

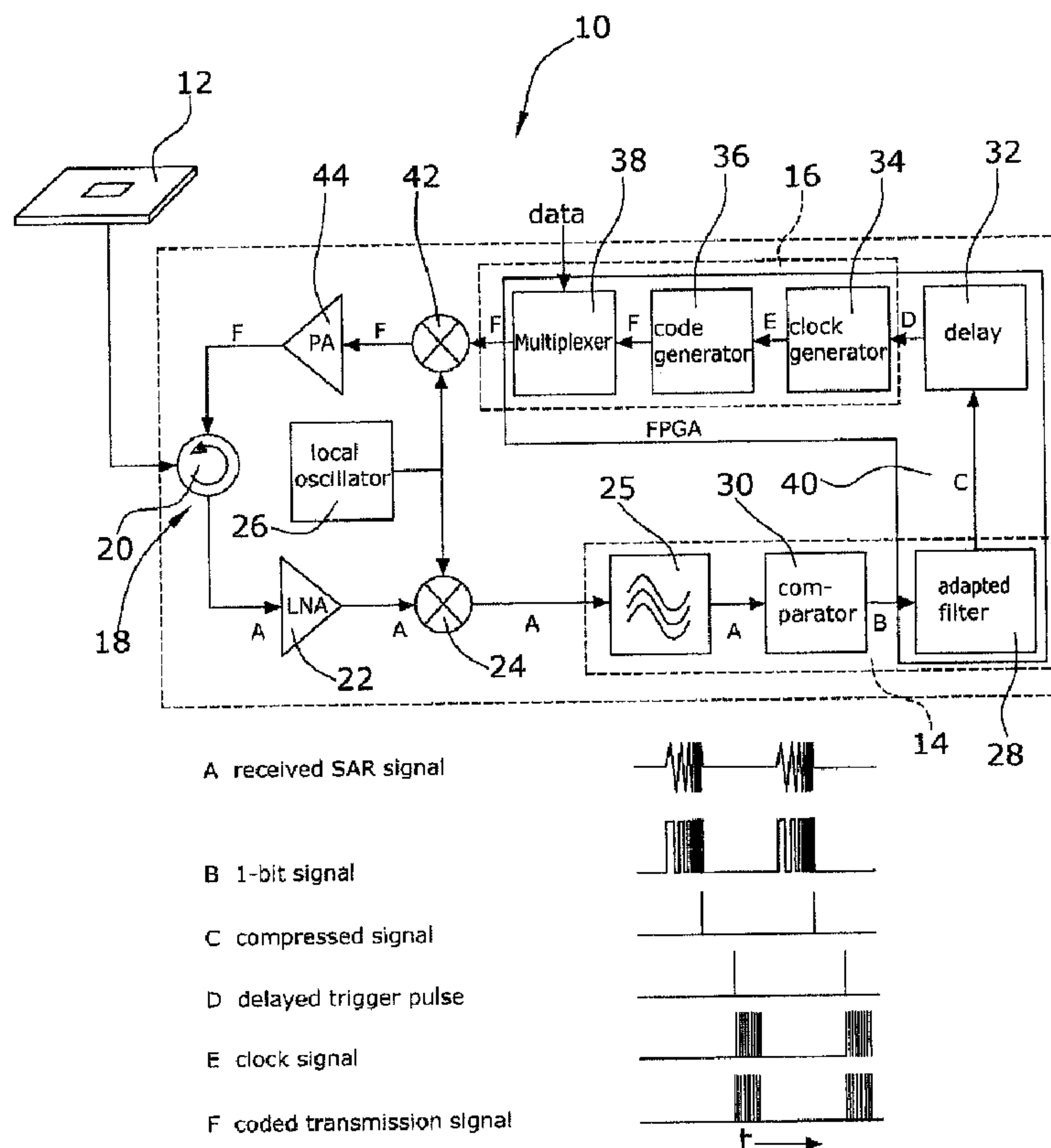


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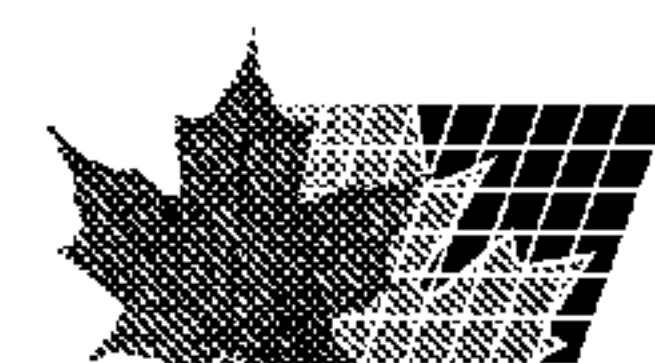
(54) Titre : PROCEDE POUR LA LOCALISATION D'OBJETS AU MOYEN D'UN SYSTEME RADAR A  
REPRESENTATION ET TRANSPONDEUR POUR LA LOCALISATION D'OBJETS AU MOYEN DE TELS  
SYSTEMES RADAR

(54) Title: METHOD FOR LOCALIZING OBJECTS BY MEANS OF AN IMAGING RADAR SYSTEM AND  
TRANSPONDER FOR LOCALIZING OBJECTS BY MEANS OF SUCH RADAR SYSTEMS



(57) Abrégé/Abstract:

The transponder (10) for localizing objects by means of an imaging radar system having radar signal compression and, in particular, a SAR system (radar with synthetic aperture) is provided with an antenna (12), which optionally serves as a receiving



(57) **Abrégé(suite)/Abstract(continued):**

antenna for receiving a radar transmission signal (A) and as a transmitting antenna for a transponder transmission signal (F). Furthermore, the transponder (10) is provided with a decoupling unit (18), which is connected to the antenna (12) and which has an outlet for routing a radar transmission signal (A) received from the antenna (12) and an inlet decoupled from the outlet for routing a transponder transmission signal to be transmitted through the antenna (12), and a signal compression unit (14), which compresses a received radar transmission signal (A) present at the outlet of the decoupling unit (18) into a signal compression pulse (C). The transponder has a delay unit (32) to delay the signal compression pulse (C) to generate a trigger pulse (D) delayed for a predetermined delay time relative to the signal compression pulse (C), and a transponder transmission signal-generating unit (16) to generate a transponder transmission signal (F) triggered by the trigger pulse (D), which can be fed to the inlet of the decoupling unit (18).

ABSTRACTMethod for localizing objects by means of an imaging radar system  
and transponder for localizing objects by means of such radar systems

The transponder (10) for localizing objects by means of an imaging radar system operative with radar signal compression and, in particular, a SAR system (radar with synthetic aperture) is provided with an antenna (12) which optionally serves as a receiving antenna for receiving a radar transmission signal (A) and as a transmitting antenna for a transponder transmission signal (F). Furthermore, the transponder (10) is provided with a decoupling unit (18) which is connected to the antenna (12) and which has an outlet for routing a radar transmission signal (A) received from the antenna (12), and an inlet decoupled from the outlet for routing a transponder transmission signal (F) to be transmitted through the antenna (12), and with a signal compression unit (14) which compresses a received radar transmission signal (A) present at the outlet of the decoupling unit (18) into a signal compression pulse (C). The transponder has a delay unit (32) to delay the signal compression pulse (C) to generate a trigger pulse (D) delayed for a presettable delay time relative to the signal compression pulse (C), and a transponder transmission signal generating unit (16) to generate a transponder transmission signal (F) triggered by the trigger pulse (D), which can be fed to the inlet of the decoupling unit (18).

