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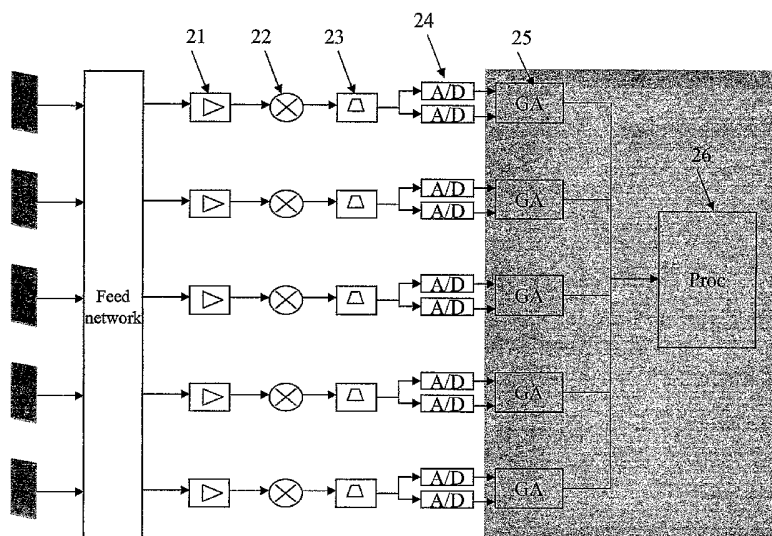
(57) Abstract: A digitizer arrangement for converting an analogue signal into a digital signal, including a first A/D converter, said first A/D converter being arranged to convert said analogue signal into a first digital signal with a first sampling rate, the first sampling rate being lower than the frequency of the analogue signal, a second A/D converter, said second A/D converter being arranged to convert said high frequency analogue signal into a second digital signal with a second sampling rate, the second sampling rate being lower than the frequency of the analogue signal, means for combining said first and second digital signals into a third digital signal with a third sampling rate that is at least a multiple of said first and second sampling rates.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

A DIGITIZER ARRANGEMENT

Technical background

The present invention discusses a novel structure for a
high resolution/high sample rate digitizer. The digitizer
is intended for use in radio receivers with digital signal
processing, and is particularly suited for use in a
direction-finder system for detecting and localising radio
frequency emitters.

Modern radio receivers often use digital signal processing
(DSP) for processing received signals. Such receivers use
analogue front-ends with an Analogue/Digital (A/D)
converter somewhere in the receiving chain. Ideally, the
A/D converter should have as high resolution as possible,
both in bit rate and bit resolution, either to sample high
frequency signals, e.g. in a receiver with few conversion
steps, or in order to cover a large frequency band.

While there is a steady increase in the performance of
commercially available A/D converters, one is still faced
with a choice of either using an A/D converter with fast
sampling rate and few bits, or use a converter with higher
resolution at a slower sampling rate.

In the so-called "gain-ranging" technique an A/D converter
are preceded by an amplifier with programmable gain. A
logic unit control the gain of the amplifier to expand the
dynamic range of the digitiser system. Other solutions
stack multiple fast/few bit A/D converters to obtain a
composite fast converter with high bit resolution. This is
done by connecting converters to a number of amplifiers
with different gains and bit stack the output signals from
the converters. The company Stagetech markets such

digitiser systems for audio use, and it is also known from marine depth sounders.

Summary of the invention

An object of the present invention is to provide a
5 digitizer for converting an analogue signal into a digital signal, which has an improved efficiency compared with prior art systems.

This object is achieved in an arrangement as claimed in the appended patent claims.

10 In particular the invention relates to a digitizer employing two stacked A/D converters with different sampling frequencies.

Brief description of the drawings

The invention will now be described in detail in reference
15 to the appended drawings, in which:

Fig. 1 illustrates a particular application of the inventive digitizer, in the receiver chains of a direction-finder system,

Fig. 2 is a schematic diagram of a receiver system
20 including a digitizer according to the present invention,

Fig. 3 illustrates a digitizer according to the present invention, including two stacked A/D converters,

Fig. 4 is a schematic frequency domain diagram illustrating how an input signal is under-sampled by the two A/D
25 converters with different sampling frequency.

