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(54) **RADIO FREQUENCY SIGNAL TRANSMISSION METHOD AND DEVICE**

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See application file for complete search history.

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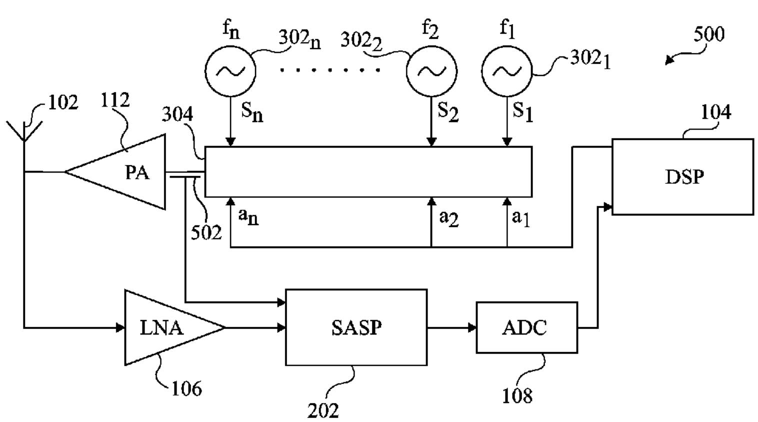
(57) **ABSTRACT**

A method for generating a radio frequency signal, wherein a signal to be transmitted is decomposed into a weighted sum of periodic basic signals of different frequencies.

14 Claims, 3 Drawing Sheets



(51) **Int. Cl.**
H04B 1/403 (2015.01)
H04L 27/26 (2006.01)
H04B 1/04 (2006.01)

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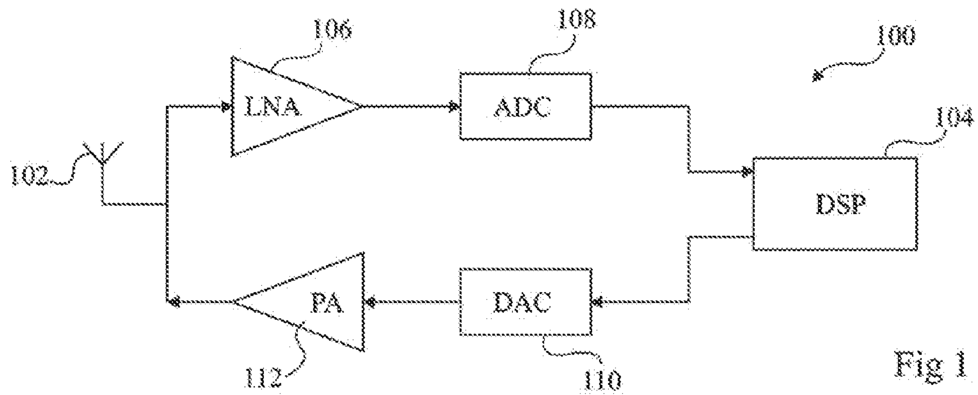

Fig 1
(PRIOR ART)

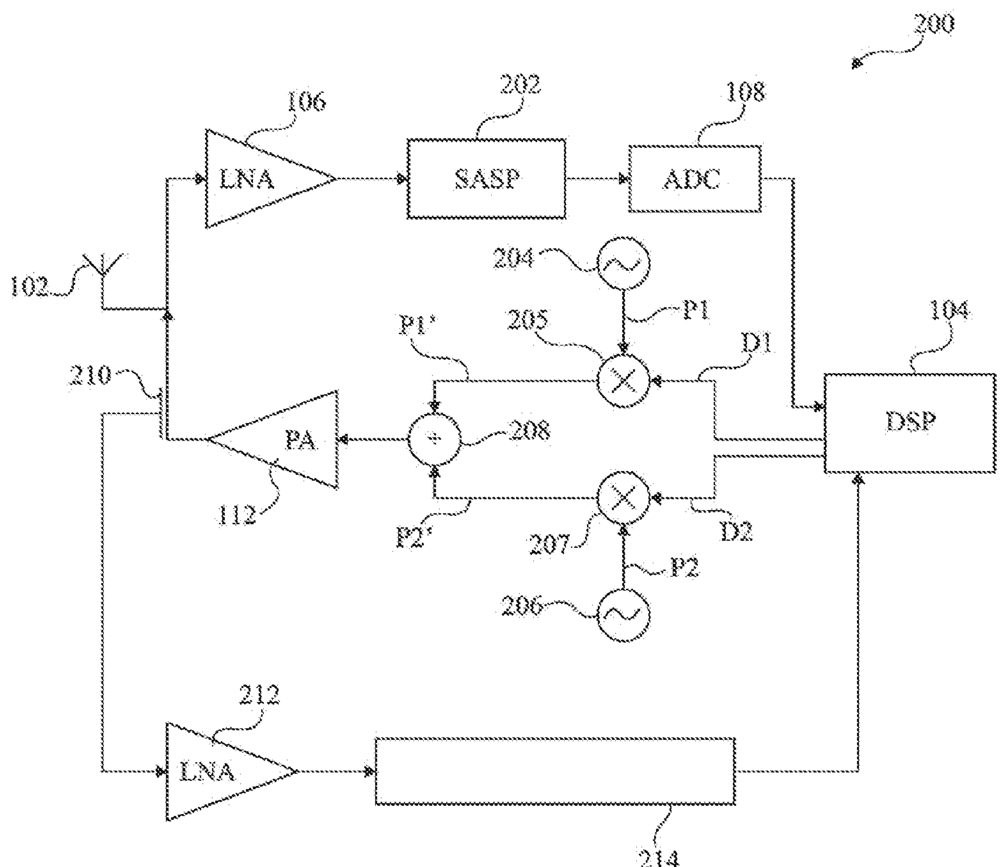

Fig 2
(PRIOR ART)

