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Datasheet for the decision of 16 April 2013

Case Number: T 1683/10 - 3.4.02

Application Number: 04252481.9

Publication Number: 1475629

IPC: G01N25/72, G01N29/06, G06T7/00, G01N21/70

Language of the proceedings: EN

Title of invention:
Infrared defect detection via broad-band acoustics

Applicant:
United Technologies Corporation

Relevant legal provisions:
EPC Art. 54(1), 56, 84

Keyword:
Clarity (yes - amended claims)
Novelty and inventive step (yes - amended claims)

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Case Number: T 1683/10 - 3.4.02

D E C I S I O N
of Technical Board of Appeal 3.4.02
of 16 April 2013

Appellant: (Applicant)	United Technologies Corporation United Technologies Building, 1 Financial Plaza Hartford, CT 06101 (US)
Representative:	Leckey, David Herbert Dehns St Bride's House 10 Salisbury Square London EC4Y 8JD (GB)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted on 11 March 2010 refusing European patent application No. 04252481.9 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman: A. G. Klein
Members: F. J. Narganes-Quijano
D. Rogers

Summary of Facts and Submissions

I. The appellant (applicant) lodged an appeal against the decision of the examining division refusing European patent application No. 0425481.9 (publication No. 1475629).

In its decision the examining division held that the subject-matter of the sets of claims of the main and the two auxiliary requests then on file was not clear (Article 84 EPC) and was anticipated (Articles 52(1) and 54 EPC) by the disclosure of each of the following documents:

D1: US-A-2002/0172410
D2: US-B-6399948
D3: WO-A-0153821
D4: WO-A-2004020993.

II. With the statement setting out the grounds of appeal the appellant submitted sets of claims amended according to a series of requests and requested that the decision under appeal be set aside and a patent be granted.

III. In an annex to summons to oral proceedings the Board referred to the following documents:

A1: "Continuous-time signals" Y. S. Shmaliy; Springer (NL), 2006; front pages and pages 13 and 14
A2: "Broadband active sonar: Implications and constraints" H. Lew; Department of Defence, DSTO Aeronautical and Maritime Research Laboratory, Melbourne (AU), 1996; front pages and pages 2 to 4.

IV. In reply to the comments of the Board in the annex to the summons the appellant submitted with its letter dated 4 April 2013 an amended set of claims 1 to 19 and amended pages 1a and 2 to 4 of the description replacing the corresponding application documents on file, with Figures 8A and 8B on drawing sheet 4/4 of the application being deleted.

In view of the amendments submitted by the appellant, the oral proceedings were cancelled.

V. The wording of independent claims 1 and 8 and of dependent claims 3 and 17 amended according to the main and sole request of the appellant reads as follows:

"1. A method of detecting defects in structures, comprising the steps of:

inducing mechanical energy in a structure (11) via the emission of an acoustic signal and introducing said acoustic signal to said structure (11) via an acoustic source (13);

capturing over a time interval a plurality of images (20, 40, 50) of said structure (11) each of said plurality of images (20, 40, 50) comprised of a plurality of pixels arranged in a plurality of rows and columns each of said pixels indicative of an intensity of infrared energy emitted by a portion of said structure (11) wherein said capturing said plurality of images (20, 40, 50) comprises the steps of:

capturing a background image (20) of said structure (11) prior to said inducing said mechanical energy such that each pixel in said background image (20) possesses a value equal to said intensity of infrared light emitted by a portion of said structure (11) at a first time;

capturing at least one additional image (40, 50) each coincident with said background image (20) such that each corresponding pixel in each of said at least one additional image (40, 50) possesses a value equal to said intensity of infrared light emitted by a portion of said structure (11) at a different time; and

computing a curve (31) for each of said plurality of pixels forming said plurality of images (20, 40, 50) whereby each curve (31) is computed from each of said intensities recorded at a single pixel position in said plurality of images (20, 40, 50) at each of said different times;

characterised in that:

said mechanical energy is induced in said structure by:

generating a broad-band acoustic signal comprised of a plurality of frequencies spread out across a spectrum from 1 KHz to 1 MHz."

"3. The method of claim 1 or 2 wherein said generating said broad-band acoustic signal comprises the step of generating an acoustic signal comprising a frequency spectrum between 10 KHz and 50 KHz."

