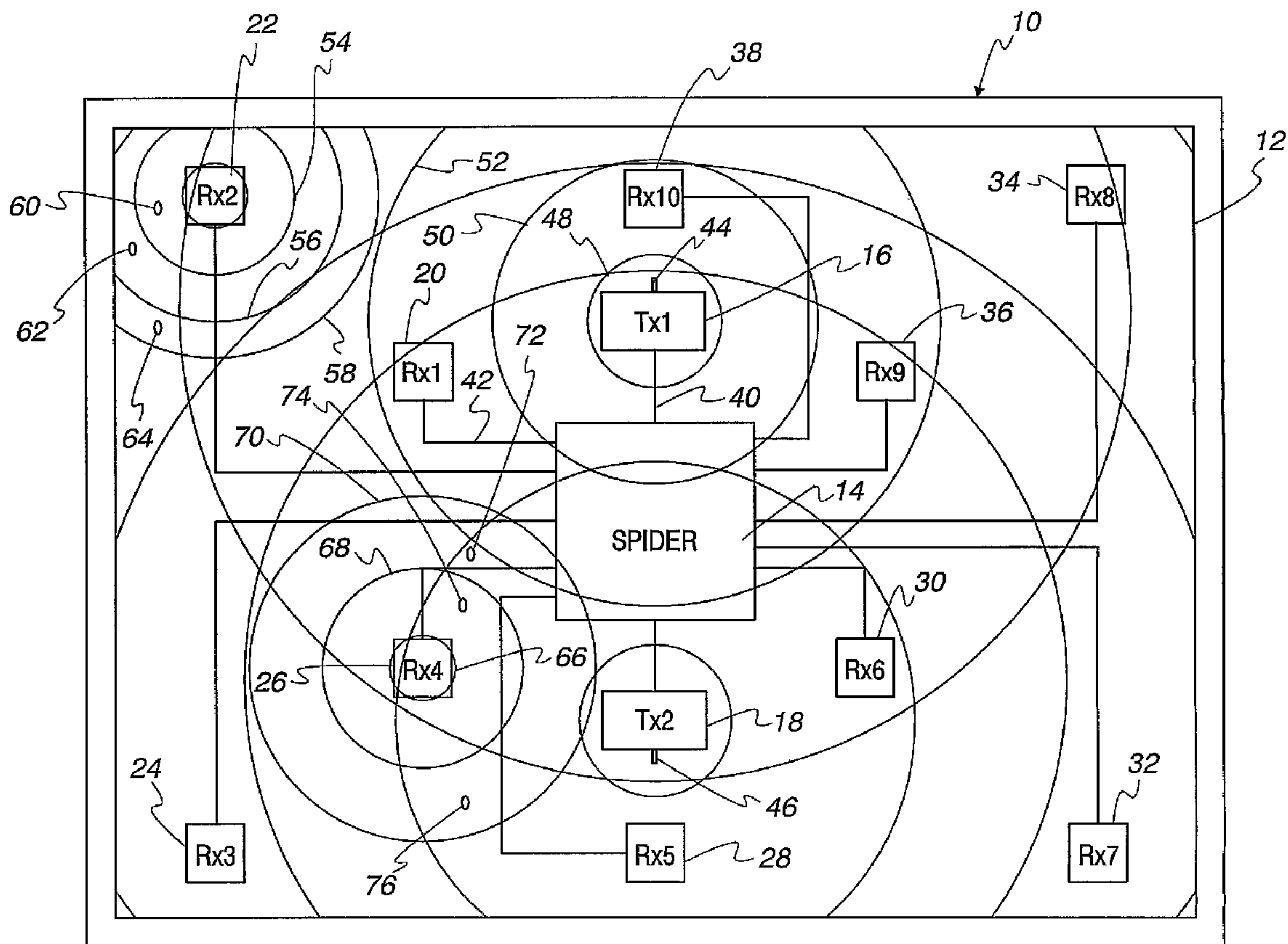




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 (54) Title: DISTRIBUTED ANTENNA ARRAY WITH CENTRALIZED DATA HUB FOR DETERMINING PRESENCE AND LOCATION OF RF TAGS



(57) **Abrégé/Abstract:**  
 A distributed antenna array with a centralized data hub (14) for determining the presence and location of RF tags (24, 28, and 32) is disclosed. A single BRT/hub with multiple antennas attached to transmit and receive ports is used to cover an entire facility.

(57) **Abrégé(suite)/Abstract(continued):**

Large facilities are covered by a small number of the BRT/hub (18) combinations. The BRT/hub (18) has transmit antennas (18) coupled thereto, preferably by co-axial cable, that transmit signals to a portion or all of the RF tags and all or a portion of them modulate and reflect the RF signal to a particular receiving antenna. The receiving antenna then returns the RF signal with tag data to the BRT/hub, preferably by co-axial cable (40).

