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Grossman

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(54) **COMMUNICATION SYSTEM FOR SPATIALLY-ENCODED WIRELESS COMMUNICATIONS**

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H04L 7/02	(2006.01)
H04B 7/06	(2006.01)
H01Q 21/06	(2006.01)
H04L 27/26	(2006.01)
H04L 1/06	(2006.01)

(52) **U.S. Cl.**
CPC ***H04B 7/06*** (2013.01); ***H01Q 21/061*** (2013.01); *H04B 7/0602* (2013.01); *H04L 1/0625* (2013.01); *H04L 27/2626* (2013.01)

(58) **Field of Classification Search**
CPC H04B 7/04; H04B 7/0404; H04B 7/0602; H04B 7/0604; H04B 7/0669; H04B 7/0697; H04L 1/0606; H04L 1/0625; H04L 1/0612; H04L 1/0675; H04L 5/0023; H04L 27/00; H04L 27/0002; H04L 27/2601; H04L 27/2626
USPC 455/101, 102, 272, 107; 375/260, 315
See application file for complete search history.

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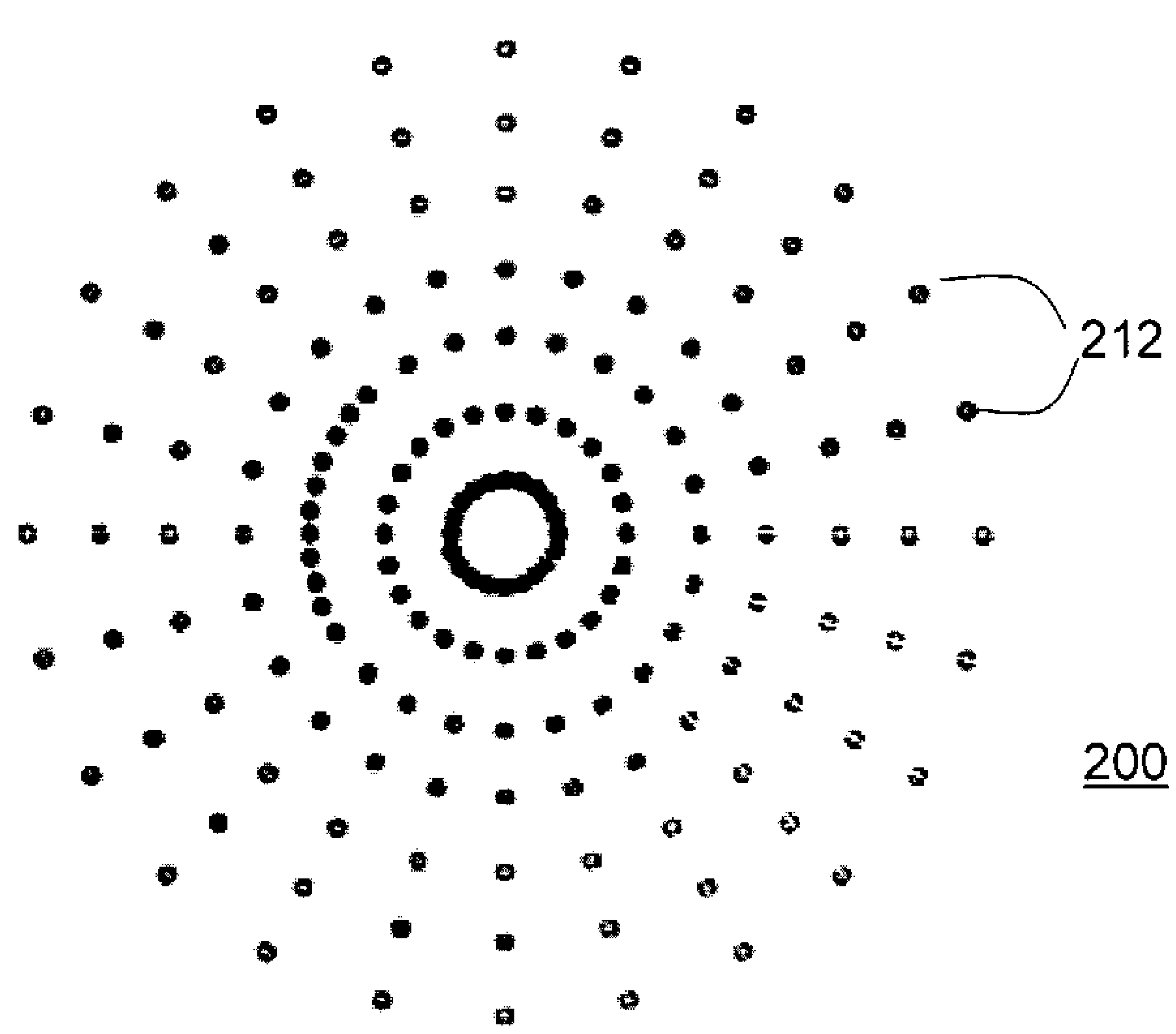
(57) **ABSTRACT**

A method of spatially-encoded wireless transmission using a wireless communications device that is configured with an electromagnetic radiator involves applying a modulated carrier to one or more radiator elements of the electromagnetic radiator. The radiator elements are selected based on instantaneous samples of baseband information, and the modulated carrier is generated from the baseband information. The modulated carrier is then transmitted via the selected radiator elements.

