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**Datasheet for the decision
of 8 February 2013**

Case Number: T 0130/09 - 3.5.05

Application Number: 00307597.5

Publication Number: 1087582

IPC: H04L 27/26

Language of the proceedings: EN

Title of invention:

Coarse and fine frequency offset estimation in a digital audio broadcasting system

Applicant:

Lucent Technologies Inc.

Headword:

Two-stages frequency offset estimation/LUCENT

Relevant legal provisions:

EPC Art. 54, 56
RPBA Art. 13(1)

Keyword:

"Novelty - main request and auxiliary request I (no)"
"Inventive step - auxiliary requests II and III (no)"
"Admissibility of request - auxiliary request IIa (no)"

Decisions cited:

-

Catchword:

-



Case Number: T 0130/09 - 3.5.05

D E C I S I O N
of the Technical Board of Appeal 3.5.05
of 8 February 2013

Appellant: Lucent Technologies Inc.
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Decision under appeal: Decision of the Examining Division of the
European Patent Office posted 6 August 2008
refusing European patent application
No. 00307597.5 pursuant to Article 97(2) EPC.

Composition of the Board:

Chair: A. Ritzka
Members: P. Cretaine
F. Blumer

Summary of Facts and Submissions

I. The appeal is against the decision of the examining division, posted 6 August 2008, refusing European patent application No. 00307597.5 on the grounds of lack of novelty of claim 1 of a sole request (Article 54 EPC), having regard to the disclosure of

D2: CLASSEN F. et al. : "Frequency Synchronization Algorithms for OFDM Systems suitable for Communication over Frequency Selective Fading Channels", 44th Vehicular Technology Conference, Stockholm, Sweden, 8-10 June 1994, IEEE, NEW-YORK, NY, USA, pages 1655 to 1659.

The examining division appended additional remarks to the decision (see section IV.) with respect to lack of clarity, lack of novelty or lack of inventive step of the other claims of the sole request.

II. Notice of appeal was received on 17 September 2008 and the appeal fee was paid on the same day. The statement setting out the grounds of appeal was received on 12 December 2008. The appellant requested that the decision of the examining division be set aside and a patent be granted on the basis of the set of claims submitted as Main Claim Set (claims 1 to 26) or as Auxiliary Claim Set I (claims 1 to 24), Auxiliary Claim Set II (claims 1 to 20) and Auxiliary Claim Set III (claims 1 to 20) with the statement setting out the grounds of appeal. The claims of the Main Claim Set corresponded to the claims filed with letter of 23 October 2007, on which the decision under appeal was based.

- III. A summons to oral proceedings scheduled for 8 February 2013 was issued on 30 October 2012. In an annex accompanying the summons, the board expressed its preliminary opinion that none of the four claim sets appeared to be allowable since their claims did not appear to meet the requirements of Article 54 and/or 56 EPC having regard to the disclosure of D2. The board gave its reasons for the objections and explained that the appellant's arguments were not convincing.
- IV. During oral proceedings, held on 8 February 2013, the appellant filed an Auxiliary Claim Set IIa (claims 1 to 20). The appellant requested that the appealed decision be set aside and that a patent be granted on the basis of the Main Claim Set as filed with the statement setting out the grounds of appeal dated 12 December 2008, or, subsidiarily, on the basis of any of the Auxiliary Claim Set I or the Auxiliary Claim Set II, both as filed with the statement setting out the grounds of appeal, or on the basis of the Auxiliary Claim Set IIa as filed during the oral proceedings before the Board, or on the basis of the Auxiliary Claim Set III as filed with the statement setting out the grounds of appeal.
- V. After due deliberation on the basis of the appellant's arguments presented in the written submissions and during oral proceedings, the board announced its decision at the end of the oral proceedings.
- VI. Independent claim 1 of the Main Claim Set reads as follows:

"1. A method for coarse frequency offset estimation in an OFDM communication system, characterized by the steps of:
receiving a digital signal containing a signature sequence;
correlating said received digital signal using at least two frequencies; and
selecting one of said frequencies that provides a correlation peak having the largest magnitude to position said correlation peak near a bin (310, 330)."

Independent claim 7 of the Main Claim Set reads as follows:

"7. A method for estimating the partial frequency offset in an OFDM communication system, characterized by the steps of:
estimating a coarse frequency offset to position a correlation peak associated with a signature sequence near an OFDM bin within a predefined distance of an OFDM bin separation;
evaluating a change in phase of an unmodulated bin over at least two frames; and
estimating the partial frequency offset based on said change in phase."

