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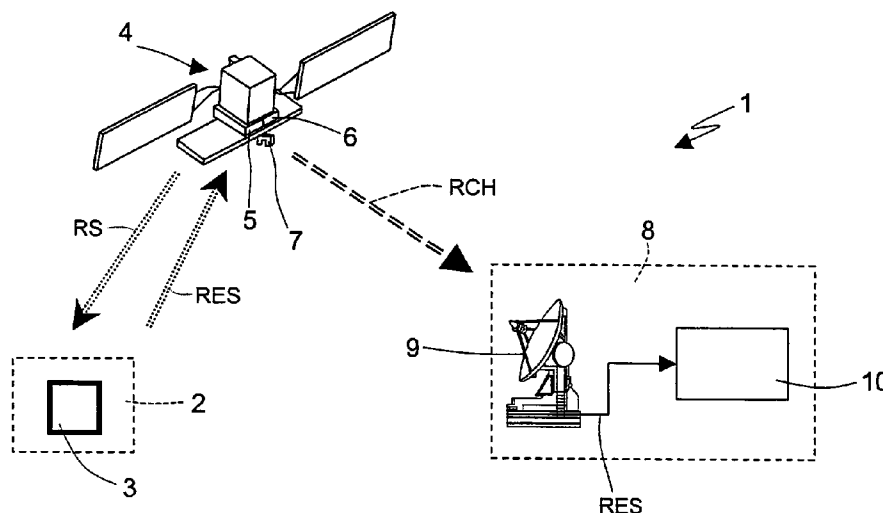
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(54) Title: TARGET IDENTIFICATION METHOD FOR A SYNTHETIC APERTURE RADAR SYSTEM



(57) Abstract: In a synthetic aperture radar system (1) monitoring an area containing at least one moving target (2) for identification, the target (2) is equipped with an identification device (3), which receives the radar signal (RS) transmitted by the radar system (1), and transmits a processed radar signal (ES) obtained by modulating the incoming radar signal (RS) with a modulating signal (MODS) containing target (2) information (ID, MSG), such as identification (ID) and status (MSG) information, and by amplifying the modulated radar signal (RS); the radar echo signal (RES) reflected by the monitored area and containing the processed radar signal (ES) is received and processed by a control station (8) of the radar system (1) to locate the target (2) on a map of the monitored area, and to extract the target (2) information (ID, MSG) to identify the target (2).

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TARGET IDENTIFICATION METHOD FOR A SYNTHETIC APERTURE  
RADAR SYSTEM

10      TECHNICAL FIELD

The present invention relates to a target identification method for a synthetic aperture radar system.

The present invention may be used to particular  
15 advantage, though not exclusively, for identifying moving targets in an area monitored by a synthetic aperture radar system comprising at least one movable platform connected by radio to a remote processing station, to which application the following  
20 description refers purely by way of example.

BACKGROUND ART

A synthetic aperture radar (SAR) system  
comprises a radar signal transmitter and receiver  
operating on a movable platform, such as an aeroplane  
25 or satellite; and a remote processing station connected over a radio channel to the movable platform. The transmitter sends a radar signal into a monitored ground or sea area, and the receiver

receives the radar echo reflected by the area, and transmits it to the remote processing station, which processes the radar echo to obtain a two-dimensional map of the monitored area.

5       The transmitted radar signal comprises a succession of microwave-band electromagnetic pulses modulated by linear frequency, or so-called CHIRP, modulation and transmitted at regular time intervals. And the processing station coherently combines the  
10 radar echoes corresponding to the transmitted pulses to obtain high-azimuth-resolution maps of extensive areas using relatively small transmitting antennas. CHIRP pulse modulation, on the other hand, provides for achieving high resolution perpendicular to the  
15 azimuth direction.

Exceptionally large areas may be covered using a number of satellites or so-called satellite constellation.

Fixed reference points on the maps are located  
20 using transponders or so-called "corner reflectors", which are located at the fixed reference points to receive the radar signal and retransmit it transparently, after simply amplifying it. The retransmitted radar signal is usually stronger than  
25 the signals reflected by the surrounding environment and constituting the radar echo, so the fixed reference points appear brighter on the constructed map.

The above method, however, is not very effective in identifying a number of fixed and/or moving targets, e.g. ships, vehicles, or people, within the monitored area. That is, though positions (brighter points) can always be detected on the map, the targets corresponding to the detected positions cannot be identified accurately, especially in the case of fast-moving targets.

