

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

JOHNSON CONTROLS INC.,
Petitioner,

v.

FRACTUS, S.A.,
Patent Owner.

Case No. IPR2026-00338
Patent No. 8,738,103

EXPERT DECLARATION OF HOSSEIN HASHEMI, Ph.D.

I, Hossein Hashemi, Ph.D., do hereby declare as follows:

I. Introduction

1. I am a Professor of Electrical Engineering at the University of Southern California ("USC"). I am, however, currently on a leave of absence and temporarily working as a full-time employee at Astera Labs, Inc.

2. I have been retained by Edell, Shapiro and Finnan, LLC (hereinafter "the Edell Firm"), to provide various opinions regarding U.S. Patent No. 8,738,103 ("the '103 Patent"). I understand that my declaration is being submitted in connection with a Patent Owner Preliminary Response in an inter partes review of the '103 Patent. Unless otherwise noted, the statements made herein are based on my personal knowledge and, if called to testify with regards to this declaration, I could and would do so competently and truthfully.

3. I have been retained in this matter by the Edell Firm as a technical expert in the field of electrical engineering, particularly within the context of antenna design and operation in multifunction wireless devices. I am being compensated for my work in this matter at my usual and customary rate of \$760.00 per hour. I have no personal or financial stake or interest in the outcome of the inter partes review or any related action. My compensation in no way depends upon my testimony or the outcome of the inter partes review.

4. I have been advised that the Edell Firm represents Fractus, S.A. (hereinafter "Patent Owner") in this matter and that Johnson Controls, Inc. (hereinafter "Petitioner") have petitioned for inter partes review of the '103 Patent. I have no personal or financial stake or interest in Patent Owner, Petitioner, or the '103 Patent.

5. I reserve the right to supplement and/or amend my opinions in this declaration based on future positions taken by Petitioner or its experts, additional documents, testimony or other information provided by Petitioner or its witnesses, any actions from the Patent Trial and Appeal Board ("Board"), or as otherwise necessary.

II. Qualifications

6. My qualifications for forming the opinions set forth in this expert report are summarized here and explained in more detail in my *curriculum vitae* which is attached as Exhibit A to this Declaration. Exhibit A includes a full list of my publications and other professional contributions and achievements, and a list of the cases in which I have testified at deposition, hearing, or trial.

7. I am currently the Ming Hsieh Electro-Physics Professor of Electrical and Computer Engineering, and a Co-Director of the Ming Hsieh Institute at USC. I received my Bachelor of Science degree in Electronics Engineering from Sharif University of Technology in 1997. I received my Master's degree in Electronics

Engineering from Sharif University of Technology in 1999. I received my Master's degree and Ph.D. in Electrical Engineering from the California Institute of Technology in 2001 and 2003, respectively.

8. From 1997 to 1999 I was a radiofrequency integrated circuit design engineer at Keresem Communications Research. I became an Assistant Professor of Electrical Engineering at USC in October 2003 and remained in that position until May 2009. From November 2007 to May 2009, I also occupied the Gordon S. Marshall Early Career Chair at USC. In May 2009 I became a tenured Associate Professor of Electrical Engineering at USC and remained in that position until my promotion to Professor in December 2014, a title I have held since then.

9. I have over 25 years of industry and academic experience. In particular, I have experience with antennas and electromagnetic technologies including designing, simulating, taping out, and measuring complex electromagnetic structures spanning frequency ranges of 100 MHz – 170 GHz, as well as infrared frequencies (1550 nm wavelength), and demonstrating numerous phased arrays (multi-antenna systems) spanning radiofrequency to infrared frequencies.

10. I have been privileged to receive a number of awards and honors throughout my career. These include:

- Fellow, Optica 2023
- Fellow, Institute of Electrical and Electronics Engineers (IEEE) - 2019

- Winner, Nokia Bell Labs Prize - 2016
- Outstanding Young Engineer Award of the IEEE Microwave Theory and Techniques Society (MTT-S) - 2015
- Distinguished Lecturer, IEEE Solid State Circuits Society 2013 – 2014
- Distinguished Scholar for "Outstanding Achievement in Advancement of Engineering," Association of Professors and Scholars of Iranian Heritage -2011
- Inaugural Winner, Maseeh Entrepreneurship Prize Competition, USC - 2011
- NSF CAREER Award - 2009
- USC Viterbi School of Engineering Junior Faculty Research Award - 2008
- DARPA Young Faculty Award - 2008
- Lewis Winner Award for Outstanding Paper, IEEE International Solid-State Circuits Symposium (ISSCC) - 2007
- Best Paper Award, IEEE Journal of Solid-State Circuits - 2004
- Charles Lee Powell Foundation Research Award - 2004
- Young Scholar Award, Association of Professors and Scholars of Iranian Heritage - 2003
- Graduate Fellowship Award, Intel Foundation - 2002
- Outstanding Student Designer Award, Analog Devices - 2001
- Outstanding Accomplishment Award, von Brimer foundation - 2000
- Engineering and Applied Science Division Fellowship, California Institute of Technology - 1999

- Ranked first in Ph.D. EE qualifying exam, California Institute of Technology - 2000
- Ninth place out of 300,000 in national qualifying exam for undergraduate studies – 1993

11. I have co-authored two books and over 125 peer-reviewed journal and conference papers. I have also spoken at numerous invited workshops, talks and short courses. Many of these relate directly or indirectly to antennas, antenna arrays and various modes of wireless communication and electronics design.

12. I am the named inventor on 15 United States Patents, including patents related to antenna technology, including U.S. Patent Nos. 10,615,949 (Hybrid-based cancellation in presence of antenna mismatch) and 8,203,484 (Path-sharing transceiver architecture for antenna arrays).

III. Legal Standards

13. While I am not an attorney, I have been informed by counsel of certain legal principles I should apply in reaching my opinions in this matter. Also, as an inventor, expert witness and otherwise in the course of my work, I have experience studying and analyzing patents and patent claims from the perspective of a person of ordinary skill in the art (POSITA or "skilled artisan").

