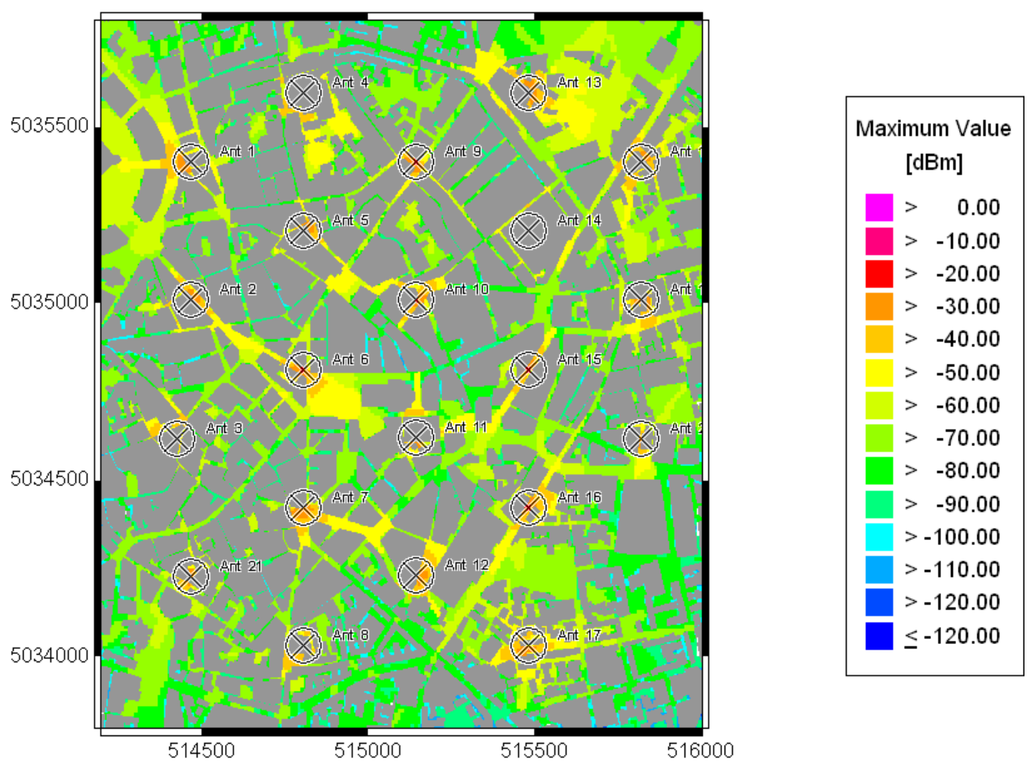




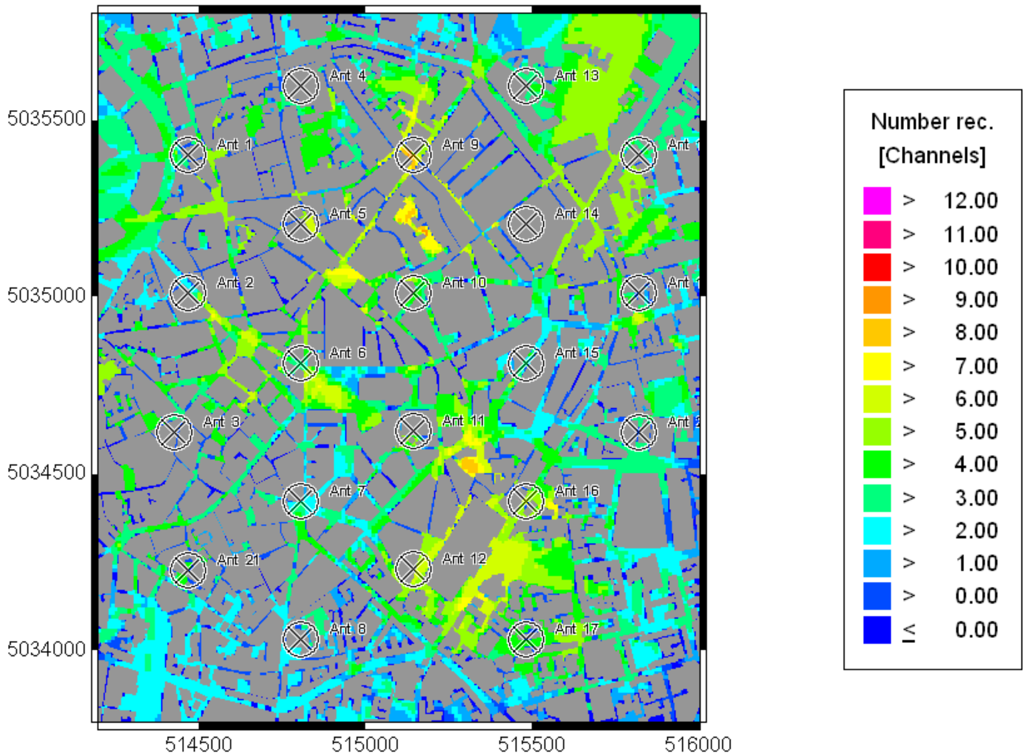
These two graphs indicate that the coverage of the cell using antenna 3 is increased and the coverage of the cells using antenna 7 and 8 are decreased. The most decreased areas are belong to the cell using antenna 21 now.



