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GSM Cellular Link Balance

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□ ABSTRACT □

Cellular link balance one of the main requirements for the GSM (Global System for Mobiles) networks, usually downlink is stronger than uplink at cell border which means link unbalance, this can be solved by TMA (tower mounted amplifier). The TMA is mounted on the antenna tower close to the receiving antennas, where it amplifies the received signal before it enters the antenna feeder. The amplification can be set stepwise and its maximum is about 10 dB for 900 MHz.

This Research presents the results of the TMA trial on site-Town Hall159S4. The aim of the tests was to verify the effect of using a TMA on that rural site, applying the strategy described below. Main performance software (BO) tool and cell traffic recording were used to analyze the performance of the TMA.

The goal of this research is to study the effect of using a TMA on cellular link balance.

Main conclusions taken from this study are:

The introduction of the TMA in the system leads to an improvement of the uplink performance in terms of drop call. The coverage was also increased.

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توازن الوصلة الخليوية في شبكات GSM

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الملخّص

إن توازن الوصلة الخليوية هو أحد الشروط الضرورية للشبكة الخليوية الرقميةGSM وعادة تكون الوصلة الخليوية الهابطة أقوى من الوصلة الصاعدة في الشبكة الخليوية وذلك على حدود الخلايا وهذا يعني أن الوصلة الخليوية غير متوازنة وهذه المشكلة يمكن حلها عن طريق مضخمات يتم تركيبها على أبراج المحطات الخليوية وذلك بالقرب من هوائيات الاستقبال للمحطة الخليوية حيث يتم تضخيم الإشارة المستقبلة قبل أن تدخل إلى كبل الهوائي ويمكن التحكم بهذا التضخيم بشكل تدريجي ويبلغ حده الأعظمي حوالي 10 dB وذلك للشبكات الرقمية العاملة على التردد 900 MHz.

يعرض هذا البحث نتائج تجارب مشروع استخدام المضخمات المركبة على برج هوائي المحطة المسماة Town Hall 159S4. ولقد كان الهدف من هذه الأختبارات التأكد من مدى تأثير المضخمات على أداء المحطات الخليوية الريفية وذلك بتطبيق أستراتيجية مطبقة كما هو مبين في طريقة البحث أدناه.

ولقد تم استخدام أداتين برمجيتن الاولى تدعى الأداء الرئيسي (من شركة BO) والثانية الاداة المسماة تسجيل حركة الخلية وذلك من أجل تحليل الإداء لمشروع المضخمات المركبة على الأبراج والهدف من هذا البحث هو دراسة التوازن القدروي للوصلة الهوائية الخليوية . والاستنتاج الرئيسي من هذه الدراسة :

أن تركيب المضخمات على أبراج المحطات الخليوية يؤدي إلى تحسين إداء الوصلة الخليوية الصاعدة وذلك بالنسبة لعدد الاتصالات الخليوية غير الناجحة كما أن التغطية الخليوية تتحسن بشكل ملحوظ.

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1. Introduction

The TMA will allow us to increase the BTS (Base transceiver station) power by keeping a balanced link budget. That could be useful to increase the coverage area of a cell [1],[2]. In order to achieve balance between two transmitting directions the following rough equation should be used:

$$P_{at\ BTS} = P_{at\ MS} + G_{div} - L_{fC} \qquad (1)$$

Where:
$P_{at\ BTS}$ – Base station transmit power /dBm;
$P_{at\ MS}$ – Mobile station transmit power /dBm;
G_{div} – Diversity Gain / dB;
L_{fC} – Feeder, jumper and combiner Loss /dB.

