White Paper

Network Coverage at its Best

Tower Mounted Amplifiers

an INFINITe company

Overview

As cellular mobile networks continue to expand, operators keep trying to find cost-effective ways to improve network performance. Recent years have seen the introduction of remote radio head (RRH) modules as part of the base stations (BS). These provide the operator with the benefits of a less expensive solution by placing all the active radio frequency (RF) components at the top of the tower. However, this solution cannot be used in all situations. Tower loading, site access restrictions, or concerns with radio failures can in many instances restrict the installation of RRH at the top of the tower. Hence, the older generic site installation practice of using an RF feeder to go from the antenna to the base transceiver station (BTS) is still used in many applications. This scenario does introduce the potential need for tower-mounted amplifiers that can provide increased capacity and better coverage.

Achieving maximum coverage is often as easy as boosting the uplink signal from the network user's handset at the BS, but this should not be confused with increasing the possible coverage from a site by boosting the downlink as well (increasing the link budget).

Appropriately installed low noise amplifiers (LNAs) in the BS uplink (receive channel) will significantly improve receiver system sensitivity when installed as close as possible to the receive antenna (particularly where cable losses are significant). LNAs located here are referred to as tower-mounted amplifiers (TMAs). This paper provides a general overview of BS receiver system sensitivity, and the benefits of installing a quality TMA.

Introduction

The following discussion attempts to simplify the technical issues relevant to improving BS cell coverage, with the aim being to provide a broad yet substantial understanding of the subject for all network stakeholders.

The issues covered include:

- BS cell coverage fundamentals
- BS cell coverage in practice
- BTS receiver sensitivity
- Site installation influence on BS sensitivity
- Benefit of installing a TMA
- Choosing the right TMA

Base Station Cell Coverage Fundamentals

The two primary components of any cell are the operator’s BS installation and thecustomer handset or user equipment (UE). These two items must effectively and consistently communicate with each other.

Installed at a fixed location, the BS is the major component of the cell. While there are many geographic and environmental issues to consider, this is where all network coverage improvements are to be made.

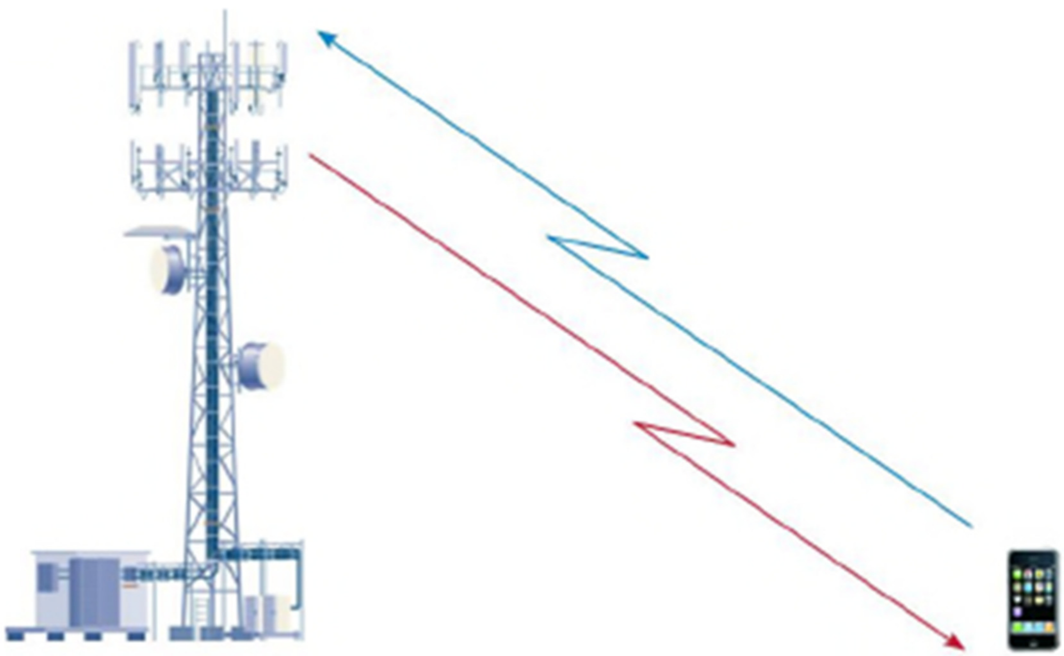


Figure 1

The UE is powered from a battery. It has low transmit (Tx) power and a small antenna, and is therefore often the weak link in the communications chain. The amount of “talk time” available is a function of the rate that stored power is consumed from the battery. The less power that the UE needs to output, the longer the battery will last

