



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
03.12.2008 Bulletin 2008/49

(51) Int Cl.:
G08G 1/015^(2006.01)

(21) Application number: **07425302.2**

(22) Date of filing: **21.05.2007**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK RS

(71) Applicant: **C.R.F. SOCIETÀ CONSORTILE PER AZIONI**
10043 Orbassano (IT)

(72) Inventors:
• **Zangherati Silvia**
10043 Orbassano (IT)
• **Corongiu Alessio**
10043 Orbassano (IT)

(74) Representative: **Bergadano, Mirko et al Studio Torta S.r.l.**
Via Viotti, 9
10121 Torino (IT)

(54) **System for monitoring vehicle transit along a highway section**

(57) A system for monitoring transit of vehicles along a highway section (2), the system having a number of transmitting-receiving stations (4a, 4b, 4c) installed along the highway section and forming part of a wireless sensor network; each of the transmitting-receiving stations (4a, 4b, 4c) being configured to communicate with the other transmitting-receiving stations (4a, 4b, 4c), and having an independent power source, and a charging device for charging the independent power source; and the system being characterized in that a number of pairs (A₁, A₂, A₃, A₄) of the number of transmitting-receiving stations (4a,

4b) are configured to operate:
- in a first operating mode (ACTIVE), in which transit of vehicles along the highway section (2) is detected, and the type of vehicles in transit along the highway section (2) is determined; and
- in a second charge operating mode (SLEEP), in which the charging device for charging the independent power source is activated;
and in that at least one pair of transmitting-receiving stations (4a, 4b) operates in one of the first and second operating modes (ACTIVE, SLEEP), which differs from the operating mode of the other pairs.

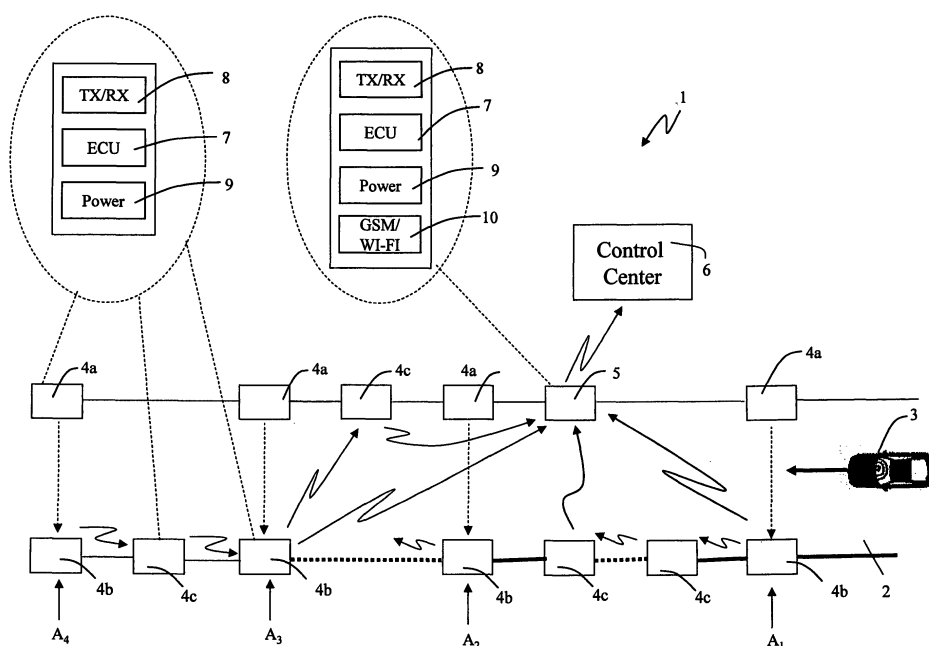


Fig.1

Description

[0001] The present invention relates to a system for monitoring vehicle transit along a highway section.

[0002] Vehicle transit along a highway section, e.g. preferential city or motorway lanes, is monitored by systems based, for example, on video cameras, which transmit the acquired images to a remote operating centre; or on transmitting-receiving stations, which continuously transmit a directional signal, with given spectral characteristics, onto the monitored highway section, and detect vehicle passage on the basis of the characteristics of the signals reflected by the vehicles in transit which, in passing, alter the signal transmitted by the transmitting-receiving stations; or on coils laid under the road surface.

[0003] The efficiency of these systems depends closely on factors, such as the quality of the acquired images and incoming signals. As is known, image quality depends, among other things, on external visibility and lighting, and is therefore seriously impaired by external factors, such as darkness, fog, snow, or dirt on the video camera optical system; while incoming signal quality is seriously affected, for example, by interference, weather conditions, etc.

