MULTIBAND MIXER, AND CORRESPONDING METHOD
MEHRBANDMISCHER UND ENTSPRECHENDES VERFAHREN
MELANGEUR MULTIBANDES ET PROCEDE CORRESPONDANT

References cited:
The invention relates to a device for frequency conversion, comprising a mixer with means for transferring a signal that is applied to the signal input of said mixer from said signal's source frequency band to one of a plurality of target frequency sub-bands at a time, yielding a transferred signal at the signal output of said mixer, wherein said plurality of target frequency sub-bands defines at least a first and a second target frequency band, and a bank of at least two switchable Variable Gain Amplifiers (VGAs) for amplifying said transferred signal, wherein each of said switchable VGAs is adapted to one of said target frequency bands and is connected to the signal output of said mixer.

In prior art dual-band mobile phones, two mixers in-  

terconnected base-band signal can be transferred to both the GSM900 and GSM1800 band. The basic set-up of a RF transmitter for such a dual-band phone is depicted in Fig. 1. [0005] Fig. 1 shows an I/Q-Filter 1, that low-pass filters the I/Q-modulated base-band signal that is output by a GSM modulator (not shown), yielding a filtered I/Q-modulated base-band signal 2. GSM uses a Gaussian Minimum Shift Keying (GMSK) or 8-Phase Shift Keying (8-PSK) as modulation techniques, so that the modulated complex-valued base-band signal can be represented by an Inphase (I) component and Quadrature (Q) component. The transfer of the I/Q-modulated base-band signal to the RF frequency bands with centre frequencies of 900 or 1800 MHz is accomplished by the mixers 3-1 and 3-2, respectively. Mixer 3-1 is capable of transferring the I/Q-modulated signal applied to its input to the lower GSM900 band, whereas mixer 3-2 is capable of transferring the I/Q-modulated signal applied to its input to the GSM1800 band. The signal at the output of the mixers 3-1 and 3-2 are denoted as transferred signals 4-1 and 4-2, respectively. Note that, in the process of mixing, the I/Q-modulated signal is transferred to the frequency of the RF sub-band (the RF channel) the mobile phone was assigned to, i.e. to a centre frequency in the range 900 ± 25/2 MHz and 1800 ± 25/2 MHz. Each mixer 3-1, 3-2 comprises a Voltage-Controlled Oscillator (VCO) for generating the required RF sub-band centre frequency, and a Phase-Locked-Loop (PLL) circuit that controls the VCO in order to accurately maintain said RF sub-band frequency. The bandwidth (around 25MHz) and centre frequency (900 or 1800 MHz) of the frequency band that can be covered by each mixer 3-1, 3-2 is thus defined by the deployed VCO and PLL. The transferred signals 4-1 or 4-2 are then fed into Variable Gain Amplifiers (VGAs) 5-1 and 5-2 for the GSM900 and GSM1800 band, respectively, yielding amplified transferred signals 6-1 and 6-2, respectively. The design of the VGAs 5-1 and 5-2 generally depends on the frequency of the signals that are to be amplified, so that the VGAs 5-1 and 5-2 are different. The amplified transferred signals 6-1 and 6-2 are then fed into power amplifiers 7-1 and 7-2, respectively, and the output signals 8-1 and 8-2 of said power amplifiers 7-1 and 7-2 are transmitted by the transmit antennas 9-1 and 9-2 corresponding to the GSM900 and GSM1800 band, respectively. Note that the design of the power amplifiers 7-1 and 7-2 and the transmit antennas 9-1 and 9-2 depend on the frequency of the input signals as well. [0006] Another example of a dual band ratio communication system is given in document EP 0 798 880.

In today's digital mobile radio systems, such as for instance the Global System for Mobile Communications (GSM), in general more than one frequency band is available for RF transmission. GSM in Europe uses two frequency bands of 25 MHz bandwidth centred at 900 MHz (GSM900) and 1800 MHz (GSM1800), respectively, wherein each of these frequency bands comprises an up-link (information transfer from mobile station to base station) and a down-link (information transfer from base station to mobile station) frequency band, and wherein each of these up- and down-link bands further comprises a plurality of FDM sub-bands (RF channels) of 200 kHz bandwidth each. In the US, said frequency bands are centred at 850 and 1900 MHz, respectively. [0003] In today’s digital mobile radio systems, such as for instance the Global System for Mobile Communications (GSM), in general more than one frequency band is available for RF transmission. GSM in Europe uses two frequency bands of 25 MHz bandwidth centred at 900 MHz (GSM900) and 1800 MHz (GSM1800), respectively, wherein each of these frequency bands comprises an up-link (information transfer from mobile station to base station) and a down-link (information transfer from base station to mobile station) frequency band, and wherein each of these up- and down-link bands further comprises a plurality of FDM sub-bands (RF channels) of 200 kHz bandwidth each. In the US, said frequency bands are centred at 850 and 1900 MHz, respectively. [0004] A dual-band European GSM mobile phone is capable of transmitting and receiving in both the GSM900 and GSM1800 band. The basic set-up of a RF transmitter for such a dual-band phone is depicted in Fig. 1. [0005] Fig. 1 shows an I/Q-Filter 1, that low-pass filters the I/Q-modulated base-band signal that is output by a GSM modulator (not shown), yielding a filtered I/Q-modulated base-band signal 2. GSM uses a Gaussian Minimum Shift Keying (GMSK) or 8-Phase Shift Keying (8-PSK) as modulation techniques, so that the modulated complex-valued base-band signal can be represented by an Inphase (I) component and Quadrature (Q) component. The transfer of the I/Q-modulated base-band signal to the RF frequency bands with centre frequencies of 900 or 1800 MHz is accomplished by the mixers 3-1 and 3-2, respectively. Mixer 3-1 is capable of transferring the I/Q-modulated signal applied to its input to the lower GSM900 band, whereas mixer 3-2 is capable of transferring the I/Q-modulated signal applied to its input to the GSM1800 band. The signal at the output of the mixers 3-1 and 3-2 are denoted as transferred signals 4-1 and 4-2, respectively. Note that, in the process of mixing, the I/Q-modulated signal is transferred to the frequency of the RF sub-band (the RF channel) the mobile phone was assigned to, i.e. to a centre frequency in the range 900 ± 25/2 MHz and 1800 ± 25/2 MHz. Each mixer 3-1, 3-2 comprises a Voltage-Controlled Oscillator (VCO) for generating the required RF sub-band centre frequency, and a Phase-Locked-Loop (PLL) circuit that controls the VCO in order to accurately maintain said RF sub-band frequency. The bandwidth (around 25MHz) and centre frequency (900 or 1800 MHz) of the frequency band that can be covered by each mixer 3-1, 3-2 is thus defined by the deployed VCO and PLL. The transferred signals 4-1 or 4-2 are then fed into Variable Gain Amplifiers (VGAs) 5-1 and 5-2 for the GSM900 and GSM1800 band, respectively, yielding amplified transferred signals 6-1 and 6-2, respectively. The design of the VGAs 5-1 and 5-2 generally depends on the frequency of the signals that are to be amplified, so that the VGAs 5-1 and 5-2 are different. The amplified transferred signals 6-1 and 6-2 are then fed into power amplifiers 7-1 and 7-2, respectively, and the output signals 8-1 and 8-2 of said power amplifiers 7-1 and 7-2 are transmitted by the transmit antennas 9-1 and 9-2 corresponding to the GSM900 and GSM1800 band, respectively. Note that the design of the power amplifiers 7-1 and 7-2 and the transmit antennas 9-1 and 9-2 depend on the frequency of the input signals as well. [0006] Another example of a dual band ratio communication system is given in document EP 0 798 880.

