

Communication device for a railway vehicle

The present invention concerns a device for communication between one or more railway vehicles and a control post in general, and relates more particularly to a radiating waveguide continuous communication device.

From the document FR 2 608 119 of the Applicant, a device is known for continuous communication with a waveguide radiating in dominant mode, also termed mode TE_{01} , between a railway vehicle and a control post. The device comprises a hollow tube parallel to a transport track and deposited continuously along the track, forming a waveguide, only a single emissive face of which is pierced by a network of geometrically asymmetrical openings for the passage of hyperfrequency electromagnetic radiation. The network of openings (termed "slots" in the remainder of the description, owing to their narrow and elongate geometry) is itself then disposed so as to direct its emissive face at a short distance from the antenna integral with the vehicle, movable along the radiating waveguide. The geometry, the dimensions of the slots and also the spacing between the slots are dimensioned according to the frequency ranges used. The cross-section of the guide is of the order of the wavelength and the large dimension of the slots is small compared with the wavelength. The frequency range which it is permitted to use varies according to the country. In France, and in many regions of the world, it may advantageously be in the 2.4 GHz range, where the channels are located which can be utilised according to standards IEEE 802.11b and g, standards known as Wi-Fi for Wireless Fidelity, or in

the 5.8 GHz band according to standard IEEE 802.11a. Electromagnetic theory considers that for distances between antennae of the order of magnitude of the wavelength or of a small number of wavelengths, the antennae are said to function in near field and require a particular approach in order to study their coupling. By way of example, at 2.4 GHz, i.e. for a wavelength in the air of 12.5 cm, the near field state as expressed conventionally in electromagnetism is valid up to a distance of the order of magnitude of three to four wavelengths, or 40 to 50 centimetres. Beyond this distance, the antenna begins to function in distant field.

Along the guide, and at distances of less than four wavelengths, the overall signal radiated by the waveguide may be likened to the sum of each of the radiations in near field of the several slots located upstream and downstream of the current point where the antenna of the vehicle is located. The energy is radiated perpendicularly to the plane of the slots. It is not possible to show clearly, for these short ranges, a privileged direction of the radiation such as would be obtained by considering the combination of radiations in distant field of the slots when the latter exhibit, between them, appropriate phase and power relationships. As a result, the vehicle is equipped with an antenna for transmitting and/or receiving hyperfrequency waves facilitating the near field coupling between the emissive part of the waveguide and the antenna of the vehicle, without any particular favourable orientation.

The traffic control post is equipped with a device for supplying the waveguide with hyperfrequency waves

and/or with at least one device for receiving hyperfrequency waves coming from the waveguide. This device makes it possible to maintain continuously a wide passband link (> 100 MHz) between the control post on the ground and the vehicles. In near field, the device also permits, simultaneously, the measurement of speed of the vehicles without physical contact with the ground and also the location of the vehicles by reading a pseudo-random sequence recorded in the structure of the waveguide. The device is operational whatever the environment of the track (tunnel, viaduct, cutting, etc.). The use of high frequencies in the 2 - 6 GHz range makes it possible to overcome the majority of the problems of electromagnetic compatibility which are constraining in a railway environment.

The waveguide is made of metal. The choice of metal constitutes a compromise between the constraints of cost and the constraints of inherent conductivity of the metal, affecting the performance of conduction of the wave in the waveguide. Thus, depending on the metal selected, the longitudinal attenuation will be more or less high and the number of transmitters/receivers necessary per kilometre of waveguide will be proportionally more or less high. The total longitudinal attenuation is the sum of the loss by the Joule effect and of the loss due to the drawing off of the energy of the wave which is radiated through the slots of the waveguide.

For example, in a particular embodiment at 2.4 GHz, an aluminium waveguide exhibits a linear loss by the Joule effect of 15-16 dB/km and a linear loss by drawing off limited by construction at 2-3 dB/km.

