596408 73267/87

COMMONWEALTH of AUSTRALIA

PATENTS ACT 1952

APPLICATION FOR A STANDARD PATENT

~~I~~ We ZELLWEGER TELECOMMUNICATIONS LTD of
Eichtalstrasse, CH-8634 Hombrechtikon,
Switzerland.

APPLICATION ACCEPTED AND AMENDMENTS
ALLOWED 22-2-90

hereby apply for the grant of a Standard Patent for an invention entitled:

"METHOD AND DEVICE FOR BUILDING UP A CONNECTION IN SHORTWAVE RADIO NETWORKS"

which is described in the accompanying ~~provisional~~ complete specification.

Details of basic application(s):—

Number	Convention Country	Date
01773/86-8	Switzerland	30th April, 1986

LODGED AT SUB-OFFICE
30 APR 1987
Melbourne

The address for service is care of DAVIES & COLLISON, Patent Attorneys, of 1 Little Collins Street, Melbourne, in the State of Victoria, Commonwealth of Australia.

Dated this 30th day of APRIL, 1987

To: THE COMMISSIONER OF PATENTS

K. H. Rimington
(a member of the firm of DAVIES & COLLISON for and on behalf of the Applicant).

Davies & Collison, Melbourne and Canberra.

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952

DECLARATION IN SUPPORT OF CONVENTION OR NON—CONVENTION APPLICATION FOR A PATENT

Insert title of invention.

In support of the Application made for a patent for an invention entitled: "METHOD AND DEVICE FOR BUILDING UP A CONNECTION IN SHORTWAVE RADIO NETWORKS"

Insert full name(s) and address(es) of declarant(s) being the applicant(s) or person(s) authorized to sign on behalf of an applicant company.

~~I~~ ~~We~~ We Walter Schellenberg, Furenstrasse 16, CH-8707 Uetikon a. See, Switzerland

and Bruno Stillhart, Haldenweg 2, CH-8634 Hombrechtikon, Switzerland

Cross out whichever of paragraphs 1(a) or 1(b) does not apply

1(a) relates to application made by individual(s)

1(b) relates to application made by company; insert name of applicant company.

do solemnly and sincerely declare as follows :—

~~1. (a) I am / We are the applicant.......... for the patent~~

or (b) I am authorized by

ZELLWEGER TELECOMMUNICATIONS LTD of Eichtalstrasse, CH-8051 Hombrechtikon, Switzerland

the applicant............. for the patent to make this declaration on its ~~their~~ behalf.

Cross out whichever of paragraphs 2(a) or 2(b) does not apply

2(a) relates to application made by inventor(s)

2(b) relates to application made by company(s) or person(s) who are not inventor(s); insert full name(s) and address(es) of inventors.

~~2. (a) I am / We are the actual inventor............ of the invention~~

or (b) Roland KUENG, of Blattenstrasse 100, CH-8634 Hombrechtikon, Switzerland; and Hanspeter WIDMER, of Ueberlandstrasse 287, CH-8051 Zurich, Switzerland.

~~is~~ are the actual inventor.s........ of the invention and the facts upon which the applicant........... is ~~are~~ entitled to make the application are as follows :—

State manner in which applicant(s) derive title from inventor(s)

The applicant would, if a patent were granted upon an application made by the said actual inventors, be entitled to have the patent assigned to it.
Zellweger Uster AG Assigned to the applicant, the right to claim priority from the undermentioned basic application.

Cross out paragraphs 3 and 4 for non-convention applications. For convention applications, insert basic country(s) followed by date(s) and basic applicant(s).

3. The basic application........... as defined by Section 141 of the Act was ~~were~~ made

in Switzerland on the 30th April, 1986

by Zellweger Uster AG

in .... on the ....

by ....

in .... on the ....

by ....

4. The basic application.......... referred to in paragraph 3 of this Declaration was ~~were~~ the first application.......... made in a Convention country in respect of the invention the subject of the application.

Insert place and date of signature.

Declared at Uster this third day of November 1987

Signature of declarant(s) (no attestation required)

Note: Initial all alterations.

[signature] Walter Schellenberg

[signature] Bruno Stillhart

DAVIES & COLLISON, MELBOURNE and CANBERRA.

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ESTABLISHING CONNECTION IN SHORT WAVE NETWORKS

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DE 2042133

(57) Claim

1. Method of establishing a connection in a short wave radio network having several stations with at least one of a transmitter and a receiver, including the step of sending out a call signal via a transmission channel, said call signal including a synchronization signal and an address signal, characterised in that the synchronization signal includes narrow band mark and space signals forming component signals of a diversity pair, the mark and space signals being keyed on/off separated in time by a keying signal having a frequency which is a power of two supporting fast Fourier transform algorithms in the receiver.

COMMONWEALTH OF AUSTRALIA

PATENT ACT 1952

COMPLETE SPECIFICATION

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(Original)

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This document contains the amendments made under Section 49 and is correct for printing.

Name of Applicant: ZELLWEGER TELECOMMUNICATIONS LTD

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1 Little Collins Street, Melbourne, 3000.

Complete Specification for the invention entitled:

"METHOD AND DEVICE FOR BUILDING UP A CONNECTION IN SHORTWAVE RADIO NETWORKS"

The following statement is a full description of this invention, including the best method of performing it known to us :-

METHOD AND DEVICE FOR BUILDING UP A CONNECTION IN SHORTWAVE RADIO NETWORKS

The invention relates to a method of building up a connection in shortwave radio networks having several stations with one transmitter and/or one receiver, by means of a call signal sent out from a transmitter and consisting of a synchronization- and an address - signal.

Shortwave connections primarily use the spread of skywaves which are reflected at the ionosphere in order to realise the transmission of news over great distances. In spite of the insufficiencies of the transmission channel for a skywave connection - such as noise-like channel interferences, time-variant, dispersive channel behaviour and the presence of selective sources on interference - this means of transmission has recently enjoyed a considerable increase in importance, thanks to new microprocessor techniques and, by comparison with satellites, low cost.

Special problems occur during building up of the connection, because there is always a greater or smaller frequency difference (off-set) between transmitter and receiver frequencies and because no time synchronization is given before the connection between transmitter and receiver is taken up.

Transmissions usual today result in the economic use of the frequency supply by means of single side band technology, in which at the transmitter end a frequency translation of the signal is undertaken out of the acoustic frequency band (300 Hz to 3.4 KHz) into a chosen high frequency band and the reverse operation is carried out by the high frequency receiver. The received signal is passed on in the low frequency region to demodulator and decoder circuits. The high frequency receivers dispose of automatic gain stabilizers, in which the total power or voltage within the chosen receiving channel band width constitutes the output quantity. In the process, depending on the spectural covering of desired and interfering signals, noise and desired levels varying between broad limits appear at the output. Especially selective sources of interference, with more signal energy than the desired signal, are commonly met with and the channel then normally counts as engaged.

In a selective call network various stations are to be activated either individually or with a collective word. The selective call transmitters and receivers of the individual stations are accommodated in their modulator or demodulator block. The call signals are composed of a group of suitable amplitude-time-functions, which can be recognised in the channel noise and distinguished from one another by the individual receivers. Even in transmissions of low quality, on the one hand, wrong stations should never be activated and, on the other hand, the wanted stations should always be activated.