Summary of the invention

[0007] In prior art dual-band mobile phones, two mixers 3-1 and 3-2 are provided, so that the filtered I/Q-modulated base-band signal 2 can be transferred to both the GSM900 and GMS1800 bands. Providing two mixers increases the size of the silicon area required for the RF hardware and thus increases both the costs and the size...
of a dual-band mobile phone.

Motivated by these disadvantages encountered in the RF hardware of prior art dual-band mobile phones, it is thus the object of the invention to provide a more efficient device and method for frequency conversion of a signal from a source frequency band to a sub-band of at least two different target frequency bands.

The object of the invention is solved by proposing a device according to claim 1.

The multi-band mixer according to the present invention is able to transfer the signal that is applied to its input to one target frequency sub-band at a time, where said target frequency sub-band is located in one of at least a first and a second target frequency bands. The signal does not necessarily have to be a base-band signal, and also the transfer of a signal from an intermediate frequency band to a target sub-band in one of at least first and second RF frequency bands is possible.

The signal that has been transferred to a target frequency sub-band in one of at least a first and second target frequency band by the multi-band mixer is output from the signal output of the multi-band mixer and subsequently input to all switchable VGAs in said bank of switchable VGAs. Each of said switchable VGAs is frequency-dependent and may for instance be optimised for the centre frequency of exactly one of said at least first and second target frequency bands, so that for all target frequency sub-bands that lie within one of said target frequency bands, optimum amplification or a reduced noise contribution is achieved. In contrast to prior art solutions, thus only one multi-band mixer instead of several single-band mixers is used, which vastly reduces the required silicon area and simplifies the layout of the RF transmitter. As in the prior art, separate frequency-dependent VGAs still have to be provided for each frequency band, but the VGAs according to the present invention have to be switchable.

The device according to the present invention preferably further comprises means for controlling the switching of said switchable VGAs in said bank of VGAs so that only the VGA that is adapted to said target frequency band that contains the target frequency sub-band the signal has been transferred to has an amplification factor larger than zero and so that all other VGAs in said bank of VGAs have an amplification factor equal or close to zero. The transferred signal is thus only amplified by that switchable VGA in the bank of VGAs that corresponds to the target frequency band that contains the target frequency sub-band the signal has been transferred to by the multi-band mixer. The switching of the switchable VGAs may for example be controlled by a bias signal. The means for controlling the switching of said switchable VGAs then represents a control interface that outputs the bias signals, where the bias signal input ports of the VGA then represent the interface between the switchable VGA and the means for controlling the switching of said switchable VGAs. Note that the adjustment of the gain of said VGA may be handled separately from or jointly with the control of the switching.

According to the present invention, it is further preferred that the device further comprises a bank of Power Amplifiers (PAs), wherein for each of said target frequency bands, one PA is provided that is adapted to said target frequency band and is connected to the signal output of that switchable VGA that is adapted to the same target frequency band, respectively. After amplification with a switchable VGA that is designed for that target frequency band that contains the target frequency sub-band the signal has been transferred to, the transferred and amplified signal is further amplified by a PA, which also corresponds to one of said target frequency bands, i.e. is designed for maximum amplification of the transferred amplified signal or less generation of noise for the frequency of one of said target frequency bands. The PAs in the bank of PAs may also be switchable, but need not be switchable, because due to the switching of the preceding switchable VGAs in the bank of switchable VGAs, only the output of one of said switchable VGAs produces a non-zero signal, and, correspondingly, only at the input of one PA, a non-zero signal is present.

According to the present invention, it is further preferred that said signal is an I/Q-modulated base-band signal, and that said multi-band mixer comprises means for combining said I/Q-modulated base-band signal with sinusoids the frequency of which corresponds to said target frequency sub-band. Said signal thus may for instance be a GMSK, 2-PSK, 4-PSK or 8-PSK complex-valued base-band signal, which can be represented by an Inphase (I) and Quadrature (Q) component.

According to the present invention, it is further preferred that said multi-band mixer comprises a tunable Voltage-Controlled Oscillator (VCO) and a Phase-Locked-Loop (PLL) circuit. The VCO generates the frequency for said sinusoids in accordance to the centre frequency of the target frequency sub-band the signal is transferred to.

