

DESCRIPTION

Title: Method for receiving radiofrequency signals that are not spread-spectrum

Technical field:

[0001] The invention relates to the field of telecommunications, in particular digital communications operated in the HF (high-frequency) frequency band, a frequency band typically lying between 3 MHz and 30 MHz.

[0002] It relates more particularly to a method for receiving radiofrequency (RF) digital signals that are not spectrally spread, contributing to the solving of the errors linked to the multipath phenomena of the transmitted signals, and to a receiver configured to implement the reception method according to the invention.

Prior art:

[0003] Hereinbelow, the invention is described in relation to radiofrequency communications operated in the HF band, in which the invention offers particularly advantageous performance levels. However, it can be applied identically regardless of the frequency band.

[0004] The communications operated in HF band are often affected by complex multipath phenomena. The conditions of propagation (reflections on the ionosphere, influence of latitude, etc.) in HF render the channel seen by the receiver doubly selective: in frequency and in time. The frequency selectivity is reflected by interference between symbols, that must be processed in order to be able to decode the transmitted information. The time selectivity is reflected by the need to adapt the processing of the interference between symbols as the information is being received. In HF, the channel seen by a receiver is very often composed of few paths (generally two, even a few more), but paths that

can have similar average powers. There is therefore a particular interest in correctly processing these different paths.

[0005] The modulations used in HF are mostly single-carrier modulations, for peak factor considerations. The processing of the time and frequency selectivity of the channel is therefore usually done in the time domain.

[0006] There are three families of processing operations that make it possible to process the interference between symbols in the HF receivers:

- the processing operations based on maximum likelihood: these processing operations are optimal, that is to say that, for a given signal-to-noise ratio, and on average, the bit error rate (BER) obtained is the lowest that can possibly be obtained. This solution is defective in that the complexity of the receiver increases exponentially with the length of the propagation channel seen by the receiver and the order of the constellation used, and it is therefore generally prohibitive;
- the equalization processing operations: these processing operations consist in applying the reverse effect of the propagation channel to the received signal. An equalizer is generally a good trade-off between the performance levels obtained and the associated complexity. The existing equalizers can be classified as follows:
 - the non-iterative equalizers: they can be linear or non-linear. For the HF transmission channels, the non-linear equalizers with decision feedback (for example a DFE equalizer, DFE standing for *Decision Feedback Equalization*, or a BDFE equalizer, BDFE standing for *Block Decision Feedback Equalization*), offer good performance levels and are the most widely used. However, the performance levels of these equalizers are not optimal and can be further enhanced;

- the iterative equalizers: “Turbo Equalization” consists in iteratively associating the channel decoding function with an adaptive equalization function. The performance levels of these equalizers are overall very good for high bit rates. However, the gains brought about by this type of equalizer are low for low to moderate bit rates, as is the case in HF when wanting to transmit robustly. In addition, these equalizers have a high computational complexity and necessitate a fine knowledge of the evolution of the channel;
- the Rake receivers: they are used when the useful symbols are spectrally spread/repeated before being transmitted. Spectrum spreading consists in repeating the transmitted symbols, by replacing each useful symbol to be transmitted by a spreading sequence. That generally corresponds to a succession of symbols which are transmitted at a rate that is commensurately higher. The Rake receivers consist in taking a place at the instants corresponding to the various paths of interest, then in “despreading” the signal for each of these instants. The “despread” signals are then recombined coherently and the final signal is demodulated. In the processing of each of the paths of interest, the other paths are considered as interference signals. The reception quality of each path can then be qualified by the SINR (acronym for *Signal to Interference-plus-Noise Ratio*). The receiver benefits from the use of spreading sequences in order to reject the interferences and to maximize the SINR for each of the paths of interest. The drawback with this type of receiver is that it presupposes that one or more spreading sequences are used, which is not necessarily the case for the HF transmissions.

[0007] The technical issue not resolved by the prior art that the invention seeks to resolve is therefore that of how to enhance the performance levels of the radiofrequency signal reception processing operations, in

particular for the HF signals which intrinsically are not spread and have moderate bit rates (0.15 to 0.6 bits/sec/Hz approximately), and do so with a contained computational complexity.

