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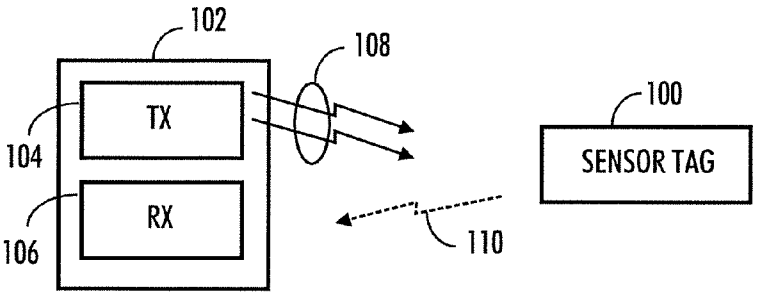


FIG. 1

(57) Abstract: An apparatus and a method are disclosed. The apparatus comprises a transmitter (104) for transmitting wirelessly an interrogation signal (108) to a passive sensor tag (100); a receiver (106) for receiving a response (110) from the passive sensor tag; a measuring circuit (106) for determining the amount of intermodulation signal in the interrogation signal, the intermodulation signal being created by the transmitter; a first control circuit (106) for determining a compensation signal on the basis of the amount of intermodulation signal, the compensation signal cancelling at least partly the intermodulation signal and a second control circuit (106) for adding the compensation signal to the interrogation signal transmitted by the transmitter.

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INTERROGATING WIRELESS SENSORS

Technical Field

The exemplary and non-limiting embodiments of the invention relate generally to interrogating wireless sensors. Embodiments of the invention relate especially to solutions where passive wireless sensors are interrogated using intermodulation communication methods.

Background

The following description of background art may include insights, discoveries, understandings or disclosures, or associations together with disclosures not known to the relevant art prior to the present invention but provided by the invention. Some of such contributions of the invention may be specifically pointed out below, whereas other such contributions of the invention will be apparent from their context.

Sensors are used to gather information from different kinds of sources. The number of types of sensors available is large and applications where sensors are used may be quite different. Many types of the sensors are based on some type of change in the electrical properties of the sensor where the change has some known relation to the physical phenomenon which is observed.

In the past, a wired connection to a sensor was required to read the sensor. However, the advancements in communication technology have made wireless sensors more and more attractive. Wireless sensors have a great deal of potential in numerous applications where wired read-out is difficult, for example, due to harsh conditions, rotating parts, or cost and complexity of wiring.

Sensors may be active or passive. Active sensors require a power source to be operative. Passive sensors operate without a power source. Passive sensors have many advantages over active sensors. Battery-free operation can increase reliability of operation and significantly decrease installation and maintenance costs. Maintaining of passive and wireless sensors in hard to service locations and scaling a sensor network is easier than with wired sensors.

One problem related to wireless sensors has been the relatively short operation range provided by current technologies such as RFID (Radio Frequency IDentification) based sensors and SAW (Surface Acoustic Wave) sensors. However, sensor architectures based on the intermodulation communication principle have been demonstrated recently. The intermodulation communication is a principle to wirelessly read out passive sensors over long distances - reaching

up to several tens of metres.

Brief description

According to an aspect, there is provided an apparatus comprising: a transmitter for transmitting wirelessly an interrogation signal to a passive sensor tag; a receiver for receiving a response from the passive sensor tag; a measuring circuit for determining the amount of intermodulation signal in the interrogation signal, the intermodulation signal being created by the transmitter; a first control circuit for determining a compensation signal on the basis of the amount of intermodulation signal, the compensation signal cancelling at least partly the intermodulation signal and a second control circuit for adding the compensation signal to the interrogation signal transmitted by the transmitter.

According to an aspect, there is provided a method comprising: creating an interrogation signal to be transmitted; determining the amount of intermodulation signal in the interrogation signal, the intermodulation signal being created by the transmitter; determining a compensation signal on the basis of the amount of intermodulation signal, the compensation signal cancelling at least partly the intermodulation signal; and adding the compensation signal to the interrogation signal transmitted by the transmitter.

Some embodiments of the invention are disclosed in the dependent claims.

Brief description of the drawings

In the following the invention will be described in greater detail by means of preferred embodiments with reference to the attached [accompanying] drawings, in which

Figure 1 illustrates a sensor system based on intermodulation communication principle;

Figure 2A illustrates an example of a passive sensor tag usable with intermodulation communication principle;

Figure 2B illustrates an embodiment of how to process received response;

Figure 3 is a flow chart illustrating an embodiment;

Figures 4A, 4B, 4C and 4D illustrate some embodiments of the invention;

Figure 5 illustrates an embodiment of how to create and process the interrogation signal;

Figures 6A, 6B and 6C illustrate another embodiments of how to create and process the interrogation signal; and

Figures 7A, 7B and 7C illustrate further examples of embodiments.

Detailed description of some embodiments

Figure 1 illustrates an example of employing intermodulation communication principle with passive sensors. Figure 1 shows a passive sensor tag 100 which is interrogated wirelessly by an interrogator or reader apparatus 102. The apparatus 102 comprises a transmitter 104 and a receiver 106.

Figure 2A illustrates an example of a passive sensor tag 100. The sensor tag may comprise an antenna 200, a matching circuit 202, a mixing element 204, a resonant circuit 206 having a resonance frequency f_R and a sensor 208.

In an example embodiment, the transmitter 104 of the reader apparatus 102 may be configured to transmit two continuous waves at two close frequencies f_1 and f_2 108. When these signals are received by the antenna 200 and matching circuit 202, a voltage across the mixing element 204 is generated at those frequencies. Due to the non-linear characteristics of the mixing element, the mixing element generates intermodulation products of the two input frequencies f_1 and f_2. The low frequency resonant circuit 206 of the sensor tag 100 is designed such that its resonance frequency corresponds to the difference frequency $f_R = f_1 - f_2$. The resonant circuit may be an RLC-circuit comprising a resistor (R), an inductor (L), and/or a capacitor (C), connected in series or in parallel and whose capacitance, inductance, or resistance changes according to the changes of physical or environmental parameters. Only the excitation current at the frequency f_R is amplified by the RLC-resonant circuit and this current is reflected back to the mixing element. It in turn mixes with the input frequencies f_1 (and f_2), resulting in the intermodulation frequency $f_{IM} = 2f_1-f_2$ (and $f_{IM} = 2f_2-f_1$). Any changes in the impedance of the RLC-resonant circuit originating from changes in the measured quantity will be directly reflected in the value of the difference frequency f_R, which will hence influence the value at the intermodulation frequencies. Thus, when the receiver 106 of the reader apparatus 102 measured the sensor tag's response 110 at one of the intermodulation frequencies, the reader apparatus can solve the measured parameter quantity, e.g. temperature or pressure, acceleration.

Figure 2B illustrates an example of a receiver 106 of the reader

apparatus 102. The receiver receives a response 110 from the sensor tag. The response may be of the form $2f_2$-f_1. The response is multiplied in multiplier 220 with center frequency f_C, amplified and filtered in amplifier 222 and finally multiplied in multiplier 224 with f_L, thus obtaining the resonance frequency f_R.

