



Efficient Mobile WiMAX Deployments: Tower-Top Electronics

SOMA Networks' FlexMAX™ Mobile WiMAX System is the industry's best solution for cost efficient, highly effective and profitable multi-service broadband networks. Through support for the Mobile WiMAX (802.16e-2005) standard, and SOMA's tradition of leading edge technologies, capabilities such as tower-top electronics must be thoroughly evaluated. These enhanced Mobile WiMAX features are necessary for the highest quality service and best subscriber experience, with minimal initial investment and low ongoing operational costs.

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White Paper

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Introduction

When deploying a wireless network, the choice of the base station architecture can make or break a service provider's business case. The base station sets the stage for many key business model parameters:

- *The size of the cell.* Bigger cells require fewer base stations to cover a given area. Fewer base stations mean lower capital for equipment, lower cell site acquisition costs, and lower operating costs. The cell size is set, for the most part, by the link budget, which is in turn set by the base station architecture.
- *Access to antenna towers.* Access to existing antenna towers (or the permission to build new towers) is a key requirement for deploying a wireless network. Base station architectures that impose a heavy load on the tower have fewer opportunities to access existing towers or will require a more expensive tower installation on new sites.
- *Support for new multiple antenna wireless technologies.* Multiple antenna processing is the fastest growing new technology in the wireless industry. This technology requires multiple antennas to be deployed on the cell site tower. The base station architecture should enable the support of this technology without unduly affecting the previous two parameters.

Of all the base station designs on the market, only designs based upon architectures supporting tower-top electronics make a strong business case: they are inherently the best for minimizing the equipment, deployment, and operational costs of a wireless network.

Base Station Architectures

While there are many base station designs on the market, they can all be grouped under two categories: those with radio subsystems located within the enclosure on the ground, and those the radio subsystems located on the tower near the antennas. We'll call the former Tower-Base Radio (TBR) base stations and the latter Tower-Top Radio (TTR) base stations.

Both categories of architectures share the same major subsystems:

- A radio subsystem containing the radio transceivers (receivers and transmitters) and associated radio digital signal processing (A/D and D/A converters, digital filters, etc.).
- A wireless modem subsystem that processes the signals to (transmitter function) and from (receiver function) the radio subsystem according to the supported wireless standard (i.e. IS95, 3GPP, WiMAX, etc).
- A base station controller that manages the system and provides an interface to the backhaul medium.
- An antenna system that connects to the radio subsystem.

There may be other parts such as power supplies, batteries, timing clocks or routers depending upon the supported standard and the product design. For the purpose of this paper, however, we'll consider a base station to have two major subsystems: the radio subsystem as mentioned above, and everything else which we'll call the

common equipment. With these descriptions we can now contrast the two base station architectures mentioned earlier.

Tower-Based Radio (TBR) Base Stations

TBR base stations, the typical architecture of cellular base stations today, co-locate the radio subsystem and the common equipment in the same housing at or near the base of the antenna tower. The housing is either an on-site hut or a base station specific environmental enclosure. The radio subsystem is connected to the tower-mounted antennas via coaxial cable.

These systems typically also use a small tower-top box containing a Low Noise Amplifier (LNA) to improve the receiver performance. One coaxial cable is used for each antenna on the tower.

Tower-Top Radio (TTR) Base Stations

TTR base stations locate the radio subsystem at the top of the tower near the antennas. The common equipment is located on the ground, either near the tower or at a remote location. The antennas are often integrated with the TTR or directly mount onto the TTR. The TTR is connected to the common equipment via a small diameter cable that contains glass or plastic fibers for transporting digital signals and a pair of copper wires to supply power. A single cable can support multiple antennas at the tower top as all the signals are multiplexed onto the high bandwidth optical fiber.

Key Differences between TBR and TTR Base Stations

The key product differences between the two architectures are:

- TBR base stations must be located very close to the antenna tower in order to minimize signal loss due to coaxial cable length. TTR base station can locate the common equipment remotely from the antenna tower, as fiber optic interconnect can support very long cable runs (i.e. several kilometers).
- TTR base stations have far greater flexibility in the choice of indoor equipment locations. For example, the TTR can be on the roof of a building while the common equipment is located in the basement. This scenario is not supported by TBR base stations.
- The TTR base station does not require an additional tower-top LNA. The LNA is already located at the tower top in the TTR.
- Only one small diameter cable is installed on the tower with TTR base stations independent of the number of antennas supported. On the other hand, TBR base stations require a large diameter coaxial cable for each antenna.

The architectural differences of these two deployment methods have a direct impact on the three most important attributes of wireless systems: link budget, antenna tower loading, and suitability for supporting multiple antenna processing. Each of these attributes is discussed in the following sections.