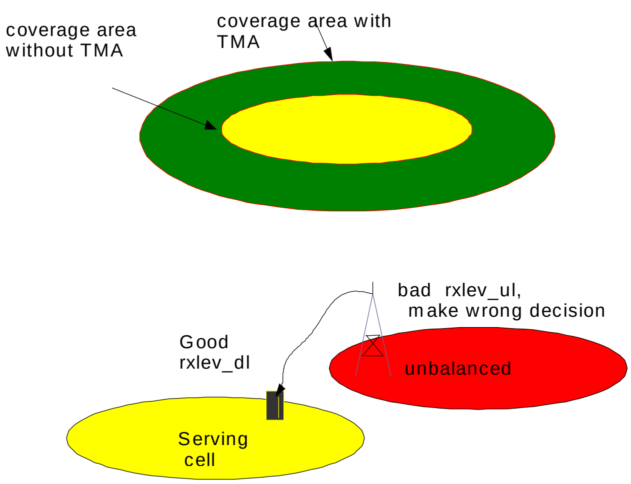
It is obvious that a balanced link budget will help improving the speech quality and the handover performance. A one way speech is usually observed in the uplink with an unbalanced link and since the handover decision is based on the downlink measurements of the neighbors, any unbalance will lead to bad handover performance.

In figure 1, for example the unbalanced neighbor, may be the best neighbor in the RXLEV DL (receive level down link) and the MS (mobile station) will decide to handover to it, but since it is unbalanced the MS may be wrong and once on this cell it may handover back for bad uplink quality.

Basically, a TMA system amplifies the received signal strength. The system sensitivity is therefore increased and the cell range is extended[4].

Normally, this device should be used in rural areas where electromagnetic pollution is reduced (noise-limited areas). In an area limited by interference, typically cities with tight frequency re-use, the use of TMA is not recommended as C/I before and after amplification stays the same and also as the noise level already high in that type of environment is increased as well.

Figure 1. TMA coverage and unbalanced neighbor without TMA



The improved RX (receive) sensitivity should, as already mentioned, enlarge the cell area and following Nokia it may improve the uplink speech quality and decrease the drop call rate. The power consumption can be reduced as well. Figure 8 illustrates TMA hardware installation.

2. Research methodology

This document presents the results of the TMA trial on Town Hall 159S4. The aim of the tests was to verify the effect of using a TMA on that rural site, applying the strategy described below. Main performance software tool (Mainperf BO) and cell traffic recording (CTR) were used to analyze the performance of the TMA.
Five scenarios have been studied:

Scenario 1: Reference - BTS (Base Station) without TMA;
Scenario 2: BTS with TMA installed with no BTS parameters adjustments;
Scenario 3: Scenario 2 plus (SSDES and INSSDES) signal receive parameters adjusted;
Scenario 4: Scenario 3 plus power control parameters adjusted;
Scenario 5: Scenario 4 plus BTS intracell parameters and IC (interference component) thresholds adjusted;

The benefit of using TMAs is an improved uplink performance. Basically, a TMA system amplifies the received signal strength in the BTS. The system sensitivity is therefore increased and the uplink cell range may be extended. For a more detailed description of the advantages see [2].

Mainperf Report

For each scenario, considering that the supplier of the site Town Hall is Nokia, the following indicators were analyzed in Mainperf[5]:

TCH_Traffic-Average – average of carried traffic in Erlangs
TCH_Drop_Cause_LowSS_uplink% - drop call rate due to low signal strength in the uplink direction;
TCH_Drop_Cause_LowSS_Downlink% - drop call rate due to low signal strength in the downlink direction;
TCH_Drop_Cause_LowSS_Bothlink% - drop call rate due to low signal strength in both directions at same time;
TCH_DropCalls% - drop call rate due to all causes.

3. Measurements Scenarios and results

3.1 Scenario 1

Period: before installation of TMA - [2July – 16July]

Before introducing the TMA in the system, the percentage of drop calls in sectors 1 and 2, caused by low signal strength uplink (LSS UL) was much higher than percentage of drops verified in downlink (»0%) (See Table 6 and Table 7).

Analyzing TCH_Drop_Cause_LowSS_Bothlink% , different situations occur for the two sectors:

Sector 1 – has a high TCH_Drop_Cause_LowSS_Bothlink%, but inferior to TCH_Drop_Cause_LowSS_uplink%, according to [1] this means the cell is balanced, however slightly unbalanced uplink;

Sector 2 – has also a high TCH_Drop_Cause_LowSS_Bothlink% but in this sector it is higher TCH_Drop_Cause_LowSS_uplink%, which means, also according to [1], that the cell is balanced and more balanced than the cell of sector 1.

