

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

JOHNSON CONTROLS INC.

Petitioner,

v.

FRACTUS S.A.,

Patent Owner.

Case IPR 2026-00338

U.S. Patent No. 8,738,103

Title: Multiple-Body-Configuration Multimedia
and Smartphone Multifunction Wireless Device

DECLARATION OF DR. EMMANOUIL TENTZERIS

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I, Dr. Emmanouil Tentzeris, declare as follows:

I. INTRODUCTION

1. I have been retained by Petitioner Johnson Controls Inc. (“Petitioner” or “JCI”) to serve as an independent expert consultant in the Inter Partes review proceedings regarding U.S. Patent No. 8,738,103 (“the ’103 patent”) (Ex.1001). I have been asked to consider the validity of claims 1-11, 13-14, and 16-20 of the ’103 patent (“Challenged Claims”). My opinions are set forth below.

2. I am being compensated at my normal rate of \$750/hour for all services rendered. My compensation is not dependent, in any way, on the nature of my findings, the content of my testimony, or the outcome of this proceeding or any other proceeding.

3. My analysis of the materials produced in this proceeding is ongoing and I will continue to review any new material that is provided. This declaration is indicative of only those opinions that I have formed to date. I reserve the right to amend, revise, and/or supplement my opinions stated herein based on any new information that may become available to me or my continuing analysis of the materials already provided.

II. QUALIFICATIONS

4. My qualifications for forming the opinions in this declaration are summarized here and explained in more detail in my Curriculum Vitae (“CV”),

which is attached hereto as Appendix A.

5. I am currently the Ed and Pat Joy Chair Professor with the School of Electrical and Computer Engineering at Georgia Tech. I have over 30 years of industry and academic experience, including in the area of antennas, fractal RF structures, and circuit design for these systems. I supervise Doctoral students, as well as visiting students, post-doctoral fellows, and other researchers.

6. I received my Bachelor of Science in Electrical Engineering from National Technical University of Athens Greece in 1992. I earned my Master's degree and Ph.D. from the University of Michigan at Ann Arbor in 1994 and 1998, respectively. A complete list of my academic positions, activities, and publications is set out in my CV.

7. Between 1991 and 1992, I was a research assistant in the Microwave Lab at the National Technical University of Athens, Greece. From 1992 to 1998, I was a research assistant in the Radiation Laboratory at the University of Michigan, Ann Arbor. I became an assistant professor at the School of Electrical and Computer Engineering at Georgia Technical Institute in 1998, lasting until I became an Associate Professor in the same School in 2004. I then served as Associate Professor until my promotion to Professor in 2016, a title I have held since then. Also in 2016, I was appointed as the Ken Byers Professor in Flexible Electronics.

8. As a professor of Electrical and Computer Engineering, I have taught

courses relating to antenna and electromagnetic technologies. A complete list of my teaching positions, honors, and classes taught is set out in my CV. As professor, I have collaborated with over 130 Undergraduate, Masters and Doctoral students, as well as visiting students, post-doctoral fellows and other researchers.

9. Throughout my career I have received a variety of awards. I am a Fellow of IEEE, a member of the MTT-15 Committee, an Associate Member of European Microwave Association (EuMA), a Fellow of the Electromagnetics Academy, and a member of Commission D, URSI and of the Technical Chamber of Greece. In recognition of my world-leading achievements in the area of antennas and miniaturized/fractal RF structures, I have served as an IEEE C-RFID (Committee on RFID technologies) Distinguished Lecturer from 2016-2022 and I served as an IEEE MTT Distinguished Microwave Lecturer (DML) from 2010-2012, and I am currently serving as an IEEE EPS (Electronic Packaging Society) Distinguished Lecturer. I have won multiple awards for my contributions in developing various technologies, including numerous multiband antenna topologies operating at different frequencies and integrated RF model up to sub-THz frequencies. My achievements include, but are not limited to, the following:

- IEEE fellow — a distinction reserved for select IEEE members whose extraordinary accomplishments in any of the IEEE fields of interest are deemed fitting of this prestigious grade elevation. IEEE, About the IEEE Fellow Program, <http://www.ieee.org/membership/fellows/>.
- 2025 IEEE Journal of Microwaves Best Paper Award
- 2024 Georgia Tech Outstanding Achievement in Research Innovation Award

- 2024 IEEE International Microwave Symposium (IMS) Best Student Paper Award
- 2022 Georgia Tech Outstanding Doctoral Thesis Advisor Award
- 2021 IEEE Antennas and Propagation Symposium (APS) Best Student Paper Award (co-authored)
- 2019 Humboldt Research Prize
- 2019 IEEE Antennas and Propagation (APS) Conference Co-Chair
- 2018 Intel IEEE ECTC 2018 Best Student Paper Award
- 2015-present IEEE CRFID Distinguished Lecturer
- 2010-2012 IEEE MTT-S Distinguished Microwave Lecturer
- 2017 Georgia Tech Outstanding Achievement in Research Program Development Award
- 2017 Archimedes IP Salon Gold Medal
- 2016 Bell Labs Prize Third Award
- 2015 IET Microwaves, Antennas and Propagation Premium Award
- 2014 Georgia Tech ECE Distinguished Faculty Achievement Award
- 2014 IEEE RFID-TA Best Student Paper Award
- 2013 IET Microwaves, Antennas and Propagation Premium Award
- 2012 Finland Distinguished Professor (Fi.Di.Pro.) Award
- 2012 Architecture Award of Excellence, Architecture World Summit
- 2010 IEEE Antennas and Propagation Society Piergiorgio L. E. Uslenghi Letters Prize Paper Award
- 2010 Georgia Tech Senior Faculty Outstanding Undergraduate Research

10. In Google scholar, there are over 34,290 citations to my work and my work has an h-index of 91. An h-index represents the number of papers with the same number of citations, meaning I have over 91 papers with 91 citations.

11. I have authored or contributed to over 36 books and 920 journal and conference papers; spoke in over 150 presentations, many of which relate to antennas, antenna arrays, RFID systems, and other modes of wireless communication and electronic design. A complete list of my publications and conference presentations is provided in my CV.

12. I am a named inventor on 28 patents in the US and Europe. These include patents relating to antenna design, RF systems, and means of reducing signal interference in RF applications. A complete list of my patents and published applications is included in my CV.

13. In addition to gaining expertise via my academic training, professional experience, and research accomplishments described above, I continue to keep abreast of various sub-disciplines within the antennas space, by reading, reviewing and analyzing technical literature, attending and presenting at conferences, and attending and presenting at symposia. I have served as an editor for various journals and participated in the peer reviewed process for various technical journals and conferences, and have reviewed manuscripts submitted by other scholars relating to antenna topologies. I have contributed further to the profession by chairing conference committees and planning conferences and panels. Furthermore, I have collaborated with or have communicated with many scholars and engineers in the field of antenna systems.

14. I am not an attorney and offer no legal opinions, but in the course of my work, I have had experience studying and analyzing patents and patent claims from the perspective of a person of ordinary skill in the art.

III. MATERIALS CONSIDERED

15. In coming to my opinions set forth herein, I have reviewed and/or

considered each of the Challenged Claims and relevant portions of their prosecution histories, as well as background literature and prior art as cited throughout this Declaration. The bases for my opinions include the prior art and observations cited in this Declaration, my education and experience.

IV. LEGAL STANDARD

16. I am not a lawyer and therefore Counsel has informed me that the following patent law is applicable to the relevant issues in this case. In coming to my opinions in this Declaration, I have applied my understanding of the below patent law principles.

A. The Presumption of Validity

17. I understand that an issued U.S. patent is presumed valid. I also understand that each Challenged Claim is presumed valid. To find a patent claim invalid/unpatentable, a defendant bears the burden of proving invalidity by preponderance of the evidence. I am informed that this preponderance of the evidence standard means that Petitioner must show that invalidity/unpatentability is more probable than not.

B. Claim Construction and Level of Ordinary Skill in the Art

18. I understand that there is a two-step process that must be applied in order to determine whether a Challenged Claim is anticipated or obvious based on the prior art: First, the patent claims must be construed. Second, the properly construed claims must be examined in view of the scope and content of the prior art.

19. Regarding construing the claim terms, I have been told the claim term(s) should be analyzed under their ordinary and customary meaning as understood from the perspective of one of ordinary skill in the art at the time of the invention, taking into account the claim language itself, patent specification, and prosecution history pertaining to the patent, as well as relevant extrinsic evidence.

20. I have also been informed that the validity of a patent claim is evaluated from the perspective of a “person of ordinary skill in the art” (“POSA”) or a “skilled artisan” at the time of the invention. I understand that a POSA is a hypothetical person considered to have the skill level and knowledge of a particular field related to an alleged invention claimed in a patent.

21. I also understand that a POSA is presumed to have before them all of the relevant prior art that was publicly available at the time of the invention. A POSA can be more than one person and/or have access to a team of people at the time of the invention.

C. Obviousness

22. I understand that a patent claim may be invalid if, as a whole, it would have been obvious to a POSA as of the effective filing date of the patent claim. A patent claim is obvious if a single prior-art reference/disclosure or a combination of prior-art references/disclosures and a POSA’s knowledge would have rendered the claimed invention an obvious implementation as of the effective filing date of the

patent. Obviousness can be shown by demonstrating that a POSA would have been motivated to combine references and/or knowledge with a reasonable expectation of success in applying the prior art teachings.

23. I also understand that absent demonstration of criticality, ranges of a parameter recited in Challenged Claims, do not indicate nonobviousness over prior art that disclosed a different value for the same parameter.

24. Whether a patent claim would have been obvious requires an analysis of the scope and content of the prior art and a comparison of the prior art to the patent claim in light of the level of ordinary skill in the pertinent art.

25. I understand that the named inventor's path to making or conceiving of the claimed subject matter cannot, however, serve to demonstrate the subject matter's obviousness. Therefore, in my analysis set forth herein, I did not use the inventor's path, nor did I start with patent claims and work backwards. In my analysis, I reviewed the prior art leading up to the effective filing date of the patent and determined what conclusions a POSA would have reached about obvious implementations, and then applied my opinions to the Challenged Claims.

26. I understand that one must also consider if there is evidence of objective indicia (or "secondary consideration") of non-obviousness, which may include commercial success of the claimed subject matter, fulfilling a long-felt but unresolved need, copying of the claimed subject matter, failure of others to make the

claimed subject matter, praise for the invention, and/or unexpected results. If any of these secondary considerations is asserted, then I understand that a patent owner must also show a nexus or connection between the secondary consideration and the inventive aspect of the claims to which that secondary consideration allegedly apply.

V. PERSON OF ORDINARY SKILL IN THE ART

27. As noted above, I have been informed by counsel that my analysis is to be conducted from the perspective of a hypothetical person of ordinary skill in the art (“POSA”) and what a POSA would have known, understood, and be familiar with in view of the relevant prior art, and that such person is not an automaton, but rather a person of ordinary creativity.

28. I understand that Fractus has previously defined a POSA as

[A] person with at least a bachelor’s degree in electrical engineering, computer science, or a similar degree and at least four years experience in applied electromagnetics with an emphasis on antennas. Alternatively, the person of ordinary skill in the art would have a master’s degree in electrical engineering (or similar discipline) and at least two years of similar experience.

Ex.1008, 9. I generally agree with this definition of a POSA and have applied the above definition in coming to my opinions set forth herein.

29. As of the earliest priority date for the ’103 patent, I possessed at least the level of skill of a POSA to which the ’103 patent is directed.

VI. THE ’103 PATENT

30. I have reviewed and analyzed the ’103 patent, which is titled “Multiple-

Body-Configuration Multimedia and Smartphone Multifunction Wireless Devices,” including the issued claims, specification and excerpts of the prosecution history. The ’103 patent issued May 27, 2014, from application no. 11/614,429.

A. Priority Date

31. In coming to my opinions set forth herein, Counsel has asked that I assume July 18, 2006, as the earliest possible priority date for the ’103 patent. Therefore, I have not personally conducted an analysis to determine the earliest possible priority date for the claims of the ’103 patent in coming to my opinions set forth herein.

B. Prosecution History

32. The application from which the ’103 patent issued (No. 11/614,429) was filed on December 21, 2006. During prosecution, the applicant filed 27 different Information Disclosure Statements (“IDS”) that identified potential prior art references.

33. On August 16, 2010, the examiner issued a non-final office action that rejected original pending claims 1-3, 6-9, 11, 14 and 20 as being unpatentable over the combination of U.S. Patent No. 7,548,915 (“Ramer”) and U.S. Application Publication No. 2004/0119644 (Baliarda). Pending claims 12 and 13 were rejected as being unpatentable over a combination of Ramer, Baliarda, and U.S. Patent No. 7,183,983 (“Ozden”). *Id.*,174. Pending claims 16-19 were rejected as being

unpatentable over the combination of Ramer, Baliarda, and U.S. Patent Application Publication No. 2002/0175211 (“Dominquez”). *Id.*, 178. Pending claims 10 and 15 were rejected as being unpatentable over the combination of Ramer, Baliarda, and U.S. Patent Application No. 2007/0229383 (“Koyanagi”). *Id.*, 183. On February 11, 2011, Applicant responded and made no amendments nor cancellations to any of their then pending claims. *Id.*, at 147.

34. On March 7, 2011, the examiner issued a final rejection maintaining the original rejections based on various combinations of Ramer, Baliarda, Ozden, Dominquez, and Koyanagi. *Id.*, 117-45. Applicant requested continued examination on March 21, 2011. *Id.*, 115. Examiner issued a final rejection on May 27, 2011. *Id.*, 87-114.

35. On November 23, 2011, applicant filed a request for continued examination and amended the pending independent claims 1, 6, 18, and 20. *Id.*, 70-85. Examiner issued a non-final rejection on March 19, 2013, which stated that pending claims 1-3, 6-9, 11-14, and 20 were unpatentable over U.S. Patent No. 6,989,794 (“Tran”) in view of Ramer. *Id.*, 52. Pending claims 4-5 were rejected as being unpatentable over Tran in view of Ramer and Dominquez. *Id.*, 61. Pending claims 10 and 15 were rejected as being unpatentable over Tran in view of Ramer and Koyanagi. *Id.*, 62. Pending claim 16 was rejected as unpatentable over Tran in view of Dominquez. *Id.*, 64. Pending claim 17 was rejected as being unpatentable

over Tran in view of Dominquez and Ramer. *Id.*, 66. Pending claims 18-19 were rejected as being unpatentable over U.S. Patent No. 6,476,769 (“Lehtola”) in view of Ramer and Dominquez. *Id.*, 67.

36. On July 17, 2013, Applicant cancelled pending claims 1-20 and added pending claims 21-40. *Id.*, 35-48. Examiner responded that the amendment was non-responsive and withdrew pending claims 21-40 from consideration as being directed to a non-elected invention. *Id.*, 32-34. Applicant responded on November 13, 2013, by amending pending claims 1-5 and 16-20, canceling pending claims 6-15, and adding pending claims 21-30. *Id.*, 10-30.

37. A notice of allowance was issued on January 8, 2014 and the Examiner’s reason for allowance was that the prior art did not render obvious or anticipate the limitation: “wherein a perimeter of the second antenna element defines an antenna contour having a complexity level defined by the factor F_{21} having a value of at least 1.20 and complexity factor F_{32} having a value less than 1.75 and

wherein a perimeter of the first antenna element defines a first antenna contour comprising at least thirty five segments, the first antenna element defining an antenna box, an orthogonal projection of the antenna box along a normal to a face with a largest area of the antenna box defining an antenna rectangle, wherein a length of the first antenna contour is greater than four times a diagonal of the antenna rectangle; and a second antenna element configured to operate in at least one frequency band used by a 4G communication standard, wherein a perimeter of the second antenna element defines a second antenna contour comprising at least twenty segments.”

Id., 7-9.

C. IPR2024-0087

38. In October 2023, Vivint, Inc. (“Vivint”) filed IPR2024-0087 asserting that claims 12 and 15 of the ’103 patent are unpatentable and should be canceled. I submitted an expert declaration (IPR2024-0087, Ex.1002) in support of Vivint’s IPR petition asserting that in my opinion claims 12 and 15 were obvious in view of Johnson and Boireau; and Zeilinger and Boireau. I understand that Vivint and Fractus settled their dispute and the IPR2024-0087 was dismissed before Fractus submitted a preliminary response.

D. *Ex Parte* Reexamination No. 90/019,500

39. I understand that on July 24, 2024, the USPTO issued an Order Granting Request for *Ex Parte* Reexamination of claims 12 and 15 of the ’103 patent because Boireau and Zeilinger—i.e., the same prior art that I relied on in coming to my opinions regarding the obviousness of claims 12 and 15—“do raise a substantial new question of patentability.” Ex.1004, 8.

40. I understand that as part of the *ex parte* proceedings, on November 7, 2024, the Examiner rejected claims 12 and 15 as obvious, in part, because

[i]t would have been obvious to achieve the claimed invention by modifying the wireless device of Boireau to include two internal antenna elements and a ground plane layer, such as disclosed by Zeilinger, because Boireau expressly teaches incorporating an antenna system comprising one or more PIFAs into the wireless device at

paragraph [0025], and Zeilinger teaches that the claimed configurations of the first and second antenna elements were conventional configurations of PIFA-style antenna suitable for use in handheld wireless communication devices [and] the projection of the antenna rectangle on the ground plane rectangle partially overlapping the ground plane rectangle (i.e., as illustrated in FIG. 3 of Zeilinger, the ground plane layer 50 is substantially rectangular in shape and is overlapped by the rectangular footprint of the antenna 40).

Ex.1005, 11-12.

41. I understand that in response, the patent owner chose not to substantively address the assertions from the examiner's rejection and instead "cancel[ed] claims 12 and 15 without prejudice or disclaimer." Ex.1006, 4. An Ex Parte Reexamination Certificate issued thereafter stating that "As a Results [sic] of Reexamination, it has been determined that: claims 12 and 15 are cancelled. Claims 1-11, 13, 14, and 16-20 were not reexamined." Ex.1003, 1:7-12.

E. Specification of the '103 Patent

42. The '103 patent generally describes "A multifunction wireless device having at least one of multimedia functionality and smartphone functionality, the multifunction wireless device." Ex.1001, Abstract. "The multifunctional wireless device further includes an antenna system disposed within at least one of the upper body and the lower body and having a shape with a level of complexity of an antenna contour defined by complexity factor F_{21} having a value of at least 1.05 and not greater than 1.80 and F_{32} having a value of at least 1.10 and not greater than 1.90."

Id.

43. The '103 patent specification catalogs constraints and concerns related to the integration of multiband antennas into compact handheld devices such as smartphones. *Id.*, 1:30-4:31. However, the “problems” identified in the '103 patent—i.e., achieving small, efficient, multiband internal antennas; integrating multiple internal antennas with acceptable mutual coupling and efficiency, choosing practical placements with respect to a handset ground plane and other modules; and maintaining multi-standard coverage including higher-throughput services—were not new by July 2006 and had been substantively addressed with concrete engineering solutions as disclosed in the prior art literature and otherwise embodied in contemporaneous device architectures in the field. For example:

- Bandwidth – Citing to Chu (1948) and Wheeler (1947), the '103 patent specification states that “[s]mall antennas may not exceed a certain bandwidth”, that bandwidth “decreases in proportion to the volume”, and that high-permittivity miniaturization increases Q and reduces bandwidth, linking reduced size to reduced data rate. *Id.*, 2:52-62. However, Ciais-Quadband’s internal quad-band PIFA had already addressed this issue. The Ciais-Quadband antenna introduced a slot into “a dual-band PIFA antenna tuned to operate at center frequencies of 935 MHz and 1930 MHz” to “allow[] a frequency decrease of its fundamental resonance while the use of an end

positioned capacitive load allows its higher order modes to be decreased in frequency.” Ex.1014, 1. The Ciais-Quadband antenna also added “three quarter-wave parasitic elements . . . to create new resonances and thus enlarge both lower and upper impedance bandwidth.” *Id.* This approach yielded GSM/DSC/PCS and UMTS coverage with $VSWR \leq 2.5/2$ on a realistic 40.5 mm x 105 mm PCB, thereby demonstrating a practical path to useful bandwidth at small volume despite the known size-bandwidth tradeoffs. *Id.*

- Narrow bandwidths of patch/PIFA antennas – The ’103 patent specification also notes that patch/PIFA antennas are “known to have poor gain and narrow bandwidths, typically in the range of 1% to 5%,” that increasing patch-ground separation to widen bandwidth “destroys the advantage of patch antennas being flat” and distorts patterns, and further discloses that using high-dielectric material to reduce size “tend[s] to reduce the bandwidth.” Ex.1001, 3:43-56.

As, already discussed above, Ciais-Quadband had already shown concrete solutions that broaden both low and high bands with use of parasitic quarter-wave elements, placed and loaded to couple with the main folded PIFA. Measured and simulated results of this approach showed computed efficiencies above approximately 69% (GSM) and 74% (DSC/PCS/UMTS). Ex.1014, 3.

- Interaction of multi-branches – The '103 patent specification states that in multiband designs “currents and charges in the respective parts always interact with one another by strong and far-reaching electromagnetic fields,” that “those different antenna branches are . . . never completely independent,” and that “trying to add a new branch . . . changes entirely the previous antenna frequencies.” So, “all previously achieved optimizations . . . are lost.” Ex.1001, 3:60-4:4.

Ciais-Quadband also addresses this issue. Ciais-Quadband describes stepwise design where parasitic elements are added individually and jointly, with careful adjustment of their dimensions and gaps to achieve “the best possible coupling between the resonances,” transforming narrow, separated modes into broader, usable bands in a controlled repeatable way on a hand-scale PCB. Ex.1014, 2; Fig. 2.

Coupling – The '103 patent states that using “two closely neighboring bands” requires additional resonant structures and space, that elements “may not be provided too close together since . . . electric coupling . . . [prevents] merging . . . into a single band,” and that “for broadband operation the resonating physical structure needs a certain width,” which is hard to achieve in small antennas. Ex.1001, 3:11-38.

Pre-2006 literature already supplied layout and ground-engineering recipes to

suppress inter-element coupling and preserve efficiency with multiple internal antennas. CN456 taught a four-element internal PIFA system arranged in PCB quadrants with explicit inter-element spacing windows of just $0.1-0.5\lambda$, orthogonal alignment of like edges, and two key decoupling measures: (i) a via-stitched cross-shaped grounded metal island between elements, and (ii) a slot between quadrants to interrupt chassis-current coupling. Ex.1016, 7, Claims 3, 4. Measured S-parameters showed inter-port transmission kept modest with spacing under 0.5λ and in-band average radiation efficiency exceeding 80% around 2.25-2.30 GHz, validating low coupling without sacrificing efficiency in a compact mobile device. *Id.*, 8-9.

- Other challenges – The specification further generalizes that designing three or more bands causes a linear to exponential growth in parameters, that isolation between multiple RF devices on shared antennas is “a very difficult task,” and that mechanical and platform variations perturb antenna characteristics. Ex.1001, 4:5-18.

The art as of 2006 had also addressed these issues through progress on both the physical and system sides of antenna development in compact devices. Physically, CN456 disclosed a multi-element, low-coupling internal layout for compact terminals, with quantified spacing, orientation, and grounded island/slot countermeasures to preserve efficiency and reduce correlation—

thereby addressing the multi-antenna isolation and efficiency problem within a compact device. Ex.1016, Abstract, [57].

As for the system-level solution, Boireau implemented sharing under control of an antenna management module and switch/filter front-end so multiple radios (e.g., cellular, 802.11x, Bluetooth) share one internal antenna or an array while time-multiplexing access, coordinating transmit/receive activities and coexistence protocols to prevent simultaneous TX/TX or TX/RX conflicts and to avoid LNA overload; Boireau explicitly teaches that this architecture reduces antenna interference, size, and complexity in smartphones while preserving user-perceived QoS in substantially simultaneous Wi-Fi/Bluetooth usage scenarios. Ex.1015, Abstract, [0016].

Ciais-Quadband also addressed these issues. Ciais-Quadband grounds its multiband antenna development on a realistic handset PCB and documents how PCB length and placement (e.g., locating the feed and shorting structures at the top of the PCB) shape bandwidth and patterns through antenna–chassis interaction, giving practitioners rules of thumb already used before the earliest priority date of the '103 patent. Ex.1014, 1 (“the PCB size, especially its length, has a strong influence on the performance of mobile phone antennas”); *id.*, 1-2 (“it has been previously shown that both the antenna with its feeding and shorting pins always have to be positioned at the top of the PCB to obtain

an efficient antenna-chassis combination, especially maximum bandwidth behavior.”).

44. Moreover, the “solution” for these already well-recognized issues proffered by the ’103 patent specification are the same pre-2006 antenna engineering operations that were already well-known to the field and routinely implemented for internal, multiband smartphone antennas: adding and shaping slots and apertures; folding or bending to add capacitive loading; dividing a radiator into multiple elements; exploiting chassis currents through ground-edge placement; and applying terminal-level layout/ground strategies to mitigate coupling when multiple antennas are used. Ex.1001, 12:41-13:2. Indeed, as already discussed above, Ciais-Quadband, CN456, and Boireau had already disclosed using these same strategies.

45. The ’103 patent specification merely packages these known geometric and placement solutions in the context of numerically bounded contour “complexity factors” denoted as “ F_{21} ” and “ F_{32} .” Ex.1001, 16:28-35 (“the level of complexity of an antenna contour can be advantageously parameterized by means of two complexity factors, hereinafter referred to as F_{21} and F_{32} , which capture and characterize certain aspects of the geometrical details of the antenna contour (such as for instance its edge-richness, angle-richness and/or discontinuity-richness) when viewed at different levels of scale.”); *id.*, 35:4-13 (“a set of specifications for an antenna system can be translated into a certain level of geometrical complexity of

the antenna contour associated to the structure of said antenna system, which is advantageously parameterized by means of factors F_{21} and F_{32} Therefore, once a set of specifications has been compiled one embodiment of the design method of the present invention translates a set of specifications into a target region of the (F_{21} , F_{32}) plane.”).

46. While the '103 patent specification allegedly discloses at least one new way to describe the geometric and spatial characteristics of an antenna—i.e., “complexity factor”, “ F_{21} ” and “ F_{32} ” are terms created by the inventors and are not recognized terms of art within the field of antennas—it does not disclose any previously unknown solutions. For example, it does not disclose a new electromagnetic structure, a new physical decoupling mechanism, or an unexpected performance regime that departs from established practice as of 2006. Instead, the '103 patent's examples show a familiar step-by-step slotting/folding path to improve performance. Ex.1001, 37:62-39:32 (disclosing steps 0-7). The F_{21}/F_{32} values are merely tracked as a proxy for geometric convolution while the real tuning work is accomplished by pre-existing techniques. *Id.*, 20:39-47. The '103 patent even concedes that the “complexity factors” “give good hints on possible changes of antenna in order to obtain improved antennas” and that “may also be used in numerical optimization algorithms as target values or to define target intervals,” underscoring that the factors serve as *heuristic* targets for design navigation rather

than as operative structures that themselves produce performance. *Id.*, 20:39-47. As such, the flowchart in Figure 16 “translates” mechanical/functional specifications “into a target region” on the (F_{21} , F_{32}) plane and then directs the designer to “gradually modify the structure” by “creating slots, apertures and/or openings” or “bending and/or folding” to “adjust the complexity factors,” confirming that the physical tuning is accomplished by conventional geometric modifications while F_{21}/F_{32} are tracked as the progress indicator. *Id.*, 35:25-32.

47. Importantly, the claimed inventions of the '103 patent is not directed to a method of improving antenna performance using the “complexity factor” and/or “ F_{21}/F_{32} ” approach disclosed in the '103 patent specification. Rather, the claimed invention is directed, in part, to an antenna that is characterized by a “complexity factor, F_{21} having a value of at least 1.20 and . . . F_{32} having a value less than 1.75.” As I discuss in this Declaration, there already existed, in the prior art, antennas that meet these specifications.

F. Claim Construction

48. I apply relevant claim construction below in relation to the elements of the Challenged Claims.

49. Based on my review of the '103 patent, it is my opinion that the specification expressly defines several claim terms, including, “antenna contour,” “complexity factor,” “ F_{21} ,” “ F_{32} ,” “antenna box”, and “antenna rectangle.”

b. “antenna rectangle”

51. The '103 patent states that “an antenna rectangle is defined as being the orthogonal projection of the antenna box along the normal to the face with largest area of the antenna box.” Ex.1001, 13:55-58. The '103 patent also shows an example of an “antenna rectangle” in Figure 1B’s element 110 (blue outline below):

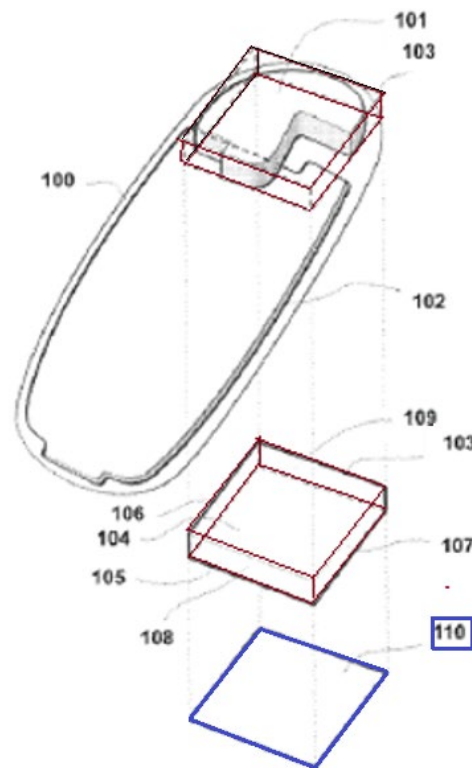


FIG. 1B

Ex.1001, Fig. 1B (annotated).

c. “antenna contour”

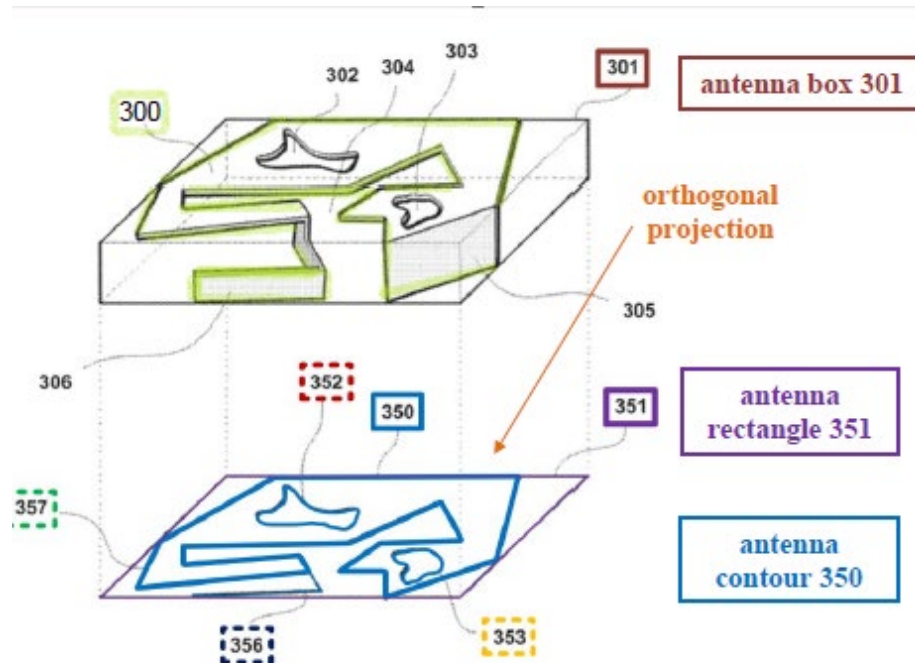
52. The '103 patent states “[t]he antenna contour of the antenna system is a set of joined and/or disjointed segments comprising:

- [1] the perimeter of one or more antenna elements placed in the antenna

rectangle,

[2] the perimeter of closed slots and/or closed apertures defined within the antenna elements, and/or the orthogonal projection onto the antenna rectangle of perimeters of antenna elements, or perimeters of or parts of antenna elements that are place in the antenna box but not in the antenna rectangle and further “[n]ot all the segments that form the antenna contour need to be connected (i.e., to be joined). In some cases, the antenna contour comprises two, three, four or more disjointed subsets of segments.” Ex.1001, 14:49-59.

53. The '103 patent also provides Figure 3, which shows the “antenna contour” 350 (blue outline below) “associated with the antenna element 300” (green outline below) within “antenna rectangle” 351 (purple outline below) formed from an orthogonal projection through “antenna box” 301. Ex.1001, 27:5-8; 27:44-28:4, Fig. 3 (annotated below).



EX1001, Fig. 3 (annotated)

d. “complexity factor”, “ F_{21} ”, “ F_{32} ”

54. The “complexity factor F_{21} ” and “ F_{32} ” have no plain and ordinary meaning to a POSA. In fact, I have never heard of this terminology used in my over 30 years of experience working with the development of antennas and antenna systems.

55. I understand that a judge has construed the term “complexity factor” to be indefinite. Ex.1027, at 32-33. I agree with the judge that “antenna contour” provides some uncertainty with respect to how it is determined, however, for purposes of this opinion, I rely on one of the inventor’s definitions for “complexity factor” that is set forth in the ’103 patent specification.

56. The ’103 patent provides a definition of “complexity factor”, “ F_{21} ”, and

F₃₂” as the numerical result of a calculation based on operations involving overlaying a series of three specifically-formulated grids (G₁, G₂, G₃, respectively) on the “antenna rectangle”—with each grid scale differing so that G₂ cells are ½ the size of G₁ cells and G₃ cells are ½ the size of G₂ (i.e., G₃ is ¼ the size of G₁). Ex.1001, 16:28-55.

57. Prior to the judge’s decision mentioned above, I understand that the same Court (but in the ADT litigation) provided the following explanation regarding how to compute the “complexity factor”:

The first step in computing the complexity factors is finding the antenna contour. To do this, one starts by determining an ‘antenna box’ and an ‘antenna rectangle.’ . . . Next, the complexity-factor calculation requires finding an ‘antenna contour.’ . . . After determining an antenna contour, that contour is overlaid on ‘a first, a second, and a third grid (hereinafter called grid G₁, grid G₂, and grid G₃ respectively) of substantially square or rectangular cells The Three grids are adaptive to the antenna rectangle. That is, the size and aspect ratio of the cells of each one of said three grids is determined by the size and aspect ratio of the antenna itself. The use of adaptive grids is advantageous because it provides a sufficient number of cells within the antenna rectangle to fully capture the geometrical features of the antenna contour at different levels of detail.’ Ex.1001, 16:36-46.