Let us study two examples of interrogating a sensor and receiving the signal from the sensor. In a first method, both waves f_1 and f_2 are simultaneously swept into opposite directions while f_C is kept constant. In this case f_L must be swept as well. This method may be denoted as dual side band (DSB) method. Referring to the receiver of Figure 2B, the constant $f_C = (f_1 + f_2)/2$.

In a second method, only one of the waves f_1 and f_2 is swept while the other is kept constant. Thus, f_C is also swept but f_L remains constant. This method may be denoted as single side band (SSB) method. Referring to the receiver of Figure 2B, in this case $f_C = 2f_1 - f_2 + f_L$ or $f_C = 2f_2 - f_1 - f_L$, depending which of the waves f_1 or f_2 is swept.

Utilising intermodulation communication with passive sensor has several advantages. The method enables relatively long distances between sensor tags and reader apparatus. Reading distances exceeding 7 meters have been demonstrated at Ultra High Frequency (UHF) band. The method is suitable to use with many different kinds of sensors. Interfaces to capacitive, resistive and inductive sensors are available. It is possible to interrogate multiple sensors each having own IDs. This is accomplished using Frequency Division Multiple Access (FDMA).

However the range and resolution of the measurements is limited by the sensitivity of the receiver at the intermodulation frequency. The sensitivity is not set by the thermal noise, but by the intermodulation signal created by the transmitter of the reader apparatus itself. This intermodulation signal can be 30-60 dB higher than the thermal noise. Hence reducing the intermodulation created by the reader could extend the range and resolution of the sensor system.

In an embodiment of the invention, the amount of the intermodulation signal created by the transmitter is measured. On the basis of the measurement, an additional signal is added to the signal to be transmitted to cancel out the unwanted intermodulation signal.

Figure 3 is a flow chart illustrating an embodiment.

In step 300, an interrogation signal to be transmitted wirelessly to a passive sensor tag is created. The signal may be a combination of two continuous waveforms at two frequencies f_1 and f_2, for example. The creation may comprise

combining these two waves together in the transmitter, for example.

In step 302, the intermodulation signal created by the transmitter is measured from the signal to be transmitted. The measurement may be performed prior the transmission. In step 304, a compensation signal is determined on the basis of the measured amount of intermodulation signal, the compensation signal cancelling at least partly the intermodulation signal.

In step 306, the compensation signal is added to the interrogation signal to be transmitted by the transmitter.

The method ends in step 308.

There are various ways to realise the above steps in the reader apparatus. Figures 4A, 4B, 4C and 4D illustrate some embodiments of the invention.

Figure 4A illustrates the reader apparatus comprising a transmitter 104 for transmitting wirelessly an interrogation signal to a passive sensor tag and a receiver 106 for receiving a response from the passive sensor tag.

The transmitter has as an input first wave of frequency f_1 and a second wave of frequency f_2. The waves are taken to power amplifiers 400, 402 and combined in a combiner 404 to create an interrogation signal which is taken to the antenna 406 via the circulator 408.

In an embodiment, the apparatus comprises a coupling circuitry 410 connecting the interrogation signal to be transmitted to a measuring circuitry 412. The measuring circuitry 412 is configured to determine the amount of intermodulation signal in the interrogation signal, the intermodulation signal being created by the transmitter.

The apparatus may further comprise a first control circuitry 414 for determining a compensation signal on the basis of the measured amount of intermodulation signal, the compensation signal cancelling at least partly the intermodulation signal. In an embodiment, the first control circuitry 414 has as an input a feedback signal $f_{feedback}$. In an embodiment, the feedback signal is a linear combination of waves f_1 and f_2, such as f_2-f_1 or $2f_2$ or $2f_2$-f_1, for example. The first control circuitry 414 may change the phase and amplitude (or amplitude in I and Q phases) of the feedback signal on the basis of the measured amount of intermodulation signal.

The apparatus may further comprise a second control circuitry 416 for adding the compensation signal to the interrogation signal transmitted by the transmitter. In an embodiment, the second control circuitry 416 is a combiner.

In the example of Figure 4A, the compensation signal is added to f_2. However, the compensation signal may as well be added to f_1 or both f_1 and f_2. The feedback can be either always on or only time-domain multiplexed with the measurement. In an embodiment, it is advantageous to add the compensation signal prior the power amplifiers, which are the most nonlinear elements of the transmitter. The same nonlinearity that creates the unwanted signal also processes the compensation signal.

As the apparatus comprises separate circuitries 106 and 412 for processing the received response and measuring the amount of intermodulation signal, the measurement and compensation may be active during the reading process.

In an embodiment in time-domain multiplexing, the same receiver 106 can be used for feedback and measurement. Figure 4B illustrates this example. In this example, the receiver 106 performs both measuring the amount of intermodulation signal in the signal to be transmitted and the processing of the received response. These operations are separated in time.

The measurement of the amount of intermodulation signal at receiver is done prior the circulator 408 in the absence of the sensor tag, e.g. at a frequency separation f_2-f_1, where the tag has no resonance (e.g. one sensor resonance bandwidth or about 1 kHz lower or higher in frequency). The attenuation and phase shift found at this frequency can be used thorough the frequency sweep, because the sweep is only about 10 ppm in carrier frequency (<10 kHz at 1 GHz).

Figure 4C illustrates another embodiment, where there are separate circuitries 106 and 412 for processing the received response and measuring the amount of intermodulation signal. However, the measurement and processing the received response are separated in time as the measurement is made from the signal received from the sensor tag. In this case the sensor tag 100 must not be present during measurement.

Figure 4D illustrates yet another embodiment. The receiver 106 performs both measuring the amount of intermodulation signal in the signal to be transmitted and the processing of the received response.

The measurement and processing the received response are separated in time as the measurement is made from the signal received from the sensor tag. In this case the sensor tag must not be present during measurement.

Figure 5 illustrates an embodiment of how to create and process the

interrogation signal in the apparatus 102. A high frequency carrier f_0 is generated 500. A lower frequency signal f_d is also generated 502. The lower frequency f_d corresponds to the initial resonance frequency f_R of the resonant circuit 206 of the sensor tag 100. The carrier frequency f_0 is mixed 504 with the frequency f_d so that the output of the mixer 504 results into $f_0 + f_d$ and $f_0 - f_d$. The signal comprising these two frequencies is amplified 506 and transmitted via circulator 408 and antenna 410 wirelessly to the sensor tag. The sensor tag 100 (not shown in Figure 5) extracts the difference frequency f_d, which wakes up the resonant circuit 206, which in turns produces the intermodulation frequencies $f_0 + 3\ f_d$ and $f_0 - 3\ f_d$ after mixing in the sensor tag with the input frequencies.

The receiver of the apparatus 102 detects these frequencies in the response of the sensor tag 100 and operates a demodulation scheme by first doing a down-conversion of the received signal 508 mixed with the input f_0 510. After appropriate filtering 512, 514 and amplification 516, 518 the down-converted signal is mixed 520, 522 with the sweeping signal of frequency $f_L = (3 \times f_d)$ (for third intermodulation, $5 \times f_d$ for fifth intermodulation...) from the output of the multiplier 524 so that the signal of interest containing the sensor information is extracted. The signal may be amplified 526, 528 and digitised 530. The low frequency f_d may be swept over time to reconstruct the sensor response.

