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Information transmission system comprising at least one base station and at least one satellite station.

Description:

The present invention relates to an information transmission system, comprising at least one base station and at least one satellite station, which stations
5 exchange their information by way of a plurality of time multiplex signals which are transported by way of a plurality of carriers.

The invention also relates to a satellite station and to a base station suitable for use in such a system.

A system of this kind is widely used notably in the field of private radio
10 communications.

In this field a problem is encountered in that resources are scarce. In this context "resource" is to be understood to be the possibility of using a more or less large number of frequency channels having more or less limited passbands. It is to be noted that despite these limited resources, the quality of the traffic must be as high as
15 possible. A current source of traffic degrading is selective fading. A first known step for counteracting fading is the use of error correction codes; a second known step is the use of different frequency channels for the transmission of consecutive information. This step is described in detail in the article: "Performance of Trellis Coded Modulation Using Multi-Frequency Channels in Land Mobile Communications" by Yukiyoshi
20 Kamio, Proc. of IEEE VEB. TECH., May 1990 (CH2846-4/90/0000-455).

The present invention proposes a system of this kind in which notably the second step is executed, without suffering from the requirements often imposed by the authorities in view of the scarcity of resources.

To achieve this, such an invention is characterized in that for the
25 transmission of useful information between stations there are provided replica means for forming a plurality of replicas of the useful information, frequency dispersion means for transmitting the plurality of replicas in the plurality of time signals, receiving means for receiving the plurality of replicas thus transmitted, and combinatory means for restoring the information on the basis of the plurality of replicas received.

30 The following description, accompanied by the attached drawings, given

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by way of non-limitative examples, will offer a better understanding as to how the invention can be carried out.

Fig. 1 shows a transmission system in accordance with the invention.

Fig. 2a shows a customarily used TDMA frame structure.

5 Figs. 2b and 2c show a TDMA frame structure in accordance with the invention.

Fig. 3 shows a block diagram of a satellite station and a base station.

Fig. 4 shows a first example of the use of a frequency dispersion circuit.

Fig. 5 shows a first embodiment of a combinatory circuit.

10 Fig. 6 shows a preferred embodiment of a frequency dispersion circuit.

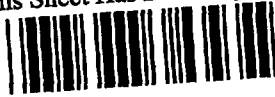
Fig. 7 shows a preferred embodiment of a combinatory circuit.

The system which is diagrammatically shown in Fig. 1 is formed by a plurality of cells, only the cells CELL1 and CELL2 being shown in the Figure. In each cell CELL1 and CELL2 there is situated a radio transmission/reception base station
15 STB1 and STB2, respectively. Different vehicles comprising satellite stations STM1 and STM2 can travel within the cells. A switching network RC enables the exchange of information between all cells.

In the present example, two frequency channels CF1, CF2 which are centred around carrier frequencies F1 and F2 are used for the exchange of information
20 between the satellite stations STM1, STM2 and the base station STB1. Evidently, if so required by the traffic, other frequency channels can always be added without departing from the scope of the invention. These frequency channels are used for transmitting time multiplex signals of the type TDMA for which Fig. 2a shows a feasible customary organization. Each frequency channel CF1, CF2 transports time slots which are denoted
25 by ..., $T1^0$, $T2^0$, $T3^0$, $T4^0$, $T1^1$, $T2^1$, $T3^1$, $T4^1$, ... for the first channel and by ..., $T5^0$, $T6^0$, $T7^0$, $T8^0$, $T5^1$, $T6^1$, $T7^1$, $T8^1$, ... for the second channel. These references represent the time channels, four of which are thus provided for each of the frequency channels: T1 to T4 for the frequency channel CF1 and T5 to T8 for the frequency channel CF2. The exponent of each time slot represents the number of the parcel
30 transported.

Fig. 3 is a more detailed representation of a satellite station, for example the station STM1, and the main station STB1.

A given number of subscriber members AM1, AM2 and AM3 is



connected to the satellite station STM1. AM1 and AM3 are telephone sets and AM2 is a data device. The outputs of the various subscriber members are connected to the inputs of a multiplexer MX, *via* interface circuits IM1, IM2 and IM3 which perform the customary operations for conditioning the signals so that they are ready for

5 transmission. The signals supplied by the multiplexer Mx are ultimately transmitted *via* the frequency channels, after processing in a frequency dispersion circuit MMF (whose function will be described in detail hereinafter) after amplification by a high-frequency amplifier APTM whose output is connected to an antenna ATM. The waves thus transmitted by the antenna ATM can be received by the antenna ARB of the base station
10 STB1, after which they are amplified by the amplifier APRB before undergoing, in the combinatory circuit DBF, the inverse of the treatment performed by the circuit MMF. The signals are thus demultiplexed by the demultiplexer DBMX in order to be applied, *via* interface circuits IB1, IB2, ..., IB6, to the subscribers AB1, AB2, ..., or to the switching network RC.

15 The station STB1 transmits in a similar manner, utilizing successively a multiplexer BMZ, a circuit MBF, a high-frequency amplifier APTB, and an antenna ATB. The station STM1 also receives information by utilizing a receiving antenna ARM, an amplifier APRM, a circuit DMF and a demultiplexer DMMX.

A control circuit AMRT, denoted by the references MAMRT and
20 BAMRT, respectively, controls the various accesses to the time slots of the multiplex signal for transmission as well as for reception by controlling the circuits MMX, DMMX, MMF and DMF for the former and BMX, DBMX, MBF and DBF for the latter.

A system of this kind has the following problems.

25 The waves transmitted often suffer from a fading phenomenon and also from additive noise, limiting the performance of the system. In order to counteract this limitation, the use of error correction codes has been proposed.

These codes further reduce the probability of an error as the errors occurring are decorrelated more. Therefore, the fading autocorrelation function is not
30 very compatible with error correction codes.

It has also been proposed to use, in combination with the error correction codes, a time interleaving process which distributes in time the various bits constituting the information to be transmitted so that when the fading phenomenon has a short



duration, few bits will be affected. However, if this interleaving is too deep or too extensive, it induces delays which are inadmissible for suitable duplex traffic, notably for the exchange of speech.

In accordance with the invention, there are provided circuits MMF and MBF which serve to improve the immunity of the system to the fading phenomena and which perform a frequency multiplexing operation, and also circuits DBF and DMF which perform the corresponding frequency demultiplexing operation and combine the signals.

In order to execute this multiplexing operation, use is made of the TDMA method chosen for this system; thus, any communication will utilize the frequency channels CF1 and CF2 in an alternating manner. Fig. 2b shows the use of the time channels for carrying out the invention without necessitating supplementary resources. Thus, for the transport of two consecutive information parcels in the same time channel, the frequency channels CF1 and CF2 are alternately used. The time slot $T1^0$ of a first time channel transporting a first parcel is thus transported by means of the frequency channel CF1; the slot of the same time channel which transports the next parcel is transported by means of the channel CF2 and so on alternately for the time slots $T1^2$, $T1^3$, etc. The same holds for the other time slots.

Fig. 2c shows a feasible distribution of the time channels for the transmission directions; given time slots, for example $U1^0$, $U1^1$, $U2^0$, $U2^1$, $U3^0$, $U3^1$, $U4^0$, $U4^1$ are assigned to the transmission direction: satellite station - main station. The transmission in the opposite direction, i.e. base station - satellite station, will utilize the time slots $D1^0$, $D1^1$, $D2^0$, $D2^1$, $D3^0$, $D3^1$, $D4^0$, $D4^1$ utilizing the frequency channels CF1 and CF2. The difference in frequency between the carriers of the channels F1 and F2 must be greater than a few hundreds of kHz. Simultaneity in time occurs between the various channels: $U1^0$ is simultaneous with $U1^1$, $D4^0$ with $D4^1$, etc.

Fig. 4 shows a first example of the circuit MMF. The data applied to its input is modulated, in the modulators 1 and 2, by the carrier frequencies F1 and F2, respectively; a juxtaposition circuit 5 combines the signals modulated by 1 and 2 in order to supply the signals in the correct time slot of the TDMA links as represented by a switch 7 which is controlled by the circuit MAMRT.

Fig. 5 shows a first example of the circuit DBF. The wave received is derived from the correct time slot of the link AMRT; this is represented by a switch 9



which is controlled by the circuit BAMRT. After demodulation of the wave by the demodulators 11 and 13 by way of the carrier frequencies F1 and F2, a combinatory circuit 15 restores the data which is subsequently decoded. The fact that two data symbols consecutively applied to the decoder are subject to independent fading phenomena, due to the multiplexing/demultiplexing process in two sufficiently spaced frequency channels, makes decoding firmer and reduces the residual error rate.

Fig. 6 shows a preferred embodiment of the circuit MMF.

It is composed of a processing circuit 20 which operates on the basis of a fast inverse Fourier transform. This circuit comprises two inputs, each of which receives one data from two as represented by the switch 22. At the output of the circuit the signal has a spectrum with two components which are aligned by a sampling frequency equal to $2 |F1-F2|$, said double spectrum being centred around a frequency $F = 1/2(F1+F2)$ by a modulator 24 so that the signals at the output of this modulator can be placed in the time slot of the multiplex signal AMRT having the carrier frequencies F1 and F2. This is represented by a switch 26 which is controlled by the circuit MAMRT.

Fig. 7 shows a preferred embodiment of the circuit DBF.

In the time slot allocated to the reception, the signal having two spectrum components centred around F1 and F2 is received; this is represented by a switch 32 which is controlled by the circuit BAMRT. A demodulator 34 transforms these signals into base band signals by means of a signal having a frequency $2 |F1-F2|$ and a receiver processing circuit 36 which operates on the basis of a fast Fourier transform supplies the data on these two outputs. This data is thus supplied, one after the other, alternately on the two outputs as represented by a switch 38.

Thus, in this preferred embodiment, the system in accordance with the invention does not necessitate the use of supplementary resources, because each time slot whose number may be doubled for carrying out the invention transports only half the number of data.

Thus, interleaving of the correct depth can be performed which, while introducing a reasonable delay, does not burden the speech communications excessively and which is somehow combined with frequential interleaving.

For example, assuming a noise rate of 8 kbauds, an 8-PSK modulation and a trellis code with a yield of $2/3$, an (interleaving/de-interleaving) time of 100 ms, a

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transmission at 900 MHz, and a vehicle speed of 10 km/h, digital simulations will prove that the use of two sub-carriers enables a coding gain of approximately 11 dB.

Thus, a system in accordance with the invention leads to a particularly significant gain in efficiency without modifying existing frequency levels nor the
5 standards of radio equipment and their compatibility, nor the structure of the TDMA frames used nor the rate per frequency channel.



APPENDIX

Operation of the circuit 20

For a more general description, the circuit 20 is considered to have N inputs. In order to be compatible with what has already been described, N is taken to be
5 equal to 2.

