

RADIOFREQUENCY FRONT-END ARCHITECTURE FOR A POSITIONING RECEIVER, AND METHOD FOR RECEIVING SIMULTANEOUSLY A FIRST AND A SECOND FREQUENCY BAND OF A SATELLITE SIGNAL

DESCRIPTION

The present invention relates to the field of multiband satellite receivers.

More in particular, the present invention relates to a radiofrequency front-end architecture for reconfigurable multiband, multichannel satellite receivers, as well as to a method for receiving simultaneously a first and a second frequency band of a satellite signal.

5 After having been widely used in the military field, having become indispensable in the field of weather forecasts and earth observation, and having changed the world of research and communications, satellites are now about to become strategic allies for everyday mobility and safety.

10 In fact, increasingly complex satellite systems will allow us, in the near future, to move and travel faster and safer.

Satellite positioning systems, however, are not so new an invention; they were originally conceived for military and research applications, like the US satellite system called GPS (“Global Positioning System”) or the less notorious Russian satellite system called Glonass (“Globalnaya Navigatsionnaya Sputnikova Sistema”, i.e. “Global Navigation Satellite
15 System”), also used for marine salvage applications.

On the other hand, the European satellite positioning system called Galileo has been specifically conceived mainly for civil applications.

The Galileo system has a larger number of available bands than the current GPS system. In fact, the GPS system only transmits the so-called L1 band (at about 1.5 GHz) for civil
20 applications and the so-called L2 band (at about 1.2 GHz) for military applications. The GPS system will however be upgraded with additional civil bands, e.g. L5 and L2c. The Galileo system currently uses four bands: E5a (1176.45 MHz), E5b (1207.14 MHz), E5 (1191.795 MHz), E6 (1278.75 MHz) and E1-L1 (1575.42 MHz). Although some frequency bands of the Galileo system coincide with those of the GPS system, they have
25 been designed in such a manner as to not interfere with the signals of the GPS system.

In order to be able to fully exploit the additional signals provided by the Galileo and GPS systems, future positioning receivers will have to operate in multiband mode.

However, each additional frequency band requires additional hardware in the receiver, thus leading to an increased cost of the receiver itself; this additional cost is not acceptable, especially when the receiver is meant for low-cost civil applications.

Moreover, since it is not practical to design a receiver capable of receiving all possible
5 frequency bands, the designer must also choose the frequency bands which are to be received by the receiver.

It is therefore desirable to design a dynamically reconfigurable multiband receiver which requires minimal costs and minimal circuit complexity.

A few solutions to this problem have been already proposed so far.

10 For instance, United States patent application US 7,035,613 relates to a multiband receiver which can receive simultaneously both the L1 and L2 signals of a GPS system or even just one of said signals. The receiver comprises a fixed phase-locked loop (PLL), and the associated voltage-controlled oscillator (VCO) is so configured as to obtain a low-power configuration by using conventional integer frequency dividers for the second mixing
15 stage. While on the one hand this circuit arrangement only requires little power for operating the receiver, on the other hand it cannot make the circuit suitable for selecting signals other than L1 and L2 in a reconfigurable manner.

For example, International patent application WO 2006/086118 describes a multiband positioning receiver which can receive simultaneously two satellite signals such as L1/E2
20 and L2, L5/L5a and L2, L1/E2 and E5b, L5/E5a and E5b. However, this type of receiver cannot receive all possible satellite signals of positioning systems; for example, its architecture is so conceived that it cannot obtain the frequency band E5, thus preventing the use of any types of modulation requiring that specific band, e.g. "Alt-BOC" modulation.

25 It is therefore the object of the present invention to provide a radiofrequency front-end architecture for a positioning receiver and a method for receiving simultaneously two frequency bands of a satellite positioning system which allow to receive any pair of signals of any satellite positioning system.

It is another object of the present invention to provide a radiofrequency front-end
30 architecture for a positioning receiver and a method for receiving simultaneously two frequency bands of a satellite positioning system which allow to manufacture a receiver with minimal circuit complexity and therefore a low cost receiver.

It is a further object of the present invention to provide a radiofrequency front-end

architecture for a positioning receiver and a method for receiving simultaneously two frequency bands of a satellite positioning system which allow for mass production of a high-integratability receiver intended for consumer applications.