14 Claims, 4 Drawing Sheets



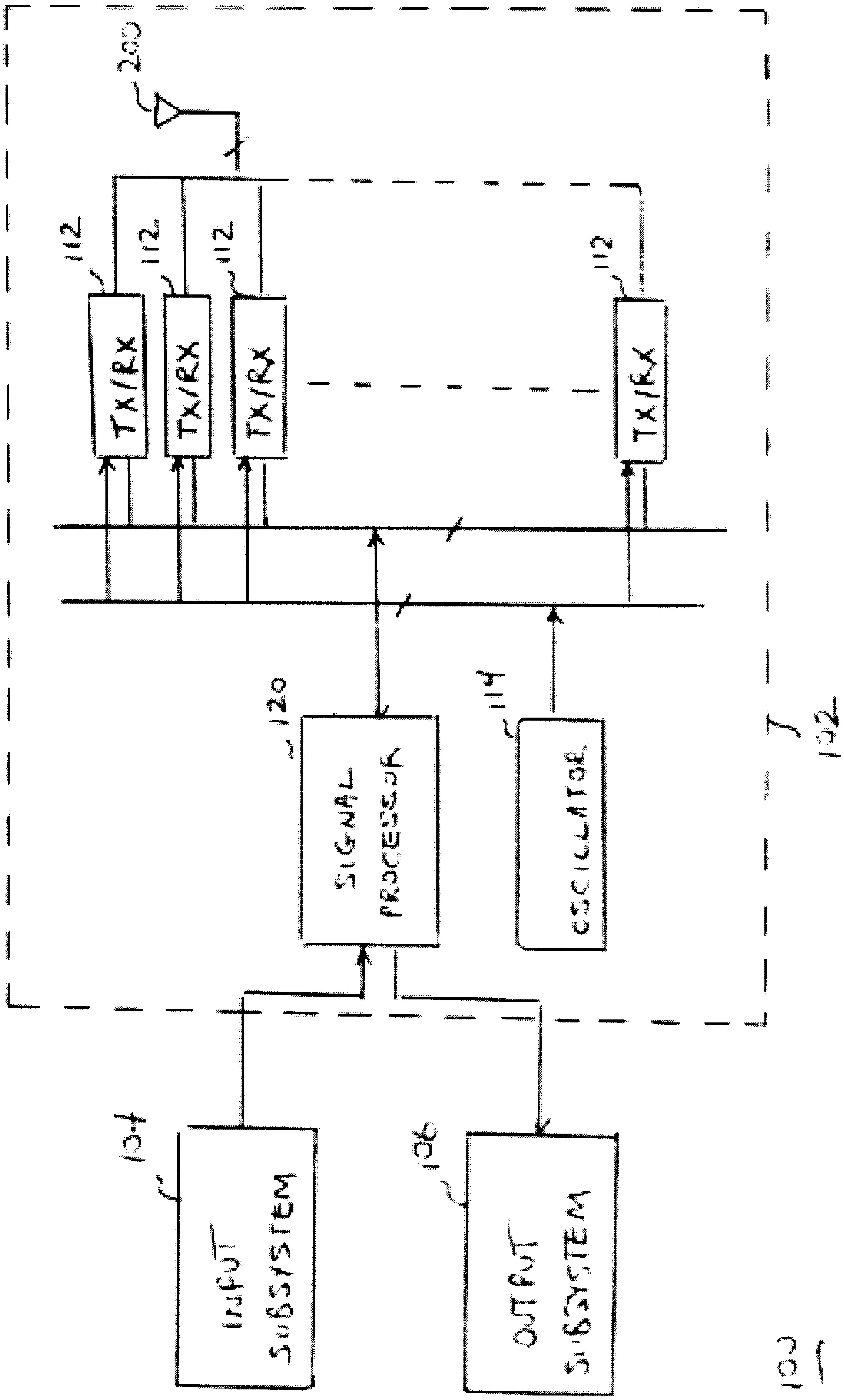

200
112
TX/RX
TX/RX
TX/RX
TX/RX
120
SIGNAL PROCESSOR
114
OSCILLATOR
102
104
INPUT SUBSYSTEM
106
OUTPUT SUBSYSTEM
100

Fig. 1

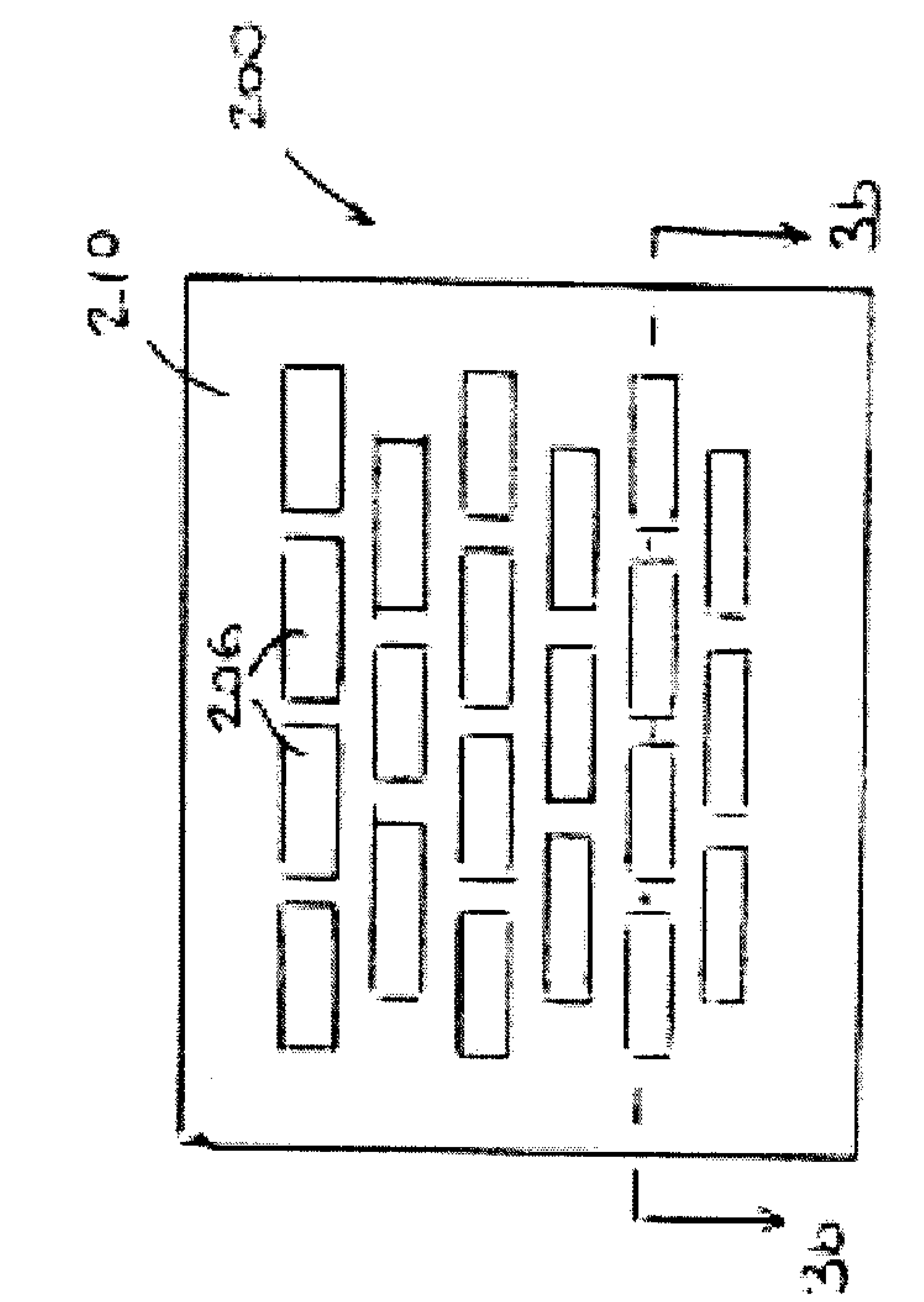


