

SUMMARY OF THE INVENTION

5 According to a first aspect of the present invention, there is provided a system for cancelling interference in a wireless network, the system comprising: apparatus for computing and outputting N weighting vectors by estimating a spatial signature while distinguishing interference spatial signature from desired signal spatial signature although both are received simultaneously; and apparatus for cancelling interference from N antennae outputs received by the system using the N weighting vectors respectively, and wherein, if a spatial signature of a source is identified which is not constant over different frequencies, the source is not treated as interference.

10 According to a second aspect of the present invention, there is provided a method for cancelling interference in a wireless network, the method comprising: computing and outputting N weighting vectors by estimating a spatial signature while distinguishing interference spatial signature from desired signal spatial signature although both are received simultaneously; and cancelling interference from N antennae outputs received
15 by a system using the N weighting vectors respectively, and wherein, if a spatial signature of a source is identified which is not constant over different frequencies, the source is not treated as interference.

20 Certain embodiments of the invention seek to provide an antenna array system operative to increase or maximize the signal to interferers and noise ratio (SINR). The antenna array may be a "piggy back" type, e.g., the antenna array may be autonomous, and does not cooperate with the base station (BS). The only connection between the antenna array and base station may be that the output of antenna array system may be connected to the antenna input of the BS.

25 Certain embodiments of the invention seek to provide a system for spatial suppression of interferences e.g. in LTE-Type cellular communication networks.

30 Certain embodiments of the invention seek to provide a system in which interference cancellation is performed and causes a delay to transmissions which is small enough to be insignificant in cellular applications e.g. in that the delay is small enough such that the base station does not erroneously conclude that the mobile stations are further away than they are in fact.

Certain embodiments of the invention seek to provide a system connected to a base station operative to mitigate interference and having no control interface with the base station other than a radio connector replacing the base station antenna as an input device to the base station.

5 Certain embodiments of the invention seek to provide a system connected to a base station operative to mitigate interference by receiving uplink radio signals, processing these for interference mitigation and transmitting the processed signals to the base station radio input (e.g. antenna input in Fig. 1).

10 Certain embodiments shown and described herein are suitable for multi-carrier communication protocols such as LTE or FDM or single-carrier FDMA.

Certain embodiments shown and described herein are suitable for a multiple-access scheme yielding a signal such that in each frame along a time-axis there are a number of mobile stations from different azimuthal directions distributed throughout the sector whereas the interference to be mitigated comes from a single direction.

15 An optional one-radio frame delay may be provided, downstream of the array of receiving elements.

An RF/IF (radio/intermediate frequency) to base-band down-converter may be provided which is operative to enable interference mitigation to be performed in baseband, along with a base-band to RF up-converter to convert the interference-mitigated signals back to RF/IF.

~~The present invention typically includes at least the following embodiments:~~

~~Embodiment 1. — A~~ In an embodiment, there is provided a system for cancelling interference in a wireless network, the system comprising:

apparatus for computing and outputting at least N weighting vectors; and
apparatus for cancelling interference from antennae outputs received by the system using
the weighting vectors respectively by converting the weighting vectors into FIR filter
coefficients and applying FIR filters corresponding to the FIR filter coefficients to
derivatives of antennae outputs received by the system.

~~Embodiment 2. — A~~ In an embodiment, there is provided a system for cancelling interference in a wireless network, the system comprising:

apparatus for computing and outputting N weighting vectors by estimating a
spatial signature while distinguishing interference spatial signature from desired signal
spatial signature although both are received simultaneously; and

apparatus for cancelling interference from N antennae outputs received by the
system using the N weighting vectors respectively.

~~Embodiment 3. — A system according to embodiment 1 wherein~~ In an embodiment, in the above system the apparatus for computing and outputting weighting vectors is operative by estimating a spatial signature while distinguishing interference spatial signature from desired signal spatial signature although both are received simultaneously.

~~Embodiment 4. — A system according to any of embodiments 2, 3 wherein~~ In an embodiment, in the above system the estimating comprises computing a mean covariance matrix of the signal from all antennas.

~~Embodiment 5. — A system according to embodiment 4 wherein~~ In an embodiment, in the above system the mean is taken over the time when the channel remains unchanged.