The Main Claim Set includes further independent claims 14 and 20 seeking protection for a frequency offset estimator corresponding to claim 1 and an estimator circuit corresponding to claim 7, respectively.

Independent claim 1 of the Auxiliary Claim Set I reads as follows:

"1. A method for coarse frequency offset estimation in an OFDM communication system, characterized by the steps of:

receiving a digital signal containing a signature sequence, wherein said signature sequence provides reference information contained in discrete known frequency points in the frequency domain;

performing a Fast Fourier Transform on said received digital signal;

correlating said transformed received digital signal using at least two frequencies;

and

selecting one of said frequencies that provides a correlation peak having the largest magnitude to position said correlation peak near a bin (310, 330)."

Independent claim 6 of the Auxiliary Claim Set I reads as follows:

"6. A method for estimating the partial frequency offset in an OFDM communication system, characterized by the steps of:

performing a Fast Fourier Transform on a received digital signal;

estimating a coarse frequency offset to position a correlation peak associated with a signature sequence near an OFDM bin within a predefined distance of an OFDM bin separation, wherein said signature sequence provides reference information contained in discrete known frequency points in the frequency domain;

evaluating a change in phase of an unmodulated bin over at least two frames; and

estimating the partial frequency offset based on said change in phase."

The Auxiliary Claim Set I includes further independent claims 13 and 18 seeking protection for a frequency offset estimator corresponding to claim 1 and an estimator circuit corresponding to claim 6, respectively.

Independent claim 1 of the Auxiliary Claim Set II reads as follows:

"1. A method for coarse frequency offset estimation in an OFDM communication system, characterized by the steps of:
receiving a digital signal containing a signature sequence, wherein said signature sequence provides reference information contained in discrete known frequency points in the frequency domain;
performing a Fast Fourier Transform on said received digital signal;
correlating said transformed received digital signal using a first frequency and a second frequency, wherein said second frequency is shifted by half an inter-bin frequency amount; and
selecting one of said frequencies that provides a correlation peak having the largest magnitude to position said correlation peak near a bin (310, 330)."

Independent claim 6 of the Auxiliary Claim Set II reads as follows:

" 6. A method for estimating the partial frequency offset in an OFDM communication system, characterized by the steps of:
performing a Fast Fourier Transform on a received digital signal;

estimating a coarse frequency offset to position a correlation peak associated with a signature sequence near an OFDM bin within a predefined distance of an OFDM bin separation, wherein said signature sequence provides reference information contained in discrete known frequency points in the frequency domain;
evaluating a change in phase of an unmodulated bin over at least two frames;
estimating the partial frequency offset based on said change in phase, wherein the extent of the frequency offset is a function of a rate of rotation of said change in phase; and
making said rate of rotation equal to zero."

The Auxiliary Claim Set II includes further independent claims 11 and 16 seeking protection for a frequency offset estimator corresponding to claim 1 and an estimator circuit corresponding to claim 6, respectively.

Independent claim 1 of the Auxiliary Claim Set IIa reads as follows:

" 1. A method for coarse frequency offset estimation in an OFDM communication system, characterized by the steps of:
receiving a digital signal containing a signature sequence, wherein said signature sequence provides reference information contained in discrete known frequency points in the frequency domain;
performing a Fast Fourier Transform on said received digital signal;
correlating said transformed received digital signal using exactly two frequencies, a first frequency and a

second frequency, wherein said second frequency is shifted by half an inter-bin frequency amount; and selecting one of said frequencies that provides a correlation peak having the largest magnitude to position said correlation peak near a bin (310, 330)."

Independent claim 6 of the Auxiliary Claim Set IIa is identical to claim 6 of the Auxiliary Claim Set II.

The Auxiliary Claim Set IIa includes further independent claims 11 and 16 seeking protection for a frequency offset estimator corresponding to claim 1 and an estimator circuit corresponding to claim 6, respectively.

Independent claim 1 of the Auxiliary Claim Set III reads as follows:

"1. A method for coarse frequency offset estimation in an OFDM communication system, characterized by the steps of:
receiving a digital signal containing a signature sequence, wherein said signature sequence provides reference information contained in discrete known frequency points in the frequency domain;
performing a Fast Fourier Transform on said received digital signal;
correlating said transformed received digital signal using a first frequency and a second frequency to down-convert said received digital signal, wherein said second frequency is shifted by half an inter-bin frequency amount; and

selecting one of said frequencies that provides a correlation peak having the largest magnitude to position said correlation peak near a bin (310, 330)."