These and other objects of the invention are achieved by the method and the system as claimed in the appended claims, which are intended as an integral part of the present description.

The above objects will become apparent from the detailed description of the method and system according to the invention, with particular reference to the annexed figures, wherein:

- Figs. 1 and 2 are block diagrams relating to a first and a second embodiment, respectively, of a radiofrequency front-end architecture according to the invention for a positioning receiver;

- Fig. 3 is a frequency plan relating to the two types of embodiment of the radiofrequency front-end architecture shown in Figs. 1 and 2.

Referring now to Fig. 1, there is shown a block diagram of a first embodiment of a radiofrequency front-end architecture 1 according to the invention.

In said first embodiment, front-end architecture 1 comprises a first circuit chain 2 for receiving a first radiofrequency signal, e.g. L2, E6, E5a, E5b or E5 type, and a second circuit chain 4 for receiving L1/E1 signal.

According to this first embodiment, L1/E1 signal, which is intended for civil applications, is always received; this signal can always be used for fast position fixing and can always be used by the other bands for carrying out a fixing operation by starting from a known point. The choice of receiving L1/E1 is advantageous because the other satellite signals have broader frequency bands than L1/E1 signal.

First circuit chain 2 comprises the following components in cascade:

- a first antenna 5 for receiving a radiofrequency signal;
- a first radiofrequency filter 7, e.g. SAW ("surface acoustic wave") type, which may vary depending on a chosen first frequency band, e.g. L2, E5, E5a, E5b or E6;
- a first low-noise amplifier 9 for amplifying the output signal of first filter 7;
- a second radiofrequency filter 11, e.g. SAW type, which may vary depending on the chosen first frequency band, for rejecting the image signal;
- a first active mixer stage 13,15, comprising a first radiofrequency gain amplifier 13 and a first mixer 15 which mixes the signal outputted by first gain amplifier 13 with a signal

generated by a fixed-frequency local oscillator 31;

- a first signal amplifier 17 for amplifying the output signal of first mixer 15;
- a first filter 19 operating at an intermediate frequency IF_1 , e.g. SAW type, which may vary according to the chosen first frequency band and which is adapted to perform channel selection;
- a first automatic gain control (AGC) amplifier 21 for amplifying the output signal of first filter 19 operating at intermediate frequency IF_1 , and
- a first analog-digital converter (ADC) 23 with selectable sampling rate, controlled by a variable-type integer frequency divider 40.

10 Second circuit chain 4 comprises the following components in cascade:

- a second antenna 6 for receiving a radiofrequency signal;
- a first fixed-radiofrequency filter 8, e.g. SAW type, for filtering a chosen second frequency band, e.g. L1;
- a second low-noise amplifier 10 for amplifying the output signal of first filter 8;
- a second fixed-radiofrequency filter 12, e.g. SAW type, for rejecting the image signal;
- a second active mixer stage 14,16, comprising a second radiofrequency gain amplifier 14 and a second mixer 16 which mixes the signal outputted by second gain amplifier 14 with a signal generated by fixed-frequency local oscillator 31;
- a first filter 18 operating at a fixed intermediate frequency IF_1 , e.g. SAW type, for filtering the output signal of second mixer 16;
- a third mixer 20 which mixes the signal outputted by first filter 18 operating at a fixed intermediate frequency IF_1 with a fixed-frequency signal generated by local oscillator 31, treated by a first fixed-type frequency divider 32;
- a second signal amplifier 22 for amplifying the output signal of third mixer 20;
- a second filter 24 operating at a fixed intermediate frequency IF_1 , e.g. SAW type, adapted to perform channel selection;
- a second automatic gain control (AGC) amplifier 26 for amplifying the output signal of second filter 24 operating at a fixed intermediate frequency, and
- a second analog-digital converter (ADC) 28 with selectable sampling rate, controlled by a second fixed-type frequency divider 38.

Local oscillator 31 comprises a phase-locked loop (PLL) 36 controlled by an oscillator 34, the latter being preferably of the compensated type, in particular a TCXO ("Temperature Controlled Xstall Oscillator"). PLL 36 generates a control signal for a voltage-controlled

oscillator (VCO) 30.

