

Description

The present invention relates generally to improvements in spread-spectrum transmission systems and in a preferred embodiment the invention is applied to a vehicle location and tracking system.

5 A number of information bearing channels can share the same medium and approximately the same frequency band and yet be separated at the receiving end with satisfactory interchannel isolation if suitable pseudo-noise (PN) codes are used asynchronously to direct-sequence modulate the channel carriers at a high rate relative to the data rate. This has the effect of spreading the spectrum of the transmitted energy.

At the receiver, the information in each channel is extracted by cross-correlating the incoming
10 composite stream with the code associated with the desired channel. When the clock rate and the epochs of the in-coming and locally-generated codes match, the spread-spectrum energy is collapsed to the relatively narrow, data bandwidth for that channel whilst all the other channel spectra remain spread.

This method enables a particular medium (eg a coaxial-cable transmission line) to carry a virtually unlimited number of channels, separation being achieved at the receiving end by code-division multiple
15 access (CDMA). The performance of the scheme in terms of signal-to-noise ratio depends on the relative orthogonality of the codes; that is, on their cross-correlation properties. A unique feature is the smooth degradation of signal-to-noise ratio as more users come into the system compared to the sudden loss of performance which occurs in a conventional frequency division multiple access (FDMA) system once the channel capacity is exceeded.

20 The capability of a spread-spectrum channel to reject interference from other signals in other channels and from noise is called the process gain. Mathematically, process gain is given as:

$$G_p = 10 \log_{10} B/b \text{ (dB)} \quad (1)$$

25 where

B = bandwidth of spread-spectrum signal
b = data or information bandwidth

and it is assumed that the spectral line spacing of the PN codes are small enough for the spectra to be considered continuous.

30 Consider now the case of one transmitter, one receiver and no data. According to equation (1) the process gain is infinite because $b \rightarrow 0$. The zero-data example might be a ranging system where it is necessary only to locate the code epoch and, knowing the propagation delay, the range to the transmitter may be calculated; range ambiguity can be avoided by making the code repetition period much greater than the propagation delay. In practice the process gain can be very large, but not infinite, and is limited
35 mainly by the extent of the loss of coherence of the carrier at the receiver relative to the receiver local oscillator. If the 'coherence time' of the received carrier is τ then $b \sim \tau^{-1}$ and process gain can be increased only by spreading the spectrum of the transmitted signal still further. This can be done by increasing the chip-rate (code clock rate) of the PN code up to a limit set by the electronics or by the ability of the transmission medium to support the spread-spectrum bandwidth.

40 Referring to Fig. 1 it may be seen that in a spread-spectrum location and tracking system, the vehicle 10 or object to be located emits a continual direct sequence spread-spectrum radio signal 11. This transmission is received at a number of well-spaced receiving stations 12 in the coverage area and the differences in the times of arrival of the signals at these receivers are measured. Inverse hyperbolic navigation techniques then may be used to compute the position of the transmitter at the central computer
45 13 which then sends this information to an operator terminal.

Direct sequence spread-spectrum modulation is employed for a number of reasons, one of which is to minimise multi-path effects. Also, since for location and tracking purposes there is no data transmission requirement, there would appear to be potential for very high process gain. Unfortunately the process gain is severely limited in practice. Firstly transmissions from a vehicle moving in an urban, or suburban, area
50 experience Rayleigh scattering and Doppler frequency-shift. As a result, at each receiving site 12 the received signal spectrum is bandlimited to within $\pm \Delta f$ of the centre frequency where $\Delta f = f_0 v/c$ is the maximum Doppler frequency-shift for a vehicle with speed v transmitting on a frequency f_0 (c is the speed of radio propagation). The coherence time of the carrier depends roughly inversely on the width of the frequency-modulation spectrum so that this scattering sets a lower limit to b , the post-correlation bandwidth.
55 Secondly, the radio-frequency spread-spectrum bandwidth cannot be made arbitrarily wide because of limitations on the coherence bandwidth caused by different fading in different parts of the spectrum.

A rough estimate of the available process gain using urban mobile transmitters may be obtained from published data. For a centre frequency of about 450 MHz the minimum coherence time is about 5 ms and

the coherence bandwidth is around 1 MHz giving an available process gain of approximately 37 dB. This figure gives a measure of the level of signal enhancement, over broadband spectrally-continuous noise and interference, achievable by receiver processing.

For a spread-spectrum multi-vehicle location and tracking system in which M transmitters are operating simultaneously, each transmitter to be located and tracked has (M-1) interferers. If CDMA is used, the cross-correlation properties of the codes of the wanted and unwanted signals will determine the extent of the interference. In the commonly-used binary Gold code family, the cross-correlation between any pair of codes generated using n-bit shift registers is bounded by

$$\begin{aligned} |\theta(r)| &\leq 2^{(n+1)/2} + 1 & (n \text{ odd}) \\ |\theta(r)| &\leq 2^{(n+2)/2} - 1 & (n \text{ even}) \end{aligned}$$

Since these sequences are of maximal length, the number of bits in the code is:

$$N = 2^n - 1$$

and for $n \gg 1$ the ratio of the auto-correlation peak to the maximum cross-correlation bound is

$$\begin{aligned} R &\sim 2^{(n-1)/2} & (n \text{ odd}) \\ &\sim 2^{(n-2)/2} & (n \text{ even}) \end{aligned}$$

The larger n is made, the better the wanted signal can be distinguished from the unwanted ones. In other words, the longer the sequence length (N) the better. However,

$$N = T_R f_C \quad (2)$$

where

$$\begin{aligned} T_R &= \text{code repetition period} \\ f_C &= \text{chip rate} \end{aligned}$$

and, as we have seen already, for an urban vehicle-tracking system, both T_R and f_C have practical upper limits set by the coherence time and coherence bandwidth respectively so there is a practical upper limit set on the choice of N. For the particular example quoted above we have $N \sim 5000$. With this value of N we have $n \sim 12$ and hence $R \sim 32$ giving a maximum 'process gain' of about 15 dB. Clearly in this case CDMA falls well short when its performance is compared to the available process gain (over an interference continuum) of 37 dB.

It is important to understand that the spectral components of a spread-spectrum signal are spaced by $f_R = 1/T_R = f_C/N$. For a given chip rate, long PN codes have spectral lines very close together and short PN codes have widely-separated lines. A long code may be modelled to have a continuous power spectrum but with a short code the discrete lines must be considered, particularly as they affect the process gain which varies in discrete steps according to the number of spectral lines falling into the passband of the post-correlation filter.

The usefulness of a vehicle-tracking or locating system is enhanced in proportion to the number of vehicles which can be located or tracked at the same time. A high, realisable, process gain is needed in such a spread-spectrum multi-vehicle tracking system because of the necessity of isolating each received transmission from the others; a requirement which is exacerbated by the 'near-far problem'.

United States Patent No 3714573 discloses a system capable of monitoring the position of vehicles, each vehicle being provided with a transmitter arranged to transmit a uniquely coded spread-spectrum identification signal. The signals from each respective transmitter are arranged to be transmitted at predetermined time intervals. The spacing between these intervals is arranged for each transmitter to give sufficient time to reduce the probability that signals from other transmitters in the system will be received during overlapping time intervals. In other words, the signals from each transmitter are asynchronously spaced to reduce the possibility of deleterious interference with each other.

Japanese patent application No 59-2458 discloses a spread spectrum communication system, in which an information signal and plural differential signals having a prescribed relation with the information signal are added to same PN code and different carriers, to result in a signal for transmission so as to improve the demodulation of the information signal.

The present invention exploits the quasi-discrete nature of the mobile transmitters' spectra and employs a novel form of frequency division multiple access(FDMA) to effect this isolation.

According to the present invention a multi-channel spread-spectrum transmission system, wherein a plurality of spread-spectrum signals are frequency division multiplexed to provide multiple transmission channels, comprises

a plurality of transmitters each for transmitting a signal having a plurality of spaced spectral lines or bands produced by modulating a carrier with a pseudo-noise code, such that the transmitted signal of each channel has an information bandwidth which is significantly less than its spectral line or band spacing, characterised in that the spread-spectrum signals each have centre frequencies which are spaced, respectively, by frequency increments selected to cause the spectral lines or bands of the respective transmitted signals to be interleaved; the selected frequency increments being less than the transmitted bandwidth of each signal.

In preferred embodiments of the invention the transmission bandwidth for an M-channel system is increased only slightly over that of a single channel while achieving substantially greater channel isolation than is possible using CDMA techniques.

The invention is applicable to all spread-spectrum transmission systems where the information bandwidth is much less than the spectral line or band spacing of the transmitted spectrum. The utility of spread-spectrum systems in which the information bandwidth is essentially zero, such as systems using spread-spectrum signals for ranging purposes, is particularly enhanced.

According to another aspect, the invention includes a receiver for receiving a plurality of transmitted spread-spectrum signals which are frequency division multiplexed to provide a plurality of transmission channels, wherein the channels are distinguished by respective signal centre frequencies, each signal comprising a plurality of spaced spectral lines or bands produced by modulating a carrier with a pseudo-noise code, the carrier consisting of a band of frequencies due to the statistical uncertainty of its frequency, the transmitted signal of each channel having an information bandwidth which is significantly less than its spectral line or band spacing, and where the centre frequencies of the spread-spectrum signals are spaced by frequency increments selected to cause spectral lines or bands of the respective transmitted signals to be interleaved, the selected frequency increments being less than the transmitted bandwidth of each signal, said receiver being characterised by :

receiver means including a plurality of receiver channels, correlation means being provided for each receiver channel to cause the spread-spectrum signal received on a respective channel to be collapsed to a narrow bandwidth corresponding to the transmission channel signal bandwidth which comprises the sum of the carrier frequency uncertainty bandwidth and the channel information bandwidth such that it is selected by being passed through a narrowband filter having a bandwidth corresponding to said transmission channel signal bandwidth, eliminating essentially all interference from other channels as well as wideband noise lying outside the filter bandwidth.