(drawing)

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Method for localizing objects by means of an imaging radar system  
and transponder for localizing objects by means of such radar systems

The invention relates to a method for localizing objects by means of an imaging radar system operative with signal compression, said system particularly being a SAR system (radar with synthetic aperture). The invention further relates to a transponder for localizing objects by means of an imaging radar system operative with radar signal compression and particularly by means of a SAR system.

Due to their independence from meteorological conditions, visual conditions and the orientation of the sun, preferred use is made of radar systems of the imaging type. Such systems are used, for instance, for reconnaissance and for the tagging of objects (RFID) which e.g. can be localized and identified by means of an imaging radar system of the airplane- or satellite-borne type or of the stationary type. Especially useful in this regard are radar systems wherein the radar transmission signals, which are transmitted in a temporally successive manner, are subjected to compression. Thereby, while obtaining a relatively high spatial resolution, it is still possible to transmit relatively long, individual, modulated radar transmission signals whose peak energy can be correspondingly small, which is of advantage for the energy consumption of such systems while the spatial resolution is nonetheless high.

To make it possible that objects which are to be localized can be detected with higher reliability on the basis of the reflected radar transmission signals, it is known to provide so-called transparent echo pulse transmitters (transponder). Transponders of this type as well as a method for the use of such transponders in a radar system with synthetic aperture (SAR) as an

example of a radar system with radar signal compression are known from DE 32 48 879 A1 and DE 196 20 682 C2.

Because of the physical conditions, (SAR) transponders cannot be easily miniaturized. This is so because such transponders perform the receiving of the radar transmission signals and the transmitting of the transponder transmission signals by use of spatially separated, highly bundled antennae. For decoupling of the transmission and reception antennae of a (SAR) transponder, the antennae must have a minimum distance of several tens of centimeters (in the normal case, at least 70 cm). Further, the known transponders have to be relatively precisely oriented to the SAR radar device to be able to receive the radar transmission signals and the transponder transmission signals. All of such factors impose restrictions on the range of uses of known transponders.

It is an object of the invention to provide a method for localizing objects by means of an imaging radar system, and a transponder for use in such a method, wherein a miniaturization of the transponder as well as an improvement of the localizing possibilities by use of such a transponder are to be accomplished.

For achieving the above object, there is proposed, according to the invention, a transponder for localizing objects by means of an imaging radar system operative with radar signal compression and, in particular, a SAR system (radar with synthetic aperture), said transponder comprising

- an antenna optionally serving as a receiving antenna for receiving a radar transmission signal and as a transmitting antenna for a transponder transmission signal,
- a decoupling unit connected to the antenna and having an outlet for routing a radar transmission signal received from the antenna, and an inlet decoupled from the outlet for routing a transponder transmission signal to be transmitted through the antenna,

- a signal compression unit compressing a received radar transmission signal present at the outlet of the decoupling unit into a signal compression pulse,
- a delay unit for delaying the signal compression pulse to generate a trigger pulse delayed for a presettable delay time relative to the signal compression pulse, and
- a transponder transmission signal generating unit for generating a transponder transmission signal triggered by the trigger pulse, which can be fed to the inlet of the decoupling unit.

In the inventive method for localizing objects by means of an imaging radar system operative with radar signal compression and, in particular, by means of a SAR system,

- a radar transmission signal is received by an antenna of a transponder assigned to the object which is to be localized,
- the received radar transmission signal is subjected to a signal compression for generating a signal compression pulse,
- the signal compression pulse is temporally delayed for generating a time-delayed trigger pulse,
- a transponder transmission signal is generated which is triggered by the temporally delayed trigger pulse, and
- the transponder transmission signal is transmitted via that antenna which before had received the radar transmission signal.