#### DISCLOSURE OF INVENTION

10 It is an object of the present invention to provide a target identification method for a synthetic aperture radar system, and a synthetic aperture radar system implementing such a method, designed to eliminate the aforementioned drawbacks, and which at the same time are cheap and easy to produce.

According to the present invention, there are provided a target identification method for a synthetic aperture radar system, a target identification device for a synthetic aperture radar system, and a synthetic aperture radar system, as claimed in the accompanying Claims.

Basically, the present invention provides for equipping a moving target, within an area monitored by a synthetic aperture radar system, with an identification device, which receives a radar signal transmitted by the radar system, processes the radar signal to assign target information to the radar

signal, and transmits the processed radar signal;  
receiving, by means of the radar system, a radar echo  
signal comprising the processed radar signal  
transmitted by the identification device; and  
5 processing the radar echo signal, by means of the  
radar system, to locate the target within the area  
and extract the target information to identify the  
target.

#### BRIEF DESCRIPTION OF THE DRAWINGS

10 A number of preferred, non-limiting embodiments  
of the present invention, in which the synthetic  
aperture radar system employs a satellite, will be  
described by way of example with reference to the  
accompanying drawings, in which:

15 Figure 1 shows an overall diagram of a synthetic  
aperture radar system in accordance with the present  
invention;

Figure 2 shows a preferred embodiment of an  
identification device, in accordance with the present  
20 invention, for the Figure 1 synthetic aperture radar  
system;

Figure 3 shows a sequence of messages supplied  
to the Figure 2 identification device;

Figure 4 shows a detail of part of the Figure 1  
25 synthetic aperture radar system;

Figure 5 shows another preferred embodiment of  
the identification device, according to the present  
invention, for the Figure 1 synthetic aperture radar

system.

BEST MODE FOR CARRYING OUT THE INVENTION

Number 1 in Figure 1 indicates as a whole a synthetic aperture radar system for monitoring a ground or sea area containing at least one moving target 2, such as a vehicle, person, or vessel. Target 2 is equipped with an identification device 3 enabling radar system 1 to locate and identify target 2 in the monitored area, and which, for example, is fitted to the vehicle or vessel, or to a person's clothing.

Radar system 1 comprises a moving platform defined, for example, by a satellite 4, which supports a transmitter 5 for transmitting a known radar signal RS into a monitored area (not shown), a receiver 6 for receiving a radar echo signal RES reflected by the surface of the monitored area, and a radio communication module 7 connected to receiver 6 to transmit radar echo signal RES over a radio channel RCH to a control station 8 of radar system 1. Control station 8 comprises a radio link 9 for receiving radar echo signal RES from satellite 4 over radio channel RCH; and a processing device 10 connected to radio link 9 to numerically process radar echo signal RES.

More specifically, the radar signal RS from transmitter 5 comprises a succession of CHIRP-modulated microwave pulses (not shown) transmitted at

given time intervals and of a given radar pulse duration DSAR.

With reference to Figure 2, identification device 3 comprises a receiving antenna 11 for receiving radar signal RS; a low-noise amplifier (LNA) 12 connected to receiving antenna 11 to amplify the incoming radar signal RS; a modulator 13 having an input 14 for receiving the amplified radar signal RS from low-noise amplifier 12, an input 15 for receiving a modulating signal MODS comprising information relative to target 2, and an output 16 for supplying a modulated signal MS obtained by modulating radar signal RS with modulating signal MODS; an amplifier 17 connected to the output of modulator 13 to supply a processed radar signal ES obtained by amplifying modulated signal MS with a given gain G; and a transmitting antenna 18 connected to amplifier 17 to transmit the processed radar signal ES.

Identification device 3 also comprises a detecting unit 19 connected to receiving antenna 11 to detect the presence of radar signal RS at receiving antenna 11, and to provide a time reference indicating the start of the pulses in radar signal RS; and an activating unit 20 defined, for example, by a switch which, when commanded by detecting 19 detecting the presence of radar signal RS, connects the output of low-noise amplifier 12 to input 14 of

modulator 13.

Finally, identification device 3 comprises an encryption unit 21 connected to input 15 to encrypt the information in modulating signal MODS by means of a programmable encryption key; and a memory unit 22 for storing the key.