Tx power from the handset is controlled by a command from the BS. Here the quality of the received (Rx) signal from the UE is continually monitored. The result is a bit error rate (BER) value that the BS attempts to minimise by instructing the UE to increase its Tx power.

Generally, a BS installation will support a number of cells or sectors from a common antenna tower. Each of these sectors has a theoretical footprint within which UEs will operate. This is the BS cell coverage referred to in this paper.

BS equipment is designed to have enough Tx power for its signals to reach the outer limits of a cell, as well as matching Rx sensitivity to detect signals from UEs transmitting at this outer limit. Both are generally measured in dB and are referred to as the link budgets. The signal strength relationship between the BS downlink (Tx) and uplink (BS Rx or UE Tx) is referred to as the link budget balance.

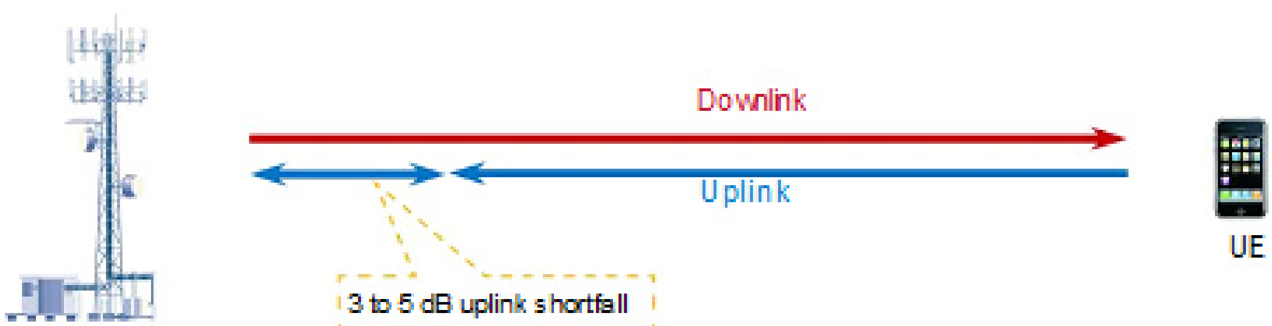
In theory, improving the uplink sensitivity (link budget) should be matched by the same improvement to the downlink Tx power in order to maintain link balance

Base Station Cell Coverage in Pratice

Cell coverage is also a function of the gain and positioning of the BS antenna. Regardless of the design choices made while considering these factors. The following remains true.

In practice, network operators have found through field tests that the uplink is the cause of less than expected theoretical coverage. The downlink signal strength at the outer limit of a cell is generally well within specification, but the received signal from the UE is either marginal or not detected by the BS receiver at all. Generally, this is caused by an uplink shortfall (imbalance) of typically 3 to 5 dB.

The following model shows this problem. Here the downlink arrow shows sufficient power to



Comprehersively reach the cell phone while the uplink arrow shows a shortfall in uplink signal 3 to 5 dB to balance the link.

BS

Figure 2

Base Transceiver Station Receiver Sensitivity

BTS Receiver sensitivity is a function of the sum of three fundamental factors (in decibels).

1. Thermal Noise: This is a measure of the noise in nature—noise being the random electromagnetic signals resulting from the movement of atomic particles of all matter. It can be calculated as:

Thermal Noise= kTB (W)

Where:

k = Boltzmann constant = 1.3806488(13) X 10^{-23} J/K

T = Temperature in Kelvin (K)

B = Bandwiths (Hz)

2. **Signal-to-Noise Ratio (SNR):** This is a measure of the relative strength that the received signal must maintain in relation to the noise floor to ensure satisfactory detection. It can be a positive or negative value based on the air interface technology (e.g. positive in GSM, negative in UMTS and LTE).