Pilot sound transmissions usual today are not capable of fulfilling these requirements because the probability of faulty synchronization increases with the presence of certain interferences.

It is known how to use a relatively costly appliance system in addition to the transmitter-receiver parts of the stations, with which it may be determined which channel is free and undisturbed by neighbouring transmitters, and what are the momentary spreading conditions over the ionosphere (Frequency Management system, Defence Electronics, May 1980, p21, 22). Yet the fully automatic building up of a shortwave connection is not possible with this system. In the case of deliberate interferers (ECM), a prior analysis is only of little use as in every case the channel in use is immediately jammed.

The object of the invention is to provide a method of the kind mentioned at the beginning, by which the building up of shortwave connections between the stations of a radio network may be carried out fully automatically, and where even in transmissions of poor quality only the wanted stations will ever be activated.

This object is realised according to the invention by using a prominent synchronization signal adapted to the transmission channel, this synchronization signal consisting of narrow band mark and space signals which form the part-signals of a diversity pair.

More specifically the invention provides a method of establishing a connection in a short wave radio network having several stations with at least one of a transmitter and a receiver, including the step of sending out a call signal via a transmission channel, said call signal including a synchronization signal and an address signal, characterised in that the synchronization signal includes narrow band mark and space signals forming component signals of a diversity pair, the mark and space signals being keyed on/off separated in time by a keying signal having a frequency which is a power of two supporting fast Fourier transform algorithms in the receiver.

The use of the synchronization signal according to the invention has the advantage that it enables a bit synchronization between the stations simultaneously with the determination of the frequency offset, in that the phase of the modulation signal modulating the carrier signal is determined at the place of reception. The modulation signal is recovered in a mathmatically exact manner, as the expected signal is known. By this means an increase in the probability of faulty synchronization caused by the presence of certain interferences is largely avoidable. The build up of the synchronization signal out of narrow band mark and space signals which form the part-signals of a diversity pair opens up the possibility of a separate detection of these part-signals, which increases the dependability of the construction of the connection quite considerably. For the probability that an interfering source is present and striking the marker signal simultaneously in both diversity channels is equal to zero. A centre frequency error of few hertz between the source of interference and the marker signal is uncritical, as 500 sub-channels each of 1 Hz are investigated in the region between 250 and 750 Hz by means of a special operation of signal processing.

The invention relates further to apparatus for carrying out the procedure mentioned, with a synchronization signal receiver.

The apparatus according to the invention is characterized in that the synchronization signal receiver comprises digital signal processing means for independently detecting and evaluating each component signal of said diversity pair.

In the following, the invention is more closely explained by means of an embodiment represented in the diagrams;

Fig. 1 shows a modular mimic display of a customary shortwave connection with transmitter and receiver,

Fig. 2 shows a schematic representation of a call signal,
Fig. 3 shows a schematic representation of a synchronization signal according to the invention,
Fig. 4 shows a diagram for the explanation of function,
Fig. 5 shows a block schemar of the input part of a synchronization signal receiver according to the invention,
Fig. 6 shows a diagram to represent the frequency composition of the individual filters of the input part of Fig. 5,
Fig. 7a, 7b shows a block diagram of the numerical signal processing of a synchronization signal receiver according to the invention, and
Fig. 8 shows a diagram for the explanation of function.

According to Fig. 1, a customary shortwave connection used today consists of a transmitter 1 and a receiver 2 between which the signals are transmitted through a transmission medium 3. The transmitter - side data input goes into a modulator/coder circuit 4, to which a time base 5 is assigned. The output signal of the modulator/coder circuit 4 is a low frequency signal in the accoustic frequency band between 300 Hz and 3.4KHz. With this low frequency signal, a frequency translation into a chosen high frequency band is carried out by means of transmitter 1, which is a high frequency (SSB) transmitter. A frequency base 6 is assigned to transmitter 1 in the region of the high frequency band. The high frequency output signal of transmitter 1 sent out into the time-variant transmission medium 3 lies for example in the region between 3 and 30 MHz. In the transmission medium 3 an additive interference noise (ST) is added to this high frequency signal.

In the high frequency (SSB) receiver 2, to which a high frequency base 6' is assigned, the high frequency signal is transformed into a low frequency signal in the transmission-side acoustic frequency band and supplied to a demodulator/decoder circuit 7, to which a time base 5' is assigned. The data output occurs at the output of the demodulator/decoder circuit 7.

If a shortwave radio network forms a so-called selective call network, then there is a number of different stations present which can be activated individually or with a collective call. To that end, each of the stations involved disposes of a selective call transmitter and receiver, which are both housed in the modulator and demodulator block 4 or 7 in the arrangement of Fig. 1 (see for example DE-PS 32 11 325). The signals for calling, the so-called call signals, are composed of a group of suitable amplitude time functions, which can be discerned from in the channel noise and distinguished from one another by the individual receivers.

In Fig. 2 a call signal used according to the method of the invention is schematically presented. This consists according to the representation of a synchronization signal (SS) and of an address signal (AS). At any one time the receiver observes time intervals of length T and decides whether a synchronization signal (SS) is present or not within the respective interval. The observation intervals are weighted by a window function (Fig. 4). A duration τ of 2s is preferably reserved for the synchronization signal (SS). So that in the original, desynchronous state at least one observation interval overlaps completely with the transmitter signal, T must be at most 4/3 seconds. There, the length T of the observation interval is only purposefully chosen if it is shorter than the coherence time T_C of the signal received. With the window time chosen, T_C should be $> \frac{T}{2}$. Further criteria such as the broadening of the spectral components of the synchronization signal SS by phase variations on the transmission channel and the frequency drift between transmitter and receiver stations, which both diminish the observation time, have led to a length of the observation interval of T = 1 second.

In the case of the method according to the invention, the receiver does not know the exact carrier frequency of the transmitter, yet there is a domain of expectation in which, with very high probability, a call signal will appear. This domain of expectation can, depending on the technology of transmitter and receiver, cover upto 500 Hz and in the example of embodiment described is of $\pm$ 234 Hz. Within this region call signal is to be perfectly detectable and, depending on these signal/noise ratio, its frequency off set should be determined to at least $\pm$ 1 Hz A definite detection should be possible for a signal/noise ratio of up to at least -24 dB referring to 2 KHz band width.

Because of the large domain of expectation, no very narrow filters for the filtering of the wanted signal from the noise can be used. In particular, strong, selective interfering sources prevent a determination of the exact frequency offset by means of conventional analogue technology. For that reason a prominent signal is chosen for the synchronization signal SS, which is adapted to the transmission channel and easily detected in surroundings with a lot of interference.

In Fig. 3 the synchronization signal used in the method according to the invention is represented, where the amplitude v is entered on the ordinate of the diagram and the time t is entered on the abscissa. This synchronization signal sent out during the time period T_O is a low frequency carrier signal, which is frequency modulated with a square wave function and also known as an FSK signal. According to the presentation it consists of "mark" and "space" signals.

The synchronization signal SS makes possible a bit synchronization between the stations simultaneously with the determination of the frequency offset, in that the phase of the modulation signal is determined at the place of reception. At the transmitter-side the modulation frequency is previously given with quartz accuracy and is known to the receiver. The phase should be determinable to at least 0.5 rad.

