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(54) A method of compensating for non-linearities in an end amplifier incorporated in a radio transmitter.

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(56) References cited :  
EP-A- 421 533  
EP-A- 423 666  
DE-A- 2 304 352  
FR-A- 2 469 826  
GB-A- 2 073 516  
US-A- 4 229 821  
US-A- 4 291 277

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## Description

## TECHNICAL FIELD

5 The present invention relates to a method of compensating for those non-linearities that occur in an end amplifier forming part of a radio transmitter which operates with linear, digital quadrature modulation. A radio transmitter of this kind is used, for instance, within mobile telephony in the mobile telephone part, for transmitting digitized speech, data and control information to a base station.

## 10 BACKGROUND ART

The radio transmitter of the mobile telephone in mobile telephony has a compact and space saving construction. The signal information (data, speech, control signals) to be transmitted are modulated on a carrier wave having a given angular frequency  $w_c$ . The modulation method applied is so-called quadrature modulation, 15 i.e. the carrier wave is divided into two quadrature components,  $\sin w_c t$  and  $\cos w_c t$ . These two components are then modulated with sine and cosine components of the information signal phase by, e.g., phase shift keying (QPSK). The information signal consists in a digital signal in the form of a bit flow of "ones" and "zeros". In the case of QPSK, a binary "one" corresponds to a given positive phase change or shift and a "zero" corresponds to a negative phase change or shift in the transmitted radio signal. The phase changes always start 20 from the phase position of the preceding bit, so that subsequent to filtration the phase of the transmitted radio signal will have continuous progress in the absence of abrupt changes.

In order to form the radio signal  $r(t)$  to be transmitted, it is therefore necessary to form the sine and cosine values of a given phase angle (= phase change), these values being projected onto the two carrier wave components in the modulation process. These two values are called quadrature components and are normally designated I and Q respectively. It is known to use waveform generators which comprise memory stores in which 25 these components are formed for a given phase change. For instance, US Patent Specification 4,229,821 describes a waveform generator which contains two table look-up memories for each  $\sin \phi$  and  $\cos \phi$ . These two memories are addressed by a signal vector  $\underline{a}$  with a given number of bits depending on the duration of the low-pass-filter impulse response (the impulse response of the premodulation filters) included in the tables. 30 The duration of the impulse response is normally truncated to a given number of bits, this number depending on the required quality of the transmitted radio signal.

Downstream of the modulator circuits in the transmitter is a final amplifier which operates in amplifying the radio signal  $r(t, \underline{a})$  to a given power for transmission from the transmitter antenna of the mobile telephone. Since the quadrature modulation applied is linear, i.e. the transmitted information influences both the amplitude and phase position of the radio signal, the amplification of the final amplifier must also be linear both 35 with respect to amplitude and phase position.

A known predistorsion method and arrangement to compensate a quadrature modulated radio signal for the non-linearities of the final amplifier is disclosed in the US patent 4,291,277. This compensation is made by comparing the incoming quadrature modulated signals I and Q with the predistorted and amplified quadrature signals in the final amplifier and in dependence on this comparison, a predistorsion RAM is updated. 40 This known method uses a feedback path which is avoided by the present method which instead addresses a predistorsion RAM at each instant of the incoming signal vector.

## DISCLOSURE OF THE INVENTION

45 The final stage of the transmitter, which normally consists of the end amplifier, operates in class C, i.e. its transistor circuits are biased so as to be located beneath the cut-off of the collector current when at rest. This means, however, that the quadrature components of an incoming signal will be distorted, because the amplifier does not operate within its linear range. Consequently, it is necessary to weigh the advantage of having the amplifier working within the class C region (high electric efficiency) against this disadvantage. 50 The present invention utilizes the fact that the waveform generator includes the aforesaid table units for forming the quadrature components, i.e. the signal which is later to be amplified. It is possible to compensate for the non-linearity of the final amplifier, by modifying the digital values stored in the table units.

The inventive method is therewith characterized by the features set forth in the characterizing clause of 55 the following Claim 1.

## BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described in more detail with reference to the accompanying drawings. Figure 1 is a block diagram of a theoretic model of a radio transmitter for digital modulation;

Figure 2 is a block diagram of a known type of waveform generator in a radio transmitter and in which the proposed invention is applied;

Figure 3 is a diagram which illustrates the quadrature components of the phase position of a radio signal; Figures 4a-4c illustrate the various positions of the quadrature components in a radio signal which varies in time;

Figure 5 is a block diagram of a hardware solution according to the proposed method;

Figure 6 is a block diagram illustrating another type of waveform generator to that shown in Figure 3, where the proposed method can be applied.

Figure 1 is a simplified block diagram of a quadrature modulator. An incoming signal is applied to an NRZ-converter 1, so as to form a binary coded signal. A premodulation filter 2 of lowpass character produces an impulse response of given length, which is determined by the number of transmitted symbols which are to be stored in the subsequent quadrature modulator 3 at each moment in time. The modulator 3 is described below with reference to Figures 3 and 4. A final stage 4 is connected to the output of the quadrature modulator and to the input of the transmitted antenna 5, so as to give the radio signal sufficient power upstream of the antenna.