Front-end architecture 1 is also connected to a demodulation block 42, wherein the signals outputted by first circuit chain 2 and from second circuit chain 4 are processed in order to demodulate the signals into baseband, so that they can be processed appropriately for the purpose of extracting useful information therefrom.

Synchronization between demodulation block 42 and front-end architecture 1 is ensured in that demodulation block 42 has a SYS CLK input that receives the signal generated by compensated oscillator 34.

Through front-end architecture 1, the desired frequency bands can only be tuned by changing the sampling rate of first analog-digital converter 23; this can be done by acting upon integer frequency divider 40. In this manner, the signal supplied to mixers 15,16 by local oscillator 31 will have a fixed frequency for all tunable frequency bands.

The different frequency bands that can be obtained on first circuit chain 2 can be selected by varying variable filters 7, 11 and 19, which are preferably switchable LC type or, as aforementioned, SAW type.

The choice of a front-end architecture 1, wherein one circuit chain is dedicated to receiving L1 signal only, while the other circuit chain is dedicated to receiving any one of the other satellite signals, is also dictated by requirements of silicon integration in CMOS technology.

In fact, in CMOS technology a low-noise amplifier is not a broadband amplifier as, for example, in SiGe or GaAs technology, but a low-noise amplifier with typically a very narrow passband centred on the desired band.

Therefore, the exclusive use of one circuit chain for L1 signal allows for integrating into one chip low-noise amplifier 10 and the following components of second circuit chain 4 (except for filters 8, 12 and 18, which are typically highly frequency-selective filters of the Surface Acoustic Wave type, and therefore cannot be integrated on silicon), since the frequency band of L1 signal is known a priori.

Because L1 is received through a specific circuit chain, the other signals to be received and low-converted on first circuit chain 2 have very close frequencies, since they range between 1176.45 MHz of E5a signal and 1278.75 MHz of E6 signal. As aforementioned, a reduced frequency range is a specification required for designing and integrating a low-noise amplifier in CMOS technology. As a result, low-noise amplifier 9 and the following circuit components of first circuit chain 2 (except for filters 7 and 11, which are typically

highly frequency-selective filters of the Surface Acoustic Wave type, and therefore cannot be integrated on silicon) can also be integrated into said chip.

A deep integration of front-end architecture 1 is certainly advantageous for manufacturing low-cost consumer satellite receivers comprising said architecture 1.

5 Referring now to Fig. 2, there is shown a second embodiment of a front-end architecture 1' according to the invention, wherein a first circuit portion 3 of Fig. 1 has been replaced with a second circuit portion 3' of Fig. 2, while all other circuit components remain unchanged from Fig. 1.

10 In said second embodiment, front-end architecture 1' comprises an initial portion wherein the two satellite signals to be received simultaneously are filtered on one circuit chain, instead of two as in Fig. 1.

Second circuit portion 3' of Fig. 2 comprises:

- a third multiband antenna 51 for receiving radiofrequency signals;
- a first broadband amplifier 53 for amplifying the signal received by third antenna 51;
- 15 - a first band-pass filter 55 which filters the signal outputted by first broadband amplifier 53 in order to extract two frequency bands RF1 and RF2;
- an active mixer stage comprising a first buffering amplifier 57 and a second mixer 59, which is mixer 16 of Fig. 1;
- a second buffering amplifier 61 which subdivides the signal outputted by second mixer
- 20 59 into two channels, wherein a first channel reconnects, through an additional amplifier 63, to first signal amplifier 17 of first circuit chain 2, and a second channel reconnects, through an additional amplifier 65, to third filter 18 of second circuit chain 4.

Fig. 3 is a table which contains a frequency plan used by front-end architecture 1,1' according to the invention.

25 From left to right, the columns of the table of Fig. 3 have the following headers:

- "Satellite": indicates the type of satellite, i.e. GPS or Galileo;
- "Band": indicates the frequency band of the satellite signal to be low-converted, e.g. L1/E1, L2, E5, E5a, E5b or E6;
- "Carrier": indicates the frequency, in MHz, of the carrier of the frequency band of the
- 30 respective signal;
- "TXCO": indicates the fixed oscillation frequency, in MHz, of compensated oscillator 34;
- "MIX1": indicates the fixed frequency, in MHz, of the signal generated by VCO 30;
- IF1": indicates the frequency, in MHz, of the output signal of mixers 15 and 16, obtained

by subtracting the fixed frequency stated in column "MIX1" from the carrier frequency;

