Abstract: A method for receiving/emanating radio signals from/to a moving object, said radio signals having at least one carrier frequency within an operating frequency interval, said method comprising substantially suppressing signals substantially in a direction of movement of the moving object and having substantially a determined carrier frequency within the operating frequency interval, by means of an antenna array consisting of two antenna elements and beamforming means, the antenna array being arranged such that two opposite nulls are created substantially in the direction of movement for signals having substantially the determined carrier frequency.
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Field of the invention

The present invention relates to the field of radio reception/emission on a moving object, such as a vehicle or the like, which is inherently affected by Doppler Effect.

Although the present description focuses mainly on multicarrier modulation and digital video broadcasting, the possible fields of application of the invention are manifold. For example, the invention may be used for digital audio broadcasting, Internet wireless access, etc.

Background of the invention

Radio reception on a moving vehicle may be affected by Doppler Effect, the importance of which varies with the carrier frequency of the radio signals, the speed of the vehicle and the angle of arrival of the radio signals. The Doppler Effect provides a frequency shift in the received signals, which may be harmful to the decoding of the digital content carried by said signals.

The Doppler shift/spreading may cause particular damages for narrowband signals. For example, a multicarrier modulation, e.g. Orthogonal Frequency Division Multiplexing (OFDM), may be used as being relatively robust against multi-path fading due to the increase of the symbol duration. However, if the receiver or the emitter is mobile, the Doppler spreading/shifts may cause the orthogonality among carriers to be lost, thus resulting in Inter-Carrier-Interference (ICI). The performance gets worse as the vehicle speed and/or carrier frequency increases.

It is known to form a plurality of beams with antennas, each beam focusing on a determined direction, and to provide for each beam a frequency correction to the signal corresponding to the beam, said frequency correction depending on the vehicle speed and on the direction of the beam.
The aim of this invention is to provide a simpler method for improving the reception/emission of radio signals on/from a moving vehicle.

**Summary of the invention**

In a first aspect, the present invention provides a method for receiving/emitting radio signals at/from a moving object such as a vehicle, said radio signals having at least one carrier frequency within an operating frequency interval, said method comprising substantially suppressing signals substantially in a direction of movement of the moving object and having substantially a determined carrier frequency within the operating frequency interval, by means of an antenna array consisting of two antenna elements and beamforming means, the antenna array being arranged such that two opposite nulls are created substantially in the direction of movement for signals having substantially the determined carrier frequency.

By "null" we mean a region in which the signal emitted from or received at an antenna array cancels out almost entirely.

By "substantially in a or the direction of movement", we mean in a direction that forms an angle with the direction of movement of less than 40°, preferably less than 10°, preferably less than 5°, and preferably less than 2°.

Such antenna array hence exhibits poor receptivity in the direction of movement of the vehicle, at least for signals having the determined carrier frequency. Since Doppler shift mainly affects signals in the instantaneous direction of movement, the antenna array allows substantially suppressing the most Doppler affected signals and focusing on signals that are relatively unaffected by Doppler shift.

The most Doppler affected signals are substantially suppressed by means of the antenna array, thus avoiding a complex processing of the received signals to digitally attenuate the damages caused by the Doppler Effect. A reduction of the damages caused by Doppler spreading/shifts is hence provided without consuming the signal processing power.

The present invention allows a relatively proper decoding of the digital content corresponding to the received signals, with a relatively simple and inexpensive method.
One may notice that in a scattered environment, information is carried by several signals reaching the antenna elements with various directions of arrival, thus avoiding a loss of information due to the substantial suppression of the signals in the direction of movement.

The direction of movement may be a preferred direction of movement relative to the vehicle. In that case, the direction of movement is typically the front of the vehicle-back of the vehicle direction. Most of the time, and especially when the vehicle is at a relatively high speed, the front/back direction is substantially the effective direction of movement of the vehicle, that is the direction of the speed. An antenna array having substantially a poor receptivity in the front/back direction and focusing on lateral sides of the vehicle, for signals with the determined carrier frequency, hence generally allows substantially suppressing signals particularly affected by Doppler shift.

