Fiber Enables Wireless to Move 'A Head'

Typically, if a wireless carrier wants to install equipment that exceeds a tower's load capacity, the carrier must pay to upgrade the tower. The use of remote radio heads may avoid the need for the upgrade.

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Economically, 2009 has been a rather dreary year. News outlets regularly highlighted the number of jobs lost in the previous month or week. By the second half of the year, this could hardly be considered news. The only thing new about it seemed to be how rapidly the numbers grew. Everywhere you looked, there were 1,000 jobs eliminated, 10 percent workforce reductions, lowered quarterly estimates, further declines in sales, and so forth. There was, and still is, one bright, shining light among all this doom and gloom: the wireless industry.

Earlier this year, AT&T announced it was going to create 3,000 new jobs and spend nearly $18 billion, largely within the wireless portion of its business. Verizon Wireless is busy preparing its network for the commercial LTE launch next year, with the consumer launch following in 2011. Clearwire launched its "Clear" WiMAX service in 14 markets this year, covering more than 10 million potential subscribers. Furthermore, the portion of the federal economic stimulus package devoted to broadband is going to provide nearly $4.5 billion for broadband coverage to underserved and unserved areas over the next three years, and wireless technology is expected to play a large role in those rollouts. In addition to all of this activity in the wireless market space, needed changes are forthcoming that will create even more growth opportunities. Suffice it to say that despite the economy, it's a great time to be part of the wireless industry.

The most exciting change in the wireless industry is the evolution of RF equipment at the cell site. Remote radio heads (RRHs), also called remote radio units, essentially relocate RF equipment from the base of the tower to the top. RRHs have been and are still being widely deployed in Asia, the Pacific region, Europe and Canada. Let's focus on three of the benefits of using RRH technology and how to prepare for this paradigm shift.

Cellular antenna connection

The first aspect focuses mostly on wireless operators and illustrates how RRHs will reduce their operating expenses. Cellular antennas have traditionally been connected to base transceiver stations (BTSs) via long lengths of coaxial cable, normally 1-5/8 inches or 1-7/8 inches in diameter. A typical three-sector cell site would require a minimum of nine of these coaxial cables running the entire vertical span. Ever wonder why such fat coaxial cable is required for a cell site when you can watch 200+ channels plus high-definition television over the thin coaxial cable in your home? Well yes, the technology is a bit different, but it is largely about signal strength. Depending on the carrier frequency (1850 MHz to 1990 MHz for the FCC-licensed Personal Communications Service [PCS] in the United States), as much as 3 decibels (50 percent) of signal strength is lost — absorbed by the transmission feed line — as it travels up the tower before it reaches the antenna. That means the RF gear at the base has to produce nearly twice as much output signal power to deliver the specified power at the antenna. To make matters a little worse, legacy radio-frequency power amplifiers have typically been horribly inefficient. In fact, 11 percent efficiency was considered to be quite good only a few years ago. Amplifiers in today's RRHs are as much as 40 percent efficient. That means less energy is wasted creating the actual RF signal in the first place. And if you can relocate the radio head from the base of the tower to the top of the tower, then you eliminate the high loss associated with that long piece of coaxial cable.

Power efficiency

As an electrical engineering student, I remember my undergraduate circuit analysis professor profoundly

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exclaiming to the class that everything that uses or passes electricity is, in some way, a toaster. Quite simply what he meant was that without a super-conductor, the act of passing electrons generates some amount of heat. It follows that all electronic devices are, to some degree, toasters. Efficiency describes how much of that circuit "makes toast" and how much actually does just what we want it to do. If we can improve the efficiency of an electrical circuit (or anything else, for that matter) then we lose less energy to heat. Furthermore, electronic equipment has an acceptable operating temperature range, and cellular radios are no exception. It has been reported that as much as 30 percent of the electricity consumed at a typical cell site is used solely for keeping the electronics within their specified temperature range. Care to guess what generates the most heat at a cell site? Yep, that 11-percent-efficient legacy radio head. Modern RRHs have no cooling fans; they are passively cooled. In all, they require less energy to generate the desired output power because of their improved efficiency, *and* less electricity is needed to cool them — a double-whammy of energy savings. Basically, they are more radio head and less toaster. Backup power as a necessary component of cellular architecture received ample attention in the aftermath of Hurricane Katrina, and you can bet the FCC will re-address this concern in the near future. A more efficient cell site leads to more-practical and less-expensive backup power facilities.

