Tower Mounted Amplifier (TMA)

TMA is a low noise amplifier (LNA) installed as close as possible to the antenna and usually consists of a preselector filter. As way of improving the system performance, TMA helps in increasing the cell coverage, data throughput and site ability to maintain connection within and across the cells. Also using a TMA reduces the power requirements from the consumer mobile handset thus increasing the battery life which is critical with today’s data intensive applications. When the TMA is used, the BTS requests less power from the handset and this increases the handset’s battery life. The reduction of power in the handset also reduces the intercell interface which increases the capacity of the adjacent cell. The most important parameters which need to be considered when choosing the TMA are the gain, noise figure and intermodulation. Here we explain how these parameters can affect the overall RX chain performance.

Receiver sensitivity

The TMA increases the receive sensitivity by improving the path loss and therefore the system noise figure which have a direct impact on the sensitivity. Below we explain how the TMA has effect on improving the sensitivity of the uplink path.

Having a specific Signal to noise ratio (SNR), receiver sensitivity is the minimum input signal (Smin) required to generate a specified output signal. The sensitivity is defined as:

\[ S_{\text{min}} = KTB \times (SNR)_{\text{min}} \times (NF) \]

Where \((SNR)_{\text{min}}\) is the minimum required signal to noise ratio, KTB is the mean thermal noise and NF noise figure of the system.
Amongst these three effective factors on the receive sensitivity, operators have no control over the first two. The SNR is a function of BTS design, and the thermal noise is a function of nature’s noise which is spread more or less uniformly over the spectrum (It is -174dB at ambient temperature over 1Hz of bandwidth). Therefore the only factor that the operators can use to improve the network sensitivity is the system noise figure.

Below we will discuss how adding the TMA after the antenna can improve the system noise figure and therefore the sensitivity of the RX path.

![Figure 1. The block diagram of a cascaded network consist of multiple stages within a RX path](image)

In a system that consists of cascaded blocks i.e the RX path in figure.1, the cascaded noise figure is calculated using Friis equation:

\[
NF_{tot} = NF_1 + \frac{NF_2 - 1}{G_2} + \frac{NF_3 - 1}{G_1 G_2} + \ldots + \frac{NF_n - 1}{G_1 G_2 \ldots G_{n-1}}
\]

Where \(NF_n\) and \(G_n\) are the noise figure and the power gain of the \(n\) stage respectively. It should be mentioned that any loss in the chain is considered as \(1/G\) in the equation. Looking at the equation we can see in a cascaded network, the noise figure contributed by each stage decreases as the gain of the preceding stage increases. Therefore the first few stages have the most critical effect on the noise figure and the sensitivity. In particular, the first stage i.e a TMA with very low noise figure and high gain will add the most benefit in lowering the system’s overall noise figure. Besides, if any stage shows loss, the noise figure of the following stage increases. This occurs for example when lossy cables and connectors are placed between the antenna and the basestation.

Figure.2 shows an example of two situations where a TMA is not implemented (a) and implemented (b) in the RX path between the antenna and basestation receiver. In this example, If we consider the ideal RX sensitivity of -121.3dBm at the antenna port, path loss of 4.2dB between the antenna and BTS (Including feeder cables, BTS bias Tee and BTS connection jumper) and BTS noise figure of 5dB for both cased, the actual
sensitivity of the receiver would be -112.1dBm (without using the TMA) and -118.4dBm (with using the TMA). This is explained below;

In Figure 2(a), the total noise figure of RX system = Total attenuation of Passive components between antenna and TBS + basestation noise figure

\[
NF_{total} = Loss \ of \ the \ passive \ path + NF_{BTS}
\]

\[
NF_{total} = 4.2 + 5 = 9.2 dB
\]

![Diagram of RX system with and without TMA](image)

Figure 2. The receive path where a TMA is (a) not used and (b) is used between the antenna and BTS receiver.

In Figure 2(b) where a TMA with 12dB gain and 1.7dB noise figure is placed between antenna and receive BTS as close as possible to the antenna,

\[
F_{total} = F_{TMA} + \frac{F_{passive \ path+BTS}}{G_{TMA}}
\]

\[
F_{total} = 1.47 + \frac{8.3}{16} = 1.98
\]

\[
NF_{total} = 2.8 dB
\]

Where \( F \) is the non-decibel value of \( NF \) and \( G \) is the gain. In this case the system’s \( NF = 2.8 dB \). As we can see by adding an active element (TMA) after the antenna, the total noise figure of the system is reduced from 9.2dB to 2.9dB. This is equivalent to the sensitivity improvement of
6.3dBm. In this case the ideal sensitivity is reduced by just 2.9dB comparing to 9.2dB when no TMA is being used. This results in an improved link balance, larger cell/sector coverage area and improved user experience with less data drop out and improved battery life.