3.2 Scenario 2

Period: [17July –4August]

TMA was installed in the 17th of July 2000.

After installing the TMA in the system, the uplink performance was clearly improved. In this scenario TCH_Drop_Cause_LowSS_uplink%, decreased dramatically in both sectors 1 and 2 (See Tables 6, 7 and figures 3, 4).

On the other hand, the downlink performance got worse, as the percentage of drop call caused to low signal strength downlink increased. For sector 2 this increase was higher than in sector 1.

The two sectors are now downlink unbalanced. This is due to the fact that the BTS output power was not increased and the gain of the TMA is as good as to provoke this unbalance.

3.3 Scenario 3

Period: [4August–11August]

The first parameter corrections implemented were SSDES and INSSDES:

SSDES defines the target value for the desired signal strength uplink as measured by the BTS in different parts of the power control interval during the stationary phase.

INSSDES defines the target value for the desired signal strength uplink as measured by the BTS in different parts of the power control interval during the initial phase.

These corrections were necessary, as after the TMA was installed, the value for the desired signal strength uplink as measured by the BTS was shifted by the gain of the TMA. So, in order to trigger the power control at more or less the same locations as the situation before TMA, those parameters were increased by roughly the TMA gain, 10 dB.

In this scenario, the tuned parameters were[7]:

Table 1. Signal strength parameter correction.

Parameter Name	Without TMA	With TMA
INISSDES	70	60
SSDES	90	80

These parameters were implemented on the 4th of August 00. They had no visible impact in the drop calls caused by low signal strength downlink in the two sectors (see Tables 6, 7 and figures 3,4).

3.4 Scenario 4a and 4b

In order to balance the cell, it was necessary to make some BSC parameters corrections for power control. This scenario has two phases, corresponding to two different tunings of the power control parameters.

3.4.1 Scenario 4a

Period: [11August-24August]

The implemented power parameters corrections were[2]:

BSPWRB (BTS output power before the combiner for BCCH carrier)
BSPRWT (BTS output power before the combiner for non BCCH carrier)
BSPWR (BTS output power after the combiner for BCCH carrier)
BSTXPWR (BTS output power after the combiner for non BCCH carrier)

Table 2. BTS power parameter correction for scenario 4a.

Parameter Name	Without TMA	With TMA
BSPWRB	43	45
BSPWRT	43	45
BSPWR	41	43
BSTXPWR	41	43

After implementing these changes, it was verified that the percentage of the drop calls due to low signal strength downlink decreased significantly (see Table 6).

3.4.2 Scenario 4b

Period: [24August-1Sept.]

In this scenario the power parameters were increased for more 2dB.

The power parameters corrections implemented were:

Table 3. BTS power parameters correction for scenario 4b.

Parameter Name	Scenario 4a	Scenario 4b
BSPWRB	45	47
BSPWRT	45	47
BSPWR	43	45
BSTXPWR	43	45

By increasing the power parameters to the maximum value, an improvement in the downlink performance was expected. However, there were no major differences between the two scenarios 4a and 4b (see Table 6 and 7). There was verified an increase in the traffic as well as an increase in the drop call rate, probably caused by the interference from others cells, as the coverage of 159S4 has increased also.

3.5 Scenario 5

Period: [1Sept-9Sept]

The cells in study have a small volume of intracell handovers, however, in order to maintain the same strategy defined for all the network, some correction needed to be implemented. In order to trigger an intra-cell handover at the same signal strength uplink, as before the installation of the TMA, the parameter signal strength offset for uplink - SSOFFSETUL was shifted by the TMA gain.

The implemented corrections can be found in the following table.

Table 4. intra-cell handover parameter correction.

Intracell Handover	Without TMA	With TMA
SSOFFSETUL	-10	-20

As already mentioned, the percentage of intracell handovers was very small (and this parameter correction had no visible impact in the intracell performance.

Also for interference component (IC) limits, the reason for tuning them, was the same for intracell handovers: to keep the initial strategy of the network. In this case, the reason was to keep the same channel distribution allocation.

Table 5. interference component parameters correction.

