(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
13 February 2003 (13.02.2003)

PCT

(10) International Publication Number
WO 03/012473 A1

(51) International Patent Classification[7]: G01S 13/00, 13/92

(21) International Application Number: PCT/EP02/08334

(22) International Filing Date: 25 July 2002 (25.07.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0118707.9 1 August 2001 (01.08.2001) GB
0202412.3 4 February 2002 (04.02.2002) GB

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(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

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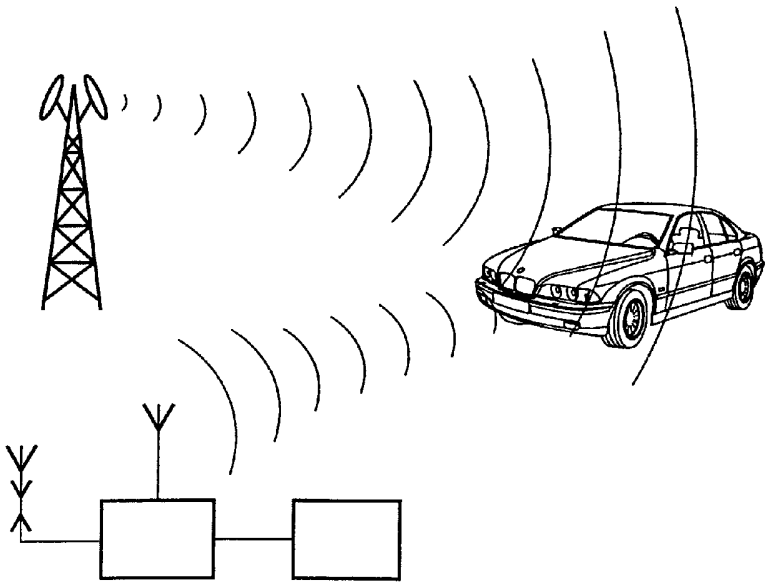
(54) Title: PASSIVE MOVING OBJECT DETECTION SYSTEM AND METHOD USING SIGNALSTRANSMITTED BY A MOBILE TELEPHONE STATION



(57) Abstract: A passive object detection system (1) comprises first and second antennas (4, 6) and a processor (8). The first antenna (4) is adapted to receive a signal transmitted by a mobile telephone base station; the second antenna (6) is adapted to receive the signal transmitted by a mobile telephone base station (2) after it has been reflected off an object (3) and the processor compares the signal received from the mobile telephone base station with the signal reflected from the object to derive speed or position information relating to the object therefrom.

WO 03/012473 A1

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

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PASSIVE MOVING OBJECT DETECTION SYSTEM AND METHOD USING SIGNALS TRANSMITTED BY A MOBILE TELEPHONE STATION

This invention relates to a system and method for object detection, in particular for detecting moving objects.

There are many situations in which it is desirable to detect moving objects and to provide position and/or speed information about those objects, for example, to detect aircraft, monitor traffic flow or to detect vehicles exceeding the speed limit. Active radar systems are often used for these purposes, however this requires RF transmissions. Use of RF transmissions has some disadvantages. The transmissions can be detected by simple receivers, which gives away the presence of the sensor (e.g. car radar detectors used by speeding motorists). Also, there are many legal restrictions on the transmission of radio frequencies, which may differ from one country to another, so a system suitable for use in one country may be illegal in another.

Passive systems using television transmitters have been proposed, however these have certain disadvantages. Although they use high power transmitters, the objects being detected are often far away and the received signal power may be weak.

In accordance with the present invention, a passive object detection system comprises first and second antennas; and processing means; wherein the first antenna is adapted to receive a signal transmitted by a mobile telephone base station; wherein the second antenna is adapted to receive the signal transmitted by a mobile telephone base station after it has been reflected off an object and wherein the processing means compares the signal received from the mobile telephone base station with the signal reflected from the object and derives speed or position information relating to the object therefrom.

In accordance with a second aspect of the present invention a passive method of detecting an object comprises receiving a first signal transmitted by a mobile phone base station, receiving a second signal comprising the first signal from the mobile phone base station after it has been reflected off an object; and comparing the first and second signal to derive data relating to position or speed of movement of the object.