3. **Noise Figure (NF):** Noise figure is a measure of extra noise caused by the receiver circuitry. It can be as high as 5dB.

As far as the network operator is concerned, both thermal noise and SNR are fixed. The only component affecting receiver sensitivity that may be improved by the operator is the system noise figure, or NF.

Site Installation Influence on Base Station Sensitivity

In any given installation, the BTS equipment must be connected to antennas. These are generally mounted at the top of a tower, some distance from the BTS equipment, and connected via coaxial cable. Depending on site configuration, filters and duplexers may also be used in the signal path. These components introduce a loss in the signal path which is added directly to the BTS receiver NF. Typically these additional losses can be as much as 6dB.

Assuming 4dB feeder losses and 2dB NF for the BTS receiver, the BS system NF is:

BS system NF = NFBS = BTS NF + feeder losses = 2 + 4 = 6 dB

Benefit of Installing a Tower Mounted Amplifier

A TMA reduces the system NF and therefore increases sensitivity. As previously mentioned, a TMA is an LNA mounted as close as practical to the sector Rx antenna. In this way, the cable losses are negligible and do not significantly affect system NF.

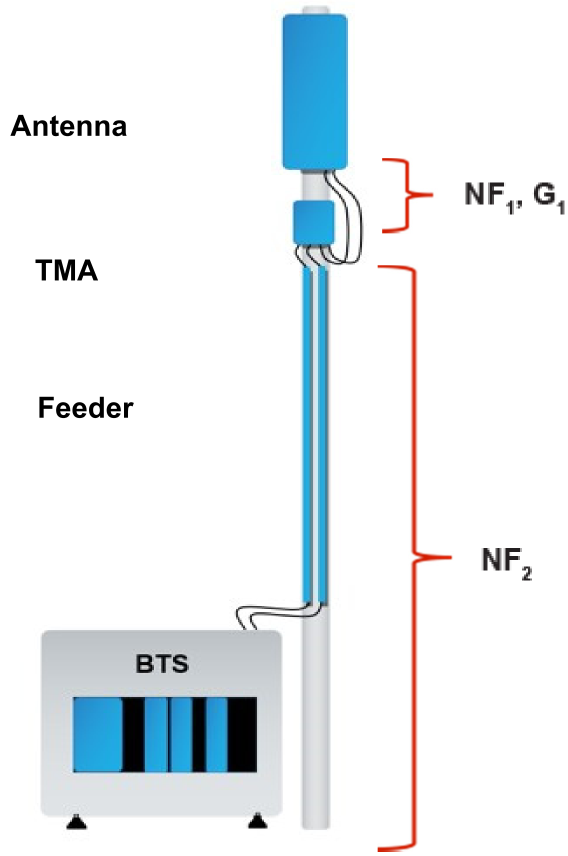


Figure 3

System NF is calculated using Friis formula as follows:

$$nf_{BS} = nf_1 + \frac{nf_2 - 1}{g_1}$$

Where

nfBS = BS system noise factor

nf_1 = noise factor of the TMA

nf_2 = noise factor of the BTS receiver and feeder losses

g_1 = gain of the TMA (multiplier, not dB)

Note: noise factor (nf) is a multiplier, and noise figure (NF) is in dB

If a TMA with the noise figure of 1.2dB and gain of 16dB is added to the BS assumed before, the new BS system noise figure calculates as:

NF_1 = 1.2 dB $\Longrightarrow$ nf_1 = 1.32

NF_2 = 6 dB $\Longrightarrow$ nf_2 = 3.98

G_1 = 16dB $\Longrightarrow$ g_1 = 39.81

$$nfBS = 1.32 + \frac{3.98 - 1}{39.81} = 1.39 = NFas = 10 \log (1.39) = 1.44 \text{ dB}$$

Here, by adding the TMA, the NF of the BS system is improved by 4.56dB (6 - 1.44= 4.56), thereby improving the sensitivity of the BS system by 4.56dB. This upgrade can result in as much as 80% improvement in the cell coverage area.

The following diagram provides a conceptual view of the benefit of using a TMA.

