**CSHP902 repeater installation sensitivity calculations, Rev B**

In the calculations below some different installations are examined with the following fixed parameters:

| | | | |
|---|---|---|---|
| BTS sensitivity | -106 | dBm | without diversity gain |
| BTS output power | +41 | dBm | |
| Repeater noise figure | 4 | dB | (Remote) |
| Donor unit output power | +33 | dBm | |
| Remote unit output power | +38 | dBm | |
| MS sensitivity | -102 | dBm | GSM Small MS GSM 05.05 (ETS 300 577, ETS 300 910) |
| MS output power | +33 | dBm | Power Class 4 GSM 05.05 (ETS 300 577, ETS 300 910) |

The Downlink path is very straightforward to set up in the repeater installation, and also gives a good indication on the *actual* path loss between the donor and the remote unit. The gain in the units is simply adjusted until the desired output levels are achieved. This procedure is greatly simplified by the built in monitoring functions in the Avitec repeaters. Remember that the repeater is not a piece of measurement equipment, and has a limited accuracy when presenting input and output levels. (+/-3dB and +/-2dB respectively)

In this document two different link path losses will be analysed, representing two extremes regarding the distance between the Donor and Remote unit: 6.5 kilometres and 26 kilometres. Free space path loss is assumed in both cases. (Feeder losses are varied to get further extreme values).

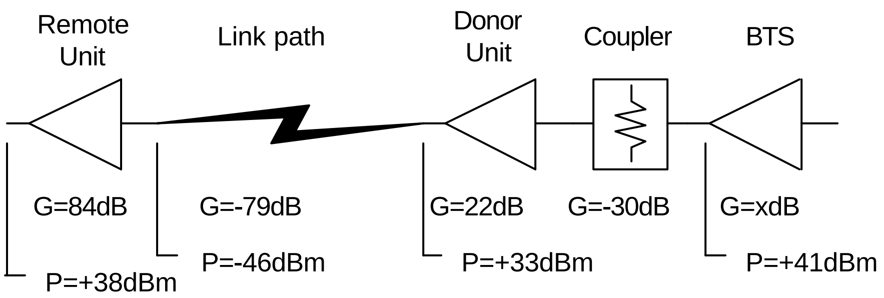
**Total Link loss (6.5km)** = -0.5 + 15 -108 +15 - 0.5 **= - 79dB**

```
|       |      |      |       |
|       |      |      |       --------- Feeder loss between Remote unit and Link antenna
|       |      |      ---------------- Link antenna at Remote site 15dBi
|       |      --------------------- Free space path loss at 925MHz / 6.5km
|       -------------------------- Link antenna at Donor site 15dBi
---------------------------------- Feeder loss between Donor unit and link antenna
```

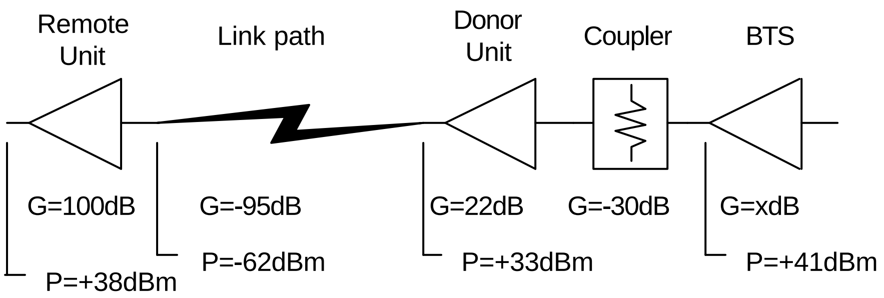
**Total Link loss (26km)** = -2.5 + 15 -120 +15 - 2.5 **= - 95dB**

```
|       |      |      |       |
|       |      |      |       -------- Feeder loss between Remote unit and Link antenna
|       |      |      ---------------- Link antenna at Remote site 15dBi
|       |      --------------------- Free space path loss at 925MHz / 26km
|       -------------------------- Link antenna at Donor site 15dBi
---------------------------------- Feeder loss between Donor unit and link antenna
```

The Downlink path would then look like the following figure for 6.5km:




and like the following figure for 26km:




Note that the shorter link distance gives the opportunity to reduce the Donor Downlink gain and increase the Remote Downlink gain. This will reduce the output power in the link antenna and minimise interference caused by the link, and thereby simplify frequency planning.