The measurement of the amount of intermodulation signal in the signal to be transmitted, determination of the compensation signal and adding the compensation signal to the signal to be transmitted may be performed as described earlier in connection with Figures 4A to 4D.

Figure 6A illustrates another embodiment of how to create and process the interrogation signal in the apparatus 102. In the example embodiment of Figure 6A is based on using two waves f_1 and f_2 so that the difference frequency $f_1 - f_2$ matches with the resonance circuit of the sensor tag f_R. In this example, waves of both frequencies f_1 and f_2 are swept over time. The signals may be generated in generators 600, 602 from an amplified signal from a common signal 604 source.

On the receiving side, the demodulator 511 first performs a down-conversion of the received signal 508 mixed with the constant center frequency $f_C = (f_1 + f_2)/2$ generated in generator 606. After appropriate filtering 512, 514 and amplification 516, 518 the down-converted signal is mixed 520, 522 with the sweeping signal of frequency $f_L = (3/2) \times f_R$ (for third intermodulation, 5/2 for fifth intermodulation...) so that the signal of interest containing the sensor

information is extracted. The signal may be amplified 526, 528 and digitised 530.

The embodiments of both Figure 5 and 6A realize the DSB method, which results in a robust reading method, dedicated to applications where long reading distances and mitigated measurements accuracy are needed.

Figure 7C illustrates also the example of sweeping both frequencies. Waves 718, 720 are swept into opposite directions, so $f_C = (f_1 + f_2)/2$ remains constant, but f_L does not. f_L moves three times as much and three times as fast as f_1, so that it follows the changes of $(2f_1 - f_2)$ 722 and $(2f_2 - f_1)$ 716.

Again, the measurement of the amount of intermodulation signal in the signal to be transmitted, determination of the compensation signal and adding the compensation signal to the signal to be transmitted may be performed as described earlier in connection with Figures 4A to 4D.

Figures 6B and 7A illustrate yet another embodiment of how to create and process the interrogation signal in the apparatus 102.

In the embodiments of Figures 6B and 7A the high input frequency f_2 generated in generator 620 is swept in the transmitter and the high frequency used for down-conversion f_C generated in generator 622 is swept in the receiver. Thus, this example illustrates the SSB method. In this solution, the frequency f_C is shifted out of the frequency band $[f_1, f_2]$ and is set to $(2f_1 - f_2) + f_L$. f_L remains constant in this method.

Figure 7A illustrates example where f_2 is swept, but f_1 is kept constant. As f_2 is swept 700 over time, frequency $2f_1 - f_2$ moves 702 as much as f_2 but in the opposite direction. Frequency f_C sweep 704 is as wide and as fast as f_2 sweep but in the opposite direction as to follow the move of frequency $2f_1 - f_2$ 702 and to keep f_L constant.

Figures 6C and 7B illustrate yet another embodiment of how to create and process the interrogation signal in the apparatus 102.

In the embodiments of Figures 6C and 7B the high input frequency f_1 generated in generator 600 is swept in the transmitter and the high frequency used for down-conversion f_C generated in generator 622 is swept in the receiver. Thus, also this example illustrates the SSB method. In this solution, the frequency f_C is shifted out of the frequency band $[f_1, f_2]$ and is set to $(2f_2 - f_1) - f_L$. f_L remains constant in this method.

In Figure 7B f_1 is swept 710 but f_2 is kept constant. Consequently, frequency $2f_2 - f_1$ moves 712 as much as f_1 but in the opposite direction. Frequency f_C sweep 714 is as wide and as fast as f_1 sweep but in the opposite

direction as to follow the move of frequency $2f_2 - f_1$ 712 and to keep the f_L constant.

Referring to Figure 2B, the first downconverted signal provided by the mixing 220 output between the received signals and f_C is then mixed 224 with the constant signal f_L to obtain the signal of interest. This way, in the SSB method, the frequency step in the sweeps is only limited by the output resolution of the high frequency synthesizers and does not anymore depend on the product combination between the high and low frequencies. At the same time, this solution may allow to freely select the low frequency value f_L (within a certain range) without any changes in hardware components. Any needed changes can be realized with software procedures that can be re-programmed.

The solutions of Figures 7A and 7B provide a generic way of reading the response of passive wireless sensors, in which the values of frequencies f_C and f_L used in downconversions can be chosen independently of the sensor's resonance frequency f_R. In this way, the system has potential for higher accuracy measurements. With very precise sweeps, a quasi-analogue operation (multivalued sensor output) can be obtained. However, receiving only one side band of the sensor tag's response naturally leads to a maximal reading distance that is shorter than the one achievable with solution of FIG. 7C.

Again, the measurement of the amount of intermodulation signal in the signal to be transmitted, determination of the compensation signal and adding the compensation signal to the signal to be transmitted may be performed as described earlier in connection with Figures 4A to 4D.

The proposed solutions for creating and processing the interrogation signal provide high accuracy measurements as the accuracy is directly related to the accuracy in frequency steps of the high frequency synthesizers. The described embodiments provide a novel and low-cost solution to implement industrial intelligence for machine control and reliability, and life-cycle cost reduction but also for medical and consumer application.

As used in this application, the term 'circuit' or 'circuitry' refers to all of the following: (a) hardware-only circuit implementations, such as implementations in only analog and/or digital circuitry, and (b) combinations of circuits and software (and/or firmware), such as (as applicable): (i) a combination of processor(s) or (ii) portions of processor(s)/software including digital signal processor(s), software, and memory(ies) that work together to cause an apparatus to perform various functions, and (c) circuits, such as a

microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present.

This definition of 'circuitry' applies to all uses of this term in this application. As a further example, as used in this application, the term 'circuitry' would also cover an implementation of merely a processor (or multiple processors) or a portion of a processor and its (or their) accompanying software and/or firmware.

The reader apparatus may also be implemented as one or more integrated circuits, such as application-specific integrated circuits ASIC. Other hardware embodiments are also feasible, such as a circuit built of separate logic components. A hybrid of these different implementations is also feasible. When selecting the method of implementation, a person skilled in the art will consider the requirements set for the size and power consumption of the apparatus, the necessary processing capacity, production costs, and production volumes, for example.

It will be obvious to a person skilled in the art that, as the technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

Claims

1. An apparatus comprising:
a transmitter (104) for transmitting wirelessly an interrogation signal (108) to a passive sensor tag (100);
a receiver (106) for receiving a response (110) from the passive sensor tag;
a measuring circuit (106, 412) for determining the amount of intermodulation signal in the interrogation signal, the intermodulation signal being created by the transmitter;
a first control circuit (414) for determining a compensation signal on the basis of the amount of intermodulation signal, the compensation signal cancelling at least partly the intermodulation signal and
a second control circuit (416) for adding the compensation signal to the interrogation signal transmitted by the transmitter.

2. The apparatus of claim 1, wherein the passive sensor tag comprises a resonance circuit (206) having a given resonance frequency, the measuring circuit being configured to measure the amount of intermodulation signal on the given resonance frequency.

3. The apparatus of claim 1, further comprising a coupling circuitry (410) connecting the interrogation signal to be transmitted to the measuring circuit.