Assuming that $\{d_k, k=0 \dots \infty\}$ is the sequence of the 8-PSK coded symbols at the output of the encoder, and $g(t)$ is the shaping function:

$$g(t) = \begin{cases} 1 & 0 \leq t < NT_s \\ 0 & \text{otherwise} \end{cases}$$

10 The signal in each channel is written as:

$$x^0(t) = \sum_{k=0}^{\infty} d_{kN} g(t - kNT_s)$$

$$x^1(t) = \sum_{k=0}^{\infty} d_{kN+1} g(t - kNT_s)$$

...

$$x^{N-1}(t) = \sum_{k=0}^{\infty} d_{kN+N-1} g(t - kNT_s)$$

15

The signal of the i^{th} channel is thus actually written as:

$$x^i(t) = \sum_{k=0}^{\infty} d_{kN+i} g(t - kNT_s)$$



Each signal is subsequently transposed to the frequency f_i and the signal transmitted is the sum of these N signals:

$$y(t) = \sum_{k=0}^{N-1} \sum_{i=0}^{\infty} d_{kN+i} g(t-kNT_s) e^{j2\pi f_i t}$$

5

The equivalent expression is obtained by reversing the sum signs:

$$y(t) = \sum_{k=0}^{\infty} \sum_{i=0}^{N-1} d_{kN+i} e^{j2\pi f_i t} g(t-kNT_s)$$

Subsequently, a sampling operation is performed at the frequency $f_s = B_{ut}$, so a position
10 in time $t = mT_s$ is chosen:

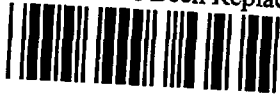
$$y(mT_s) = \sum_{k=0}^{\infty} \sum_{i=0}^{N-1} d_{kN+i} e^{j2\pi f_i mT_s} g(mT_s - kNT_s)$$

On the other hand, equidistant frequencies f_i have been assumed, so $f_i = \frac{if_s}{N}$:

15

$$y_m = y(mT_s) = \sum_{k=0}^{\infty} \sum_{i=0}^{N-1} d_{kN+i} e^{j2\pi \frac{im}{N}} g(mT_s - kNT_s)$$

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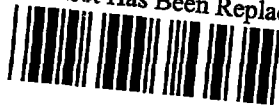
$$y_m = \sum_{k=0}^{\infty} \left\{ \sum_{i=0}^{N-1} d_{kN+i} e^{j2\pi \frac{im}{N}} \right\} g(mT_e - kNT_s)$$

Where $m = m \bmod N$.

Therefore, the second sum is nothing but the inverse discrete Fourier
5 transform of the points $\{d_{kN+i}\}_{i=0}^{N-1}$
taken at the instant $\tilde{m}f_s$, $\tilde{m} = 0, \dots, N-1$.

A similar reasoning could be followed for the circuit DBF.

Such circuits could be realised on the basis of commercially available
10 specific circuits for this type of processing.



Claims:

1. An information transmission system, comprising at least one base station and at least one satellite station, which stations exchange their information by way of a plurality of time multiplex signals which are transported by means of a plurality of carriers, characterized in that for the transmission of useful information between stations
5 there are provided replica means for forming a plurality of replicas of the useful information, frequency dispersion means for transmitting the plurality of replicas in the plurality of multiplex signals, receiving means for receiving the plurality of replicas thus transmitted, and combinatory means for restoring the information on the basis of the plurality of replicas received.
- 10 2. A transmission system as claimed in Claim 1, characterized in that each replica represents a part of the useful information.
3. A transmission system as claimed in any one of the Claims 1 or 2, characterized in that the multiplexing is of the type TDMA.
4. A transmission system as claimed in any one of the Claims 1 to 3,
15 characterized in that the frequency dispersion means are formed on the basis of a fast inverse Fourier transform whereas the combinatory means are formed on the basis of a direct fast Fourier transform.
5. A satellite station suitable for an information transmission system as claimed in any one of the Claims 1 to 4, characterized in that for the transmission of
20 useful information between the stations there are provided replica means for forming a plurality of replicas of the useful information, frequency dispersion means for transmitting the plurality of replicas in the plurality of multiplex signals, receiving means for receiving the plurality of replicas thus transmitted, and combinatory means for restoring the information on the basis of the plurality of replicas received.
- 25 6. A base station suitable for an information transmission system as claimed in any one of the Claims 1 to 4, characterized in that for the transmission of useful information between the stations there are provided replica means for forming a plurality of replicas of the useful information, frequency dispersion means for transmitting the plurality of replicas in the plurality of multiplex signals, receiving
30 means for receiving the plurality of replicas thus transmitted, and combinatory means for restoring the information on the basis of the plurality of replicas received.



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"Information transmission system comprising at least one base station and at least one satellite station".

Abstract:

This system is formed by a base station STB1 and two mobile stations STM1 and STM2. The information exchange between these stations is performed by means of two time multiplex signals which are transported via frequency channels with carriers F1 and F2. In accordance with the invention, the information systematically
5 uses the two frequency channels. The resistance against fading is notably improved.

Application: private mobile radio.

Reference: Fig. 1.

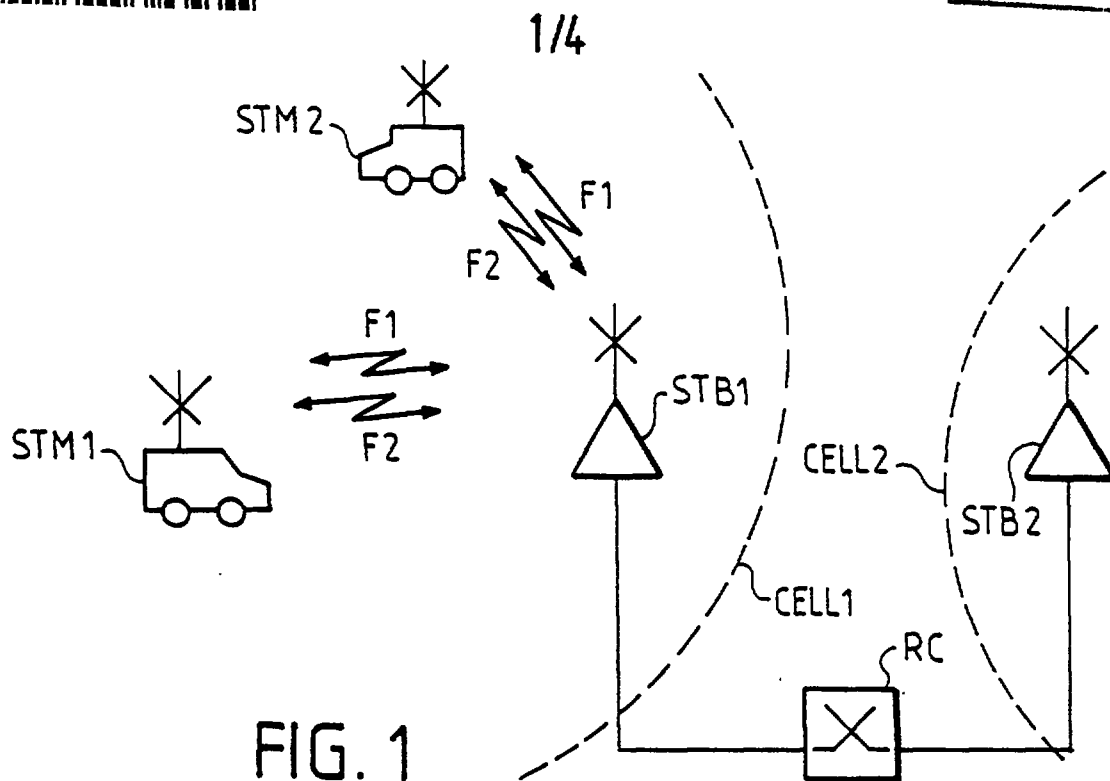
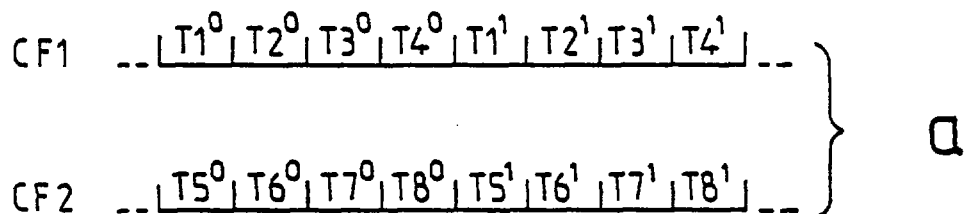
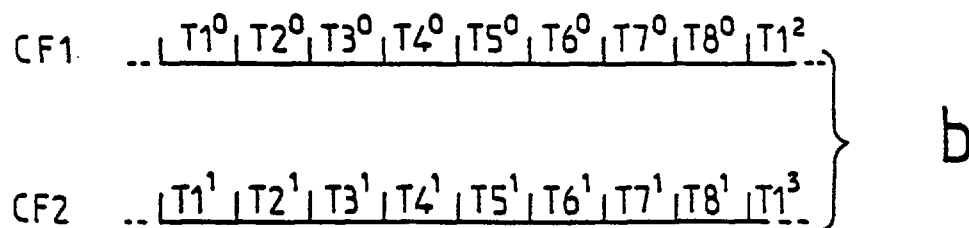
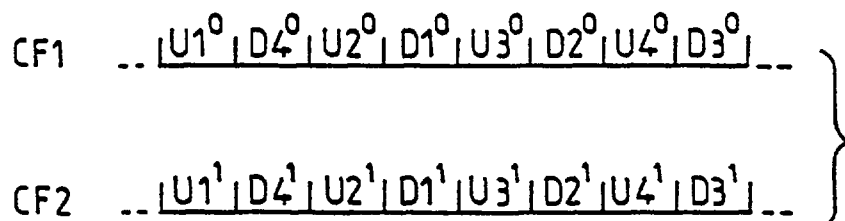