Fig. 4a

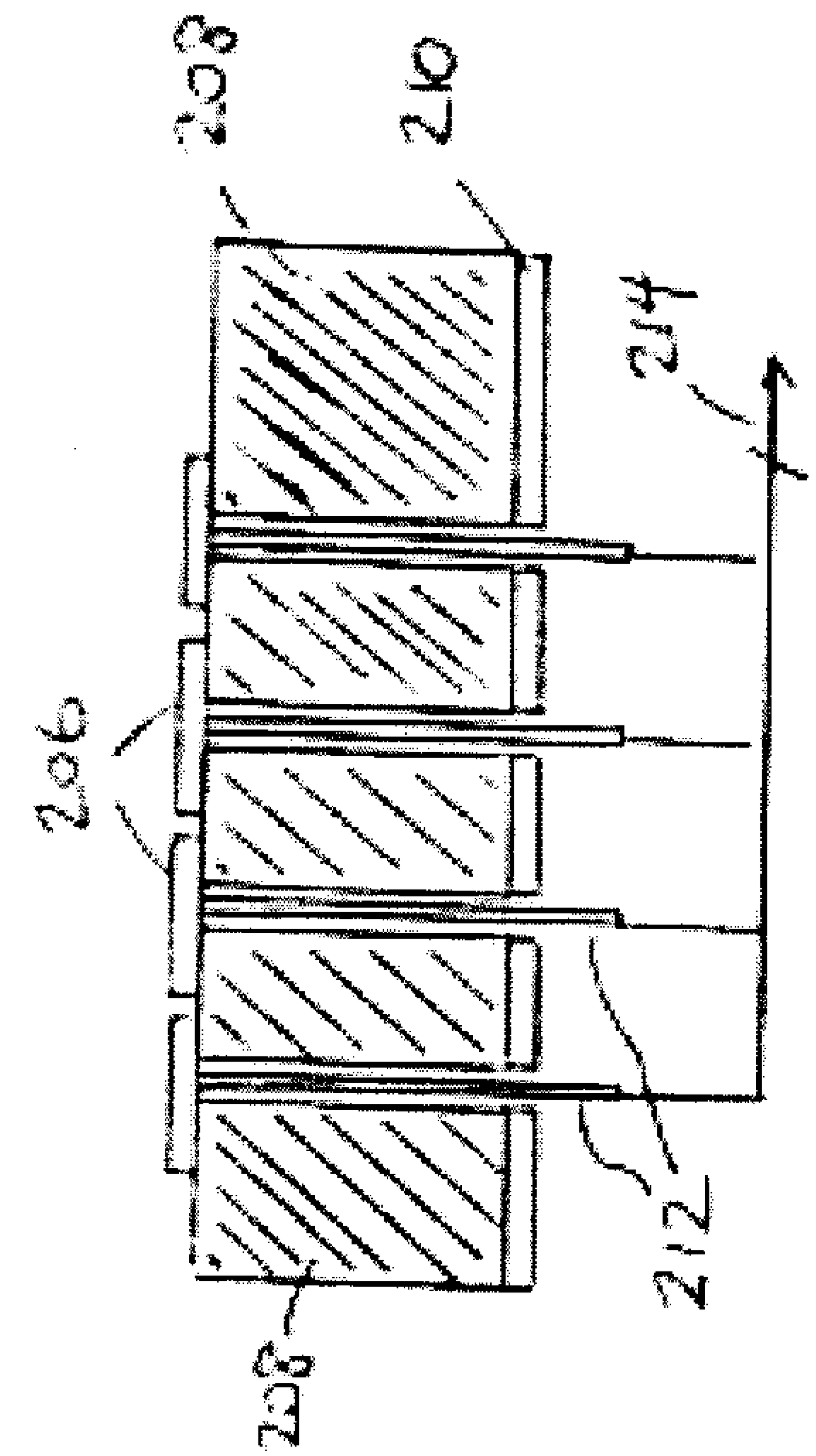


Fig. 4b

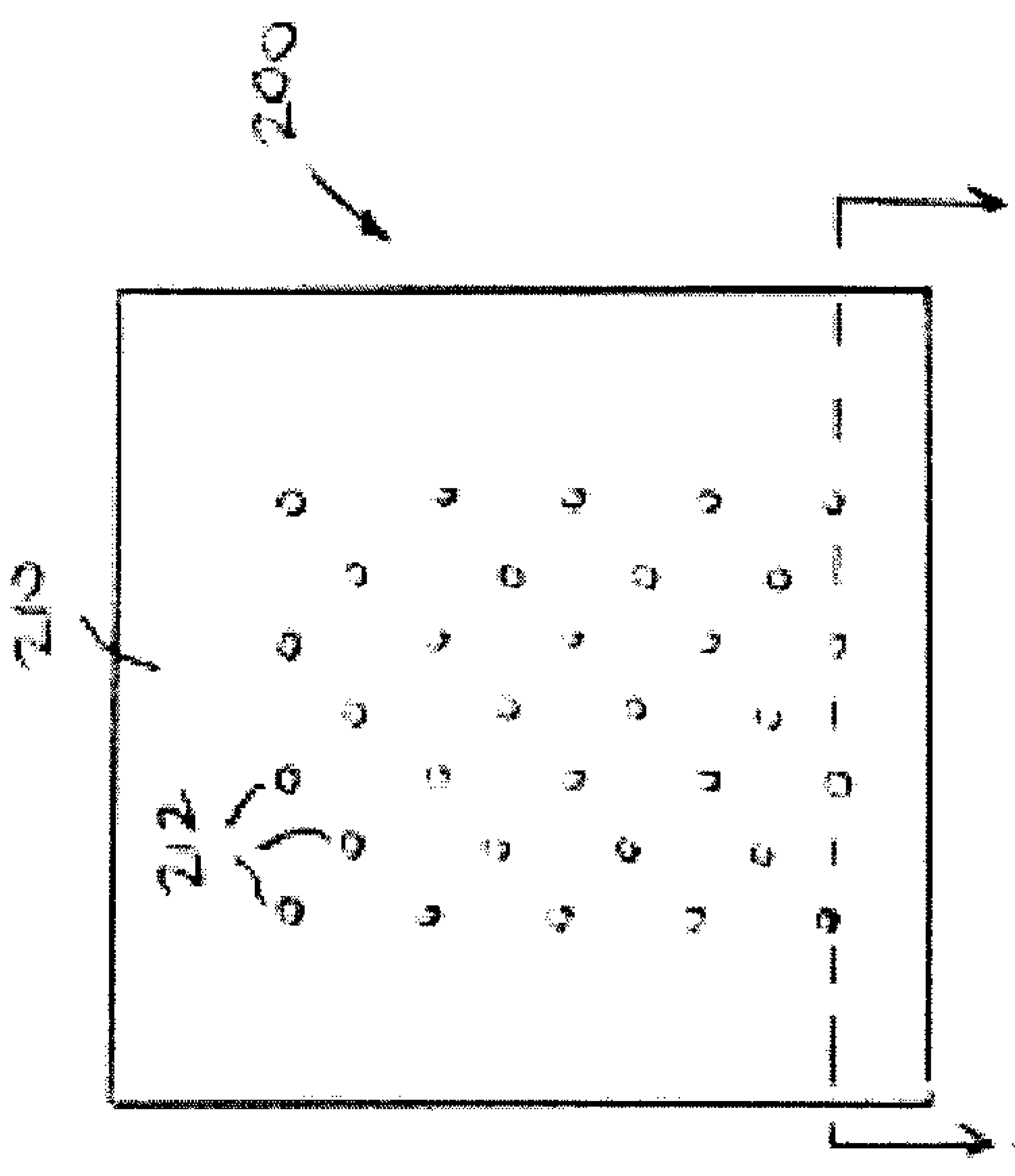


Fig. 2a

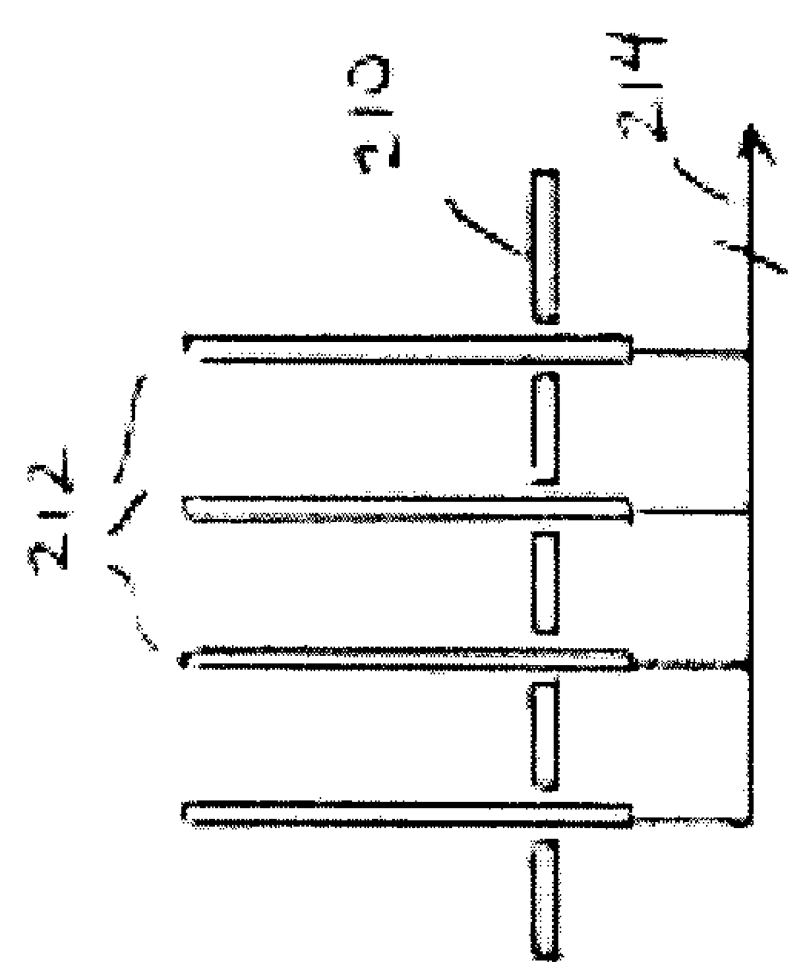


Fig. 2b

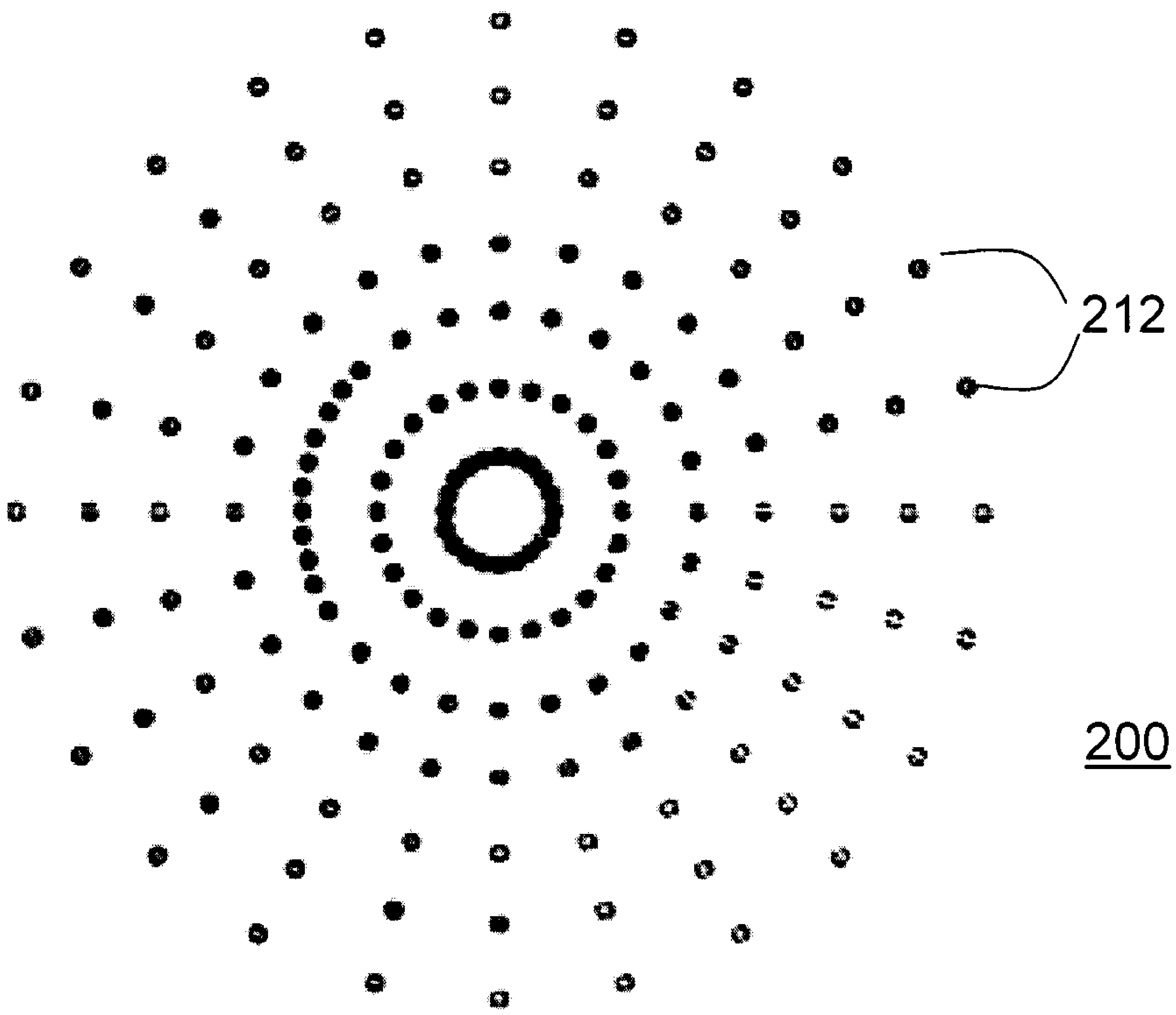


Fig. 3

