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(54) Title: LOCALIZING, WAKING-UP, AND ESTIMATING DIRECTION OF FEMTO-SATELLITES

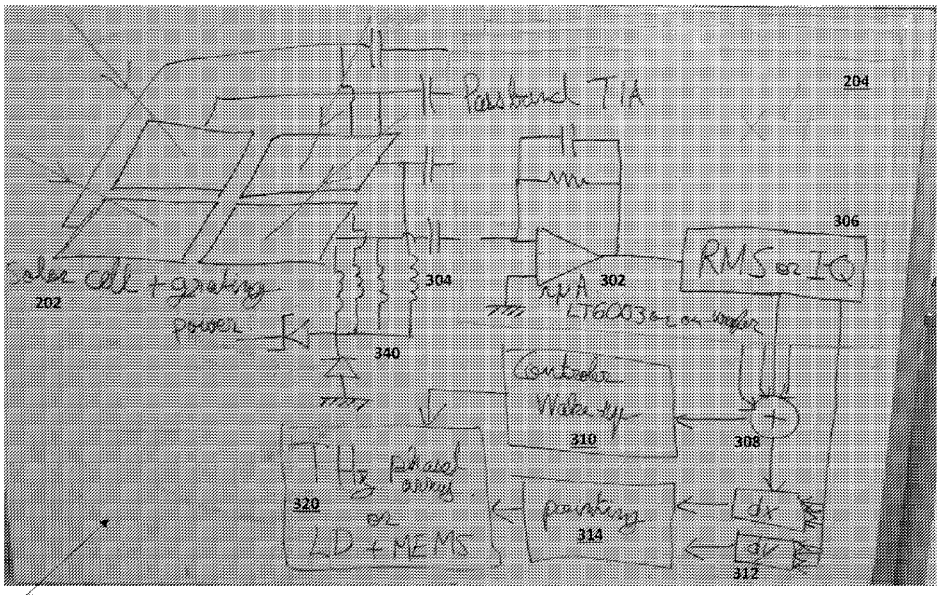

FIG. 2B

(57) Abstract: Femto-satellites are very small satellites that can be deployed in constellations from a larger mothership satellite for distributed measurement. They are too small to accommodate the GNSS receivers that many satellites use for navigation, but they can be located with an electromagnetic beam from the mothership satellite. The mothership satellite scans this beam across a constellation of femto-satellites. When the beam scans across a particular femto-satellite, the femto-satellite transmits an acknowledgement to the mothership satellite, e.g., by retroreflecting the beam or via a separate radio link. The beam can be modulated with commands for the femto-satellite, such as to make a measurement or transmit previously acquired data, as well with commands for determining the femto-satellite' s location, such as a time stamp or beam pointing information. The femto-satellite can determine its location from the information modulated onto the beam or transmit the time stamp to the mothership satellite for localization.

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[Continued on next page]

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 22/27491

A. CLASSIFICATION OF SUBJECT MATTER

IPC - INV. G01S 5/00, G01S 19/00, H04B 7/185, B64G 1/10; ADD. H04W 84/06 (2023.01)

CPC - INV. G01S 5/0009, G01S 19/00, H04B 7/18515, H04B 7/18513, H04B 7/18521, B64G 1/10; ADD. H04W 84/06, H04B 7/18552, G01S 19/01

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)
See Search History document

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2018/0269130 A1 (Ejeckam et al.) 20 September 2018 (20.09.2018); entire document, especially, abstract, FIG. 1, para [0005], [0051]	1-12
A	US 5,787,336 A (Hirschfield et al.) 28 July 1998 (28.07.1998); entire document, especially, abstract, FIG. 3, col.1, ln 5-8, col.6, ln 39-52,	1-5
A	US 2017/0272149 A1 (Michaels) 21 September 2017 (21.09.2017); entire document, especially, abstract, para [0016],[0017],[0022]	1-12
A	US 9,621,850 B1 (Rockwell Collins, Inc.) 11 April 2017 (11.04.2017); entire document	1-12
A	US 2019/0326774 A1 (We Care Solar) 24 October 2019 (24.10.2019); entire document	1-12

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"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
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 22/27491

Continuation of - A.CLASSIFICATION OF SUBJECT MATTER -

IPC - ADD. G01S 19/01 (2023.01)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 22/27491

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I: claims 1-12: drawn to: A femto-satellite: convert incident solar radiation into DC components and filters operably coupled to respective solar cells.
Group II: claims 13-20: drawn to: A method of locating a femto-satellite.