The direction of movement of the vehicle may alternatively comprise a direction defined as the speed direction of the vehicle, i.e. the antenna array may be arranged so as to dynamically form two opposite nulls substantially in said speed direction. For example, the method may comprise estimating the speed direction and modifying the arrangement of the antenna array accordingly.

 Advantageously, the determined carrier frequency for which the antenna array is designed is substantially equal to the highest frequency of the operating frequency interval. For a given vehicle speed, higher carrier frequencies experience higher Doppler Effect. Thus, higher frequencies are more sensitive to speed than the lower ones. The antenna array may hence be designed considering the worst-case scenario.

 Alternatively, the determined carrier frequency may be substantially equal to another frequency of the frequency interval, e.g. a frequency that is frequently used

The beamforming means may simply comprise an adder. Arranging the antenna array so as to focus on lateral sides for a determined carrier frequency may comprise adjusting a direction and modulus of a spacing between the antenna elements as a function of said carrier frequency. For
example, the antenna elements may be substantially aligned with the
direction of movement and the modulus of the spacing may be around half
the wavelength corresponding to said carrier frequency. Alternatively, the
antenna elements may be aligned in another direction than the direction of
movement, e.g. a direction perpendicular to the direction of movement.

In the following description, the term "spacing" may be used to
designate the modulus of the spacing.

Alternatively, the beamforming means may comprise means to
provide a linear combination of the received signals or of the signals to be
emitted. That is signal paths are formed by combining weighted signals. In
this latter case, the beamforming means may for example comprise
multipliers to multiply the received signals or of the signals to be emitted by
weight coefficients, and adders to add the multiplied signals. The
beamforming is therefore performed directly on analogous signals, thus
reducing digital processing, and avoiding multiple frequency conversions
and multiple analog to digital conversions. The means to provide a linear
combination of the received signals or of the signals to be emitted may also
be digital processing means.

Advantageously, the method further comprises modifying the
arrangement of the antenna array according to a carrier frequency of the
arriving signals (or of the signals to be emitted). In the case of arriving
signals for example, such adaptive antenna array is arranged to adapt to a
carrier frequency of the arriving signals so as to exhibit a relatively low
receptivity for said signals if arriving substantially from the direction of
movement.

This may be done for example by modifying the weight coefficients
used in the beamforming, and/or by modifying the spacing between the two
antenna elements of the antenna array.

In this latter case, the method may comprise determining which pair
of only two antenna elements among a set of antenna elements comprising
more than two antenna elements forms an antenna array that creates two
opposite nulls for signals arriving from (or to be emitted with) substantially
the direction of movement, as a function of a carrier frequency of said
signals. The method may also comprise selecting the determined pair of antenna elements so as to form said antenna array.

Such adaptive antenna array may be realized with selecting means, e.g. a multiplexer, for selecting the pair of antenna elements among a set of at least three antenna elements. The selecting means may be controlled by calculating means, e.g. a processor, that determine which pair of two antenna elements among the set of antenna elements forms an antenna array that exhibits a substantially null receptivity for signals arriving substantially from the direction of movement, as a function of a carrier frequency of said signals.

The radio signals may for example be modulated according to a multicarrier modulation, e.g. OFDM. That is, the method further comprises modulating signals to be emitted/demodulating the received signals according to a multicarrier modulation/demodulation. The present invention hence allow a more proper transmission of such narrowband signals, that are particularly affected by Doppler Effect in the prior art.