4. The apparatus of claim 1, further comprising a coupling circuitry (408) connecting the received response to the measuring circuit.

5. The apparatus of claim 1, wherein the interrogation signal is composed of two continuous waves at two frequencies f_1 and f_2, and the compensation signal is a linear combination of the two frequencies.

6. The apparatus of claim 5, wherein the second control circuit is configured to add the compensation signal either to the continuous wave at frequency f_1, the continuous wave at frequency f_2 or both.

7. The apparatus of claim 1, wherein the measurement circuit is a part of the receiver (106).

8. The apparatus of claim 1, where in the first control circuit is configured to determine amplitude and phase for the compensation signal on the basis of the amount of intermodulation signal.

9. The apparatus of claim 2, wherein the interrogation signal comprises a carrier signal f_0 with which a signal of the given resonance frequency is mixed.

10. The apparatus of claim 9, further comprising a demodulator configured to multiply the response with the carrier signal f0, obtaining down-converted response and one or more multipliers for multiplying the down-converted response with a multiple of the resonance frequency, thus obtaining desired response signal.

11. The apparatus of claim 2, wherein the apparatus is configured to
utilise as the interrogation signal a combination of two continuous waves at two frequencies f_1 and f_2, where f_1-f_2 equals the given resonance frequency; and
sweep the continuous waves over time during transmission of the interrogation signal.

12. The apparatus of claim 2, wherein the apparatus is configured to
utilise as the interrogation signal a combination of two continuous waves at two frequencies f_1 and f_2,
sweep either one of the continuous waves over time during transmission of the interrogation signal; and
during reception of the response multiply the response with a continuous wave which is swept as fast and as much as one of the continuous waves but into the opposite direction.

13. A method comprising:
creating (300) an interrogation signal to be transmitted;
determining (302) the amount of intermodulation signal in the interrogation signal, the intermodulation signal being created by the transmitter;

determining (304) a compensation signal on the basis of the amount of intermodulation signal, the compensation signal cancelling at least partly the intermodulation signal; and

adding (306) the compensation signal to the interrogation signal transmitted by the transmitter.

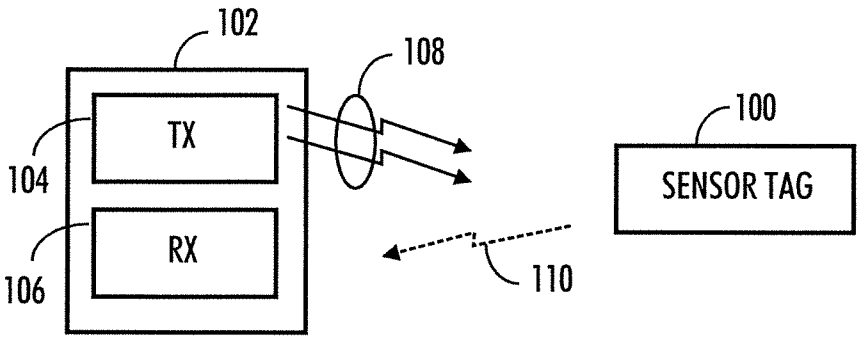


FIG. 1

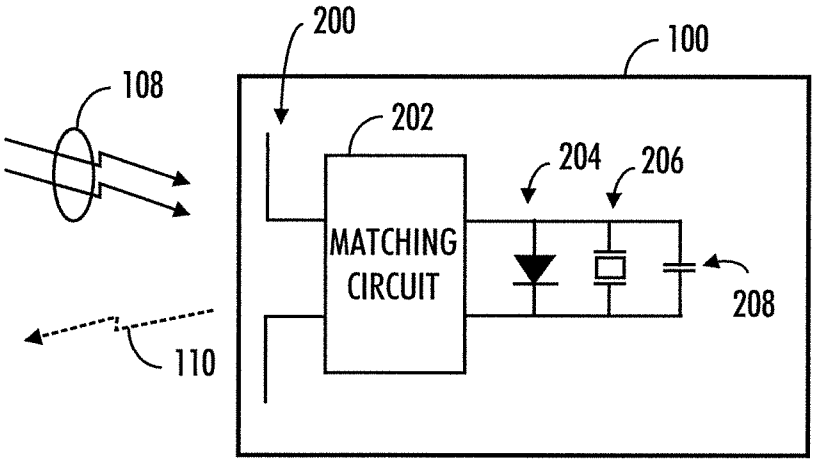


FIG. 2A

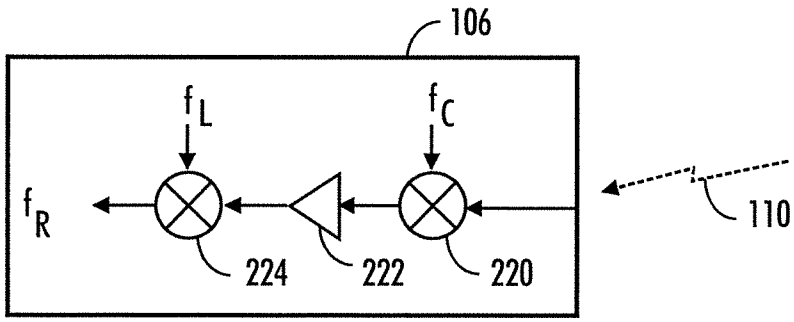


FIG. 2B

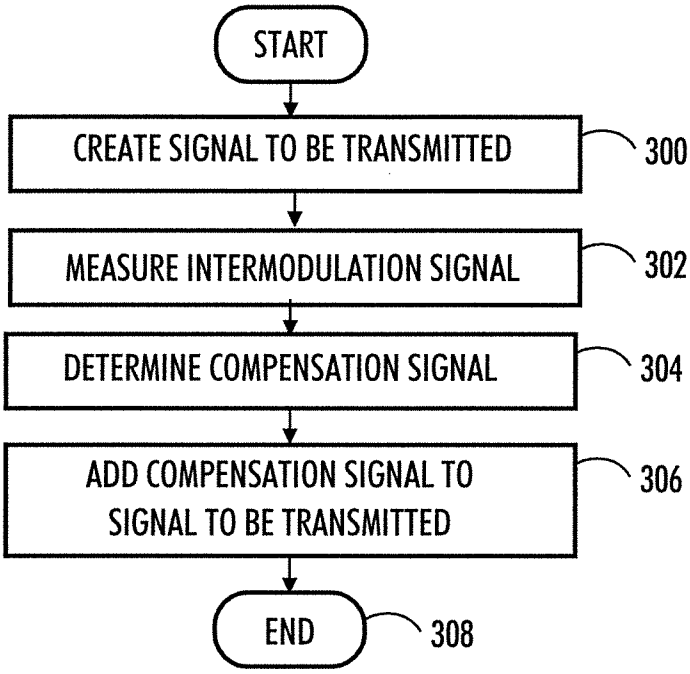

START
CREATE SIGNAL TO BE TRANSMITTED
300
MEASURE INTERMODULATION SIGNAL
302
DETERMINE COMPENSATION SIGNAL
304
ADD COMPENSATION SIGNAL TO SIGNAL TO BE TRANSMITTED
306
END
308