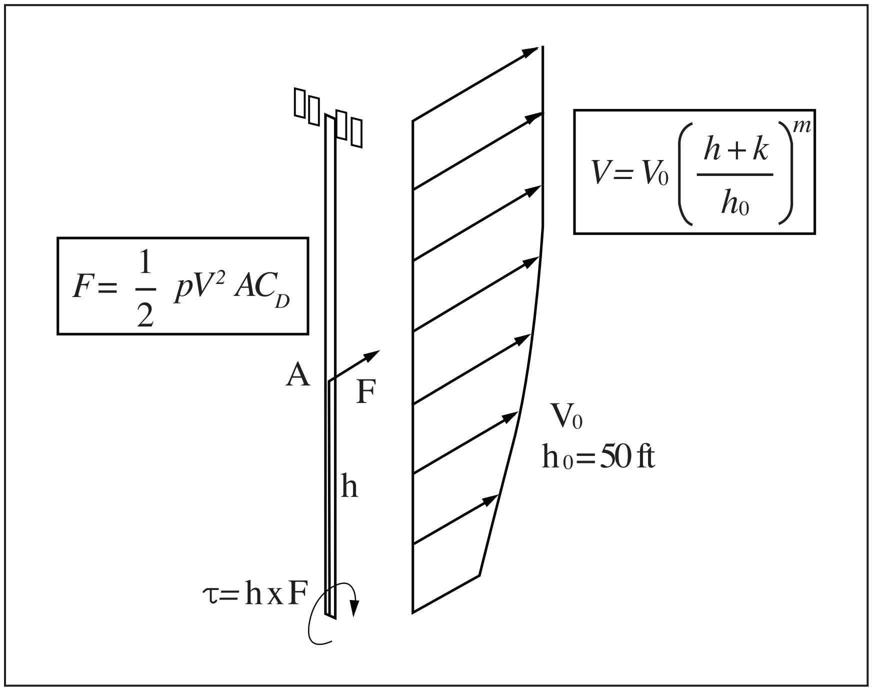


Figure 1. This model shows how the forces were applied to a tower with a surface wind velocity. To make the model more accurate, we increased wind velocity at altitude by a value decreasing exponentially over the model height. This effect resembles how actual wind velocities relate in the field. Most of the United States falls within an area that experiences 90 mph as the maximum wind at a 50-foot elevation above ground level. This is the base wind velocity we used. Finally, we removed all tower structure from the model because it is present regardless of which solution is installed. This model applies most accurately to self-supporting and guyed structures.

Overcrowding

Another issue RRH technology can help address is overcrowded space within the cellular compound. I visited a monopole site in Charlotte, N.C., where the compound was recently expanded to accommodate another wireless operator, bringing the total to six. This tower is in a metropolitan area, directly adjacent to an office building. The only way to expand the compound was to creep into the parking lot of the office building. Through the use of RRHs, this sixth operator could have instead placed their BTS at another geographic location several kilometers away. This concept is called base station hotelling and is already commonplace in indoor and outdoor distributed antenna systems (DAS). Because the radio head is mounted at the tower top and connected to the BTS via optical fiber, there is no need for the base station to be anywhere near the actual tower. Maximum distances between BTS and RRHs being discussed are nine to 40 km, and two key factors determine this distance. They are *optical attenuation* and *circuit latency*. Attenuation can be mitigated somewhat by using single-mode fiber throughout the system, more powerful optics and low-loss optical interconnects. Latency is simply a factor of distance and "hops." Because backhaul is evolving from time-division multiplexed circuits to Internet protocol packet-based circuits, level II switching equipment helps to mitigate latency.