[0004] Moreover, currently used traffic monitoring systems are expensive and take a long time to install, involve complicated wiring, create traffic hold-ups for maintenance, etc.

[0005] It is an object of the present invention to provide a system for monitoring vehicle transit along a highway section, designed to eliminate the drawbacks of known systems.

[0006] More specifically, the present invention proposes a monitoring system comprising small, low-energy electronic devices installed along the road.

[0007] According to the present invention, there is provided a system for monitoring vehicle transit along a highway section, as claimed in the accompanying Claims.

[0008] A preferred, non-limiting embodiment of the present invention will be described by way of example with reference to the attached drawing, which shows a schematic of the architecture of the monitoring system according to the invention.

[0009] Number 1 in the attached drawing indicates as a whole a system for monitoring vehicle transit along a highway section 2, in accordance with the present invention.

[0010] By way of a non-limiting example, the highway section 2 shown schematically in the drawing is a lane of a one-way highway, e.g. motorway or main road, travelled by vehicles, e.g. vehicle 3.

[0011] More specifically, monitoring system 1 according to the invention comprises:

- a known self-configuring wireless sensor network comprising a number of transmitting-receiving stations 4a, 4b, 4c, which are installed on both sides of highway section 2, and are configured to communi-

cate with one other by known communication protocols specific to this type of network, and to perform specific functions as described below;

- a transmitting-receiving Gateway station 5 located close to the monitored highway section 2 to collect information from transmitting-receiving stations 4a, 4b, 4c; and
- a remote control centre 6 communicating with Gateway station 5.

[0012] More specifically, each pair of transmitting-receiving stations 4a, 4b of the wireless sensor network installed on opposite sides of highway section 2 is configured to detect passage of vehicle 3 along highway section 2, and to type-classify the vehicles in transit on the basis of a wireless signal transmitted by transmitting-receiving station 4a.

[0013] Transmitting-receiving stations 4c, on the other hand, are configured to transmit the vehicle transit and vehicle type information, processed by transmitting-receiving station 4b, to Gateway station 5, which transmits the information to remote control centre 6. As shown in the enlarged detail in the drawing, transmitting-receiving stations 4a, 4b, 4c all have the same hardware configuration, and each comprise:

- a control and processing unit 7 configured to control operation of transmitting-receiving stations 4a, 4b, 4c;
- a transmitting-receiving unit 8; and
- an independent power source 9.

[0014] The specific functions of transmitting-receiving stations 4a, 4b, 4c are therefore performed by specific software stored in control and processing unit 7 of each station 4a, 4b, 4c.

[0015] Control and processing unit 7 of transmitting-receiving station 4a is configured to control transmitting-receiving unit 8 of station 4a to enable station 4a to :

- transmit and receive wireless signals, containing network configuration information, to and from the other transmitting-receiving stations 4a, 4b, 4c to optimize routing performance; and
- transmit a directional wireless signal S_i , of given spectral characteristics and power, to transmitting-receiving station 4b.

[0016] Transmitting-receiving station 4a comprises a sensor or device (not shown), e.g. a microphone or television camera, for detecting arrival of vehicle 3.

[0017] Control and processing unit 7 of transmitting-receiving station 4b is configured to control transmitting-receiving unit 8 of station 4b to enable station 4b to :

- transmit and receive wireless signals, containing network configuration information, to and from the other transmitting-receiving stations 4a, 4b, 4c to op-

timize routing performance;

- receive the directional wireless signal S_b of given spectral characteristics and power, transmitted by transmitting-receiving station 4a; and
- transmit vehicle transit and vehicle type information to Gateway station 5;

and to detect transit of vehicle 3 along highway section 2, and type-classify the vehicle 3 in transit on the basis of the wireless signal S_t received by station 4b.

[0018] Control and processing unit 7 of transmitting-receiving station 4c is configured to control transmitting-receiving unit 8 of station 4c to enable station 4c to :

- transmit and receive wireless signals, containing network configuration information, to and from the other transmitting-receiving stations 4a, 4b, 4c to optimize routing performance;
- receive the vehicle transit and vehicle type information processed and transmitted by transmitting-receiving station 4b; and
- transmit the vehicle transit and vehicle type information, received from transmitting-receiving station 4b, to Gateway station 5.