A preferred embodiment of the present invention is represented by a device for frequency conversion that comprises exactly one multi-band mixer with means for transferring a signal that is applied to the signal input of said multi-band mixer from said signal's source frequency band to one out of a plurality of target frequency sub-bands at a time, yielding a transferred signal at the signal output of said multi-band mixer, wherein said plurality of target frequency sub-bands defines at least a first and a second target frequency band; and a bank of switchable Variable Gain Amplifiers (VGAs) for amplifying said transferred signal, wherein for each of said target frequency bands, one switchable VGA is provided that is adapted to said target frequency band and is connected to the signal output of said multi-band mixer, wherein said multi-band mixer comprises a first and a second group of transistors; wherein each of said switchable VGAs comprises a first and a second transistor; wherein the emitter of said first transistor of each of said switchable VGAs is connected to all collectors of the transistors.
of said first group of transistors of said multi-band mixer, respectively, in the form of a cascode circuit; and wherein the emitter of said second transistor of each of said switchable VGAs is connected to all collectors of the transistors of said second group of transistors of said multi-band mixer, respectively, in the form of a cascode circuit.

[0016] A cascode circuit thus is formed by the first transistor of the first switchable VGA and each single transistor in the first group of transistors of the multi-band mixer, or by the second transistor of the first switchable VGA and each single transistor in the second group of transistors of the multi-band mixer, etc. The cascode circuit that is composed of a transistor in each switchable VGA and a transistor in the multi-band mixer has the advantage that switching between the frequency bands is performed by current and not by voltage, so that interference with other parts of the RF transmitter can be reduced. This is due to the fact that in switching by current, the oscillations of the voltage are low because of the low node impedance at the emitter of the switchable VGAs. In addition, in the cascode circuit, no switches are present in the RF signal path.

[0017] The preferred embodiment of the present invention may advantageously further comprise means for controlling the switching of said switchable VGAs in said bank of VGAs so that only the VGA that is adapted to said target frequency band that contains the target frequency sub-band the signal has been transferred to has an amplification factor larger than zero and so that all other VGAs in said bank of VGAs have an amplification factor equal or close to zero, wherein the bases of said first and second transistors of each of said switchable VGAs are connected to said means for controlling the switching of said switchable VGAs, respectively.

[0018] According to the preferred embodiment of the present invention, it is further advantageous that said signal is an I/Q-modulated base-band signal; that said multi-band mixer comprises means for combining said I/Q-modulated base-band signal with sinusoids the frequency of which corresponds to said target frequency sub-band; and that the bases of the transistors of said first and second group of transistors of said multi-band mixer are modulated with signals that are generated by circuitry that combines said sinusoids with said I/Q-modulated base-band signal.

[0019] The preferred embodiment of the present invention is advantageously a device, wherein the device comprises means for controlling the switching of said switchable VGAs in said bank of VGAs so that only the VGA that is adapted to said target frequency band that contains the target frequency sub-band the signal has been transferred to has an amplification factor larger than zero and so that all other VGAs in said bank of VGAs have an amplification factor equal or close to zero, and wherein each of said switchable VGAs further comprises a third and fourth transistor and a waste branch, wherein the collectors of said third and fourth transistors are connected to said waste branch, wherein the emitters of said third and fourth transistor are connected to the emitters of said first and second transistors, respectively, wherein the bases of said third and fourth transistors are connected to said means for controlling the switching of said switchable VGAs, wherein the bases of said first and second transistors are connected to said means for controlling the switching of said switchable VGAs, and wherein all the emitters of said first and second group of transistors of said multi-band mixer are connected to ground directly or by means of further electronic components.

[0020] The object of the invention is further solved by proposing a method according to claim 9.

[0021] The method according to the present invention preferably comprises the step of controlling the switching of said switchable VGAs in said bank of VGAs so that only the VGA that is adapted to said target frequency band that contains the target frequency sub-band the signal has been transferred to has an amplification factor larger than zero and so that all other VGAs in said bank of VGAs have an amplification factor equal or close to zero.

[0022] According to the method of the present invention, it is preferred that said signal is an I/Q-modulated base-band signal and that said I/Q-modulated base-band signal are combined in said multi-band mixer with sinusoids the frequency of which corresponds to said target frequency sub-band.

Brief description of the figures

[0023] These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter. In the figures show:

Fig. 1: A block diagram of a prior art dual-band RF transmitter,

Fig. 2: A block diagram of a dual-band RF transmitter according to the present invention, and

Fig. 3: A circuit diagram of a preferred embodiment of a frequency conversion device according to the present invention with a multi-band mixer and multiple VGAs in a cascode structure.

Detailed description of the invention

[0024] Fig. 2 depicts a block diagram of a dual-band RF transmitter according to the present invention. Similar to the prior art RF transmitter as illustrated in Fig. 1, a filtered I/Q-modulated base-band signal 2 is output by an I/Q-Filter 1. However, in the RF transmitter according to the present invention, the I/Q-modulated signal 2 is only fed into one mixer, this mixer being a multi-band mixer 3, yielding a transferred signal 4. The I/Q-modulated signal is thus transferred from the source frequency band it originally resided in to a target frequency sub-band that may lie in a first or a second target frequency band, e.g.
The multi-band mixer 3 also comprises a first and, in comparison to the RF frequency of several fed with sinusoids that are modulated with binary signals waves with different phases that stem from GMSK or may for instance take the shape of 66.7 kHz sine/cosine signals represent an I/Q-modulated base-band signal and are controlled by a Voltage Controlled Oscillator (VCO). An alternative solution may also provide one oscillator and a frequency divider, depending on the desired target frequency ranges. In any case, a Phase-Locked-Loop (PLL) is used to control and stabilise the generated frequencies. The transferred signal 4 then is fed into switchable VGAs 5-1 and 5-2, respectively. The VGAs are optimised for either of the target frequency ranges, i.e. VGA 5-1 may be optimised for a centre frequency of 900 MHz and VGA 5-2 may be optimised for a centre frequency of 1800 MHz. Both VGAs comprise bias inputs 10-1 and 10-2 that allow for the control of the switching of said switchable VGAs. E.g., in the case that the signal 2 is to be transferred to the GSM900 target frequency band, VGA 5-1 that is adapted to the GSM900 band is controlled by means of its bias input 10-1 to amplify the transferred signal 4, yielding the amplified transferred signal 6-1. The bias input 10-2 of VGA 5-2 then is set to zero in order to prevent the switchable VGA 5-2 to generate a non-zero output signal 6-2. The amplified transferred signal 6-1 then is further amplified by power amplifier 7-1, yielding the signal 8-1 that finally is transmitted by antenna 9-1. The signal path through power amplifier 7-2 and antenna 9-2 is not used in this case.