With reference to Figure 3, modulating signal MODS comprises a sequence of messages, in turn comprising an identification message or code ID unequivocally identifying target 2 and, hence, the identification device 3 of target 2; and one or more status messages MSG following identification message ID and containing information, e.g. target 2 status information, to be sent from target 2 to control station 8.

Identification code ID is coded by a respective sequence of a given number NID of binary digits, each of a given digit duration DID; and each status message MSG is coded by a respective sequence of a given number NMSG of binary digits, each of a given digit duration DMSG normally differing from digit duration DID.

Digit durations DID and DMSG depend, in absolute value, on the radar pulse duration DSAR, i.e. the total duration of the message sequence does not exceed radar pulse duration DSAR. The ratio between digit durations DID and DMSG depends on identification operating requirements, and generally

on the number NID of digits required to identify all the tracked targets, and the number NMSG of binary digits required to code status messages MSG. To simplify implementation as far as possible, when no particular operating requirements are involved, digit duration DMSG equals digit duration DID.

With reference to Figure 4, processing device 10 of control station 8 comprises a known SAR processing unit 23 connected to the output of radio link 9 to process radar echo signal RES to provide a two-dimensional map of the monitored area and locate identification device 3 on the map, i.e. supply position information POS; a demodulating unit 24, also connected to the output of radio link 9 to demodulate radar echo signal RES and extract identification code ID and status message MSG; and a decryption unit 25 connected to the output of demodulating unit 24 to decrypt identification code ID and status message MSG using the same encryption key as identification device 3.

Demodulating unit 24 comprises a number of matched filters (not shown), which operate successively on respective successive portions of radar echo signal RES defined by digit durations DID, DMSG of the binary digits composing the message sequence. More specifically, each filter is matched to a respective portion of modulated signal MS defined by a corresponding binary digit of the

message sequence, so the number of matched filters equals the number of binary digits composing the message sequence.

In actual use, when receiving antenna 11 of  
5 identification device 3 receives a radar signal RS pulse, detecting unit 19 commands activating unit 20 to connect low-noise amplifier 12 to input 14 of modulator 13 to activate modulation of radar signal RS with modulating signal MODS containing  
10 identification code ID and encrypted status messages MSG. The resulting modulated signal MS is amplified by amplifier 17, and the resulting processed radar signal ES is transmitted by transmitting antenna 18.

Satellite 4 receives the radar echo signal RES -  
15 which corresponds to the transmitted radar signal RS pulse and comprises the processed radar signal ES transmitted by identification device 3 - and transmits radar echo signal RES to control station 8 over radio channel RCH. On receiving radar echo  
20 signal RES from radio link 9, SAR processing unit 23 processes radar echo signal RES to locate target 2 on the monitored area map. More specifically, the position of identification device 3, and hence target 2, is shown by a brighter spot on the map, due to the  
25 stronger radar echo signal RES produced at that point by identification device 3 transmitting the processed radar signal.

The cascade of demodulating unit 24 and

decryption unit 25 operates in parallel with SAR processing unit 23 to identify target 2. More specifically, the matched filters demodulate successive portions of the radar echo signal RES pulse to extract the information contained in corresponding binary digits of identification code ID and status messages MSG transmitted by target 2.

It should be pointed out that, by comprising a number of filters equal to the number of binary digits composing the message sequence, the matched filters as a whole act as a sub-optimum filter matched to the modulating signal MODS.

In a second preferred embodiment not shown, modulating signal MODS comprises a number of successive repetitions of the message sequence. And digit durations DID and DMSG are such that the total duration of the message sequence repetitions does not exceed radar pulse duration DSAR.

In a third preferred embodiment, radar system 1 comprises at least one identification device 3 as shown in Figure 5, and which differs from identification device 3 in Figure 2 by comprising one antenna 26, as opposed to receiving antenna 11 and transmitting antenna 18; and a selection unit 27 for connecting antenna 26 selectively to the input of low-noise amplifier 12 to receive radar signal RS, and to the output of amplifier 17 to transmit processed radar signal ES.

Radar system 1 according to the present invention has the main advantage of even locating and identifying a moving target 2 within the monitored area. Moreover, a number of stationary or moving  
5 targets 2 with different identification codes ID can also be located. Finally, radar system 1 as described safeguards against false findings when reconstructing the map, or location of more than one target 2 in the same resolution cell of the map.

