CLAIMS

1. A method for determining imperfections of a transmit pathway and of a receive pathway of an apparatus, the transmit pathway comprising a first device for frequency transposition of an analogue sequence to an analogue signal, using a first transposition frequency, said receive pathway comprising a second device for frequency transposition of an analogue signal to an analogue sequence, using a second transposition frequency different from the first transposition frequency, said method comprising the following sequential steps:

generating at least two different first analogue sequences,

performing a frequency transposition at said first transposition frequency of the first analogue sequences to analogue signals, by the transmit pathway,

transmitting the analogue signals of the transmit pathway to the receive pathway,

performing a frequency transposition from said second transposition frequency of the analogue signals received to second analogue sequences, by the receive pathway,

calculating first amplitudes and first phases, of a plurality of spectral components of at least two of the first analogue sequences at first frequencies of interest and second amplitudes and second phases, of a plurality of spectral components of at least two of the second analogue sequences at second frequencies of interest,

said method comprising at least one of the following two independent steps:

determining the imperfections of the transmit pathway on the basis solely of the first amplitudes, first phases, second amplitudes and second phases, and

determining the imperfections of the receive pathway on the basis solely of the second amplitudes and second phases.

2. The method according to claim 1, wherein at least two of the first

analogue sequences are non-zero, are not a delayed version of one another and are not an amplified version of one another.

3. The method according to claim 1, wherein one of the first analogue sequences includes an imaginary sequence and another of the first sequences includes a real sequence.

4. The method according to claim 1, wherein at least two of the first analogue sequences are multi-tone sequences of OFDM-Orthogonal Frequency Division Multiplexing-type or of SC-FDE-Single-Carrier Frequency Domain Equalization-type or of FBMC-Filter Bank MultiCarrier modulation-type or analogue sequences using a cyclic prefix and/or cyclic postfix.

5. The method according to claim 1, wherein the imperfections of the transmit pathway are modelled by a first gain and a first phase shift affecting the analogue signal during its transmission by the transmit pathway.

6. The method according to claim 1, wherein the imperfections of the receive pathway are modelled by a second gain and a second phase shift affecting the analogue signal during its reception by the receive pathway.

7. The method according to claim 1, wherein:

said transmit pathway furthermore comprises a device for converting first digital sequences to the first analogue sequences,

said receive pathway furthermore comprises a device for converting the second analogue sequences to second digital sequences,

said first frequencies of interest are:

$$f_8 = -k_2 \frac{f_{smp}}{Nfft} \quad \text{and} \quad f_9 = k_2 \frac{f_{smp}}{Nfft} = -f_8;$$

where:

$$k_2 \in \left[+1; \frac{Nfft}{2} - 1\right],$$

f_{smp} represents a sampling frequency of the device for converting the second analogue sequences to the second digital sequences and

$Nfft$ represents a number of samples used to calculate the second amplitudes and the second phases, of the spectral components of the second analogue sequence or sequences.

8. The method according to claim 1, wherein:

said transmit pathway furthermore comprises a device for converting first digital sequences to the first analogue sequences,

said receive pathway furthermore comprises a device for converting the second analogue sequences to second digital sequences,

said second frequencies of interest are:

$$f_1 = (-k_2 - k_1)\frac{f_{smp}}{Nfft},$$

$$f_2 = (-k_2 + k_1)\frac{f_{smp}}{Nfft},$$

$$f_6 = (+k_2 - k_1)\frac{f_{smp}}{Nfft} = -f_2,$$

$$f_7 = (+k_2 + k_1)\frac{f_{smp}}{Nfft} = -f_1,$$

where:

$$k_1 \in \left[-\frac{Nfft}{2} + 1; \frac{Nfft}{2}\right],\ k_1\frac{f_{smp}}{Nfft} = \Delta f,$$

Δf represents the difference between the first transposition frequency and the second transposition frequency,

$$k_2 \in \left[+1; \frac{Nfft}{2} - 1\right],$$

f_{smp} represents the sampling frequency of the device for converting the second analogue sequences to the second digital sequences and $Nfft$ represents a number of samples used to calculate the second amplitudes and the second phases, of the spectral components of the second analogue sequence or sequences.

