Description

Flatness Compensation Method and Apparatus, Storage Medium and Electronic Device

Technical Field

The present disclosure relates to the field of communication, and in particular to a flatness compensation method and apparatus, a storage medium and an electronic device.

Background

In the field of communication, with the application of 4G/5G, an operating frequency band of a radio transceiver is increasingly wider, reaching several hundreds of megahertz. In such a wide frequency range, gain flatness of a radio frequency device is difficult to guarantee. A filter needs to be employed to conduct gain pre-compensation on a baseband signal to solve the problem of an uneven in-band gain caused by gain imbalance of device hardware. In the related art, a conventional inverse fast fourier transform (IFFT) or training method can be used for generating a filter, and then the generated filter is used for gain pre-compensation. However, the filter generated through the IFFT or training method has a poor compensation effect on the baseband signal, and the filter grown in this way usually fails to accurately assess a compensated in-band flatness peak-to-peak value. No effective technical solution has been provided to solve the problem of a poor compensation effect when the filter generated through the conventional IFFT or training method is used for pre-compensating the baseband signal in the related art.

Summary

The embodiments of the present disclosure provides a flatness compensation method and apparatus, a storage medium and an electronic device so as to at least solve the problem of a poor compensation effect when the filter generated through the conventional IFFT or training method is used for pre-compensating the baseband signal in the related art.

According to one aspect of the embodiment of the present disclosure, provided is a flatness compensation method, including: sampling, at an oversampling interval, a gain of a transceiver link in a frequency range influenced by a baseband signal to obtain a gain sequence; generating an deviation sequence according to the gain sequence and a gain reference value, where the gain reference value is an expected flat link gain value; conducting extraction on the deviation sequence with an oversampling multiple corresponding to the oversampling interval to obtain an initial

correction sequence, where the initial correction sequence is a subsequence of the deviation sequence; optimizing the initial correction sequence to obtain an optimized correction sequence; converting the optimized correction sequence to obtain filter tap coefficients; and generating a target filter according to the filter tap coefficients, and compensating the baseband signal by using the target filter.

According to another aspect of the embodiment of the present disclosure, further provided is a flatness compensation apparatus, including: a first processing unit, configured to sample, at an oversampling interval, a gain of a transceiver link in a frequency range influenced by a baseband signal to obtain a gain sequence; a second processing unit, configured to generate an deviation sequence according to the gain sequence and a gain reference value, where the gain reference value is an expected flat link gain value; a third processing unit, configured to conduct extraction on the deviation sequence with an oversampling multiple corresponding to the oversampling interval to obtain an initial correction sequence, where the initial correction sequence is a subsequence of the deviation sequence; an optimization unit, configured to optimize the initial correction sequence to obtain an optimized correction sequence; a conversion unit, configured to convert the optimized correction sequence to obtain filter tap coefficients; and a fourth processing unit, configured to generate a target filter according to the filter tap coefficients, and compensate the baseband signal by using the target filter.

According to yet another aspect of the embodiment of the present disclosure, further provided is a non-transitory computer-readable storage medium. A computer program is stored in the computer-readable storage medium, and the computer program is configured to perform the flatness compensation method when running by a processor~~at runtime~~.

According to still another aspect of the embodiment of the present disclosure, further provided is an electronic apparatus, including a memory, a processor and a computer program stored on the memory and operable on the processor, where the processor performs the flatness compensation method by means of the computer program.

According to the present disclosure, at the oversampling interval, the gain of the transceiver link in the frequency range influenced by the baseband signal is sampled to obtain the gain sequence; the deviation sequence is generated according to the gain sequence and the gain reference value, where the gain reference value is the expected flat link gain value; extraction is conducted on the deviation sequence with the oversampling multiple corresponding to the oversampling interval to obtain the initial correction sequence, where the initial correction sequence is the subsequence of the deviation sequence; the initial correction sequence is optimized to obtain

the optimized correction sequence; the optimized correction sequence is converted to obtain the filter tap coefficients; and the target filter is generated according to the filter tap coefficients, and the baseband signal is compensated by using the target filter. By means of the above-mentioned method, more information of the baseband signal may be obtained in the process of oversampling the baseband signal, and then the filter tap coefficients are determined step by step according to the information in the above-mentioned manner, such that the obtained filter tap coefficient is more accurate; and finally, the target filter is generated according to the filter tap coefficients, and the baseband signal is compensated by using the target filter, such that the compensation effect on the baseband signal is improved.

Brief Description of the Drawings

The accompanying drawings described herein are used to provide further understanding of the present disclosure, which form a part of the disclosure, and illustrative embodiments of the present disclosure and the description thereof are used to explain the present disclosure, which are not intended to unduly limit the present disclosure. In the accompanying drawings:

Fig. 1 is a schematic diagram of an application environment of a flatness compensation method according to an embodiment of the present disclosure;

Fig. 2 is a schematic flow diagram of an optional flatness compensation method according to an embodiment of the present disclosure;

Fig. 3 is a schematic flow diagram of another optional flatness compensation method according to an embodiment of the present disclosure;

Fig. 4 is a structural schematic diagram of an optional flatness compensation apparatus according to an embodiment of the present disclosure; and

Fig. 5 is a structural schematic diagram of an optional electronic apparatus according to an embodiment of the present disclosure.

Detailed Description of the Embodiments

In order to enable those skilled in the art to better understand the solution of the present disclosure, the technical solutions in the embodiments of the present disclosure will be clearly and completely described in conjunction with the accompanying drawings in the embodiments of the present disclosure, and it is obvious that the embodiments described are merely a portion of embodiments of the present disclosure, not all embodiments. On the basis of the embodiments of the present disclosure, all other embodiments obtained by those of ordinary skill in the art without

making inventive efforts should all fall within the scope of protection of the present disclosure.

It should be noted that “first”, “second”, etc. in the description, claims and above-mentioned accompanying drawings of the present disclosure are used for distinguishing similar subjects instead of being used for describing a specific order or precedence order. It should be understood that data used in this way may be interchanged where appropriate, such that the embodiments of the present disclosure described herein may be implemented in an order other than those orders illustrated or described herein. In addition, the terms “including” and “being provided with” and any variations thereof are intended to cover the non-exclusive inclusion, and for example, a process, method, system, product, or device including a series of steps or units is not necessarily limited to those steps or units clearly listed, but may include other steps or units not clearly listed or inherent to such a process, method, product, or device.

The method embodiment provided in the embodiment of the disclosure may be executed in a mobile terminal, a computer terminal or a similar computing apparatus. For example, the method runs on the mobile terminal, and Fig. 1 is a structure block diagram of hardware of the mobile terminal of a flatness compensation method of an embodiment of the present disclosure. As shown in Fig. 1, the mobile terminal may include one (as shown in Fig. 1) or more processors 102 (the processor 102 may include, but not limited to, a processing apparatus, such as a microprogrammed control unit (MCU) or a field programmable gate array (FPGA)) and a memory 104 for storing data, where the mobile terminal may further include a transmission apparatus 106 with a communication function and an input/output device 108. Those of ordinary skill in the art may appreciate that the structure shown in Fig. 1 is merely schematic and does not pose a limitation on the structure of the above-mentioned mobile terminal. For example, the mobile terminal may further include more or fewer assemblies than that shown in Fig. 1, or have a different configuration from that shown in Fig. 1.

