2G, 3G Network Planning and Optimization...

Archives

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2.12 Repeater Planning

2.12.1 Application Background

With rapid development of mobile communication networks, people have higher requirements on service quality. They hope to enjoy mobile services anywhere and anytime. As for telecommunication carriers, they cannot enable a base station in some dead zones due to the reasons such as cost and transmission conditions. In this case, a repeater can provide an auxiliary and economical means to coverage the dead zones.

I. Repeater types

A wireless repeater adopts a set of donor antenna to receive the signals from the base station. After amplifying the signals, it adopts a set of retransmission antenna to forward the signals in another direction. Generally, a wireless repeater has only one receiving path, so the diversity antenna is unnecessary.

Optical repeater

An optical repeater transmits signals using optical fibers, so the repeater side and base station side must have the optical transmission capability.

Channel bandwidth

Bandwidth selection repeater

A bandwidth selection repeater is also called wideband repeater, and it can select a frequency (for example, the frequency with a bandwidth of 6M, 19M, or 25M) and amplify it.

Channel selection repeater

A channel selection repeater is also called narrow band repeater or frequency selection repeater. It amplifies the selected channel numbers only. It is a narrow band repeater and amplifies a limited channel numbers.

New style

Solar energy repeater

A solar energy repeater is of the wideband type. It is similar to a general wideband repeater except that its power is solar energy.

Product type

Wireless frequency selection repeater

Currently, the types of the repeaters listed in the left column are in commercial use.

Optical frequency selection repeater

Wireless wideband repeater

Optical wideband repeater

II. Comparison between repeater and micro cell

Many equipments and a long period are needed for constructing a micro cell.

A repeater is installed in a flexible way and the base station equipments and transmission equipments are unnecessary.

A micro cell can expand the system capacity. When the cells near a base station are busy, a micro cell can be used to ease the congestion.

A repeater can absorb traffic. When a cell is idle, it brings the traffic to this cell, thus enhancing the utilization ratio of the equipments. A repeater does not expand the capacity for a system.

The system needs to allocate channel numbers to a micro cell, but this is hard to be realized in the areas where the frequency resource is scarce.

The system does not need to allocate channel numbers to a repeater, but it must prevent the repeater from interfering with other cells.

Note:

The filter of an intra-frequency repeater will produce a delay of about 5μs. Theoretically, the maximum effective coverage distance of a GSM cell will be smaller than 35km in this case.

A GSM system must enable the dynamic power control function, which is transparent to a repeater. Generally, you must adopt the automatic level control technologies (ALC) for a repeater.

& Note:

When the ALC technology is applied to a repeater, if a mobile station is too near to the repeater, the repeater will reduce the gains for all the mobile stations within its service area. In this case, the conversation quality of some mobile stations will become poor, or even call drop may occur; especially the mobile stations far away from the repeater are greatly affected.

III. Application characteristics

Repeaters are mainly used to cover the dead zones in vast open land, and they are the extension of the base stations. A repeater improves the coverage but does add up to the traffic capacity of a network. However, because it enlarges the coverage of the base station, the total traffic volume increases.

A wireless repeater applies the radio transmission mode, with short construction period and effective cost. An optical repeater adopts optical fiber as transmission medium, so the transmission loss is small and transmission distance is large, but construction cost is greater than that of the wireless repeater.

The application advantage of the wireless repeater lies in low transmission requirement. If you plant the optical fiber, there is no price advantage against the construction of a micro cell base station. In this case, considering the network quality, you are recommended to select the micro cell base station.

Compared with wideband repeater, a narrow band repeater has better performance and provides better signal quality. However, the following problems are still present in application:

The carriers of a narrow band repeater must outnumber the carriers configured for the source base