The starting point for constructing the three grids is grid 2, for which “the size of a cell and its aspect ratio . . . are first chosen so that the antenna rectangle is perfectly tessellated with an odd number of columns and an odd number of rows.” Ex.1001, 16:58-62; *see also id.* at 17:20-23 (“the number of columns and rows of cells of the second grid that tessellate the antenna rectangle are selected to produce

a cell as square as possible”). Other parts of the specification suggest a grid G_2 with nine columns is preferred. *See id.* at 17:12-18 (“It has been found that setting to nine (9) the number of columns that tessellate the antenna rectangle provides an advantageous compromise, for the preferred sizes” of the devices); see also *id.* at 17:36 (“the antenna rectangle is tessellated perfectly with 9 by $(2n+1)$ cells of grid G_2 , wherein n is an integer larger than zero (0) and smaller than five (5)”).

After constructing G_2 , constructing G_1 and G_3 is straightforward. “A cell of grid size G_2 is half the size of a cell of grid G_1 [and] a cell of grid size G_3 is half the size of a cell of grid G_2 , or one fourth the size of a cell of grid G_1 .” *Id.*, 16:48-52.

From there, F_{21} and F_{32} are computed by counting the number of cells N_1 , N_2 , and N_3 , of the grids G_1 , G_2 , and G_3 , respectively, that are at least partially inside the antenna rectangle and include at least a point of the antenna contour. After counting N_1 , N_2 , and N_3 , [the following formula is applied]

$$F_{21} = -(\log(N_2) - \log(N_1)) / \log(1/2), \text{ and}$$

$$F_{32} = -(\log(N_3) - \log(N_2)) / \log(1/2).$$

Id., 18:36-50 (explaining the calculation of F_{21}); *id.*, 19:26-38 (explaining the calculation of F_{32}).

Ex.1009, 4-7. For purposes of my validity analysis, I will use this reasoning.

58. Additionally, I understand that in IPR proceedings related to the '677 patent, Dr. Daniel van der Weide provided his own analysis of how to determine the “complexity factor” and “ F_{21} ” and “ F_{32} .” IPR2025-01026, Ex.1027, 31-42. I note that the specification for the '677 patent is substantially the same as the specification for the '103 patent. I also note that while Dr. Van der Weide engages in relatively

more detailed explanation of “complexity factor” calculations, it comports with the Court’s analysis in the ADT Litigation. For the purpose of thoroughness, I summarize Dr. Van der Weide’s analysis, which I also adopt as my own for purposes of this declaration, here:

i. Second Grid G_2

59. The specification defines G_2 as “the ratio between [cell] width and . . . height” and are chosen to “perfectly tessellate[]” the “antenna rectangle” with “an odd number of columns and an odd number of rows.” Ex.1001, 16:58-62. The specification associates the antenna rectangle’s long side (e.g., “width”) with grid columns, while it associates the short side (e.g., “height”) with grid rows. *Id.*

60. The ’103 patent states that each grid has “substantially square or rectangular cells” (*id.*, 16:36-38) and further requires that if “two different combinations of a number of columns and a number of rows of cells of the second grid produce a cell as square as possible, a second grid is selected such that the aspect ratio”—the ratio of cell width to cell height—“is larger than 1.” *Id.*, 17:32-35. The closer the cell’s aspect ratio is to 1, the closer the cell is to square.

61. The ’103 patent discloses that “setting to nine (9) the number of columns that tessellate the antenna rectangle provides an advantageous compromise, for the preferred sizes of an MFWD, and the corresponding available volume for the antenna system, according to the present invention.” Ex.1001, 17:12-16. Thus Figure

14B of the '103 patent shows “G₂” 1402 “tessellat[ing]” antenna rectangle 1400 with 9 columns and 5 rows. *Id.*, Fig. 14B (annotated below).

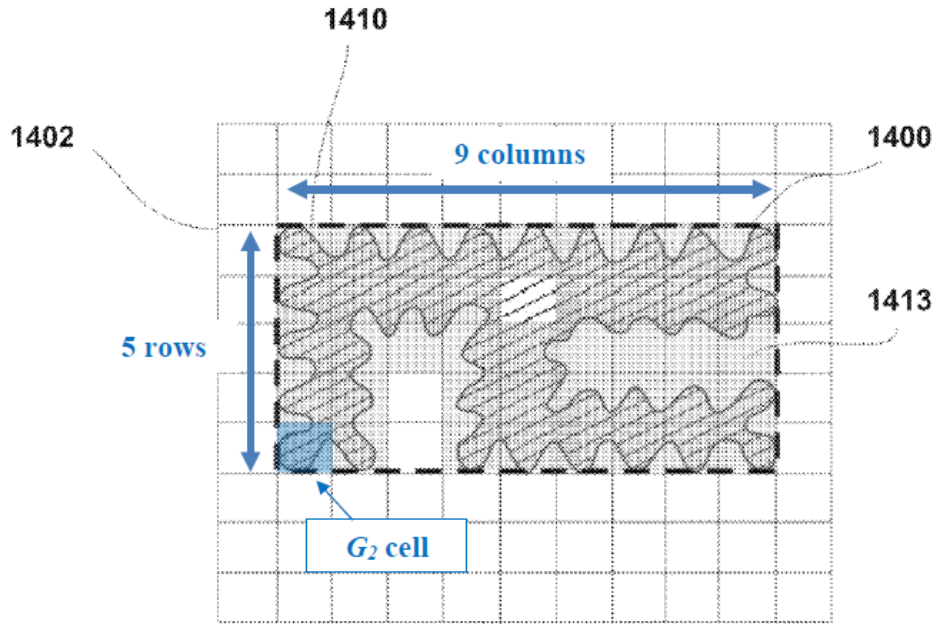


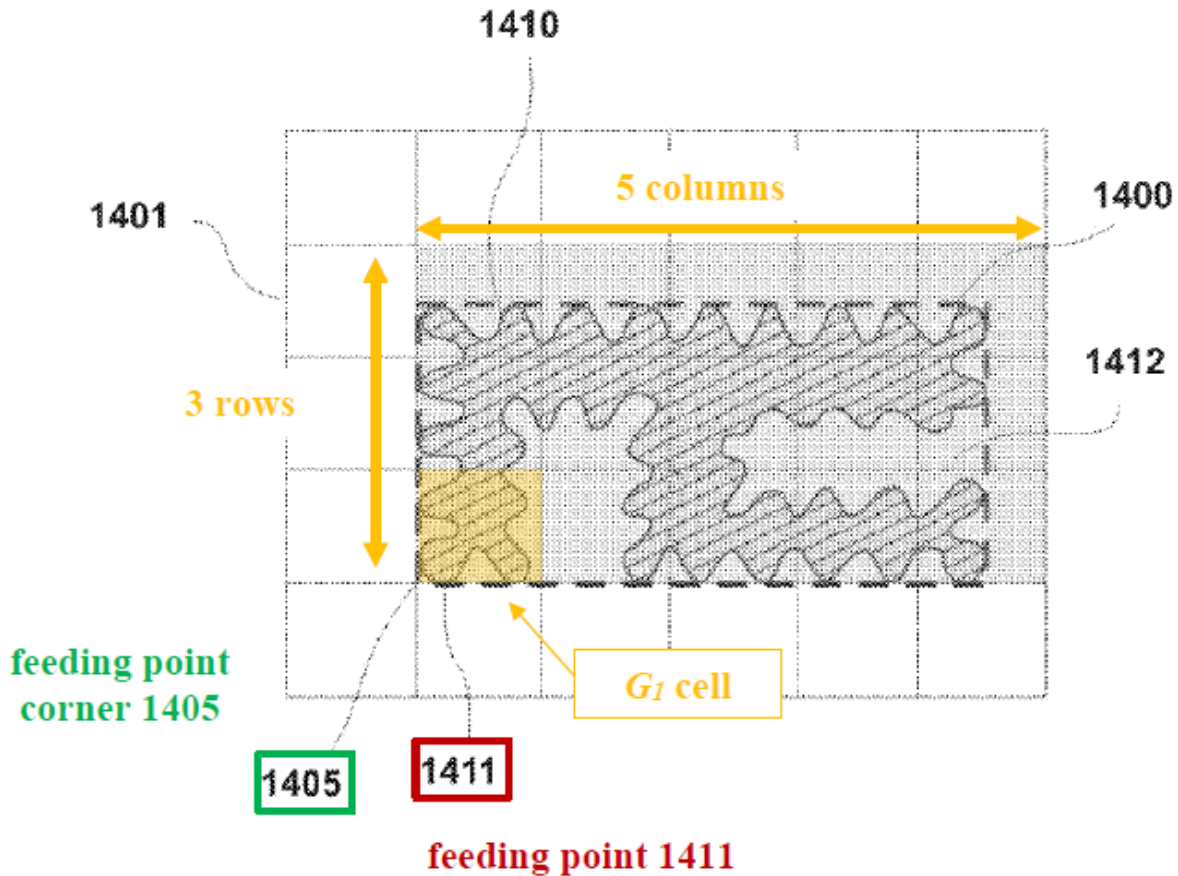
FIG. 14B

ii. First Grid G₁

62. The '103 patent states that “[a] first cell of the grid G₁ is . . . created by grouping four cells of Grid G₂ in such a manner that a corner of the first cell is the feeding point corner, and the first cell is positioned completely inside the antenna rectangle.” *Id.*, 18:24-27.

63. The '103 patent defines a “feeding point corner” as “the corner of the antenna rectangle closest to the feeding point of the antenna system responsible for the [system’s] operation in its lowest frequency band.” *Id.*, 17:54-57. After “placing”

the first cell, “other $[G_1]$ cells can be placed uniquely defining the relative position of $[G_1]$ with respect to the antenna rectangle.” *Id.*, 18:28-30. As shown below, the relevant cells of a first grid are the minimum set of cells that are all of the same size as the first cell and encompass the entire antenna contour.



Ex.1001, Fig. 14A (annotated).

64. The '103 patent says that Figure 14A shows a first grid 1401, with “feeding point 1411, located substantially close to the bottom left corner of the antenna rectangle 1405 (being thus the feeding point corner).” *Id.*, 33:56-58, Fig. 14A.

iii. Third Grid G_3

65. The third grid (G_3) fits twice as many rows and columns within the antenna rectangle as the second grid (G_2), thereby replacing “each cell of ... grid G_2 ... with 2-by-2 cells of ... grid G_3 [.]” Ex.1001, 17-25. Each third grid’s cell has width (W_3) that is half the second grid cell width, and height (H_3) that is half the second grid cell height. *Id.* Figure 14C shows an overlay of third grid 1403 formed from second grid 1402. Ex.1001, Fig. 14B, 14C (annotated below).

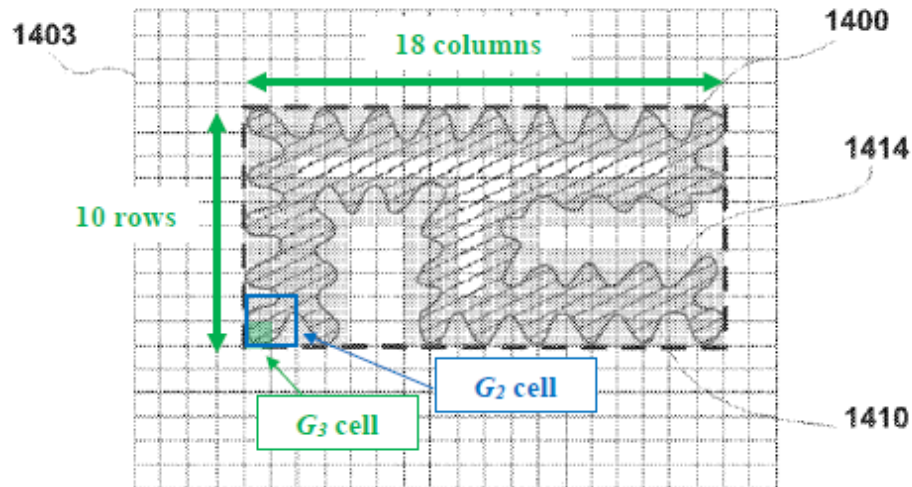


FIG. 14C

iv. Calculation

66. The claims recite two “complexity factors” named “ F_{21} ” and “ F_{32} ”. The ’103 patent defines each “complexity factor” as follows.

1. “ F_{21} ”

67. The ’103 patent computes “ F_{21} ” by:

- [1] counting the number of cells N_1 in grid G_1 that [a] “are at least partially

inside the antenna rectangle” and [b] “include at least a point of the “antenna contour”; and

- [2] counting the number of cells N_2 in grid G_2 that [a] “are completely inside the antenna rectangle” and [b] “include at least a point of the antenna contour[.]”

Ex.1001, 18:37-40. The ’103 patent states “in the present invention the boundary of the cell is also part of the cell[.]” Ex.1001, 18:40-41.

68. The ’103 patent defines “ F_{21} ” as:

$$F_{21} = -\frac{\log(N_2) - \log(N_1)}{\log(1/2)}$$

Ex.1001, 18:45-50.

69. A POSA would have understood “log” to mean base 10 logarithm. However, since the logarithm in different bases are related by a multiplicative constant, it would not matter what base was used to evaluate this complexity factor equation so long as the same base was used for each logarithm. The ratio in the complexity factor equation cancels out the multiplicative factor (highlighted in the example below). In other words, expressing

$$A = 10^x = 2^y,$$

then

$$\log_{10}(A) = x \log_{10}(10) = x = y \log_{10}(2),$$

and

$$\log_2(A) = x \log_2(10) = y \log_2(2) = y.$$

This means, depending on whether the logarithm is base 2 or 10 in this example,

$$x = y \log_{10}(2),$$

$$x \log_2(10) = y$$

70. As a numeric example, suppose $N_2 = 42$ and $N_1 = 15$. Then using a base 10 logarithm,

$$\begin{aligned} F_{21} &= -\left(\frac{\log_{10}(N_2) - \log_{10}(N_1)}{\log_{10}(1/2)}\right) = -\left(\frac{\log_{10}(42) - \log_{10}(15)}{(-1)\log_{10}(2)}\right) \\ &= \left(\frac{\log_{10}(42/15)}{\log_{10}(2)}\right) = \left(\frac{0.447}{0.301}\right) = 1.49. \end{aligned}$$

Using a base 2 logarithm gives the same result,

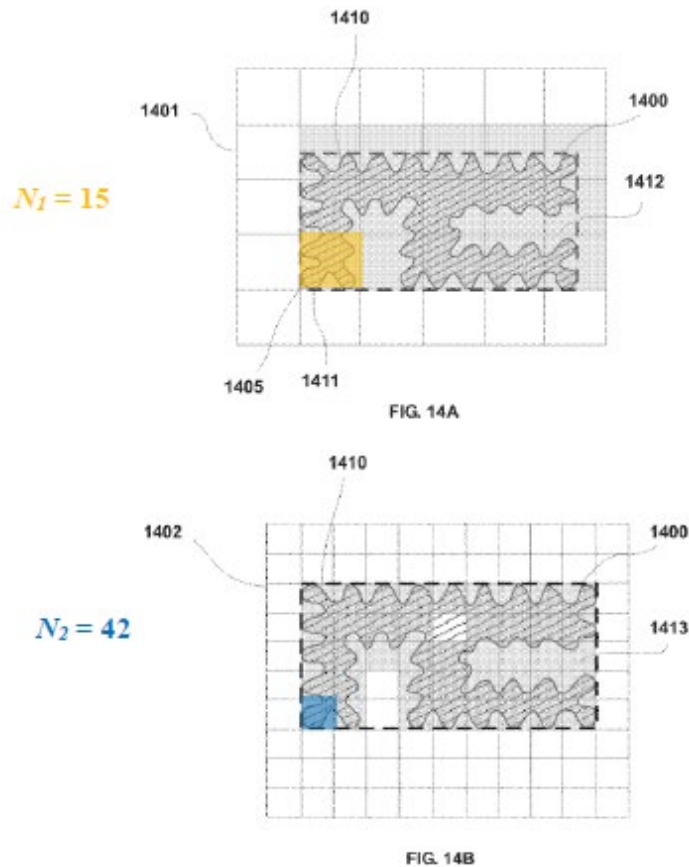
$$\begin{aligned} F_{21} &= -\left(\frac{\log_2(N_2) - \log_2(N_1)}{\log_2(1/2)}\right) = -\left(\frac{\log_2(42) - \log_2(15)}{(-1)\log_2(2)}\right) \\ &= \left(\frac{\log_2(42/15)}{\log_2(2)}\right) = \left(\frac{1.49}{1}\right) = 1.49. \end{aligned}$$

71. In my analysis of the prior art and the Challenged Claims of the '103 patent below, I use the base 10 logarithm as the "log" function to evaluate the patent's complexity factor calculations. But again, any logarithm may be used.

72. Using '103 patent Figure 14's "antenna contour" 1410, the patent describes:

- A first grid (Fig. 14A, 1401) with $N_1 =$ "Fifteen (15) cells," shown as shaded group 1412, meeting [1][a]-[b] above; and
- A second grid (Fig. 14B, 1402): with $N_2 =$ "Forty-two (42) cells," shown as shaded group 1413, meeting [2][a]-[b] above. Within antenna rectangle 1400, unshaded cells do not meet the requirement to [2][b] "include at least a point of the antenna contour."

Ex. 1001, 33:59-34:2, Figs. 14A-14B (annotated).



73. The complexity factor F_{21} for antenna contour 1410 is thus:

$$\begin{aligned}
F_{21} &= -\left(\frac{\log(N_2) - \log(N_1)}{\log(1/2)}\right) = -\left(\frac{\log(42) - \log(15)}{(-1)\log(2)}\right) \\
&= \left(\frac{\log(42/15)}{\log(2)}\right) = \left(\frac{0.447}{0.301}\right) = 1.49.
\end{aligned}$$

Ex.1001, 34:11-15.

74. In performing this calculation, I used the relationship that the logarithm of a product is $\log(AB) = \log(A) + \log(B)$, so that

$$\begin{aligned}
\log\left(\frac{A}{B}\right) &= \log(A \times B^{-1}) = \log(A) + (-1)\log(B) \\
&= \log(A) - \log(B).
\end{aligned}$$

2. “F₃₂”

75. The '103 patent calculates “F₃₂” by counting the number of cells N₃ in grid G₃ that “are completely inside the antenna rectangle” and “include at least a point of the antenna contour.” Ex.1001, 19:26-32. The '103 patent defines complexity factor F₃₂ as:

$$F_{32} = -\frac{\log(N_3) - \log(N_2)}{\log(1/2)}$$

Id., 19:33-38.

76. Using Figure 14’s antenna contour 1410, the patent describes a third grid (Fig. 14C, 1403) with N₃= “one hundred and forty-two (142) cells,” shown as shaded group 1414, including the number of cells N₃ in grid G₃ that “are completely

inside the antenna rectangle” and “include at least a point of the antenna contour”:

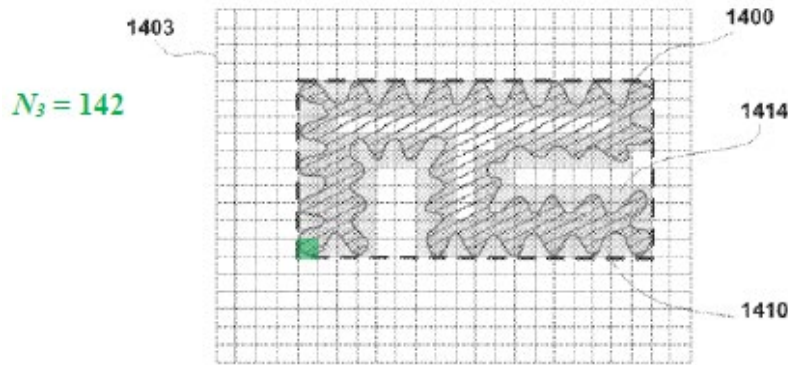


FIG. 14C

77. Using the $N_2 = 42$ results for Figure 14B, the complexity factor F_{32} for antenna contour 1400 is thus:

$$\begin{aligned}
 F_{32} &= -\left(\frac{\log(N_3) - \log(N_2)}{\log(1/2)}\right) = -\left(\frac{\log(142) - \log(42)}{(-1)\log(2)}\right) \\
 &= \left(\frac{\log(142/42)}{\log(2)}\right) = \left(\frac{0.529}{0.301}\right) = 1.76.
 \end{aligned}$$

Ex.1001, 34:17-22.

G. Challenged Claims

78. The Challenged Claims are generally directed to “handheld multifunctional wireless device[s] having at least one of multimedia functionality and smartphone functionality” and comprising several antennas configured to transmit and/or receive signals from a range of frequency bands.

79. The Challenged Claims are reproduced in their entirety below¹:

1. A handheld multifunction wireless device having at least one of multimedia functionality and smartphone functionality, the handheld multifunction wireless device comprising:

a touch screen;

a geolocalization system; and

an antenna system comprising a ground plane layer and three antenna elements within the handheld multifunction wireless device, the handheld multifunction wireless device being configured to transmit and receive signals from at least four frequency bands, each of the at least four frequency bands being used by at least one communication standard, the antenna system comprising:

a first antenna element having a conductive plate configured to simultaneously support radiation modes for at least first, second and third of the at least four frequency bands; and

a second antenna element configured to receive signals from a 4 G communication standard, wherein a perimeter of the second antenna element defines an antenna contour having a level of complexity defined by complexity factor F_{21} having a value of at least 1.20 and complexity factor F_{32} having a value less than 1.75.

2. The handheld multifunction wireless device of claim **1**, wherein the first frequency band is contained within 810-960 MHz frequency range, the second frequency band is contained within 1710-1990 MHz frequency range, and

¹ I understand that Claims 12 has already been cancelled pursuant to an *ex parte* review proceeding. I reproduced it here, however, because it is an independent claims from which Challenged Claims 13-14 depend.

the third frequency band is contained within 1900-2170 MHz frequency range.

3. The handheld multifunction wireless device of claim **1**, wherein the first antenna element is proximate to a short side of a ground plane rectangle defined by the ground plane layer, and the second antenna element is proximate to a short side of the ground plane rectangle.

4. The handheld multifunction wireless device of claim **1**, wherein the first antenna element is proximate to a short side of a ground plane rectangle defined by the ground plane layer, and the second antenna element is proximate to a long side of the ground plane rectangle.

5. The handheld multifunction wireless device of claim **1**, wherein the third antenna element is configured to operate in a fifth frequency band within 2400-2480 MHz frequency range.

6. A handheld multifunction wireless device having at least one of multimedia functionality and smartphone functionality, the handheld multifunction wireless device comprising:

a touch screen;

a microprocessor and an operating system adapted to permit running of word-processing, spreadsheet, and slide software applications;

an image recording system comprising an at least two-Megapixel image sensor;

an antenna system within the handheld multifunction wireless device and configured to operate in at least five frequency bands, the antenna system comprising:

a ground plane layer;

a first antenna element having a conductive plate configured to support first, second, and third

radiation modes respectively providing first, second, and third paths for current respectively associated with first, second, and third frequency bands, the first, the second, and the third radiation modes overlapping at least partially with each other, the first frequency band being contained within a first frequency region of an electromagnetic spectrum, the second and the third frequency bands being contained within a second frequency region of the electromagnetic spectrum that is higher in frequency than the first frequency region; and

a second antenna element configured to operate in at least one frequency band, the at least one frequency band being used by a 4 G communication standard, wherein:

a perimeter of the first antenna element defines a first antenna contour having a level of complexity defined by first complexity factor F_{21} having a value of at least 1.20 and first complexity factor F_{32} having a value less than 1.75; and

a perimeter of the second antenna element defines a second antenna contour having a level of complexity defined by second complexity factor F_{21} having a value of at least 1.20 and second complexity factor F_{32} having a value less than 1.75.

7. The handheld multifunction wireless device of claim **6**, wherein the first antenna element is configured to transmit and receive signals from a 4 G communication standard.

8. The handheld multifunction wireless device of claim **6**, wherein the first antenna contour comprises at least thirty-five segments.

9. The handheld multifunction wireless device according to claim **8**, wherein the second antenna contour comprises at least twenty segments.

10. The handheld multifunction wireless device according

to claim 6, wherein the first antenna contour comprises at least two disjointed subsets of segments, each of the at least two subsets of segments comprising at least ten segments.

11. The handheld multifunction wireless device according to claim 6, wherein the handheld multifunction wireless device comprises a third antenna configured to operate in a frequency band within 2400-2480 MHz frequency range.

12. A handheld multifunction wireless device having at least one of multimedia functionality and smartphone functionality, the handheld multifunction wireless device comprising²:

a touch screen;

a processing module;

a memory module;

a communication module;

a power management module;

an antenna system within the handheld multifunction wireless device and comprising:

a ground plane layer;

a first antenna element configured to simultaneously support radiation modes for first, second, and third frequency bands, the first frequency band being contained within a first frequency region of an electromagnetic spectrum, the second frequency band being contained within a second frequency region of the electromagnetic spectrum that is higher in frequency than the first frequency region, the third frequency band of

² Claim 12 was cancelled pursuant to *ex parte* proceeding, but I reproduce it here because it is the independent claim from which claims 13 and 14 depend.

operation being used by a 4 G communication standard, wherein a perimeter of the first antenna element defines a first antenna contour comprising at least thirty-five segments, the first antenna element defining an antenna box, an orthogonal projection of the antenna box along a normal to a face with a largest area of the antenna box defining an antenna rectangle, wherein a length of the first antenna contour is greater than four times a diagonal of the antenna rectangle; and

a second antenna element configured to operate in at least one frequency band used by a 4 G communication standard, wherein a perimeter of the second antenna element defines a second antenna contour comprising at least twenty segments.

13. The handheld multifunction wireless device according to claim **12**, wherein the communication module is configured to simultaneously transmit signals from a CDMA communication standard, a WiFi communication standard, and a 4 G communication standard.

14. The handheld multifunction wireless device according to claim **12**, wherein each of the first frequency band and the second frequency band is used by at least one communication standard selected from: GSM, UMTS, CDMA, and W-CDMA.

16. A handheld multifunction wireless device having at least one of multimedia functionality and smartphone functionality, the handheld multifunction wireless device comprising:

a touch screen;

a microprocessor;

at least one memory module; and

a communication module configured to operate in a first frequency band used by at least one

communication standard and contained within a first frequency region of an electromagnetic spectrum, in a second frequency band used by at least one communication standard and contained within a second frequency region of the electromagnetic spectrum that is higher in frequency than the first frequency region, and in a third frequency band used by a 4 G communication standard;

the communication module comprising an antenna system within the handheld multifunction wireless device having at least a first and a second antenna elements and a ground plane layer, the first antenna element being configured to transmit and receive signals from a 4 G communication standard, and the second antenna element being configured to receive signals from a 4 G communication standard, wherein:

the ground plane layer defines a ground plane rectangle;

the first antenna element is proximate to a first short side of the ground plane rectangle;

the second antenna element is proximate to a second short side of the ground plane rectangle; and

a perimeter of the second antenna element defines an antenna contour having a level of complexity defined by complexity factor F_{21} having a value of at least 1.20 and complexity factor F_{32} having a value less than 1.75.

17. The handheld multifunction wireless device according to claim **16**, wherein an antenna box is defined by the first antenna element, an antenna rectangle is defined by an orthogonal projection of the antenna box along a normal to a face with a largest area of the antenna box, and wherein a longer side of said antenna rectangle is substantially parallel to the first short side of the ground plane rectangle.

18. The handheld multifunction wireless device according

to claim **16**, wherein the first frequency region is delimited by 810-960 MHz frequency range, and the second frequency region is delimited by 1710-1990 MHz frequency range.

19. The handheld multifunction wireless device according to claim **16**, wherein the complexity factor F_{21} has a value less than 1.45.

20. The handheld multifunction wireless device according to claim **16**, wherein the handheld multifunction wireless device is configured to use the first antenna element and the second antenna element as a diversity system.

VII. SCOPE OF THE PRIOR ART

A. Boireau (US2007/0238483) – Ex. 1015

80. Boireau is a U.S. patent application published on October 11, 2007, with a filing date of April 5, 2006. I understand that, because Boireau was filed before the earliest priority date of the '103 patent (July 18, 2006) and was later published, it qualifies as prior art to the '103 patent.

81. Boireau taught “antenna sharing techniques” for mobile computing devices, using a switch and an antenna management module (“AMM”) so that multiple transceivers can share a single antenna or antenna array under coexistence control to reduce interference, size, and power consumption in a smartphone-class device architecture that also includes a processing subsystem and a power management subsystem. Ex.1015, Abstract, [0016], [0027], [0044].

82. Boireau disclosed a mobile computing device implemented as a “combination handheld computer and mobile telephone, sometimes referred to as a

smart phone.” *Id.*, [0019]. Boireau expressly references Palm® Treo™ smartphones as examples. *Id.* Additionally, Boireau’s processing sub-system can execute application programs such as “office suites, business software, educational software, databases, communications software” and system programs including operating systems. Ex.1015, [0065]. The device’s processing sub-system can run operating systems such as Palm OS, Microsoft Windows CE, Microsoft Pocket PC, Microsoft Mobile, and Symbian OS. *Id.*, [0066].

83. Boireau further disclosed that the mobile computing device display 138 may be implemented as “a touch screen, touch panel, touch screen panel, and so forth,” utilizing pressure-sensitive (resistive), electrically-sensitive (capacitive), acoustically-sensitive (surface acoustic wave), or photo-sensitive (infrared) techniques. *Id.*, [0023]. Boireau further specifies that the display may be a “touch-sensitive color (e.g., 16-bit color) display screen.” *Id.*, [0024].

84. Boireau further discloses that a processing sub-system comprising a processor and memory, as well as a power management sub-system that manages power for the entire mobile computing device, including batteries for DC power and AC interfaces. *Id.*, [0028], [0029], [0064].

85. Boireau also discloses a radio sub-system 202 with a transceiver module 304 containing multiple transceivers. *Id.*, [0035], [0036]. Specifically, the device may include at least three types of transceivers: “a cellular radiotelephone

system transceiver for voice communications, a wireless networking transceiver for longer range data communications . . . , and a personal area network transceiver for shorter range data communications.” *Id.*, [0026]. Boireau identifies support for cellular standards including GSM, CDMA, WCDMA, UMTS, TDMA, and others, as well as data communication systems including GPRS, EDGE, EV-DO, HSDPA, and HSUPA. *Id.*, [0031], [0032]. The WiFi transceiver (transceiver 308-1) supports IEEE 802.11b/g operations, and the Bluetooth transceiver (transceiver 308-2) supports Bluetooth v1.2+EDR operations. *Id.*, [0040], [0041].

86. Boireau further discloses an antenna system that may include internal antennas, external antennas, or a combination of both. *Id.*, [0025]. The antenna types listed include “a planar inverted-F antenna, a planar inverted-L antenna, an inverted-F antenna with a helical structure, an inverted-L antenna with a helical structure, a monopole antenna, a meandered monopole antenna, a dipole antenna, a balanced antenna, a printed helical antenna, a chip antenna, a ceramic antenna, and so forth.” *Id.* The antenna may be a single antenna or part of an antenna array, including for MIMO systems. *Id.*, [0048]. A switch 314 controlled by the AMM 326 alternates electrical connections between the transceivers and antenna 318. *Id.*, [0037], [0045].

B. Ciais-Quadband – Ex. 1014

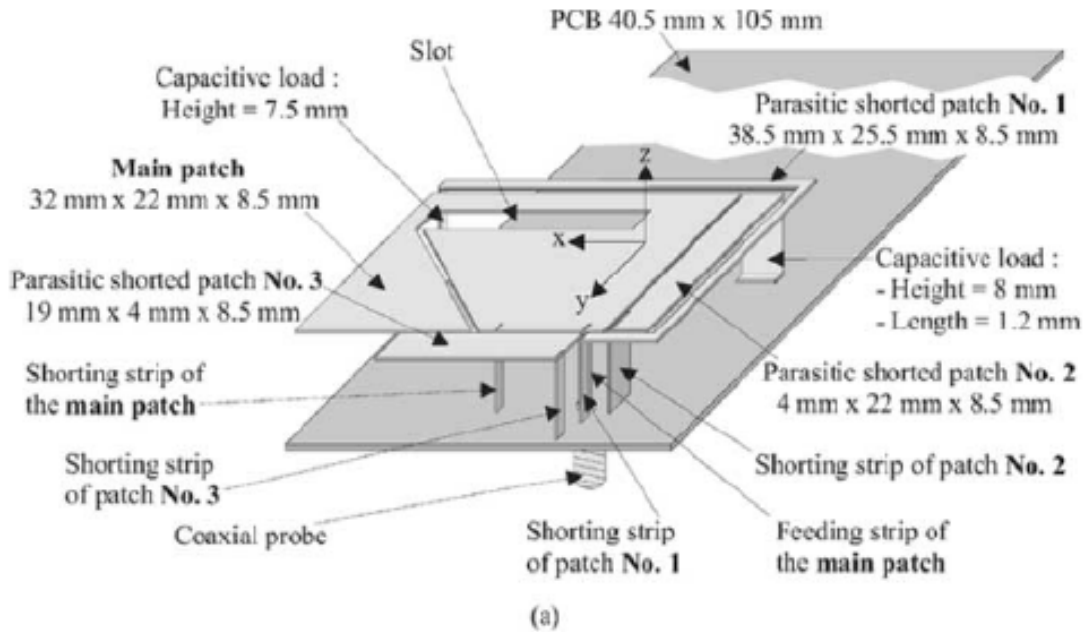
87. Ciais-Quadband was published in April 2004, which is more than one year before the priority date of the ’103 patent (July 18, 2006). Therefore, I

understand that Ciais-Quadband qualifies as prior art to the '103 patent.

88. Ciais-Quadband disclosed a compact, internal, multiband PIFA designed on a handset-representative PCB that covers DCS (1710-1880 MHz), PCS (1850-1990 MHz), and UMTS (1920-2170 MHz) with VSWR < 2.0, using a main dual-band resonator with a capacitive load plus three quarter-wavelength parasitic elements to create additional resonances and broaden both the lower and upper bands. Ex.1014, 1.

89. Ciais-Quadband reports quasi-omnidirectional patterns and computed efficiencies above roughly 69% (GSM) and 74% DCS/PCS/UMTS), confirming feasibility for internal integration in a realistic handset platform. *Id.*, 3. Ciais-Quadband further disclosed that “further work will be concentrated on the coverage of new 2.4 GHz and 5.2 GHz standards.” Pointing to WiFi/WLAN evolution as of 2004. *Id.*, 3.