We've already discussed the environmental requirements of cellular equipment, and how RRHs can reduce those demands. Further efficiency can be obtained by using a single cooling unit for multiple sets of equipment in a setting such as a data center. Collocating equipment also reduces maintenance expenses because technicians spend less time traveling among sites for routine maintenance and spend more time servicing equipment. The only serviceable equipment at the cell site with RRHs is a box about 17 inches by 14 inches that weighs less than 50 pounds. Because RRHs have no moving parts and are passively cooled, they have several hundred thousand hours of mean time between failures.

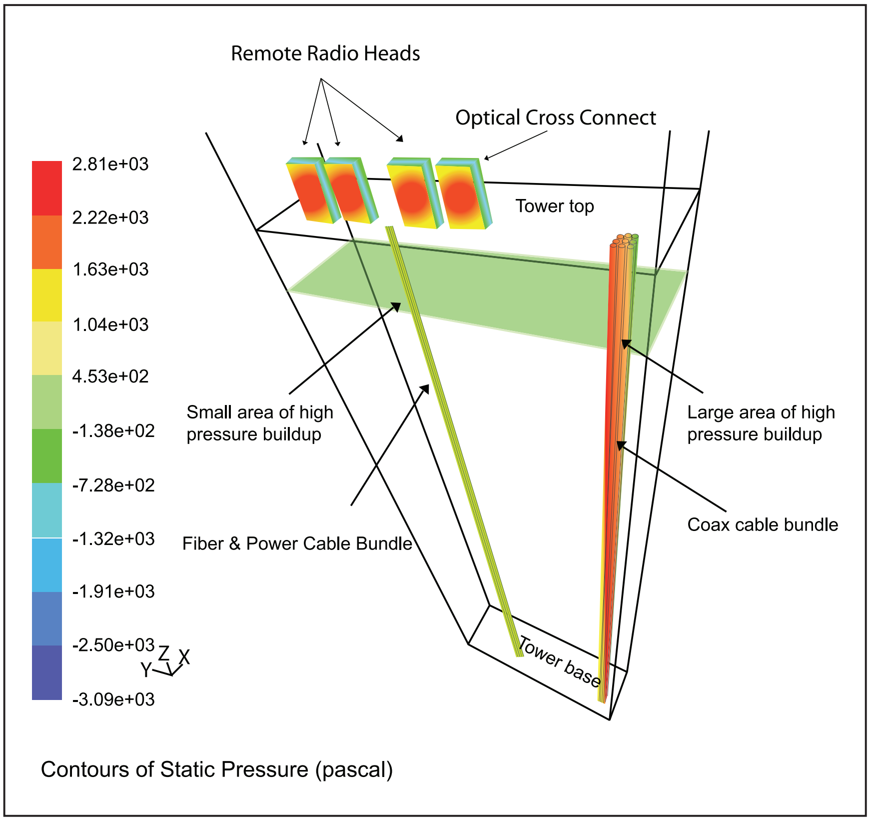


Figure 2. A pressure contour comparison shows the two solutions side by side, and the coloration shows the amount of force. Although the radios heads and fiber-optic interconnect housing have the highest force because of the wind, the force is localized only at the top of the tower. The coaxial cable, on the other hand, spreads a somewhat lower force over the entire height of the tower.