The method of the present invention may be applied to DVD-T and DVB-H systems (Digital Video Broadcasting-Terrestrial and Digital Video Broadcasting-Handheld). For those systems, the operating frequency interval may comprise the 426MHz to 858MHz frequency band, and channels, e.g. 8MHz large channels, may be selected within the 426-858MHz interval. For a determined channel, the signal is likely to carry simultaneously a plurality of carrier frequencies, e.g. a set of substantially 8000 carrier frequencies within the corresponding channel. Each carrier frequency corresponds to a sub-band. The method may comprise determining which pair of only two antenna elements among the set of antenna elements forms an adequate antenna array, as a function of the central frequency of the selected channel. That is, the determination of the pair of antenna elements is performed at each selecting of a new channel, and the determined carrier frequency for which the antenna array is designed is the central frequency of the selected channel.

It should be understood that the sentence "suppressing signals having a determined carrier frequency" does not limit the scope of the
The present invention relates to radio reception/emission of signals having a single carrier frequency. The antenna array is arranged so as to substantially suppress signals substantially in the direction of movement of the moving object and having substantially the determined carrier frequency, but other signals received simultaneously in the direction of movement may also be at least partially suppressed by the antenna array.

Alternatively, a simple carrier modulation may be used.

It is to be understood that the present invention is by no means limited to a specific application. The invention may for example be applied to spread spectrum modulations, Multi Carrier Code Division Multiple Access (MC-CDMA), Direct Sequence CDMA (DS-CDMA), Digital Audio Broadcasting (DAB), Digital radio Mondiale (DRM), Discrete Multitone Modulation (G-DMT), IEEE 801.11a standard, WiFi, WiMax, fourth generation mobile phone etc.

In a second aspect, the present invention provides a radio system for receiving/emitting radio signals within an operating frequency interval at/from a moving object, e.g. a vehicle, said radio system comprising an antenna array consisting of two antenna elements and beamforming means, the antenna array being arranged such that two opposite nulls are created substantially in the direction of movement for signals having substantially a determined carrier frequency within the operating frequency interval.

The radio system hence allows substantially reducing the damages caused by Doppler Effect, with a very simple apparatus.

The radio system may typically comprise processing means to demodulate the received signals (or modulate the signals to be emitted).

In the case of received signals, and for said determined carrier frequency, the antenna array allows substantially suppressing the signals arriving in the direction of movement, i.e. the processing means process substantially only signals corresponding to side directions of the vehicle.

In the case of signals to be emitted, and for said determined carrier frequency, the antenna array allows substantially suppressing the signals in the direction of movement.
Although the description mainly relates to signal reception, it is to be understood that the invention may also be applied to signal emission from the vehicle.

By "signal", we mean either the radio waves arriving at or emitted from the vehicle, or the corresponding electrical signal at the antenna elements, the electrical signal at the antenna array or the digital signal at the processing means.

In a third aspect, the present invention provides a moving object, e.g. a vehicle, comprising the radio system according to an aspect of the invention.

In a fourth aspect, the present invention provides a method for manufacturing a radio system according to an aspect of the invention.

In a fifth aspect, the invention provides a method comprising installing on a moving object a radio system according to an aspect of the invention.

The method according to the fifth aspect of the invention may for example be carried out during a manufacturing of a vehicle.

Alternatively, one may improve an existing vehicle by installing the plurality of antenna elements on said existing vehicle, so as to null signals arriving from the direction of movement of the vehicle.

The vehicle may comprise a car, a bus, a truck, a train, a motorcycle, a plane, etc.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

Brief description of the drawings

FIG. 1 shows an example of a vehicle according to an embodiment of the present invention in a scattered environment.

FIG. 2 shows a radio system according to the embodiment illustrated in FIG. 1.

FIG. 3 shows some examples of antenna array patterns for different spacing between antenna elements.
FIG. 4 is a graph showing signal to noise ratio and signal to interference ratio as a function of the spacing between two antenna elements in an embodiment of the invention.

FIG. 5A is a graph showing signal to interference ratio for a single antenna element as a function of the vehicle speed.

FIG. 5B is a graph showing signal to interference ratio as a function of the vehicle speed for an antenna array in radio system according to an embodiment of the invention.

FIG. 6A is a graph showing signal to interference and noise ratio for a single antenna element as a function of the vehicle speed.