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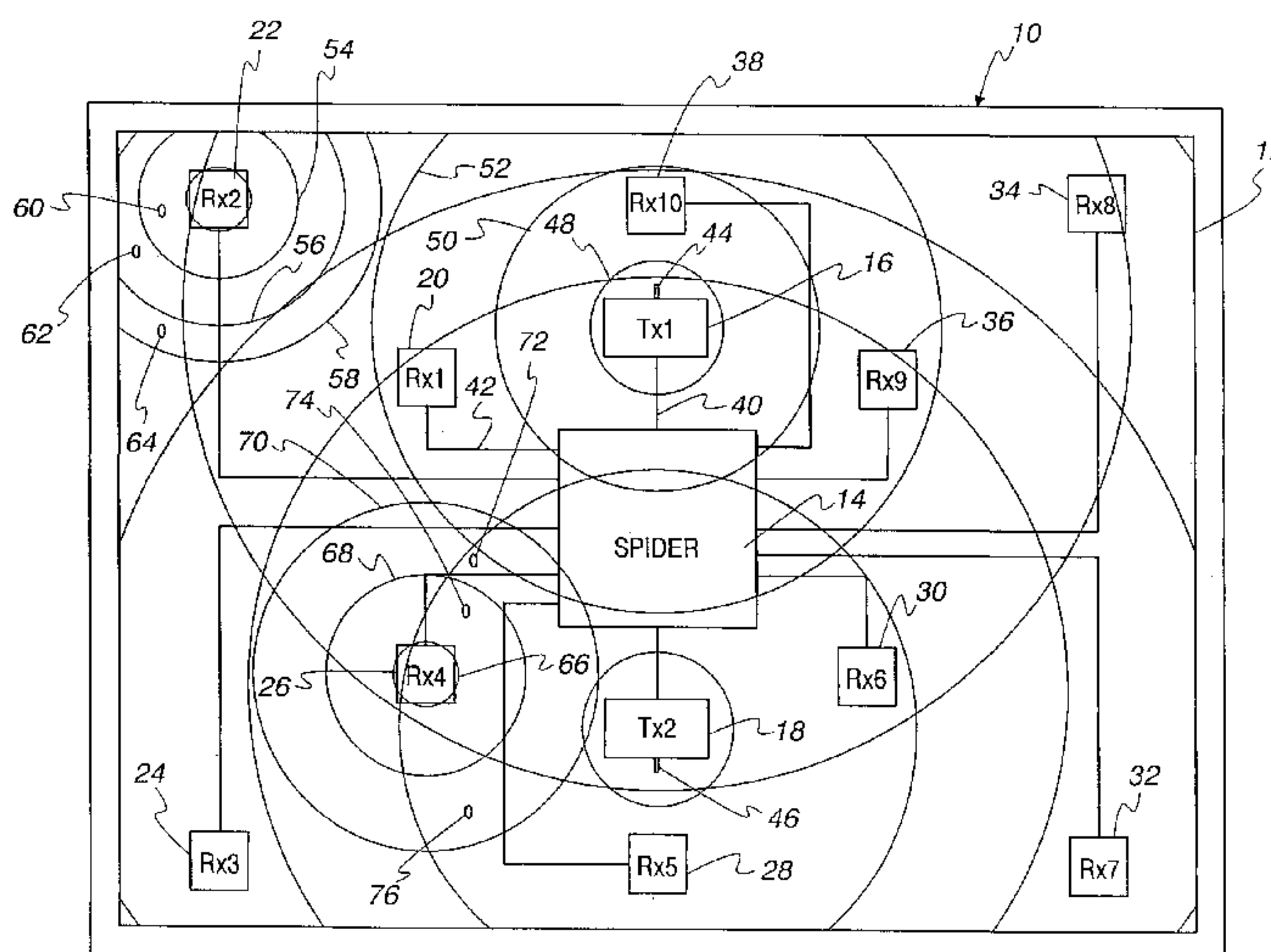
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(57) Abstract: A distributed antenna array with a centralized data hub (14) for determining the presence and location of RF tags (24, 28, and 32) is disclosed. A single BRT/hub with multiple antennas attached to transmit and receive ports is used to cover an entire facility. Large facilities are covered by a small number of the BRT/hub (18) combinations. The BRT/hub (18) has transmit antennas (18) coupled thereto, preferably by co-axial cable, that transmit signals to a portion or all of the RF tags and all or a portion of them modulate and reflect the RF signal to a particular receiving antenna. The receiving antenna then returns the RF signal with tag data to the BRT/hub, preferably by co-axial cable (40).

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**DISTRIBUTED ANTENNA ARRAY WITH CENTRALIZED  
DATA HUB FOR DETERMINING PRESENCE AND  
LOCATION OF RF TAGS**

**FIELD OF THE INVENTION**

The present invention relates in general to a system and method of monitoring compliance with a Point of Purchase (POP) advertising program that displays one or more advertising signs or marketing materials and, specifically, to an improved method and system for monitoring of and exposure to advertising signs or marketing materials displayed at gas stations, convenience stores, grocery stores, mass merchandising outlets, drug stores, specialty retail outlets, consumer electronic stores, and the like. The improved method and system utilizes a Distributed Antenna Array with a Centralized Data Transmitter/Reader for Determining Presence and Location of RF Tags. The improved method and system also utilizes a Switched Backscatter Tag that cleanly switches on and off a resonant aperture to greatly increase the ratio of a reflected “mark” versus “space” in the received backscatter data.

**BACKGROUND OF THE INVENTION**

This invention is an improvement over the invention disclosed and claimed in commonly assigned and published application S.N. US 2004 /0056091, incorporated herein by reference in its entirety. In that patent application, it was pointed out that a need exists for an advertising compliance monitoring system that provides versatility and flexibility by providing an RF tag, associated with a specific sign or product display, that communicates tag data to an external reader.

The prior system includes RF tags of various types (e.g. passive, semi-passive, active, and the like), Backscatter Reader Transmitters (BRT), and hubs. Typically, each BRT is a fully self-contained, battery operated unit, and utilizes three antennas. Two medium-gain patch antennas are used to read the tags, and a whip antenna is used to report the received data over a wireless link to the hub. The major components of the BRT are (1) a backscatter transmitter, (2) a backscatter receiver, (3) a data relay transmitter, (4) a command receiver, and (5) digital processing electronics such as a

micro-controller and a complex programmable logic device (CPLD). The hub contains a higher-end microcomputer module, a data relay receiver, and a two-way pager modem. Each hub has two whip antennas, one to receive the BRT data relay packets, and one to communicate with a pager network. Phone or LAN connections may be substituted for the pager network.

The above described system functions well and is capable of detecting and reporting tags in a variety of retail environments and at different distances. It is desirable, however, to provide an even more economical approach to current functionality by centralizing some or all of the electronics that have been distributed across areas or sub-areas in a given facility, thereby removing redundancy and cost. It is also desirable to increase the read range of tags by the system to minimize the number of antennas required, and to increase the reliability of tags being read under marginal conditions.

### **SUMMARY OF THE INVENTION**

The present invention modifies the prior approach to detecting and reporting presence and location of Radio Frequency (RF) tags across selected zones in retail stores, centralizing the RF transmission and receiving function and means to greatly reduce the expense of recurring components. In this approach, a single BRT/hub (called a "Spider") with antennas attached to multiple transmit and receive ports is used to cover a designated area of a facility, such as drug, grocery, or mass merchandise stores that sell products to consumers and display signage and other advertising material. In small outlets such as a drug store, a single BRT/hub could cover the entire store as the designated area. The "Spider" can be connected to AC power to eliminate cost and maintenance of batteries, as well as allowing more read cycles, if desired. This would also permit higher wattage to be used in the transmit function, potentially increasing the size and reliability of detection zones.

Thus, the use of multiple transmitting antennas and a large number of receiving antennas coupled to the reader enables a single Spider to detect tags in an even larger number of zones or designated areas.

In a small facility, the entire facility can be a designated area and one Spider can detect and reports all tags in the designated area (the entire facility).