The invention also includes a multi-vehicle location and tracking system capable of tracking a plurality of vehicles at the same time, comprising :

a plurality of mobile radio-frequency transmitters each mounted on a vehicle to transmit a spread-spectrum signal comprising a plurality of spaced spectral lines or bands and having an information bandwidth which is significantly less than its spectral line or band spacing, the spread-spectrum signal being produced by modulating a carrier with a pseudo-noise code;

at least three multi-channel receivers positioned at known spaced locations each being arranged to receive the spread-spectrum signals transmitted by each of the transmitters;

control means communicating with each of the receivers and including signal processing means to measure differences in the propagation time from a respective transmitter to each receiver for each one of said transmitted signals and to thereby calculate the position of the respective transmitter relative to the receivers characterised in that, the transmitters are arranged such that the spread-spectrum signals from respective individual transmitters have centre frequencies which are spaced from each other by frequency increments selected to cause spectral lines or bands of the respective transmitted signals to be interleaved, the selected frequency increments being less than the transmitted bandwidth of each signal, and in that correlation means is included in each channel receiver to cause the spread-spectrum signal received from an individual transmitter associated with the respective channel to be collapsed to a narrow bandwidth corresponding to the transmitted channel signal bandwidth which comprises the sum of the carrier frequency uncertainty bandwidth and the channel information bandwidth such that it is selected by being passed through a narrowband filter thereby eliminating essentially all interference from the transmitted signals of other channels as well as wideband noise.

The invention also includes the corresponding methods.

BRIEF DESCRIPTION OF THE DRAWINGS

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings in which:

- 5 Fig. 1 generally illustrates a vehicle tracking system in which the spread-spectrum multiplexed transmission system of the present invention might be used;
- Fig. 2 graphically illustrates the frequency domain representation of a spread-spectrum signal;
- Fig. 3 is a block diagram of a spread-spectrum transmitter for use in a vehicle tracking system using the present invention;
- 10 Fig. 4 is a block diagram of a remote site receiver installation for use in a vehicle tracking system using the present invention; and
- Fig. 5 is a block diagram of the installation of Fig. 4 showing the receiver arrangement in greater detail.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

15 The present invention exploits the quasi-discrete nature of the transmitters' spectra and employs a novel form of frequency division multiple access (FDMA). To understand the principles involved we refer to Fig. 2 which shows details of the spectrum emitted by a transmitter using a maximal PN code of length N to direct-sequence bi-phase modulate a carrier on a frequency f_0 .

20 The diagram shows that the spectral lines are spaced by the code repetition frequency $f_R = f_0/N$ and that the spectrum of the transmitted signal is symmetrical about the carrier frequency f_0 . When this signal is emitted from a mobile vehicle in an urban area it undergoes Rayleigh scattering and Doppler frequency-shift as the radio waves propagate by a multitude of paths to the receiver. Each line in the spectrum of the received signal exhibits random frequency modulation (as described above) with most of the energy of the
 25 line being contained within a bandwidth of twice the maximum Doppler frequency-shift. Specifically, if the speed of the vehicle is v and the speed of radio propagation is c , the energy of a spectral line is contained essentially in a bandwidth $2\Delta f$ where $\Delta f = f_0 v/c$. As an example, if f_0 is 450 MHz and $v = 100$ km/hr we have $2\Delta f \sim 85$ Hz. In order to enhance the signal-to-noise ratio of this signal by processing in the receiver, the final local oscillator can be direct-sequence modulated with the same PN code as used in the
 30 transmitter, the local epoch of the code being adjusted until it matches that of the incoming code. When this happens, the energy contained in all the spectral lines of the received signal is concentrated essentially into the bandwidth $2\Delta f$ centered on the final intermediate frequency. In other words, the spectrum is collapsed or 'despread' and the process gain is achieved. From the foregoing it is clear that the bandwidth of the final IF must be wide enough to accommodate the collapsed spectral energy. Allowing for an uncertainty $\pm \delta f$ in
 35 the carrier frequency of the transmitter, the final IF bandwidth should not be less than $2(\Delta f + \delta f)$.

The radiated spread-spectrum signal from each transmitter occupies a relatively wide bandwidth B (typically of the order of 1MHz). When M transmitters are operating simultaneously, as in a multi-vehicle tracking system, the use of FDMA would suggest a bandwidth requirement of at least $M \times B$ for the system as a whole. In urban areas particularly, the radio-frequency spectrum is viewed as a scarce resource much
 40 in demand. Consequently, the use of a bandwidth $M \times B$ is likely to be considered extravagant. The present invention offers an acceptable answer to these objections without the degradation in process gain associated with CDMA.

The present invention uses the fact that although the bandwidth of the signal received from each transmitter is very wide, it has a quasi-discrete line spectrum arranged symmetrically about the carrier. If
 45 the spacing between the 'lines' is made large compared to the frequency band each one occupies and if the same spacing is used for all transmitters, it is possible to interleave these 'lines' (or bands) by offsetting the centre frequencies of all the transmitters by relatively small amounts in the following way:

Let the number of simultaneous transmissions be M . If all the transmitters have centre-frequency offsets which are multiples of $f_R P/M$ where P is a non-zero integer such that P and M have no common factors then
 50 the i^{th} channel has a centre frequency offset

$$f_i = (i - 1)f_R P/M \quad (3)$$

where

$$55 \quad i = 1, 2, \dots, M$$

Now providing the width of the individual 'lines' is less than f_R/M the individual channels have been

interleaved in such a way as to produce no interchannel interference. The extent to which the bandwidth is increased over that of a single channel is $f_R P(M-1)/M$ compared to an increase of at least $(M-1) \times B$ for a conventional FDMA approach. This represents a very substantial saving. In the limit, where $P=1$, the bandwidth extension is insignificant since $B \gg f_R$.

Consider now the process gain. If the effective bandwidth of the final IF filter is b , then in the presence of a continuous spectrum of broadband noise and interference, a process gain of B/b is realisable. However, the received spectrum from M simultaneously-operating transmitters with carrier frequency offsets as in eqn (3) above consists of quasi-discrete spectral lines separated by

$$f_s = f_c/MN = f_R/M \quad (4)$$

If we increase the number of simultaneously operating transmitters, M , whilst keeping the IF bandwidth b fixed, the spectral 'line' spacing decreases according to eqn (4). As this happens, the number of spectral 'lines' entering the IF bandwidth increases. If we define the process gain, in the context of multiple transmitters, as the ratio of the power from the wanted transmitter to that from the unwanted ones, it is clear that the process gain will fall as M increases due to the power contributed by the unwanted transmissions to the signal within the filter bandwidth b .

Other kinds of radio interference must be considered also. For example, a continuous radio-frequency wave (CW) in the receiver passband will be spread into discrete lines when it is mixed with the phase-encoded local oscillator. The spacing between these lines will be $f_R = f_c/N$ where f_c is the chip rate of the local code and N is the length of the code. Just as for a transmitter, the spectrum will be symmetrical about the frequency difference between the continuous wave and the local oscillator. Since the frequency of the interfering signal is determined by factors external and unrelated to the spread-spectrum transmission system it is possible for a single spectral line to fall into the passband b of the final IF stage (assuming $b < f_R$) with a probability proportional to N and with a power level roughly inversely proportional to N . This means, for example, that the smaller N is made for a given chip rate f_c the less likely it is for an interfering spectral line to fall into the final IF bandwidth b . When this does happen however, the effect of the interference is greater although a single interfering CW will affect only one of the M channels in the receiver.

It may seem from the foregoing that, given f_c , a multi-vehicle locating system is implemented more effectively by using a shorter code. (A lower limit to the code length is set by the need to avoid range ambiguity; that is, $f_c^{-1} = N/f_c$ must be much greater than the signal propagation delay.) In fact, however, it is preferable to use a longer code in order to approximate more closely a spectral continuum in the radiation emitted by each transmitter whilst still being able to exploit the quasi-discrete nature of its spectrum. This is so because in an urban environment, it is desirable to diffuse the transmitted energy as nearly as possible into a continuum in order to minimise interference to conventional radio receivers.

In the preferred embodiment of the invention all transmitters use the same maximal PN code to direct-sequence, bi-phase modulate their respective carriers which are separated in the frequency domain in accordance with equation (3). Maximal PN sequences are preferred because of their well-controlled autocorrelation properties. The choice of the code length N is determined by the factors discussed above and, along with other parameters, is given by way of example in Table 1 for a ten-vehicle location system.

TABLE 1

Parameters of the preferred embodiment given by way of example but not limitation.		
Number of Channels:	(M)	10
Nominal centre frequency of mobile transmitter band:	(f_o)	440 MHz
Code length:	(N)	511 bits
Modulation type:		Bi-phase (0 or π), direct sequence
Code clock rate:	(f_c)	1.024 MHz
Frequency increments of mobile transmitters:	($f_R P/M$)	14.2 kHz
Nominal power radiated in the main spread-spectrum lobe:		20 mW

The transmitter which is attached to the vehicle is shown schematically in Fig. 3. A crystal-controlled oscillator and divider 21 provide a clock for the pseudo-noise code generator 22 and a reference to which the voltage-controlled radio-frequency oscillator 23 is locked via a programmable divider 24 and phase comparator 25. The output from the pseudo-noise generator is applied to the modulator 26 which bi-phase

modulates (0 or π) the RF carrier. This modulated wave is amplified in the output amplifier 27 and radiated from the antenna 28.

The vehicle-borne transmitter may transmit continuously, or it may be considered preferable to switch the transmitter on and off locally or by remote control.

5 A block diagram of the remote receiving station electronics of an M-channel system is shown in Fig. 4. In the preferred embodiment the timing at all remote sites is synchronised to a received timing signal radiated from a fixed location. This timing transmission is received preferably by means of a high-gain antenna 31 such as a Yagi connected to the radio frequency (RF) section 32 of the timing receiver. The intermediate frequency (IF) stages of both the timing reference and main receivers are housed in the same
10 unit 33 where the local clock is synchronised by control signals from the channel 0 timing reference receiver 37, which also supplies a reference epoch signal 50 (see Fig. 5) for distribution through this common unit to the M main receiver channels 34.