[0019] More specifically, as shown in the enlarged detail of the drawing, transmitting-receiving Gateway station 5 comprises:

- a control and processing unit 7 configured to control operation of Gateway station 5;
- a transmitting-receiving unit 8;
- an independent power source 9; and
- a long-range transmitting-receiving unit 10.

[0020] At least one software is stored in control and processing unit 7 of Gateway station 5 to control transmitting-receiving unit 8 of Gateway station 5 to enable Gateway station 5 to:

- receive the wireless signals containing the vehicle transit and vehicle type information transmitted by transmitting-receiving stations 4c; and
- control long-range transmitting-receiving unit 10, e.g. a GSM or WI/FI unit, to enable unit 10 to transmit the vehicle transit and vehicle type information, received by transmitting-receiving station 8 of Gateway station 5, to remote control centre 6, where the information is stored and analysed.

[0021] More specifically, vehicles travelling along the monitored highway section are detected and type-classified as follows: on detecting an on-coming vehicle by means of the sensor, e.g. a microphone, a transmitting-receiving station 4a begins transmitting wireless signal S_t - e.g. a 433 MHz, 868 MHz, or 2.4 GHz signal - to transmitting-receiving station 4b, which measures the power level of the incoming signal, compares it with the

power level of the transmitted signal, and detects passage of the vehicle on the basis of the comparison.

[0022] The vehicle driving past transmitting-receiving stations 4a and 4b, in fact, noticeably distorts and attenuates the wireless signal S_t transmitted by transmitting-receiving unit 8 of transmitting-receiving station 4a, and control and processing unit 7 of transmitting-receiving station 4b detects passage of the vehicle on the basis of attenuation of the power level of the incoming signal. To type-classify the vehicles in transit, control and processing unit 7 of transmitting-receiving station 4b compares the power level of the incoming signal with predetermined threshold values of specific categories of vehicles, e.g. cars, buses, trucks, etc., and classifies the vehicles in transit on the basis of the comparison.

[0023] As stated, to minimize the infrastructures and energy consumption required to operate monitoring system 1, transmitting-receiving stations 4a, 4b, 4c and Gateway station 5 each have an independent power source 9, e.g. a battery (not shown) connected to a charging device, e.g. a photovoltaic, wind-driven, or vibration module (not shown); and monitoring system 1 is configured so that each pair of transmitting-receiving stations 4a, 4b (the drawing shows four pairs of stations 4a, 4b, indicated by arrows A_1, A_2, A_3, A_4) and transmitting-receiving stations 4c can operate in two modes.

[0024] More specifically, in a first SLEEP charge operating mode, control and processing units 7 of transmitting-receiving stations 4a, 4b, 4c totally disable the respective stations, and enable the respective charging devices of independent power sources 9.

[0025] In SLEEP mode, transmitting-receiving station 4a obviously detects no on-coming vehicles by means of the sensor, and transmits no wireless signal to transmitting-receiving station 4b, which, likewise, detects no passing vehicles.

[0026] In a second ACTIVE operating mode, transmitting-receiving station 4a detects on-coming vehicles by means of the sensor, and transmits the wireless signal to respective transmitting-receiving station 4b, which detects transit of, and type-classifies, the vehicles; and stations 4c transmit the vehicle transit and vehicle type information, received from transmitting-receiving station 4b, to Gateway station 5.

[0027] Each pair of transmitting-receiving stations 4a, 4b switches automatically from charge SLEEP mode to ACTIVE mode on the basis of switching logic designed by the Applicant to ensure reliable vehicle transit monitoring and minimum energy consumption. More specifically, system 1 is configured so that the pairs of transmitting-receiving stations 4a, 4b forming part of the wireless sensor network are never all in the same operating mode (ACTIVE or SLEEP) at the same time.

[0028] More specifically, pairs A_1, A_2, A_3, A_4 of transmitting-receiving stations 4a, 4b are activated singly or in groups for a predetermined time and/or as a function of the charge level of the respective batteries.

[0029] For example, in a first embodiment, monitoring

system 1 may be configured so that pairs A_1 and A_2 operate in ACTIVE mode, and, simultaneously, pairs A_3 and A_4 operate in SLEEP mode. In this embodiment, pairs A_1 and A_2 are activated simultaneously for redundant vehicle monitoring, and remain in ACTIVE mode for a predetermined time Δt , or for as long as the charge level of the respective batteries remains above a minimum threshold value guaranteeing operation of each station 4a, 4b.

