Archives

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1.7 Frequency Hopping

With the ever growing traffic volume and the limited frequency resource, frequency reuse is more and more aggressive. Therefore, the problem of how to reduce frequency interference becomes more and more remarkable. The essence of anti-interference is to fully utilize the current spectrum, time domain, and space resources. The key measures include frequency hopping, discontinuous transmission (DTX), and power control. Frequency hopping also can effectively reduce the influence of fast fading.

1.7.1 Types of Frequency Hopping

GSM radio interface uses slow frequency hopping (SFH) technology. The difference between slow frequency hopping and fast frequency hopping is that the frequency of latter changes faster than frequency modulation. In GSM, the frequency remains the same during burst transmission. Therefore, GSM frequency hopping belongs to slow frequency hopping.

In frequency hopping, the carrier frequency is controlled by a sequence and hops with time. This sequence is frequency hopping sequence. Frequency hopping sequence is a sequence of frequencies decided by hopping sequence number (HSN), mobile allocation index offset (MAIO) and frame number (FN) through a certain algorithm in the mobile allocation containing N frequencies. The N channels of different timeslots can use the same hopping sequence. The different channels of the same timeslot in the same cell adopt different MAIO.

Frequency hopping can be divided into frame hopping and timeslot hopping according to time domain and RF hoping and baseband hopping according to implementation mode.

Frame hopping: the hopping frequency changes once in each TDMA frame period. Each TRX can be regarded as a channel. The TCH of BCCH TRX cannot join in the frequency hopping in a cell. The hopping TRX should have a different MAIO. Frame hopping is an exception of timeslot hopping.

Timeslot hopping: the timeslot frequency of each TDMA frame changes once. The TCH of BCCH TRX can join in the frequency hopping, which happens in baseband hopping.

RF hopping: both transmission and reception of TRX join in the frequency hopping. The number hopping frequencies can exceed the number of TRXs in the cell.

Baseband hopping: each transceiver works at a fixed frequency. TX does not join in frequency hopping. Frequency hopping is performed through the handover of banseband signal. Therefore, the number of hopping frequencies cannot exceed the number of TRXs in the cell.

The two frequency hopping modes above are based on BTS. As for MS, since each MS has only one TRX unit, RF hopping is the only mode.

I. Baseband Hopping

The system has multiple baseband and TRX processing unit. Each TRX processing unit has a fixed working frequency; each baseband processing unit processes one line of service information and sends the processed information to the TRX unit with bus topology in time sequence according to frequency hopping rule. This kind of frequency hopping is called “baseband hopping”.

In baseband hopping, each transceiver works with a fixed frequency. The bursts on the same speech path are sent to each transceiver. Baseband hopping is based on the handover of baseband signals. Since the transceiver of each BTS has a fixed working frequency, both broadband combiner and cavity combiner can be adopted. The number of TRXs decides the maximum number of frequency hopping. The problem for baseband hopping is that if one TRX board fails, the corresponding code word will be lost, thus affecting all the calls under hopping mode in the cell.

II. RF Hopping

Under this mode, each line of service information is processed by fixed baseband unit and frequency band unit. The working frequency of frequency band unit is provided by frequency combiner. Under the control of control unit, frequency can be changed according to certain rules. In RF hopping, the frequencies used by a TRX to handle all the bursts of a call come from the frequency change of combiner, instead of the handover of baseband signals. The number of TRXs is not limited by carrier frequency. As the working frequency of TRX changes, which means the frequency of the input port to combiner changes, only broadband combiner can be adopted. This kind of broadband combiner leads to about 3dB insertion loss in two-in-one combination and the loss is greater in the link insertion of multi-combiner. GSM protocol does not specify which kind of frequency hopping is used in GSM BTS. The mode of frequency hopping can be decided by operators according to the equipments.