Link Budget Comparison

The amount of downlink transmit power that reaches the antenna is a major consideration when deploying broadband wireless networks. More power translates into an increased range and/or higher throughput. Increasing the range of a base station increases its coverage area, which means fewer base stations are needed to cover a given area. This alternative not only decreases the capital outlay in equipment, it also reduces the number of sites that need to be acquired, managed, and maintained. These improvements in savings ripple throughout the entire business case.

Base station designs with TTRs have a definite link budget advantage over designs with TBRs. TTRs do not require long RF coaxial cables to connect to the antennas. TBRs on the other hand, need lengthy RF cables to connect the tower top antennas to the radios located on the ground. All RF cables have loss, and the longer the cable, the higher the loss. All the power lost in the cables that connect TBRs to the antennas directly reduces the power available at the antenna, ultimately reducing the coverage area of a given base station.

It is not just the length of the cable that contributes to the power loss; there are other TBR installation-related losses. Given that TBR base stations typically have a long cable run to the antenna, installations often use a series of cable types to complete the link. To keep the losses to a minimum, the majority of the cable run uses a large diameter coaxial cable that has a lower loss per meter of run length. Typical cable diameters are in the order of 7/8" to 1-1/4". These thick cables are quite rigid and difficult to bend and are unsuitable for direct connection to either the antenna or the base station equipment. Instead, the cable is installed with the ends terminated a few meters from the TBR and antenna by connectors. A smaller diameter, flexible, higher loss cable connects the large cable to the antenna and the TBR. These cables, called "jumpers," have a typically loss of 0.25 to 0.5 dB, depending upon the length, and add to the loss of the large cable.

In addition to this simple TBR deployment scenario, many TBR systems have the added complexity of a tower-mounted LNA to improve the uplink link budget. These devices have no gain in the downlink direction and actually add some loss. The typical insertion loss of a tower-top LNA is about 0.5 dB. But the extra loss does not stop there. An additional jumper cable would be required to connect the LNA into the system. There is one jumper from the thick main antenna cable to the LNA, and one from the LNA to the antenna.

A typical TBR base station deployment cable loss budget is shown in the following table.

Tower-Base Radio (TBR) Base Station Feeder Cable Loss Budget 50 Meter Cable Run Illustration		
	Purpose	Loss
TBR Jumper	Connect TBR to main antenna cable	0.5 dB
Main Antenna Cable	Low loss cable for the majority of the cable run	3 dB per 50 meters for 7/8" cable
LNA Jumper	Connects main antenna cable to the LNA	0.25 dB
LNA	Improve the uplink link budget	0.5 dB
Antenna Jumper	Connect LNA to antenna	0.25 dB
Total Loss		4.5 dB

A 50 meter cable will cover a 40 meter antenna tower. The remaining 10 meters are used to run from the tower base to the base station equipment hut. TTRs have none of these losses.

A typical TBR deployment will reduce the power available at the antenna by 4.5 dB compared to TTR deployment. That's about 1/3rd of the TBR power actually reaching the antenna. The other 2/3rds of the power is dissipated as heat in the cable.

The reduced power has a large impact on the coverage of the TBR base station compared to the TTR base station. The coverage area of the TBR base station is 40% to 50% less than the coverage area of the TTR base station. In other words, when compared to TTRs, twice as many TBR base stations would be needed to have equivalent coverage. Twice the number of base stations also means twice the equipment cost, twice the number of sites to acquire, and twice the build-out costs.

Tower-Loading Comparison

Tower-loading is an accounting of the total weight of the equipment deployed on the tower, including antennas, cables, and tower-mounted electronics. One of the primary objectives of base station design is to minimize the amount of load on the tower. This section compares the tower loading of two architectures, using a typical deployment scenario to illustrate the differences.

TBR Base Station Tower Loads

A single sector of a TBR base station contains the following tower-mounted equipment:

- Two antennas (one for main, one for diversity). These are typically 16 dB gain 90° beamwidth antennas.
- Two TT-LNAs (one for each antenna). The amplifier improves the receiver noise figure to help with the uplink link budget.
- Two low-loss main feeder cables (one for each antenna). Large diameter coaxial cables are used to minimize the loss. These are bulky, heavy, and difficult to deploy.
- Jumper cables to complete the interconnections. A total of four jumpers are required, two for each antenna. One jumper connects the main feeder cable to the TT-LNA. The second jumper connects the tower top LNA to the antenna.

The following table summarizes these items and accounts for their load on the tower. The total tower weight per sector is about 64 kg for the TBR base station.