There is also known from the document US 3 648 172 a circular waveguide with two longitudinal networks of circular openings disposed in the upper part of the waveguide. At the very high frequencies mentioned (7.5-
5 10 GHz), the waveguide utilises modes of propagation of higher order generally termed TE_{mn} ($m, n > 1$) in order to obtain a limited longitudinal attenuation in relation to its utilisation along a transport network. In order to permit the propagation of these modes, the diameter of
10 the waveguide is at least three times greater than the wavelength of the waves propagated in the guide. The circular openings pierced on the waveguide simultaneously emit a plurality of components of electromagnetic radiation. They therefore emit electromagnetic energy in
15 different spatial directions. However, the train antenna generally receives a single electric field component oriented in a privileged spatial direction and therefore exhibits only a fraction of the energy emitted from the guide, the other part proving to be radiated without
20 being used. As a result, this reduces the signal-to-noise ratio of the link, which in turn limits the useful output of the ground-to-train communication which should however be high in a modern ground-to-train communication system. Moreover, the propagation possible in this
25 waveguide of a plurality of simultaneous propagation modes generates between these different propagation modes beating and local attenuation of signals, requiring the use of a sandwich guide structure acting like a mode filter, complex to produce with materials acceptable in
30 the railway environment, with regard to mechanical durability or emission of toxic fumes in the event of fire.

When the railway network to be equipped with communication devices is a double track network, waveguides are disposed parallel to each track, with as many transmitters/receivers as necessary on each side.

5 The traffic control post thus communicates with each train travelling on each of the tracks by sending the hyperfrequency waves into the two communication devices.

The problem which the invention aims to solve is that of reducing the number of transmitters/receivers installed on the ground and of limiting the length of

10 guides to be installed along double railway tracks, in order to limit the quantity of material and the quantity of components that are necessary without generating any particular mechanical stress, to limit the installation

15 or maintenance time of the device while allowing a control post to communicate at a high data output with the trains travelling on the two parallel tracks, with the same security and the same availability as the communication device of the prior art. The two parallel

20 tracks are spaced by a significant distance, as expressed in wavelengths of the hyperfrequency communication signals used.

The device for continuous communication according to the invention between at least one railway vehicle and a

25 control post includes at least one waveguide disposed between two parallel tracks resting on a non-emissive face, comprising two emissive faces, each pierced by a network of openings for the passage of hyperfrequency electromagnetic radiation of given wavelength, at least

30 one vehicle equipped with at least one antenna for transmitting and receiving hyperfrequency waves, the control post being equipped with at least one device for

supplying the waveguide with hyperfrequency waves and with at least one device for receiving hyperfrequency waves coming from the waveguide, and is such that the waveguide is in the shape of a parallelepiped, the
5 openings of which are formed by slots.

The communication device also includes one or more of the following features:

- the large dimension of the emissive faces of the waveguides is of the order of magnitude of the
10 wavelength of the electromagnetic radiation propagated in the waveguide,
- the large dimension of the slots is less than at least five times the wavelength of the electromagnetic radiation propagated in the
15 waveguide,
- the inter-slot spacing is less than the half-wavelength of the signals emitted in the air,
- the two networks of slots are identical,
- one of the networks of slots is of larger size than
20 the other,
- the emissive faces are disposed vertically,
- the slots are disposed vertically,
- the distance between the antenna disposed on board a vehicle and the communication device is at least
25 four wavelengths,
- the antenna disposed on board a vehicle has a directivity of radiation identical to that of the communication device.

A first advantage of the waveguide communication
30 device with double network of slots is therefore that of dividing by two the quantity of material necessary for

producing the waveguide, while increasing only slightly the number of transmitters/receivers.

A second advantage of the waveguide communication device with double network of slots is that of subjecting
5 the track to fewer installation stresses by bringing the waveguide out of the actual track, thereby facilitating the maintenance operations for the latter.

A third advantage is that with this arrangement the waveguide, although robust, proves to be less exposed to
10 material damage linked to objects or falling or trailing from vehicles, especially those for track maintenance.

A fourth advantage is that the vertical arrangement of the double network of slots renders it less sensitive to the accumulation of dirt, water, snow, ice, etc. on
15 its emissive surfaces.

In addition, the dimensions of the waveguide are such that only the dominant propagation mode TE_{01} is utilised, thereby leading to mechanical simplification of the guide since the different propagation modes no longer
20 need to be filtered.

The invention will become clearer from the following description with reference to the appended drawings, in which:

- Figure 1 is a diagrammatic view of the communication
25 device for a railway network,
- Figure 2 shows a sectional view of the waveguide according to the invention,
- Figure 3 shows a sectional view of the waveguide according to the invention according to a second
30 embodiment,
- Figure 4 shows an embodiment of the communication device according to the invention,

- Figure 5 shows the radiation diagram measured in azimuth of the communication device according to the invention, associated with a physical representation of the waveguide.