"8. An apparatus for detecting defects in structures comprising:

an acoustic frequency generator (15) adapted to generate an acoustic energy signal;

an acoustic energy source (13) adapted to transmit said acoustic energy signal to said structure (11);

an optical device (17) for detecting and recording as a plurality of images (20, 40, 50) an amount of infrared energy emitted by said structure (11) at a plurality of locations; and

an image processor (3) for processing said images (20, 40, 50);

said optical device is configured to record a background image of said structure prior to transmitting said acoustic energy signal to said structure such that each pixel in said background image (20) possesses a value equal to said intensity of infrared light emitted by a portion of said structure (11) at a first time;

said optical device is further configured to record at least one additional image (40, 50) each coincident with said background image (20) such that each corresponding pixel in each of said at least one additional image (40, 50) possesses a value equal to said intensity of infrared light emitted by a portion of said structure (11) at a different time; and

said image processor is configured to compute a curve (31) for each of said plurality of pixels forming said plurality of images (20, 40, 50) whereby each curve (31) is computed from each of said intensities recorded at a single pixel position in said plurality of images (20, 40, 50) at each of said different times;

characterised in that:

said acoustic frequency generator is adapted to generate a broad-band acoustic energy signal comprised of a plurality of frequencies spread out across a spectrum from 1 KHz to 1 MHz."

"17. The apparatus of any one of claims 8 to 16 wherein said broad-band acoustic energy signal spans a spectrum between 10 KHz and 50 KHz."

The appellant's request also includes dependent claims 2 and 4 to 7 and dependent claims 9 to 16, 18 and 19 referring back to independent claims 1 and 8, respectively.

Reasons for the Decision

1. The appeal is admissible.

2. *Amendments*

The Board is satisfied that the application documents amended according to the present request of the appellant satisfy the formal requirements of the EPC. In particular, independent claims 1 and 8 are based on independent claims 1 and 14 as originally filed, respectively, together with the features defined in dependent claims 2, 4, 11 and 12 and in the passages on page 3, lines 12 to 14 and page 4, lines 18 to 21 of the description of the application as originally filed; and dependent claims 2 to 7 and 9 to 19 are based on dependent claims 3, 5, 8 to 10, 13, 15 to 22, 24, 27 and 28 as filed, respectively (Article 123(2) EPC).

As regards the description, its content has been revised and brought into conformity with the invention as defined in the claims as presently amended (Article 84 EPC, second sentence and Rule 42(1) (c) EPC) and the pertinent prior art has been appropriately acknowledged in the introductory part of the description (Rule 42(1) (b) EPC).

3. *Clarity*

3.1 The method defined in present claim 1 corresponds in substance to that of claim 1 of the main request underlying the decision under appeal. In its decision the examining division held that the subject-matter of claim 1 was not clear (Article 84 EPC) because the claimed method referred to "a broad-band acoustic signal comprised of a plurality of frequencies spread

out across a spectrum from 1 KHz to 1MHz" and this feature was vague and unclear in the light of the preferred embodiment defined in dependent claims 4 and 5 of the main request then on file relating to a broad-band acoustic signal "comprising at least two non-harmonically related frequencies".

As noted by the Board in the communication annexed to the summons to oral proceedings with reference to document A1 (Figure 1.11 and section 1.2.7) and document A2 (Figure 3 and paragraphs bridging pages 2 and 3) and in agreement with the disclosure of the application relating to Figure 7A (page 3, lines 12 to 20 of the description), a broad-band acoustic signal is a signal having a spectrum of frequencies distributed over a wide range of frequencies and presupposes that the spectrum of frequencies is either continuous or at least constituted by a high number of discrete frequencies extending over the wide range. An acoustic signal having in the spectral domain only two or a relatively small number of discrete frequencies within a predetermined range of frequencies - as it appears to be the case in the previous dependent claims 4 and 5 and in the embodiment disclosed in the application as filed with reference to Figures 8A and 8B - cannot therefore be considered a broad-band acoustic signal within the proper meaning of the term.

In reply to the Board's comments the appellant deleted the previous dependent claims 4 and 5 as well as Figures 8A and 8B of the drawings and the corresponding passages of the description. As a result of these amendments, the Board considers that the method defined in claim 1 is clear and that no part of the application as now amended sheds doubts on the technical meaning of the subject-matter of claim 1.