Independent claim 6 of the Auxiliary Claim Set III reads as follows:

"6. A method for estimating the partial frequency offset in an OFDM communication system, characterized by the steps of:
performing a Fast Fourier Transform on a received digital signal;
estimating a coarse frequency offset to position a correlation peak associated with a signature sequence near an OFDM bin within a predefined distance of an OFDM bin separation, wherein said signature sequence provides reference information contained in discrete known frequency points in the frequency domain;
evaluating a change in phase of an unmodulated bin over at least two frames;
estimating the partial frequency offset based on said change in phase, wherein the extent of the frequency offset is a function of a rate of rotation of said change in phase and wherein integration is continuously performed over N consecutive $\Delta\theta$ values; and
making said rate of rotation equal to zero."

The Auxiliary Claim Set III includes further independent claims 11 and 16 seeking protection for a frequency offset estimator corresponding to claim 1 and an estimator circuit corresponding to claim 6, respectively.

Reasons for the Decision

1. Admissibility

The appeal complies with Articles 106 to 108 EPC (see Facts and Submissions, point II). It is therefore admissible.

2. Admissibility of request

The Auxiliary Claim Set IIa was filed during the oral proceedings before the board. Claim 1 of this request had been amended with respect to claim 1 according to the Auxiliary Claim Set II by solely adding the feature that "exactly two frequencies" are used in the correlating step. The board decided not to admit this late filed request to the procedure since the addition of said feature was prima facie not capable of dispelling the inventive step objection raised against claim 1 according to the Auxiliary Claim Set II (see section 3.4 below) and was rather just intended for clarifying the subject-matter of claim 1 (Article 13(1) RPBA).

3. Novelty - inventive step

3.1 Prior art

Document D2 represents the closest prior art and discloses a two stage synchronisation unit for frequency offset adjustment in an OFDM system. A first stage achieving a coarse frequency offset adjustment is described in paragraph 3.2 ("Acquisition Algorithm Structure"). This stage uses a PN sequence transmitted

on LF sync-subchannels. The detection of the offset is based on the maximum search procedure of equation (8), by varying a frequency f_{trial} correcting the N input samples of an FFT. The second stage achieves a partial frequency offset adjustment and is performed after the coarse adjustment (see paragraph 3.1: "Tracking Algorithm Structure"). This stage assumes that the remaining offset is less than half the bin (or OFDM subchannel) separation. The partial offset is estimated based on the phase shift between two subsequent subchannels samples, the symbols being taken from a training sequence transmitted on sync-subchannels.

3.2 Main Claim Set

3.2.1 Interpretation of claims

The board considers that independent claims 1 and 7 have to be interpreted in the light of the description for the assessment of novelty and inventive step. In that respect, the board assumes that the correlating step of claim 1 is performed in the frequency domain by down-converting the received signal at at least two different frequencies, as stated in the originally filed description (see paragraphs [0008], [0011], [0018] and shown on figure 4 of the published application). Moreover the term "unmodulated bin" present in claim 7 has to be construed as an OFDM sub-carrier transmitting an element of a training sequence (see paragraphs [0033] and [0034]).

3.2.2 Claim 1

Paragraph 3.2 of D2 discloses that an initial frequency offset is acquired by searching for known training symbols transmitted on LF sync-subchannels. The training symbols are defined in paragraph 3.1 of D2 as being training symbol pairs, the symbols of a pair being transmitted on the same subchannel but at a different time period. Therefore the signal transmitted on the LF sync-subchannels represents a digital signal containing a signature reference. According to equation (8) in paragraph 3.2, this signal is correlated in the frequency domain, after an FFT, with the known sequence of training symbols. The input samples of the FFT are, according to paragraph 3.2, corrected by f_{trial} before being correlated in the frequency domain. This implies that the frequency of the receiver VCO is corrected by f_{trial} . Since f_{trial} is varied stepwise in the algorithm disclosed in D2, paragraph 3.2, at least two frequencies are used for f_{trial} . The step of correlating the received digital signal using at least two frequencies is thus known from D2. Figure 4 and equation (8) of D2 further show that the frequency f_{trial} achieving the largest correlation peak is chosen; moreover, by choosing a frequency f_{trial} which maximizes the expression of equation (8), the correlation peak is positioned close to a bin.

