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CLAIMS

What is claimed is:

1. An apparatus to measure signals indicative of properties downhole, the apparatus comprising:

a tool having an arrangement of transmitters and receivers along a longitudinal axis of the tool to capture, when the tool is disposed downhole, a signal from a first downhole region in the vicinity of the tool, such that signal contributions from a second downhole region in the vicinity of the tool can be substantially canceled based on placement of the transmitters and receivers with respect to each other.

2. The apparatus of claim 1, wherein the first region is one of around the tool or ahead of the tool, and the second region is, respectively, the other of ahead of the tool or around the tool.

3. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers is structured to capture a signal from anomalies ahead of the tool such that contributions from direct transmitter-to-receiver signals and formation signals around the tool can be substantially canceled.

4. The apparatus of claim 3, wherein the arrangement of transmitters and receivers includes:

a first transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the longitudinal axis of the tool such that the transmitter antenna and the receiver antenna are separated by a first distance; and

a second transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the

longitudinal axis of the tool such that the transmitter antenna and the receiver antenna are separated by a second distance, the second distance equal to the first distance.

5. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers is structured such that signal contributions from anomalies ahead of the tool can be substantially canceled.

6. The apparatus of claim 5, wherein the arrangement of transmitters and receivers includes:

a first transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the longitudinal axis of the tool such that the transmitter antenna is separated from a reference cross-section of the tool by a first distance and the receiver antenna is separated from the reference cross-section of the tool by a second distance; and

a second transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the longitudinal axis of the tool such that the transmitter antenna is separated from the reference cross-section of the tool by a third distance and the receiver is separated from the reference cross-section of the tool by a fourth distance, the sum of the first and second distances equals the sum of the third and fourth distances.

7. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers is structured to capture a signal from around the tool such that a horizontal resistivity signal can be substantially decoupled from a vertical resistivity signal.

8. The apparatus of claim 7, wherein the arrangement of transmitters and receivers includes:

a pair of transmitter antennas, each transmitter antenna tilted with respect to the longitudinal axis of the tool such that center points of the transmitter antennas are collocated, one transmitter antenna of the pair of transmitter antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other transmitter antenna of the pair; and

a pair of receiver antennas, each receiver antenna tilted with respect to the longitudinal axis of the tool such that center points of the receiver antennas are collocated, one receiver antenna of the pair of receiver antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other receiver antenna of the pair.

9. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers is structured to capture a signal from anomalies ahead of the tool such that contributions from direct transmitter-to-receiver signals and formation signals around the tool can be substantially canceled and structured such that signal contributions from anomalies ahead of the tool can be substantially canceled.

10. The apparatus of claim 9, wherein the arrangement of transmitters and receivers includes:

a first transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the longitudinal axis of the tool such that the transmitter antenna and the receiver antenna are separated by a separation distance; and

a second transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the longitudinal axis of the tool such that the transmitter antenna and the receiver antenna are separated by the separation distance, the first transmitter / receiver pair separated from the second transmitter / receiver pair by the separation distance.

11. The apparatus of claim 9, wherein the arrangement of transmitters and receivers includes:

a transmitter / transmitter pair arranged as a first transmitter antenna separated from a second transmitter antenna by a first distance, both transmitter antennas tilted with respect to the longitudinal axis of the tool;

a receiver / receiver pair arranged as a first receiver antenna separated from a second receiver antenna by the first distance, both receiver antennas tilted with respect to the longitudinal axis of the tool, the transmitter / transmitter pair separated from the receiver / receiver pair by a second distance.

12. The apparatus of claim 9, wherein the arrangement of transmitters and receivers includes:

a first transmitter / transmitter pair arranged as a first transmitter antenna separated from a second transmitter antenna by a first distance, both transmitter antennas tilted with respect to the longitudinal axis of the tool;

a second transmitter / transmitter pair arranged as a third transmitter antenna separated from a fourth transmitter antenna by the first distance, both transmitter antennas tilted with respect to the longitudinal axis of the tool; and a receiver / receiver pair arranged as a first receiver antenna separated from a second receiver antenna by the first distance, both receiver antennas tilted with respect to the longitudinal axis of the tool, the receiver / receiver pair disposed between the first transmitter / transmitter pair and the second transmitter / transmitter pair such that the receiver / receiver pair is separated from the first transmitter / transmitter pair and from the second transmitter / transmitter pair by a second distance.