A. Claim Construction

14. I understand that claim terms are to be interpreted from the point of view of a POSITA at the time of the invention. I further understand that claim terms are generally to be given their ordinary meaning, considered in light of the claim language, patent specification, and prosecution history. I further understand that a patentee may act as its own lexicographer and depart from the ordinary and customary meaning by defining a term with reasonable clarity, deliberateness, and precision, but that there is a presumption that a claim term carries its ordinary and customary meaning.

B. Person of Ordinary Skill in the Art

15. I understand that a person of ordinary skill in the art is a hypothetical person who is presumed to have known the relevant art at the time of the invention. He or she is a person of ordinary creativity who understands the scientific and engineering principles applicable to the pertinent art. I am familiar with the knowledge and capabilities of one of ordinary skill in the art in the field of the '103 Patent at the time of invention.

C. Validity

16. I understand that for an *inter partes* review to be instituted, Petitioner must show that there is a reasonable likelihood that they will prevail with respect to at least one of the claimed challenged in the petition. I understand that Petitioner bear the burden of proving any instituted grounds of invalidity by a preponderance of the evidence. I understand that a "preponderance" means "more likely than not." I understand that general and conclusory assertions, without underlying factual evidence, may not support a conclusion that something is "more likely than not." Rather, the preponderance of the evidence standard requires that a reasonable finder of fact be convinced that the existence of a specific material fact is more probable than the non-existence of that fact. The preponderance of the evidence standard does not support speculation regarding specific facts and is instead focused on whether the evidence more likely than not demonstrates the existence or non-existence of specific material facts. Here, I understand that Petitioners have argued that the claims at issue are obvious over different grounds, two grounds applying a combination of two or more references, and third ground based on a parent application to the '677 Patent.

17. I also understand that, in performing a proper invalidity analysis, an expert must do more than simply provide quotes from the evidentiary record along with conclusory allegations of unpatentability. To the contrary, an expert's conclusions regarding unpatentability must be supported by actual analysis and reasoning set forth in the expert declaration, such that the theoretical and factual foundation for the expert's conclusions can be properly evaluated.

18. I understand that a patent claim may be found unpatentable as obvious under 35 U.S.C. § 103 only if the Board establishes by a preponderance of the evidence that, as of the priority date, the subject matter of the claim, considered as a whole, would have been obvious to a person having ordinary skill in the field of the technology (the "art") to which the claimed subject matter belongs.

19. I understand that the analysis of whether a claim is obvious depends on a number of necessary factual inquiries, for example, (1) the scope and content of the prior art; (2) the differences between the claimed subject matter and the prior art; (3) the level of ordinary skill in the art; and (4) objective evidence of non-obviousness.

20. I understand that the claimed invention must be considered as a whole in analyzing obviousness or non-obviousness. In determining the differences

between the prior art and the claimed invention, the question under the obviousness inquiry is not whether the differences themselves would have been obvious, but whether the claimed invention as a whole would have been obvious. Relatedly, I understand that it may be appropriate to consider whether there is evidence of a "teaching, suggestion, or motivation" to combine the prior art teachings in the prior art, the nature of the problem to be solved, or the knowledge of a person having ordinary skill in the art. I further understand arguments in support of obviousness cannot be sustained by mere conclusory statements; instead, there must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness.

21. I understand that one indicator of non-obviousness is when prior art "teaches away" from combining certain known elements. For example, a prior art reference teaches away from the patent's particular invention if it leads in a different direction or discourages a combination with another reference, recommends steps that would not likely lead to the patent's result, or otherwise indicates that a seemingly inoperative device would be produced.

22. I understand that an obviousness determination also requires that a person of ordinary skill in the art would have had a reasonable expectation of success in making any modifications to the cited references.

23. I further understand that certain objective indicia (sometimes called “secondary considerations”) can be important evidence regarding whether a patent is nonobvious, including the existence of a long-felt but unsolved need, unexpected results, commercial success, copying, and industry acceptance or praise. Evidence of such objective indicia must be considered when present. It is generally an error to reach a conclusion on obviousness before considering the evidence of such secondary considerations and then evaluating the latter solely in terms of whether it may fill any gaps in the initial conclusion on obviousness. On the other hand, such evidence is not a requirement for patentability, and the absence of such evidence is a neutral factor in the obviousness analysis.

24. I understand that the obviousness analysis cannot be based on “hindsight.” The skilled artisan must view prior art at the time of the invention and without using the disclosure of the subject patent as a guide.

25. To the extent Petitioners argue a prior art reference anticipates the claimed invention of the ’103 Patent, a prior art reference must be enabled to

anticipate a patent. That is, I understand that the prior art reference's description must be such that a person of ordinary skill in the field of the invention can practice the subject matter based on the reference without undue experimentation.

IV. Materials Reviewed

26. In forming the opinions offered in this Declaration I reviewed and considered as appropriate the following materials: the '103 Patent and its prosecution history, the Petition, the Expert Declaration of Dr. Emmanouil Tentzeris (Ex. 1012), and the remaining exhibits to the Petition and any additional materials cited herein.

V. Background

A. Person of Ordinary Skill in the Art

27. I understand that Petitioners has relied upon the following definition of a POSITA utilized by Fractus in prior litigation involving the '103 Patent:

[A] person with at least a bachelor's degree in electrical engineering, computer science, or a similar degree and at least four years of 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.

Petition, 16, *citing* Ex. 1008.

28. For the purpose of forming my opinions as set forth in this Declaration, I have applied this definition of a POSITA.

B. Overview of the '103 Patent

29. U.S. Patent No. 8,738,103, (“’103 Patent”) entitled "Multiple-body-configuration multimedia and smartphone multifunction wireless devices," issued on May 27, 2014, from U.S. Patent Application No. 11/614,429, which was filed on December 21, 2006, and claims priority to an application filed on July 18, 2006. EX1001 at 1. The patent is assigned to Patent Owner Fractus S.A. and is directed to compact antenna systems for smartphones and other handheld multifunction wireless devices. *Id.* The invention addresses the challenge of integrating antennas capable of operating across multiple wireless frequency bands while occupying the limited space available within modern portable electronic devices.