station; otherwise the repeater cannot capture a channel.
The number of paths of many repeaters is set to 4, so the base stations outnumber 4 carriers cannot work as the signal source.
For the base stations with radio frequency and frequency hopping, if the frequencies in the frequency hopping set outnumber the paths selected by the repeater, the conversation cannot be maintained.
When the channel number of the donor cell of the repeater changes, you must adjust the channel number, otherwise the problems such as channel assignment failure, call drop, and interference will occur.
The wideband repeater allows the base station to adopt frequency hopping, and you do not have to adjust the channel number of the repeater after the channel number of the donor cell changes if the channel number is within the bandwidth of the repeater. However, the wideband repeater will amplify all the signals within the band, so it causes great interference against other cells.
No matter whether the optical fiber or wireless repeater is applied, the sum of the radius of the service area of the repeater and the distance between the repeater and base station cannot break the TA limitation. For general base stations, the distance between a repeater and the base station must be shorter than 35 kilometers.
The optical repeater can be used in the areas where the GSM radio signals cannot reach and no space is left for a repeater. Because the transmission loss of optical fiber is small and its bandwidth is wide, the optical repeater is quite helpful for transmitting RF signals.
Either an omni antenna or a directional antenna can be selected for an optical repeater according to the actual landforms. For an optical repeater, its transmission does not have to be isolated from the reception. In addition, the address of an optical repeater is easy to be decided. Generally, an optical repeater is applied in the dead zones within countryside, highroads, touring areas, factories, and urban areas.
In remote mountain areas and along highroads, you can also consider using a solar energy repeater.
In conclusion, the repeater is used for the following purposes:
Enlarge coverage area and eliminate dead zones.
Strength the field strength and enlarge converge of the base stations in urban areas.
Ensure the coverage along the highroads and tunnels.
Realize indoor coverage.

2.12.2 Working Principles of Repeater

I. Wireless frequency selection repeater
Figure 5-45 shows the working principles of a wireless frequency selection repeater. The repeater receives the RF signals from the selected base station (donor antenna) and amplifies and forwards the signals. The antenna receiving the signals from the base station is called donor antenna, the other antenna is called retransmission antenna.
Working principles of a wireless frequency selection repeater are as follows:
1) The low-noise power amplifier processes the signals (received by the donor antenna) from downlink carriers.
2) The signals (900 MHz RF signals) are down converted into 71 MHz intermediate frequency (IF) signals.
3) The IF filter (with a bandwidth of 200 KHz) amplifies the 71 MHz IF signals and up converts the signals into the 900 MHz RF signals.
4) The retransmission antenna (service antenna) transmits the signals to the coverage areas.
The uplink signals are also processed according to the previous procedures.
II. Wireless wideband repeater
The wireless wideband repeater works as the same way as the wireless frequency selection repeater except the filter part. The bandwidth of the filter of the wireless wideband repeater is fixed. Generally, it is 6M, 19M, or 25M.
III. Optical repeater
The difference between the optical frequency selection repeater and the optical wideband repeater lies in the coverage end. The former adopts the frequency selection components, but the later adopts the variable bandwidth options.
Compared with the wireless repeater, the optical repeater does require isolation between donor antenna and retransmission antenna.

2.12.3 Repeater Network Planning

I. Repeater address selection
There is no special requirement on the repeater address selection except the following items:
A repeater address must lie between the donor base station and the dead zone, and the azimuth angle between the donor antenna and the retransmission antenna cannot be smaller than 90°, as shown in the following figure.
If the service antenna is a directional antenna, the repeater must be installed about 200 to 500 meters beyond the dead zone. If the repeater is installed within the dead zone, the coverage quality cannot reach the best, as shown in the following figure.
When the repeater is used to coverage the dense residential areas at the edges of the urban area, it cannot face the buildings, because great penetration loss will be caused. In this case, the repeater must be installed at the one side of the building, as shown in the following figure.
The areas to be covered must meet the requirement of line-of-sight transmission.
The repeater address must ensure the received signal level required by the repeater. Generally, the received signal level ranges from -50 dBm to -80 dBm.
No strong carrier whose channel number is the same as that of the donor base station is present at near the repeater address.
The landforms, buildings, or towers where the donor antenna and retransmission antenna can be installed. (The donor antenna must be directed to the base station and the retransmission antenna must be directed to the service area of the repeater. In addition, the isolation between the two antennas must be greater than 170 dBc.)
II. Antenna selection
When selecting the antenna for a repeater, you must consider the followings:
Select the proper antenna gain according to the signals and coverage condition
Do not adopt the omni antenna because the wireless repeater is affiliated to the intra-frequency relay system, otherwise the system will perform self-excitation.
The communication between the donor antenna and the donor base station antenna is point-to-point communication, so you must select the antenna with high gain or narrow horizontal beam width. For