5 Figure 1 shows a device for communication between a control post P and at least one vehicle A travelling on a track, comprising a plurality of fixed waveguides 1, 1', 1ⁿ, etc., disposed continuously and end to end along the track. The length of the communication device depends on
10 the type of network. A waveguide is several hundreds of metres in length, and the communication device comprises n waveguides covering the whole railway network.

 Since all the guides are identical, only the waveguide 1 will be described. The waveguide 1 is formed
15 of two separate sections 1a and 1b, into which the waves are injected, for example by means of a coaxial-to-waveguide transition, at the ends 2a and 2b of the sections 1a and 1b. The ends 3a and 3b of the waveguide 1 are charged in order to avoid the establishment of a
20 regime of stationary waves in the waveguide, for example by means of a waveguide-to-coaxial transition and an adapted resistive charge, or by the arrangement of a hyperfrequency absorbent material disposed in front of a metallic short-circuit plane of the guide. The ends 3a,
25 3b transmit no wave to the adjacent waveguides 1' and 1ⁿ.

 The waves are emitted or received by a transmitter/receiver 4 which is connected to a communications network R linking all the transmitters/receivers 4, 4', 4ⁿ..., to the control post
30 P. The data thus flow from the control post P to the vehicle A, or vice versa, via the communications network

R, the transmitters/receivers 4, 4', 4ⁿ and the waveguides 1, 1', 1ⁿ.

As Figure 2 indicates, in this particular embodiment the waveguide 1 is in the shape of a parallelepiped, the large faces 6a, 6b being pierced by slots 8a, 8b (shown vertical here) which radiate or receive the waves. The faces 6a, 6b are termed "large" because their side b is larger than the side a of the "small" faces 7a, 7b. The large dimension b of the emissive faces 6a, 6b is of the order of magnitude of the wavelength. Owing to this characteristic, only the dominant mode TE₀₁ is utilised, i.e. only the first mode can propagate in the guide to the exclusion of any other mode.

The large dimension D of the slots is much smaller than the length of the side b: it is at least five times less than the wavelength propagated in the guide. This makes it possible to limit the radiation losses per unit length to 2-3 dB/km while maintaining a power radiated by the guide sufficient to ensure high output communication with the vehicle.

In other terms,

$$b \sim \lambda$$

$$D \leq \lambda/5$$

λ being the wavelength of the electromagnetic radiation being propagated in the guide.

Preferably, the large dimension D of the slots is disposed in the vertical direction, perpendicularly to the direction of the waveguide. This arrangement and the very asymmetrical shape of the slots (D is at least 6 times greater than the small dimension of the slots) make it possible to radiate substantially a single electric field component, oriented in the direction of the guide.

This electric field component is utilised by the antenna of the vehicle. In this way the energy drawn off from the guide and radiated towards the outside is limited to the minimum necessary for ground-to-vehicle communication.

5 In practice, a waveguide functioning at a low frequency of 2.4 GHz in dominant mode has a large face b of approximately 12.5 cm, or the wavelength λ of the electromagnetic radiation being propagated in the guide. The large dimension of the slots D is 19 mm, the small
10 dimension of the slots is 3 mm and the inter-slot pitch is 61 mm.

As a variant, as shown in Figure 3, the large dimension D_1 of all the slots 8a of one emissive face, for example the emissive face 6a, may be uniformly increased
15 relative to the large dimension D_2 of the slots 8b of the other emissive face 6b. This arrangement makes it possible to reinforce the electromagnetic radiation towards one of the two tracks. By way of example, this makes it possible to compensate for an absence of
20 symmetry of the laying of the waveguide between the tracks as linked to the configuration imposed by the site, it being possible for one track to be further from the waveguide 1 than the other.

As a variant (not shown), the guide could be of
25 circular or oval cross-section and would exhibit a similar behaviour of its electromagnetic radiation in the air.

Figure 4 is a view of the device for continuous communication between the traffic control post P (not
30 shown) and two trains A and B travelling in two opposed directions on two parallel tracks, 2 and 3. The following description is provided when two trains are

present on the tracks 2 and 3, but it is understood that the functioning of the device is exactly identical even if there is only one train travelling on a single track.

The waveguide 1 is disposed between the two tracks 2
5 and 3, its small face 7b being placed on the ground, or on a support at a certain distance from the ground, the large faces 6a, 6b, which are emissive, being vertical. Alternatively, the waveguide 1 could be suspended in a tunnel vault, between two tracks (2, 3).