13. The apparatus of claim 9, wherein the arrangement of transmitters and receivers includes:

a first pair of transmitter antennas, each transmitter antenna of the first pair of transmitter antennas tilted with respect to the longitudinal axis of the tool such that center points of the transmitter antennas of the first pair of transmitter antennas are collocated, one transmitter antenna of the first pair of transmitter antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other transmitter antenna of the first pair of transmitter antennas;

a second pair of transmitter antennas, each transmitter antenna of the second pair of transmitter antennas tilted with respect to the longitudinal axis of the tool such that center points of the transmitter antennas of the second pair of transmitter antennas are collocated, one transmitter antenna of the second pair of transmitter antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other transmitter antenna of the second pair of transmitter antennas; a first pair of receiver antennas tilted with respect to the longitudinal axis of the tool such that center points of the receiver antennas of the first pair of receiver antennas are collocated, one receiver antenna of the first pair of receiver antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other receiver antenna of the first pair of receiver antennas; and

a second pair of receiver antennas tilted with respect to the longitudinal axis of the tool such that center points of the receiver antennas of the second pair of receiver antennas are collocated, one receiver antenna of the second pair of receiver antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other receiver antenna of the second pair of receiver antennas, such that the first pair of receiver antennas is separated from the first pair of transmitter antennas by a separation distance, the second pair of transmitter antennas is separated from the first pair of receiver antennas by the separation distance, and the second pair of receiver antennas is separated from the second pair of transmitter antennas by the separation distance.

14. The apparatus of claim 13, wherein the first pair of receiver antennas is disposed between the first and second pairs of transmitter antennas.

15. The apparatus of claim 9, wherein the arrangement of transmitters and receivers includes:

a first pair of transmitter antennas, each transmitter antenna of the first pair of transmitter antennas tilted with respect to the longitudinal axis of the tool such that center points of the transmitter antennas of the first pair of transmitter antennas are collocated, one transmitter antenna of the first pair of transmitter antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other transmitter antenna of the first pair of transmitter antennas;

a second pair of transmitter antennas, each transmitter antenna of the second pair of transmitter antennas tilted with respect to the longitudinal axis of the tool such that center points of the transmitter antennas of the second pair of transmitter antennas are collocated, one transmitter antenna of the second pair of transmitter antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other transmitter antenna of the second pair of transmitter antennas, the second pair of transmitter antennas being separated from the first pair of transmitter antennas by a first distance;

a first pair of receiver antennas, each receiver antenna of the first pair of receiver antennas tilted with respect to the longitudinal axis of the tool such that center points of the receiver antennas of the first pair of receiver antennas are collocated, one receiver antenna of the first pair of receiver antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other receiver antenna of the first pair of receiver antennas; and

a second pair of receiver antennas, each receiver antenna of the second pair of receiver antennas tilted with respect to the longitudinal axis of the tool such that center points of the receiver antennas of the second pair of receiver antennas are collocated, one receiver antenna of the second pair of receiver antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other receiver antenna of the second pair of receiver antennas, the second pair of receiver antennas being separated from the first pair of receiver

antennas by the first distance, the first and second pairs of receiver antennas being separated from the first and second pairs of transmitter antennas such that neither of the pairs of receiver antennas are placed between the pairs of transmitter antennas.

16. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers includes:

a first transmitter antenna tilted with respect to the longitudinal axis of the tool;

a second transmitter antenna tilted with respect to the longitudinal axis of the tool;

a third transmitter antenna tilted with respect to the longitudinal axis of the tool;

a first pair of receiver antennas, each receiver antenna of the first pair of receiver antennas tilted with respect to the longitudinal axis of the tool, the receiver antennas of the first pair of receiver antennas separated from each other by a first distance, the first pair of receiver antennas disposed between the first transmitter antenna and the second transmitter antenna and separated from both the first transmitter antenna and the second transmitter antenna by a second distance; and

a second pair of receiver antennas, each receiver antenna of the second pair of receiver antennas tilted with respect to the longitudinal axis of the tool, the receiver antennas of the second pair of receiver antennas separated from each other by the first distance, the second pair of receiver antennas disposed between the second transmitter antenna and the third transmitter antenna and separated from both the second transmitter antenna and the third transmitter antenna by the second distance.

17. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers includes:

a first receiver antenna tilted with respect to the longitudinal axis of the tool;

a second receiver antenna tilted with respect to the longitudinal axis of the tool, the second receiver antenna separated from the first receiver antenna by a first distance;

a third receiver antenna tilted with respect to the longitudinal axis of the tool, the third receiver antenna separated from the second receiver antenna by the first distance;

a first pair of transmitter antennas, each transmitter antenna of the first pair of transmitter antennas tilted with respect to the longitudinal axis of the tool, the transmitter antennas of the first pair of transmitter antennas separated from each other by the first distance; and

a second pair of transmitter antennas, each transmitter antenna of the second pair of transmitter antennas tilted with respect to the longitudinal axis of the tool, the transmitter antennas of the second pair of transmitter antennas separated from each other by the first distance, the second pair of transmitter antennas separated from the first pair of transmitter antennas by the first, second, and third receiver antennas.

18. The apparatus of any preceding claim, the apparatus including:

a control unit to control activation of the transmitters of the tool and to process signals received from the receivers in the tool.