FIG. 6B is a graph showing signal to interference and noise ratio as a function of the vehicle speed for an antenna array in a radio system according to an embodiment of the invention.

FIG. 7A is a graph showing signal to interference and noise ratio for a single antenna element as a function of the vehicle speed.

FIG. 7B is a graph showing signal to interference and noise ratio as a function of the vehicle speed for an antenna array in a radio system according to an embodiment of the invention.

FIG. 8 shows an example of radio system according to an embodiment of the invention.

**Description of the preferred embodiments**

FIG. 1 shows an example of a vehicle, e.g. a car 1, in a scattered environment.

The radio signals to be received at the car 1 may have undergone reflections over obstacles 4. The signals may hence arrive at the car with various angles of arrivals \( \alpha \).

In this embodiment, the radio signals are multicarher modulated. An OFDM modulation may for example by used as OFDM is relatively robust against multipaths fading.
As the car 1 is mobile, the arriving signals may possibly be frequency shifted because of the Doppler Effect. The frequency shift $\Delta f$ may be written as:

$$\Delta f = \frac{v}{c} \cos \alpha,$$

wherein $f_0$ is the carrier frequency of the radio signals, $v$ is the speed of the vehicle, $c$ is the speed of light, i.e. $c$ substantially equals $3 \times 10^8$ m/s.

Such frequency shifts may be relatively harmful for narrowband signals, e.g. 8MHz wide DVB-T OFDM signals.

Each scattered component of the signal arrives with a distinct angle of arrival $\alpha$. Each scattered component hence undergoes a different Doppler shift and has different characteristics in terms of inter-carrier interference. As the angle of arrival of a scattered signal is closer to the direction of the movement 11, it induces more inter-carrier interference than the scattered signals coming perpendicular to the direction of movement of the car 1.

The car 1 is provided with a radio system 7, illustrated in FIG.2, for receiving and/or emitting radio signals over an operating frequency interval. The operating frequency interval may comprise the 426MHz to 858MHz frequency band for DVD-T and DVB-H systems (Digital Video Broadcasting-Terrestrial and Digital Video Broadcasting-Handheld).

The radio system 7 comprises an antenna array 3.

The antenna array 3 consists of two antenna elements 2A, 2B and an adder 5. The antenna elements 2A, 2B are spaced apart from each other and are substantially aligned with the front/back direction 11. The signals $r_A(t)$, $r_B(t)$ received at each of the antenna elements 2A, 2B respectively are summed up by means of the adder 5. Processing means 6 allow to demodulate and digitalize the signal $r(t)$ at the output of the adder 5.

The antenna array 3 is arranged so as to create two opposite nulls in the front-back direction. The antenna array 3 hence allows to substantially suppress the scattered signals that generate high inter-carrier interference and emphasize the scattered signals with low inter-carrier interference.
The correlation between the channels that each antenna element will experience and the coupling of the antenna elements depend on the antenna spacing, c/. Thus, different antenna array patterns may be obtained for different antenna spacing. FIG.3 shows different possible patterns, where λ is the wavelength of the signal and α is the angle of arrival with respect to the direction of the movement for a pair of antenna elements aligned with the direction of movement.

From FIG.3, one may notice that for c/=0.5 λ, the antenna array nulls the signals received in the direction of movement 11 (α=0° and α=180°) and has the highest array gain at α=±90°.

As can be seen from FIG.3, the antenna spacing c/ highly influences the antenna array pattern. The signal received by each array pattern generates different levels of inter-carrier interference and signal power. To quantify the effect of antenna pattern on signal power and inter-carrier interference, one may define the power of the signal received by the antenna array and the power of inter-carrier interference generated by it as $S_{array}$ and $P_{i\text{CI-array}}$, respectively. Similarly, one may define the power of the signal received by a single antenna element and the power of inter-carrier interference generated by the single antenna element as $S_{\text{single}}$ and $P_{i\text{CI-single}}$, respectively. Using $S_{array}$, $P_{i\text{CI-array}}$, $S_{\text{single}}$ and $P_{i\text{CI-single}}$, the signal-to-interference ratio performance of the antenna array and the single antenna element may be respectively expressed as

$$SIR_{array} = \frac{S_{array}}{P_{i\text{CI-array}}}$$
$$SIR_{\text{single}} = \frac{S_{\text{single}}}{P_{i\text{CI-single}}}$$

