# Minimising WiMAX/LTE Network Costs with Digital Remote Radio Heads

By Steve Cooper, Axis Network Technology

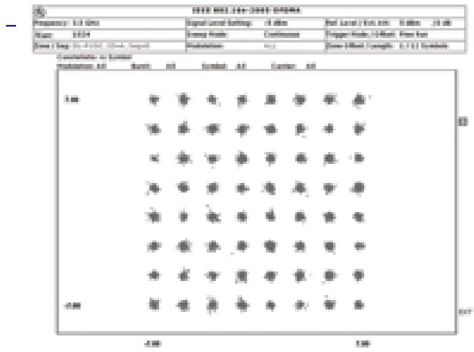
WiMAX has recently come of age with two significant network roll-outs being implemented (one in Moscow and another in Baltimore), and the announcement of the imminent availability of a number of WiMAX-equipped notebook PCs and handheld terminals. This provides the opportunity for this technology to make its mark as a mass-market wireless broadband standard, and operators are looking to rapidly realise their return on investment by keeping both capital and operating costs as low as possible.

Figure 1. The Axis RHH offers two paths of 14 W (QPSK) RF power in a 12 kg housing.

With traditional base station architecture, the radio power amplifier and other electronics are located in a cabinet at the base of the mast. Typically only 2% of the total DC power consumed is actually transmitted as useful RF power, mainly because the inefficiency of the power amplifier causes most of the power to be dissipated as heat. Large heatsinks, cabinets and air conditioning are needed to dissipate the heat energy. These items increase energy consumption even further as well as cause noise pollution.

In addition, 50% of the RF power is normally lost in the feeder cables that link the ground-mounted cabinet to the antennas. These cables are expensive, not to mention being difficult to transport and deploy because of their weight.

Installing a cabinet base station typically requires ground works, including a concrete base, shelter and a crane. This not only limits the operator's options on leasing sites, but also slows down network rollouts.



[1]

click to enlarge
Figure 2a. 64QAM constellation without DPD.

Using advanced digital radio techniques to improve efficiency has now enabled infrastructure systems, if light enough, to be deployed next to an antenna and reliable enough not to require onerous tower climbs for servicing.

Remote Radio Heads (RRH), such as those developed by Axis, use advanced DSP techniques to develop and supply smart, power-efficient wireless systems that can eliminate the high losses and waste incurred in normal RF cabling. These RRHs can result in significantly lower costs, both in upfront deployment expenditure and ongoing leasing or energy costs. With the new infrastructure needed for WiMAX and LTE (Long Term Evolution) network implementations, the possibility of utilising these signal processing techniques in order to reduce initial installation and running expenses seems certain to be an attractive option.

**Efficiency**

The latest telecommunications standards, including WiMAX and LTE, have a high peak-to-average power ratio (or crest factor). This means that the power amplifier has to operate well away (backed off) from its most efficient point in order to achieve the large range of dynamic linearity that it requires, making it less energy efficient than for older standards such as GSM.

Equipment and site preparation are major contributors to CAPEX costs, while major OPEX costs are site leasing, backhaul, and energy, all of which can be improved by the use of RRHs. Reducing power consumption is key to making RRHs successful in terms of size and reliability.

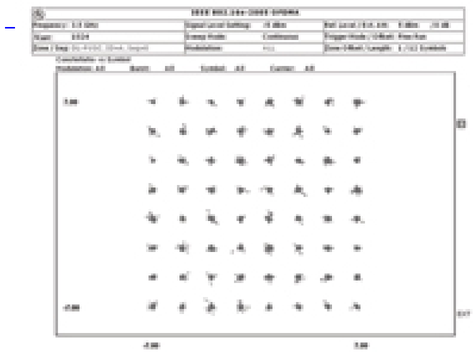


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Figure 2b. 64QAM constellation with DPD.

Axis has developed a 2-channel WiMAX RRH weighing only 12 kg. This small convection-cooled product is light enough to be mounted at the antenna, saving the cost of both the feeder cable and the air conditioning.