[0008] The invention addresses this issue by processing the interference between symbols provoked by the HF propagation channel (or that have similar characteristics) more efficiently than the processing operations of the state-of-the-art.

[0009] "Efficiently" is understood to mean with a controlled complexity and for a signal-to-noise ratio that is the lowest possible.

Summary of the invention:

[0010] To this end, the present invention describes a method for receiving a radiofrequency (RF) signal that is not spectrally spread. The signal is transmitted by frames, each frame comprising one or more reference sequences and one or more sequences of useful symbols. The method according to the invention comprises:

- a first step of receiving, transposing and digitizing a frame of the RF signal, then, for at least one sequence of useful symbols,
- a second step of estimating an impulse response of the propagation channel associated with the sequence of useful symbols, using one or more of the reference sequences,
- a third step of extracting the delays and amplitudes of the K strongest paths of said impulse response of the propagation channel, with K greater than 1,
- a fourth step of processing the sequence of useful symbols by a Rake receiver with K paths by using the delays and amplitudes calculated in the third step.

[0011] According to one embodiment of the invention, the second step of estimating an impulse response of the propagation channel associated with the sequence of useful symbols comprises:

- estimating a first impulse response of the propagation channel based on a reference sequence situated before said sequence of useful symbols,
- estimating a second impulse response of the propagation channel based on a reference sequence situated after said sequence of useful symbols, and
- calculating an average between said first impulse response and said second impulse response.

[0012] The fourth step of processing the sequence of useful symbols by a Rake receiver with K paths comprises:

- for each path, applying a temporal realignment and a gain to the sequence of useful symbols,
- summing the sequences of useful symbols realigned and adjusted in gain and normalizing the resulting sequence of symbols by a coefficient dependent on the gains applied to the paths.

[0013] Advantageously, the method for receiving an RF signal that is not spectrally spread according to the invention further comprises a step of estimating soft decision bits on the useful symbols derived from the fourth step, said soft decision bits being used subsequently as inputs of an error correcting decoding algorithm.

[0014] According to one embodiment of the method for receiving an RF signal that is not spectrally spread according to the invention, the RF signal is transmitted in the high-frequency band.

[0015] The invention relates also to a receiver of radiofrequency (RF) signals, characterized in that it comprises a radio chain configured to perform the first step of a method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention, and computation means configured to implement the following steps of said method for receiving an RF signal that is not spectrally spread according to the invention.

Brief description of the figures:

[0016] The invention will be better understood, and other features, details and advantages will become more apparent, on reading the following description, given as a non-limiting example, and using the attached figures, given by way of example, in which:

- figure 1 is a functional diagram representing a conventional HF signal transmission structure on which a method for receiving a radiofrequency signal that is not spectrally spread can be implemented according to an embodiment of the invention;
- figure 2 represents a conventional HF frame structure, on which a method for receiving a radiofrequency signal that is not spectrally spread can be implemented according to an embodiment of the invention;
- figure 3 schematically represents the steps of a method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention;
- figure 4 illustrates the raw performance levels achieved by implementing the method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention on an HF signal;
- figure 5 is a functional diagram representing a method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention;
- figure 6 represents in more detail the channel estimation and Rake reception functions in a method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention;
- figure 7 gives an example of impulse response calculated by the estimator of impulse response of the propagation channel in a method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention;

- figure 8 represents the performance levels of the method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention for a bit rate class of 600 bits per second;
- figure 9 represents the performance levels of the method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention for a bit rate class of 1200 bits per second;
- figure 10 represents the performance levels of the method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention for a bit rate class of 1800 bits per second;
- figure 11 schematically represents a radiofrequency receiver configured to implement a method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention.

[0017] Identical references are used in different figures when they denote identical or comparable elements.