## CLAIMS

1) A target (2) identification method for a synthetic aperture radar system (1), the method  
5 comprising:

- equipping the target (2) with an identification device (3);

- receiving, by the identification device (3), a radar signal (RS) transmitted by the radar system  
10 (1);

- processing, by the identification device (3), the incoming radar signal (RS) to obtain a processed radar signal (ES);

- transmitting the processed radar signal (ES)  
15 by the identification device (3);

- receiving, by the radar system (1), a radar echo signal (RES) comprising the processed radar signal (ES); and

- processing the radar echo signal (RES) by the  
20 radar system (1) to locate the target (2);

the method being **characterized in that** processing the incoming radar signal (RS) by the identification device (3) comprises:

- assigning target (2) information (ID, MSG) to  
25 the incoming radar signal (RS).

2) A method as claimed in Claim 1, wherein processing the radar echo signal (RES) by the radar system (1) comprises:

- extracting said target (2) information (ID, MSG) from the radar echo signal (RES) to identify the target (2).

3) A method as claimed in Claim 2, wherein  
5 assigning target (2) information (ID, MSG) to the incoming radar signal (RS) by the identification device (3) comprises:

- modulating the incoming radar signal (RS) with a modulating signal (MODS) comprising said target (2)  
10 information (ID, MSG);

extracting the target (2) information (ID, MSG) from the radar echo signal (RES) by the radar system (1) comprising:

- demodulating the radar echo signal (RES).

15 4) A method as claimed in Claim 3, wherein processing the incoming radar signal (RS) by the identification device (3) comprises:

- amplifying the incoming radar signal (RS).

5) A method as claimed in Claim 4, wherein the  
20 incoming radar signal (RS) is modulated before the incoming radar signal (RS) is amplified.

6) A method as claimed in any one of the foregoing Claims, wherein processing the incoming radar signal (RS) by the identification device (3)  
25 comprises:

- encrypting said target (2) information (ID, MSG) by means of a programmable key;

extracting the target (2) information (ID, MSG)

from the radar echo signal (RES) by the radar system  
(1) comprising:

- decrypting the target (2) information (ID, MSG) by means of the programmable key.

5 7) A method as claimed in Claim 6, wherein said target (2) information (ID, MSG) is encrypted by the identification device (3) before the incoming radar signal (RS) is modulated.

8) A method as claimed in Claim 6 or 7, wherein  
10 said target (2) information (ID, MSG) is decrypted by the radar system (1) after the radar echo signal (RES) is demodulated.

9) A method as claimed in any one of Claims 3 to 8, wherein processing the incoming radar signal (RS)  
15 by the identification device (3) comprises:

- detecting the presence of the radar signal (RS); and

- only activating modulation of the incoming radar signal (RS) in the presence of the radar signal  
20 (RS).

10) A method as claimed in any one of the foregoing Claims, wherein said target (2) information (ID, MSG) comprises at least an identification code (ID) unequivocally identifying the target (2).

25 11) A method as claimed in any one of the foregoing Claims, wherein said target (2) information (ID, MSG) comprises at least one status message (MSG) relative to the status of the target (2).

12) A method as claimed in Claim 11, wherein said target (2) information (ID, MSG) comprises at least a message sequence comprising a said identification code (ID) and at least one said status message (MSG) following the identification code (ID).  
5

13) A method as claimed in Claim 12, wherein said target (2) information (ID, MSG) comprises a number of successive repetitions of said message sequence.

10 14) A method as claimed in any one of Claims 11 to 13, wherein said identification code (ID) is coded by a respective first sequence of a given first number (NID) of binary digits, each of a given first digit duration (DID); and said status message (MSG)  
15 is coded by a respective second sequence of a given second number (NMSG) of binary digits, each of a given second digit duration (DMSG).

15) A method as claimed in Claim 14, wherein said second digit duration (DMSG) equals said first  
20 digit duration (DID).

16) A method as claimed in Claim 14 or 15, wherein said radar signal (RS) comprises at least one radar pulse of a given pulse duration (DSAR); said first digit duration (DID) and said second digit  
25 duration (DMSG) being such that the total duration of the binary digits coding said target (2) information (ID, MSG) does not exceed the pulse duration (DSAR).