30. The ’103 Patent teaches that antenna performance can be improved through the use of specially configured conductive antenna contours having predetermined geometric complexity. EX1001 at 4:65-6:29. Rather than relying solely on conventional antenna dimensions, the inventors propose evaluating antenna shapes using complexity factors that characterize the degree to which an

antenna contour is complex or convoluted. *E.g., id.* at 16:28-35. These complexity measures provide designers with objective criteria for selecting antenna geometries that achieve a desirable balance between miniaturization, bandwidth, and radiation performance. *E.g., id.* at 31:58-65.

29. For example, a complexity factor F_{21} , determined from the cell counts from grids with large-sized and medium-sized cells, characterizes the complexity and degree of convolution of features of the antenna contour that appear when the contour is viewed at relatively coarser levels of scale. *Id.* at 18:51-54. Consequently, complexity factor F_{21} tends to increase with the number of antenna portions within the structure of the antenna system, typically associated with more frequency bands or radiation modes. *Id.* at 19:5-16. A complexity factor F_{32} , determined from the cell counts from grids with medium-sized and small-sized cells, characterizes the complexity and degree of convolution of features of the antenna contour that appear when the contour is viewed at relatively finer levels of scale. *Id.* at 19:39-43. Consequently, complexity factor F_{32} tends to increase when the antenna contour includes a highly convoluted curve and reveals the degree of miniaturization achieved by the antenna system. *Id.* at 19:46-56. Evaluating an antenna using such complexity factors reveals its suitability for specific applications and allows for

antennas to be selected that meet desired operation parameters and allow multiple antennas to fit within a single device. *See, e.g., Id.* at 20:48-26:7.

31. The '103 Patent specification describes numerous antenna embodiments that can be incorporated into wireless devices. The antenna elements may be formed from conductive plates, traces, or other conductive structures positioned adjacent to a ground plane within the device housing. By selecting antenna contours having appropriate complexity characteristics, the disclosed designs are capable of supporting multiple cellular and wireless communication bands while fitting within increasingly compact wireless devices. *E.g., id.* at 20:51-57.

32. The claims are directed generally to handheld multifunction wireless devices having antenna systems with conductive antenna elements that satisfy specified contour complexity characteristics. Independent claim 1, for example, recites a handheld wireless device including a touch screen, a geolocalization system, and an antenna system comprising a ground plane and three or more antenna elements configured to operate over at least four communication frequency bands. A first antenna element is configured to simultaneously support three of the at least four frequency bands. A second antenna element is configured to receive signal from

a 4G communication standard and having a contour that meets prescribed complexity factor values.

C. Claim Construction

33. I have reviewed and understand Petitioner's claim construction arguments (Petition at 16-27), and do not necessarily agree with them. Any differences I have with Petitioner's claim constructions, however, are not directly pertinent to any of the opinions that I am offering in this Declaration and, accordingly, are not addressed. I reserve, however, the right to disagree with Petitioners' claim constructions and to provide different and additional opinions on claim construction if an IPR is instituted.

D. Technical Background

1. Antenna Size

34. The operating frequency of an antenna is related to its physical size. In general, an antenna must have dimensions that are a significant fraction of the wavelength of the electromagnetic signals that it is intended to transmit or receive. Because wavelength is inversely proportional to frequency, antennas designed for lower frequencies are generally larger, while antennas designed for higher frequencies can be made smaller. Although modern antenna designs often use

loading techniques, folded structures, dielectric materials, or other methods to reduce their physical dimensions, the effective electrical length of the antenna remains closely tied to its operating wavelength.

35. For example, a monopole antenna is one of the simplest antenna types and can be implemented as a single conductive element and a conductive ground plane. A quarter-wave monopole has a physical length of approximately one-quarter of the operating wavelength. A dipole antenna generally consists of two conductive elements extending in opposite directions from a feed point. A resonant dipole typically has an overall length of approximately one-half of the operating wavelength, with each arm being about one-quarter wavelength long. A planar inverted-F antenna (PIFA), explained in more detail below, is an antenna that has historically been used in mobile phones and other portable wireless devices. The current path along the radiating element is typically designed to be approximately one-quarter of the operating wavelength.

2. Multiple Input Multiple Output Systems

36. A multiple-input multiple-output (“MIMO”) system is a wireless communication architecture that uses multiple transmitting antennas, multiple receiving antennas, or both to improve the performance of a radio link. Rather than

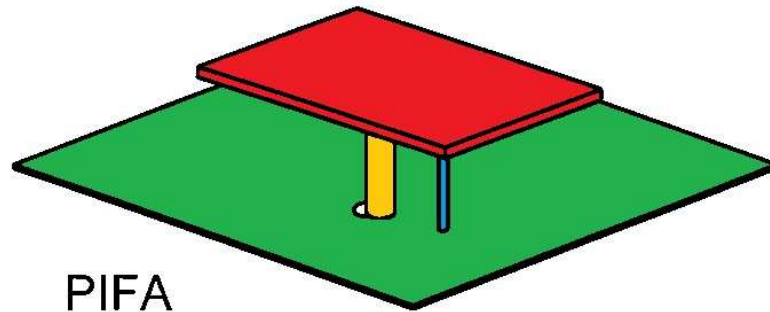
relying on a single antenna at each end of the communication channel, a MIMO system relies on multiple antennas to increase data throughput, improve reliability, and enhance spectral efficiency. By exploiting the fact that radio signals travel along multiple propagation paths due to reflections, diffraction, and scattering, a MIMO system can either transmit multiple independent data streams (spatial multiplexing) or transmit redundant information to improve signal robustness (spatial diversity).