19. A method of measuring properties downhole, the method comprising: controlling activation of a tool disposed downhole, the tool having an arrangement of transmitters and receivers along a longitudinal axis of the tool to capture signals from formations in the vicinity of the tool;

obtaining an ahead-of-tool signal such that contributions from direct transmitter-to-receiver signals and formation signals around the tool are substantially canceled, based on the arrangement of the transmitters and receivers with respect to each other;

obtaining an at-the-tool signal such that signal contributions from anomalies ahead of the tool are substantially canceled, based on the arrangement of the transmitters and receivers with respect to each other;

performing an inversion operation of the at-the-tool signal to determine a property of the formation around the tool; and

performing an inversion operation of the ahead-of-tool signal using the determined property of the formation around the tool to determine one or more properties of the formation ahead of the tool including resistivity from anomalies ahead of the tool~~.~~

20. The method of claim 19, wherein performing an inversion operation of the at-the-tool signal includes determining formation resistivity from around the tool.

~~21. The method of claim 19 or 20, wherein performing an inversion operation of the ahead-of-tool signal using the determined property of the formation around the tool includes determining resistivity from anomalies ahead of the tool.~~

21~~2~~. The method of ~~claim 19, 20 or 21~~ any of the preceding claims, wherein performing an inversion operation of the ahead-of-tool signal using the determined property of the formation around the tool includes applying a forward model subjected to an iterative process.

22~~3~~. The method of ~~claim 19, 20, 21 or 22~~ any of the preceding claims, wherein controlling activation of the tool includes applying signals to transmitters of the tool electrically, in correlated magnitudes and polarity, to perform subtraction and/or addition operations.

23~~4~~. The method of ~~any one of claims 19 to 23~~ any of the preceding claims, wherein controlling activation of the tool includes applying current to two different transmitters of

the tool simultaneously such that the current applied to one of the two transmitters is of a same amount as and of opposite direction to the current applied to the other transmitter.

245. The method of ~~any one of claims 19 to 24~~ any of the preceding claims, wherein the method includes applying results from the determination of the one or more properties of the formation ahead of the tool to steering a drilling operation.

256. The method of ~~any one of claims 19 to 25~~ any of the preceding claims, wherein the method includes stopping a drilling operation to make measurements using the tool.

267. The method of ~~any one of claims 19 to 26~~ any of the preceding claims, wherein the method includes monitoring resistivity from ahead of a drill bit located ahead of the tool and correlating resistivity changes, determined from the monitoring, to determine changes in pressure ahead of the drill bit.

278. The method of ~~any one of claims 19 to 27~~ any of the preceding claims, wherein the performing of the inversion of the at-the-tool signal includes obtaining horizontal resistivity and vertical resistivity of a formation and the performing of the inversion of the ahead-of-tool signal includes obtaining elevation angle and distance to an anomaly.

289. The method of ~~any one of claims 19 to 28~~ any of the preceding claims using the apparatus of any one of claims 1 to 18.

2930. The method of any of the preceding claims being performed on ~~A~~ a machine-readable storage medium having instructions stored thereon.

~~, which, when performed by a machine, cause the machine to perform operations, the operations comprising the method of any of claims 19 to 29.~~

301. The method of any of the preceding claims being performed on ~~A~~an apparatus used to measure properties downhole, the apparatus comprising: a tool having an arrangement of transmitters and receivers along a longitudinal axis of the tool; and

a control unit to control activation of the transmitters of the tool and to process signals received from receivers in the tool, wherein the control unit includes a machine-readable storage medium having instructions stored thereon, which when executed by a processor, cause the apparatus to perform operations, the operations comprising the method of any of claims 19 to 29.

CLAIMS

What is claimed is:

1. An apparatus to measure signals indicative of properties downhole, the apparatus comprising:

a tool having an arrangement of transmitters and receivers along a longitudinal axis of the tool to capture, when the tool is disposed downhole, a signal from a first downhole region in the vicinity of the tool, such that signal contributions from a second downhole region in the vicinity of the tool can be substantially canceled based on placement of the transmitters and receivers with respect to each other.

2. The apparatus of claim 1, wherein the first region is one of around the tool or ahead of the tool, and the second region is, respectively, the other of ahead of the tool or around the tool.

3. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers is structured to capture a signal from anomalies ahead of the tool such that contributions from direct transmitter-to-receiver signals and formation signals around the tool can be substantially canceled.

4. The apparatus of claim 3, wherein the arrangement of transmitters and receivers includes:

a first transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the longitudinal axis of the tool such that the transmitter antenna and the receiver antenna are separated by a first distance; and

a second transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the longitudinal axis of the tool such that the transmitter antenna and the receiver antenna are separated by a second distance, the second distance equal to the first distance.

5. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers is structured such that signal contributions from anomalies ahead of the tool can be substantially canceled.