In a larger facility, the facility can be divided into multiple designated areas with a plurality of sub-areas forming each of the designated areas. A plurality of display signs and the like are located in each of the sub-areas. Each display sign has an RF tag associated therewith. A single backscatter reader/transmitter (BRT) is placed in each designated area to form the "Spider". The "Web" of antennas in the designated area includes a distributed antenna array that comprises at least one transmitting antenna in or near each designated area that is electronically coupled to the single Spider and positioned to illuminate at least a portion of the plurality of RF tags in each designated area, and also has a single RF signal receiving antenna positioned in each sub-area to receive data from each of the RF tags in the sub-area that have been illuminated by the at least one transmitting antenna and then transfers that data to the single hub for processing. A single transmitting antenna may illuminate tags in a plurality of sub-areas, each containing their own RF receiving antenna.

A novel Switched Backscatter Tag (SBT) is preferably used as the RFID tag. It has a unique antenna that can be switched to change the wavelength of the antenna to cause relatively poor or relatively good reception properties.

Thus, it is an object of the present invention to provide a distributed antenna array with a centralized reader for determining the presence and location of RF tags in a designated area or sub-areas thereof.

It is also an object of the present invention to utilize a plurality of the distributed antenna systems in large facilities wherein the facility is subdivided into designated areas and each designated area has its own distributed antenna array with a centralized reader/transmitter for determining the presence and location of RF tags in sub-areas of each designated area.

It is also an object of the present invention to utilize a Switched Backscatter Tag (SBT) as the RFID tag to provide a dramatic improvement in the ability of the BRT to track the modulated signal containing the RFID tag data across greater distances than can be obtained with traditional RFID tags.

It is another object of the present invention to provide a master hub for receiving tag data from a plurality of centralized reader/transmitters in a plurality of designated

areas and conveying that data to a remote server that processes data from a plurality of facilities.

Thus, the present invention relates to a distributed antenna array with a centralized data reader/transmitter for determining presence and location of RF tags comprising at least one designated area in a selected facility, a plurality of sub-areas in each of the designated areas, a plurality of RF tags in each sub-area, each of the tags being associated with a particular object in the sub-area that is to be monitored, a single backscatter reader/transmitter in each designated area, and a distributed antenna array comprising at least one transmitting antenna electronically coupled to the single reader and positioned to illuminate at least a portion of the plurality of the RF tags in each designated area with a signal, and a single RF signal antenna in each sub-area, and each of the single RF signal antennas in each sub-area receiving data from each of the RF tags in the respective sub-area that has been illuminated by the at least one transmitting antenna and transferring the received tag data to the single hub for transmission back to a remote server that processes data from a plurality of facilities.

The invention also relates to a method of determining presence and location of RF tags using a distributed antenna array with a centralized data reader/transmitter comprising the steps of selecting at least one designated area in a particular facility; selecting a plurality of sub-areas in each of the designated areas; placing a plurality of RF tags in each sub-area, each of the RF tags being associated with a particular object in the sub-area; forming a "Spider" in each sub-area with a single backscatter reader/transmitter; and forming a distributed antenna array ("Web") comprising the steps of positioning at least one transmitting antenna in or near the designated area to illuminate at least a portion of the plurality of the RF tags in the sub-area with a signal; the sub-area having at least one RF signal transmitting antenna being electronically coupled to the single reader; and placing a single RF signal receiving antenna in each sub-area; and receiving data from each of the RF tags in each sub-area that have been illuminated by the at least one transmitting antenna with the single RF signal receiving antenna and transferring the received tag data to the single hub for data transmission to a remote server that processes data from a plurality of facilities. The signal may comprise communication data, depending upon the type of tag used.

The invention further relates to a Switched Backscatter Tag (SBT) for communicating with a BRT comprising an antenna with each side having in one disclosed embodiment a  $1/4\lambda$  (i.e.,  $1/4$  wavelength) antenna element, a switch coupled to one of the  $1/4\lambda$  elements for selectively closing and connecting both antenna elements together to form a  $1/2\lambda$  antenna that reflects the BRT carrier and for opening to create a  $1/4\lambda$  antenna that absorbs at least some of the BRT carrier, and a backscatter frequency generator coupled to the switch for opening and closing the switch cleanly.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

These and other detailed objects of the invention will be described when taken in conjunction with the following detailed description of the drawings in which like numerals represent like elements and in which:

FIG. 1 is a schematic representation of the present invention illustrating a BRT hub (Spider) that covers a designated area such as an entire commercial sales facility;

FIG. 2 is a schematic representation of the present invention in which a plurality of BRT hubs (Spiders) are used in a like plurality of designated areas to cover a larger facility;

FIG. 3 is a schematic representation of an RF transmitter with a High Power Amplifier and a Band-pass filter;

FIG. 4 is a schematic representation of an object having an RF tag associated therewith;

FIG. 5 is a graph illustrating a quadrafilier helix antenna gain patterns to show that the antenna has a low gain on the axis and a high gain on the sides; and

Fig. 6 is a schematic drawing of a Switched Backscatter Tag (SBT) illustrating the manner in which the switch is opened and closed to accept or reject a BRT carrier signal.

### **DETAILED DESCRIPTION OF THE INVENTION**

FIG.1 is a schematic representation of a distributed antenna array with centralized data hub (Spider) for determining the presence and/or location of RF tags.

In FIG. 1, the selected location 10 may be a small store and the designated area 12 covers the entire store. A plurality of sub-areas 20-38 enables coverage of the entire designated area 12 (the entire facility). A BRT hub 14 has attached thereto, preferably by coaxial cables, a plurality of transmitters (TX 1,2) 16-18 and a plurality of receivers (RX

1-10) 22-38. Preferably, only one TX and one RX are active at a time. It will be noted that RX 22 is able to receive data from RF tags 60, 62, and 64 at different distances in the sub-area covered by RX 22 as illustrated by concentric circles 54, 56, and 58. Also it will be noted that the transmitter TX 16 has concentric rings 48, 50, and 52 that illustrate the transmitter-to-tag zones covered by the range of transmitter TX 16 thus showing that the transmitting antenna TX 16 is positioned to illuminate at least a portion of the RF tags (in the RX zones covered by RX 20, 22, 26, 30, 34, 36, and 38) in the designated area. In like manner, TX 18 shows corresponding concentric rings illustrating illumination coverage ranges and representing transmitter-to-tag zones covering at least a portion of the RF tags. Between the two transmitters TX 16 and 18, all of the RF tags in the designated area (the facility 12) are capable of illumination.

Each of the transmitters TX 16 and 18 is coupled to the BRT hub 14 with coaxial cable in the preferred embodiment. In like manner, each of the receiver antennas in each sub-area is coupled to the BRT hub 14 by means of co-axial cable. Of course, wireless connections, or other well-known types of connections could be used, but the preferred embodiment is likely far more economical in operation and installation as compared to multiple battery operated BRT's disposed for adequate coverage over a similar size area.