10 The traffic control post P communicates with the trains A and B by injecting into the waveguides 1, 1', 1ⁿ signals S1, S2 in the form of a group of hyperfrequency waves, which propagate according to an "outward" propagation mode within the waveguide 1a, 1b and which
15 are all radiated by the emissive faces of the waveguide 1a, 1b in the direction of the antennae 5 of the trains A and B (the waves emitted are represented in Fig. 4 by two-directional double arrows). Each onboard antenna therefore receives all the waves injected into the
20 waveguide 1a, 1b (Fig. 1), the receiver of each antenna processing in a known manner the signals S1, S2 received so as to identify which signal is addressed to it. One or more antennae may be disposed on board, on the same side or on each side of the train.

25 Taking into account the energy loss due to the loss by the Joule effect and losses due to the drawing off of energy from the slots 8a, 8b, the power of the waves is maximum close to the ends 2a, 2b (Fig. 2) when it is injected by the transmitter/receiver 4. Conversely, at
30 the ends 3a, 3b, the power of the waves is minimum, since the wave has lost energy by propagating along the guide and by radiating through the slots 8a, 8b.

The onboard antennae 5 (Fig. 4) are transmitters and receivers. Thus, the trains A and B communicate with the control post P by emitting signals in hyperfrequency waves via the onboard antennae 5 towards the waveguide 1, the signals then being propagated from the slots 8a, 8b of the emissive faces 6a, 6b towards the ends 2a, 2b (Fig. 1) of the waveguide 1 with a "return" propagation mode identical to that of the "outward" mode.

In this case, taking into account the energy loss, the power of the wave injected into the waveguide 1 decreases in the direction of the ends 2a, 2b to reach the transmitter/receiver 4 (Fig. 1).

It is known that the radiation diagram of a waveguide of the prior art, very long and pierced with slots over only one surface, the slots being of dimensions much smaller than the wavelength, exhibits in near field a radiation directed, in a plane perpendicular to that of the openings, towards the outside of the guide, without it being possible to obtain focusing of the energy in a privileged spatial direction.

It is also known that antennae may be produced starting from a transmission line of the waveguide type. Thus the "Antenna Engineering Handbook" by Richard C. Johnson and Henry Jasik publishes, in its second edition edited by McGraw-Hill Book Company (chapter 10, page 11), a description of an antenna termed "Leaky wave antenna". This antenna is constructed starting from a waveguide of rectangular cross-section having a short length. It uses slots in which the large dimension is of the order of magnitude of the half-wavelength. These antennae are developed in order to obtain on the one hand high efficiency, i.e. in particular to have the capacity for

radiating by means of an antenna of reduced size (of the order of a few wavelengths) all the energy which is communicated to them and, on the other hand, to focus at great distance the energy radiated in the desired privileged spatial direction. Such an antenna therefore functions in far field and its radiation diagram is directional.

In the same chapter, the authors describe another antenna produced by means of slots pierced on the four faces of the guide in order obtain circular polarisation of the signals emitted in a privileged spatial direction. In these cases in point, the radiations of the different openings interfere strongly and are composed so as to produce the required directivity and polarisation. A strong coupling between these openings and the field present in the guide is therefore produced and utilised.

The aim of the invention on the other hand is to limit the radiation of the structure severely in order to draw off only very little energy from the interior of the guide. The waveguide 1 is therefore pierced by very small slots 8a, 8b which individually draw off only an extremely limited amount of energy from the interior of the guide, as described previously.

The Applicant has now demonstrated that each slot 8a, 8b of the waveguide 1 according to the invention, unlike the antennae with waveguide pierced by four networks of slots described previously, radiates independently without significant interaction with the energy propagated in the guide or with other nearby slots 8a, 8b. The radiations of different networks of slots 8a, 8b disposed on opposed emissive faces 6a, 6b of the waveguide 1 take place in fact substantially

independently, without significant coupling between the two emissive faces 6a, 6b. This effect therefore makes it possible to transmit and to receive signals continuously and over great distances via n waveguides 1
5 disposed at the track, each waveguide 1 radiating via two networks of slots 8a, 8b, the radiation characteristics of which are independent of one another.

In fact, in the case of slots of very small dimensions provided in a conducting plane, polarisability
10 theory demonstrates that the radiation of a slot having transverse dimensions that are very small in relation to the wavelength, if it is effected in a thin conducting plane, and in the far field state, is comparable to that of an elementary magnetic dipole oriented along the axis
15 of the large dimension of the slot which radiates an electric field component oriented in the direction of the guide. The elementary magnetic dipole arises from the fact of the interruption of current lines at the surface of the metal, linked to the presence of the opening.
20 This magnetic dipole of equivalent radiation is oriented perpendicularly to the plane of the slot.