9. The method according to claim 5, wherein the step of determining the imperfections of the transmit pathway comprises the use of the following relations:

$$\begin{cases} \varphi_{TX}est = Angle[K1_{TX}finalest - K2_{TX}finalest*] \\ g_{TX}est = |K1_{TX}finalest - K2_{TX}finalest*| \end{cases}$$

where:

φ_{TX} represents an estimation of the first phase shift of the transmit pathway,

g_{TX} represents an estimation of the first gain of the receive pathway,

$K1_{TX}finalest = \frac{K1_{TX}est1 + K1_{TX}est2}{2}$,

$K2_{TX}finalest = 1 - K1_{TX}finalest^*$,

$*$ represents the conjugate operator,

$$K1_{TX}est1 = \frac{R_{f_7}(seq_1)\cdot E_{f_8}{}^*(seq_2) - \frac{R_{f_7}(seq_2)}{\exp(+j\cdot\varphi_{\Delta f})}\cdot E_{f_8}{}^*(seq_2)}{R_{f_7}(seq_1)\cdot\left[E_{f_8}{}^*(seq_2) - E_{f_9}(seq_2)\right] - \frac{R_{f_7}(seq_2)}{\exp(+j\cdot\varphi_{\Delta f})}\cdot\left[E_{f_8}{}^*(seq_1) - E_{f_9}(seq_1)\right]}$$

$$K1_{TX}est2 = \frac{R_{f_2}(seq_1)\cdot E_{f_9}{}^*(seq_2) - \frac{R_{f_2}(seq_2)}{\exp(+j\cdot\varphi_{\Delta f})}\cdot E_{f_9}{}^*(seq_2)}{R_{f_2}(seq_1)\cdot\left[E_{f_9}{}^*(seq_2) - E_{f_8}(seq_2)\right] - \frac{R_{f_2}(seq_2)}{\exp(+j\cdot\varphi_{\Delta f})}\cdot\left[E_{f_9}{}^*(seq_1) - E_{f_8}(seq_1)\right]}$$

$E_{f_i}(seq_i)$ represents a spectral component of one of the first sequences seq_i at the frequency f_j,

$R_{f_j}(seq_i)$ represents a spectral component of one of the second sequences seq_i at the frequency f_j, and

$\varphi_{\Delta f}$ represents a phase shift caused by a difference between the first transposition frequency and the second transposition frequency.

10. The method according to claim 6, wherein said step of determining said imperfections of said receive pathway comprises the use of the following relations:

$$\begin{cases} \varphi_{RX}est = Angle[K1_{RX}finalest - K2_{RX}finalest*] \\ g_{RX}est = |K1_{RX}est - K2_{RX}est*| \end{cases}$$

where:

φ_{RX} represents an estimation of the second phase shift of the receive pathway,

g_{RX} represents an estimation of the second gain of the receive pathway,

$K1_{RX}finalest = \frac{K1_{RX}est(seq_1)+[1-K2^{*}_{RX}est(seq_1)]+K1_{RX}est(seq_2)+[1-K2^{*}_{RX}est(seq_2)]}{4}$,

$K2_{RX}finalest = 1\text{-}K1_{RX}finalest^{*}$,

$*$ represents the conjugate operator,

$$K1_{RX}est(seq_i) = \frac{R_{f_7}(seq_i)}{R_{f_7}(seq_i) + R_{f_1}*(seq_i)},$$

$$K2_{RX}est(seq_i) = \frac{R_{f_6}(seq_i)}{R_{f_6}(seq_i) + R_{f_2}*(seq_i)},$$

$R_{f_j}(seq_i)$ represents a spectral component of one of the second sequences seq_i at the frequency f_j.