Spread-spectrum signals from the vehicle transmitters are received by means of the vertical antenna-array 35 and main receiver RF section 36, and are converted to intermediate frequencies retaining their
15 offsets in accordance with equation (3) above. This is effected in the IF stages. Fig. 5 shows in more detail how the M individual transmissions are acquired and their epochs are tracked. With reference to this diagram we note that all received spread-spectrum signals are amplified in the first wideband amplifier 41 at an intermediate frequency F. This amplifier has a bandwidth wide enough to pass all the spread-spectrum signals from the mobile transmitters. These amplified signals are split equally and passed to M identical first
20 mixers 42 each of which is fed by a different local oscillator 43. The frequencies of the local oscillators $F_1, F_2, \dots, F_M$ are offset from each other in accordance with equation (3) just as for the transmitter carrier frequencies. Consequently receiver channel i with local oscillator frequency F_i locates the centre frequency of the signal received from transmitter i at F_0 where $i = 1, 2, \dots, M$. The outputs of the first mixers are amplified in second wideband amplifiers 44 and applied to second mixers 45 where the PN code generated
25 in code generators 47 operates on the local oscillator ports. Although the same PN code is used, the epochs in each channel are independently varied in response to epoch control signals 48 produced by microcontrollers contained in the detector and microcontroller blocks 46. Each epoch is adjusted until it matches that of the incoming signal for that channel. When this occurs, the spectrum of this signal collapses to the relatively narrowband of frequencies (determined by the Doppler frequency-shift and
30 transmitter crystal-oscillator uncertainty as discussed in section 2 above) all centred on F_0 . This narrowband signal appears at the output of the second mixer 45 and passes through the narrowband filter 49 to the detector and microcontroller block 46 which detects the signal and maintains a match between the incoming and locally-generated code epoch by appropriate advance/retard adjustment of the locally-generated code. There are many ways of achieving code epoch tracking which will be familiar to those skilled in the art and
35 need not be described here. Finally, the time difference between the epoch of the code in a tracking channel and the timing reference 50 is measured in the detector and microcontroller block 46 and the time measured for each channel is passed to the remote site computer 38 and finally via the modem 39 and land line 14 of Fig. 4 to the central computer 13 shown in Fig. 1.

40 Claims

1. A multi-channel spread-spectrum transmission system, wherein a plurality of spread-spectrum signals are frequency division multiplexed to provide multiple transmission channels, comprises
45 a plurality of transmitters (21-28) each for transmitting a signal having a plurality of spaced spectral lines or bands produced by modulating a carrier with a pseudo-noise code, such that the transmitted signal of each channel has an information bandwidth which is significantly less than its spectral line or band spacing, characterised in that the spread-spectrum signals each have centre frequencies which are spaced, respectively, by frequency increments selected to cause the spectral lines or bands of the respective transmitted signals to be interleaved, the selected frequency increments being less than the
50 transmitted bandwidth of each signal.
2. The system as claimed in claim 1, wherein the transmitted signal of each channel has an information bandwidth of essentially zero.
- 55 3. The system as claimed in claim 1, wherein the spectral lines or bands of each of the spread-spectrum signals are spaced by a frequency f_R and the centre frequencies of the respective signals are spaced by frequency increments of $f_R P/M$ where P is a non-zero integer and M is a number of channels greater than 1 such that P and M have no common factors.



modulates (O or π) the RF carrier. This modulated wave is amplified in the output amplifier 27 and radiated from the antenna 28.

The vehicle-borne transmitter may transmit continuously, or it may be considered preferable to switch the transmitter on and off locally or by remote control.

5 A block diagram of the remote receiving station electronics of an M-channel system is shown in Fig. 4. In the preferred embodiment the timing at all remote sites is synchronised to a received timing signal radiated from a fixed location. This timing transmission is received preferably by means of a high-gain antenna 31 such as a Yagi connected to the radio frequency (RF) section 32 of the timing receiver. The intermediate frequency (IF) stages of both the timing reference and main receivers are housed in the same
10 unit 33 where the local clock is synchronised by control signals from the channel 0 timing reference receiver 37, which also supplies a reference epoch signal 50 (see Fig. 5) for distribution through this common unit to the M main receiver channels 34.

Spread-spectrum signals from the vehicle transmitters are received by means of the vertical antenna-array 35 and main receiver RF section 36, and are converted to intermediate frequencies retaining their
15 offsets in accordance with equation (3) above. This is effected in the IF stages. Fig. 5 shows in more detail how the M individual transmissions are acquired and their epochs are tracked. With reference to this diagram we note that all received spread-spectrum signals are amplified in the first wideband amplifier 41 at an intermediate frequency F. This amplifier has a bandwidth wide enough to pass all the spread-spectrum signals from the mobile transmitters. These amplified signals are split equally and passed to M identical first
20 mixers 42 each of which is fed by a different local oscillator 43. The frequencies of the local oscillators $F_1, F_2, \dots, F_M$ are offset from each other in accordance with equation (3) just as for the transmitter carrier frequencies. Consequently receiver channel i with local oscillator frequency F_i locates the centre frequency of the signal received from transmitter i at F_0 where $i = 1, 2, \dots, M$. The outputs of the first mixers are amplified in second wideband amplifiers 44 and applied to second mixers 45 where the PN code generated
25 in code generators 47 operates on the local oscillator ports. Although the same PN code is used, the epochs in each channel are independently varied in response to epoch control signals 48 produced by microcontrollers contained in the detector and microcontroller blocks 46. Each epoch is adjusted until it matches that of the incoming signal for that channel. When this occurs, the spectrum of this signal collapses to the relatively narrowband of frequencies (determined by the Doppler frequency-shift and
30 transmitter crystal-oscillator uncertainty as discussed in section 2 above) all centred on F_0 . This narrowband signal appears at the output of the second mixer 45 and passes through the narrowband filter 49 to the detector and microcontroller block 46 which detects the signal and maintains a match between the incoming and locally-generated code epoch by appropriate advance-retard adjustment of the locally-generated code. There are many ways of achieving code epoch tracking which will be familiar to those skilled in the art and
35 need not be described here. Finally, the time difference between the epoch of the code in a tracking channel and the timing reference 50 is measured in the detector and microcontroller block 46 and the time measured for each channel is passed to the remote site computer 38 and finally via the modem 39 and land line 14 of Fig. 4 to the central computer 13 shown in Fig. 1.

40 Claims

1. A multi-channel spread-spectrum transmission system, wherein a plurality of spread-spectrum signals are frequency division multiplexed to provide multiple transmission channels, comprises
45 a plurality of transmitters (21-28) each for transmitting a signal having a plurality of spaced spectral lines or bands produced by modulating a carrier with a pseudo-noise code, such that the transmitted signal of each channel has an information bandwidth which is significantly less than its spectral line or band spacing, characterised in that the spread-spectrum signals each have centre frequencies which are spaced, respectively, by frequency increments selected to cause the spectral lines or bands of the respective transmitted signals to be interleaved, the selected frequency increments being less than the
50 transmitted bandwidth of each signal.
2. The system as claimed in claim 1, wherein the transmitted signal of each channel has an information bandwidth of essentially zero.
- 55 3. The system as claimed in claim 1, wherein the spectral lines or bands of each of the spread-spectrum signals are spaced by a frequency f_R and the centre frequencies of the respective signals are spaced by frequency increments of $f_R P/M$ where P is a non-zero integer and M is a number of channels greater than 1 such that P and M have no common factors.



4. The system as claimed in claim 1, wherein the selected increments by which the centre frequencies of the respective signals are spaced are such that the bandwidth occupied by all transmitted signals of the system as a whole is not substantially greater than the bandwidth of the individual spread-spectrum signals.
5. The system as claimed in claim 3, wherein P is chosen such that the bandwidth occupied by all transmitted signals of the system as a whole is not substantially greater than the bandwidth of the individual spread-spectrum signals.
- 10 6. The system as claimed in claim 3, wherein P is selected to be less than M.
7. The system as claimed in claim 3, wherein P is selected to be 1 and the centre frequencies of the respective signals are spaced by the frequency f_R/M .
- 15 8. The system as claimed in claim 3, wherein P is selected to be $M + 1$.
9. The system as claimed in claim 1, wherein each carrier consists of a band of frequencies due to the statistical uncertainty of its frequency and the spacing between spectral lines or bands of a composite signal of all transmitted signals is approximately equal to the sum of the channel information bandwidth and the statistical uncertainty bandwidth of the carriers, a code length of the pseudo-noise code and a clock rate of the code being chosen such that $f_R = Mf_L$ where M is the number of system channels, f_R is the spectral-line frequency spacing of individual spread-spectrum signals and f_L is the frequency spacing between spectral lines or bands of the composite signal.
- 20 10. A receiver (31-38) for receiving a plurality of transmitted spread-spectrum signals which are frequency division multiplexed to provide a plurality of transmission channels, wherein the channels are distinguished by respective signal centre frequencies, each signal comprising a plurality of spaced spectral lines or bands produced by modulating a carrier with a pseudo-noise code, the carrier consisting of a band of frequencies due to the statistical uncertainty of its frequency, the transmitted signal of each channel having an information bandwidth which is significantly less than its spectral line or band spacing, and where the centre frequencies of the spread-spectrum signals are spaced by frequency increments selected to cause spectral lines or bands of the respective transmitted signals to be interleaved, the selected frequency increments being less than the transmitted bandwidth of each signal, said receiver being characterised by:
 - 35 receiver means including a plurality of receiver channels (34), correlation means (42-48) being provided for each receiver channel to cause the spread-spectrum signal received on a respective channel to be collapsed to a narrow bandwidth corresponding to the transmission channel signal bandwidth which comprises the sum of the carrier frequency uncertainty bandwidth and the channel information bandwidth such that it is selected by being passed through a narrowband filter (49) having a bandwidth corresponding to said transmission channel signal bandwidth, eliminating essentially all interference from other channels as well as wideband noise lying outside the filter bandwidth.
- 40 11. The receiver as claimed in claim 10, wherein each channel signal has an information bandwidth of essentially zero.
- 45 12. The receiver as claimed in claim 10, wherein the spectral lines or bands of each of the spread-spectrum signals are spaced by a frequency f_R and the centre frequencies of the respective signals are spaced by frequency increments of $f_R P/M$ where P is a non-zero integer and M is a number of channels greater than 1 such that P and M have no common factors.
- 50 13. The receiver as claimed in claim 10, wherein the selected increments by which the centre frequencies of the respective signals are spaced are such that the bandwidth occupied by all received signals of the system as a whole is not substantially greater than the bandwidth of the individual spread-spectrum signals.
- 55 14. The receiver as claimed in claim 12, wherein P is chosen such that the bandwidth occupied by all received signals of the system as a whole is not substantially greater than the bandwidth of the individual spread-spectrum signals.



15. The receiver as claimed in claim 12, wherein P is selected to be less than M.

16. The receiver as claimed in claim 12, wherein P is selected to be 1 and the channel centre frequencies are spaced by the frequency f_R/M .