After adding the antenna 21, we can see that the co-channel interference in the left down areas is getter better comparing with the previous one.



After adding the antenna 21 and moving antenna 3, we can find the signal power increases 10-20dBm in the left down areas.



As we think, the available channels in the left down areas is increased by adding the antenna 21.

Conclusion

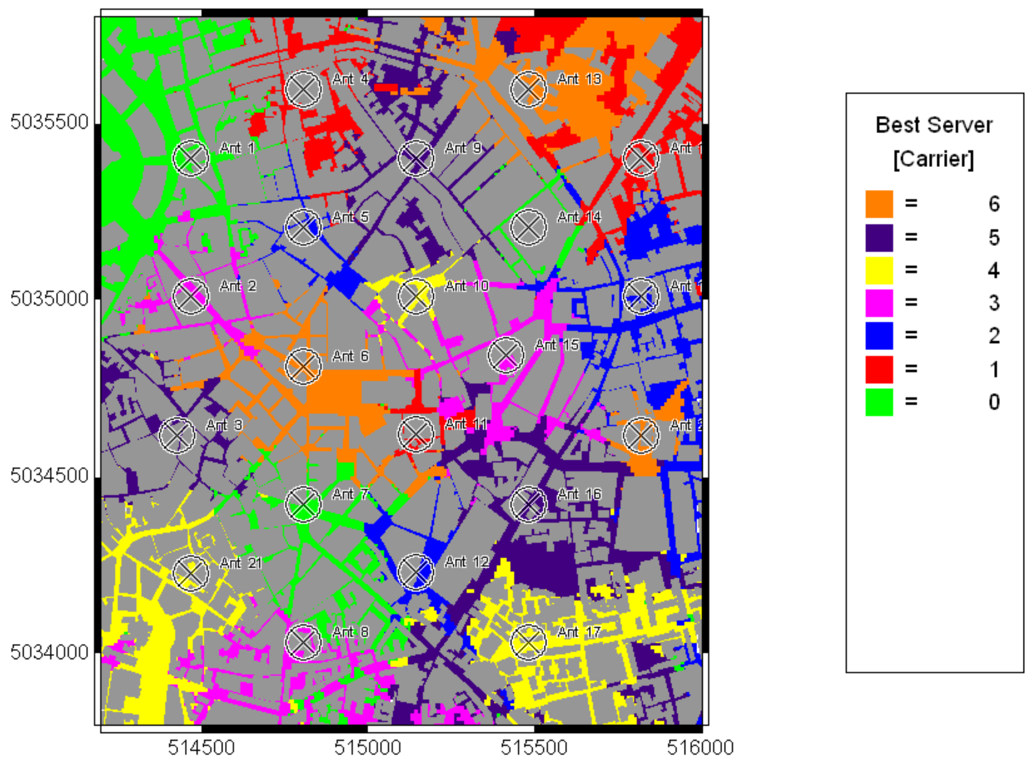
Moving the location of the antenna and adding more antennas will improve the system. When moving the location of the antenna, we should not move too far away from the previous location, because that will affect other antenna too much and lead to the unstable system. Adding more antennas will improve the system, but it will also increase the cost. Anyway, in this system, adding the antenna 21 is the reasonable choice because it makes the whole areas covered by better signal.