90. Ciais-Quadband discloses the below detailed image and description of the PIFA disclosed therein:



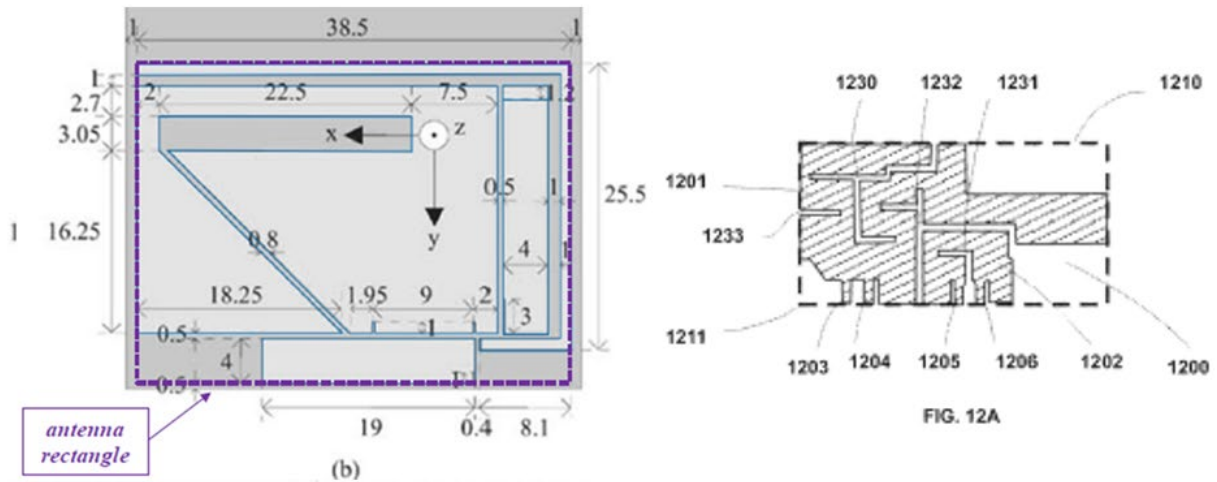
Ex.1014, Fig. 1(a).

91. As shown above, the Ciais-Quadband PIFA has a planar “main patch” over vertical elements and a 1.2 mm long “capacitive load.” Ex.1014, Fig. 1(a). The main patch has the antenna elements comprising the “largest area” of any surface of a box enclosing the quadband antenna.

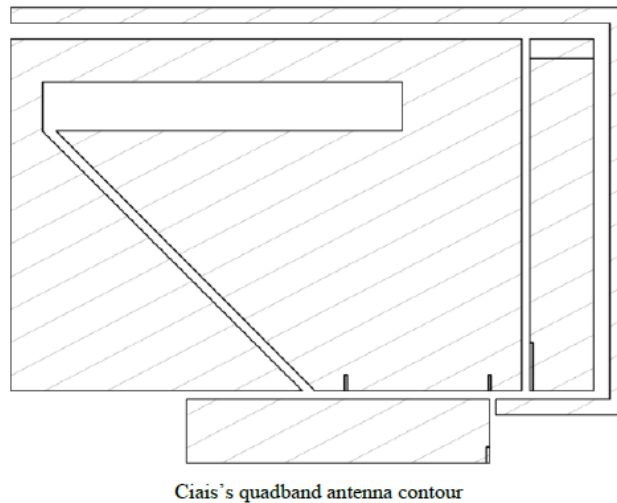
92. The minimum rectangle enclosing an orthogonal projection of the Ciais-Quadband PIFA (“antenna rectangle”) through the main patch is 38.5 mm x 28.5 mm. *Id.*

93. Parasitic shorted patches Nos. 1-3 are in the same plane as the main patch at least because “the separation distance” “between all patches and the PCT” is 8.5 mm—meaning they must all be the same height from the top PCB surface.

Ex.1014, 1.



96. Following the '103 patent's usage (e.g., Figs, 12A, 13A), the below figure shows the Ciais-Quadband PIFA contour with slant fill marking the main patch conductive elements bounded by the antenna contour.



97. A scaled rendering of the Ciais-Quadband PIFA's “antenna contour” can be generated using the dimensions provided in Fig. 1(b). The images below show a scaled rendering of the Ciais-Quadband PIFA and, for comparison, a side-by-side comparison of the PIFA alongside Fig. 1(b):

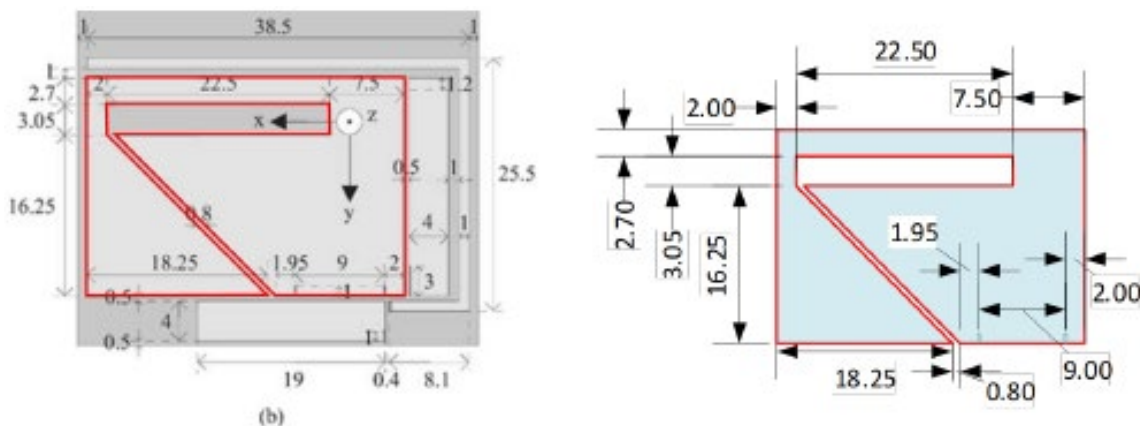
of the antenna box that contains the largest area of antenna surfaces.

99. The Ciais-Quadband PIFA antenna contour therefore includes segments of its antenna elements in the main patch, and projections of parasitic shorted patches and their shorting strips, capacitive loads, and feeding strip. Segments corresponding to each of these features are included in the Ciais-Quadband PIFA shown above.

100. The PIFA antenna disclosed in Ciais-Quadband includes the perimeter of the main patch, as shown in red below. The main patch's dimensions are explicitly stated as "32 mm x 22 mm," with a height of 8.5 mm above the ground plane.

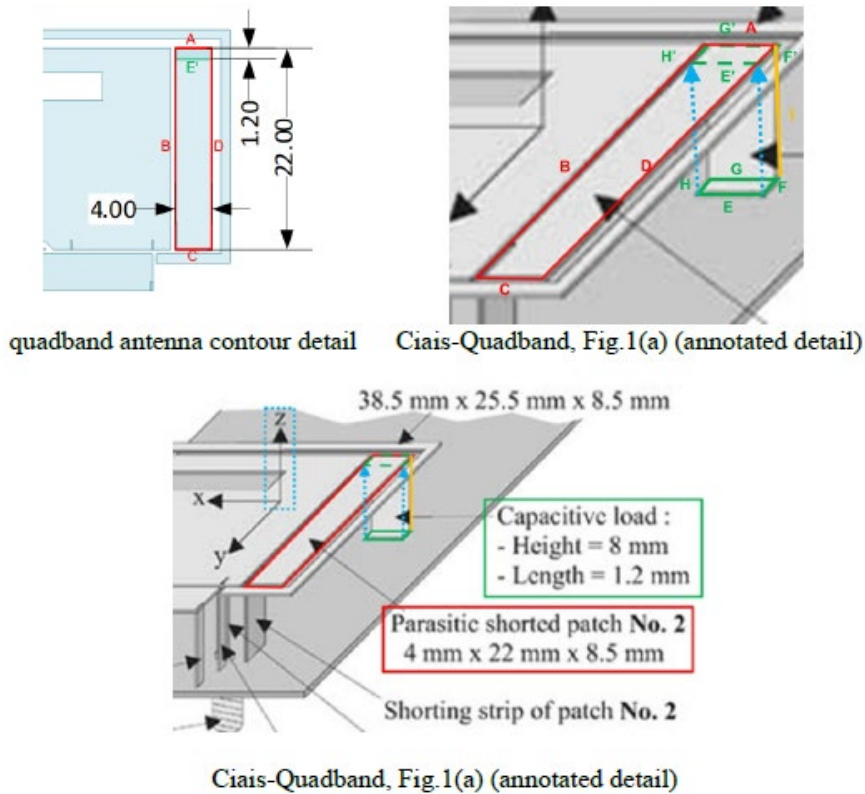
Ex.1014, Fig. 1(b), 148. In Figure 1(b):

- the length of the top edge is 32 mm (2.00 + 22.50 + 0.80 + 1.95 + 9.00 + 2.00),
- the length of the lower edge (including the 0.80 mm gap) is 32 mm (18.25 + 0.80 + 1.95 + 9.00 + 2.00)
- the length of the left edge is 22 mm (2.70 + 3.05 + 16.25).



101. The PIFA disclosed in Ciais-Quadband includes the perimeter of

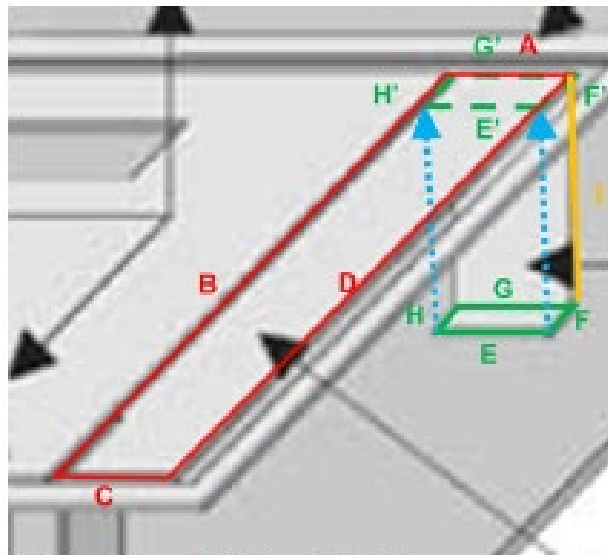
parasitic shorted patch No. 2 and the projection of the perimeter of the lower horizontal portion. The perimeter of the parasitic shorted patch No. 2 is outlined in red in the images below:



The dimensions of “Parasitic shorted patch No. 2” is “4 mm x 22 mm x 8.5 mm.” A POSA would understand that the 4 mm refers to the width (segments A and C above) and 22 mm refers to the length (segments B and D above).

102. The Ciais-Quadband PIFA antenna contour includes the perimeter of projections of capacitive load of parasitic shorted patch No. 2. As Ciais-Quadband explains, a capacitive load is “added to the parasitic patch[] by vertically folding their strip ends.” Ex.1014, 2. In Fig. 1(a), Ciais-Quadband discloses, “Capacitive

load: Height = 8 mm[,] Length = 1.2 mm” (annotation in the green box in the images above). This vertical portion (with one of its vertical edges highlighted in orange) is part of the capacitive load added “by vertically folding” patch No. 2. The capacitive load shares the same width as patch No. 2. Therefore $G = A = 4$ mm, and the “Height = 8 mm” refers to the length of vertical edge (e.g., edge annotated in orange in the close-up below).



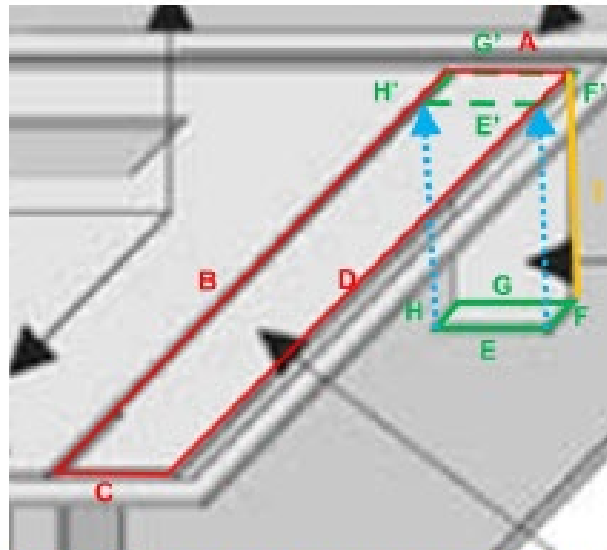
Ciais-Quadband, Fig 1(a) (annotated detail)

103. In addition to the vertical portion, the capacitive load of patch No. 2 includes an end portion horizontally folded (Figure 1(a)) from the bottom of the vertical portion, and deposited on the ground plane, parallel to patch No. 2.

104. The four edges of this horizontal end portion are annotated with green solid lined above and labeled E, F, G, and H. The PIFA disclosed in Ciais-Quadband has a capacitive load “length = 1.2 mm” refers to the length of edges F and H, because the length of all other segments of the capacitive load are otherwise

identified. Adding the physical lengths of patch no. 2 and its capacitive load results in 31.2 (D + I + F or 22 + 8 + 1.2), and matches the paper’s statement that the “[p]hysical length of elements no. 2” is “31.2 mm” and thus confirms that edges F and H are 1.2 mm long. Ex.1014, 2.

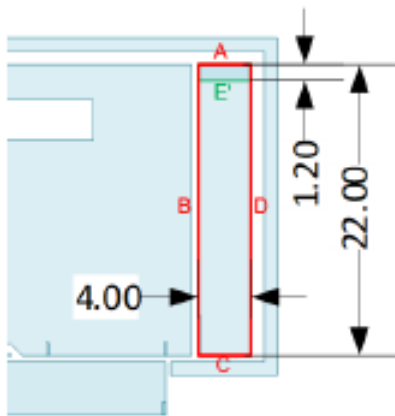
105. In the close-up of the Ciais-Quadband PIFA below, green dashed lines mark the orthogonal projection of the end of the end portion of the capacitive load of patch no. 2 onto the antenna rectangle.



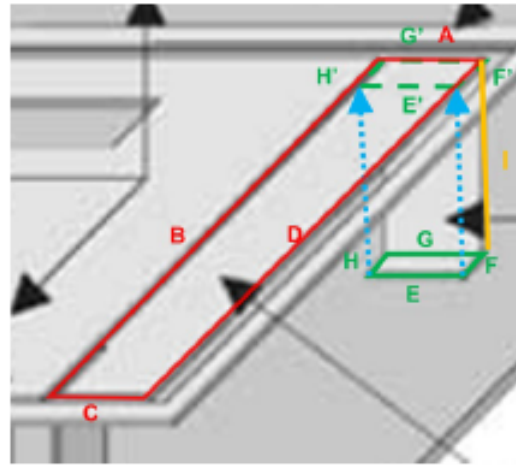
Ciais-Quadband, Fig. 1(a) (annotated detail)

106. The projection is orthogonal because the direction of the projection is along the z direction annotated in blue, which is perpendicular to the plane of the antenna rectangle (i.e., the plane defined by x and y directions in Fig. 1(a)). The capacitive loads for patches No. 1 – No. 3 are antenna elements that contribute to the antenna contour at least because they are parts of the “electrical lengths” and “physical lengths” of resonators of Ciais-Quadband’s PIFA, which are designed to

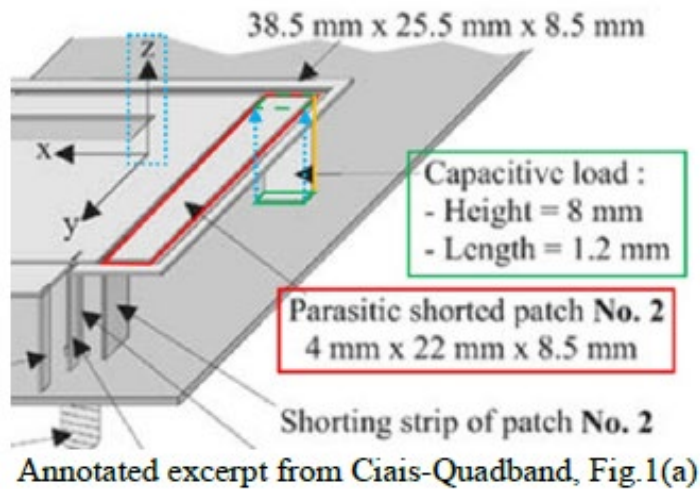
enable the antenna to work at desired frequencies, e.g., by matching the total lengths of each resonator with “quarter-wavelengths” of a desired frequency. Ex.1014, 2. Therefore, the perimeter of the capacitive load (including its end portion), is a perimeter of an antenna element. The antenna contour thus at least includes the orthogonal projection of the end portion as annotated with green dashed line. For example, the antenna contour at least includes the segment E' shown below left:



Ciais's quadband antenna contour (detail)

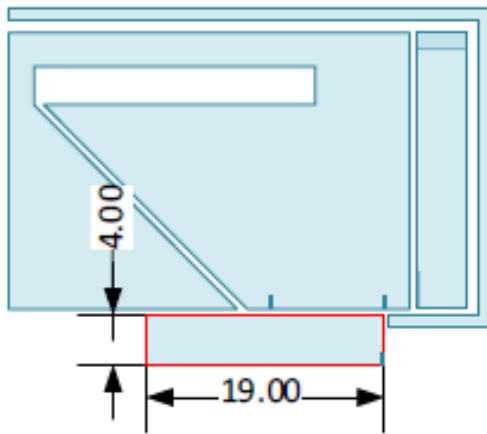


Ciais-Quadband, Fig.1(a) (annotated detail)

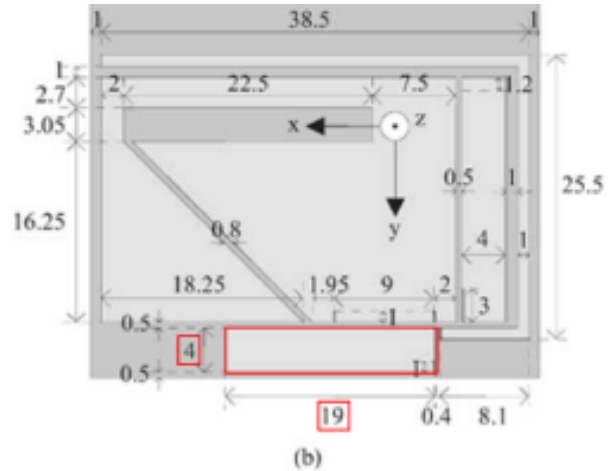


Annotated excerpt from Ciais-Quadband, Fig.1(a)

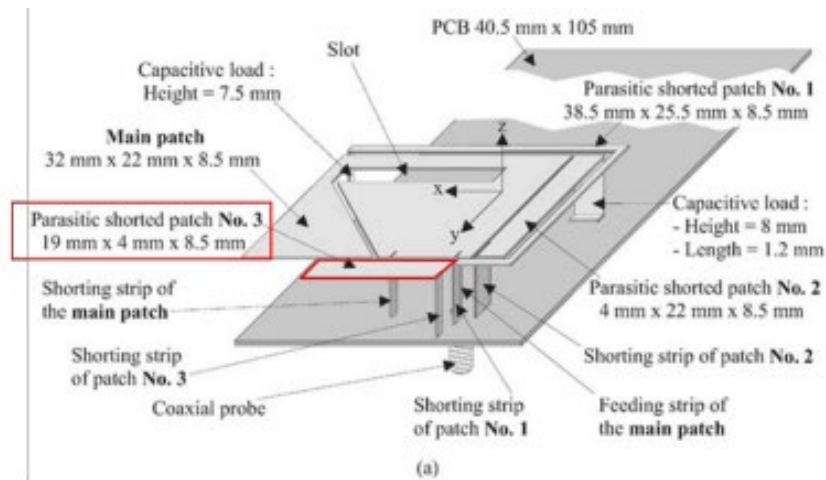
107. The PIFA disclosed by Ciais-Quadband includes the perimeter of a parasitic shorted patch No. 3. Figure 1(a) disclosed in Ciais-Quadband shows the dimensions of patch no. 3 are “19 mm x 4 mm x 8.5 mm.” The portion co-planar with the main patch has dimensions 19 mm x 4 mm.



Quadband antenna contour



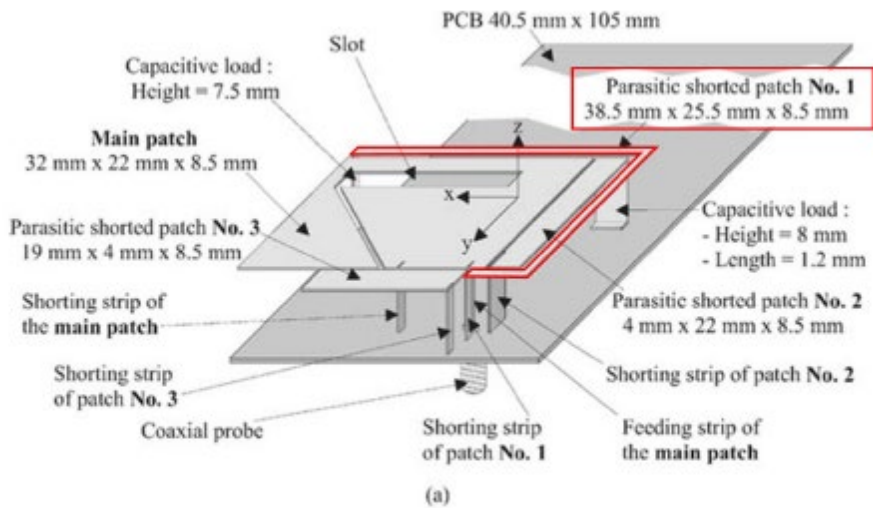
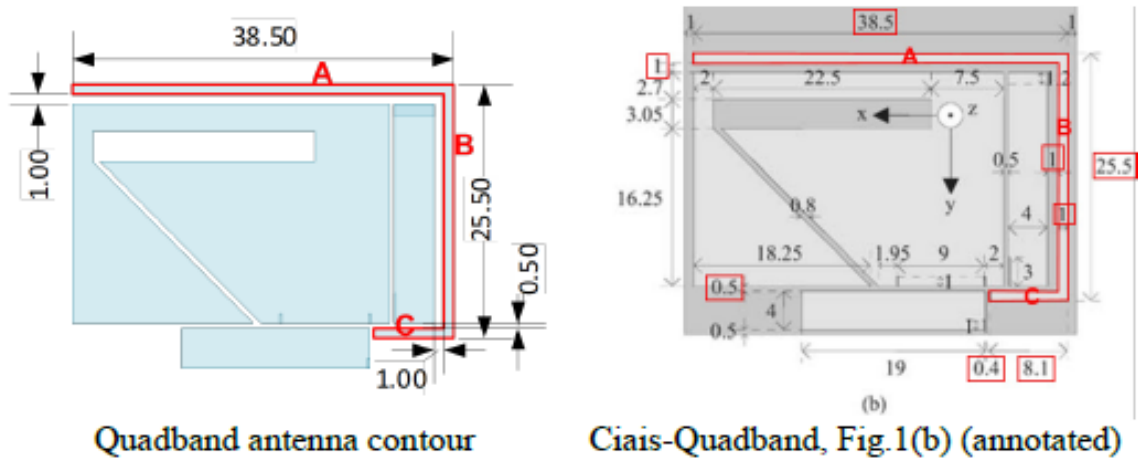
Ciais-Quadband, Fig.1(b) (annotated)



Ciais-Quadband, Fig.1(a) (annotated)

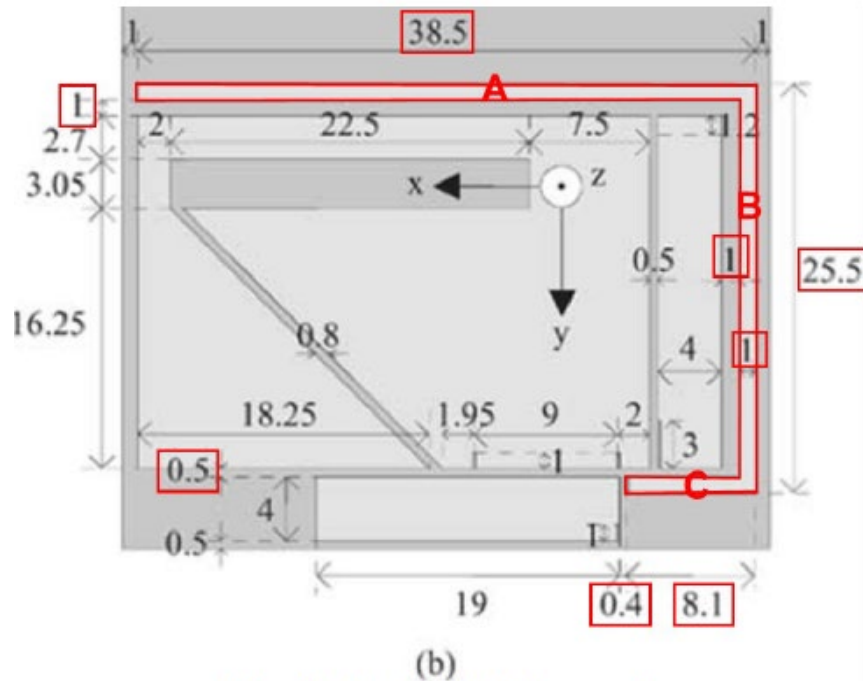
108. The PIFA contour includes the perimeter of parasitic shorted patch No. 1, having dimensions 38.5 mm x 25.5 mm x 8.5 mm. Ex.1014, Fig. 1(a). For ease of reference, the below identified the three arms of patch No. 1 as A, B, and C. Figure

1(b) disclosed in Ciais-Quadband shows that arm A has a length of 38.5 mm; arm B has a length of 25.5 mm; arm C has a length of 8.1 mm; and each arm has width 1 mm.



Ciais-Quadband, Fig.1(a) (annotated)

109. Figure 1(b) shows that the lower edge of arm A is placed 1 mm from upper edge of the main patch; the left edge of arm B is placed 1 mm from right edge of the parasitic patch No. 2; and the upper edge of arm C is placed 0.55 mm from the lower edge of parasitic patch No. 2.



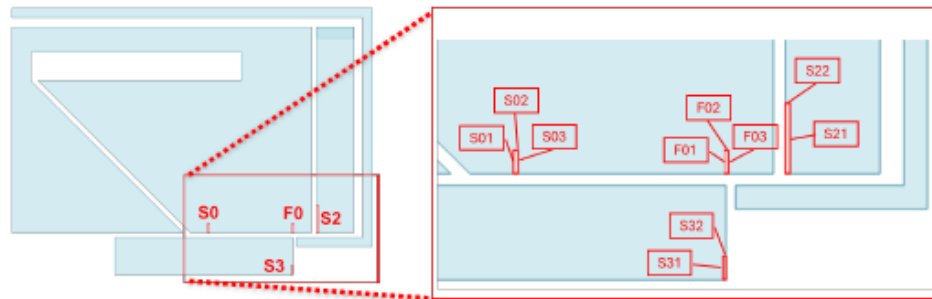
(b)
Ciais-Quadband, Fig.1(b) (annotated)

110. The Ciais-Quadband PIFA antenna contour includes the orthogonal projections of the shorting strips and the feeding strips as shown below.

111. The main patch has a shorting strip (“S0” below) and a feeding strip (“F0” below). Ex.1014, Fig. 1(a). Parasitic shorted patch No. 2 has shorting strip (“S2”), and parasitic shorted patch No. 3 has a shorting strip (“S3”). *Id.*

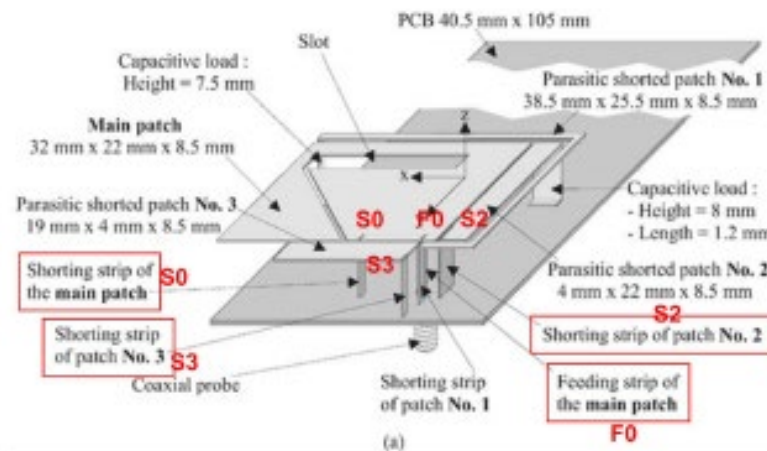
112. The strips are oriented in the vertical direction (i.e., z direction). Because these strips have physical dimensions, the orthogonal projection of these antenna elements results in antenna contour segments forming rectangles S0, S2, S3, and F0 as shown in red below, wherein at least some segments do not overlap with segments from other antenna elements. The quadband antenna contour thus includes at least segments of orthogonal projections of these strips listed in the below table.

Strip	Segment	Segment Length (mm)
S0	S01	1
S0	S02	about 0.2
S0	S03	1
F0	F01	1
F0	F02	about 0.2
F0	F03	1
S2	S21	3
S2	S22	about 0.2
S3	S31	1
S3	S32	about 0.2



Quadband antenna contour

Quadband antenna contour (detail)



Ciais-Quadband, Fig.1(a) (Annotated)

C. CN1728456 (CN456) – Ex.1016

113. CN456 is Chinese patent application published February 1, 2006, and filed July 1, 2005, which is before the earliest priority date for the '103 patent (July 18, 2006). Therefore, I understand that CN456 qualifies as prior art to the '103

patent.

114. CN456 taught a four-antenna element (denoted as 2a, 2b, 2c, 2d) where those four antennas are sequentially located in four quadrants on the PCB. Ex.1016, Fig. 1. Adjacent antenna units have their corresponding ground plane edges arranged mutually perpendicular, with spacing between adjacent units in the range of 0.1 to 0.5 times the operating wavelength. Ex.1016, Abstract, Claim 1, Fig. 1. The antenna units in the first and third quadrants are rotationally symmetric ($180^\circ \pm 10^\circ$) about the midpoint of a line connecting their identical geometric points, and the same relationship applies to the units in the second and fourth quadrants. *Id.*

115. The system disclosed in CN456 is designed for MIMO wireless communications, exploiting spatial diversity, polarization diversity, and radiation-pattern diversity. *Id.*, Abstract, 4, 6. The radiation patterns of the individual antenna units are complementary and together form an approximately omnidirectional pattern over a spherical surface, with gain in main radiation directions exceeding 3 dB. *Id.*, 8. The illustrated embodiment operates in the 2250–2300 MHz frequency range, with average in-band radiation efficiency greater than 80% and transmission coefficient S-parameters between ports less than -8.5 dB. *Id.*, 8, 9.

116. CN456 further discloses a rear metallic layer on the PCB that serves as a common reference ground, that may be connected to the individual antenna unit ground planes through vias. *Id.*, Abstract, 7, 9, claim 3. The system is described as

suitable for compact wireless terminal devices. *Id.*, 6.

117. CN456 frames the disclosed design against the recognized compact-terminal problem—strong mutual coupling, detuning, and low efficiency—and ties the multi-antenna approach to next-generation mobile communications and WLAN contexts (e.g., IEEE 802.11n), i.e., the “4G” family of high-speed services contemplated for terminals. *Id.*, 4-6.

D. Cho – Ex.1026

118. Cho is a 2005 published article, which is before the earliest priority date for the '103 patent (July 18, 2006). Therefore, I understand that Cho qualifies as prior art to the '103 patent.

119. The Cho reference presents the design, simulation, and measurement of an internal PIFA intended for dual-band wireless local area network (WLAN) operation at 2.4 GHz and 5 GHz. Ex.1026, 1. The paper is motivated by the increasing deployment of WLAN standards in notebook computers, including IEEE 802.11b (2.4–2.48 GHz), IEEE 802.11a (5.15–5.35 GHz, 5.725–5.825 GHz), and HIPERLAN/2 (5.15–5.35 GHz, 5.47–5.725 GHz). *Id.* The proposed antenna is a PIFA-type structure consisting of a hook-shaped radiation element and a small rectangular ground plate, both made of copper plate with a thickness of 0.2 mm, occupying a total volume of $47.5 \times 20 \times 7 \text{ mm}^3$. *Id.* The antenna is fed directly by a 50Ω coaxial cable, with the inner conductor connecting to the radiation patch and

the outer conductor connecting vertically to the small ground plate, while a shorting pin provides the characteristic PIFA short circuit between the radiation element and the ground plate. *Id.*

120. The design achieves dual-band resonance through careful adjustment of the shorting pin position and the length of the radiation element. *Id.* In particular, “Path A,” starting from the shorting point to the open end of the radiation patch, is approximately 32 mm, corresponding to roughly a quarter wavelength at 2.4 GHz, while “Path B,” the length between the feeding point and the shorting point, is approximately 12 mm, corresponding to roughly a quarter wavelength at 5.5 GHz. *Id.* These two path lengths serve as the dominant mechanisms controlling the lower (2.4 GHz) and upper (5 GHz) resonant frequencies, respectively, and the two radiation modes are supported simultaneously by a single hook-shaped conductive plate element. *Id.* Cho also presents a parametric study showing the effects of varying two key dimensional parameters (designated ① and ②) on the VSWR performance, demonstrating that when parameter ① is shortened, Path A lengthens and the lower band shifts downward while Path B shortens and the upper band shifts upward, revealing the simultaneous but inverse coupling between the two paths. *Id.* Varying parameter ② primarily affects the lower resonant band by changing Path A, while the upper band remains relatively stable, with optimized values of ① = 12 mm and ② = 16 mm. *Id.*, 1–2.

121. Through both simulation (using SEMCAD) and measurement (using an Agilent 8722ES network analyzer), the paper demonstrates that the antenna achieves an impedance bandwidth ($VSWR \leq 2$) of 110 MHz at the lower band (2.38–2.49 GHz), satisfying the bandwidth requirement for IEEE 802.11b, and 900 MHz at the upper band (5.1–6.0 GHz), covering the required bandwidth for both IEEE 802.11a and HIPERLAN/2. *Id.*, 2. The measured and simulated VSWR results are in good agreement. *Id.*, 2. The radiation patterns are approximately omni-directional in both frequency bands, with maximum measured gains of 2.39 dBi at 2.44 GHz and 3.70 dBi at 5.8 GHz. *Id.*, 2.

VIII. MOTIVATION TO COMBINE AND REASONABLE EXPECTATION OF SUCCESS (as of July 2006)

122. In 2006, a person of ordinary skill in the art of mobile multifunctional wireless devices (“MFWDs”) and the antennas used therein would have been motivated to develop an MFWD incorporating multiple Planar Inverted-F Antenna (PIFA) elements capable of transmitting and receiving in frequency ranges between approximately 810–2170 MHz, arranged to optimize polarity diversity. This motivation would have arisen from the state of wireless communication technology, the operational requirements of contemporary mobile devices, and the known advantages of antenna diversity techniques in portable wireless systems. As contemporaneous references recognized, “[a] mobile computing device such as a smart phone may have voice and data communications capabilities as well as

processing capabilities” and “may use multiple communications transceivers.” Ex.1015, [0001]. The need for multiband, multi-protocol operation in compact devices drove ongoing efforts to improve antenna architectures for such devices. In addition to cellular communication, WLAN capabilities were becoming a standard expectation for portable computing devices. As Cho recognized, “note book computers are increasingly being equipped with [WLAN] for the IEEE 802.11b (2.4 - 2.48 GHz), 802.11a (5.15 - 5.35 GHz, 5.725 - 5.825 GHz) in the US.” Ex.1026, 1. These parallel demands for cellular and WLAN operation in compact devices further reinforced the motivation to develop efficient, multiband internal antenna systems.