6. The apparatus of claim 5, wherein the arrangement of transmitters and receivers includes:

a first transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the longitudinal axis of the tool such that the transmitter antenna is separated from a reference cross-section of the tool by a first distance and the receiver antenna is separated from the reference cross-section of the tool by a second distance; and

a second transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the longitudinal axis of the tool such that the transmitter antenna is separated from the reference cross-section of the tool by a third distance and the receiver is separated from the reference cross-section of the tool by a fourth distance, the sum of the first and second distances equals the sum of the third and fourth distances.

7. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers is structured to capture a signal from around the tool such that a horizontal resistivity signal can be substantially decoupled from a vertical resistivity signal.

8. The apparatus of claim 7, wherein the arrangement of transmitters and receivers includes:

a pair of transmitter antennas, each transmitter antenna tilted with respect to the longitudinal axis of the tool such that center points of the transmitter antennas are collocated, one transmitter antenna of the pair of transmitter antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other transmitter antenna of the pair; and

a pair of receiver antennas, each receiver antenna tilted with respect to the longitudinal axis of the tool such that center points of the receiver antennas are collocated, one receiver antenna of the pair of receiver antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other receiver antenna of the pair.

9. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers is structured to capture a signal from anomalies ahead of the tool such that contributions from direct transmitter-to-receiver signals and formation signals around the tool can be substantially canceled and structured such that signal contributions from anomalies ahead of the tool can be substantially canceled.

10. The apparatus of claim 9, wherein the arrangement of transmitters and receivers includes:

a first transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the longitudinal axis of the tool such that the transmitter antenna and the receiver antenna are separated by a separation distance; and

a second transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the longitudinal axis of the tool such that the transmitter antenna and the receiver antenna are separated by the separation distance, the first transmitter / receiver pair separated from the second transmitter / receiver pair by the separation distance.

11. The apparatus of claim 9, wherein the arrangement of transmitters and receivers includes:

a transmitter / transmitter pair arranged as a first transmitter antenna separated from a second transmitter antenna by a first distance, both transmitter antennas tilted with respect to the longitudinal axis of the tool;

a receiver / receiver pair arranged as a first receiver antenna separated from a second receiver antenna by the first distance, both receiver antennas tilted

with respect to the longitudinal axis of the tool, the transmitter / transmitter pair separated from the receiver / receiver pair by a second distance.

12. The apparatus of claim 9, wherein the arrangement of transmitters and receivers includes:

a first transmitter / transmitter pair arranged as a first transmitter antenna separated from a second transmitter antenna by a first distance, both transmitter antennas tilted with respect to the longitudinal axis of the tool;

a second transmitter / transmitter pair arranged as a third transmitter antenna separated from a fourth transmitter antenna by the first distance, both transmitter antennas tilted with respect to the longitudinal axis of the tool; and

a receiver / receiver pair arranged as a first receiver antenna separated from a second receiver antenna by the first distance, both receiver antennas tilted with respect to the longitudinal axis of the tool, the receiver / receiver pair disposed between the first transmitter / transmitter pair and the second transmitter / transmitter pair such that the receiver / receiver pair is separated from the first transmitter / transmitter pair and from the second transmitter / transmitter pair by a second distance.

13. The apparatus of claim 9, wherein the arrangement of transmitters and receivers includes:

a first pair of transmitter antennas, each transmitter antenna of the first pair of transmitter antennas tilted with respect to the longitudinal axis of the tool such that center points of the transmitter antennas of the first pair of transmitter antennas are collocated, one transmitter antenna of the first pair of transmitter antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other transmitter antenna of the first pair of transmitter antennas;

a second pair of transmitter antennas, each transmitter antenna of the second pair of transmitter antennas tilted with respect to the longitudinal axis of the tool such that center points of the transmitter antennas of the second pair of transmitter antennas are collocated, one transmitter antenna of the second pair of transmitter antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other transmitter antenna of the second pair of transmitter antennas;

a first pair of receiver antennas tilted with respect to the longitudinal axis of the tool such that center points of the receiver antennas of the first pair of receiver antennas are collocated, one receiver antenna of the first pair of receiver antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other receiver antenna of the first pair of receiver antennas; and

a second pair of receiver antennas tilted with respect to the longitudinal axis of the tool such that center points of the receiver antennas of the second pair of receiver antennas are collocated, one receiver antenna of the second pair of receiver antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other receiver antenna of the second pair of receiver antennas, such that the first pair of receiver antennas is separated from the first pair of transmitter antennas by a separation distance, the second pair of transmitter antennas is separated from the first pair of receiver antennas by the separation distance, and the second pair of receiver antennas is separated from the second pair of transmitter antennas by the separation distance.

14. The apparatus of claim 13, wherein the first pair of receiver antennas is disposed between the first and second pairs of transmitter antennas.

