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3.4 Normal Frequency Reuse Technology

3.4.1 C/I under 4 x 3 Frequency Reuse Pattern

The spectrum utilization ratio can be expressed by frequency reuse degree, which reveals the aggressiveness of the frequency reuse. The frequency reuse degree can be expressed by the following equation: $f_{reuse}=N_{ARFCN}/N_{TRX}$

Here N_{ARFCN} is the total number of the available channel numbers, and N_{TRX} is the number of TRXs configured for the cell.

For the n x m frequency reuse pattern, "n" indicates the number of the base stations in the reuse clusters, and "m" indicates the number of the cells under each base station. In this case, the frequency reuse degree can be expressed by the following equation:

$f_{reuse}= n \times m$

In actual planning, however, the allocated number of channel numbers will be greater than n x m, so the actual f_{reuse} is usually greater than n x m. Therefore, the smaller the f_{reuse}, the more aggressive the frequency is reused and the higher the frequency utilization ratio is. As the aggressiveness of the frequency reuse grows, however, it will bring greater interference to the network. In this case, you must enable the technologies, including DTX and power control, to solve this problem. The more aggressive the frequency is reused, the lower the spectrum utilization ratio is, but the conversation quality is better at this time.

The purpose the frequency planning is to reach a balance between the frequency utilization ratio and the network capacity. Based on the assurance of the network quality, you must take measures to maximize the network capacity.

In the GSM system, the 4 x 3 frequency reuse pattern is in basic use. Here "4" indicates 4 base stations (each base station consists of 3 cells), and "3" indicates the 3 cells under the control of each base station. Therefore, there are 12 sectors are available. And the 12 sectors makes up of a frequency reuse cluster, but the frequency in the same cluster cannot be reused.

For the 4 x 3 frequency reuse pattern, the intra-frequency spacing is great, so it can meet GSM system's requirement on the intra-frequency interference protection ratio and adjacent frequency interference protection ratio. As a result, this frequency reuse pattern is good for the network quality and security. Under the 4 x 3 frequency reuse pattern, the frequency reuse aggressiveness is 12.

For the aggressive reuse introduced hereunder, because the BCCH plays an important role in the network and you cannot use the apply the anti-interference measures, such as downlink power control and DTX, to the BCCH, you must apply the 4 x 3 frequency reuse pattern or looser reuse patterns to the BCCH carriers.

Normal 4 x 3 frequency reuse pattern.

3.4.2 10MHz Bandwidth 4 x 3 Frequency Reuse

Hereunder are several assumptions:

- The available bandwidth is 10MHz.
- The channel number is 45–94.
- If the channel numbers ranging from 81–94 (14 channel numbers in total) are allocated to the BCCH, and the other channel numbers are allocated to TCH.

If the previous assumptions are present, the frequency planning under 4 x 3 frequency reuse pattern is provided in Table:

Frequency planning under 4 x 3 frequency reuse pattern (a)

Frequency group number	A1	B1	C1	D1	A2	B2	C2	D2	A3	B3	C3	D3
Channel number of each frequency group	94	93	92	91	90	89	88	87	86	85	84	83
	80	79	78	77	76	75	74	73	72	71	70	69
	68	67	66	65	64	63	62	61	60	59	58	57
	56	55	54	53	52	51	50	49	48	47	46	45

According to this table, the channel numbers in the first line are BCCH numbers, in which

the channel numbers 81 and 82 are standby channel numbers. The channel number of BCCH of the cell A1 is 94. It is 80, 68 and 56 for other carriers, and so on.

In a cluster which contains 12 cells, the frequency group for base station A is {A1, A2, and A3}; the frequency group for base station B is {B1, B2, and B3}; the frequency group for base station C is {C1, C2, and C3}; and the frequency group for base station D is {D1, D2, and D3}.

Therefore, as listed in this table, no channel number is reused within a cluster. In addition, the intra-frequency and adjacent frequency are not available for the adjacent cells and the same cell.

However, the drawbacks of this frequency reuse pattern are that the frequency reuse ratio is low and the capacity expansion needs a great amount of the frequency resources. Therefore, this reuse pattern is not used in the areas where the network capacity needs to be constantly expanded.