IC Limits	Without TMA	With TMA
Limit 1	0	10
Limit 2	2	12
Limit 3	7	17
Limit 4	16	26

The ranges of the bands defined by the Limits 1-4, determine the resolution of the measurements. For each channel allocation, the channel administration feature of Nokia, can use the information from Idle Channel measurements to select the most suitable channel. These limits were shifted by the TMA gain, in order to maintain the general quality of radio connections in the network as they were before the introduction of TMA[6].

Tuning IC and SSOFFSETUL parameters have achieved an improvement in the downlink performance achieved in both sectors. However, There an increase in the traffic was verified as well as an increase in the drop call rate, probably caused by the interference from others cells, as the coverage of 159S4-2 has increased also (see Table 6 and 7).

4 Daily Total Indicators Evaluation

In table 6 and 7 the average values of the indicators observed are represented for the five scenarios studied.

Table 6. Evaluation of main indicators for cell 159S4-1 (Daily Total).

	Scenarios					
Mainperf Indicators	**1**	**2**	**3**	**4a**	**4b**	**5**
TCH_Traffic.-Average (Erlang)	23.23	24.85	26.88	25.99	30.41	30.29
TCH_Drop_Cause_LowSS_uplink%	0.54	0.02	0.00	0.00	0.00	0.01
TCH_Drop_Cause_LowSS_downlink%	0.02	0.29	0.4	0.24	0.22	0.16
TCH_Drop_Cause_LowSS_Bothlink%	0.26	0	0.01	0.01	0.01	0.00
TCH_DropCalls%	**1.34**	**1.2**	**1.23**	**0.82**	**0.95**	**0.76**

Table 7. Evaluation of main indicators for cell 159S4-2 (Daily Total).

	Scenarios					
Mainperf Indicators	**1**	**2**	**3**	**4a**	**4b**	**5**
TCH_Traffic.-Average (Erlang)	18.37	19.43	21.23	23.73	26.99	31.21
TCH_Drop_Cause_LowSS_uplink%	0.26	0.01	0.00	0.00	0.00	0.00
TCH_Drop_Cause_LowSS_downlink%	0.02	0.35	0.29	0.23	0.27	0.19
TCH_Drop_Cause_LowSS_Bothlink%	0.36	0.00	0.00	0.00	0.01	0.01
TCH_DropCalls%	**1.02**	**0.94**	**0.89**	**0.8**	**0.97**	**0.85**

The percentage of drop calls has decreased even when the traffic was increasing, especially on sector 1.

This increase of the traffic is due not only to the fact that the coverage of the cell has been enlarged (see TA analyses in figure 2), but more likely also by the natural traffic increase which was observed in all the area see (Table 6). An increase in the drop call rate was observed, probably caused by the interference from others cells, as the coverage of 159S4-2 has increased also see (Table 7).

5 Cell traffic recoding analysis

Cell traffic recoding CTR allows us to make further check, as it collects during an interval of time all the measurement reports on the Abis interface. It is useful to perform the following studies:

-Path Balance Distribution;

-Power Balance Distribution;

-Timing Advance (TA) distribution.

To assess the coverage as well as the traffic gain, the TA distribution can be used[8],[9].