The present invention covers a passive electronic system which makes use of the radio emissions from mobile phone base stations and in particular the reflection of those radio waves from objects, such as cars, people and animals, to detect the location and, if moving, the velocities of those objects. No transmissions from the system are required

and the detection system can be carried from place to place and used in conjunction with an existing mobile phone base station nearby. It is particularly beneficial to police forces enforcing speed limits, that the vehicle cannot detect the existence of the sensor. The proliferation of mobile phone bases stations in towns and on main roads gives good coverage, in the areas required.

An example of a passive object detection system and method according to the present invention will now be described with reference to the accompanying drawings in which:-

Figure 1 is a plan view of a prior art system;

Figure 2 is a schematic diagram of one example of a passive object detection system according to the invention;

Figure 3 is a plan view illustrating operation of the system of Fig. 2

Figure 4 illustrates a sensor of the system of Fig. 2 in more detail;

Figure 5 illustrates alternative arrangements for the sensor of Fig. 2; and

Figure 6 is a flow diagram illustrating an algorithm for use in the system of Fig. 2.

Fig. 1 shows in plan view how a prior art system for detecting objects, in this case using a television transmitter, operates. A tv transmitter 20 emits a signal which travels a distance R_1 and is reflected off an object 21. The reflected signal travels a distance R_2 and is received at a receiver 22. The power P_R of the signal received at the receiver 22 can be calculated from the equation:

$$P_R = \frac{P_T G_1 G_2 \sigma}{(4\pi)^3 R_1^2 R_2^2} \lambda^2$$

where P_T is is the transmitted power

G_1 is the gain of the first antenna

G_2 is the gain of the second antenna

σ is the radar cross section of the object of interest

λ is the wavelength of the transmitted signal

R_1 is the distance between the transmitter and the object

R_2 is the distance between the receiver and the object

In the prior art system using a tv transmitter, when the object is moving away from the transmitter the distances R_1 and R_2 increase at a similar rate, so one can assume that the received power P_R is proportional to $1/R^4$, i.e. as the object moves away there is a fast and significant reduction in received power.

Figure 2 illustrates how a passive object detection system 1 according to the present invention is used in conjunction with radio waves transmitted by a mobile phone base station 2 and reflected off an object 3. In this example, the object in question is a vehicle, but other objects could be sensed equally well. The object may be moving or stationary. The system comprises a first antenna 4 which points directly at the base station 2 and detects radio waves 5 which have travelled along the shortest path. A second antenna 6 points in the direction of the object of interest and detects radio waves 7 reflected off that object 3. The antennas may be of any suitable type, such as Yagi or phased arrays. A processor 8 analyses the signals received by the first and second antennas 4, 6 and compares the phase and frequencies of these two received signals. This is illustrated in more detail in Fig. 4. The processor also measures the time delay between the two received signals. The signals may then be displayed or stored.

A display device 9 takes the output of the processor and displays the information derived about frequency difference and time delay between the two signals. The display may convert the information into distance off and speed of the object, if it is moving. A recording mechanism may also be provided. Such a system would be particularly useful in monitoring traffic flow.

The advantages of the present invention can be seen from Fig. 3 which is a plan view of the system in operation. As in the prior art, there is a receiver 22, however the present invention does not rely on a single transmitter. Instead, it takes advantage of the proliferation of mobile phone transmitter aerials 23. This has the effect that instead of the object moving out of range of the transmitter and so increasing the distance R_1, when the object moves out of range of one transmitter, it comes into range for another, so that the distance R_1 remains subtantially constant whilst R_2 changes. From this, P_R can be taken to be proportional to $1/R^2$, thereby significantly increasing the received power. By using transmitters further away from the receiver, the range of the device is increased over prior art systems because the target is always close to a transmitter, despite mobile phone transmitters operating at higher frequency and lower power than tv transmitters.