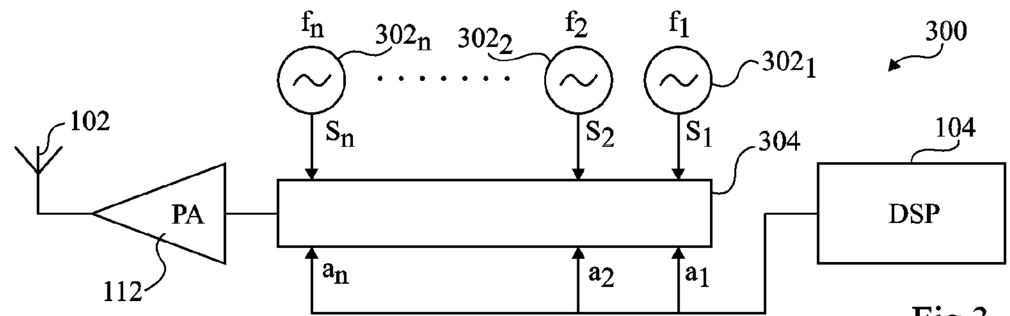

Fig 3

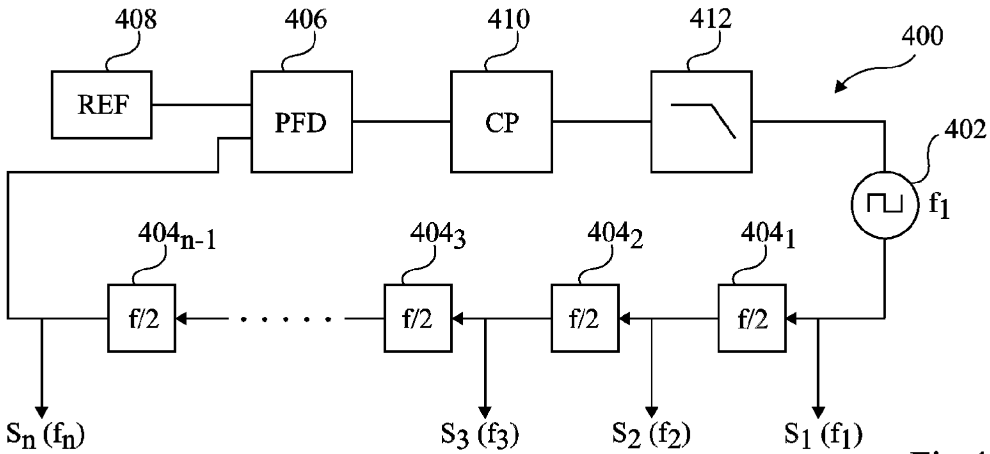

Fig 4

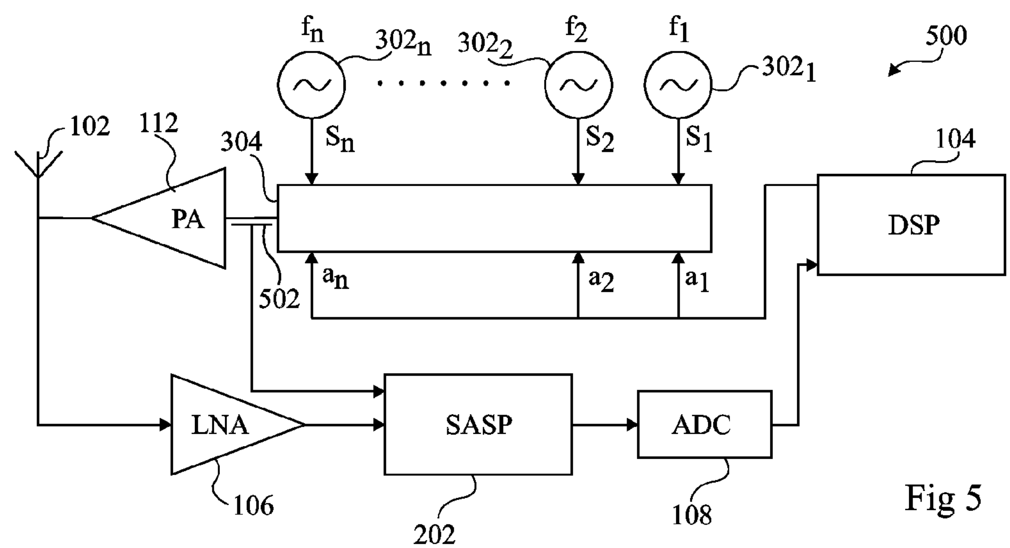

Fig 5

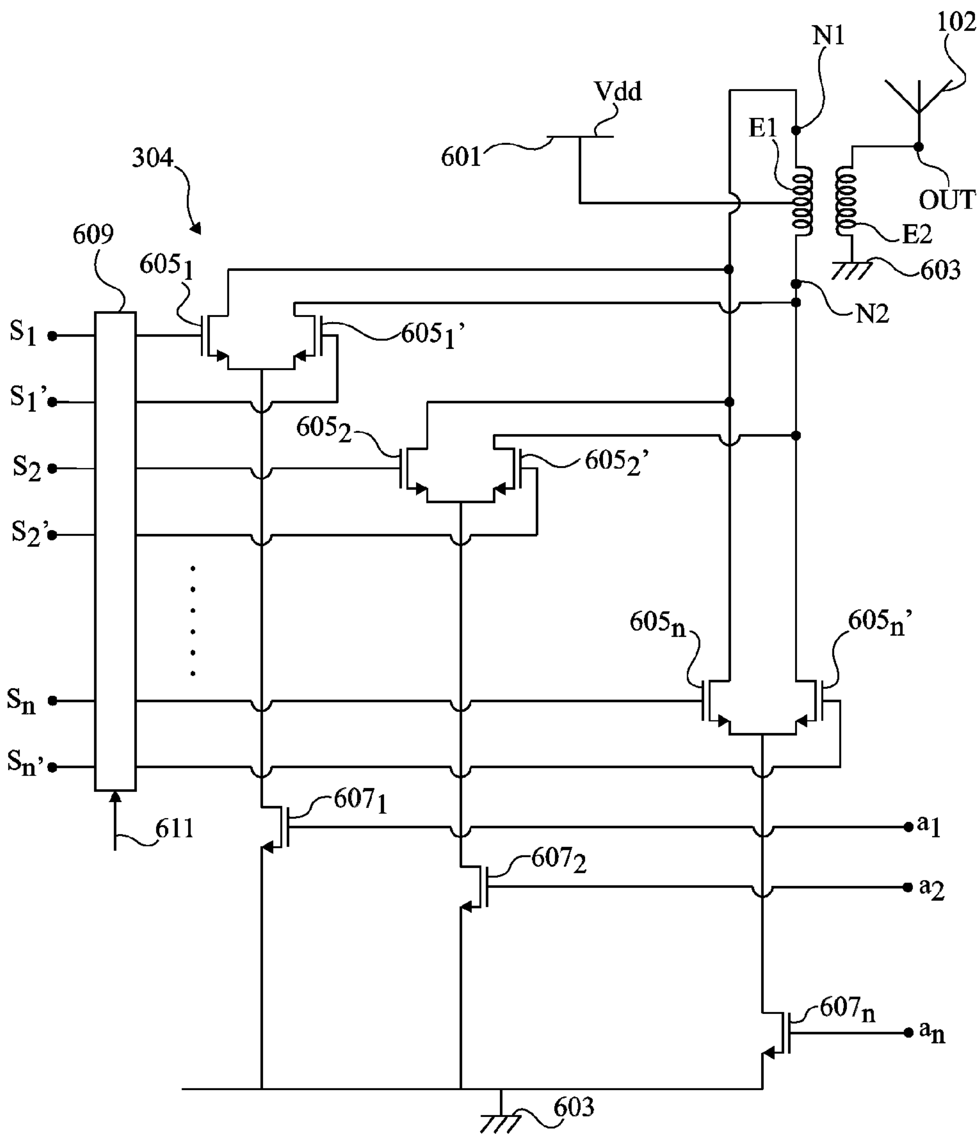
102
N1
Vdd
E1
601
OUT
304
E2
603
609
605_1
N2
S_1
605_1'
S_1'
605_2
S_2
605_2'
S_2'
605_n
605_n'
S_n
S_n'
607_1
611
a_1
607_2
a_2
607_n
a_n
603

Fig 6

RADIO FREQUENCY SIGNAL TRANSMISSION METHOD AND DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to French Patent Application No. 13/51307, filed Feb. 15, 2013, which is hereby incorporated by reference to the maximum extent allowable by law.

BACKGROUND

1. Technical Field

The present disclosure relates to the field of wireless communications, and more specifically aims at methods and devices for transmitting radio frequency signals.

2. Discussion of the Related Art

FIG. **1** is a simplified block diagram of a radio frequency signal transceiver device **100** where the processing of the radio frequency signals is of essentially digital nature.

Device **100** comprises an antenna **102** and a digital signal processor **104** (DSP) for example comprising a microprocessor. In the receive direction, the analog signal received by antenna **102** crosses a low-noise amplifier **106** (LNA), and is then directly converted into a digital signal by an analog-to-digital converter **108** (ADC) having its output connected to an input of digital processor **104**. The basic signal processing operations, and especially carrier demodulation operations, are digitally carried out by device **104**. In the transmit direction, device **104** directly generates a digital signal having the shape of a carrier wave modulated by the data to be transmitted, ready to be transmitted over the network. This signal is simply converted into an analog signal by a digital-to-analog converter **110** (DAC) placed at the output of device **104**, and then amplified by a power amplifier **112** (PA), before being transmitted by antenna **102**.

This type of device is sometimes called "radio software" since the processing implemented by the receiver and by the transmitter are essentially software in nature.

An advantage of such a device is that it is sufficient to reprogram the software part to make the device compatible with new communication standards (new carrier frequencies, new modulations, etc.).

However, in practice, the use of transceiver devices of purely software nature often may not be considered since this may require extremely fast converters and a digital processor capable of providing considerable computing power. Indeed, present communication standards use carrier frequencies on the order of a few GHz. To be able to process such signals in real time, the bandwidth of the converters and of the calculation device should be at least equal to 10 GHz. Further, to have satisfactory signal quality, a sampling over at least 16 bits should generally be provided. Converters and calculation devices capable of fulfilling such constraints have a considerable power consumption, conventionally ranging from 500 to 1,000 watts. Such a power consumption is incompatible with most network devices, and in particular with portable terminals.

FIG. **2** is a simplified block diagram of a radio frequency signal transceiver device **200**, illustrating a solution which has been provided to decrease the constraints on converters and on the signal digital processor.