The modulator 3 is a so-called QPSK-modulator and utilizes the division of the signal into quadrature components. These components consist of the projections of the radio signal on two versions of an imaginary carrier wave  $\sin \omega_c t$  and  $\cos \omega_c t$  phase-shifted through  $90^\circ$ , where  $\omega_c$  is the carrier angle frequency. The quadrature components or the quadrature signals have a lowpass character and constitute baseband signals.

In theory, QPSK has an infinite bandwidth. In practical applications, the modulation is always complemented with some form of prefiltration with the aid of the premodulation filter 2 illustrated in Figure 1.

The traditional method of generating a QPSK-signal prior to dividing the signal into quadrature signals with subsequent modulation, is to apply the binary signals to an array of digital flip-flops and analogue filters. Figure 2 illustrates a QPSK-generator with table look-up and a shift register whose length is equal to the number of bits (= two) used for QPSK. The shift register comprises a number of flip-flops D1-D7 equal to the number of symbols which are to be stored with respect to the impulse response of the premodulation filter. In the present case, each symbol consists of two bits and the number of symbols is equal to eight. The impulse response of the premodulation filter is thus truncated to a length which corresponds, in the present case, to the duration of eight symbols. The length of the impulse response is determined by the quality requirements placed on the generated radio signal. The shift register is terminated with an up-down counter QM which memorizes the output point of the waveforms of the symbol stored at that moment. This is necessary because the information is transferred by means of state transitions instead of absolute positions in the I-Q plane. Thus, during one symbol interval  $T_s$  the shift register D1-D8 and the memory counter QM store a signal vector  $\underline{\alpha}$  which consists of the symbol concerned and its nearest neighbour, and a value (in the counter QM) which denotes the starting point of the phase position.

Figure 3 is a rotating vector diagram of an arbitrary radio signal  $r(t, \underline{\alpha})$  which is to be transmitted with an absolute magnitude (amplitude)  $R(t, \underline{\alpha})$  and a phase angle  $\phi(t, \underline{\alpha})$ . The radio signal is divided into two quadrature components  $I(t, \underline{\alpha})$  and  $Q(t, \underline{\alpha})$ , which constitute "the projections" of the two carrierwave components  $\cos \omega_c t$  and  $\sin \omega_c t$  respectively of the carrierwave components and phase displaced through  $90^\circ$ . The quadrature components  $I(t, \underline{\alpha})$  and  $Q(t, \underline{\alpha})$  are stored in the table units ST and CT respectively in the modulator shown in Figure 2, for all possible signal vectors  $\underline{\alpha}$ . The following relationship applies for the radio signal  $r(t, \underline{\alpha})$ :

$$r(t, \underline{\alpha}) = R(t, \underline{\alpha}) \cdot \cos [\omega_c t + \phi(t, \underline{\alpha})]$$

where

$$R(t, \underline{\alpha}) = \sqrt{I^2(t, \underline{\alpha}) + Q^2(t, \underline{\alpha})}$$

and

$$\phi(t, \underline{\alpha}) = \arg [I(t, \underline{\alpha}) + j Q(t, \underline{\alpha})]$$

Figures 4a-4c illustrate three different radiosignals  $r(t, \underline{\alpha})$  corresponding to three different signal vectors  $\underline{\alpha}_1$ ,  $\underline{\alpha}_2$  and  $\underline{\alpha}_3$ , which are delivered from the shift register D1-D8 and the counter QM. Each of the signal vectors indicates the two quadrature components  $I(t, \underline{\alpha})$  in the table units ST and CT. These components are stored respectively as a sine and cosine waveform in the table units. The waveform samples are brought forward in sequence with the aid of the counter SR, and the thus obtained digital values are applied to the digital-analogue converters DAC1, DAC2. The signals are then low-pass filtered in the filters FR1, FR2 prior to modulation of the carrier waveform components in the multipliers M1, M2 and addition in the summing circuit ADD.

If the impulse response  $h_T$  of the premodulation filter is truncated to a given length  $N_T \cdot T_s$ , where  $N_T$  is an

integer and  $T_s$  is the symbol time, and if the truncated impulse response has its centre at  $t = 0$  and a propagation from  $-T_s N/2$  to  $+T_s N/2$ , the following expression is obtained for the quadrature components:

5

$$I(kT_s + t, \alpha) = \sum_{i=0}^{N_1-1} h_T(t+T_s \cdot [\frac{N_T}{2} 1 - i]) \cdot \cos(\frac{2\pi}{N} \cdot \alpha(i+k))$$

10

15

$$Q(kT_s + t, \alpha) = \sum_{i=0}^{N_1-1} h_T(t+T_s \cdot [\frac{N_T}{2} 1 - i]) \cdot \sin(\frac{2\pi}{N} \cdot \alpha(i+k))$$

20

It will be evident from the above formulae that  $I(t, \alpha)$  and  $Q(t, \alpha)$  are stored as cosine and sine waveforms respectively in respective table units ST and CT.