~~Embodiment 6. — A system according to embodiment 5 wherein~~ In an embodiment, in the above system the mean is taken over at least a portion of a single cellular frame.

Embodiment 7. — A system according to ~~embodiment 5 or embodiment 6~~ wherein In an embodiment, in the above system the mean comprises a weighted average.

Embodiment 8. — A system according to ~~embodiment 7~~ wherein In an embodiment, in the above system the weighted average is computed using weights which
5 change over time.

Embodiment 9. — A system according to ~~any of embodiments 4—8 and also comprising~~ In an embodiment, the above system further comprises identifying anomalies with the spatial signature estimation over frequency pointing on a table desired signal over time.

Embodiment 10. — A system according to ~~embodiment 9 and also comprising~~ In an embodiment, the above system further comprises performing spatial whitening.

Embodiment 11. — A system according to ~~embodiment 10~~ wherein In an embodiment, in the above system the spatial whitening includes computing a weighting vector for each frequency.

Embodiment 12. — A system according to ~~embodiment 11~~ wherein In an embodiment, in the above system the power of R_q in the computing is a programmable parameter.

Embodiment 13. — A system according to ~~any of embodiments 1—12~~ wherein In an embodiment, in the above system at least one interference typically is at static
20 location.

Embodiment 14. — A system according to ~~embodiment 2~~ wherein In an embodiment, in the above system the apparatus for cancelling interference from N antennae outputs received by the system using the N weighting vectors respectively is operative for multiplying each frequency of each input antenna by a respective weight.

Embodiment 15. — A system according to ~~embodiment 1~~ wherein In an embodiment, in the above system the converting the weighting vectors into FIR filter coefficients and applying FIR filters corresponding to the FIR filter coefficients to derivatives of antennae outputs received by the system comprises converting N weighting vectors corresponding in number to the number of antennae outputs into FIR filter
25 coefficients and wherein the derivatives of antennae outputs comprises the antennae outputs themselves.

Embodiment 16. — A system according to ~~embodiment 1~~ wherein In an embodiment, in the above system the apparatus for cancelling interference comprises separating each antenna output into frequency bands, applying a different FIR filter to
30 each band, thereby to obtain frequency-band specific results, and summing the results to obtain a full-frequency output.

Embodiment 17. — A system according to ~~embodiment 6~~ wherein In an embodiment, in the above system the mean is taken over a single subframe of a cellular frame.

Embodiment 18. — A system according to embodiment 6 wherein In an embodiment, in the above system the mean is taken over a single time-slot of a cellular frame.

Embodiment 19. — A system according to embodiment 6 wherein In an embodiment, in the above system the mean is taken over an entire single cellular frame.

Embodiment 20. — A system according to any of embodiments 4—8 and wherein, In an embodiment, in the above system if a spatial signature of an anomaly is identified which is not constant over different frequencies, the anomaly is not treated as interference.

Embodiment 21. — A system according to any of the preceding embodiments and wherein In an embodiment, in the above system the wireless network is operative in accordance with a multi-carrier protocol such as LTE.

Embodiment 22. — A system according to any of the preceding embodiments and wherein In an embodiment, in the above system the wireless network is operative in accordance with an HSPA protocol.

Embodiment 23. — A system according to any of the preceding embodiments and wherein In an embodiment, in the above system the wireless network is operative in accordance with a WiMAX protocol.

Embodiment 24. — A system according to any of the preceding embodiments and wherein In an embodiment, in the above system the wireless network is operative in accordance with a WiFi protocol.

Embodiment 25. — A system according to any of the preceding embodiments and wherein In an embodiment, in the above system the wireless network is operative in accordance with a WCDMA protocol.

Embodiment 26. — A system according to any of the preceding embodiments and wherein In an embodiment, in the above system the wireless network is operative in accordance with a GSM protocol.

Embodiment 27. — A In an embodiment, there is provided a computer program product, comprising a non-transitory computer usable medium having a computer readable program code embodied therein, the computer readable program code adapted to be executed to implement a method according to any of the preceding embodiments.

