8.7 DIVERSITY TECHNIQUES

As has been explained earlier, the biggest problem encountered in the use of the urban mobile radio channel is the large and rapid fluctuations that can occur in RSS due to multipath fading. It is impractical to try and counteract the diminished RSS by raising the system transmitting power since typical fades can cover several orders of magnitude with deep fades covering over three or four orders of magnitude, well beyond the limits of transmitter power control systems. The most effective technique that can be used to mitigate the effects of fading is to employ some form of time, space, or frequency diversity for either or both the transmission and reception of the desired signal. The basic idea behind these solutions is that fading will not remain the same as time passes nor will it be the same over different signal paths or for different frequencies over the same paths. There are several methods that can be used to provide diversity to a wireless mobile system. In each case, several different received signals are usually combined to improve the system's performance. Some of the more popular ways to obtain two or more signals for this purpose are to make use of specialized receivers, physically provide additional antennas, operate over more than one frequency, and use smart antenna technology. The operation of a system over more than one frequency has been previously addressed during the discussions of FHSS, GSM frequency hopping, and multicarrier systems. Therefore, this topic will not be pursued any further here. The next several sections will address the other techniques that have been mentioned and some newly emerging technologies.

Specialized Receiver Technology

In an effort to combat multipath effects, several innovative receiver implementations have been created. Recognizing that multiple signals will arrive at a receiver over the mobile radio channel, these receivers exploit that fact by isolating the signal paths at the receiver. Furthermore, if one recognizes that the fading of each multipath signal is different, then it can be seen that this isolation process will in fact yield the diverse signals needed to improve receiver performance. An early embodiment of this concept is the **RAKE receiver** originally designed in the 1950s for the equalization of multipath. See Figure 8–16 for a block diagram of the structure of a typical RAKE receiver used for CDMA.

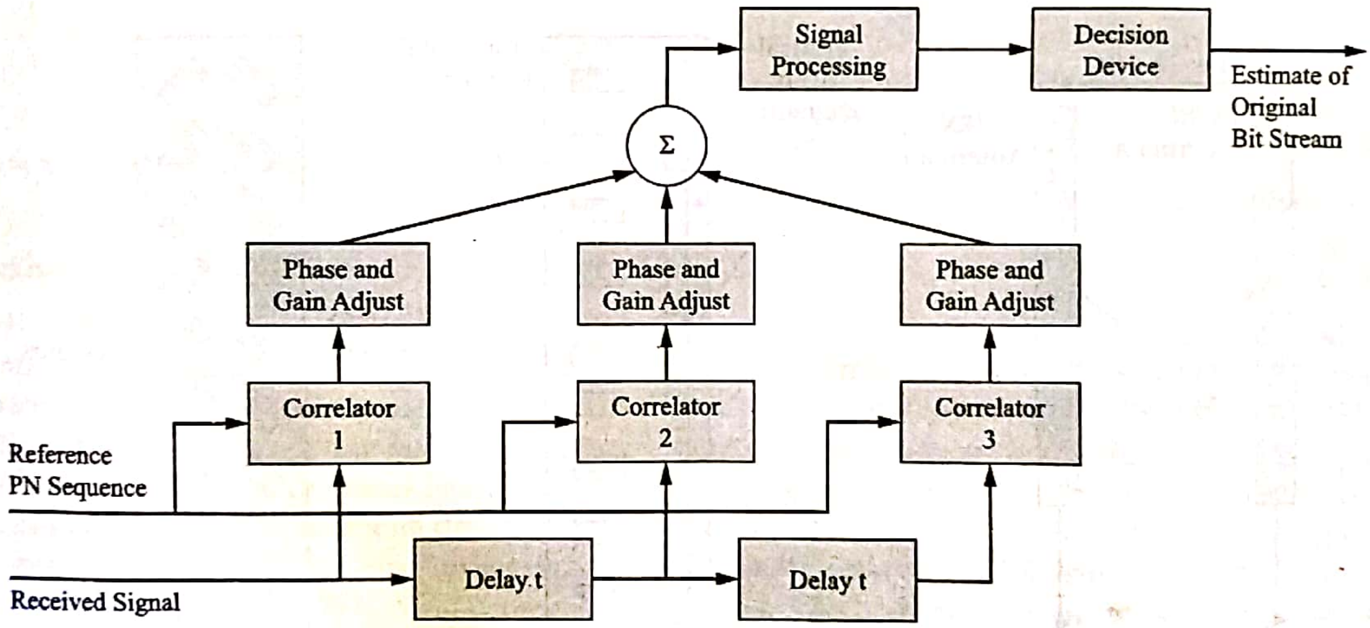

Figure 8–16 RAKE receiver block diagram.

Modern, digitally implemented RAKE receivers used in today's CDMA wireless mobile systems may only have a few RAKE taps but possess the ability to dynamically adjust the taps (move the rake fingers) in response to a search algorithm used to locate multipath components. These smart receivers can generate several signals that can be further combined by several standard diversity combining techniques to provide a more reliable receiver output and therefore improve system performance.

