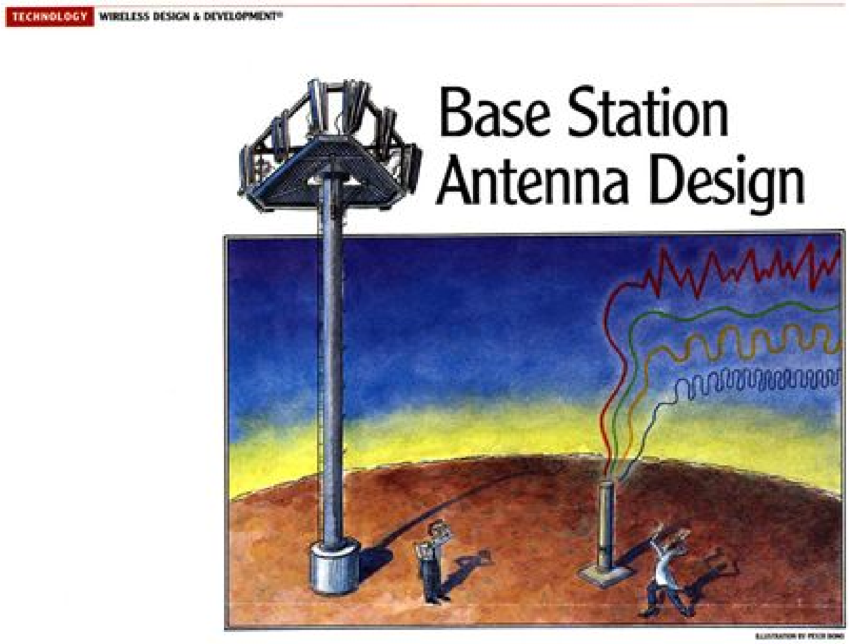
The specification of antennas for PCS requires attention to more than the familiar parameters of gain, VSWR and azimuth beamwidth

Brian Collins



Anyone opening a typical 800/900 MHz cellular antenna catalog will see antenna design and construction methods have remained basically unchanged since the end of World War II — antenna arrays constructed from lengths of coaxial cable and antenna elements made of aluminum or brass, screwed and soldered together. The antennas are complex, so their reliability and lifetime are poor; VSWR, radiation patterns and intermodulation performance are variable from sample to sample.

This article describes CSA's approach to base station antenna design, and highlights the proven advantages available from the adoption of new design methods and materials.

The Challenge of the New Frequency Bands

There is a major challenge to the antenna maker in moving from 800MHz to modern all-digital systems at 1800/1900 MHz.

• Path losses are higher, so greater antenna gains are needed if the same cell radius is to be maintained

• Antenna elements are smaller and at the same time tighter electrical and mechanical tolerances must be maintained in production

• PCS-1900 systems operate with low C/I ratios, so antenna pattern and gain performance are critical to network operation

• CDMA systems are noise limited on the return link, so high antenna gain and low receive system noise temperature is essential in range-limited cells

• The new networks are more complex and require higher equipment reliability, or maintenance costs will spiral out of control

• PCS-l900 networks depend on the application of intensive frequency reuse; this requires precise control of antenna elevation patterns

• Extensive multiplexing of transmitters and receivers demands very low thru-life levels of passive IMPs generated in antennas and cables

• New dense networks will face ever-increasing zoning problems, while small cell sizes make it vital that cells can be located where the network designer needs them.

The New Networks

The first DCS1800 networks to be launched were in the UK where two national operators are licensed and have now acquired a total of 400,000 subscribers. A German national network (E-Plus) is rolling out extremely rapidly, followed by a nation-wide French network (ByTel).

Following the FCC spectrum auctions, a large number of US networks are preparing to roll out using PCS1900 or CDMA technology. These networks have the advantage that they will be able to benefit from the learning curve of European network operators (most of which have US partners) and their international vendors. The new US networks are set to roll out very aggressively—manufacturers of all network components will be expected to deliver high-spec, reliable products, in large volumes, on time.

Antennas: A Vital Link in the Chain

Seen by most network designers as a necessary evil, antennas are a vital link in the network. Operators invest heavily in each base station, and it is the antennas which determine the area served and the signal quality available to the mobiles. As one of the few outdoor components of a base station, their reliability is constantly tested by exposure to the environment.