FIG. 3

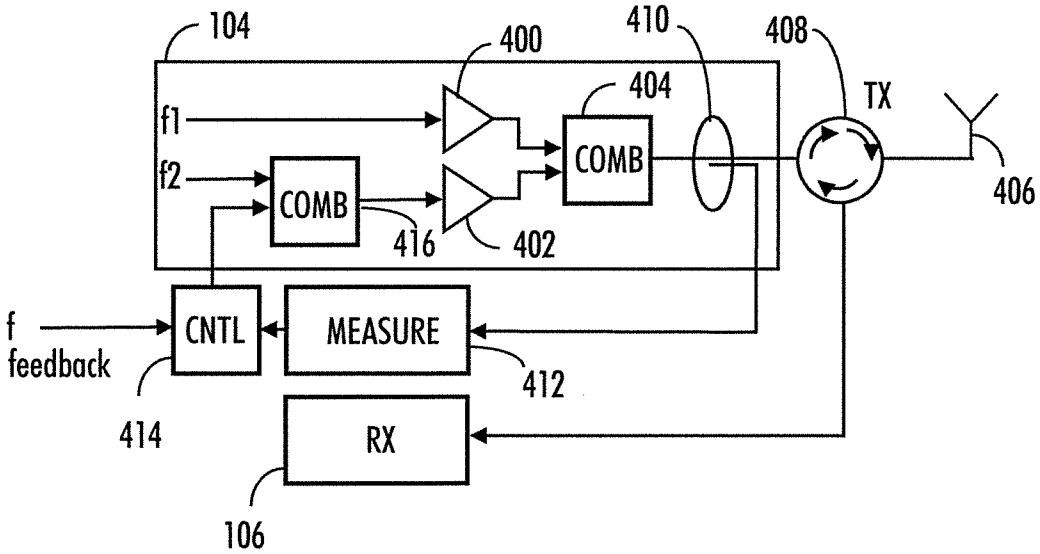

104
400
410
408
404
TX
f1
f2
COMB
COMB
416
402
406
f
feedback
CNTL
MEASURE
412
414
RX
106