[0030] In this embodiment, system 1 is configured so that, at the end of time Δt , or when the charge level of at least one of the batteries of stations 4a, 4b in pairs A_1 and A_2 falls below the minimum threshold level, transmitting-receiving stations 4a, 4b in pairs A_1 and A_2 switch from ACTIVE mode to charge SLEEP mode, and the vehicle transit monitoring function is taken over by the next two pairs A_3 , A_4 switching from SLEEP mode to ACTIVE mode.

[0031] The above switching procedure is performed, on the basis of the above time or charge level conditions, between the two currently active pairs and the next adjacent two pairs in SLEEP mode, until all the pairs of stations 4a, 4b in monitoring system 1 are used up.

[0032] In a second, alternative, embodiment, the system is configured to activate two successive, but not necessarily adjacent, pairs of transmitting-receiving stations 4a, 4b, e.g. pair A_1 and pair A_3 , which, as in the first embodiment, remain active for a predetermined time Δt , or for as long as the charge level of the respective batteries remains above a minimum threshold value guaranteeing operation of each station.

[0033] In a third, alternative, embodiment, the system may be configured to only activate one pair of transmitting-receiving stations 4a, 4b at a time, and so that the pair remains active for a predetermined time Δt , or for as long as the charge level of the respective batteries remains above a minimum threshold value guaranteeing operation of each station, and otherwise switches from ACTIVE mode to charge SLEEP mode; and the vehicle transit monitoring function is taken over by the adjacent pair or by the currently available pair switching from SLEEP mode to ACTIVE mode.

[0034] In all three embodiments described, to correctly determine ACTIVE operating mode of the pairs of transmitting-receiving stations 4a, 4b, transmitting-receiving stations 4a, 4b of the wireless sensor network periodically exchange current operating mode information.

[0035] The energy consumption of each transmitting-receiving station 4a, 4b and 4c in ACTIVE operating mode depends on the connection time t_{conn} stations 4a, 4b and 4c operates in ACTIVE mode; and the energy consumption of each transmitting-receiving station 4 in SLEEP mode depends on the time t_{SLEEP} stations 4a, 4b and 4c operates in SLEEP operating mode.

[0036] Given that time t_{conn} is much shorter than time t_{SLEEP} , that the energy consumption of each station 4 in SLEEP mode is negligible compared to energy consumption in ACTIVE mode, that the number of connection cy-

cles N_{cycles} of each transmitting-receiving station 4 equals $t_{conn}/\Delta t$, and that the wireless sensor network comprises n pairs of wireless transmitting-receiving stations 4, then the actual working life of the charge of the wireless network, for a given energy charge of each station 4, equals:

$$n * (N_{cycles} + N_{charge}) * \Delta t$$

where N_{charge} is the number of cycles Δt recovered by each transmitting-receiving station 4 being charged during time t_{SLEEP} .

[0037] The system according to the invention has the following advantages: minimum infrastructure; high degree of reliability; and low energy consumption.

[0038] Clearly, changes may be made to the system as described and illustrated herein without, however, departing from the scope of the present invention, as defined in the accompanying Claims.

Claims

1. A system (1) for monitoring transit of vehicles along a highway section (2), comprising a first number of transmitting-receiving stations (4a, 4b, 4c) installed along said highway section and forming part of a wireless sensor network; each of said transmitting-receiving stations (4a, 4b, 4c) being configured to communicate with the other transmitting-receiving stations (4a, 4b, 4c), and having an independent power source, and a charging device for charging said independent power source;

characterized in that a number of pairs (A_1 , A_2 , A_3 , A_4) of said first number of transmitting-receiving stations (4a, 4b) are configured to operate:

- in a first operating mode (ACTIVE), in which transit of said vehicles along said highway section (2) is detected, and the type of said vehicles in transit along said highway section (2) is determined; and
- in a second charge operating mode (SLEEP), in which said charging device for charging said independent power source is activated;

and in that at least one pair of transmitting-receiving stations (4a, 4b) operates in one of said first and second operating modes (ACTIVE, SLEEP), which differs from the operating mode of the other pairs.