There are potential problems with this type of receiver that are tied to the multipath delay and spread introduced to the radio link. The multipath components that can be resolved have a time dependence that is proportional to the inverse of the system chip rate and the system-tolerated multipath spread is proportional to the inverse of the symbol time. For the IS-95 CDMA system, using a chip rate of 1.2288 mcps allows the resolution of multipath components of the order of approximately 1/1.2288 mcps or 800 ns by the RAKE receiver. For a symbol rate of 14.4 kbps (encoded with QPSK) a multipath spread of up to approximately

1/7200 or 140 s may be tolerated without ISI. Since the typical multipath spread for an outdoor environment is in the order of tens of microseconds and for indoor environments nanoseconds, CDMA systems do not suffer from ISI and these types of receiver can be implemented. However, in an indoor environment the CDMA RAKE receiver would not be able to resolve multipath components.

The GSM system employs an equalization technique at the receiver to improve system performance. As outlined in Chapter 5, a training sequence of 0s and 1s is transmitted during the middle of a normal burst of user data (refer back to Figure 5–15). The receiver uses this training sequence to train the complex adaptive equalizer incorporated into the GSM mobile receiver to improve system performance. Due to the complexity of these systems no further details will be presented here.

Space Diversity

A typical technique used to improve mobile wireless system performance is to employ **space diversity** in the form of additional receiving antennas located at the base station. At this time it is still problematic to achieve antenna diversity for a mobile station due to its typically small size in relation to a wavelength of the radio frequency employed. This fact may change in the near future with the adoption of advanced antenna technology schemes (MINO, smart antennas, etc.). In theory, the paths taken by the reverse signal to arrive at each antenna will not be affected equally by multipath fading or spread. There are many ways to achieve the needed space diversity at the base station site. Figures 8–17 shows several practical implementations.

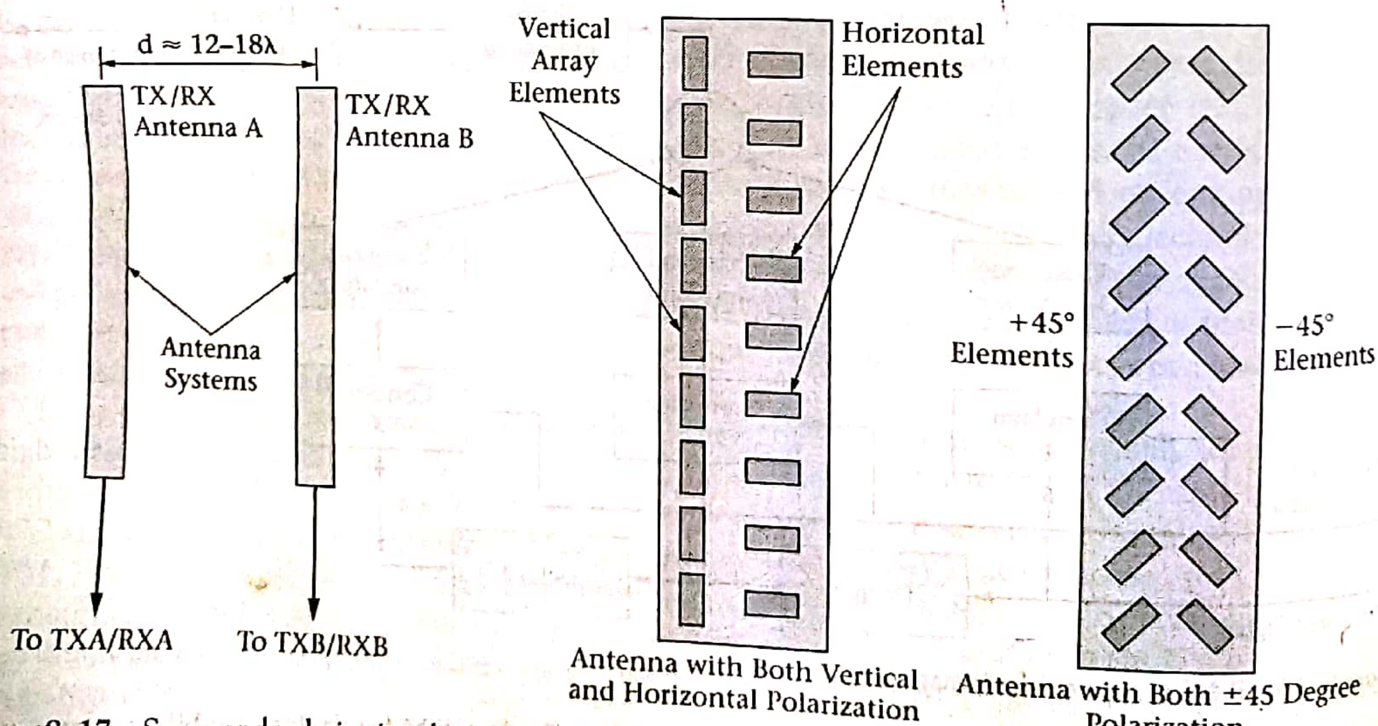

Figure 8–17 Space and polarization diversity antenna schemes.

