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Multiple Antenna Technology: When is it MIMO? When is it Diversity?

Over the past several years, there has a lot of publicity about Multiple Input/Multiple Output (MIMO) technology. Many academic and commercial technical presentations have been made at conferences worldwide. Despite all this attention, many engineers hoping to find an introduction to MIMO are confused by some of the statements made in those papers.

It appears that some of the papers discuss multiple antennas in systems that do not have the signal content that defines MIMO. Attendees at the conference, however, hear those papers in the same sessions with MIMO papers and become confused. Worse, they may believe that all multiple antenna systems can be referred to as "MIMO," which is, of course, not correct.

This note points out the difference between the long-standing technique of *diversity reception* using two or more receiving antennas, and true MIMO, which uses two or more antennas at both the transmitter and receiver locations.

Antenna Diversity

Figure 1 shows the simple concept of diversity. In this case, there are two antennas at the receiver, with sufficient spatial separation to assure that propagation from the transmitter to each antenna has different characteristics.

All or part of the receiver is duplicated to monitor the inputs independently. Decision-making circuitry switches the signal recovery to the antenna that has the strongest signal, or in advanced systems, the antenna that produces the lowest bit-error rate. Thus, the amount of time where there is a loss of signal due to multipath or atmospheric effect is reduced.

The MIMO Concept

Figure 2 is a block diagram of a basic MIMO system. In this case, there are two antennas shown at each site: transmitter and receiver. However, the transmitter is sending different signals to each antenna. These two signals are orthogonal, transmitting outputs of the data matrix that splits the main data stream into lower data rate streams that modulate the transmitters. Also, remember that this is a simplistic illustration; MIMO can utilize more than two transmitters/antennas.

Like diversity, MIMO tolerates propagation problems by using multiple signal paths—but that is only a superficial similarity. It is the matrix relationship

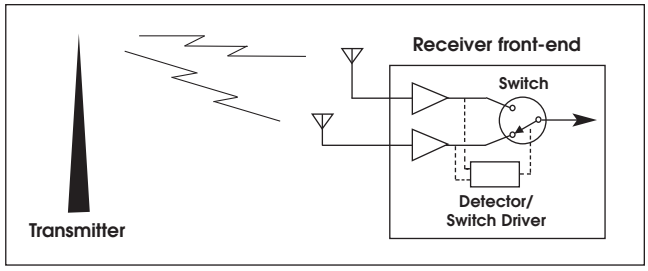

Figure 1 · Diversity uses multiple antennas to select the most robust of the available signal path.

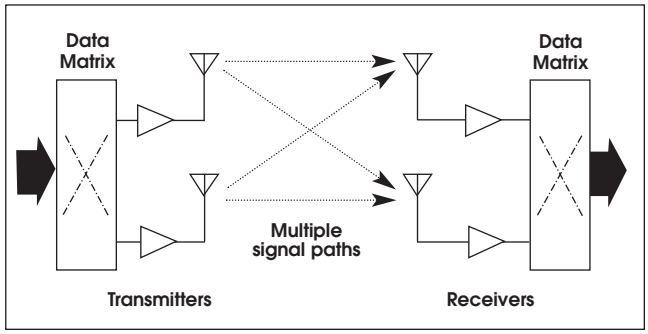

Figure 2 · MIMO uses multiple antennas at both the transmitter and receiver, with each transmitted signal carrying different information.

among those data paths that is the key to MIMO's power. It allows increased data throughput by having four independent signal paths on the same channel, as shown in the center of Fig. 2. The lower data rate on each path helps reduce propagation effects.

Confusion Possibilities

In practice, MIMO is much more complex than the minimal implementation used for this illustration, which is part of the problem of understanding it "simply and quickly." It does not help that MIMO, under poor propagation conditions, may in fact revert to a diversity system mode.

Also, there are non-MIMO diversity systems that use multiple-antenna diversity at the transmitter, also using a type of orthogonal coding to distinguish between the two antennas. Other systems in the "smart antenna" category use multiple antennas in steerable arrays rather than in a diversity mode.

All of these techniques have made it harder for engineers and technology management to gain an initial grasp of the powerful MIMO concept. Hopefully, this short note removes some of the confusion.