11. An apparatus, comprising a transmit pathway and a receive pathway, wherein:

said transmit pathway comprises a first device for frequency transposition of an analogue sequence to an analogue signal, using a first transposition frequency,

said receive pathway comprises a second device for frequency transposition of an analogue signal to an analogue sequence, using a second transposition frequency,

said apparatus furthermore comprises a calculation device able to implement a method for determining imperfections of a transmit pathway and of a receive pathway, the method comprising the following sequential steps:

generating at least two different first analogue sequences,

performing a frequency transposition from said first transposition frequency of the first analogue sequences to analogue signals, by the transmit pathway,

transmitting the analogue signals of the transmit pathway to the receive pathway,

performing a frequency transposition from said second transposition frequency of the analogue signals received to second analogue sequences, by the receive pathway,

calculating first amplitudes and first phases, of a plurality of spectral components of at least two of the first analogue sequences at first frequencies of interest and second amplitudes and second phases, of a plurality of spectral components of at least two of the second analogue sequences at second frequencies of interest,

said method comprising at least one of the following two independent steps:

determining the imperfections of the transmit pathway on the basis solely of the first amplitudes, first phases, second amplitudes and second phases, and

determining the imperfections of the receive pathway on the basis solely of the second amplitudes and second phases.

12. A radio transmission apparatus, comprising a transmit pathway and a receive pathway, wherein:

said transmit pathway comprises a first device for frequency transposition of an analogue sequence to an analogue signal, using a first transposition frequency, and a device for converting first digital sequences to the first analogue sequences,

said receive pathway comprises a second device for frequency transposition of an analogue signal to an analogue sequence, using a second transposition frequency, and a device for converting the second analogue sequences to second digital sequences,

said apparatus furthermore comprises a calculation device able to implement a method for determining imperfections of a transmit pathway and of a receive pathway, the method comprising the following sequential steps:

generating at least two different first analogue sequences,

performing a frequency transposition from said first transposition frequency of the first analogue sequences to analogue signals, by the transmit pathway,

transmitting the analogue signals of the transmit pathway to the receive pathway,

performing a frequency transposition from said second transposition frequency of the analogue signals received to second analogue sequences, by the receive pathway,

calculating first amplitudes and first phases, of a plurality of spectral components of at least two of the first analogue sequences at first frequencies of interest and second amplitudes and second phases, of a plurality of spectral components of at least two of the second analogue sequences at first frequencies of interest,

said method comprising at least one of the following two independent steps:

determining the imperfections of the transmit pathway on the basis solely of the first amplitudes, first phases, second amplitudes and second phases, and

determining the imperfections of the receive pathway on the basis solely of the second amplitudes and second phases.

CLAIMS

1. Method for determining the imperfections of a transmit pathway (501) and of a receive pathway (502) of an apparatus,
the said transmit pathway comprising a first device (504) for frequency transposition of an analogue sequence to an analogue signal, using a first transposition frequency,
the said receive pathway comprising a second device (505) for frequency transposition of an analogue signal to an analogue sequence, using a second transposition frequency different from the said first transposition frequency,
the said method comprising the following sequential steps:

- a step (601) of generating at least two different first analogue sequences,
- a step (602) of frequency transposition to analogue signals of the said first analogue sequences, by the said transmit pathway,
- a step (603) of transmitting the analogue signals of the said transmit pathway to the said receive pathway,
- a step (604) of frequency transposition to second analogue sequences of the said analogue signals received, by the said receive pathway,
- a step (605) of calculating first amplitudes and first phases, of a plurality of spectral components of at least two of the first analogue sequences at first frequencies of interest and second amplitudes and second phases, of a plurality of spectral components of at least two of the second analogue sequences at first frequencies of interest,

the said method being characterized in that it comprises at least one of the following two independent steps:

- a step (606) of determining the said imperfections of the said transmit pathway on the basis solely of the first amplitudes, first phases, second amplitudes and second phases, and
- a step (607) of determining the said imperfections of the said receive pathway on the basis solely of the said second amplitudes and second phases.