37. Cell phones are one application of MIMO technology. Cellular and Wi-Fi networks use MIMO because the available radio spectrum is limited, making it desirable to increase data capacity without requiring additional bandwidth. A smartphone equipped with multiple antennas can simultaneously transmit and/or receive multiple spatial streams, allowing substantially higher download and upload rates than would be possible with a single antenna. In addition to increasing throughput, multiple antennas can improve reception in environments where signal reflections create fading. If one antenna experiences a deep fade, another antenna located elsewhere within the handset may receive a much stronger signal, allowing the device to maintain a reliable communication link.

3. Planar Inverted-F Antennas

38. Because the available space inside a smartphone is extremely limited, PIFAs were sometimes used as antenna elements in MIMO systems. A PIFA consists of a generally planar radiating element positioned above a conductive ground plane, with one portion of the radiating element connected directly to the ground plane through a shorting element or shorting pin and another portion connected to the radio-frequency circuitry through a feed structure.

39. A PIFA is a low-profile antenna previously used in wireless communication devices. A typical PIFA includes four principal components: a conductive radiating structure (annotated in red), a conductive ground plane (annotated in green), a feed structure (annotated in orange), and a shorting connection between the radiating structure and the ground plane (annotated in blue).



40. The radiating structure is spaced above the ground plane by a dielectric material or an air gap. The ground plane functions as the return conductor for antenna currents and forms an integral part of the resonant structure rather than merely serving as a mechanical support. The spacing between the radiating structure and the ground plane influences the antenna's resonant frequency, bandwidth, and radiation efficiency.

41. The radiating structure of a PIFA typically comprises a conductive element that may be rectangular, square, or another shape selected to achieve desired operating characteristics. Current flows across the radiating structure and returns through the shorting connection and the ground plane, producing electromagnetic radiation. The effective electrical length of the radiating structure, together with the

shorting connection, determines the antenna's resonant frequency, which is often approximately one-quarter wavelength of the operating frequency rather than one-half wavelength as in conventional dipole antennas. Various slots, meandered traces, parasitic elements, or other conductive features may be incorporated into the radiating structure to reduce the antenna's physical dimensions, create multiple resonant frequencies, or broaden the operating bandwidth without substantially increasing the overall footprint.

42. The ground plane serves both as an electrical reference and as an element that supports return currents induced by the radiating structure. Because the ground plane participates in the antenna's operation, its size, shape, and conductivity significantly influence the antenna's impedance, efficiency, radiation pattern and resonant frequency.

43. In portable electronic devices, the ground plane is frequently formed by a printed circuit board ground layer. A sufficiently large ground plane generally improves impedance bandwidth, improves radiation efficiency and provides a more stable radiation pattern, whereas a smaller ground plane may reduce impedance bandwidth, reduce radiation efficiency or shift the resonant frequency. Consequently, the dimensions of the ground plane are often selected together with

the dimensions of the radiating structure to satisfy the desired electrical performance.

See, e.g., EX2020; EX2021; EX2022; EX2023.

44. The feed structure supplies radio-frequency energy to the radiating structure and establishes the impedance match between the antenna and the associated transmitter or receiver circuitry. One common feeding arrangement employs a coaxial feed line. In such a configuration, the center conductor of the coaxial cable is electrically connected to the radiating structure at a selected feed point, while the outer conductor, or shield, of the coaxial cable is electrically connected to the ground plane.

45. A distinguishing characteristic of the PIFA is the shorting connection that electrically couples the radiating structure directly to the ground plane. This connection may be formed by a conductive pin, post, strip, wall, or other low-impedance conductor extending between the radiating structure and the ground plane. The shorting connection establishes a current path that effectively folds the resonant structure, allowing the antenna to achieve quarter-wavelength operation while maintaining a compact physical profile. During operation, radio-frequency current supplied through the feed point travels across the radiating structure, returns

through the shorting connection to the ground plane, and produces the electromagnetic fields responsible for radiation.

E. Overview of the Cited Art

1. Boireau

46. U.S. Patent Application Publication No. US 2007/0238483 A1 (“Boireau” EX1015), titled "Antenna Sharing Techniques," was filed by Palm, Inc. on April 5, 2006, published on October 11, 2007, and later issued as U.S. Patent No. 7,873,385 on January 18, 2011. EX1015 at 1. The application is directed to reducing the number of antennas required in a portable wireless device by allowing multiple radio transceivers to selectively share one or more antennas through switching circuitry. *Id.* at ¶ [0027]. The disclosed techniques are intended to conserve the limited space available inside handheld wireless devices while still supporting multiple wireless communication standards and frequency bands. *Id.*

47. The publication explains that portable communication devices often include several independent wireless radios, such as cellular, Bluetooth, Wi-Fi, and GPS, each of which might traditionally require its own dedicated antenna. *Id.* at ¶ [0022]. Because the physical size of handheld devices limits the number of antennas that can be incorporated without degrading performance or increasing cost, the

invention proposes an antenna sharing architecture in which switching circuitry dynamically connects selected transceivers to one or more shared antennas. *Id.* at ¶ [0027]. The switching may be controlled according to which radios are active, allowing different communication systems to utilize a common antenna without requiring every radio to have a separate radiating element. *Id.*

48. The Palm Treo smartphone serves as the principal exemplary device throughout the disclosure. The reference describes the invention in the context of a Treo-type handheld communication device that integrates numerous wireless capabilities into a compact housing. *Id.* at ¶ [0019]. The Treo is presented as an example of a multifunction mobile device that may simultaneously support cellular voice and data communications, Bluetooth connectivity, Wi-Fi networking, GPS reception, and other wireless technologies. Because the Treo's compact form factor leaves little room for multiple dedicated antennas, it illustrates the practical need for sharing antennas among several radio systems. The patent emphasizes that the invention is not limited to the Treo, but the Treo provides a concrete example of the type of integrated smartphone for which the antenna sharing architecture was developed.