17) A method as claimed in any one of Claims 14

to 17, wherein extracting the target (2) information (ID, MSG) from the radar echo signal (RES) by the radar system (1) comprises:

- performing a succession of matched-filter demodulations of respective successive portions of the radar echo signal (RES) defined by the digit durations (DID, DMSG) of all the said binary digits coding said target (2) information (ID, MSG).

18) A method as claimed in Claim 17, wherein assigning said target (2) information (ID, MSG) to the incoming radar signal (RS) by the identification device (3) comprises:

- modulating the incoming radar signal (RS) with a modulating signal (MODS) comprising said target (2) information, to obtain a modulated signal (MS);

each of said matched filters being matched to a respective portion of the modulated signal (MS) defined by a corresponding one of said binary digits of said message sequence.

19) A target (2) identification device for a synthetic aperture radar system (1), the identification device (3) comprising receiving means (11; 26) for receiving a radar signal (RS) transmitted by the radar system (1); amplifying means (17) for amplifying the incoming radar signal (RS); and transmitting means (18; 26) for transmitting a processed radar signal (ES) supplied by said amplifying means (17); the identification device (3)

**being characterized by** comprising signal processing means (13, 19, 20, 21, 22) for assigning to the incoming radar signal (RS) target (2) information (ID, MSG) allowing identification of the target (2)  
5 by the radar system (1).

20) A device as claimed in Claim 19, wherein said signal processing means (13, 19, 20, 21, 22) comprise modulating means (13) for modulating the incoming radar signal (RS) with a modulating signal  
10 (MODS) comprising said target (2) information (ID, MSG).

21) A device as claimed in Claim 20, wherein said modulating means (13) are connected between said receiving means (11; 26) and said amplifying means  
15 (17).

22) A device as claimed in Claim 20 or 21, wherein said signal processing means (13, 19, 20, 21, 22) comprise encryption means (21) for encrypting said target (2) information (ID, MSG) by means of a  
20 programmable key; and memory means (22) for storing the programmable key.

23) A device as claimed in Claim 22, wherein said encryption means (21) are connected to the input of said modulating means (13).

25 24) A device as claimed in any one of Claims 20 to 23, wherein said signal processing means (13, 19, 20, 21, 22) comprise detecting means (19) connected to the output of said receiving means (11; 26) to

detect the presence of the radar signal (RS); and activating means (20) for connecting the receiving means (11; 26) to the input of said modulating means (13) when commanded by the detecting means (19) detecting the presence of the radar signal (RS).

25) A device as claimed in any one of Claims 19 to 24, wherein said receiving and transmitting means (11, 18; 26) comprise antenna means (26); the device comprising selecting means (27) for connecting the antenna means (26) selectively to the input of said signal processing means (13, 19, 20, 21, 22) to receive said radar signal (RS), and to the output of said amplifying means (17) to transmit said processed radar signal (ES).

26) A synthetic aperture radar system comprising transmitting means (5) for transmitting a radar signal (RS); receiving means (6) for receiving a radar echo signal (RES) comprising a processed radar signal (ES) transmitted by an identification device (3) of the type claimed in any one of Claims 19 to 25; and processing means (10) connected to the receiving means (6) to process the radar echo signal (RES), and which are configured to process said processed radar signal (ES) to identify said target (2).

27) A system as claimed in Claim 26, wherein the processing means (10) comprise demodulating means (24) for demodulating said radar echo signal (RES) to

extract said target (2) information (ID, MSG).

28) A system as claimed in Claim 26 or 27, wherein said processing means (10) comprise decryption means (25) for decrypting said target (2) information (ID, MSG) by means of a programmable key.

29) A system as claimed in Claim 28, wherein said decryption means (25) are connected to the output of said demodulating means (24).

30) A system as claimed in any one of Claims 26 to 29, wherein said modulating signal (MODS) comprises a sequence of binary digits for coding said target (2) information (ID, MSG); the binary digits having respective digit durations (DID, DMSG); and said demodulating means (24) comprising a number of matched filters, which operate in succession on respective successive portions of the radar echo signal (RES) defined by the digit durations (DID, DMSG).

31) A system as claimed in Claim 30, wherein said modulating means (13) supply a modulated signal (MS); each of said matched filters being matched to a respective portion of the modulated signal (MS) defined by the digit duration (DID, DMSG) of a corresponding said binary digit.