The memory 104 may be configured to store a computer program such as a software program and module of application software, for example, a computer program corresponding to the flatness compensation method in the embodiment of the present disclosure, and the processor 102 executes various functional applications and flatness compensation by running the computer program stored in the memory 104, that is, the above-mentioned method is achieved. The memory 104 may include a high-speed random access memory, and may further include a non-volatile memory, for example, one or more magnetic storage apparatuses, flash memories, or other non-volatile solid-state memories. In some examples, the memory 104 may further include memories remotely disposed with respect to the processor 102, the remote memories may be connected to the mobile terminal by means of networks. Examples of the above-mentioned

networks include, but not limited to, the Internet, enterprise intranets, local area networks, mobile communication networks, and combinations thereof.

The transmission apparatus 106 is configured to receive or transmit data by means of one network. Specific examples of the above-mentioned networks may include a wireless network provided by a communication provider of the mobile terminal. In one example, the transmission apparatus 106 includes a network interface controller (NIC), which may be connected to other network devices by means of a base station so as to communicate with the Internet. In one example, the transmission apparatus 106 may be a radio frequency (RF) module, which is configured to communicate wirelessly with the Internet.

Optionally, in this embodiment, the terminal device may include, but not limited to, at least one of: a cell phone (such as an Android cell phone and an iOS cell phone), a laptop computer, a tablet computer, a palmtop computer, Mobile Internet Devices (MID), a portable Android device (PAD), a desktop computer, etc. The above-mentioned networks may include, but not limited to, wired networks and wireless networks, where the wired networks include local area networks, metropolitan area networks and wide area networks, and the wireless networks include Bluetooth, WIFI, and other networks that achieve wireless communication. The above-mentioned server may be a single server or a server cluster composed of a plurality of servers. The foregoing is merely an example, and the present embodiment is not intended to do any limiting thereto.

Optionally, as an optional implementation, as shown in Fig. 2, the process of the above-mentioned flatness compensation method may include the steps:

Step S202, sample, at an oversampling interval, a gain of a transceiver link in a frequency range influenced by a baseband signal to obtain a gain sequence.

Optionally, during sampling of a baseband signal, an oversampling interval may be set to sample, at an oversampling manner, a gain of a transceiver link in a frequency range influenced by the baseband signal to obtain a gain sequence.

Step S204, generate a deviation sequence according to the gain sequence and a gain reference value, where the gain reference value is an expected flat link gain value.

Optionally, a gain reference value may be set in advance, and then one deviation sequence is generated according to the gain sequence and the gain reference value, where the gain reference value is an expected flat link gain value.

Step S206, conduct extraction on the deviation sequence with an oversampling multiple

corresponding to the oversampling interval to obtain an initial correction sequence, where the initial correction sequence is a subsequence of the deviation sequence.

Optionally, on the basis of the deviation sequence, further processing is conducted on the deviation sequence with an oversampling multiple corresponding to the oversampling interval to obtain the initial correction sequence, where the initial correction sequence is a subsequence of the deviation sequence.

Step S208, optimize the initial correction sequence to obtain an optimized correction sequence.

Optionally, the initial correction sequence is further optimized. For example, the initial correction sequence is optimized in an iterative manner to obtain an optimized correction sequence.

Step S210, convert the optimized correction sequence to obtain filter tap coefficients.

Optionally, on the basis of optimizing the initial correction sequence, the optimized correction sequence is converted to obtain filter tap coefficients.

Step S212, generate a target filter according to the filter tap coefficients, and compensate the baseband signal by using the target filter.

Optionally, the filter tap coefficients may be obtained according to the above-mentioned steps, then, a target filter is generated according to the filter tap coefficients, and therefore, the baseband signal may be compensated by using the target filter. Gain pre-compensation is conducted on the baseband signal by means of the filter, and the program of an uneven in-band gain caused by gain imbalance of device hardware may be solved.

It should be noted that the target filter may be a finite impulse response (FIR) filter.

Optionally, the above-mentioned flatness compensation method may be applied to, but not limited to, scenes such as gain pre-compensation of a baseband signal by means of a filter in a communication system. For example, in scenes where a receiver is used to receive a baseband signal and a transmitter is used to transmit the baseband signal, the baseband signal may be compensated in accordance with the above-mentioned flatness compensation method.

According to the embodiment, at an oversampling interval, the gain of the transceiver link in the frequency range influenced by the baseband signal is sampled to obtain the gain sequence; the deviation sequence is generated according to the gain sequence and the gain reference value, where the gain reference value is the expected flat link gain value; extraction is conducted on the deviation sequence with the oversampling multiple corresponding to the oversampling interval to

obtain the initial correction sequence, where the initial correction sequence is the subsequence of the deviation sequence; the initial correction sequence is optimized to obtain the optimized correction sequence; the optimized correction sequence is converted to obtain the filter tap coefficients; and the target filter is generated according to the filter tap coefficients, and the baseband signal is compensated by using the target filter. By means of the above-mentioned method, more information of the baseband signal may be obtained in the process of oversampling the baseband signal, and then the filter tap coefficients are determined step by step according to the information in the above-mentioned manner, such that the obtained filter tap coefficient is more accurate; and finally, the target filter is generated according to the filter tap coefficients, and the baseband signal is compensated by using the target filter, such that the compensation effect on the baseband signal is improved.

In one optional embodiment, before the step of sampling, at the oversampling interval, the gain of the transceiver link in the frequency range influenced by the baseband signal, the method further includes: set the number N of the filter tap coefficients and a compensation range R, where N is an integer larger than or equal to 2, the compensation range R∈[Fc-Fs/2, Fc+Fs/2], Fc is a radio frequency center frequency point corresponding to the baseband signal, and Fs is a baseband signal sampling rate; and

the step of sampling, at the oversampling interval, the gain of the transceiver link in the frequency range influenced by the baseband signal to obtain the gain sequence includes: sample, at the oversampling interval, the gain of the transceiver link in the compensation range R of the baseband signal to obtain N*K gain values, and obtain the gain sequence according to the N*K gain values, where the frequency range includes the compensation range R, the oversampling interval=Fs/(N*K), K is the oversampling multiple and is an integer greater than or equal to 2, the gain sequence is G(n)={g(0), g(1), ..., g(N*K-1)}, and the N*K gain values are g(0), g(1), ..., g(N*K-1).

Optionally, a suitable number N of the filter tap coefficients is selected according to hardware resource consumption, where N is an integer greater than or equal to 2.