15. The apparatus of claim 9, wherein the arrangement of transmitters and receivers includes:

a first pair of transmitter antennas, each transmitter antenna of the first pair of transmitter antennas tilted with respect to the longitudinal axis of the tool such that center points of the transmitter antennas of the first pair of transmitter antennas are collocated, one transmitter antenna of the first pair of transmitter antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other transmitter antenna of the first pair of transmitter antennas;

a second pair of transmitter antennas, each transmitter antenna of the second pair of transmitter antennas tilted with respect to the longitudinal axis of the tool such that center points of the transmitter antennas of the second pair of transmitter antennas are collocated, one transmitter antenna of the second pair of transmitter antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other transmitter antenna of the second pair of transmitter antennas,

the second pair of transmitter antennas being separated from the first pair of transmitter antennas by a first distance;

a first pair of receiver antennas, each receiver antenna of the first pair of receiver antennas tilted with respect to the longitudinal axis of the tool such that center points of the receiver antennas of the first pair of receiver antennas are collocated, one receiver antenna of the first pair of receiver antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other receiver antenna of the first pair of receiver antennas; and

a second pair of receiver antennas, each receiver antenna of the second pair of receiver antennas tilted with respect to the longitudinal axis of the tool such that center points of the receiver antennas of the second pair of receiver antennas are collocated, one receiver antenna of the second pair of receiver antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other receiver antenna of the second pair of receiver antennas, the second pair of receiver antennas being separated from the first pair of receiver antennas by the first distance, the first and second pairs of receiver antennas being separated from the first and second pairs of transmitter antennas such that neither of the pairs of receiver antennas are placed between the pairs of transmitter antennas.

16. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers includes:

a first transmitter antenna tilted with respect to the longitudinal axis of the tool;

a second transmitter antenna tilted with respect to the longitudinal axis of the tool;

a third transmitter antenna tilted with respect to the longitudinal axis of the tool;

a first pair of receiver antennas, each receiver antenna of the first pair of receiver antennas tilted with respect to the longitudinal axis of the tool, the receiver antennas of the first pair of receiver antennas separated from each other by a first distance, the first pair of receiver antennas disposed between the first transmitter antenna and the second transmitter antenna and separated from both

the first transmitter antenna and the second transmitter antenna by a second distance; and

a second pair of receiver antennas, each receiver antenna of the second pair of receiver antennas tilted with respect to the longitudinal axis of the tool, the receiver antennas of the second pair of receiver antennas separated from each other by the first distance, the second pair of receiver antennas disposed between the second transmitter antenna and the third transmitter antenna and separated from both the second transmitter antenna and the third transmitter antenna by the second distance.

17. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers includes:

a first receiver antenna tilted with respect to the longitudinal axis of the tool;

a second receiver antenna tilted with respect to the longitudinal axis of the tool, the second receiver antenna separated from the first receiver antenna by a first distance;

a third receiver antenna tilted with respect to the longitudinal axis of the tool, the third receiver antenna separated from the second receiver antenna by the first distance;

a first pair of transmitter antennas, each transmitter antenna of the first pair of transmitter antennas tilted with respect to the longitudinal axis of the tool, the transmitter antennas of the first pair of transmitter antennas separated from each other by the first distance; and

a second pair of transmitter antennas, each transmitter antenna of the second pair of transmitter antennas tilted with respect to the longitudinal axis of the tool, the transmitter antennas of the second pair of transmitter antennas separated from each other by the first distance, the second pair of transmitter antennas separated from the first pair of transmitter antennas by the first, second, and third receiver antennas.

18. The apparatus of any preceding claim, the apparatus including:

a control unit to control activation of the transmitters of the tool and to process signals received from the receivers in the tool.

19. A method of measuring properties downhole, the method comprising:

controlling activation of a tool disposed downhole, the tool having an arrangement of transmitters and receivers along a longitudinal axis of the tool to capture signals from formations in the vicinity of the tool;

obtaining an ahead-of-tool signal such that contributions from direct transmitter-to-receiver signals and formation signals around the tool are substantially canceled, based on the arrangement of the transmitters and receivers with respect to each other;

obtaining an at-the-tool signal such that signal contributions from anomalies ahead of the tool are substantially canceled, based on the arrangement of the transmitters and receivers with respect to each other;

performing an inversion operation of the at-the-tool signal to determine a property of the formation around the tool; and

performing an inversion operation of the ahead-of-tool signal using the determined property of the formation around the tool to determine one or more properties of the formation ahead of the tool.

20. The method of claim 19, wherein performing an inversion operation of the at-the-tool signal includes determining formation resistivity from around the tool.

21. The method of claim 19 or 20, wherein performing an inversion operation of the ahead-of-tool signal using the determined property of the formation around the tool includes determining resistivity from anomalies ahead of the tool.

22. The method of claim 19, 20 or 21, wherein performing an inversion operation of the ahead-of-tool signal using the determined property of the formation around the tool includes applying a forward model subjected to an iterative process.

