RADIO FREQUENCY SYSTEMS

TMA usage in CDMA networks

TMAs give CDMA networks a boost

Escalating consumer dependence on wireless data networks is placing growing pressure on existing CDMA wireless infrastructure. This is highlighting the role of tower-mount amplifiers as an economical solution for improving BTS receiver sensitivity – thus improving overall network performance and network revenue.

In the space of a few short years, tower-mount amplifiers (TMAs) have become globally indispensable in many mobile wireless communications networks. Initially widely deployed in first-generation networks, then global system for mobile communications (GSM) networks to overcome link budget imbalances between uplink and downlink, TMAs essentially boost the uplink signal to overcome receive-path losses, thereby improving base transmitter station (BTS) uplink sensitivity.

Historically, however, TMAs have not found as wide an acceptance in code division multiple access (CDMA)-based networks. Early network planners considered that TMAs would increase the noise floor of the spread-spectrum technology, leading to reductions in cell capacity. Moreover, since CDMA was adjudged an 'interference limited' system, popular opinion supposed that improving uplink sensitivity would be masked by user interference as cell-loading increased.

Developments in BTS technology – along with the established global dependence on TMAs for wideband CDMA systems such as universal mobile telecommunications system (UMTS) – have altered this scenario from both a technical and ideological point of view. In fact, TMAs are now becoming an essential component of CDMA-based networks, particularly those that are uplink-limited, where they promote not only coverage improvements, but also capacity enhancements.

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Uplink city limits

Put simply, the balance between the CDMA uplink and downlink has changed since the early days of CDMA. For one thing, base transmitter power has improved significantly, from 10 or 20W up to around 100W: with the downlink thus bolstered, any uplink limitations become more of a factor.

Moreover, a characteristic of spread-spectrum CDMA networks is the dynamic relationship between downlink and uplink, where the uplink performance is uniquely dependent on the number of users in a cell. This means that as the user demand on urban networks escalates – particularly the volume of transmitted data – the variability of uplink performance has a much more significant impact on the network.

This uplink variability in CDMA-based systems is known as 'cell breathing', and results from the BTS commanding specific handset output powers to achieve the minimum signal-to-noise ratio in the receiver. As the number of users in a cell increases, the power output of handsets near the outer limits of the cell is eventually exceeded and calls are dropped. Hence the uplink boundary of the cell begins to shrink – or 'breathe'.

Significantly, CDMA cells can be either purely uplink limited, or a dynamic mix of downlink and uplink limited. Whether a cell is one or the other can often be difficult to predict. It is largely dependent on the 'orthogonality factor' (a measure of the impact of multi-path dispersion) of the downlink, along with BTS technology and the number of users. If the downlink orthogonality factor is high, and the propagation path protracted, the downlink limitations are more likely to come into play, and the cell is more likely to be a mix of uplink and downlink limited.

TMA usage in CDMA networks

Nevertheless, in both types of networks, the deployment of TMAs to amplify the uplink signal can play a key role in improving overall network performance – and ultimately network revenue.

TMAs to the rescue

Consider first a typical purely uplink limited scenario. **Figure 1** illustrates the variation of the 'allowed path loss' of both the uplink and downlink with the number of users in a cell. The introduction of a TMA to the uplink clearly increases the allowable path loss for a given number of users, yielding a corresponding increase in coverage area.

However, an alternative view is that for a given coverage area (or allowed path loss), the number of users able to communicate increases. In other words, with a TMA installed to boost the uplink signal, cell breathing is delayed to a higher cell loading, thereby improving overall capacity of the cell.

In contrast, **Figure 2** illustrates a mixed scenario where the cell is uplink limited in terms of coverage for a moderate number of users, but downlink limited in terms of capacity beyond a specific number of users. Introduction of a TMA to the uplink improves the uplink coverage, or alternatively allows increased capacity for a given coverage area until the downlink limitation is reached. In such capacity-downlink-limited networks, TMAs will provide the greatest benefit in rural or suburban cells, where capacity is less of an issue.

Irrespective of whether a cell is uplink or downlink limited, TMAs significantly reduce the power generated by consumer mobile handsets, compared with non-TMA use. Essentially, the BTS monitors the signal provided by the handset, instructing the handset to increase its power as required in order to reduce the bit error rate (BER). When TMAs are employed, the BTS demands less power from the handset, thereby maximizing its battery life. This reduction of handset power also reduces inter-cell interference, which has a flow-on effect of increasing the capacity of adjacent cells.