Detailed description:

[0018] Figure 1 is a functional diagram representing a conventional HF signal transmission structure on which a method for receiving a radiofrequency signal that is not spectrally spread can be implemented according to an embodiment of the invention. This architecture is given purely by way of illustration.

[0019] The transmission chain represented in figure 1 comprises:

- A coder configured to apply an error correcting code 102 (*Forward Error Correction*, or FEC) to the information bits 101 to be transmitted. The error correcting code makes it possible to correct any errors present on reception,

- An interleaver 103, configured to interleave the coded bits so as to distribute the errors on reception as randomly as possible, and derive full benefit from the available diversity,
- A modulator 104, configured to form symbols of a constellation based on the coded and interleaved bits,
- A modulated symbol generator 105, configured to transmit symbols corresponding to one or more reference sequences that can be used by the receiver for the purposes of synchronization and estimation of the propagation channel,
- A multiplexer 106, configured to generate a stream of modulated symbols corresponding alternately to the interleaved, coded and modulated information bits 101 and to the reference sequences 105,
- An interpolator 107, configured to upsample the signal at the symbol rate, for example by a factor of 4,
- A forming filter 108, configured to filter the complex symbols of upsampled data, for example a half-Nyquist filter.

[0020] The signal 109 at the output of this transmitter corresponds to an upsampled digital signal, which will then be converted into analog, set to HF carrier frequency and amplified before being transmitted. This signal is not spectrally spread.

[0021] The functions represented in figure 1 are typical functions of HF communications, which make it possible to minimize the presence of errors in the data recovered by the receiver. These functions are not strictly essential to the implementation of the invention, except for the presence of reference sequences that make it possible to estimate the impulse response of the propagation channel.

[0022] Figure 2 represents a conventional HF frame structure, on which can be implemented a method for receiving a radiofrequency signal that is not spectrally spread according to an embodiment of the invention.

[0023] The frames comprise, alternately:

- a block R 202 corresponding to a reference sequence, or pilot sequence, of N_{Ref} symbols, that can be used by the receiver to detect the signal, estimate the propagation channel and perform the tracking of time and frequency synchronization,
- a block D 203 corresponding to the useful data symbols to be transmitted, of length N_{Data} .

[0024] The number of symbols N_{Ref} and N_{Data} depends on the choice of implementation, and result from a trade-off between the performance levels sought and the spectral efficiency of the transmission.

[0025] The frame format represented in figure 2 is given purely by way of illustration. The invention applies identically regardless of the frame format, provided that it comprises at least one reference sequence allowing the receiver to estimate the propagation channel, and at least one useful data sequence.

[0026] Advantageously, the information bits are interleaved over a time horizon corresponding to the successive transmission of N_{Frame} frames, called superframes, which makes it possible to distribute the errors in time.

[0027] A preamble sequence 201 of N_P symbols can be inserted at the start of the superframe, allowing the receiver to perform the detection of the signal and the time and frequency synchronization steps.

[0028] The invention applies therefore in the context of a conventional HF transmission that is not spectrally spread, with a frame format comprising one or more reference sequences and one or more useful symbol sequences transporting forming information bits.

[0029] Figure 3 schematically represents the steps of a method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention.

[0030] The method comprises a first step 301, conforming to the state-of-the-art, of receiving an RF signal, in particular in the HF frequency band, comprising at least the acquisition of the signal, the transposition thereof

into baseband or intermediate frequency, and the digitization thereof by an analog-digital converter.

[0031] The method according to the invention next comprises a second step 302 of estimating the impulse response associated with a sequence of useful symbols using one or more reference sequences known to the receiver. The estimating of the impulse response is done based on the reference sequences, and can be implemented in different ways known to the person skilled in the art, such as for example by using a *Least Square* criterion, a *Zero Forcing* criterion, a *Minimum Mean Squared Error* criterion, a *Maximum Likelihood Sequence Estimator* criterion, or any other criterion that makes it possible to estimate a vector corresponding to the impulse response of the propagation channel affecting the sequences of useful symbols.

