

CLAIMS

1. A method of learning channels between a transmitter and a plurality of receivers in a wireless power network, the transmitter comprising an array of wireless power transmission antennas, the method comprising:
 - transmitting a pilot signal from the wireless power transmission antennas of the transmitter;
 - receiving feedback signals from each receiver of the plurality of receivers, the feedback signals comprising received signal power indications for each respective receiver;
 - calculating channel matrices for channels between the wireless transmission antennas and wireless power reception antennas of each receiver by minimizing an objective function of a channel matrix and the received signal power indications for the respective receiver; and
 - estimating spatial channel signatures of the reception antennas on the array of wireless power transmission antennas from the dominant eigenvalue and corresponding eigenvector of the respective channel matrix.
2. A method according to claim 1, wherein the objective function is the sum squared difference between the estimated power delivered to each respective receiver calculated using the channel matrix and the received signal power indications for each respective receiver.
3. A wireless power transmission method in a wireless power network, the wireless power network comprising a wireless power transmitter and a plurality of wireless power receivers, the wireless power transmitter comprising an array of wireless power transmission antennas and each wireless receiver of the plurality of wireless power receiver comprising a wireless power reception antenna, the method comprising:
 - estimating spatial channels between the array of wireless power transmission antennas and the wireless power reception antennas of the plurality of wireless power receivers;

dividing a wireless power transmission time into a plurality of timeslots, wherein each timeslot is allocated to a respective one of the wireless power receivers; and

in each timeslot of the plurality of timeslots, transmitting power from the array of wireless power transmission antennas according to a transmitter signal vector that maximizes the delivered power to the wireless power receiver to which the timeslot is allocated.

4. A method according to claim 3, wherein the amplitude of the power transmitted from the array of wireless power transmission antennas is modified according to a total power transmission constraint.

5. A method according to claim 3 or claim 4, wherein each timeslot has an equal duration.

6. A method according to claim 3 or claim 4, further comprising optimizing the duration of each respective timeslot.

7. A wireless power transmission method in a wireless power network, the wireless power network comprising a wireless power transmitter and a plurality of wireless power receivers, the wireless power transmitter comprising an array of wireless power transmission antennas and each wireless receiver of the plurality of wireless power receivers comprising a wireless power reception antenna, the method comprising:

estimating spatial channels between the array of wireless power transmission antennas and the wireless power reception antennas of the plurality of wireless power receivers; and

dividing a wireless power transmission time into a plurality of timeslots; in each timeslot of the plurality of timeslots, transmitting power from the array of wireless power transmission antennas according to a transmitter signal vector, wherein the duration of respective timeslots is optimized according to a target constraint on the power delivered to each respective antenna over the plurality of timeslots.

8. A method according to any of claims 3 to 7, wherein estimating spatial channels between the array of wireless power transmission antennas and the wireless power reception antennas of the plurality of wireless power receivers comprises learning the spatial channels according to the method of claim 1 or claim 2.

9. A wireless power transmission method in a wireless power network, the wireless power network comprising a wireless power transmitter and a plurality of wireless power receivers, the wireless power transmitter comprising an array of wireless power transmission antennas and each wireless receiver of the plurality of wireless power receivers comprising a wireless power reception antenna, the method comprising:

transmitting wireless power from the array of wireless power transmission antennas;

receiving an indication from a wireless receiver of the plurality of wireless power receivers, the indication indicating a signal power received by the wireless receiver during the wireless power transmission;

comparing the signal power received by the wireless receiver during the wireless power transmission with a signal power received by the wireless receiver during a previous frame of wireless power transmission to determine a drop in signal power received by the wireless receiver; and

if the drop in signal power received by the wireless receiver exceeds a threshold initiating a channel learning sequence in a succeeding frame of wireless power transmission.

10. A method according to claim 9, wherein further comprising determining a number of pilot signals for the channel learning sequence based on the drop in signal power received by the wireless receiver.

11. A method according to claim 9 or claim 10, wherein the channel learning sequence comprises learning the spatial channels according to the method of claim 1 or claim 2.