Similarly, defining the noise power as $N_0$, the signal to noise ratio of the antenna array $SNR_{array}$, the signal to interference and noise ratio of the antenna array $SINR_{array}$, the signal to noise ratio of the single antenna element $SNR_{\text{single}}$ and the signal to interference and noise ratio of the single antenna $SINR_{\text{single}}$ are:
\[ \text{SNR}_\text{array} = \frac{S_{\text{array}}}{2N_0} \quad \text{SNK}_{\text{single}} = \frac{S_{\text{single}}}{N_0} \]

\[ S_{\text{SNR}} = P_{\text{ICI-array}} + 2N_0 \quad S_{\text{SINR}} = P_{\text{ICI-single}} + N_0 \]

The performance improvement in decibels for the signal-to-noise ratio obtained by using the two-element antenna array becomes:

\[ \text{Gain(SNR)} = 10 \log \left( \frac{\text{SNR}_\text{array}}{\text{SNR}_\text{single}} \right) \]

and

\[ \text{Gain(SIR)} = 10 \log \left( \frac{\text{SIR}_\text{array}}{\text{SIR}_\text{single}} \right) \]

for the signal-to-interference ratio.

FIG.4 illustrates the effect of the antenna spacing on the signal-to-noise ratio gain and signal-to-interference ratio gain for a near scatter environment with uniformly distributed angles of arrival, considering the effect of mutual coupling effects of the two antenna elements.

One may observe that the antenna spacing \( d \) highly influences the SNR and SIR. At a spacing \( c/\lambda = 0.55 \), the SNR is reduced by 0.7dB whereas the SIR is increased by 5.8dB. Thus, an SIR enhancement of 5.8dB is provided at a cost of some loss in SNR.

Since there exists a trade-off between the SNR and SIR for different antenna spacings, the antenna spacing may be chosen appropriately.

It is known that non-mobile DVB-T and DVB-H systems have satisfactory reception quality when SNR is greater than 20 and 16.2dB, respectively. To support mobile users, the broadcasters are willing to increase their transmission power for an additional +3dB, leading to SNR of 23dB for DVB-T systems and SNR of 19.2dB for DVB-H systems in order to tolerate some inter-carrier interference power level for mobile users.
Considering these facts, the antenna spacing may be chosen such that the maximum tolerable vehicle speed is maximized. It may be observed that depending on the SNR at which the system is operating, the optimum distance that maximizes the speed limit varies between 0.55λ and 0.56λ.

Since the SNR and SIR performance of the antenna array does not change much over this interval, and for the sake of simplicity, antenna arrays with d=0.55λ antenna spacing are chosen.

Another important point in designing the two element antenna array is that for a fixed spacing d, the antenna array has different c//λ values for different carrier frequencies, f_c, thus has different antenna array patterns.

Also, for a given speed, higher carrier frequencies experience higher maximum Doppler frequency, thus higher inter-carrier interference power. Thus, higher carrier frequencies are more sensitive to speed than the lower ones. Considering this fact, the antenna array may be designed considering the worst-case scenario for f_c = 858MHz and the optimum antenna spacing should be \( d_{op} = 0.55 \cdot \lambda_{g58MHz} \).

FIG.5A and 5B are graphs showing signal to interference ratios (SIR) as a function of the vehicle speed, respectively for a single antenna element and for an antenna array in a radio system according to an embodiment of the invention. In this example, the environment is a near scatter environment with uniformly distributed angles of arrival. In this embodiment, the spacing between the antenna elements is chosen \( d_{op} = 0.55X \cdot 58MHz \), i.e. \( d_{op} \) substantially equals 0.192 meters. Also, the antenna elements are substantially aligned with the direction of movement.