The longer link distance is probably close to the maximum useful distance, since Timing Advance will only allow a repeater cell radius of 5-6 kilometres in this case. (The delay through the repeater chain is typically 2 x 6 us, equal to an increase of Timing Advance by 6-7 units)
In the case of a BTS with extended range capability longer link paths are possible, but then link antennas with more gain should be considered. 20dBi antennas have been used in some installations, reducing total link loss by 10dB compared to the above numbers. Keeping everything else constant, this would allow for another 23km of link distance.

Uplink path

The settings of the Repeater Uplink path requires much more careful planning than the Downlink.
Very different results can be obtained depending on the Repeater Uplink gain setting, and there will always be a trade off situation between the Repeater cell sensitivity and BTS cell sensitivity. Low Repeater Uplink gain will result in poorer Repeater cell sensitivity but only a small BTS cell sensitivity degradation. The opposite is also true; high Repeater Uplink gain will result in good repeater cell sensitivity but a larger reduction in BTS cell sensitivity.

The calculations to determine the sensitivity in the Repeater cell and the BTS cell is based on the formula for determining the total noise figure for a cascade of amplifiers and attenuators:

NFtot = NF1 + (F2-1) / G1 + (F3-1) / (G1 * G2) + (F4-1) / ( G1 * G2 * G3 ) + …     (units, NOT dB's)

This equation is used to find the total noise figure at TWO points in the cascade made up by the Repeater installation. The first point is the entire chain INCLUDING the BTS receiver noise figure. This value is then directly used to calculate the Repeater cell sensitivity. The second point is the same cascade EXCLUDING the BTS receiver *and coupler* noise figure. This noise figure is, in combination with the gain to this point, converted to an equivalent noise floor. This is then added to the BTS receiver equivalent noise floor. The sum of the noise is then converted back to a noise figure used to calculate the BTS cell sensitivity.

Several example calculation examples will be described below:

Firstly the equivalent BTS noise figure corresponding to the BTS sensitivity must be calculated from the following equation:

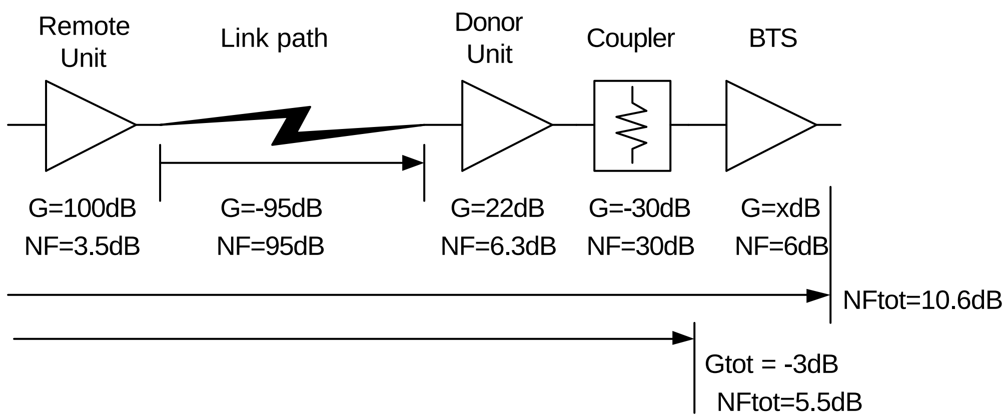
**Eq. BTS noise figure** = -106 - ( -174 + 54 + 8 ) dB **= 6 dB**

```
                       |      |     |    |
                       |      |     |    |
                       |      |     |    ---------- C/N for 0.4% BER (ETSI ETR 103)
                       |      |     -----------------10 x log(BW)  BW=251kHz (ETSI ETR 103)
                       |      -------------------------Thermal noise floor
                       ----------------------------------- BTS sensitivity
```

This value is used in all calculations below.

**Example 1: Rule of thumb setup with 26km link**

As a starting point ("rule of thumb") the uplink gain can be set equal to the downlink gain settings.
For the -95dB link this will give the situation shown in the figure below:




**The 8.1dB noise figure through the repeater chain corresponds to a sensitivity of**

-174 + 54 + 8 + 10.6 dBm = **-101.4 dBm**

```
  |    |    |    |
  |    |    |    ---------------  Repeater chain total noise figure with BTS
  |    |    |-------------------  C/N for 0.4% BER (ETSI ETR 103)
  |    ---------------------------  10 x log(BW)  BW=251kHz
  ---------------------------------  Thermal noise floor
```