Fig. 4 illustrates the signal processing in more detail. The signal received by each antenna 4, 6 is amplified in respective pre-amplifiers 10, 11, then converted to a digital signal by analogue to digital converters (ADC's) 12, 13. In practice the received signals would probably be mixed down to a lower frequency before being sampled by the ADC, for example as shown in Fig. 3.

The output signals from the ADC's 12, 13 are fed into the processor 8, which may be a digital signal processor or some hardware implementation of the algorithm such as an FPGA, EPLD, ASIC or similar. The processor is set up to run an algorithm as illustrated in the flow diagram of Fig. 6. This algorithm has two separate functions. Firstly, the algorithm will determine the delay difference between the two signals, and secondly it will determine any Doppler shift due to motion of the target.

To determine the time delay the algorithm performs a cross correlation of the signal from the first antenna with the signal from the second antenna. The Doppler effect is then used to determine the speed of the target. To do this the results from successive cross correlations are stored, and the change in relative phase between the signal from antenna 1 and antenna 2 at the delay (or delays) of interest is calculated by means of a DFT (Discrete Fourier Transform) or FFT (Fast Fourier Transform), or similar algorithm. The "delays of interest" may include all possible delays calculated by the cross correlation.

CLAIMS

1. A passive object detection system, the system comprising first and second antennas; and processing means; wherein the first antenna is adapted to receive a signal transmitted by a mobile telephone base station; wherein the second antenna is adapted to receive the signal transmitted by a mobile telephone base station after it has been reflected off an object and wherein the processing means compares the signal received from the mobile telephone base station with the signal reflected from the object and derives speed or position information relating to the object therefrom.

2. A system according to claim 1, wherein the object is a moving object.

3. A system according to claim 1 or claim 2, wherein an accurate speed of the object derived.

4. A passive method of detecting an object, the method comprising receiving a first signal transmitted by a mobile phone base station, receiving a second signal comprising the first signal from the mobile phone base station after it has been reflected off an object; and comparing the first and second signals to derive data relating to position or speed of movement of the object.

5. A method according to claim 4, the method further comprising determining a time delay between receiving the first and second signals, by performing a cross correlation of the signal from the first antenna with the signal from the second antenna; . determine the speed of the target using the Dopplar effect; storing results from successive cross correlations, calculating the change in relative phase between the signal from the first antenna and the second antenna at the delay of interest .

6. A method according to claim 5, wherein the change in relative phase is calculated by means of a Discrete Fourier Transform (DFT); Fast Fourier Transform(FFT); or similar algorithm.