Thus, when the transmitting antenna 16 illuminates RF tags within its range, preferably one of the RF signal receiving antennas such as RX 22 receives the modulated tag signals and conveys them to the BRT hub 14 over co-axial cable (such as 42) for transmission to a remote server. A modulated RF tag (such as 76) signal may be received by more than one RX antenna when read sequentially (for example RX 26 and RX 28). In such cases, the BRT hub (Spider 14) will forward both RX events to the server, and it will ascertain location within a store using closest zone readings, Received Signal Strength Indicator (RSSI) readings, antenna intersection, or other algorithms known to those skilled the art.

The transmitting antennas 44 and 46, associated with respective transmitters TX 16 and 18, must be omni-directional in order to illuminate tags over a large area. A shaped beam with low gain on axis and a high gain to the sides would be ideal. The well-known quadrafilier helix antenna has those properties. Such antennas have been the choice in orbiting spacecraft communications for years. It has circular polarization and a

shaped beam for high gain when the spacecraft is farthest away on the earth's horizon, and low gain when the spacecraft is closest or overhead. Also, for the present invention, equally important is the low profile of the quadrafilier helix antenna. To a consumer or other observer in the facility, a quadrafilier helix antenna looks like a small white paper towel tube that hangs down a few inches vertically from the ceiling.

Typically, the transmit beam gain from TX 16 to RX 38 would be lower than the transmit beam gain from TX 16 to RX 22. Quadrafilier helix antennas are range compensating. As stated previously, the gain of the antenna is higher for objects farther away, and that feature compensates for free-space power loss due to distance. This is illustrated in FIG. 5 which shows power vs. antenna angle. Higher power levels (gain) at 70 degrees are offset by the bore sight of the antenna.

Further, quadrafilier helix antennas are quite inexpensive. The antennas 44 and 46 shown in FIG. 1, for example, were constructed of materials from a local hardware store and included PVC piping, #12 copper wire, and a small circuit card to maintain proper phasing between the elements. This type of antenna has been experimentally tested in a retail environment, and it has performed flawlessly.

Under FCC rules, part 15, a conducted RF output power of 1 Watt is allowed. The existing BRT's that are used in the system disclosed in commonly assigned, published co-pending patent application, serial number US 2004/0056091, are battery powered, and have a maximum output power of 200mW to conserve battery life while "illuminating" tags (i.e., reflect and receive backscatter modulated signals produced by the tags). Increasing conducted transmitter power will illuminate tags in a larger area and better illuminate tags marginally located in existing zones. The use of the quadrafilier helix antenna enables a gain of approximately 6dbic translating into an Effective Isotropic Radiated Power (EIRP) of +36dBm or 4W. This is an increase of approximately 9dB over the existing BRT patch antenna disclosed in the above identified published and commonly assigned co-pending patent application. This translates into an increase of 8 times the power.

A challenge for any backscatter RF reader is the transmitter power being coupled into the BRT receiver through the receiver antenna. The backscattered signal from the RF tag is extremely small, and its detection can easily be overwhelmed by the backscatter

transmitter carrier wave signal. Therefore, the separation of the TX antenna and the RX antenna as shown in FIG. 1 results in better performance because the deployment system shown in FIG. 1 allows for excellent separation.

Also, the use of the novel Switched Backscatter RFID Tag (SBT) 102 shown in Fig. 6 will also improve the signal communications between the SBT and the BRT. In one embodiment, the SBT 102 has an antenna with each side 104 and 106 of the antenna being approximately  $1/4\lambda$  (i.e.,  $1/4$  wavelength). In the case of a 915 MHz tag, each side is about 3.2 inches long. For a 2.45 GHz tag, these lengths would be approximately 1.2 inches long. Thus, as is well known in the art, for different frequencies, the antenna lengths would also be different. A backscatter generator 110 produces a sub-carrier frequency that contains data such as a tag ID. This backscatter signal opens and closes the RF switch 108 that connects the resonant  $1/4\lambda$  antenna elements 104 and 106. When the switch 108 is in the closed position, the antenna acts as a  $1/2\lambda$  element, which is not a good receiver, and that reflects a higher percentage of the reader carrier frequency back to the reader.

When the switch 108 is in the open position as shown, each antenna side is  $1/4$  of the wavelength of the carrier frequency, which makes it a good receiver, and therefore absorbs more of the reader carrier frequency so it is not reflected back to the reader.

This combination results in a substantial increase in the ratio of a “mark” (a 1 in binary state monitoring) to “space” (a 0 in binary state monitoring) signal received by the BRT. The increased ratio results in a dramatic improvement in the reader’s ability to track the modulated signal containing the tag data across much larger distances. It also allows tags to be read more easily under marginal conditions, such as when they are close to liquid or metal (conditions well known in the art to be quite challenging for tags in the UHF band). In one embodiment, the tag has excellent performance because the antenna is T-shaped, with the antenna elements across the top of the tag, pointing out and away from other circuitry on the printed circuit board. This increases the effectiveness of the available frequency aperture and reduces antenna de-tuning.

Therefore, it is the clean switching between “on” and “off” of a resonant aperture that greatly increases the mark-to-space ratio of the backscatter data as received by the BRT. It is this increased ratio that dramatically improves the BRT’s ability to detect tags

in a specific area of the store area being monitored using a carrier frequency, thereby allowing tags with a cleanly-switched resonant aperture to be detected at a much greater distance than tags without a cleanly-switched resonant aperture.

The system shown in FIG. 1 is ideal for a small commercial sales establishment such as a drug store, but a single Spider would likely be insufficient for larger-format retailers such as grocery or mass merchandiser outlets. In such cases, several Spiders, each with separate Webs, could be used to cover the establishment. Connectivity to phone lines and redundant external communication electronics across multiple Spiders in a store could be circumvented by centralizing those functions into one Master Spider 84. Such a system is shown in FIG. 2.

Note in FIG. 2 that the selected location, or retail sales facility 10, is too large for one Spider. Therefore, in this example, it requires four designated areas 72, 74, 76, and 78 to cover the entire facility 10. Each of the systems in each of the designated areas 72-78 is identical to the system shown in FIG. 1 and operates in an identical manner as described above. However, each of the spiders 80, 82, 84, and 86 could be electronically coupled to a Master Spider 84 as shown.