Leasing and installation costs are directly linked to the size, weight and complexity of a base station. Small, convection-cooled RRHs provide many more deployment options, and hence a reduction in leasing costs.

Naturally, the ten-fold increase in conversion efficiency causes a similarly significant reduction in electricity costs.

**Crest Factor Reduction**

High level DSP technology can be used to reduce the peaks of the OFDMA signal, which makes it possible to obtain significantly more RF power from the same power transistor, or to use smaller (and more cost-effective) transistors and still achieve the same output requirements. These techniques require close co-operation with baseband partners, but typically give strong performance metrics.

An unclipped LTE waveform typically has a 10 dB peak-to-average ratio. Thus, a 20 W LTE base station without a crest factor reduction (CFR) algorithm requires 200 W of peak power handling. Using one of these crest factor algorithms can reduce the peak requirement by half, saving significant cost and power per transmit path. CFR also significantly improves the power efficiency of the base station because the transistor's power consumption is also proportional to its peak power. It is typically possible to achieve 70% more average power from the same power transistor if clipping is used, while driving the amplifier 2 dB higher results in a power consumption increase of only 25%.

**Limitations of CFR**

There is, however, a cost for this improved efficiency. Clipping the peaks of a signal degrades its purity and increases the occurrence of bit errors, especially in areas of weak reception and for higher-level schemes such as 16 and 64QAM (used by LTE and WiMAX).

The tolerance of the system to any impurity is diminished compared to the QPSK scheme used for UMTS. This is because the relative distance between each point on the constellation diagram is reduced. Impurities in the signal will cause the detection points to merge together, creating bit errors.

Currently algorithms are only providing 8 dB of peak-to-average ratio levels while meeting the tight error vector magnitude (EVM) requirements for 64QAM signals. In order to improve the efficiency of systems using higher-level modulation schemes, additional techniques are required.

**Digital Pre-Distortion**

Another important parameter affecting the power transistor choice is the adjacent channel power ratio (ACPR). Linearization allows the operation of the amplifier even further into its highest efficiency area, the newest technique being digital pre-distortion (DPD).

Pre-distorters have been demonstrated that have almost perfect performance, removing all non-linearity and minimising the adjacent channel power down to the noise floor of the system. Using the latest DSP techniques to implement pre-distortion allows the power amplifier designer to implement a custom algorithm tailored to the specific amplifier being pre-distorted. This is advantageous for compact integrated products, as the transceiver, algorithm and amplifier are permanently integrated together in one field-upgradeable unit.

By optimising the design of the power amplifier and focusing the pre-distortion algorithm around the specific parameters of the amplifier, Axis has developed very code-efficient, custom DPD algorithms that also have a significantly positive effect on the signal EVM. Tests show this DPD can provide a typical improvement from a poor -24 dBc to a spec compliant -32 dBc. It is also possible to use the DPD to meet the new multi-carrier GSM spectral requirements.

**Doherty Efficiency Improvement**

Among the additional techniques used for improving efficiency in the analogue/RF domain, the Doherty technique uses two output stage transistors biased at different points (one of the transistors is on all the time; the second only turns on as the signal approaches its peak). This reduces current consumption as the transistors are not constantly turned on, and when they are on, they are operating in their more efficient regions.

It is important to note that Doherty works at its best for signals with 6 dB of peak-to-average. Axis has demonstrated efficiencies of greater than 40% for signals with a 6 dB peak-to-average ratio. Efficiencies for signals such as 64 QAM are lower, but still significant.

**Conclusion**

A base station with the enhancements outlined in this article can benefit from as much as a ten-fold increase in conversion efficiency. The cumulative affect of CFR and DPD techniques, and the reduction of cable losses by locating the radio adjacent to the antenna, allows operators to see approximately a 60% reduction in their energy bills for running base stations. These same techniques are equally applicable to all higher order modulation schemes, meaning the RRHs are effectively future proof for use in LTE networks.

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