123. By the mid-2000s, mobile devices were expected to operate across multiple cellular standards and frequency bands. Commercial handsets commonly supported networks operating in the 810–960 MHz range, including GSM-850 and GSM-900, as well as higher-frequency bands extending up to approximately 2480 MHz, including DCS-1800, PCS-1900, and UMTS-2100 used for emerging third-generation services. As Ciais-Quadband explained, the relevant standards included “GSM (Global System for Mobile communications, 880–960 MHz)” as well as “DCS (Digital Communication System, 1710–1880 MHz), PCS (Personal Communication Services, 1850–1990 MHz) and UMTS (Universal Mobile Telecommunications System, 1920–2170 MHz).” Ex.1014, 1. Beyond cellular frequencies, devices were also expected to support WLAN bands at 2.4 GHz and 5

GHz, with Cho confirming that “the dual band 802.11a/b and HIPERLAN/2 antennas are required toward a small size and high gain while retaining the high efficiency.” Ex.1026, 1. A device intended for broad geographic compatibility and multimode operation therefore needed antenna structures capable of efficiently transmitting and receiving across both lower cellular bands and higher bands approaching 2 GHz. A person of ordinary skill in the art would have recognized that designing a single antenna to cover this wide range while maintaining adequate efficiency, bandwidth, and impedance matching in a compact handset presented significant but surmountable challenges. Indeed, “[w]ith the rapid progress in new communication standards, miniature multiband internal antennas are needed for modern mobile handsets” and “[s]everal techniques applied simultaneously are thus necessary to reduce the size of these antennas while maintaining good multiband/wideband performance.” Ex.1014, 1. Accordingly, the use of multiple antenna elements was a known and practical approach to meeting multiband operational requirements.

124. At the time, and even now, the Planar Inverted-F Antenna (PIFA) had become a widely adopted antenna architecture in mobile handsets. As CN456 recognized, “[a] planar inverted-F antenna (PIFA) is a typical type of built-in antenna” possessing “the advantages of small physical size and high radiation efficiency.” Ex.1016, 4. Cho likewise confirmed that “[i]nternal PIFAs are very

suitable in WLAN applications since they are compact, low profile and easy to manufacture.” Ex.1026, 1. PIFA structures were favored because they provided a low-profile configuration suitable for internal placement within compact devices, exhibited favorable radiation efficiency when coupled with the handset ground plane, and could be adapted to support multiple frequency bands through structural modifications such as slots, parasitic branches, or multiple resonant paths. For instance, Ciais-Quadband described a PIFA design in which “[t]he quarter-wavelength antenna combines the use of a slot, shorted parasitic patches and capacitive loads to achieve multi-band operation,” resulting in an antenna that “can operate from 880 to 960 MHz and 1710 to 2170 MHz covering GSM, DCS, PCS, and UMTS standards with a VSWR better than 2.5.” Ex.1014, 1. That antenna was designed on a ground plane “whose size is representative of the Printed Circuit Board (PCB) of a typical mobile phone” and achieved “[t]he computed efficiency . . . respectively above 69% and 74% in the GSM and DCS/PCS/UMTS bands which is suitable for mobile phone communication terminals.” Ex.1014, 1, 3. Similarly, Cho demonstrated a dual-band PIFA for WLAN applications in which the resonant length of the radiation path was “chosen to be about 32 mm corresponding approximately to a quarter wavelength of 2.4 GHz,” and a second path of “about 12 mm” was “selected to an electrically quarter wavelength at the resonant frequency of 5.5 GHz band,” achieving “impedance bandwidth of 110 MHz (2.38 ~ 2.49 GHz) in the

Bluetooth band and 900 MHz (5.1 ~ 6.0 GHz) near 5 GHz in WLAN band within 2:1 voltage standing wave ratio (VSWR).” Ex.1026, 1. Further, the Cho PIFA occupied a compact volume of only “ $47.5 \times 20 \times 7 \text{ mm}^3$.” *Id.* Boireau similarly recognized the suitability of PIFA antennas for handheld devices, listing among the available internal antenna types “a planar inverted-F antenna, a planar inverted-L antenna, an inverted-F antenna with a helical structure, an inverted-L antenna with a helical structure, a monopole antenna, a meandered monopole antenna, a dipole antenna, a balanced antenna, a printed helical antenna, a chip antenna, a ceramic antenna, and so forth.” Ex.1015, [0025]. These characteristics made PIFA antennas particularly suitable for integration into MFWDs where internal space was limited and where external protruding antennas were increasingly undesirable for aesthetic and mechanical reasons. Consequently, a person of ordinary skill would have viewed PIFA elements as an appropriate and predictable choice for implementing internal multiband antenna systems in a handset operating across the 800–2170 MHz range, and Cho’s work confirmed the same conclusion in the WLAN context for frequencies at 2.4 GHz and 5 GHz.

125. In addition to supporting multiple frequency bands, engineers designing wireless devices in 2006 were concerned with mitigating signal degradation caused by multipath propagation. In typical urban and indoor environments, radio signals often reach a receiver through multiple reflected paths,

producing constructive and destructive interference that results in fading and fluctuations in signal strength. As CN456 explained, “

[w]hen a radio wave propagates from a transmitting antenna to a receiving antenna, multiple propagation paths exist in the propagation environment. Each propagation path has a different propagation distance, and therefore the phases of the arriving waves are different. The strength of the electromagnetic field of the signal at each point in space is the result of superposition of these multiple paths having different phases.

Ex.1016, 5. The same reference further observed that “[i]n multipath-rich wireless propagation environments, such as urban environments and indoor environments, the signal amplitude at different points in space can still vary dramatically over distances within one wavelength, meaning that small-scale spatial fading of the signal is very pronounced.” *Id.* Antenna diversity techniques were widely known to reduce the adverse effects of multipath fading by providing multiple signal reception paths with low correlation. CN456 recognized that “MIMO diversity techniques, in terms of antenna implementation methods, include spatial diversity, polarization diversity, and radiation-pattern diversity.” Ex.1016, 4.

126. Polarization diversity, in particular, was well understood to provide improved reception reliability by utilizing antennas that radiate and receive electromagnetic waves with differing polarizations. Because signals arriving through multipath propagation frequently exhibit varying polarization states, antennas configured with different polarizations increase the likelihood that at least

one antenna will receive a sufficiently strong signal. CN456 explained that “[a]fter a wireless signal having a given polarization propagates through a propagation environment, polarization dispersion occurs, such that signal power exists both in the polarization direction identical to that of the transmitting antenna and in a polarization direction perpendicular thereto,” and that “a MIMO antenna system may employ antenna units having different polarization directions, thereby obtaining stable received power through polarization diversity.” Ex.1016, 5. A person of ordinary skill in the art would have understood that employing multiple antennas arranged to provide polarization diversity could significantly improve link reliability, receiver sensitivity, and overall communication performance in fading environments. Ciais-Quadband confirmed the practical relevance of mixed-polarization reception in mobile phone contexts, noting that its PIFA antenna patterns revealed “a quasi omnidirectional character in the θ -plane as well as a lack of polarization purity due to the radiation from the PCB,” but explaining that “these two properties are not a drawback in mobile phone applications where omnidirectional radiation patterns as well as both vertical and horizontal electromagnetic field polarization occur in urban environments.” Ex.1014, 3. Cho’s PIFA likewise exhibited “approximately omni-directional radiation pattern[s]” at both the 2.4 GHz and 5 GHz bands. Ex.1026, 1. Thus, Cho further demonstrated that PIFA structures inherently produced the type of broad radiation characteristics

amenable to diversity reception in practical wireless environments.

127. The use of polarization diversity was especially attractive in handheld devices because it could provide diversity gain without requiring large physical separation between antenna elements. Space constraints within mobile handsets limited the feasibility of implementing substantial spatial diversity, whereas polarization diversity could be achieved through the orientation and configuration of antenna elements within the existing device structure. CN456 recognized this advantage, teaching that “[t]he main polarization directions of certain antenna units are mutually perpendicular, thereby achieving polarization diversity,” and that the invention aimed to obtain “[l]ow-correlation data links . . . with a minimum spacing between antenna units, so that the MIMO antenna structure is as compact as possible, particularly within small-sized wireless terminals.” Ex.1016, 6. By arranging multiple PIFA antennas so that they exhibited differing polarization characteristics, a designer could reduce signal correlation between antenna elements while maintaining a compact internal layout.

128. A POSA would also have recognized antenna array switching, sometimes referred to as antenna selection or antenna diversity switching, as another known technique for improving wireless performance in compact devices. In antenna array switching systems, multiple antenna elements are provided, and switching circuitry selects one or more antennas based on signal quality, operating

band, or other performance metrics. This approach allows the device to dynamically select the antenna that provides the best instantaneous performance under prevailing propagation conditions. Such switching techniques were well known in wireless receivers and were used to mitigate fading, improve signal-to-noise ratio, and optimize radiation performance in devices with multiple antenna elements. Boireau described a shared antenna architecture in which “a mobile computing device may include an antenna, a switch, and multiple transceivers” and “[a]n antenna management module may control the switch to electrically connect one of the transceivers to the antenna in order for a given transceiver to transmit or receive information over the antenna.” Ex.1015, [0016]. Boireau further explained that the antenna management module “may control the position of switch 314 to alternate use of antenna 318” such that “[s]ince only one of transceivers 308-1, 308-2 is electrically connected to antenna 318 at a given moment in time, transceivers 308-1, 308-2 may be prevented from interfering with each other.” Ex.1015, [0079]. In the context of an MFWD incorporating multiple PIFA antennas, a POSA would have understood that antenna array switching could be used in conjunction with polarity diversity to further enhance communication reliability. For example, switching circuitry could select between antennas exhibiting different polarization characteristics or different radiation patterns depending on which antenna provided the strongest received signal or best link quality at a given moment. Boireau

confirmed that “[m]ultiple antennas may be desirable when implementing spatial diversity techniques (e.g., beamforming) and/or high-throughput Multiple-Input-Multiple-Output (MIMO) systems (e.g., 802.11n and 802.16e systems).” Ex. 1015, [0048]. This approach would allow the device to take advantage of diversity benefits while maintaining efficient operation across multiple frequency bands.

129. Furthermore, designers of MFWDs in this period faced numerous practical constraints associated with handset architecture, including the presence of batteries, displays, and other electronic components, as well as performance degradation caused by user interaction such as hand placement. As Boireau recognized, “[e]ach antenna may potentially increase device power requirements, create interference between antennas, increase complexity and cost, and affect a size and shape for a mobile computing device.” Ex.1015, [0001]. CN456 similarly acknowledged that “for handheld mobile terminals,” antenna configurations can result in “ground currents excited on the conductive ground planes interacting strongly with the surrounding environment, such as a user’s hand,” and that “instability in matching characteristics and degradation in radiation efficiency will significantly increase terminal power consumption and reduce standby time.” Ex.1016, 6. Cho’s PIFA design illustrated one approach to managing these constraints, achieving dual-band WLAN coverage in a total volume of only “ $47.5 \times 20 \times 7 \text{ mm}^3$ ” and demonstrating “a high gain[.]” of “2.39 dBi at 2.44 GHz and 3.70

dBi at 5.8 GHz.” Ex.1026, 1. These results confirmed that compact internal PIFA structures could deliver practical gain and bandwidth performance within the tight dimensional constraints of portable devices. Moreover, the use of multiple PIFA antennas located at different positions within the device and configured with differing polarizations provided a known method for improving overall radiation performance and mitigating detuning or blockage effects caused by the device chassis or the user's hand.

130. For these reasons, as of 2006, a POSA would have been motivated to implement an MFWD employing multiple PIFA antennas capable of transmitting and receiving in the approximate frequency ranges of 810–2480 MHz and arranged to optimize polarity diversity. Such a configuration represented a predictable and technically reasonable approach for achieving multiband operation, improving signal reliability in multipath environments, and accommodating the physical constraints of compact multifunction wireless devices. The prior art—including Ciais-Quadband’s demonstration that PIFA structures with parasitic elements could achieve “[a] compact multiband PIFA antenna” covering “both GSM and DCS/PCS/UMTS bands” with “good efficiency over the covered frequency bands,” (Ex.1014, 3); CN456’s teaching that multiple PIFA antennas could be arranged with perpendicular polarization directions to achieve “low mutual coupling, high radiation efficiency, and large system capacity,” (Ex.1016, Abstract); Cho’s

confirmation that internal PIFAs were “very suitable in WLAN applications” and could achieve dual-band operation covering the 2.4 GHz and 5 GHz bands with “approximately omni-directional radiation pattern[s]” and high gain in a compact device, (Ex.1026, 1); and Boireau's disclosure of antenna switching architectures enabling shared antenna use among multiple transceivers to reduce “device power requirements, interference between antennas, device size, device shape, device complexity, device component count” (Ex.1015, [0016])—collectively provided ample motivation and technical guidance for such a design.

131. More specifically, a POSA would have been motivated, as of July 2006, to combine the teachings from Boireau, Ciais-Quadband, Cho, and CN456 with a reasonable expectation of success of arriving at the inventions of the '103 patent. Indeed, the impetus to combine the teachings of Ciais-Quadband, Cho, Boireau, and CN456 flows directly from their complementary approaches to satisfying the motivation of the mobile smartphone device industry as of 2006.

IX. GROUND 1:

A. Claim 1

132. Claim 1 of the '103 patent recites: (i) A handheld multifunction wireless device having at least one of multimedia functionality and smartphone functionality, the handheld multifunction wireless device comprising: (ii) a touch screen; (iii) a geolocalization system; and; (iv) an antenna system comprising a ground plane layer

and three antenna elements within the handheld multifunction wireless device, the handheld multifunction wireless device being (v) configured to transmit and receive signals from at least four frequency bands, each of the at least four frequency bands being used by at least one communication standard, (vi) the antenna system comprising: (vii) a first antenna element having a conductive plate configured to simultaneously support radiation modes for at least first, second and third of the at least four frequency bands; and (viii) a second antenna element configured to receive signals from a 4 G communication standard, (ix) wherein a perimeter of the second antenna element defines an antenna contour having a level of complexity defined by complexity factor F_{21} having a value of at least 1.20 and complexity factor F_{32} having a value less than 1.75.

133. As already discussed above, as of 2006, a POSA would have been motivated to use multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at the alleged invention of claim 1.

a. A handheld MFWD having at least one of multimedia functionality and smartphone functionality, the handheld multifunction wireless device comprising

134. Boireau disclosed a “mobile computing device [that] may be implemented as a combination handheld computer and mobile telephone, sometimes referred to as a smart phone” with voice and data, processor, memory, multiple

radios, touch screen, camera, PS (e.g., Palm OS, Windows Mobile, Symbian) and multimedia card slot.” Ex.1015, [0001], [0019-0024], claim 10. A POSA would have recognized that such a computing device including a combination handheld computer and mobile telephone is “a handheld MFWD.”

135. Boireau further disclosed that the “mobile computing device ... may comprise . . . a microphone, an audio headset, a camera.” *Id.*, [0021]. Per the ’103 patent specification multimedia functionality would include “means to reproduce digital music and sound signals, . . . digital camera to record still (pictures, photos) and/or moving images (videos), combined with a microphone or microphone system to record live sound and convert it to a digital compressed format.” Ex.1001, 5:57-65. Thus, a POSA would understand that Boireau discloses a handheld MFWD having multimedia functionality. Further Boireau explicitly disclosed that the device discussed therein is a “smartphone.” Ex.1015, [0018], [0019], [0020].

136. Further, a POSA would have recognized that the Ciais-Quadband PIFA, which “is suitable for cellular telephone applications,” “achieve[s] multiband operation,” “can operate from 880 to 960 MHz and 1710 to 2170 MHz covering GSM, DCS, PCS, and UMTS standards with a VSWR better than 2.5” which is intended to be used in “modern mobile handsets” would also be compatible with and facilitate the capabilities of the Boireau MFWD. Ex.1014, 1.

137. Moreover, a POSA would have recognized that CN456 teaches how to

arrange multiple antennas including the Ciais-Quadband PIFA within Boireau's MFWD to "exhibit polarization diversity performance." Ex. 1016, 9.

138. Therefore, a POSA would combine the teachings from Boireau, Ciais-Quadband, and CN456 to arrive at a handheld MFWD having at least one multimedia functionality and smartphone functionality."

b. touch screen

139. Boireau disclosed that the "[m]obile computing device . . . may comprise various input/output (I/O) devices, such as . . . a touch-sensitive display screen." Ex.1015, [0021]. Boireau further disclosed the "display . . . may be implemented as an additional I/O device, such as a touch screen, touch panel, touch screen panel, and so forth. Touch screens are display overlays which are implemented using one of several different techniques, such as pressure sensitive (resistive) techniques, electrically-sensitive (capacitive) techniques, acoustically-sensitive (Surface acoustic wave) techniques, photo-sensitive (infra-red) techniques, and so forth. The effect of such overlays allows a display to be used as an input device, to remove or enhance the keyboard and/or the mouse as the primary input device for interacting with content provided on display." *Id.* at [0023].

140. Therefore, Boireau disclosed a handheld multifunction wireless device comprising a touch screen.

c. “a geolocalization system”

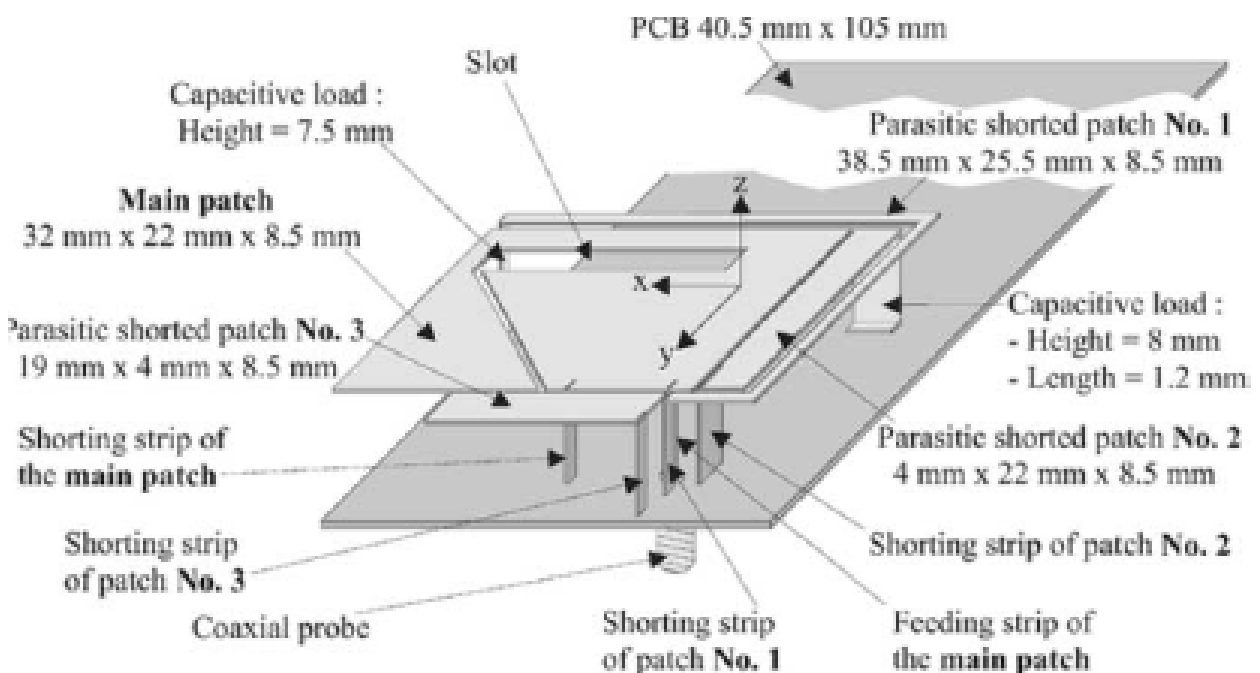
141. Boireau disclosed that “[i]n various embodiments, antenna 318 may be implemented as one or more internal antenna” and “[a]lthough FIG. 3 illustrates a single antenna 318 for purposes of clarity, it may be appreciated that radio sub-system 202 may use multiple antennas in the form an array.” Ex.1015, [0048]. Boireau further disclosed that “[i]n various embodiments, radio sub-system 202 may include various other transceivers and accompanying antennas, such as . . . a GPS transceiver.” *Id.* at [0061]. The ’103 patent states that “a geolocalization system [includes] e.g. GPS or Galileo or mobile network related terrestrial system.” Ex.1001, 9:15-16. A POSA would understand that GPS stands for global positioning satellite. Thus, Boireau disclosed a handheld multifunction wireless device comprising a geolocalization system.

142. Therefore, a POSA would have been motivated to use at least one internal antenna capable of sending and receiving signals for geolocalization purposes and arrange it within the MFWD of Boireau according to the teachings of CN456 to improve performance across all antennas.

d. An antenna system comprising a ground plane layer and three antenna elements within the handheld multifunction wireless device

143. Ciais-Quadband disclosed a single internal “[PIFA] suitable for cellular telephone applications” that “can operate from 880 to 960 MHz and 1710 to 2170

MHz covering GSM, DCS, PCS, and UMTS standards with a VSWR better than 2.5.” Ex.1014, 1. Ciais-Quadband further disclosed that “[t]he antenna consists of a main patch with three additional parasitic elements placed on the corner of a ground plane whose size is representative of the [PCB] of a typical mobile phone: 40.5 mm x 105 mm (Fig. 1).” *Id.* Ciais-Quadband provides the below image of the PIFA disclosed therein:



Ex.1014, Fig 1(a). A POSA would know that the “ground plane layer” is typically necessary for most antennas including PIFA and that the conductive layer on the PCB in the above image serves as the “ground plane layer”.

144. CN456 similar to Ciais-Quadband also disclosed an antenna system comprising a ground plane layer associated with a printed circuit board. Specifically, CN456 discloses that “[t]he present invention is characterized in that: the antenna

system comprises: printed circuit board (PCB) (1), wherein a rear surface of the [PCB] is provided with a metallic layer.” Ex.1026, claims 1, 6. CN456 also provides Fig. 1 as one possible embodiment depicting the PCB (1). A POSA would understand that the metallic layer on the surface of the PCB disclosed in CN456 is a “ground plane layer.” CN456 further disclosed “four ground-plane-shortened [PIFA] units are respectively denoted as (2d), (2a), (2b), and (2c)” that are placed on the ground plane:

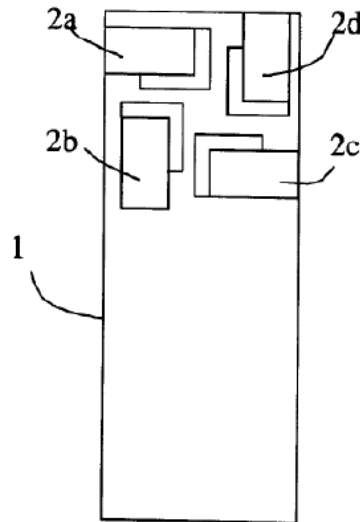


FIG. 1

145. Boireau disclosed that “[i]n various embodiments 318 may be implemented as one or more internal antennas” and that “[a]lthough FIG. 3 illustrates a single antenna 318 for purposes of clarity, it may be appreciated that radio sub-system 202 may use multiple antennas.” Ex.1015, [0048].

146. Therefore, a POSA would have been motivated to use multiple

antennas, including Ciais-Quadband PIFA arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at an antenna system comprising a ground plane layer and three antenna elements within the handheld MFWD of Boireau.

- e. **the handheld MFWD being configured to transmit and receive signals from at least four frequency bands, each of the at least four frequency bands being used by at least one communication standard**

147. Boireau disclosed cellular (GSM/UMTS family for voice and data, including HSDPA/HSUPA), Wi-Fi (802.11), and Bluetooth radios, implying multiple bands across 900/1800/1900/2100 MHz and 2.4 GHz. Ex.1015, [0032] (“In addition to voice communication services, various embodiments of radio sub-system 202 may be arranged to perform data communications in accordance with different types of cellular radiotelephone systems. Examples of cellular radiotelephone systems offering data communications services may include GSM with [GPRS] systems . . . , CDMA/1xRTT systems, [EDGE] systems, (EV-DO) systems, [EV-DV] systems, [HSDPA] systems, [HSUPA] systems, and so forth); Ex.1015, [0033] (“radio sub-system 202 may be arranged to perform voice and/or data communications in accordance with different types of wireless network systems [including] [WLAN] systems, [WMAN] systems, [WWAN] system [and] may include [IEEE] 802.xx series of protocols, such as the IEEE 802.11a/b/g/n series of standard protocols and variants (also referred to as ‘WiFi’, the IEEE 802.16 series of standard protocols and variants (also referred to as ‘WiMAX’), the IEEE 802.20

series of standard protocols and variants and so forth)”).

148. Further, a POSA would have been motivated to use the PIFA disclosed in Ciais-Quadband with the MFWD of Boireau because that PIFA is capable of sending and receiving electromagnetic radiation at 870-960 MHz and 1710-2170 MHz. Ex.1014, Fig. 3, 1-3.

149. As of July 2006, a POSA would have understood that a “frequency band” is a frequency range specified by a regulatory or standards body for a particular use, such as a type of wireless communication. Ciais-Quadband’s PIFA supports “frequency bands” that are contained within the antenna’s supported frequency ranges. Although Ciais-Quadband describes its PIFA as “quad-band” (Ex.1014, 1), the antenna is actually “configured to transmit and receive signals” from at least twenty-five frequency bands.

150. The 870-960 MHz range contains at least four “frequency bands” shown in Table a below:

Table 1: Frequency bands within 870-960 MHz.

Band	Range (MHz)
standard GSM900	890-960
extended GSM900	880-960
ISM	902-928
LTE Band 8	880-960

Ex.1017, 8-9 (“Standard or primary” and “Extended” “GSM 900 band”); Ex.1023, 13, Table 5.5-1 (“E-UTRA operating bands”); Ex.1024, 11 (listing LTE FDD and TDD bands); Ex.1018, 162-166.

151. The 1710-2170 MHz range contains at least twenty-one “frequency bands” shown in Table 2 below:

Table 2: Frequency bands within 1710-2170 MHz.

Band	Range (MHz)
DCS1800	1710-1880
PCS1900	1850-1990
UMTS Band I	1920-2170
UMTS Band II	1880-1990
UMTS Band III	1710-1880
UMTS Band IV	1710-2155
UMTS Band a	1900-1920, 2010-2025
UMTS Band b	1850-1910, 1930-1990
UMTS Band c	1910-1930
LTE Band 1	1920-2170
LTE Band 2	1850-1990
LTE Band 3	1710-1880
LTE Band 4	1710-2155
LTE Band 9	1749.9-1879.9
LTE Band 10	1710-2170
LTE Band 33	1900-1920
LTE Band 34	2010-2025
LTE Band 35	1850-1910
LTE Band 36	1930-1990
LTE Band 37	1910-1930
LTE Band 39	1880-1920

Ex.1014, 1 (DCS, PCS, UMTS); Ex.1017, 8-9 (DCS1800, PCS1900). Ex.1018, 139 (reference [100] identifies HSDPA specifications), 162-166, 182 (reference [100] is 3GPP TS 25.308 (Ex.1019)); Ex.1019 (UMTS, HSDPA description); Ex.1020, 12-13 (UMTS standard comprises TS 25.101 (Ex.1021), 25.102 (Ex.1022), TS 25.308

(Ex.1019)); Ex.1021, 12-13 (Table 5.0 “UTRA FDD frequency bands”); Ex.1022, 11 (UTRA/TDD frequency bands); Ex.1023, 13 (Table 5.5-1 (“E-UTRA operating bands” defining LTE bands); Ex.1024, 11 (listing LTE FDD and TDD bands).

152. Therefore, a POSA would have been motivated to use multiple antennas including Ciais-Quadband PIFAs arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at a handheld MFWD being configured to transmit and receive signals from at least four frequency bands, each of the at least four frequency bands being used by at least one communication standard.

- f. The antenna system comprising a first antenna element having a conductive plate configured to simultaneously support radiation modes for at least first, second, and third of the at least four frequency bands.**

153. The Ciais-Quadband PIFA is capable of sending and receiving electromagnetic radiation at 870-960 MHz and 1710-2170 MHz. Ex.1014, Fig. 3, 1-3.

154. A POSA would know that PIFA must have a conductive radiating element—i.e., a “conductive plate”—that acts as a surface or resonator in order to work. For example, the main patch of the Ciais-Quadband PIFA may be considered the “conductive plate.” Thus, Ciais-Quadband PIFA must have a conductive plate or else a POSA would be motivated to use a conductive plate with Ciais-Quadband PIFA.

155. The Ciais-Quadband PIFA comprises the main patch and three parasitic

patches that together result in at least five radiation modes. *Id.*, Fig. 1. The main patch alone, produces two radiation modes. *Id.*, 1 (“The main resonator is a dual-band PIFA antenna tuned to operate at center frequencies of 935 MHz and 1930 MHz.”). Additionally, each parasitic patch provides additional radiation modes. Specifically, parasitic patch 1 is designed at a theoretical quarter-wavelength of 76 mm at 888 MHz, creating a radiation mode in the lower portion of the GSM band; parasitic patch 2 is designed at a theoretical quarter-wavelength of 34.1 mm at 1760 MHz, creating a radiation mode just below the main patch’s center/resonant frequency within the DCS/PCS/UMTS bands; and parasitic patch 3 is designed at a theoretical quarter-wavelength of 26.9 mm at 2120 MHz, creating a radiation mode just above the main patch’s center/resonant frequency within the DCS/PCS/UMTS bands.

156. Moreover, as discussed above, the 870-960 MHz frequency range covers four frequency bands: standard GSM900, extended GSM900, ISM and LTE Band 8; and the frequency range of 1710-2170 MHz covers at least 21 frequency band: DCS1800, PCS1900, UMTS Band I, UMTS Band II, UMTS Band III, UMTS Band IV, UMTS Band a, UMTS Band b, UMTS Band c, LTE Band 1, LTE Band 2, LTE Band 3, LTE Band 4, LTE Band 9, LTE Band 10, LTE Band 33, LTE Band 34, LTE Band 35, LTE Band 36, LTE Band 37 and LTE Band 39, of which standard GSM900, extended GSM900, and ISM are the “at least first, second, and third of the

at least four frequency bands.”

157. For purposes of the analysis here, any one of GSM900 (890-960 MHz), extended GSM900 (880-960 MHz), ISM (902-928 MHz), and LTE Band 8 (880-960 MHz) can be considered the “first frequency band”; any one of DCS1800 (1710-1880 MHz), PCS1900 (1850-1990 MHz) can be considered the “second frequency band”, and any one of UMTS Band I (1920-2170 MHz), UMTS Band a (1900-1920, 2010-2025 MHz), UMTS Band c (1910-1930 MHz), LTE Band 1 (1920-2170 MHz), LTE Band 33(1900-1920 MHz), LTE Band 34 (2010-2025 MHz), and LTE Band 36 (1930-1990 MHz) can be considered the “third frequency band.”

158. Therefore, a POSA would have been motivated to use multiple antennas including Ciais-Quadband PIFAs arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at an antenna system comprising a first antenna element having a conductive plate configured to simultaneously support radiation modes for at least first, second, and third of the at least four frequency bands.

g. A second antenna element configured to receive signals from a 4G communication standard

159. Ciais-Quadband’s PIFA is configured to received signals from a 4G communication standard. The Verizon Litigation Claim Construction Order construed “4G communications standard(s)” to mean “4G communications standards that had been adopted or proposed as of the effective filing date of the ’677 Patent and the ’200 Patent, including but not limited to Long Term Evolution

(‘LTE’).” Ex.1027, 18. Ciais-Quadband’s PIFA covers LTE Band 1, LTE Band 2, LTE Band 3, LTE Band 4, LTE Band 9, LTE Band 10, LTE Band 33, LTE Band 34, LTE Band 35, LTE Band 36, LTE Band 37 and LTE Band 39. Thus, Ciais-Quadband’s PIFA is configured to receive signals from a 4G communication standard.

160. Additionally, the ’103 patent expressly defines HSDPA as a “4G feature” and “4G service” that it equates with a “4G standard.” Ex.1001, 24:22-35 (“A MFWD incorporating 3.5G or 4G features (i.e. comprising 3G and other advanced services such as for instance HSDPA)”). HSDPA is part of the Universal Mobile Telecommunications System (UMTS) and supported by UMTS frequency bands. Ex.1018, 63, 182; Ex.1019 (UMTS HSDPA description); Ex.1020, 11 (UMTS standard comprises 3GPP TS 25.101 (Ex.1021), 25.102 (Ex.1022)), 12 (UMTS standard comprises 3GPP TS 25.308 (Ex.1019)). The Ciais-Quadband PIFA supports seven UMTS frequency bands (UMTS Band I (1920-2170 MHz), UMTS Band II (1880-1990 MHz), UMTS Band III (1710-1880 MHz), UMTS Band IV (1710-2155 MHz), UMTS Band a (1900-1920, 2010-2025 MHz), UMTS Band b (1850-1910, 1930-1990 MHz), UMTS Band c (1910-1930 MHz)). Therefore, Ciais-Quadband PIFA is capable of receiving signals from a 4G communication standard for this additional reason.

161. Further, CN456 taught a four antenna MIMO system arranged to

achieve low mutual coupling, high radiation efficiency, wide and complementary radiation patterns, and increased system capacity in compact devices. Ex.1016, Abstract, 6. CN456, however, did not disclose the specific PIFA antenna to be used. Ciais-Quadband, however, does disclose a specific PIFA antenna that achieves measured coverage from 880-960 MHz and 1710-2170 MHz and therefore supports GSM, DCS, PCS, and UMTS with VSWR thresholds suitable for handset deployment. Thus, a POSA would have been motivated to use four Ciais-Quadband PIFA in the mobile device of Boireau arranged according to the teachings of CN456. As such the Ciais-Quadband PIFA would serve as a second antenna.

162. Therefore, a POSA would be motivated to use multiple Ciais-Quadband PIFA arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at an antenna system comprising a second antenna element configured to receive signals from a 4G communication standard.

- h. wherein a perimeter of the second antenna element defines an antenna contour having a level of complexity defined by complexity factor F_{21} having a value of at least 1.20 and complexity factor F_{32} having a value less than 1.75.**

163. The Ciais-Quadband PIFA meet this limitation.

- i. Calculating F_{21}**

- 1. Grid G_2**

164. The '103 patent identifies a preferred embodiment wherein second grid G_2 has nine columns. Ex.1001, 17:12-16. The Ciais-Quadband antenna has

dimensions 38.5 mm x 28.5 mm resulting in a rectangle. Ex.1014, Fig. 1(b), 1. Applying nine columns to the Ciais-Quadband antenna yields cell width of 4.28 mm (38.5 mm / 9).