FIG. 4A

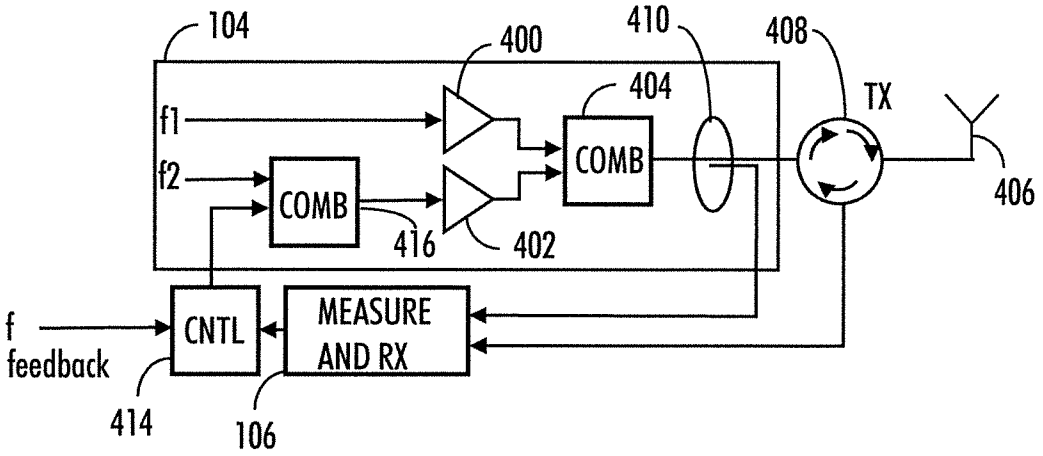


FIG. 4B

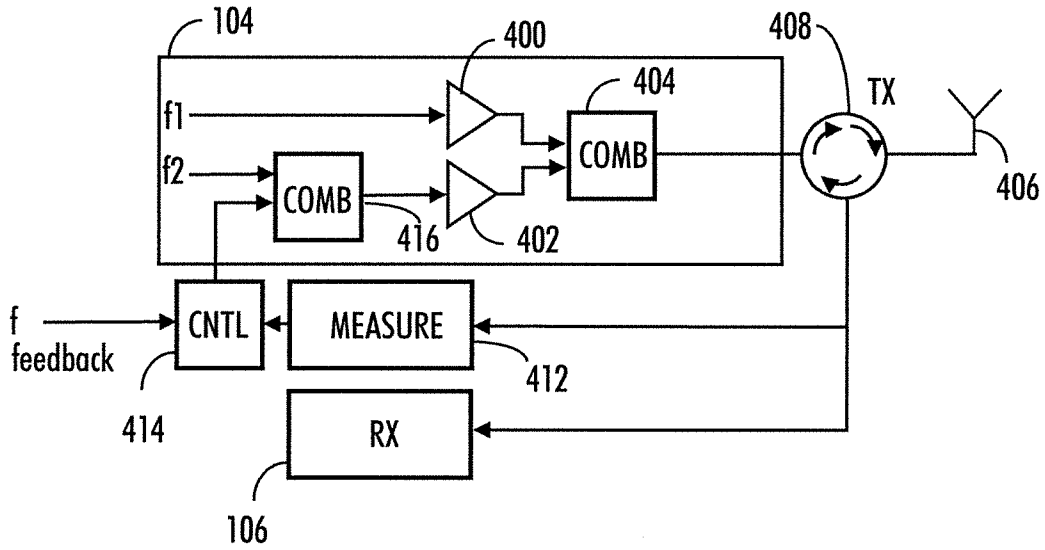


FIG. 4C

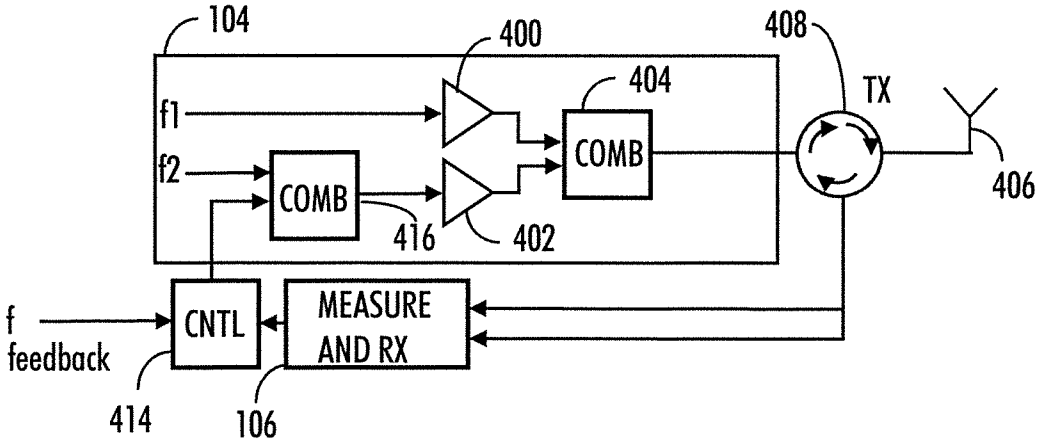


FIG. 4D

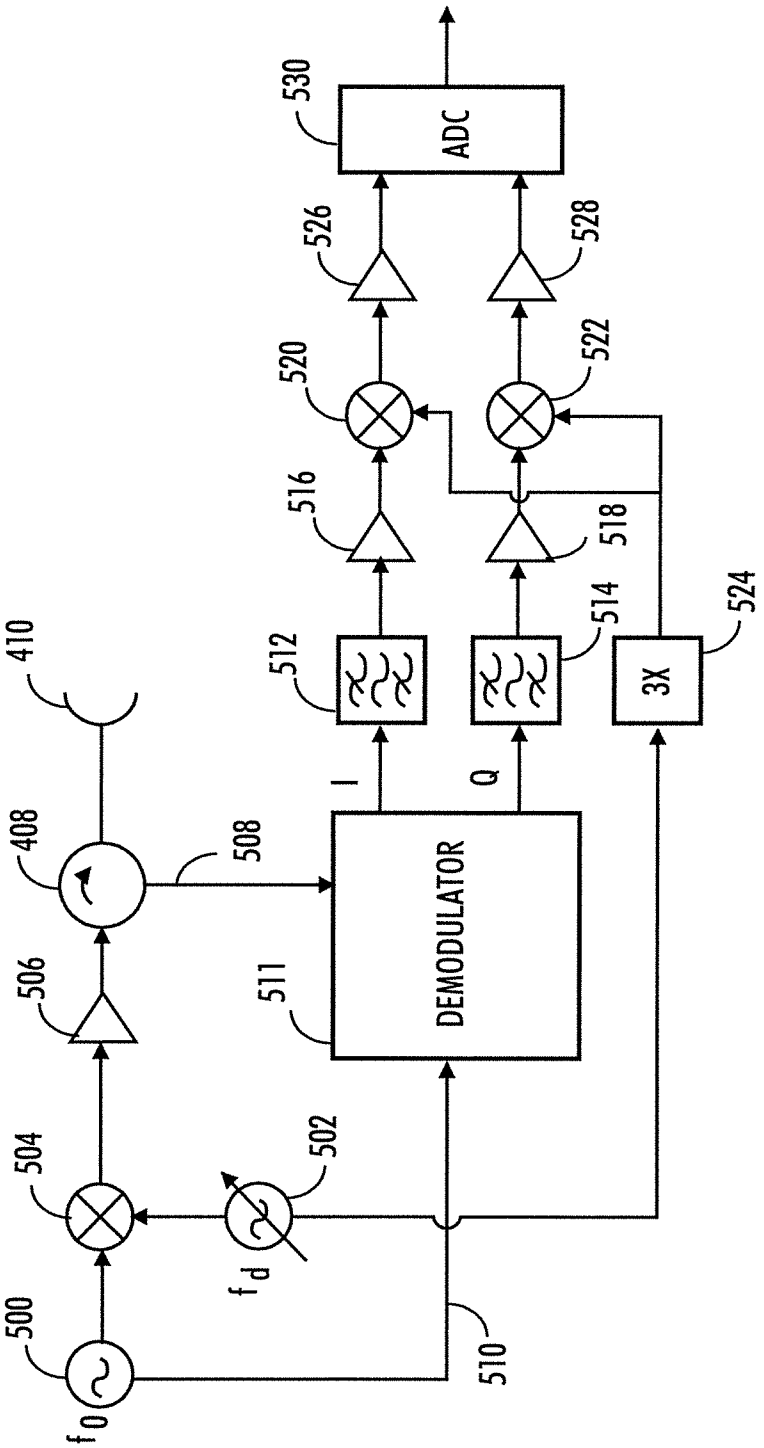

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FIG. 5

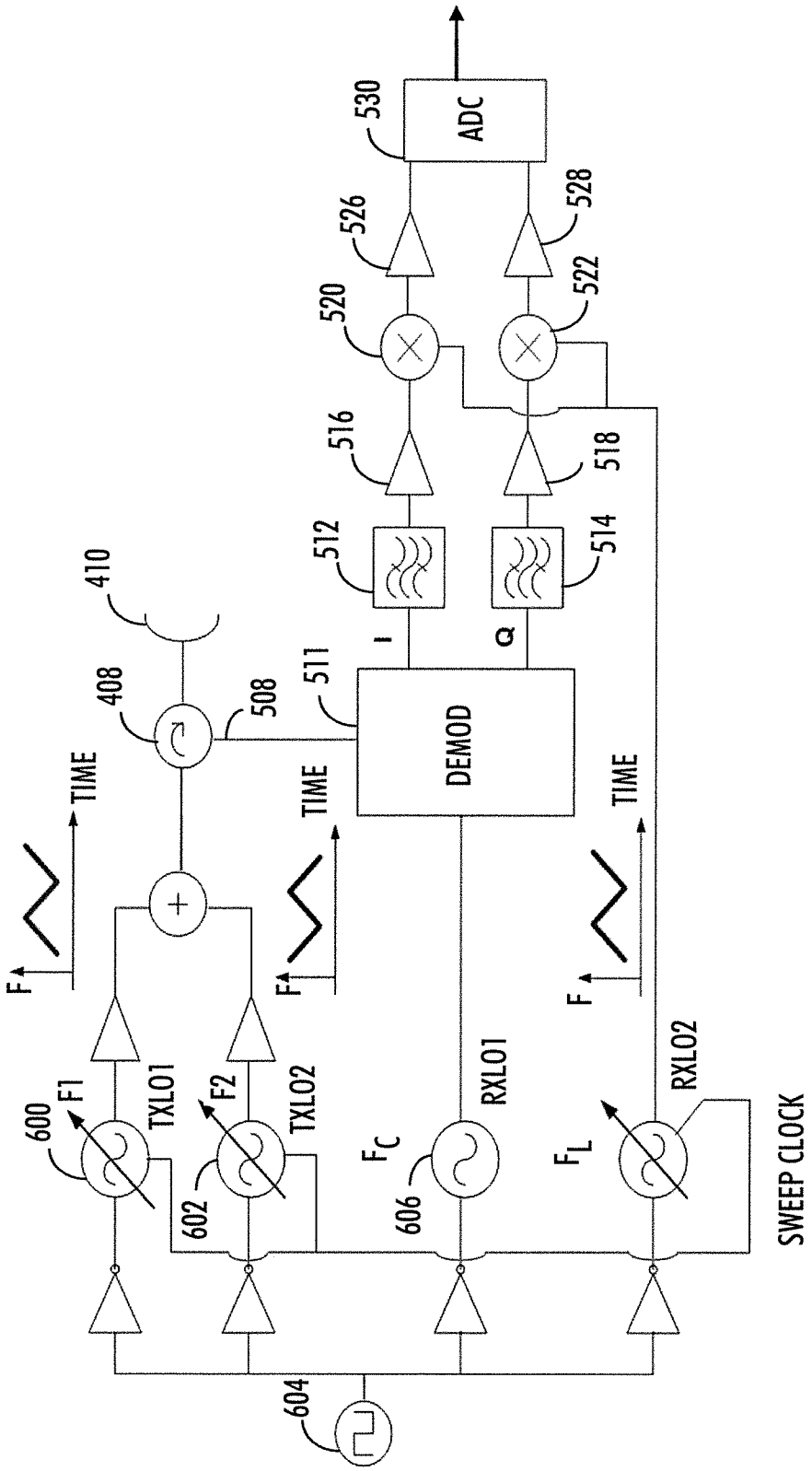

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RXLO1
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FIG. 6A