example, to reduce interference, you can select the reflector antenna or the log-periodical antenna. Select retransmission antenna according to the characteristics of a coverage area. For a large coverage area, you can select the general directional antenna with high gain. For tunnel coverage, you can select the Yagi antenna or the spiral antenna. For indoor coverage, you must select the antenna specially designed for indoor use. No matter in what occasions, you must control the transmit direction of the retransmission antenna to prevent the retransmitted signals from feeding in the donor antenna.
The front-to-back ratio of the antenna must be as great as possible (it is better to be greater than 30 dB) so that a better isolation between the donor antenna and retransmission antenna can be ensured.
III. Requirements on antenna isolation
The isolation between repeater antennas depends on the host gain, but the host gain cannot excel the isolation coefficient for self-excitation. According to the requirements in GSM protocols 03.30, the isolation must be at least 15 dB greater than the host gain. In actual project design, you can judge whether the installation position meets the requirements on antenna isolation according to on-site measurement.
According to the formulas calculating the antenna horizontal isolation, the following formula can be deducted:
AH = 31.6 + 20 lgd – (Gt + Gr) dB (900 MHz)
AH = 37.6 + 20 lgd – (Gt + Gr) dB (1800 MHz)
Here, "d" indicates the distance between the donor antenna and retransmission antenna, in the unit of meter. Gt and Gr indicate the antenna gain relative to the major lobe in the direction of the two antennas. If the two antennas are back-to-back installed, Gt and Gr indicate the front-to-back ratio of the antenna.
Horizontal isolation of repeater antennas:
The formula calculating the vertical isolation of repeater antennas is as follows:
Av = 47.3 + 40 logd dB (900 MHz)
Av = 59.3 + 40 logd dB (1800 MHz)
Vertical isolation of repeater antennas:
If the horizontal isolation and vertical isolation are present simultaneously, the total isolation can be calculated by the following formula:
AS = (AV - AH) a/90 + AH, here AV indicates the vertical isolation; AH indicates the horizontal isolation; and "a" indicates the antenna included angle.
Donor antenna and retransmission antenna are installed on the top of the building. Suppose the host gain is 100 dB, the isolation between the two antennas can be 120 dB. If the front-to-back ratio of the donor antenna and the retransmission antenna is 30 dB, when no barriers are present between the two antennas, the requirement on the isolation can be met.
If the space loss of the signals between the two antennas is 60 dB, the horizontal isolation distance can be obtained, that is, d = 26m.
During project implementation, you must select the antenna installation position according to on-site measurement. You can use a signal source and a receiver for the repeater. If the signal attenuation between the signal source and the receiver reaches 60 dB, it means that the antenna installation position meets the requirement on antenna isolation.
When installing the antenna for a repeater, you must pay attention to the following items:
If the antennas are horizontally installed, the host of the repeater must be installed between the donor antenna and the retransmission antenna (it must be nearer to the donor antenna.)
A good isolation must be ensured regardless that the antennas are horizontally or vertically installed. When they are horizontally installed, it is better that there are some barriers lying between the donor antenna and the retransmission antenna, because you do not have to particularly design a large installation space to ensure antenna isolation in this case.
IV. Uplink and downlink balancce calculation
For a GSM repeater, the link balance is realized by four links, namely, the uplink and downlink between the donor base station and repeater, and the uplink and downlink between the repeater and mobile station.
This section employs the wireless repeater applied in outdoors as an example to calculate the link balance. To simplify the calculation, we introduce the effective donor path loss (EDoPL), which includes all the loss and gain from the output end of the base station combiner or the input end of the multi-path coupler to the input end of the repeater.

The link balance is calculated according to the following two formulas:
For downlinks, Pbout - EDoPL + GRD - LRF + GRA - Lpass - Pmn = Pmin.
For uplinks, Pmout - Lpass + GRA - LRF + GRU - EDoPL - Pbn = Pbin.
Here,
Pbout indicates the output power of the base station.
Pmout indicates the output power of the mobile station.
GRD indicates the downlink gain of the repeater.
GRU indicates the uplink gain of the repeater.
LRF indicates the feeder loss of the retransmission antenna.
GRA indicates the gain of the retransmission antenna.
Lpass indicates the path loss the mobile stations from the repeater to the service area.
Pbn indicates the attenuation margin of the mobile station.
Pbin indicates the receiving level of the base station.
Pmin indicates the receiving level of the mobile station.
BTSsens indicates the base station sensitivity.
MSsens indicates the mobile station sensitivity.
If the uplink EDoPL and downlink EDoPL are equal to the uplink path loss and the downlink path loss from the repeater and mobile station, the attenuation margin of the base station is equal to that of the mobile station. Therefore, if you subtract the formula calculating uplink balance from the formula calculating downlink balance, you can get Pbout - Pmout + GRD - GRU = Pmin - Pbin.
If the links are balance, the equation Pmin - Pbin = Dsens = MSsens- BTSsens is present. In this case, the formula calculating link balance is Pbout - Pmout + GRD - GRU = Dsens.
Therefore, the Dsens is fixed after the base station equipments are selected. Moreover, the output power of the base station and mobile station may be decided in GSM system planning. As a result, to achieve the balance of the whole links, you need to adjust the uplink gain and downlink gain of the repeater only.
The followings employ the repeater system installed in outdoors as an example to calculate the whole link balance.