25 The aforescribed modulation method is linear, i.e. the relationship between incoming signal vectors  $\alpha$  and the output signals  $I(t, \alpha)$  and  $Q(t, \alpha)$  present a number of linear properties. This means, however, that the units included in the transmitter downstream of the table units must also be linear, in order to ensure that the relationship between incoming signal vectors and output signals will also be maintained, and thereby avoid impairing quality and disturbing other subscribers. The problem of obtaining a linear end amplifier F (Figure 2) can occur in particular. The method proposed in accordance with the invention ignores the problem of linearizing the end amplifier and instead endeavours to compensate for this non-linearity in the table units ST and CT.

If the transmission function of the end amplifier is  $H_R$  and  $H_\phi$  for the input signal amplitude  $R_1$  and its phase angle  $\phi_1$ , the following applies with respect to the output signal:

35

$$R_2 = H_R(R_1) \cdot R_1$$

$$\phi_2 = H_\phi(R_1) + \phi_1$$

The inverse of  $H_R$  and  $H_\phi$  can be written as:

$$R_1 = H_R^{-1}(R_2) \cdot R_2$$

and

40

$$\phi_1 = H_\phi^{-1}(R_2) + \phi_2$$

where

$$H_R^{-1} = 1/H_R \text{ and } H_\phi^{-1} = -H_\phi$$

The inverse transfer functions  $H_R^{-1}$  and  $H_\phi^{-1}$  can be calculated by measuring a number of output signals  $R_2$  for a given number of input signals  $R_1$  and constitute static time-independent functions.

45 In order to obtain a correct output signal from the distorted end amplifier F, it is necessary to modify the contents of the look-up tables ST and CT according to Figure 3 with  $H_R^{-1}$  and  $H_\phi^{-1}$ . This is effected mathematically in accordance with the following relationship:

50

$$i(t, \alpha) = H_R^{-1}(R) [I(t, \alpha) \cdot \cos H_\phi(R) - Q(t, \alpha) \cdot \sin H_\phi(R)] \tag{1}$$

$$q(t, \alpha) = H_R^{-1}(R) [I(t, \alpha) \sin H_\phi(R) + Q(t, \alpha) \cos H_\phi(R)]$$

55 where  $i(t, \alpha)$ ,  $q(t, \alpha)$  are the modified waveform values which are intended to replace the original values  $I(t, \alpha)$ ,  $Q(t, \alpha)$ .

Since  $H_R$  and  $H_\phi$  are statically time-independent functions, these functions can be stored in the tables ST and CT for the transfer function of a given final amplifier.

According to the foregoing, the value of  $R$  of a given signal vector  $\underline{\alpha}$  can be calculated from the relationship:

$$R = \sqrt{I^2(t, \underline{\alpha}) + Q^2(t, \underline{\alpha})} \quad (2)$$

since  $I(t, \underline{\alpha})$  and  $Q(t, \underline{\alpha})$  for the signal vector is stored in respective table units ST, CT. Thus, when  $R$  is known,  $H_R$  and  $H_\phi$  and therewith also  $H_R^{-1}$  and  $H_\phi^{-1}$  can be calculated. This enables the new coefficients in  $(t, \underline{\alpha})$  and  $q(t, \underline{\alpha})$  for the signal vector  $\underline{\alpha}$  to be calculated from the relationship (1) above.

Thus, in the case of a given signal vector  $\underline{\alpha}_k$  whose waveforms are to be calculated, the various steps in modifying the content  $I(t, \underline{\alpha})$  and  $Q(t, \underline{\alpha})$  in respective table units ST and CT will be as follows:

1. Calculation of the amplitude  $R$  from the non-modified values  $I(t, \underline{\alpha})$ ,  $Q(t, \underline{\alpha})$  for the signal vector  $\underline{\alpha}_k$  according to relationship (2) above.
2. Calculation of the value of the transfer functions  $H_R(R)$  and  $H_\phi(R)$  for the value of  $R$  calculated according to step 1. The transfer functions  $H_R(R)$  and  $H_\phi(R)$  are calculated from measuring data and stored in respective units ST and CT.
3. Calculation of the new modified values  $i(t, \underline{\alpha}_k)$  and  $q(t, \underline{\alpha}_k)$  from the relationship (1) above. The new values are stored during the whole of the sampling interval  $0 \leq t < T_s$ .
4. Sampling of the new values  $i(t, \underline{\alpha}_k)$ ,  $q(t, \underline{\alpha}_k)$  at the sampling time points  $t_1, t_2, \dots$  in a known manner during the symbol interval  $0 \leq t < T_s$ .
5. Transmission of the sampled digital values to the digital-analogue converters DAC1, DAC2 and further to remaining units according to Figure 2.
6. New signal vectors  $\underline{\alpha}_{k+1}$  occur over the inputs to the table units ST, CT from the registers D1-D8 and the quadrature memory QM, steps 1-5 above being repeated.