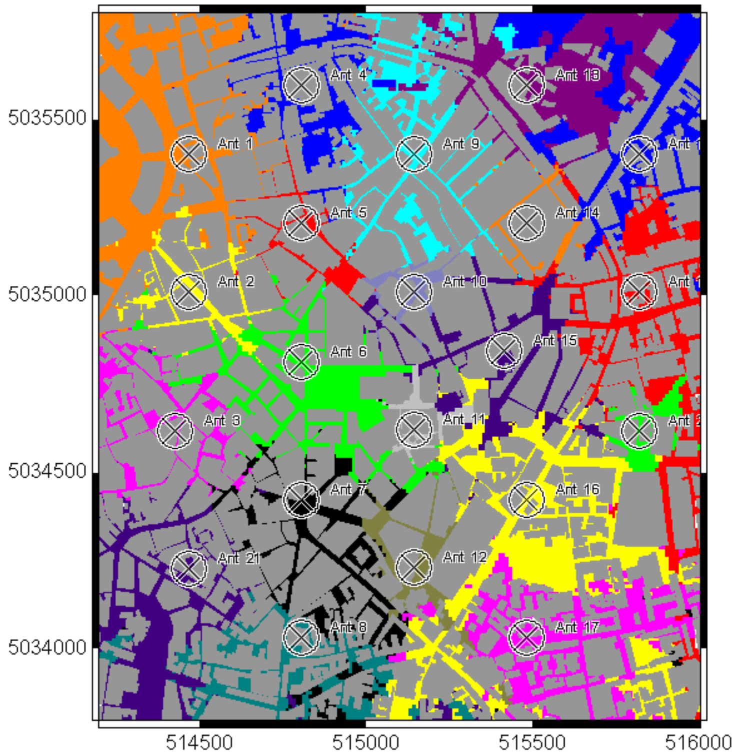
Improving the Co-Channel Interference by Changing the Locations and Height of Antennas

Setting Parameters

Base on the previous improvement, I want to decrease the co-channel interference in the centre area. In order to do that, I decide to move the antenna 15 towards the area where co-channel interference is poor. So I move the antenna to the location (x=515411.27, y=5034842.26), that also leads to the height of antenna increases from 34m to 45m.