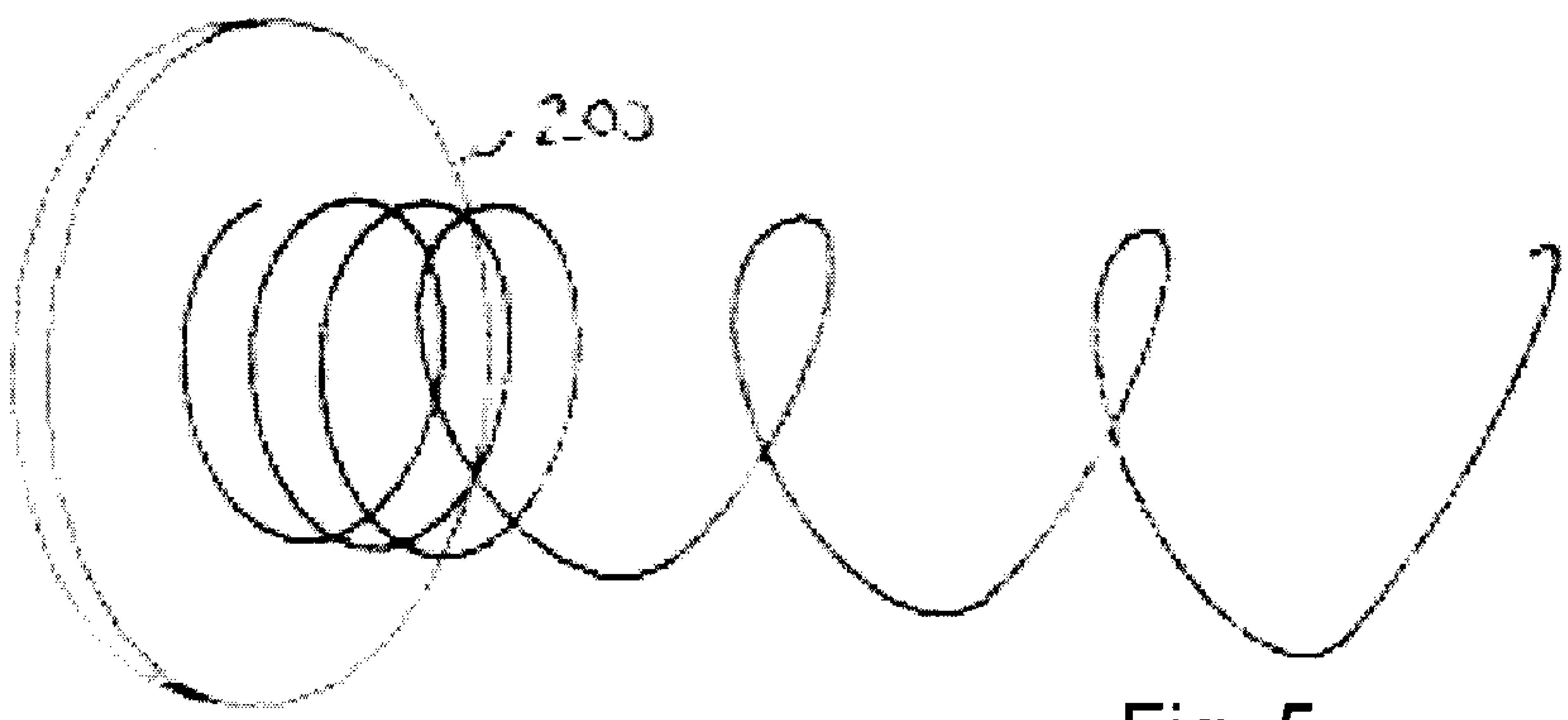


Fig. 5

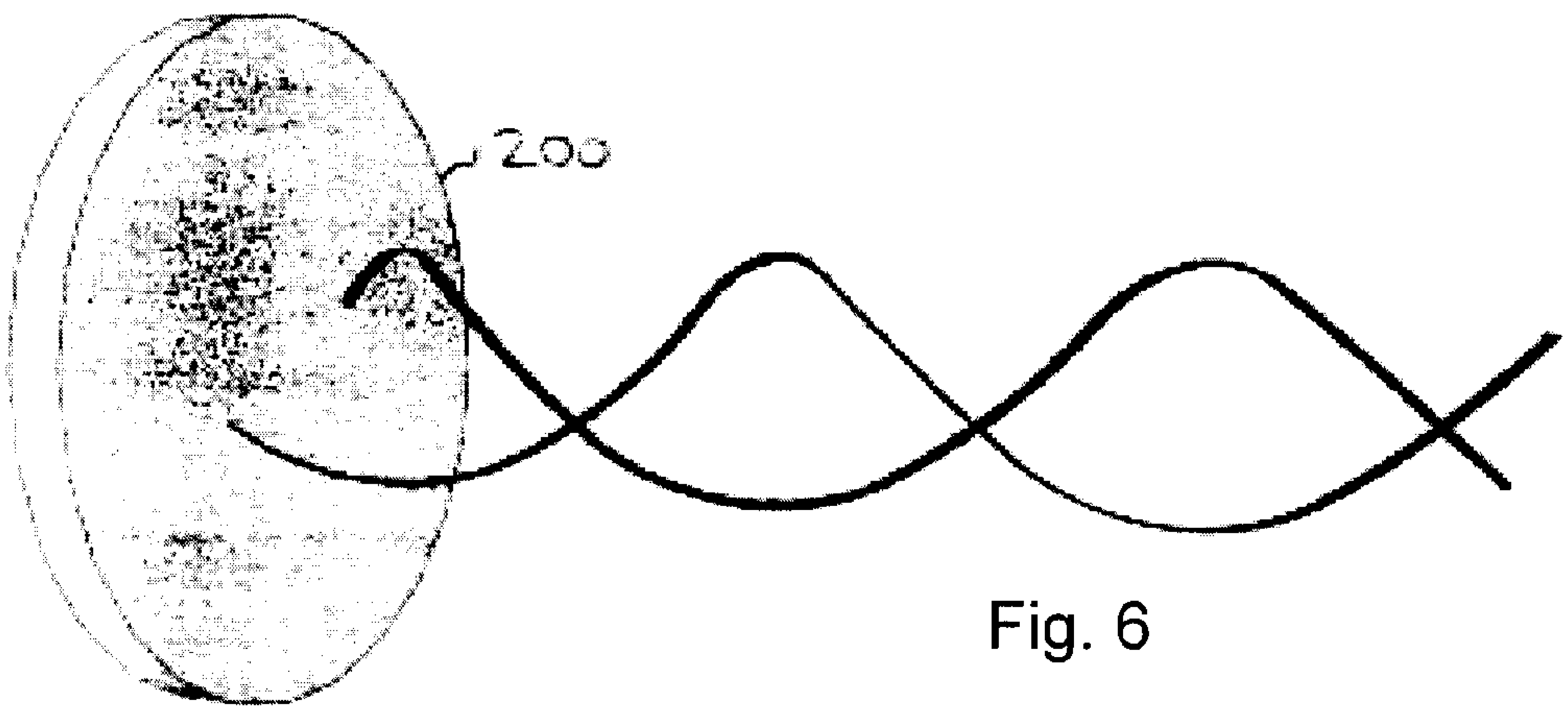


Fig. 6

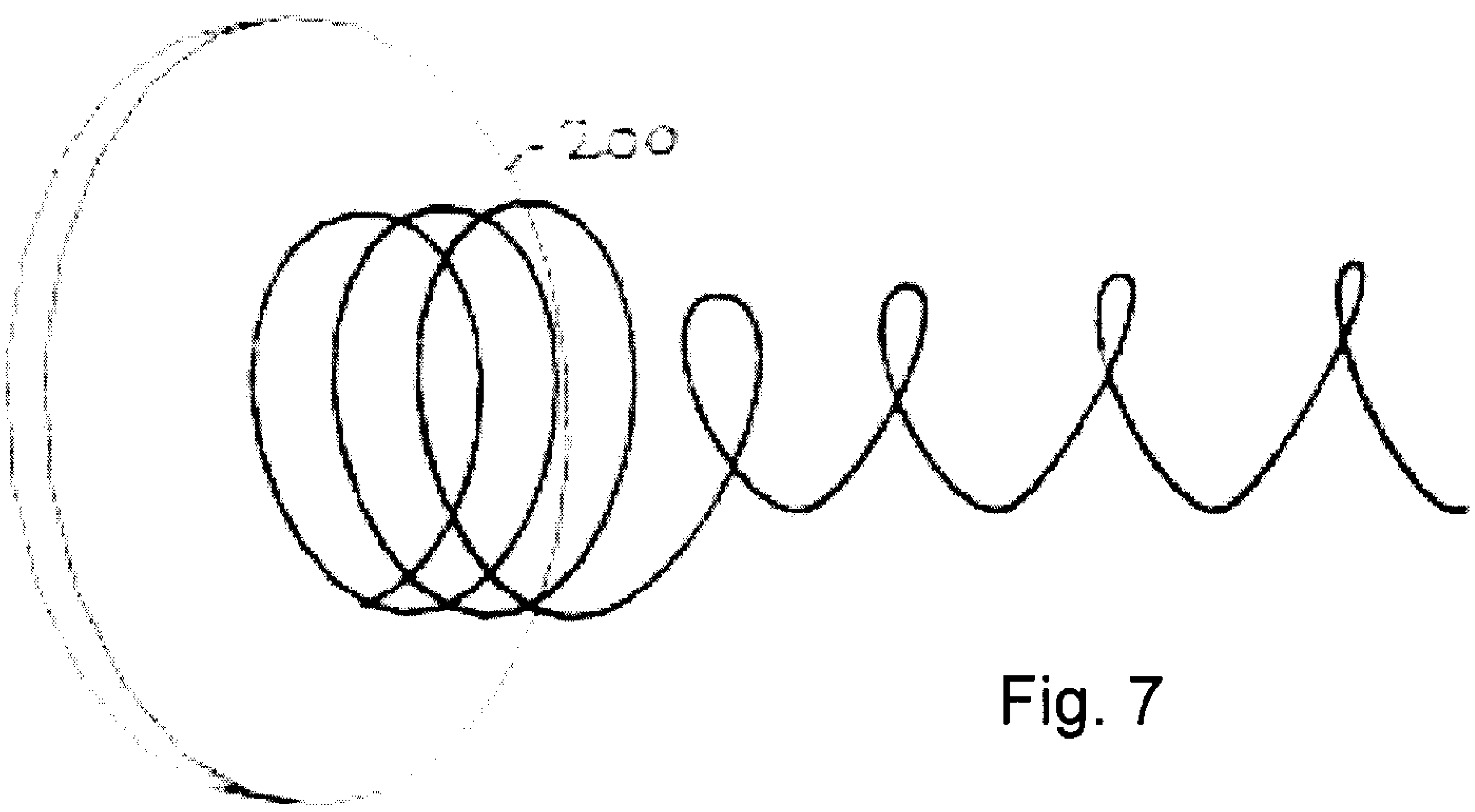


Fig. 7

COMMUNICATION SYSTEM FOR SPATIALLY-ENCODED WIRELESS COMMUNICATIONS

RELATED APPLICATIONS

This patent application claims the benefit of the filing date of U.S. provisional patent application Ser. No. 61/515,117, filed Aug. 4, 2011, entitled "Communication System for Spatially-Encoded Wireless Communications".