The previous dependent claims 20 and 21 then on file and referring back to independent apparatus claim 10 of the then main request (now independent claim 8) were also objected to by the examining division on the same grounds and have also been omitted from the set of claims presently on file. Therefore, the same conclusion above also applies to present independent claim 8.

3.2 In its decision the examining division also objected that the skilled person would not consider a frequency spectrum from 10 to 50 kHz as defined in dependent claim 3 to be spread out across a spectrum from 1 kHz to 1 MHz as required by claim 1 (Article 84 EPC). Claim 1, however, requires a broad-band acoustic signal comprising frequencies "spread out across a spectrum from 1 KHz to 1 MHz" and this requirement will be understood by the skilled person in its technical context not in the sense that the wide range of frequencies of the broad-band signal covers the whole claimed range 1 kHz to 1 MHz, but - as submitted by the appellant - rather in the sense that the wide range of frequencies of the signal is included within, or encompassed by the range 1 kHz to 1MHz. There is therefore no inconsistency between the subject-matter of claim 1 and the features defined in dependent claim 3.

The same considerations apply to the subject-matter of independent claim 8 and the features of dependent claim 17.

3.3 In view of the above considerations, the Board concludes that the subject-matter of the claims is clear within the meaning of Article 84 EPC.

4. *Novelty and inventive step*

4.1 Claim 1 is directed to a method of detecting defects in structures consisting essentially in capturing an infrared background image of the structure, applying to the structure mechanical energy in the form of an acoustic signal, subsequently capturing an infrared image of the structure, and carrying out a computation on the basis of the intensities of the two images at each of a plurality of image pixel positions.

Claim 1 further requires that the acoustic signal is a broad-band acoustic signal comprised of a plurality of frequencies spread out across a spectrum from 1 kHz to 1 MHz.

In its decision the examining division - relying in part on the objections of lack of clarity - held that the subject-matter of claim 1 was anticipated by each of documents D1, D2 and D3. In an *obiter dictum* the examining division also expressed its view that document D4 anticipated the claimed invention. In view of the amendments brought to the claims, however, the Board cannot follow the examining division's view in this respect for the following reasons:

4.1.1 Document D1 discloses a vibrothermographic method of identifying cracks and sub-surface anomalies in a material (abstract), the method consisting in generating acoustic energy by means of an ultrasonic transducer, applying the energy to the material, and using an infrared camera for detecting transient local temperature variations in the material (Figure 19 and paragraph [0119] *et seq*.).

According to the disclosure of the document the acoustic energy is "in the range of 10 kHz to 30 kHz" (page 10, second column, lines 7 to 10). The examining division interpreted this feature as an indication that different frequencies of the corresponding acoustic signal are present within the range 10 to 30 kHz and concluded that the signal was a broad-band acoustic signal as claimed. However, as submitted by the appellant in the statement of grounds of appeal, prior art vibrothermographic techniques as that referred to in document D1 generally involve the use of an acoustic signal having a single frequency - or a narrow band of frequencies centered about a single frequency - and, in the absence of any indication to the contrary, the skilled person would understand the aforementioned disclosure of document D1 in the sense that the frequency of the acoustic signal is between 10 and 30 kHz, and not in the sense that - as assumed by the examining division - the range 10 to 30 kHz constitutes the actual spectral band of frequencies of the acoustic signal.

Consequently, there is no clear and unambiguous disclosure in document D1 of a broad-band acoustic signal within the proper meaning of the expression as set forth in point 3.1 above, second paragraph.

4.1.2 Document D2 discloses the non-destructive inspection of a component using an infrared imaging technique and the introduction of pulsed sound signals in the component (title and abstract; see also Figures 1 and 3 to 5 and the corresponding description). The document further specifies that the frequency of the pulsed signal can be changed with time (abstract, column 3, lines 24 to 30, column 4, lines 38 to 43, and column 7, line 54 to column 8, line 4) and that the time varying signal can

be, in particular, a stepped frequency signal having discrete frequency values or a swept frequency having a continuous range of rapidly swept frequencies (column 8, lines 4 to 10). Thus, the frequency of the sound signal varies with time, but at each time instant the pulsed signal has a predetermined frequency (*cf.* column 3, lines 41 to 45, column 4, lines 43 to 47, column 5, lines 32 and 33, column 6, lines 5 to 9, and column 7, line 67 to column 8, line 10).