For downlink budget of the outdoor repeater , output power of the transmitter (+43dBm) – loss of the combiner (4dB) – EdoPL (90dB) = input power of the repeater (-51dBm) + downlink gain of the repeater (80dB) = downlink output power of the repeater (+29dBm) – feeder loss of the retransmission antenna (3dB) + gain of the retransmission antenna (18dBi) – path loss of the repeater in the coverage area (127dB) = input level of the mobile station (-83dBm) – attenuation margin (20dBm) = the mobile station sensitivity (-103dBm).
& Note:
To obtain the value of EDoPL, you can measure the input level of the donor repeater and output level of the base station combiner first, and then obtain the difference between the two, and the difference is the value of EDoPL. In addition, the gain of the mobile antenna must be converted to 0 dBi.

For uplink budget of the outdoor repeater, output power of the mobile station transmitter (+33dBm) – path loss of the repeater in the coverage area (127dB) + gain of the retransmission antenna (18dBi) – feeder loss of the retransmission antenna (3dB) = input power of the repeater (-79dBm) + uplink gain of the repeater (80dB) = output power of the repeater (+1dBm) –EdoPL (90dB) = input level of the base station (-89dBm) – attenuation margin (20dBm) = base station sensitivity (-109dBm).
& Note:
Because you do not have to consider the diversity function, the attenuation margin on uplinks is the same as that on downlinks. According to the previous link budget, the downlinks are restricted by the output power of the repeater, the uplinks are restricted by the output power of the mobile station, and the noise restricts the maximum gain (EDoPL-10 dB), so the link balance is present. However, this is the most common situation. Actually, you must calculate the margin for all links when installing or optimizing the repeater system. The latest repeater supports the uplink gain and downlink gain to be set respectively.

