

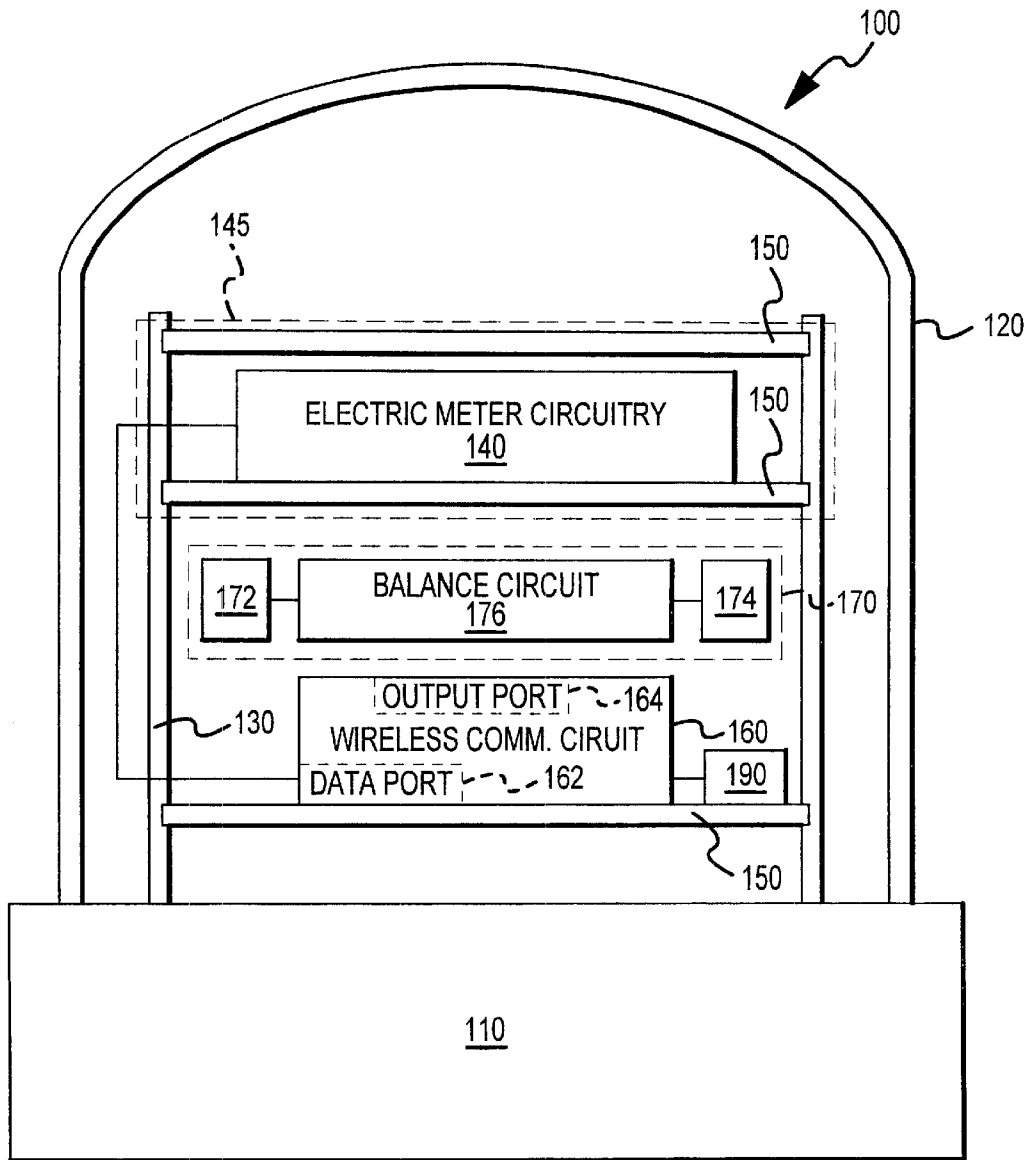


FIG.1

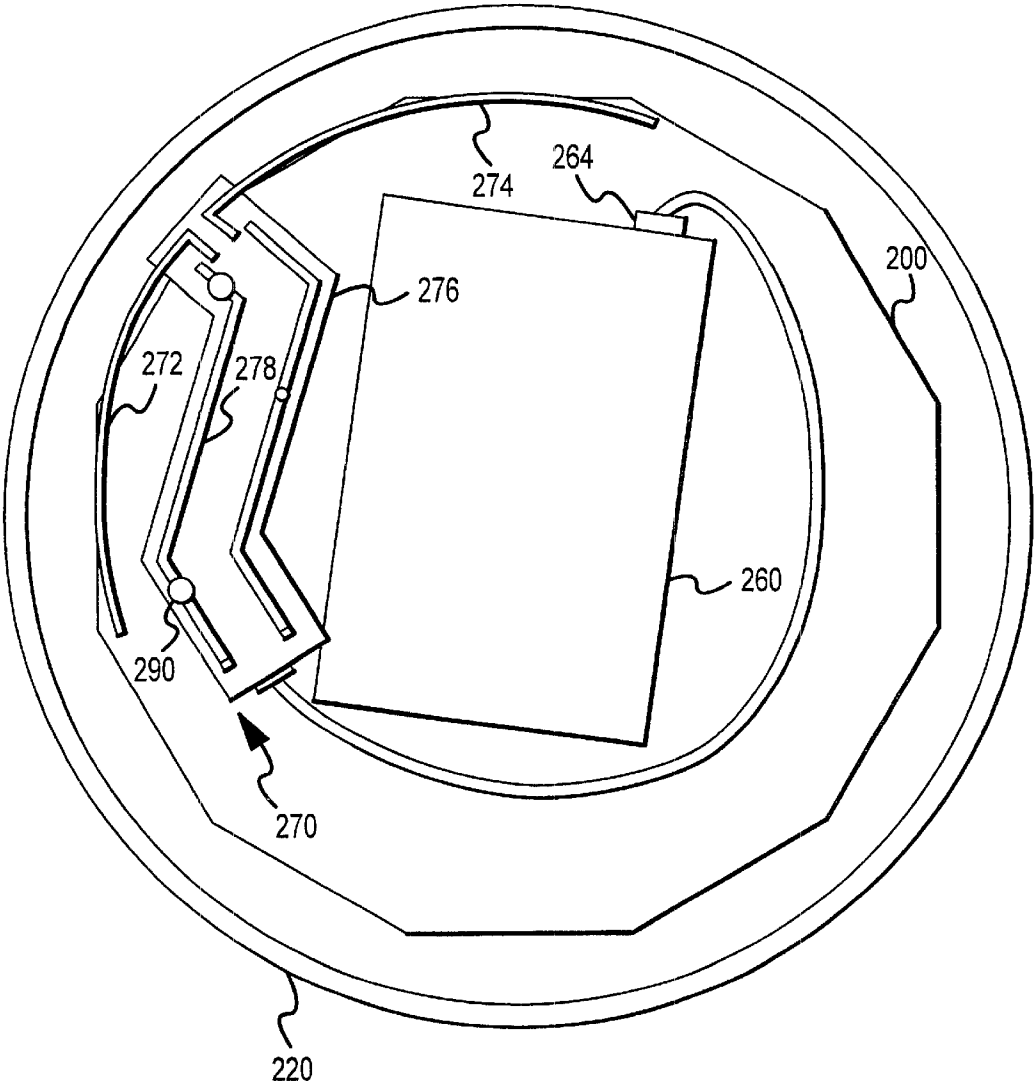


FIG.2

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ANTENNA FOR ELECTRIC METER AND METHOD OF MANUFACTURING THEREOF

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of Ser. No. 09/040,113 filed Mar. 17, 1998, now U.S. Pat. No. 6,181,294, entitled "Antenna For Electric Meter And Method of Manufacture Thereof" to Lawrence R. Porter, et al., which is incorporated herein by reference.

TECHNICAL FIELD OF THE INVENTION

The present invention is directed, in general, to electric meters and, more specifically, to an antenna for an electric meter to enable the meter to communicate over a public wireless data network, a method of manufacturing the antenna and an electric meter employing the antenna.