The mark and space signals, each in itself an AM signal, are narrow band, in order to effect an identically shaped variation of the most intensive spectral parts with selective fading. The frequency difference between them is chosen to be as large as possible in order to obtain two signals decorrelated with respect to selective fading, yet which both lie within the same channel. The keying frequency is distinctly greater than the fading frequency and running time differences should be of little consequence.

Because of these conditions and considerations a modulation frequency of 16 Hz, a base band carrier of around 2 KHz for the mark signal, and for the space signal a base band carrier of around 500 Hz are chosen. Yet both carriers are variable, in order to make possible adaptive translations of the AM signals.

Mark and space signals are viewed by the receiver as an AM diversity pair and detected separately. This has the additional advantage that the dependability of the detection increases strongly with unequal interference signal distribution over the channel. The total signal has constant power (no FSK, AM part), makes possible a non-linear amplifier action and an optimal exploitation of the transmitter step and is in addition distinctly distinguishable from selective interference signals.

If the high frequency receiver is on automatic scan-operation, for example CELLSCAN (registered trade mark of the firm Rockwell-Collins), it periodically investigates a determined number of programmed channels upon a synchronization signal where applicable. This is sent out by the transmitter for as long as a scan cycle lasts. After successful detection of a synchronization signal the receiver stops the scan operation and waits for the address signal AS (Fig. 2).

As already mentioned, the receiver observes time intervals of length T and decides whether a synchronization signal is present within the relevent interval. Here, the observation intervals are weighted by a window function. In Fig. 4 a synchronization signal SS of length T_0 is represented in line a, in lines b and c (not in proportion) the windows of the observation intervals, the even-numbered windows F_{n-2}, F_n, F_{n+2} etc in line b and the uneven windows F_{n-1}, F_{n+1}, etc in line c.

As maybe seen from a comparison of lines b and c of Fig. 4, the individual intervals overlap for half the time, in order to make possible as unbroken an observation as possible over the time access t The length T of an observation interval is 1 second and is determined by the length T_0 of the synchronization signal SS and by the coherence time T_C of the channel.

Detection values of two overlapping observation intervals are practically statistically independent on account of the window function, so that during a period T of emission of the synchronization signal SS roughly $2T_0/T$ detection values will be taken. In addition the suitable choice of the window function makes possible a high dynamic ratio in the spectral region after the fast fourier transformation FFT is carried out (Fig. 7A).

Of course an increase in the probability of detection would result from an increase in the length of emission of the synchronization signal SS.

Yet a considerably greater additional advantage results from middling the detection values over several observation intervals. Thereby the receiver continually accumulates detection values in a "lossy integrator" or in a digital low-pass filter. In this integrator the required components crystalise out of the stocastic components piece by piece as in a puzzle, so that up to a certain usable integration period an increasingly sharpening picture of the synchronization signal emerges, from which the carrier frequency as well as the phase angle may be determined.

The minimal signal/noise ratio for a successful detection and synchronization can thereby be lowered, within certain limits depending on the length of emission of the synchronization signal, down to about - 24 dB at 2 KHz noise band width.

After emission of the synchronization signal SS and its detection all the selective call receivers on the same call channel are synchronized. Immediately after the synchronization signal SS there now follows an address signal AS, which makes that actual selective appeal. After successful detection of the address signal the word synchronization, that is the complete time synchronization between transmitter and receiver, is then also produced.

The receiver carries out two independent detections and evaluations of both of the part-signal of the diversity pair and subsequently compares the results. After preliminary analogue processing (filtering and mixing), the two additively disturbed receiving signals are transformed by an analogue - digital convertor into a sequence of N numerical values each during each period of observation T. In this connection, may it be pointed out that by receiver a demodulator/decoder in a low NF frequency region (of demodulator/decoder 7 in Fig. 1) is meant here.

In Fig. 5, the input part E of the synchronization signal receiver carrying out the analogue processing is represented. The signal received r(t) is first led through a total channel filter 8 with a pass band region of 300 Hz to 3.4 KHz, at whose output two paths 9_A and 9_B for both of the part-signals of the diversity pair are connected. By means of a first ~~mixer~~ collator 10_A or 10_B, the signals in each path are mixed up into the same reception band A or B by a variable oscillator (cf Fig. 6) and subsequently filtered by an intermediate frequency filter 11_A, 11_B whose transmission curve lies at around 4.5 KHz. In this way spectral overlaps during this pre-selection of the signals and hence in the best possible manner an overloading of the receiver as well as the "aliaising" affect (scanning frequency lower than twice the highest signal frequency) to be cut out in digital signal processing are avoided.

An AGC amplifier 12 is connected to each ZF filter 11_A, 11_B. In order to keep the scanning rate as low as possible, in each part 9_A, 9_B both of the frequency regions mark and space of 500 Hz band width are mixed down by a second ~~mixer~~ collator 13 into the base band of 250 Hz to 750 Hz that is used as a fixed processing band. Afterwards, there follows a filtering by an image frequency filter 14_A, 14_B for the purpose of damping. The output signal $r_A(t)$ and $r_B(t)$ of the image frequency filter 14_A or 14_B respectively arrives at a sampler 15 with a topped analogue-digital converter 16, at whose output a single vector $\vec{r}_A$ or $\vec{r}_B$ lies.

The signal vectors $\vec{r}_A$ and $\vec{r}_B$ each have N values, which first of all arrive in a buffer store, from where they can be called out by a signal processor. The buffer store 17 consists of 2 part-stores of size N/2 one part is at the disposal of the analogue-digital convertor 16 and two parts are at the disposal of the processor for processing.

The frequency composition through the different filters of the input part E (Fig. 5) is represented in Fig 6, where the frequency f is given in KHz on the abscissa. The characteristic curve H_8 (f) entered in a broken line corresponds to the transmission characteristic of the total channel filter 8, the dotted broken characteristic curve H_{14}(f) to those of the image frequency filter 14_A, 14_B, and the arrow P represents the scanning signal. The scanning signal is represented as being of 2,048 KHz. The characteristic curve H_C (f) represents the fixed processing band (base band of 250 to 750 Hz), the characteristic line H_A(f) the variable receiving band for the one part-signal (path 9_A, Fig. 5) and the characteristic curve H_B (f) the variable receiving band for the other part-signal (path 9_B, Fig. 5) of the diversity pair. H_{11} (f) finally is the transmission curve of the intermediate frequency filter 11_A, 11_B (Fig. 5)

Subsequent to the analogues described by means of Fig. 5 there follows the numerical signal processing of the synchronization signal receiver, which is represented in a block diagram in Fig. 7. This block diagram shows the individual functional steps of the signal processing as it is carried out by the corresponding part of the synchronization receiver formed by means of a signal processor. In connection with Fig. 7 only one half of the diversity receiver (signal vector $\vec{r}_A$ is now observed, since this is built up completely symmetrically. The same signal processing occurs with the second signal vector ($\vec{r}_B$) as with the first ($\vec{r}_A$), only with different number values. Fig. 7 is split into two figures, 7a and 7b, for reasons of accessability to view. Fig. 7a shows the signal processing up to the so-called hypothesis decision and Fig. 7b shows the remaining functional steps. The result of the signal processor according to the numerical signal processing contains the chosen hypothesis, whether a synchronization signal is present (H_1) or not (H_0). In the case of it being present (H_1) an estimate of the frequency offset and the phase of both signals $\vec{r}_A$ and $\vec{r}_B$ as for the values of their signal/noise ratio are given. By means of the numerical signal processing, which is carried out in real time, it is essentially tested whether the receiving vector $\vec{r}$ of the N-dimensional vector space $\mathbb{R}$ lies in the decision region of hypothesis H_1 or H_0. The decision region has the shape of an N-dimensional cone whose tip is in the origin of $\mathbb{R}$. The amount $\vec{r}$ (or the total power of the receiving signal) do not influence this decision. For the hypothesis value is based alone on the direction of $\vec{r}$. The decision region is thus an N-dimensional solid angle region. The investigation of $\vec{r}$ in relation to its decision region occurs by means of the calculating algorithms described in the following in connection with Fig. 7, which represent linear and non-linear coordinate transformations.