The radio frequency range R which is set for compensation, and R may be a single range or a plurality of ranges. R satisfies R∈[Fc-Fs/2, Fc+Fs/2], where Fc is a radio frequency center frequency point corresponding to the baseband signal, and Fs is a baseband signal sampling rate. Further, gain values of the N*K sampling points are tested in the frequency range [Fc-Fs/2, Fc+Fs/2] by taking the radio frequency point Fc corresponding to the baseband signal DC as an original point and Fs/(N*K) as the oversampling interval. The measured gain values are arranged according to the frequency from small to large to obtain a sequence G(n)={g(0), g(1), ..., g(N*K-1)}, where a unit of the gain values is Db, and K is the oversampling multiple.

Optionally, in the embodiment, the step of generating the deviation sequence according to the gain sequence and the gain reference value includes: generate the deviation sequence according to the following formula:

$$C(n) = \begin{cases} T - G(n) & f(n) \in R \\ A & f(n) \notin R' \end{cases}$$

where G(n) is the gain sequence, C(n) is the deviation sequence, T is the gain reference value, f(n) is a function related to n radio frequency points corresponding to the baseband signal, A is an expected stop-band gain of the target filter and is a preset value set according to N.

f(n) is a mapping function of an element index in the G(n) sequence and a radio frequency point corresponding to the baseband signal, and the deviation sequence is a target reference of target filter response. A is the expected stop-band gain of the target filter, is usually set according to the number of the filter tap coefficients, and may be generally set by means of the formula A=-10*log2(N).

In one optional embodiment, the step of extracting the deviation sequence with the oversampling multiple corresponding to the oversampling interval to obtain the initial correction sequence includes: obtain the initial correction sequence according to the following formula:

$$D(n) = \begin{cases} C(Kn) & N \text{ being an odd number} \\ C(Kn+1) & N \text{ being an even number} \end{cases} \quad (n = 0,1,\dots,N-1),$$

where C(n) is the deviation sequence, D(n) is the initial correction sequence, K is the oversampling multiple corresponding to the oversampling interval and is an integer greater than or equal to 2.

In one optional embodiment, the step of optimizing the initial correction sequence to obtain the optimized correction sequence includes: input the initial correction sequence into an iterator; and iteratively optimize the initial correction sequence in the iterator according to the following formula:

$$P = \begin{bmatrix} B(n) \\ \vdots \\ B(n) \end{bmatrix} + STEP \cdot I_N, \text{ and}$$

$$M = \begin{bmatrix} B(n) \\ \vdots \\ B(n) \end{bmatrix} - STEP \cdot I_N,$$

where P and M are both perturbation matrices of N*N, STEP is an iterative step size, IN is a unit matrix of N*N, and an initial sequence of B(n) is the initial correction sequence D(n); filter conversion is conducted on elements in each row of P and M, and deviation values of the elements

in each row of P and M are calculated; the deviation values of the elements in each row are stored into corresponding rows of corresponding result matrices Rp and Rm; a minimum value in Rp and Rm is determined, and a corresponding row element sequence in a matrix corresponding to the minimum value is taken as a correction sequence R(n) output by the iterator; and the correction sequence R(n) output at the last time is determined as the optimized correction sequence O(n) in a case that a convergence condition is satisfied.

Optionally, the initial correction sequence is input into an iterator and is processed according to the above-mentioned manner to obtain a result R(n) output by the iterator for the first time, the output result R (n) at the first time is input into the iterator again, cyclic processing continues according to the above-mentioned manner to obtain an output result R(n) at the second time, ..., and so on until a convergence condition is satisfied, and the output result of the iterator at the last time is taken as a final optimization correction sequence O(n).

In one optional embodiment, the step of converting the optimized correction sequence to obtain the filter tap coefficients includes: obtain the filter tap coefficients according to the following formula:

$L(n) = 10^{\frac{O(n)}{20}}$, n=(0, 1, ..., N-1), and

$$\mathrm{H(n)} = \sum_{k=0}^{\mathrm{N}-1} \frac{\mathrm{L(k)}}{\mathrm{N}} \cdot \exp\left[\frac{2\mathrm{i}*\pi}{\mathrm{N}} * \left(\mathrm{n} - \frac{\mathrm{N}-1}{2}\right) * \left(\mathrm{k} - \left\lfloor\frac{\mathrm{N}}{2}\right\rfloor\right)\right],$$

where H(n) is the filter tap coefficients, and O(n) is the optimized correction sequence.

It should be noted that i is a complex symbol.

In one optional embodiment, after the step of converting the optimized correction sequence to obtain the filter tap coefficients, the method further includes: obtain a deviation value sequence and a target deviation value according to the following formula:

$$K(n) = \begin{cases} H(n) & 0 \le n < N \\ 0 & N \le n < K * N \end{cases},$$

$$P(n) = DFT\big(K(n)\big), n = 0,1,2 \dots, K * N - 1,$$

$$Q(n) = \{P\left(\left\lfloor\frac{KN}{2}\right\rfloor\right), P\left(\left\lfloor\frac{KN}{2}\right\rfloor + 1\right), \dots P(KN-1), P(0), P(1) \dots P\left(\left\lfloor\frac{KN}{2}\right\rfloor - 1\right)\},$$

$$M(n) = 20 * log_{10}(|Q(n)|) \qquad n = 0,1, \dots, N * K - 1,$$

$$E(n) = \begin{cases} C(n) - M(n) & f(n) \in R \\ 0 & f(n) \notin R \end{cases}, \text{ and}$$

$E = Max(E(n)) - Min(E(n))$; and

generate a compensation curve according to E(n), and evaluate a compensation effect of the baseband signal according to the compensation curve and the target deviation value E, where E(n) is the deviation value sequence, E is the target deviation value and is an evaluation value of a flatness peak-to-peak value of the compensation curve.

The process of the flatness compensation method is described below in combination with one optional example, and as shown in Fig. 3, the method may include the following steps:

It should be noted that the test interval frequency is required to be equal to the baseband signal sampling rate/the number of the tap coefficient in test steps of a receiver and a transmitter, in order to reduce resource consumption, when the number of the tap coefficient is small, a test interval is large, test data fail to reflect high-frequency fluctuation and detail loss of an in-band gain, and finally compensation performance is reduced. A filter generated by using the IFFT or training method generally fails to accurately evaluate a compensated in-band flatness peak-to-peak value. Therefore, the compensation performance may be better and the compensated in-band flatness peak-to-peak value may be better evaluated only by finding a more suitable tap coefficient.

Step 1, set the number of the filter tap coefficients. Optionally, a suitable number N of the filter tap coefficients is selected according to hardware resource consumption, where N is an integer greater than or equal to 2.

Step 2, set the radio frequency range R which is set for compensation. Optionally, R may be a single interval or may be a plurality of intervals. R satisfies R∈[Fc-Fs/2, Fc+Fs/2], where Fc is a radio frequency center frequency point, and Fs is a baseband signal sampling rate.