Within the multi-band mixer 3, a local oscillator, e.g. a VCO that is controlled by a PLL, generates four phase-shifted sinusoids that are denoted as L0_0, L0_90, L0_180 and L0_270, that represent a sine, cosine, negative sine and negative cosine signal with a frequency that corresponds to the centre frequency of the target frequency sub-bands the signal is to be transferred to. The multi-band mixer is broadband enough so that all desired target frequency sub-bands within both target frequency bands GSM900 and GSM1800 can be accurately generated. Said phase-shifted sinusoids are combined with the signals from inphase inputs I_0 and I_180 and quadrature inputs Q_0 and Q_180, where said signals represent an I/Q-modulated base-band signal and may for instance take the shape of 66.7 kHz sine/cosine waves with different phases that stem from GMSK or PSK modulation. Both the I- and the Q-inputs are thus fed with sinusoids that are modulated with binary signals (0,1) and, in comparison to the RF frequency of several 100 MHz, can be considered as base-band signals.

The multi-band mixer 3 also comprises a first group of transistors 11-1 ... 11-4 and a second group of transistors 12-1 .. 12-4. The emitters of all of said transistors are connected to ground via resistors 13. The collectors of all transistors 11-1 .. 11-4 of the first group are connected with each other and to the signal output 4-a of the multi-band mixer, and equivalently the collectors of all transistors 12-1 .. 12-4 of the second group of transistors are connected with each other and to the signal output 4-b of the multi-band mixer. The bases of the transistors 11-1 .. 11-4 of the first group of transistors are modulated with the combination of the signals (Q_180, L0_90), (Q_0, L0_90), (I_0, L0_180) and (I_180, L0_180), respectively, where said combination is achieved by connecting the I/Q-inputs to said bases via resistors 14 and by connecting the LO-inputs to said bases via capacitors 15, respectively. The combination of the I/Q-inputs and the LO-signals represents a multiplication of the low- frequency signals present at the I/Q-inputs with the high- frequency LO-signals. Similarly, the bases of the transistors 12-1 .. 12-4 of the second group of transistors are modulated with the combination of the signals (Q_180, L0_270), (Q_0, L0_270), (I_0, L0_0) and (I_180, L0_0), respectively, where said combination is achieved by connecting the I/Q-inputs to said bases via resistors 14 and by connecting the LO-inputs to said bases via capacitors 15, respectively.

Within the switchable VGA 5-1, the collectors of a first transistor 16-1 and a second transistor 17-1 are connected to the negative RF signal output RF_M-1 and positive RF signal output RF_P-1, respectively, which lead to a PA (not shown). The bases of the transistors 16-1 and 17-1 are both connected to the VGA bias signal input V_Bias-1b. The emitter of the first transistor 16-1 is connected to the signal output 4-a of the multi-band mixer, which in turn is connected to the collectors of all transistors 11-1 .. 11-4 of the first group of transistors in the multi-band mixer, and the emitter of the second transistor 17-1 is connected to the signal output 4-b of the multi-band mixer, which in turn is connected to the collectors of all transistors 12-1 .. 12-4 of the second group of transistors in the multi-band mixer. Thus the first transistor 16-1 in the switchable VGA 5-1 and the transistors 11-1 .. 11-4 in the first group of transistors of the multi-band mixer 3 form a cascode circuit, where the input ports of the cascode circuits are the bases of the transistors 11-1 .. 11-4, and where the output port of the cascode circuits is the collector of the first transistor 16-1. Equivalent cascode circuits are formed by the second transistor 17-1 and the transistors of the second group of transistors 12-1 .. 12-4, which are connected via signal output 4-b of the multi-band mixer 3. The switchable VGA 5-1 further comprises a third and fourth transistor 18-1 and 19-1, the bases of which are connected to the bias signal input V_Bias-1a, and the collectors of which are connected to a waste branch Vss. The bias signal inputs V_Bias-1a and V_Bias-1b thus form a differential bias signal input V_Bias-1 that allows both to control the gain of the switchable VGA 5-1 and to switch the switchable VGA 5-1 on.
and off. Finally, the emitter of third transistor 18-1 is connected to the emitter of the first transistor 16-1, and the emitter of the fourth transistor 19-1 is connected to the emitter of the second transmitter 17-1.

[0029] The second VGA 5-2 has an equivalent set-up with a first transistor 16-2, a second transistor 17-2, a third transistor 18-2 and a fourth transistor 19-2, where the negative signal output is denoted as RF_M-2, the positive signal output is denoted as RF_P-2 and the differential bias signal inputs are denoted as V_Bias-2a and V_Bias-2b. Note that due to the adaptation of the VGAs 5-1 and 5-2 to different frequency bands, the parameters of the transistors 16-1 .. 19-1 and 16-2 .. 19-2 might substantially differ.

[0030] Further note that the input signals of both switchable VGAs 5-1 and 5-2, i.e. the signal outputs 4-a and 4-b of the multi-band mixer 3, are the same. The bias signal inputs V_Bias-1a/b and V_Bias-2a/b now can be used to switch both VGAs on and off and thus to control which of both VGAs amplifies the output signal 4-a, 4-b of the multi-band mixer 3 and produces an output at the VGA outputs RF_P and RF_M. E.g., if the voltage of both V_Bias-1a and V_Bias-1b is zero, the VGA 5-1 is switched off. To switch on VGA 5-1, the voltage of both V_Bias-1a and V_Bias-1b has to be so high that the whole cascode is biased correctly (typically 2 Volts). In the case that VGA 5-2 is switched off and VGA 5-1 is switched on, if both voltages of V_Bias-1a and V_Bias-1b are equal, then RF current from output signals 4-a and 4-b of the multi-bank mixer 3 are divided equally to the wanted signal outputs of VGA 5-1 (RF_P-1 and RF_M-1) and the waste branch Vss. The current gain of the VGA 5-1 then amounts 0.5. If the voltage of V_Bias-1a is higher than the voltage of V_Bias-1b then most of the RF current from the output signals 4-a and 4-b goes to the waste branch Vss, and if the voltage of V_Bias-1b is higher than the voltage of V_Bias-1a, most of the RF current goes to the signal outputs RF_P-1 and RF_M-1. Thus if VGA 5-1 is switched on and VGA 5-2 is switched off, current from the output signals 4-a and 4-b of the multi-bank mixer 3 is divided between the signal outputs RF_P-1 and RF_M-1 and the waste branch Vss. The maximum current gain of the VGA 5-1 is 1 when all RF current is driven to the signal outputs RF_P-1 and RF_M-1, and maximum attenuation is achieved when all RF current is driven to the waste branch. The differential bias signal input V_Bias-1 thus allows both to switch the VGA 5-1 on and off and to control its gain factor. The same switching and gain control functionality is available for VGA 5-2 by properly selecting the bias signals at the inputs V_Bias-2a/b.