Table 1 shows an example of noise figure improvement by using a TMA at 1880MHz when different feeder cables are used. The TMA is assumed to have 12dB of gain and 1.7dB noise figure. As can be seen in the table adding a TMA in the RX path can improve the noise figure from 4 to 6.12dB at different scenarios in this example.

| Table 1. The calculation of noise figure improvement by using a TMA in the RX path at 1880MHz with different feeder cables between the antenna and the BTS |
|---|---|---|
| **Uplink Noise Figure Analysis 1880 MHz** | **Feeder Only** | **With TMA** |
| TMA Gain: | 0 | 12.00 dB |
| TMA NF: | 0 | 1.70 dB |
| 7/8” Feeder Loss | | |
| • 100 ft @ 1880 MHz: | -1.80 dB |
| • 200 ft @ 1880 MHz: | -3.60 dB |
| 1 5/8” Feeder Loss | | |
| • 100 ft @ 1880 MHz: | -1.00 dB |
| • 200 ft @ 1880 MHz: | -2.00 dB |
| BTS/RRH Bias Tee Loss: | -0.10 dB |
| BTS/RRH Connection Jumper | -0.50 dB |
| BTS/RRH NF: | 5.00 dB |

<table>
<thead>
<tr>
<th><strong>Uplink Noise Figure (NF) Comparison</strong></th>
<th><strong>No TMA</strong></th>
<th><strong>With TMA</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>7/8” Feeder @ 100 ft:</td>
<td>7.20 dB</td>
<td>2.46 dB</td>
</tr>
<tr>
<td>7/8” Feeder @ 200 ft:</td>
<td>9.00 dB</td>
<td>2.88 dB</td>
</tr>
<tr>
<td>1 5/8” Feeder @ 100 ft:</td>
<td>6.40 dB</td>
<td>2.32 dB</td>
</tr>
<tr>
<td>1 5/8” Feeder @ 200 ft:</td>
<td>7.40 dB</td>
<td>2.50 dB</td>
</tr>
</tbody>
</table>

**TMA Vs GMA**

In the previous section we showed the benefits of installing the LNA as close as possible to the antenna. However, the low noise amplifier is sometime installed on the ground level which is called GMA (Ground Mounted Amplifier). GMA has the benefit of being easier to install and not occupying the precious tower space.

When the LNA is installed closer to the BTS, the loss of the RX path, typically 2-4dB, is directly added to the noise figure and consequently reduces the sensitivity. Therefore GMA is more limited in the performance improvement it can add to the system.

On the other hand, because there is no pressure in considering size and weight the GMA can be optimised for the performance. For example, superconductors and cryogenic cooling can be used to partially offset the disadvantage of ground level location at the expense of higher power consumption.
TMA Architecture

TMA consists of a low noise amplifier (LNA) and very selective filters in the RX path. The filters are used to reject the unwanted signals within the RX band and also to protect the LNA from the transmit power of the radio presented at both BTS and antenna ports.

A band selective filter is also used in the TX path which also prevents the oscillation within the LNA due to the close loop effect, Figure 3 (a). The TX filter also helps to reject any additional wider-band noise from degrading the RX input. It should be mentioned that no amplification is applied to the TX path.

In some configurations, a non amplified path can be integrated to the TMA as a bypass or pass through path and is used to provide an option for failsafe operation and diagnostics, Figure 3 (b).

AISG Feature

The AISG (Antenna Interface Standard Group), defines the standards for communication between the base stations and tower-mounted equipment in order to optimize the performance and enable the remote supervision of the RF path. The AISG standard is used in the TMA in controlling the LNA gain and providing error/alarm message as feedback. It is also used in monitoring and adjusting the beam (tilt) in Remote Electric Tilt (RET) antennas.

The TMA gain and alarm and the antenna tilt is controlled remotely by a controller at the base station and the control signal is called AISG signal. While the coaxial cables between the BTS and the antenna (feeder cables) are carrying the high power RF signals, the AISG signal is carried out through RS-485 control cables. Nowadays, the common way of establishing the communication between the base station controller and the tower mounted equipment ie TMA and antenna is to use the AISG modem to modulate the 9.6kbit/sec AISG control signals of the RS-485 cable at the bottom of the tower onto a 2.176MHz carrier and send it on the RF feeder cable. The ON-OFF Keying (OOK) is used to modulate the 2.176MHz carrier signal and therefore these modems are called AISG OOK modems.