Detailed description of the invention

Initially, we will give an overview of a direction-finder
system in which the present invention may find its
application. As shown in Fig. 1, the direction-finder

5   system includes an antenna unit 1 at left receiving RF
signals from a number of emitter sources. The signals are
delivered to an RF unit 2, center, where they are
amplified, transposed down to baseband and demodulated. The
demodulated signals are delivered to a processing unit 3

10   for processing and analysis. The antenna unit 1 is
described in detail in co-pending patent application with
title "An antenna arrangement", while the details of the RF
unit are disclosed in co-pending patent application with
title "Arrangements for receiving channels in a direction-

15   finding system".

Briefly, the antenna arrangement includes four antenna
panels mounted in a 2X2 relationship, as well as an omni-
directional guard antenna that may be mounted at the center
of the antenna unit.

20   Fig. 2 shows the receiver and processor section in the
direction-finder system of Fig. 1. The receiver section
comprises four phase channels and one guard channel. The
figure shows the main components included in the receiver
chains, i.e. amplifier 21, mixer 22 and bandpass filter 23.

25   After the bandpass filter 23, the signals are digitized in
a digitizer 24 according to the present invention. The
digital signals are then processed in the following
processor chain including gate arrays 25, which perform the
main data reduction, and a CPU common for all chains, which

30   perform the final signal analysis. The receivers
illustrated in Fig. 2 are superheterodyne receivers with a
single intermediate frequency. However, receivers with more
conversion stages may also be used. Typically, the
bandwidth at baseband will be about 200 MHz. The digitizer

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should ideally sample with a sampling frequency of at least
400 MHz, to satisfy Nyquist's theorem.

The digitizer system illustrated in Fig 3 includes an anti-
aliasing filter 31 at the input. The filter is designed
5   with a break frequency f3 which restrict the frequency of
signals entering the subsequent digitizer to half the
effective sampling rate of the digitizer. Signals that have
passed the filter 31 are fed to two A/D converters 32, 33
in parallel. The A/D converters 32, 33 samples with
10 different sampling frequencies (in the following example we
will assume that the sampling frequencies are 70MHz and
50MHz, respectively). This utilizes the fact that the
signals have a typical bandwidth of up to 15 MHz, and
allows the system to operate on a substantially lower data
15 rate than a single A/D with a sampling rate of 500 MHz (2.5
times the total bandwidth). At the reduced sampling
frequency, A/D converters with up to 14 bits (84dB) are
available while at 500 MHz the resolution is typically 8
bits (48dB). The digitiser samples the band continuously,
20 and feed a signal processing gate array with a data stream
of approximately 120 MS/s. The signal processing gate array
combines the signals from the two A/D converters into a
single signal with 14 bits resolution and 350 MHz sampling
frequency. The new sampling rate should be a multiple of
25 the two sampling rates, or a further multiple of this. Thus
with 70 and 50 MHz digitizers, the lowest sampling rate
becomes 350 MHz.

An under-sampled signal will appear as having a lower
frequency within the pass-band of the A/D converter. Fig. 4
30 illustrates the principle of the present invention. The
figure shows a signal f_i within a receiver pass-band
stretching from 0 to f_3, f_3 being the cut-off frequency of
the anti-aliasing filter 31. Due to the under-sampling, f_i
will be folded down into the pass-band of the respective
35 A/D converter 32, 33. The pass-bands of the A/D converters
are represented by dark and lighter shaded triangles. The

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triangles are symmetrical about half the sampling frequency
(i.e. the Nyquist frequency). Folding occurs about
multiples of the Nyquist frequency. The lighter shaded
triangles represent areas of negative frequency.

5   If we had only one A/D converter, we could not know if the
original signal was outside the converter pass-band, and
the folding ratio in relation to the sampled "apparent"
frequency. However, by using two converters, the frequency
of the signal may be reconstructed unambiguously.