2. A system as claimed in Claim 1, and also comprising:

- a second number of transmitting-receiving stations (4c) configured to receive and transmit vehicle transit and vehicle type information trans-

- mitted by said pairs (A_1, A_2, A_3, A_4) of transmitting-receiving stations (4a, 4b) when operating in said first operating mode (ACTIVE);
- a first transmitting-receiving station (5) configured to receive and transmit said vehicle transit and vehicle type information transmitted by said second number of transmitting-receiving stations (4c) and by said pairs (A_1, A_2, A_3, A_4) of transmitting-receiving stations (4a, 4b); and
 - a remote data processing centre (6) configured to communicate with said first transmitting-receiving station (5).
3. A system as claimed in Claim 2, wherein said first transmitting-receiving station (5) is a GSM or WI-FI station.
4. A system as claimed in Claim 2, wherein said second number of transmitting-receiving stations (4c) are configured to operate:
- in a third operating mode (ACTIVE), in which they receive said information transmitted by said pairs (A_1, A_2, A_3, A_4) of transmitting-receiving stations, and transmit said information to said first transmitting-receiving station (5); and
 - in said second charge operating mode (SLEEP), in which said charging device for charging said independent power source is activated.
5. A system as claimed in Claims 1 to 4, wherein an adjacent first and second pair (A_1, A_2) of transmitting-receiving stations (4a, 4b) switch from said first (ACTIVE) to said second (SLEEP) operating mode and from said second (SLEEP) to said first (ACTIVE) operating mode respectively.
6. A system as claimed in Claims 1 to 5, wherein said pairs (A_1, A_2, A_3, A_4) of transmitting-receiving stations (4a, 4b) and said second number of transmitting-receiving stations (4c) are configured to switch, respectively, from said first (ACTIVE) to said second (SLEEP) and from said third (ACTIVE) to said second (SLEEP) operating mode, or vice versa, on the basis of a threshold value of a charge level of the respective said independent power sources and/or on the basis of a predetermined time period.
7. A system as claimed in any one of the foregoing Claims, wherein each pair (A_1, A_2, A_3, A_4) of transmitting-receiving stations (4a, 4b) comprises:
- a second transmitting-receiving station (4a) installed along a first edge of said highway section (2), and comprising sensor means configured to detect an on-coming said vehicle, and first electronic transmitting means (8) configured to con-
- tinuously transmit a radio signal onto said highway section (2); and
- a third transmitting-receiving station (4b) installed along a second edge, opposite said first edge, of said highway section (2), and comprising first electronic receiving means for receiving said radio signal transmitted by said first electronic transmitting means (8), and first processing means (7) configured to detect transit of said vehicle along said highway section (2) on the basis of analysis of the incoming said radio signal.
8. A system as claimed in any one of the foregoing Claims, wherein each said second and third transmitting-receiving station (4a, 4b) and each of said second number of transmitting-receiving stations (4c) also comprise:
- interconnecting and data-exchange means (8) for exchanging information with each of said transmitting-receiving stations (4a, 4b, 4c) forming part of said wireless sensor network; and
 - second processing means (7) configured to process information from said number of transmitting-receiving stations (4a, 4b, 4c), and to control switching of said transmitting-receiving stations (4a, 4b) from said first (ACTIVE) to said second (SLEEP) operating mode, and vice versa.
9. A system as claimed in any one of the foregoing Claims, wherein said first electronic transmitting means (8) of said second transmitting-receiving station (4a) transmit a radio signal of predetermined power, frequency, and modulation mode.
10. A system as claimed in any one of the foregoing Claims, wherein said first processing means (7) of said third transmitting-receiving station (4b) are configured to :
- receive said radio signal of predetermined power, frequency, and modulation mode; and
 - detect transit of said vehicle along said highway section (2), and
 - determine the type of said vehicle in transit,
- on the basis of the power of the incoming said radio signal.