49. The figures depicting the exemplary Treo device illustrate a conventional smartphone having a display, keyboard, processor, memory, and multiple radio-frequency transceivers connected through switching circuitry to one or more antennas. *Id.* at ¶ [0019] (“As shown in FIG. 1, mobile computing device 100 may be implemented as a combination handheld computer and mobile telephone, sometimes referred to as a smart phone. Examples of smart phones include, for example, Palm® products such as Palm® Treo™ smart phones.”).

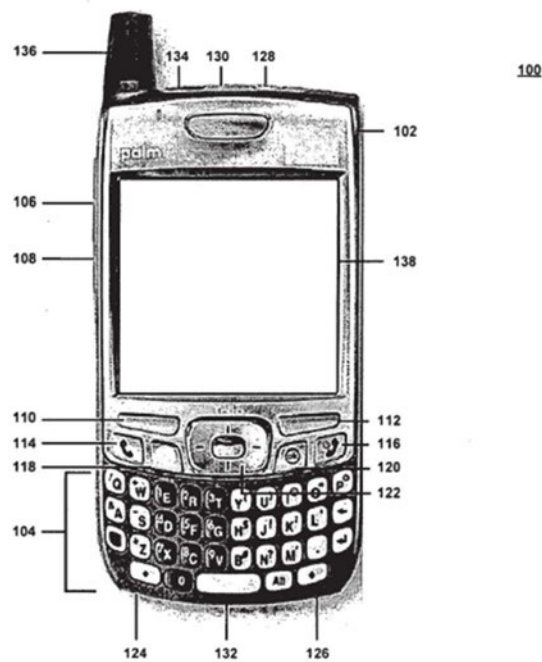


FIG. 1

50. Rather than focusing on the detailed physical construction of the antennas themselves, the disclosure concentrates on the electrical architecture that allows the radios to selectively access shared antennas. Various embodiments describe switches that route RF signals between transceivers and antennas while maintaining acceptable performance across multiple frequency bands. The invention, therefore, addresses system-level integration rather than introducing a new antenna geometry.

2. Chinese Published Patent Application No. CN1728456A

52. Chinese Patent Application CN1728456A (“CN456,” EX1016), titled "Four-Plane Inverted-F Antenna System for a Multiple-Input Multiple-Output (MIMO) Wireless Communication Terminal," was filed on July 1, 2005 by Tsinghua University and published on February 1, 2006. As explained in more detail below, the CN456 disclosure is directed to:

1. Modified PIFA antennas for use in MIMO and diversity systems to address the large size of prior systems. EX1016 at 3, 5.
2. Leveraging the smaller sized of the modified PIFA antenna units, and their small ground plans in particular, to enable close spacing of the units while maintaining sufficient isolation. *Id.* at 1. More specifically, the modified

PIFA antenna units utilize small unit-specific ground planes to support the underlying goal of compactness. *Id.* at 6.

3. Achieving wide radiation patterns from the modified PIFA antenna unit systems. *Id.*

53. The invention is directed to a compact MIMO antenna system for wireless communication terminals, such as mobile phones. *Id.* at 6. The invention is able to create the compact MIMO system by using uniquely structured single band PIFA antenna units, which the disclosure names *shortened* PIFA antenna units. *Id.* at 6-8. These *shortened* PIFA antenna units are then arranged in a particular structure to purportedly provide improved diversity and increased communication capacity while remaining suitably compact for integration into a handheld device. *Id.* at 7.

54. The shortened PIFA antenna units are illustrated in FIG. 3 of the reference (reproduced below). As illustrated, each shortened PIFA antenna unit 2a includes a respective conductive ground plane 2a-1 (annotated in green), a conductive radiating plane 2a-2 (annotated in red), a short circuit plane 2a-3 (annotated in blue) connecting the conductive radiating plane to the conductive ground plane, and a feeding post 2a-4 (annotated in orange). The shortened PIFA antenna units also share the metallic layer 3 on the rear surface of the PCB (annotated

in pink). The shortened PIFA antenna elements are connected to the shared metallic layer 3 by vias 2a-5 (annotated in purple).

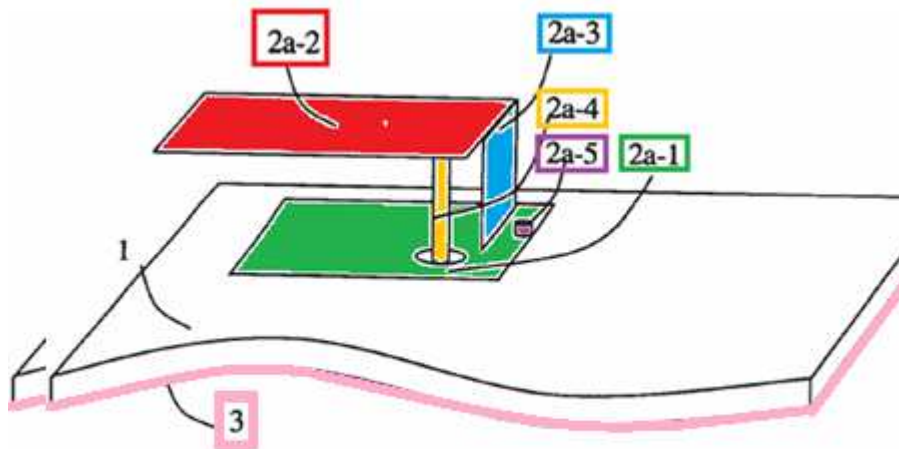


FIG. 3

55. CN456 also explains that the length and width constraints on the shortened PIFA element-specific ground plane need to be smaller than the length and width constraints placed on the radiating element. The conductive radiating plane 2a-2 has a length and width constrained to less than 0.25 times an operating wavelength of the antenna (EX1016 at 1, 4, FIGs. 2(a)-(c), 3, 7(a)-(b)), while the ground plane 2a-1 has a length and width constrained to less than 0.2 times an operating wavelength of the antenna (*Id.* at 1, 4, FIGs. 2(a)-(c), 3, 7(a)-(b)). CN456 also explains that the length of the ground plane 2a-1 should be less than that of the conductive radiating plane 2a-2. Specifically, the difference between the length of

radiating plane 2a-2 to the ground plane 2a-1 should be greater than $1/5$ the length of the radiating plane 2a-2, disclosing that “a value obtained by subtracting the length of the conductive ground plane from the length of the conductive radiating plane and then dividing the resulting difference by the length of the conductive radiating plane is greater than 0.2.” *Id.* at 2, 7.