FIELD OF THE INVENTION

This patent application relates to a method and system of wireless communication.

BACKGROUND

RF wireless communications devices include a RF antenna and transceiver that allows the communications device to transmit and receive wireless information via a wireless communications protocol. Known wireless communications protocols include long-range protocols (e.g. GSM, GPRS, CDMA, EDGE, UMTS, EvDO, HSPA) and short-range protocols (irDA, Bluetooth (IEEE 802.15), and WiFi (IEEE 802.11x)). None of these communications protocols make optimum use of the available communications bandwidth.

SUMMARY

This patent application describes a wireless communications device and associated communications protocol that allows the communications device to wirelessly transmit information by spatially-encoding an electromagnetic carrier (e.g. modulating the diameter and/or radial position and/or angular position of the carrier) with a portion of the information to be transmitted.

In accordance with a first aspect of the disclosure, there is provided a wireless communications device that comprises an electromagnetic radiator and a signal processor coupled to the radiator. The electromagnetic radiator comprises an array of electromagnetic radiator elements. The signal processor is configured to effect applying of a modulated electromagnetic carrier to one or more of the radiator elements selected, in real-time, based on instantaneous samples of baseband information, and to effect transmission of the modulated carrier via the selected radiator elements. The modulated carrier is generated from the baseband information.

In accordance with a second aspect of the disclosure, there is provided a method of wireless transmission of baseband information using a wireless communications device. The wireless communications device is configured with an electromagnetic radiator comprising an array of electromagnetic radiator elements. The method comprises the wireless communications applying a modulated carrier to one or more of the radiator elements of the electromagnetic radiator, and transmitting the modulated carrier via the selected radiator elements. The wireless communications device selects the one or more radiator elements, in real time, based on instantaneous samples of baseband information. The wireless communications device generates the modulated carrier from the baseband information.

The signal processor may be configured to select the one or more radiator elements so as to vary the diameter of the transmitted carrier based on the instantaneous baseband information. The signal processor may be configured to select the one or more radiator elements so as to vary the radial position of the transmitted carrier, relative to a centre of the transmission, based on the instantaneous baseband information. The signal processor may be configured to select the one or more radiator elements so as to vary the angular position of the transmitted carrier, relative to a reference angular position, based on the instantaneous baseband information.

Since a portion of the baseband data is encoded into the carrier by modulating the diameter and/or the radial position and/or the angular position of the carrier, the wireless communications device and the method of wireless transmission can make better use of the available communications bandwidth.

BRIEF DESCRIPTION OF THE DRAWINGS

An exemplary wireless communications device, and method of wireless transmission will now be described, with reference to the accompanying drawings, in which:

FIG. **1** is a schematic view of the communications device, depicting the signal processor, a local oscillator, and an electromagnetic radiator;

FIGS. **2***a* and **2***b* are respectively a top plan view and a side elevation of a first embodiment of the electromagnetic radiator;

FIG. **3** depicts a second embodiment of the electromagnetic radiator;

FIGS. **4***a* and **4***b* depict a third embodiment of the electromagnetic radiator;

FIG. **5** depicts a sample wireless transmission according to the method of wireless transmission in which the rate of change of angular position of the transmitted carrier varies based on the baseband information;

FIG. **6** depicts a sample wireless transmission in which the radial position of the transmitted carriers vary based on the baseband information; and

FIG. **7** depicts a sample wireless transmission in which the radial position and the rate of change of angular position of the transmitted carrier varies based on the baseband information.

DETAILED DESCRIPTION

FIG. **1** is a schematic view of a wireless communications device, denoted generally as **100**. Preferably, the wireless communications device **100** is a two-way wireless communications device. Depending on the exact functionality provided, the wireless communications device **100** may be referred to as a wireless data communication device, a wireless telephone, a portable computer, or a wireless base station, as examples.

The wireless communications device **100** includes a communication subsystem **102**, and may also include an input subsystem **104** and an output subsystem **106** both coupled to the communication subsystem **102**. The input subsystem **104** allows the user of the wireless communications device **100** to provide data and/or voice input to the wireless communications device **100**, and may include a keyboard and/or a microphone, as examples. The output subsystem **106** provides visual and/or sound output for the user of the wireless communications device **100**, and may include a LCD display and/or a speaker, as examples.

The communication subsystem **102** performs communication functions, such as data and voice communications, and includes a plurality of transceivers (transmitters/receivers) **112**, and a local oscillator **114**, an electromagnetic radiator **200** and a signal processor **120** coupled to the transceivers **112**. Electromagnetic signals are received by the electromagnetic radiator **200** and intended for receipt by the output subsystem **106** are input to the transceivers **112**, which perform functions such as frequency down conversion and analog to digital conversion, in preparation for more complex communication functions performed by the signal processor **120**. Conversely, data intended to be transmitted by the input subsystem **104** are processed by the signal processor **120** and input to the transceivers **112** in preparation for transmission via the electromagnetic radiator **200**.

Preferably, the electromagnetic radiator **200** comprises an array of electromagnetic radiator elements. Each radiator element is configured to transmit and/or receive electromagnetic radiation. Multiple embodiments of the electromagnetic radiator **200** are envisaged. In one embodiment, depicted in FIGS. **2***a* and **2***b*, the electromagnetic radiator **200** may comprise an RF antenna array, and the electromagnetic radiator elements are configured as a plurality of grounded monopoles which comprise a ground plane **210**, and a plurality of elongate conductors **212**. Each elongate conductor **212** may be electrically isolated from the ground plane **210**, but extending through the ground plane **210** from a respective radiator feed point **214** that is disposed below the ground plane **210**.

In the embodiment of FIGS. **2***a* and **2***b*, the elongate conductors **212** are substantially equidistantly spaced about the surface **210**. In another embodiment, depicted in FIG. **3**, the elongate conductors **212** define a plurality of concentric circles. Moreover, the density of elongate conductors **212** in each circle may be greater in the inner circles than in the outer circles. For instance, each circle may include the same number of elongate conductors **212**, with the result that the distance between adjacent conductors **212** in the inner circles is less than the distance between adjacent conductors **212** in the outer circles.

In another embodiment, depicted in FIGS. **4***a* and **4***b*, the electromagnetic radiator **200** may again comprise an RF antenna array, but the electromagnetic radiator elements are configured as a plurality of patch antennas which comprise a conductive layer **206**, the ground plane **210**, and the plurality of elongate conductors **212**. A dielectric substrate **208** may be disposed between the conductive layer **206** and the ground plane **210**. In this embodiment, the conductive layer **206** and the ground plane **210** are disposed on opposite faces of the dielectric substrate, and the conductive layer **206** is provided as a plurality of planar antenna elements that are electrically isolated from each other. Preferably, the conductive layer **206** is oriented substantially parallel to the ground plane **210**. Each elongate conductor **212** is electrically isolated from the ground plane **210**, but extends through the ground plane **210** and the dielectric, from a respective radiator feed point **214** that is disposed below the ground plane **210**, and terminates at a respective planar antenna element.