By using a sole antenna for transmission and reception as well as by a corresponding signal processing within the transponder, it is rendered possible to construct a transponder which does not need to be oriented precisely and which is small enough to be mounted to small and possibly moveable objects, while these objects can then be detected and localized by an imaging radar system with radar signal compression. According to the invention, this is accomplished, on the level of signal processing, in that the radar transmission signal which has been transmitted and is received by the trans-

ponder, will be regenerated and, if required, will be modified at the same time. Thus, according to the invention, a transponder transmission signal is generated in the transponder that, in the simplest case, is a copy of the radar transmission signal which has been received before. In accordance with the invention, the transponder transmission signal is delayed until the received radar transmission signal has faded. Within the interval between two successive radar transmission signals, the transponder transmission signal can then be transmitted. In this manner, a sole antenna can be used for reception and transmission so that the size of the transponder can be noticeably reduced and particularly is not defined anymore by a minimum distance between a transmission antenna and a reception antenna.

According to an advantageous embodiment of the invention, it is further provided that the transponder transmission signal will be coded. Up to now, the known transponders had only been able to transmit back coded radar transmission signals. Thus, previously, it had only been possible to perform a coding via the radar transmission signal itself and thus from radar transmission signal to radar transmission signal. By use of the inventive concept of a (re-) generation of the transponder transmission signal, it is now rendered possible to perform the coding in a decentralized manner, i.e. in the transponder, thereby improving the reliability of the detection and the identification, respectively. Thus, it is now possible to transmit external data (coding data and other data) from the transponder to the radar signal transmission station, notably in coded form together with the transponder transmission signal.

According to a further embodiment of the invention, it is further possible to use, as an (only) antenna of the transponder, an omnidirectional antenna whose advantage resides in that its signals can be irradiated across a relatively large range of spatial angles and that, on the other hand, these antennae can receive radar signals within a larger range of spatial angles.

Under the constructional aspect, a decoupling unit is arranged between the antenna of the transponder and the signal decoupling unit on the one hand as well as the transponder transmission signal generating unit on the other hand, said decoupling unit being operative to connect the antenna either with the signal compression unit or to the transponder transmission signal generating unit. Such a decoupling unit is preferably realized in the form of a circulator.

The invention serves for the detection of targets and for the transmission of data in SAR systems. In doing so, according to the invention, the signal is modulated from pulse to pulse wherein the received signal is used for the generation of the transponder echo signal by sampling the signal and, with the aid of a trigger pulse derived from the received signal, by modulating, reconstructing and transmitting the signal. In the invention, no signal generator is required (see claim 2). Further, suitably, specific detection signals are broadcast (see claims 3 and 7). Finally, it is of advantage to use an antenna with an omnidirectional characteristic. The coding of the signal in the transponder as required according to the invention is not comparable with a pulsed compression.

The invention will be explained in greater detail hereunder by way of an embodiment thereof and with reference to the drawing. This drawing schematically shows a circuit diagram of an embodiment of a transponder.

The SAR transponder 10 schematically illustrated in the drawing is a device by which the radar transmission signal (subsequently referred to as a SAR signal) transmitted by a radar with synthetic aperture (SAR radar) is received, processed and emitted again in such a manner that, when received by the SAR radar device (not illustrated), it can be localized in an unadulterated manner and can be unambiguously identified by a change of the signal shape. On the basis of the changed signal shape, the transponder transmission signal can be better distinguished from the reflected radar

transmission signals of the environment of an object to be localized and can be detected with higher reliability.

The transponder 10 comprises a (sole) antenna 12 serving both for reception of a radar transmission signal and for the transmission of a transponder transmission signal. Transponder 10 includes a signal compression unit 14 for compression of the received SAR signal A; in the signal compression unit 14, there is obtained, as a compressed signal C, a trigger impulse which is stable with respect to the phase of the SAR signal A. Now, with the aid of the trigger impulse, there can be generated, after a temporal delay, a delayed transponder transmission signal F of a different type, which is performed in a transponder transmission signal generating unit 16. The transponder transmission signal F can then be irradiated again via the same antenna 12 without causing a disturbance of the reception of the antenna. Notably, by the temporal delay, it is effected the received SAR signal A will have faded when the transponder transmission signal F is transmitted. Thus, the transponder 10 will need only one antenna.