- "Sampling divider": indicates the integer by which divider 32 divides the fixed frequency, in MHz, of the signal generated by VCO 30;

5 - "MIX2": indicates the fixed frequency, in MHz, resulting from the division of the frequency stated in column "MIX1" by the integer stated in column "Sampling divider";

- "IF2": indicates the fixed frequency, in MHz, of the signal outputted by mixer 20, corresponding to the difference between the frequency values stated in columns "IF1" and "MIX2";

10 - "Subsampling rate": hereafter also referred to as F_s , indicates a possible subsampling rate at which first analog-digital converter 23 or second analog-digital converter 28 is operated in order to obtain a satellite signal among L2, E5, E5a, E5b, E6 and L1/E1;

- "BW": indicates the bandwidth of the satellite signal specified in the second column;

- "Remarks": indicates whether the signal is converted directly or through a two-stage conversion process.

15 The table of Fig. 3 highlights the fact that analog-digital converter 23 is operated at a sampling rate which is a function of local oscillator 31 and which allows subsampling of the intermediate-frequency signal.

The selected subsampling rate must fulfill two requirements:

20 a) $IF1 - n \cdot F_s > BW/2$, where n is an integer greater than 1, so that the replica of the sampled signal will be located in a positive half-plane, thus not generating any "aliasing" effect, i.e. spectrum overlay;

b) $0 < 2 \cdot (IF1 - n \cdot F_s + BW/2) < F_s$, thus fulfilling Nyquist's theorem according to which a signal, in order to be sampled, must have a band smaller than or at most equal to half the sampling rate.

25 The features of the present invention, as well as its advantages, are apparent from the above description.

A first advantage is that front-end architecture 1,1' according to the present invention allows to receive simultaneously any combination of satellite signals of the GPS and Galileo systems.

30 A further advantage of front-end architecture 1,1' according to the present invention is that it allows to receive E5, E5a and E5b signals. Being able to obtain E5 signal is advantageous because, among other things, E5 signal is used in "Alt-BOC" modulation types.

A further advantage of front-end architecture 1,1' is that it is necessary to reconfigure only one radiofrequency filter and only one intermediate-frequency filter in order to tune the frequency band. In principle, a fully reconfigurable multiband receiver can be obtained by simply adding a chain of electronically interchangeable filters arranged in parallel and
5 centred on the frequencies of interest.

A further advantage of front-end architecture 1 according to the invention is that it can be deeply integrated into a chip in CMOS technology, thus allowing to manufacture low-cost consumer positioning receivers.

A further advantage of front-end architecture 1,1' according to the invention is that it is a
10 superheterodyne-type architecture and therefore it does not require the use of any image rejection mixers, thus allowing the signal to be treated at intermediate frequencies of about 100 MHz: this results in the signal being treated better than by other architectures which go down to very low intermediate frequencies.

A further advantage of the front-end architecture according to the invention is that, by
15 dedicating a circuit chain to receiving L1 signal, for the other signals it is only necessary to use one analog-digital converter with configurable sampling rate, since the other analog-digital converter is sampled in a fixed manner in order to receive L1 signal.

A further advantage of the front-end architecture according to the present invention is that it uses no fraction dividers to obtain the required frequency bands, thus reducing spurious
20 frequencies and, as a result, crosstalk.

The radiofrequency front-end architecture for a positioning receiver and the method for receiving simultaneously a first and a second frequency band of a satellite signal described herein by way of example may be subject to many possible variations without departing from the novelty spirit of the inventive idea; it is also clear that in the practical
25 implementation of the invention the illustrated details may have different shapes or be replaced with other technically equivalent elements.

For example, instead of dedicating one circuit chain to receiving L1 signal and the other circuit chain to receiving one of the other possible signals, it is possible to dedicate one circuit chain to receiving a signal among E2, E5, E5a, E5b and E6, and the other circuit
30 chain to the remaining signals.

For example, the front-end architecture described herein may also receive other satellite signals which may be added in the near future to the Galileo satellite positioning system or to other similar satellite positioning systems.