FIG. 2

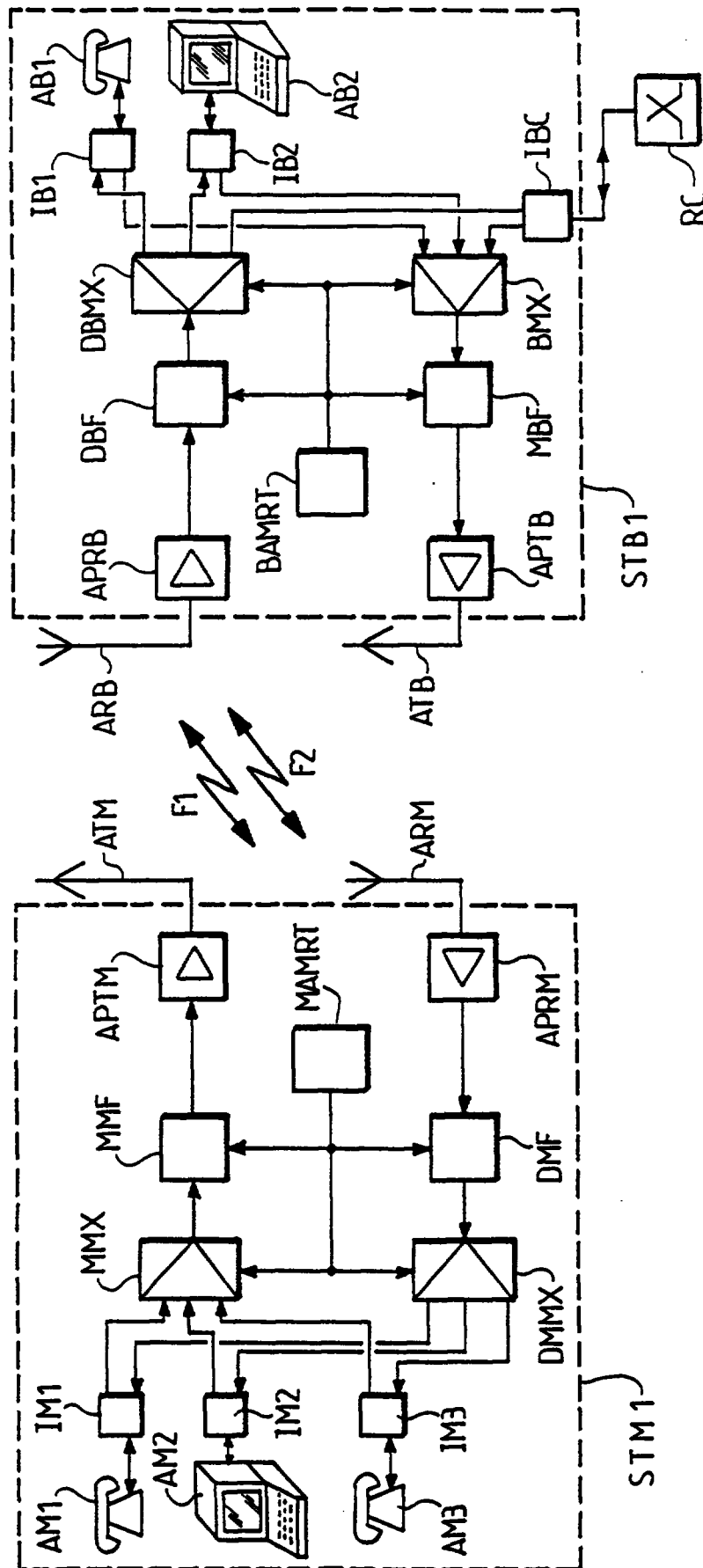


FIG. 3

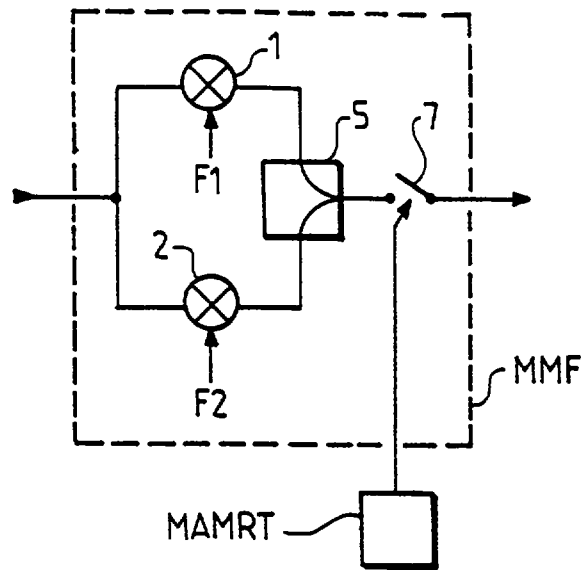


FIG. 4

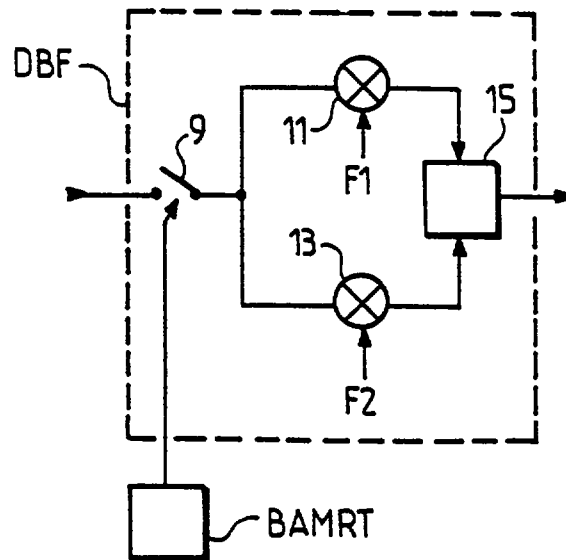


FIG. 5

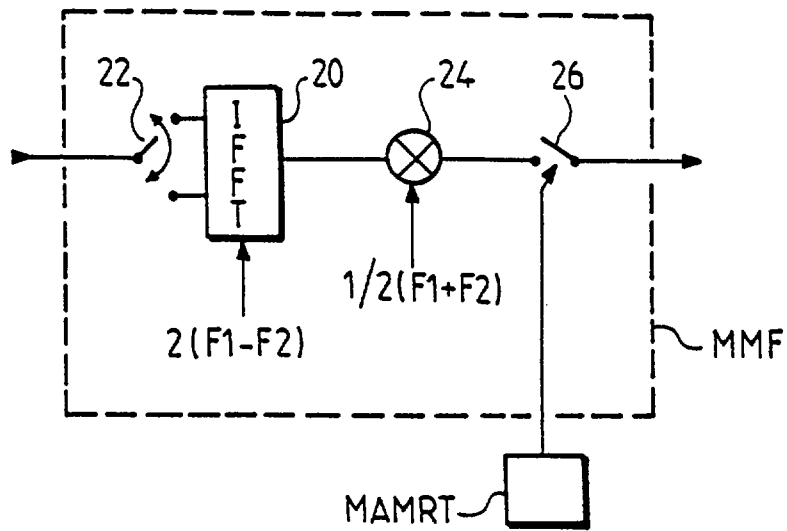


FIG. 6

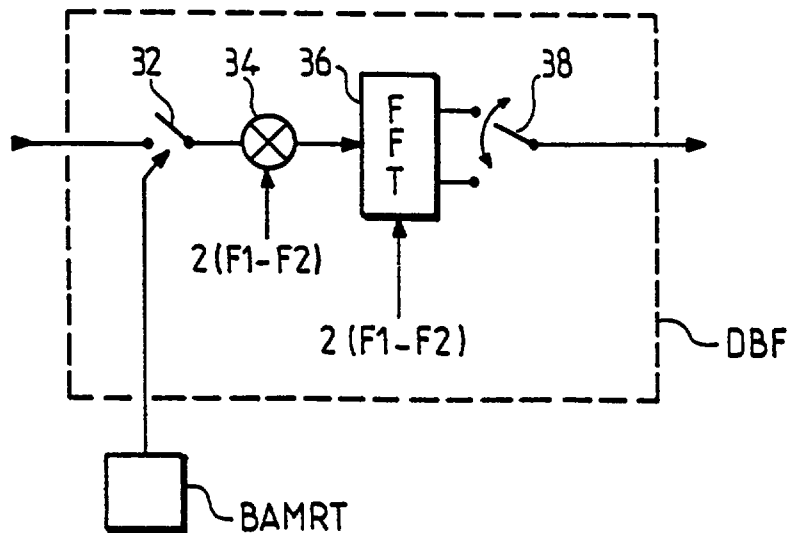


FIG. 7

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Information transmission system comprising at least one base station and at least one satellite station.

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Description:

The present invention relates to an information transmission system, comprising at least one base station and at least one satellite station, which stations exchange their information by way of a plurality of time multiplex signals which are transported by way of a plurality of carriers.

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A system of this kind is widely used notably in the field of private radio communications.

In this field a problem is encountered in that resources are scarce. In this context "resource" is to be understood to be the possibility of using a more or less large number of frequency channels having more or less limited passbands. It is to be noted that despite these limited resources, the quality of the traffic must be as high as possible. A current source of traffic degrading is selective fading. A first known step for counteracting fading is the use of error correction codes; a second known step is the use of different frequency channels for the transmission of consecutive information. This step is described in detail in the article: "Performance of Trellis Coded Modulation Using Multi-Frequency Channels in Land Mobile Communications" by Yukkyoshi Kamio, Proc. of IEEE VEB. TECH., May 1990 (CH2846-4/90/0000-455).

The present invention proposes a system of this kind in which notably the second step is executed, without suffering from the requirements often imposed by the authorities in view of the scarcity of resources.

To achieve this, such an invention is characterized in that for the transmission of useful information between stations there are provided replica means for forming a plurality of replicas of the useful information, frequency dispersion means for transmitting the plurality of replicas in the plurality of time signals, receiving means for receiving the plurality of replicas thus transmitted, and combinatory means for restoring the information on the basis of the plurality of replicas received.

The following description, accompanied by the attached drawings, given

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by way of non-limitative examples, will offer a better understanding as to how the invention can be carried out.

Fig. 1 shows a transmission system in accordance with the invention.

Fig. 2a shows a customarily used TDMA frame structure.

Figs. 2b and 2c show a TDMA frame structure in accordance with the invention.

Fig. 3 shows a block diagram of a satellite station and a base station.

Fig. 4 shows a first example of the use of a frequency dispersion circuit.

Fig. 5 shows a first embodiment of a combinatory circuit.

Fig. 6 shows a preferred embodiment of a frequency dispersion circuit.

Fig. 7 shows a preferred embodiment of a combinatory circuit.

The system which is diagrammatically shown in Fig. 1 is formed by a plurality of cells, only the cells CELL1 and CELL2 being shown in the Figure. In each cell CELL1 and CELL2 there is situated a radio transmission/reception base station STB1 and STB2, respectively. Different vehicles comprising satellite stations STM1 and STM2 can travel within the cells. A switching network RC enables the exchange of information between all cells.

In the present example, two frequency channels CF1, CF2 which are centred around carrier frequencies F1 and F2 are used for the exchange of information between the satellite stations STM1, STM2 and the base station STB1. Evidently, if so required by the traffic, other frequency channels can always be added without departing from the scope of the invention. These frequency channels are used for transmitting time multiplex signals of the type TDMA for which Fig. 2a shows a feasible customary organization. Each frequency channel CF1, CF2 transports time slots which are denoted by ..., $T1^0$, $T2^0$, $T3^0$, $T4^0$, $T1^1$, $T2^1$, $T3^1$, $T4^1$, ... for the first channel and by ..., $T5^0$, $T6^0$, $T7^0$, $T8^0$, $T5^1$, $T6^1$, $T7^1$, $T8^1$, ... for the second channel. These references represent the time channels, four of which are thus provided for each of the frequency channels: T1 to T4 for the frequency channel CF1 and T5 to T8 for the frequency channel CF2. The exponent of each time slot represents the number of the parcel transported.

Fig. 3 is a more detailed representation of a satellite station, for example the station STM1, and the main station STB1.