Further, the changed shape of the transponder transmission signal relative to the radar transmission signal can be used to mark the transponder transmission signal, i.e. to distinguish it from natural signals of the environment or to mix the signal with data which can be read and processed by the SAR radar device (not shown). By use of the same antenna 12 for the reception of the radar transmission signal and the transmission of the transponder transmission signal, the transponder 10 can be considerably reduced in size. Further, the compression of the radar transmission signal leads to such an increase of the sensitivity of the transponder 10 that an omnidirectional antenna can be used. Thus, an exact orientation of the transponder 10 to the SAS radar device is not required anymore.

As evident from the drawing, the SAR signal A is received by antenna 12 and is passed on to a receiving amplifier 22 via a decoupling unit 18 which in the present embodiment is formed as a circulator 20. By use of a mixing

unit 24 with a local oscillator 26 acting thereon, the SAR signal A, which is frequency-modulated, will be mixed to attain an intermediate frequency suited for further processing in a filter 25. By the filter 25, undesired frequency portions will be suppressed.

A possible algorithm for compressing the frequency-modulated SAR signal A comprises a so-called adapted filter 28 according to the method of 1-bit convolution in the time domain, as described e.g. by Franceschetti, G.; Alberti, G.; Pascazio, V.; Schirinzi, G. in "Time-domain convolution of one-bit coded radar", IEEE Proceeding Radar and Signal Processing, October 1991. In this known method, the intermediate frequency signal is, within a comparator 30, converted into a 1-bit sequence (see signal B), i.e. a sequence of 0- and 1-states. The adapted filter 28 delivers a pulse (signal C) which represents the compressed SAR signal A and serves for triggering the to-be-generated transponder transmission signal F. The compressed signal C is bound to the SAR signal A in a temporal as well as a phase-locked manner. By triggering a temporal delay in the delay unit 32, the compressed signal C is delayed into a temporally delayed trigger pulse (signal D).

Now, with the aid of the trigger pulse D temporally delayed relative to the compressed signal C, a clock generator 34 is activated which in the present embodiment is operative to clock a code generator 36 (see signal F). The code serves for marking the transponder transmission signal F so that the signal can be unambiguously identified in the SAR data and in the SAR radar device, respectively. The coding can be performed from SAR pulse to SAR pulse (azimuth modulation) as proposed in Hounam, D.; Waegel, K.; Dill, S.: "Verfahren zur Lokalisierung und Identifizierung von Objekten mittels eines codierten Transponders", Patent DE 196 20 682, 2001, or within the SAR pulses or according to both methods. The combination of both variants has the advantage of effectively offering an enlarged bandwidth in order i) to increase the reliability of detection, ii) to improve the unambiguity of the identification (more codes) and iii) to transmit data, or iv) to use all of these measures together. Further, a sole transponder transmis-

sion signal can be used for transmitting the information, i.e. the code data or the additional data.

The coded transponder transmission signal F is passed through a multiplexer 38 which allows for the adding of freely selectable external data. Thus, local data can be transmitted back to the SAR radar device together with the transponder transmission signal and be evaluated during the processing of the SAR data. Advantageously, all of the above described signal processing steps from said adapted filter 28 to said multiplexer 38 can be realized by a highly integrated digital circuit such as, e.g., a FPGA 40 (floating point gate array).

Now, the transponder transmission signal F temporally delayed relative to the received SAR signal A, which can also be coded and in the present embodiment is coded and which optionally can include external data, will be mixed, with the aid of a mixer unit 42 with the same local oscillator 26, so as to reach the frequency level of the radar transmission signals, and will be amplified in a power amplifier 44. Via said circulator 20, the signal will then be supplied to the antenna 12 from where it will be radiated to the SAR radar device.