Multiple Web antennae are connected to a single backscatter transmitter/receiver in the Spider through co-axial cables, in the preferred embodiment, as explained earlier. These co-axial cables will pass through a switch matrix, well-known in the art. This matrix and the long co-axial cables combine to create additional attenuation, thereby lowering the received signal level. To overcome this loss, a Low Noise Amplifier (LNA) is positioned at each RX antenna. These amplifiers draw small amount of current ( $\approx 5\text{mA}$ ) through the co-axial cable using bias tees as is well-known in the art. Locations in retail environments that are difficult or expensive to monitor via co-axial cable, such as external fuel pump signage, could still be served by the previously-designed BRT's with distributed reader/transmitter electronics, and forward their data wirelessly to the Master Spider.

FIG. 3 is a schematic representation of a quadrafilier helix antenna 90. Each such TX antenna is coupled to the Spider through a co-axial cable 92 and has associated therewith a High Power Amplifier 94 to recover co-axial cable signal attenuation. It also

has associated therewith an ISM (Industrial, Scientific, and Medical) band pass filter to reduce noise or harmonics.

FIG. 4 is a schematic representation of an object 98 having an RF tag 100 associated therewith. The object may be a permanent display, Point of Purchase (POP) temporary display, signage, advertising material, stock-alert sensors, merchandising material, category section marker, individual product, or other material desired to be monitored by retailers, manufacturers, or point-of-sale producers. The object may also be a consumer (or movable object) to whom an RF tag is attached so that the shopping (movement) pattern of the consumer can be monitored. In addition, such use will enable the consumer exposure to a given display to be tracked. The RF tag given to a consumer may be a small Active Transmitter Tag (ATT) that uses the same frequency and protocol as the reflection from the semi-passive backscatter tags.

Thus, there has been disclosed a distributed antenna array system with a centralized transmitter/reader hub for determining the presence and location of RF tags that substantially reduces the costs of installation and operation of such existing systems through the elimination of redundant components and batteries. Performance in the present novel system is improved through the addition of transmission power, the use of quadrafilier helix antennas, and elimination of the BRT-hub link. Independent control over each antenna's read periodicity and power provides additional fine-tuning capability for store nuances and monitoring of additional functions such as consumer exposure to displays or stock-alert sensors described elsewhere.

Further, there has been disclosed a novel Switched Backscatter RFID Tag (SBT) that uses an antenna with two  $1/4\lambda$  elements that are connected by a switch that is either closed to create a single  $1/2\lambda$  antenna that is not receptive to the reader signals, or is open to create  $1/4\lambda$  antenna elements that are very good receptors of the reader signals. This SBT results in a significant increase in the "mark" to "space" ratio detected by the reader, and causes dramatic improvement in the reader's ability to track the modulated signal containing the RFID tag data across much larger distances than previously available.

While particular embodiments of the invention have been shown and described in detail, it will be obvious to those skilled in the art that changes and modifications of the present invention, in its various embodiments, may be made without departing from the

spirit and scope of the invention. Other elements, steps, methods, and techniques that are insubstantially different from those described herein are also within the scope of the invention. Thus the scope of the invention should not be limited by the particular embodiments described herein but should be defined by the appended claims and equivalents thereof.

## WHAT IS CLAIMED IS:

1. A distributed antenna array system with a centralized data reader/transmitter for determining presence and location of RF tags comprising:
  - at least one designated area in a facility;
  - a plurality of sub-areas in each of the designated areas;
  - a plurality of RF tags to be dispersed in each sub-area, each of the tags being associated with a particular object in the sub-area;
  - a single backscatter reader/transmitter (BRT) in each designated area; and
  - a distributed antenna array in the facility comprising:
    - at least one transmitting antenna electronically coupled to the single BRT and positioned to illuminate at least a portion of the plurality of the RF tags in each designated sub-area with a carrier signal containing:
      - a single RF signal receiving antenna in each sub-area; and
      - each of the single RF signal antenna in each sub-area receiving data from each of the RF tags in the sub-area that have been illuminated by the at least one BRT transmitting antenna and transferring the received tag data to the single hub.
2. The system of claim 1 wherein:
  - the selected facility is a product sale facility; and
  - the particular object associated with a tag is a product display, sign, merchandising or advertising material ("Display").
3. The system of claim 1 wherein the system determines that the Display is present in a sub-area in the facility where a person may see or interact with the Display.
4. The system of claim 1 wherein the system determines that the Display is properly installed in a particular location in the sub-area.
5. The system of claim 4 wherein the system determines that the Display is present in the particular location for an appropriate period of time.

6. The system of claim 1 wherein the RF tag is carried by a person in the facility to enable market testing through the use of data collected concerning the Displays in the particular locations visited by the person and the time spent in each particular location.

7. The system of claim 1 wherein the at least one transmitting antenna is a quadrafilier helix antenna having a shaped beam with low gain on axis and high gain to the sides.

8. The system of claim 1 wherein:  
each transmitting antenna is connected to the single backscatter reader/transmitter by a coaxial cable; and  
each transmitter antenna contains a high power amplifier to recover coaxial cable signal attenuation and a band-pass filter at the proper frequency to reduce noise and/or harmonics.

9. The system of claim 1 wherein the distributed antenna array comprises:  
a plurality of transmitting antennae, each of the transmitting antennae being located in or near the designated area to transmit communication signals to at least a portion of the RF tags located in at least some of the sub-areas.10. The system of claim 1 further comprising:

a plurality of designated areas in the facility;  
a single BRT/hub ("Spider") for illuminating at least a portion of the RF tags in each designated area; and  
a plurality of Spiders for receiving response signals from at least a portion of the illuminated RF tags and coupling the response signals to the single master BRT/hub that transmits the data to a server that processes data.

10. The system of claim 1 wherein each RF tag comprises:  
an antenna system with a resonant aperture; and  
a switch coupled to one or more elements of the antenna system to cleanly

connect and disconnect selected portions of one or more elements of the antenna system to greatly increase the mark-to-space ratio of the backscatter data.

11. The system of claim 1 wherein each RF tag comprises:

an antenna with two  $1/4\lambda$  antenna elements;

a switch coupled to one of the  $1/4\lambda$  antenna element for selectively closing and connecting both antenna elements together to form a  $1/2\lambda$  antenna that reflects the BRT carrier signal and for opening to create two  $1/4\lambda$  antenna elements that absorb at least some of the BRT carrier signal; and

a backscatter frequency generator coupled to the switch for selectively opening and closing the switch.

12. A method of determining presence and location of RF tags using a

distributed antenna array with a centralized data hub comprising the steps of:

selecting at least one designated area in a particular facility;

selecting a plurality of sub-areas in each of the designated areas;

placing a plurality of RF tags in each sub-area, each of the tags being associated with a particular object in the sub-area;

placing a reader/transmitter in each designated area; and

forming a distributed antenna array comprising the steps of:

positioning at least one transmitting antenna in or near the designated area to illuminate at least a portion of the plurality of the RF tags in the sub-areas with communication data; the transmitting antenna being electronically coupled to the single reader/transmitter; and

placing a single RF signal receiving antenna in each sub-area; and

receiving data from each of the RF tags in each sub-area that has been illuminated by at least one transmitting antenna with the single RF signal receiving antenna and transferring the received data to the single hub for data transmission to a server for processing.