The appellant argued that the scheme of D2 does not achieve a correlation peak near to a bin. The board is not convinced by this argument since D2 explicitly discloses that the acquisition process reduces the frequency offset below the tracking process pull-in range of $|\Delta f T_{\text{sub}}| \leq 0.5$ (see page 1658, left-hand column, lines 8 to 12 and Figure 4). The frequency

offset Δf achieved by the acquisition process of D2 is thus smaller than half the inter-bin interval $1/T_{\text{sub}}$, which implies that the correlation peak between the sync-subchannels and the received signal is "near a bin" as defined in claim 1.

The appellant further argued that the acquisition process of D2 uses a plurality of frequencies f_{trial} whereas the method according to claim 1 relies on "at least two frequencies" and can thus be performed using two frequencies only. The board however considers that the teaching of D2 does not exclude that the acquisition process is applied using two frequencies f_{trial} . This may be sufficient in particular in the case where the initial frequency offset is lower than one bin interval and the spacing between the f_{trial} frequencies is chosen to be half a bin.

Thus the combination of steps of claim 1 is considered to be disclosed in D2. Consequently, the subject-matter of claim 1 lacks novelty.

- 3.2.3 It is further to be noted with respect to independent claim 7 that paragraph 3.1 of D2 relates to a partial frequency offset adjustment which is performed after the coarse frequency offset adjustment defined in paragraph 3.2. According to paragraph 3.1, the phase shift between two subsequent sub-channels samples corresponding to known symbols of a training sequence are evaluated and the partial frequency offset adjustment is estimated based on that phase shift. Since the sub-channels taken into account are the LF sync-subchannels, they may be considered as unmodulated bins since they do not carry information data.

Therefore the combination of steps of independent claim 7 is known from D2 and the subject-matter of claim 7 lacks novelty.

3.2.4 In conclusion, the Main Claim Set is not allowable under Article 54 EPC.

3.3 Auxiliary Claim Set I

3.3.1 Claim 1

Claim 1 adds to claim 1 according to the Main Claim Set that:

(a) the signature sequence provides reference information contained in discrete known frequency points in the frequency domain; and that

(b) a Fast Fourier Transform is performed on the received digital signal.

Feature (a) is known from D2 (see paragraph 3.2 and Figure 3), which discloses that the training symbols "c" used for the coarse frequency offset adjustment are transmitted on LF sync-subchannels.

Feature (b) is also known from D2 (see paragraph 3.2 and Figure 1), which discloses that the N samples of the received digital signal are transformed by an FFT, after having being corrected by the frequency f_{trial} .

The appellant's arguments were identical to those presented with respect to the Main Claim Set, features

(a) and (b) having been introduced only for clarifying the subject-matter of the independent claims.

Therefore the board judges that the subject-matter of claim 1 is already disclosed in D2.

3.3.2 Further, it is to be noted that independent claim 6 adds to independent claim 7 according to the Main Claim Set that:

(a) the signature sequence provides reference information contained in discrete known frequency points in the frequency domain; and that

(b) a Fast Fourier Transform is performed on the received digital signal.

Features (a) and (b) are both disclosed in D2, as mentioned in section 3.3.1 above.

Therefore the subject-matter of independent claim 6 is not novel.

3.3.3 In conclusion, the Auxiliary Claim Set I is not allowable under Article 54 EPC.

3.4 Auxiliary Claim set II

3.4.1 Claim 1

Claim 1 adds the following feature to claim 1 according to the Auxiliary Claim Set I:

(a') the correlating step uses a first frequency and a second frequency, wherein said second frequency is shifted by half an inter-bin frequency amount.

D2 teaches a generic maximum search procedure using the trial parameter frequency f_{trial} which corrects the input samples of the FFT (see equation (8) in page 1658, left-hand column). A practical implementation is described using a step of $0,1/T_{\text{sub}}$ for f_{trial} , i.e. a step of $0,1$ times the inter-bin frequency amount, and a $(f_{\text{trial}} - f_0)$ range varying from -4 to $+4$ expressed in inter-bin frequency amount, f_0 being the actual frequency offset.

The subject-matter of claim 1 therefore differs from the disclosure of D2 only in that the selection of the trial parameter frequency is limited to two values only, separated by half the inter-bin frequency amount.