Figure 5 is a simplified block diagram which illustrates those memory and arithmetical units which effect modification of the quadrature components  $I(t, \underline{\alpha})$ ,  $Q(t, \underline{\alpha})$  stored in the table units ST and CT.

The non-modified (original) values of  $I(t, \underline{\alpha})$  and  $Q(t, \underline{\alpha})$  are obtained from an outgoing bus  $b_1$  at a given sampling time point  $t=t_1$ . These values are delivered to a calculating unit MR which calculates the value  $|r(t_1, \underline{\alpha})| = \sqrt{I(t_1, \underline{\alpha})^2 + Q(t_1, \underline{\alpha})^2} = R(t_1, \underline{\alpha})$ .

This calculated value  $R(t_1, \underline{\alpha})$  is caused to address two memory units MH1 and MH2. The memory unit MH1 stores a quantity of inverted values of the amplifying factor  $H_R(R)$ , i.e.  $H_R^{-1}(R)$  for different input signals  $R$  to the end amplifier F. The values  $H_R(R)$  can be obtained by carrying out measurements on the amplifier F and, according to the foregoing, constitute a static, time-independent function of  $R$ . The memory unit MH2 stores corresponding values  $H_\phi(R)$  of the phase characteristic of the end amplifier F, which similar to  $H_R(R)$  is static and time-independent. The memories MH1, MH2 thus constitute static addressable ROMs.

The addressed value of  $H_\phi(R)$  in the memory unit MH2 is applied to a table unit MS which calculates sine  $H_\phi(R)$  and cosine  $H_\phi(R)$ . These two values are transferred to the table units ST and CT and are multiplied by the non-modified values  $I(t_1, \underline{\alpha})$ ,  $Q(t_1, \underline{\alpha})$  according to relationship (1) above. The value of  $H_R^{-1}(R)$  is delivered to the memory unit MH1 at the same time and is multiplied by  $I(t_1, \underline{\alpha})$ ,  $Q(t_1, \underline{\alpha})$  according to (1).

When the next sampling takes place at  $t=t_2$  (but for the same symbol vector  $\underline{\alpha}$ ) the unit MR is again addressed and calculates the modified values  $i(t, \underline{\alpha})$ ,  $q(t, \underline{\alpha})$ , for  $t=t_2$  in the manner described above. The values  $i(t_1, \underline{\alpha})$ ,  $q(t_1, \underline{\alpha})$  are, at the same time, delivered to the digital-analogue converters DAC1, DAC2 over the busses  $b_2$ .

The above method for compensating non-linearities can also be applied with a quadrature modulator of the configuration illustrated in Figure 6. In this embodiment, the waveform generator tables have been divided into several part tables: One I-table and one Q-table of simplified form and two mutually identical waveform tables SV and CV. In this embodiment the coefficients in the tables ST and CT are modified in accordance with the method above described.

## Claims

1. A method suitable for an end amplifier (F) having a transfer function  $H_R$ ,  $H_\phi$ , said amplifier being included in a radio transmitter of the quadrature type for linear digital modulation based on table look-up of an incoming signal vector  $\alpha$  of given length containing the binary values of a momentary and an accumulated phase angle of an incoming information signal to the radio transmitter, said method comprising the steps of
  - storing (ST, CT) the digital values  $I(t, \alpha)$ ,  $Q(t, \alpha)$  of the sine and cosine waveforms associated with the quadrature components to be supplied to the end amplifier, said digital values being addressed by means of said signal vector  $\alpha$ ,

multiplying (M1, M2) and adding said quadrature components in order to project these on two carrier wave components (sine  $\omega_c t$ , cos  $\omega_c t$ ) before supplying the thus obtained quadrature modulated radio signal  $r(t, \alpha)$  to the end amplifier (F), and

modifying said digital quadrature component values  $I(t, \alpha)$ ,  $Q(t, \alpha)$  in dependence on amplitude and phase values which are supplied to the end amplifier for various input signals,

**characterized in**

storing (MH1, MH2), before operation of the radio transmitter a plurality of the inverse amplifying values ( $H_R^{-1}$ ) and the corresponding phase value ( $H_\phi$ ) of the transfer function of the end amplifier for various values of the incoming information signal to the radio transmitter, and

modifying said quadrature component values by

a) calculating an absolute value of said quadrature modulated radio signal  $r(t, \alpha)$  from said quadrature component values as non-compensated and, for each instant ( $t_1$ ),

b) addressing said plurality of stored inverse amplifying values and corresponding phase values in dependence on said calculated absolute value,

c) forming (MS) sine- and cosine component values ( $\sin H_\phi$ ,  $\cos H_\phi$ ) of said phase value addressed in step b), and

d) multiplying the inverse amplifying values obtained in step b) by the sine- and cosine values obtained in step c) combined with the non-modified quadrature component values  $I(t, \alpha)$ ,  $Q(t, \alpha)$ , respectively, such as to get modified quadrature component values  $i(t, \alpha)$ ,  $q(t, \alpha)$  with amplitude and phase modified in dependence on said stored values only and at each instant of the signal vector  $\alpha$  which compensate the radio signal for said non-linearities in the end amplifier (F).