10 The "reconstruction" process may be performed by first
identifying the corresponding signals in the two channels.
Signal pairs are identified by detecting coincidence
between the channels. Signals having a correlation factor
over 0.9 over integration time $1/f_3$ are considered as valid
15 pairs, while signals with lower correlation factor are
muted. The two frequencies of a given signal pair, i.e. the
absolute frequency values, and the relative difference
between the frequencies, will hold information identifying
the correct factor to use when up-converting the signal
20 back to its correct frequency. The spectrum is divided into
separate frequency bands 1, 2, 3..., as shown in the figure.
In each of these bands there is a specific relationship
between frequencies in A/D channels 1 and 2, and we may
apply rules for the reconstruction of the signal f_i. The
25 frequency shift factor n is given by the relationships:

$$f_{r1} = \left(f_i - n f_1 \right) \qquad\qquad , n = 0,\ 1,\ 2,\ 3 \ldots$$

$$f_{r2} = \left(f_i - m f_2 \right) \qquad\qquad , m = \left\{ \begin{array}{c} n \\ n+1 \end{array} \right\}$$

Where f_i is the frequency of the incoming signal, f_1 is the
sampling rate of A/D converter 1, f_2 is the sampling rate
30 of A/D converter 2, f_{r1} is the apparent frequency of the

incoming signal registered by A/D converter 1 and f_{r2} is the apparent frequency registered by A/D converter 2.

The value of n is dependent on in which bands f_{r1} and f_{r2} are falling. In the example shown in Fig. 4, we only need
5   to consider two cases: If the apparent signal falls within the lower dark shaded triangles of both channels, i.e. both f_{r1} and f_{r2} is within band 1, then m = n. The other case is when one of the apparent signals falls in band 1 and the other falls in band 2. Then m = n+1. This is as shown in
10   Fig. 4. Other cases do not apply.

Thus, the signal in A/D channel 1 is up-converted using a known frequency shift factor n, while the signal in A/D channel 2 is up-converted using a known and possibly different frequency shift factor m. When the signals have
15   been up-converted, the signals from A/D channel 1 and A/D channel 2 are added. Alternatively, only the signal in one of the channels is up-converted. However, by using both signals, an improved signal-to-noise ratio is obtained.

While the example illustrated in Fig. 4 utilizes two A/D
20   converters, the inventive digitizer may use more A/D converters. Another option is to combine the inventive way of stacking with the prior art multiple combination method mentioned in the introduction, and thus obtain a matrix of A/D converters. The combination may then have both high bit
25   rate and high resolution.

Claims

1.   A method for digitizing a high frequency analogue
signal, c h a r a c t e r i z e d   i n
converting said analogue signal into a first digital signal
with a first sampling frequency (f_1),
converting said analogue signal into a second digital
signal with a second sampling frequency (f_2),
correlating said first digital signal with said second
digital signal,
identifying a frequency ratio between said first and second
digital signals,
determining a first transponation ratio (n) from said
frequency ratio,
transposing said first digital signal into a higher
frequency with the first transponation ratio (n).

2.   A method as claimed in claim 1,
c h a r a c t e r i z e d   i n   determining a second transponation
ratio (m) from said frequency ratio,
transposing said second digital signal into the higher
frequency with the second transponation ratio (m), and
adding the first transposed signal to the second transposed
signal.

3.   A method as claimed in claim 1,
c h a r a c t e r i z e d   i n   retaining signals with a
correlation figure over 0.9 over an integration time of
1/f3 and muting signals with a lower correlation ratio, f3
being equal to the multiple of said first and second
sampling frequencies (f_1, f_2).

4.   A method as claimed in claim 1,
c h a r a c t e r i z e d   i n   filtering said analogue signal
with an anti-aliasing filter before it is converted, said
anti-aliasing filter having a cut-off frequency (f3) equal
to the multiple of said first and second sampling
frequencies (f_1, f_2).

5.   A digitizer arrangement for converting an analogue
signal into a digital signal, c h a r a c t e r i z e d   i n
a first A/D converter (32), said first A/D converter being
arranged to convert said analogue signal into a first
digital signal with a first sampling rate (f_1), the first
sampling rate (f_1) being lower than the frequency of the
analogue signal (f_i),
a second A/D converter (33), said second A/D converter
being arranged to convert said high frequency analogue
signal into a second digital signal with a second sampling
rate (f_2), the second sampling rate (f_2) being lower than
the frequency of the analogue signal (f_i),
means for combining said first and second digital signals
into a third digital signal with a third sampling rate (f_3)
that is at least a multiple of said first and second
sampling rates.