Hereunder is an example.
There is a base station covering parts of a highroad. Its coverage radius is about 20 km.
The measured signal strength at the edges of the base station cells is -93dBm.
The microwave link tower on the top of the hill near the base station is selected as the address of the repeater.
In the areas (including mountains) 350m below the top of the tower, the received level of the mobile station is -71 dBm.
The log-periodical antenna with a gain of 18dBi and an azimuth angle of 35°is used as the donor antenna.
The antenna is installed at 15 meters under the tower top and faces the base station.
If the previous conditions are present, the signals output by the repeater are -54 dBm. If a plane antenna with a gain of 17 dBi and a horizontal azimuth angle of 60 degrees is installed at the top of the tower and the antenna radiates to the reverse direction of the donor antenna, the requirements on antenna isolation can be met even if the gain of the repeater reaches 85 dB. In this case, the output power of the repeater is 30 dBm. And the level of the signals in the areas along the highroad which are 20 km beyond the tower can reach -90 dBm. Therefore, the radius of the cell along the highroad is enlarged by 50%.
& Note:
If a retransmission antenna is installed at the top of the tower, you must ensure that the received signal level in the zero point filling areas near the tower.
V. Repeater output power control
When adopting a repeater, you must pay special attention to the effect of the intermodulation products against the system. The intermodulation products of the repeater depend on the number of the amplified carriers, the output power of each carrier, and the linearity of the amplifier.
Linearity of the amplifier:
Third order intermodulation will increase with output power due to the nonlinearity of the amplifier. Therefore, you must control the output to a certain degree to ensure that that the indexes on third order intermodulation meet the requirements. The following formula shows the relationship between the output power of each carrier of the repeater and the requirements on third order intermodulation.
Po = IP3 + (PIMP/2) +10 lg (N/2)
Here,
Po indicates the output power of each carrier (dBm)
IP3 indicates the third order section of the amplifier (dBm)
PIMP indicates the level of the third order intermodulation (dBc)
N indicates the number of carriers
If the third order section of the amplifier of a typical repeater is 50 dBm, and the intermodulation level must be lower than -45 dBc according to the requirement of the wireless communication institutes in Britain.
VI. Repeater gain setting
The gain of the early repeaters must be set manually, but the latest gain of the latest repeaters can be automatically set. For the repeaters whose gain is set manually, the sum of the repeater gain and the protection margin must be equal to or smaller than the repeater isolation; otherwise, the self-excitation of the repeater will be caused. Here the repeater isolation indicates the isolation between the donor antenna and the retransmission antenna of the repeater. Generally, the protection margin ranges from 10 dB to 15 dB.
VII. Repeater adjacent cell planning
The coverage areas of a repeater may overlap other donor cells, so you must configure the corresponding adjacent cell relationship for the repeater to ensure normal handover. In addition, you must pay attention that the frequencies in the coverage areas of the repeater and that in the donor cells cannot be the same frequency and neighbor frequency.
VIII. Effect of delay processing against repeater planning
If only one repeater cannot fully cover an area (such as a narrow and long tunnel), you can use several cascaded repeaters to provide the coverage. The selection of the address and antenna for the repeater of each level is the same as that for a single repeater.
However, the repeater will amplify the same frequency and it takes some time for the repeater to process the signal, so there is a delay for each signal segment. If the delay is greater than the time for the GSM system to identify the time window, the intra-frequency interference will occur. Therefore, you must consider the effect of the delay when adopting cascaded repeaters, because the delay will also accelerate the time dispersion and shorten the coverage distance.
If adopting the optical repeater, you must consider that the transmission speed of the signals in optical

fibers is 2/3 that of in free space, namely, if the extension cell technology is not used, the maximum transmission distance of the signals in optical fiber is 35 km multiplies 2/3 (about 23.3 km) due to the restriction on transmission delay.
In addition, if one of three synchronous cells adopting the optical repeater, the TA of two cells will be different due to the difference of transmission mode and rate. In this case, the synchronous handover failure will occur. Therefore, you must adopt the asynchronous handover to obtain the TA of a new cell, which works as the handover target cell.
The delay processing varies with repeater types. Some take 2 to 3 µs and some takes 5 to 6µs. In a GSM system, the delay of two signals cannot be greater than 16µs. For the effect of repeater delay processing against time dispersion.
Distance between point A and the repeater “d” is 2.1km. The delay for the mobile station at point A to receive the signals from the repeater and the cell is as follows:
(2.1km + 2.1km)/c (light speed) + 3µs = 14µs + 3µs = 17µs > 16µs.
In this case, the intra-frequency interference may be present. If the difference of the levels of the two signals is equal to or lower than 12 dB, the conversation quality will be affected.
The time dispersion will cause intra-frequency interference, and the time dispersion is caused by the overlap of the signal source cell and the repeater coverage area. Therefore, you must select the signal of the secondary cells in the coverage areas of the repeater instead of the signals of the major service cell as the source signal of the repeater. In this case, the time dispersion caused by overlap can be avoided.
IX. Effect of background noise against repeater planning
Suppose that the maximum received noise level allowed by the base station is DN, if the uplink background noise level of the repeater host is too great, the base station channels will be congested when the noise level at the base station is greater than DN. However, how to set the repeater without affecting the base station? They are introduces as follows.
If the following assumptions are present:
The transmitted signal strength of the base station is Tb.
The received signal strength of the base station is Rb.
The received downlink signal strength of the base station host is Dr.
The transmitted uplink signal strength of the base station host is Ut.
In this case, the path loss between the base station and the repeater is Tb-Dr, so Rb = Ut – (Tb-Dr). As a result, if the repeater does not affect the base station, Rb < DN, so the following two inequities are present:
Ut – (Tb - Dr) < DN
Ut < Tb-Dr + DN
According to the previous analysis, the repeater does not affect the base station if the uplink background noise level output by the repeater host is lower than (Tb-Dr+DN). From this perspective of review, the background noise must be particularly emphasized in repeater planning because it is easier to bring interference than other types of base stations.
X. Specifications of wireless repeaters
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