It can therefore be easily understood that the present invention is not limited to the above described radiofrequency front-end architecture for a positioning receiver and method for receiving simultaneously a first and a second frequency band of a satellite signal, but may be subject to many modifications, improvements or replacements of equivalent parts and
5 elements without departing from the inventive idea, as clearly specified in the following claims.

CLAIMS

1. Front-end architecture (1,1') for receiving simultaneously a first and a second satellite signal of a satellite positioning system,

said architecture comprising:

- conversion means for converting a radiofrequency signal into an intermediate-frequency signal, said conversion means (3) comprising a fixed-frequency local oscillator (31);

- extraction means (23,28) for extracting said first and said second satellite signals from said intermediate-frequency signal,

characterized in that said extraction means (23,28) can be operated at a sampling rate which is a function of an oscillation frequency generated by said local oscillator (31) and

which allows undersampling of said intermediate-frequency signal.

2. Front-end architecture according to claim 1, characterized in that said extraction means (23,28) comprise a first (23) and a second (28) analog-digital converters for extracting said first and said second satellite signals, respectively, wherein said first analog-digital converter (23) can be operated through a variable-type integer frequency divider (40) and said second analog-digital converter (28) can be operated through a fixed-type integer frequency divider (38).

3. Front-end architecture according to claim 1, characterized in that said local oscillator (31) comprises an oscillator (34), preferably of the compensated type (TXCO), a phase-locked loop (36), and a voltage-controlled oscillator (30).

4. Front-end architecture according to claim 1, characterized by comprising at least one variable-type radiofrequency filter (7,11;55) and at least one variable-type intermediate-frequency filter (19) for selecting a frequency band of said first satellite signal.

5. Front-end architecture according to claim 4, characterized in that said at least one variable-type radiofrequency filter (7,11;55) and said at least one variable-type intermediate-frequency filter (19) are LC filters.

6. Front-end architecture according to claim 4, characterized in that said at least one variable-type radiofrequency filter (7,11;55) and said at least one variable-type intermediate-frequency filter (19) are SAW filters.

7. Front-end architecture according to claim 1, characterized in that said conversion means further comprise a first mixer (15,16) which mixes said radiofrequency signal with a fixed-frequency signal supplied by said local oscillator (31).

8. Front-end architecture according to claim 7, characterized in that said conversion means

comprise a second mixer (20) adapted to mix the signal outputted by said first mixer (15,16) with said fixed-frequency signal supplied by said local oscillator (31), which has been divided by a fixed-type integer frequency divider (32).

9. Front-end architecture according to claim 7 or 8, characterized by further comprising a single antenna (51) and a broadband amplifier (53) for receiving said first and said second satellite signals.

10. Front-end architecture according to claim 7 or 8, characterized by comprising a first circuit chain (2) and a second circuit chain (4) respectively adapted to treat a first radiofrequency signal and a second radiofrequency signal received by a first antenna (5) and a second antenna (6), respectively.

11. Front-end architecture according to claim 10, characterized in that a first mixer (15) is arranged on said second circuit chain (4) and said radiofrequency signal is said second radiofrequency signal, and that a second mixer (16) is provided on said first circuit chain (2) for mixing said first radiofrequency signal with said fixed-frequency signal supplied by said local oscillator (31).

12. Front-end architecture according to one or more of the preceding claims, characterized in that downstream of said architecture there is a demodulation block (42), wherein said first and second satellite signal are processed into baseband, so that they can be further processed appropriately for the purpose of extracting useful information therefrom.

13. Front-end architecture according to one or more of the preceding claims, characterized in that said first satellite signal is a signal among the L2, E5, E5a, E5b, E6 signals, and said second satellite signal is the L1 signal.

14. Front-end architecture according to any of the preceding claims, characterized in that it can be integrated into a single chip, preferably in CMOS technology.

15. Receiver comprising a front-end architecture according to any of claims 1 to 14.

16. Method for receiving simultaneously a first and a second satellite signal of a satellite positioning system,

said method comprising the steps of:

- converting a radiofrequency signal into an intermediate-frequency signal through conversion means, said conversion means comprising a fixed-frequency local oscillator (31);
- extracting said first and said second satellite signals from said intermediate-frequency signal through extraction means (23,28),

said method being characterized in that said extraction means (23,28) are operated at a sampling rate which is a function of said local oscillator (31) and which allows undersampling of said intermediate-frequency signal.