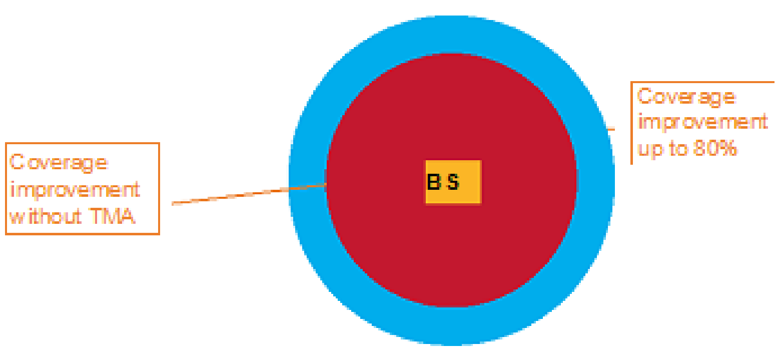


Figure 4

This increase in coverage is a direct result of improving the BS uplink sensitivity.

The benefits are considerable:

- More content network users, lower BER, therefore fewer dropped calls and higher data throughput;
- Lower Tx power from the user handset, therefore longer battery life;
- Improved network performance, leading to a better investment returns; and
- Happy customers, good coverage.

Choosing the Right TMA

Adding TMAs increases the investment in the network. Selecting the right product is paramount to achieving greater returns without increasing maintenance costs.

Clearly, the NF of the TMA is added directly to the BS system NF. Therefore, it is very important to select a TMA that has a low NF (in the order of 1.5dB). The choice of gain in the TMA is as crucial as its NF. BTS manufacturers design their equipment so that the dynamic range of the BTS receiver is sufficient to ensure undistorted detection of the closest transmitting UE to those on the outer perimeter of the cell.

While a TMA will improve BTS uplink sensitivity, it also introduces additional gain to the Rx system. This has the effect of reducing the dynamic range of the receiver by making strong signals even stronger. Typically the range of 8dB to 16dB for TMA gain is adequate. Less than 8dB gain reduces the NF improvement considerably, and with more than 16dB the detrimental effect on signal detection is significant.

The possibility of additional of high power interfering signals immediately adjacent to the inband uplink signals can also be of a concern. The likelihood of a weak in-band Rx signal being blocked by these signals should be considered when selecting the TMA. Well-designed TMAs will include highly selective bandpass filtering prior to the LNA stage. For well-designed BS installations, the out-of-band rejection characteristic of these filters will neutralise potential Rx blocking problems and possibly even improve cell performance.

The TMA should be selected, installed and forgotten. It should be as reliable as the coaxial cable to which it is connected.

Many companies can supply TMAs with very good gain and NF specifications; however, to “install and forget” requires the selection of a product designed and manufactured to survive often hostile installation environments.

The TMA must:

- Be easily added to a site installation
- Include excellent out-of-band frequency rejection
- Incorporate Antenna Interface Standards Group (AISG) recommended specifications for digital remote control and monitoring
- Use heavily de-rated electronic components and robust moisture-proof

coaxial cable connectors - Be housed in a strong weatherproof

enclosure made from materials that are corrosion resistant - Be lightning

strike protected

- Be physically tested for the following at time of design and manufacture:
  - Sound design and construction by vibration testing
  - Thermal reliability and stability by temperature testing
  - Pressure tested to ensure the design continues to work over a range of different installation altitudes

These last three tests can only be achieved using the right laboratory equipment.

(A) **(B)** **(C)**

Figure 5

Shown above is:

a. Thermal oven with a testing range of -40 to + 65 Deg C.

b. Pressure testing apparatus with altitude simulation to >4000m

c. Vibration table with a capability of 5-3000Hz and up to 100g

Kaelus is a recognised leader in RF conditioning including TMAs since 1995. Kaelus provides a large range of high-performance, high-quality TMAs to leading mobile operators around the globe, and supports an installed base of greater than half a million units. Kaelus provides a wide range of solutions, including single-band, dual-band, and customized products with interference filter integration requirements where needed. For further information on Tower Mounted Amplifiers please contact us at +1 303 768 8080 or visit our website at www.kaelus.com.