A given number of subscriber members AM1, AM2 and AM3 is

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connected to the satellite station STM1. ~~AM1 and AM3~~ are telephone sets and AM2 is a data device. The outputs of the various subscriber members are connected to the inputs of a multiplexer MX, *via* interface circuits IM1, IM2 and IM3 which perform the customary operations for conditioning the signals so that they are ready for transmission. The signals supplied by the multiplexer Mx are ultimately transmitted *via* the frequency channels, after processing in a frequency dispersion circuit MMF (whose function will be described in detail hereinafter) after amplification by a high-frequency amplifier APTM whose output is connected to an antenna ATM. The waves thus transmitted by the antenna ATM can be received by the antenna ARB of the base station STB1, after which they are amplified by the amplifier APRB before undergoing, in the combinatory circuit DBF, the inverse of the treatment performed by the circuit MMF. The signals are thus demultiplexed by the demultiplexer DBMX in order to be applied, *via* interface circuits IB1, IB2, ..., IB6, to the subscribers AB1, AB2, ..., or to the switching network RC.

The station STB1 transmits in a similar manner, utilizing successively a multiplexer BMZ, a circuit MBF, a high-frequency amplifier APTB, and an antenna ATB. The station STM1 also receives information by utilizing a receiving antenna ARM, an amplifier APRM, a circuit DMF and a demultiplexer DMMX.

A control circuit AMRT, denoted by the references MAMRT and BAMRT, respectively, controls the various accesses to the time slots of the multiplex signal for transmission as well as for reception by controlling the circuits MMX, DMMX, MMF and DMF for the former and BMX, DBMX, MBF and DBF for the latter.

A system of this kind has the following problems.

The waves transmitted often suffer from a fading phenomenon and also from additive noise, limiting the performance of the system. In order to counteract this limitation, the use of error correction codes has been proposed.

These codes further reduce the probability of an error as the errors occurring are decorrelated more. Therefore, the fading autocorrelation function is not very compatible with error correction codes.

It has also been proposed to use, in combination with the error correction codes, a time interleaving process which distributes in time the various bits constituting the information to be transmitted so that when the fading phenomenon has a short

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duration, few bits will be affected. However, if this interleaving is too deep or too extensive, it induces delays which are inadmissible for suitable duplex traffic, notably for the exchange of speech.

In accordance with the invention, there are provided circuits MMF and MBF which serve to improve the immunity of the system to the fading phenomena and which perform a frequency multiplexing operation, and also circuits DBF and DMF which perform the corresponding frequency demultiplexing operation and combine the signals.

In order to execute this multiplexing operation, use is made of the TDMA method chosen for this system; thus, any communication will utilize the frequency channels CF1 and CF2 in an alternating manner. Fig. 2b shows the use of the time channels for carrying out the invention without necessitating supplementary resources. Thus, for the transport of two consecutive information parcels in the same time channel, the frequency channels CF1 and CF2 are alternately used. The time slot $T1^0$ of a first time channel transporting a first parcel is thus transported by means of the frequency channel CF1; the slot of the same time channel which transports the next parcel is transported by means of the channel CF2 and so on alternately for the time slots $T1^2$, $T1^3$, etc. The same holds for the other time slots.

Fig. 2c shows a feasible distribution of the time channels for the transmission directions; given time slots, for example $U1^0$, $U1^1$, $U2^0$, $U2^1$, $U3^0$, $U3^1$, $U4^0$, $U4^1$ are assigned to the transmission direction: satellite station - main station. The transmission in the opposite direction, i.e. base station - satellite station, will utilize the time slots $D1^0$, $D1^1$, $D2^0$, $D2^1$, $D3^0$, $D3^1$, $D4^0$, $D4^1$ utilizing the frequency channels CF1 and CF2. The difference in frequency between the carriers of the channels F1 and F2 must be greater than a few hundreds of kHz. Simultaneity in time occurs between the various channels: $U1^0$ is simultaneous with $U1^1$, $D4^0$ with $D4^1$, etc.

Fig. 4 shows a first example of the circuit MMF. The data applied to its input is modulated, in the modulators 1 and 2, by the carrier frequencies F1 and F2, respectively; a juxtaposition circuit 5 combines the signals modulated by 1 and 2 in order to supply the signals in the correct time slot of the TDMA links as represented by a switch 7 which is controlled by the circuit MAMRT.

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It is composed of a processing circuit 20 which operates on the basis of a fast inverse Fourier transform. This circuit comprises two inputs, each of which receives one data from two as represented by the switch 22. At the output of the circuit the signal has a spectrum with two components which are aligned by a sampling frequency equal to $2 |F1-F2|$, said double spectrum being centred around a frequency $F = 1/2(F1+F2)$ by a modulator 24 so that the signals at the output of this modulator can be placed in the time slot of the multiplex signal AMRT having the carrier frequencies $F1$ and $F2$. This is represented by a switch 26 which is controlled by the circuit MAMRT.

Fig. 7 shows a preferred embodiment of the circuit DBF.

In the time slot allocated to the reception, the signal having two spectrum components centred around $F1$ and $F2$ is received; this is represented by a switch 32 which is controlled by the circuit BAMRT. A demodulator 34 transforms these signals into base band signals by means of a signal having a frequency $2 |F1-F2|$ and a receiver processing circuit 36 which operates on the basis of a fast Fourier transform supplies the data on these two outputs. This data is thus supplied, one after the other, alternately on the two outputs as represented by a switch 38.

Thus, in this preferred embodiment, the system in accordance with the invention does not necessitate the use of supplementary resources, because each time slot whose number may be doubled for carrying out the invention transports only half the number of data.

Thus, interleaving of the correct depth can be performed which, while introducing a reasonable delay, does not burden the speech communications excessively and which is somehow combined with frequential interleaving.

For example, assuming a noise rate of 8 kbauds, an 8-PSK modulation and a trellis code with a yield of $2/3$, an (interleaving/de-interleaving) time of 100 ms, a

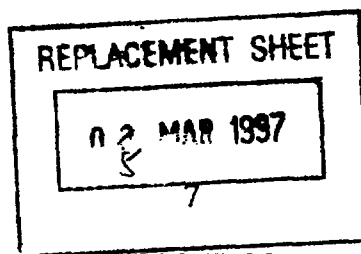
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transmission at 900 MHz, and a vehicle speed of 10 km/h, digital simulations will prove that the use of two sub-carriers enables a coding gain of approximately 11 dB.

Thus, a system in accordance with the invention leads to a particularly significant gain in efficiency without modifying existing frequency levels nor the standards of radio equipment and their compatibility, nor the structure of the TDMA frames used nor the rate per frequency channel.



APPENDIX

Operation of the circuit 20

For a more general description, the circuit 20 is considered to have N inputs. In order to be compatible with what has already been described, N is taken to be equal to 2.

Assuming that $\{d_k, k=0 \dots \infty\}$ is the sequence of the 8-PSK coded symbols at the output of the encoder, and $g(t)$ is the shaping function:

$$g(t) = \begin{cases} 1 & 0 \leq t < NT_s \\ 0 & \text{otherwise} \end{cases}$$

The signal in each channel is written as:

$$x^0(t) = \sum_{k=0}^{\infty} d_{kN} g(t - kNT_s)$$

$$x^1(t) = \sum_{k=0}^{\infty} d_{kN+1} g(t - kNT_s)$$

$$x^{N-1}(t) = \sum_{k=0}^{\infty} d_{kN+N-1} g(t - kNT_s)$$

The signal of the i^{th} channel is thus actually written as:

$$x^i(t) = \sum_{k=0}^{\infty} d_{kN+i} g(t - kNT_s)$$

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Each signal is subsequently transposed to the frequency f_i and the signal transmitted is the sum of these N signals:

$$y(t) = \sum_{k=0}^{N-1} \sum_{i=0}^{\infty} d_{kN+i} g(t-kNT_s) e^{j2\pi f_i t}$$

The equivalent expression is obtained by reversing the sum signs:

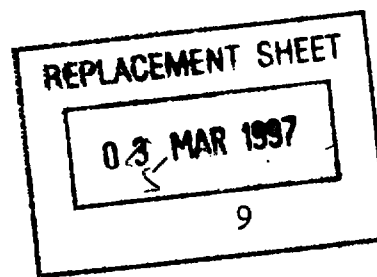
$$y(t) = \sum_{k=0}^{\infty} \sum_{i=0}^{N-1} d_{kN+i} e^{j2\pi f_i t} g(t-kNT_s)$$

Subsequently, a sampling operation is performed at the frequency $f_e = B_{ut}$, so a position in time $t = mT_e$ is chosen:

$$y(mT_e) = \sum_{k=0}^{\infty} \sum_{i=0}^{N-1} d_{kN+i} e^{j2\pi f_i mT_e} g(mT_e - kNT_s)$$

On the other hand, equidistant frequencies f_i have been assumed, so $f_i = \frac{if_e}{N}$:

$$y_m = y(mT_e) = \sum_{k=0}^{\infty} \sum_{i=0}^{N-1} d_{kN+i} e^{j2\pi \frac{im}{N}} g(mT_e - kNT_s)$$



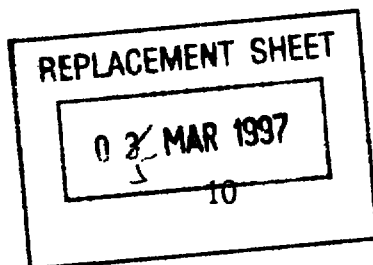
$$y_m = \sum_{k=0}^{\infty} \left\{ \sum_{i=0}^{N-1} d_{kN+i} e^{j2\pi \frac{im}{N}} \right\} g(mT_c - kNT_s)$$

Where $m = m \bmod N$.

Therefore, the second sum is nothing but the inverse discrete Fourier transform of the points $\{d_{kN+i}\}_{i=0}^{N-1}$ taken at the instant $\tilde{m}f_s$, $\tilde{m} = 0, \dots, N-1$.

A similar reasoning could be followed for the circuit DBF.

Such circuits could be realised on the basis of commercially available specific circuits for this type of processing.



Claims:

1. An information transmission system, comprising at least one base station and at least one satellite station, which stations exchange their information by way of a plurality of time multiplex signals which are transported by means of a plurality of carriers, characterized in that for the transmission of useful information between stations there are provided replica means for forming a plurality of replicas of the useful information, frequency dispersion means for transmitting the plurality of replicas in the plurality of multiplex signals, receiving means for receiving the plurality of replicas thus transmitted, and combinatory means for restoring the information on the basis of the plurality of replicas received.
2. A transmission system as claimed in Claim 1, characterized in that each replica represents a part of the useful information.
3. A transmission system as claimed in any one of the Claims 1 or 2, characterized in that the multiplexing is of the type TDMA.
4. A transmission system as claimed in any one of the Claims 1 to 3, characterized in that the frequency dispersion means are formed on the basis of a fast inverse Fourier transform whereas the combinatory means are formed on the basis of a direct fast Fourier transform.
5. A satellite station suitable for an information transmission system as claimed in any one of the Claims 1 to 4, characterized in that for the transmission of useful information between the stations there are provided replica means for forming a plurality of replicas of the useful information, frequency dispersion means for transmitting the plurality of replicas in the plurality of multiplex signals, receiving means for receiving the plurality of replicas thus transmitted, and combinatory means for restoring the information on the basis of the plurality of replicas received.
6. A base station suitable for an information transmission system as claimed in any one of the Claims 1 to 4, characterized in that for the transmission of useful information between the stations there are provided replica means for forming a plurality of replicas of the useful information, frequency dispersion means for transmitting the plurality of replicas in the plurality of multiplex signals, receiving means for receiving the plurality of replicas thus transmitted, and combinatory means for restoring the information on the basis of the plurality of replicas received.