5 17. Method according to claim 16, characterized in that said extraction means (23,28) are operated at a sampling rate which is a fraction of the frequency of the signal generated by said local oscillator (31).

18. Method according to claim 16, characterized in that said first satellite signal can be selected among a plurality of satellite signals, which can be tuned by varying at least one radiofrequency filter and one intermediate-frequency filter.

10 19. Method according to claim 16, characterized in that said sampling rate is chosen in such a manner as to fulfill Nyquist's theorem and cause no "aliasing" effect.

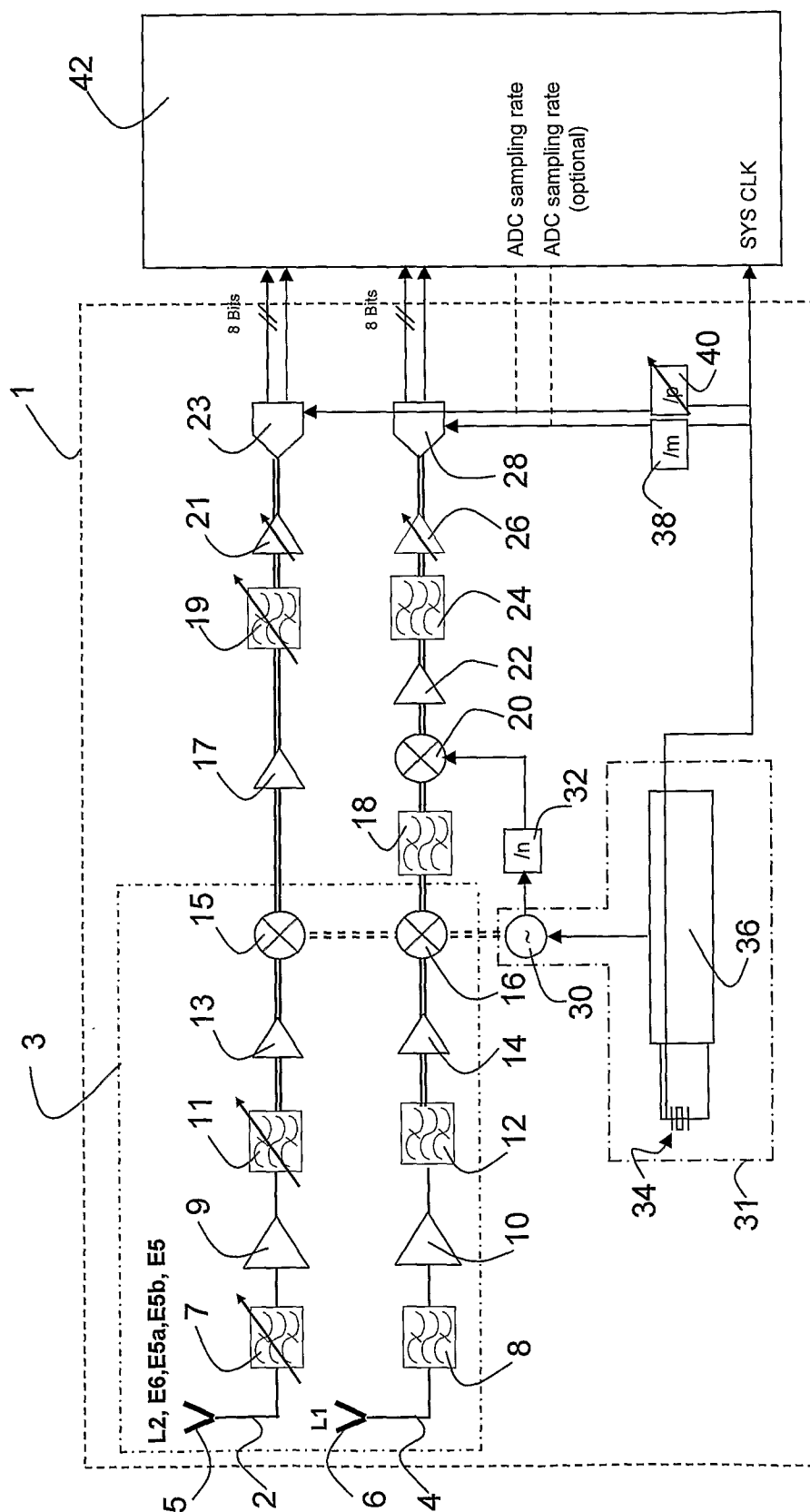