[0031] Note that the collectors of the first (11-1 .. 11-4) and second (12-1 .. 12-4) group of transistors of the multi-band mixer 3 represent the outputs of the multi-band mixer 3. A collector of a transistor can be modelled as a controllable current source. Thus the multi-bank mixer has a current mode output (4-a, 4-b). The collectors are connected to the VGAs 5-1 and 5-2 in parallel, so that there are no switches in the RF signal path: The RF current finds it way to the VGA 5-1 or 5-2 which is switched on.

[0032] The invention has been described above by means of a preferred embodiment. It should be noted that there are alternative ways and variations which are obvious to a skilled person in the art and can be implemented without deviating from the scope of the appended claims, e.g. the signal may be transferred to more than two target frequency bands by the multi-band mixer, and frequency conversion from an intermediate frequency band to target RF frequency bands may be performed instead of transferring signals from base-band. Various other types of modulations may be represented by the I/Q-modulated base-band signals, such as all kinds of Phase-Shift Keying (PSK) modulation.

Claims

1. Device for frequency conversion, comprising:

   exactly one multi-band mixer (3) with means for transferring a signal (2) that is applied to a signal input of said multi-band mixer (3) from a source frequency band of said signal to one out of a plurality of target frequency sub-bands at a time, yielding a transferred signal (4) at a signal output of said multi-band mixer (3), wherein said plurality of target frequency sub-bands define at least a first target frequency band and a second target frequency band, and wherein said multi-band mixer (3) comprises a first (11-1 .. 11-4) and a second (12-1 .. 12-4) group of transistors; and

   a bank of switchable variable gain amplifiers (VGAs) (5-1, 5-2) for amplifying said transferred signal (4), wherein for each of said at least first target frequency band and said second target frequency band, a corresponding switchable VGA (5-1, 5-2) is provided that is adapted to said corresponding target frequency band and is connected to the signal output of said multi-band mixer (3), wherein each of said switchable VGAs (5-1) comprises a first (16-1) and a second transistor (17-1); wherein an emitter of said first transistor (16-1) of each of said switchable VGAs (5-1) is connected to collectors of all the transistors (11-1 .. 11-4) of said first group of transistors of said multi-band mixer (3) in the form of a cascode circuit; and wherein an emitter of said second transistor (17-1) of each of said switchable VGAs (5-1) is connected to collectors of all the transistors (12-1 .. 12-4) of said second group of transistors of said multi-band mixer (3) in the form of a cascode circuit.

2. Device according to claim 1,
wherein the device further comprises means (10-1, 10-2) for controlling the switching of said switchable VGAs (5-1, 5-2) in said bank of VGAs so that only the VGA (5-1) that is adapted to said target frequency band that contains the target frequency sub-band the signal (2) has been transferred to has an amplification factor larger than zero and so that all other VGAs (5-2) in said bank of VGAs (5-1, 5-2) have an amplification factor equal or close to zero.

5. Device according to claim 1, wherein bases of said first (16-1) and second (17-1) transistors of each of said switchable VGAs (5-1) are connected to said means for controlling the switching of said switchable VGAs, respectively.

6. Device according to claim 2, wherein bases of said first (11-1 .. 11-4) and second (12-1 .. 12-4) group of transistors of said multi-band mixer (3) are modulated with signals that are generated by circuitry (14, 15) that combines said sinusoids with said I/Q-modulated base-band signal.

8. Device according to claim 1, wherein said multi-band mixer (3) comprises a tuneable voltage-controlled oscillator (VCO) and a phase-locked loop (PLL) circuit.

9. Method for frequency conversion, comprising the steps of:

transferring a signal (2) that is applied to a signal input of a multi-band mixer (3) from a source frequency band of said signal to one out of a plurality of target frequency sub-bands at a time, yielding a transferred signal (4) at the signal output of said multi-band mixer, wherein said plurality of target frequency sub-bands defines a plurality of target frequency bands including at least a first target frequency band and a second target frequency band, and wherein said multi-band mixer (3) comprises a first (11-1 .. 11-4) and a second (12-1 .. 12-4) group of transistors; and

amplifying said transferred signal (4) in a bank of switchable variable gain amplifiers (VGAs) (5-1, 5-2), wherein for each of said target frequency bands, a corresponding switchable VGA (5-1, 5-2) is provided that is adapted to said corresponding target frequency band and is connected to the signal output of said multi-band mixer (3), wherein each of said switchable VGAs (5-1) comprises a first (16-1) and a second transistor (17-1); wherein an emitter of said first transistor (16-1) of each of said switchable VGAs (5-1) is connected to collectors of all the transistors (11-1 .. 11-4) of said first group of transistors of said multi-band mixer (3) in the form of a cascode circuit; and wherein an emitter of said second transistor (17-1) of each of said switchable VGAs (5-1) is connected to collectors of all the transistors (12-1 .. 12-4) of said second group of transistors of said multi-band mixer (3) in the form of a cascode circuit.

10. Method according to claim 9, wherein the method further comprises the step of controlling switching of said switchable VGAs (5-1, 5-2) in said bank of VGAs so that only a VGA (5-1) that is adapted to a target frequency band that contains a target frequency sub-band the signal (2) has been transferred to has an amplification factor larger than zero and so that all other VGAs (5-2) in said bank of VGAs (5-1, 5-2) have an amplification factor equal or close to zero.

11. Method according to claim 9,
wherein said signal (2) is an I/Q-modulated base-band signal, and
wherein said I/Q-modulated base-band signal (2) is combined in said multi-band mixer (3) with sinusoids with frequency corresponding to said target frequency sub-band.