17. The receiver as claimed in claim 12, wherein P is selected to be $M + 1$.

18. The receiver as claimed in claim 10, wherein the spacing between spectral lines or bands of a composite signal of all received signals is approximately equal to the sum of the channel information bandwidth and an uncertainty bandwidth of the carriers, a code length of the pseudo-noise code and a clock rate of the code being chosen such that $f_R = Mf_L$ where f_L is the frequency spacing between spectral lines or bands of the composite signal, f_R is the spectral-line frequency spacing of the individual spread-spectrum signals and M is the number of channels.

19. A multi-vehicle vehicle location and tracking system capable of tracking a plurality of vehicles at the same time, comprising:

a plurality of mobile radio-frequency transmitters each mounted on a vehicle to transmit a spread-spectrum signal comprising a plurality of spaced spectral lines or bands and having an information bandwidth which is significantly less than its spectral line or band spacing, the spread-spectrum signal being produced by modulating a carrier with a pseudo-noise code;

at least three multi-channel receivers (31-38) positioned at known spaced locations each being arranged to receive the spread-spectrum signals transmitted by each of the transmitters;

control means communicating with each of the receivers and including signal processing means to measure differences in the propagation time from a respective transmitter to each receiver for each one of said transmitted signals and to thereby calculate the position of the respective transmitter relative to the receivers characterised in that, the transmitters are arranged such that the spread-spectrum signals from respective individual transmitters have centre frequencies which are spaced from each other by frequency increments selected to cause spectral lines or bands of the respective transmitted signals to be interleaved, the selected frequency increments being less than the transmitted bandwidth of each signal, and in that correlation means (42-48) is included in each channel receiver to cause the spread-spectrum signal received from an individual transmitter associated with the respective channel to be collapsed to a narrow bandwidth corresponding to the transmitted channel signal bandwidth which comprises the sum of the carrier frequency uncertainty bandwidth and the channel information bandwidth such that it is selected by being passed through a narrowband filter (49) thereby eliminating essentially all interference from the transmitted signals of other channels as well as wideband noise.

20. The vehicle tracking system as claimed in claim 19, wherein the spectral lines or bands of each of the transmitted spread-spectrum signals are spaced by a frequency f_R and the centre frequencies of the respective signals are spaced by frequency increments of $f_R P/M$ where P is a non-zero integer and M is a number greater than 1 of vehicles to be tracked at the same time such that P and M have no common factors.

21. The vehicle tracking system as claimed in claim 19, wherein the selected frequency increments, by which the centre frequencies of the respective signals are spaced, are such that the bandwidth occupied by all transmitted signals of the system as a whole is not substantially greater than the bandwidth of the individual transmitted spread-spectrum signals.

22. The vehicle tracking system as claimed in claim 20, wherein P is chosen such that the bandwidth occupied by all transmitted signals of the system as a whole is not substantially greater than the bandwidth of the individual transmitted spread-spectrum signals.

23. The vehicle tracking system as claimed in claim 20, wherein P is selected to be less than M.

24. The vehicle tracking system as claimed in claim 20, wherein P is selected to be 1 and the centre frequencies of the individual transmitted spread-spectrum signals are spaced by the frequency f_R/M .

25. The vehicle tracking system as claimed in claim 20, wherein P is selected to be $M + 1$.



26. The vehicle tracking system as claimed in claim 19, wherein each of the received carrier frequencies has a statistical uncertainty which is the sum of a statistical uncertainty of the transmitted carrier frequency and a motion and/or medium-induced uncertainty in the received frequency from the mobile transmitters, and the spacing between spectral lines or bands of a composite signal of all transmitted signals is approximately equal to the carrier frequency uncertainty bandwidth due to the statistical uncertainties of the received frequencies, the pseudo-noise code having a code length and a clock-rate which are chosen such that $f_R = Mf_L$ where M is the number of simultaneously tracked vehicles, f_R is the spectral line frequency spacing of the individual spread-spectrum signals and f_L is the frequency spacing between spectral lines or bands of the composite signal.
27. The vehicle tracking system of claim 19 wherein the transmitted spread-spectrum signals have an information bandwidth of essentially zero.
28. A method of providing multi-channel communication within a spectrum, comprising:
 transmitting a plurality of spread-spectrum signals frequency multiplexed within said spectrum, each signal comprising a plurality of frequency-spaced spectral lines or bands produced by modulating an information bearing carrier with a pseudo-noise code such that each channel has an information bandwidth significantly less than the frequency spacing of its spectral lines or bands, characterised in that each spread-spectrum signal carrier frequency is selected to be spaced from adjacent carrier frequencies by a frequency increment such as to cause the spectral lines or bands of respective transmitted signals to be interleaved, said frequency increment being less than the transmitted bandwidth of each signal; and
 processing each received signal of said transmitted signal by correlating a composite signal of all the received spread-spectrum signals with a locally-generated pseudo-noise code to cause the spread-spectrum signal on a respective channel to be collapsed to a narrow bandwidth substantially corresponding to the transmitted signal information bandwidth, and passing said collapsed signal through a narrowband filter (49) corresponding to the respective channel centre frequency so as to pass only transmitted signal information and eliminate interference from other received spread-spectrum signals as well as wideband noise lying outside the filter bandwidth.
29. A method of transmitting in a multi-channel communications system, a plurality of spread-spectrum signals being frequency division multiplexed within said spectrum, comprising:
 for each signal, modulating an information-bearing carrier with a pseudo-noise code to provide a plurality of frequency-spaced spectral lines or bands, such that each channel has an information bandwidth significantly less than the frequency spacing of its spectral lines or bands; characterised by
 selecting each spread-spectrum signal carrier frequency to be spaced from adjacent carrier frequencies by a frequency increment such as to cause the spectral lines or bands of respective transmitted signals to be interleaved, said frequency increment being less than the transmitted bandwidth of each signal.
30. The method of claim 29, further including modulating each channel such that it has an information bandwidth of essentially zero.
31. The method as claimed in claim 29 further including selecting the spectral lines or bands of each of the spread-spectrum signal to be spaced by frequencies f_R and the centre frequencies of the respective signals to be spaced by frequency increments of $f_R P/M$ where P is a non-zero integer and M is a number of channels greater than 1 such that P and M have no common factors.
32. The method as claimed in claim 29 further including spacing the selected increments of the centre frequencies of the respective signals such that the bandwidth occupied by all transmitted signals of the system as a whole is not substantially greater than the bandwidth of the individual spread-spectrum signals.
33. The method as claimed in claim 31 further including choosing P such that the bandwidth occupied by all transmitted signals of the system as a whole is not substantially greater than the bandwidth of the individual spread-spectrum signals.
34. The method as claimed in claim 31 further including choosing P to be less than M .



35. The method as claimed in claim 31 further including choosing P to be 1 and selecting the centre frequencies of the respective signals to be spaced by the frequency f_R/M .
36. The method as claimed in claim 31 further including selecting P to be $M + 1$.
37. The method as claimed in claim 29, further including modulating each carrier such that it consists of a band of frequencies due to the statistical uncertainty of its frequency, and the spacing between spectral lines or bands of a composite signal of all transmitted signals is approximately equal to the sum of the channel information bandwidth and the statistical uncertainty bandwidth of the carriers, and selecting a code length of the pseudo-noise code and a clock-rate of the code such that $f_R = Mf_L$ where M is the number of system channels. f_R is the spectral-line frequency spacing of individual spread-spectrum signals and f_L is the frequency spacing between spectral lines or bands of the composite signal.
38. A method of processing, in a multi-channel communication system, each of a plurality of spread-spectrum signals being multiplexed within said spectrum, wherein the channels are distinguished by respective signal centre frequencies, each signal comprising a plurality of spaced spectral lines or bands, and the respective signal centre frequencies being such that the spectral lines or bands of the individual channel signals are interleaved to form a composite signal, characterised by
 correlating a composite signal of all the received spread-spectrum signals with a locally generated pseudo-noise code to cause the spread-spectrum signal on a respective channel to be collapsed to a narrow bandwidth substantially corresponding to the transmitted signal information bandwidth; and
 passing said collapsed signal through a narrowband filter (49) corresponding to the respective channel centre frequency so as to pass only transmitted signal information and eliminate interference from other received spread-spectrum signals as well as wideband noise lying outside the filter bandwidth.
39. The method as claimed in claim 38 further selecting the narrowband filter (49) of each channel to have an information bandwidth of essentially zero.
40. The method as claimed in claim 38 further including selecting the spectral lines or bands of each of the spread-spectrum signals to be spaced by a frequency f_R and the centre frequencies of the respective signals to be spaced by frequency increments of $f_R P/M$ where P is a non-zero integer and M is a number of channels greater than 1 such that P and M have no common factors.
41. The method as claimed in claim 38 further including selecting the increments by which the centre frequencies of the respective signals are spaced to be such that the bandwidth occupied by all received signals of the system as a whole is not substantially greater than the bandwidth of the individual spread-spectrum signals.
42. The method as claimed in claim 40 further including choosing P such that the bandwidth occupied by all received signals of the system as a whole is not substantially greater than the bandwidth of the individual spread-spectrum signals.
43. The method as claimed in claim 40 further including selecting P to be less than M.
44. The method as claimed in claim 40 further including selecting P to be 1 and the channel centre frequencies to be spaced by the frequency f_R/M .
45. The method as claimed in claim 40 further including selecting P to be $M + 1$.
46. The method as claimed in claim 38, wherein the spacing between spectral lines or bands of a composite signal of all received signals is approximately equal to the sum of the channel information bandwidth and an uncertainty bandwidth of the carriers, a code length of the pseudo-noise code and a clock-rate of the code being chosen such that $f_R = Mf_L$ where f_L is the frequency spacing between spectral lines or bands of the composite signal, f_R is the spectral-line frequency spacing of individual spread-spectrum signals and M is the number of channels.



Patentansprüche

1. Mehrkanal-Streuspektrum-Übertragungssystem, in dem eine Vielzahl von Streuspektrumssignalen frequenzgeteilt gleichzeitig übertragen werden, um Mehrfachübertragungskanäle vorzusehen, bestehend aus:

einer Vielzahl von Sendern (21-28), jeder zur Übertragung eines Signals, das eine Vielzahl von beabstandeten Spektrallinien oder Spektralbändern, erzeugt durch Modulieren eines Trägers mit einem Pseudo-Rausch-Code, aufweist, so daß das übertragene Signal jedes Kanals eine Informationsbandbreite besitzt, die wesentlich geringer ist als sein Spektrallinien oder Spektralbandabstand, **dadurch gekennzeichnet**, daß jedes Streuspektrumssignal beabstandete mittlere Frequenzen besitzt, die beabstandet sind bzw. durch Frequenzzunahme gewählt werden, um zu bewirken, daß die Spektrallinien oder Bänder der jeweils übertragenen Signale durchgeleitet werden, wobei die gewählten Frequenzzunahmen geringer sind als die übertragene Bandbreite jedes Signals.