On the receive chain side, device **200** comprises the same elements as device **100** of FIG. **1**, and further comprises a device **202** (SASP—Sampled Analog Signal Processor) for pre-processing the analog signal, arranged between the output of low-noise amplifier **106** and the input of analog-to-digital converter **108**. Device **202** is configured to perform an analog pre-processing of the signal, enabling to lower the operating frequency to be able to return to conditions compatible with low power consumption conversion and digital processing devices. Functionally, device **202** selects a frequency envelope (or several envelopes in the case of a multistandard terminal) of the signal received by antenna **102**, and lowers the frequency of the signal contained in this envelope. To achieve this, device **202** comprises a sampling circuit capable of delivering analog samples of the input signal, and a processing circuit capable of performing a discrete Fourier transform processing on the signal samples and of delivering first intermediate analog samples. Device **202** further comprises a processing circuit capable of modifying the spectral distribution of the first intermediate samples and of delivering second intermediate analog samples, and a processing circuit capable of performing an inverse discrete Fourier transform on the second intermediate samples and of delivering analog samples of an output signal having a lower frequency than the input signal. Detailed examples of embodiment of device **202** are described in patent application WO 2008/152322 and in article "65 nm CMOS Circuit Design of a Sampled Analog Signal Processor dedicated to RF Applications" by François Rivet et al.

The receive chain of device **200** has the advantage of providing a particularly advantageous rapidity and consumed power saving, especially in mobile telephony applications, while allowing a multistandard use and being easily reconfigurable in case of a modification of a communication standard or in case of the occurrence of a new standard.

On the transmit chain side, device **200** comprises conventional means for modulating a carrier signal with digital data. In the shown example, device **200** can alternately or simultaneously transmit data on two carrier waves P**1** and P**2** having different frequencies. Carrier signals P**1** and P**2** are respectively generated by a wave generator **204** and by a wave generator **206**. Each wave generator for example comprises a voltage-controlled oscillator controlled by a quartz. A first modulator **205**, for example comprising a multiplier, receives on the one hand signal P**1** provided by generator **204**, and on the other hand a bit train D**1** of data to be transmitted provided by digital processor **104**. Modulator **205** generates a signal P**1'** corresponding to carrier P**1** modulated by data D**1** to be transmitted. A second modulator **207**, for example comprising a multiplier, receives on the one hand signal P**2** provided by generator **206**, and on the other hand a bit train D**2** of data to be transmitted provided by digital processor **104**. Modulator **207** generates a signal P**2'** corresponding to carrier P**2** modulated by data D**2** to be transmitted. Signals P**1'** and P**2'** are added by an adder **208**, and the resulting signal is amplified by power amplifier **112**, and then emitted by antenna **102**.

The transmit chain of device **200** is fast and saves consumed power but has the disadvantage of not being easily reconfigurable in case of a modification of communication standards or in the case where new standards appear.

In the example of FIG. **2**, the transmit chain of device **200** further comprises a counter-feedback loop enabling to verify that the signal transmitted by antenna **102** comprises no error. The counter-feedback loop comprises a coupler **210** which samples part of the output signal of power amplifier **112** (signal transmitted by antenna **102**). The signal sampled by coupler **210** crosses a low-noise amplifier **212** (LNA) and a demodulation and digitization circuit **214**. The digitized signal provided by circuit **214** is sent to digital processor **104**, which verifies whether the signal actually coincides with that which was desired to be transmitted.

The provision of the counter-feedback loop, which actually corresponds to a simplified receive chain arranged in parallel with the main receive chain, has the disadvantage of increasing the bulk, the cost, and the power consumption of the device.

Another disadvantage is that circuit **214** generally comprises, for each communication standard capable of being used in transmit mode, a specific analog hardware demodulator. Circuit **214** is thus not easily reconfigurable in the case of a modification of communication standards.

SUMMARY

Thus, an embodiment provides methods and devices for transmitting radio frequency signals at least partly overcoming some of the disadvantages of known methods and devices for transmitting radio frequency signals.

A first embodiment provides a device for generating a radio frequency signal capable of operating according to one or several communication standards, and easily reconfigurable in the case where a standard should be modified or where a new standard should appear.

Another embodiment provides a device for transmitting a radio frequency signal, comprising means for verifying the integrity of the transmitted signal.

A second embodiment provides a device capable of summing up analog periodic input signals by assigning a weighting coefficient to each of them.

Thus, an embodiment provides a method for generating a radio frequency signal, wherein a signal to be transmitted is decomposed into a weighted sum of periodic basic signals of different frequencies.

According to an embodiment, the highest carrier frequency comprised in said signal to be transmitted is lower than the frequency of at least one of the periodic basic signals of the decomposition.

According to an embodiment, the highest carrier frequency comprised in said signal to be transmitted is lower by at least a factor ten than the frequency of at least one of the periodic basic signals of the decomposition.

According to an embodiment, the coefficients of the decomposition are calculated by means of a digital processor.

According to an embodiment, the above-mentioned method comprises the analog generation of the basic signals, and further comprises a step of summing of said analog basic signals weighted by the coefficients calculated by the digital processor.

Another embodiment provides a device for generating a radio frequency signal, comprising a digital processing circuit configured to decompose a signal to be transmitted into a weighted sum of periodic basic signals of different frequencies.

According to an embodiment, the highest carrier frequency comprised in said signal to be transmitted is lower than the frequency of at least one of the periodic basic signals of the decomposition.

According to an embodiment, the above-mentioned device comprises means for generating in analog fashion the periodic basic signals, and means for summing up the analog signals by applying to each of them a weighting coefficient calculated by the digital processor.

According to an embodiment, the means for generating the periodic basic signals comprise a single voltage-controlled oscillator assembled in a phase-locked loop and, in series with the oscillator, a plurality of frequency dividers.

According to an embodiment, the basic signals are sinusoidal signals and the decomposition is a Fourier series decomposition.