---See Continuation on Supplemental page---

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-12

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 22/27491

Continuation of Box No. III - Observations where unity of invention is lacking -

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Special technical features:
Group I requires: a solar cell array to convert incident solar radiation into direct current (DC) components not found in the other groups.

Group II requires: detecting the electromagnetic beam, the acknowledgement indicating a time stamp associated with the electromagnetic beam; and determining a pointing angle of the electromagnetic beam associated with the time stamp not found in the other groups.

Shared Features:
The only technical features shared by Groups I-II that would otherwise unify the groups are:
A femto-satellite,
an electromagnetic beam scanned by a spacecraft across a portion of outer space containing the femto-satellite,
An acknowledgement of the electromagnetic beam.

However, these shared technical features do not represent a contribution over prior art, because the shared technical features are disclosed by:
US 2020/0024012 A1 to Telespazio S.P.A. (hereinafter 'Telespazio') 23 January 2020 (23.01.2020), which discloses:
A femto-satellite (1, FIG. 1, para [0083] "The satellite TT&C system 1 is an automatic low data rate communication system for LEO satellites, preferably of the small/micro/nano/pico/femto type..."),
An electromagnetic beam (FIG. 2, para [0066] "FIG. 2 schematically illustrates a preferred architecture for the on-board TT&C units of the satellite TT&C system 1."; para [0069] "a receiving/transmitting (Rx/Tx) unit 133 operable to transmit the downlink signals carrying the telemetry data and receive the uplink signals carrying the commands;"

Telespazio does not explicitly disclose:
The beam: scanned by a spacecraft across a portion of outer space containing the femto-satellite,
An acknowledgement of the electromagnetic beam.

Additionally, US 2017/0272149 A1 to Michaels (hereinafter 'Michaels') 21 September 2017 (21.09.2017) discloses:

The beam scanned by a spacecraft across a portion of outer space containing the femto-satellite (para [0016] "In one embodiment of the present invention a satellite transmitter operating at a center frequency of 60 GHz inputs a modulated ultra-wideband signal at a maximum AC power of 24 dBm to a 60 dBi directional antenna beam pointed at a target satellite 301 in orbit at a 600 km altitude above the Earth."; para [0022] "In another aspect of the embodiment of the invention the antenna is a 2-dimensional phased array antenna 401 which forms beams 400 that can be scanned in the X and Y planes with a resolution of less than 0.1 degree. The antenna beam scanning and control sub-system 404 is coupled to the satellite Attitude Determination and Control System (ADCS) 407 and system central processing unit 406 such that the antenna 401 can accurately point and track the target satellite 300 and 301 while compensating residual motion that would otherwise upset the accurate pointing of the antenna."),

An acknowledgement of the electromagnetic beam (para [0017] 'The target satellite may acknowledge (ACK) successful or unsuccessful (NACK) transmissions in either a time domain duplex (TDD) or Frequency domain duplex (FDD) fashion, either transmitting to the source satellite at the same frequency or preferably at another duplex frequency lying within the same or a different absorption band.").

It would have been obvious to a person of ordinary skill in the art to have included the method of scanning the beam and further receiving/transmitting an acknowledgment as per Michaels for the femto-satellite of Telespazio since it allows for tracking the target satellite as required (Michaels, para [0022]).

As the shared technical features were known in the art at the time of the invention, they cannot be considered special technical features that would otherwise unify the groups.

Groups I-II therefore lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.