2. System nach Anspruch 1, in dem das übertragene Signal jedes Kanals eine Informationsbandbreite von im wesentlichen Null besitzt.

3. System nach Anspruch 1, in dem die Spektrallinien oder Bänder jedes der Streuspektrumssignale durch eine Frequenz f_R beabstandet sind und die mittleren Frequenzen der jeweiligen Signale durch Frequenzzunahmen von $f_R P/M$ beabstandet sind, wobei P eine von Null verschiedene ganze Zahl und M eine Anzahl von Kanälen größer als 1 ist, so daß P und M keine gemeinsamen Faktoren besitzen.

4. System nach Anspruch 1, in der die gewählten Zunahmen, durch die die mittleren Frequenzen der jeweiligen Signale beabstandet sind, so sind, daß die durch alle übertragenen Signale des ganzen Systems belegte Bandbreite nicht wesentlich größer ist, als die Bandbreite der einzelnen Streuspektrumssignale.

5. System nach Anspruch 3, in dem P so gewählt ist, daß die durch alle übertragenen Signale des ganzen Systems belegte Bandbreite nicht wesentlich größer ist, als die Bandbreite des einzelnen Streuspektrumssignals.

6. System nach Anspruch 3, in der P kleiner als M gewählt ist.

7. System nach Anspruch 3, in dem P gleich 1 gewählt ist und die mittleren Frequenzen der jeweiligen Signale durch die Frequenz f_R/M beabstandet sind.

8. System nach Anspruch 3, in dem P gleich $M + 1$ gewählt ist.

9. System nach Anspruch 1, in dem jeder Träger wegen der statistischen Unbestimmtheit seiner Frequenz aus einem Frequenzband besteht und der Abstand zwischen den Spektrallinien oder Spektralbändern eines aus allen übertragenen Signalen zusammengesetzten Signals etwa gleich der Summe der Informationskanalbandbreite und der Bandbreite der statistischen Unbestimmtheit der Träger, der Codelänge des Pseudo-Rauschcodes und der Taktfrequenz des gewählten Codes, wie z.B. $f_R = M f_L$, wobei H die Anzahl der Systemkanäle, f_R der Spektrallinienfrequenzabstand der einzelnen Streuspektrumssignale und f_L der Frequenzabstand zwischen den Spektrallinien oder Spektralbändern des zusammengesetzten Signals ist.

10. Ein Empfänger (31-38) für den Empfang einer Vielzahl von gesendeten Streuspektrumssignalen, die frequenzgeteilt gleichzeitig gesendet werden, um eine Vielzahl von Übertragungskanälen vorzusehen, wobei die Kanäle durch die jeweiligen mittleren Signalfrequenzen unterschieden werden, jedes Signal aus einer Vielzahl von beabstandeten Spektrallinien oder Spektralbändern, erzeugt durch Modulieren eines Trägers mit einem Pseudo-Rauschcode, besteht, der Träger aus einem Frequenzband besteht, das sich aus der statistischen Unbestimmtheit seiner Frequenz ergibt, das übertragene Signal jedes Kanals eine Informationsbandbreite besitzt, die wesentlich geringer als sein Spektrallinien- oder Spektralbandabstand ist und wobei die mittleren Frequenzen der Streuspektrumssignale durch Frequenzzunahmen beabstandet sind, die gewählt sind, um zu bewirken, daß die Spektrallinien oder die Spektralbänder des jeweils übertragenen Signals durchgeleitet werden, und die gewählten Frequenzzunahmen kleiner sind als die übertragene Bandbreite jedes Signals und der Empfänger gekennzeichnet ist durch



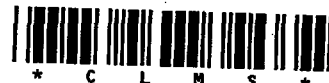
- Empfängermittel, einschließlich einer Vielzahl von Empfängerkanälen (34), Korrelationsmittel (42-48) für jeden Empfängerkanal, um zu bewirken, daß das Streuspektrumssignal auf dem jeweiligen Kanal auf eine Schmalbandbreite entsprechend der Übertragungskanal-Signalbandbreite, die die Summe der Unbestimmtheitsbandbreite der Trägerfrequenz und der Kanalinformationsbandbreite ist, gebracht wird, so daß es durch Passieren eines Schmalbandfilters (49) mit einer Bandbreite entsprechend der Übertragungskanalsignalbandbreite gewählt wird und im wesentlichen alle Interferenzen von anderen Kanälen sowie Breitbandrauschen von außerhalb der Filterbandbreite eliminiert werden.
11. Empfänger nach Anspruch 10, bei dem jedes Kanalsignal eine Informationsbandbreite von im wesentlichen Null besitzt.
 12. Empfänger nach Anspruch 10, in dem die Spektrallinien oder Spektralbänder jedes der Streuspektrumssignale durch eine Frequenz f_R beabstandet sind und die mittleren Frequenzen der jeweiligen Signale durch Frequenzzunahmen von $f_R P/M$ beabstandet sind, wobei P eine von Null verschiedene ganze Zahl und M eine Anzahl von Kanälen größer als 1 ist, so daß P und M keine gemeinsamen Faktoren besitzen.
 13. Empfänger nach Anspruch 10, bei dem die gewählten Zunahmen, durch die die mittleren Frequenzen der jeweiligen Signale so voneinander beabstandet sind, daß die von allen empfangenen Signalen des ganzen Systems belegte Bandbreite nicht wesentlich größer ist, als die Bandbreite des einzelnen Streuspektrumssignals.
 14. Empfänger nach Anspruch 12, bei dem P so gewählt ist, daß die durch alle empfangenen Signale des ganzen Systems belegte Bandbreite nicht wesentlich größer ist, als die Bandbreite des einzelnen Streuspektrumssignals.
 15. Empfänger nach Anspruch 12, bei dem P kleiner als M gewählt ist.
 16. Empfänger nach Anspruch 12, bei dem P gleich 1 gewählt ist und die mittleren Kanalfrequenzen durch die Frequenz f_R/M beabstandet sind.
 17. Empfänger nach Anspruch 12, bei dem P mit $M+1$ gewählt ist.
 18. Empfänger nach Anspruch 10, bei dem der Abstand zwischen den Spektrallinien oder Spektralbändern eines aus allen empfangenen Signalen zusammengesetzten Signals etwa gleich der Summe der Kanalinformationsbandbreite und einer Unbestimmtheitsbandbreite der Träger, einer Codelänge des Pseudo-Rauschcodes und der Taktfrequenz des gewählten Codes, wie z.B. $f_R = M f_L$, wobei f_L der Frequenzabstand zwischen den Spektrallinien oder Spektralbändern des zusammengesetzten Signals, f_R der Spektrallinienfrequenzabstand des einzelnen Streuspektrumssignals und M die Anzahl der Kanäle ist.
 19. Fahrzeugortungs- und -verfolgungssystem, das eine Vielzahl von Fahrzeugen gleichzeitig verfolgen kann, bestehend aus:
 - einer Vielzahl von mobilen Hochfrequenzsendern, jeder angebracht auf einem Fahrzeug, um ein Streuspektrumssignal, bestehend aus einer Vielzahl von beabstandeten Spektrallinien oder Spektralbändern und mit einer Informationsbandbreite, die wesentlich geringer ist, als sein Spektrallinien- oder Spektralbandabstand, zu übertragen, das Streuspektrumssignal durch Modulieren eines Trägers mit einem Pseudo-Rauschcode erzeugt wird;
 - mindestens drei Mehrkanalempfängern (31-38), angeordnet an Orten mit bekanntem Abstand und so eingerichtet, daß sie die Streuspektrumssignale empfangen können, die von jedem der Sender übertragen werden;
 - Steuerungsmitteln, die mit jedem der Empfänger in Verbindung stehen und Signalverarbeitungseinrichtungen für die Messung der Ausbreitungszeitdifferenzen vom jeweiligen Sender zu jedem Empfänger und dadurch Berechnung der Position des jeweiligen Senders in Bezug auf die Empfänger, **dadurch gekennzeichnet**, daß die Sender so ausgeführt sind, daß die Streuspektrumssignale von den jeweiligen Einzelsendern mittlere Frequenzen besitzen, die voneinander durch Frequenzzunahmen beabstandet sind, die gewählt sind, um zu bewirken, daß die Spektrallinien oder Spektralbänder der jeweils