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"Information transmission system comprising at least one base station and at least one satellite station".

Abstract:

This system is formed by a base station STB1 and two mobile stations STM1 and STM2. The information exchange between these stations is performed by means of two time multiplex signals which are transported via frequency channels with carriers F1 and F2. In accordance with the invention, the information systematically uses the two frequency channels. The resistance against fading is notably improved.

Application: private mobile radio.

Reference: Fig. 1.

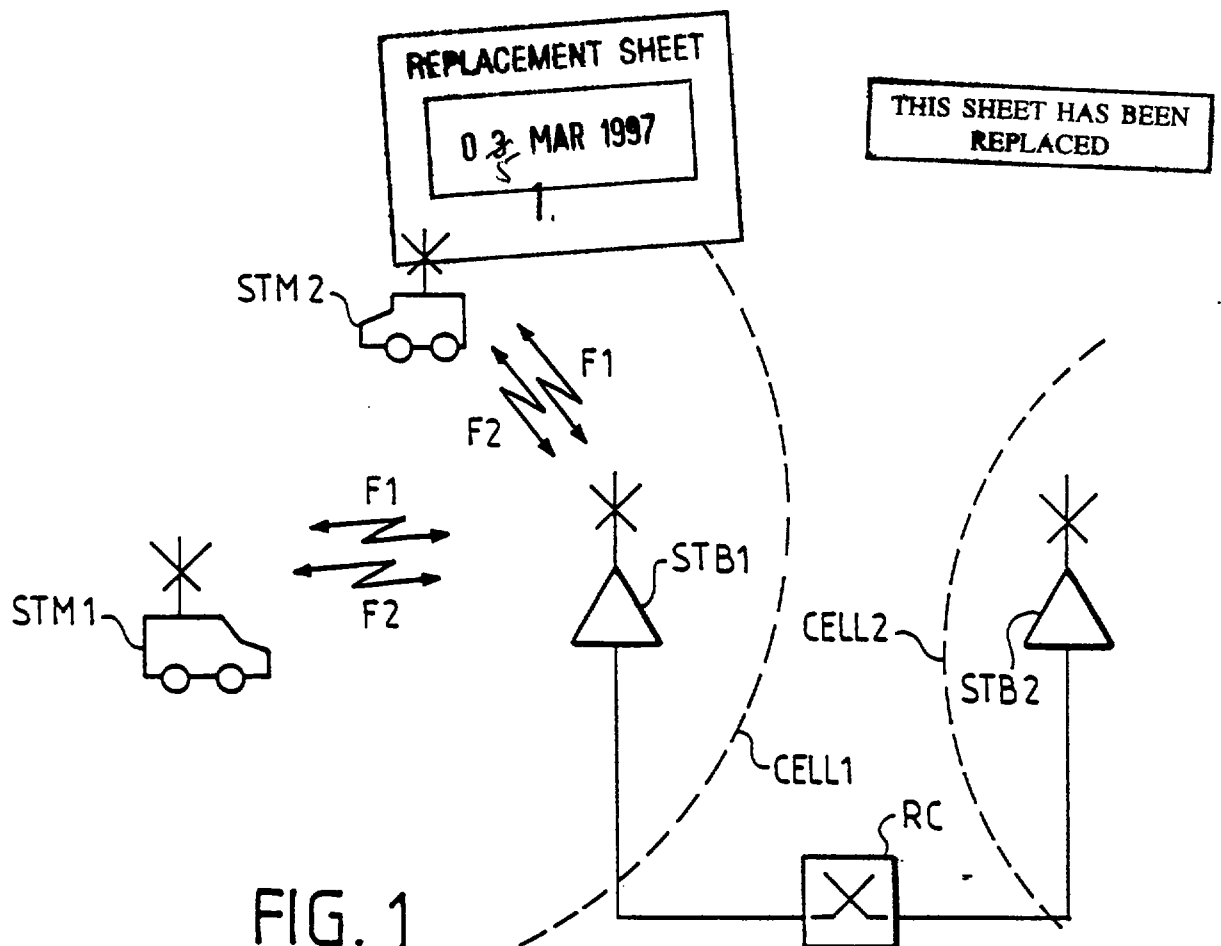
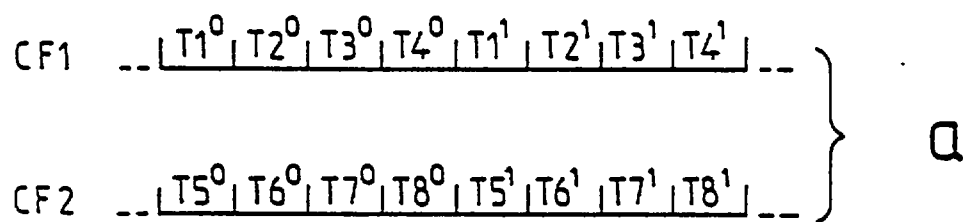
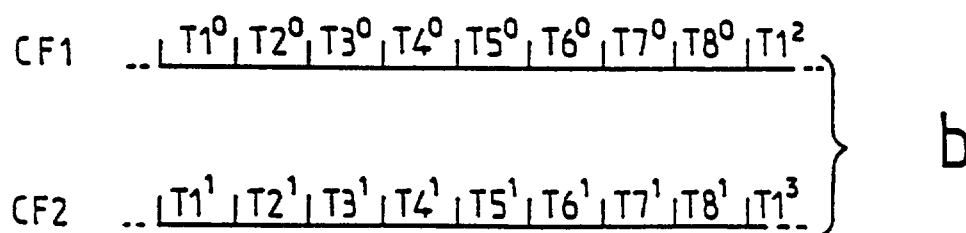
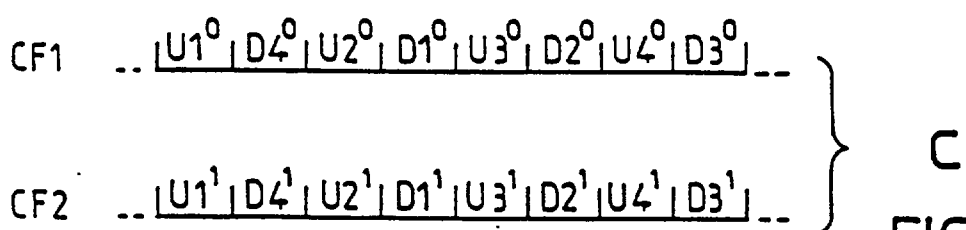


FIG. 2

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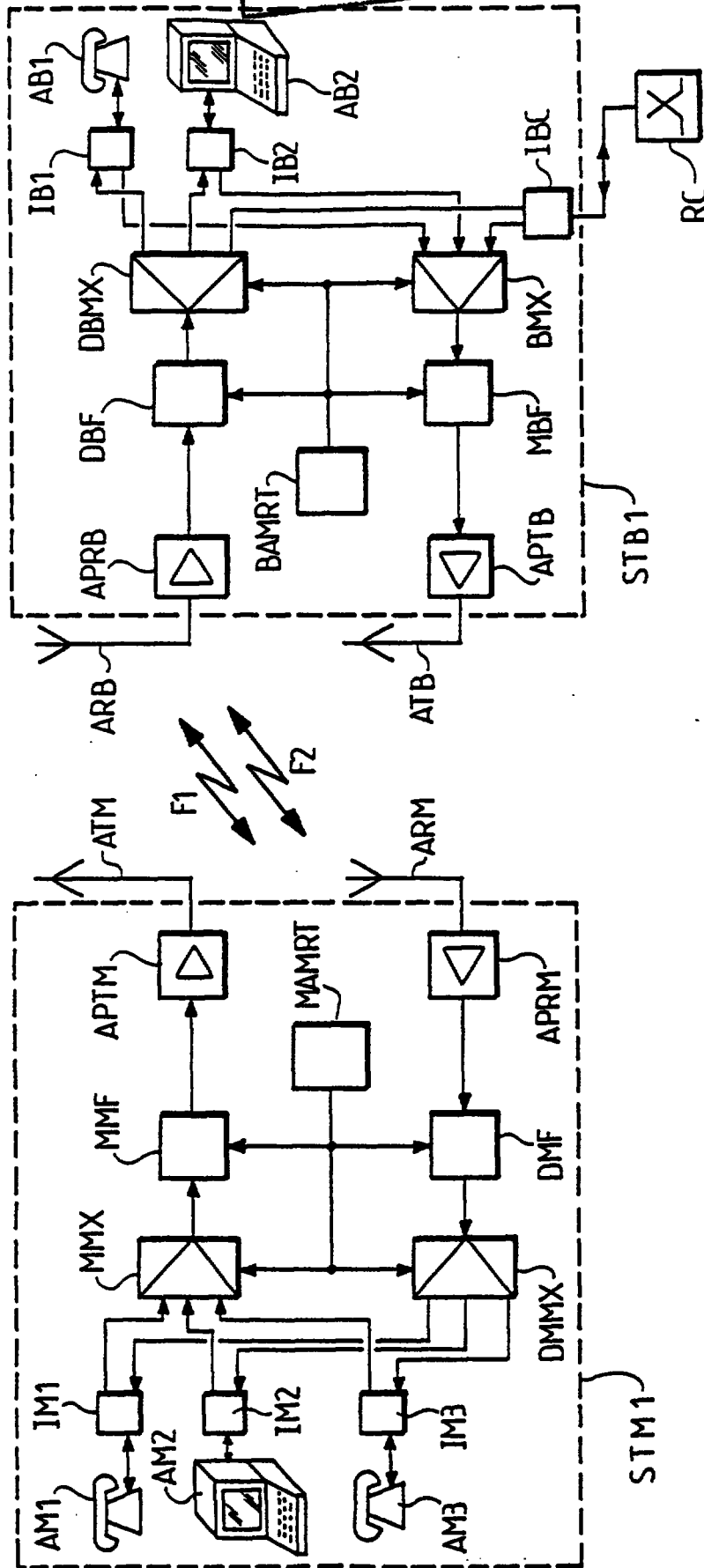