According to an embodiment, the basic signals are square signals.

Another embodiment provides a radio frequency transceiver device, comprising a transmit device of the above-mentioned type; and a receive device comprising at least an analog pre-processing device comprising sampling means capable of delivering analog samples of an input radio frequency signal, and processing means capable of performing a discrete Fourier transform on the analog samples.

According to an embodiment, the transceiver device is configured to, during transmission phases, sample a signal representative of the transmitted signal, determine the discrete transform of this signal by means of the analog pre-processing device, digitize the discrete Fourier transform signal, and send the digitized signal to the digital processing means.

According to an embodiment, the digital processing means are configured to verify whether the received digital Fourier transform signal coincides with the decomposition in periodic basic signals calculated before the transmission.

The foregoing and other features and advantages will be discussed in detail in the following non-limiting description of specific embodiments in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**, previously described, is a simplified block diagram illustrating the operation of a radio frequency signal transceiver device;

FIG. **2**, previously described, is a simplified block diagram illustrating the operation of another radio frequency signal transceiver device;

FIG. **3** is a simplified block diagram illustrating the operation of an embodiment of a radio frequency signal transmit device;

FIG. **4** is a block diagram illustrating the operation of an embodiment of a generator of analog periodic signals;

FIG. **5** is a simplified block diagram illustrating an embodiment of a radio frequency signal transceiver device; and

FIG. **6** is a schematic diagram of an embodiment of a device capable of summing up periodic analog input signals by assigning a weighting coefficient to each of them.

For clarity, the same elements have been designated with the same reference numerals in the different drawings.

DETAILED DESCRIPTION

FIG. **3** is a simplified block diagram illustrating the operation of an embodiment of a device **300** for transmitting radio frequency signals, capable of being easily reconfigured in the case where a communication standard should be modified or where one or several new standards should appear.

Like devices **100** of FIGS. **1** and **200** of FIG. **2**, device **300** comprises an antenna **102**, and a device **104** for digitally processing the signal for example comprising a microprocessor. Device **300** further comprises means for generating a range of a plurality of analog periodic basic signals of different frequencies. In the shown example, device **300** comprises n periodic signal generators (n being an integer greater than 1) bearing references $\mathbf{302}_1$ to $\mathbf{302}_n$. Each generator $\mathbf{302}_i$ (with i ranging from 1 to n) provides a periodic signal S_i of frequency f_i, for example, a sinusoidal signal or a square signal. Each generator $\mathbf{302}_i$ for example comprises a voltage-controlled oscillator, controlled by a reference source which may comprise a quartz, by means of a phase-locked loop. Device **300** further comprises a circuit **304** capable of performing a weighted sum of the n periodic signals S_i in the range, by assigning a weighting coefficient a_i to each of them. In the shown example, device **304** comprises n inputs connected to generators $\mathbf{302}_1$ to $\mathbf{302}_n$ and intended to respectively receive the n signals S_1 to S_n in the range, and further comprises n inputs connected to the output of digital processing device **104** and intended to respectively receive the n weighting coefficients a_1 to a_n to be assigned to signals S_1 to S_n. Digital-to-analog converters, not shown, may be provided between the output of device **104** and inputs a_1 to a_n of device **304**. The output of circuit **304** is connected to antenna **102**, for example, via a power amplifier **112**.

When the range of basic signals contains a sufficient number of basic frequencies f_i, any signal capable of being transmitted by device **300** may be approximated by a weighted sum of signals S_1 to S_n.

According to a first aspect, digital processor **104** is configured, for example, by means of an adapted software, to calculate coefficients a_1 to a_n so that the weighted sum of basic signals S_i of the range corresponds to the radio frequency signal which is desired to be transmitted or, in other words, to decompose the signal to be transmitted into a weighted sum of basic signals S_i of the range.

In the specific case where signals S_1 to S_n are sinusoidal signals, the decomposition is a Fourier series decomposition. Weighting coefficients a_i may be determined by calculation by digital processing unit **104**, by means of mathematical formulas, by taking into account the data to be transmitted, the frequency of the carrier wave(s) to be transmitted, and the type of modulation used.

In the case where signals S_1 to S_n have a shape other than sinusoidal, for example, a square shape, weighting coefficients a_1 to a_n may be calculated by digital processing unit **104** either directly, by means of mathematical decomposition formulas, or, if such formulas cannot be easily determined, by means of an iterative method of minimization of the error function between the signal to be transmitted and the decomposition into the series of basic signals. As an example, it may be provided, in an initial step, to use as weighting coefficients the coefficients of the Fourier series decomposition of the signal to be transmitted, and then to iteratively adjust the coefficients to minimize the error between the weighted sum of the basic signals and the signal which is effectively desired to be transmitted.

In practice, the decomposition of the signal to be transmitted may be calculated in successive time windows, for example, windows having a duration ranging between a few microseconds and a few hundreds of microseconds, for example, between 10 and 200 microseconds. To accelerate the processing, it may be provided to implement the decomposition calculation on a sliding window, that is, between two successive steps of calculation of the weighting coefficients, the processing slot is offset by a number of samples smaller than its total width.

Number n of basic signals S_i of the range preferably ranges between 5 and 20, and each signal S_i has a frequency f_i equal to half frequency f_{i-1} of signal S_{i-1} of previous rank. Frequency f_1 of signal S_1, provided by generator $\mathbf{302}_1$ having the lowest rank, is preferably selected to be at least ten times greater than the highest carrier frequency on which the device should be able to transmit. Frequency f_1 is for example on the order of 60 GHz for mobile telephony applications. The described embodiments are not however limited to the described examples, and it will be within the abilities of those

skilled in the art to provide other adapted choices for the basic signal range. Anyway, at least part of basic signals S_i of the range have a frequency f_i greater than the highest carrier frequency at which the device is capable of transmitting.