Tower Base Radio (TBR) Base Station Tower Loads				
	Purpose	Weight	Quantity	Tower Load
Antenna	Radiating element, 16 dB gain	6 kg	2	12 kg
LNA	Low noise amplifier	5 kg	2	10 kg
Main coaxial cable	Low loss feeder cable, 7/8", 0.5 kg/m, 40 m on tower	20 kg	2	40 kg
Jumpers	Connect to LNA to antenna and main feeder cable	0.5 kg	4	2 kg
Total				64 kg

TTR Base Station Tower Loads

The single sector TTR base station contains the following tower mounted equipment:

- Two antennas (one for main, one for diversity). These are the same type of antennas as used for TBRs, but they are integrated with the TTR.
- One tower top radio subsystem. The single package of tower top electronics contains the radios for both antennas.
- Combined fiber optic and DC power cable. The single cable carries power, two channels of Tx signals, and two channels of Rx signals to/from the TTR. This is a light weight small diameter integrated cable that is about the size of typical household electrical cable.

The following table summarizes these items and accounts for their load on the tower. The total tower weight is 33 kg, which is just over ½ of the tower loading of the TBR base station.

Tower –Top Radio (TTR) Base Station Tower Loads				
	Purpose	Weight	Quantity	Tower Load
Antenna	Radiating element, 16 dB gain	6 kg	2	12 kg
Tower Top Electronics	Complete radio subsystem on tower containing two radios	15 kg	1	15 kg
Feeder cable	Combined fiber optic and DC power cable, 0.15 kg/m, 40 m on tower	6 kg	1	6 kg
Total				33 kg

TTRs substantially reduce the tower loading over TBRs. In addition, TTR deployments do not require the installation of bulky, difficult to install large diameter coaxial cables. It is substantially easier to pull a small diameter flexible 6 kg cable up a 40 meter tower than it is to pull the semi-rigid 20 kg coaxial cable.

Multiple Antenna Support

The biggest technology change in wireless today is the use of multiple antenna processing at the base station. Multiple antenna processing dramatically improves the coverage and capacity of wireless deployments. These improvements are achieved by adding more antennas to the base station and implementing advanced signal processing algorithms in the wireless modem.

While improvements in capacity and coverage continue to increase as one adds more antennas, most implementations envision four antenna elements per sector at the base station. This is double the number of antenna elements conventionally deployed in wireless systems.

The impact on the link budget, and hence coverage, is clear. With beam-forming algorithms implemented in the modem, the downlink link budget improves by 9 dB with the addition of two more antennas. That's equivalent to almost a doubling of the cell radius, or a quadrupling of the cell coverage area. So, with only modest increases in equipment cost, the number of cell sites can be reduced by a factor of four.

The tower-loading cost of adding more antennas depends upon the base station architecture. The loading cost for TBR base stations is far greater than it is for TTR base stations, as shown in the following table.

Tower Loading Comparison				
Tower Base Radio (TBR) Base Stations				
	Purpose	Weight	Quantity	Tower Load
Antenna	Radiating element, 16 dB gain	6 kg	2	12 kg
LNA	Low noise amplifier	5 kg	4	20 kg
Main coaxial cable	Low loss feeder cable, 7/8", 0.5 kg/m, 40 m on tower	20 kg	4	80 kg
Jumpers	Connect LNA to antenna and main feeder cable	0.5 kg	8	4 kg
Total Weight				116 kg
Tower –Top Radio (TTR) Base Stations				
	Purpose	Weight	Quantity	Tower Load
Antenna	Radiating Element, 16 dB gain, cross polarized	6 kg	2	12 kg
Tower Top Electronics	Complete Radio subsystem on tower containing four radios	25 kg	1	25 kg
Feeder cable	Combined fiber optic and DC power cable, 0.15 kg/m, 40 m on tower	6 kg	1	6 kg
Total Weight				43 kg

The tower loading increase is dramatic for TBR architectures. The load has almost doubled with the addition of two antennas. The load increase for TTR architectures is far more modest. The only element that increases in weight is the tower-top electronics to accommodate the two extra radio transceivers for the two additional antennas.

For both TBR and TTR base stations, we've added no weight to the antennas by using cross polarized antennas. A single cross polarized antenna package contains two antenna elements. Thus, four antenna elements can be deployed on the tower by deploying just two antenna packages. Cross polarized antennas are readily

available in the antenna market today and are a natural choice for multiple antenna processing systems.

Multiple antenna processing base stations provide a significant and clear coverage advantage. The number of base stations required in a deployment can be reduced by a factor of four with only a modest increase in cost. In addition, base stations that employ multiple antenna processing must use the TTR architecture in order to realize practical and feasible tower loading, making them the suitable choice for cost effective and efficient network deployments.

Conclusion

The TTR base station architecture is the clear choice for advanced wireless systems. It offers the following advantages over the TBR architecture:

- Improved link budget due to the removal of antenna feeder cables, resulting in a reduction in the number of cell sites and equipment.
- Reduced tower loading. The tower loading is reduced by a factor of two in traditional two antenna deployments.
- The best architecture for multiple antenna systems as it can reduce the number of base stations required by up to a factor of 4 without adding significant infrastructure weight to the tower.

These base station attributes are key for minimizing the equipment, deployment, and operational cost of a wireless network. In short, the TTR base station makes for the best business case.

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