The signal to interference ratio (SIR) is represented for three different channels with \( f_c = 474, 626 \) and 858MHz respectively.

One may observe on FIG.5A and FIG.5B that the SIR improvement achieved by using the two-element antenna array varies with the carrier frequency. For a carrier frequency of 858MHz, the improvement is 5.8 dB, whereas the SIR of the lowest carrier frequency (474MHz) is improved of 1.3dB, and for the middle carrier frequency, (626MHz), the improvement is
2,8dB. Although the SIR improvement is different over the carrier frequencies, the antenna array particularly improves the SIR of the carrier frequencies where the improvement is most needed, at higher carrier frequencies. Considering the performance of the worst-case scenario over all carrier frequencies, i.e., the highest carrier frequency (858MHz) for single antenna systems in FIG.5A and the middle carrier frequency (626MHz) for the two-element antenna array in FIG.5B, the SIR improvement is about 5,5dB.

FIG.6A and 6B are graphs showing signal to interference and noise ratios (SINR) as a function of the vehicle speed, respectively for a single antenna element and for an antenna array in a radio system according to an embodiment of the invention. In this example, the environment is a near scatter environment with uniformly distributed angles of arrival. In this embodiment, the spacing between the antenna elements is chosen $d_{opt} = 0.55 \times 858\text{MHz}$. Also, the antenna elements are substantially aligned with the direction of movement. The SINR performances depend on the SNRs at which the systems are operating. In the examples of FIG.6A and 6B, the SNR substantially equals 23dB, i.e. a SNR level at which a DVB-T system is expected to operate properly.

Since the inter-carrier interference power increases when the vehicle speed is increased, the SINR improvement obtained with the radio system of an embodiment of the present invention increases with the vehicle speed. Although the SINR improvement also varies with the carrier frequency, one may observe that the lowest SINR over all carrier frequencies is improved around 0,6dB at a speed of 13,89m/s (50 km/h) and around 4,7dB at a speed of 69,44m/s (250km/h) for DVB-T systems with an SNR of 23dB.

FIG.7A and 7B are graphs showing signal to interference and noise ratios (SINR) as a function of the vehicle speed, respectively for a single antenna element and for an antenna array in a radio system according to an embodiment of the invention. In this example, the environment is a near
scatter environment with uniformly distributed angles of arrival. In this
embodiment, the spacing between the antenna elements is chosen \( d_{op,t} = 0.55 \lambda \) 58MHz. Also, the antenna elements are substantially aligned with the
direction of movement.

In the examples of FIG.7A and 7B, the SNR substantially equals
19.2dB, i.e. a SNR level at which a DVB-H system is expected to operate
properly.

One may observe an SINR improvement in the rage of 0dB to 3.9dB
as the vehicle speed varies from substantially 13.89m/s (50km/h) to
69.44m/s (250km/h).

Thus, a simple two element antenna array according to an
embodiment of the invention allows improving both SIR and SINR
performance.

FIG.8 shows an exemplary radio system according to an alternative
embodiment of the invention.

In this embodiment, the radio system comprises a set of antenna
elements \( 2_A, 2_B, 2_C, 2_D, 2_E, 2_F \) substantially aligned with the direction of
movement. The spacing between the antenna elements \( 2_A \) and \( 2_B \) is chosen
as substantially equal to \( d_{sss} = 0.55 \lambda \) 58MHz, i.e. \( d_{op,t} \) substantially equals
0.192 meters. The spacing between the antenna elements \( 2_A \) and \( 2_E \) is
chosen as substantially equal to \( d_{42} = 0.55 \lambda \) 26MHz, i.e. \( d_{op,t} \) substantially equals
0.384 meters.

The antenna elements \( 2_A \) and \( 2_B \) hence form with the adder 5 an
antenna array that creates two nulls in the front-back direction for signals
having a carrier frequency around 858MHz, i.e. substantially the highest
frequency within the 426-858MHz interval.