Accordingly, there is no explicit or implicit disclosure in document D2 of the use of a broad-band acoustic signal as claimed. This conclusion is not affected by the fact that - as noted by the examining division in its decision - the claimed broad-band acoustic signal may also include swept frequency components as disclosed in the application with reference to Figure 7B because these components relate to the time varying characteristics of the signal and not to the spectral characteristics of the signal at each time instant.

4.1.3 Document D3 discloses the detection of impact damage in a material by inducing ultrasonic energy in the material and capturing the resulting thermal radiation by means of an infrared camera (abstract together with Figures 1 and 2 and the corresponding description). The ultrasonic energy is generated by two ultrasonic probes operating at different frequencies, namely at 35 and 40 kHz, respectively (page 6, last paragraph).

Thus, the technique disclosed in document D3 involves the use of two discrete frequencies which - as noted in point 3.1 above - do not constitute a broad band of frequencies as required by the claimed invention.

4.1.4 Document D4 constitutes prior art within the meaning of Article 54(3) EPC. The document discloses a method of detecting defects in a structure, the method including the steps of energizing the structure by means of sound energy having one or more frequencies and imaging the structure by means of a thermal imaging camera (abstract and page 4, lines 6 to 12). The camera generates images constituted by an arrangement of pixels (page 8, lines 24 and 25), but the document is silent as to a processing operation of the intensities of the images at each of a plurality of image pixel positions as required by the claimed method.

4.1.5 Having regard to the above, the method defined in claim 1 is new over the disclosure of documents D1 to D4 considered by the examining division in its decision. The remaining documents on file are less relevant than documents D1 to D4.

4.2 According to the disclosure of the application, the bandwidth characteristics of a broad-band acoustic signal as claimed improves the detection of defects in structures having complex geometries (page 1, lines 19 to 23, and page 3, lines 20 to 22 and 33 to 35). None of the documents on file constituting prior art within the meaning of Article 54(2) EPC discloses or suggests the use of a broad-band acoustic signal in an inspection method of the type under consideration, nor the technical effects achieved therewith. In particular, document D3 addresses the problem of improving the detection capability of the inspection method (page 1, second paragraph, page 7, second and third paragraphs, and page 8, second paragraph), but the document only proposes the use of an acoustic signal having two signal components intensity-modulated $\pi/2$ out of phase and having respectively a frequency of

35 and 40 Hz (page 6, last paragraph, and page 3, second paragraph); and documents D1 and D2 are - as already concluded in points 4.1.1 and 4.1.2 above - silent as to the use of a broad-band acoustic signal.

Accordingly, the method defined in claim 1 involves an inventive step within the meaning of Article 56 EPC over the available prior art.

4.3 Independent claim 8 is directed to an apparatus for detecting defects in structures, and the functional and structural features of the different means of the claimed apparatus are essentially in one-to-one correspondence with the steps of the method defined in claim 1. Accordingly, the assessment of novelty and of inventive step of the method of claim 1 in points 4.1 and 4.2 above is readily applicable to the apparatus defined in independent claim 8.

4.4 The Board concludes that the subject-matter of independent claims 1 and 8, as well as that of dependent claims 2 to 7 and 9 to 19, is new and involves an inventive step over the available prior art (Article 52(1) together with Articles 54(1) and 56 EPC).

5. The Board is also satisfied that the application documents amended according to the present request of the appellant and the invention to which they relate meet the remaining requirements of the EPC within the meaning of Article 97(1) EPC. The Board therefore concludes that the decision under appeal is to be set aside and a patent be granted on the basis of the application documents amended according to the present request of the appellant.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the department of first instance with the order to grant a patent on the basis of the following application documents:
   - claims: claims 1 to 19 filed with the letter dated 4 April 2013;
   - description: page 1 filed with the letter dated 18 December 2007, pages 1a and 2 to 4 filed with the letter dated 4 April 2013, and pages 5 and 6 of the application as filed; and
   - drawings: sheets 1/4 to 3/4 of the application as filed, sheet 4/4 of the application being cancelled.

The Registrar: The Chairman:

M. Kiehl A. G. Klein

Decision electronically authenticated