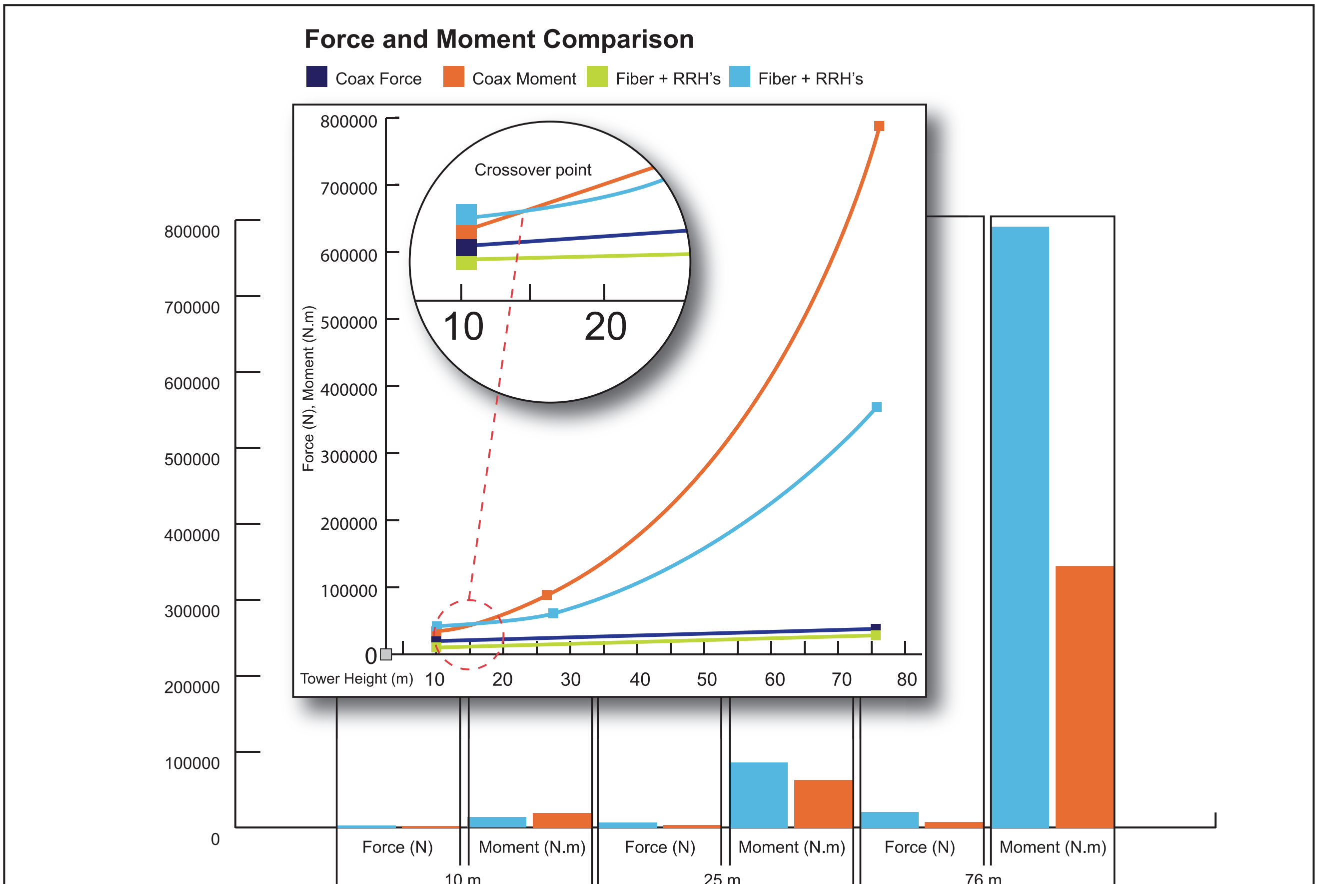
The aspect of RRH technology that most concerns tower owners and operators, however, is the reduced wind load the radio head equipment places on a cell tower compared with traditional coaxial cables. For the most part, cell sites are either rooftop or tower mounted. Among towers, the three dominant types are monopoles, self-supporting towers and guyed towers, with the majority of cell towers being monopoles. Monopoles are usually designed to contain all vertical cable runs inside the pole itself, so the only wind load placed on the structure would derive from antennas and possibly from tower-mounted amplifiers at the top. All too often, though, monopoles are retrofitted with several runs of coaxial cable strapped to the outside as antennas for incremental wireless operators are added after the pole has become overcrowded. For self-supporting and guyed towers, every device added to the structure increases the wind load, including the cables themselves. The key to avoiding excessive wind loading is to identify which cable breaks the proverbial camel's back before it is ever placed on the tower.