FIG 1

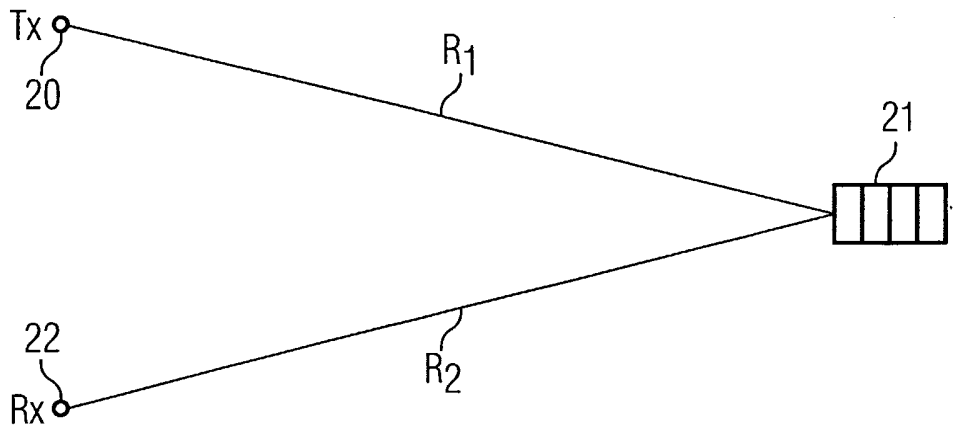


FIG 2

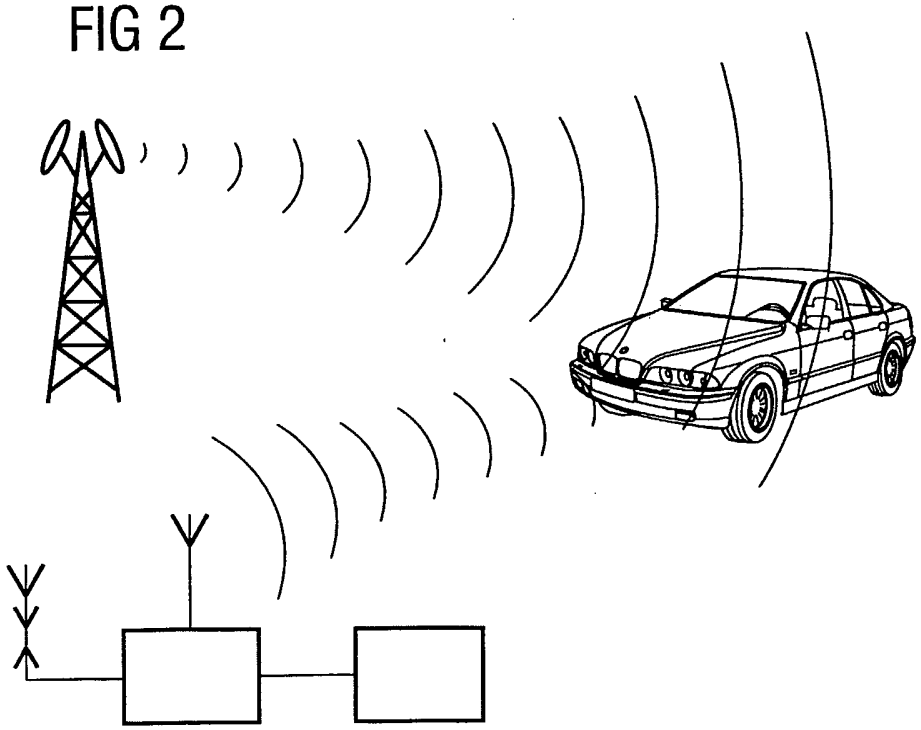