An advantage of the transmit device described in relation with FIG. **3** is that, in case of a modification of one or several transmission standards (carrier frequency, modulation type, etc.), the device can easily be reconfigured, for example, by simple software reprogramming, to be made compatible with the new standard(s).

Another advantage is that the determination of the n weighting coefficients a_i corresponding to the radio frequency signal to be transmitted only requires a lower calculation power, and in particular does not require generating a full digital version of the radio frequency signal to be transmitted.

Another advantage is that the selection of the hardware components provided between digital processor **104** and power amplifier **112** (and the selection of generators $\mathbf{302}_i$ in the example of FIG. **3**) is independent from the number of communication standards with which device **300** should be able to transmit. Thus, a transmission chain provided to transmit in a large number of standards will not be more bulky, expensive, or power consuming than a transmit chain provided to transmit in a single standard.

FIG. **4** illustrates a preferred embodiment where a single generator **400** is used to provide all the basic signals S_1 to S_n of the range. FIG. **4** is a block diagram illustrating an embodiment of such a generator.

Generator **400** comprises a voltage-controlled oscillator **402**, providing a periodic analog signal S_1 of frequency f_1, for example, a square signal at 60 GHz. Generator **400** further comprises n−1 frequency dividers, bearing references $\mathbf{404}_1$ to $\mathbf{404}_{n-1}$ in the drawing. Dividers $\mathbf{404}_1$ to $\mathbf{404}_n$ are series—connected, first divider $\mathbf{404}_1$ of the series receiving signal S_1 as an input. Each divider $\mathbf{404}_i$ delivers a signal S_{i+1}, for example, square, having a frequency f_{i+1} equal to half frequency f_i of signal S_i that it receives. Oscillator **402** is for example controlled by a signal provided by a reference source which may comprise a quartz. In the shown example, oscillator **402** and dividers $\mathbf{404}_1$ to $\mathbf{404}_{n-1}$ are assembled in a phase-locked loop comprising a phase comparator **406** (PFD—Phase Frequency Detector) receiving, on the one hand, signal S_n provided by last divider $\mathbf{404}_{n-1}$ of the series and, on the other hand, a reference signal provided by a reference source **408** (REF) comprising a quartz. In this example, the output of phase comparator **406** is connected to the input of a charge pump **410** (CP), and the signal provided by charge pump **410** passes through a loop filter **412** having its output connected to the voltage control input of oscillator **402**. In operation, basic analog signals S_1 to S_n are respectively available at the output of oscillator **402** and at the output of frequency dividers $\mathbf{404}_1$ to $\mathbf{404}_{n-1}$.

An advantage of the embodiment of FIG. **4** is that all the basic signals S_i in the range are generated by using a single voltage-controlled oscillator, and a single phase-locked loop, which decreases the bulk, the cost, and the power consumption of the transmit device.

It will be within the abilities of those skilled in the art to adapt the generator described in relation with FIG. **4** to obtain other ranges of basic signals S_i, for example, by varying the division ratios of frequency dividers $\mathbf{404}_i$.

FIG. **5** is a simplified block diagram illustrating an embodiment of a radio frequency transmit/receive device **500**, this device comprising control circuits for verifying the integrity of the signals that it transmits over the network.

Device **500** comprises a transmit chain of the type described in relation with FIGS. **3** and **4**, that is, where the transmitted signal is generated by weighted summing of a plurality of analog periodic basic signals S_i, the weighting coefficients being determined by means of a digital processor. In the shown example, the transmit chain of device **500** comprises the same elements as transmit chain **300** of FIG. **3**. Device **500** further comprises a receive chain of the type described in relation with FIG. **2**, that is, comprising a pre-processor for processing analog samples of the signal, capable of selecting one or several frequency envelope(s) of the radio frequency signal received by the antenna and of lowering the frequency of the signal contained in these envelope(s). In the shown example, the receive chain of device **500** comprises the same elements as the receive chain of device **200** of FIG. **2**.

In the embodiment of FIG. **5**, when device **500** operates in transmission mode, a signal representative of the signal transmitted by antenna **102** is sampled from the transmit chain, processed by analog pre-processor **202** (SASP) of the receive chain, and sent to digital processor **104**, which verifies its integrity. In the shown example, a portion of the output signal of circuit **304** (that is, the weighted sum of analog basic signals S_i) is sampled via a coupler **502**, and sent to analog pre-processing device **202**. As previously discussed in relation with FIG. **2**, device **202** comprises a sampling circuit capable of delivering analog samples of an input signal, and a processing circuit capable of performing a discrete Fourier transform processing on the signal samples. It is provided, when device **500** operates in transmission mode, to activate device **202** to calculate the discrete Fourier transform of the signal provided by coupler **502**. The discrete Fourier transform signal generated by device **202** is then digitized by converter **108**, and then sent to digital processor **104**. Device **104** is configured, for example, by means of an adapted software, to verify that the received Fourier transform signal is coherent with the previously-calculated decomposition into periodic basic signals S_i.

An advantage of the transceiver device of FIG. **5** is that it enables to verify the integrity of the signal transmitted by antenna **102** without requiring, for this purpose, providing a specific counter-feedback loop of the type described in relation with FIG. **2**. This enables to decrease the bulk, the cost, and the power consumption with respect to the device of FIG. **2**.

Another advantage of device **500** is that, in case one or several communication standards have been modified, it can easily be made compatible with the new standard(s). In particular, the function of verification of the integrity of the transmitted signal requires no specific update or reconfiguration to operate with new transmission standards.