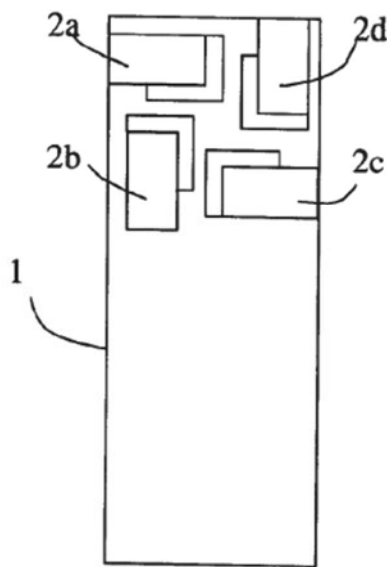


FIG. 1

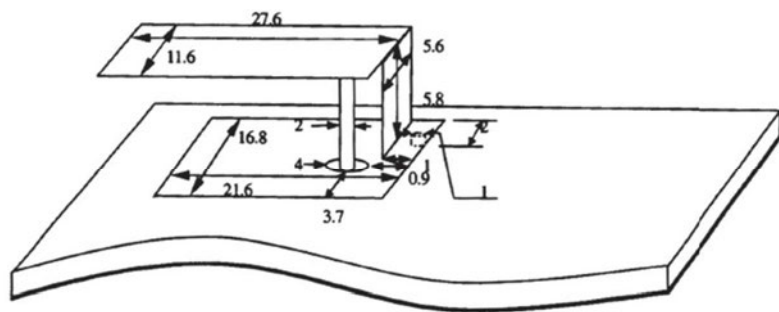


FIG. 7(a)

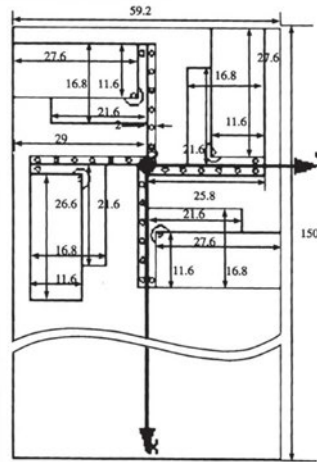


FIG. 7(b)

56. The example of FIGs. 7(a) and 7(b) is illustrative. In this example, CN456 provides explicit dimensions for its ground plane 2a-1 and its radiating plane 2a-2. The ground plane has a length of 21.6 mm, and the radiating plane has a length of 27.6 mm. The length of the ground plane is less than 80% that of the radiating plane. *Id.* at FIGs. 7(a) and 7(b).

57. Further, CN456 is explicit that its shortened PIFA antenna units operate over a single band with a narrow bandwidth: “[i]n the illustrated embodiment of the present invention, the operating frequency range is 2250–2300 MHz.” *Id.* at 9. This single band operation is confirmed in FIG. 5(b), in which the shortened PIFA antenna units are confirmed as operating exclusively within the 2250-2300 MHz frequency band:

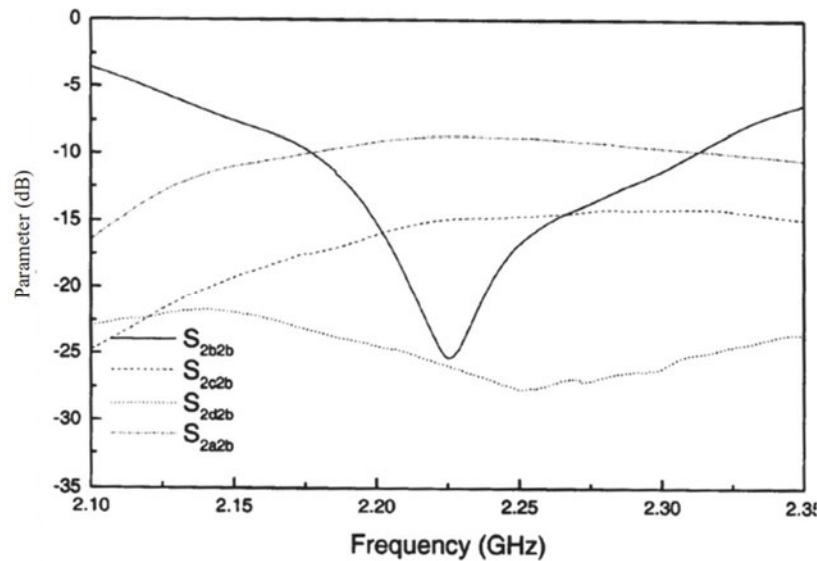


FIG. 5(b)

58. With this structure of the PIFA antenna units in place, the reference places separation constraints on the shortened PIFA antenna units so that the elements can be arranged as illustrated in FIG. 1:

A spacing between any two adjacent planar inverted-F antenna units is equal to a perpendicular distance between the respective ground planes thereof, and such distance is within a range of 0.1 to 0.5 times an operating wavelength of the planar inverted-F antenna units. The term “identical edges” refers to edges that are located at identical geometric positions on the respective planar inverted-F antenna units. **A spacing between feed points of the planar inverted-F antenna units located in the first quadrant and the third quadrant, and a spacing between feed points of the planar inverted-**

F antenna units located in the second quadrant and the fourth quadrant, are both greater than 0.25 times the operating wavelength of the planar inverted-F antenna. The planar inverted-F antenna units located in the first quadrant and the third quadrant are arranged to be rotationally symmetric with respect to a rotation of 180 ± 10 degrees about a midpoint of a line connecting respective identical points thereof. The planar inverted-F antenna units located in the third quadrant and the fourth quadrant are arranged to be rotationally symmetric with respect to a rotation of 180 ± 10 degrees about a midpoint of a line connecting respective identical points thereof in the same horizontal plane. The term “identical points” refers to points that are located at identical geometric positions on the respective planar inverted-F antenna units.