Improving sensitivity

In principle, a TMA is a low-noise amplifier installed in the RF receive path as close as possible to the receive antenna. Its purpose is to overcome or mask the impact of the receive path (which might include transmission line, duplexers and filters) on the system noise figure, which has a direct impact on receiver sensitivity.

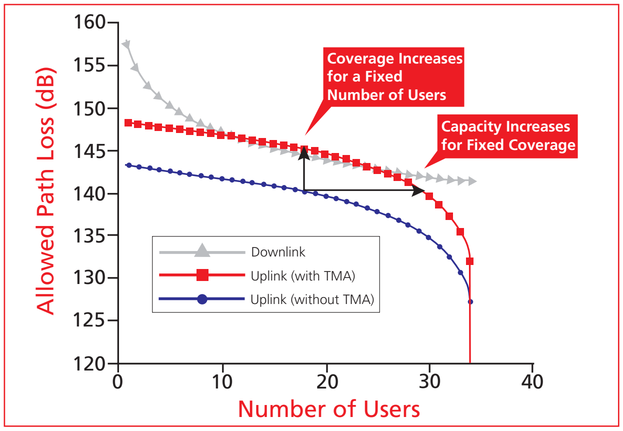

Figure 1 "Uplink Limited" Case

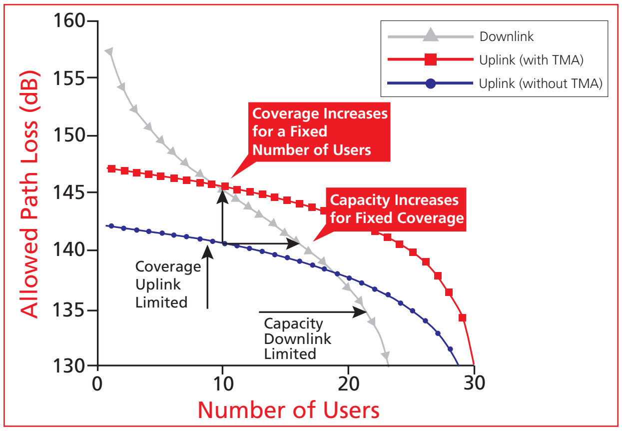

Figure 2 "Downlink Limited" Case

For example, the sensitivity of a receiver channel is a function of the sum of three fundamental factors:

- Ambient noise power (NP)
- Carrier-to-noise ratio (C/N)
- Noise figure (NF)

Network operators have no influence on the first two of these: the ambient noise power is a measure of the noise in nature and therefore fixed for a specific carrier bandwidth; carrier-to-noise ratio, a function of BTS design, is a measure of the relative strength between the received signal and noise floor. Noise figure, on the other hand, can be addressed.

Noise figure is the decibel equivalent of 'noise factor' (F), which is the ratio of signal-to-noise ratio (SNR) 'in' to SNR 'out' of an RF line component. In other words, NF is a measure of the degradation of SNR caused by components in the RF signal chain. Consequently, it is the 'system NF' that becomes the targeted parameter for improvement.

The following example illustrates how installation of a TMA (an active device) close to the antenna can mask the losses attributed to the passive devices in the RF chain, thereby substantially improving receiver sensitivity.

Figure 3a illustrates, for a typical scenario where no TMA is installed, the RF receive path and signal losses due to the different line components:

- The 'ideal' sensitivity of the BTS receiver is 121.3dBm
- The system NF is 4.5dB (receiver circuitry) + 4dB (RF line components) = 8.5dB
- The 'actual' receiver sensitivity is consequently 112.8dBm

Now consider **Figure 3b**, where a TMA is installed close to the receive antenna. The system noise factor, F, from which the 'effective system NF' is determined, is in this case defined by the following formula:

$F = F1 + (F2-1)/G1$

Where

F1 = the noise factor of the TMA

F2 = the noise factor of the BTS receiver

G1 = the gain of the TMA

The noise factor formula uses non-decibel figures, where (in the current example)

F1 = 1.4 (from 1.5dB)

F2 = 7.1 (from 8.5dB-the system NF defined above)

G1 = 20 (from 13dB)

This yields a system noise factor value of F = 1.7, which corresponds to an effective system or cascaded NF of 2.3dB. In other words, the effective losses of the system are 2.3dB with the active TMA installed, instead of the 8.5dB losses associated with the passive RF line. This means that the 'actual' sensitivity of the receiver becomes -119dB instead of -112.8dB (when no TMA was installed), an improvement of 6.2dB.