6.   A digitizer as claimed in claim 5,
c h a r a c t e r i z e d   i n means for correlating the first
and second digital signals, said means being arranged to
mute signals with a correlation factor lower than 0.9 over
integration time 1/f3, f3 being equal to the multiple of
said first and second sampling frequencies.

7.   A digitizer as claimed in claim 6,
c h a r a c t e r i z e d   i n means for identifying a
corresponding signal pair in the first and second digital
signals,
means for determining a first conversion factor (n) based
on the frequencies of said signal pair,
means for transposing the frequency of said first digital
signal to the third digital signal with said first
conversion factor (n).

8.   A digitizer as claimed in claim 6,
c h a r a c t e r i z e d   i n means for identifying a
corresponding signal pair in the first and second digital
signals,

means for determining a first conversion factor (n) based
on the frequencies of said signal pair,
means for transposing the frequency of said first digital
signal to a fourth digital signal with said first
5 conversion factor (n),
means for determining a second conversion factor (m) based
on the frequencies of said signal pair,
means for transposing the frequency of said second digital
signal to a fifth digital signal with said second
10 conversion factor (m),
means for adding the fourth digital signal to the fifth
digital signal and obtaining said third digital signal.

AMENDED CLAIMS
[received by the International Bureau on 13 June 2005 (13.06.2005)]

1.   A method for digitizing a high frequency analogue
signal, c h a r a c t e r i z e d   i n
converting said analogue signal into a first digital signal
with a first sampling frequency (f_1),
converting said analogue signal into a second digital
signal with a second sampling frequency (f_2), said first
and second sampling frequencies being different and with a
non-harmonic relationship,
correlating said first digital signal with said second
digital signal,
identifying a frequency ratio between said first and second
digital signals,
determining a first transponation ratio (n) from said
frequency ratio,
transposing said first digital signal into a higher
frequency with the first transponation ratio (n).

2.   A method as claimed in claim 1,
c h a r a c t e r i z e d   i n determining a second transponation
ratio (m) from said frequency ratio,
transposing said second digital signal into the higher
frequency with the second transponation ratio (m), and
adding the first transposed signal to the second transposed
signal.

3.   A method as claimed in claim 1,
c h a r a c t e r i z e d   i n retaining signals with a
correlation figure over 0.9 over an integration time of
$1/f_3$ and muting signals with a lower correlation ratio, f_3
being equal to the multiple of said first and second
sampling frequencies (f_1, f_2).

4.   A method as claimed in claim 1,
c h a r a c t e r i z e d   i n filtering said analogue signal
with an anti-aliasing filter before it is converted, said

AMENDED SHEET (ARTICLE 19)

anti-aliasing filter having a cut-off frequency (f3) equal
to the multiple of said first and second sampling
frequencies (f₁, f₂).

5.   A digitizer arrangement for converting an analogue
signal into a digital signal, c h a r a c t e r i z e d in
a first A/D converter (32), said first A/D converter being
arranged to convert said analogue signal into a first
digital signal with a first sampling frequency (f₁), the
first sampling frequency (f₁) being lower than the
frequency of the analogue signal (fi),
a second A/D converter (33), said second A/D converter
being arranged to convert said high frequency analogue
signal into a second digital signal with a second sampling
frequency (f₂), the second sampling frequency (f₂) being
lower than the frequency of the analogue signal (fi), said
first and second sampling frequencies being different and
with a non-harmonic relationship,
means for combining said first and second digital signals
into a third digital signal with a third sampling frequency
(f₃) that is at least a multiple of said first and second
sampling frequencys.

6.   A digitizer as claimed in claim 5,
c h a r a c t e r i z e d i n means for correlating the first
and second digital signals, said means being arranged to
mute signals with a correlation factor lower than 0.9 over
integration time 1/f3, f3 being equal to the multiple of
said first and second sampling frequencies.

7.   A digitizer as claimed in claim 6,
c h a r a c t e r i z e d i n means for identifying a
corresponding signal pair in the first and second digital
signals,
means for determining a first conversion factor (n) based
on the frequencies of said signal pair,
means for transposing the frequency of said first digital

AMENDED SHEET (ARTICLE 19)

signal to the third digital signal with said first
conversion factor (n).