2. A method according to claim 1,

**characterized** in that said multiplying step d) implies multiplying said inverse amplitude value  $H_R^{-1}$  of the end amplifier by said non-modified quadrature components  $I(t, \alpha)$ ,  $Q(t, \alpha)$  combined with the sine-cosine components of said phase value  $H_\phi$ , respectively, such that new modified quadrature values  $i(t, \alpha)$ ,  $q(t, \alpha)$  thus obtained have an absolute value which is equal to the absolute value of said non-modified quadrature values multiplied with said inverse amplitude  $H_R^{-1}$ .

3. A method according to claim 1,

**characterized** in that said multiplying and adding step d) to obtain the modified quadrature values is done according to the following relations

$$i(t, \alpha) = H_R^{-1}(R) [I(t, \alpha) \cos H_\phi(R) - Q(t, \alpha) \sin H_\phi(R)]$$

$$q(t, \alpha) = H_R^{-1}(R) [I(t, \alpha) \sin H_\phi(R) + Q(t, \alpha) \cos H_\phi(R)]$$

where  $H_R^{-1}(R)$  and  $H_\phi(R)$  are said stored and addressed values of the end amplifier (F).

## Patentansprüche

1. Verfahren, das sich für einen Endverstärker (F) mit einer Übertragungsfunktion  $H_R$ ,  $H_\phi$  eignet, wobei der Verstärker Teil eines Radiosenders ist, der vom Quadraturtyp ist und eine lineare Digitalmodulation auf der Grundlage von Tabellen durchführt, auf die in Abhängigkeit von einem empfangenen Signalvektor  $\alpha$  vorgegebener Länge mit den Binärwerten eines momentanen und eines akkumulierten Phasenwinkels zugegriffen wird, der von einem in dem Radiosender empfangenen Informationssignals abhängt, wobei das Verfahren folgende Schritte enthält:

Speichern (ST, CT) der Digitalwerte  $I(t, \alpha)$ ,  $Q(t, \alpha)$  der Sinus- und Cosinus-Signale, die mit den um  $90^\circ$  phasenverschobenen und dem Endverstärker zuzuführenden Komponenten in Zusammenhang stehen, wobei die Digitalwerte mit Hilfe des Signalvektors  $\alpha$  adressiert werden,

Multiplizieren (M1, M2) und Addieren der um  $90^\circ$  phasenverschobenen Komponenten, damit diese auf zwei Trägersignalkomponenten ( $\sin \omega_c t$ ,  $\cos \omega_c t$ ) abgebildet werden, bevor das hierdurch erhaltene quadraturmodulierte Sendesignal  $r(t, \alpha)$  dem Endverstärker (F) zugeführt wird, und

Modifizieren der digitalen und um  $90^\circ$  phasenverschobenen Komponentenwerte  $I(t, \alpha)$ ,  $Q(t, \alpha)$  in Abhängigkeit von Amplituden- und Phasenwerten, die dem Endverstärker für mehrere Eingangssignale zugeführt werden,

dadurch **gekennzeichnet**, daß

vor dem Betrieb des Radiosenders mehrere inverse Amplitudenwerte ( $H_R^{-1}$ ) und entsprechende Phasenwerte ( $H_\phi$ ) der Übertragungsfunktion des Endverstärkers für mehrere Werte des bei dem Radiosender empfangenen Informationssignals gespeichert werden (MH1, MH2), und die um  $90^\circ$  phasenverschobenen

Komponentenwerte in folgender Weise modifiziert werden:

- a) Berechnen eines Absolutwertes des quadraturmodulierten Sendesignals  $r(t, \alpha)$  aus den um  $90^\circ$  phasenverschobenen Komponentenwerten in nicht kompensierter Weise und für jeden Zeitpunkt ( $t_1$ ),
- b) Adressieren der mehreren gespeicherten inversen Verstärkungswerte sowie der entsprechenden Phasenwerte in Abhängigkeit von dem berechneten Absolutwert,
- c) Bilden (MS) der Sinus- und Cosinus-Komponentenwerte ( $\sin H_\phi$ ,  $\cos H_\phi$ ) des im Schritt b) adressierten Phasenwertes, und
- d) Multiplizieren der in Schritt b) erhaltenen inversen Verstärkungswerte jeweils mit den in Schritt c) erhaltenen Sinus- und Cosinuswerten, die mit den nicht veränderten und um  $90^\circ$  phasenverschobenen Komponentenwerten  $I(t, \alpha)$ ,  $Q(t, \alpha)$  kombiniert sind, so daß sich die veränderten und um  $90^\circ$  phasenverschobenen Komponentenwerte  $i(t, \alpha)$ ,  $q(t, \alpha)$  mit lediglich in Abhängigkeit von den gespeicherten Werten veränderten Amplituden und Phase zu jedem Zeitpunkt des Signalvektors  $\alpha$  so ergeben, daß bei dem Sendesignal die Nichtlinearitäten des Endverstärkers (F) ausgeglichen werden.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß der Schritt d) zum Multiplizieren des inversen Amplitudenwertes ( $H_R^{-1}$ ) des Endverstärkers mit dem unveränderten und um  $90^\circ$  phasenverschobenen Komponenten  $I(t, \alpha)$ ,  $Q(t, \alpha)$ , die jeweils mit den Sinus- und Cosinus-Komponenten des Phasenwertes  $H_\phi$  kombiniert sind, mit einbezieht, so daß die hierdurch gewonnenen neuen, veränderten und um  $90^\circ$  phasenverschobenen Werte  $i(t, \alpha)$ ,  $q(t, \alpha)$  einen Absolutwert aufweisen, der dem Absolutwert der nicht veränderten und um  $90^\circ$  phasenverschobenen Werte entspricht, die mit dem inversen Wert ( $H_R^{-1}$ ) multipliziert sind.

3. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß der Schritt d) zum Multiplizieren und Addieren, mit dem die veränderten und um  $90^\circ$  phasenverschobenen Werte gebildet werden, entsprechend der folgenden Beziehungen ausgeführt wird:

$$i(t, \alpha) = H_R^{-1}(R) [I(t, \alpha) \cos H_\phi(R) - Q(t, \alpha) \sin H_\phi(R)]$$

$$q(t, \alpha) = H_R^{-1}(R) [I(t, \alpha) \sin H_\phi(R) + Q(t, \alpha) \cos H_\phi(R)]$$

wobei  $H_R^{-1}(R)$  und  $H_\phi(R)$  den gespeicherten und adressierten Werten des Endverstärkers (F) entsprechen.

## Revendications

1. Un procédé approprié pour un amplificateur final (F) ayant une fonction de transfert  $H_R$ ,  $H_\phi$ , cet amplificateur étant inclus dans un radioémetteur du type travaillant en quadrature pour effectuer une modulation numérique linéaire basée sur une consultation de table concernant un vecteur de signal entrant  $\alpha$  d'une longueur donnée, contenant les valeurs binaires d'un angle de phase instantané et d'un angle de phase accumulé d'un signal d'information entrant qui est appliqué au radioémetteur, ce procédé comprenant les étapes suivantes :
  - on enregistre (ST, CT) les valeurs numériques  $I(t, \alpha)$ ,  $Q(t, \alpha)$  des formes d'onde en sinus et en cosinus qui sont associées aux composantes en quadrature à appliquer à l'amplificateur final, ces valeurs numériques étant adressées au moyen du vecteur de signal  $\alpha$ ,
  - on multiplie (M1, M2) et on additionne les composantes en quadrature, afin de projeter ces composantes sur deux composantes d'onde porteuse ( $\sin w_c t$ ,  $\cos w_c t$ ) avant d'appliquer à l'amplificateur final (F) le signal de radio modulé en quadrature  $r(t, \alpha)$  qui est ainsi obtenu, et on modifie les valeurs numériques de composantes en quadrature  $I(t, \alpha)$ ,  $Q(t, \alpha)$  sous la dépendance de valeurs d'amplitude et de phase qui sont appliquées à l'amplificateur final pour divers signaux d'entrée, caractérisé en ce que
    - on enregistre (MH1, MH2), avant le fonctionnement du radioémetteur, un ensemble des valeurs d'amplification inverses ( $H_R^{-1}$ ) et les valeurs de phase correspondantes  $H_\phi$  de la fonction de transfert de l'amplificateur final, pour diverses valeurs du signal d'information entrant qui est appliqué au radioémetteur, et
    - on modifie les valeurs de composantes en quadrature par les opérations suivantes
      - a) on calcule une valeur absolue du signal de radio modulé en quadrature  $r(t, \alpha)$ , à partir des valeurs de composantes en quadrature non compensées et, pour chaque instant ( $t_1$ ),
      - b) on adresse l'ensemble de valeurs d'amplification inverse enregistrées et de valeurs de phase correspondantes, sous la dépendance de la valeur absolue calculée,
      - c) on forme (MS) des valeurs de composantes de sinus et de cosinus ( $\sin H_\phi$ ,  $\cos H_\phi$ ) de la valeur de

phase adressée à l'étape b), et

d) on multiplie les valeurs d'amplification inverse obtenues à l'étape b) par les valeurs de sinus et de cosinus qui sont obtenues à l'étape c), combinées avec les valeurs de composantes en quadrature non modifiées, respectivement  $I(t, \alpha)$ ,  $Q(t, \alpha)$ , de façon à obtenir des valeurs de composantes en quadrature modifiées  $i(t, \alpha)$ ,  $q(t, \alpha)$  avec une amplitude et une phase modifiées sous la dépendance des valeurs enregistrées seulement, et à chaque instant du vecteur de signal  $\alpha$ , qui compensent le signal de radio vis-à-vis des non-linéarités dans l'amplificateur final (F).