12. A controller for a wireless power transmitter configured to cause the wireless power transmitter to carry out a method according to any one of claims 1 to 11.
13. A computer readable carrier medium carrying processor executable instructions which when executed on a processor cause the processor to carry out a method according to any one of claims 1 to 11.
14. A wireless power transmitter comprising an array of wireless power transmission antennas and a controller configured to:
- control the transmission antennas to transmit a pilot signal;
 - receive feedback signals from each receiver of a plurality of receivers, the feedback signals comprising received signal power indications for each respective receiver;
 - derive channel matrices for channels between the wireless transmission antennas and wireless power reception antennas of each respective receiver by minimizing an objective function of a channel matrix and the received signal power indications for the respective receiver; and
 - estimate spatial channel signatures of the reception antennas on the array of wireless power transmission antennas from the dominant eigenvalue and corresponding eigenvector of the respective channel matrix.
15. A wireless power transmitter according to claim 14, wherein the objective function is the sum squared difference between the estimated power delivered to each respective receiver calculated using the channel matrix and the received signal power indications for each respective receiver.
16. A wireless power transmitter comprising an array of wireless power transmission antennas and a controller configured to:
- estimate spatial channels between the array of wireless power transmission antennas and the wireless power reception antennas of a plurality of wireless power receivers;
 - divide a wireless power transmission time into a plurality of timeslots, wherein each timeslot is allocated to a respective one of the wireless power receivers; and

in each timeslot of the plurality of timeslots, control the array of wireless power transmission antennas to transmit power according to a transmitter signal vector that maximizes the delivered power to the wireless power receiver to which the timeslot is allocated.

17. A wireless power transmitter according to claim 16, wherein the controller is configured to control the amplitude of the power transmitted from the array of wireless power transmission antennas according to a total power transmission constraint.

18. A wireless power transmitter according to claim 16 or claim 17, wherein each timeslot has an equal duration.

19. A wireless power transmitter according to claim 16 or claim 17, wherein the controller is further configured to optimize the duration of each respective timeslot.

20. A wireless power transmitter comprising an array of wireless power transmission antennas and a controller configured to:

estimate spatial channels between the array of wireless power transmission antennas and wireless power reception antennas of a plurality of wireless power receivers; and

divide a wireless power transmission time into a plurality of timeslots; in each timeslot of the plurality of timeslots, transmitting power from the array of wireless power transmission antennas according to a transmitter signal vector, wherein the duration of respective timeslots is optimized according to a target constraint on the power delivered to each respective antenna over the plurality of timeslots.

21. A wireless power transmitter according to any one of claims 16 to 20, wherein the controller is further configured to:

control the transmission antennas to transmit a pilot signal;

receive feedback signals from each receiver of a plurality of receivers, the feedback signals comprising received signal power indications for each respective receiver;

derive channel matrices for channels between the wireless transmission antennas and wireless power reception antennas of each respective receiver by minimizing an objective function of a channel matrix and the received signal power indications for the respective receiver; and

estimate spatial channel signatures of the reception antennas on the array of wireless power transmission antennas from the dominant eigenvalue and corresponding eigenvector of the respective channel matrix.

22. A wireless power transmitter comprising an array of wireless power transmission antennas and a controller configured to:

control the array of wireless power transmission antennas to transmit wireless power;

receive an indication from a wireless receiver of a plurality of wireless power receivers, the indication indicating a signal power received by the wireless receiver during the wireless power transmission;

compare the signal power received by the wireless receiver during the wireless power transmission with a signal power received by the wireless receiver during a previous frame of wireless power transmission to determine a drop in signal power received by the wireless receiver; and

if the drop in signal power received by the wireless receiver exceeds a threshold initiate a channel learning sequence in a succeeding frame of wireless power transmission.

23. A wireless power transmitter according to claim 22, wherein the controller is further configured to determine a number of pilot signals for the channel learning sequence based on the drop in signal power received by the wireless receiver.

24. A wireless power transmitter according to claim 22 or 23, wherein the controller is further configured to:

control the transmission antennas to transmit pilot signals;

receive feedback signals from each receiver of a plurality of receivers, the feedback signals comprising received signal power indications for each respective receiver;

estimate a channel matrix for channels between the wireless transmission antennas and wireless power reception antennas of the respective receivers by minimizing an objective function of the channel matrix and the received signal power indications for each respective receiver; and

estimate spatial channel signatures of the reception antennas on the array of wireless power transmission antennas from the dominant eigenvalue and corresponding eigenvector of the channel matrix.