EX1016 at 2 (emphasis added).

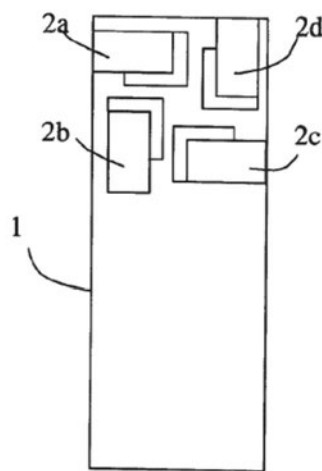
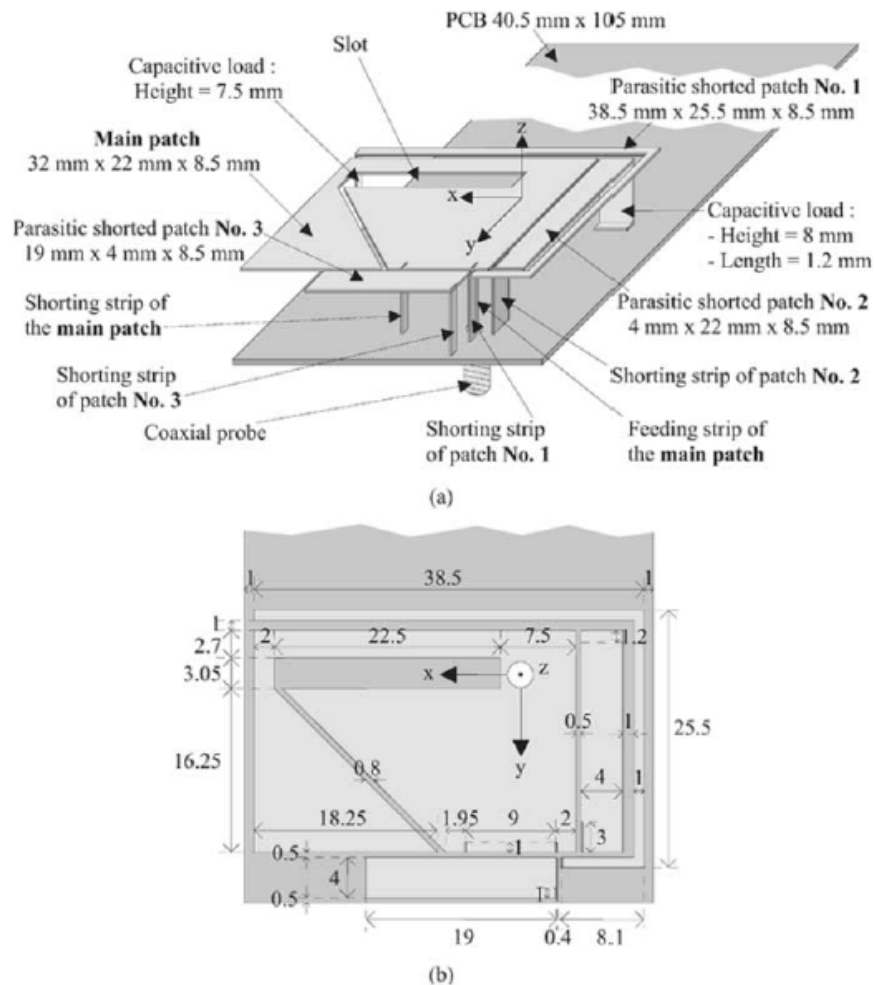


FIG. 1

3. Ciais-Quadband

59. Pascal Ciais et al., “Design of an Internal Quad-Band Antenna for Mobile Phones,” *IEEE Microwave and Wireless Components Letters*, vol. 14, no. 4, pp.148-150, April 2004 (“Ciais-Quadband,” EX1014) discloses a planar inverted-F antenna (PIFA) for cellular telephone applications. In the sole embodiment described by Ciais-Quadband and shown in FIGs. 1A and 1B, a single multiband antenna is located at a short end of a PCB ground plane and consists of a main patch with a slot, three quarter-wavelength parasitic elements, and capacitive loads that create additional resonances at four different frequencies. EX1014 at 148.



60. As shown in FIGs. 1A and 1B, the overall dimensions of Ciais-Quadband's antenna patches are 38.5 mm x 28.5 mm with a height (spacing from the PCB) of 8.5 mm. The antenna has clearances of 0.5 mm from the end (short) edge of the PCB and 1.0 mm from each of the side (long) edges of the PCB. The PCB serves as the ground plane for the antenna and has dimensions of 40.5 mm x

105.0 mm, a size representative of those found in typical mobile phones. *Id.* at 148-149 (“The 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 Printed Circuit Board (PCB) of a typical mobile phone”). Ciais-Quadband identifies the lowest band of the antenna as 870-960 MHz, i.e., 870 MHz is the lowest frequency of the Ciais-Quadband antenna. *Id.* at 149.

61. Ciais-Quadband explains that the size of its ground plane, and its **length** in particular, was specifically chosen to provide operation at its intended bands:

The PCB size, especially its length, has a strong influence on the performances of mobile phone antennas. **In our case, the chosen length is not the best choice for an optimum GSM bandwidth (around 130 mm [9]–[11]) or an optimum DCS bandwidth (around 70 mm [9]–[11]) but it will equally helps [sic] in these both bands for an efficient antenna-chassis combination.**

Id. at 148 (emphasis added).