[0032] Depending on the embodiment and the frame scheme, the reference sequence used to estimate the impulse response associated with a sequence of useful symbols can be the reference sequence which precedes it, the reference sequence which follows it, an average of the sequences which surround it, or a smoothed value estimated over several successive reference sequences.

[0033] The method according to the invention next comprises a third step 303 of extracting the delays Δ_k and amplitudes α_k of the K strongest paths of said impulse response of the propagation channel. This step consists in identifying the K peaks of the impulse response calculated in the second step 302, and in memorizing their respective delays and amplitudes.

[0034] Finally, the method according to the invention comprises a fourth step 304, executed when K is greater than 1, of processing the sequence of useful symbols considered using a Rake receiver with K paths, by using the delays and amplitudes calculated in the third step (303).

[0035] Figure 4 illustrates the raw performance levels achieved by implementing the method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention on an HF signal.

Figure 4 gives the bit error rate as a function of the Signal-to-Noise Ratio (SNR) before channel decoding for BPSK (*Binary Phase Shift Keying*), QPSK (*Quadrature Phase Shift Keying*) and 8PSK (8-state Phase Shift Keying) modulations, for a standard propagation channel of CCIR Poor type (standardized by the International Radio Consultative Committee (CCIR) and which has two paths of the same average power spaced apart by 2 ms), typically transmissions in the HF frequency band. The results are given for an equalizer according to the state-of-the-art (here an equalizer of BDFE type, BDFE being the acronym for *Block Decision Feedback Equalizer*, known to exhibit very good performance levels in HF) and for a reception method according to an embodiment of the invention.

[0036] The curves 401, 403 and 405 correspond to the results obtained with the BDFE equalizer, respectively for BPSK, QPSK and 8PSK modulations. The curves 402, 404 and 406 correspond to the results obtained by implementing the reception method according to the invention, respectively for BPSK, QPSK and 8PSK modulations.

[0037] It can be seen that the BDFE equalizer processes the interference between symbols with strong SNRs (> 8 dB approximately) much better than the proposed receiver, for which an error floor can be observed. On the other hand, for lower SNRs (< 8 dB approximately), the receiver according to the invention exhibits better performance levels. For these SNR levels, the bit error rate before channel decoding depends on the constellation used, but is of the order of 10^{-1} . At these operating points, the modern error correcting codes having adequate packet sizes (> 1000 information bits, approximately) and coding efficiencies ranging from $1/3$ to $1/2$ approximately are capable of decoding the packets with low error probabilities (less than 10^{-4}). The gain compared to the BDFE equalizer is approximately 3 dB with $\text{BER} = 10^{-1}$ for a BPSK modulation, and approximately 1 dB with $\text{BER} = 10^{-1}$ for a QPSK modulation. When associated with a powerful error correcting coding algorithm, such as for example a turbo code, an LDPC (acronym for *Low Density Parity Check*) code or a polar code, the receiver according to the invention is therefore

likely to therefore offer better performance levels than an equalizer of BDFE type for a disturbed propagation channel.

[0038] The method according to the invention therefore consists in using a Rake receiver for signals that do not use spreading sequences.

[0039] The similarity between a reception method according to the invention and a Rake receiver used to receive a spread signal such as a DSSS (acronym for *Direct-Sequence Spread Spectrum*) signal and/or a CDMA (acronym for *Code Division Multiple Access*) signal stems from the fact that, in both cases, each path of interest of a multipath channel is processed independently, then the paths are recombined coherently before carrying out the demodulation of the symbols.

[0040] The main difference with the Rake reception techniques for DSSS and/or CDMA signals relates to the estimation of the impulse response of the propagation channel. Indeed, the recombining of the paths performed in the Rake receiver according to an MRC (acronym for *Maximum Ratio Combining*) technique necessitates knowledge of the delays and complex amplitudes of the paths to be considered. In the case of the Rake receivers applied to the DSSS and/or CDMA signals, the channel estimation is obtained based on the complex amplitudes of the paths observed over the correlation between the received signal and the spreading sequences used. The method according to the invention applies to the case where, contrary to the DSSS and/or CDMA signals, the received signal does not comprise spreading sequences. The invention then proposes using reference sequences and performing a channel estimation over these sequences to configure the Rake receiver.