**The noise floor from the repeater chain at the BTS receiver input is:**

-174 + 54 + 5.5 - 3 dBm = **-117.5 dBm**

```
  |    |    |    |
  |    |    |    ---------------  Total gain in Repeater chain
  |    |    |-------------------  Repeater chain total noise figure without BTS & coupler
  |    ---------------------------  10 x log(BW)  BW=251kHz
  ---------------------------------  Thermal noise floor
```

This must now be added to the BTS receiver noise floor, which is:

-174 + 54 + 6  dBm = **-114.0 dBm**

```
  |    |    |
  |    |    |-------------------  BTS receiver noise figure
  |    ---------------------------  10 x log(BW)  BW=251kHz
  ---------------------------------  Thermal noise floor
```

And when they are added the total noise floor at the BTS receiver input becomes:

10 * LOG [ 10^(-117.5/10) + 10^(-114.0/10) ] **= -112.4 dBm**

This is a 1.6dB higher BTS receiver noise floor compared to the starting value (114-112.4=1.6), which means that the BTS receiver sensitivity has degraded from -106 dBm to -104.4dBm **without diversity.**

**Summary of example 1:**

The calculations in example 1 used a very simple setup technique for the uplink path. The gain in the Uplink was simply set equal to the Downlink gain in both the Donor and Remote unit. This resulted in :

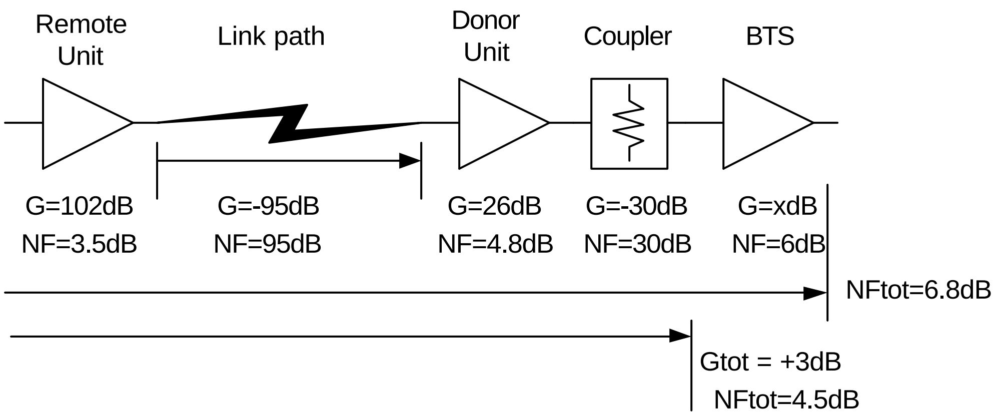
**Sensitivity in Repeater cell = -101.4 dBm**
**Sensitivity in BTS cell = -104.4 dBm without diversity, a reduction of 1.6dB.**

Note that the BTS Diversity receiver **will maintain its original sensitivity of -106dBm** since no Repeater noise it emitted into its input. However, the diversity gain will be lower than normal because of the Repeater noise emitted into the BTS main receiver input.

Also note that all traffic through the Repeater will only enter the BTS main receiver input, NOT the diversity receiver input. **This may cause a "Diversity alarm"** on some types of BTS's. **This is normal** and should be a simple matter of configuring the alarms in the BTS.

**Example 2: 26km link with high Repeater cell sensitivity**

To get good Repeater cell sensitivity, the Uplink gain must be increased compared to example 1. If the gain from the Repeater server cell antenna to the BTS receiver antenna input is positive ( larger than 0 dB ), the Repeater can in fact be considered to be Tower Mounted Amplifier (TMA). The major difference is of course that the antenna is located 26km from the BTS in this case. The sensitivity of the original BTS cell will be degraded more than in example 1 because the noise floor will be higher at the BTS receiver input.
The example 2 setup looks like the figure below:

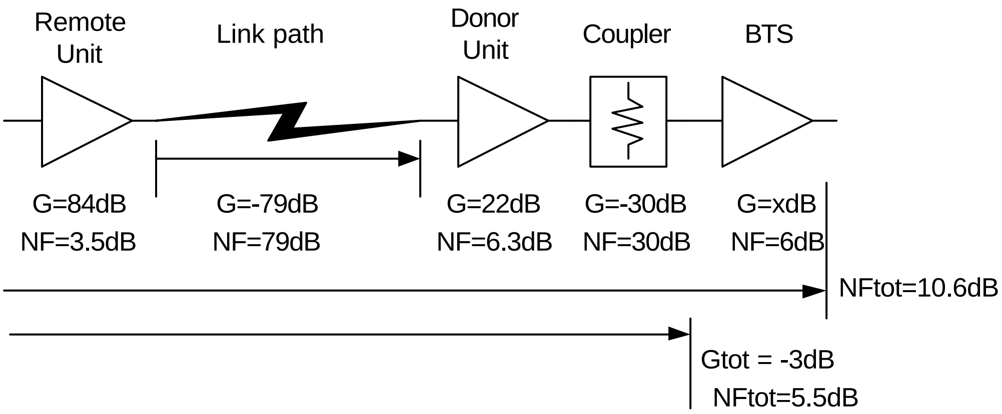



Doing the calculations yields:

**Sensitivity in Repeater cell = -105.2 dBm**
**Sensitivity in BTS cell = -102.2 dBm without diversity, a reduction of 3.8dB.**

It is obvious that the increased Uplink gain has improved Repeater cell sensitivity. It can be improved more by further increasing the gain, but BTS cell sensitivity will then be reduced more.

**Example 3: Rule of thumb setup with 6.5km link**



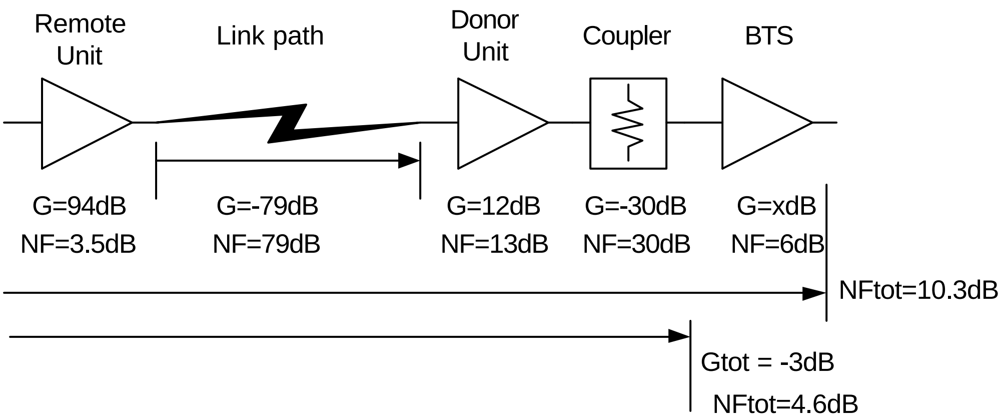

Doing the calculations yields:

**Sensitivity in Repeater cell = -101.4 dBm**
**Sensitivity in BTS cell = -104.4 dBm without diversity, a reduction of 1.6dB.**

This is in fact identical values compared to example 1. In this case however, it is possible to increase the Uplink gain in the Remote unit and reduce it equally much in the Donor unit. This will improve the overall noise figure as dictated by the NFtot equation on page 3. This is examined in the next example.

**Example 4: 6.5km link with high BTS sensitivity and optimised Repeater sensitivity**

The Donor Uplink gain in example 3 was 22dB. Since the minimum configurable gain in the Donor unit is 12dB, it can be reduced by 10dB. This is compensated for in the Remote unit and this setup looks like:

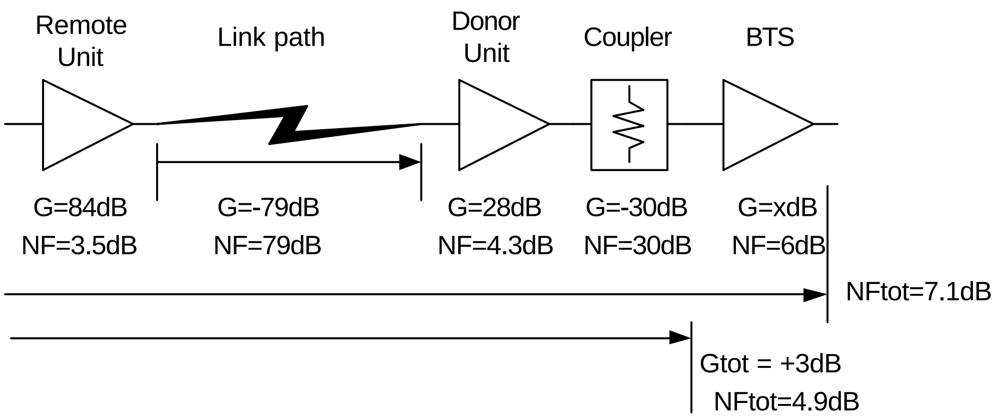



Doing the calculations yields:

**Sensitivity in Repeater cell = -101.7 dBm**
**Sensitivity in BTS cell = -104.7 dBm without diversity, a reduction of 1.3dB.**

Although the improvement compared to Example 3 is only a few tens of a dB, the ”cost” of the improvement is just a few moments of calculations. With more total Uplink gain the improvement is larger. See the next examples.