In each embodiment, preferably the ground plane **210** comprises a planar ground plane, and the elongate conductors **212** are disposed about the ground plane **210**, perpendicular to the ground plane **210**, to thereby provide a planar antenna array. Alternately, the ground plane **210** may comprise an arcuate ground plane, and the elongate conductors **212** are disposed about the ground plane **210** to thereby provide an arcuate antenna array. Further, each radiator feed point **214** is coupled to a respective one of the transceivers **112**, and each transceiver **112** is connected to the signal processor **120** via a local bus.

Alternately, the electromagnetic radiator **200** depicted in FIGS. **2***a*, **2***b*, **3**, **4***a* and **4***b* may comprise a laser array, with the electromagnetic radiator elements being configured as laser transmitter/receivers **212**. Each laser transmitter/receiver **212** may mounted on a substrate **210**, and may be connected to a respective radiator feed point **214** that is disposed below the substrate **210**. As an example, each laser transmitter/receiver **212** may comprise a semiconductor laser diode that is closely-mounted or integrated with a laser phototransistor. Preferably, each semiconductor laser diode is configured to produce a beam of monochromatic, low divergent, singularly-polarized light, and the wave-front of each light beam is coherent over the distance between the electromagnetic radiator **200** and the corresponding receiver. Similarly, preferably each laser phototransistor is configured to detect a beam of monochromatic, low divergent, singularly-polarized light directed at the phototransistor.

The signal processor **120** is configured with computer processing instructions which, when executed by the signal processor **120**, implements a signal processing procedure. The operation of the signal processing procedure will be discussed in greater detail below. However, it is sufficient at this point to note that the signal processing procedure is configured to initiate electromagnetic (RF or laser) transmission of baseband information received from the input subsystem **104** by selecting one or more of the transceivers **112** (and their associated radiator elements) for transmission by the electromagnetic radiator **200**, based on the received baseband information. The signal processing procedure is also configured to facilitate delivery of baseband information to the output subsystem **106** based on the transceivers **112** (and the associated radiator elements) from which the signal processor receives demodulated electromagnetic (RF or laser) transmissions. It should also be understood that although the signal processing procedure may be implemented as a set of computer processing instructions, the functionality of the signal processing procedure may be implemented in electronics hardware instead.

When the communication subsystem **102** is in signal transmission mode, the signal processor **120** receives the baseband information from the input subsystem **104** as a series of digital values, and uses a portion of the received baseband information to select one or more transceivers **112** and transmits the baseband information to each of the selected transceivers **112**. Each selected transceiver **112** performs digital to analog conversion on the baseband information, and uses the analog baseband information to modulate the amplitude and/or phase of the carrier generated by the local oscillator **114**. Each transceiver **112** applies the modulated carrier to the associated radiator feed point(s) **214**. As a result, the modulated carrier is only transmitted (as a RF or laser transmission) from the radiator elements that are associated with the selected radiator feed points **214**.

The signal processor **120** selects transceivers **112** and varies the selection thereof (and hence also varies the selection of radiator feed points **214**), in real-time, in accordance with a portion of each digital baseband value. In one implementation, the signal processor **120** varies the selection of transceivers **112** (and hence the location of active radiator feed points **214**), in real-time, so that the instantaneous angular position of each modulated carrier, as each modulated carrier is transmitted by the electromagnetic radiator **200**, varies based on the baseband information.

For example, assuming that the location of each radiator feed point **214** on the surface of the electromagnetic radiator **200** can be specified by its polar co-ordinates (e.g. radius from a reference point on the surface of the electromagnetic radiator **200**, and angular position relative to a reference angular position on the surface of the electromagnetic radiator **200**), the signal processor **120** may select the radiator feed point(s) **214** such that the instantaneous angular position of each electromagnetic (RF or laser) transmission from the surface of the electromagnetic radiator **200**, relative to a reference angular position on the surface of the electromagnetic radiator **200**, increases, in real-time, as a characteristic (e.g. amplitude, frequency, phase) of the baseband information increases, and the instantaneous angular position of each electromagnetic transmission from the surface of the electromagnetic radiator **200**, relative to a reference angular position on the surface of the electromagnetic radiator **200**, decreases, in real-time, as the characteristic of the baseband information decreases. At the same time, the signal processor **120** may also cause each selected transceiver **112** to increase the frequency and/or phase of each electromagnetic transmission, in real time, as the same or a different characteristic of the baseband information increases, and may cause each selected transceiver **112** to decrease the frequency and/or phase of each electromagnetic transmission, in real time, as the same or a different characteristic of the baseband information decreases.

Alternately, as shown in FIG. **5**, the signal processor **120** may select the radiator feed point(s) **214** such that the instantaneous rate of change of the angular position of each electromagnetic (RF or laser) transmission from the surface of the electromagnetic radiator **200**, increases, in real-time, as a characteristic of the baseband information increases, and the instantaneous rate of change of the angular position of each electromagnetic transmission decreases, in real-time, as the characteristic of the baseband information decreases. The signal processor **120** may also simultaneously activate multiple radiator feed points **214**, and vary the instantaneous rate of change of the angular position of each transmission based on respective characteristics of the baseband information. Although not shown in FIG. **5**, at the same time, the signal processor **120** may also cause each selected transceiver **112** to increase the frequency and/or phase of each transmission, in real time, as the same or a different characteristic of the baseband information increases, and may cause each selected transceiver **112** to decrease the frequency and/or phase of each electromagnetic transmission, in real time, as the same or a different characteristic of the baseband information decreases.

In another implementation, the signal processor **120** varies the selection of transceivers **112** (and hence the location of active radiator feed points **214**), in real-time, so that the instantaneous radial position of each modulated carrier, as the modulated carrier is transmitted by the electromagnetic radiator **200**, relative to the centre of all such electromagnetic transmissions, varies based on the baseband information.

For example, assuming again that the location of each radiator feed point **214** on the surface of the electromagnetic radiator **200** can be specified by its polar co-ordinates (e.g. radius from a reference point on the surface of the electromagnetic radiator **200**, and angular position relative to a reference angular position on the surface of the electromagnetic radiator **200**), the signal processor **120** may select the radiator feed point(s) **214** such that the instantaneous radial position of each electromagnetic (RF or laser) transmission from the surface of the electromagnetic radiator **200**, relative to the centre of all such electromagnetic transmissions, increases, in real-time, as a characteristic of the baseband information increases, and the instantaneous radial position of each electromagnetic transmission from the surface of the electromagnetic radiator **200**, relative to the centre of all such electromagnetic transmissions, decreases, in real-time, as the characteristic of the baseband information decreases. At the same time, the rate of change of the angular position of each electromagnetic transmission may remain constant.

As shown in FIG. **6**, the signal processor **120** may simultaneously activate multiple radiator feed points **214**, and vary the instantaneous radial position of each electromagnetic transmission, relative to the centre of all such transmissions, based on respective characteristics of the baseband information. Preferably, the radiator feed points **214** are activated/deactivated in a sequence that produces two (or more) distinct simultaneous electromagnetic transmissions. Moreover, preferably the simultaneous electromagnetic transmissions do not interfere with one another, in the sense that a receiver that receives the two (or more) electromagnetic transmissions can correctly decode the information that is encoded in each electromagnetic transmission. The electromagnetic radiator **200** depicted in FIG. **3** may be particularly advantageous for implementing this modulation scheme.

At the same time, the signal processor **120** may also cause each selected transceiver **112** to increase the frequency and/or phase of each electromagnetic transmission, in real time, as the same or a different characteristic of the baseband information increases, and may cause each selected transceiver **112** to decrease the frequency and/or phase of each electromagnetic transmission, in real time, as the same or a different characteristic of the baseband information decreases.