Analysing Results




Ant 4
Ant 13
Ant 1
Ant 9
Ant 5
Ant 14
Ant 2
Ant 10
Ant 6
Ant 15
Ant 3
Ant 11
Ant 7
Ant 16
Ant 21
Ant 12
Ant 8
Ant 17
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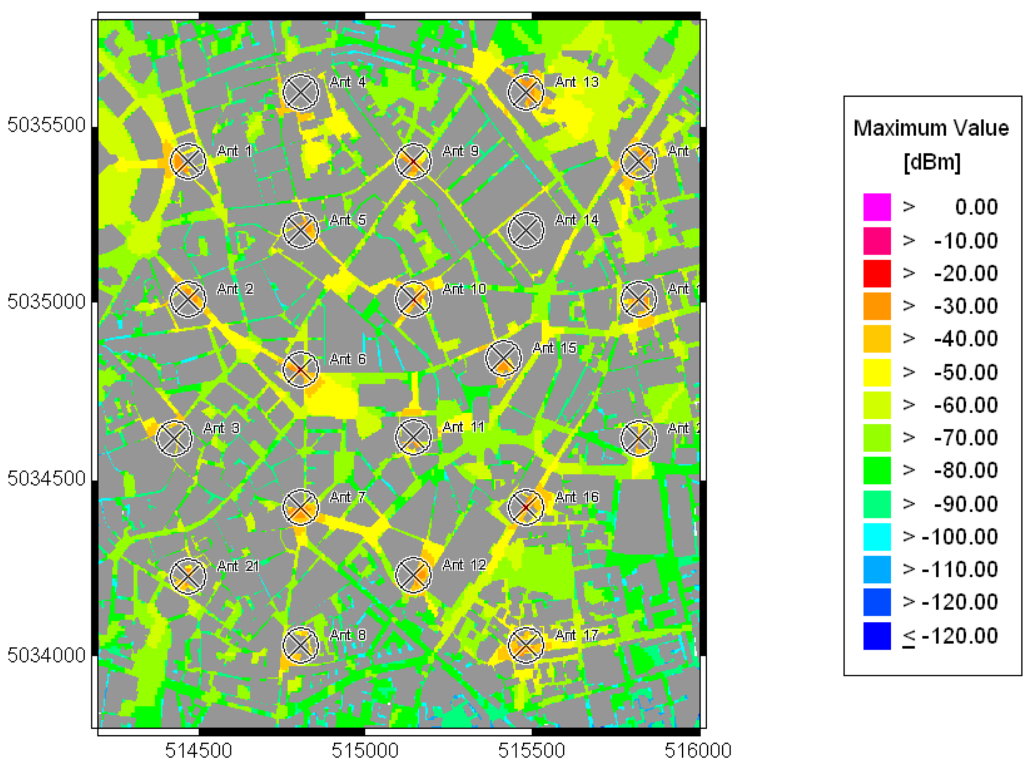
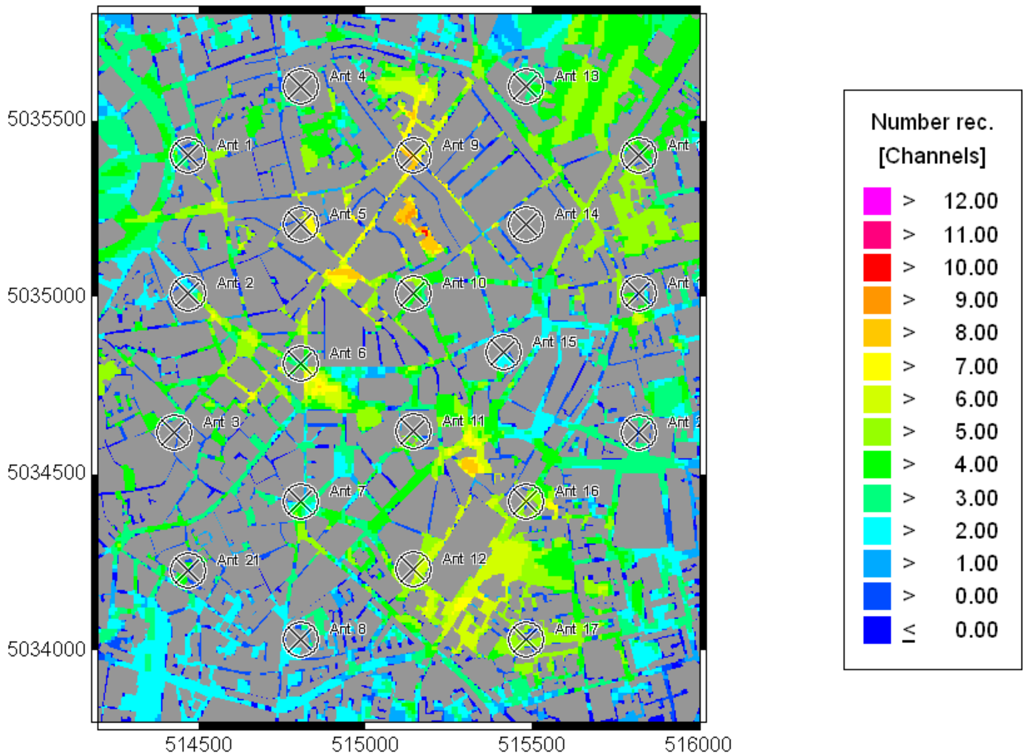
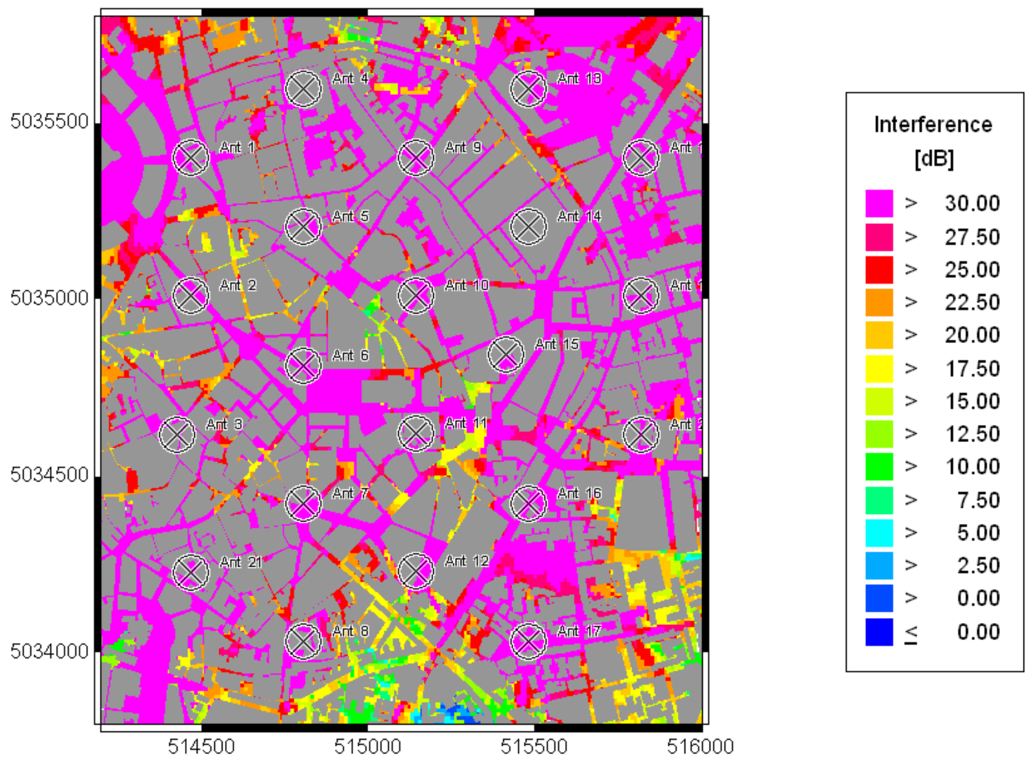
5034500
5034000
514500
515000
515500
516000