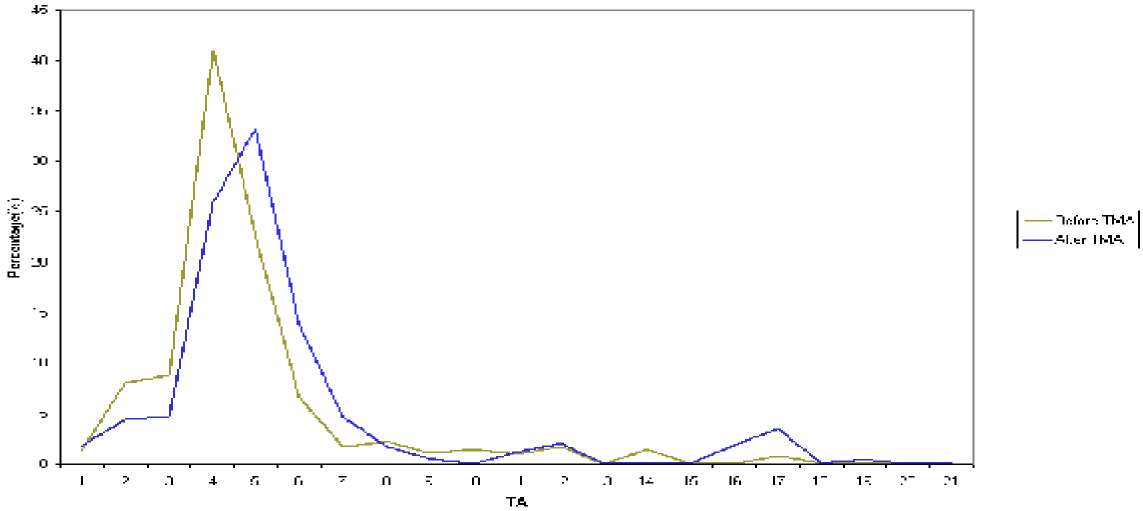


Fig.2 Timing Advance Distribution for sector 1: After and before the installation of the TMA.

As it can be seen in the figure 2 the TA distribution for sector 1 is shifted towards a bigger value of TA:

Before TMA the average TA was around 4. After TMA the average TA was around 5, which means an increase of about 1 km in cell range.

For sector 2 this shift was not so obvious as in sector 1.

5.1. Evaluation of the % drop calls caused by Low Signal Strength

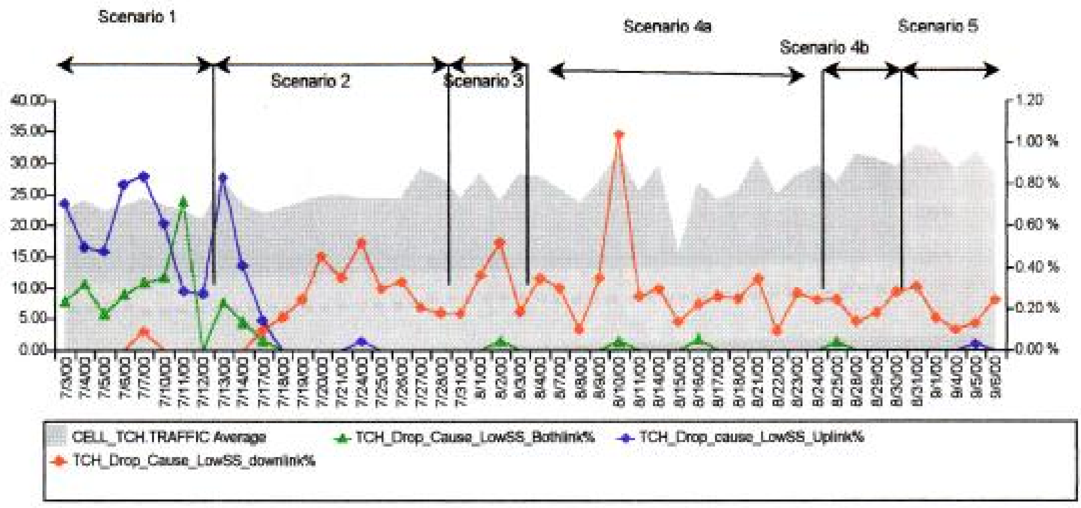


Figure 3. Cell 159S4 sector 1 – daily total.