2. Un procédé selon la revendication 1,

caractérisé en ce que l'étape de multiplication d) implique la multiplication de la valeur d'amplitude inverse  $H_R^{-1}$  de l'amplificateur final par les composantes en quadrature non modifiées  $I(t, \alpha)$ ,  $Q(t, \alpha)$ , combinées avec les composantes en sinus-cosinus de la valeur de phase  $H_\phi$ , respectivement, de façon que de nouvelles valeurs en quadrature modifiées  $i(t, \alpha)$ ,  $q(t, \alpha)$  qui sont ainsi obtenues aient une valeur absolue qui est égale à la valeur absolue des valeurs en quadrature non modifiées multipliées par l'amplitude inverse  $H_R^{-1}$ .

3. Un procédé selon la revendication 1,

caractérisé en ce que l'étape de multiplication et d'addition d) visant à obtenir les valeurs en quadrature modifiées est accomplie conformément aux relations suivantes :

$$i(t, \alpha) = H_R^{-1}(R) [I(t, \alpha) \cos H_\phi(R) - Q(t, \alpha) \sin H_\phi(R)]$$

$$q(t, \alpha) = H_R^{-1}(R) [I(t, \alpha) \sin H_\phi(R) + Q(t, \alpha) \cos H_\phi(R)]$$

dans lesquelles  $H_R^{-1}(R)$  et  $H_\phi(R)$  sont les valeurs enregistrées et adressées de l'amplificateur final (F).