Ant 4
Ant 13
Ant 1
Ant 9
Ant 5
Ant 14
Ant 2
Ant 10
Ant 6
Ant 15
Ant 3
Ant 11
Ant 7
Ant 16
Ant 21
Ant 12
Ant 8
Ant 17
5035500
5035000
5034500
5034000
514500
515000
515500
516000
Maximum Value
[dBm]
> 0.00
> -10.00
> -20.00
> -30.00
> -40.00
> -50.00
> -60.00
> -70.00
> -80.00
> -90.00
> -100.00
> -110.00
> -120.00
≤ -120.00



Through the pictures above, we can see that moving antenna 15 does bring bad effects to the system.

Because our aim is to reduce the co-channel interference in the area, we get the CoChannel Interference graph below.



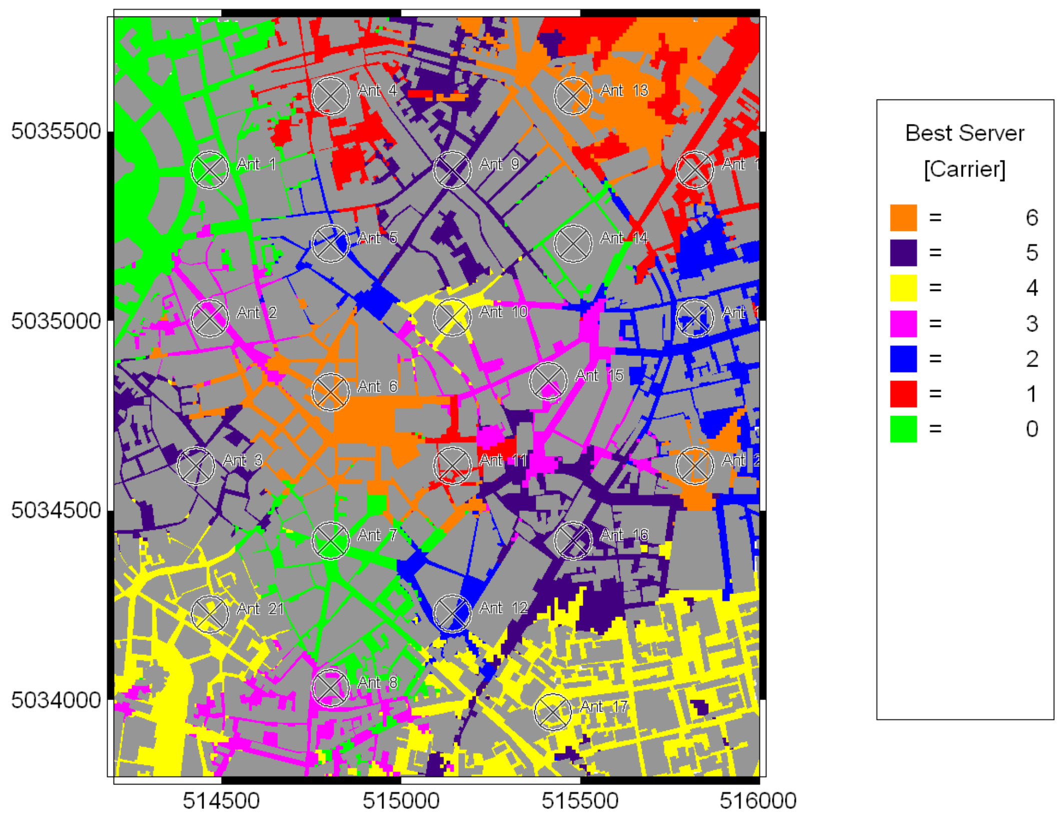
We can see that the co-channel interference is decreased (The centre blue region has disappeared). However, there is a blue area appearing at the centre bottom region. We should do further improvement to deal with that.