The first calculating operation, to which the N values of the signal vector $\vec{r}_A$ (and also $\vec{r}_B$, which however, is not represented, as already mentioned), is the weighting by a window function F, following which is a fourier transformation. This last depicts the vector $\vec{r}$ of $\mathbb{R}$ in $\vec{r}'$ of $\mathbb{R}'$. The fourier transformation used is a so-called fast fourier transformation FFT, the arithmetically faster version of the discrete transformation. As the synchronization signal is periodic in nature, at the transition into the frequency region $\vec{r}'$ undergoes a separation into actual signal and noise components. This separation in the manner of a filtering is so much the better for a higher spectral resolution of the fourier transformation The resolution for its part is determined by the observation period T or the "size" of the FFT.

With T = 1 S and a scanning frequency f_r of 2,048 KHz or N = 2,048 a spectral resolution of 1 Hz results in principle though upon insertion of a window function F a broadening of the main peak to 2 Hz and a correlation of neighbouring support values in the noise spectrum occurs. The fine resolution, however, results in sufficient uncorrelated calculation values between the carrier and the 16 Hz side lines of the AM-modulated signal in order to be able simply to assess the noise. The separation of signal and noise now allows the search for a synchronization signal present where applicable, whose localisation in the frequency region between 250 and 750 Hz and the determination of the modulation phase angle.

The part of the signal processing following the Fourier transformation FFT serves for the demodulation (identification) of the diversity pair, the noise estimation, a signal integration (accumulation) for wanted signals that are hard to detect and for the hypothesis decision. All these parts of the signal processing are of course solved as numerical operations in the signal processor.

In the spectrum previously calculated a special demodulation adapted to the marker signal is now undertaken, in which as many characteristic distinguishing marks as possible are determined. In the embodiment represented a kind of synchronious AM-demodulation is carried out for a modulation frequency λ = 16 Hz and for every possible place of stay m of the signal that is, when M = Number of Values m, for roughly M = 500 Values. The demodulation occurs in the frequency region. The method used is characterised as a Frequency-Auto-Correlation function:

$$\lambda = 16 \text{ Hz} \quad \Gamma(\lambda) = \int_{-\infty}^{\infty} S(f)\, S^{*}(f-\lambda)\, df + \int_{-\infty}^{\infty} S^{*}(f)\, S(f+\lambda)\, df$$

Here, $S(F+\lambda)$ is the upper sideband, $S(f-\lambda)$ is the lower sideband and $S(f)$ is the carrier, S^{*} is in each case the complex conjugate value.

The numerical version of the Frequency-Auto-Correlation function is as follows:

$$\Gamma_M(\tilde{\lambda}) = \frac{1}{T} \sum_{m-fg.T}^{m+fg.T} S(m)\, S^{*}(m-\tilde{\lambda}) + \frac{1}{T} \sum_{m-fg.T}^{m+fg.T} S^{*}(m)\, S(m+\tilde{\lambda})$$

Here, $\tilde{\lambda} = \lambda T = 16$ and f_g is the spectral band width of the window function.

Here, interference signals, even AM signals with a different modulation than 16 Hz produce among other things only small signal energies, as the vectors for $S(f+\lambda)$, $S(f-\lambda)$ and $S(f)$ do not support themselves. In figure 7a two demodulators 18 and 19 are drawn in; in the first demodulator 18 the vector $\vec{\underline{Z}}_{\tilde{\lambda}}$ of the numerical version of the Frequency-Auto-Correlation function $\Gamma_M(\tilde{\lambda})$ is determined and in the second demodulator 19 the corresponding error vector $\Delta\vec{\underline{Z}}_{\tilde{\lambda}}$ is determined. There, the following characteristics of the demodulation will be taken into consideration:

- The sideband lines must be at the right frequency location
- In respect of the carrier, the sideband line - signal energy must fall within a certain region of use for AM
- The vector $\vec{\underline{Z}}_{\tilde{\lambda}}$ of the numerical version of the Frequency-Auto-Correlation function and the corresponding error vector $\Delta\vec{\underline{Z}}_{\tilde{\lambda}}$ must lie within certain limits; $\vec{\underline{Z}} \to \infty$, $\Delta \vec{\underline{Z}} = 0$. would be ideal.

This numerical synchronisation signal demodulation is represented in Fig. 8. It will be seen that one starts out from the carrier $\underline{r}'_m$ (Components of the Vector $\vec{\underline{r}}'$ for S(f), and from the upper and lower sidebands $\underline{r}'_{m+\lambda}$ and $\underline{r}'_{m-\lambda}$ (Components of the Vector $\vec{\underline{r}}'$ for $S(f+\lambda)$ and $S(f-\lambda)$).

The values $\underline{r}'_{m-\lambda}$, $\underline{r}'_{m+\lambda}$ and $\underline{r}'_m$ are in a frequency support value store 24. The complex conjugate value of $\underline{r}'_{m-\lambda}$ and or $\underline{r}'_m$ is in each case multiplied by $\underline{r}'_m$ or by $\underline{r}'_{m+\lambda}$ and the results of the multiplication are added and subtracted, by which means the Vector $\vec{\underline{Z}}'_\lambda$ (numerical version of the Frequency-Auto-Correlation function) and for the error Vector $\Delta\vec{\underline{Z}}'_\lambda$ are formed. These values are deposited in the corresponding stores 25 and 26 for the numerical version of the Frequency-Auto-Correlation function or for the error Vector.

This operation is relatively simple for an AM-Signal. Yet in principal a different ideal demodulator exists for every type of modulation and for every marker signal. With the choice of $f_g.T=0.5$, the optimal and also simple demodulation algorithm was found. For the carrier m of the AM-Signal in the chosen embodiment: $266 \leq m \leq 734$. The results of the demodulation for each frequency in the region of expectation of the signal are first stored away.

The noise estimater is indicated in Fig. 7a by the reference numeral 20. The decision about the hypothesis, whether a synchronisation signal is present or not, must, as neither signal energy nor noise power are known to the receiver in advance, be judged on the grounds of the Signal/Noise ratio. The decision threshold derives from the probability of a false alarm.

The determination of the noise (corresponds to the estimated value of the variance $\vec{\underline{Z}}_\lambda$) occurs by means of the spectural support values lying in the close neighbourhood of $\underline{r}'_m$, $\underline{r}'_{m-\lambda}$

and $\underline{r}'_{-m+\hat{\lambda}}$ (Fig. 8) and in this manner delivers a local power density in the neighbourhood of the synchronization signal. The support values chosen are demodulated in exactly the same way as the sidebands are demodulated in the demodulation described by means of Fig. 8. Only $\hat{\lambda}$ is no longer equal to 16.