Also In an embodiment, there is provided is a computer program comprising computer program code means for performing any of the methods shown and described herein when the program is run on a computer; and a computer program product, comprising a typically non-transitory computer-usable or -readable medium or computer readable storage medium, typically tangible, having a computer readable program code embodied therein, the computer readable program code adapted to be executed to implement any or all of the methods shown and described herein. It is appreciated that any or all of the computational steps

may be written in any conventional programming language, and optionally a machine for executing the program such as but not limited to a general purpose computer which may optionally be configured or activated in accordance with the teachings of the present invention. Any of the teachings incorporated herein may where-ever suitable operate on
5 signals representative of physical objects or substances.

The embodiments referred to above, and other embodiments, are described in detail in the next section.

Any trademark occurring in the text or drawings is the property of its owner and occurs herein merely to explain or illustrate one example of how an embodiment of the
10 invention may be implemented.

Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions, utilizing terms such as, "processing", "computing", "estimating", "selecting", "ranking", "grading", "calculating", "determining", "generating", "reassessing", "classifying", "generating", "producing",
15 "stereo-matching", "registering", "detecting", "associating", "superimposing", "obtaining" or the like, refer to the action and/or processes of a computer or computing system, or processor or similar electronic computing device, that manipulate and/or transform data represented as physical, such as electronic, quantities within the computing system's registers and/or memories, into other data similarly represented as physical quantities
20 within the computing system's memories, registers or other such information storage, transmission or display devices. The term "computer" should be broadly construed to cover any kind of electronic device with data processing capabilities, including, by way of non-limiting example, personal computers, servers, computing system, communication devices, processors (e.g. digital signal processor (DSP), microcontrollers, field programmable gate array (FPGA), application specific integrated circuit (ASIC),
25 etc.) and other electronic computing devices.

The Embodiments of the present invention may be described, merely for clarity, in terms of terminology specific to particular programming languages, operating systems, browsers, system versions, individual products, and the like. It will be appreciated that
30 this terminology is intended to convey general principles of operation clearly and briefly, by

CLAIMS

1. A system for cancelling interference in a wireless network, the system comprising:
5 apparatus for computing and outputting at least N weighting vectors; and
 apparatus for cancelling interference from antennae outputs received by the system using the weighting vectors respectively by converting the weighting vectors into FIR filter coefficients and applying FIR filters corresponding to the FIR filter coefficients to derivatives of antennae outputs received by the system.
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2. A system for cancelling interference in a wireless network, the system comprising:
 apparatus for computing and outputting N weighting vectors by estimating a spatial signature while distinguishing interference spatial signature from desired signal
15 spatial signature although both are received simultaneously; and
 apparatus for cancelling interference from N antennae outputs received by the system using the N weighting vectors respectively.
3. A system according to claim 1 wherein said apparatus for computing and
20 outputting weighting vectors is operative by estimating a spatial signature while distinguishing interference spatial signature from desired signal spatial signature although both are received simultaneously.
4. A system according to claim 2 wherein said estimating comprises computing a
25 mean covariance matrix of the signal from all antennas.
5. A system according to claim 4 wherein the mean is taken over the time when the channel remains unchanged.
- 30 6. A system according to claim 5 wherein the mean is taken over at least a portion of a single cellular frame.

7. A system according to claim 5 wherein the mean comprises a weighted average.
8. A system according to claim 7 wherein the weighted average is computed using
5 weights which change over time.
9. A system according to claim 4 and also comprising identifying anomalies with
the spatial signature estimation over frequency pointing on a table desired signal over
time.
10. A system according to claim 9 and also comprising performing spatial whitening.
11. A system according to claim 10 wherein said spatial whitening includes
computing a weighting vector for each frequency.
12. A system according to claim 11 wherein the power of R_q in said computing is a
programmable parameter.
13. A system according to claim 1 wherein at least one interference typically is at
20 static location.
14. A system according to claim 2 wherein said apparatus for cancelling interference
from N antennae outputs received by the system using the N weighting vectors
respectively is operative for multiplying each frequency of each input antenna by a
25 respective weight.
15. A system according to claim 1 wherein said converting the weighting vectors into
FIR filter coefficients and applying FIR filters corresponding to the FIR filter coefficients
to derivatives of antennae outputs received by the system comprises converting N
30 weighting vectors corresponding in number to the number of antennae outputs into FIR

filter coefficients and wherein said derivatives of antennae outputs comprises the antennae outputs themselves.