2. Method according to Claim 1, in which at least two of the said first analogue sequences are non-zero, are not a delayed version of one another and are not an amplified version of one another.

3. Method according to Claim 1, in which one of the first analogue sequences consists of an imaginary sequence and another of the first sequences consists of a real sequence.

4. Method according to Claim 1, in which at least two of the said first analogue sequences are multi-tone sequences of OFDM -Orthogonal Frequency Division Multiplexing- type or of SC-FDE -Single-Carrier Frequency Domain Equalization- type or of FBMC -Filter Bank MultiCarrier modulation- type or analogue sequences using a cyclic prefix and/or cyclic postfix.

5. Method according to one of Claims 1 to 4, in which the said imperfections of the said transmit pathway are modelled by a first gain and a first phase shift affecting the said analogue signal during its transmission by the said transmit pathway.

6. Method according to one of Claims 1 to 5, in which the said imperfections of the said receive pathway are modelled by a second gain and a second phase shift affecting the said analogue signal during its reception by the said receive pathway.

7. Method according to one of Claims 1 to 6, in which
the said transmit pathway furthermore comprises a device (506) for converting first digital sequences to the said first analogue sequences,
the said receive pathway furthermore comprises a device (507) for converting the said second analogue sequences to second digital sequences,

the said first frequencies of interest are:

$$f_8 = -k_2 \frac{f_{smp}}{Nfft} \text{ and}$$

$$f_9 = k_2 \frac{f_{smp}}{Nfft} = -f_8.$$

where:

$k_2 \in \left[+1; \frac{Nfft}{2} - 1\right]$,

f_{smp} represents a sampling frequency of the said device for converting the said second analogue sequences to the said second digital sequences and $Nfft$ represents a number of samples used to calculate the said second amplitudes and the said second phases, of the said spectral components of the second analogue sequence or sequences.

8. Method according to one of Claims 1 to 7, in which
the said transmit pathway furthermore comprises a device (506) for converting first digital sequences to the said first analogue sequences,

the said receive pathway furthermore comprises a device (507) for converting the said second analogue sequences to second digital sequences,

the said second frequencies of interest are:

$$f_1 = (-k_2 - k_1)\frac{f_{smp}}{Nfft},$$
$$f_2 = (-k_2 + k_1)\frac{f_{smp}}{Nfft},$$
$$f_6 = (+k_2 - k_1)\frac{f_{smp}}{Nfft} = -f_2,$$
$$f_7 = (+k_2 + k_1)\frac{f_{smp}}{Nfft} = -f_1,$$

where:
$k_1 \in \left[-\frac{Nfft}{2} + 1; \frac{Nfft}{2}\right]$,
$k_1 \frac{f_{smp}}{Nfft} = \Delta f$,
Δf represents the difference between the said first transposition frequency and the said second transposition frequency,
$k_2 \in \left[+1; \frac{Nfft}{2} - 1\right]$,
f_{smp} represents the said sampling frequency of the said device for converting the said second analogue sequences to the said second digital sequences and
$Nfft$ represents a number of samples used to calculate the said second amplitudes and the said second phases, of the said spectral components of the second analogue sequence or sequences.

9. Method according to Claims 5, 7 and 8, in which the said step (606) of determining the said imperfections of the said transmit pathway comprises the use of the following relations:

$$\begin{cases} \varphi_{TX}est = Angle[K1_{TX}finalest - K2_{TX}finalest*] \\ g_{TX}est = |K1_{TX}finalest - K2_{TX}finalest*| \end{cases}$$

where:

φ_{TX} represents an estimation of the said first phase shift of the said transmit pathway,

g_{TX} represents an estimation of the said first gain of the said receive pathway,