FIG. **6** is a schematic diagram illustrating an embodiment of a circuit **304** according to the second aspect, capable of summing up a plurality of analog periodic input signals S_i by assigning a weighting coefficient a_i to each of them. Circuit **304** of FIG. **6** may for example be used as a weighted summing circuit in the radio frequency transmit devices of FIGS. **3** and **5**.

Circuit **304** comprises a high power supply terminal or line **601** (V_{dd}) and a low power supply terminal or line **603** (or ground terminal). It further comprises n inputs S_1 to S_n intended to respectively receive n periodic analog signals to be summed up and n inputs S_1' to S_n' intended to respectively receive the complementaries of the signals to be summed up, that is, signals having the same characteristics as the signals to be summed up, but with a 180° phase shift. Circuit **304** comprises a balun comprising two conductive windings E**1** and E**2** coupled to each other. The ends of winding E**1** define differential access terminals N**1** and N**2**, an intermediate point of winding E**1** being connected to a reference terminal, for example, high power supply terminal **601**. The ends of common-mode winding E**2** are respectively connected to an output terminal OUT and to a reference terminal, for example, low power supply terminal **603**. Circuit **304** further comprises, associated with each of input terminals S_i, a switch **605**$_i$, and a variable current source **607**$_i$. A first conduction electrode of switch **605**$_i$ is connected to node N**1**, and the second conduction electrode of switch **605**$_i$ is connected to low power supply terminal **603** via variable current source **607**$_i$. The control terminal of switch **605**$_i$ is connected to input terminal S_i. In the example of FIG. **6**, switch **605**$_i$ is an N-channel MOS transistor having its drain connected to node N**1** and having its gate connected to terminal S_i, and current source **607**$_i$ is an N-channel MOS transistor having its source and its drain respectively connected to low power supply terminal **603** and to the source of transistor **605**$_i$. Circuit **304** further comprises, associated with each of input terminals S_i', a switch **605**$_i$' having a first conduction electrode connected to node N**2** and having its second conduction electrode connected to the second conduction electrode of switch **605**$_i$. The control terminal of switch **605**$_i$' is connected to input terminal S_i'. In the example of FIG. **6**, switch **605**$_i$' is an N-channel MOS transistor having its drain connected to node N**2**, having its gate connected to terminal S_i', and having its source connected to the source of transistor **605**$_i$. Circuit **304** further comprises n inputs a_1 to a_n intended to receive voltage references proportional to the absolute values of the weighting coefficients to be applied to the signals to be summed up. Inputs a_1 to a_n are successively connected to the control terminals of variable current sources **607**$_1$ to **607**$_n$, that is, to the gates of N-channel MOS transistors **607**$_1$ à **607**$_n$ in the shown example.

In operation, input terminals S_1 to S_n and S_1' to S_n' receive the signals to be summed up and their complementaries, and input terminals a_1 to a_n receive voltage references proportional to the absolute values of the weighting coefficients to be applied to the signals to be summed up. As an example, in the case where circuit **304** is used in a radio frequency transmission circuit of the type described in relation with FIGS. **3** and **5**, the references to be applied to terminals a_1 to a_n are digitally determined by digital processor **104**, and digital-to-analog converters, not shown, convert the digital reference values into analog values applicable to terminals a_1 to a_n. To take into account, in the weighted sum, the sign of the weighting coefficients, the fact of having, at the input, not only basic signals S_i to be summed up, but also their complementaries S_i', is used. When the coefficient to be applied to a given input signal S_i is negative, the complementary signal S_i' to which the absolute value of the weighting coefficient is applied is used to generate the corresponding term of the weighted sum. To achieve this, between input terminals S_i and S_i', on the one hand, and the control terminals of switches **605**$_i$ and **605**$_i$' on the other hand, a circuit **609** configured to activate terminal S_i and deactivate S_i' is provided when coefficient a_i to be applied has a positive sign, and to deactivate terminal S_i and activate terminal S_i' when coefficient a_i to be applied has a negative sign. Circuit **609** comprises an input **611** for receiving the sign information of coefficients a_i, for example, from digital processor **104** in the case where circuit **304** is used in a radio frequency transmission circuit of the type described in relation with FIGS. **3** and **5**. If the coefficient to be applied to a given input signal S_i is positive, switch **605**$_i$' connected to the corresponding complementary input S_i' is deactivated, that is, it is forced to the off state by circuit **609**, and switch **605**$_i$

remains active, that is, its state is a function of the state of signal S_i. If the coefficient to be applied to a given input signal S_i is negative, switch **605**$_i$ connected to input S_i is deactivated (forced to the off state by circuit **609**) and switch **605**$_i$' remains active (state depending on the state of complementary signal S_i').

Input signals S_i and S_i' being periodic A.C. signals (for example, sinusoidal or square signals), active switches **605**$_i$ or **605**$_i$' (according to whether the sign of weighting coefficient a_i is positive or negative) periodically switch from an on state to an off state. In the case of a positive weighting coefficient a_i (switch **605**$_i$ active), when switch **605**$_i$ is conductive (high state of input signal S_i), a current flows from high power supply terminal **601** to low power supply terminal **603**, through the portion of winding E**1** located between terminal **601** and node N**1**, through switch **605**$_i$, and through current source **607**$_i$. The intensity of this current depends on the voltage applied to control terminal a_i of variable voltage source **607**$_i$. When switch **605**$_i$ is non-conductive (low state of input signal S_i), this current stops. In the case of a negative weighting coefficient a_i (switch **605**$_i$' active), when switch **605**$_i$' is conductive (high state of input signal S_i'), a current flows from high power supply terminal **601** to low power supply terminal **603**, through the portion of winding E**1** located between terminal **601** and node N**2**, through switch **605**$_i$', and through current source **607**$_i$. The intensity of this current depends on the voltage applied to control terminal a_i of variable voltage source **607**$_i$. When switch **605**$_i$' is non-conductive (low state of input signal S_i'), this current stops.