BACKGROUND OF THE INVENTION

Until recently, a single utility provided electric service to all consumers in a given area. Establishment of electric service, maintenance, meter reading and billing were centralized in the single utility. Customers had no freedom to choose their electricity provider. Now, the kind of deregulation that changed the face of the telecommunications industry is sweeping through the electric power industry. One by one, states are allowing electric power resellers to buy electricity in quantity and to resell the electricity directly to consumers.

At the same time, electricity providers are becoming more sophisticated about billing practices. Gone are the days when consumers were billed flat rates. Numbered are the days that consumers are simply billed on the basis of kilowatt-hours consumed. Now, electricity providers are interested in gathering qualitative and additional quantitative data regarding electrical service delivered to consumers in an effort to correlate charges and costs of the service provided.

In response, consumers (particularly commercial consumers) are becoming more sophisticated regarding their use of electricity. Realizing that management of electrical usage may result in monetary savings, consumers are also demanding greater amounts of qualitative and quantitative data.

The electric meter industry has responded with digital electric meters that measure such characteristics as volt-hours, volt-squared-hours, watt-hours, kilowatt-hours, Q-hours, VAR-hours and VA-hours over time, giving both the electricity provider and the consumer a greater quantity of, and more timely, data regarding electricity use. Examples of digital meters may be found in U.S. Pat. No. 4,884,021, issued Nov. 28, 1989, to Hammond, et al., entitled "Digital Power Metering" and U.S. Pat. No. 5,122,735, issued Jun. 16, 1992, to Porter, et al., also entitled "Digital Power Metering," commonly assigned with the present invention and incorporated herein by reference. Digital meters can measure these characteristics instantaneously or over a period of time, allowing electricity providers to track peak electricity usage and to better plan generator capacity. Electricity providers may then allow consumers to reduce costs by avoiding peak usage periods. Overall, digital meters have brought about more accurate measurement and billing and, in some cases, have resulted in more cost-effective use on the consumer's part.

Like traditional mechanical meters, many digital meters must be read by direct visual observation. In large urban

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areas with millions of customers, this represents a considerable labor cost, even when spread out over an entire month. Additionally, meters have proven difficult to read from distances over 12 feet. Intervening fences, brush, trees, yard tools and pets may make close access difficult or even impossible. Sun glint and bad weather may add to the problem, particularly in remote areas with poor roads or during winter storms that may cover the meters with snow or ice. Ever-present is the risk that a meter reading may be erroneous. Deregulation of electric power may exacerbate this problem by creating geographically distributed electricity providers, thereby dramatically increasing the cost of reading meters and potentially threatening the economics of deregulation.

The electric meter industry has responded by adding wire-based communication circuitry to newer models of electric meters. Such circuitry typically employs a telephone line to communicate with a central location. While adequately addressing the cost issue of meter reading, the use of telephone lines introduces other problems.

If an electric meter is given a dedicated telephone line, the cost of the dedicated line must be considered when calculating the cost of reading the meter. On the other hand, if the electric meter shares a telephone line with another user (e.g., a residential meter may employ the residence's main telephone line), the line may not be available when required by the meter. In fact, a consumer may intentionally make the line unavailable to the meter, thereby preventing the meter from reporting its data.

Alternatively, the meter may be provided with an external antenna to allow wireless communication over a range of a few hundred feet. A roving truck carrying a transceiver may then establish communication with the meter as it passes nearby, thus reading the meter. Unfortunately, the truck must be physically deployed to locations proximate the meters. Truck-based wireless reading, therefore, provides only a marginal advantage over direct visual observation. Further, the meter's external antenna may be subject to tampering and to severe weather.

Accordingly, what is needed in the art is a more effective way to receive frequent, timely and accurate electrical consumption data from, and provide remote commands to, geographically-distributed electric meters.