Fig. 1

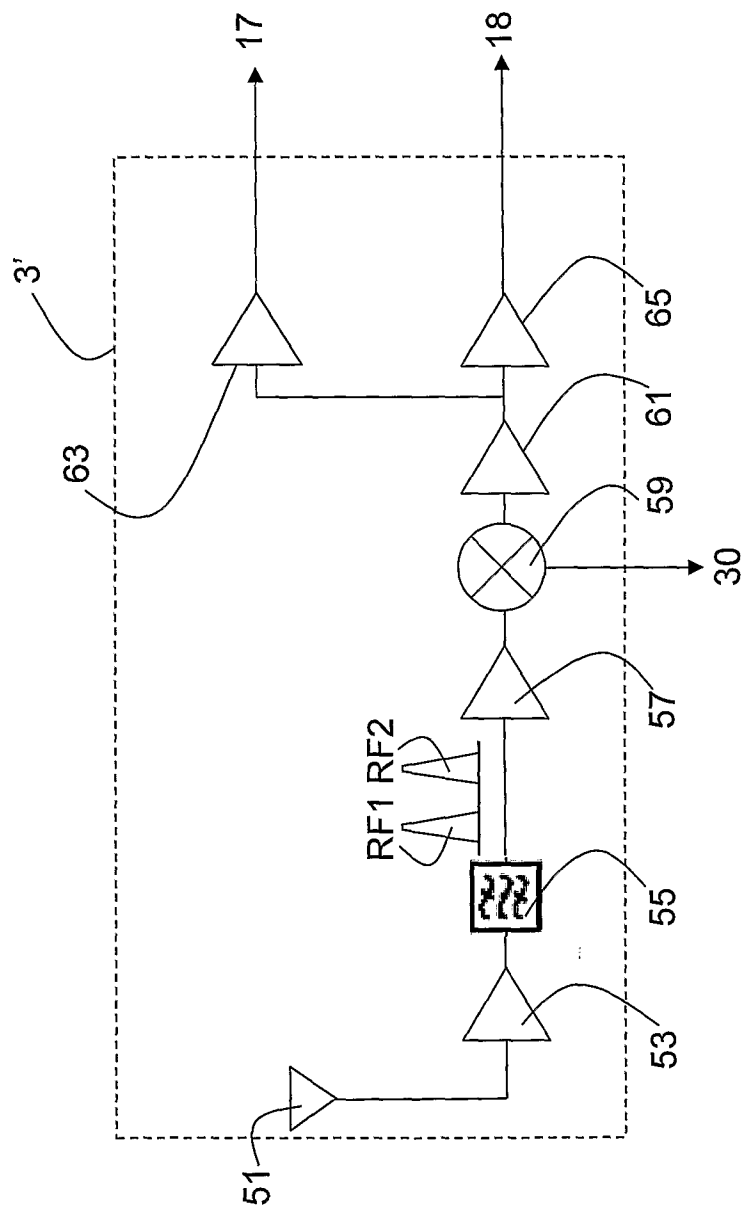


Fig. 2

Satellite	Band	Carrier (MHz)	TXCO (MHz)	MIX1 (MHz)	IF1 (MHz)	Sampling divider	MIX2 (MHz)	IF2 (MHz)	Subsampling rate (MHz)	BW (MHz)	Remarks
GPS	L2	1227,60	49,1028	1129,3644	98,24	-	-	-	23,0	10	direct conversion
Galileo	E6	1278,75	49,1028	1129,3644	149,39	-	-	-	69,0	30	direct conversion
Galileo	E5a	1176,45	49,1028	1129,3644	47,09	-	-	-	37,0	16	direct conversion
Galileo	E5b	1207,14	49,1028	1129,3644	77,78	-	-	-	67,0	20	direct conversion
Galileo	E5	1191,80	49,1028	1129,3644	62,43	-	-	-	124,9	50	direct conversion
Galileo/GPS L1/E1		1575,42	49,1028	1129,3644	446,06	3	376,455	69,60	16,3676	6	two-stage conversion

Fig. 3