Step 3: measure a gain curve. Optionally, gain values of N*K sampling points are tested in the frequency interval [Fc-Fs/2, Fc+Fs/2] by taking the radio frequency point Fc corresponding to the baseband signal DC as an original point and Fs/(N*K) as the oversampling interval. The measured gain values are arranged according to the frequency from small to large to obtain a sequence G(n)={g(0), g(1), ..., g(N*K-1)}, where a unit of the gain values is Db, and K is the oversampling multiple.

Step 4: set a gain reference value T. Optionally, the reference value T is an expected flat link gain value.

Step 5: generate a deviation sequence C(n). Optionally, the deviation sequence C(n) is generated according to the following formula:

$$\mathrm{C(n)} = \begin{cases} T - G(n) & f(n) \in R \\ A & f(n) \notin R \end{cases},$$

where f(n) is a mapping function of an element index in the G(n) sequence and a radio frequency point corresponding to the baseband signal, and the deviation sequence is a target reference of target filter response. Optionally, T is the gain reference value, namely, the expected flat link gain value. A is the expected stop-band gain of the target filter, is usually set according to the number of the filter tap coefficients, and may be generally set by means of the formula A=-10*log2(N).

Step 6: generate an initial correction sequence D(n). Optionally, D(n) is a subsequence of the deviation sequence, where C(n) is K times D(n), and D(n) may be obtained by selecting portion of values from C(n).

$$\mathrm{D(n)} = \begin{cases} \mathrm{C(Kn)} & \mathrm{N\ being\ an\ odd\ number} \\ \mathrm{C(Kn+1)} & \mathrm{N\ being\ an\ even\ number} \end{cases} \quad (n = 0,1,\dots,N-1).$$

Step 7: generate an optimized correction sequence O(n). Optionally, the method for generating the optimized correction sequence O(n) specifically includes the following steps: step (1) input a correction sequence B(n) having a length N into an iterator, where an initial sequence of B(n) is the initial correction sequence D(n); step (2) introduce a perturbation matrix P of N*N, and M is defined as follows:

$$\mathrm{P} = \begin{bmatrix} B(n) \\ \vdots \\ B(n) \end{bmatrix} + STEP \cdot I_N, \text{ and}$$

$$\mathrm{M} = \begin{bmatrix} B(n) \\ \vdots \\ B(n) \end{bmatrix} - STEP \cdot I_N,$$

where STEP is an iterative step size, and I_N is a unit matrix of N*N;

step (3) conduct filter conversion on elements in each row of P and M matrices, calculate deviation values E of the elements in each row of P and M matrices, and store results thereof into corresponding rows of corresponding result matrices Rp and Rm, where the result matrix has a size of 1*N; and

step (4) obtain a minimum unit in Rp and Rm by means of comparison, take the minimum unit as a deviation value of current iteration to be output, and take a corresponding row element sequence of the matrix corresponding to the minimum value as an iteration output correction sequence R(n).

It should be noted the iteration steps in the above-mentioned steps (1)-(4) may be set in the following manner: by passing the iteration output R(n) to the iteration input B(n), the optimized correction sequence O(n) and the final deviation value Ef may be obtained by cycling the above-mentioned steps (1)-(4) multiple times. The step size value of iteration may be changed to conduct multi-section execution, for example, the iteration is conducted by using a smaller step size 0.01 after a certain number of times of iteration with STEP=0.1, such that the convergence speed and the performance are optimized.

Optionally, in a process of determining the optimized correction sequence O(n), the convergence condition may be set in the following manner: 1, the number of iterations is fixed; 2, the deviation value E does not change significantly (for example, is smaller than a set threshold value) after a certain number of iterations; and 3, the deviation value E reaches a system expectation.

Optionally, the filter conversion method is as follows: assume that the input is the correction sequence O(n), the output is the filter tap coefficients H(n), and all lengths are N.

The correction sequence O(n) in units of Db will be converted into a linear correction sequence L(n),

$L(n) = 10^{\frac{O(n)}{20}}\ n = (0,1, \dots, N-1)$, and

$$\mathrm{H(n)} = \sum_{k=0}^{N-1} \frac{L(k)}{N} \cdot \exp\left[\frac{2i*\pi}{N} * \left(n - \frac{N-1}{2}\right) * \left(k - \left\lfloor \frac{N}{2} \right\rfloor\right)\right].$$

Optionally, how to generate the deviation value is described in detail below:

The input is the filter tap coefficients H(n) and the deviation sequence C(n), the output is the deviation value E, the smaller the deviation value represents the better a compensation effect of the filter tap coefficients are, and the generation method is as follows:

S1, add 0 to H(n) to obtain a new sequence K(n), where the specific formula is as follows:

$$K(n) = \begin{cases} H(n) & 0 \le n < N \\ 0 & N \le n < K*N \end{cases},$$

S2, conduct K*N point DFT processing on K(n) to obtain a sequence P(n), where the specific formula is as follows:

$P(n) = DFT(K(n)), n = 0,1,2 \dots, K*N-1;$

S3, conduct sequence adjustment on P(n), and exchange front and back portions to obtain a

new sequence Q(n), where the specific formula is as follows:

$$Q(n) = \{P\left(\left\lfloor\frac{KN}{2}\right\rfloor\right), P\left(\left\lfloor\frac{KN}{2}\right\rfloor + 1\right), \ldots P(KN-1), P(0), P(1) \ldots P\left(\left\lfloor\frac{KN}{2}\right\rfloor - 1\right)\};$$

S4, conduct modular computation on each element in Q(n), and take logarithm to obtain M(n), where the specific formula is as follows:

$M(n) = 20 * log_{10}(|Q(n)|)$ $\quad n = 0,1, \ldots, NK-1$, and

M(n) is a gain compensation value of the filter coefficient H(n) on each sampling point in S3, and is arranged according to the frequency from small to large;

S5, calculate a compensation deviation sequence E(n) which reflects a compensation residual error of the filter at each frequency point, where the specific formula is as follows:

$$E(n) = \begin{cases} C(n) - M(n) & f(n) \in R \\ 0 & f(n) \notin R \end{cases}$$; and

S6, calculate the deviation value $E = Max(E(n)) - Min(E(n))$,

where a minimum value is subtracted from a maximum value in the deviation value sequence E(n) to obtain the deviation value.

Step 8, generate the filter tap coefficients,

where filter conversion is conducted on O(n) by using the filter conversion method introduced in the step 7 to obtain the filter tap coefficients of a final FIR filter.

Step 9, generate the compensation curve,

where a sequence formed by T-E(n) at the end of iteration is taken to represent an expected curve of a system gain after compensation, and obtained E is an evaluation value of the flatness peak-to-peak value of the system after compensation.