8.   A digitizer as claimed in claim 6,
c h a r a c t e r i z e d   i n   means for identifying a
corresponding signal pair in the first and second digital
signals,
means for determining a first conversion factor (n) based
on the frequencies of said signal pair,
means for transposing the frequency of said first digital
signal to a fourth digital signal with said first
conversion factor (n),
means for determining a second conversion factor (m) based
on the frequencies of said signal pair,
means for transposing the frequency of said second digital
signal to a fifth digital signal with said second
conversion factor (m),
means for adding the fourth digital signal to the fifth
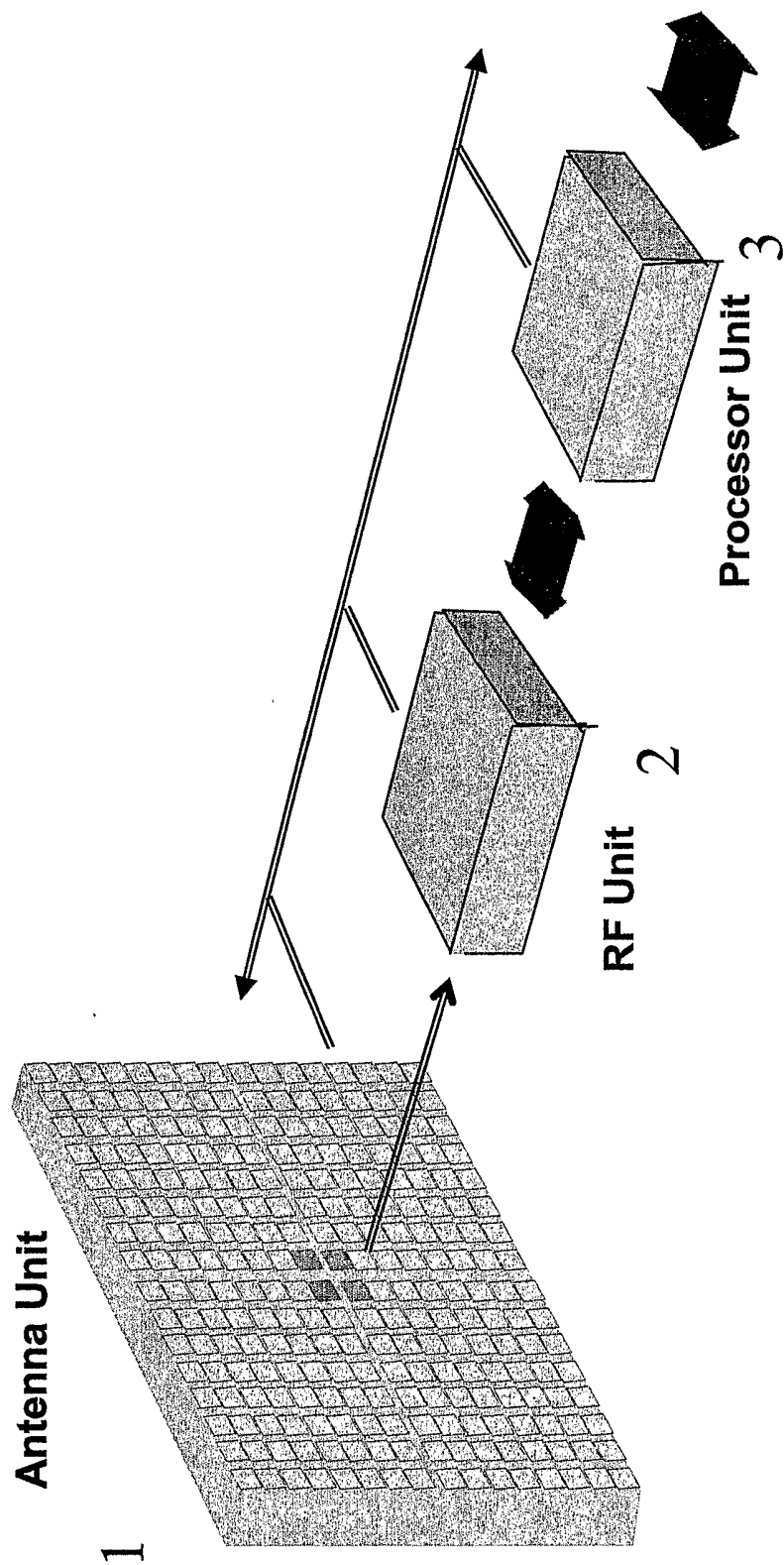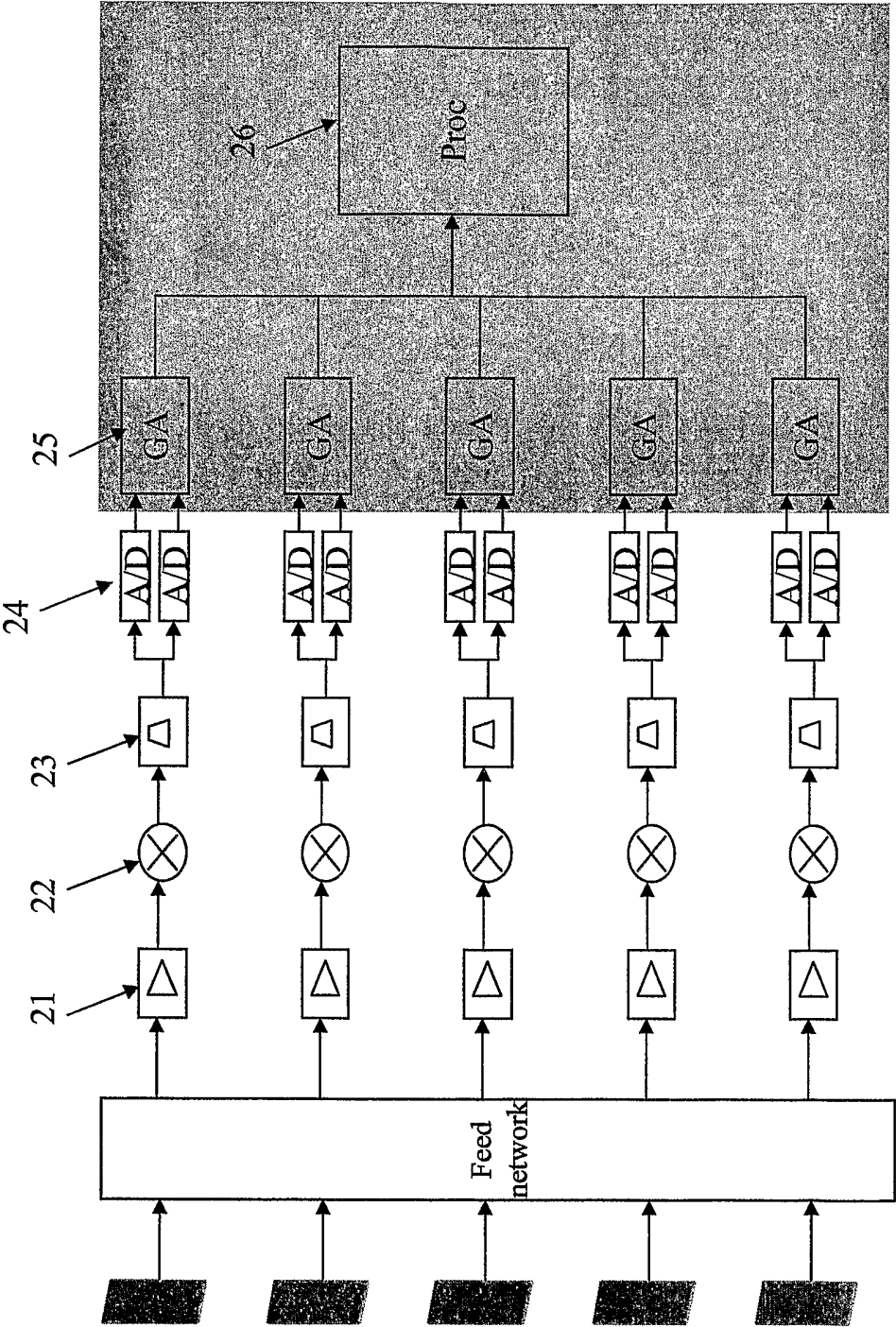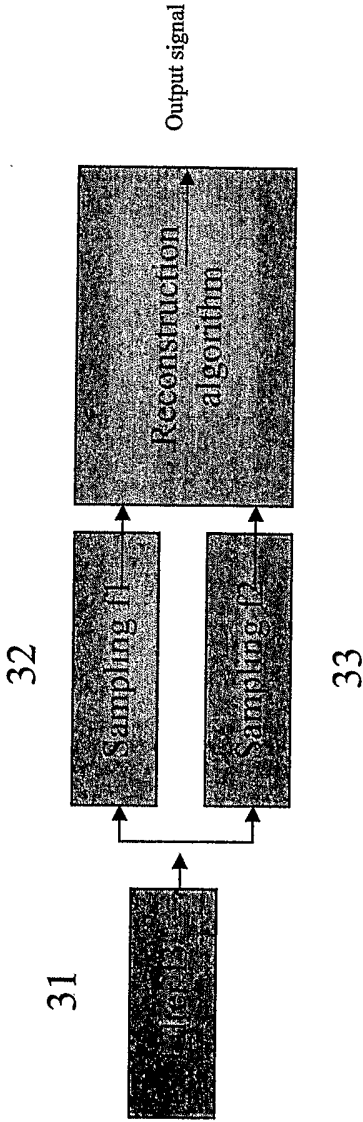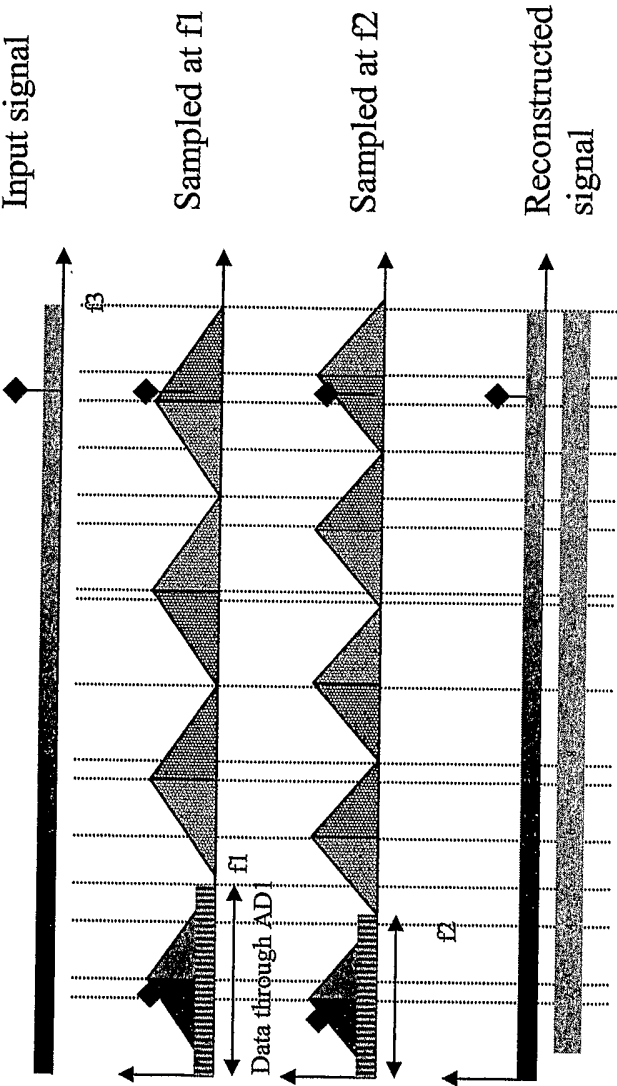digital signal and obtaining said third digital signal.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   H04B1/28   H03M1/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   H04B   H03H   H03M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/032358 A1 (ASAMI KOJI) 19 February 2004 (2004-02-19)	1,2,4-7
A	the whole document	3,8
X	US 2002/176522 A1 (FAN YIPING) 28 November 2002 (2002-11-28)	1,2,4-7
A	the whole document	3,8
A	PATENT ABSTRACTS OF JAPAN vol. 015, no. 004 (E-1020), 8 January 1991 (1991-01-08) & JP 02 260820 A (NEC HOME ELECTRON LTD), 23 October 1990 (1990-10-23) abstract	1-8

[ ] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 April 2005	12/04/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Lindhardt, U

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