23. The method of claim 19, 20, 21 or 22, wherein controlling activation of the tool includes applying signals to transmitters of the tool electrically, in correlated magnitudes and polarity, to perform subtraction and/or addition operations.

24. The method of any one of claims 19 to 23, wherein controlling activation of the tool includes applying current to two different transmitters of the tool simultaneously such that the current applied to one of the two transmitters is of a same amount as and of opposite direction to the current applied to the other transmitter.

25. The method of any one of claims 19 to 24, wherein the method includes applying results from the determination of the one or more properties of the formation ahead of the tool to steering a drilling operation.

26. The method of any one of claims 19 to 25, wherein the method includes stopping a drilling operation to make measurements using the tool.

27. The method of any one of claims 19 to 26, wherein the method includes monitoring resistivity from ahead of a drill bit located ahead of the tool and correlating resistivity changes, determined from the monitoring, to determine changes in pressure ahead of the drill bit.

28. The method of any one of claims 19 to 27, wherein the performing of the inversion of the at-the-tool signal includes obtaining horizontal resistivity and vertical resistivity of a formation and the performing of the inversion of the ahead-of-tool signal includes obtaining elevation angle and distance to an anomaly.

29. The method of any one of claims 19 to 28 using the apparatus of any one of claims 1 to 18.

30. A machine-readable storage medium having instructions stored thereon, which, when performed by a machine, cause the machine to perform operations, the operations comprising the method of any of claims 19 to 29.

31. An apparatus to measure properties downhole, the apparatus comprising:

a tool having an arrangement of transmitters and receivers along a longitudinal axis of the tool; and

a control unit to control activation of the transmitters of the tool and to process signals received from receivers in the tool, wherein the control unit includes a machine-readable storage medium having instructions stored thereon, which when executed by a processor, cause the apparatus to perform operations, the operations comprising the method of any of claims 19 to 29.

CLAIMS

What is claimed is:

1. An apparatus to measure signals indicative of properties downhole, the apparatus comprising:

a tool having an arrangement of transmitters and receivers along a longitudinal axis of the tool to capture, when the tool is disposed downhole, a signal from a first downhole region in the vicinity of the tool, such that signal contributions from a second downhole region in the vicinity of the tool can be substantially canceled based on placement of the transmitters and receivers with respect to each other.

2. The apparatus of claim 1, wherein the first region is one of around the tool or ahead of the tool, and the second region is, respectively, the other of ahead of the tool or around the tool.

3. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers is structured to capture a signal from anomalies ahead of the tool such that contributions from direct transmitter-to-receiver signals and formation signals around the tool can be substantially canceled.

4. The apparatus of claim 3, wherein the arrangement of transmitters and receivers includes:

a first transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the longitudinal axis of the tool such that the transmitter antenna and the receiver antenna are separated by a first distance; and

a second transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the

longitudinal axis of the tool such that the transmitter antenna and the receiver antenna are separated by a second distance, the second distance equal to the first distance.

5. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers is structured such that signal contributions from anomalies ahead of the tool can be substantially canceled.

6. The apparatus of claim 5, wherein the arrangement of transmitters and receivers includes:

a first transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the longitudinal axis of the tool such that the transmitter antenna is separated from a reference cross-section of the tool by a first distance and the receiver antenna is separated from the reference cross-section of the tool by a second distance; and

a second transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the longitudinal axis of the tool such that the transmitter antenna is separated from the reference cross-section of the tool by a third distance and the receiver is separated from the reference cross-section of the tool by a fourth distance, the sum of the first and second distances equals the sum of the third and fourth distances.

7. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers is structured to capture a signal from around the tool such that a horizontal resistivity signal can be substantially decoupled from a vertical resistivity signal.

8. The apparatus of claim 7, wherein the arrangement of transmitters and receivers includes:

a pair of transmitter antennas, each transmitter antenna tilted with respect to the longitudinal axis of the tool such that center points of the transmitter antennas are collocated, one transmitter antenna of the pair of transmitter antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other transmitter antenna of the pair; and

a pair of receiver antennas, each receiver antenna tilted with respect to the longitudinal axis of the tool such that center points of the receiver antennas are collocated, one receiver antenna of the pair of receiver antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other receiver antenna of the pair.

9. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers is structured to capture a signal from anomalies ahead of the tool such that contributions from direct transmitter-to-receiver signals and formation signals around the tool can be substantially canceled and structured such that signal contributions from anomalies ahead of the tool can be substantially canceled.

10. The apparatus of claim 9, wherein the arrangement of transmitters and receivers includes:

a first transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the longitudinal axis of the tool such that the transmitter antenna and the receiver antenna are separated by a separation distance; and

a second transmitter / receiver pair arranged as a transmitter antenna tilted with respect to the longitudinal axis of the tool and a receiver antenna tilted with respect to the longitudinal axis of the tool such that the transmitter antenna and the receiver antenna are separated by the separation distance, the first transmitter / receiver pair separated from the second transmitter / receiver pair by the separation distance.