SUMMARY OF THE INVENTION

To address the above-discussed deficiencies of the prior art, the present invention provides, for use with an electric meter chassis having a dielectric housing (of any geometry) protruding therefrom, an antenna for allowing electric meter circuitry within the chassis to communicate wirelessly through the dielectric housing and a method of manufacturing the same. In one embodiment, the antenna includes: (1) antenna elements, located within and generally conforming to a portion of an internal surface of the dielectric housing and adapted to transmit and receive electromagnetic radiation and (2) a balance circuit, coupled to the antenna elements to cause the antenna elements to act as a dipole and coupleable to an unbalanced output port of a wireless communication circuit, that balances an impedance of the unbalanced output port thereby to balance the dipole.

The present invention therefore introduces the broad concept of outfitting an electric meter with an internal, wireless communications antenna, allowing the electric meter circuitry within the meter to communicate via a data network wirelessly coupleable thereto. Such communication can be bidirectional, allowing the meter to report data to a

central location or to accept remotely-generated operational commands. The range of the communications antenna is preferably sufficient to allow wireless communication with a data network, thereby eliminating a need to employ roving trucks to establish communication.

In one embodiment of the present invention, the antenna elements generally conform to a portion of an internal surface of the dielectric housing. If, as in an embodiment to be illustrated and described, the dielectric housing is cylindrical, the antenna elements can assume an arcuate form (or a straight form if conforming to an end of the housing).

In one embodiment of the present invention, the antenna further includes electric meter circuitry located in a circuit board rack within the dielectric housing, the antenna elements located between circuit boards in the circuit board rack. The electric meter circuitry, which is purely environmental with respect to the antenna embodiment of the present invention, may be distributed among separate, perhaps interconnected, circuit boards in the rack. Alternatively, the electric meter circuitry may be contained in another portion of the electric meter chassis.

In one embodiment of the present invention, the antenna further includes: (1) electric meter circuitry located in the dielectric housing and (2) an electromagnetic shield located about at least a portion of the electric meter circuitry. The electromagnetic shield, while not necessary to the present invention, can improve antenna performance by decreasing interference by reason of the proximity of the electric meter circuitry to the dipole.

In one embodiment of the present invention, the antenna elements are arcuate and have a flattened lateral cross section. Of course, other conductor shapes are fully within the broad scope of the present invention.

In one embodiment of the present invention, the balance circuit is embodied on a circuit board having mounts located thereon and mechanically supports the antenna elements, the mounts allowing the antenna to be reoriented with respect to the dielectric housing. The structure and operation of the mounts and the resulting flexibility in antenna orientation will be set forth in greater detail in the description of certain embodiments of the invention that follow.

In one embodiment of the present invention, the antenna elements are first and second conductors of a dipole and the balance circuit balances an impedance of the dipole. Those skilled in the art will recognize, however, that the antenna elements can form other types of antennas, such as single pole over ground plane, Yagi or loop antennas. Although the embodiment to be illustrated and described is directed to use of a dipole, the present invention is not so limited.

In one embodiment of the present invention, the antenna further includes a wireless communication circuit having a carrier frequency of between 700 and 950 megahertz, and, more particularly, between 806 to 825 (transmit) and 851 and 870 (receive) megahertz. Those skilled in the art will realize that this range of frequencies encompasses some well-known public data wireless networks, such as Ardis® or RAM Mobile Systems®.

The foregoing has outlined, rather broadly, preferred and alternative features of the present invention so that those skilled in the art may better understand the detailed description of the invention that follows. Additional features of the invention will be described hereinafter that form the subject of the claims of the invention. Those skilled in the art should appreciate that they can readily use the disclosed conception and specific embodiment as a basis for designing or modi-

fying other structures for carrying out the same purposes of the present invention. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the invention in its broadest form.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIG. 1 illustrates a simplified block diagram of an electric meter constructed according to the principles of the present invention; and

FIG. 2 illustrates a top view of a circuit board containing a wireless communication circuit and an antenna constructed according to the principles of the present invention.

DETAILED DESCRIPTION

Referring initially to FIG. 1, illustrated is a simplified, combination electrical/mechanical, block diagram of an electric meter **100** constructed according to the principles of the present invention. The meter **100** includes an electric meter chassis **110**, having a dielectric housing **120** protruding therefrom. In the illustrated embodiment, the dielectric housing **120** is a dome of cylindrical cross-section and intended to represent a conventional electric meter housing. Of course, the use of other geometries for the dielectric housing **120** is well within the scope of the present invention.