$K1_{TX}finalest = \frac{K1_{TX}est1 + K1_{TX}est2}{2}$,

$K2_{TX}finalest = 1 - K1_{TX}finalest^{*}$,

$*$ represents the conjugate operator,

$$K1_{TX}\,est1 = \frac{R_{f_7}(seq_1)\cdot E_{f_8}{}^{*}(seq_2) - \frac{R_{f_7}(seq_2)}{\exp(+j\cdot\varphi_{\Delta f})}\cdot E_{f_8}{}^{*}(seq_2)}{R_{f_7}(seq_1)\cdot\left[E_{f_8}{}^{*}(seq_2) - E_{f_9}(seq_2)\right] - \frac{R_{f_7}(seq_2)}{\exp(+j\cdot\varphi_{\Delta f})}\cdot\left[E_{f_8}{}^{*}(seq_1) - E_{f_9}(seq_1)\right]}$$

$$K1_{TX}\,est2 = \frac{R_{f_2}(seq_1)\cdot E_{f_9}{}^{*}(seq_2) - \frac{R_{f_2}(seq_2)}{\exp(+j\cdot\varphi_{\Delta f})}\cdot E_{f_9}{}^{*}(seq_2)}{R_{f_2}(seq_1)\cdot\left[E_{f_9}{}^{*}(seq_2) - E_{f_8}(seq_2)\right] - \frac{R_{f_2}(seq_2)}{\exp(+j\cdot\varphi_{\Delta f})}\cdot\left[E_{f_9}{}^{*}(seq_1) - E_{f_8}(seq_1)\right]}$$

$E_{f_i}(seq_i)$ represents a spectral component of one of the said first sequences seq_i at the frequency f_j,

$R_{f_i}(seq_i)$ represents a spectral component of one of the said second sequences seq_i at the frequency f_j, and

$\varphi_{\Delta f}$ represents a phase shift caused by a difference between the said first transposition frequency and the said second transposition frequency.

10. Method according to Claims 6 to 9, in which the said step (607) of determining the said imperfections of the said receive pathway comprises the use of the following relations:

$$\begin{cases} \varphi_{RX}est = Angle[K1_{RX}finalest - K2_{RX}finalest*] \\ g_{RX}est = |K1_{RX}est - K2_{RX}est*| \end{cases}$$

where:

φ_{RX} represents an estimation of the said second phase shift of the said receive pathway,

g_{RX} represents an estimation of the said second gain of the said receive pathway,

$$K1_{RX}finalest = \frac{K1_{RX}est(seq_1) + [1 - K2^{*}_{RX}est(seq_1)] + K1_{RX}est(seq_2) + [1 - K2^{*}{}_{RX}est(seq_2)]}{4},$$

$K2_{RX}finalest = 1 - K1_{RX}finalest^{*}$,

* represents the conjugate operator,

$$K1_{RX}\,est(seq_i) = \frac{R_{f_7}(seq_i)}{R_{f_7}(seq_i) + R_{f_1}{}^*(seq_i)},$$

$$K2_{RX}\,est(seq_i) = \frac{R_{f_6}(seq_i)}{R_{f_6}(seq_i) + R_{f_2}{}^*(seq_i)},$$

$R_{f_j}(seq_i)$ represents a spectral component of one of the said second sequences seq_i at the frequency f_j.

11. Apparatus, comprising a transmit pathway and a receive pathway,
the said transmit pathway comprising a first device (504) for frequency transposition of an analogue sequence to an analogue signal, using a first transposition frequency,
the said receive pathway comprising a second device (505) for frequency transposition of an analogue signal to an analogue sequence, using a second transposition frequency,
the said apparatus furthermore comprising a calculation device able to implement the method according to one of Claims 1 to 6.

12. Radio transmission apparatus according to Claim 11, in which
the said transmit pathway furthermore comprises a device (506) for converting first digital sequences to the said first analogue sequences,
the said receive pathway furthermore comprises a device (507) for converting the said second analogue sequences to second digital sequences, and
the said calculation device being furthermore able to implement a method according to one of Claims 7 to 10.