By means of the embodiment, in the case that the FIR filter tap coefficient is not changed and caused hardware resource consumption is not changed, the filter tap coefficients obtained by means of the above-mentioned manner may obtain a better compensation effect. More information of the baseband signal is obtained at an oversampling interval, the information is comprehensively processed, and an iterative algorithm is used to found a more suitable filter tap coefficient. In the case that the finally generated filter tap coefficient is not changed, a better curve may be obtained, a filter which may compensate the curve more is finally obtained, and the compensation effect is improved.

It should be noted that all foregoing method embodiments are expressed as combinations of a series of actions for simplicity of description, but it should be understood by those skilled in the art that the present disclosure is not limited by the order of the actions described as some steps may be performed in other orders or concurrently in accordance with the present disclosure. Secondly, it should also be understood by those skilled in the art that the embodiments described in the specification all belong to the preferred embodiments and the actions and modules involved are not necessarily required by the present disclosure.

According to yet another aspect of the embodiment of the present disclosure, further provided is a flatness compensation apparatus. As shown in Fig. 3, the apparatus includes:

a first processing unit 402, configured to sample, at an oversampling interval, a gain of a transceiver link in a frequency range influenced by a baseband signal to obtain a gain sequence;

a second processing unit 404, configured to generate a deviation sequence according to the gain sequence and a gain reference value, where the gain reference value is an expected flat link gain value;

a third processing unit 406, configured to conduct extraction on the deviation sequence with an oversampling multiple corresponding to the oversampling interval to obtain an initial correction sequence, where the initial correction sequence is a subsequence of the deviation sequence;

an optimization unit 408, configured to optimize the initial correction sequence to obtain an optimized correction sequence;

a conversion unit 410, configured to convert the optimized correction sequence to obtain filter tap coefficients; and

a fourth processing unit 412, configured to generate a target filter according to the filter tap coefficients, and compensate the baseband signal by using the target filter.

According to the embodiment, at an oversampling interval, the gain of the transceiver link in the frequency range influenced by the baseband signal is sampled to obtain the gain sequence; the deviation sequence is generated according to the gain sequence and the gain reference value, where the gain reference value is the expected flat link gain value; extraction is conducted on the deviation sequence with the oversampling multiple corresponding to the oversampling interval to obtain the initial correction sequence, where the initial correction sequence is the subsequence of the deviation sequence; the initial correction sequence is optimized to obtain the optimized correction sequence; the optimized correction sequence is converted to obtain the filter tap

coefficients; and the target filter is generated according to the filter tap coefficients, and the baseband signal is compensated by using the target filter. By means of the above-mentioned manner, more information of the baseband signal may be obtained in the process of oversampling the baseband signal, and then the filter tap coefficients are determined step by step according to the information in the above-mentioned manner, such that the obtained filter tap coefficient is more accurate; and finally, the target filter is generated according to the filter tap coefficients, and the baseband signal is compensated by using the target filter, such that the compensation effect on the baseband signal is improved.

As an optional technical solution, the above-mentioned apparatus further includes: a setting unit, configured to set, before the step of sampling, at the oversampling interval, the gain of the transceiver link in the frequency range influenced by the baseband signal, the number N of the filter tap coefficients and a compensation range R, where N is an integer larger than or equal to 2, the compensation range R∈[Fc-Fs/2, Fc+Fs/2], Fc is a radio frequency center frequency point corresponding to the baseband signal, and Fs is a baseband signal sampling rate; and the first processing unit is further configured to sample, at the oversampling interval, the gain of the transceiver link in the compensation range R of the baseband signal to obtain N*K gain values, and obtain the gain sequence according to the N*K gain values, where the frequency range includes the compensation range R, the oversampling interval=Fs/(N*K), K is the oversampling multiple and is an integer greater than or equal to 2, the gain sequence is G(n)={g(0), g(1), ..., g(N*K-1)}, and the N*K gain values are g(0), g(1), ..., g(N*K-1).

As an optional technical solution, the above-mentioned second processing unit is further configured to generate the deviation sequence according to the following formula:

$$C(n) = \begin{cases} T - G(n) & f(n) \in R \\ A & f(n) \notin R' \end{cases}$$

where G(n) is the gain sequence, C(n) is the deviation sequence, T is the gain reference value, f(n) is a function related to n radio frequency points corresponding to the baseband signal, A is an expected stop-band gain of the target filter and is a preset value set according to N.

As an optional technical solution, the above-mentioned third processing unit is further configured to obtain the initial correction sequence according to the following formula:

$$D(n) = \begin{cases} C(Kn) & N \text{ being an odd number} \\ C(Kn+1) & N \text{ being an even number} \end{cases} \quad (n = 0,1,\dots,N-1),$$

where C(n) is the deviation sequence, D(n) is the initial correction sequence, K is the oversampling multiple corresponding to the oversampling interval and is an integer greater than or

equal to 2.

As an optional technical solution, the above-mentioned optimization unit is further configured to input the initial correction sequence into an iterator, and iteratively optimize the initial correction sequence in the iterator according to the following formula:

$$\mathrm{P} = \begin{bmatrix} B(n) \\ \vdots \\ B(n) \end{bmatrix} + STEP \cdot I_N, \text{ and}$$

$$\mathrm{M} = \begin{bmatrix} B(n) \\ \vdots \\ B(n) \end{bmatrix} - STEP \cdot I_N,$$

where P and M are both perturbation matrices of N*N, STEP is an iterative step size, IN is a unit matrix of N*N, and an initial sequence of B(n) is the initial correction sequence D(n); filter conversion is conducted on elements in each row of P and M, and deviation values of the elements in each row of P and M are calculated; the deviation values of the elements in each row are stored into corresponding rows of corresponding result matrices Rp and Rm; a minimum value in Rp and Rm is determined, and a corresponding row element sequence in a matrix corresponding to the minimum value is taken as a primary correction sequence R(n) output by the iterator; and the R(n) correction sequence output at the last time is determined as the optimized correction sequence O(n) in a case that a convergence condition is satisfied.

As an optional technical solution, the above-mentioned conversion unit is further configured to obtain the filter tap coefficients according to the following formula:

$L(n) = 10^{\frac{O(n)}{20}}$, n=(0, 1, ..., N-1), and

$$\mathrm{H(n)} = \sum_{k=0}^{\mathrm{N}-1} \frac{\mathrm{L(k)}}{\mathrm{N}} \cdot \exp\left[\frac{2\mathrm{i}*\pi}{\mathrm{N}} * \left(\mathrm{n} - \frac{\mathrm{N}-1}{2}\right) * \left(\mathrm{k} - \left\lfloor\frac{\mathrm{N}}{2}\right\rfloor\right)\right],$$

where H(n) is the filter tap coefficients, and O(n) is the optimized correction sequence.