- übertragenen Signale durchgeleitet werden, die gewählte Frequenzzunahme kleiner ist als die übertragene Bandbreite jedes Signals, und daß Korrelationsmittel (42-48) in jedem Kanalempfänger vorgesehen sind, um zu bewirken, daß das von einem Einzelsender empfangene und dem jeweiligen Kanal zugeordnete Streuspektrumssignal auf eine Schmalbandbreite entsprechend der übertragenen Kanalsignalbandbreite gebracht wird, die die Summe der Trägerfrequenz-Unbestimmtheitsbandbreite und der Kanalinformationsbandbreite ist, so daß es gewählt wird, indem es einen Schmalbandfilter (49) passiert und dadurch alle Interferenzen von den übertragenen Signalen eines anderen Kanals sowie auch Breitbandrauschen eliminiert werden.
20. Fahrzeugverfolgungssystem nach Anspruch 19, in dem die Spektrallinien oder Spektralbänder jedes der übertragenen Streuspektrumssignale durch eine Frequenz f_R voneinanderbeabstandet sind und die mittleren Frequenzen der jeweiligen Signale durch Frequenzzunahmen von $f_R P/M$ beabstandet sind, wobei P eine von Null unterschiedliche ganze Zahl ist und M die Anzahl der gleichzeitig zu verfolgenden Fahrzeuge und größer als 1 ist, so daß P und M keine gemeinsamen Faktoren besitzen.
21. Fahrzeugverfolgungssystem nach Anspruch 19, in dem die gewählten Frequenzzunahmen, um die die mittleren Frequenzen der jeweiligen Signale beabstandet sind, so sind, daß die durch alle übertragenen Signale des ganzen Systems belegte Bandbreite nicht wesentlich größer ist, als die Bandbreite der übertragenen Einzel-Streuspektrumssignale.
22. Fahrzeugverfolgungssystem nach Anspruch 20, in dem P so gewählt ist, daß die durch alle übertragenen Signale des ganzen Systems belegte Bandbreite nicht wesentlich größer ist, als die Bandbreite der übertragenen Einzel-Streuspektrumssignale.
23. Fahrzeugverfolgungssystem nach Anspruch 20, in dem P kleiner als M gewählt ist.
24. Fahrzeugverfolgungssystem nach Anspruch 20, in dem P gleich 1 gewählt ist und die mittleren Frequenzen der einzelnen übertragenen Streuspektrumssignale durch die Frequenz f_R/M voneinander beabstandet sind.
25. Fahrzeugverfolgungssystem nach Anspruch 20, in dem P gleich $M + 1$ gewählt ist.
26. Fahrzeugverfolgungssystem nach Anspruch 19, in dem jede der empfangenen Trägerfrequenzen eine statistische Unbestimmtheit aufweist, die gleich der Summe einer statistischen Unbestimmtheit der übertragenen Trägerfrequenz und einer bewegungs- und/oder medium-induzierten Unbestimmtheit in der von den mobilen Sendern empfangenen Frequenz ist und der Abstand zwischen den Spektrallinien oder Spektralbändern eines aus allen übertragenen Signalen zusammengesetzten Signals etwa gleich der Trägerfrequenz-Unbestimmtheitsbandbreite auf Grund der statistischen Unbestimmtheiten der empfangenen Frequenzen ist, der Pseudo-Rauschcode eine Codelänge und eine Taktfrequenz des Codes besitzen, die so gewählt sind, daß $f_R = M f_L$, wobei M die Anzahl der gleichzeitig verfolgten Fahrzeuge, f_R der Spektrallinienfrequenzabstand der einzelnen Streuspektrumssignale und f_L der Frequenzabstand zwischen den Spektrallinien oder Spektralbändern des zusammengesetzten Signals ist.
27. Fahrzeugverfolgungssystem nach Anspruch 19, in dem die übertragenen Streuspektrumssignale eine Informationsbandbreite von im wesentlichen Null besitzen.
28. Verfahren für eine Mehrkanal-Kommunikation in einem Spektrum, bestehend aus:
dem Übertragen einer Vielzahl von Streuspektrumssignalen, die in diesem Spektrum frequenzgeteilt gleichzeitig übertragen werden, wobei jedes Signal eine Vielzahl von frequenzbeabstandeten Spektrallinien oder Spektralbändern aufweist, erzeugt durch Modulieren eines Informationsträgers mit einem Pseudo-Rauschcode, so daß jeder Kanal eine Informationsbandbreite besitzt, die wesentlich geringer ist, als der Frequenzabstand der Spektrallinien oder Spektralbänder, **dadurch gekennzeichnet**, daß jede Streuspektrumssignalträgerfrequenz so gewählt ist, daß sie von den benachbarten Trägerfrequenzen durch eine Frequenzzunahme beabstandet ist, so daß bewirkt wird, daß die Spektrallinien oder Spektralbänder der jeweils übertragenen Signale durchgeleitet werden, die Frequenzzunahme kleiner ist als die übertragene Bandbreite jedes Signals; und
der Verarbeitung jedes empfangenen Signals des übertragenen Signals durch Korrelation eines zusammengesetzten Signals aller empfangenen Streuspektrumssignale mit einem lokal erzeugten



- Pseudo-Rauschcode, um zu bewirken, daß das Streuspektrumssignal auf dem jeweiligen Kanal auf eine Schmalbandbreite gebracht wird, die im wesentlichen der übertragenen Signalinformationsbandbreite entspricht und Passieren des auf die Schmalbandbreite gebrachten Signals durch einen Schmalbandfilter (49) entsprechend der jeweiligen mittleren Kanalfrequenz, so daß nur die übertragene Signalinformation passieren kann und um Interferenz von anderen empfangenen Streuspektrumssignalen sowie Breitbandrauschen von außerhalb der Filterbandbreite zu eliminieren.
29. Verfahren des Übertragens einer Vielzahl von frequenzgeteilten gleichzeitig übertragenen Streuspektrumssignalen im Spektrum in einem Mehrkanal-Kommunikationssystem, bestehend aus:
- 10 für jedes Signal Modulieren eines Informationsträgers mit einem Pseudo-Rauschcode, um eine Vielzahl von frequenzbeabstandeten Spektrallinien oder Spektralbändern vorzusehen, so daß jeder Kanal eine Informationsbandbreite besitzt, die wesentlich geringer ist, als der Frequenzabstand der Spektrallinien oder Spektralbänder; **gekennzeichnet durch**
- 15 Wahl jeder Streuspektrumssignalträgerfrequenz, daß sie von den benachbarten Trägerfrequenzen durch eine Frequenzzunahme beabstandet ist, die bewirkt, daß die Spektrallinien oder Spektralbänder der jeweils übertragenen Signale durchgeleitet werden und die Frequenzzunahme kleiner ist als die übertragene Bandbreite jedes Signals.
30. Verfahren nach Anspruch 29, weiterhin das Modulieren jedes Kanals in der Weise einschließend, daß er eine Bandbreite von im wesentlichen Null besitzt.
31. Verfahren nach Anspruch 29, weiterhin das Wählen der Spektrallinien oder Spektralbänder jedes Streuspektrumssignals in der Weise einschließend, daß sie durch die Frequenzen f_R beabstandet sind und die mittleren Frequenzen der jeweiligen Signale durch die Frequenznahmen $f_R P/M$ beabstandet sind, wobei P eine von Null verschiedene gerade Zahl ist und M eine Anzahl von Kanälen größer als 1, so daß P und M keine gemeinsamen Faktoren besitzen.
- 25 32. Verfahren nach Anspruch 29, bei dem weiterhin die gewählten Zunahmen der mittleren Frequenzen der jeweiligen Signale so beabstandet werden, daß die durch alle übertragenen Signale des ganzen Systems belegte Bandbreite nicht wesentlich größer ist, als die Bandbreite der einzelnen Streuspektrumssignale.
- 30 33. Verfahren nach Anspruch 31, bei dem weiterhin eine solche Wahl von P erfolgt, daß die durch alle übertragenen Signale des ganzen Systems belegte Bandbreite nicht wesentlich größer ist, als die Bandbreite der einzelnen übertragenen Streuspektrumssignale.
- 35 34. Verfahren nach Anspruch 1, in dem weiterhin P kleiner als M gewählt wird.
35. Verfahren nach Anspruch 31, in dem weiterhin $P = 1$ gewählt wird und die mittleren Frequenzen der jeweiligen Signale so gewählt werden, daß sie durch die Frequenz f_R/M beabstandet sind.
- 40 36. Verfahren nach Anspruch 31, in dem weiterhin $P = M + 1$ gewählt wird.
37. Verfahren nach Anspruch 29, in dem weiterhin ein solches Modulieren jedes Trägers erfolgt, daß er aus einem Frequenzband auf Grund der statistischen Unbestimmtheit seiner Frequenz besteht und der Abstand zwischen den Spektrallinien oder Spektralbändern eines aus allen übertragenen Signalen zusammengesetzten Signals etwa gleich der Summe der Kanalinformationsbandbreite und der statistischen Unbestimmtheitsbandbreite des Trägers ist und eine solche Codelänge des Pseudo-Rauschcodes und eine solche Taktfrequenz des Codes gewählt wird, daß $f_R = M f_L$, wobei M die Anzahl der Systemkanäle, f_R der Spektrallinienfrequenzabstand der einzelnen Streuspektrumssignale und f_L der Frequenzabstand zwischen den Spektrallinien oder Spektralbändern des zusammengesetzten Signals ist.
- 45 50 38. Ein Verfahren der Verarbeitung jedes einer Vielzahl von Streuspektrumssignalen, die gleichzeitig in diesem Spektrum übertragen werden, in einem Mehrkanal-Kommunikationssystem, wobei die Kanäle durch die jeweiligen mittleren Signalfrequenzen unterschieden werden und jedes Signal aus einer Vielzahl von beabstandeten Spektrallinien oder Spektralbändern besteht und die jeweiligen mittleren Signalfrequenzen so sind, daß die Spektrallinien oder Spektralbänder der einzelnen Kanalsignale



durchgeleitet werden, um ein zusammengesetztes Signal zu bilden, **gekennzeichnet durch**

Korrelation eines zusammengesetzten Signals aller empfangenen Streuspektrumssignale mit einem lokal erzeugten Pseudo-Rauschcode, um zu bewirken, daß das Streuspektrumssignal auf dem jeweiligen Kanal auf eine Schmalbandbreite gebracht wird, die im wesentlichen der Informationsbandbreite des übertragenen Signals entspricht; und

Passieren des auf Schmalbandbreite gebrachten Signals durch einen Schmalbandfilter (49) entsprechend der jeweiligen mittleren Kanalfrequenz, so daß nur die übertragene Signalinformation durchgeht und Interferenz von anderen empfangenen Streuspektrumssignalen sowie Breitbandrauschen von außerhalb der Filterbandbreite eliminiert werden.

39. Verfahren gemäß Anspruch 38 und weiterhin Wahl des Schmalbandfilters (49) jedes Kanals, um eine Informationsbandbreite von im wesentlichen Null zu erhalten.

40. Verfahren nach Anspruch 38 und weiterhin einschließend die Wahl der Spektrallinien oder Spektralbänder jedes der Streuspektrumssignale beabstandet durch eine Frequenz f_R und der mittleren Frequenzen der jeweiligen Signale beabstandet durch Frequenzzunahmen von $f_R P/M$, wobei P eine von Null verschiedene ganze Zahl ist und M die Anzahl der Kanäle größer als 1, so daß P und M keine gemeinsamen Faktoren besitzen.

41. Verfahren nach Anspruch 38, weiterhin einschließend die Wahl der Zunahmen, durch die die mittleren Frequenzen der jeweiligen Signale voneinander beabstandet sind in der Weise, daß die von allen Signalen des ganzen Systems belegte Bandbreite nicht wesentlich größer ist, als die Bandbreite der einzelnen Streuspektrumssignale.

42. Verfahren gemäß Anspruch 40, weiterhin einschließend die Wahl von P in der Weise, daß die von allen empfangenen Signalen des ganzen Systems belegte Bandbreite nicht wesentlich größer ist, als die Bandbreite der einzelnen Streuspektrumssignale.