[0041] The invention also runs counter to the preconceptions of the person skilled in the art, since it is common practice to use Rake receivers for spread signals in very low operating ranges (typically for negative signal-to-noise ratios), and equalizers on non-spread signals in higher operating ranges (typically for positive signal-to-noise ratios). The invention proposes using a Rake receiver on non-spread signals, in an operating

range in which it is common practice to use equalizers. Unexpectedly, the performance levels obtained are very good. Indeed, in the case of a CCIR poor channel with two paths of the same power, and in the absence of noise, the SINR seen by each path is on average 0 dB, and the SINR after recombination is 3 dB. As figure 4 and figures 8 to 10 show, in these conditions, the reception method according to the invention makes it possible to obtain bit error rates that are sufficient to ensure a good data decoding rate at error correcting code output.

[0042] Figure 5 is a functional diagram representing a method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention, given as a non-limiting example.

[0043] Figure 5 represents only the digital processing operations necessary to recover the information bits transmitted. The receiver takes as input upsampled modulated symbols 501 supplied by an analog-digital converter of the radio part of the receiver. In the example, the signal is assumed to be received at a frequency four times greater than the symbol rate. It is first of all filtered by a suitable filter 502 corresponding to the forming filter 108 of figure 1, namely here a half-Nyquist filter. The presence of a filtering and the choice of the filter depend on the modulation used.

[0044] A channel estimation 504 is performed on the filtered and upsampled signal 503, in order to be able to finely select the paths of interest and calculate their complex amplitudes. These processing operations correspond to an embodiment of the second step 302 of the method according to the invention. The estimation of the impulse response of the propagation channel is next used to configure a Rake receiver 505, responsible for the MRC recombining of the signals corresponding to the main paths. The decimation of the signal at the symbol rate is performed during the Rake reception processing.

[0045] In an advantageous embodiment, the receiver calculates the signal-to-noise ratio 507 of the output signal of the Rake receiver 506, and uses it to calculate, in 508, soft decoding bits (better known as *Soft Bits*),

through an LLR (acronym for *Log Likelihood Ratio*) algorithm. Finally, the soft decision bits are deinterleaved in 509, and processed by the channel decoder 510, thus making it possible to recover the information bits 511.

[0046] The processing operations performed in the receiver mirror the processing operations implemented in the transmitter. In particular, if the transmitter does not perform filtering 108, interleaving 103 or coding 102, the blocks 502, 509 and 510 will not exist in the receiver. With respect to the upsampling of the signals, this involves an implementation choice for which the transmission and the reception are independent. The soft decoding is an advantageous variant implementation that makes it possible to maximize the performance levels of the error correcting code.

[0047] Figure 6 represents in more detail the channel estimation 504 and Rake reception 505 functions in a method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention. In this embodiment, the sequences of useful symbols are bracketed by reference sequences. The impulse response of the channel is estimated based on the sequences situated before and after the useful symbols.

[0048] The channel estimation 504 is performed for each sequence of symbols of the frame, by considering in isolation a piece of the received signal 601 comprising the sequence of useful symbols D of interest and the two reference sequences R which surround it. A first estimate $h_1(n)$ 602 of the impulse response of the propagation channel is calculated on the reference sequence which precedes the sequence of symbols, and a second estimate $h_2(n)$ 603 is made on the sequence which follows it. These estimations are done at the rate of the upsampled signal, that is to say, in the example, at four times the baud rate.

[0049] The average impulse response $h_{moy}(n)$ 604 is then calculated by averaging the two channel estimations $h_1(n)$ and $h_2(n)$. It is assumed that the propagation channel is relatively constant during the transmission of a block of useful symbols, but that low to high channel variations can occur based on the Doppler spreading of the paths. The calculation of an average impulse response then makes it possible to

enhance the quality of the estimation of the propagation channel if it varies little, and/or to define an average channel response if the channel varies more quickly.