The noise estimation should be a combined variable $\vec{\chi}$ comprising noise energy and noise estimation, in order to grasp the influence of "white" noise as well as interference signals. The detected $\vec{\underline{z}}'_{\hat{\lambda}}$ are normed to the local noise variable ($\vec{\chi}$) for every possible frequency and these normed values ($\vec{\underline{l}}$, $\Delta\vec{\underline{l}}$) are lead into a decider 21 where for the components of $\vec{\underline{l}}$ and $\Delta\vec{\underline{l}}$:

$$\underline{l}_m = \frac{z_{\lambda m}}{\chi m} \quad \Delta\, \underline{l}_m = \frac{\Delta z_{\lambda m}}{\chi m} \quad 266 \leq m \leq 734$$

In cases of very low signal/noise ratios an accumulation in the form of digital filters is provided which uses the values $\vec{\underline{l}}$ and $\Delta\vec{\underline{l}}$ over several observation periods, which leads to an improvement in the signal/noise ratio. An example of such a filtering is indicated in Fig. A with the reference mark 22. The improvement can, without difficulty be of 14 dB, with an accumulation of 20 observation intervals.

Only the background noise is decisive for signal detection to which the detection threshold relates. Individual narrow lines with large power densities in comparison to this background noise must be separated out of the noise statistic. A shield against dangerous false signals is achieved with the help of the noise estimation. In the process, false signals are signals similar to the synchronization signal with eg. almost the same modulation frequency or shorter duration of presence.

In order to avoid the wrong evaluation of such false signals as synchronisation signals, a second noise statistic is formed out of values directly neighbouring the carrier for the demodulation and the sidebands $\underline{r}'_m$ or $\underline{r}'_{m+16}$, $\underline{r}'_{m-16}$ (Modulation frequency equals 16 Hz and the two noise. statistics are divided, where the quotent determines which noise statistic is to be used. But in general the combined variable $\vec{\Sigma}$ already mentioned is produced.

The presently normed test magnitudes $\underline{l}_m$, $\Delta\underline{l}_m$, $\underline{l}'_m$ and $\Delta\underline{l}'_m$, which results from N scanning values of a time function of duration T or several T are tested in the decider 21 (Decision Gate). For every observation interval T overlapping the previous and the following interval, the magnitudes $\underline{l}_m$ and $\Delta\underline{l}_m$ are brought into play initially for each frequency m ($266 \leq m \leq 734$). The interval overlap is consciously used in the fast Fourier transformation FFT in order to win back energy losses resulting from the window function F.

The first test runs:

$$\left| \underline{l}_m \right| \underset{H_o}{\overset{H_1}{\gtrless}} a \qquad 266 \leq m \leq 734$$

If the outward is possitive ie. H_1 (= Synchronisation Signal Present), then:

$$\left| \Delta\underline{l}_m \right| \underset{H_1}{\overset{H_o}{\gtrless}} b'+b'' \left| \underline{l}_m \right|$$

is tested. In this condition, with which the spectral symmetry is tested, the threshold must be dependent on the magnitude $\left|\underline{l}_m\right|$. The magnitude a of the first test is for its part a certain function of the noise statistic. For each determinate number of noise support values used, an optimal threshold maybe given in each case, which is stored in an RAM-table. If $\underline{l}_m$ or $\Delta\underline{l}_m$ does not fullfil the test, these Vector components are set at 0. The values $\underline{l}'_m$ and $\Delta\underline{l}'_m$ are decided according to the same method.

In order to determine the signal/noise combination magnitude SNR_A (or SNR_B of the other part of the diversity pair) (Fig 7b.) the maximum of $|\underline{l}_m|$ and $|\underline{l}'_m|$ must be searched. This maximum is then equal to the signal noise ratio for this channel in the neighbourhood of the Synchronisation Signal.

A so called diversity combining (Fig. 7b.) is necessary for the determination of the frequency and phase of the chosen synchronisation signal with the utilisation of some kind of diversity. Here, it is important that known, rigid relations obtain between the individual signals during the synchronisation signal preparation. Thanks to the detector symmetry, with the chosen diversity pair of 2 AM signals it is simply necessary to take consideration of the phase shift of the modulation signals of 16 Hz through an angle π , ie. one forms:

$$\vec{\underline{l}}_{A}|_{H_1} - \vec{\underline{l}}_{B}|_{H_1} = \vec{\underline{l}}_{A-B}|_{H_1}$$

and

$$\vec{\underline{l}}'_{A}|_{H_1} - \vec{\underline{l}}'_{B}|_{H_1} = \vec{\underline{l}}'_{A-B}|_{H_1}$$

So a diversity combining 23 only then takes place if hypothesis H_1 was decided for in both of channels A and B In the case of the combination, there results thus a gain of 3 dB for the phase and frequency estimation. Yet on shortwave channels the use of frequency diversity is already encumbered with a great gain, as one channel section is often strongly interfered with or suffers from fading.

The frequency and the phase estimation are realised by means of the sum

$$\vec{\underline{1}}_{A-B}\Big|_{H_1} + \vec{\underline{1}}'_{A-B}\Big|_{H_1} = \overrightarrow{\sum \underline{1}}$$

If H_1 is fulfilled at several places on the frequency access, then the frequency with the largest $\left|\sum \underline{1}_m\right|$ is chosen. $\hat{m}$ then signifies the estimated frequency position and the phase $\hat{\varphi}$ is determined out of the Vector components $\sum \underline{1}_{\hat{m}}$ in a table with aretg-values.

The synchronisation signal receiver working according to the method described has the advantage that thanks to complete software-real time-realisation of the receiver many parameters can be optimised and varied; so for example the detection sensitivity can be optimised for a previously given estimation dependibility. The main advantages of the receiver consist in the great flexibility in specification, in the ageing-free realisation and in achievement of a detection certainty that lies close to the maximal theoretically achievable. This is made possible by means of the operation execution represented in Fig. 7 and the digital signal processing which alone makes possible the required precision.

The signal can be extended to several transmitter channels for scan-operations without additional expenditure and micro-scan operation (division of a channel of 3 Khz width into 500 Hz channel sections) is also possible. In addition frequency and phase drifting can be continuously corrected after detection of the degrees of freedom and in place of the synchronisation signal a slow data connection can appear where the now known degrees of freedom are replaced by new ones. With the hardward described such a selective call system may be constructed and from that again a data modem for low building data may be derived, in that in place of the selective call address data appears.

In addition, thanks to the great expectation region of the synchronization signal, the system described is in a position to undertake a frequency displacement beside interference signals because of its own channel measurements (equal passive channel analysis) adaptively at the beginning, without the receiver having to display a scan-operation on that account. The construction of a connection is almost always guaranteed without change of channel, ie. without synthesiser intervention. Yet another kind of radio operation exploits the great S/J superiority of the invention, namely in that connections with smaller transmitter powers are "bad" antennae can be safely constructed in the same manner. For example, the hiding of ones own signal behind strong (for example, enemy) transmitters is possible as an ECCM Operation. This makes impossible a quick location of position or interference during the construction of the network or during network control/network operation.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. Method of establishing a connection in a short wave radio network having several stations with at least one of a transmitter and a receiver, including the step of sending out a call signal via a transmission channel, said call signal including a synchronization signal and an address signal, characterised in that the synchronization signal includes narrow band mark and space signals forming component signals of a diversity pair, the mark and space signals being keyed on/off separated in time by a keying signal having a frequency which is a power of two supporting fast Fourier transform algorithms in the receiver.