FIG. 3

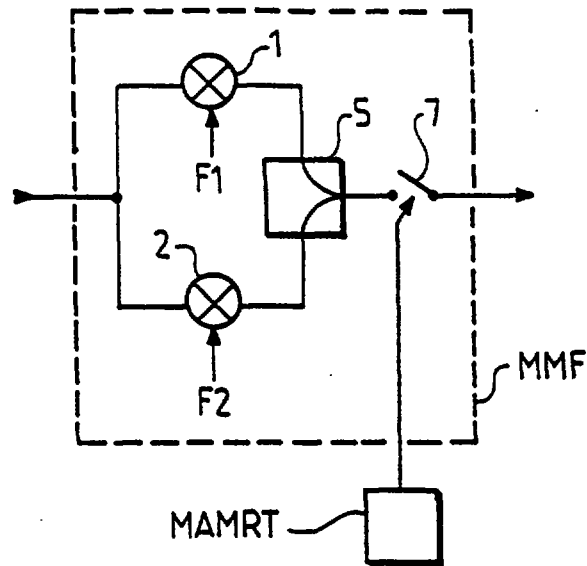


FIG. 4

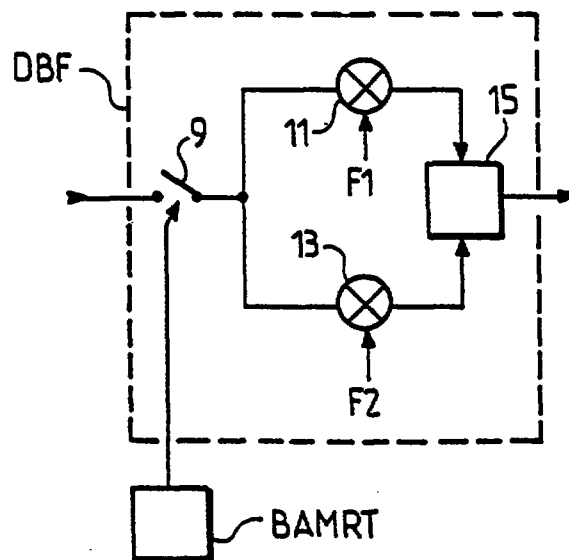


FIG. 5

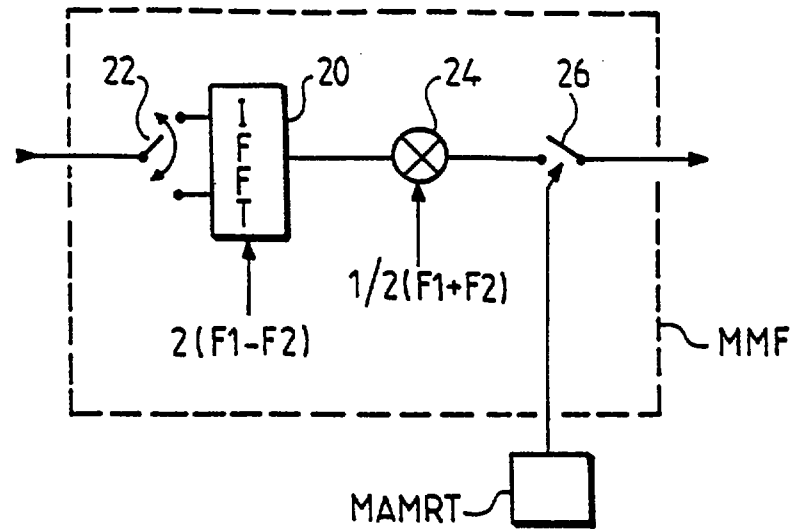


FIG. 6

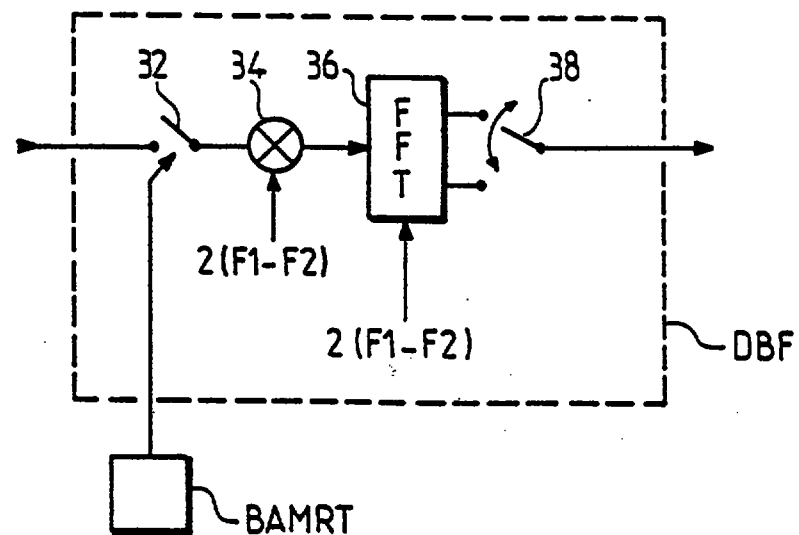


FIG. 7

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INFORMATION TRANSMISSION SYSTEM WITH AT LEAST ONE BASE STATION
AND ONE SATELLITE STATION

The invention relates to an information transmission system, comprising at least one base station and at least one satellite station, exchanging payload information signals by a plurality of time multiplexed signals which are transported by a plurality of carriers, which system comprises for transmitting the payload information signals between the stations:

- replica-forming means for forming a plurality of replicas by a time-dependent sub-division of the payload information
- frequency spreading means (MMF) for transmitting the plurality of replicas in the plurality of multiplexed signals,
- receiving means for receiving the thus transmitted plurality of replicas, and
- combining means (DBF) for restoring the payload information signals based on the plurality of received replicas.

The invention also relates to a satellite station and a base station suitable for use in such a system.

A system of this kind is widely used notably in the field of private radio communications.

In this field a problem is encountered in that resources are scarce. In this context "resource" refers to a possibility of using a more or less large number of frequency channels having more or less limited passbands. It is to be noted that despite these limited resources, the quality of the traffic must be as high as possible. A current source of traffic degrading is selective fading. A first known step for counteracting fading is the use of error correction codes; a second known step is the use of different frequency channels for the transmission of consecutive information signals. This step is described in detail in the article: "Performance of Trellis Coded Modulation Using Multi-Frequency Channels in Land Mobile Communications" by Yukiyoshi Kamio, Proc. of IEEE VEB. TECH., May 1990 (CH2846-4/90/000-455).

The present invention proposes a system of this kind in which the

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spreading means and combining means can be realised in a simple and economic manner.

Therefore, according to an aspect of the invention such a system is characterized in that the frequency spreading means are formed from a fast inverse Fourier transform.

According to another aspect of the invention such a system is characterized in that the combining means are formed from a fast direct Fourier transform.

The invention will be described in detail hereinafter with reference to the accompanying drawings.

Fig. 1 shows a transmission system in accordance with the invention.

Fig. 2a shows a customarily used TDMA frame structure.

Figs. 2b and 2c show a TDMA frame structure in accordance with the invention.

Fig. 3 shows a block diagram of a satellite station and a base station.

Fig. 4 shows a first example of the use of a frequency dispersion circuit.

Fig. 5 shows a first embodiment of a combining circuit.

Fig. 6 shows a preferred embodiment of a frequency dispersion circuit.

Fig. 7 shows a preferred embodiment of a combining circuit.

The system which is diagrammatically shown in Fig. 1 is formed by a plurality of cells, only the cells CELL1 and CELL2 being shown in the Figure. In each cell CELL1 and CELL2 there is situated a radio transmission/reception base station STB1 and STB2, respectively. Various vehicles comprising satellite stations STM1 and STM2 can travel within the cells. A switching network RC enables the exchange of information between all cells.

In the present example, two frequency channels CF1, CF2 which are centred around carrier frequencies F1 and F2 are used for the exchange of information between the satellite stations STM1, STM2 and the base station STB1. Evidently, if so required by the traffic, other frequency channels could be added without departing from the scope of the invention. These frequency channels are used for transmitting time multiplexed signals of the TDMA type for which Fig. 2a shows a feasible customary organization. Each frequency channel CF1, CF2 is divided into time slots which are denoted ..., $T1^0$, $T2^0$, $T3^0$, $T4^0$, $T1^1$, $T2^1$, $T3^1$, $T4^1$, ... for the first channel and ...,

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$T5^0, T6^0, T7^0, T8^0, T5^1, T6^1, T7^1, T8^1, \dots$ for the second channel. These references represent the time channels, four of which are thus provided for each of the frequency channels: T1 to T4 for the frequency channel CF1 and T5 to T8 for the frequency channel CF2. The exponent of each time slot represents the number of the transported packet.

Fig. 3 is a more detailed representation of a satellite station, for example, the station STM1, and the base station STB1.

A given number of subscriber members AM1, AM2 and AM3 are connected to the satellite station STM1. AM1 and AM3 are telephone sets and AM2 is a data device. The outputs of the various subscriber members are connected to the inputs of a multiplexer MX, *via* interface circuits IM1, IM2 and IM3 which perform the customary operations for conditioning the signals, so that they are ready for transmission. The signals supplied by the multiplexer MX are ultimately transmitted *via* the frequency channels, and then processed in a frequency dispersion circuit MMF (whose function will be described in detail hereinafter) after being amplified by a high-frequency amplifier APTM whose output is connected to an antenna ATM. The waves thus transmitted by the antenna ATM can be received by the antenna ARB of the base station STB1, after which they are amplified by the amplifier APRB before undergoing, in the combining circuit DBF, the reverse treatment performed by the circuit MMF. The signals are thus demultiplexed by the demultiplexer DBMX in order to be applied, *via* interface circuits IB1, IB2, ..., IB6, to the subscribers AB1, AB2, ..., or to the switching network RC.

The station STB1 transmits in a similar manner, utilizing successively a multiplexer BMZ, a circuit MBF, a high-frequency amplifier APTB, and an antenna ATB. The station STM1 also receives information signals by utilizing a receiving antenna ARM, an amplifier APRM, a circuit DMF and a demultiplexer DMMX.

A TDMA control circuit, denoted by the references MAMRT and BAMRT, respectively, controls the various accesses to the time slots of the multiplex signal for transmission as well as for reception by controlling the circuits MMX, DMMX, MMF and DMF for the former and BMX, DBMX, MBF and DBF for the latter.

A system of this kind has the following problems.

The transmitted waves often suffer from a fading phenomenon and also

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from additive noise, limiting the performance of the system. In order to counteract this limitation, the use of error correction codes has been proposed.

These codes further reduce the probability of an error as the errors occurring are decorrelated more. Therefore, the fading autocorrelation function is not very compatible with error correction codes.

It has already been proposed to use, in combination with the error correction codes, a time interleaving process which distributes in time the various bits constituting the information to be transmitted, so that, when the fading phenomenon has a short duration, few bits will be affected. However, if this interleaving is too deep or too extensive, it induces delays which are inadmissible for suitable duplex traffic, notably for the exchange of speech.

In accordance with the invention, there are provided circuits MMF and MBF which serve to improve the immunity of the system to the fading phenomenon and which perform a frequency multiplexing operation, and also circuits DBF and DMF which perform the corresponding frequency demultiplexing operation and combine the signals.