Most wireless telecommunications towers were originally designed and constructed to serve two wireless network operators. The wireless industry has changed tremendously since many of the towers were built, and the number of operators has grown. It's not uncommon now to see antennas for as many as eight wireless operators on a single structure. All that equipment can be rather heavy, but more importantly, all those antennas and the cables that feed them act as wind sails on the tower. The wind force generated applies a tremendous amount of torque (technically, a *moment*) at the tower base, and it has been known to eventually lead to structural failure. Commonly, the incremental wireless network operator whose gear would tip the scale is made responsible for upgrading the tower and for 100 percent of the expense involved. Obviously, an operator placed in this position would not be pleased about it, but it beats the next-best alternative.

RRH technology presents a third option for wireless operators wanting to lease space on a tower that is near its maximum wind load. By the way, the wind loads involved are by no means trivial. In fact, they are rather dramatic. In order to show a conservative comparison between traditional coaxial-fed antennas and RRH installation, we built a computer model comparing a best-case coaxial cable installation with a worst-case RRH installation fed by optical fiber and independent electrical power cables.

Making the model accurate

Keep in mind that the items with the greatest effect on moment at the tower base are those closest to the top of the tower. For the coaxial cable portion of the model, we used nine 1-5/8-inch cables installed in a three-by-three matrix, with a half-inch between each cable. These cables run the entire vertical span of the tower. For the RRH, we used a 0.5-inch optical cable and three 0.5-inch power cables for the vertical span, and then placed three radio heads and one optical interconnect housing at the top of the tower. For the model, we assume a continuous worst-case scenario for the radio heads by having all of them facing full into the wind. In reality, the coaxial cables are likely to be installed in a row, not a matrix, and the fiber and power cables would most likely be smaller than those used for this model. In those more realistic cases, the disparity would only be greater than the case modeled. Figure 1 shows how the forces were applied with a surface wind velocity. To make



	10 m Force (N)	10 m Moment (N.m)	25 m Force (N)	25 m Moment (N.m)	76 m Force (N)	76 m Moment (N.m)
Coax	2765	13741	6920	86062	20946	791862
Fiber + Box	2308	19357	3510	62859	7590	344960

Figure 3. The disparity between towers fitted with traditional coax and antennas and with remote radio heads is not linear. In fact, for structures 40 feet and under, the coaxial cable solution came out ahead. Similarly, operators with antennas at the highest elevation benefit the most from using RRHs. This is a worst-case comparison, and the more realistic break-even point would be much closer to the ground if the coax were installed in a row and lower still if tower-mounted amplifiers were used.

the model more accurate, we increased wind velocity at altitude by a value decreasing exponentially over the model height. (This is actually very close to how actual wind velocities relate in true life.) Most of the United States falls within areas that experience 90 miles per hour as the maximum wind at a 50-foot elevation above ground level. This is the base wind velocity we used. Finally, we removed all tower structure from the model, as it is present regardless of which solution is installed. (Obviously, this model applies most accurately to self-supporting and guyed structures.)

For a tower 200 feet in height, the results show that for coaxial cable, the total force on the tower is about 2,689 pounds, and the total moment at the base is 321,866 foot-pounds of torque. I was shocked at how great these forces came out to be. The total force is a bit greater than a ton, and that's a great amount, but the torque figure really blew me away. For the radio head solution, the total force was 1,626 pounds, and the total moment at the base is 262,587 foot-pounds of torque. Keeping in mind that this model is designed to show a worst-case wind load difference, it still shows a 20 percent reduction in torque. That is a fairly impressive reduction in moment force and could extend the service life of many towers. Figure 2 shows the two solutions side by side, and the coloration shows the amount of force. Although it is true that the radio heads and fiber-optic interconnect housing have the highest force attributable to wind, the force is localized only at the top of the tower. The coaxial cable, on the other hand, spreads a somewhat lower force over the entire height of the tower.

What is really impressive is that the disparity is not linear. In fact, for structures up to 40 feet tall, the coaxial cable solution came out ahead, as shown in Figure 3. Similarly, operators with antennas at the highest elevation benefit the most from using RRHs. Again, keep in mind this is a worst-case comparison, and the more realistic break-even point would be much closer to the ground if the coaxial cables were installed in a row and even lower still if tower-mounted amplifiers were used.