As can be seen in the figures, both space and polarization diversity can be used by the appropriate positioning of the antenna units. The antennas feed multiple receivers, with the strongest received signal being used by the system. This technique is universally implemented by wireless mobile service providers in the design of their systems. Polarization diversity is used to counter the change in EM signal polarization that can be induced by the environment during reflection, scattering, and so on.

Smart Antennas

In the 3G specifications, the support of smart antenna technology is included. This technique to improve system performance makes use of phased array or "beam steering" antenna systems. These types of antennas can use narrow pencil-beam patterns to communicate with a subset of the active users within a cell. Once a mobile subscriber has been located by the system, a narrow radio beam may be pointed in the user's direction through the use of sophisticated antenna technology. The use of a radio link that approaches point-to-point type link characteristics is extremely useful in a mobile environment. Besides the elimination of most multipath signals, a fact that will certainly improve system performance, the amount of interference received will be reduced and system capacity can be increased. As the mobile user moves about the coverage area, the smart antenna will track the mobile's motion. See Figure 8–18 for a depiction of a smart antenna system.

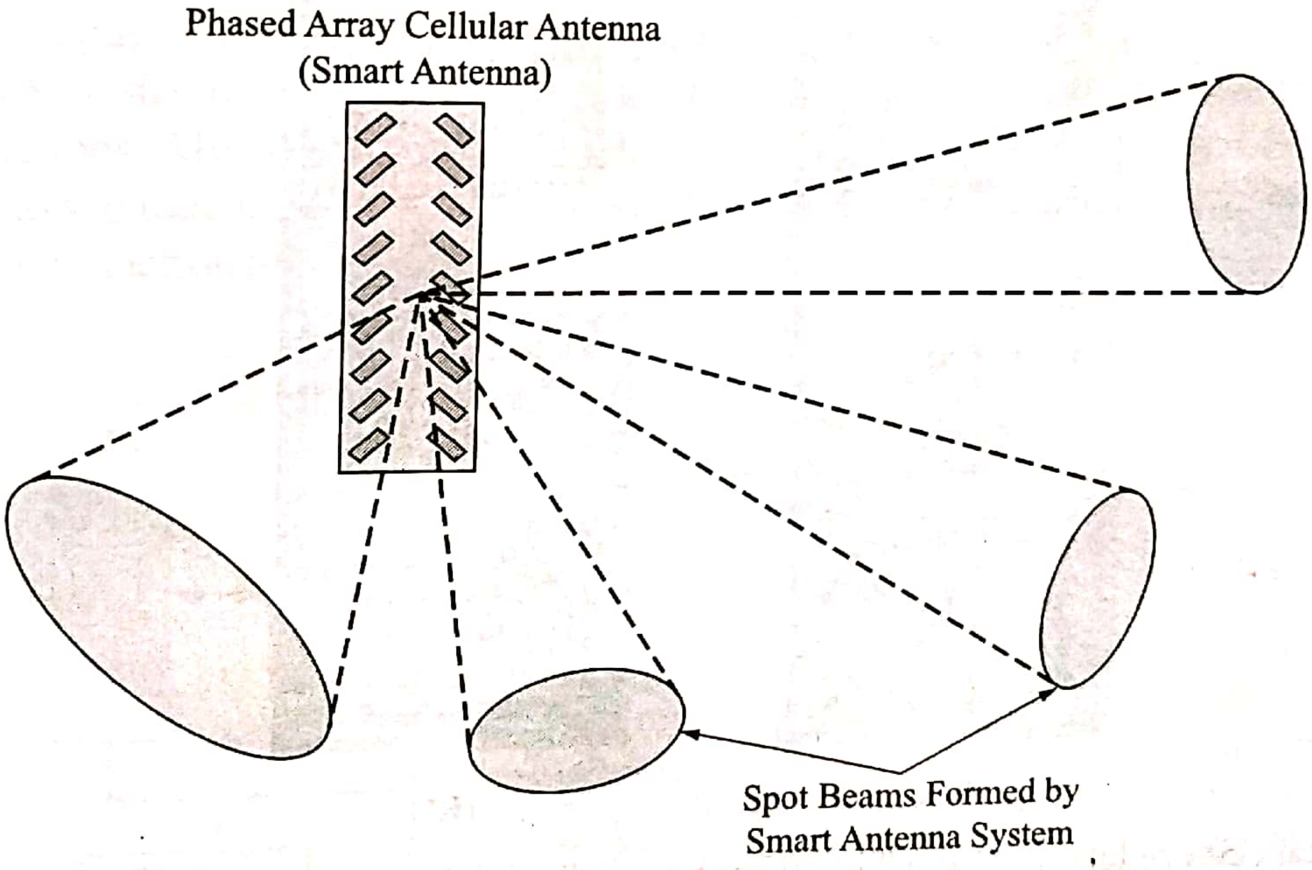

Figure 8–18 Depiction of a 3G smart antenna system.