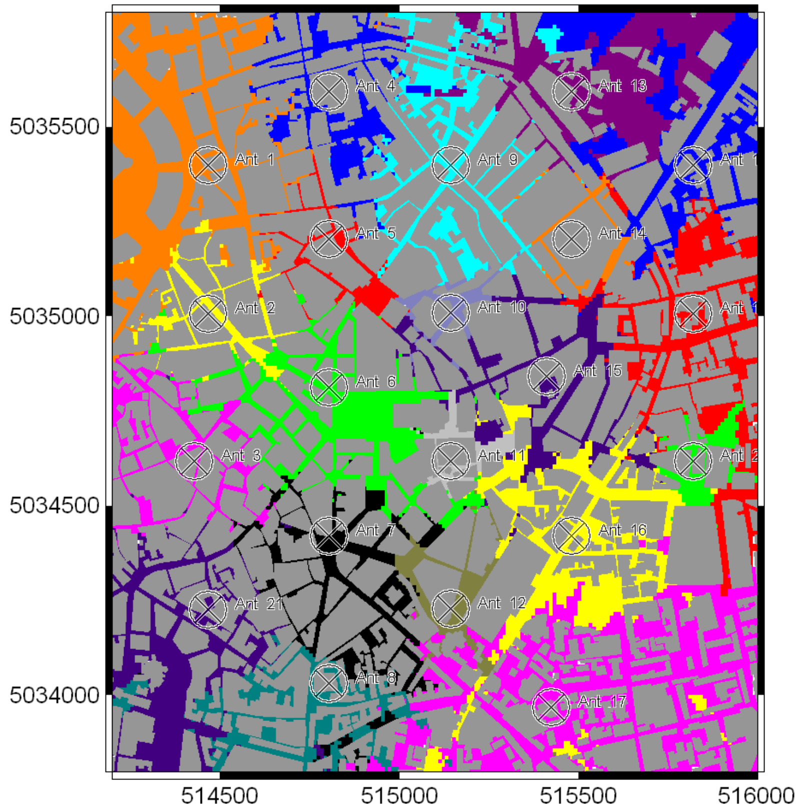
Improving the System to Minimise the Co-channel Interference

Setting Parameters

We use the same method as above to decrease the co-channel interference at the centre bottom area. We move the antenna 17 to the location (x=515424.35, y=5033967.49) with height 20m.