165. Setting an odd number of five, seven, and nine rows to the Ciais-Quadband PIFA yields the following aspect ratios:

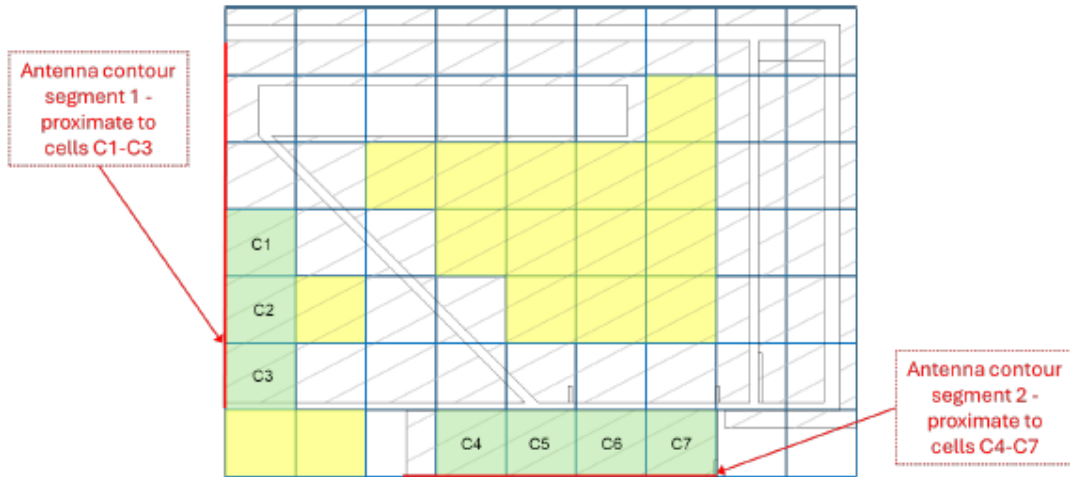
# rows	cell height (mm)	aspect ratio
5	$\left(\frac{28.5 \text{ mm}}{5}\right) = 5.7$	$\left(\frac{4.28}{5.7}\right) = 0.75$
7	$\left(\frac{28.5 \text{ mm}}{7}\right) = 4.07$	$\left(\frac{4.28}{4.07}\right) = 1.05$
9	$\left(\frac{28.5 \text{ mm}}{9}\right) = 3.17$	$\left(\frac{4.28}{3.17}\right) = 1.35$

166. Therefore, seven rows provide grid cells “as square as possible,” e.g., an aspect ratio closest to one. Ex.1001, 16:36-39, 16:58-17:35. Thus, grid G₂ with nine (9) columns and seven (7) rows has cells “as square as possible[.]”

2. N₂ = 47

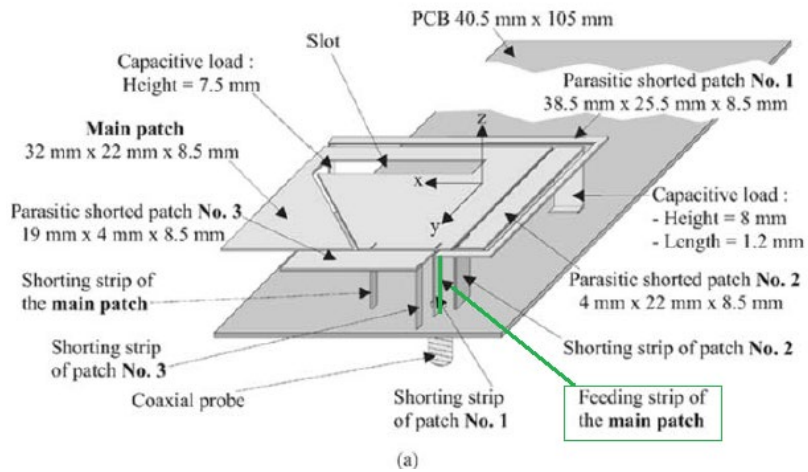
167. I superimpose G₂ for the Ciais-Quadband PIFA (blue outline) over its antenna contour here:

C3 each “include at least a point of the antenna contour.” Similarly, the bottom of cells marked C4-C7 matches the bottom of patch no. 3 (“Antenna contour segment 2” in red), and thus “include at least a point of the antenna contour.”

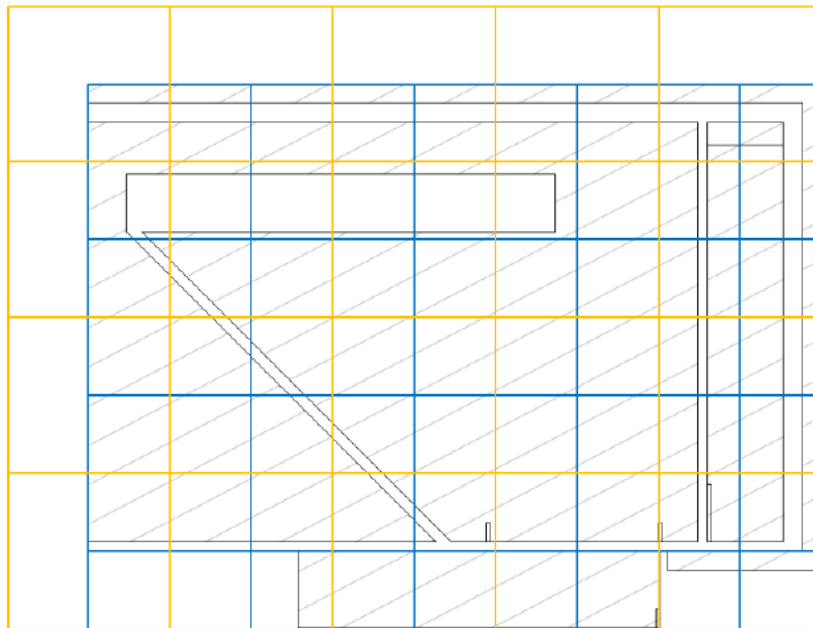


3. Grid G_1

170. The Ciais-Quadband PIFA feed for the lowest frequency operation is closest to the bottom right corner (“feed point corner” identified in green below) of the antenna rectangle, so G_1 is placed from the bottom right corner below. Ex.1014, Fig. 1(a) (“feeding strip of main patch); Ex.1001, 17:54-18:23.

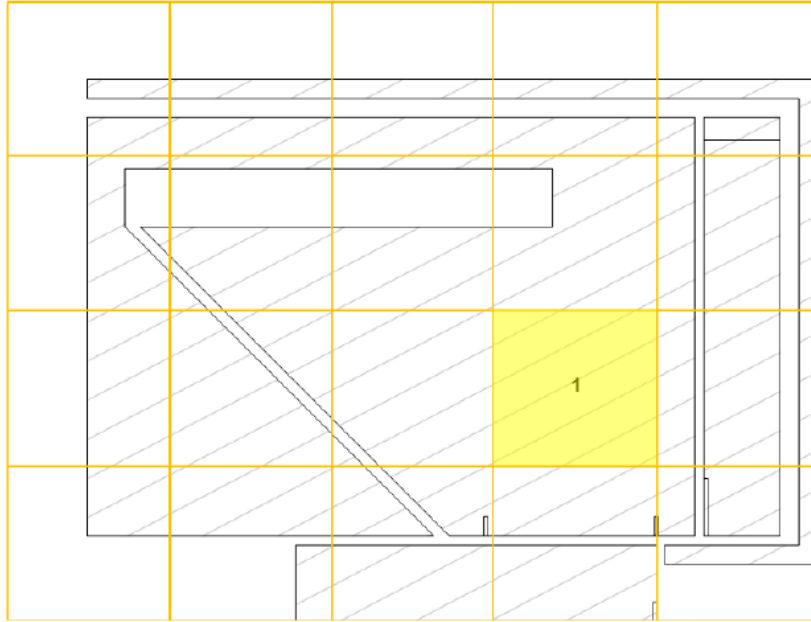


Grouping four G_2 cells (blue grid lines) into a single G_1 cell results in the 4 x 5 grid G_1 shown in below (orange grid lines). Ex.1001, 18:24-27.



4. $N_1 = 19$

171. A single cell within G_1 (yellow below) does not “include at least a point of the antenna contour.” Ex.1001, 18:37-44. Therefore, the G_1 cell count N_1 is 19 (20 – 1).



5. $F_{21} = 1.31$

172. The complexity factor F_{21} for the quadband antenna contour is thus:

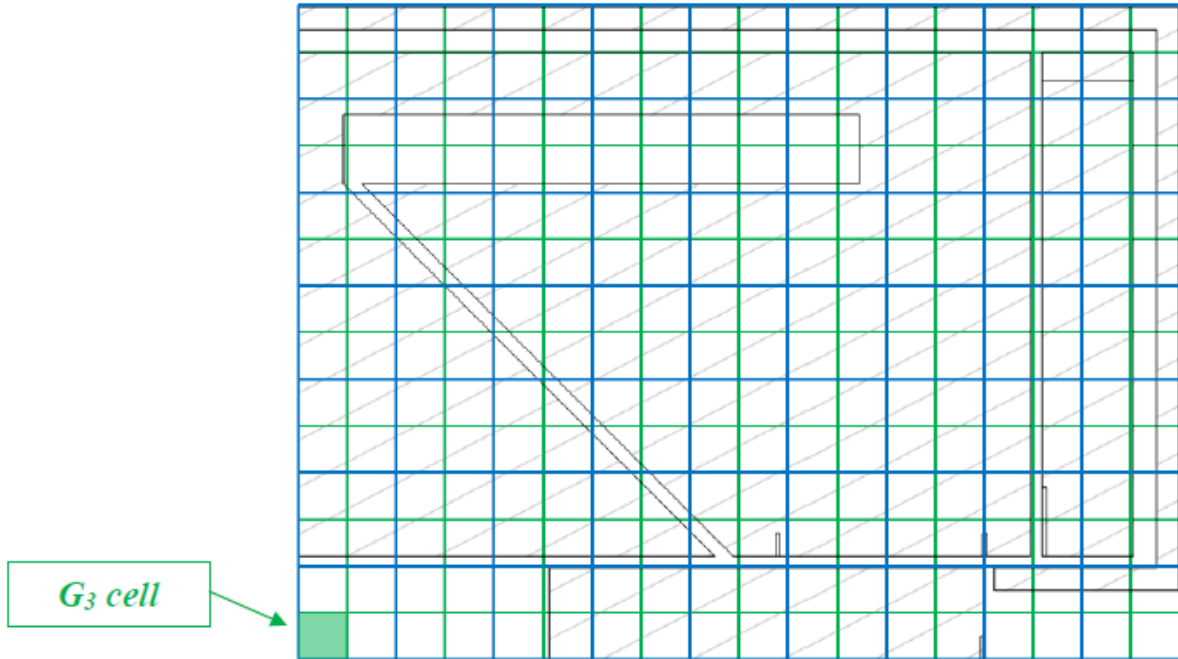
$$\begin{aligned}
 F_{21} &= -\left(\frac{\log(N_2) - \log(N_1)}{\log(1/2)}\right) = -\left(\frac{\log(47) - \log(19)}{(-1)\log(2)}\right) \\
 &= \left(\frac{\log(47/19)}{\log(2)}\right) = \left(\frac{0.393}{0.301}\right) = 1.31.
 \end{aligned}$$

Ex.1001, 18:45-50.

ii. Calculating F_{32}

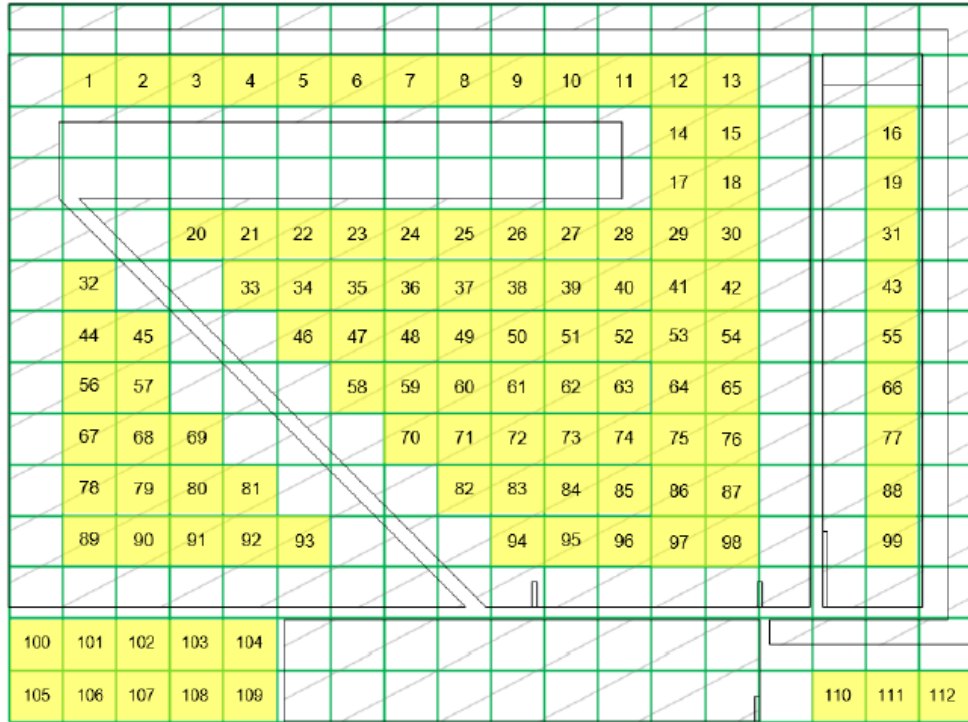
1. Grid G_3

173. Grid G_3 (green outline below) is 14 rows by 18 columns so that four G_3 cells comprise a single G_2 cell (blue outline below). Ex.1001, 19:16-25. The G_3 cells have width of 2.139 mm (38.5 mm / 18) and a height of 2.036 mm (28.5 mm / 14).



2. $N_3 = 140$

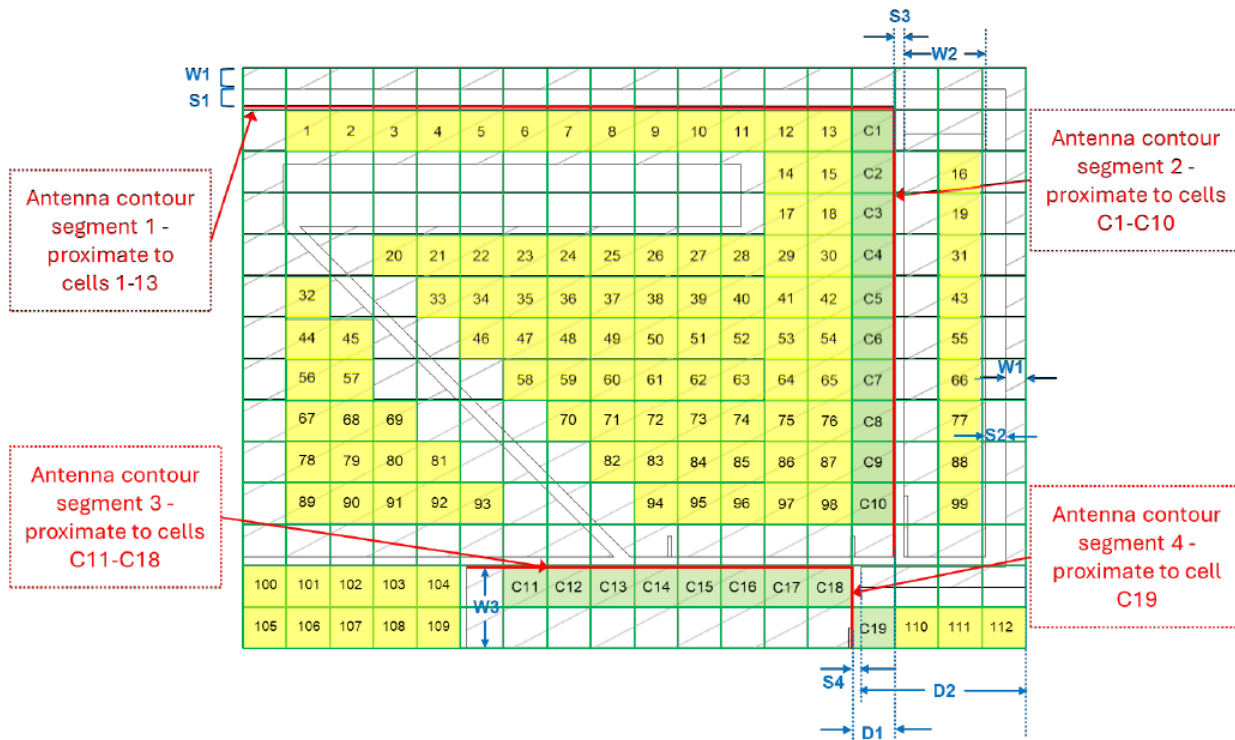
174. As shown below 112 numbered G_3 cells for the Ciais-Quadband PIFA do not “include at least a point of the antenna contour.” Ex.1001, 19:26-32. As such the cell count N_3 is 140 (252 – 112). The cells shaded yellow in the image below are completely within the quadband antenna contour (cells 1-99) or completely outside of the antenna contour (cells 100-112). Therefore, cells 1-112 do not “include at least a point of the antenna contour.” Ex.1001, 19:26-32.



175. Below, using annotated plots and a table summarizing relevant dimensions, I also provide an explanation for why certain G_3 cells “include at least a point of the antenna contour” Ex.1014, Fig. 1(b), 1. The top edge of cells numbered 1-13 (yellow shaded cells) is 2.036 mm (a G_3 cell height) from the top of the antenna rectangle. The proximate antenna contour edge (“segment 1” highlighted in red) is

$$W1 + S1 = 1.0 + 1.0$$

Symbol	Length (mm)	Explanation
W1	1	Width of parasitic patch no. 1
W2	4	Width of parasitic patch no. 2
W3	4	Width of parasitic patch no. 3
S1	1	Spacing between patch no. 1 and main patch
S2	1	Spacing between patch no. 1 and patch no. 2
S3	0.5	Spacing between patch no. 2 and main patch
S4	0.4	Spacing between patch no. 1 and patch no. 3
D1	2	Distance between right edge of main patch and center line of projection of feeding strip
D2	8.1	Length of the bottom arm of patch no. 1



176. The top edge of cells 1-13 in the image above is 2.036 mm (a G_3 cell height) from the top of the antenna rectangle. The proximate antenna contour edge (segment 1 highlighted above in red) is 2 mm ($W1 + S1 = 1.0 + 1.0$) from the top of the antenna rectangle and therefore lies above the top edge of cells 1-13. Therefore, cells 1-13 do not “include at least a point of antenna contour.” Ex.1014, Fig. 1(b), 1.

177. The right edges of cells numbered C1-C10 are 6.417 mm (2.139×3 or three times the G_3 cell width) from the right edge of the antenna rectangle. The proximate antenna contour edge (segment 2 highlighted in red above) is 6.5 mm ($W1 + S2 + W2 + S3 = 1 + 1 + 4 + 0.5$) from the right edge of the antenna rectangle, and therefore lies inside cells C1-C10. Ex.1014, Fig. 1(b), 1. Cells C1-C10 therefore “include at least a point of the antenna contour.”

178. The top edges of C11-C18 are 4.072 mm (2.036×2 or two times the G_3 cell height) from the bottom of the antenna rectangle. The proximate antenna contour edge (segment 3 highlighted in red above) is 4 mm—i.e., the width of parasitic patch no. 3) from the bottom of the antenna rectangle and thus within cells C11-C18. Ex.1014, Fig. 1(b), 1. C11-C18 therefore include the antenna contour passing through them and thus “include at least a point of the antenna contour.”

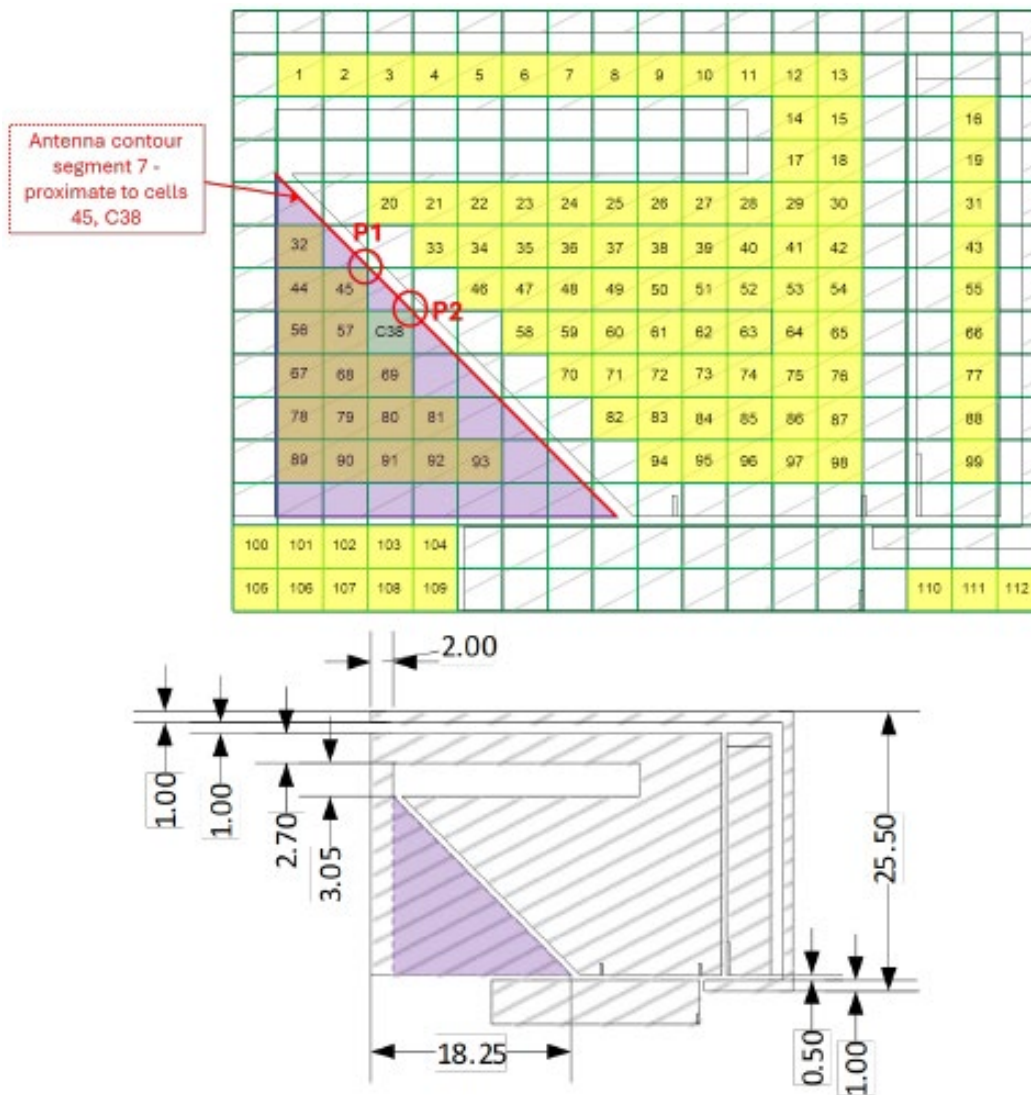
179. The left edge of cell C19 is 8.556 mm (2.139×4 or four times the G_3 cell width), because C19 is at the fourth column from the right edge of the antenna rectangle. The proximate antenna contour edge (segment 4 highlighted in red above) is 8.5 mm ($W1 + S2 + W2 + S3 + D1 = 1 + 1 + 4 + 0.5 + 2$) from the right edge of the antenna rectangle. Ex.1014, Fig. 1(b), 1. This distance is confirmed by calculating it in another way: $D2 + S4 = 8.1 + 0.4 = 8.5$ mm. Thus, the proximate antenna contour edge lies *within* C19, i.e., goes through cell C19. Cell 19 therefore “include[s] at least a point of the antenna contour.” Ex.1014, Fig. 1(b), 1.

180. I note that the '103 patent states that “in the present invention the boundary of the cell is also part of the cell[.]” Ex.1001, 19:40-41. This means that even if a grid cell only includes points of the antenna contour on its cell boundary, e.g., the antenna contour matches the cell boundary and does not further extend into the cell, the cell still “include[s] at least a point of the antenna contour.” As shown below, the left edges of C20-C29 match the left edge of the main patch (“Antenna contour segment 5” in red below), and thus C20-C29 each “include at least a point of the antenna contour.” Likewise, the bottom of C20-C27 match the bottom of patch no. 3 (“Antenna contour segment 6” in red below) and thus “include at least a point of the antenna contour.”



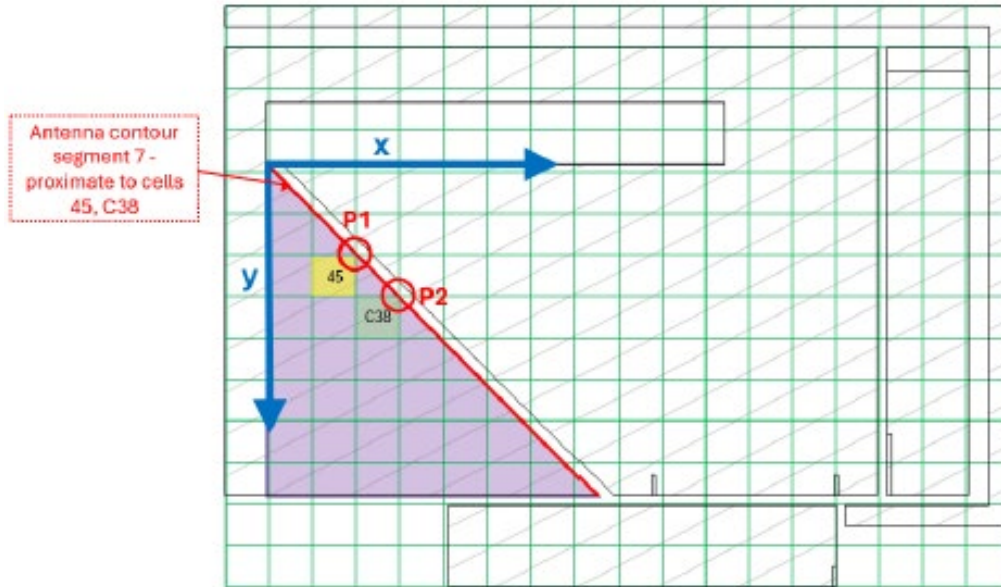
181. Below, the purple portion of the main patch is a right triangle, as confirmed by calculating the vertical and horizontal sides using dimensions disclosed in Ciais-Quadband (reproduced in the plots below). Ex.1014, Fig. 1(b), 1.

The vertical side is taken as a line segment parallel to the left edge of the main patch, and its length is 16.25 ($25.50 - 1.00 - 1.00 - 2.70 - 3.05 - 0.50 - 1.00$). The length of the triangle's horizontal side (along the bottom of the main patch) is 16.25 mm ($18.25 - 2.00$). Because the vertical and horizontal sides are of equal length and perpendicular to each other, the triangle shaded in purple below must be an isosceles right triangle:



182. The top right corner of cell 45—i.e., P1 in the images above and

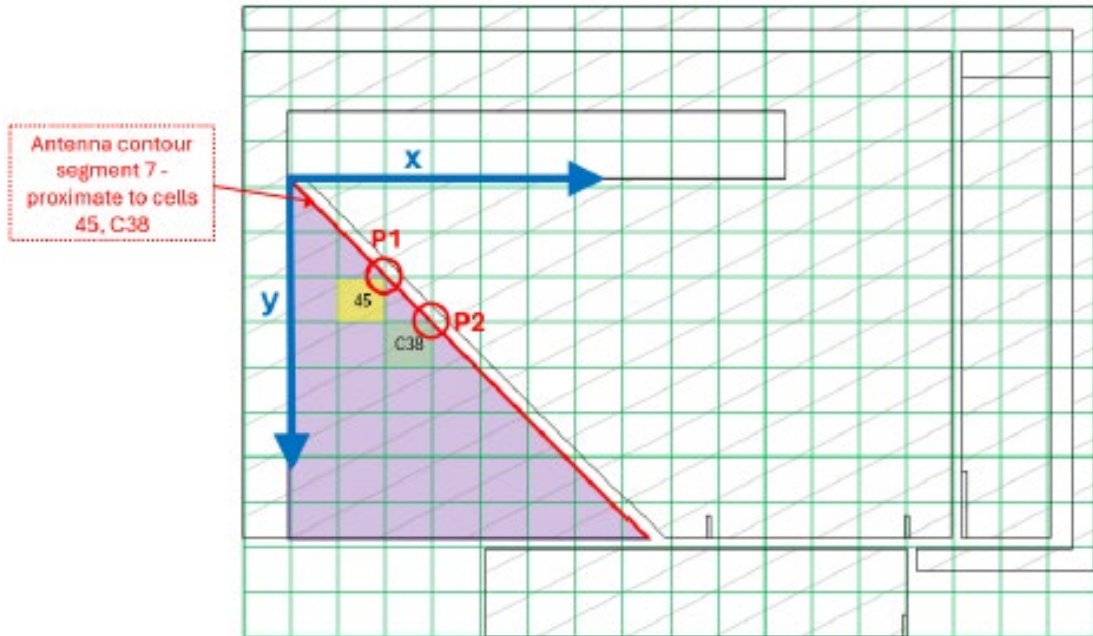
below—is 6.417 mm (2.139×3 or three times a G_3 cell width) from the left edge of the antenna rectangle. P1 is also 12.216 mm (2.036×6) from the top of the Ciais-Quadband antenna rectangle.



183. Looking at the image above, relative to the purple triangle’s x , y coordinates, P1’s x -position is 4.417 mm ($6.417 - 2$) and its y -position is 4.466 mm ($12.216 - 1 - 1 - 2.7 - 3.05$). Further, for any point that lies on “segment 7”—i.e., the hypotenuse of the purple triangle (outlined in red above)—the horizontal (x) and vertical (y) offsets will be equal. Thus, when the x -position is 4.417 mm then so too will the y -position be 4.417 mm. This is less than P1’s y -position. As such, at the same x -position as P1, the “segment 7” is closer to the top of the Ciais-Quadband antenna rectangle—i.e., above P1—meaning P1 lies below “segment 7” and is within the main patch and thus cell 45 is completely within the main patch does *not*

“include at least a point of the antenna contour.”

184. The top right corner of cell 38—i.e., P2 in the two immediately preceding images—is 8.556 mm (2.139×4 or four times a G_3 cell width) from the left edge of the Ciais-Quadband antenna rectangle, and 14.252 mm (2.036×7) from top of the Ciais-Quadband antenna rectangle. Relative to the purple triangle’s x-y coordinates, P2’s x-position is 6.556 mm ($8.556 - 2$), and y-position is 6.502 mm ($14.252 - 1 - 1 - 2 - .7 - 3.05$). Further, for any point that lies on “segment 7”—i.e., the hypotenuse of the purple triangle (outlined in red above)—the horizontal (x) and vertical (y) offsets are equal, and thus when x-position is 6.556 mm, the y-position is also 6.556 mm. This is more than P2’s y-position. Thus, at the same x-position as P2, “segment 7” is farther from the top of the Ciais-Quadband antenna rectangle—i.e., below P2—meaning P2 extends beyond “segment 7” and is outside the main patch, and thus cell 38 “include[s] at least a point of the antenna contour.”



3. $F_{32} = 1.57$

185. The complexity factor F_{32} for the PIFA disclosed in Ciais-Quadband antenna contour is 1.57:

$$\begin{aligned}
 F_{32} &= -\left(\frac{\log(N_3) - \log(N_2)}{\log(1/2)}\right) = -\left(\frac{\log(140) - \log(47)}{(-1)\log(2)}\right) \\
 &= \left(\frac{\log(140/47)}{\log(2)}\right) = \left(\frac{0.474}{0.301}\right) = 1.57.
 \end{aligned}$$

Ex.1001, 19:34-38.

i. Conclusion

186. Accordingly, a POSA would have been motivated with a reasonable expectation of success to use multiple antennas including multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at a handheld multifunction wireless device having at least one of multimedia

functionality and smartphone functionality, the handheld multifunction wireless device comprising: a touch screen; a geolocalization system; and; an antenna system comprising a ground plane layer and three antenna elements within the handheld multifunction wireless device, the handheld multifunction wireless device being configured to transmit and receive signals from at least four frequency bands, each of the at least four frequency bands being used by at least one communication standard, the antenna system comprising: a first antenna element having a conductive plate configured to simultaneously support radiation modes for at least first, second and third of the at least four frequency bands; and a second antenna element configured to receive signals from a 4 G communication standard, wherein a perimeter of the second antenna element defines an antenna contour having a level of complexity defined by complexity factor F_{21} having a value of at least 1.20 and complexity factor F_{32} having a value less than 1.75.

B. Claim 2

a. The handheld MFWD of claim 1

187. Claim 2 of the '103 patent depends from claim 1 and therefore includes all of the limitations of claim 1. Therefore, I incorporate my analysis of claim 1 into my analysis of claim 2 as if fully set forth herein.

b. wherein the first frequency band is contained within 810-960 MHz frequency range

188. As discussed above with respect to claim 1's requirement that "the

handheld multifunction wireless device” be “configured to transmit and receive signals from at least four frequency bands, each of the at least four frequency bands being used by at least one communications standard,” the Ciais-Quadband PIFA is capable of sending and receiving electromagnetic radiation at 870-960 MHz. Ex.1014, Fig. 3, 1-3. Further, there are four frequency bands—i.e., standard GSM900, extended GSM900, ISM, and LTE Band 8—contained within 870-960 MHz. *See*, ¶¶149-151, above (Tables listing frequency bands in 870-960 MHz and 1710-2170 MHz). Any one of these frequency bands can satisfy claim 2 requirement that “first frequency band is contained within 810-960 MHz.”

c. the second frequency band is contained with 1710-1990 MHz frequency range, and

189. As discussed above with respect to claim 1’s requirement that “the handheld multifunction wireless device” be “configured to transmit and receive signals from at least four frequency bands, each of the at least four frequency bands being used by at least one communications standard,” the Ciais-Quadband PIFA is capable of sending and receiving electromagnetic radiation at 1710-2170 MHz. Ex.1014, Fig. 3, 1-3. As such, the PIFA disclosed in Ciais-Quadband is capable of sending and receiving signals at the narrower claimed range of 1710-1990 MHz.

190. Further, there are at least 20 frequency bands within 1710-1990 MHz. Ex.1014, 1 (DCS, PCS, UMTS); *see*, ¶¶ 149-151, above (Table 2 listing frequency bands in 1710-2170 MHz). These include DCS1800, PCS1900, UMTS Bands I-IV,

UMTS Bands a-c, LTE Bands 1-4, LTE Bands 9-10, LTE Band 33, LTE Bands 35-37, LTE Band 39. *Id.* Any one of these frequency bands can satisfy claim 2's requirement that "the second frequency band is contained within 1710-1990 MHz frequency range."

d. the third frequency band is contained within 1900-2170 MHz frequency range.