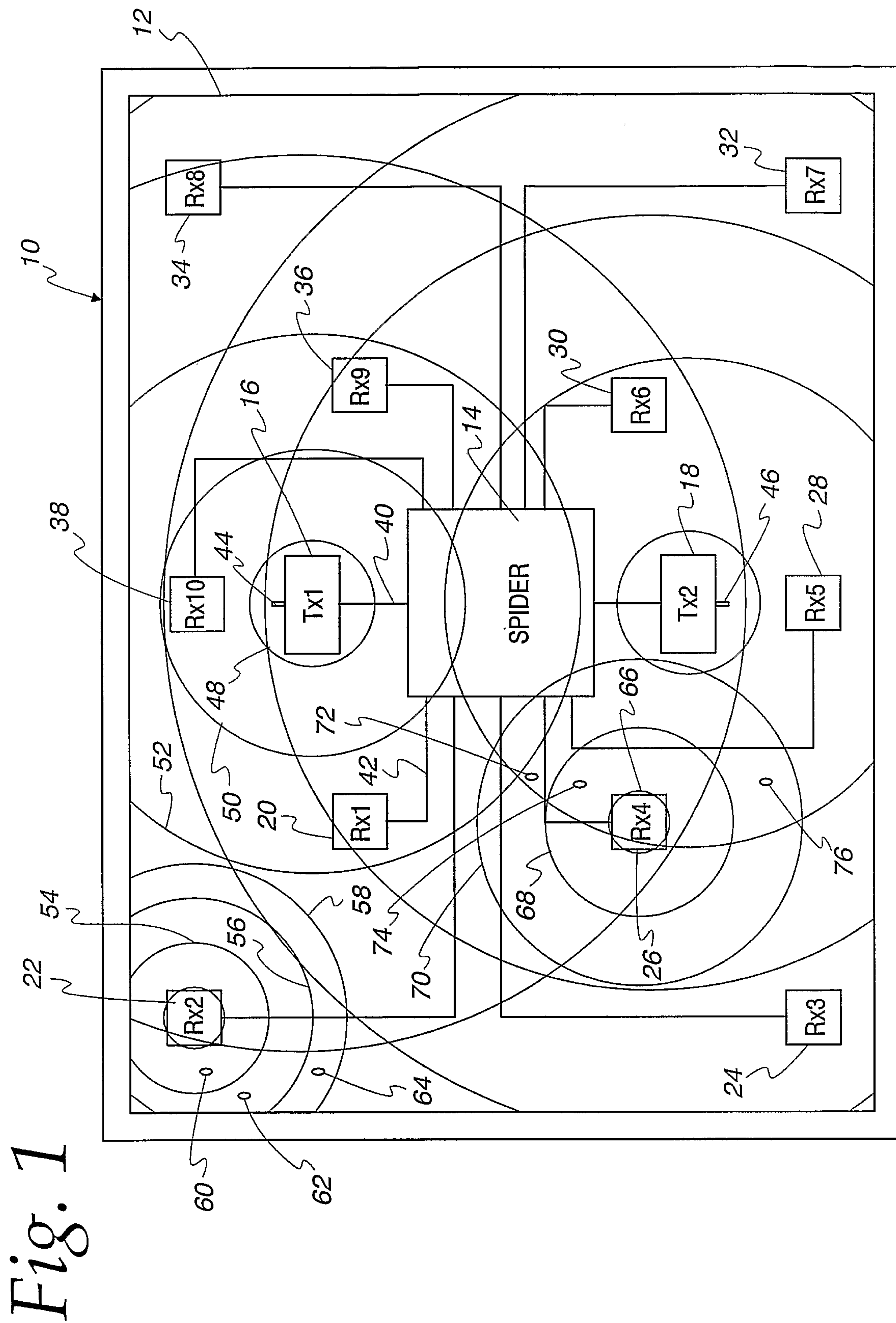


Fig. 1

Fig. 2

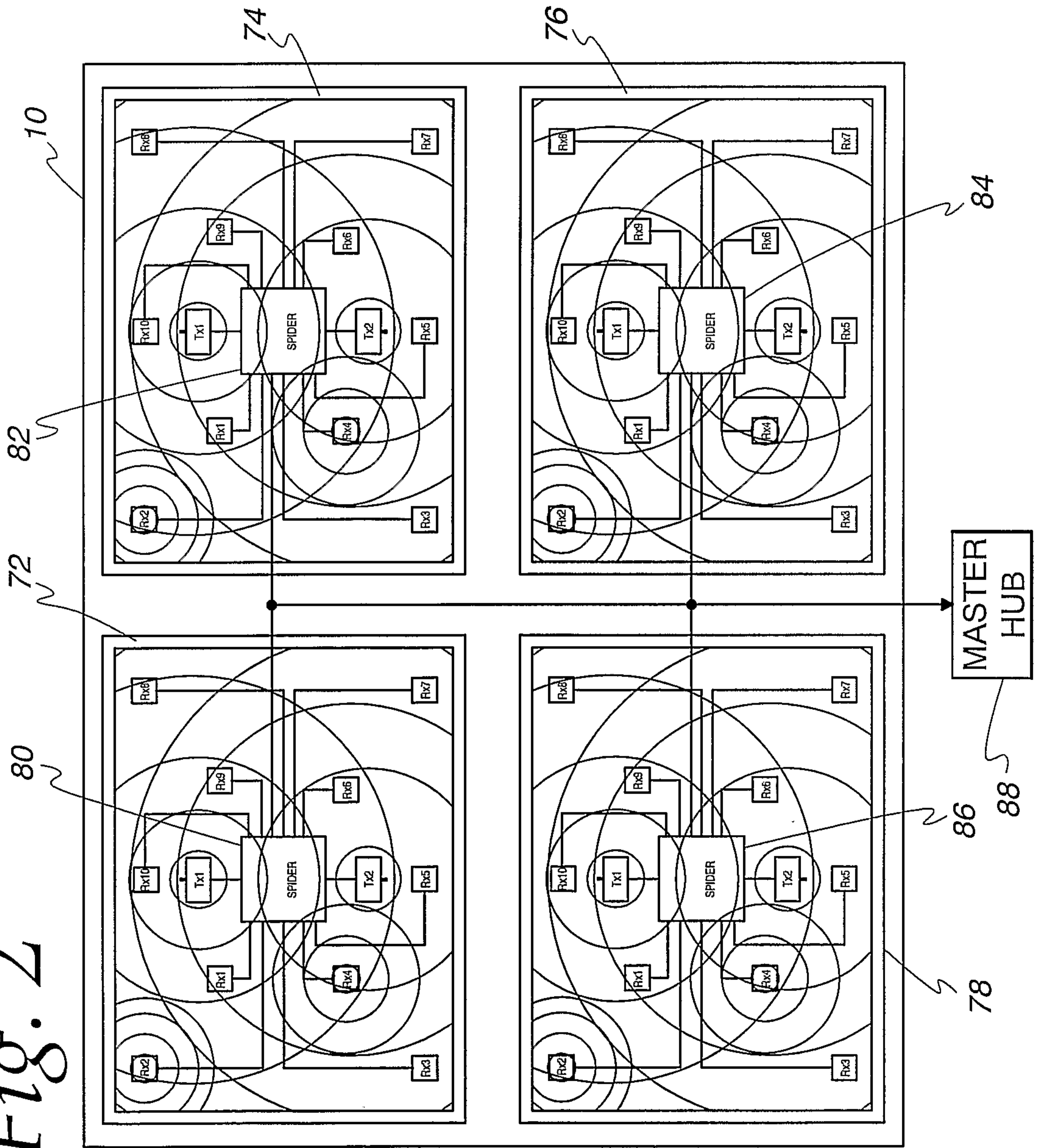