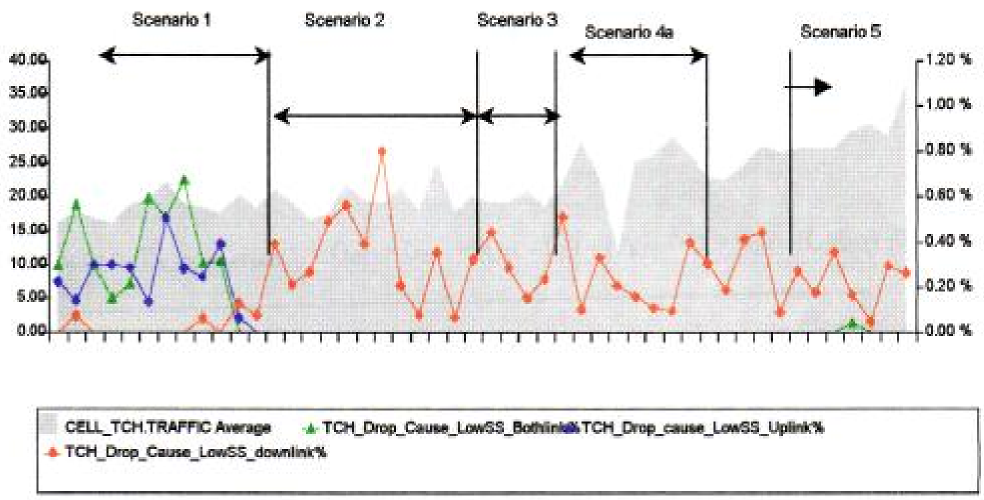


Figure 4. Cell 159S4 sector 2 daily total.

5.1 Path Balance

The Nokia operation and maintenance OMC doesn't calculate the path balance, but it calculates the power balance. The information of the path balance may be extracted from the one given by power balance.

According to [7] power balance is given by:

Power balance = $P_{at\ BTS} - P_{at\ MS}$ (2)

Power balance = $(P_{at\ MS} - L_{rf\ pathUL} + G_{BTS} + G_{div} + G_{LNA} - L_f) - (P_{BTS} - L_f + G_{BTS} - L_{rfpathDL})$ (3)

Power balance = $(P_{at\ MS} - P_{at\ BTS}) + G_{div} + G_{LNA} + (L_{rfpathDL} - L_{rf\ pathUL})$ (fig.5) (4)

Where:

$P_{at\ BTS}$ -Transmit power of the BTS at the reference point
$P_{at\ MS}$ - Power received at mobile
$L_{rf\ pathUL}$ - RF path loss uplink
$L_{rfpathDL}$ - RF path loss downlink
G_{BTS} - BTS antenna gain
G_{div} - Diversity gain
G_{LNA}- Gain of the TMA
L_f – Feeder and jumper Loss

As $P_{at\ MS}$, $P_{at\ BTS}$, G_{LNA} and G_{div} have fixed values, it is possible to conclude about the path balance:

path balance = $L_{rfpathDL} - L_{rf\ pathUL}$ (fig.6)

So, if the cell is balanced, the path balance is approximately zero dB and we expected to observe a power balance equal to: $(P_{at\ MS} - P_{at\ BTS}) + G_{div}$ before the TMA is introduced and when it was introduced, power balance should be shifted by the gain of the TMA.

In conlusion:

-before TMA: Power balance should be centered in –11dB
-after TMA: Power balance should be centered in 3dB