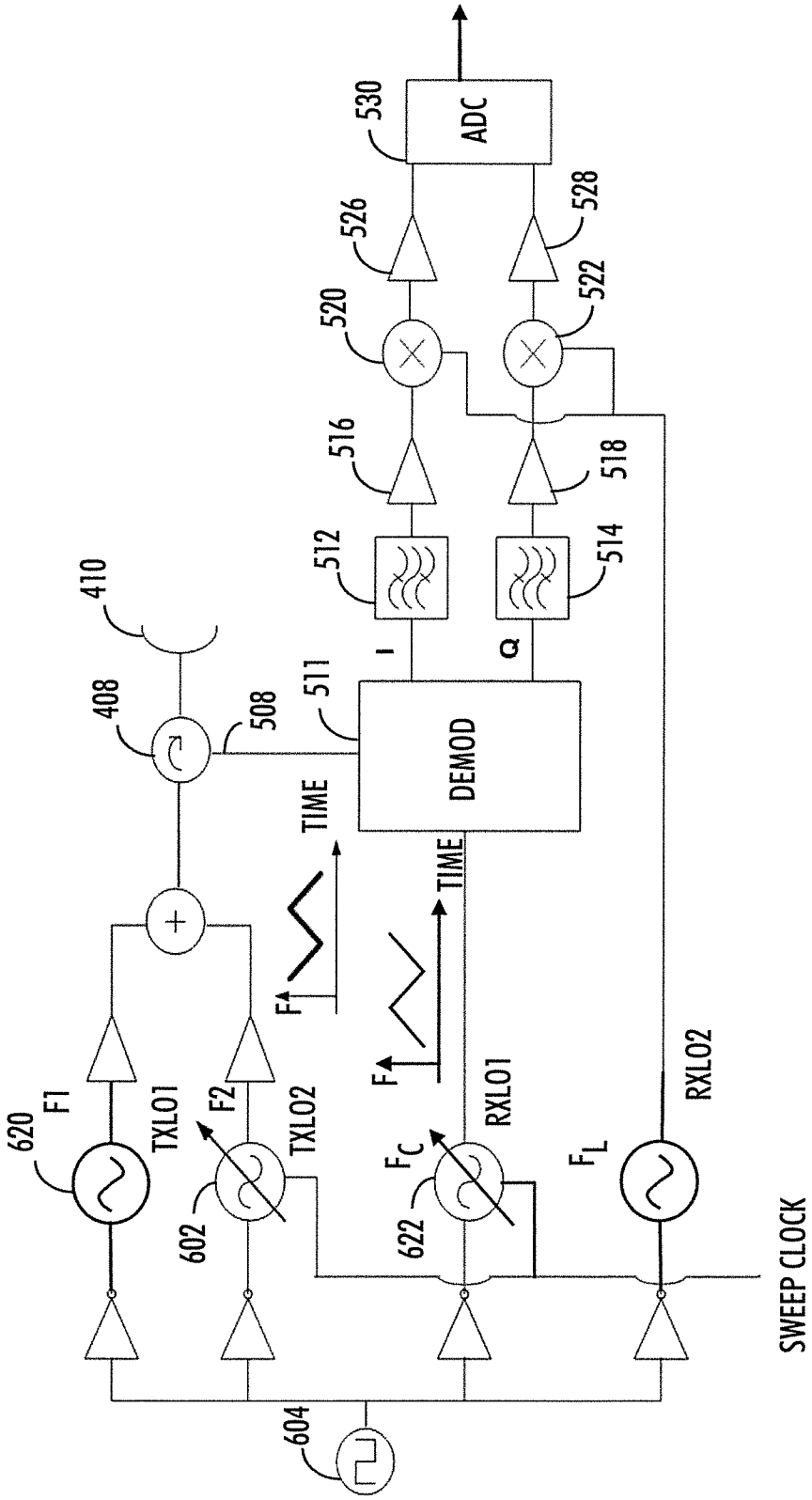

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FIG. 6B

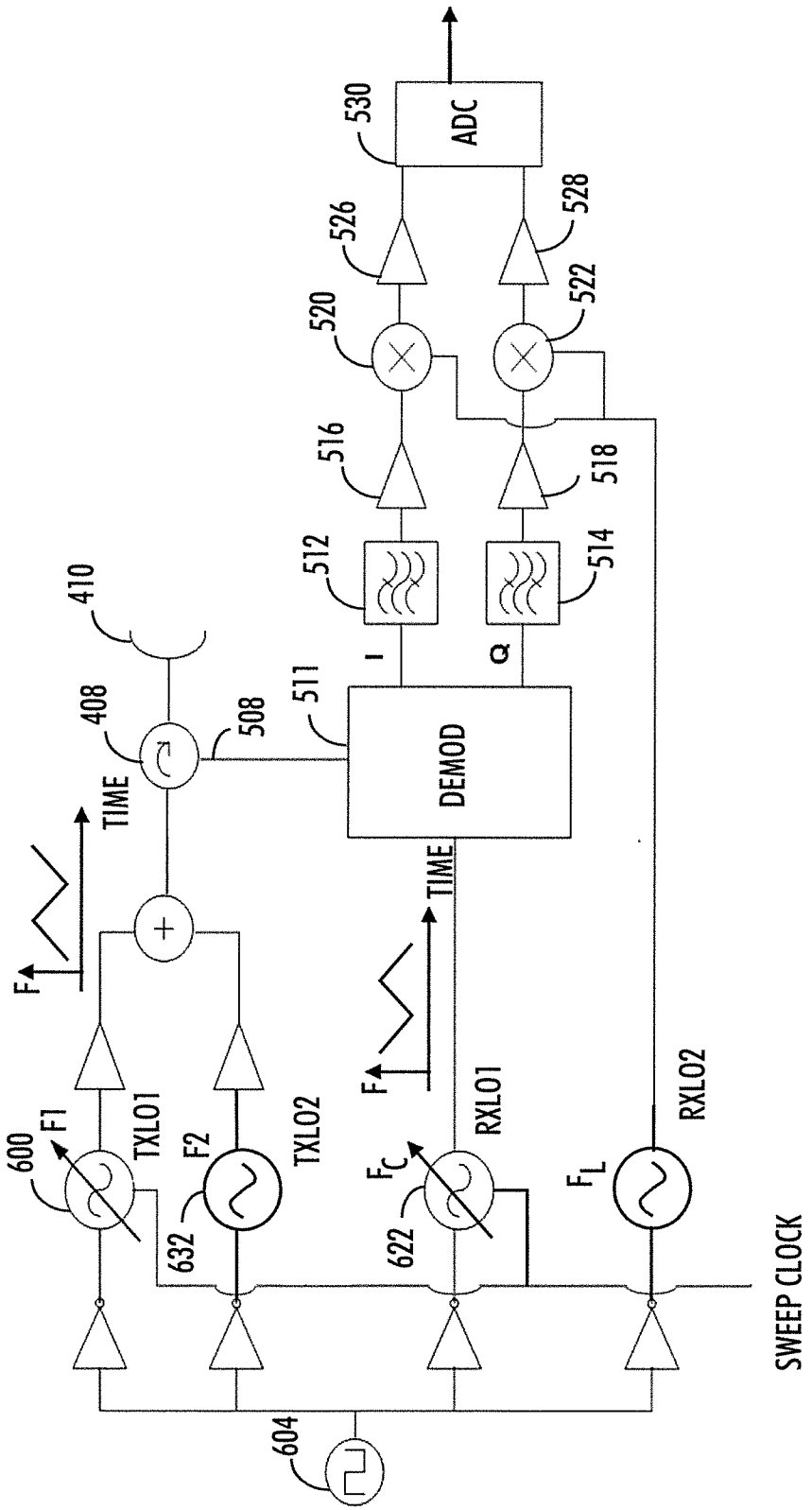

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FIG. 6C

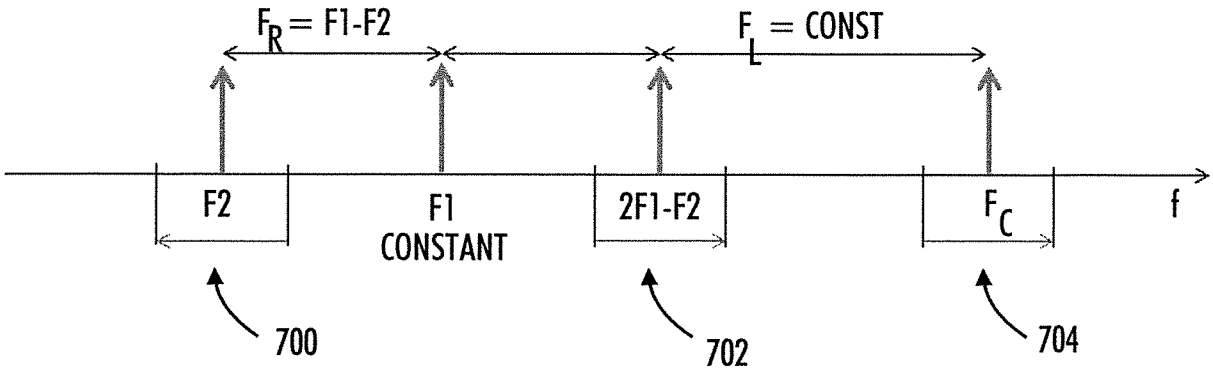


FIG. 7A

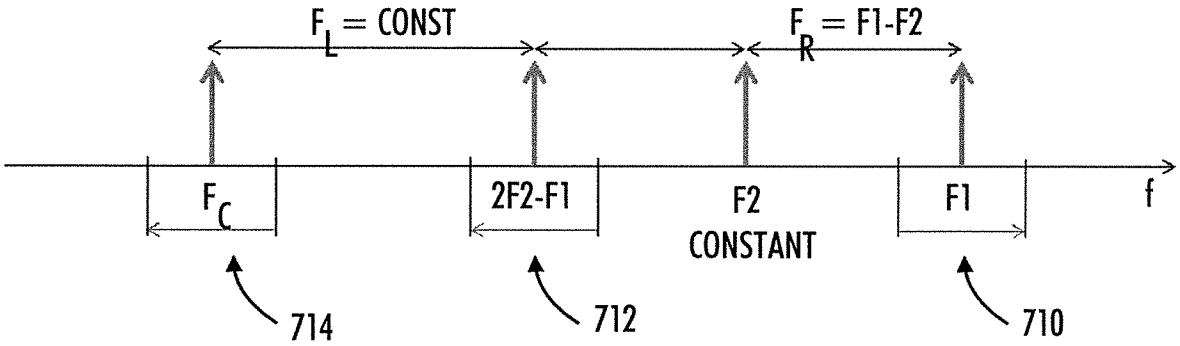


FIG. 7B

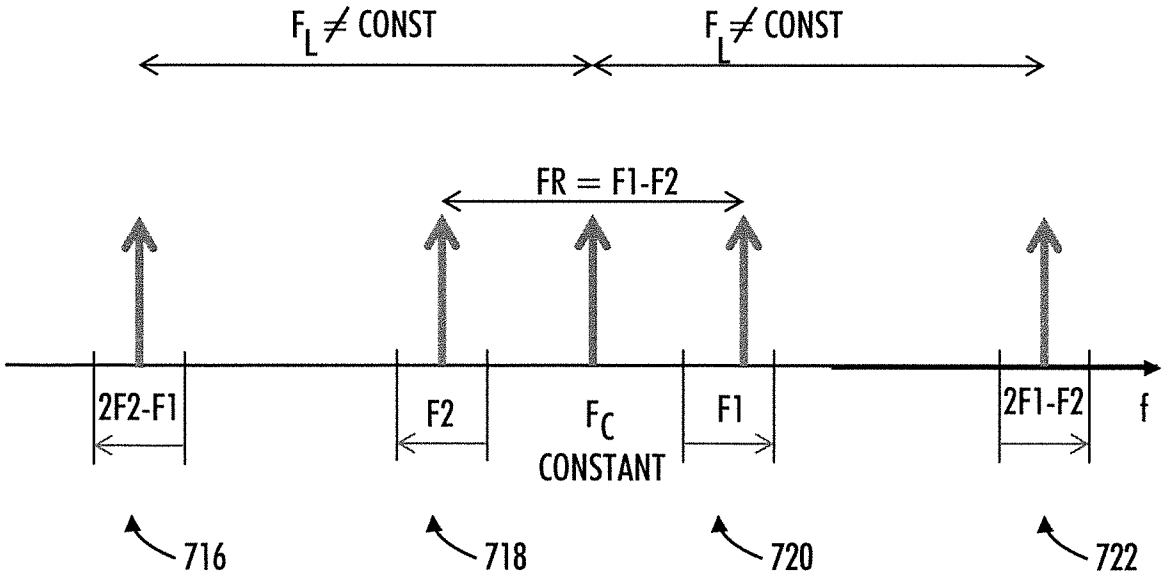


FIG. 7C

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2016/050930

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B5/00 G06K7/10
ADD.

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)
H04B G06K

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 practicable, 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.
A	PURSULA PEKKA ET AL: "Intermodulation communication principle: Passive wireless sensor networks for internet-of-things", 2015 INTERNATIONAL CONFERENCE ON ELECTROMAGNETICS IN ADVANCED APPLICATIONS (ICEAA), IEEE, 7 September 2015 (2015-09-07), pages 1012-1015, XP032793165, DOI: 10.1109/ICEAA.2015.7297267 [retrieved on 2015-10-12] the whole document ----- -/--	1-13

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
17 May 2017	30/05/2017

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, Fax: (+31-70) 340-3016	Degrendel, Antoine

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2016/050930

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SONG JINSONG ET AL: "On the use of the intermodulation communication towards zero power sensor nodes", 2013 EUROPEAN MICROWAVE CONFERENCE, EUROPEAN MICROWAVE ASSOCIATION, 6 October 2013 (2013-10-06), pages 124-127, XP032535557, [retrieved on 2013-12-17] the whole document -----	1-13

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