16. A system according to claim 1 wherein said apparatus for cancelling interference comprises separating each antenna output into frequency bands, applying a different FIR filter to each band, thereby to obtain frequency-band specific results, and summing the results to obtain a full-frequency output.

17. A system according to claim 6 wherein the mean is taken over a single subframe of a cellular frame.

18. A system according to claim 6 wherein the mean is taken over a single time-slot of a cellular frame.

19. A system according to claim 6 wherein the mean is taken over an entire single cellular frame.

20. A system according to claim 4 and wherein, if a spatial signature of an anomaly is identified which is not constant over different frequencies, the anomaly is not treated as interference.

21. A system according to claim 1 and wherein said wireless network is operative in accordance with a multi-carrier protocol such as LTE.

22. A system according to claim 1 and wherein said wireless network is operative in accordance with an HSPA protocol.

23. A system according to claim 1 and wherein said wireless network is operative in accordance with a WiMAX protocol.

24. A system according to claim 1 and wherein said wireless network is operative in accordance with a WiFi protocol.

25. A system according to claim 1 and wherein said wireless network is operative in accordance with a WCDMA protocol.

26. A system according to claim 1 and wherein said wireless network is operative in accordance with a GSM protocol.

5 27. A method for cancelling interference in a wireless network, the method comprising:

computing and outputting at least N weighting vectors; and

cancelling interference from antennae outputs received by a system using the weighting vectors respectively by converting the weighting vectors into FIR filter coefficients and applying FIR filters corresponding to the FIR filter coefficients to
10 derivatives of antennae outputs received by the system.

28. A computer program product, comprising a non-transitory computer usable medium having a computer readable program code embodied therein, said computer readable program code adapted to be executed to implement a method for cancelling
15 interference in a wireless network, the method comprising:

computing and outputting at least N weighting vectors; and

cancelling interference from antennae outputs received by a system using the weighting vectors respectively by converting the weighting vectors into FIR filter coefficients and applying FIR filters corresponding to the FIR filter coefficients to
20 derivatives of antennae outputs received by the system.

29. A method for cancelling interference in a wireless network, the method comprising:

computing and outputting N weighting vectors by estimating a spatial signature
25 while distinguishing interference spatial signature from desired signal spatial signature although both are received simultaneously; and

cancelling interference from N antennae outputs received by a system using the N weighting vectors respectively.

30. A system according to claim 3 wherein said estimating comprises computing a
5 mean covariance matrix of the signal from all antennas.

31. A system according to claim 2 and wherein said wireless network is operative in accordance with at least one of:

- a multi-carrier protocol such as LTE;
- 10 an HSPA protocol;
- a WiMAX protocol;
- a WiFi protocol;
- a WCDMA protocol; and
- a GSM protocol.

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Claims:

1. A system for cancelling interference in a wireless network, the system comprising:

apparatus for computing and outputting N weighting vectors by estimating a spatial signature while distinguishing interference spatial signature from desired signal spatial signature although both are received simultaneously; and

apparatus for cancelling interference from N antennae outputs received by the system using the N weighting vectors respectively, and

wherein, if a spatial signature of a source is identified which is not constant over different frequencies, the source is not treated as interference.
2. A system according to claim 1, wherein said estimating comprises computing a mean covariance matrix of the signal from all antennas.
3. A system according to claim 2, wherein the mean is taken over the time when the channel remains unchanged.
4. A system according to claim 3, wherein the mean is taken over at least a portion of a single cellular frame.
5. A system according to claim 3, wherein the mean comprises a weighted average.
6. A system according to claim 5, wherein the weighted average is computed using weights which change over time.
7. A system according to claim 2, further comprising identifying anomalies with the spatial signature estimation over frequency pointing on a stable desired signal over time.
8. A system according to claim 7, further comprising performing spatial whitening.
9. A system according to claim 8, wherein said spatial whitening includes computing a weighting vector for each frequency.