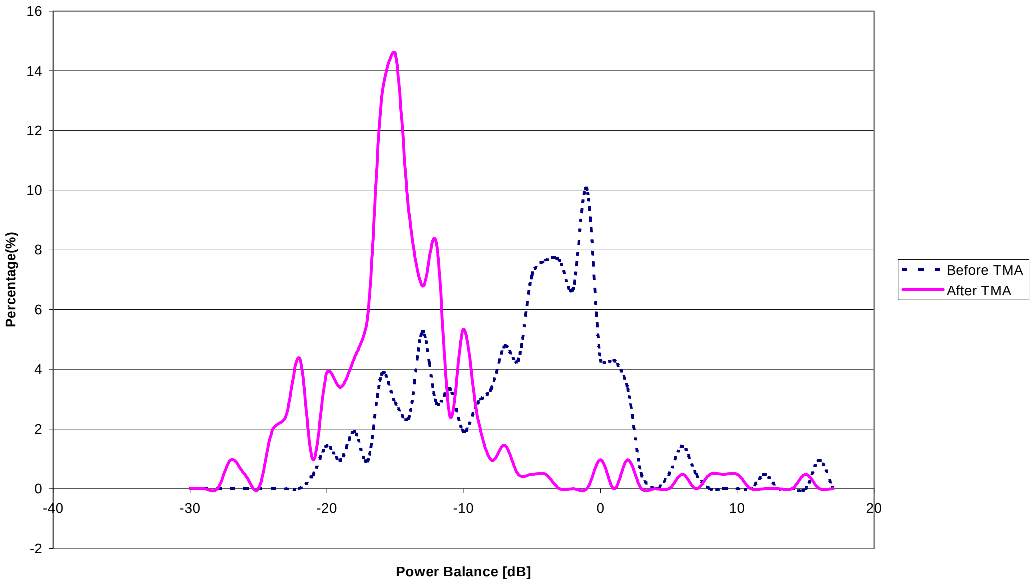


Figure 5- Power Balance before and after the introduction of the TMA in the system.

Nokia operation and maintenance tool does not allow any further calculations. The path loss uplink and downlink is available, however, they are presented as percentages. This way it is not possible to calculate the path balance, as the difference of these two paths, as they are in percentages. Figures 6 and 7 are the graphs obtained for the path loss up/downlink.

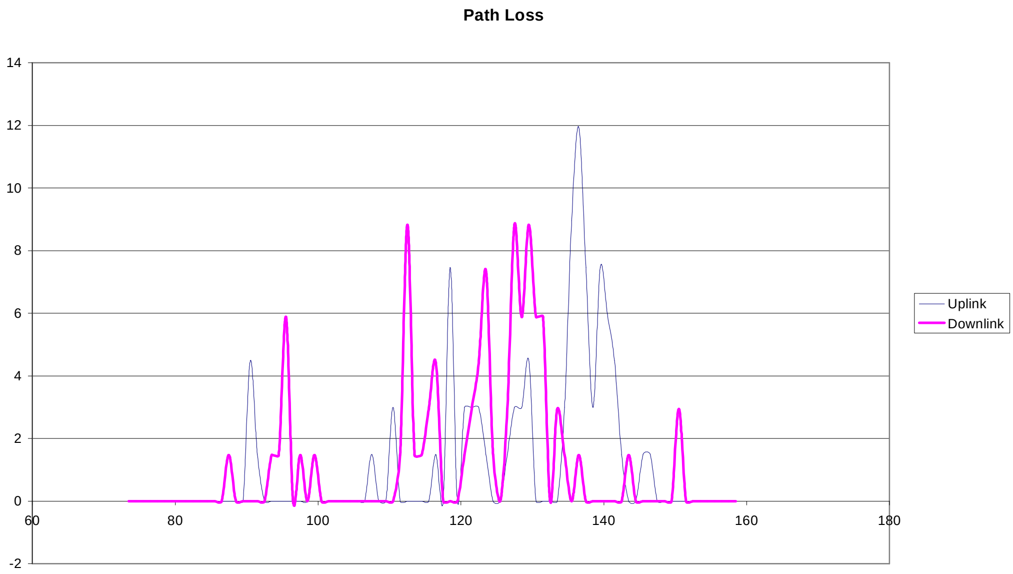


Figure 6. Path loss uplink/downlink before the installation of the TMA.