2. Method according to claim 1, characterised in that base band carriers for the mark and space signals are chosen independently within a frequency range of about 300 Hz to about 3400 Hz without notifying the receiver of the exact location of the said mark and space signals.

3. Method according to claim 2, characterised in that the base band carrier for the mark signal has a frequency of about 2 kHz and for the space signal of about 500 Hz in order to obtain two decorrelated signals about selective fading, said mark and space signals lying within the same base band channel, and wherein said keying signal is an extreme narrowband signal of 16 Hz.

4. Method according to claim 3, characterised in that said mark and space signals form a true diversity pair by said frequency values, said diversity pair having a constant amplitude waveform.

5. Method according to claim 1, characterised in investigating, via said receiver, overlapping time intervals of said synchronization signal, said time intervals being weighted by a window function; transforming said component

signals into a sequence with a number of numerical values; and, numerically processing, via analogue preprocessing, said component signals during each of said time intervals.

6. Method according to claim 5, characterised in that the analogue preprocessing forms a vector with a number of values corresponding to the said number of numerical values.

7. Method according to claim 6, characterised in testing whether said vector lies in a decision region of a hypothesis synchronization signal present, or a synchronization signal not present.

8. Method according to claim 7, characterised in that the first operation of the numerical signal processing is formed through a fast Fourier transformation, in which a separation into actual signal - and noise - components occurs.

9. Method according to claim 8, characterised in that subsequent to the fast Fourier transformation a demodulation of the diversity pair, a noise estimation and if necessary a signal integration for wanted signals difficult to detect occurs, and that the results of these operations form the basis of the hypothesis decision.

10. Method according to claim 9, characterised in that the wanted signal is scaled in respect of the noise, so that only a magnitude depending on the signal/noise ratio reaches the hypothesis decision and interference carriers and false signals are eliminated by the numerical exact demodulation.

11. Method according to claim 10, characterised in that the numerical signal processing for both of the part-signals of the diversity pair occurs separately, and that after the hypothesis decision a diversity combination takes place, as a result of which frequency and phase of the synchronizations signal are determined.

12. Apparatus for carrying out the method according to claim 1, with a synchronization signal receiver, characterised in that the synchronization signal receiver comprises digital signal processing means for independently detecting and evaluating each component signal of said diversity pair.

13. Apparatus according to claim 12, characterised in that the synchronization signal receiver has an input part, in which the signal received is parted into the two part-signals of the diversity pair and subsequently processed in analogue manner.

14. Apparatus according to claim 13, characterised in that the input part has a total channel filter to which two paths for the two part-signals connect.

15. Apparatus according to claim 14, characterised in that each of the paths have a first and a second collator, an intermediate frequency filter between the collators and an analogue-digital converter.

16. Apparatus according to claim 15, characterised in that each analogue-digital converter has an output signal generating N values of a vector r_A, r_B formed for said numerical processing, and that a buffer store is coupled to each analogue-digital converter, said buffer store being provided for said N values.

17. Apparatus according to claim 16, characterised in a signal processor coupled to said buffer store, said signal processor carrying out a fast Fourier transformation, demodulation of said diversity pair, noise estimation, and a decision for an hypothesis that a synchronization signal is present or is not present.

18. Apparatus according to claim 17, characterised in that after the hypothesis decision, the signal processor, in the case of positive results, delivers output signals for the signal/noise combination magnitude of both part-signals of the diversity pair.

19. Apparatus according to claim 18, characterised in that the signal processor is designed for an operation diversity-combination to be undertaken in connection with the operation hypothesis decision, during which frequency and phase of the synchronization signal are determined.

20. A method for building up a connection in a shortwave ratio network substantially as hereinbefore described with reference to the drawings.

21. An apparatus for building up a connection in a shortwave radio network substantially as hereinbefore described with reference to the drawings.

DATED this 15th day of February, 1990
ZELLWEGER TELECOMMUNICATIONS LTD.
By its Patent Attorneys
DAVIES & COLLISON