It's clear that you should become familiar with RRH technology as wireless operators continue to roll out their 3G networks and especially as they begin to deploy LTE in earnest.

What type of optical cable will need to be installed on the tower to connect RRHs? Several types exist, and Telcordia GR-20 is the commonly accepted industry standard for outdoor-rated optical cable. Any cable selected should meet or exceed this guideline. Additionally, the unique environment of a tower structure will help determine precisely which cable type is best suited for this application. Even then, there are flat cables, round cables, tactical cables, self-supporting cables, indoor/outdoor cables and so on. The choices can become confusing.

Preconnectorized cable

To keep things simple, it is advisable to also use preconnectorized cable assemblies rather than attempt to install optical connectors in the field. This ensures the best possible performance, and for operators with plans to eventually implement base station hotels, this is one of the most important factors to consider. Preconnectorized cable assemblies are also more robust and provide enhanced longevity in the field. Any connectors exposed to the elements should meet or exceed Telcordia GR-3120 and, at a minimum, IP-67 ratings.

A typical operator will deploy three or even six RRHs on its tier. One option is to install a single cable from the base of the tower to each individual radio head. This is the simplest arrangement, but it is probably also the most costly because of the large amount of time and labor required to install and fasten the individual cables to the tower structure. Furthermore, in the event a cable is damaged for whatever reason, replacement cost is rather high because the entire length will need to be replaced. This solution places a moderate wind load on the tower, certainly lower than coaxial cable, but it can be improved upon.

Single, high-count cable

The most flexible solution is to place a single, high-count cable vertically on the tower, and terminate that cable into an outdoor-rated optical cross-connect box. Then, to connect each radio, a short cable assembly is installed from the cross-connect box over to the radio head. Because radio head manufacturers use different connector types, this solution allows the operator to connect to virtually any variety of outdoor connectors via a short hybrid assembly, using the custom connector on the RRH end and an industry standard connector on the other. In the event radio heads are later exchanged or upgraded to some other type of connector, only the hybrid cable assembly would need to be replaced. This solution places the highest wind load (for optical solutions) on the tower because the cross-connect housing would reside at the top of the tower where it has the greatest effect on total moment. Some of this load can be mitigated by creative placement of the housing. Mounting it tight against the tower or horizontally would reduce the surface area directly exposed to the wind. Obviously, the smaller the cross-connect housing, the lower the resulting wind load.

A best-of-both-worlds solution would marry the small surface area of the first solution with the flexibility of the second. Recent advancements in hardened connector technology do just that. It is now possible to install six multi-fiber hardened connectors in a single housing only slightly wider than 1-7/8-inch coax and about 9 inches in length. This product presents a very small cross-sectional area, and all flexibility is retained through the use of hybrid cable assemblies at the top of the tower. This type of system has historically only been available with single-fiber connectors, but recent advancements enable up to 12 fibers per port. The small size and light weight simplify installation and provide flexibility for moves, adds and changes in the future. Another recent improvement in optical fiber design allows optical cable to be installed using methods previously incompatible with fiber optics. Cables constructed with newer bend-insensitive fibers allow installers to more securely fasten cable to supporting structures and to use cable pathways designed specifically for copper cables, such as those using l-boxes instead of sweeping bends.

Reduced power consumption benefit

Wireless has become a second wind for telcos as their wireline business slowly declines. As the remainder of 3G systems are built and as 4G LTE and WiMAX systems are rolled out, significant changes must be made to the way cellular networks are built. The benefits of reduced power consumption because of higher efficiency and reduced cooling requirements alone are enough to warrant careful consideration. Add to that the benefits of base station hotelling, and it becomes clear that RRHs will become the standard means of implementation over the next few years. For tower climbers and tower operators, that means a new way of doing business as well. More fiber is going to be deployed vertically on cell towers to help reduce overall wind load and extend the life of tower structures, especially self-supporting and guyed towers.

Fiber-optic cables will be used to connect these RRHs, and we have discussed several solutions. Become familiar with the options available to help reduce capex and opex associated with 4G systems, including preconnectorized cable assemblies and bend-insensitive fiber. agl

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