Most traffic is currently carried by tri-sector base stations. Omnidirectional antennas are used for some rural locations and urban fill-in, but they do not form a major component of any current 1800/1900 MHz network. Base stations with more than 3 sectors will appear at a later stage of network growth, especially in CDMA systems.

The typical antenna complement for a BTS is currently six vertically polarized sector antennas. Two antennas are used for each sector, separated laterally to provide space-diversity reception; both antennas are also used for the transmission of one or more downlinks. Some operators are concerned about the viability of duplexing and will use three antennas per sector.

Adaptive ("smart") antennas and a wide variety of signal processing techniques are on the horizon, but will not make their full impact during the initial roll-out period of the new networks in 1996.

Diversity on the Uplink

The up-link path is more fragile than the downlink, as the handset has a much smaller transmitter power than the BTS. This imbalance is partly reduced by using two receiving antennas and a dual-diversity receiver. Space diversity has typically been used, with the two receiving antennas horizontally spaced by around 10 feet. This arrangement works well, but is mechanically complex; it requires a mounting frame with a high visual profile which is becoming increasingly unacceptable to zoning authorities.

There are several methods for obtaining diversity operation on the uplink. The criterion for their effectiveness is that as the mobile is moved through the environment the statistical correlation between the two received signals must be low. So in spacial diversity, the antennas are sited at physically separate locations; when multipath propagation has caused the signal at one antenna to fall below an acceptable level, it is not probable that the signal at the other antenna is affected at the same time. This probability — and so the effectiveness of the diversity arrangement—is measured by the *correlation coefficient* between the two antenna outputs. The signal correlation falls and the system becomes more effective as the antenna separation increases. Were is no "magic" separation, but as separation is increased beyond a few wavelengths, a law of diminishing returns sets in.

Spacial Diversity is available using vertical rather than horizontal distance between the receiving antennas. Unfortunately the scatterers on a path between a handset and BTS are pre-dominantly spread in the azimuth plane, so for a given separation between the antennas the correlation is much lower (better diversity operation) when the antennas are spaced horizontally.

Frequency Diversity is already exploited by both GSM-based systems (as SFH and FFH) and CDMA systems (by frequency spreading). Information transmitted at frequencies at which signals are lost is recovered by the data coding provided in higher protocol layers.

Polarization Diversity requires that signals are derived from two antennas which receive signals with different polarizations and whose outputs have as low a correlation as possible. Various polarization pairs can be used — horizontal/ vertical, +45° linear, right/left hand circular — but if common antennas are used for transmission and reception the choice of polarization for the uplink will affect the choice of polarization available for the down-link.

In urban areas it is reported that the diversity gain available from polarization diversity is only about 1dB lower than that available from a conventional laterally-spaced diversity pair, although in the less scattered rural environment the difference is larger. Polarization-diversity antennas can be designed to fit into the same size envelope as a single conventional antenna — two antennas have become one, with a much simpler mounting and far less wind area.

CSA's UNICELL™ antenna combines three polarization-diversity sector antennas into a single physical unit suitable for mounting on top of a unipole. This arrangement is very attractive, especially for urban use, where it makes polarization diversity an irresistible option.

Antenna Specifications

The specification of antennas for PCS requires attention to more than the familiar parameters of gain, VSWR and azimuth beamwidth. The following list does not attempt to identify all the parameters which need to be specified, but highlights those which are critical to the success of a network.

Azimuth Radiation Pattern For trisector sites an azimuth beamwidth of 85° (at the -3dB points) is usually specified to provide the right beam overlap and coverage. For an obstructed inner-city area an antenna beamwidth of 65° is sometimes used, as the effective propagation path loss is higher, effectively blunting the beam. To avoid unnecessary handoffs, a clean sidelobe-free azimuth pattern is needed, together with a back-to-front ratio of 25-30dB (with a required C/I ratio of only 8dB, there is no advantage to be gained by increasing it beyond these figures).

Gain With the high propagation losses familiar at L-Band, antenna gains need to be as large as possible. Several factors limit what it is practicable to achieve, as with a defined azimuth beam shape, more gain can only be obtained by making the antenna longer and reducing its elevation beamwidth. A very narrow elevation beam is difficult to point accurately and demands a very stable (costly, heavy, obtrusive) mounting structure for the antenna. As antennas become longer they may suffer wind deflection and vibration.