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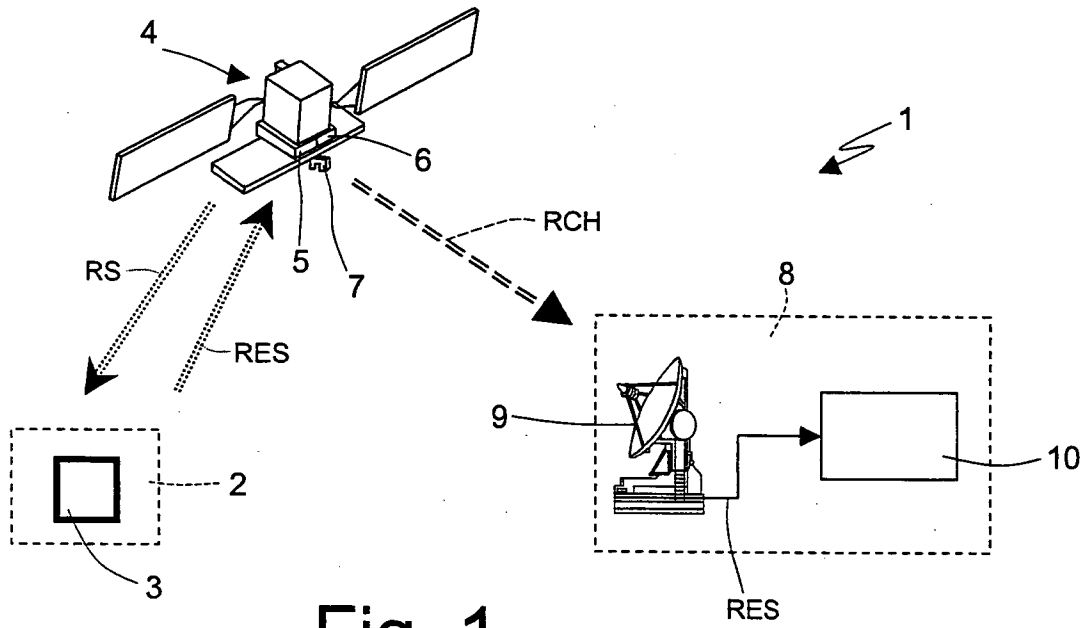