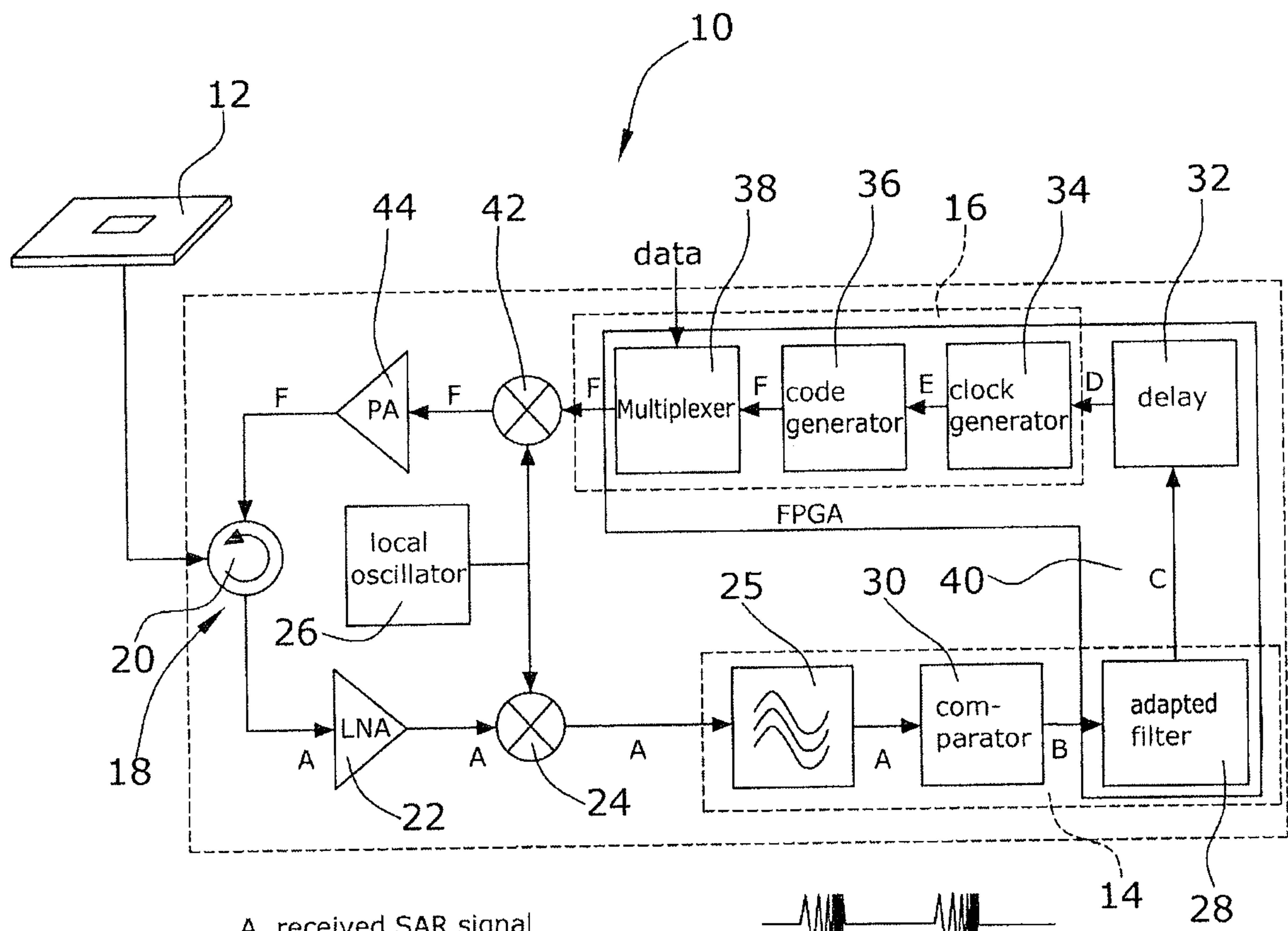
Claims

1. A transponder for localizing objects by means of an imaging radar system operative with radar signal compression and, in particular, a SAR system (radar with synthetic aperture), said transponder comprising
  - an antenna (12) optionally serving as a receiving antenna for receiving a radar transmission signal (A) and as a transmitting antenna for a transponder transmission signal (F),
  - a decoupling unit (18) connected to the antenna (12) and having an outlet for routing a radar transmission signal (A) received from the antenna (12), and an inlet decoupled from the outlet for routing a transponder transmission signal (F) to be transmitted through the antenna (12),
  - a signal compression unit (14) compressing a received radar transmission signal (A) present at the outlet of the decoupling unit (18) into a signal compression pulse (C),
  - a delay unit (32) for delaying the signal compression pulse (C) to generate a trigger pulse (D) delayed for a presettable delay time relative to the signal compression pulse (C), and
  - a transponder transmission signal generating unit (16) for generating a transponder transmission signal (F) triggered by the trigger pulse (D), which can be fed to the inlet of the decoupling unit (18).
2. The transponder according to claim 1, characterized in that, in the transponder transmission signal generating unit (16), a copy of a radar transmission signal (A) can be generated as a transponder transmission signal (F).
3. The transponder according to claim 1, characterized in that, in the transponder transmission signal generating unit (16), a coded signal can be generated as a transponder transmission signal (F) for identification of the transponder by the radar system.

4. The transponder according to any one of claims 1 to 3, characterized in that the antenna (12) is an omnidirectional antenna or the like antenna for transmission and reception, respectively, of signal across a larger range of spatial angles.
5. The transponder according to any one of claims 1 to 4, characterized in that the decoupling unit (18) is a circulator (20).