Alternately, the signal processor **120** may select the radiator feed point(s) **214** based on a combination of the foregoing controls. For example, as shown in FIG. **7**, the signal processor **120** may select the radiator feed point(s) **214** such that the rate of change of the angular position of each electromagnetic transmission from the surface of the electromagnetic radiator **200**, increases, in real-time, as a characteristic of the baseband information increases, and the instantaneous radial position of each electromagnetic transmission from the surface of the electromagnetic radiator **200**, relative to the centre of all such transmissions, increases, in real-time, as another characteristic of the baseband information increases. Conversely, the rate of change of the angular position of each electromagnetic transmission from the surface of the electromagnetic radiator **200** may increase, in real-time, as a characteristic of the baseband information decrease, and the instantaneous radial distance of each electromagnetic transmission from the surface of the electromagnetic radiator **200**, relative to the centre of all such transmissions, may decrease, in real-time, as another characteristic of the baseband information increases. Again, the electromagnetic radiator **200** depicted in FIG. **3** may be particularly advantageous for implementing this modulation scheme.

Although not shown in FIG. **6**, at the same time, the signal processor **120** may also cause each selected transceiver **112** to increase the frequency and/or phase of each electromagnetic transmission, in real time, as the same or a different characteristic of the baseband information increases, and may cause each selected transceiver **112** to decrease the frequency and/or phase of each electromagnetic transmission, in real time, as the same or a different characteristic of the baseband information decreases.

In another implementation, the signal processor **120** varies the instantaneous number of transceivers **112** that are selected, in real-time, so that the diameter of the modulated carrier, as it is transmitted by the electromagnetic radiator **200**, varies based the baseband information. Simultaneously, the signal processor **120** may also cause each selected transceiver **112** to vary a different characteristic of each electromagnetic transmission, in real time, based the baseband information.

For example, the signal processor **120** may increase the instantaneous number of transceivers **112** (and hence the instantaneous number of radiator feed points **214**) selected, in real-time, as a characteristic of the baseband information increases, and may decrease the instantaneous number of transceivers **112** (and hence the instantaneous number of radiator feed points **214**) selected, in real-time, as the characteristic of the baseband information decreases. At the same time, the signal processor **120** may also cause each selected transceiver **112** to increase the frequency and/or phase of each electromagnetic transmission, in real time, as the same or a different characteristic of the baseband information increases, and may also cause each selected transceiver **112** to decrease the frequency and/or phase of each electromagnetic transmission, in real time, as the same or a different characteristic of the baseband information decreases.

When the communication subsystem **102** is in signal reception mode, each transceiver **112** receives a modulated carrier from the associated radiator feed point **214** of the electromagnetic radiator **200**, and uses the carrier generated by the local oscillator **114** to demodulate the modulated carrier and recover a portion of the information that was encoded in the modulated carrier. Each transceiver **112** performs analog to digital conversion on the recovered information, and forwards the recovered information to the signal processor **120** as a series of digital values. Based on the transceivers **112** (and hence antenna feed points **214**) from which the signal processor **120** receives the digital values, the signal processor **120** recovers the remainder of the digital baseband information that was encoded in the modulated carrier.

As above, the instantaneous diameter of the modulated carrier may vary based on the baseband information, in which case the signal processor **120** may recover each digital baseband value, in real-time, from the instantaneous diameter of the modulated carrier as at the surface of the electromagnetic radiator **200**. Alternately, the instantaneous radial position of the modulated carrier may vary based on the baseband information, in which case the signal processor **120** may recover each digital baseband value, in real-time, from the instantaneous radial distance of the received modulated carrier relative to the centre of the reception at the surface of the electromagnetic radiator **200**. Alternately, or additionally, the instantaneous angular position of the modulated carrier may vary based on the baseband information, in which case the signal processor **120** may recover each digital baseband value, in real-time, from the instantaneous angular position of the received modulated carrier relative to a reference angular position at the surface of the electromagnetic radiator **200**. Depending on the wavelength selected, the foregoing methods of modulation may be advantageously implemented in short-range and/or line-of-sight wireless communications networks.

The invention claimed is:

1. A wireless communications device comprising:

an electromagnetic radiator comprising an array of radiator elements; and

a signal processor coupled to the electromagnetic radiator, the signal processor being configured to receive baseband information, the signal processor further configured to transmit an electromagnetic signal from the electromagnetic radiator by applying a carrier signal to the electromagnetic radiator, the applying a carrier signal comprising continuously rotating a feed point of the carrier signal between the radiator elements at an instantaneous rate of angular rotation and varying the instantaneous rate of angular rotation, in real-time, based on the received baseband information.

2. The wireless communications device according to claim **1**, wherein the radiator elements each has a respective angular position relative to a common reference point, and the transmitting an electromagnetic signal comprises selecting one or more of the radiator elements in real-time each based on the respective angular position thereof and the instantaneous rate of angular rotation, and applying the carrier signal to the one or more selected radiator elements.

3. The wireless communications device according to Claim **2**, wherein the signal processor is configured to vary a diameter of the electromagnetic signal, in real time, by varying an instantaneous number of the one or more radiator elements based on the instantaneous baseband information.

4. The wireless communications device according to claim **2**, wherein the transmitting an electromagnetic signal further comprises varying at least one of a frequency and a phase of the carrier signal based on the baseband information.

5. The wireless communications device according to Claim **2**, wherein the signal processor is configured to vary a radial position of the electromagnetic signal, relative to the common reference point, in real-time, based on one characteristic of the received baseband information, and to vary the instantaneous rate of angular rotation based on another aspect of the received baseband information.

6. The wireless communications device according to claim **2**, wherein the transmitting an electromagnetic signal further comprises varying at least one of a frequency and a phase of the carrier signal based on the baseband information.

7. The wireless communications device according to claim **2**, wherein the selecting the one or more radiator elements comprises selecting the one or more radiator elements so as to produce at least two distinct simultaneous transmissions of the electromagnetic signal.

8. A method of spatially-encoded wireless transmission of baseband information using a wireless communications device, the wireless communications device being configured with an electromagnetic radiator comprising an array of radiator elements, the method comprising:

the wireless communications device receiving baseband information; and

the wireless communications device transmitting an electromagnetic signal from the electromagnetic radiator by applying a carrier signal to the electromagnetic radiator, the applying a carrier signal comprising continuously rotating a feed point of the carrier signal between the radiator elements at an instantaneous rate of angular rotation and varying the instantaneous rate of angular rotation, in real time, based on the received baseband information.

9. The method according to claim **8**, wherein the radiator elements each has a respective angular position relative to a common reference point, and the transmitting an electromagnetic signal comprises selecting one or more of the radiator elements in real-time each based on the respective angular position thereof and the instantaneous rate of angular rotation, and applying the carrier signal to the one or more selected radiator elements.

10. The method according to claim **9**, wherein the selecting the one or more radiator elements comprises varying a diameter of the electromagnetic signal, in real time, by varying an instantaneous number of the one or more radiator elements based on the baseband information.

11. The method according to claim **10**, wherein the transmitting an electromagnetic signal further comprises varying at least one of a frequency and a phase of the carrier signal based on the baseband information.

12. The method according to claim **9**, wherein the transmitting an electromagnetic signal comprises varying a radial position of the electromagnetic signal, relative to the common reference point, in real-time, based on one characteristic of the received baseband information, and varying the instantaneous rate of angular rotation based on another aspect of the received baseband information.

13. The method according to claim **9**, wherein the transmitting an electromagnetic signal further comprises varying at least one of a frequency and a phase of the carrier signal based on the baseband information.

14. The method according to claim **9**, wherein the selecting the one or more radiator elements comprises selecting the one or more radiator elements so as to produce at least two distinct simultaneous transmissions of the electromagnetic signal.

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