The antenna elements \( 2_A \) and \( 2_E \) hence form with the adder 5 an
antenna array that creates two nulls in the front-back direction for signals
having a carrier frequency around 426MHz, i.e. substantially the smallest
frequency within the 426-858MHz interval.
The processing means 6 comprise demodulating means and allow to estimate the carrier frequency of the arriving signals. The processing means further comprise calculating means that determine as a function of the carrier frequency of the arriving signals which antenna element 2_B, 2_C, 2_D, 2_E, 2_F forms with the antenna element 2_A and with the adder 5 an antenna array that creates two opposite nulls for said arriving signals when arriving from the front-back direction.

A multiplexer 10 controlled by the processing means 6 allows selecting the determined antenna element, as illustrated in FIG.8. Such adaptive antenna array hence allows forming two opposite nulls in the front-back direction for more than one carrier frequency, thus providing a relatively efficient substantial suppression of the most Doppler affected signals.
1. A method for receiving/emitting radio signals at/from a moving object \((1)\), said radio signals having at least one carrier frequency within an operating frequency interval, said method comprising substantially suppressing signals substantially in a direction of movement of the moving object and having substantially a determined carrier frequency within the operating frequency interval, by means of an antenna array \((3)\) consisting of two antenna elements \((2A, 2B)\) and beamforming means \((5)\), the antenna array being arranged such that two opposite nulls are created substantially in the direction of movement for signals having substantially the determined carrier frequency.

2. The method according to claim 1, wherein the determined carrier frequency is substantially equal to the highest frequency of the operating frequency interval.

3. The method according to any one of the preceding claims, wherein the beamforming means comprise means to provide a linear combination of the received signals/the signals to be emitted.

4. The method according to any one of the preceding claims, wherein the beamforming means comprise an adder \((5)\).

5. The method according to any one of the preceding claims, further comprising determining which pair of only two antenna elements \((2A, 2E)\) among a set of antenna elements \((2A, 2B, 2C, 2D, 2E, 2F)\) comprising more than two
antenna elements, forms with the beamforming means (5) an antenna array that creates a null substantially for signals arriving from/to be emitted with substantially the direction of movement, as a function of a carrier frequency of said signals, and

selecting the determined pair of antenna elements so as to form said antenna array.

6. The method according to any one of the preceding claims, further comprising

10 modulating/demodulating the signals to be emitted/the received signals according to a multicarrier modulation/demodulation.

7. A radio system (7) for receiving/emitting radio signals within an operating frequency interval at/from a moving object, said radio system comprising:

an antenna array (3) consisting of two antenna elements (2_A, 2_B) and beamforming means (5), the antenna array being arranged such that two opposite nulls are created substantially in the direction of movement for signals having substantially a determined carrier frequency within the operating frequency interval.

8. A moving object (1) comprising a radio system (7) according to claim 7.

9. A method for manufacturing a radio system for receiving/emitting radio signals within an operating frequency interval at/from a moving object, said method comprising:

providing an antenna array (3) consisting of two antenna elements (2_A, 2_B) and beamforming means (5), the antenna array being arranged such that two opposite nulls are created substantially in the direction of movement for signals having substantially a determined carrier frequency within the operating frequency interval.
10. A method for manufacturing a moving object (1) or improving an existing moving object, comprising 
    installing on the moving object (1) a radio system according to 
    Claim 7.

11. A computer program product comprising program code means for 
    causing a computer to carry out the steps of the method as claimed in 
    claims 1 to 6.
FIG. 5A
FIG. 6A
FIG. 6B
FIG. 7B
INTERNATIONAL SEARCH REPORT

PCT/IB2008/050743

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01Q1/32 H01Q3/26 H01Q9/16 H01Q9/30 H01Q21/29

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
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<td>1,7-11</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search
25 June 2008

Date of mailing of the international search report
04/07/2008

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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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