DETAILED DESCRIPTION OF THE INVENTION

The following description is not to be taken in a limiting sense, but is made merely for the purpose of describing the general principles of the invention. The scope of the invention should be determined with reference to the claims.

Referring to FIG. **1**, there is illustrated a multi-antenna element structure **20** made in accordance with an embodiment of the present invention. The multi-antenna element structure **20** is ideal for use as a diversity antenna and overcomes the disadvantages described above. It provides receive and/or transmit diversity in a multipath environment so that wireless communication link bit error rate (BER) performance is improved. The multi-antenna element structure **20** is extremely well suited to small form-factor applications that are to be used at high frequencies, including the 5 to 6 gigahertz (GHz) frequency band. Moreover, the multi-antenna element structure **20** is particularly suited for use in wireless local area networks (WLAN).

The multi-antenna element structure **20** may be conveniently inserted into an interface slot **22** of a computer **24**. Although a notebook computer is illustrated, it should be well understood that the computer **24** may comprise any type of computer, such as for example, a desktop computer, laptop computer, palmtop computer, hand-held computer, etc. Furthermore, the multi-antenna element structure **20** may also be inserted into interface slots associated with a plethora of other types of devices that may need to communicate wirelessly, such as for example, set-top boxes (including cable and XDSL), information appliances, printers, fax machines, scanners, storages devices, televisions, stereos, etc. The multi-antenna element structure **20** can be used for performing wireless communications to and from any of these devices.

In the illustrated embodiment, the interface slot **22** comprises a Personal Computer Memory Card International Association (PCMCIA) compliant slot, and the multi-antenna element structure **20** is constructed on a PCMCIA card **26**. A PCMCIA card is a well-known, approximately credit card-size adapter which is inserted into a PCMCIA slot. PCMCIA cards are usable for many different types of I/O devices and are widely used, for example, with notebook computers. Although embodiments of the invention described herein are implemented on PCMCIA cards, it should be well understood that the antenna structures described herein may alternatively be implemented on many other types of cards, such as for example, interface cards, adapter cards, circuit boards, printed circuit boards, smart cards, etc., in accordance with the present invention. Furthermore, the interface slot **22** may comprise many different types of interface slots in accordance with the present invention. By way of example, the interface slot **22** may comprise a Peripheral Component Interconnect (PCI) compliant slot, Industry Standard Architecture (ISA) compliant slot, etc.

FIG. **2**A illustrates the top surface **28** of the multi-antenna element structure **20**, and FIG. **2**B illustrates its bottom surface **30**. One or more connectors **32** are typically located at one end of the card **26**. The connectors **32** normally comprise a configuration or type that is appropriate for the particular interface being used, e.g., PCMCIA, PCI, ISA, etc.

Two or more antenna elements are preferably located at the other end of the card **26**, i.e., the end opposite the connectors **32**. The two or more antenna elements may be comprised of antenna elements A_{t1} through A_{tn} located on the top surface **28** of the card **26** and/or antenna elements A_{b1} through A_{bn} located on the bottom surface **30** of the card **26**. Thus, the two or more antenna elements may be comprised of antenna elements located on the top surface **28**, antenna elements located on the bottom surface **30**, or antenna element(s) located on the top surface **28** and antenna element(s) located on the bottom surface **30**.

The cloud-like shape of the antenna elements A_{t1} through A_{tn} and A_{b1} through A_{bn} shown in the drawings is intended to indicate that many different types of antennas may be used for implementing the antenna elements A_{t1} through A_{tn} and A_{b1} through A_{bn}. Several exemplary types of antennas will be discussed in the examples below. Furthermore, it will be demonstrated that different types of antennas may even be used among the antenna elements A_{t1} through A_{tn} and A_{b1} through A_{bn}.

Active circuitry, such as radio frequency (RF) circuitry, may also be conveniently located on the card **26**. For example, active circuitry **34** may be located on the top surface **28** and/or active circuitry **36** may be located on the bottom surface **30**. The active circuitry **34** and/or **36** may comprise power amplifiers for driving the antenna elements, low noise amplifiers (LNAs) for amplifying the received signals, RF switches for selecting signals routed to and from transmit and receive antenna elements, and/or digital baseband processing application specific integrated circuits (ASICs). The active circuitry **34** and/or **36** may also comprise additional circuitry that processes the transmitted and received signals, for example frequency translation from/to an intermediate frequency (IF) to/from the final radio frequency (RF) frequency.

Locating the active circuitry **34** and/or **36** on the card **26** has the advantage of allowing the active circuitry **34** and/or **36** to interface directly with the antenna elements, which simplifies signal routing and eliminates the need for coaxial antenna connections. Such location places the active circuitry **34** and/or **36** intimately close to the antenna elements, which minimizes signal losses. By way of example, traces T_{t1} through T_{tn} may be used to directly interface the antenna elements A_{t1} through A_{tn}, respectively, with the active circuitry **34**. Similarly, traces T_{b1} through Tbn may be used to directly interface the antenna elements A_{b1} through A_{bn}, respectively, with the active circuitry **36**. Although traces T_{t1} through T_{tn} and T_{b1} through T_{bn} are illustrated as being located on the top surface **28** and bottom surface **30**, respectively, it should be well understood that one or more of such traces may alternatively be located on one or more interior layers of the card **26**. Examples of separate, interior layers of a card will be discussed below.

Because the active circuitry **34** and/or **36** is intimately close to the antenna elements, traces T_{t1} through T_{tn} and T_{b1} through T_{bn} can be very short, which means that the antenna elements are connected almost immediately to the inputs of the active circuitry **34** and/or **36**. No coaxial antenna connections are necessary with this scheme. Short trace lengths are highly advantageous when operating at very high frequencies, such as 5GHz, due to the losses that can occur with long traces. Preferably, trace lengths of less than or equal to 0.5 to 1.0 inches are used.

The active circuitry **34** may be optionally coupled to the connectors **32** by means of one or more traces **40**. Similarly, the active circuitry **36** may be optionally coupled to the connectors **32** by means of one or more traces **42**. This way, information or data can be transferred to and from the active circuitry **34** and/or **36** by the device in which the card **26** is inserted, such as the computer **24**. For example, data can be