A search based on two frequencies only represents a selection of a very small number of frequencies compared to the whole teaching of paragraph 3.2 in D2, as based on the single example disclosed therein (see figure 4), which relies on a much larger number of frequencies. The board therefore considers that the subject-matter of claim 1 is novel.

The technical effect achieved by the above-mentioned distinguishing features is that the maximum search procedure is limited to a comparison of two correlation peaks only and that one of the obtained correlation peaks is clearly larger than the other one.

The objective technical problem can thus be formulated as how to simplify the coarse frequency offset adjustment process. In order to simplify the search procedure defined by equation (8) of D2, the skilled person would obviously consider as an alternative to reduce the number of f_{trial} parameters and increase their separation interval, to the price of a reduced accuracy in the determination of the offset frequency.

Moreover the skilled person would readily contemplate in advance that a separation of half an inter-bin frequency amount leads to the two correlation peaks being clearly differentiated in amplitude, which facilitates their comparison. Therefore the selection of two frequencies only, shifted by half an inter-bin frequency amount, represents a drastic simplification of the maximum search procedure disclosed in D2 which the skilled person would consider to implement, without exercising any inventive skills, by balancing the expected advantages and drawbacks.

The board therefore judges that the subject-matter of claim 1 does not involve an inventive step (Article 56 EPC) having regard to the disclosure of D2.

3.4.2 It is further to be noted that independent claim 6 adds to independent claim 6 of the Auxiliary Claim set I the features that:

(b') the extent of the frequency offset is a function of a rate of rotation of the evaluated change in phase; and that

(c') the rate of rotation is made to zero.

D2 teaches that the frequency offset estimation problem in the partial adjustment mode can be reduced to a phase estimation problem by considering the phase shift between two subsequent subchannel samples (see page 1657, left-hand column, lines 27 to 32). Moreover, the present application describes (see paragraph [0033]) that, in presence of a partial frequency offset, i.e. less than half the inter-bin separation, the complex bins start rotating, that the change in phase from one frame to the next is proportional to the rate of rotation and that the rate of rotation is a function of the extent of the frequency offset. This statement of the description also applies to the system disclosed in D2 since it is inherent to an OFDM system wherein the frequency offset has been first adjusted to be a fraction of the inter-bin separation. Thus, in the board's judgment, feature (b') is already known from D2.

Feature (c') only represents an aim to be achieved, without defining how this aim might be achieved. The board considers that this feature is implicitly disclosed in D2 since the aim of the tracking algorithm structure of paragraph 3.1 is to correct the frequency offset and thus, a fortiori, to cancel any rotation of the complex bins.

Therefore, the subject-matter of independent claim 6 is not novel (Article 54 EPC).

3.4.3 In conclusion the Auxiliary Claim Set II is not allowable under Article 56 EPC (claim 1) and Article 54 EPC (claim 6).

3.5 Auxiliary Claim Set III

3.5.1 Claim 1

Claim 1 adds to claim 1 according to the auxiliary claim set II the feature that

(a'') the first frequency and the second frequency are used to down-convert the received digital signal.

This feature is already disclosed in D2 (see for instance paragraph 3.2: "N input samples are frequency corrected by f_{trial} ", and Figure 1). Thus the board judges that the subject-matter of claim 1 does not involve an inventive step (Article 56 EPC).

3.5.2 It is further to be noted that independent claim 6 adds to independent claim 6 according to the Auxiliary Claim Set II the feature that

(b'') integration is continuously performed over N consecutive $\Delta\theta$ values.

This feature solves the problem of improving the phase rotation estimation in presence of inter-bin interference from the adjacent modulated bins and background noise and fading (see [0036] of the published application). In the partial offset adjustment scheme of D2 (see paragraph 3.1), the phase shift between two subsequent sub-channel samples is estimated, i.e. the phase shift over two frames. Improving the estimation of a value by integrating several measurements over a certain period of time represents a common measure in the field of data

processing. The skilled person would thus readily, in order to suppress or filter the interferences or noise in the estimation process and obtain a more accurate value of the partial frequency offset, contemplate repeating the phase shift estimation over several consecutive frames and continuously integrating the results. Therefore the subject-matter of claim 6 does not involve an inventive step, having regard to D2 and the common general knowledge of the skilled person (Article 56 EPC).

3.5.3 In conclusion the Auxiliary Claim Set III is not allowable under Article 56 EPC.

4. Having regard to the findings set forth above (cf. 2. and 3.), none of the appellant's requests are allowable.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar:

The Chair:

K. Götz

A. Ritzka