[0050] Figure 7 gives an example of impulse response calculated by the estimator of impulse response of the propagation channel 504 in a method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention. In the example, the impulse response comprises K paths (here K=2) 701 and 702 each having a delay Δ_k and a complex amplitude α_k , with k an index ranging from 1 to K.

[0051] The third step 303 of the method according to the invention consists in extracting the values of α_k and Δ_k associated with the K most significant paths, that is to say the K paths of highest amplitude α_k .

[0052] The fourth step 304 of the method according to the invention consists in coherently recombining the multipaths using the Rake receiver 505. It is executed when K is greater than 1.

[0053] In the example of figure 6, the Rake receiver is configured to process K paths. It therefore comprises K branches, each branch taking as input the sequence of useful symbols D considered, and being configured with respect to a delay/amplitude pairing Δ_k/α_k calculated in 605.

[0054] The Rake receiver is configured to, initially, resynchronize the paths based on the delay information Δ_k , by applying to the sequence of useful symbols D the reverse delay 610 on each branch of the Rake receiver.

[0055] Next, when necessary, the Rake receiver, in 611, brings the sequences of symbols to the symbol rate, in the example by decimating it by four, then applies to the signals a gain 612 by multiplying each signal by a factor corresponding to the complex amplitude α_k .

[0056] The Rake receiver 505 finally performs a coherent recombination MRC of the signals of each branch, that is to say a coherent summing followed by a normalization by a factor equal to the inverse of the sum of the squared moduli of the complex amplitudes α_k applied, i.e.:

$$\frac{1}{|\alpha_1|^2 + \dots + |\alpha_K|^2}.$$

[0057] The symbols $Symb_{Rx}$ at the output of the MRC processing are then written as follows:

$$Symb_{Rx}(n) = \frac{\sum_{k=1}^K \alpha_k^* \cdot r(4n + \Delta_k)}{\sum_{k=1}^K |\alpha_k|^2}$$

with K the number of paths of interest, α_k the complex amplitudes of the paths of interest, Δ_k the delays of the paths of interest and $r(n)$ the received signal filtered by the adapted and upsampled filter.

[0058] This operation is repeated for all the sequences of useful symbols of the frame.

[0059] Figures 8, 9 and 10 represent the performance levels of the method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention, for bit rate classes of 600, 1200 and 1800 bits per second. By way of comparison, the performance levels obtained by an HF receiver according to the state-of-the-art using a BDFE equalizer are represented in these same figures. The bit error rate is a bit error rate after deinterleaving and decoding.

[0060] Figure 8 presents the performance levels for a parameterizing that provides approximately 600 information bits per second, with blocks of useful symbols of 108 symbols and a propagation channel with two paths of identical average powers, spaced apart by 2 ms. The curves 801 and 802 represent the performance levels obtained by implementing the invention, respectively for 1 Hz and 10 Hz of Doppler spreading. The curves 803 and 804 represent the performance levels obtained with a BDFE equalizer, respectively for 1 Hz and 10 Hz of Doppler spreading. For 1 Hz of Doppler spreading, the reception method according to the invention exhibits a gain of close to 4 dB with respect to the state-of-the-art for a bit error rate of 10^{-2} . This gain is more than 7 dB for a Doppler spreading of 10 Hz.

[0061] Figure 9 presents the performance levels for a parameterizing that gives approximately 1200 information bits per second, with blocks of useful symbols of 108 symbols and a propagation channel with two paths of identical average powers, spaced apart by 2 ms. The curves 901 and 902 represent the performance levels obtained by implementing the invention, respectively for 1 Hz and 9 Hz of Doppler spreading. The curves 903 and 904 represent the performance levels obtained with a BDFE equalizer, respectively for 1 Hz and 9 Hz of Doppler spreading. For 1 Hz of Doppler spreading, the reception method according to the invention exhibits a gain of close to 3 dB with respect to the state-of-the-art for a bit error rate of 10^{-2} . This gain is more than 7 dB for a Doppler spreading of 9 Hz.