191. As discussed above with respect to claim 1's requirement that "the handheld multifunction wireless device" be "configured to transmit and receive signals from at least four frequency bands, each of the at least four frequency bands being used by at least one communications standard," the Ciais-Quadband PIFA is capable of sending and receiving electromagnetic radiation at 1710-2170 MHz. Ex.1014, Fig. 3, 1-3. Thus, Ciais-Quadband is also capable of sending and receiving electromagnetic radiation at the narrower claimed 1900-2170 MHz frequency range.

192. Further, within this range, there are at least 17 frequency bands, including PCS1900, UMTS Band I, UMTS Band II, UMTS Band IV, UMTS Bands a-c, LTE Bands 1-2, LTE Band 4, LTE Band 10, LTE Bands 33-37, and LTE Band 39. Ex.1014, 148 (DCS, PCS, UMTS); *see*, ¶¶ 149-151, above (Tables listing frequency bands). Any one of these frequency bands can satisfy claim 2's requirement that "the third frequency band is contained within 1900-2170 MHz frequency range."

e. Conclusion

193. Accordingly, a POSA would have been motivated with a reasonable expectation of success to use multiple antennas including multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at the invention of claim 1, wherein the first frequency band is contained within 810-960 MHz frequency range, the second frequency band is contained within 1710-1990 MHz frequency range, and the third frequency band is contained within 1900-2170 MHz frequency range.

C. Claim 3

a. The handheld MFWD of claim 1, wherein

194. Claim 3 of the '103 patent depends from claim 1 and therefore includes all of the limitations of claim 1. Therefore, I incorporate my analysis of claim 1 into my analysis of claim 3 as if fully set forth herein.

b. The first antenna element is proximate to a short side of a ground plane rectangle defined by the ground plane layer, and the second antenna element is proximate to a short side of the ground plane rectangle

195. As discussed above, a POSA would have been motivated with a reasonable expectation of success to follow the arrangement of multiple PIFAs in a MFWD according to the teachings in CN456.

196. CN456 discloses an antenna system comprising a ground plane layer associated with a printed circuit board. Specifically, CN456 discloses that “[t]he

present invention is characterized in that: the antenna system comprises: printed circuit board (PCB) (1), wherein a rear surface of the [PCB] is provided with a metallic layer.” Ex.1016, claim 1, 6. A POSA would understand that the PCB with a metallic layer is the ground plane layer.

197. Further, Figure 1 from CN456 defines the rectangle of the PCB—i.e., the “ground plane rectangle” (blue outline below)—because it “is a rectangle whose edges are tangent to at least one point of the ground plane.” Ex.1001, 14:9-11. CN456 further discloses “four ground-plane-shortened [PIFA] units are respectively denoted as (2d), (2a), (2b), and (2c)” that are placed on the ground plane.

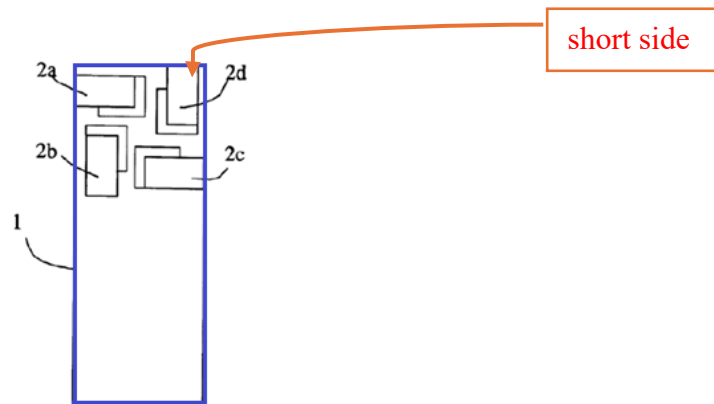


FIG. 1

Id., Fig. 1 (annotated).

198. Ciais-Quadband teaches a rectangular (40.5 mm x 105 mm) PCB, also backed by a ground plane, that Ciais-Quadband explains is representative of PCBs for typical mobile phones. Ex.1014, Fig. 1, 1. The top/shorter edge of the PCB depicted in CN456 Fig. 1 is the “short side of a ground plane rectangle defined by the ground plane layer.” Ex.1016, Fig. 1. Disposing a first Ciais-Quadband PIFA (the

“first antenna element”) and a second Ciais-Quadband PIFA (the “second antenna element) at 2a or 2d, respectively, as taught by CN456 results in both first and second antenna elements that are “proximate to a short side of a ground plane rectangle defined by the ground plane layer.”

c. Conclusion

199. Accordingly, a POSA would have been motivated with a reasonable expectation of success to use multiple antennas including multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at the invention of claim 1, wherein the first antenna element is proximate to a short side of a ground plane rectangle defined by the ground plane layer and the second element is proximate to a short side of the ground plane rectangle.

D. Claim 4

a. The handheld MFWD of claim 1, wherein

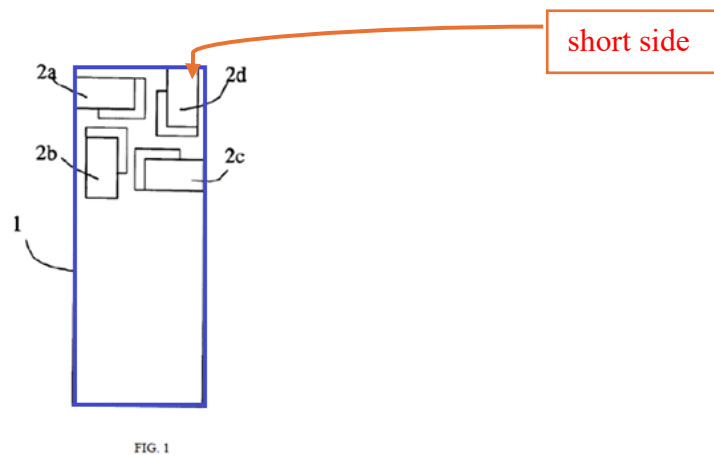
200. Claim 4 of the '103 patent depends from claim 1 and therefore includes all of the limitations of claim 1. Therefore, I incorporate my analysis of claim 1 into my analysis of claim 4 as if fully set forth herein.

b. The first antenna element is proximate to a short side of a ground plane rectangle defined by the ground plane layer, and the second antenna element is proximate to a long side of the ground plane rectangle.

201. As discussed above, a POSA would have been motivated with a reasonable expectation of success to follow the arrangement of multiple PIFAs in a

MFWD according to the teachings in CN456.

202. As discussed above with respect to claim 3, a POSA would understand that the PCB with a metallic layer disclosed in CN456 is the ground plane layer. Further, Figure 1 from CN456 defines the rectangle of the PCB—i.e., the “ground plane rectangle”—because it “is a rectangle whose edges are tangent to at least one point of the ground plane.” Ex.1001, 14:9-11. CN456 further discloses “four ground-plane-shortened [PIFA] units are respectively denoted as (2d), (2a), (2b), and (2c)” that are placed on the ground plane. Ex.1016, claims 1, 7.



Ex.1016, Fig. 1 (annotated).

203. Ciais-Quadband teaches a rectangular (40.5 mm x 105 mm) PCB, also backed by a ground plane, that Ciais-Quadband explains is representative of PCBs for typical mobile phones. Ex.1014, Fig. 1, 1. The top/shorter edge of the PCB depicted in CN456 Fig. 1 is the “short side of a ground plane rectangle defined by the ground plane layer.” Ex.1016, Fig. 1. The left and right edges of the PCB depicted in CN 456 Fig. 1 are the long side of the ground plane rectangle. Disposing

a first Ciais-Quadband PIFA (“first antenna element”) at 2a or 2b as taught by CN456 results in a first antenna elements that is “proximate to a short side of a ground plane rectangle defined by the ground plane layer.” Disposing a second Ciais-Quadband PIFA (“second antenna element”) at either 2b or 2c results in a second antenna element that is “proximate to a long side of the ground plane rectangle defined by the ground plane layer.”

c. Conclusion

204. Accordingly, a POSA would have been motivated with a reasonable expectation of success to use multiple antennas including multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at the invention of claim 1, wherein the first antenna element is proximate to a short side of a ground plane rectangle defined by the ground plane layer and the second element is proximate to a long side of the ground plane rectangle.

E. Claim 6

205. Claim 6 of the ’103 patent recites (i) A handheld multifunction wireless device having at least one of multimedia functionality and smartphone functionality, the handheld multifunction wireless device comprising: (ii) a touch screen; (iii) a microprocessor and an operating system adapted to permit running of word-processing, spreadsheet, and slide software application; (iv) an image recording system comprising an at least two Megapixel image sensor; (v) an antenna system

within the handheld multifunction wireless device and (vi) configured to operate in at least five frequency bands, the antenna system comprising: (vii) a ground plane layer; (viii) a first antenna element having a conductive plate configured to support first, second, and third radiation modes respectively providing first, second, and third paths for current respectively associated with first, second, and third frequencies bands, (ix) the first, second and the third radiation modes overlapping at least partially with each other, (x) the first frequency band being contained within a first frequency region of an electromagnetic spectrum, (xi) the second and third frequency bands being contained within a second frequency region of the electromagnetic spectrum that is higher in frequency than the first frequency region; and (xii) a second antenna element configured to operate in at least one frequency band, the at least one frequency band being used by a 4G communication standard, wherein (xiii) a perimeter of the first antenna element defines a first antenna contour having a level of complexity defined by first complexity factor F_{21} having a value of at least 1.20 and first complexity factor F_{32} having a value less than 1.75; and (xiv) a perimeter of the second antenna element defines a second antenna contour having a level of complexity defined by second complexity factor F_{21} having a value of at least 1.20 and second complexity factor F_{32} having a value less than 1.75.

a. A handheld multifunction wireless device having at least one of multimedia functionality and smartphone functionality, the handheld multifunction wireless device comprising

206. This limitation is also recited in Claim 1 of the '103 patent. Therefore, I incorporate my analysis of this limitation from claim 1, as if fully set forth herein.

b. Touch screen

207. This limitation is also recited in Claim 1 of the '103 patent. Therefore, I incorporate my analysis of this limitation from claim 1, as if fully set forth herein.

c. a microprocessor and an operating system adapted to permit running of word-processing, spreadsheet, and slide software application

208. Boireau discloses that the handheld MFWD disclosed therein “may be implemented using one or more hardware elements and/or software elements” and “hardware elements may include processors, microprocessors.” Ex.1015, [0036]. Boireau further discloses that “[i]n various embodiments, radio sub-system 202 may include processor 302. Processor 302 may be implemented using any processor or logic device, such as complex instruction set computer (CISC) microprocessor, a reduced instruction set computing (RISC) microprocessor, a very long instruction word (VLIW) microprocessor, a processor implementing a combination of instruction sets, or other processor device.” *Id.*, [0049]. A POSA would know that CISC, RISC are capable of running word-processing, spreadsheet, and slide software.

209. Boireau further discloses that “[p]rocessing sub-system 206 may

provide computing or processing operations for mobile computing device” disclosed therein and that “[s]ystem programs assists in the running of a computer system” and “may be directly responsible for controlling, integrating, and managing the individual hardware components of the computer system. Examples of system programs may include operating systems (OS).” Ex.1015, [0065]. Boireau goes on to disclose that

[i]n various embodiments, processing sub-system 206 of mobile computing device 100 may be capable of executing different OS. In computing, an OS is the system software responsible for the direct control and management of hardware and basic system operation. Additionally, it provides a foundation upon which to run application software such as word processing programs and web browsers. Mobile computing device 100 may utilize any OS suitable for smaller form factor devices, such as a Palm OS®, Microsoft Windows® CE, Microsoft Pocket PC, Microsoft Mobile, Symbian OS, Embedix OS, and others.

Ex.1015, [0066]. A POSA would know that the operating systems disclosed in Boireau are capable of running word-processing, spreadsheets, and slide software.

210. Therefore, a POSA would be motivated to use multiple Ciais-Quadband PIFA arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at a microprocessor and an operating system adapted to permit running of word-processing, spreadsheet, and slide software application.

d. an image recording system comprising an at least two Megapixel image sensor;

211. Boireau discloses that the handheld MFWD disclosed therein “may

comprise various input/output (I/O) devices, such as ... a camera.” Ex.1015, [0021]. A POSA would know that cameras in mobile devices require megapixel image sensors to function, as they use millions of light sensitive ‘photosites’ to create an image. Boireau further discloses that “the display 138 may comprise one or more thin-film transistors (TFT) LCD including embedded transistors. In such implementation, the display 138 may comprise a transistor for each pixel to implement an active matrix.” While the Boireau does not explicitly disclose two megapixel image sensor, as of 2006, POSAs were well aware that LCD are typically integrated with or used in screens displays that have three or more megapixel sensors; and that, as of 2006, “cell phones have 3- to 5-megapixel image sensors, and 8 megapixels are on the horizon.” Ex. 1025, 2. In fact, Sony had introduced a 2-megapixel smartphone camera in 2005, and Micron Technologies announced 5 MP sensors towards the end of 2005. Ex.1029, 2-3; Ex.1028, 1-2. Thus, it would have been obvious to have an image recording system comprising at least a two megapixel image sensor.

212. Therefore, a POSA would be motivated to use multiple Ciais-Quadband PIFA arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at an image recording system comprising an at least two Megapixel image sensor.

e. an antenna system within the handheld MFWD and

213. Boireau disclosed that the handheld multifunctional wireless device disclosed therein “may comprise an antenna system including one or more antennas.” Ex.1015, [0025].

214. Further, CN456 disclosed a PIFA antenna system arrangement for use in a wireless terminal device “to reduce mutual coupling among the respective [antennas], so as to improve antenna radiation efficiency and extend the standby time of a wireless terminal, particularly in compact terminal devices in which the spacing between antenna units is within a range of 0.25 to 1 wavelength.” Ex.1016, 6.

215. Further still, Ciais-Quadband discloses specifications for a PIFA that could be arranged inside of the handheld multifunctional device of Boireau according to the disclosures in CN456.

216. Therefore, a POSA would be motivated to use multiple Ciais-Quadband PIFA arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at an antenna system within the MFWD.

f. configured to operate in at least five frequency bands, the antenna system comprising:

217. As discussed with respect to claim 1’s requirement that “the handheld [MFWD] be[] configured to transmit and receive signals from at least four frequency bands,” Ciais-Quadband’s PIFA is “configured to transmit and receive signals” from at least twenty-five frequency bands because it is capable of sending and receiving

electromagnetic radiation at 870-960 MHz and 1710-2170 MHz. Ex.1014, Fig. 3, 1-3; *see also*, Section IX.A, above.

218. Therefore, a POSA would be motivated to use multiple antennas including Ciais-Quadband PIFA arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at an antenna system configured to operate in at least five frequency bands.

i. a ground plane layer;

219. This limitation is also recited in Claim 1 of the '103 patent. Therefore, I incorporate my analysis of this limitation from claim 1, as if fully set forth herein.

ii. a first antenna element having a conductive plate configured to support first, second, and third radiation modes respectively providing first, second, and third paths for current respectively associated with first, second, and third frequencies bands

220. A POSA would know that PIFA *must* have a conductive radiating element—i.e., a “conductive plate”—that acts as a surface or resonator in order to work. For example, the main patch of the Ciais-Quadband PIFA may be considered the “conductive plate.” Thus, Ciais-Quadband PIFA must have a conductive plate or else a POSA would be motivated to use a conductive plate with Ciais-Quadband PIFA.

221. Ciais-Quadband’s PIFA “covers the GSM standard (Global System for Mobile communications, 880-960 MHz) with a VSWR (Voltage Standing Wave

Ratio) better than 2.5 and also the DCS (Digital Communication System, 1710-1880 MHz), PCS (Personal Communication Services, 1850-1990 MHz) and UMTS (Universal Mobile Telecommunications System, 1920-2170 MHz) standards with a VSWR less than 2.” Ex.1014, 1. Because the Ciais-Quadband PIFA operates from 1710-2170, it also covers LTE bands. For example, DCS1800, UMTS Band II, and LTE Band 1 may be the claimed first, second, and third, frequency bands.

222. Further, the Ciais-Quadband PIFA is configured to support at least five separate radiation modes. Ciais-Quadband discloses that “[t]he main resonator [i.e., the main patch] is a dual-band PIFA antenna tuned to operate at center frequencies of 935 MHz and 1930 MHz.” Ex.1014, 1. A POSA would know that this means that the main patch is configured to support two radiation modes: 935 MHz in the GSM band, and 1930 MHz in the DCS/PCS/UMTS range. Additionally, each parasitic patch provides additional radiation modes. Specifically, parasitic patch 1 is designed at a theoretical quarter-wavelength of 76 mm at 888 MHz, creating a radiation mode in the lower portion of the GSM band; parasitic patch 2 is designed at a theoretical quarter-wavelength of 34.1 mm at 1760 MHz, creating an additional radiation mode just below the main patch’s radiation mode center/resonant frequency within the DCS/PCS/UMTS bands; and parasitic patch 3 is designed at a theoretical quarter-wavelength of 26.9 mm at 2120 MHz, creating an additional radiation mode just above the main patch’s radiation mode center/resonant frequency within the

DCS/PCS/UMTS bands. *Id.*, 149. For purposes of my analysis here, the second parasitic patch's 1760 MHz creates the first radiation mode, the main patch's center frequency of 1930 MHz creates the second radiation mode; and the third parasitic patch's 2120 MHz creates the third radiation mode. Thus, the Ciais-Quadband PIFA is "a first antenna element having a conductive plate configured to support first, second, and third radiation modes."

223. Moreover, each of the Ciais-Quadband PIFA's first, second and third radiation modes provides a first, second, and third path for current respectively associated with the Ciais-Quadband PIFA's first, second, and third frequency bands. For example, the first radiation mode created by parasitic patch 2's quarter-wavelength of 34.1 mm at 1760 MHz is just below the main patch's radiation mode and may be associated with the first frequency band—e.g., DCS1800 (1710-1880 MHz); the second radiation mode created by the main patch's center frequency at 1930 MHz may be associated with the second frequency band—e.g., UMTS II (1880-1990); and the third radiation mode created by parasitic patch 3's quarter-wavelength of 26.9 mm at 2120 MHz is just above the main patch's radiation mode and may be associated with LTE Band I (1920-2170).

224. Thus, Ciais-Quadband discloses a first antenna element having a conductive plate configured to support first, second, and third radiation modes respectively providing first, second, and third paths for current respectively

associated with first, second, and third frequencies band.

225. Therefore, a POSA would be motivated to use multiple antennas including Ciais-Quadband PIFA arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at an antenna system comprising a first antenna element having a conductive plate configured to support first, second, and third radiation modes respectively providing first, second, and third paths for current respectively associated with first, second, and third frequencies bands.

iii. the first, second and the third radiation modes overlapping at least partially with each other

226. The radiation mode for the main patch (~1930 MHz), parasitic patch 2 (~1760 MHz), and parasitic patch 3 (~2120 MHz) overlap to yield a measured 460 MHz continuous bandwidth from 1710 to 2170 MHz. Ex.1014, 3 (“the upper bandwidth is 460 MHz (1710-2170 MHz) with a VSWR less than 2.”). Ciais-quadband explicitly discloses “parasitic no. 2 works below the 3rd resonance of the main patch while parasitic no. 3 works above,” and their simultaneous addition produces the wide upper bandwidth. Ciais-Quadband Figure 2 (annotated below) shows the overlapping radiation modes:

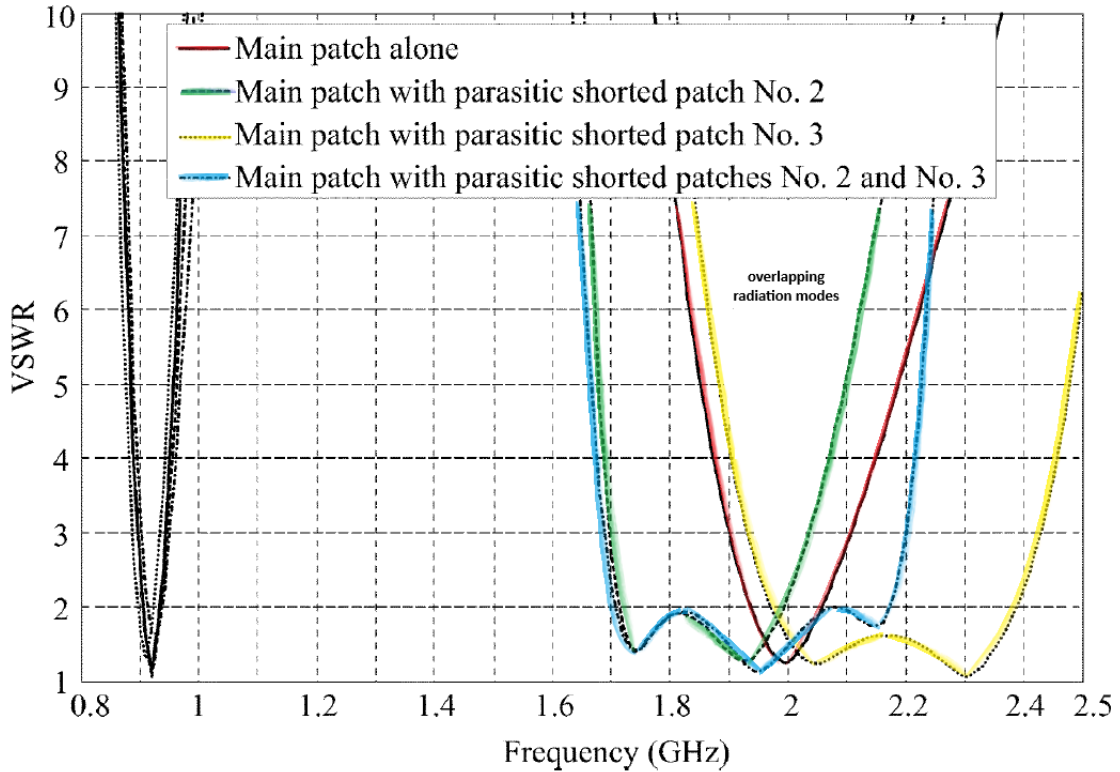


Fig. 2. Simulated VSWR of the main patch with and without parasitic shorted 227. Therefore, a POSA would be motivated to use multiple antennas including Ciais-Quadband PIFA arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at an antenna system wherein the first, second and the third radiation modes overlap at least partially with each other.

iv. the first frequency band being contained within a first frequency region of an electromagnetic spectrum,

228. As discussed above, the Ciais-Quadband PIFA’s “first frequency band” may be DCS1800, which is included in the 1710–1880 MHz region (“first frequency region”).

229. Therefore, a POSA would be motivated to use multiple antennas

including Ciais-Quadband PIFA arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at an antenna system wherein the first frequency band is contained within a first frequency region of an electromagnetic spectrum.

- v. the second and third frequency bands being contained within a second frequency region of the electromagnetic spectrum that is higher in frequency than the first frequency region; and**

230. As discuss above, the Ciais-Quadband PIFA's "second frequency band" may be UMTS Band II, which is included in the 1880-1990 MHz frequency regions, and the "third frequency band" may be LTE Band 1, which is in the 1920-2170 MHz frequency region ("third frequency region"). The 1880-1990 MHz (i.e., "second frequency region") and 1920-2170 MHz (i.e., "second frequency region") are higher in frequency than 1710-1880 MHz (i.e., "first frequency region").

231. Therefore, a POSA would be motivated to use multiple antennas including Ciais-Quadband PIFA arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at an antenna system wherein the second and third frequency bands are contained within a second frequency region of the electromagnetic spectrum that is higher in frequency than the first frequency region.

- vi. a second antenna element configured to operate in at least one frequency band, the at least one frequency band being used by a 4G communication standard, wherein**

232. Ciais-Quadband disclose a specific PIFA antenna that achieves

measured coverage from 880-960 MHz and 1710-2170 MHz and therefore supports GSM, DCS, PCS, and UMTS with VSWR thresholds suitable for handset deployment. CN456 meanwhile disclosed arranging multiple PIFAs to achieve improved performance. Thus, a POSA would have been motivated to use the Ciais-Quadband PIFA in the mobile device of Boireau arranged according to the teachings of CN456. As such the Ciais-Quadband PIFA would serve as a first, second, third, or fourth antenna element.

233. Ciais-Quadband's PIFA element is configured to received signals from a 4G communication standard. As discussed above, the Ciais-Quadband PIFA supports seven UMTS frequency bands (UMTS Band I (1920-2170 MHz), UMTS Band II (1880-1990 MHz), UMTS Band III (1710-1880 MHz), UMTS Band IV (1710-2155 MHz), UMTS Band a (1900-1920, 2010-2025 MHz), UMTS Band b (1850-1910, 1930-1990 MHz), UMTS Band c (1910-1930 MHz). *See*, ¶ 160, above (listing UMTS Bands I-IV and a-c).

234. HSDPA is part of the Universal Mobile Telecommunications System (UMTS) and supported by UMTS frequency bands. Ex.1018, 63, 182; Ex.1019 (UMTS HSDPA description). The '103 patent expressly defines HSDPA as a "4G feature" and "4G service" that it equates with a "4G standard." Ex.1001, 24:22-35 ("A MFWD incorporating 3.5G or 4G features (i.e. comprising 3G and other advanced services such as for instance HSDPA)"). Thus, each of Ciais-Quadband's

UMTS bands is a “4G communication standard” at least because they support HSDPA.

235. Therefore, a POSA would be motivated to use multiple antennas including Ciais-Quadband PIFA arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at an antenna system wherein a second antenna element is configured to operate in at least one frequency band, the at least one frequency band being used by a 4G communication standard.

- vii. a perimeter of the first antenna element defines a first antenna contour having a level of complexity defined by first complexity factor F_{21} having a value of at least 1.20 and first complexity factor F_{32} having a value less than 1.75; and**

236. This limitation is also recited in Claim 1 of the '103 patent. Therefore, I incorporate my analysis with respect to this limitation from claim 1, as if fully set forth herein.

- viii. a perimeter of the second antenna element defines a second antenna contour having a level of complexity defined by second complexity factor F_{21} having a value of at least 1.20 and second complexity factor F_{32} having a value less than 1.75.**

237. For reasons set forth above, a POSA would have been motivated to use multiple Ciais-Quadband PIFAs. As such, the Cias-Quadband PIFA would also serve as the “second antenna element” recited in claim 6. Therefore, my analysis in claim 1 showing that the Ciais-Quadband PIFA has a complexity factor F_{21} of at least 1.20

and complexity factor F_{32} less than 1.75 is equally applicable here. Accordingly, I incorporate my analysis with respect to this limitation from claim 1, as if fully set forth herein.

g. Conclusion

238. Accordingly, a POSA would have been motivated to use multiple antennas, including multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at a handheld MFWD having at least one of multimedia functionality and smartphone functionality, the handheld multifunction wireless device comprising: a touch screen; a microprocessor and an operating system adapted to permit running of word-processing, spreadsheet, and slide software application; an image recording system comprising an at least two Megapixel image sensor; an antenna system within the handheld multifunction wireless device and configured to operate in at least five frequency bands, the antenna system comprising: a ground plane layer; a first antenna element having a conductive plate configured to support first, second, and third radiation modes respectively providing first, second, and third paths for current respectively associated with first, second, and third frequencies bands, the first, second and the third radiation modes overlapping at least partially with each other, the first frequency band being contained within a first frequency region of an electromagnetic spectrum, the second and third frequency bands being contained

within a second frequency region of the electromagnetic spectrum that is higher in frequency than the first frequency region; and a second antenna element configured to operate in at least one frequency band, the at least one frequency band being used by a 4G communication standard, wherein a perimeter of the first antenna element defines a first antenna contour having a level of complexity defined by first complexity factor F_{21} having a value of at least 1.20 and first complexity factor F_{32} having a value less than 1.75; and a perimeter of the second antenna element defines a second antenna contour having a level of complexity defined by second complexity factor F_{21} having a value of at least 1.20 and second complexity factor F_{32} having a value less than 1.75.

F. Claim 7.

a. The handheld multifunctional wireless device of claim 6, wherein

239. Claim 7 of the '103 patent depends from claim 6 and therefore includes all of the limitations of claim 6. Therefore, I incorporate my analysis of claim 6 into my analysis of claim 7 as if fully set forth herein.

b. The first antenna element is configured to transmit and receive signals from a 4G communication standard.

240. This limitation is substantively addressed in my analysis of Claim 6's requirement that the "second antenna element [is] configured to operate in at least one frequency band, the at least one frequency band being used by a 4G communication standard." The only difference here is that claim 7 requires that the

“first antenna element is configured to transmit and receive signals from a 4G communication standard.” However, as discussed throughout this declaration, a POSA would have been motivated to use multiple Ciais-Quadband PIFAs pursuant to the teachings in CN456 and thus the Ciais-Quadband PIFA may also serve as the first antenna element. Therefore, I incorporate my analysis of this limitation for claim 6 into my analysis of claim 7, as if fully set forth herein.

c. Conclusion

241. Accordingly, a POSA would have been motivated to use multiple antennas, including multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at the handheld MFWD of claim 6, wherein the first antenna element is configured to transmit and receive signals from a 4G communication standard.

G. Claim 8

a. The handheld MFWD of claim 6, wherein

242. Claim 8 of the '103 patent depends from claim 6 and therefore includes all of the limitations of claim 6. Therefore, I incorporate my analysis of claim 6 into my analysis of claim 8 as if fully set forth herein.

b. The first antenna contour comprises at least thirty-five segments.

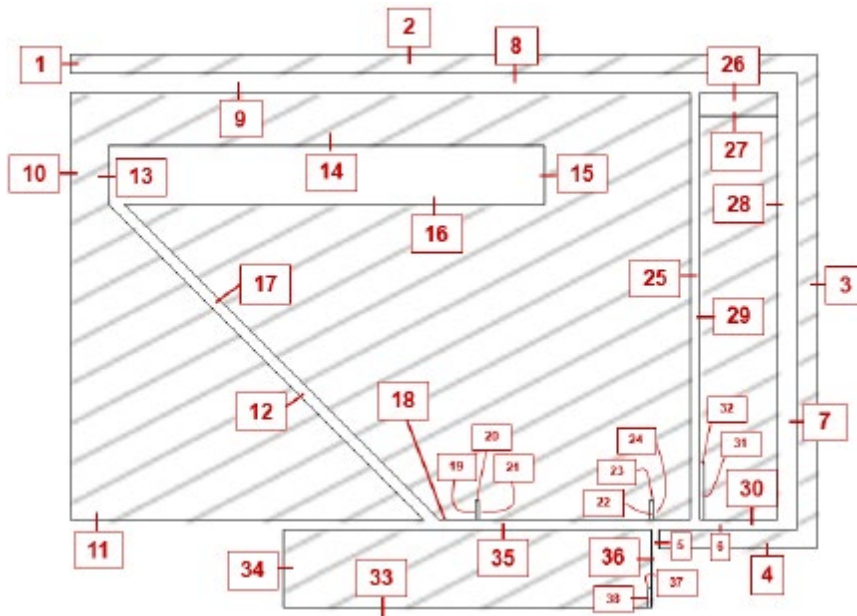
243. The '103 patent explains that “[t]he antenna contour, i.e., its peripheral both internally and externally, can comprise straight segments, curved segments, or

a combination thereof. Not all the segments that form the antenna contour need to be connected (i.e., to be joined).” Ex.1001, 14:60-62. The ’103 patent goes on to explain that

[a]long the contour different segments can be identified e.g., by corner between two segment, wherein the corner is given by a point on the contour where no unique tangent can be identified. At the corners the contour has an angle. The segment next to a corner may be straight or curved. Further, segments may be separated by a point where the curvature changes from left to right or from right to left. In a sine curve, for example such points are given where the curve intersects the horizontal axis (x-axis, abscissa, $\sin(x)=0$).

Ex.1001, 15:4-13.

244. Below I show that Ciais-Quadband antenna has at least 35 segments, applying the disclosures regarding segments from the ’103 patent:



c. Conclusion

245. Accordingly, a POSA would have been motivated to use multiple antennas, including multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at the handheld MFWD of claim 6, wherein the first antenna contour comprises at least thirty-five segments.

H. Claim 9

a. The handheld MFWD of claim 8, wherein

246. Claim 9 of the '103 patent depends from claim 8 and therefore includes all of the limitations of claim 8. Therefore, I incorporate my analysis of claim 8 into my analysis of claim 9 as if fully set forth herein.

b. The second antenna contour comprises at least twenty segments

247. As discussed above, a POSA would have been motivated to use multiple Ciais-Quadband PIFAs arranged according to the instructions in CN456 in the MFWD of Boireau. Thus, the second antenna contour would also be from a second Ciais-Quadband PIFA. Further, as explained above with respect to claim 8, Ciais-Quadband PIFA has at least 32 segments and therefore must also have at least twenty segments.

c. Conclusion

248. Accordingly, a POSA would have been motivated to use multiple antennas, including multiple Ciais-Quadband PIFAs arranged according to the

teachings in CN456 in the MFWD of Boireau to arrive at the handheld MFWD of claim 8 wherein the second antenna contour comprises at least twenty segments.

I. Claim 10

a. The handheld multifunctional wireless device according to claim 6, wherein

249. Claim 10 of the '103 patent depends from claim 6 and therefore includes all of the limitations of claim 6. Therefore, I incorporate my analysis of claim 6 into my analysis of claim 10 as if fully set forth herein.

b. Wherein the first antenna contour comprises at least two disjointed subsets of segments comprising at least ten segments.

250. The '103 patent provides an example of disjointed subsets of segments in its discussion of Fig. 12A. Specifically, the '103 patent discloses that

[t]he antenna contour of the structure of antenna system 1200 of the example in Fig. 12A is formed by the combination of two disjoint subsets of segments. A first subset is given by the perimeter of the antenna element 1201 and comprises forty-eight segments. A second subset is given by the perimeter of the antenna element 1202 and comprises twenty -six (26) segments.