43. Verfahren nach Anspruch 40, weiterhin einschließend die Wahl von P kleiner als M .

44. Verfahren nach Anspruch 40, weiterhin einschließend die Wahl von P gleich 1 und des Abstandes der mittleren Kanalfrequenzen gleich der Frequenz f_R/M .

45. Verfahren nach Anspruch 40, weiterhin einschließend die Wahl von $P = M + 1$.

46. Verfahren nach Anspruch 38, bei dem der Abstand zwischen den Spektrallinien oder Spektralbändern eines zusammengesetzten Signals aus allen empfangenen Signalen etwa gleich der Summe der Kanalinformationsbandbreite und einer Unbestimmtheitsbandbreite der Träger ist, eine Codelänge des Pseudo-Rauschcodes und die Taktfrequenz des Codes so gewählt ist, daß $f_R = M f_L$, wobei f_L der Frequenzabstand zwischen den Spektrallinien oder Spektralbändern des zusammengesetzten Signals, f_R der Spektrallinienfrequenzabstand der einzelnen Streuspektrumssignale und M die Anzahl der Kanäle ist.

Revendications

1. Système de transmission multicanaux à spectre étalé dans lequel une pluralité de signaux du spectre étalé sont multiplexés par répartition de fréquence pour fournir de multiples canaux de transmission, comprend

une pluralité d'émetteurs-récepteurs (22-28) transmettant chacun un signal ayant une pluralité de bandes ou de lignes de spectres espacés ou de bandes produites en modulant une porteuse avec un code de bruit pseudo-aléatoire, de telle sorte que le signal transmis par chaque canal a une largeur de bande d'informations qui est inférieure de façon significative à sa ligne spectrale ou son espacement de bande, caractérisé en ce que les signaux de bandes étalés ont chacun des fréquences centrales qui sont espacées, respectivement, par les incréments fréquentiels sélectionnés pour provoquer l'imbrication des lignes ou bandes spectrales des signaux respectifs transmis, les incréments fréquentiels sélectionnés étant inférieurs à la largeur de bande transmise par chaque signal.



2. Système selon la revendication 1, dans lequel le signal transmis par chaque canal a une largeur de bande d'informations pratiquement nulle.
3. Système selon la revendication 1, dans lequel les lignes ou bandes spectrales de chacun des signaux à spectre étalé sont espacés d'une fréquence f_R et les fréquences centrales des signaux respectifs sont espacés par des incréments fréquentiels de $f_R P/M$ où P est un entier non-nul et M est un nombre de canaux supérieur à 1 de telle sorte que P et M n'ont pas de facteurs communs.
4. Système selon la revendication 1, dans lequel les incréments sélectionnés grâce auxquels les fréquences centrales des signaux respectifs sont espacées de telle sorte que la largeur de bande occupée dans son ensemble par tous les signaux transmis du système n'est pas sensiblement supérieure à la largeur de bande des signaux individuels à spectre étalé.
5. Système selon la revendication 3, dans lequel P est choisi de telle sorte que la largeur de bande occupée dans son ensemble par tous les signaux transmis du système n'est pas sensiblement supérieure à la largeur de bande des signaux individuels à spectre étalé.
6. Système selon la revendication 3, dans lequel on sélectionne P pour qu'il soit inférieur à M .
7. Système selon la revendication 3, dans lequel on sélectionne P pour qu'il soit égal à 1 et que les fréquences centrales des signaux respectifs soient espacées de la fréquence f_R/M .
8. Système selon la revendication 3, dans lequel on sélectionne P pour qu'il soit égal à $M+1$.
9. Système selon la revendication 1, dans lequel chaque porteuse se compose d'une bande de fréquences due à l'incertitude de sa fréquence, l'espacement entre des lignes ou des bandes spectrales d'un signal composite formé par tous les signaux transmis est approximativement égal à la somme de la largeur de bande d'informations du canal et de la largeur de bande de l'incertitude statistique des porteuses, une longueur de code du code de bruit pseudo-aléatoire et une fréquence d'horloge du code étant choisies de telle sorte que $f_R = M f_L$ où M est le nombre de canaux du système, f_R est l'espacement fréquentiel des lignes spectrales des signaux individuels à spectre étalé et f_L est l'espacement fréquentiel entre des lignes ou des bandes spectrales du signal composite.
10. Récepteur (31-38) pour recevoir une pluralité de signaux à spectre étalé transmis qui sont multiplexées par répartition de fréquence pour fournir une pluralité de canaux de transmission, dans lesquels les canaux sont distingués par des fréquences centrales respectives, chaque signal comprenant une pluralité de lignes ou de bandes spectrales espacées produites en modulant une porteuse avec un code de bruit pseudo-aléatoire, la porteuse comprenant une bande de fréquence due à l'incertitude statistique de sa fréquence, le signal transmis par chaque canal ayant une largeur de bande d'informations qui est inférieure de façon significative à son espacement des bandes ou des lignes spectrales, et où les fréquences centrales des signaux à spectre étalé sont espacées par des incréments fréquentiels sélectionnés pour provoquer l'imbrication des bandes ou des lignes spectrales des signaux transmis respectifs, les incréments fréquentiels sélectionnés étant inférieurs à la largeur de bande transmise de chaque signal, ledit récepteur étant caractérisée par:
 - un dispositif de réception comportant une pluralité de canaux de réception (34), un dispositif de corrélation (42-48) étant fourni pour chaque canal de réception pour provoquer l'effondrement du signal à spectre étalé reçu sur un canal respectif en une largeur de bande étroite correspondant à la largeur de bande du signal du canal de transmission qui comprend la somme de la largeur de bande de l'incertitude de la fréquence porteuse et de la largeur de bande du canal d'informations de telle sorte qu'il est sélectionné en passant par un filtre à bande étroite (49) ayant une largeur de bande correspondant à ladite largeur de bande du signal du canal de transmission, éliminant principalement toutes les interférences des autres canaux ainsi que le bruit de la bande large s'étendant à l'extérieur de la largeur de la bande du filtre.
11. Récepteur selon la revendication 10, dans lequel chaque signal du canal a une largeur de bande d'informations pratiquement nulle.



12. Récepteur selon la revendication 10, dans lequel les bandes et les lignes spectrales de chacun des signaux à spectre étalé sont espacés d'une fréquence f_R et les fréquences centrales des signaux respectifs sont espacés par des incréments fréquentiels de $f_R P/M$ où P est un entier non-nul et M est un nombre de canaux supérieur à 1 de telle sorte que P ou M n'ont pas de facteurs communs.
13. Récepteur selon la revendication 10, dans lequel les incréments sélectionnés grâce auquel les fréquences centrales des signaux respectifs sont espacées de telle sorte que la largeur de bande occupée dans son ensemble par tous les signaux reçus du système n'est pas sensiblement supérieure à la largeur de bande des signaux à spectres étalés individuels.
14. Récepteur selon la revendication 12, dans lequel P est choisi de telle sorte que la largeur de bande occupée dans son ensemble par tous les signaux reçus du système n'est pas sensiblement supérieure à la largeur de bande des signaux à spectre étalés individuels.
15. Récepteur selon la revendication 12, dans lequel on sélectionne P pour qu'il soit inférieur à M .
16. Récepteur selon la revendication 12, dans lequel on sélectionne P pour qu'il soit égal à 1 et les fréquences centrales du canal sont espacées de la fréquence f_R/M .
17. Récepteur selon la revendication 12, dans lequel on sélectionne P pour qu'il soit égal à $M+1$.
18. Récepteur selon la revendication 10, dans lequel la distance entre les bandes ou les lignes spectrales d'un signal composite formé par tous les signaux reçus est approximativement égale à la somme de la largeur de bande d'informations du canal et d'une largeur de bande de l'incertitude des porteuses, une longueur de code du code pseudo-aléatoire et une fréquence d'horloge du code étant choisie de telle sorte que $f_R = M f_L$ où f_L est l'espacement fréquentiel entre des lignes ou des bandes spectrales du signal composite, f_R est l'espacement fréquentiel des lignes spectrales des signaux individuels à spectre étalé et M est le nombre de canaux.
19. Système de suivi et de localisation de multiples véhicules capable de suivre une pluralité de véhicules en même temps, comprenant:
une pluralité d'émetteurs-récepteurs de fréquences radio montés chacun sur un véhicule pour transmettre un signal à spectre étalé comprenant une pluralité de lignes ou de bandes spectrales espacées et ayant une largeur de bande d'informations qui est inférieure de façon significative à son espacement de bande ou de ligne spectrale, le signal à spectre étalé étant produit en modulant une porteuse avec un code pseudo-aléatoire; au moins trois récepteurs à canaux multiples (31-38) positionnés à des emplacements espacés connus chacun étant disposé pour recevoir les signaux à spectre étalé transmis par chacun des émetteurs-récepteurs;
un dispositif de commande (43) communiquant avec chacun les récepteurs et comportant un dispositif de traitement du signal pour mesurer des différences du temps de propagation entre un émetteur-récepteur respectif et chaque récepteur pour chacun desdits signaux transmis et pour calculer ainsi la position de l'émetteur-récepteur respectif par rapport aux récepteurs caractérisés en ce que, les émetteurs-récepteurs sont disposés de telle sorte que les signaux à spectre étalé des émetteurs-récepteurs individuels respectifs ont des fréquences centrales qui sont espacées les unes des autres par des incréments fréquentiels sélectionnés pour provoquer l'inbrication des bandes ou des lignes spectrales des signaux transmis respectifs, les incréments fréquentiels sélectionnés étant inférieurs à la largeur de bande transmise de chaque signal, et en ce que ce dispositif de corrélation (42-48) est compris dans chaque récepteur de canal pour provoquer l'effondrement du signal du spectre étalé reçu à partir d'un émetteur-récepteur individuel associé au canal respectif, en une largeur de bande étroite correspondant à la largeur de bande du signal du canal transmis qui comprend la somme de la largeur de bande de l'incertitude de la fréquence de la porteuse et de la largeur de la bande d'informations du canal de telle sorte qu'il est sélectionné en passant par un filtre à bande étroite (49) éliminant ainsi essentiellement toutes les interférences des signaux transmis des canaux autres ainsi que le bruit de la bande large.
20. Système de suivi de véhicules selon la revendication 19, dans lequel les bandes ou les lignes spectrales de chacun des signaux à spectre étalé transmis sont espacées par une fréquence f_R et les fréquences centrales des signaux respectifs sont espacées par des incréments fréquentiels de $f_R P/M$



où P est un entier non nul et M est un nombre supérieur à 1 de véhicules à suivre en même temps de telle sorte que P et M n'ont pas de facteurs communs.