As an optional technical solution, the above-mentioned apparatus further includes: obtaining a deviation value sequence and a target deviation value according to the following formula:

$$K(n) = \begin{cases} H(n) & 0 \leq n < N \\ 0 & N \leq n < K * N \end{cases},$$

$$P(n) = DFT\big(K(n)\big), n = 0,1,2 \ldots, K * N - 1,$$

$$Q(n) = \{P\left(\left\lfloor\frac{KN}{2}\right\rfloor\right), P\left(\left\lfloor\frac{KN}{2}\right\rfloor + 1\right), \ldots P(KN-1), P(0), P(1) \ldots P\left(\left\lfloor\frac{KN}{2}\right\rfloor - 1\right)\},$$

$$M(n) = 20 * log_{10}(|Q(n)|) \qquad n = 0,1,\dots,N * K - 1,$$

$$E(n) = \begin{cases} C(n) - M(n) & f(n) \in R \\ 0 & f(n) \notin R \end{cases}, \text{ and}$$

$$E = Max(E(n)) - Min(E(n)).$$

A compensation curve is generated according to E(n), and a compensation effect of the baseband signal is evaluated according to the compensation curve and the target deviation value E, where E(n) is the deviation value sequence, E is the target deviation value and is an evaluation value of a flatness peak-to-peak value of the compensation curve.

According to still another aspect of the embodiment of the present disclosure, further provided is a non-transitory computer-readable storage medium. A computer program is stored in the storage medium, where the computer program is configured to execute the steps of any one of the above-mentioned method embodiments when running by a processor~~at runtime~~.

Optionally, in this embodiment, the above-mentioned storage medium may be configured to store setting so as to execute the computer program in the following steps: S1, sample, at an oversampling interval, a gain of a transceiver link in a frequency range influenced by a baseband signal to obtain a gain sequence; S2, generate a deviation sequence according to the gain sequence and a gain reference value, where the gain reference value is an expected flat link gain value; S3, conduct extraction on the deviation sequence with an oversampling multiple corresponding to the oversampling interval to obtain an initial correction sequence, where the initial correction sequence is a subsequence of the deviation sequence; S4, optimize the initial correction sequence to obtain an optimized correction sequence; S5, convert the optimized correction sequence to obtain filter tap coefficients; and S6, generate a target filter according to the filter tap coefficients, and compensate the baseband signal by using the target filter.

Optionally, in this embodiment, the above-mentioned storage medium may be configured to store setting so as to execute the computer program in the above-mentioned steps.

Optionally, in this embodiment, those of ordinary skill in the art may appreciate that all or portion of the steps in the various methods of the above-mentioned embodiments may be accomplished by instructing hardware associated with a terminal device by means of a program, which may be stored in a computer-readable storage medium, which may include: a flash disk, a read-only memory (ROM), a random access memory (RAM), a magnetic or optical disk, etc.

According to still another aspect of the embodiment of the present disclosure, further provided is an electronic apparatus which is configured to execute the above-mentioned flatness

compensation method. The electronic apparatus includes a memory 502 and a processor ~~505~~504, where the memory 502 stores a computer program, and the processor 504 is configured to execute the steps of any one of the above-mentioned method embodiments by means of the computer program.

Optionally, in this embodiment, the above-mentioned electronic apparatus may be located in at least one network device of a plurality of network devices.

Optionally, in this embodiment, the above-mentioned processor may be configured to execute, by means of the computer program, the following steps: S1, sample, at an oversampling interval, a gain of a transceiver link in a frequency range influenced by a baseband signal to obtain a gain sequence; S2, generate a deviation sequence according to the gain sequence and a gain reference value, where the gain reference value is an expected flat link gain value; S3, conduct extraction on the deviation sequence with an oversampling multiple corresponding to the oversampling interval to obtain an initial correction sequence, where the initial correction sequence is a subsequence of the deviation sequence; S4, optimize the initial correction sequence to obtain an optimized correction sequence; S5, convert the optimized correction sequence to obtain filter tap coefficients; and S6, generate a target filter according to the filter tap coefficients, and compensate the baseband signal by using the target filter.

Optionally, those of ordinary skill in the art may appreciate that the structure shown in Fig. 5 is illustrative only, and the electronic apparatus may be a smartphone (such as an Android cell phone and an iOS cell phone), a tablet computer, a palmtop computer, Mobile Internet Devices (MID), a portable Android device (PAD) and other terminal devices. Fig. 5 does not limit the structure of the electronic apparatus. For example, the electronic apparatus may further include more or fewer assemblies (such as a network interface) than that shown in Fig. 5, or have a different configuration from that shown in Fig. 5. The memory 502 may be configured to store a software program and module, for example, a program instruction/module corresponding to the flatness compensation method and apparatus in the embodiment of the present disclosure. The processor 504 executes various functional applications and flatness compensation by running the software program and module stored in the memory 502, that is, the above-mentioned flatness compensation method is achieved. The memory 502 may include a high-speed random access memory, and may further include a non-volatile memory, such as one or more magnetic storage apparatuses, flash memories, or other non-volatile solid-state memories. In some examples, the memory 502 may further include a memory remotely disposed with respect to the processor 504, the remote memory may be connected to a terminal by means of networks. Examples of the above-mentioned networks include, but not limited to, the Internet, enterprise intranets, local area networks, mobile communication

networks, and combinations thereof. Particularly, the memory 502 may, but not limited to, be configured to store information such as a target height of a target object. As an example, as shown in Fig. 5, the above-mentioned memory 502 may include, but not limited to, the first processing unit 402, the second processing unit 404, the third processing unit 406, the optimization unit 408, the conversion unit 410, and the fourth processing unit 412 in the above-mentioned flatness compensation apparatus. In addition, the memory may further include, but not limited to, other modular units in the above-mentioned flatness compensation apparatus, which is not repeated in this example.

Optionally, the above-mentioned transmission apparatus 506 is configured to receive or transmit data by means of one network. Specific examples of the above-mentioned network may include a wired network and a wireless network. In one example, the transmission apparatus 506 includes a network interface controller (NIC), and may be connected to other network devices and a router by means of a network cable so as to communicate with the Internet or a local area network. In one example, the transmission apparatus 506 is of a radio frequency (RF) module, which is configured to communicate wirelessly with the Internet.

In addition, the above-mentioned electronic apparatus also includes: a connection bus 508 configured to connect each of module components in the above-mentioned electronic apparatus.

In other embodiments, the terminal or server may be a node in a distributed system, where the distributed system may be a blockchain system, and the blockchain system may be a distributed system formed by connecting a plurality of nodes via network communication, where the nodes may form a peer to peer (P2P) network, and a computing device in any form, such as a server, a terminal, etc. may be added to the P2P network to become one node in the blockchain system.

Optionally, in this embodiment, those of ordinary skill in the art may appreciate that all or portion of the steps in the various methods of the above-mentioned embodiments may be accomplished by instructing hardware associated with a terminal device by means of a program, which may be stored in a computer-readable storage medium, which may include: a flash disk, a read-only memory (ROM), a random access memory (RAM), a magnetic or optical disk, etc.