Fig. 3

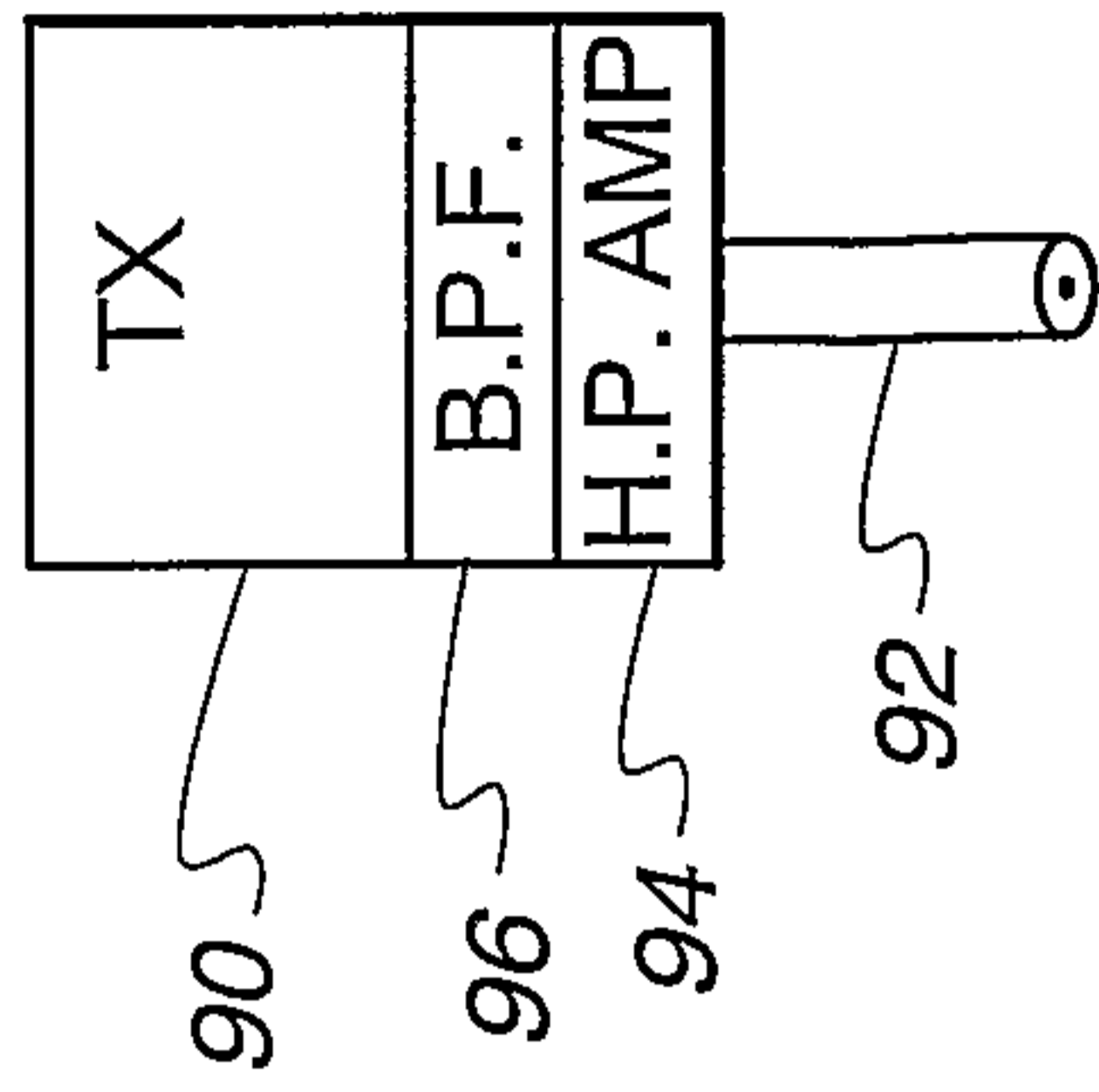


Fig. 4