A second AISG modem is used at the top of the tower to get the control carrier from the RF feeder cable and convert it to the logic levels for the TMA or antenna control. The second modem can be integrated in to the TMA. In this case, the TMA also outputs the AISG control signal on a RS-485 cable for connecting to the RET antennas.
TMA with diversity feature

In the applications where the RF or baseband diversity is required, the TMA can be designed to provide the appropriate diversity signals. Figure 4 shows the block diagram of a TMA which preserves the receive and transmit diversity with minimum loss. ANTA and ANTB are the main and diversity ports of the antenna and in both uplink and downlink directions.

Multiband TMAs for Equipment Sharing Scenarios

Due to the increasing restriction on Tower infrastructure deployments by local municipal policies and the towers physical limitations, operators are facing difficulties in adding new antenna systems to their existing sites. Network equipment sharing between multiple operators or multiple technologies can be seen as a cost-effective solution to the deployment of current and next generation base stations. Network sharing can take many forms including feeder sharing, antenna sharing, band-combining, RAN sharing, etc in Inter or Intra-operator sharing scenarios. Depending on the level of sharing, different equipment are required to support the market. Multi-band TMAs are one of the equipment developed to address the equipment sharing market with structures advanced to support various sharing scenarios. Filtronic’s involvement in multiple projects for equipment sharing market has resulted in developed expertise and wide range of products including multi-band TMAs to support various sharing scenarios. Filtronic has developed a wide range of multi-band TMAs to support various network sharing scenarios with offering the optimum performance.
When only the feeders are shared between multiple base stations / eNodeBs, Multi-band TMA can be designed in a duplex form with separate RF paths for each band at the antenna port, Figure 5 (a). In the scenarios where both feeders and antennas are shared (the single band antennas are replaced with multiband antennas), Multi-band TMAs can be designed with one RF path at the antenna and BS ports (diplexed), Figure 5 (b).

![Figure 5. The Multiband TMA with (a) duplexed and (d) diplexed structure](image)

In the multiband TMA structure, duplexed or diplexed, the RET control can be given to each individual BTS / eNodeB by using two separate AISG modems, Figure 6. This gives more flexibility and control over the network performance when the equipments are shared between multiple operators.

![Figure 6. The multiband TMA with duplexed and diplexed structure and individual RET control for each BTS / eNodeB](image)
TMA Examples

Filtronic offers a wide range of tower mounted amplifiers for different scenarios in the wireless infrastructure market. The TMAs are designed for single or multiple frequency operation within 800, 900, 1200, 1800, 2100 and 2600MHz bands.

For example, SXC064 is a dual TMA for 2600MHz band with 12dB of gain and excellent noise figure of 1.3dB. The unit provides extremely low loss over the RX band with very high OIP3 of a 26dB. It also provide the LNA bypass path for failsafe operation and diagnostics.

As another example, SXC092 is a twin dual band TMA which provides 12dB of gain across two operational bands of 1800 and 2600MHz. The TMA has an excellent noise figure and very low loss across both bands. There is also AISG modem and PCU integrated with this TMA.

Filtronic also offers a triple band TMA, SXD003, for operation in 1800, 2100 and 2600 bands. The unit has excellent noise figure, 12dB of gain, High OIP3 and low RX loss across all operational bands.

Similarly there are a wide range of TMAs for different frequency bands to fulfill the requirements for different scenarios. For more information please review our product portfolio.

General Features of Tower Mounted Amplifier

- Covers wide range of wireless frequency bands; 800, 900, 1200, 1800, 2100 and 2600MHz
- Supports different technologies; GSM, UMTS, CDMA, WCDMA and LTE
- Excellent noise figure
- 12 ± 1dB of gain across all frequency bands
- Minimal RX insertion loss over all frequency bands
- Very high output intercept point (OIP3)
- AISG Modem
- N x 7/16 DiN female connectors

Conclusion

Filtronic offers a wide range of TMAs for the wireless infrastructure market. The wide range of TMAs covers different scenarios of equipment and technology sharing. The TMAs are designed with an excellent noise figure, high gain, high OIP3 and minimum insertion loss within RX path.