Fig. 1

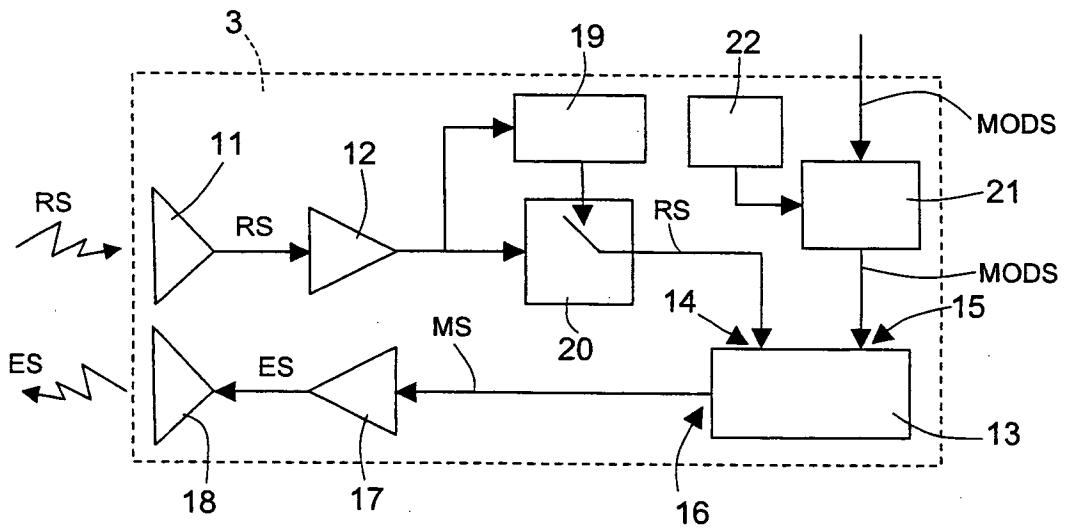


Fig. 2

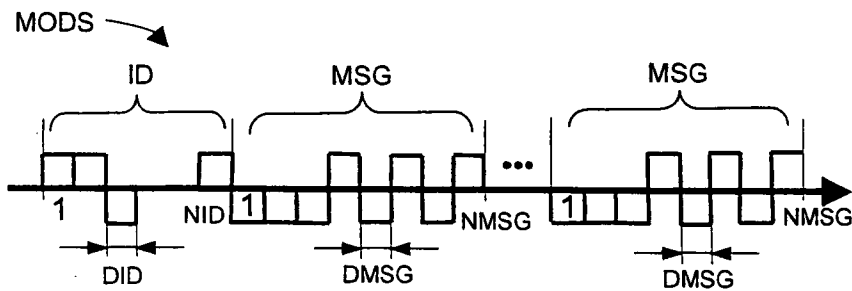


Fig. 3

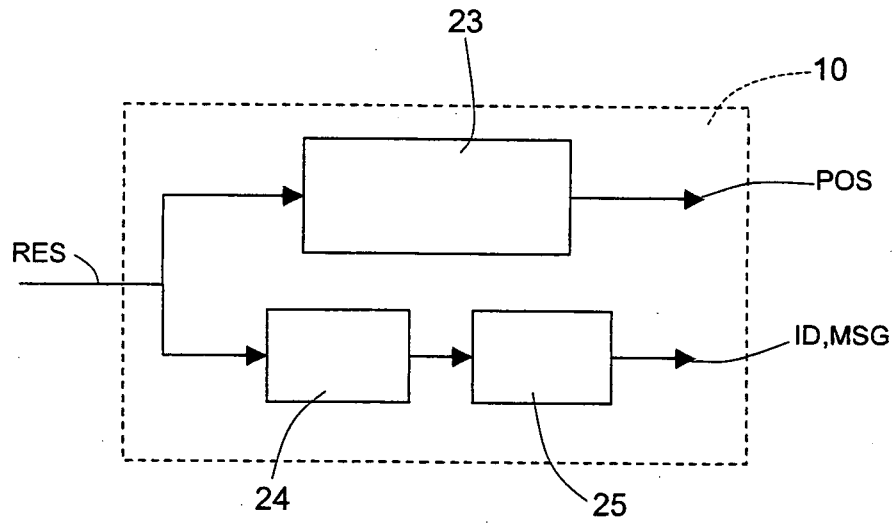


Fig. 4

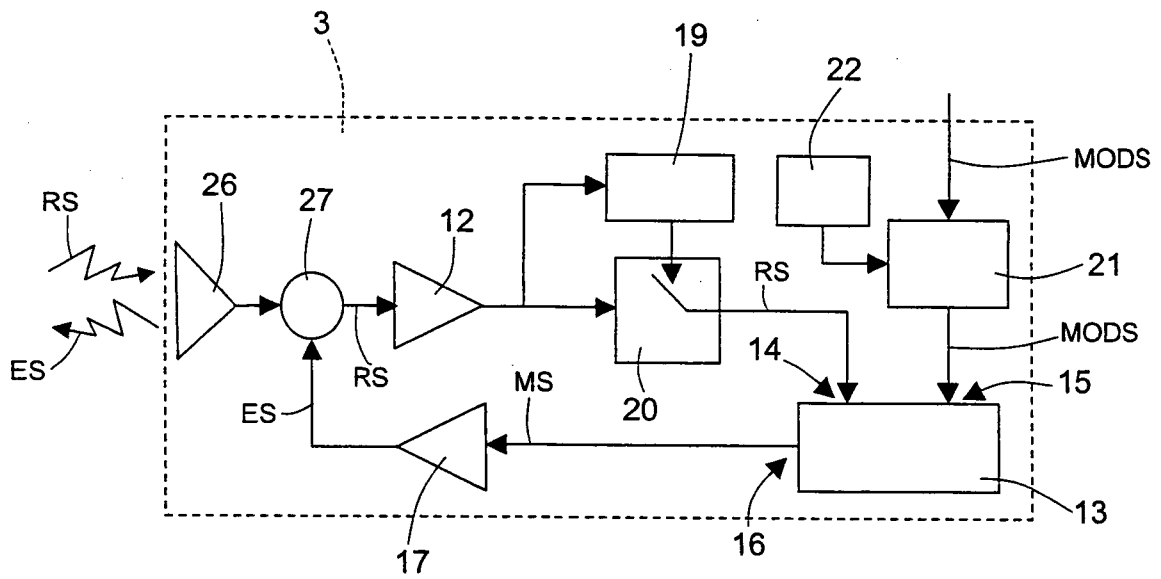


Fig. 5