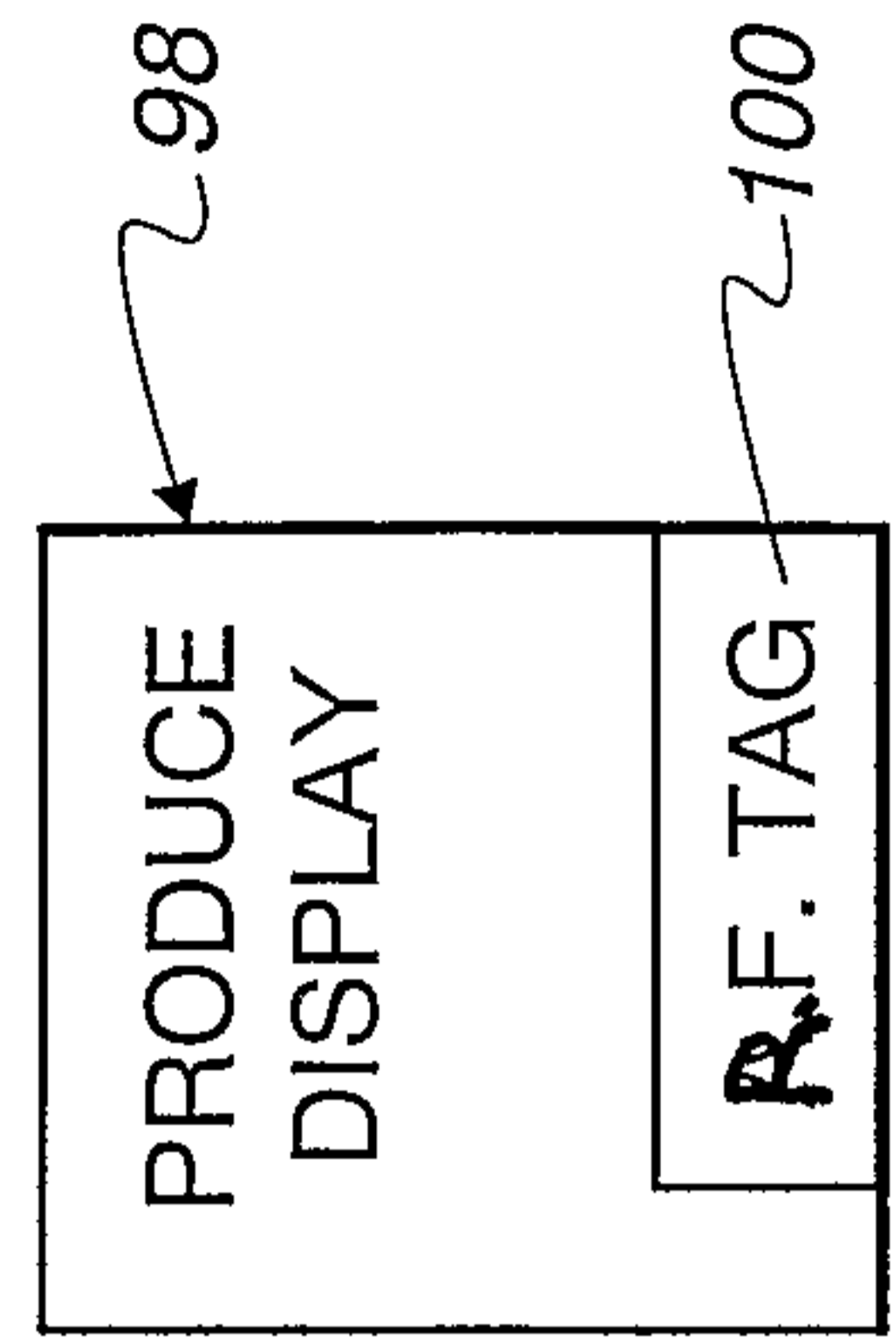


Fig. 5

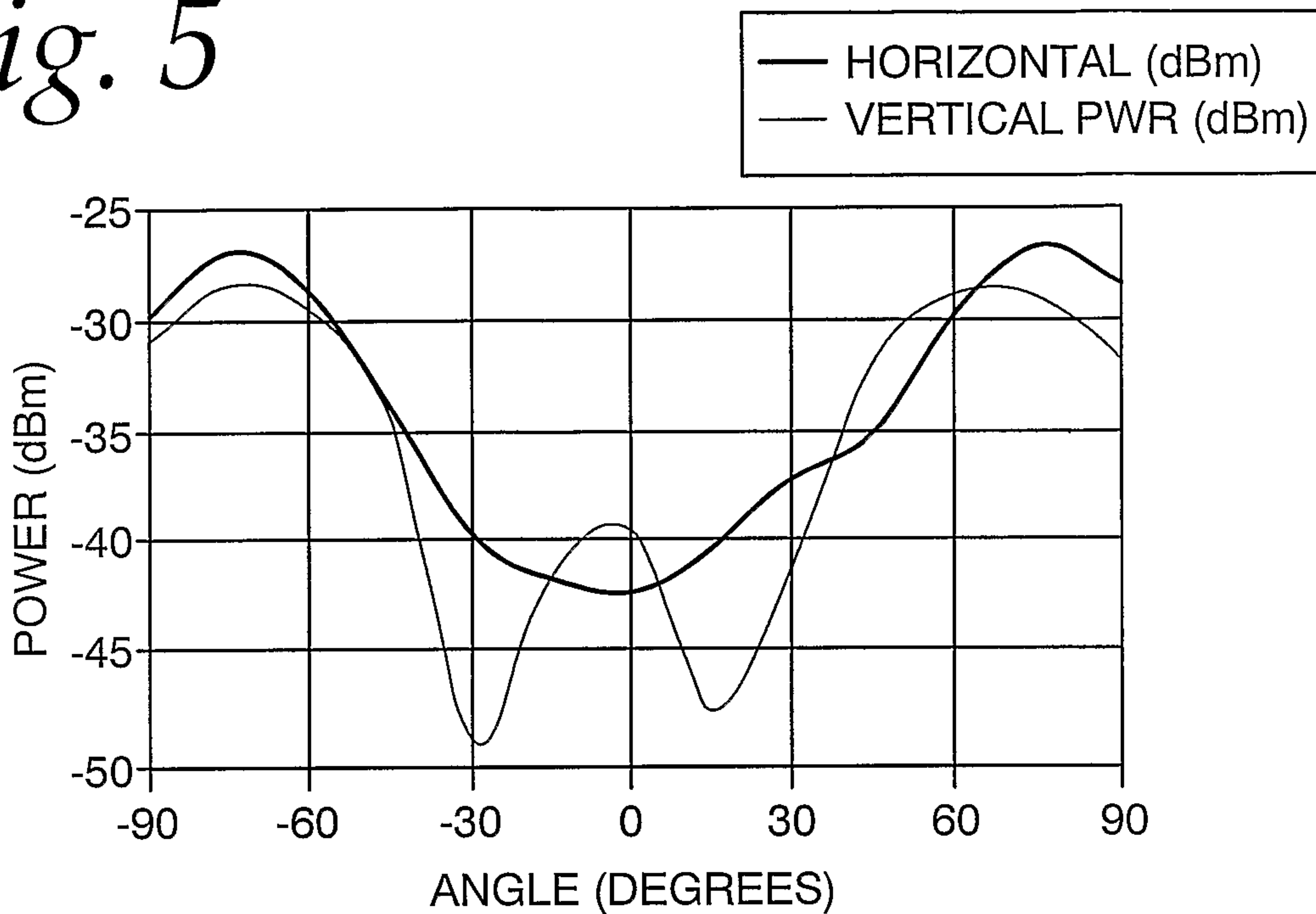


Fig. 6