6. The transponder according to any one of claims 1 to 5, characterized in that the delay unit (32) is operative to delay the trigger pulse (D) by less than the temporal distance between two successive radar transmission signals (A) or two successive signal compression pulses (C).
7. The transponder according to any one of claims 1 to 6, characterized in that the transponder transmission signal generating unit (16) comprises a coding unit (36) provided for coding the transponder transmission signal for identification of the transponder by the radar system, the coding being performed from transponder transmission signal (A) to transponder transmission signal (A), or within the transponder transmission signal, or according to both methods.
8. A method for localizing objects by means of an imaging radar system operative with radar signal compression and, in particular, by means of a SAR system, wherein
  - a radar transmission signal (A) is received by an antenna (12) of a transponder (10) assigned to the object which is to be localized,
  - the received radar transmission signal (A) is subjected to a signal compression for generating a signal compression pulse (C),
  - the signal compression pulse (C) is temporally delayed for generating a time-delayed trigger pulse (D),
  - a transponder transmission signal (F) is generated which is triggered by the temporally delayed trigger pulse (D), and

- the transponder transmission signal (F) is transmitted via that antenna (12) which before had received the radar transmission signal (A).
9. The method according to claim 8, characterized in that a copy of the radar transmission signal (A) is generated as said transponder transmission signal (F).
  10. The method according to claim 8, characterized in that the transponder transmission signal (F) is coded.
  11. The method according to claim 10, characterized in that the coding is performed from radar transmission signal (A) to radar transmission signal (A) or within the processing of a radar transmission signal (A).
  12. The method according to any one of claims 8 to 10, characterized in that the trigger pulse (D) is temporally delayed by less than the temporal distance between two successive radar transmission signals (A).
  13. The method according to any one of claims 8 to 12, characterized in that further data are added to the transponder transmission signal (F).