1.7.2 Frequency Hopping Algorithm

The parameters related to frequency hopping algorithm are as follows:

CA: cell allocation, the collection of frequencies used by a cell

FN: TDMA frame number, broadcasted on sync channel. FN (0–2715647) synchronizes BTS with MS

MA: mobile allocation, the collection of radio frequencies used for MS frequency hopping. It is a subset of CA. MA contains N frequencies, 1≤N≤64.

MAIO: mobile allocation index offset, (0–N-1). During communication, the radio frequency at air interface is an element of MA. Mobile allocation index (MAI, 0–N-1) is used to determine the element of MA. That is to say, the actual frequency used is decided by MAI. MAIO is the initial offset of MAI and it is used to avoid the contention of frequency by several channels at the same time.

HSN: hopping sequence number (0–63). It determines that the hopping sequence with concentrated frequencies is adopted in frequency hopping. When HSN=0, the hopping is cyclic hopping; when HSN≠0, the hopping is random hopping.

The proper setting of parameters is based on the understanding of the use of each parameter in hopping algorithm and the hopping theory. The proper setting ensures the healthy working state of the system.

Remarks: For the cyclic hopping in discontinuous transmission (DTX), the number of hopping frequencies should avoid N mod 13 = 0, because under such condition, the probability of transmission and measurement of SACCH frame at the same frequency is rather high, and the harms are obvious.

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When HSN=0, S equals the frame number, in other cases, S is only related to frame number and frequency hopping number. When HSN is fixed and frame number is the same, S must be the same. Therefore, as the TRXs of each sync cell have the same frame number, different hopping groups in sync cells can adopt the same HSN. A proper configuration of MAIO can avoid the inter-cell or intra-cell frequency collision within the same BTS. The aggressive frequency reuse adopts this theory.

1.7.3 Benefits of Frequency Hopping

In GSM, frequency hopping has two benefits: frequency diversity and interference averaging.

I. Frequency Diversity

Frequency hopping can reduce the influence of signal strength change due to multipath transmission. This effect equals that of frequency diversity. In mobile communications, Rayleigh fading leads to the great change of radio signal in a short time. This kind of change is related to frequency: a more independent fading accompanies a greater frequency difference. The 200 KHz interval generally ensures the independence of inter-frequency fading, while the 1 MHz interval can fully guarantee this kind of independence. Through frequency hopping, all the bursts containing the code word of the same speech frame are protected from the damage of Rayleigh fading in the same way.

Statistics shows that frequency hopping gain is related to environmental factors, especially to the moving speed of MS. When the MS moves at a high speed, the location difference between two bursts on the same channel is also affected by other kinds of fading. The higher the speed is, the lower the gain will be. Frequency diversity benefits a lot to a large number of MSs moving at low speed.

Frequency hopping gain is also related to the number of frequencies. When the number of frequencies decreases, the hopping gain falls. The relationship between the number of frequencies and hopping gain can be explained in this way: frequency hopping is pseudo spectrum spread, and the hopping gain is the processing gain after transmission frequency band spread. The basic way to test frequency hopping gain is to calculate the differences between different C/I at different hopping frequencies under the same FER. These C/I differences are the frequency hopping gain.

II. Interference Averaging

Frequency hopping provides the diversity of interference on transmission channel, so that all the bursts containing the code word of the same speech frame are protected from the damage of interference in the same way. Through error correction coding and interleaving of the system, the original data can be restored from the rest part of the received flow. The hopping gain is obtained only when the interference is in narrowband distribution. If the interference is in broadband distribution, all the bursts will be destroyed and the original data cannot be restored. Therefore, no hopping gain is obtained. The common interference after frequency hopping can be regarded in narrowband distribution.

In frequency hopping, error rate tends to increase in the test, but we feel the conversation quality improves. It is because although the error rate increases, the influence of interference is homogenized in frequency hopping, the speech restoring ability improves because of the interleaving and de-interleaving before. In GPRS data services, frequency hopping can be harmful when the data rate is rather high (CS4).

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