card **202**, and FIG. **9**C illustrates the bottom surface **206**. FIG. **9**B illustrates the center layer of the card **202** where a ground plane **230** is located. The ground plane **230** comprises a shape such that it is positioned beneath each of the center patch antenna elements **210**, **216** (which may each comprise an etched copper pattern), as well as the monopole antenna elements **212**, **214**. Because there are no monopole antenna elements located on the bottom surface **206**, the monopole antenna elements **212**, **214** on the top surface **204** use the ground plane **230** underneath them to "work against." The ground plane **230** preferably extends to the edge of the card **202**. Traces can be included in the center layer for connecting the antenna elements **210**, **212**, **214**, **216** to the connectors or other circuitry (not shown) on the card **202**.

The above discussion presented various antenna means for realizing four-element diversity. The present invention, however, is not limited to the use of four antenna elements. Indeed, fewer or more than four antenna elements may be used in accordance with the present invention. Performance is increased markedly as the number of diversity antenna elements is increased from two to approximately eight. The following discussion presents a means to deliver six-element diversity.

FIGS. **10**A and **10**B illustrate a multi-antenna element structure **300** made in accordance with another embodiment of the present invention. The multi-antenna element structure **300** includes a card **302**, such as for example a PCMCIA card (but as discussed above, many different types of cards may be used). FIG. **10**A illustrates the top surface **304** of the card **302**, and FIG. **10**B illustrates the bottom surface **306**. Active circuitry and connectors, which may be included on the card **302**, are not shown.

The multi-antenna element structure **300** includes six antenna elements **310**, **312**, **314**, **316**, **318**, **320**. The top surface **304** of the card **302** includes three antenna elements **310**, **312**, **314**, and the bottom surface **306** includes three antenna elements **316**, **318**, **320**. In this embodiment, the center antenna elements **310**, **316** may comprise ¼-wave or ½-wave patch antennas, and the side antenna elements **312**, **314**, **318**, **320** may comprise ¼-wave vertically polarized monopole antennas. It should be well understood, however, that various configurations and combinations of different types of antennas may be used in accordance with the present invention.

Similar to the multi-antenna element structures **100**, **150**, **200** described above, the detailed design process for individual patch and monopole antennas is well known. Each of the antenna elements **310**, **312**, **314**, **316**, **318**, **320** is preferably individually designed to have good gain and VSWR. This is standard procedure in antenna design. In addition, the individual antenna elements **310**, **312**, **314**, **316**, **318**, **320** are preferably optimized to preserve good gain and VSWR while also delivering good inter-element isolation. Good isolation is important for achieving good diversity gain. Thus, each of the antenna elements **310**, **312**, **314**, **316**, **318**, **320** preferably provides gain while also having good isolation between itself and other antenna elements.

In this embodiment, different polarizations between the antenna elements **310**, **312**, **314**, **316**, **318**, **320** can be used to realize low cross-correlation (i.e., isolation) between them. For example, the illustrated side monopole antenna elements **312**, **314**, **318**, **320** are vertically polarized, which yields low cross-correlation with the center patch antenna elements **310**, **316**. Because the side monopole antenna elements **312**, **314** (and **318**, **320**) are capable of being horizontally spaced at approximately λ/2 or more, they result in additional diversity gain for the system.

The separate antenna elements **310**, **312**, **314**, **316**, **318**, **320** offer spatial and/or polarization diversity, which delivers good receive and transmit diversity performance. FIG. **11** illustrates the individual antenna gain patterns G_{310}, G_{312}, G_{314}, G_{316}, G_{318}, G_{320} in the y–z plane that result for the six antenna elements **310**, **312**, **314**, **316**, **318**, **320**, respectfully. When viewed in the y–z, x–z, or x–y planes, a full 360 degrees of coverage is achieved.

The vertical antenna elements **312**, **314**, **318**, **320** (FIGS. **10**A and **10**B) may comprise standard λ/4 monopole antennas, or they can be implemented using a variety of modern materials (e.g., ceramics). By way of example, the vertically polarized antenna elements **312**, **314**, **318**, **320** may comprise small circuit-board type antennas, ceramic elements, wire elements, etc. Whatever type of antenna or material that is used, a preferred feature for each of the antenna elements **312**, **314**, **318**, **320** is E-field polarization out-of-the-plane (i.e., along the z-axis).

Two configuration options are possible for the vertical antenna elements **312**, **314**, **318**, **320**. In one option, the two vertical elements **312**, **320** (and **314**, **318**) that are directly above and below each other may be used to form a traditional dipole antenna. In this scenario, the total number of diversity antenna elements realized is only four. If, however, each of the vertical antenna elements **312**, **314**, **318**, **320** is situated above a ground plane (similar to the ground plane **130** of FIG. **4**B), then a total of six different antenna branches can be realized.

In the six-element configuration where the vertical antenna elements **312**, **314**, **318**, **320** are all (electrically speaking) λ/4 vertical elements, good diversity gain is best achieved when the vertical antenna elements **312**, **314**, **318**, **320** are separated in the z-dimension by at least λ/4. In order to achieve this separation, the thickness d of the card **302** is preferably defined by the following equation:

$$d \geq \frac{\lambda}{4\sqrt{\varepsilon_r}}$$

where $\in_r$ is the relative dielectric constant of the card **302**.

The active (radiating) edges **330**, **332**, **334**, **336** of the patch antenna elements **310**, **316** are preferably orthogonal to the polarization present on the dipole/monopole antenna elements **312**, **314**, **318**, **320**. This orthogonality helps to achieve polarization diversity. Furthermore, this orthogonality permits separate transmitter power amplifier stages to drive each of the two polarizations thereby lowering the required power amplifier output power (per branch) by 3 dB. For example, referring to FIG. **12**, the active circuitry **340** which may be located on the card **302** can include one transmitter power amplifier stage **342** for driving the patch antenna element **310** and a separate transmitter power amplifier stage **344** for driving the monopole antenna elements **312**, **314**. If the same methodology is used on the under-side of the card **302**, a total of 6 dB reduction in each individual power amplifier can be used while delivering the same total output power level.

Preferably, the position of the four vertical antenna elements **312**, **314**, **318**, **320** are chosen to be symmetrically located with respect to the radiating edge edges **330**, **332**, **334**, **336** of the patch antenna elements **310**, **316**. This lowers the near-field antenna energy from the patch antenna elements **310**, **316** that is coupled into the vertical antenna elements **312**, **314**, **318**, **320**.