10. A system according to claim 9, wherein given an estimation $\hat{\mathbf{R}}_q$, the weighting factor is: $\mathbf{w} = \hat{\mathbf{R}}_q^{-\alpha} \mathbf{1}_{N_2}$ and wherein alpha, the power of $\mathbf{R}_q$ is a programmable parameter.
11. A system according to claim 1, wherein said apparatus for cancelling interference from N antennae outputs received by the system using the N weighting vectors respectively is operative for multiplying each frequency of each input antenna by a respective weight.
12. A system according to claim 4, wherein the mean is taken over a single subframe of a cellular frame.
13. A system according to claim 4, wherein the mean is taken over an entire single cellular frame.
14. A method for cancelling interference in a wireless network, the method comprising:
- computing and outputting N weighting vectors by estimating a spatial signature while distinguishing interference spatial signature from desired signal spatial signature although both are received simultaneously; and
 - cancelling interference from N antennae outputs received by a system using the N weighting vectors respectively, and
 - wherein, if a spatial signature of a source is identified which is not constant over different frequencies, the source is not treated as interference.
15. A system according to claim 1, wherein said wireless network is operative in accordance with at least one of:
- a multi-carrier protocol such as LTE;
 - an HSPA protocol;
 - a WiMAX protocol;
 - a WiFi protocol;
 - a WCDMA protocol; and
 - a GSM protocol.

16. A system according to claim 1, wherein a bank of BPFs (band pass filters) with fixed transfer function is provided and wherein to each of BPFs a FIR filter may be connected, the value of being selected to support on-line tuning of the relevant FIR filter.

17. A method according to claim 14, wherein signals from multiple antennae are received thereby to define at least one channel and wherein outputting said vectors comprises a weighting vector estimation process including:

frequency dividing of each input received from the antennae;

estimating the spatial signature including, if the desired signal is changing over time but interference is stable, computing a mean covariance matrix over all antennae including averaging over a time period during which the channel remains unchanged, and

performing spatial whitening by computing a weighting vector for each frequency.

18. A method according to claim 17, wherein anomalies with the spatial signature estimation over frequency pointing on a stable desired signal over time are identified before said spatial whitening.

19. A method according to claim 14, wherein signals from said antennae are received and wherein said cancelling interference from received antennae outputs includes converting the weighting vectors into FIR filter coefficients, applying FIR filters corresponding to the FIR filter coefficients to derivatives of received antennae outputs and summing over all antennae.

20. A method according to claim 19, wherein each input is separated into plural subfrequencies, said converting to FIR coefficients is performed for each of the subfrequencies, and the subfrequencies are rejoined before performing said summing.

21. A method according to claim 14, wherein said cancelling interference comprises frequency dividing using FFT, multiplying each frequency and antenna by a suitable weight, summing over antennae, per frequency, and rejoining all frequencies using IFFT.

22. A method according to claim 17, wherein estimation of the covariance matrix and computation of weighting vectors performed during an $(m-1)$ -th radio frame are used to cancel the interferences of an m -th radio frame, for at least one natural number m .

23. A system according to claim 16, wherein the frequency responses of at least two BPFs, overlap.

24. A method according to claim 21, wherein signals from multiple antennae are received thereby to define at least one channel and wherein outputting said vectors comprises a weighting vector estimation process including:

frequency dividing of each input received from the antennae;

estimating the spatial signature including, if the desired signal is changing over time but interference is stable, computing a mean covariance matrix over all antennae including averaging over a time period during which the channel remains unchanged, and

performing spatial whitening by computing a weighting vector for each frequency.

25. A method according to claim 24, wherein anomalies with the spatial signature estimation over frequency pointing on a stable desired signal over time are identified before said spatial whitening.

26. A system according to claim 1, wherein signals from said antennae are received and wherein said apparatus for cancelling interference from received antennae outputs is operative for converting the weighting vectors into FIR filter coefficients and applying FIR filters corresponding to the FIR filter coefficients to derivatives of received antennae outputs.

27. A method according to claim 19, wherein applying FIR filters corresponding to the FIR filter coefficients to derivatives of antennae outputs received by the system comprises converting the N weighting vectors into FIR filter coefficients, and

wherein the derivatives of antennae outputs comprises the antennae outputs themselves.

28. A system according to claim 1, wherein said apparatus for cancelling interference is operative for separating each antenna output into frequency bands, applying a different FIR filter to each band, thereby to obtain frequency-band specific results, and summing the results to obtain a full-frequency output.

29. A system according to claim 26, wherein the derivatives of antennae outputs comprise the antennae outputs themselves.