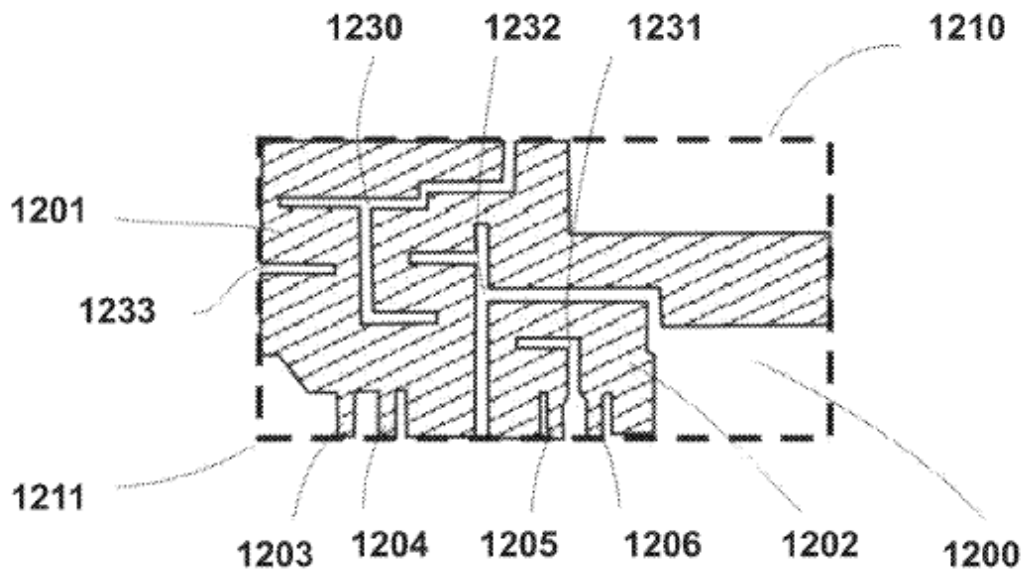
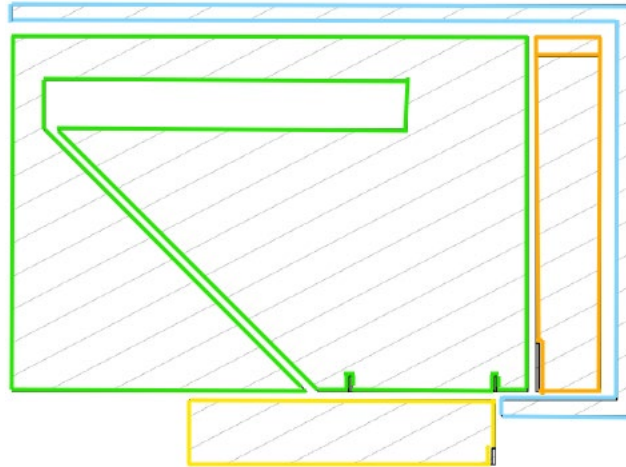
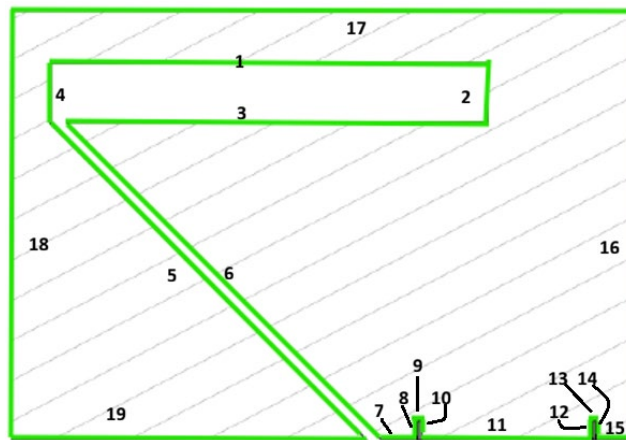


FIG. 12A

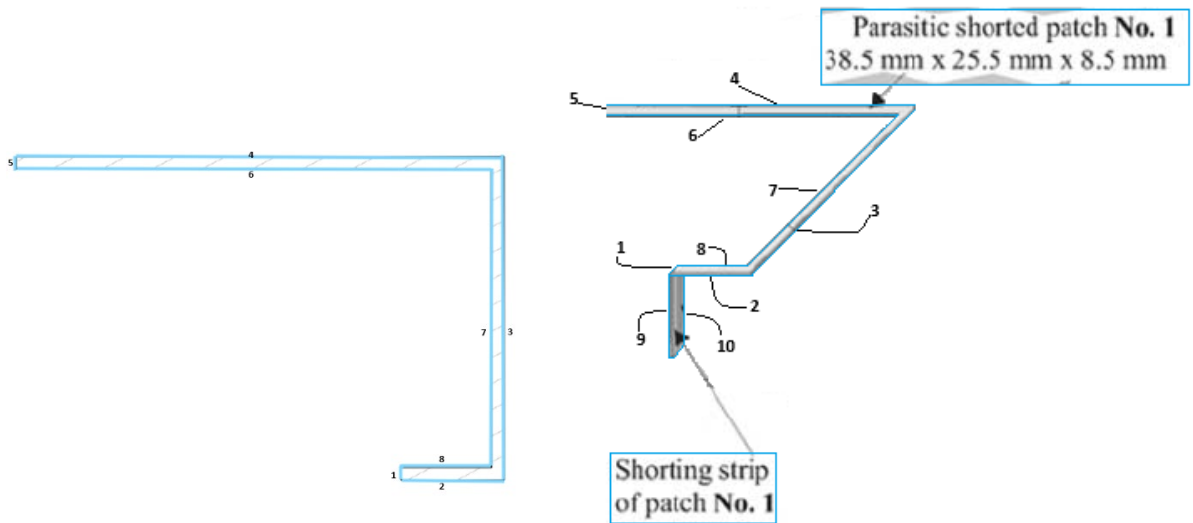
Ex.1001, 32:58-64, Fig.12A. Thus, a subset of segments are disjointed where they are not joined to another subset of segments. Applying this approach to the Ciais-Quadband PIFA reveals that there are at least 4 disjointed subset of segments that make up that antenna. In the image below I have outlined in different colors (blue, orange, green, yellow) each of the four disjointed subset of segments of the Ciais-Quadband PIFA.



251. The green disjointed subset of segments, which is identified as the “Main patch” in Ciais-Quadband, is made up of at least 19 segments:



252. The blue disjointed subset of segments, which is identified as “Parasitic shorted patch No. 1” including the segments from the “shorting strip of patch No. 1” that is joined with parasitic shorted patch no. 1 and connects it to the PCB, is made up of at least 10 segments:



c. Conclusion

253. Accordingly, a POSA would have been motivated to use multiple antennas, including multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at the handheld MFWD of claim 6 wherein the first antenna contour comprises at least two disjointed subsets of segments comprising at least ten segments.

J. Claim 12

254. Claim 12 of the '103 patent recites (i) a handheld multifunction wireless device having at least one of multimedia functionality and smartphone functionality, the handheld multifunction wireless device comprising: (ii) a touch screen; (iii) processing module; (iv) a communication module; (v) a power management module; (vi) an antenna system within the handheld multifunction wireless device and comprising: (vii) a ground plane layer; (viii) a first antenna element configured to simultaneously support radiation modes for first, second, and third frequency bands,

(ix) the first frequency band being contained within a first frequency region of an electromagnetic spectrum; (x) the second frequency band being contained within a second frequency region of the electromagnetic spectrum that is higher in frequency than the first frequency region, (xi) the third frequency band of operation being used by a 4G communication standard, wherein (xii) a perimeter of the first antenna element defines a first antenna contour comprising at least thirty-five segments, (xiii) the first antenna element defining an antenna box, (xiv) an orthogonal projection of the antenna box along a normal to a face with a largest area of the antenna box defining an antenna rectangle, wherein (xv) a length of the first antenna contour is greater than four times a diagonal of the antenna rectangle; and (xvi) a second antenna element configured to operate in at least one frequency band used by a 4G communication standard, wherein (xvii) a perimeter of the second antenna element defines a second antenna contour comprising at least twenty segments.

a. a handheld multifunction wireless device having at least one of multimedia functionality and smartphone functionality, the handheld multifunction wireless device comprising:

255. This limitation is also recited in Claim 1 of the '103 patent. Therefore, I incorporate my analysis of this limitation from claim 1, as if fully set forth herein.

b. a touch screen;

256. This limitation is also recited in Claim 1 of the '103 patent. Therefore, I incorporate my analysis of this limitation from claim 1, as if fully set forth herein.

c. processing module;

257. The '103 patent specification explains that “[t]he processing module 12 ... is the microprocessor or CPU.” Ex.1001, 8:21-22.

258. Boireau discloses that the handheld multifunction wireless device disclosed therein, “may include processor 302. Processor 302 may be implemented using any processor or logic device, such as a [CISC] microprocessor, a [RISC] microprocessor, a [VLIW] microprocessor, a processor implementing a combination of instruction sets, or other processor device.” Ex.1015, [0049]. Therefore, Boireau discloses a processing module.

259. Therefore, a POSA would have been motivated to use multiple antennas, including Ciais-Quadband PIFAs arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at a handheld MFWD comprising a processing module.

d. a communication module;

260. The '103 patent specification does not disclose a definition for “communication module” and merely refers to it as a component of the alleged inventions. *See, e.g.*, Ex.1001, 8:13-17 (“Referring first to FIG. 1A, a multifunction wireless device of the present invention 100 advantageously comprises ... communication module 14.”). The '103 patent specification, however, goes on to explain that “[t]he antenna system within the communication module 14 is an

essential element of the MFWD.” Ex.1001, 8:47-48. A POSA would thus understand that “communication module” refers to the integrated hardware components within the MFWD that functions in tandem with the antenna to transmit and receive data and thus the “communication module” is necessary for any MFWD to receive or transmit data.

261. A POSA would recognize that any MFWD configured to transmit and receive data communications must necessarily have a communication module and therefore Boireau necessarily discloses a communication module. In fact, Boireau specifically discloses the integrated hardware components that function in tandem with the antenna to transmit and receive data. For example, Boireau discloses a “mobile computing device 100 may include at least three types of transceivers, including a cellular radiotelephone system transceiver for voice communications, a wireless networking transceiver for longer range data communications (and possible voice communications), and a personal area network transceiver for shorter range data communications. In some cases, for example, the multiple transceivers may have overlapping transmit and/or receive bands.” Ex.1015, [0026]. Boireau further discloses that “[r]adio sub-system 202 may perform voice and/or data communications operations on behalf of mobile computing device 100” and that “Radio subsystem 202 and processing sub-system 206 may communicate and synchronize operations using bus 204. Bus may comprise a USB or micro USB bus

and appropriate interfaces, as well as others.” Ex.1015, [0028]. Boireau also discloses that “[i]n various embodiments, radio sub-system 202 of mobile computing device 100 may be arranged to perform voice communications in accordance with different types of cellular radiotelephone systems.” Ex.1015, [0031]. Boireau further discloses that “[i]n addition to voice communication services, various embodiments of radio sub-system 202 may be arranged to perform data communications in accordance with different types of cellular radiotelephone systems.” Ex.1015, [0032]. Therefore, Boireau discloses a communication module.

262. Therefore, a POSA would have been motivated to use multiple antennas, including Ciais-Quadband PIFAs arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at a handheld MFWD comprising a communication module.

e. a power management module;

263. The '103 patent specification explains that “[t]he MFWD 100 has a single source of energy and it is the power management module 15.” Ex.1001, 8:26-28. A POSA would understand that any mobile device, including the mobile computing devices disclosed in Boireau would necessarily require a power management module in order to function. Indeed, Boireau discloses that “[i]n various embodiments of mobile computing device 100 may further include a power management sub-system 208. Power management sub-system 208 may manage

power for mobile computing device 100, including radio sub-system 202, processing sub-system 206, and other elements of mobile computing device 100.” Ex.1015, [0029]. Therefore, Boireau disclosed a power management module.

264. Therefore, a POSA would have been motivated to use multiple antennas, including Ciais-Quadband PIFAs arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at a handheld MFWD comprising a power management module.

f. an antenna system within the handheld multifunction wireless device and comprising a ground plane layer;

265. This limitation is substantively addressed in my analysis of Claim 1’s requirement of “an antenna system comprising a ground plane layer and three antenna elements within the handheld multifunction wireless device.” Therefore, I incorporate my analysis with respect to that limitation from claim 1, as if fully set forth herein.

g. a first antenna element configured to simultaneously support radiation modes for first, second, and third frequency bands,

266. This limitation is substantively addressed in my analysis of Claim 1’s requirement of “a first antenna element having a conductive plate configured to simultaneously support radiation modes for at least first, second, and third of the at least four frequency bands.” Therefore, I incorporate my analysis of this limitation from claim 1, as if fully set forth herein.

h. the first frequency band being contained within a first frequency region of an electromagnetic spectrum;

267. The '103 patent identifies at least three separate “regions of the electromagnetic spectrum” including “the 810 MHz -960 MHz region, the 1710 MHz-1990 MHz region, and the 1900 Mhz-2170 MHz region.” Ex.1001, 4:58-62. As discussed above, the PIFA disclosed in Ciais-Quadband is capable of sending and receiving electromagnetic radiation at 870-960 MHz, which is included in the '103 patent's “810 MHz.-960 MHz region” (“first frequency region”). Ex.1014, at Fig. 3, 1-3. Between 870-960 Mhz there are at least four frequency bands—i.e., standard GSM900, extended GSM900, ISM, and LTE Band 8. *See*, ¶¶ 149-151, above. Any one of these frequency bands can satisfy claim 12's requirement that the “first frequency band be[] contained within a first frequency region of an electromagnetic spectrum.”

i. the second frequency band being contained within a second frequency region of the electromagnetic spectrum that is higher in frequency than the first frequency region,

268. The '103 patent identifies at least three separate “regions of the electromagnetic spectrum” including “the 810 MHz -960 MHz region, the 1710 MHz-1990 MHz region, and the 1900 MHz–2170 MHz region.” Ex.1001, 4:58-62. 1710-1990 MHz and 1900-2170 MHz are frequencies that are higher than 810-960 MHz. As such frequency bands that lay within 1710-1900 MHz or 1900-2170 MHz would be contained within “a second frequency region of the electromagnetic spectrum that is higher in frequency than the first frequency region.”

269. The PIFA disclosed in Ciais-Quadband is capable of sending and receiving electromagnetic radiation at 1710-2170 MHz. Ex.1014, , Fig. 3, 1-3. At least frequency bands DCS1800, UMTS Band III, LTE Band 3, and LTE Band 9 are within 1710-1990 MHz electromagnetic region. Any of these bands would thus satisfy claim 12’s requirement that “the second and third frequency bands be[] contained within a second frequency region of the electromagnetic spectrum that is higher in frequency than the first frequency regions.”

j. the third frequency band of operation being used by a 4G communication standard, wherein

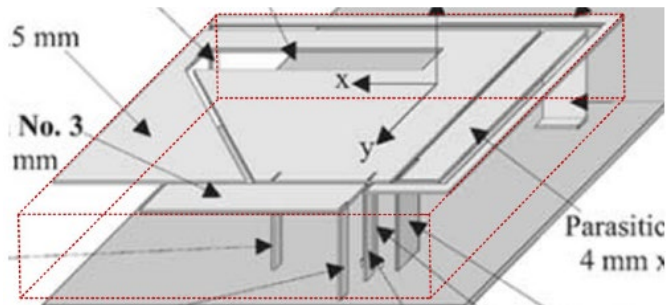
270. This limitation is substantively addressed in my analysis of claim 1’s requirement that “a second antenna element [be] configured to receive signals from a 4G communication standard.” Therefore, I incorporate my analysis of this limitation from claim 1, as if fully set forth herein.

- k. a perimeter of the first antenna element defines a first antenna contour comprising at least thirty-five segments,**

271. This limitation is substantively addressed in my analysis of claim 8's requirement that "the first antenna contour comprises at least thirty-five segments. Therefore, I incorporate my analysis of this limitation from claim 8, as if fully set forth herein.

- l. the first antenna element defining an antenna box,**

272. The Ciais-Quadband PIFA defines an antenna box as shown by the dotted red outline added to the image of the PIFA disclosed in Ciais-Quadband Fig. 1(a) below:

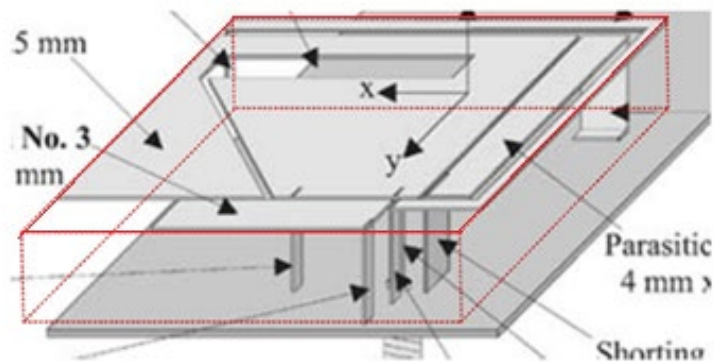


273. Therefore, a POSA would have been motivated to use multiple antennas, including Ciais-Quadband PIFAs arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at a handheld MFWD comprising a first antenna element defining an antenna box.

- m. an orthogonal projection of the antenna box along a normal to a face with a largest area of the antenna box defining an antenna rectangle, wherein**

274. This limitation recites in part the specification's "antenna contour"

definition as discussed in the claim construction section of this report above. The Ciais-Quadband PIFA meets this limitation because it has an “antenna box” (red dotted outline below) along a normal to a face with a largest area of the antenna box defining the PIFA “antenna rectangle” (solid red outline in the image below) formed by an orthogonal projection through the “main patch”. Ex.1014, , Fig. 1(b).

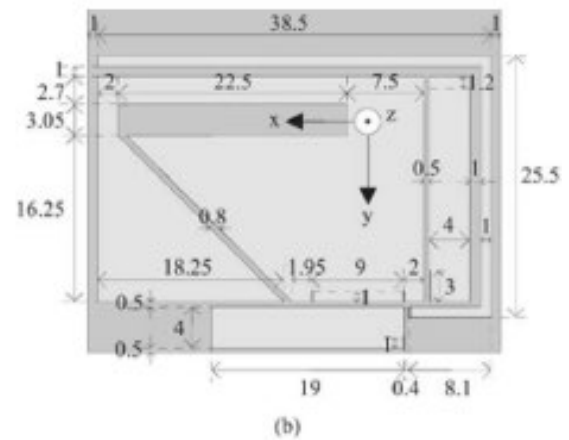
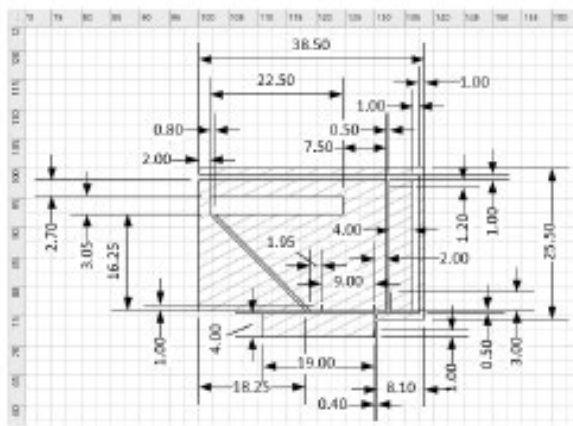


275. Therefore, a POSA would have been motivated to use multiple antennas, including Ciais-Quadband PIFAs arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at a handheld MFWD comprising a first antenna element defining an antenna box and an orthogonal projection of the antenna box along a normal to a face with a largest area of the antenna box defining an antenna rectangle.

- n. a length of the first antenna contour is greater than four times a diagonal of the antenna rectangle; and

276. The length of the antenna contour for the Ciais-Quadband PIFA is greater than four times a diagonal of the antenna rectangle.

277. To assist in the calculations necessary to show that the Ciais-Quadband PIFA meets this limitation, I first provide a scaled rendering of the Ciais-Quadband PIFA's "antenna contour" which is generated using the dimensions provided in Fig. 1(b). The images below show a scaled rendering of the Ciais-Quadband PIFA and, for comparison, a side by side comparison of the PIFA alongside Fig.1(b), followed by a more zoomed in version of the scaled rendering.

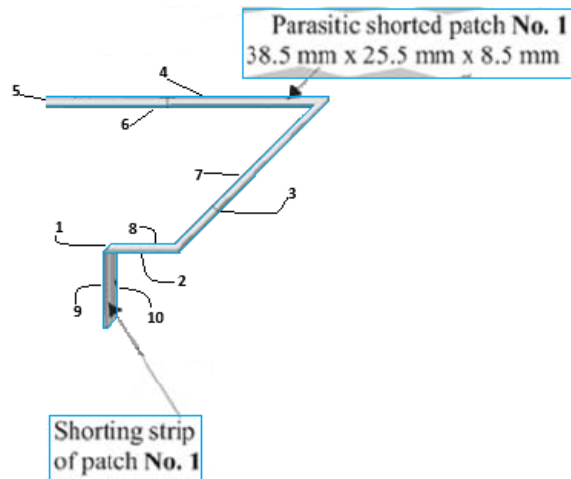


279. The '103 patent explains that “[t]he antenna contour of the antenna system is a set of joint and/or disjoint segments comprising: the perimeter of one or more antenna elements placed in the antenna rectangle, the perimeter of closed slots and/or closed apertures defined within the antenna elements, and/or the orthogonal projection onto the antenna rectangle of perimeters of antenna elements, or perimeters of or parts of antenna elements that are placed in the antenna both but not in the antenna rectangle.” Ex.1001, 14:49-59. The '103 patent states that “[t]he length of the antenna contour of an antenna system is defined as the sum of the lengths of each one of the disjointed subsets that make up the antenna contour.” Ex.1001, 16:7-9. So, to calculate the length of the antenna contour, one must add up the length of all of the joint and disjointed segments that comprise it including segments that make up orthogonal projections onto the antenna rectangle of perimeters of antenna elements. However, for purposes of simplicity in my analysis below, I do not take into account the length of segments that make up such orthogonal projections—but it should be noted that doing so would result in a greater total length of the Ciais-Quadband’s antenna contour.

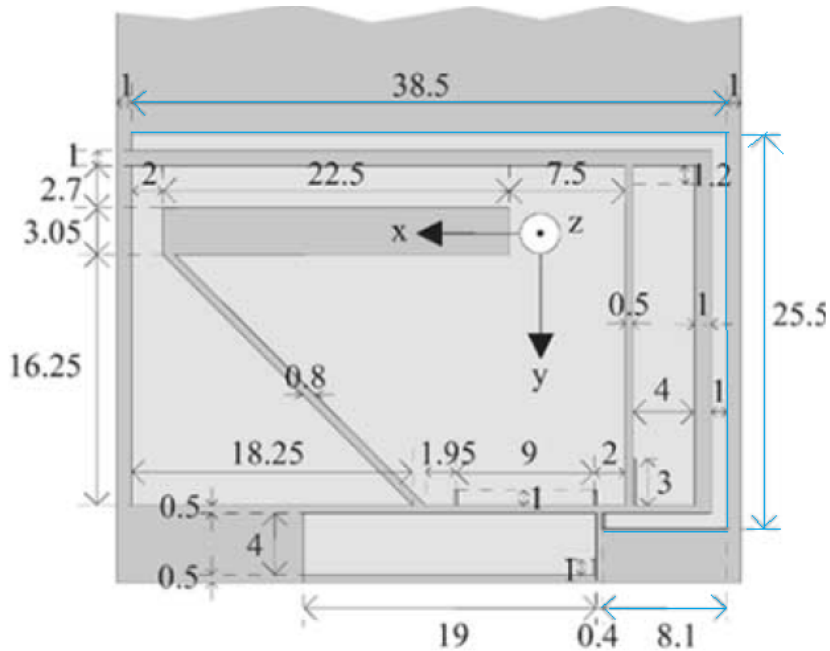
i. Parasitic Shorted Patch No. 1 = 142.2

280. As noted earlier in this declaration, the Ciais-Quadband PIFA’s parasitic shorted patch No. 1 (identified in blue below) has at least 10 segments of which Ciais-Quadband discloses measurements sufficient to determine the length of

segments 1-8.



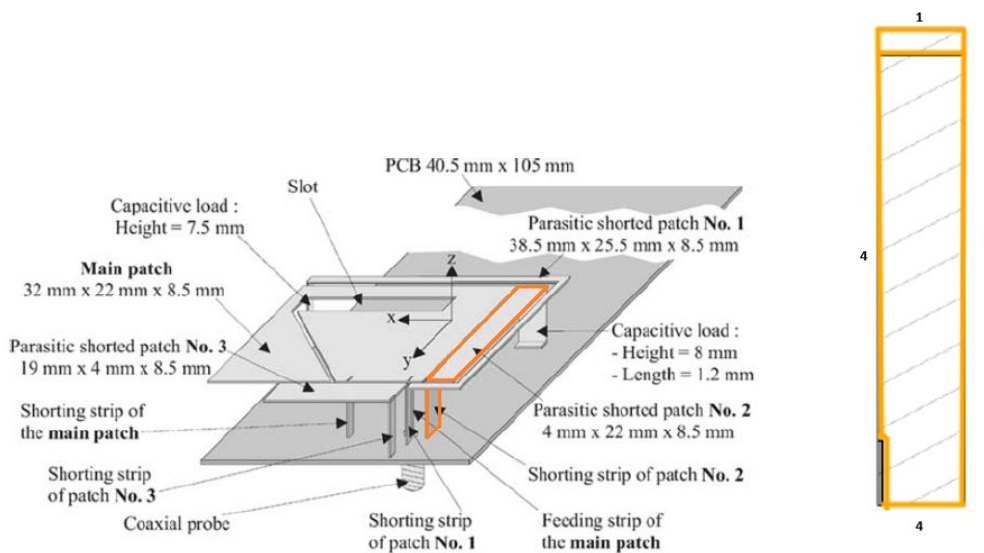
281. As shows in blue below, **segments 4, 3, 2** have a measurement of **38.5, 25.5 and 8.1**, respectively. Using the measurements provided for the segments of the other components of the Ciais-Quadband PIFA, we can also determine the measurements of segments 1 and 5-8. **Segment 6** has a measurement of **37.5** ($38.5 - 1$); **segment 7** has a measurement of **23.5** ($0.5 + 16.25 + 3.05 + 2.7 + 1.0$); **segments 1 and 5** each have a measurement of **1** ($(25.5-23.5)/2$); **segment 8** has a measurement of **7.1** ($8.1 - 1$). As such the total length of segments 1-8 of **Ciais-Quadband PIFA's parasitic shorted patch no. 1** is **142.2** ($38.5 + 37.5 + 25.5 + 8.1 + 23.5 + 1 + 1 + 7.1$).



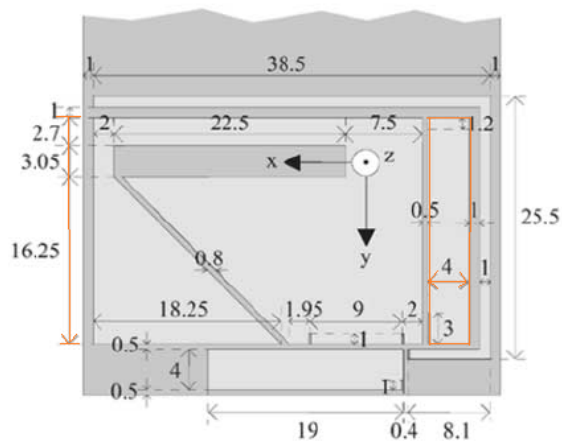
ii. Parasitic Shorted Patch No. 2 = 52

282. Next, the Ciais-Quadband PIFA's parasitic shorted patch No. 2 (identified in orange below) has at least four segments.³ Again, for simplicity my analysis of the length of the segments that make up parasitic shorted patch no. 2 will focus only on segments 1-4 though there are additional segments. I note that were I to include all segments, the total length would be greater than the length of segments 1-4 alone.

³ As noted above in ¶¶ 101-106 of this Declaration, Parasitic Shorted Patch No. 2 also includes shorting strip of Patch No. 2 and a Capacitive load. However, for purposes of simplicity, I have only calculated the length of 4 segments of parasitic Patch No. 2. The total length, however, would be longer than what I calculate here when taking into account the length of the segments that make up shorting strip of patch 2 and the capacitive load.



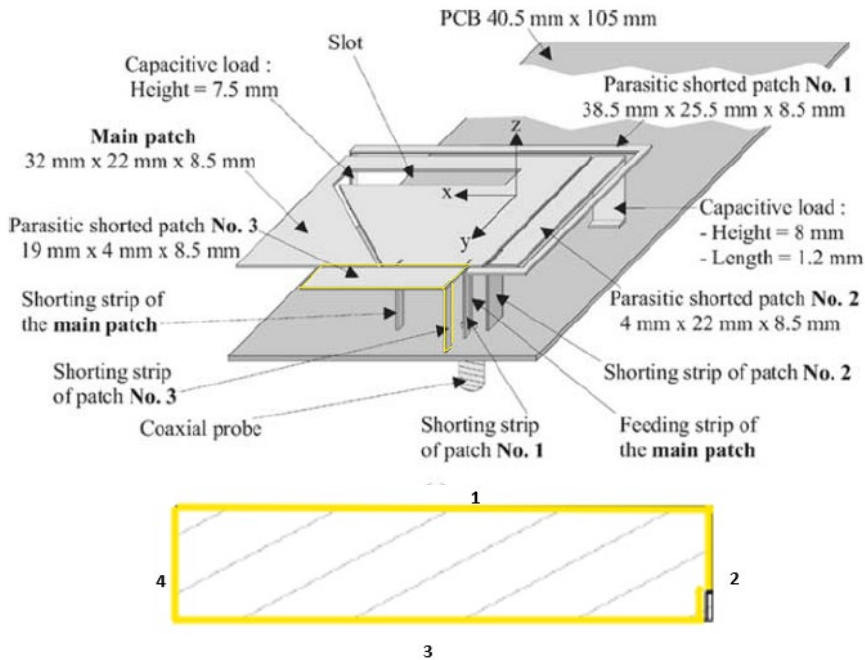
283. Using the measurements provided in Ciais-Quadband, segments 1 and 3 are each 4; segments 2 and 4 are each 22 ($2.7 + 3.05 + 16.25$). As such the total length of the at least four segments that make up parasitic patch no. 2 is 52 ($4 + 4 + 22 + 22$).



iii. Parasitic Shorted Patch No. 3 = 36

284. Next, parasitic shorted patch 3 (identified in yellow below) has at least four segments. Again, for simplicity my analysis of the length of the segments that

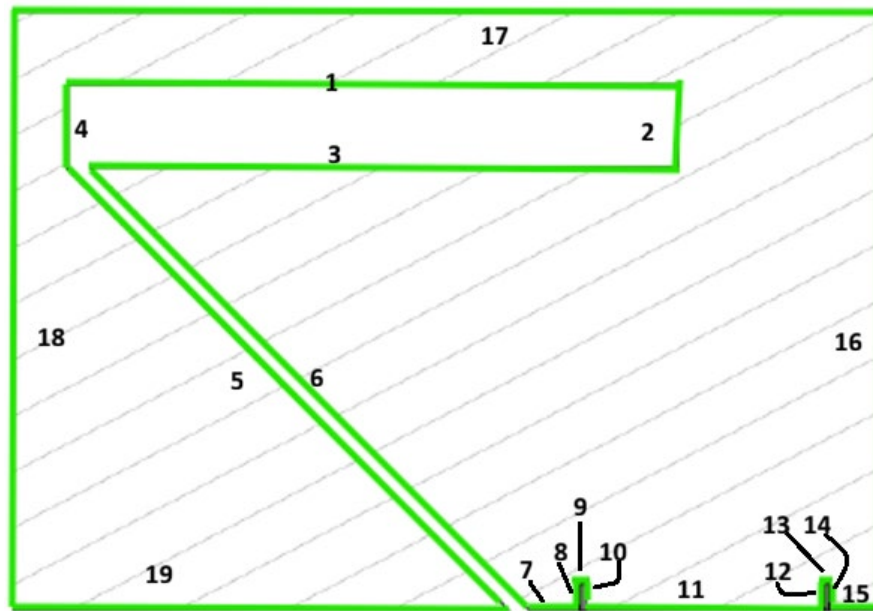
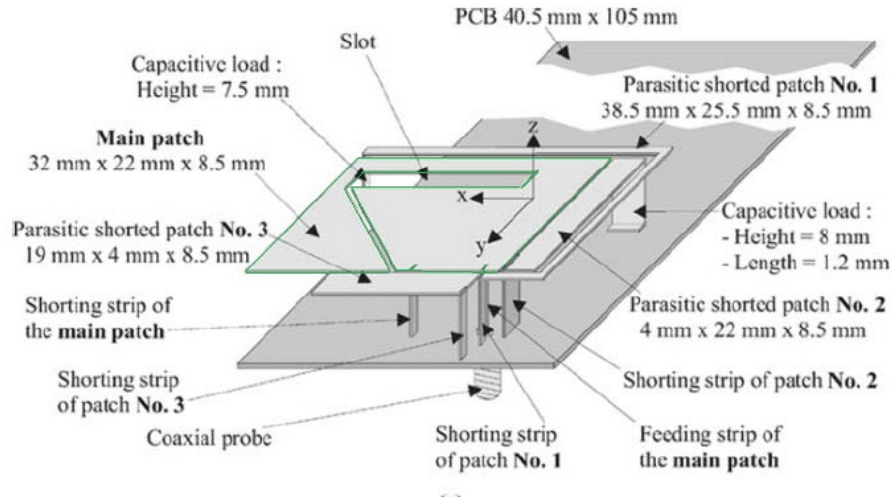
make up parasitic shorted patch no. 3 will focus only on segments 1-4 though there are additional segments. I note that were I to include all segments, the total length would be greater than the length of segments 1-4 alone.



285. Using the measurements provided in Ciais-Quadband, segments 1 and 3 are each 19; segments 2 and 4 are each 4. **As such the total length of segments 1-4 of parasitic patch no. 3 is 36 (4 + 4 + 19 + 19).**

iv. Main Patch = 203.3

286. Finally, the main patch (identified in green below) has at least 19 segments:



287. As shows in green below, **segment 17** has a measurement of **32** ($2 + 22.5 + 7.5$); **segments 16 and 18** each have a measurement of **22** ($16.25 + 3.05 + 2.7$); **segment 19** has a measurement of **18.25**; **segments 2 and 4** each have a measurement of **3.05**; **segment 1** has a measurement of **22.5**; **segment 3** has a measurement of **21.7** ($22.5 - 0.8$); **segment 7** has a measurement of **1.95**; **segment 11** has a measurement of **9**, **segment 15** has a measurement of **2**.

289. Therefore, the total length of the segments 1-7, 11, and 15-19 that make up the **Ciais-Quadband PIFA main patch is 203.3** ($32 + 22 + 22 + 18.25 + 3.05 + 3.05 + 22.5 + 21.7 + 1.95 + 9 + 2 + 22.9 + 22.9$).

v. Ciais-Quadband PIFA contour = ~ 433.5

290. The total length of the Ciais-Quadband PIFA contour is thus ~ 433.5 ($203.3 + 36 + 142.2 + 52$), which is greater than 191.6—i.e., “greater than four times a diagonal of the antenna rectangle.”

291. Therefore, a POSA would have been motivated to use multiple antennas, including Ciais-Quadband PIFAs arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at a handheld MFWD comprising a first antenna element having a length that is greater than four times greater than the diagonal of the antenna rectangle.

o. a second antenna element configured to operate in at least one frequency band used by a 4G communication standard, wherein

292. This limitation is substantively addressed in my analysis of claim 1’s requirement that “a second antenna element [is] configured to receive signals from a 4G communication standard.” Therefore, I incorporate my analysis of that limitation from claim 1, as if fully set forth herein.

p. a perimeter of the second antenna element defines a second antenna contour comprising at least twenty segments.