[0062] Figure 10 presents the performance levels for a parameterizing that gives approximately 1800 information bits per second, with blocks of useful symbols of 108 symbols and a propagation channel with two paths of identical average powers. The curves 1001 and 1002 represent the performance levels obtained by implementing the invention, respectively for 1 Hz and 5 Hz of Doppler spreading. The curves 1003 and 1004 represent the performance levels obtained with a BDFE equalizer, respectively for 1 Hz and 5 Hz of Doppler spreading. For 1 Hz of Doppler spreading, the reception method according to the invention exhibits a gain of approximately 2 dB with respect to the state-of-the-art for a bit error rate of 10^{-2} . This gain is more than 2.5 dB for a Doppler spreading of 5 Hz.

[0063] For low to moderate bit rates, the reception method according to the invention therefore exhibits performance levels much better than the equalizers according to the state-of-the-art, with a very much lower computational complexity.

[0064] The invention relates also to a receiver, represented schematically in figure 11, comprising an antenna 1101 configured to acquire a radiofrequency signal in a given frequency band, advantageously the HF frequency band, a radio chain 1102 configured to transpose the acquired signal to the baseband or an intermediate frequency and digitize it, then

computation means 1103 such as a processor, a digital signal processor (better known by the acronym DSP), a microcontroller, a dedicated circuit such as an ASIC (acronym for *Application Specific Integrated Circuit*) or an FPGA (acronym for *Field-Programmable Gate Array*), configured to implement a method for receiving an RF signal that is not spectrally spread according to an embodiment of the invention.

CLAIMS

1. A method for receiving a radiofrequency (RF) signal that is not spectrally spread, said signal being transmitted by frames, each frame comprising one or more reference sequences (202) and one or more sequences of useful symbols (203), said method being characterized in that it comprises:
 - a first step (301) of receiving, transposing and digitizing a frame of the RF signal, then, for at least one sequence of useful symbols,
 - a second step (302) of estimating an impulse response of the propagation channel associated with the sequence of useful symbols (504), using one or more of the reference sequences,
 - a third step (303) of extracting (605) the delays and amplitudes of the K strongest paths of said impulse response of the propagation channel,
 - when K is greater than 1, a fourth step (304) of processing the sequence of useful symbols by a Rake receiver with K paths (505) by using the delays and amplitudes calculated in the third step (303).
2. The method for receiving an RF signal that is not spectrally spread as claimed in claim 1, wherein the second step of estimating an impulse response of the propagation channel associated with the sequence of useful symbols (504) comprises:
 - estimating a first impulse response (602) of the propagation channel based on a reference sequence situated before said sequence of useful symbols,
 - estimating a second impulse response (603) of the propagation channel based on a reference sequence situated after said sequence of useful symbols, and
 - calculating an average (604) between said first impulse response and said second impulse response.

3. The method for receiving an RF signal that is not spectrally spread as claimed in one of the preceding claims, wherein the fourth step of processing the sequence of useful symbols by a Rake receiver with K paths (505) comprises:
 - for each path, applying a temporal realignment (610) and a gain (612) to the sequence of useful symbols,
 - summing the sequences of useful symbols realigned and adjusted in gain and normalizing the resulting sequence of symbols (613) by a coefficient dependent on the gains applied to the paths.
4. The method for receiving an RF signal that is not spectrally spread as claimed in one of the preceding claims, further comprising a step of estimating soft decision bits (508) on the useful symbols (506) derived from the fourth step (304), said soft decision bits being used subsequently as inputs of an error correcting decoding algorithm (510).
5. The method for receiving an RF signal that is not spectrally spread as claimed in one of the preceding claims, wherein the RF signal is transmitted in the high-frequency band.
6. A receiver of radiofrequency (RF) signals, characterized in that it comprises a radio chain (1102) configured to perform the first step of a method for receiving an RF signal that is not spectrally spread as claimed in one of the preceding claims, and computation means (1103) configured to implement the following steps of said method for receiving an RF signal that is not spectrally spread.