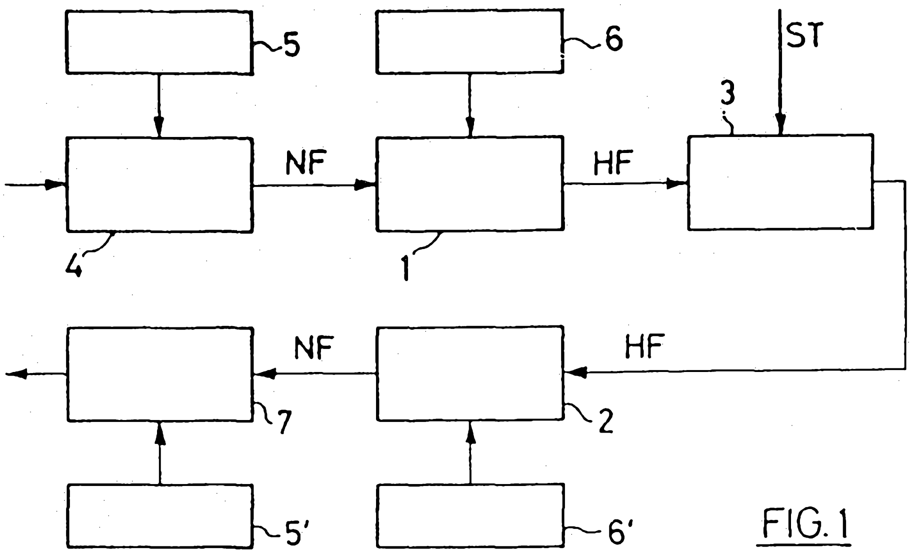


FIG. 1

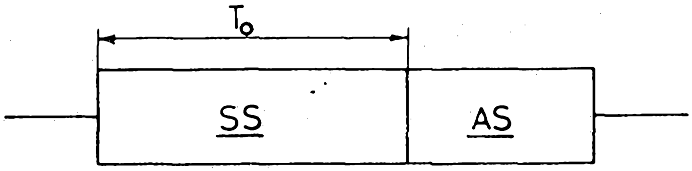


FIG. 2

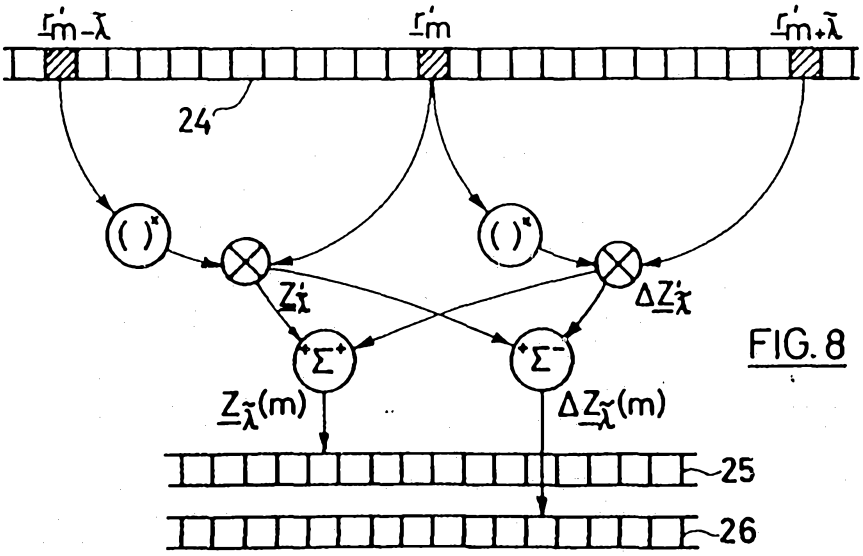
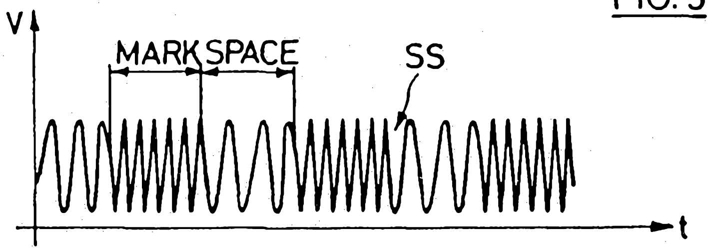