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A received SAR signal

B 1-bit signal

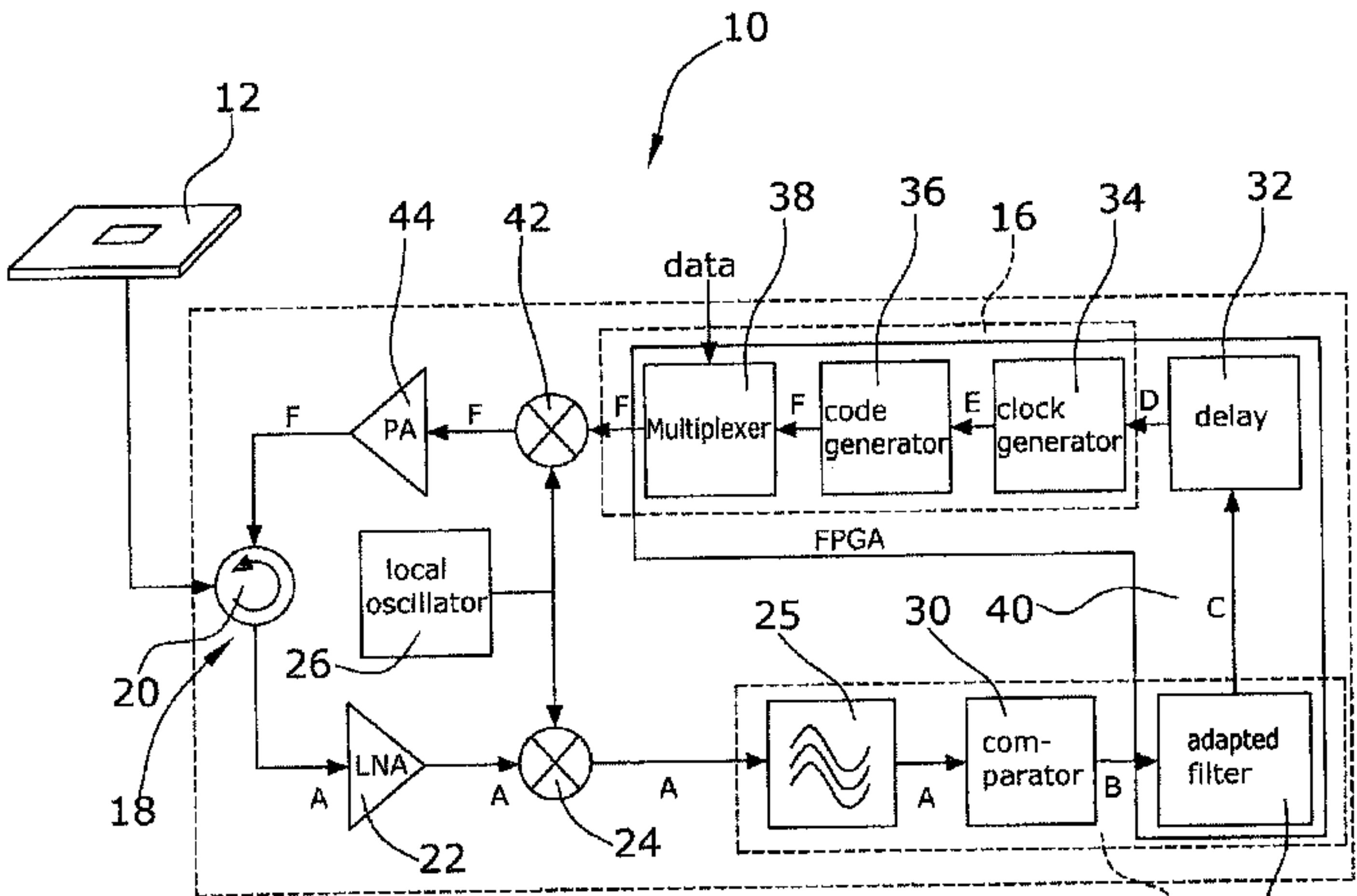
C compressed signal

D delayed trigger pulse

E clock signal

F coded transmission signal

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A received SAR signal

B 1-bit signal

C compressed signal

D delayed trigger pulse

E clock signal

F coded transmission signal