The currents provided by current sources **607**$_i$ add at the level of nodes N**1** (for positive weighting coefficients a_i) and N**2** (for negative weighting coefficients a_i). The current which flows through winding E**1** is representative of the sum of input signals S_i weighted by coefficients a_i. This current is copied, by inductive coupling, on winding E**2**. The voltage variation across winding E**2** is thus representative of the weighted sum of input signals S_i.

In the case where circuit **304** is used in a transmit circuit of the type described in relation with FIGS. **3** and **5**, node OUT may be connected to a transmit antenna **102**. If transistors **605**$_i$, **605**$_i$', **607**$_i$ and windings E**1** and E**2** are properly sized, it may advantageously be done without a power amplifier between the output of circuit **304** and antenna **102**.

An advantage of circuit **304** is that it is easy to form and enables to efficiently perform a weighted summing of periodic A.C. input signals.

The embodiments described in relation with FIG. **6** are not limited to the case where the transistors used to form switches **605**$_i$, **605**$_i$', and **607**$_i$ are N-channel MOS transistors. It will be within the abilities of those skilled in the art to implement the desired operation by using P-channel MOS transistors and by inverting, if need be, the biasing of the circuit power supply terminals.

Further, the embodiments described in relation with FIG. **6** are not limited to a use of circuit **304** in a radio frequency signal transmit device of the type described in relation with FIGS. **3** and **5**. Such a circuit may also be used in any other application requiring the implementation of a weighted sum of periodic analog signals.

Various embodiments with different variations have been described hereabove. It should be noted that those skilled in the art may combine various elements of these various embodiments and variations.

Such alterations, modifications, and improvements are intended to be part of this disclosure, and are intended to be within the spirit and the scope of the present invention. Accordingly, the foregoing description is by way of example only and is not intended to be limiting. The present invention is limited only as defined in the following claims and the equivalents thereto.

What is claimed is:

1. A method for generating a radio frequency signal to be transmitted comprising:
- generating a plurality of periodic basic signals of different frequencies;
- decomposing a digital signal into a weighted sum of the plurality of periodic basic signals of different frequencies and;
- adjusting weighting coefficients based on a sample of the weighted sum of the plurality of periodic basic signals to verify the radio frequency signal being transmitted.

2. The method of claim **1**, wherein a frequency of a highest carrier component is lower than a frequency of at least one of the plurality of periodic basic signals.

3. The method of claim **2**, wherein the frequency of the highest carrier component is lower by at least a factor of ten than the frequency of the at least one of the plurality of periodic basic signals.

4. The method of claim **1** wherein the weighting coefficients assigned to the plurality of periodic basic signals are calculated by a digital processor.

5. The method of claim **4**, comprising analog generation of the plurality of periodic basic signals, wherein the summing of said plurality of periodic basic signals weighted by the weighting coefficients is calculated by the digital processor.

6. A device for generating a radio frequency signal to be transmitted comprising:
- a processing circuit configured to
  - generate a plurality of periodic basic signals of different frequencies;
  - decompose a signal to be transmitted into a weighted sum of the plurality of periodic basic signals or different frequencies and;
  - adjust weighting coefficients based on a sample of the weighted sum of the plurality of periodic basic signals to verify the radio frequency signal being transmitted.

7. The device of claim **6**, wherein a frequency of the highest carrier component is lower than a frequency of at least one of the plurality of periodic basic signals of the decomposition.

8. The device of claim **6**, wherein the processing circuit comprises an analog circuit for analog generation of the plurality of periodic basic signals, and for summing up the plurality of periodic basic signals by applying to each of them a weighting coefficient.

9. The device of claim **8**, wherein the processing circuit comprises a voltage-controlled oscillator (VCO) assembled in a phase-locked loop, and a plurality of frequency dividers coupled to the VCO.

10. The device of claim **6**, wherein said plurality of periodic basic signals comprises sinusoidal signals and said decomposition comprises a Fourier series decomposition.

11. The device of claim **6**, wherein said plurality of periodic basic signals comprises square wave signals.

12. The device of claim **6**, further comprising:
- a receive device comprising at least one analog pre-processing device coupled to the processing circuit and configured for delivering analog samples of an input radio frequency signal, and for performing a discrete Fourier transform on said analog samples.

13. The device claim **12**, wherein the at least one analog preprocessing device is configured to, in transmission phases, sample a signal representative of the transmitted signal, determine the discrete Fourier transform of this signal, digitize the discrete Fourier transform signal, and send the digitized signal to said processing circuit.

14. The device of claim **13**, wherein said processing circuit is configured to verify whether the received digital Fourier transform signal coincides with the decomposition into the plurality of periodic basic signals calculated before the transmission.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,270,300 B2
APPLICATION NO. : 14/177358
DATED : February 23, 2016
INVENTOR(S) : Belot et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Claims

Column 10, Line 24, Claim 4	Delete: "1" Insert --1,--
Column 10, Line 37, Claim 6	Delete: "or" Insert --of--
Column 10, Line 65, Claim 13	Insert --of-- between "device" and "claim"
Column 10, Line 66, Claim 13	Delete: "preprocessing" Insert --pre-processing--

Signed and Sealed this
Third Day of May, 2016

Michelle K. Lee
Director of the United States Patent and Trademark Office