The serial numbers of the above-mentioned embodiments of the present disclosure are for description only and do not indicate the advantages and disadvantages of the embodiments.

An integrated unit in the above-described embodiment may be stored in the above-mentioned computer-readable memory medium if implemented in the form of a software functional unit and sold or used as a stand-alone product. With such understanding, the technical solution of the

present disclosure, in essence or from the view of portion contributing to the prior art, or all or portion of the technical solution may be embodied in the form of a software product, and the computer software product is stored in the memory medium and includes several instructions configured to make one or more computer devices (which may be personal computers, servers, network devices, etc.) conduct all or portion of the steps of the method in each of the embodiments of the present disclosure.

In the above-mentioned embodiments of the present disclosure, description for each of the embodiments has its own emphasis, and the portion which is not described in detail in a certain embodiment may refer to relevant description in other embodiments.

In the several embodiments provided by the disclosure, it should be understood that a disclosed client may be implemented in other ways. The apparatus embodiments described above are merely illustrative, for example, a division of the units may be a division of logical functions, and in practice there may be additional ways of division, for example, a plurality of units or assemblies may be combined or integrated into another system, or some features may be ignored or not performed. Furthermore, shown or discussed coupling or direct coupling or communication connection between each other may be an indirect coupling or communication connection by means of some interface, unit or module, and may be in an electrical or other form.

The units described as separated parts may be physically separated or not, and the parts displayed as units may be physical units or not, that is, they may be located in one place or distributed to multiple network units. Some or all of the units may be selected according to actual needs to achieve the objective of the solution of the embodiment.

In addition, all functional units in each of the embodiments of the present disclosure may be integrated into one processing unit, or may be independently and physically present, or two or more units may be integrated into one unit. The above-mentioned integrated unit may be implemented in the form of hardware or a software functional unit.

The above mentioned description is merely the preferred implementation of the present disclosure, it should be pointed out that those of ordinary skill in the art may also make some improvements and modifications without departing from the principle of the present disclosure, and these improvements and modifications should also fall within the scope of protection of the present disclosure.

Industrial Applicability

As mentioned above, the flatness compensation method and apparatus, the storage medium

and the electronic device provided by the embodiments of the present disclosure have the beneficial effects as follows: more information of the baseband signal may be obtained in the process of oversampling the baseband signal, and then the filter tap coefficients are determined step by step according to the information in the above-mentioned manner, such that the obtained filter tap coefficient is more accurate; and finally, the target filter is generated according to the filter tap coefficients, and the baseband signal is compensated by using the target filter, such that the compensation effect on the baseband signal is improved.

Claims

1. A flatness compensation method, comprising:

sampling, at an oversampling interval, a gain of a transceiver link in a frequency range influenced by a baseband signal to obtain a gain sequence;

generating a deviation sequence according to the gain sequence and a gain reference value, wherein the gain reference value is an expected flat link gain value;

extracting the deviation sequence with an oversampling multiple corresponding to the oversampling interval to obtain an initial correction sequence, wherein the initial correction sequence is a subsequence of the deviation sequence;

optimizing the initial correction sequence to obtain an optimized correction sequence;

converting the optimized correction sequence to obtain filter tap coefficients; and

generating a target filter according to the filter tap coefficients, and compensating the baseband signal by using the target filter.

2. The method according to claim 1, wherein

before sampling, at the oversampling interval, the gain of the transceiver link in the frequency range influenced by the baseband signal, the method further comprises: setting the number N of the filter tap coefficients and a compensation range R, wherein N is an integer greater than or equal to 2, the compensation range $R \in [Fc-Fs/2, Fc+Fs/2]$, Fc is a radio frequency center frequency point corresponding to the baseband signal, and Fs is a baseband signal sampling rate; and

sampling, at the oversampling interval, the gain of the transceiver link in the frequency range influenced by the baseband signal to obtain the gain sequence comprises: sampling, at the oversampling interval, the gain of the transceiver link in the compensation range R of the baseband signal to obtain N*K gain values, and obtaining the gain sequence according to the N*K gain values, wherein the frequency range comprises the compensation range R, the oversampling interval = Fs/(N*K), K is the oversampling multiple and is an integer greater than or equal to 2, the gain sequence is G(n)={g(0), g(1), ..., g(N*K-1)}, and the N*K gain values are g(0), g(1), ..., g(N*K-1).

3. The method according to claim 1, wherein generating the deviation sequence according to

the gain sequence and the gain reference value comprises:

generating the deviation sequence according to the following formula:

$$\mathrm{C(n)} = \begin{cases} \mathrm{T} - \mathrm{G(n)} & \mathrm{f(n)} \in \mathrm{R} \\ \mathrm{A} & \mathrm{f(n)} \notin \mathrm{R} \end{cases}$$

wherein G(n) is the gain sequence, C(n) is the deviation sequence, T is the gain reference value, f(n) is a function related to n radio frequency points corresponding to the baseband signal, A is an expected stop-band gain of the target filter and is a preset value set according to N.

4. The method according to claim 1, wherein extracting the deviation sequence with the oversampling multiple corresponding to the oversampling interval to obtain the initial correction sequence comprises:

obtaining the initial correction sequence according to the following formula:

$$\mathrm{D(n)} = \begin{cases} \mathrm{C(Kn)} & \mathrm{N\ being\ an\ odd\ number} \\ \mathrm{C(Kn+1)} & \mathrm{N\ being\ an\ even\ number} \end{cases} \quad (\mathrm{n} = 0,1,\dots,\mathrm{N}-1)$$

wherein C(n) is the deviation sequence, D(n) is the initial correction sequence, K is the oversampling multiple corresponding to the oversampling interval and is an integer greater than or equal to 2.

5. The method according to claim 4, wherein optimizing the initial correction sequence to obtain the optimized correction sequence comprises:

inputting the initial correction sequence into an iterator;

iteratively optimizing the initial correction sequence in the iterator according to the following formula:

$$\mathrm{P} = \begin{bmatrix} B(n) \\ \vdots \\ B(n) \end{bmatrix} + STEP \cdot I_N$$

$$\mathrm{M} = \begin{bmatrix} B(n) \\ \vdots \\ B(n) \end{bmatrix} - STEP \cdot I_N$$

wherein P and M are both perturbation matrices of N*N, STEP is an iteration step size, I_N is a unit matrix of N*N, and an initial sequence of B(n) is the initial correction sequence D(n);

conducting filter conversion on elements in each row of P and M, and calculating deviation values of the elements in each row of P and M;

storing the deviation values of the elements in each row into corresponding rows of corresponding result matrices Rp and Rm;

determining a minimum value in Rp and Rm, and taking a corresponding row element sequence in a matrix corresponding to the minimum value as a correction sequence R(n) output by the iterator; and

in a case that a convergence condition is satisfied, determining the correction sequence R(n) output at the last time as the optimized correction sequence O(n).