The meter **100** further includes a circuit board rack **130**, located within the dielectric housing **120**, that contains a plurality of circuit boards **150**. The meter **100** further includes electric meter circuitry **140**, located on one or more of the circuit boards **150**. The electric meter circuitry **140** may include, for example, a microprocessor, memory, display and current or voltage sensors. The patents cited above contain greater detail concerning possible configurations for the electric meter circuitry **140**.

The meter **100** further includes an electromagnetic shield **145** (illustrated in broken line), located about a portion of the electric meter circuitry **140**. The meter **100** further includes a wireless communication circuit **160**, coupled to the electric meter circuitry **140** via a data port **162**. In a preferred embodiment, the electric meter circuitry **140** is coupled to the wireless communication circuit **160** via a flexible strip connector. Of course, the use of other coupling devices is well within the broad scope of the present invention.

The meter **100** further includes an antenna **170** that allows the electric meter circuitry **140** to communicate wirelessly through the dielectric housing **120**. The meter **100** still further includes a capacitively backed up power supply **190** that powers the electric meter circuitry **140** and the wireless communication circuit **160**. The meter **100** may thus communicate power outage information to the electricity provider during a loss of power.

The electromagnetic shield **145** is designed to attenuate interference from the electric meter circuitry **140** that may disrupt an operation of the wireless communication circuit **160**. The electromagnetic shield **145** is also designed to protect the electric meter circuitry **140** from interference generated by the wireless communication circuit **160**. Those skilled in the art will understand, however, that the electromagnetic shield **145** is not necessary to the present invention.

The antenna **170** includes antenna elements **172**, **174**, located within the dielectric housing **120**. In the illustrated

embodiment, the antenna elements **172, 174** are located between the circuit boards **150** and proximate the electric meter circuitry **140**. Of course, the antenna elements **172, 174** may also be located elsewhere within the dielectric housing **120**. The antenna elements **172, 174** are adapted to transmit and receive electromagnetic radiation. The antenna **170** further includes a balance circuit **176**, coupled to the antenna elements **172, 174**, that causes the antenna elements **172, 174** to cooperate to act as a dipole. Again, the present invention is not limited to a dipole.

The balance circuit **176** is couplable to an unbalanced output port **164** of the wireless communication circuit **160** to balance an impedance of the output port **164** and thereby to balance the dipole. The balance circuit **176** may also compensate for unfavorable electromagnetic conditions caused by, for example, sources of constructive and destructive interference within the meter **100**. In one embodiment of the present invention, the balance circuit **176** is a microstrip. Of course, the use of other devices for the balance circuit **176** is well within the broad scope of the present invention.

In the illustrated embodiment, the electric meter circuitry **140** includes current and voltage sensors that scale input voltage and current, thereby allowing metering data (e.g., voltage, current, power, energy usage, power demand, power factor, time of use, interval recordings of energy usage, power quality information, power outage information, site analysis information, diagnostic information, and meter billing information) to be gathered. The data gathered may be instantaneous or may be gathered over a period of time. Those skilled in the art will realize that the present invention is not limited to the types of data mentioned herein, but may also be used to measure and gather other types of data related to the electric power provided and consumed.

The wireless communications circuit **160** and the antenna **170** allow the meter **100** to communicate via wireless communication networks, such as conventional Ardis® or RAM Mobile Systems® Wireless Data networks. The meter **100** may thus report data to the electricity provider. In a preferred embodiment, the communication is bidirectional, allowing the meter **100** to report data or to accept remotely-generated operational commands.