**Patentansprüche**

1. Gerät zur Frequenzumwandlung, umfassend:

   genau einen Mehrbandmischer (3) mit Mitteln zum Transferieren eines Signals (2), das an einen Signaleingang des Mehrbandmischers (3) angelegt ist, von einem Quellfrequenzband des Signals auf eines von mehreren Zielfrequency-Unterbändern zu einer Zeit, was ein transferiertes Signal (4) an einem Signalausgang des Mehrbandmischers (3) ergibt, wobei die mehreren Zielfrequenz-Unterbänder mindestens ein erstes Zielfrequenzband und ein zweites Zielfrequenzband definieren, und wobei der Mehrbandmischer (3) eine erste (11-1 .. 11-4) und eine zweite (12-1 .. 12-4) Gruppe von Transistoren umfasst; und

   eine Bank von schaltbaren Verstärkern mit variabler Verstärkung (VGAs - variable gain amplifiers) (5-1, 5-2) zum Verstärken des transferierten Signals (4), wobei für jedes des mindestens ersten Zielfrequencybandes und des zweiten Zielfrequencybandes ein entsprechender schaltbarer VGA (5-1, 5-2) bereitgestellt ist, der auf das entsprechende Zielfrequencyband angepasst und mit dem Signalausgang des Mehrbandmischers (3) verbunden ist, wobei jeder der schaltbaren VGAs (5-1) einen ersten (16-1) und einen zweiten (17-1), umweltenden, und wobei ein Emitter des ersten Transistors (16-1) jedes der schaltbaren VGAs (5-1) mit Kollektoren aller Transistoren (11-1 .. 11-4) der ersten Gruppe von Transistoren des Mehrbandmischers (3) in Form einer Kaskodenschaltung verbunden ist; und

   wobei ein Emitter des zweiten Transistors (17-1) jedes der schaltbaren VGAs (5-1) mit Kollektoren aller Transistoren (12-1 .. 12-4) der zweiten Gruppe von Transistoren des Mehrbandmischers (3) in Form einer Kaskodenschaltung verbunden ist.

2. Gerät nach Anspruch 1, wobei das Gerät ferner einen dritten (18-1) und vierten (19-1) Transistor und einen Verlustabzweig umfasst, wobei Kollektoren des dritten (18-1) und vierten (19-1) Transistors mit dem Verlustabzweig verbunden sind, wobei Emitter des dritten (18-1) und vierten (19-1) Transistors jeweils mit den Emittern des ersten (16-1) und zweiten (17-1) Transistors verbunden sind, wobei Basen des dritten (18-1) und vierten (19-1) Transistors mit den Mitteln zum Steuern des Schaltens der schaltbaren VGAs (5-1) verbunden sind, wobei Basen des ersten (16-1) und zweiten (17-1) Transistors mit den Mitteln zum Steuern des Schaltens der schaltbaren VGAs (5-1) verbunden sind, und

   wobei Emitter aller der ersten (11-1 .. 11-4) und zweiten (12-1 .. 12-4) Gruppe von Transistoren des Mehrbandmischers direkt oder mittels weiterer elektronischer Komponenten mit Masse verbunden sind.

3. Gerät nach Anspruch 2, wobei Basen des ersten (16-1) und zweiten (17-1) Transistors jedes der schaltbaren VGAs (5-1) jeweils mit den Mitteln zum Steuern des Schaltens der schaltbaren VGAs verbunden sind.

4. Gerät nach Anspruch 2, wobei jeder der schaltbaren VGAs (5-1) ferner einen dritten (18-1) und vierten (19-1) Transistor und einen Verlustabzweig umfasst, wobei Kollektoren des dritten (18-1) und vierten (19-1) Transistors mit dem Verlustabzweig verbunden sind, wobei Emitter des dritten (18-1) und vierten (19-1) Transistors jeweils mit den Emittern des ersten (16-1) und zweiten (17-1) Transistors verbunden sind, wobei Basen des dritten (18-1) und vierten (19-1) Transistors mit den Mitteln zum Steuern des Schaltens der schaltbaren VGAs (5-1) verbunden sind, wobei Basen des ersten (16-1) und zweiten (17-1) Transistors mit den Mitteln zum Steuern des Schaltens der schaltbaren VGAs (5-1) verbunden sind, und

   wobei Emitter aller der ersten (11-1 .. 11-4) und zweiten (12-1 .. 12-4) Gruppe von Transistoren des Mehrbandmischers direkt oder mittels weiterer elektronischer Komponenten mit Masse verbunden sind.

5. Gerät nach Anspruch 1, wobei das Gerät ferner eine Bank von Leistungsverstärkern (PAs - power amplifiers) (7-1, 7-2) umfasst, und

   wobei für jedes der Zielfrequenzbänder ein entsprechender PA (7-1, 7-2) bereitgestellt ist, der an das entsprechende Zielfrequencyband angepasst und mit einem Signalausgang des schaltbaren VGA (5-1, 5-2) verbunden ist.

6. Gerät nach Anspruch 1, wobei das Signal (2) ein I/Q-moduliertes Basisbandsignal ist, und

   wobei der Mehrbandmischer (3) Mittel zum Kombinieren des I/Q-modulierten Basisbandsignals (2) mit Sinusoiden umfasst, deren Frequenz dem Zielfrequency-Unterband entspricht.

7. Gerät nach Anspruch 6, wobei Basen der Transistoren der ersten (11-1 .. 11-4) und zweiten (12-1 .. 12-4) Gruppe von Transistoren des Mehrbandmischers (3) mit Signalen moduliert werden, die durch Schaltungen (14, 15) erzeugt werden, welche die Sinusoiden mit dem I/Q-modulierten Basisbandsignal kombinieren.
8. Gerät nach Anspruch 1, wobei der Mehrbandmischer (3) einen abstimmbarren spannungssteuerung Oszillator (VCO - voltages-controlled oscillator) und eine Phasenregelkreis (PLL - phase-locked loop)-Schaltung umfasst.