By calculating the overall contribution of the radiations of a large number of these correctly spaced and dephased slots, the formation of a particular
25 radiation diagram in distant field is obtained. The waveguide 1 according to the invention therefore functions in far field and its radiation diagram is directional. However, it does not function like a waveguide of the prior art, since the waveguide 1
30 according to the invention functions in far field and not in near field. Nor does it function like a waveguide-type antenna of the prior art, since the waveguide 1

according to the invention radiates only a minute part of the energy of the signal which passes through it over a very long guide distance, whereas an antenna of the prior art radiates all the energy of the signal which passes
5 through it over a very short guide distance.

The calculation of the inter-slot spacing is carried out in a known manner, taking into account on the one hand the phase shift introduced by the propagation of the hyperfrequency signals in the waveguide 1, and on the
10 other hand the phase shift of these signals introduced by the propagation of the signals in the air on each side of the waveguide 1, after the passage of the energy through the slots 8a, 8b. A critical inter-slot spacing, i.e. permitting the constructive summation of the radiations
15 of the different consecutive slots, the order of magnitude of which is a few centimetres in the 2.4 - 5.8 GHz band - or an order of magnitude slightly below the half-wavelength of the signals emitted in the air - thus provides a signal of constant amplitude above the guide,
20 whatever the position of the antenna: above a slot, between two slots, etc. Beyond this critical spacing, the signal transmitted by the network of slots fluctuates strongly from one opening to the other and consequently proves not very utilisable for maintaining ground-to-
25 train communication.

Figure 5 represents the radiation diagram of the waveguide 1 according to the invention, the slots 8a, 8b of the two emissive faces being of identical dimensions. The axis of the waveguide 1 corresponds to an angle of 0° .
30 Owing to the symmetrical formation of the two networks of slots, a diagram of radiation symmetrical in relation to the axis of the waveguide 1 constituted by two main lobes

9 and 10 appears. The two main lobes 9 and 10, transposed to the transport environment of Figure 3, make it possible to concentrate the electromagnetic energy simultaneously in the direction of the two transport
5 tracks 2 and 3, by means of a single radiating waveguide 1 disposed in a central position on the ground or in a tunnel vault.

This radiation diagram is obtained as soon as a sufficient number of radiations of slots is integrated.
10 In practice, about a hundred slots make it possible to obtain high limit beyond which the effect of summation of the contributions of the slots tends towards an asymptote. As indicated previously, the radiating waveguide 1 is installed continuously between stations,
15 over distances of several hundreds of metres. As a result, it contains several thousands of slots.

In a vertical plane, the lobes of radiation 9 and 10 have maxima which depend on the height of the waveguide above the ground. The presence of the ground and its
20 physical characteristics influence the radiation diagram in elevation of the radiating waveguide. In dependence on its effective height above the ground, as defined by the mechanical stresses of installation on site, a compatible antenna height of the vehicle will be selected
25 in order to locate the antenna of the vehicle in the main lobe of radiation 9 or 19 of the waveguide 1 at the track. In practice, the distance between the onboard antenna 5 and the waveguide 1 should be at least four wavelengths in order to function in the near field state.
30 Below four wavelengths, the antenna is placed in the near field state. However, in the far field state, the radiation diagram is not formed and does not therefore

permit the waveguide 1 to focus the hyperfrequency energy effectively towards the antennae 5, and thus to communicate between trains and ground with an optimised linkage balance.

5 Although the distance between the waveguide 1 and each antenna 5 of the vehicle A, B is in practice increased in relation to the waveguide of the prior art, the gain provided by this summation and concentration of energy compensates to a large extent for the additional
10 attenuation of the signals which pass over a greater distance in the air, from the waveguide 1 to the onboard antenna 5.

 The antenna 5 of the vehicle A or B is disposed so as to be located permanently in proximity to a network of
15 slots 8a or 8b exhibiting the radiation diagram of Figure 4, and progressively and continuously sweeps the whole of the thousands of slots 8a or 8b of the waveguide 1 during the movement of the vehicle A or B (Fig. 4). The radiation diagram permanently accompanies the movement of
20 the vehicle and continuously supplies to the two transport tracks 2 and 3 a maximum of electromagnetic energy in a privileged spatial direction.