In order to execute this multiplexing operation, use is made of the TDMA method chosen for this system; thus, any communication will utilize the frequency channels CF1 and CF2 in an alternating manner. Fig. 2b shows the use of the time channels for carrying out the invention without necessitating supplementary resources. Thus, for the transport of two consecutive information signal packets in the same time channel, the frequency channels CF1 and CF2 are alternately used. The time slot $T1^0$ of a first time channel transporting a first packet is transported by means of the frequency channel CF1; the slot of the same time channel which transports the next packet is transported by means of the channel CF2 and so on alternately for the time slots $T1^2$, $T1^3$, etc. The same holds for the other time slots.

Fig. 2c shows a feasible distribution of the time channels for the transmission directions; given time slots, for example $U1^0$, $U1^1$, $U2^0$, $U2^1$, $U3^0$, $U3^1$, $U4^0$, $U4^1$ are assigned to the transmission direction: satellite station - base station. The transmission in the opposite direction, i.e. base station - satellite station, will utilize the time slots $D1^0$, $D1^1$, $D2^0$, $D2^1$, $D3^0$, $D3^1$, $D4^0$, $D4^1$ utilizing the frequency channels CF1 and CF2. The difference in frequency between the carriers of the channels F1 and F2 must be greater than a few hundred kHz. Simultaneity in time occurs between the

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various channels: $U1^0$ is simultaneous with $U1^1$, $D4^0$ with $D4^1$, etc.

Fig. 4 shows a first example of the circuit MMF. The data applied to its input are modulated, in the modulators 1 and 2, by the carrier frequencies $F1$ and $F2$, respectively, a juxtaposition circuit 5 combines the signals modulated by 1 and 2 in order to supply the signals in the correct time slot of the TDMA links as represented by a switch 7 which is controlled by the circuit MAMRT.

Fig. 5 shows a first example of the circuit DBF. The wave received is derived from the correct time slot of the TDMA link, this is represented by a switch 9 which is controlled by the circuit BAMRT. After demodulation of the wave by the demodulators 11 and 13 by way of the carrier frequencies $F1$ and $F2$, a combining circuit 15 restores the data which are subsequently decoded. The fact that two data symbols consecutively applied to the decoder are subject to independent fading phenomena, due to the multiplexing/demultiplexing process in two sufficiently spaced frequency channels, makes decoding firmer and reduces the residual error rate.

Fig. 6 shows a preferred embodiment of the circuit MMF.

It is formed by a processing circuit 20 which operates on the basis of a fast inverse Fourier transform. This circuit has two inputs, each of which receives a data as represented by the switch 22. At the output of the circuit the signal has a spectrum with two components which are aligned by a sampling frequency equal to $2|F1-F2|$, said double spectrum being centred around a frequency $F = 1/2(F1+F2)$ by a modulator 24, so that the signals at the output of this modulator can be placed in the time slot of the TDMA multiplex signal having the carrier frequencies $F1$ and $F2$. This is represented by a switch 26 which is controlled by the circuit MAMRT.

Fig. 7 shows a preferred embodiment of the circuit DBF.

In the time slot set on reception, the signal having two spectrum components centred around $F1$ and $F2$ is received; this is represented by a switch 32 which is controlled by the circuit BAMRT. A demodulator 34 transforms these signals into baseband signals by means of a signal having a frequency $2|F1-F2|$, and a receiver processing circuit 36 which operates on the basis of a fast Fourier transform supplies the data on these two outputs. These data are thus supplied one after the other, alternately on the two outputs as represented by a switch 38.

Thus, in this preferred embodiment, the system in accordance with the invention does not necessitate the use of supplementary resources, because each time

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slot whose number may be doubled for carrying out the invention transports only half the number of data.

Thus, interleaving of the correct depth can be performed which, introducing a reasonable delay, does not excessively burden the speech communications and which is somehow combined with frequential interleaving.

For example, assuming a noise rate of 8 kbauds, an 8-PSK modulation and a trellis code with a yield of $2/3$, an (interleaving/de-interleaving) time of 100 ms, a transmission at 900 MHz, and a speed of the mobile vehicle of 10 km/h, digital simulations will prove that the use of two sub-carriers makes a coding gain of approximately 11 dB possible.

Thus, a system in accordance with the invention leads to a development bringing with it a particularly significant gain in efficiency, without modifying existing frequency levels, or the standards of radio equipment and their compatibility, or the structure of the TDMA frames used, or the rate per frequency channel.

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ANNEX

Operation of the circuit 20:

For a more general description, the circuit 20 is considered to have N inputs. In order to be compatible with that which has already been described, N is taken to be equal to 2.

Assuming that $\{d_k, k=0 \dots \infty\}$ is the sequence of the 8-PSK coded symbols at the output of the encoder, and $g(t)$ is the shaping function:

$$g(t) = \begin{cases} 1 & 0 \leq t < NT_s \\ 0 & \text{elsewhere} \end{cases}$$

The signal in each channel is written as:

$$x^0(t) = \sum_{k=0}^{\infty} d_{kN} g(t-kNT_s)$$

$$x^1(t) = \sum_{k=0}^{\infty} d_{kN+1} g(t-kNT_s)$$

$$x^{N-1}(t) = \sum_{k=0}^{\infty} d_{kN+N-1} g(t-kNT_s)$$

The signal of the i^{th} channel is thus actually written as:

$$x_i(t) = \sum_{k=0}^{\infty} d_{kN+i} g(t-kNT_s)$$

Each signal is subsequently transposed to the frequency f_i and the transmitted signal is the sum of these N signals:

$$y(t) = \sum_{i=0}^{N-1} \sum_{k=0}^{\infty} d_{kN+i} g(t-kNT_s) e^{j2\pi f_i t}$$

The equivalent expression is obtained by reversing the sum signs:

$$y(t) = \sum_{k=0}^{\infty} \sum_{i=0}^{N-1} d_{kN+i} e^{j2\pi f_i t} g(t-kNT_s)$$

Subsequently, a sampling operation is performed at the frequency $f_c = B_{\text{ut}}$, so a position in time $t = mT_c$ is chosen:

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$$y(mT_c) = \sum_{k=0}^{\infty} \sum_{i=0}^{N-1} d_{kN+i} e^{j2\pi f_i mT_c} g(mT_c - kNT_c)$$

On the other hand, equidistant frequencies f_i have been assumed, so $f_i = \frac{if_c}{N}$:

$$y(m) = y(mT_c) = \sum_{k=0}^{\infty} \sum_{i=0}^{N-1} d_{kN+i} e^{j2\pi \frac{im}{N}} g(mT_c - kNT_c)$$

$$y(m) = \sum_{k=0}^{\infty} \left[\sum_{i=0}^{N-1} d_{kN+i} e^{j2\pi \frac{im}{N}} \right] g(mT_c - kNT_c)$$

Where $m = m \bmod N$.

Therefore, the second sum is nothing but the inverse discrete Fourier

transform of the points $(d_{kN+i}) \sum_{i=0}^{N-1}$

taken at the instant $\tilde{m}f_c$, $\tilde{m} = 0, \dots, N-1$.

A similar reasoning could be followed for the circuit DBF.

Such circuits could be realised on the basis of commercially available specific circuits for this type of processing.

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CLAIMS

1. Information transmission system, comprising at least one base station (STB1, STB2) and at least one satellite station (STM1, STM2), exchanging payload information signals by a plurality of time multiplexed signals which are transported by a plurality of carriers (F1, F2), which system comprises for transmitting the payload information signals between the stations:

- replica-forming means for forming a plurality of replicas by a time-dependent sub-division of the payload information
- frequency spreading means (MMF) for transmitting the plurality of replicas in the plurality of multiplexed signals,
- receiving means for receiving the thus transmitted plurality of replicas, and
- combining means (DBF) for restoring the payload information signals based on the plurality of received replicas,

characterized in that the frequency spreading means are formed from a fast inverse Fourier transform.

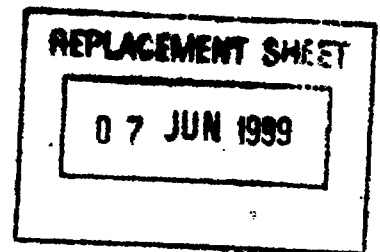
2. Information transmission system as claimed in Claim 1, characterized in that the combining means are formed from a fast direct Fourier transform.

3. Transmission system as claimed in any one of the Claims 1 or 2, characterized in that the multiplexing is of the TDMA type.

4. Satellite station suitable for a system as claimed in any one of the Claims 1 to 3 for which station there is provided for transmitting payload information signals:

- replica-forming means for forming a plurality of replicas by a time-dependent sub-division of the payload information
- frequency spreading means for transmitting the plurality of replicas in the plurality of multiplexed signals,
- receiving means for receiving the thus transmitted plurality of replicas, and
- combining means for restoring the payload information signals based on the plurality of received replicas,

characterized in that the frequency spreading means are formed from a fast direct



Fourier transform.

5. Satellite station as claimed in Claim 4, characterized in that the combining means are formed from a fast direct Fourier transform.

6. Base station suitable for a system as claimed in one of the Claims 1 to 3, for which station there is provided for transmitting payload information signals:

- replica-forming means for forming a plurality of replicas by a time-dependent sub-division of the payload information
- frequency spreading means for transmitting the plurality of replicas in the plurality of multiplexed signals,
- receiving means for receiving the thus transmitted plurality of replicas, and
- combining means for restoring the payload information signals based on the plurality of received replicas,

characterized in that the frequency spreading means are formed from a fast inverse Fourier transform.

7. Base station as claimed in Claim 6, characterized in that the combining means are formed from a fast direct Fourier transform.

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INFORMATION TRANSMISSION SYSTEM WITH AT LEAST ONE BASE STATION
AND ONE SATELLITE STATION

ABSTRACT

This system is formed by a base station STB1 and two mobile stations STM1 and STM2. The information exchange between these stations is performed by means of two time multiplex signals which are transported via frequency channels with carriers F1 and F2. In accordance with the invention, the information systematically uses the two frequency channels. The resistance against fading is notably improved.

Application: private mobile radio.

Reference: Fig. 1.