Turning now to FIG. 2, illustrated is a top view of a circuit board **200** containing a wireless communication circuit **260** and an antenna **270** constructed according to the principles of the present invention. In the illustrated embodiment, the wireless communication circuit **260** is a Motorola 505sd transmit/receive modem. Of course, the use of other commercially-available or custom wireless communication circuits is well within the broad scope of the present invention. In one embodiment of the present invention, the wireless communication circuit **260** operates with a carrier frequency of between 700 and 950 megahertz. In a preferred embodiment, the wireless communication circuit **260** transmits at a frequency of about 806 to 825 megahertz and receives at a frequency of about 851 and 870 megahertz. Those skilled in the art will realize that the illustrated frequencies are compatible with conventional Ardis® or RAM Mobile Systems® Wireless Data networks. Of course, the principles of the present invention are equally applicable to other carrier frequencies and other wireless networks.

The antenna **270** contains antenna elements **272, 274**, and a balance circuit **276**. In one embodiment of the present invention, the antenna elements **272, 274** are arcuate, have a flattened lateral cross-section, and generally conform to a portion of an internal surface of a dielectric housing **220**. In

the illustrated embodiment, the antenna elements **272, 274** are composed of 0.028" thick copper, approximately 3.1" long and 0.25" wide, with a radius of curvature of about 2.625". Of course, other conductor shapes and radii of curvature are well within the broad scope of the present invention.

In the illustrated embodiment, the balance circuit **276** is a microstrip circuit board having conductive traces (one of which is labeled **278**) located therein. The balance circuit **276** is coupled to and mechanically supports the antenna elements **272, 274**. The antenna elements **272, 274** may thus cooperate to act as a dipole. The wireless communication circuit **260** has an unbalanced output port **264**, coupled to the balance circuit **276**. In the illustrated embodiment, the conductive traces **278** vary in width and therefore in impedance to balance an output impedance of the unbalanced output port **264**. Of course, the broad scope of the present invention is not limited to this technique.

The circuit board **200** contains a plurality of mounts (one of which is designated **290**) that position the balance circuit **276** above the circuit board **200**. The antenna elements **272, 274** may thus be prevented from contacting and shorting to the circuit board **200**.

Additionally, the mounts **290** allow the balance circuit **276** to be inverted, thereby reorienting the dipole formed by the antenna elements **272, 274**, with respect to the circuit board **200**. Reorientation of the dipole may improve transmission or reception of the wireless communication circuit **260**, depending upon the location in which the meter **100** is mounted. In one embodiment of the present invention, the meter **100** may be mounted to a wall of a building. The antenna elements **272, 274** may thus cooperate to form a vertically-polarized, essentially omnidirectional dipole antenna. In a preferred embodiment, the dipole transmits and receives data over a distance of 10 to 40 miles, depending on environmental conditions, such as weather, line of site obstructions and a height of transmitting and receiving antennas. The meter **100** may thus communicate over the well-known ARDIS® or RAM Mobile Systems® Wireless Data networks.

Positioning the antenna **270** within the dielectric housing **220** may provide a number of advantages. The dielectric housing **220** may protect the antenna **270** from physical damage due to weather or contact with foreign objects. Additionally, strict criminal meter tampering laws may discourage vandals from damaging the antenna **270**. Further, since separate installation of the antenna **270** is not necessary, the meter **100** may be installed using conventional techniques.

From the above, it is apparent that the present invention provides, for use with an electric meter chassis having a dielectric housing (of any geometry) protruding therefrom, an antenna for allowing electric meter circuitry within the chassis to communicate wirelessly through the dielectric housing and a method of manufacturing the same. In one embodiment, the antenna includes: (1) antenna elements, located within and generally conforming to a portion of an internal surface of the dielectric housing and adapted to transmit and receive electromagnetic radiation and (2) a balance circuit, coupled to the antenna elements to cause the antenna elements to act as an antenna and couplable to an unbalanced output port of a wireless communication circuit, that balances an impedance of the unbalanced output port thereby to balance the antenna.

Although the present invention has been described in detail, those skilled in the art should understand that they can

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make various changes, substitutions and alterations herein without departing from the spirit and scope of the invention in its broadest form.