 An antenna termed omnidirectional, i.e. an antenna which exhibits an electromagnetic field whatever the
25 direction of arrival of an emitted signal or alternatively which in the same way radiates an electromagnetic signal in all spatial directions may be suitable. This antenna will be able to capture the signals emitted by the waveguide 1 in its privileged
30 directions of radiation and transmit signals in the direction of the waveguide, at the same level as the

signals received or transmitted in other spatial directions.

However, such an antenna does not exhibit any particular gain linked to the focusing of the energy in one or more privileged spatial directions. As a result, the signals shown by this antenna will be weak or will not make it possible to inject a high power into the waveguide, through the slots. This means that such an antenna will not make it possible to obtain high communication outputs except for increasing the power emitted by the train or ground transmitter.

A shaped beam antenna having a radiation diagram exhibiting directivities of radiation permits the best possible transfer of energy between the waveguide 1 at the track and the antenna. In other words, the radiation diagram of the antenna should have at least one main lobe of radiation in which the orientation is identical to that of one of the main lobes of the radiation diagram of the waveguide 1. The orientation is defined by the angle α formed by the axis of the main lobe with the axis of the antenna or of the waveguide. For example, as the waveguide 1 according to the invention in Fig. 4 has a main lobe directed at approximately 30° with respect to the axis of the waveguide, an antenna 5 co-linear with the train should also have a starting angle of 30° in order to receive and transmit efficiently signals in this privileged spatial direction. Such an antenna makes it possible to obtain high communication output rates.

The total attenuation per unit length in the waveguide 1 is only slightly increased since, via a double number of slots that are all identical, only the loss by drawing off energy from the waveguide is doubled.

In the particular embodiment presented at 2.4 GHz, the total attenuation per unit length thus passes from 18 dB to 21dB in the case of an aluminium waveguide, and the reduction in range would therefore be 3 : 18, or
5 approximately 17%. This reduction in range may be palliated by slightly reducing the size of the slots, which would however have the result of reducing the energy emitted and received via the waveguide.

Owing especially to the weak electromagnetic
10 coupling between adjacent networks of slots, the behaviour of the double network of slots and its radiation diagram in far field prove to be stable in a wide frequency band and in practice depends only on the proper mode of propagation existing within the wave guide
15 1.

C L A I M S

1. Device for continuous communication between at least one railway vehicle (A, B) and a control post (P),
5 including at least one waveguide (1, 1', 1n) disposed between two parallel tracks and resting on a non-emissive face (7b), comprising two emissive faces (6a, 6b) each pierced by a network of openings (8a, 8b) formed by slots for the passage of hyperfrequency electromagnetic
10 radiation of given wavelength, at least one vehicle (A, B) being equipped with at least one antenna (5) for transmitting and receiving hyperfrequency waves, the control post (P) being equipped with at least one device for supplying the waveguide (1, 1', 1n) with
15 hyperfrequency waves and with at least one device for receiving hyperfrequency waves coming from the waveguide (1, 1', 1n), characterized in that the waveguide (1, 1', 1n) is in the shape of a parallelepiped and in that the emissive faces (6a, 6b) are disposed vertically.

20 2. Device according to claim 1, characterized in that the large dimension of the emissive faces (6a, 6b) of the waveguide (1, 1', 1n) is of the order of magnitude of the wavelength of the electromagnetic radiation propagated in the waveguide.

25 3. Device according to claim 1 or claim 2, characterized in that the large dimension (D) of the slots (8a, 8b) is less than at least five times the wavelength of the electromagnetic radiation propagated in the waveguide (1, 1', 1n).

30 4. Device according to any one of claims 1 to 3, characterized in that the inter-slot spacing is less than the half-wavelength of the signals emitted in the air.

5. Device according to any one of claims 1 to 4, characterized in that the two networks of slots (8a, 8b) are identical.

6. Device according to any one of claims 1 to 4,
5 characterized in that one of the networks of slots (8a, 8b) is of larger size than the other (8a, 8b).

7. Device according to any one of claims 1 to 6, characterized in that the slots (8a, 8b) are disposed vertically.

10 8. Device according to claim 1 to 7, characterized in that the distance between the antenna (5) disposed on board a vehicle (A, B) and the communication device is at least four wavelengths.

15 9. Device according to claim 8, characterized in that the antenna (5) disposed on board a vehicle (A, B) has a directivity of radiation identical to that of the communication device.