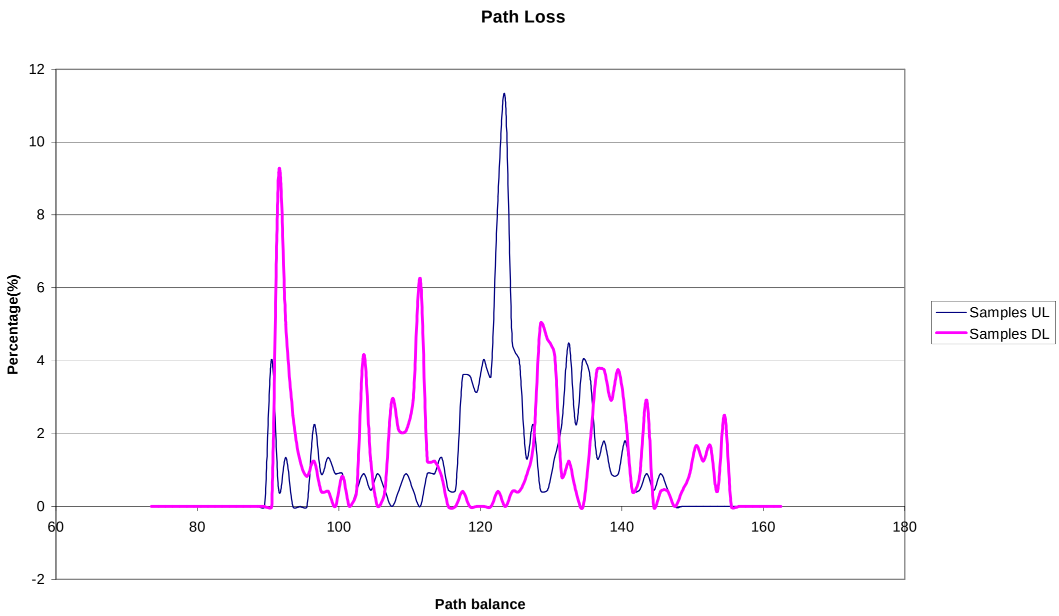


Figure 7. Path loss uplink/downlink after the installation of the TMA.

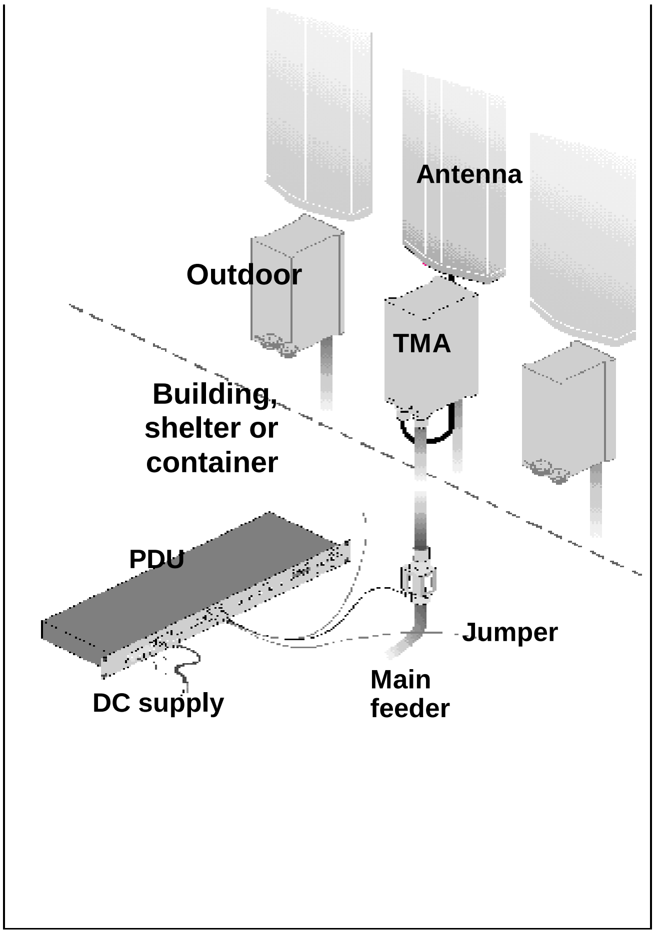


Fig.8 TMA hardware installation[9]

6 Conclusion.

The introduction of the TMA in the GSM network leads to an improvement of the uplink performance in terms of drop call rate. The coverage was also increased, which was confirmed by the increase of the TA. The dropped call rate was improved with better results in sector 1 by about 0.58%, and 0.17% in sector 2.

Results for TMA project show improvement on a number of cell performance aspects, like uplink performance, cell coverage, handover performance, and total traffic and drop call rate. The improvement scale varies between different cells and depends on proper fine tuning, and measurement results fellow up.

Thanks to the additional amplification, the uplink RX sensitivity is improved. There are two reasons for the improvement. Firstly, the feeder loss on the uplink is neutralized. Secondly, the noise figure for the BTS will decrease. In areas where noise (C/N) will limit the cell range such rural areas, the improved RX sensitivity has a potential of improving the coverage or decreasing the number of sites required for coverage. Also the uplink speech quality, handover performance and the dropped call rate may be improved. The improved sensitivity can also be used to decrease the power consumption of the MS.

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