If the bandwidth is 10MHz, the maximum base station configuration is S4/4/4 under the normal 4 x 3 frequency reuse pattern, and the frequency reuse degree is 12.5 (50/4 = 12.5).

Note:

The maximum base station type mentioned in the chapter refers to the configuration type that most continuous base stations can reach. It does not include standalone base station.

3.4.3 19MHz Bandwidth 4 x 3 Frequency Reuse

For the 19MHz frequency (1 to 94) used by China Mobile, the 4 x 3 frequency reuse pattern are used for the frequency planning. The channel numbers ranging from 79 to 94 (16 channel numbers in total) are allocated to the BCCH, and other channel numbers are allocated to TCH. No channel number is reserved for micro cells. In this case, the frequency planning solution is provided in Table:

Frequency planning under 4 x 3 frequency reuse pattern (b)

Frequency group number	A1	B1	C1	D1	A2	B2	C2	D2	A3	B3	C3	D3
Channel number of each frequency group	94	93	92	91	90	89	88	87	86	85	84	83
	78	77	76	75	74	73	72	71	70	69	68	67
	66	65	64	63	62	61	60	59	58	57	56	55
	54	53	52	51	50	49	48	47	46	45	44	43
	42	41	40	39	38	37	36	35	34	33	32	31
	30	29	28	27	26	25	24	23	22	21	20	19
	18	17	16	15	14	13	12	11	10	9	8	7
	6	5	4	3	2	1						

As listed in this table, the channel numbers ranging from 79 to 82 are standby channel numbers. For the 19MHz bandwidth, the maximum base station type can be S8/7/7 under 4 x 3 frequency reuse pattern. The frequency reuse degrees are 11.75, 13.43, and 13.43, so the average value is 12.87.

3.4.4 6MHz Bandwidth 4 x 3 Frequency Reuse

For the 6MHz frequency (96 to 124) used by China Unicom, the 4 x 3 frequency reuse pattern is used for the frequency planning. The channel numbers ranging from 111 to 124 (14 channel numbers in total) are allocated to the BCCH, and other channel numbers are allocated to TCH. No channel number is reserved for micro cells. In this case, the frequency planning solution is provided in:

Frequency planning under 4 x 3 frequency reuse pattern (c)

Frequency group number	A1	B1	C1	D1	A2	B2	C2	D2	A3	B3	C3	D3
Channel number of each frequency group	124	123	122	121	120	119	118	117	116	115	114	113
	110	109	108	107	106	105	104	103	102	101	100	99
	98	97	96									

As listed in this table, the channel numbers ranging from 111 to 112 are standby channel numbers. For the 6MHz bandwidth, the maximum base station type can be S3/2/2 under 4 x 3 frequency reuse pattern. The frequency reuse degrees are 9.67, 13.5, and 13.5, so the average value is 12.22.

3.4.5 4 x 3 Frequency Reuse Conclusion

The 4 x 3 frequency reuse pattern is a basic technology applied in frequency planning. It is applicable to other frequency aggressive reuse technologies that are used for the BCCH.

Theoretical analysis shows that when the base stations are regularly distributed and azimuths of the cells are consistent with each other, the interference can be reduced to the minimum. Therefore, if you intend to expand the network capacity, you can keep the base stations to be distributed as regular as possible and plan the azimuths of the cells along the same direction. In addition, you can also maintain the antennas at a similar height. However, sometimes you need to adjust the azimuth of the antenna to improve the coverage, which seems contradicts to the capacity expansion. Therefore, sometimes you must make find a balance between the coverage and capacity.

If the network capacity needs to be further expanded, you can take the following measures:

- Split a cell into smaller cells. At present, however, the average coverage radius of the macro cell base stations in urban areas is already shorter than 500m, so further cell splitting will meet difficulty in cost and technology.
- Utilize new frequency resources. For example, you can employ the 1800MHz band to establish a DSC 1800MHz network.
- Under the current 900MHz network, use more aggressive frequency reuse technology to expand the network capacity.

At present, the aggressive frequency reuse technology works as the most economical and convenient way to expand the network capacity, so it is also the most popular with carriers.

The typical frequency reuse technology includes 3 x 3, 2 x 6, 2 x 3, 1 x 3, and 1 x 1.

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