FIG. 8

FIG. 3



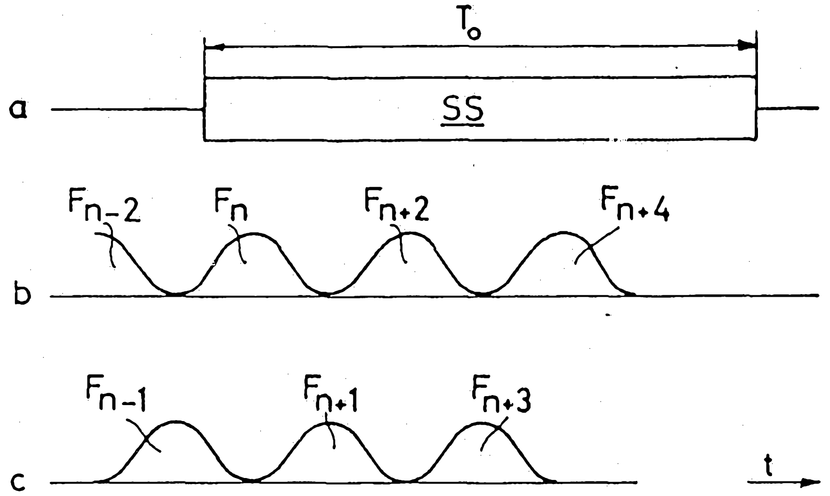


FIG. 4

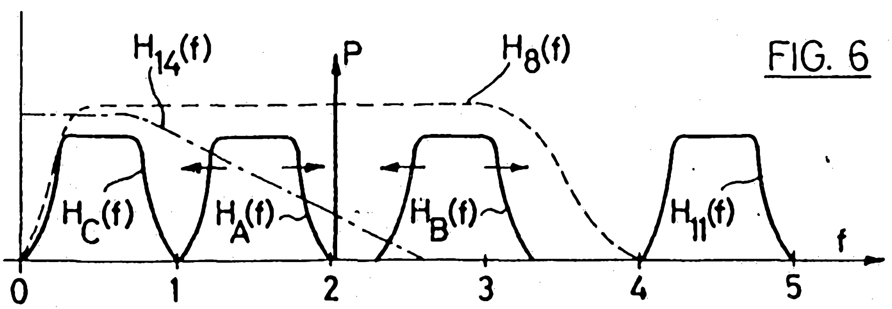


FIG. 6

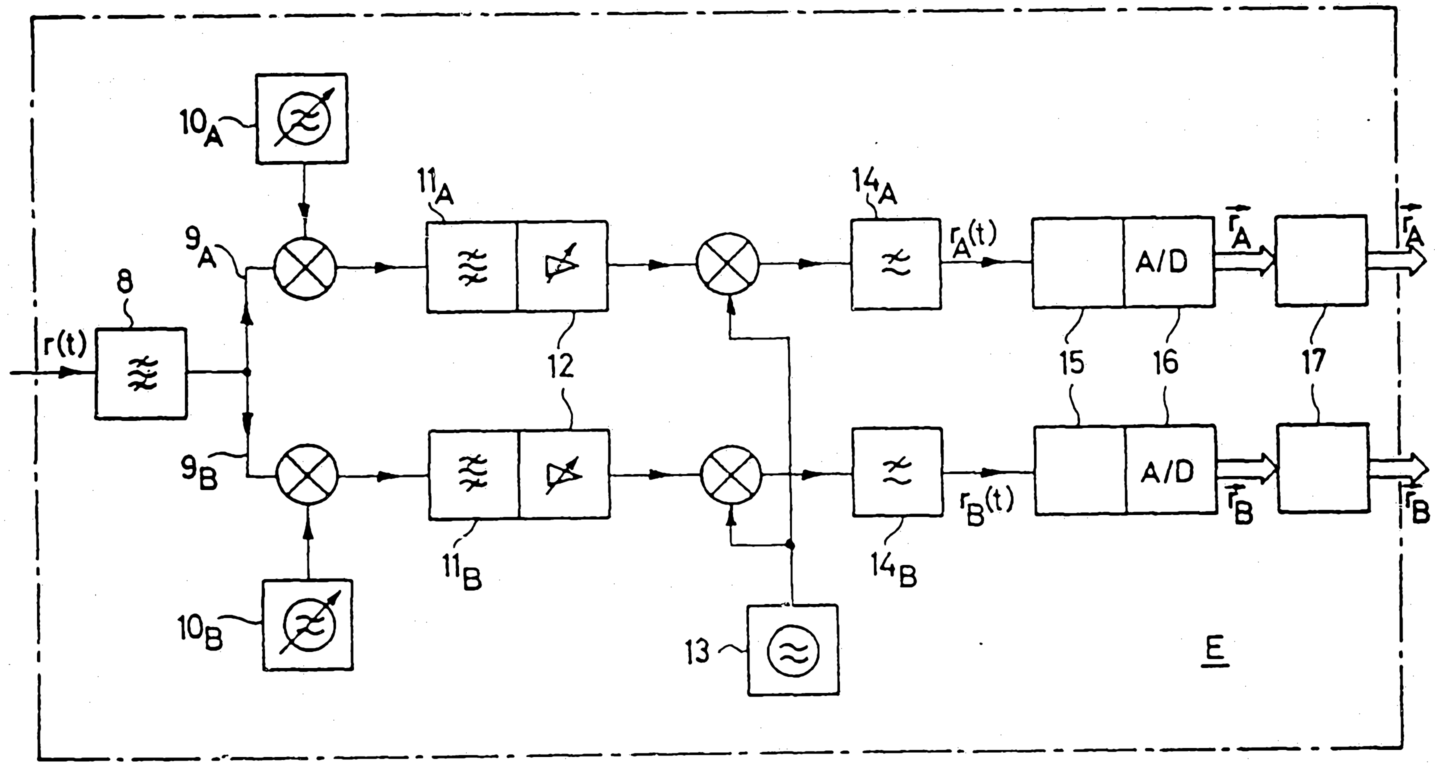


FIG. 5

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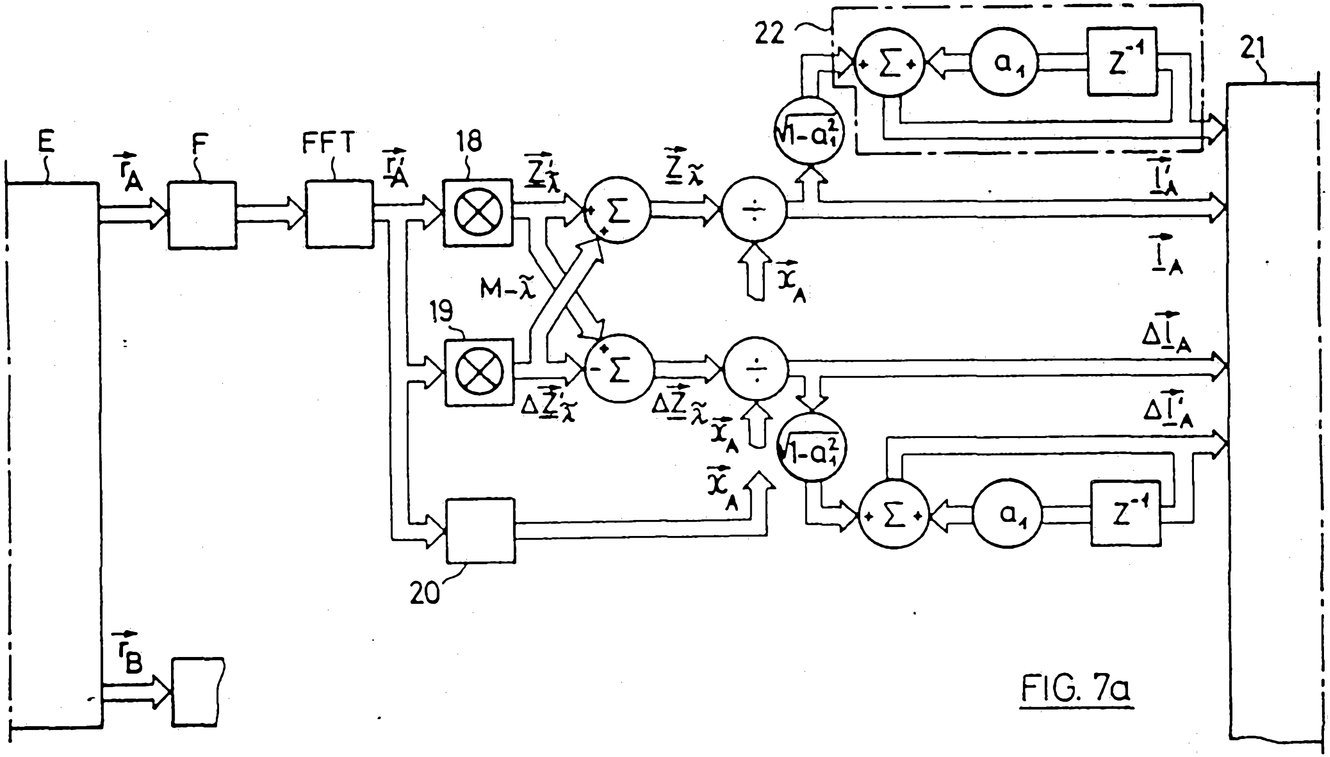

FIG. 7a

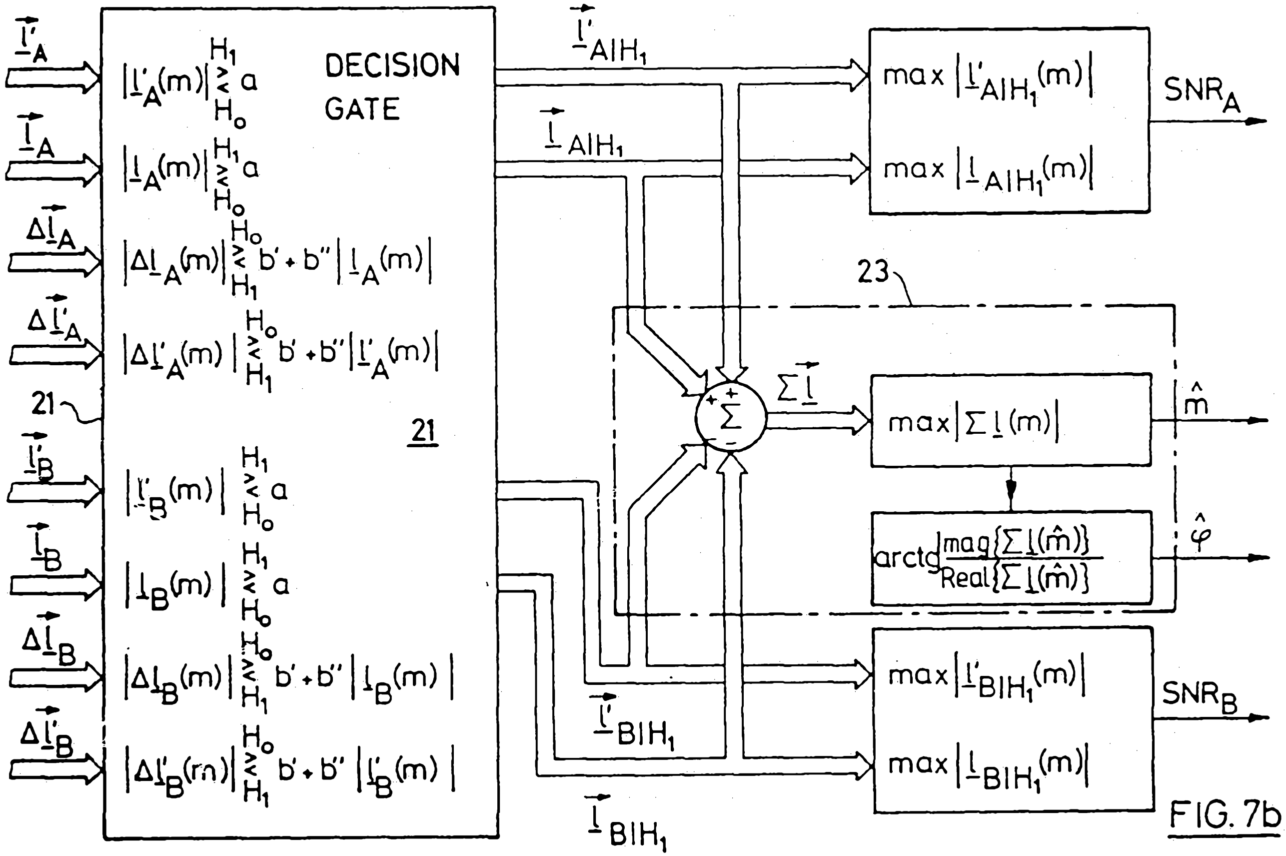
DECISION
GATE
21
23
max |I'AIH1(m)|
max |IAIH1(m)|
SNRA
ΣI
max|ΣI(m)|
m̂
φ̂
arctg Imag{ΣI(m̂)} / Real{ΣI(m̂)}
max|I'BIH1(m)|
max|IBIH1(m)|
SNRB
I'AIH1
IAIH1
I'BIH1
IBIH1

FIG. 7b

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