9. Verfahren zur Frequenzumwandlung, welches folgende Schritte umfasst:

Transferieren eines Signals (2), das an einen Signaleingang eines Mehrbandmischers (3) angelegt ist, von einem Quellfrequenzband des Signals auf eines von mehreren Zielfrequenz-Unterbänder zu einer Zeit, was ein transferiertes Signal (4) an dem Signalausgang des Mehrbandmischers (3) ergibt, wobei die mehreren Zielfrequenz-Unterbänder mehrere Zielfrequenzbänder, einschließlich mindestens eines ersten Zielfrequenzbandes und eines zweiten Zielfrequenzbandes, definieren, und wobei der Mehrbandmischer (3) eine erste (11-1 .. 11-4) und eine zweite (12-1 .. 12-4) Gruppe von Transistoren umfasst; und

Verstärken des transferierten Signals (4) in einer Bank von schaltbaren Verstärkern mit variabler Verstärkung (VGA) (5-1, 5-2), wobei für jedes der Zielfrequenzbänder ein entsprechender schaltbarer VGA (5-1, 5-2) bereitgestellt ist, der auf das entsprechende Zielfrequenzband angepasst und mit dem Signalausgang des Mehrbandmischers (3) verbunden ist, wobei jeder der schaltbaren VGAs (5-1) einen ersten (16-1) und einen zweiten Transistor (17-1) umfasst; wobei ein Emitter des ersten Transistors (16-1) jedes der schaltbaren VGAs (5-1) mit Kollektoren aller Transistoren (11-1 .. 11-4) der ersten Gruppe von Transistoren des Mehrbandmischers (3) in Form einer Kaskodenschaltung verbunden ist; und wobei ein Emitter des zweiten Transistors (17-1) jedes der schaltbaren VGAs (5-1) mit Kollektoren aller Transistoren (12-1 .. 12-4) der zweiten Gruppe von Transistoren des Mehrbandmischers (3) in Form einer Kaskodenschaltung verbunden ist.

10. Verfahren nach Anspruch 9, wobei das Verfahren ferner den Schritt des Steuerns der schaltbaren VGAs (5-1, 5-2) in der Bank von VGAs umfasst, derart, dass nur ein VGA (5-1), der auf ein Zielfrequenzband angepasst ist, welches ein Zielfrequenz-Unterband enthält, auf welches das Signal (2) transferiert wurde, einen Verstärkungsfaktor größer als Null aufweist, und derart, dass alle anderen VGAs (5-2) in der Bank von VGAs (5-1, 5-2) einen Verstärkungsfaktor gleich oder nahe Null aufweisen.

11. Verfahren nach Anspruch 9, wobei das Signal (2) ein I/Q-modulierte Basisbandsignal ist, und wobei das I/Q-modulierte Basisbandsignal (2) in dem Mehrbandmischer (3) mit Sinusoiden mit einer Frequenz entsprechend dem Zielfrequenz-Unterband kombiniert wird.

Revendications

1. Dispositif de conversion de fréquence, comprenant :

exactement un mélangeur multibande (3) avec des moyens pour transférer un signal (2) qui est appliqué à une entrée de signal dudit mélangeur multibande (3) depuis une bande de fréquence source dudit signal à une sous-bande parmi une pluralité de sous-bandes de fréquence cible à la fois, ce qui génère un signal transféré (4) au niveau d’une sortie de signal dudit mélangeur multibande (3), dans lequel ladite pluralité de sous-bandes de fréquence cible définit au moins une première bande de fréquence cible et une seconde bande de fréquence cible, et dans lequel dudit mélangeur multibande (3) comprend un premier (11 - 1 .. 11 - 4) groupe de transistors et un second (12 - 1 .. 12 - 4) groupe de transistors, et

une batterie d’amplificateurs à gain variable commutables (VGA) (5 - 1, 5 - 2) pour amplifier ledit signal transféré (4), dans lequel, pour chaque bande parmi ladite bande de fréquence cible et ladite seconde bande de fréquence cible, un amplificateur VGA commutable correspondant (5 - 1, 5 - 2) est fourni lequel est adapté à ladite bande de fréquence cible et est connecté à la sortie de signal dudit mélangeur multibande (3), dans lequel dudit mélangeur multibande (3) comprend un premier transistor (16 - 1) et un deuxième transistor (17 - 1) ; dans lequel un émetteur dudit premier transistor (16 - 1) de chacun desdits amplificateurs VGA commutables (5 - 1) est connecté à des collecteurs de la totalité des transistors (11 - 1 .. 11 - 4) dudit premier groupe de transistors dudit mélangeur multibande (3) sous la forme d’un circuit cascode et dans lequel un émetteur dudit deuxième transistor (17 - 1) de chacun desdits amplificateurs VGA commutables (5 - 1) est connecté à des collecteurs de la totalité des transistors (12 - 1 .. 12 - 4) dudit second groupe de transistors dudit mélangeur multibande (3) sous la forme d’un circuit cascode.

2. Dispositif selon la revendication 1, dans lequel le dispositif comprend en outre des
moyens (10 - 1, 10 - 2) pour commander la commutation desdits amplificateurs VGA commutables (5 - 1, 5 - 2) dans ladite batterie d’amplificateurs VGA, de sorte que seul l’amplificateur VGA (5 - 1), qui est adapté à ladite bande de fréquence cible contenant la sous-bande de fréquence cible à laquelle le signal (2) a été transféré, présente un facteur d’amplification supérieur à zéro, et de sorte que tous les autres amplificateurs VGA (5 - 2) dans ladite batterie d’amplificateurs VGA (5 - 1, 5 - 2) présentent un facteur d’amplification égal ou proche de zéro.

3. Dispositif selon la revendication 2, dans lequel les bases desdits premier (16 - 1) et deuxième (17 - 1) transistors de chacun desdits amplificateurs VGA commutables (5 - 1) sont connectées auxdits moyens de commande de la commutation desdits amplificateurs VGA commutables, respectivement.