What is claimed is:

1. For use with an electric meter chassis having a dielectric housing protruding therefrom, an antenna for allowing electric meter circuitry located in a circuit board rack within said chassis to communicate wirelessly through said dielectric housing, comprising:

a wireless communication circuit couplable to said electric meter circuitry; and

an antenna element located within said dielectric housing proximate said circuit board rack, said antenna element coupled to said wireless communication circuit.

2. The antenna as recited in claim 1 wherein said antenna generally conforms to a portion of an internal surface of said dielectric housing.

3. The antenna as recited in claim 1 wherein said chassis comprises electric meter circuitry located in said circuit board rack within said dielectric housing, said antenna located between circuit boards in said circuit board rack.

4. The antenna as recited in claim 1 wherein said chassis comprises:

electric meter circuitry located in said dielectric housing; and

an electromagnetic shield located about at least a portion of said electric meter circuitry.

5. The antenna as recited in claim 1 wherein said antenna element is arcuate and has a flattened lateral cross section.

6. The antenna as recited in claim 1 wherein said antenna is a dipole antenna.

7. The antenna as recited in claim 1 wherein said wireless communication circuit has a carrier frequency of between 700 and 950 megahertz.

8. For use with an electric meter chassis having a dielectric housing protruding therefrom, a method of manufacturing an antenna for allowing electric meter circuitry located in a circuit board rack within said chassis to communicate wirelessly through said dielectric housing, comprising the steps of:

providing a wireless communication circuit couplable to said electric meter circuitry; and

locating an antenna element within said dielectric housing proximate to said circuit board rack, said antenna element coupled to said wireless communication circuit.

9. The method as recited in claim 8 further comprising causing said antenna to generally conform to a portion of an internal surface of said dielectric housing.

10. The method as recited in claim 8 further comprising placing electric meter circuitry in said circuit board rack within said dielectric housing, said antenna located between circuit boards in said circuit board rack.

11. The method as recited in claim 8 further comprising:

placing electric meter circuitry in said dielectric housing; and

placing an electromagnetic shield about at least a portion of said electric meter circuitry.

12. The method as recited in claim 8 further comprising forming said antenna into a metal arc having a flattened lateral cross section.

13. The method as recited in claim 8 wherein said antenna is a dipole antenna.

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14. The method as recited in claim 8 further comprising generating a carrier frequency of between 700 and 950 megahertz in a wireless communication circuit.

15. An electric meter, comprising:

an electric meter chassis having a dielectric housing protruding therefrom;

electric meter circuitry located in a circuit board rack within said chassis;

a wireless communication circuit couplable to said electric meter circuitry; and

an antenna element located within said dielectric housing proximate said circuit board rack and coupled to said wireless communication circuit.

16. The meter as recited in claim 15 wherein said antenna generally conforms to a portion of an internal surface of said dielectric housing.

17. The meter as recited in claim 15 further comprising an electromagnetic shield located about at least a portion of said electric meter circuitry.

18. The meter as recited in claim 15 wherein said antenna is arcuate and has a flattened lateral cross section.

19. The meter as recited in claim 15 wherein said antenna is a dipole antenna.

20. The meter as recited in claim 15 wherein said wireless communication circuit has a carrier frequency of between 700 and 950 megahertz.

21. The meter as recited in claim 15 wherein said wireless communication circuit communicates meter billing information.

22. The meter as recited in claim 15 wherein said wireless communication circuit communicates information selected from the group consisting of:

energy usage,
power demand, and
power factor.

23. The meter as recited in claim 15 wherein said wireless communication circuit communicates information selected from the group consisting of:

time of use, and
interval recordings of energy usage.

24. The meter as recited in claim 15 wherein said wireless communication circuit communicates information selected from the group consisting of:

power quality information,
power outage information,
site analysis information, and
diagnostic information.

25. The meter as recited in claim 15 wherein said chassis comprises a capacitively backed up power supply that powers said electric meter circuitry and said wireless communication circuit, thereby allowing said wireless communication circuit to communicate power outage information during a loss of power.

26. The meter as recited in claim 15 further comprising a balance circuit that is a microstrip.

27. The meter as recited in claim 15 wherein said chassis comprises a flex strip connector that couples said wireless communication circuit to said electric meter circuitry.

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