FIG 3

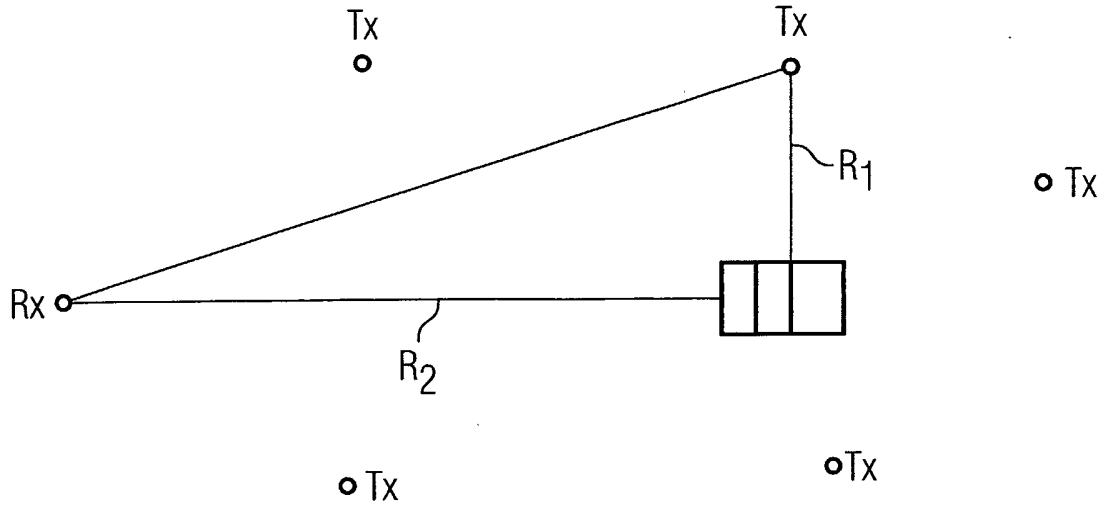
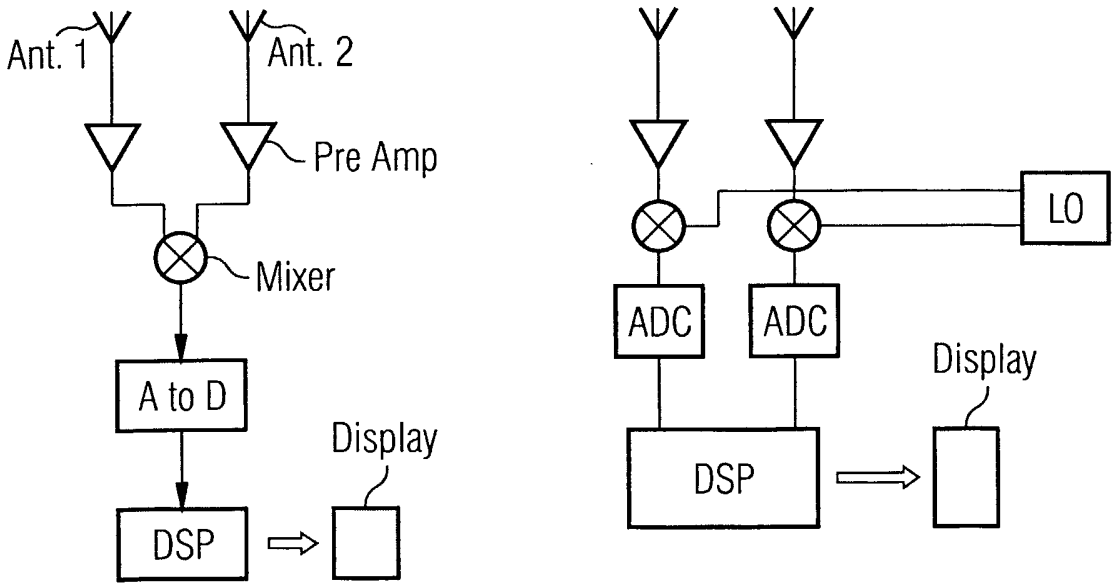