4. Dispositif selon la revendication 2, dans lequel chacun desdits amplificateurs VGA commutables (5 - 1) comprend en outre un troisième (18 - 1) et un quatrième (19 - 1) transistor, et une dérivation à déchets ; dans lequel les collecteurs desdits troisième (18 - 1) et quatrième (19 - 1) transistors sont connectés à ladite dérivation à déchets ; dans lequel les émetteurs desdits troisième (18 - 1) et quatrième (19 - 1) transistors sont connectés aux émetteurs desdits premier (16 - 1) et deuxième (17 - 1) transistors, respectivement ; dans lequel les bases desdits troisième (18 - 1) et quatrième (19 - 1) transistors sont connectées auxdits moyens de commande de la commutation desdits amplificateurs VGA commutables (5 - 1) ; dans lequel les bases desdits premier (16 - 1) et deuxième (17 - 1) transistors sont connectées auxdits moyens de commande de la commutation desdits amplificateurs VGA commutables (5 - 1) ; et dans lequel les émetteurs de la totalité desdits premiers (11 - 1 .. 11 - 4) et secondes (12 - 1 .. 12 - 4) groupes de transistors dudit mélangeur multibande sont connectés directement à la terre ou par l’intermédiaire de composants électroniques supplémentaires.

5. Dispositif selon la revendication 1, dans lequel le dispositif comprend en outre une batterie d’amplificateurs de puissance (PA) (7 - 1, 7 - 2) ; et dans lequel, pour chacune desdites bandes de fréquence cible, un amplificateur PA correspondant (7 - 1, 7 - 2) est fourni lequel est adapté à ladite bande de fréquence cible correspondante, et est connecté à une sortie de signal de l’amplificateur VGA commutable (5-1, 5-2).

6. Dispositif selon la revendication 1, dans lequel le ledit signal (2) est un signal de bande de fréquence égal ou proche de zéro.

7. Dispositif selon la revendication 6, dans lequel les bandes desdits premiers (11 - 1 .. 11 - 4) et secondes (12 - 1 .. 12 - 4) groupes de transistors dudit mélangeur multibande (3) sont modulées avec des signaux qui sont générés par un montage de circuits (14, 15) qui combine lesdits signaux modulés avec ledit signal de bande de base à modulation I/Q.

8. Dispositif selon la revendication 1, dans lequel le ledit mélangeur multibande (3) comprend un oscillateur à tension asservie accordable (VCO) et un circuit en boucle à verrouillage de phase (PLL).

9. Procédé de conversion de fréquence, comprenant les étapes ci-dessous consistant à :

transférer un signal (2) lequel est appliqué à une entrée de signal d’un mélangeur multibande (3) depuis une bande de fréquence source dudit signal à une sous-bande parmi une pluralité de sous-bandes de fréquence cible à la fois, ce qui génère un signal transféré (4) au niveau de la sortie de signal dudit mélangeur multibande, dans lequel ladite pluralité de sous-bandes de fréquence cible définit une pluralité de bandes de fréquence cible incluant au moins une première bande de fréquence cible et une seconde bande de fréquence cible, et dans lequel ledit mélangeur multibande (3) comprend un premier (11 - 1 .. 11 - 4) groupe de transistors et un second (12 - 1 .. 12 - 4) groupe de transistors ; et amplifier ledit signal transféré (4) dans une batterie d’amplificateurs à gain variable commutables (VGA) (5 - 1, 5 - 2), dans lequel, pour chaque bande parmi lesdites bandes de fréquence cible, un amplificateur VGA commutable correspondant (5 - 1, 5 - 2) est fourni lequel est adapté à ladite bande de fréquence cible correspondante, et est connecté à une sortie de signal dudit mélangeur multibande (3), dans lequel le ledit signal (2) est un signal de bande de base à modulation I/Q ; et dans lequel ledit mélangeur multibande (3) comprend des moyens pour combiner ledit signal de bande de base à modulation I/Q (2) avec des sinusoïdes dont la fréquence correspond à ladite sous-bande de fréquence cible.

10. Dispositif selon la revendication 7, dans lequel les bandes desdits premiers (11 - 1 .. 11 - 4) et secondes (12 - 1 .. 12 - 4) groupes de transistors dudit mélangeur multibande (3) sont modulées avec des signaux qui sont générés par un montage de circuits (14, 15) qui combine lesdits signaux modulés avec ledit signal de bande de base à modulation I/Q.

15. Dispositif selon la revendication 6, dans lequel le ledit signal transféré (4) dans une batterie d’amplificateurs à gain variable commutables (VGA) (5 - 1, 5 - 2), dans lequel, pour chaque bande parmi lesdites bandes de fréquence cible, un amplificateur VGA commutable correspondant (5 - 1, 5 - 2) est fourni lequel est adapté à ladite bande de fréquence cible correspondante, et est connecté à une sortie de signal dudit mélangeur multibande (3), dans lequel le ledit signal (2) est un signal de bande de base à modulation I/Q ; et dans lequel ledit mélangeur multibande (3) comprend des moyens pour combiner ledit signal de bande de base à modulation I/Q (2) avec des sinusoïdes dont la fréquence correspond à ladite sous-bande de fréquence cible.
la forme d’un circuit cascode ; et dans lequel un émetteur dudit deuxième transistor (17 - 1) de chacun desdits amplificateurs VGA commutables (5 - 1) est connecté à des collecteurs de la totalité des transistors (12 - 1 .. 12 - 4) dudit second groupe de transistors dudit mélangeur multibande (3) sous la forme d’un circuit cascode.

10. Procédé selon la revendication 9, dans lequel le procédé comprend en outre l’étape consistant à commander la commutation desdits amplificateurs VGA commutables (5 - 1, 5 - 2) dans ladite batterie d’amplificateurs VGA, de sorte que seul un amplificateur VGA (5 - 1), qui est adapté à une bande de fréquence cible contenant une sous-bande de fréquence cible à laquelle le signal (2) a été transféré, présente un facteur d’amplification supérieur à zéro, et de sorte que tous les autres amplificateurs VGA (5 - 2) dans ladite batterie d’amplificateurs VGA (5 - 1, 5 - 2) présentent un facteur d’amplification égal ou proche de zéro.

11. Procédé selon la revendication 9, dans lequel ledit signal (2) est un signal de bande de base à modulation I/Q ; et dans lequel ledit signal de bande de base à modulation I/Q (2) est combiné dans ledit mélangeur multibande (3) avec des sinusoïdes dont la fréquence correspond à ladite sous-bande de fréquence cible.