6. The method according to claim 1, wherein converting the optimized correction sequence to obtain the filter tap coefficients comprises:

obtaining the filter tap coefficients according to the following formula:

$L(n) = 10^{\frac{O(n)}{20}}$, n=(0, 1, ..., N-1)

$$\mathrm{H(n)} = \sum_{k=0}^{\mathrm{N-1}} \frac{\mathrm{L(k)}}{\mathrm{N}} \cdot \exp\left[\frac{2\mathrm{i} * \pi}{\mathrm{N}} * \left(\mathrm{n} - \frac{\mathrm{N}-1}{2}\right) * \left(\mathrm{k} - \left\lfloor\frac{\mathrm{N}}{2}\right\rfloor\right)\right]$$

wherein H(n) is the filter tap coefficients, and O(n) is the optimized correction sequence.

7. The method according to claim 6, wherein after converting the optimized correction sequence to obtain the filter tap coefficients, the method further comprises:

obtaining a deviation value sequence and a target deviation value according to the following formula:

$$K(n) = \begin{cases} H(n) & 0 \le n < N \\ 0 & N \le n < K * N \end{cases}$$

$$P(n) = DFT\big(K(n)\big), n = 0,1,2 \dots, K * N - 1$$

$$Q(n) = \{P\left(\left\lfloor\frac{KN}{2}\right\rfloor\right), P\left(\left\lfloor\frac{KN}{2}\right\rfloor + 1\right), \dots P(KN-1), P(0), P(1) \dots P\left(\left\lfloor\frac{KN}{2}\right\rfloor - 1\right)\}$$

$$M(n) = 20 * log_{10}(|Q(n)|) \qquad n = 0,1, \dots, N * K - 1$$

$$E(n) = \begin{cases} C(n) - M(n) & f(n) \in R \\ 0 & f(n) \notin R \end{cases}$$

$$E = Max(E(n)) - Min(E(n))$$

generating a compensation curve according to E(n), and evaluating a compensation effect of the baseband signal according to the compensation curve and the target deviation value E, wherein E(n) is the deviation value sequence, E is the target deviation value and is an evaluation value of a flatness peak-to-peak value of the compensation curve.

8. A flatness compensation apparatus, comprising:

a first processing unit, configured to sample, at an oversampling interval, a gain of a transceiver link in a frequency range influenced by a baseband signal to obtain a gain sequence;

a second processing unit, configured to generate a deviation sequence according to the gain sequence and a gain reference value, wherein the gain reference value is an expected flat link gain value;

a third processing unit, configured to extract the deviation sequence with an oversampling multiple corresponding to the oversampling interval to obtain an initial correction sequence, wherein the initial correction sequence is a subsequence of the deviation sequence;

an optimization unit, configured to optimize the initial correction sequence to obtain an optimized correction sequence;

a conversion unit, configured to convert the optimized correction sequence to obtain filter tap coefficients; and

a fourth processing unit, configured to generate a target filter according to the filter tap coefficients, and compensate the baseband signal by using the target filter.

9. A non-transitory computer-readable storage medium, comprising a stored program, wherein the program is configured to perform the method according to any one of claims 1 to 7 when running by a processor~~at runtime~~.

10. An electronic apparatus, comprising a memory and a processor, wherein a computer program is stored in the memory, and the processor is configured to run the computer program, so

as to perform the method according to any one of claims 1 to 7.

11. The method according to claim 1, wherein the target filter comprises a Finite Impulse Response (FIR) filter.

12. The method according to claim 2, wherein N is selected according to hardware resource consumption.

13. The method according to claim 2, wherein R comprises a single range or a plurality of ranges.

14. The method according to claim 3, wherein f(n) is a mapping function of an element index in G(n) and a radio frequency point corresponding to the baseband signal.

15. The method according to claim 3, wherein A is set according to the number of the filter tap coefficients.

16. The method according to claim 4, wherein A is set according to the following formula:

A=-10*log2(N).

17. The apparatus according to claim 8, wherein the apparatus further comprises:

a setting unit, configured to set, before sampling, at the oversampling interval, the gain of the transceiver link in the frequency range influenced by the baseband signal, the number N of the filter tap coefficients and a compensation range R, wherein N is an integer greater than or equal to 2, the compensation range R∈[Fc-Fs/2, Fc+Fs/2], Fc is a radio frequency center frequency point corresponding to the baseband signal, and Fs is a baseband signal sampling rate; and

the first processing unit is further configured to sample, at the oversampling interval, the gain of the transceiver link in the compensation range R of the baseband signal to obtain N*K gain values,

and obtain the gain sequence according to the N*K gain values, wherein the frequency range comprises the compensation range R, the oversampling interval = Fs/(N*K), K is the oversampling multiple and is an integer greater than or equal to 2, the gain sequence is G(n)={g(0), g(1), ..., g(N*K-1)}, and the N*K gain values are g(0), g(1), ..., g(N*K-1).

18. The apparatus according to claim 8, wherein the second processing unit is further configured to:

generate the deviation sequence according to the following formula:

$$C(n) = \begin{cases} T - G(n) & f(n) \in R \\ A & f(n) \notin R \end{cases}$$

wherein G(n) is the gain sequence, C(n) is the deviation sequence, T is the gain reference value, f(n) is a function related to n radio frequency points corresponding to the baseband signal, A is an expected stop-band gain of the target filter and is a preset value set according to N.

19. The apparatus according to claim 8, wherein the third processing unit is further configured to:

obtain the initial correction sequence according to the following formula:

$$D(n) = \begin{cases} C(Kn) & N \text{ being an odd number} \\ C(Kn+1) & N \text{ being an even number} \end{cases} \quad (n = 0,1,\dots,N-1)$$

wherein C(n) is the deviation sequence, D(n) is the initial correction sequence, K is the oversampling multiple corresponding to the oversampling interval and is an integer greater than or equal to 2.

20. The apparatus according to claim 19, wherein the optimization unit is further configured to:

input the initial correction sequence into an iterator;

iteratively optimize the initial correction sequence in the iterator according to the following formula:

$$P = \begin{bmatrix} B(n) \\ \vdots \\ B(n) \end{bmatrix} + STEP \cdot I_N$$

$$\mathrm{M} = \begin{bmatrix} B(n) \\ \vdots \\ B(n) \end{bmatrix} - STEP \cdot I_N$$

wherein P and M are both perturbation matrices of N*N, STEP is an iteration step size, I_N is a unit matrix of N*N, and an initial sequence of B(n) is the initial correction sequence D(n);

conduct filter conversion on elements in each row of P and M, and calculate deviation values of the elements in each row of P and M;

store the deviation values of the elements in each row into corresponding rows of corresponding result matrices Rp and Rm;

determine a minimum value in Rp and Rm, and take a corresponding row element sequence in a matrix corresponding to the minimum value as a correction sequence R(n) output by the iterator; and

in a case that a convergence condition is satisfied, determine the correction sequence R(n) output at the last time as the optimized correction sequence O(n).