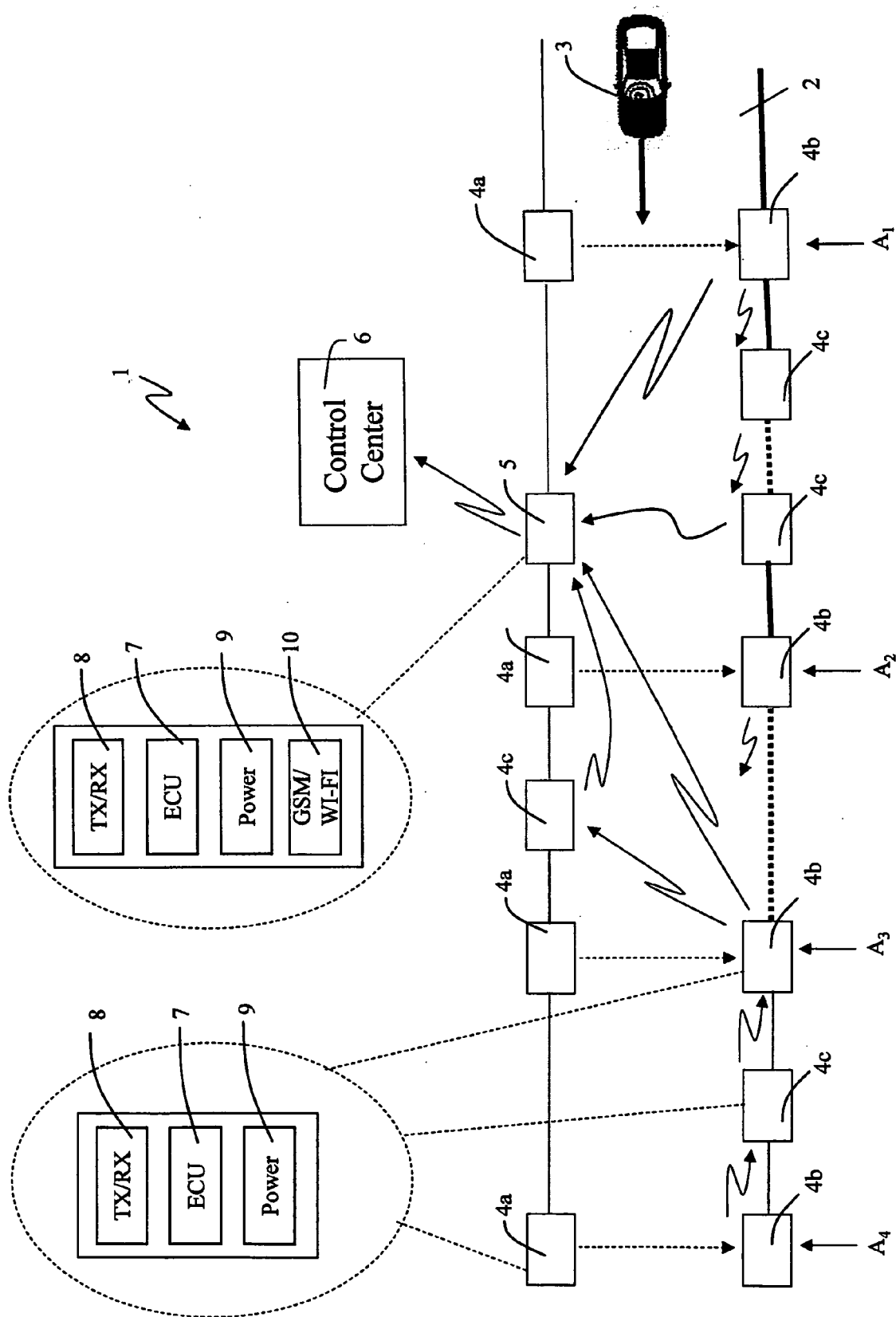


Fig.1



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 42 5302

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 6 417 783 B1 (GABLER MANFRED [DE] ET AL) 9 July 2002 (2002-07-09) * column 1, lines 54-60 * * column 2, lines 1-29 * * column 2, line 60 - column 3, line 8 * * column 3, lines 27-54 * -----	1-10	INV. G08G1/015
A	US 4 247 768 A (ELMER PETER J ET AL) 27 January 1981 (1981-01-27) * column 1, lines 25-57 * * column 2, lines 48-58 * * column 4, lines 15-23 * -----	1-10	
A	US 3 872 283 A (SMITH GERALD R ET AL) 18 March 1975 (1975-03-18) * column 3, line 60 - column 4, line 25 * -----	1-10	
A	US 6 690 292 B1 (MEADOWS VERNON [US] ET AL) 10 February 2004 (2004-02-10) * column 3, line 12 - column 4, line 36 * -----	1-10	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC) G08G
Place of search Munich		Date of completion of the search 18 October 2007	Examiner FLORES-JIMENEZ, A
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

1
EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 07 42 5302

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

18-10-2007

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6417783	B1	09-07-2002	BR 9807661 A 15-02-2000
		CA 2279465 A1 13-08-1998	
		CN 1246948 A 08-03-2000	
		WO 9835330 A1 13-08-1998	
		EP 0958564 A1 24-11-1999	
		HU 0000611 A2 28-06-2000	
		NO 993793 A 23-09-1999	
		PL 334777 A1 13-03-2000	
US 4247768	A	27-01-1981	NONE
US 3872283	A	18-03-1975	NONE
US 6690292	B1	10-02-2004	US 2004140909 A1 22-07-2004