21. Système de suivi de véhicules selon la revendication 19, dans lequel les incréments fréquentiels sélectionnés, par lequel les fréquences centrales des signaux respectifs espacés, sont tels que la largeur de bande occupée dans son ensemble par tous les signaux transmis du système n'est pas sensiblement supérieure à la largeur de bande des signaux individuels transmis à spectre étalé.
22. Système de suivi de véhicules selon la revendication 20, dans lequel P est choisi de telle sorte que la largeur de bande occupée dans son ensemble par tous les signaux transmis du système n'est pas sensiblement supérieure à la largeur de bande des signaux individuels transmis à spectre étalé.
23. Système de suivi de véhicules selon la revendication 20, dans lequel on sélectionne P pour qu'il soit inférieur à M.
24. Système de suivi de véhicules selon la revendication 20, dans lequel on sélectionne P pour qu'il soit égal à 1 et que les fréquences centrales des signaux individuels transmis à spectre étalé soient espacées par la fréquence f_R/M .
25. Système de suivi de véhicules selon la revendication 20, dans lequel on sélectionne P pour qu'il soit égal à M + 1.
26. Système de suivi de véhicules selon la revendication 19, dans lequel chacune des fréquences porteuses reçues a une incertitude statistique qui est la somme d'une incertitude statistique de la fréquence porteuse transmise et du déplacement et/ou d'une incertitude induite moyenne de la fréquence reçue des émetteurs-récepteurs mobiles, et l'espacement entre des bandes ou des lignes spectrales d'un signal composite de tous les signaux transmis est approximativement égal à la largeur de bande de l'incertitude de la fréquence porteuse due à des incertitudes statistiques des fréquences reçues, le code du bruit pseudo-aléatoire ayant une longueur de code et une fréquence d'horloge qui sont choisies de telle sorte que $f_R = Mf_L$ où M est le nombre de véhicules suivi simultanément, f_R est l'espacement fréquentiel des lignes spectrales des signaux individuels à spectre étalé et f_L est l'espacement fréquentiel entre des bandes ou des lignes spectrales du signal composite.
27. Système de suivi de véhicules selon la revendication 19 dans lequel les signaux à spectre étalé transmis ont une largeur de bande d'informations pratiquement nulle.
28. Système pour fournir une communication multicanaux dans un spectre, comprenant:
 - la transmission d'une pluralité de signaux à spectre étalé multiplexés en fréquence dans ledit spectre, chaque signal comprenant une pluralité de bandes ou de lignes spectrales espacées en fréquence produites en modulant une porteuse portant des informations avec un code de bruit pseudo-aléatoire de telle sorte que chaque canal a une largeur de bande d'informations inférieure de façon significative à l'espacement fréquentiel de ses bandes ou lignes spectrales, caractérisé en ce que chaque fréquence porteuse du signal à spectre étalé est sélectionné pour qu'elle soit espacée fréquemment des porteuses adjacentes d'un incrément fréquentiel de telle sorte qu'on provoque l'imbrication des bandes ou des lignes spectrales des signaux transmis respectifs, ledit incrément fréquentiel étant inférieur à la largeur de bande transmise de chaque signal; et
 - un traitement de chaque signal reçu dudit signal transmis en corrélant un signal composite formé de tous les signaux reçus à spectre étalé avec un code de bruit pseudo-aléatoire généré localement pour provoquer l'effondrement du signal à spectre étalé sur un canal respectif, en une largeur de bande étroite correspondant sensiblement à la largeur de bande des informations du signal transmis, et en passant ledit signal effondré à travers un filtre à bande étroite (49) correspondant à la fréquence centrale du canal respectif afin de ne passer que les informations du signal transmis et éliminer l'interférence des autres signaux reçus à spectre étalé ainsi que le bruit élargi s'étendant à l'extérieur de la largeur de bande du filtre.
29. Procédé pour transmettre dans un système à canaux multiples, une pluralité de signaux à spectre étalé multiplexés par répartition de fréquence dans ledit spectre, comprenant:
 - pour chaque signal, la modulation d'une porteuse portant des informations avec un code de bruit



pseudo-aléatoire pour fournir une pluralité de bandes et de lignes spectrales espacées en fréquence, de telle sorte que chaque canal a une largeur de bande d'informations inférieure de façon significative à l'espacement fréquentiel de ses bandes ou lignes spectrales; caractérisé par

une sélection de chaque fréquence porteuse du signal à spectre étalé, à espacer des fréquences porteuses voisines par un incrément fréquentiel de façon à provoquer l'imbrication des bandes ou des lignes spectrales des signaux transmis respectifs, ledit incrément fréquentiel étant inférieur à la largeur de bande transmise de chaque signal.

30. Procédé selon la revendication 29, comprenant en outre une modulation de chaque canal de telle sorte qu'il a une largeur de bande d'informations pratiquement nulle.
31. Procédé selon la revendication 29 comprenant de plus une sélection des bandes ou des lignes spectrales de chacun des signaux à spectre étalé à espacer par des fréquences f_R et des fréquences centrales des signaux respectifs à espacer par des incréments fréquentsiels de $f_R P/M$ où P est un entier non nul et M est un nombre de canaux supérieur à 1 et de telle sorte que P et M n'ont pas de facteurs communs.
32. Procédé selon la revendication 29 comprenant en outre un espacement des incréments sélectionnés des fréquences centrales des signaux respectifs de sorte que la largeur de bande occupée dans son ensemble par tous les signaux transmis du système n'est pas sensiblement supérieur à la largeur de bande des signaux individuels à spectre étalé.
33. Procédé selon la revendication 31 comprenant en outre le choix de P de telle sorte que la largeur de bande occupée dans son ensemble par tous les signaux transmis du système n'est pas sensiblement supérieure à la largeur de bande des signaux individuels à spectre étalé.
34. Procédé selon la revendication 31 comprenant en outre le choix de P pour qu'il soit inférieur à M .
35. Procédé selon la revendication 31 comprenant de plus le choix de P pour qu'il soit supérieur à 1 et la sélection des fréquences centrales des signaux respectifs pour qu'elles soient espacées de la fréquence f_R/M .
36. Procédé selon la revendication 31 comprenant en outre la sélection de P pour qu'il soit égal à $M + 1$.
37. Procédé selon la revendication 29, comprenant de plus la modulation de chaque porteuse de telle sorte qu'elle se compose d'une bande de fréquence due à l'incertitude statistique de sa fréquence, l'espacement entre les bandes ou les lignes spectrales d'un signal composite formé par tous les signaux transmis est approximativement égal à la somme de la largeur de bande des informations du canal et la largeur de bande de l'incertitude statistique des porteuses, la sélection d'une longueur de code, du code de bruit pseudo-aléatoire et d'une fréquence d'horloge du code de telle sorte que $f_R = M f_L$ où M est le nombre de canaux du système, f_R est l'espacement fréquentiel des lignes spectrales des signaux individuels à spectre étalé et f_L est l'espacement fréquentiel entre des lignes spectrales ou des bandes du signal composite.
38. Procédé de traitement, dans un système de communication à canaux multiples, chacun des signaux d'une pluralité de signaux à spectre étalé étant multiplexé dans ledit spectre, dans lequel les canaux sont distingués par des fréquences centrales du signal respectif, chaque signal comprenant une pluralité de lignes ou de bandes spectrales espacées, et les fréquences centrales du signal respectif étant telles que les lignes ou les bandes spectrales des signaux individuels du canal sont imbriquées pour former un signal composite, caractérisé par
 - une corrélation du signal composite de tous les signaux à spectre étalé reçus avec un code de bruit pseudo-aléatoire généré localement pour provoquer l'effondrement du signal à spectre étalé sur un canal respectif en une largeur de bande étroite correspondant essentiellement à la largeur de bande des informations du signal transmis; et
 - un passage dudit signal effondré à travers un filtre à bande étroite (49) correspondant à la fréquence centrale du canal respectif afin de ne passer que les informations du signal transmis et d'éliminer les interférences des autres signaux reçus à spectre étalé ainsi que le bruit à large bande s'étendant en dehors de la largeur de bande du filtre.



39. procédé selon la revendication 38 sélectionnant de plus le filtre à bande étroite (49) de chaque canal pour avoir une largeur de bande des informations pratiquement nulle.
- 5 40. Procédé selon la revendication 38 comprenant de plus une sélection des bandes ou des lignes spectrales de chacun des signaux du spectre étalé à espacer d'une fréquence f_R et des fréquences centrales des signaux respectifs pour qu'elles soient espacées par des incréments fréquentiels de $f_R P/M$ où P est un entier non nul et M est un nombre de canaux supérieur à 1 et de telle sorte que P et M n'ont pas de facteurs communs.
- 10 41. Procédé selon la revendication 38 comprenant de plus une sélection des incréments grâce auxquels les fréquences centrales des signaux respectifs sont espacées de telle sorte que la largeur de bande occupée dans son ensemble par tous les signaux reçus du système n'est pas sensiblement supérieure à la largeur de bande des signaux individuels à spectre étalé.
- 15 42. Procédé selon la revendication 40 comprenant de plus un choix de P tel que la largeur de bande occupée dans son ensemble par tous les signaux reçus du système n'est pas sensiblement supérieure à la largeur de bande des signaux individuels à spectre étalé.
- 20 43. Procédé selon la revendication 40 comprenant en outre une sélection de P pour qu'il soit inférieur à M .
44. Procédé selon la revendication 40 comprenant de plus la sélection de P pour qu'il soit égal à 1 et que les fréquences centrales soient espacées par la fréquence f_R/M .
- 25 45. Procédé selon la revendication 40 comprenant de plus une sélection de P pour qu'il soit égal à $M + 1$.
- 30 46. Procédé selon la revendication 38, dans lequel l'espacement entre les bandes ou les lignes spectrales d'un signal composite formé par tous les signaux reçus est approximativement égal à la somme de la largeur de bande des informations du canal et d'une largeur de bande de l'incertitude des porteuses, une longueur de code de bruit pseudo-aléatoire et une fréquence d'horloge du code étant choisies de telle sorte que $f_R = M f_L$ où f_L est l'espacement fréquentiel entre des bandes ou des lignes spectrales du signal composite, f_R est l'espacement fréquentiel des lignes spectrales des signaux individuels des spectres étalés et M est le nombre de canaux.
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