293. This limitation is also recited in claim 8 of the ’103 patent. Therefore,

I incorporate my analysis of this limitation from claim 8 as if fully set forth herein.

q. Conclusion

294. Accordingly, a POSA would have been motivated to use multiple antennas, including multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at a handheld multifunction wireless device having at least one of multimedia functionality and smartphone functionality, the handheld multifunction wireless device comprising: a touch screen; processing module; a communication module; a power management module; an antenna system within the handheld multifunction wireless device and comprising: a ground plane layer; a first antenna element configured to simultaneously support radiation modes for first, second, and third frequency bands, the first frequency band being contained within a first frequency region of an electromagnetic spectrum; the second frequency band being contained within a second frequency region of the electromagnetic spectrum that is higher in frequency than the first frequency region, the third frequency band of operation being used by a 4G communication standard, wherein a perimeter of the first antenna element defines a first antenna contour comprising at least thirty-five segments, the first antenna element defining an antenna box, an orthogonal projection of the antenna box along a normal to a face with a largest area of the antenna box defining an antenna rectangle, wherein a length of the first antenna contour is greater than four

times a diagonal of the antenna rectangle; and a second antenna element configured to operate in at least one frequency band used by a 4G communication standard, wherein a perimeter of the second antenna element defines a second antenna contour comprising at least twenty segments.

K. Claim 13

a. The handheld multifunction wireless device according to claim 12, wherein

295. Claim 13 of the '103 patent depends from claim 12 and therefore includes all of the limitations of claim 12. Therefore, I incorporate my analysis of claim 12 into my analysis of claim 13 as if fully set forth herein.

b. the communication module is configured to simultaneously transmit signals from CDMA communication standard, a WiFi communication standard, and a 4 G communication standard.

296. Boireau discloses a

mobile computing device 100 may include at least three types of transceivers, including a cellular radiotelephone system transceiver for voice communications, a wireless networking transceiver for longer range data communications (and possible voice communications), and a personal area network transceiver for shorter range data communications. In some cases, for example, the multiple transceivers may have overlapping transmit and/or receive bands.

Ex.1015, [0026]. Boireau further discloses that “[r]adio sub-system 202 may perform voice and/or data communications operations on behalf of mobile computing device 100.” Ex.1015, [0028]. Boireau also discloses that “[i]n various

embodiments, radio sub-system 202 of mobile computing device 100 may be arranged to perform voice communications in accordance with different types of cellular radiotelephone systems.” Ex.1015, [0031].

297. Boireau further discloses that “[i]n addition to voice communication services, various embodiments of radio sub-system 202 may be arranged to perform data communications in accordance with different types of cellular radiotelephone systems.” Ex.1015, [0032]. Boireau goes on to explain that “[e]xamples of cellular radiotelephone systems offering data communications services may include . . . CDMA/1xRTT systems, . . . High Speed Downlink Packet Access (HSDPA)” and further that “[e]xamples of cellular radio telephone systems may include [CDMA] cellular radiotelephone communications systems.” Ex.1015, [0031]. Thus, Boireau disclosed a communication module configured to transmit signals from CDMA. Further, as discussed above, the ’103 patent expressly defines HSDPA as a “4G feature” and “4G service” and so equates HSDPA with a “4G standard.” Ex.1001, 24:22-35. Thus, Boireau also discloses a communication module configured to transmit signals from a 4G communication standard.

298. Boireau also discloses that “[i]n various embodiments, radio sub-system 202 may be arranged to perform voice and/or data communications in accordance with different types of wireless network systems” and that “Examples of suitable wireless network systems offering data communication services may

include . . . IEEE 802.11 a/b/g/n series of standard protocols and variants (also referred to as “WiFi”).” Ex.1015, [0033]. Thus, Boireau discloses a communication module configured to transmit signals from a WiFi communication standard, it also expressly contemplates a communication module.

299. Boireau further discloses a “logic flow” that “may be representative of the operations executed by one or more embodiments described herein, such as A[ntenna] M[angement] M[odule] 326, transceiver 304, radio sub-system 202, and/or mobile computing device 100” wherein “a first connection may be formed between a first transceiver and an antenna at block 602. A second connection may be formed between a second transceiver and antenna at block 604. Switching between the first connection and the second connection may be performed at block 606.” Ex.1015, [0068]. Boireau goes on to explain that “AMM 326 may cause transceiver 308-1, 308-2 to switch between antenna 318 fast enough to enable *substantially simultaneous operation of transceivers* 308-1, 308-2 to enhance user experience. For example transceiver 308-1 may maintain a WiFi connection to another device . . . while at the same time transceiver 308-2 may maintain Bluetooth connection to another device” and “AMM 326 may alternatively switch between transceivers 308-1, 308-2 to form electrical connections between each respective transceiver and antenna 318 in a manner that *allows both connections to remain active.*” Ex.1015, [0073] (emphasis added). These disclosures in Boireau themselves

disclose that the communication modules of the MFWD disclosed therein may be configured to simultaneously transmit signals from CDMA communication standard, a WiFi communication standard, and a 4 G communication standard.

300. At the very least Boireau indicates the preference for simultaneous transmittal of signals from CDMA, WiFi, and 4G communication standards. And, as discussed above, CN456 disclosed the use of multiple PIFA arranged in such a fashion within the MFWD to make for more efficient and reliable signal transmission. Ex.1016, Abstract. Thus, the prior art motivated a POSA to use multiple antennas including multiple Ciais-Quadband PIFA arranged according to the teachings of CN456 in the MFWD of Boireau such that communication module is capable of simultaneously transmitting signals from a CDMA communication standard, a WiFi communication standard, and a 4G communication standard.

c. Conclusion

301. Accordingly, a POSA would have been motivated with a reasonable expectation of success to use multiple antennas including multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at the invention of claim 12, wherein the communication module is configured to simultaneously transmit signals from a CDMA communication standard, a WiFi communication standard, and a 4G communication standard.

L. Claim 14

a. The handheld multifunction wireless device according to claim 12, wherein

302. Claim 14 of the '103 patent depends from claim 12 and therefore includes all of the limitations of claim 12. Therefore, I incorporate my analysis of claim 12 into my analysis of claim 14 as if fully set forth herein.

b. Each of the first frequency band and the second frequency band is used by at least one communication standard selected from: GSM, UMTS, CDMA, and W-CDMA.

303. As discussed above, the PIFA disclosed in Ciais-Quadband is capable of sending and receiving electromagnetic radiation at 870-960 MHz, which is included in the '103 patent's "810 MHz.-960 MHz region." Ex.1014, Fig. 3, 1-3; Ex.1001, 4:59. Between 870-960 MHz there are at least four communication standards including GSM—i.e., standard GSM900 and extended GSM900. *See*, ¶¶ 149-151, above. Any one of these frequency bands can satisfy claim 14's requirement that "the first frequency band ... is used by at least one communication standard selected from: GSM, UMTS, CDMA, and W-CDMA."

304. Because claim 12 requires that the "second frequency band [is] contained within a second frequency region of the electromagnetic spectrum that is higher in frequency than the first frequency region," the second frequency band must be at a higher frequency region than 810 – 960 MHz. Ciais-Quadband PIFA is capable of sending and receiving electromagnetic radiation at 1710-2170 MHz,

which spans the '103 patent's 1710 MHz – 1990 MHz region and the 1900 MHz – 2170 MHz region. Ex.1014, Fig. 3, 1-3; Ex.1001, 4:58-62. Each of these regions would be higher in frequency than the 870-960 MHz region—i.e., higher in frequency than the first frequency region.

305. The 1710-1990 MHz electromagnetic region includes UMTS communication standards, including at least UMTS Band III. Additionally, at least frequency band UMTS Band I, UMTS Band a, UMTS Band b, UMTS Band c, LTE Band 1, LTE Band 33, and LTE Band 34 are within the 1900 – 2170 MHz region. Any of these bands can serve as the claimed “second frequency band used by at least one communication standard selected from: GSM, UMTS, CDMA, and W-CDMA.”

306. Thus, the Ciais-Quadband PIFA would have a first frequency band that uses at least GSM communication standard, and a second frequency band that is contained within a second frequency region that is higher in frequency than the first frequency region and uses at least UMTS communication standard.

c. Conclusion

307. Accordingly, a POSA would have been motivated with a reasonable expectation of success to use multiple antennas including multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in a MFW of Boireau to arrive at the invention of claim 12, wherein each of the first frequency band and the second frequency band is used by at least one communication standard selected

from: GSM, UMTS, CDMA, and W-CDMA.

M. Claim 15

308. I understand that claim 15 has been canceled pursuant to ex-parte proceedings. Therefore, I do not address claim 15 here.

N. Claim 16

309. Claims 16 of the '103 patent recites (i) a handheld multifunction wireless device having at least one multimedia functionality and smartphone functionality, the handheld multifunction wireless device comprising: (ii) a touch screen; (iii) a microprocessor; (iv) at least one memory module; and a communication module configured to operate (v) in a first frequency band used by at least one communication standard and contained within a first frequency region of an electromagnetic spectrum, (vi) in a second frequency band used by at least one communication standard contained within a second frequency region of the electromagnetic spectrum that is higher in frequency than the first frequency region, and (vii) In a third frequency band used by a 4G communication standard, (viii) the communication module comprising an antenna system within the handheld multifunction wireless device having (ix) at least a first and a second antenna elements and (x) a ground plane layer, (xi) the first antenna element being configured to transmit and receive signals from a 4G communication standard, and (xii) the second antenna element being configured to receive signals from a 4G

communication standard, wherein: (xiii) the ground plane layer defines a ground plane rectangle; (xiv) the first antenna element is proximate to a first short side of the ground plane rectangle; (xv) the second antenna element is proximate to a second short side of the ground plane rectangle; and (xvi) a perimeter of the second antenna element defines an antenna contour having a level of complexity factor F_{21} having a value of at least 1.20 and complexity factor F_{32} having a value less than 1.75.

a. A handheld multifunction wireless device having at least one multimedia functionality and smartphone functionality, the handheld multifunction wireless device comprising:

310. This limitation is also recited in Claim 1 of the '103 patent. Therefore, I incorporate my analysis of this limitation from claim 1, as if fully set forth herein.

b. A touch screen

311. This limitation is also recited in Claim 1 of the '103 patent. Therefore, I incorporate my analysis of this limitation from claim 1, as if fully set forth herein.

c. A microprocessor

312. This limitation is substantively addressed in my analysis of Claim 6's requirement of "a microprocessor and an operating system adapted to permit running of word-processing, spreadsheet, and slide software application." Therefore, I incorporate my analysis for that limitation from claim 6, as if fully set forth herein.

d. At least one memory module

313. Boireau discloses that the MFWD disclosed therein may comprise a "housing 102 [that] may be used to encapsulate various internal components for

mobile computing device 100, such as a processor, a memory, one or more transceivers, one or more [PCB], one or more antennas, a stylus, and so forth.” Ex.1015, [0020]. It further discloses that the “[m]obile computing device 100 may comprise . . . an expansion slot 130 to support a multimedia and/or memory card.” Ex.1015, [0021]. Boireau goes on to disclose that “[t]ransceivers 308-1, 308-2 may be connected to a memory 306. Memory 306 may include an antenna management module (AMM) 326.” Ex.1015, [0038]. It further discloses that “[m]emory 306 may be implemented using any machine-readable or computer-readable media capable of storing data, including both volatile and non-volatile memory. For example, memory 306 may include read-only memory (ROM), random-access memory (RAM), dynamic RAM (DRAM), Double-Data Rate DRAM (DDRAM), synchronous DRAM (SDRAM), static RAM (SRAM), programmable ROM (PROM), erasable programmable ROM (EPROM), electrically erasable programmable ROM (EEPROM), electrically erasable programmable ROM (EEPROM), flash memory, polymer memory, such as ferroelectric polymer memory, ovonic memory, phase change or ferroelectric memory, silicon-oxide-nitride-oxide-silicon (SONOS) memory, magnetic or optical cards, or any other type of media suitable for storing information.” Ex.1015, [0042]. Thus, Boireau discloses at least one memory module.

314. Therefore, a POSA would have been motivated to use multiple antennas, including Ciais-Quadband PIFA arranged according to the teachings in

CN456 in a MFWD of Boireau to arrive at a MFWD having a communication module configured to operate in a third frequency band used by 4G communication standard

e. A communication module configured to operate

315. This limitation is substantively addressed in my analysis of Claim 12’s requirement of “a communication module.” Therefore, I incorporate my analysis for that limitation from claim 12, as if fully set forth herein.

i. in a first frequency band used by at least one communication standard and contained within a first frequency region of an electromagnetic spectrum,

316. Boireau discloses that the “radio sub-system may be arranged to perform voice communications in accordance with different types of cellular radiotelephone systems. Examples of cellular radio-telephone systems may include [CDMA], [GSM], [NADC], [TDMA], [E-TDMA], [NAMPS], [WCDMA], [CDMA-2000], [UMTS], [3GPP], and so forth.” Ex.1015, [0031]. These communication standards operate at different frequency bands, any of which may be “a first frequency band.” Further, each of these bands are also necessarily within a frequency region of an electromagnetic spectrum—i.e., a first frequency region of an electromagnetic spectrum.

317. However, keeping in mind that claim 16 also requires “a second frequency band . . . within a second frequency region . . . that is higher in frequency

than the first frequency region,” for purposes of my analysis here, the “first frequency band” will be in a “first frequency region” that is at the lower end of the electromagnetic spectrum.

318. The '103 patent identifies the 810 MHz – 960 MHz region, which is at the lower end of the spectrum and is therefore the “first frequency region” for purposes of my analysis. Between 870-960 MHz there are at least four communication standards, including GSM—i.e., standard GSM900, extended GSM900. *See*, ¶¶ 149-151, above. Therefore, Boireau discloses a communication module configured to operate in a first frequency band used by at least one communication standard and contained within a first frequency region of an electromagnetic spectrum.

319. Further, the Ciais-Quadband PIFA “can operate from 880 to 960 MHz and 1710 to 2170 MHz covering GSM, DCS, PCS, and UMTS standards.” Ex.1014, 1.

320. Therefore, a POSA would have been motivated to use multiple antennas, including Ciais-Quadband PIFA arranged according to the teachings in CN456 in a MFWO of Boireau to arrive at a MFWO having a communication module configured to operate in a first frequency band used by at least one communication standard contained within a first frequency region of an electromagnetic spectrum.

- ii. In a second frequency band used by at least one communication standard contained within a second frequency region of the electromagnetic spectrum that is higher in frequency than the first frequency region, and**

321. This limitation requires the second frequency band be within a second frequency region that is higher in frequency than the first frequency region. Thus, for purposes of my analysis, I will consider frequency bands at a higher end of the electromagnetic spectrum than the 870-960 MHz region.

322. The '103 patent identifies frequency regions of the electromagnetic spectrum including 1710 MHz – 1990 MHz region, and 1900 MHz-2170 MHz region. Each of these regions is at a higher region than the “first frequency region” (870-960 MHz region). As such, frequency bands within either of these regions would be higher in frequency than the first frequency region.

323. As discussed above, Boireau discloses that the “radio sub-system may be arranged to perform voice communications in accordance with different types of cellular radiotelephone systems. Examples of cellular radio-telephone systems may include [CDMA], [GSM], [NADC], [TDMA], [E-TDMA], [NAMPS], [WCDMA], [CDMA-2000], [UMTS], [3GPP], and so forth. Ex.1015, [0031].

324. Further, the Ciais-Quadband PIFA is capable of sending receiving electromagnetic radiation at 1710-2170 MHz, which overlaps with the '103 patent's higher frequency regions of 1710 MHz – 1990 MHz, and 1900 MHz-2170 MHz.

The 1710-1990 MHz electromagnetic region includes UMTS communication standards, including at least UMTS Band III.

325. Therefore, a POSA would have been motivated to use multiple antennas, including Ciais-Quadband PIFA arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at a MFWD having a communication module configured to operate in a second frequency band used by at least one communication standard contained within a second frequency region of an electromagnetic spectrum that is higher than the first frequency region.

iii. In a third frequency band used by a 4G communication standard

326. The '103 patent expressly defines HSDPA as a “4G feature” and “4G service” that it equates with a “4G standard.” Ex.1001, 24:22-35 (“A MFWD incorporating 3.5G or 4G features (i.e. comprising 3G and other advanced services such as for instance HSDPA)”).

327. UMTS bands are a “4G communication standard” at least because they support HSDPA. HSDPA is part of the Universal Mobile Telecommunications System (UMTS) and supported by UMTS frequency bands. Ex.1018, 139, 599; Ex.1019 (UMTS HSDPA description).

328. Boireau discloses that the “radio sub-system may be arranged to perform voice communications in accordance with different types of cellular radiotelephone systems. Examples of cellular radio-telephone systems may include

... [UMTS].” Ex.1015, [0031]. Therefore, Boireau discloses a communication module configured to operate in a third frequency band used by a 4G communication standard.

329. Further, Ciais-Quadband PIFA supports seven UMTS frequency bands (UMTS Band I (1920-2170 MHz), UMTS Band II (1880-1990 MHz), UMTS Band III (1710-1880 MHz), UMTS Band IV (1710-2155 MHz), UMTS Band a (1900-1920, 2010-2025 MHz), UMTS Band b (1850-1910, 1930-1990 MHz), UMTS Band c (1910-1930 MHz). Thus, Ciais-Quadband PIFA supports a third frequency band used by a 4G communication standard.

330. Therefore, a POSA would have been motivated to use multiple antennas, including Ciais-Quadband PIFA arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at a MFWD having a communication module configured to operate in a third frequency band used by 4G communication standard.

f. The communication module comprising an antenna system within the handheld multifunction wireless device having

331. This limitation is substantively addressed in my analysis of Claim 1’s requirement of “an antenna system comprising a ground plane layer and three antenna elements within the handheld multifunctional device.” Therefore, I incorporate my analysis with respect to that limitation from claim 1, as if fully set forth herein.

i. at least a first and a second antenna elements and

332. This limitation is substantively addressed in my analysis of Claim 1's requirement of "a first antenna element having a conductive plate configured to simultaneously support radiation modes for at least first, second, and third of the at least four frequency bands" and "a second antenna element configured to receive signals from a 4G communication standard." Therefore, I incorporate my analysis with respect to those limitations from claim 1, as if fully set forth herein.

ii. a ground plane layer

333. This limitation is substantively addressed in my analysis of Claim 1's requirement of "an antenna system comprising a ground plane layer and three antenna elements within the handheld multifunctional device." Therefore, I incorporate my analysis with respect to that limitation from claim 1, as if fully set forth herein.

g. the first antenna element being configured to transmit and receive signals from a 4G communication standard, and

334. As discussed above, a POSA would have been motivated to use multiple Ciais-Quadband PIFA arranged according to the teachings of CN456 in the MFWD of Boireau so that the Ciais-Quadband PIFA would serve as a first and second antenna element.

335. Thus, this limitation is substantively addressed in my analysis of Claim 1's requirement that "a second antenna element [be] configured to receive signals

from a 4G communication standard.” Therefore, I incorporate my analysis with respect to that limitation from claim 1, as if fully set forth herein.

h. the second antenna element being configured to receive signals from a 4G communication standard, wherein:

336. This limitation is substantively addressed in my analysis of Claim 1’s requirement that “a second antenna element [be] configured to receive signals from a 4G communication standard.” Therefore, I incorporate my analysis with respect to that limitation from claim 1, as if fully set forth herein.

i. the ground plane layer defines a ground plane rectangle;

337. This limitation is substantively addressed in my analysis of Claim 3’s requirement that “[t]he first antenna element is proximate to a short side of a ground plane rectangle defined by the ground plane layer, and the second antenna element is proximate to a short side of the ground plane rectangle.” Therefore, I incorporate my analysis with respect to that limitation from claim 3, as if fully set forth herein.

j. the first antenna element is proximate to a first short side of the ground plane rectangle;

338. This limitation is substantively addressed in my analysis of Claim 3’s requirement that “[t]he first antenna element is proximate to a short side of a ground plane rectangle defined by the ground plane layer, and the second antenna element is proximate to a short side of the ground plane rectangle.” Therefore, I incorporate my analysis with respect to that limitation from claim 3, as if fully set forth herein.

k. the second antenna element is proximate to a second short side of the ground plane rectangle; and

339. As discussed above, a POSA would have been motivated to use multiple Ciais-Quadband PIFA arranged according to the teachings of CN456 in the MFWD of Boireau so that the Ciais-Quadband PIFA would serve as a first and second antenna element.

340. Thus, this limitation is substantively addressed in my analysis of Claim 3's requirement that "[t]he first antenna element is proximate to a short side of a ground plane rectangle defined by the ground plane layer, and the second antenna element is proximate to a short side of the ground plane rectangle." Therefore, I incorporate my analysis with respect to that limitation from claim 3, as if fully set forth herein.

l. a perimeter of the second antenna element defines an antenna contour having a level of complexity factor F_{21} having a value of at least 1.20 and complexity factor F_{32} having a value less than 1.75.

341. This limitation is also recited in claim 1 of the '103 patent. Therefore, I incorporate my analysis of this limitation from claim 1 as if fully set forth herein.

m. Conclusion

342. Accordingly, a POSA would have been motivated to use multiple antennas, including multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in the MFWD of Boireau to arrive at a handheld MFWD having at least one multimedia functionality and smartphone functionality, the handheld

multifunction wireless device comprising: a touch screen; a microprocessor; at least one memory module; and a communication module configured to operate in a first frequency band used by at least one communication standard and contained within a first frequency region of an electromagnetic spectrum, in a second frequency band used by at least one communication standard contained within a second frequency region of the electromagnetic spectrum that is higher in frequency than the first frequency region, and In a third frequency band used by a 4G communication standard, the communication module comprising an antenna system within the handheld multifunction wireless device having at least a first and a second antenna elements and a ground plane layer, the first antenna element being configured to transmit and receive signals from a 4G communication standard, and the second antenna element being configured to receive signals from a 4G communication standard, wherein: the ground plane layer defines a ground plane rectangle; the first antenna element is proximate to a first short side of the ground plane rectangle; the second antenna element is proximate to a second short side of the ground plane rectangle; and a perimeter of the second antenna element defines an antenna contour having a level of complexity factor F_{21} having a value of at least 1.20 and complexity factor F_{32} having a value less than 1.75.

O. Claim 17

- a. The handheld multifunction wireless device according to claim 16, wherein**

343. Claim 17 of the '103 patent depends from claim 16 and therefore includes all of the limitations of claim 16. Therefore, I incorporate my analysis of claim 16 into my analysis of claim 17 as if fully set forth herein.

- b. An antenna box is defined by the first antenna element,**

344. This limitation is substantively addressed in my analysis of claim 12's requirement that "the first antenna element defin[e] an antenna box." Therefore, I incorporate my analysis with respect to that limitation from claim 12, as if fully set forth herein.

- c. An antenna rectangle is defined by an orthogonal projection of the antenna box along a normal to a face with a largest area of the antenna box, and wherein**

345. This limitation is substantively addressed in my analysis of claim 12's requirement that "an orthogonal projection of the antenna box along a normal to a face with a largest area of the antenna box defining an antenna rectangle." Therefore, I incorporate my analysis with respect to that limitation from claim 12, as if fully set forth herein.

- d. A longer side of said antenna rectangle is substantially parallel to the first short side of the ground plane rectangle.**

346. Figure 1 from CN456 defines the rectangle of the PCB—i.e., the "ground plane rectangle"—because it "is a rectangle whose edges are tangent to at

least one point of the ground plane.” Ex.1001, 14:9-11. CN456 further discloses “four ground-plane-shortened [PIFA] units are respectively denoted as (2d), (2a), (2b), and (2c)” that are placed on the ground plane. Ex.1016, claim 1, 7.

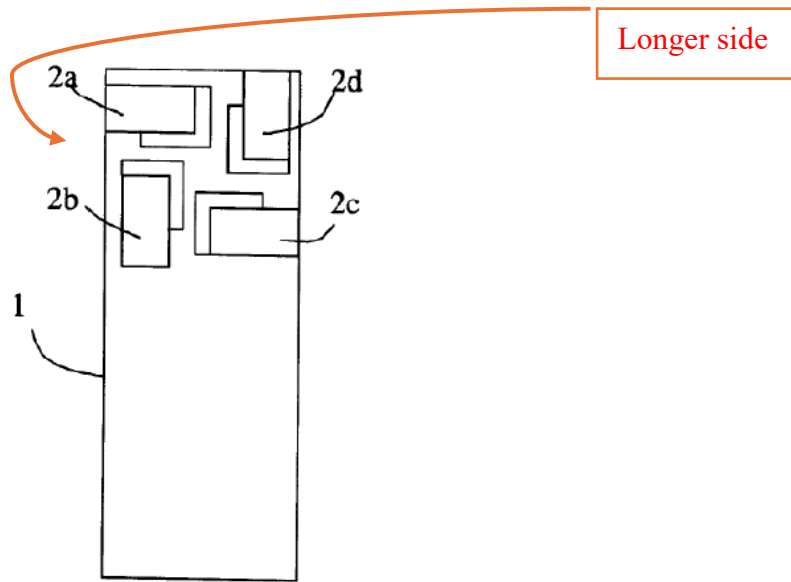
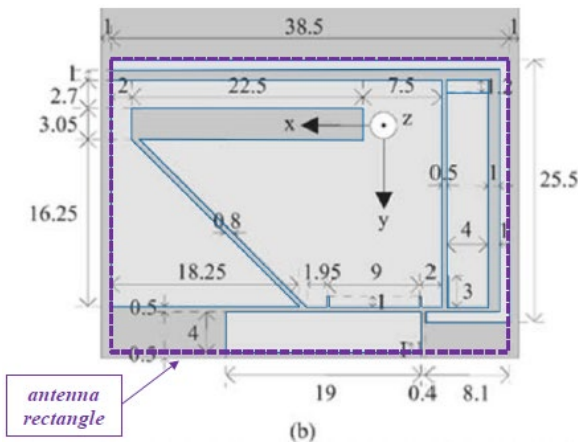


FIG. 1

Ex.1016, Fig. 1 (annotated)

347. Further, the antenna rectangle for the Ciais-Quadband PIFA is identified by the purple rectangle in the image below.



348. As discussed above, a POSA would have been motivated to use multiple Ciais-Quadband antennas arranged according to the teachings in CN456 in a MFWD of Boireau. Thus, arranging Ciais-Quadband's PIFA in position 2a from CN456 Fig. 1 would result in the longer side of the antenna rectangle being substantially parallel to the first short side of the ground plane rectangle.

e. Conclusion

349. Accordingly, a POSA would have been motivated with a reasonable expectation of success to use multiple antennas including multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at the invention of claim 16, wherein an antenna box is defined by the first antenna element, an antenna rectangle defined by an orthogonal projection of the antenna box along a normal to a face with a largest area of the antenna box, and where in a longer side of said antenna rectangle is substantially parallel to the first short side of the ground plane rectangle.

P. Claim 18

a. The handheld multifunction wireless device according to claim 16, wherein

350. Claim 18 of the '103 patent depends from claim 16 and therefore includes all of the limitations of claim 16. Therefore, I incorporate my analysis of claim 16 into my analysis of claim 18 as if fully set forth herein.

b. The first frequency region is delimited by 810-960 MHz frequency range, and the second frequency region delimited by 1710-1990 MHz frequency range.

351. As discussed above, for purposes of my analysis of claim 16, the “first frequency band” will be in a “first frequency region” that is at the lower end of the electromagnetic spectrum identified in the ’103 patent as the 810 MHz-960 MHz region. At that frequency region, there are at least four communication standards, including GSM—i.e., standard GSM900, extended GSM900. See, ¶¶ 149-151, above.

352. Boireau discloses that the “radio sub-system may be arranged to perform voice communications in accordance with different types of cellular radiotelephone systems. Examples of cellular radio-telephone systems may include [GSM]. Ex.1015, [0031]. Additionally, the Ciais-Quadband PIFA “can operate from 880 to 960 MHz . Ex.1014, 1.

353. As such a POSA would have been motivated to use the Ciais-Quadband PIFA arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at MFWD wherein the first frequency region is delimited by 810-960 MHz.

c. The second frequency region delimited by 1710-1990 MHz frequency range

354. As discussed above in my analysis of claim 16, the “second frequency band” must be within a second frequency region that is higher in frequency than the first frequency region—i.e., higher than 870-960 MHz.

355. The Ciais-Quadband PIFA is capable of sending and receiving electromagnetic radiation at 1710-2170 MHz, which includes the '103 patent's higher frequency region of 1710 MHz – 1990 MHz. The 1710-1990 MHz electromagnetic region includes UMTS communication standards, including at least UMTS Band III.

356. Additionally, Boireau discloses that the “radio sub-system may be arranged to perform voice communications in accordance with different types of cellular radiotelephone systems. Examples of cellular radio-telephone systems may include [UMTS].” Ex.1015, [0031].

357. As such a POSA would have been motivated to use the Ciais-Quadband PIFA arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at MFWD wherein the second frequency region is delimited by 1710-1990 MHz.

d. Conclusion

358. Accordingly, a POSA would have been motivated with a reasonable expectation of success to use multiple antennas including multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at the invention of claim 16, wherein the first frequency region is delimited by 810-960 MHz frequency range, and the second region is delimited by 1710-1990 MHz frequency range.

Q. Claim 19

a. The handheld multifunction wireless device according to claim 16, wherein

359. Claim 19 of the '103 patent depends from claim 16 and therefore includes all of the limitations of claim 16. Therefore, I incorporate my analysis of claim 16 into my analysis of claim 19 as if fully set forth herein.

b. The complexity factor F_{21} has a value less than 1.45

360. This limitation is substantively addressed in my analysis of claim 1's requirement that "a perimeter of the second antenna element defines an antenna contour having a level of complexity defined by complexity factor F_{21} having a value of at least 1.20." In my analysis of that limitation, I show that the F_{21} of the Ciais-Quadband PIFA is 1.31, which is less than 1.45.

c. Conclusion

361. Accordingly, a POSA would have been motivated with a reasonable expectation of success to use multiple antennas including multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at the invention of claim 16, wherein the complexity factor F_{21} has a value less than 1.45.

R. Claim 20

a. The handheld multifunction wireless device according to claim 16, wherein

362. Claim 20 of the '103 patent depends from claim 16 and therefore

includes all of the limitations of claim 16. Therefore, I incorporate my analysis of claim 16 into my analysis of claim 20 as if fully set forth herein.

b. The handheld multifunction wireless device is configured to use the first antenna element and the second antenna element as a diversity system.

363. The '103 patent states that “[f]or any wireless service, more than one antenna (system) may be provided in order to obtain a diversity system and/or a multiple input/multiple output system.” Ex.1001, 10:21-23. It further states that “[a]dvantageously MFWD including 4G services have one or more dedicated antennas for 4G services forming an antenna diversity arrangement. In those cases not only is good isolation between the antennas system and the antennas for the 4G services required but also good isolation between the two or more antennas forming the antenna diversity arrangement.” Ex.1001, 25:1-7.

364. CN456 directly addresses diversity systems with the use of multiple PIFA:

to rationally arrange the spatial positions, spacings, and mutual spatial relationships of PIFA antenna units, such that the MIMO antenna system has the following characteristics:

(1) Low-correlation data links are obtained with a minimum spacing between antenna units, so that the MIMO antenna structure is as compact as possible, particularly within small-sized wireless terminals.

(2) After the antenna units are installed in a terminal, the antenna units exhibit wide radiation patterns, such that, in a plane passing through the origin with the antenna taken

as the origin, the radiation pattern is approximately omnidirectional.

(3) The radiation patterns of the respective antenna units are complementary to each other, and together form an approximately omnidirectional radiation pattern over a spherical surface, thereby achieving radiation-pattern diversity.

(4) The main polarization directions of certain antenna units are mutually perpendicular, thereby achieving polarization diversity.

(5) Mutual coupling among the multiple antenna units is relatively low, thereby realizing low-correlation data links and high radiation efficiency.

Ex.1016, 6. Thus, arranging the Ciais-Quadband PIFAs according to the teachings in CN456 in a MFWD of Boireau results in the claimed invention.

c. Conclusion

365. Accordingly, a POSA would have been motivated with a reasonable expectation of success to use multiple antennas including multiple Ciais-Quadband PIFAs arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at the invention of claim 16, wherein the handheld MFWD is configured to use the first antenna element and the second antenna element as a diversity system.

X. GROUND 2: Ciais-Quadband, CN456, Cho, and Boireau Render Claims 5 and 11 Unpatentable

A. Claim 5

a. The handheld multifunctional wireless device according to claim 1, wherein

366. Claim 5 of the '103 patent depends from claim 1 and therefore includes

all of the limitations of claim 1. Therefore, I incorporate my analysis of claim 1 into my analysis of claim 5 as if fully set forth herein.

b. The third antenna element is configured to operate in a fifth frequency band within 2400-2480 MHz frequency range.

367. Cho would have supplied claim 5's third antenna element. Cho disclosed an internal PIFA covering 2.4 GHz (2.38-2.49 GHz). Ex.1026, 2. A POSA would recognize that 2.38-2.49 GHz is 2380-2490 MHz, which overlaps with the claimed frequency range. Further, any frequency band within Cho's 2.4 GHz range could be the claimed "fifth frequency band."

c. Conclusion

368. Accordingly, a POSA would have been motivated with a reasonable expectation of success to use multiple antennas including Ciais-Quadband's and Cho's PIFAs arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at the invention of claim 5.

B. Claim 11

a. The handheld multifunctional wireless device according to claim 6, wherein

369. Claim 11 of the '103 patent depends from claim 6 and therefore includes all of the limitations of claim 6. Therefore, I incorporate my analysis of claim 6 into my analysis of claim 11 as if fully set forth herein.

- b. The handheld multifunction wireless device comprises a third antenna configured to operate in a frequency band within 2400-2480 MHz frequency range.**

370. Cho would have supplied claim 11's third antenna element. Cho disclosed an internal PIFA covering 2.4 GHz (2.38-2.49 GHz). Ex.1026, 2. A POSA would recognize that 2.38-2.49 GHz is 2380-2490 MHz, which overlaps with the claimed frequency range.

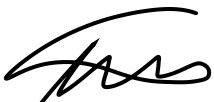
c. Conclusion

371. Accordingly, a POSA would have been motivated with a reasonable expectation of success to use multiple antennas including Ciais-Quadband's and Cho's PIFAs arranged according to the teachings in CN456 in a MFWD of Boireau to arrive at the invention of claim 11.

XI. Conclusion

I declare under penalty of perjury under the laws of the United States of America that all statements made herein of my knowledge are true, and that all statements made on information and belief are believed by me to be true.

Dated: April 14, 2026

By: 

Dr. Emmanouil M. Tentzeris