L-Band networks have rolled out with most base station antennas between 4 ft and 6ft (between 8 and 12 wavelengths) long, with the 6ft antennas in the largest numbers.

Elevation Radiation Pattern As the elevation beamwidth of a 6ft antenna is only about 5°, planners specify two additional features for the elevation pattern.

Null Fill The first minimum below the horizon is generally required to be filled to around-20dB relative to the main beam.

Beamtilt Electrical and mechanical beamtilts have different effects on the coverage of the antenna (a mechanical tilt has no significant effect when seen from the side of an antenna). Most sector antennas deployed to date (~90%) have 2° electrical tilt, with some use of 0° and 5°.

Upper Sidelobe Suppression As most antennas are operated with electrical (and often also mechanical) downtilt, the first elevation sidelobe may lie in the horizontal plane. To improve frequency re-use all elevation sidelobes within 20° of the main beam axis are often required to be suppressed to at least -20dB relative to the main beam.

To achieve elevation pattern shaping across the whole PCN/PCS band, and to avoid unnecessary loss of gain, carefully tailored amplitude/phase functions are applied to the element feed currents. These are computed using software which allows each maximum and minimum to be separately fitted to the wanted pattern template.

Bandwidth

All antenna parameters must be maintained across the whole operating frequency band. This is being regularly achieved. The achieved standard of elevation pattern performance is far greater than has been traditional in the cellular market and is similar to that demanded routinely by TV broadcasters.

The use of stripline methods also provides excellent consistency in measured VSWR over large numbers of antennas.

Intermodulation Product Generation

Many operators are duplexing transmitters and receivers onto the same antenna, saving antenna and mounting costs and reducing the visual profile of the base station. The multiplexing of multi-carrier transmission and reception on a single antenna make heavy demands on the avoidance of passive intermodulation products (PIPs) which are typically specified to be 153 dB relative to two 20 W carriers. This performance is routinely achieved by CSA Wireless, but only because the whole antenna structure was designed with the PIMP requirement firmly in mind, not only as a test target, but as a thru-life requirement.

The achievement of the same low IMPs after the antenna has been installed requires very high standards of work in the termination and sealing of the connectors on the feed cables. The use of semi-flexible cable jumpers is almost essential when the cable run is long and the cable is large and inflexible; this increases the demand for a very high standard of design in the connectors and faultless workmanship in their installation and sealing.

New Materials and Manufacturing Methods

CSA Wireless has supported the use of one-piece microstrip arrays in cellular communications systems. These antennas follow the precedents of previous radar and military users of L-Band, but are radically simpler and use materials not available a few years ago.

The simplicity and low-component count of these antennas ensure a very high degree of tolerance and performance control, together with reliability which has set new standards in the personal communications industry.

Uplink/Downlink Balance

The first networks operating on 1800MHz suffered imbalance between the up and down-links; 20W BTS units were used, and the constraints of site selection resulted in the use of antenna feed cables with losses of up to 3dB. The result was a severe deficit on the uplink, as link performance is reduced both by loss of signal and by the high noise temperature introduced by the cable. During the past couple of years almost every site has been retrofitted with low noise amplifiers placed close behind the antennas. The result is that the links are now much more correctly balanced, with one operator reporting that performance is now downlink limited by up to 3dB. The potential reliability impact of placing active devices behind the antenna has been controlled by specifying a MTBF of 750,000 hours. In addition a soft failure mode is specified in which a disabled amplifier is effectively bypassed and its failure does not result in loss of signal.

Advances in superconductor technology are now making possible complete amplifier/filter combinations suitable for tower-top use, with a combined noise figure less than 1dB. These techniques can extend cell coverage and reduce the number of sites needed.

Antenna Siting

The resistance of zoning authorities to the rapidly increasing number c wireless base stations is causing concern to everyone in the industry; as responsible citizens we are ourselves concerned for the quality of our environment. Measures which can be taken to reduce the visual impact of base stations must be taken, achieving a responsible balance between appearance, cost and effectiveness.

CSA Wireless is actively exploring possibilities for covert antenna making new use of accepted and familiar landmarks in cities and suburban areas, and on highways.

Brian Collins is Vice President of engineering of CSA Wireless in the UK.

Reprinted with permission from **Wireless Design and Development**

The text has been re-set to suit the smaller format of this file and the names of CSA's immediate predecessors has been changed to avoid confusion.