Tx
Tx
R1
Tx
Rx
R2
Tx
Tx

FIG 5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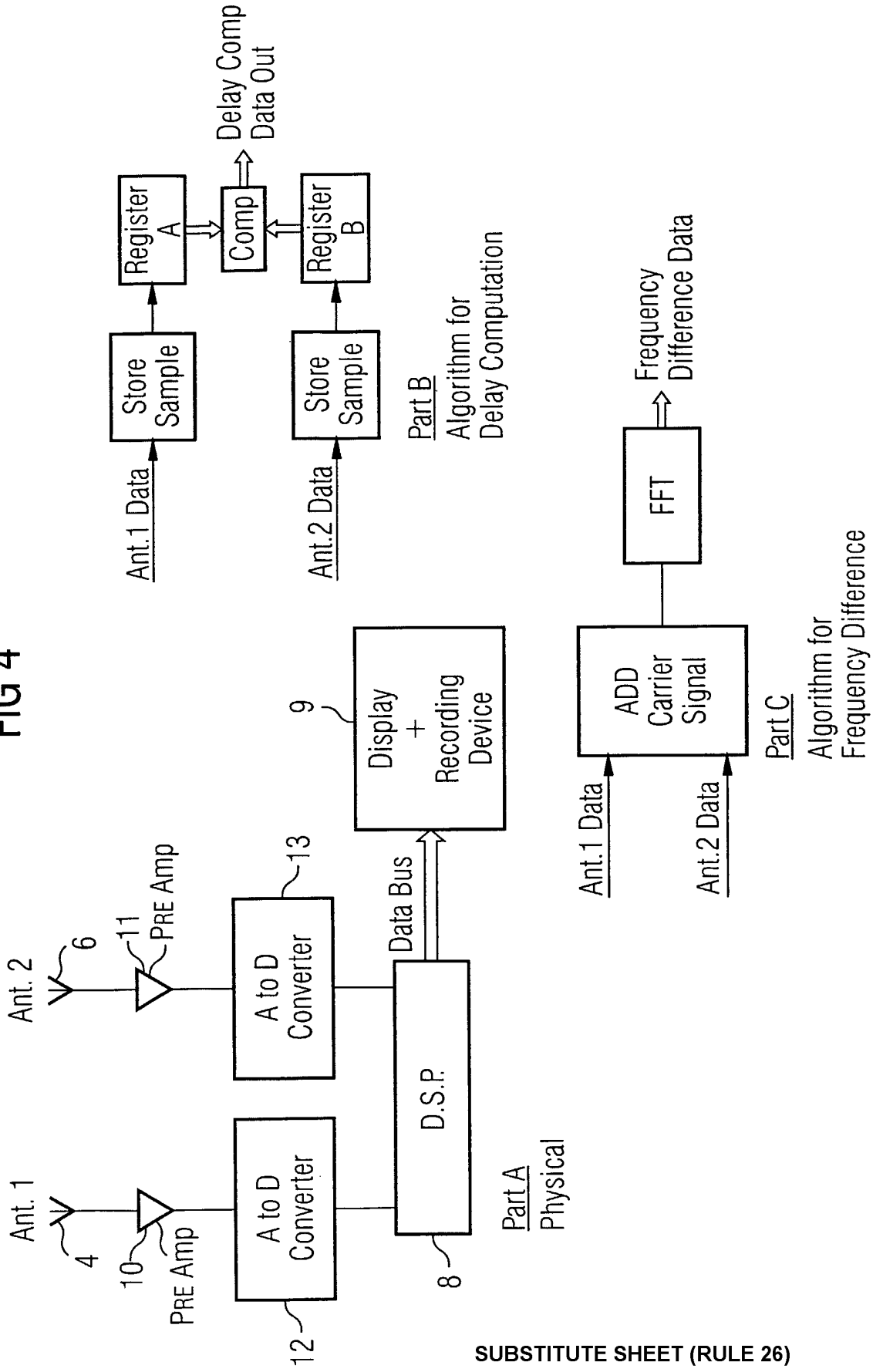
Ant. 2
Pre Amp
Mixer
A to D
Display
DSP
LO
ADC
ADC
Display
DSP

FIG 4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4
10
PRE Amp
A to D Converter
12
D.S.P.
8
Part A
Physical
Ant. 2
6
11
PRE Amp
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13
Data Bus
9
Display + Recording Device
Ant.1 Data
Store Sample
Register A
Comp
Register B
Store Sample
Ant.2 Data
Delay Comp Data Out
Part B
Algorithm for Delay Computation
Ant.1 Data
ADD Carrier Signal
Ant.2 Data
FFT
Frequency Difference Data
Part C
Algorithm for Frequency Difference