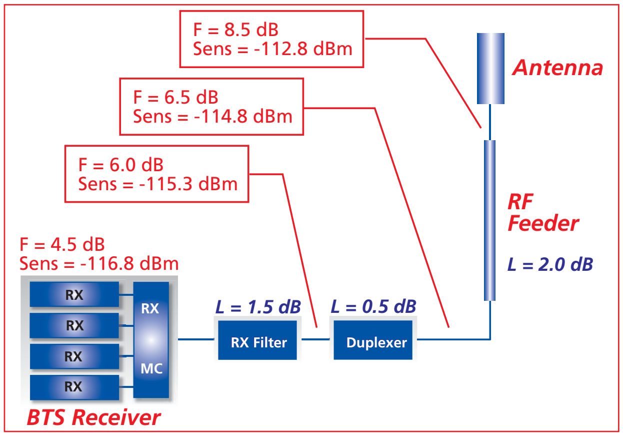

Figure 3a Sensitivity Improvement without TMA

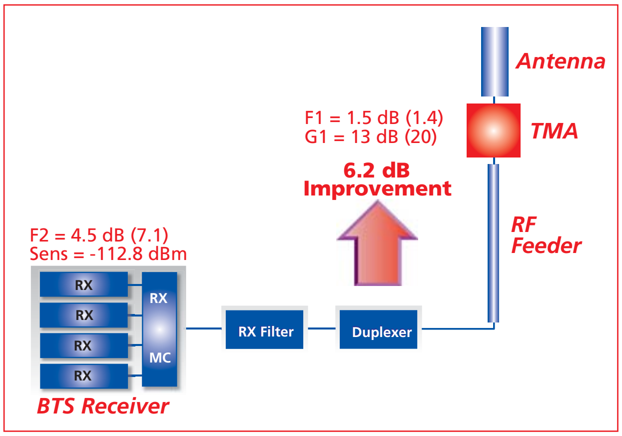

Figure 3b Sensitivity Improvement with TMA

This calculation also illustrates why it is essential to install the TMA close to the antenna: if the TMA were located at the bottom of the tower, the losses incurred to that point would need to be added to the cascaded NF. This would negate much of the positive impact of including an amplifier.

The ideal gain

It follows that the two TMA parameters of most importance are the noise factor/figure and gain. Ideally, TMA noise figures should be less than 1.4dB. As for gain, the industry range is generally 8dB to 16dB: less than 8dB engenders insignificant system NF improvement, while more than 16dB results in amplification of the noise floor and excessive BTS dynamic range compression. In practice, a gain of around 12dB has been found ideal in terms of balancing all these system considerations.

In addition to the low-noise amplifier, TMAs include highly selective bandpass filters to provide protection against out-of band signals. Ideally, these eliminate potential receiver blocking issues, which can impact the detection of weak in-band receive signals. TMAs should also include an internal bias-tee, which removes the DC current from the input port to power the amplifier.

The physical design of TMAs is also crucial for both environmental and structural reasons. Visual impact and tower loading are ever-present issues, leading TMA designers to focus on compact and lightweight units that are easy on both the eye and the pocket from a site leasing point of view. The same drivers are also leading to an expanding range of multi-band and multi-functional TMAs that offer base station developers maximum flexibility.

For example, many carriers are using the same base station sites for 800 and 1900MHz services. One scenario would be to deploy a TMA on the 1900MHz uplink only, in an attempt to balance the coverage of the two services. Alternatively, if both cells are uplink limited, including a dual-band TMA would improve the coverage/capacity of both cells. Such advanced dual-band TMAs even feature integrated diplexers to permit a single TMA to support a system utilizing shared feeders.

Conclusion

There is little doubt that the escalating volume and speed of transmitted data in cell-based wireless communications networks is placing corresponding pressure on existing network infrastructure. Significantly, the cell breathing effect that is unique to CDMA services has caused the number of cells that are at least partially uplink limited to surge. Use of TMAs in CDMA networks should therefore not be discounted, as the advantages to be gained greatly outweigh the cost.

A TMA demonstrably improves BTS receiver sensitivity, by masking the impact of the RF receive path on the signal. This results in an abundance of benefits:

- improved coverage for a set number of users
- improved capacity for a set coverage
- improved performance through minimizing BER
- improved handset battery life.

These enhancements are especially noteworthy in networks that are purely uplink limited; however, the effects are still significant in networks that experience both uplink and downlink limitations, depending on cell-loading.