Analysing Results




5035500
5035000
5034500
5034000
514500
515000
515500
516000
Ant 1
Ant 2
Ant 3
Ant 4
Ant 5
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Ant 7
Ant 8
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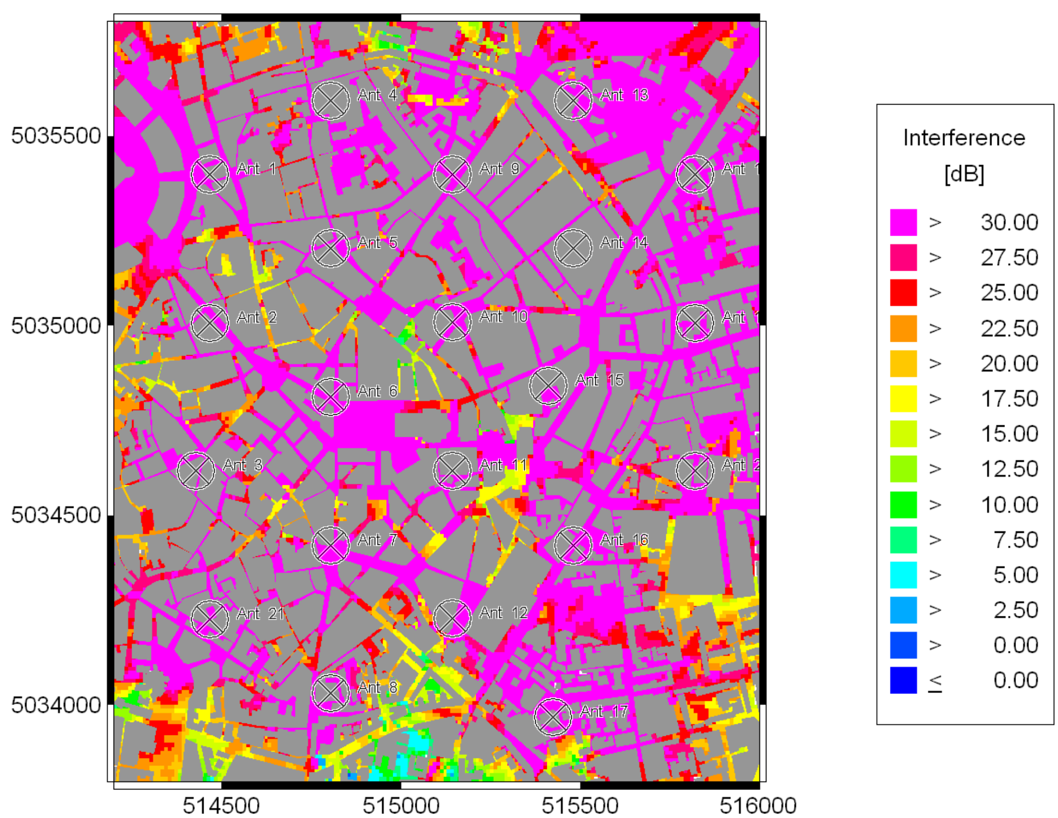
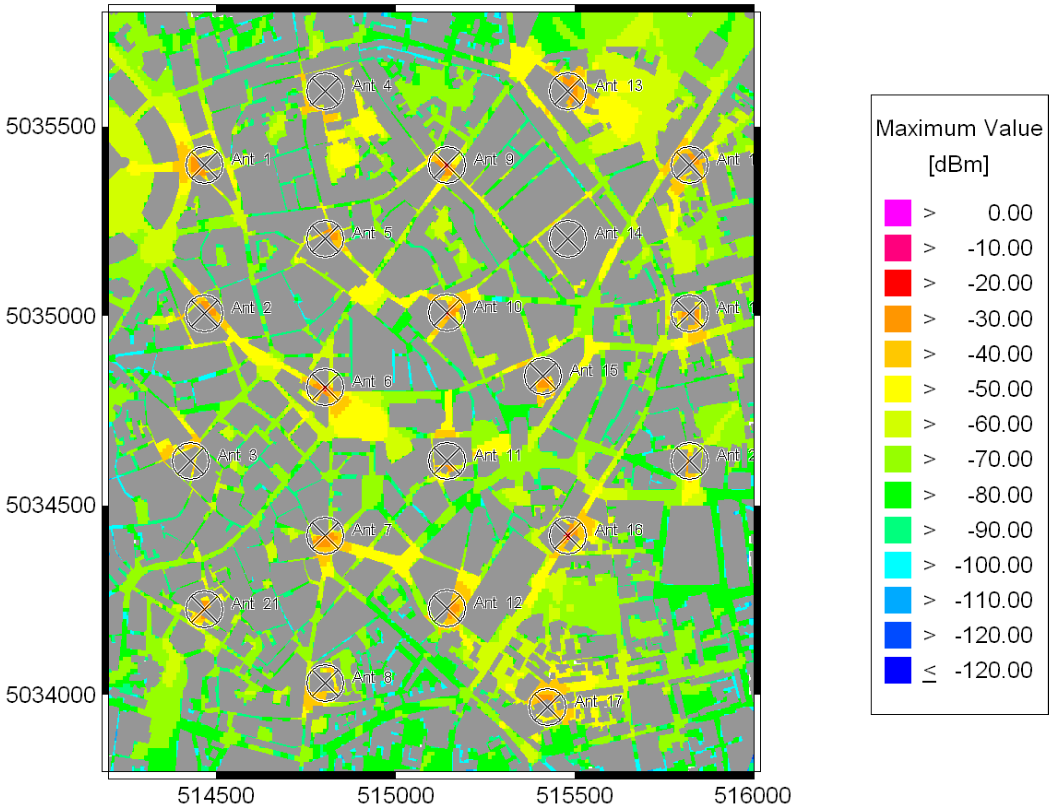
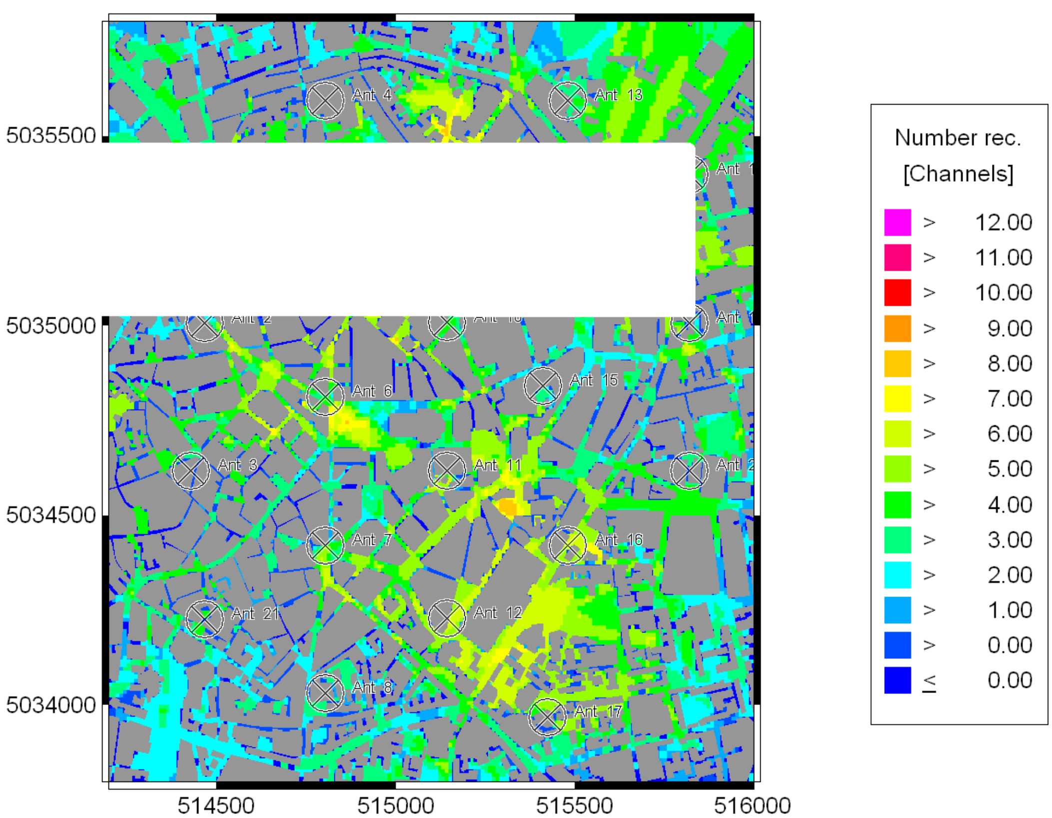
Ant 13
Ant 14
Ant 15
Ant 16
Ant 17
Ant 21