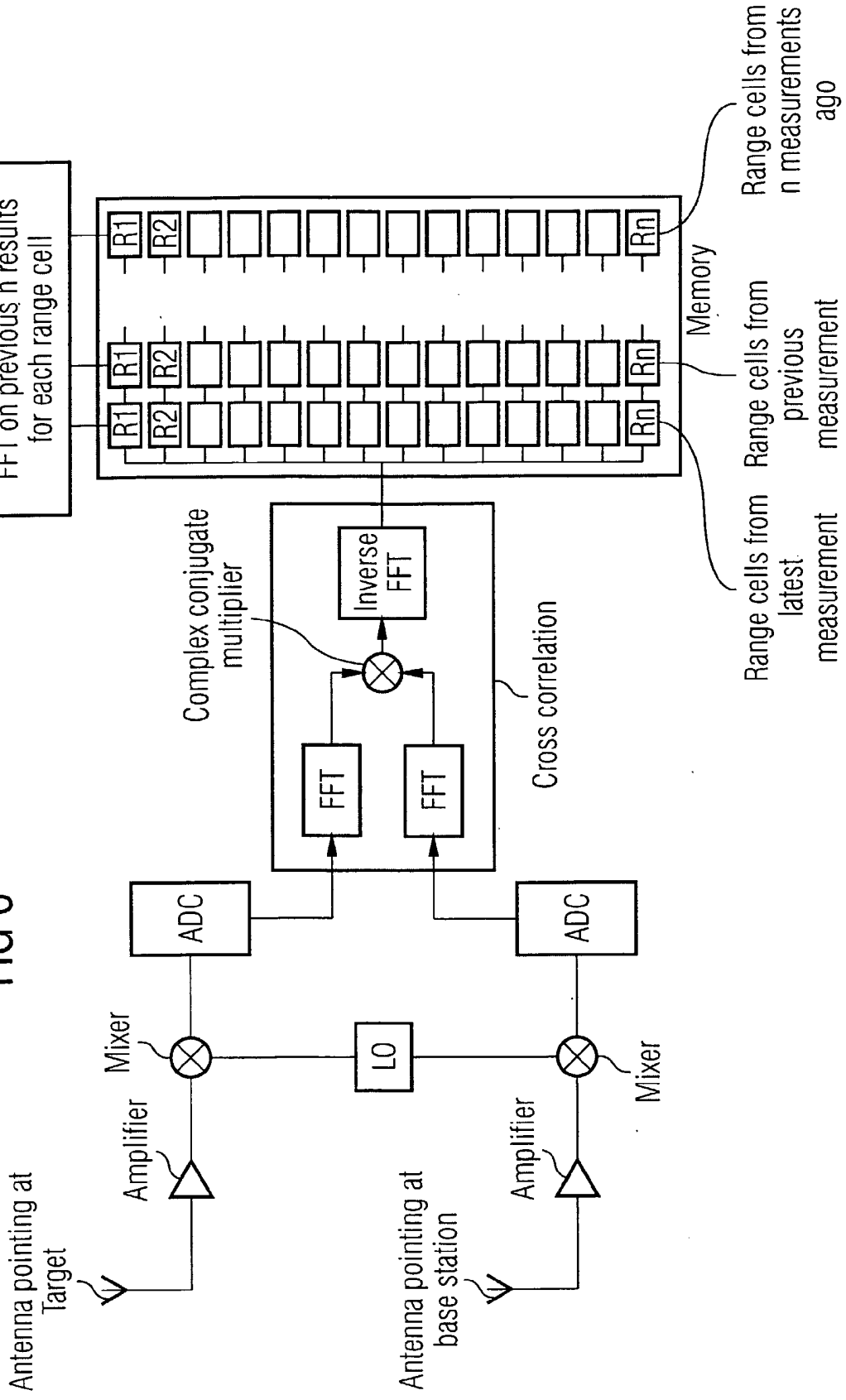
FFT on previous n results for each range cell
R1
R2
Rn
Memory
Range cells from n measurements ago
Range cells from previous measurement
Range cells from latest measurement
Complex conjugate multiplier
Inverse FFT
FFT
FFT
Cross correlation
ADC
ADC
Mixer
LO
Mixer
Amplifier
Amplifier
Antenna pointing at Target
Antenna pointing at base station

FIG 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 02/08334

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01S13/00 G01S13/92

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)
IPC 7 G01S

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

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 604 503 A (FOWLER MARK L ET AL) 18 February 1997 (1997-02-18) figure 1 column 1, line 15-32 column 3, line 16-19 column 6, line 42-47 column 7, line 56 column 8, line 40-46 ---	1-6
X	US 6 011 515 A (RADCLIFFE SCOTT T ET AL) 4 January 2000 (2000-01-04) abstract; figure 1 column 3, line 2-27 column 9, line 16-52 column 10, line 5,6 --- -/--	1-4

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
29 November 2002	05/12/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Grübl, A

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 232 922 B1 (MCINTOSH JOHN C) 15 May 2001 (2001-05-15) the whole document ---	1-6
A	WO 01 22117 A (POULLIN DOMINIQUE ;THOMSON CSF (FR); LESTURGIE MARC (FR); ONERA (O) 29 March 2001 (2001-03-29) the whole document -----	1-6

INTERNATIONAL SEARCH REPORT

Information on patent family members

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PCT/EP 02/08334

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