**Example 5: 6.5km link with high Repeater sensitivity**



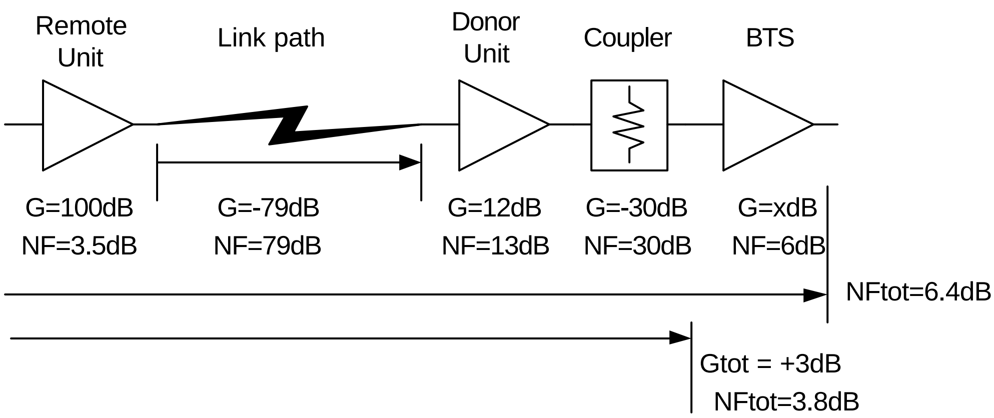

Doing the calculations yields:

**Sensitivity in Repeater cell = -104.9 dBm**
**Sensitivity in BTS cell = -101.9 dBm without diversity, a reduction of 4.1dB.**

Here the gain was increased in the Donor. In this case again, it is possible to increase the Uplink gain in the Remote unit and reduce it equally much in the Donor unit. This will improve the overall noise figure as dictated by the NFtot equation on page 3. This is examined in the next example.

**Example 6: 6.5km link with optimised Repeater sensitivity**

The Donor Uplink gain in example 5 was 28dB. Since the minimum configurable gain in the Donor unit is 12dB, it can be reduced by 16dB. This is compensated for in the Remote unit and this setup looks like:




Doing the calculations yields:

**Sensitivity in Repeater cell = -105.6 dBm**
**Sensitivity in BTS cell = -102.6 dBm without diversity, a reduction of 3.4dB.**

This is a more clear improvement compared to Example 5.

**Summary:**
It has been shown by several calculation examples that some care is needed when the Uplink gain is configured in a CSHP installation if optimum sensitivity is desired. However, ”rule of thumb” setup will only cause a small BTS sensitivity degradation with a typical BTS, but Repeater cell sensitivity will not be optimum.

Note that feeder looses between Repeater server antenna and Remote unit are **not** included in the calculations.

**Appendix: Repeater Unit Noise Figure versus gain:**

For all calculations in this document, the Noise figure of a sample CSHP Repeater from production was used. The values can be considered typical of the current revision, but may change without further notice.

| Attenuation setting | Donor Unit Gain | Donor Unit Noise Figure | Remote Unit Gain | Remote Unit Noise figure |
|---|---|---|---|---|
| 0 | 42 | 3,5 | 102 | 3,5 |
| 2 | 40 | 3,5 | 100 | 3,5 |
| 4 | 38 | 3,5 | 98 | 3,5 |
| 6 | 36 | 3,6 | 96 | 3,5 |
| 8 | 34 | 3,7 | 94 | 3,5 |
| 10 | 32 | 3,8 | 92 | 3,5 |
| 12 | 30 | 4,0 | 90 | 3,5 |
| 14 | 28 | 4,3 | 88 | 3,5 |
| 16 | 26 | 4,8 | 86 | 3,5 |
| 18 | 24 | 5,4 | 84 | 3,5 |
| 20 | 22 | 6,3 | 82 | 3,5 |
| 22 | 20 | 7,3 | 80 | 3,6 |
| 24 | 18 | 8,5 | 78 | 3,8 |
| 26 | 16 | 9,8 | 76 | 4,0 |
| 28 | 14 | 11,4 | 74 | 4,3 |
| 30 | 12 | 13,0 | 72 | 4,7 |