11. The apparatus of claim 9, wherein the arrangement of transmitters and receivers includes:

a transmitter / transmitter pair arranged as a first transmitter antenna separated from a second transmitter antenna by a first distance, both transmitter antennas tilted with respect to the longitudinal axis of the tool;

a receiver / receiver pair arranged as a first receiver antenna separated from a second receiver antenna by the first distance, both receiver antennas tilted with respect to the longitudinal axis of the tool, the transmitter / transmitter pair separated from the receiver / receiver pair by a second distance.

12. The apparatus of claim 9, wherein the arrangement of transmitters and receivers includes:

a first transmitter / transmitter pair arranged as a first transmitter antenna separated from a second transmitter antenna by a first distance, both transmitter antennas tilted with respect to the longitudinal axis of the tool;

a second transmitter / transmitter pair arranged as a third transmitter antenna separated from a fourth transmitter antenna by the first distance, both transmitter antennas tilted with respect to the longitudinal axis of the tool; and a receiver / receiver pair arranged as a first receiver antenna separated from a second receiver antenna by the first distance, both receiver antennas tilted with respect to the longitudinal axis of the tool, the receiver / receiver pair disposed between the first transmitter / transmitter pair and the second transmitter / transmitter pair such that the receiver / receiver pair is separated from the first transmitter / transmitter pair and from the second transmitter / transmitter pair by a second distance.

13. The apparatus of claim 9, wherein the arrangement of transmitters and receivers includes:

a first pair of transmitter antennas, each transmitter antenna of the first pair of transmitter antennas tilted with respect to the longitudinal axis of the tool such that center points of the transmitter antennas of the first pair of transmitter antennas are collocated, one transmitter antenna of the first pair of transmitter antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other transmitter antenna of the first pair of transmitter antennas;

a second pair of transmitter antennas, each transmitter antenna of the second pair of transmitter antennas tilted with respect to the longitudinal axis of the tool such that center points of the transmitter antennas of the second pair of transmitter antennas are collocated, one transmitter antenna of the second pair of transmitter antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other transmitter antenna of the second pair of transmitter antennas; a first pair of receiver antennas tilted with respect to the longitudinal axis of the tool such that center points of the receiver antennas of the first pair of receiver antennas are collocated, one receiver antenna of the first pair of receiver antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other receiver antenna of the first pair of receiver antennas; and

a second pair of receiver antennas tilted with respect to the longitudinal axis of the tool such that center points of the receiver antennas of the second pair of receiver antennas are collocated, one receiver antenna of the second pair of receiver antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other receiver antenna of the second pair of receiver antennas, such that the first pair of receiver antennas is separated from the first pair of transmitter antennas by a separation distance, the second pair of transmitter antennas is separated from the first pair of receiver antennas by the separation distance, and the second pair of receiver antennas is separated from the second pair of transmitter antennas by the separation distance.

14. The apparatus of claim 13, wherein the first pair of receiver antennas is disposed between the first and second pairs of transmitter antennas.

15. The apparatus of claim 9, wherein the arrangement of transmitters and receivers includes:

a first pair of transmitter antennas, each transmitter antenna of the first pair of transmitter antennas tilted with respect to the longitudinal axis of the tool such that center points of the transmitter antennas of the first pair of transmitter antennas are collocated, one transmitter antenna of the first pair of transmitter antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other transmitter antenna of the first pair of transmitter antennas;

a second pair of transmitter antennas, each transmitter antenna of the second pair of transmitter antennas tilted with respect to the longitudinal axis of the tool such that center points of the transmitter antennas of the second pair of transmitter antennas are collocated, one transmitter antenna of the second pair of transmitter antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other transmitter antenna of the second pair of transmitter antennas, the second pair of transmitter antennas being separated from the first pair of transmitter antennas by a first distance;

a first pair of receiver antennas, each receiver antenna of the first pair of receiver antennas tilted with respect to the longitudinal axis of the tool such that center points of the receiver antennas of the first pair of receiver antennas are collocated, one receiver antenna of the first pair of receiver antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other receiver antenna of the first pair of receiver antennas; and

a second pair of receiver antennas, each receiver antenna of the second pair of receiver antennas tilted with respect to the longitudinal axis of the tool such that center points of the receiver antennas of the second pair of receiver antennas are collocated, one receiver antenna of the second pair of receiver antennas having a same tilt elevation angle and opposite tilt azimuth angle as the other receiver antenna of the second pair of receiver antennas, the second pair of receiver antennas being separated from the first pair of receiver

antennas by the first distance, the first and second pairs of receiver antennas being separated from the first and second pairs of transmitter antennas such that neither of the pairs of receiver antennas are placed between the pairs of transmitter antennas.

16. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers includes:

a first transmitter antenna tilted with respect to the longitudinal axis of the tool;

a second transmitter antenna tilted with respect to the longitudinal axis of the tool;

a third transmitter antenna tilted with respect to the longitudinal axis of the tool;

a first pair of receiver antennas, each receiver antenna of the first pair of receiver antennas tilted with respect to the longitudinal axis of the tool, the receiver antennas of the first pair of receiver antennas separated from each other by a first distance, the first pair of receiver antennas disposed between the first transmitter antenna and the second transmitter antenna and separated from both the first transmitter antenna and the second transmitter antenna by a second distance; and

a second pair of receiver antennas, each receiver antenna of the second pair of receiver antennas tilted with respect to the longitudinal axis of the tool, the receiver antennas of the second pair of receiver antennas separated from each other by the first distance, the second pair of receiver antennas disposed between the second transmitter antenna and the third transmitter antenna and separated from both the second transmitter antenna and the third transmitter antenna by the second distance.

17. The apparatus of claim 1 or 2, wherein the arrangement of transmitters and receivers includes:

a first receiver antenna tilted with respect to the longitudinal axis of the tool;

a second receiver antenna tilted with respect to the longitudinal axis of the tool, the second receiver antenna separated from the first receiver antenna by a first distance;

a third receiver antenna tilted with respect to the longitudinal axis of the tool, the third receiver antenna separated from the second receiver antenna by the first distance;

a first pair of transmitter antennas, each transmitter antenna of the first pair of transmitter antennas tilted with respect to the longitudinal axis of the tool, the transmitter antennas of the first pair of transmitter antennas separated from each other by the first distance; and

a second pair of transmitter antennas, each transmitter antenna of the second pair of transmitter antennas tilted with respect to the longitudinal axis of the tool, the transmitter antennas of the second pair of transmitter antennas separated from each other by the first distance, the second pair of transmitter antennas separated from the first pair of transmitter antennas by the first, second, and third receiver antennas.

18. The apparatus of any preceding claim, the apparatus including:

a control unit to control activation of the transmitters of the tool and to process signals received from the receivers in the tool.

19. A method of measuring properties downhole, the method comprising: controlling activation of a tool disposed downhole, the tool having an arrangement of transmitters and receivers along a longitudinal axis of the tool to capture signals from formations in the vicinity of the tool;

obtaining an ahead-of-tool signal such that contributions from direct transmitter-to-receiver signals and formation signals around the tool are substantially canceled, based on the arrangement of the transmitters and receivers with respect to each other;

obtaining an at-the-tool signal such that signal contributions from anomalies ahead of the tool are substantially canceled, based on the arrangement of the transmitters and receivers with respect to each other;

performing an inversion operation of the at-the-tool signal to determine a property of the formation around the tool; and

performing an inversion operation of the ahead-of-tool signal using the determined property of the formation around the tool to determine one or more properties of the formation ahead of the tool including resistivity from anomalies ahead of the tool

20. The method of claim 19, wherein performing an inversion operation of the at-the-tool signal includes determining formation resistivity from around the tool.

21. The method of any of the preceding claims, wherein performing an inversion operation of the ahead-of-tool signal using the determined property of the formation around the tool includes applying a forward model subjected to an iterative process.

22. The method of any of the preceding claims, wherein controlling activation of the tool includes applying signals to transmitters of the tool electrically, in correlated magnitudes and polarity, to perform subtraction and/or addition operations.

23. The method of any of the preceding claims, wherein controlling activation of the tool includes applying current to two different transmitters of the tool simultaneously such that the current applied to one of the two transmitters is of a same amount as and of opposite direction to the current applied to the other transmitter.

24. The method of any of the preceding claims, wherein the method includes applying results from the determination of the one or more properties of the formation ahead of the tool to steering a drilling operation.

25. The method of any of the preceding claims, wherein the method includes stopping a drilling operation to make measurements using the tool.

26. The method of any of the preceding claims, wherein the method includes monitoring resistivity from ahead of a drill bit located ahead of the tool and correlating resistivity changes, determined from the monitoring, to determine changes in pressure ahead of the drill bit.

27. The method of any of the preceding claims, wherein the performing of the inversion of the at-the-tool signal includes obtaining horizontal resistivity and vertical resistivity of a formation and the performing of the inversion of the ahead-of-tool signal includes obtaining elevation angle and distance to an anomaly.

28. The method of any of the preceding claims using the apparatus of any one of claims 1 to 18.

29. The method of any of the preceding claims being performed on a machine-readable storage medium having instructions stored thereon.

30. The method of any of the preceding claims being performed on an apparatus used to measure properties downhole, the apparatus comprising: a tool having an arrangement of transmitters and receivers along a longitudinal axis of the tool; and

a control unit to control activation of the transmitters of the tool and to process signals received from receivers in the tool, wherein the control unit includes a machine-readable storage medium having instructions stored thereon, which when executed by a processor, cause the apparatus to perform operations, the operations comprising the method of any of claims 19 to 29.