5035500
5035000
5034500
5034000
514500
515000
515500
516000
Ant 1
Ant 2
Ant 3
Ant 4
Ant 5
Ant 6
Ant 7
Ant 8
Ant 9
Ant 10
Ant 11
Ant 12
Ant 13
Ant 14
Ant 15
Ant 16
Ant 17
Ant 21
Interference [dB]
> 30.00
> 27.50
> 25.00
> 22.50
> 20.00
> 17.50
> 15.00
> 12.50
> 10.00
> 7.50
> 5.00
> 2.50
> 0.00
≤ 0.00


5035500
5035000
5034500
5034000
514500
515000
515500
516000
Maximum Value
[dBm]
> 0.00
> -10.00
> -20.00
> -30.00
> -40.00
> -50.00
> -60.00
> -70.00
> -80.00
> -90.00
> -100.00
> -110.00
> -120.00
≤ -120.00


5035500
5035000
5034500
5034000
514500
515000
515500
516000
Number rec.
[Channels]
> 12.00
> 11.00
> 10.00
> 9.00
> 8.00
> 7.00
> 6.00
> 5.00
> 4.00
> 3.00
> 2.00
> 1.00
> 0.00
≤ 0.00

Conclusion

We can see that the co-channel interference in the centre bottom area is getter better, so the co-channel interference has been minimized. And the mobile telephone system is improved reasonably.

Discussion

Fading

$$L_p = P_T - P_{th} - M$$

$$P_T = 10w = 10 \times \log \frac{10^7 mW}{1mW} = 70\ dBm$$

$$P_{th} = -85\ dBm$$

Through matlab with cost231hata.m, we use following code to calculate the loss.

$$Frequency = 1800\ MHz$$

$$Height\ of\ Tx = 30\ m$$

$$Height\ of\ Rx = 1.5\ m$$

$$Distance = R = 0.2257\ km$$

$$Large\ City = 1$$

cost231hata (1800, 30, 1.5, 0.2257, 1)

$$L_p \approx 116\ dB$$

So

$$M = P_T - P_{th} - L_p = 70 - (-85) - 116 = 39\ dB$$

Because the standard deviation of fading is

$$\sigma = 10\ dB$$

So through the coverage.m

coverage (40, 10)

We can get the outage probability at the boundary of the cell

$$P_{out} = 3.1671 \times 10^{-5} \approx 0.003\%$$

Co-channel Interference

The co-channel interference is

$$\frac{S}{I} = \frac{1}{N_I} \times (3 \times N_c)^{\nu/2} = \frac{1}{7-1} \times (3 \times 7)^{4/2} = 73.5 = 10 \times \log 73.5 \approx 18.7\ dB$$

Conclusion

Designing a mobile telephone system is work which should consider a lot of parameters. In order to do this well, we must investigate the background information of the city, such as the population, buildings, traffic system and so on. We also need to choose suitable frequency reuse patterns, types of antennas and size of the cell by calculations. Furthermore, we should also consider the potential changes in future. Thus, the layout of the mobile telephone system is complicated and must be treated very carefully.

References

Introduction to Wireless Systems, P. Mohana Shankar, John Wiley & Sons, New York, 2002. ISBN 0-471-32167-2