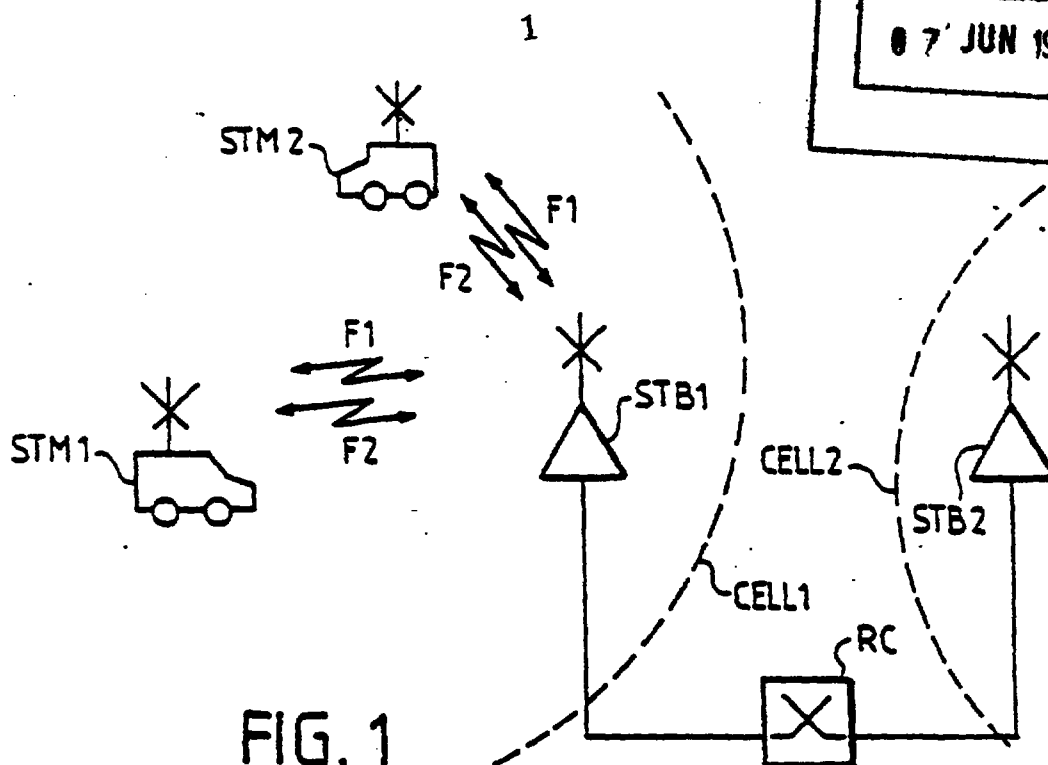


FIG. 1

CF1 ... $T1^0$ | $T2^0$ | $T3^0$ | $T4^0$ | $T1^1$ | $T2^1$ | $T3^1$ | $T4^1$ | ...

CF2 ... $T5^0$ | $T6^0$ | $T7^0$ | $T8^0$ | $T5^1$ | $T6^1$ | $T7^1$ | $T8^1$ | ...

a

CF1 ... $T1^0$ | $T2^0$ | $T3^0$ | $T4^0$ | $T5^0$ | $T6^0$ | $T7^0$ | $T8^0$ | $T1^2$ | ...

CF2 ... $T1^1$ | $T2^1$ | $T3^1$ | $T4^1$ | $T5^1$ | $T6^1$ | $T7^1$ | $T8^1$ | $T1^3$ | ...

b

CF1 ... $U1^0$ | $D4^0$ | $U2^0$ | $D1^0$ | $U3^0$ | $D2^0$ | $U4^0$ | $D3^0$ | ...

CF2 ... $U1^1$ | $D4^1$ | $U2^1$ | $D1^1$ | $U3^1$ | $D2^1$ | $U4^1$ | $D3^1$ | ...

c

FIG. 2

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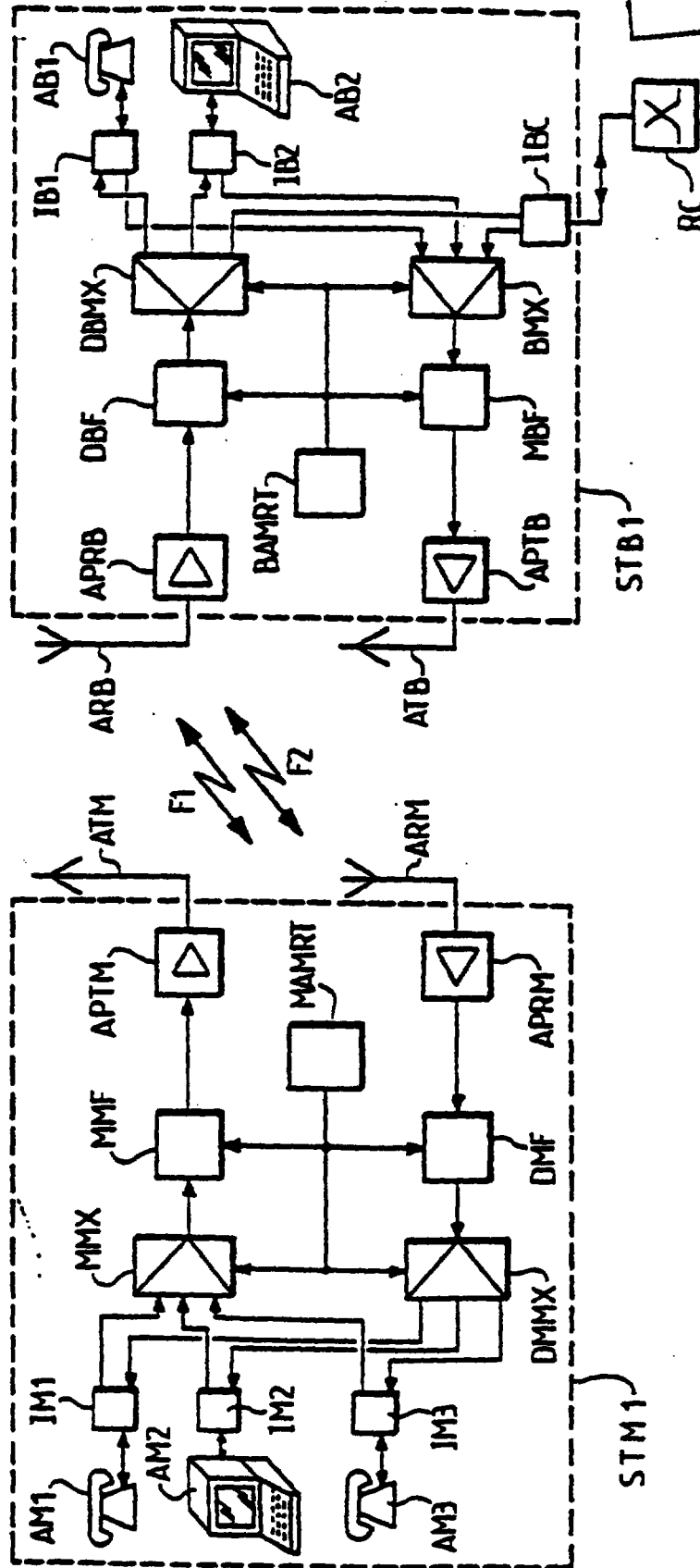


FIG. 3

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3

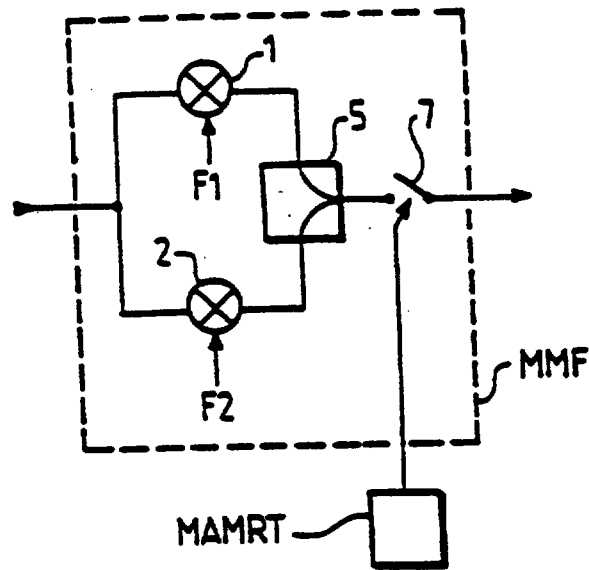


FIG. 4

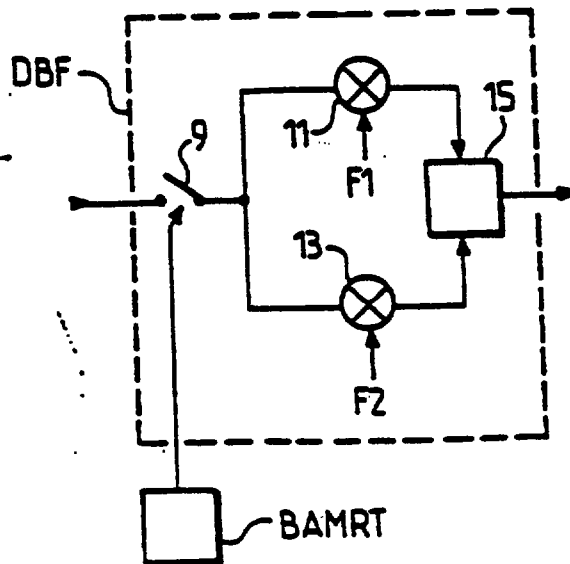


FIG. 5

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4

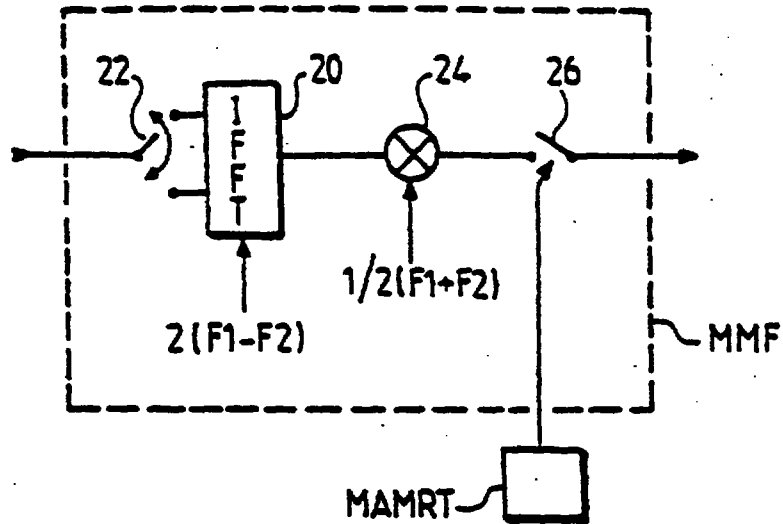


FIG. 6

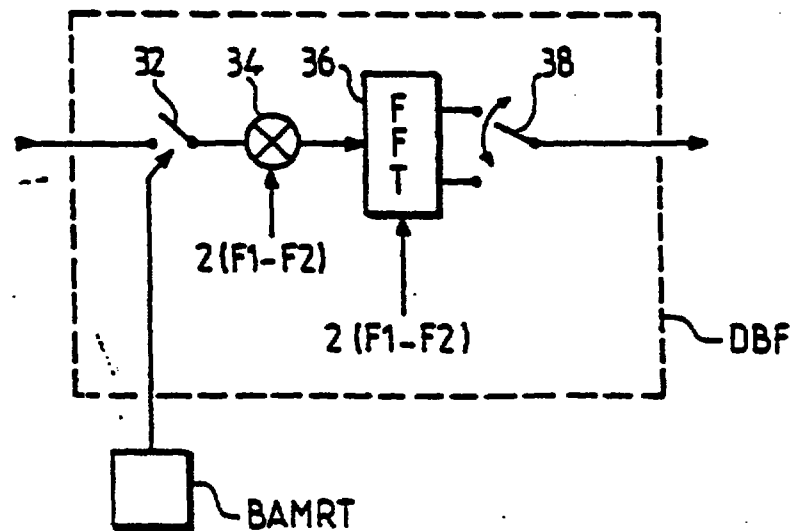


FIG. 7