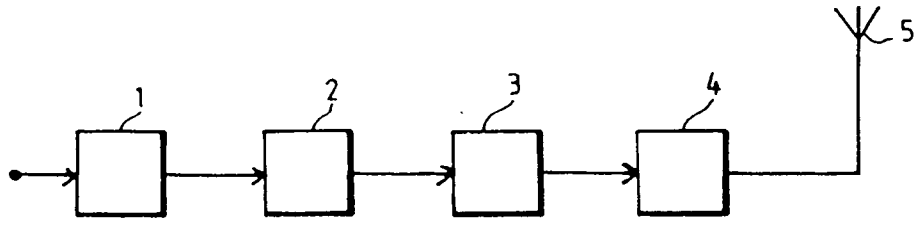


Fig.1

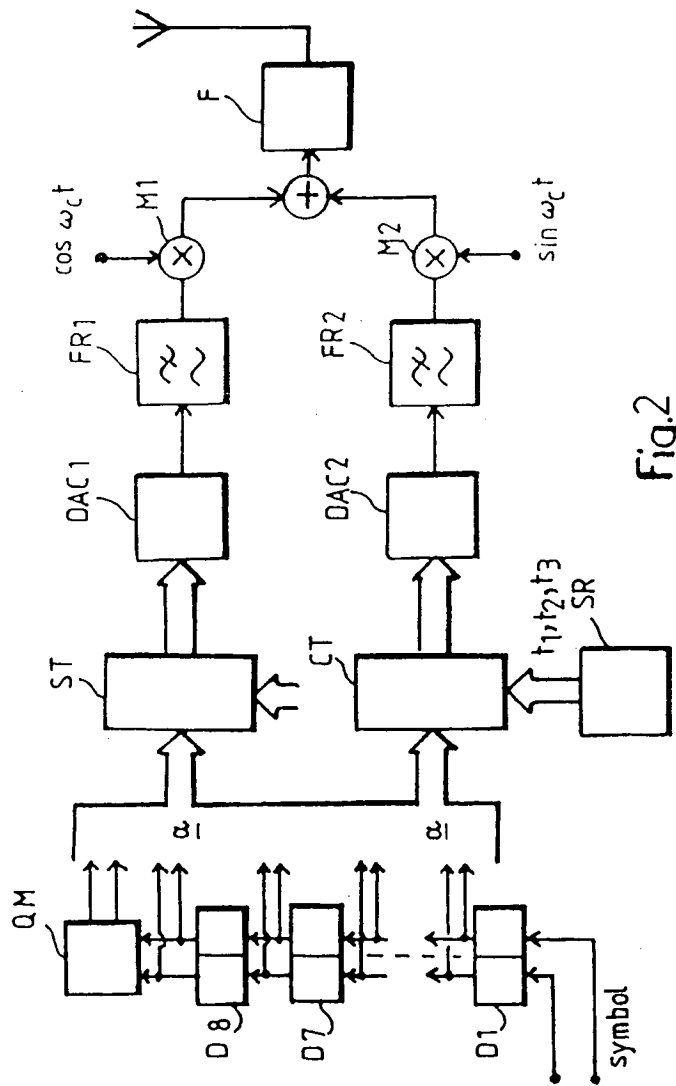


Fig.2

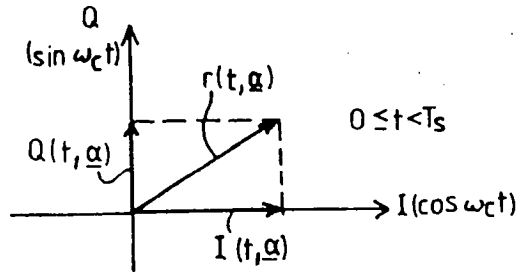


Fig.3

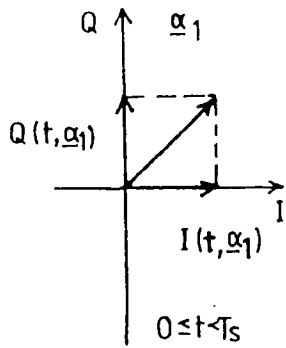


Fig.4a

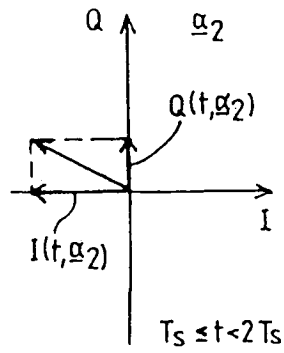


Fig.4b

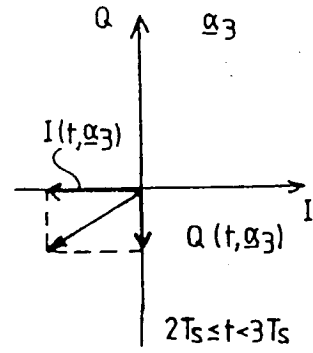


Fig.4c

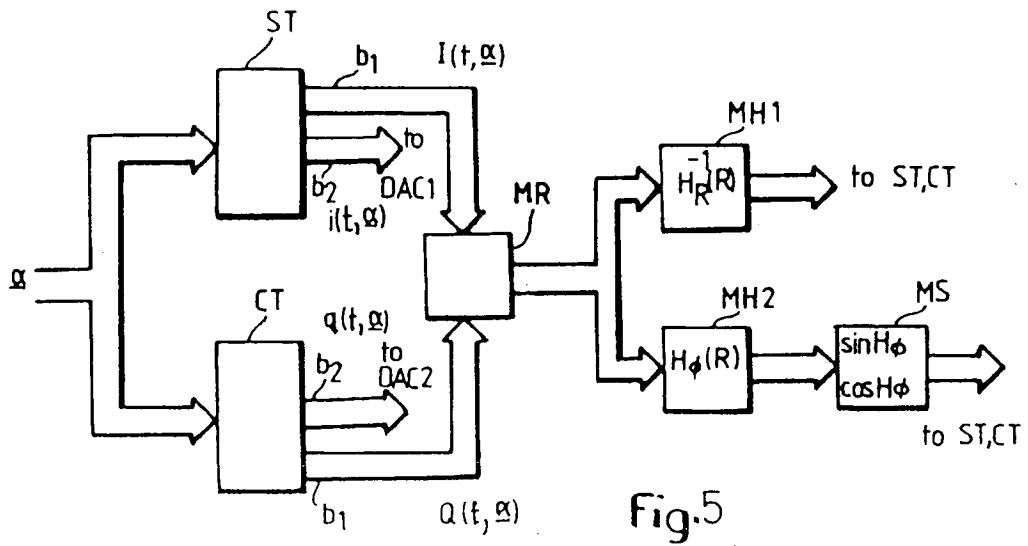


Fig.5

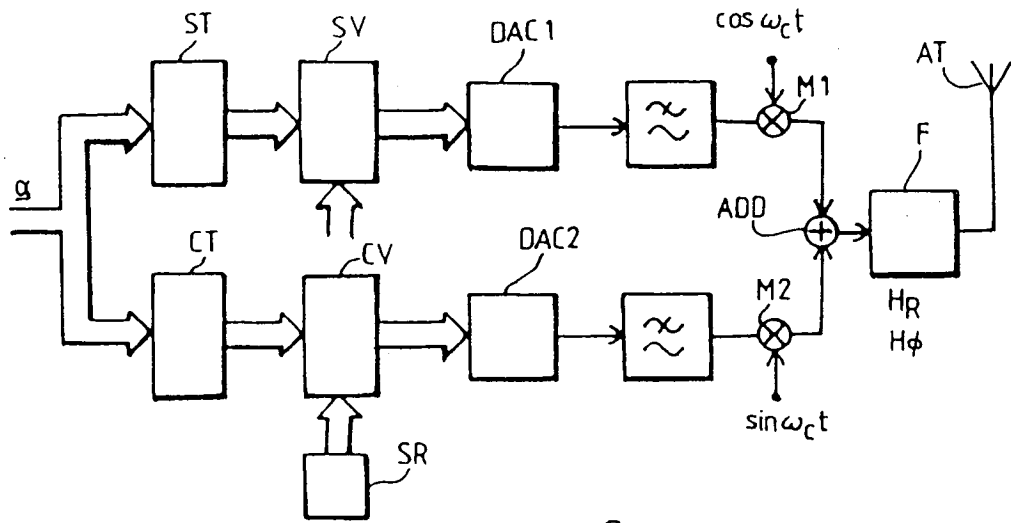


Fig.6

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