62. Because Ciais-Quadband does not attempt to provide MIMO or antenna diversity, Ciais-Quadband includes only a single quad-band antenna located at one of the short ends of the PCB. Ciais-Quadband, consequently, does not contend with the issue of a suitable spacing between two or more

such antennas to provide MIMO or diversity or whether the size and shape of such an antenna is practical to enable MIMO or diversity in a wireless device.

4. Cho

63. The reference "An Internal PIFA for 2.4/5 GHz WLAN Applications," by Young Jun Cho, Yong Sun Shin, and Seong-Ook Park ("Cho," EX1026), presents the design and performance of a compact dual-band PIFA intended for Bluetooth and wireless local area network (WLAN) applications. The authors seek to develop an internal antenna suitable for notebook computers that can simultaneously operate over the 2.4 GHz Bluetooth/IEEE 802.11b band and the 5 GHz IEEE 802.11a/HIPERLAN/2 bands while maintaining a compact size, broad impedance bandwidth, and good radiation performance. EX1026 at 1. The authors conclude that the proposed antenna provides sufficient bandwidth and gain for these applications while occupying a relatively small volume. *Id.*

64. The antenna employs a conventional PIFA structure consisting of a hook-shaped radiating element positioned above a small rectangular ground plane. *Id.* The radiating element is supported by both a shorting pin and a 50 Ω coaxial feed cable, which together form the feeding structure. *Id.* The center conductor of the coaxial cable is connected directly to the radiating patch, while the outer conductor

is electrically connected to the ground plane. *Id.* The antenna occupies a volume of approximately $47.5 \times 20 \times 7 \text{ mm}^3$, allowing it to be mounted along the perimeter or corner of a notebook computer display. *Id.* Both the radiating element and the ground plane are fabricated from 0.2 mm thick copper plate. *Id.*

65. A significant aspect of the paper is its explanation of how the antenna achieves dual-band operation. *Id.* Rather than introducing separate resonators, the authors tune two current paths within the same radiating structure. *Id.* A longer current path extending from the shorting point to the open end of the radiating patch produces resonance near 2.4 GHz, while a shorter path between the feed point and shorting point establishes resonance near 5.5 GHz. *Id.* By adjusting both the location of the shorting pin and the length of portions of the radiating element, the designers independently influence the lower- and upper-frequency resonances. *Id.* Simulation results demonstrate that moving the shorting pin simultaneously alters both resonant frequencies, whereas modifying the folded radiating element primarily affects the lower-frequency resonance. *Id.* The optimized geometry provides coverage of both WLAN bands using a single compact PIFA. *Id.*

66. The paper reports favorable measured electrical performance. The antenna exhibits a measured 110 MHz impedance bandwidth ($VSWR \leq 2$) extending

from 2.38 GHz to 2.49 GHz, covering the Bluetooth and IEEE 802.11b bands, and approximately 900 MHz bandwidth from 5.1 GHz to 6.0 GHz, encompassing IEEE 802.11a and HIPERLAN/2. *Id.* at 2. Measured radiation patterns at both operating frequencies are approximately omnidirectional, making the antenna suitable for mobile computing environments where signal direction varies. *Id.* at 3. Measured peak gains are approximately 2.39 dBi at 2.44 GHz and 3.70 dBi at 5.8 GHz, closely matching the simulated results and demonstrating that the compact antenna maintains good radiation efficiency despite its reduced size. *Id.* at 2.

67. The principal contribution of the paper is demonstrating that a single compact PIFA, using a relatively small ground plane and a simple feeding arrangement, can provide the impedance bandwidth for the 2.4 GHz and 5 GHz WLAN frequency ranges. The design relies on careful placement of the shorting pin and tuning of the radiating element, rather than increasing antenna complexity, to achieve dual-band operation. The authors conclude that the combination of structural and electrical properties makes the proposed antenna very attractive for WLAN applications.

VI. Ground 1 - Boireau, CN456 and Ciais-Quadband Would Have Failed to Render Any Claim of the '103 Patent Obvious

68. Ground 1 proposes that the combined teachings of Boireau, CN456 and Ciais-Quadband would have rendered the recitations of claims 1-4, 6-10, 13, 14 and 16-20 of the '103 Patent obvious at the time of invention. It is my opinion, however, that when these references are correctly viewed from the perspective of the POSITA it is clear that all of the challenged claims patentably distinguish over the proposed combination.

69. First, the proposed combination fails to consider the full teachings of the references, and CN456 in particular. When considered in full, the teachings of CN456 show its disclosed techniques cannot be combined with those of Ciais-Quadband. Specifically, the *shortened* PIFA antenna units in CN456 are so named because of the size constraints placed on the shortened PIFA antenna units by the reference, inclusive of the ground plane of each of those elements. The Ciais-Quadband PIFA, however, requires a ground plane whose length is more than three times the length of the radiating element to support its multiband operation. The proposed combination would require the POSITA to alter one of the disclosures in a way that is contrary to its teachings. Therefore, it would not have been obvious to the POSITA to utilize the Ciais-Quadband PIFA in the CN456 arrangement.

70. Second, the POSITA would not have had any expectation of successfully combining the teachings of the references. Specifically, the POSITA would not have expected to have been able to successfully implement the Ciais-Quadband antenna within the CN456 arrangement. CN456 is directed to an arrangement of single band *shortened* PIFA antenna units with a structure that decreases inter-element coupling. Ciais-Quadband is directed to multiband PIFAs which lack the unique structural aspects of the CN456 that decrease coupling. Accordingly, the POSITA would not have expected to be able to successfully arrange the Ciais-Quadband antennas as disclosed in CN456.

71. Third, all of the references in Ground 1 are directed, at least in part, to finding ways of decreasing the size of cellular handsets. *E.g.*, EX1015 at ¶ [0016]; EX1016 at 3; EX1014 at 1; EX1026 at 1. The proposed combination, however, would result in an antenna structure that would not fit within the example cellular devices disclosed in the art. Where the art is seeking smaller antennas and cellular devices, Ground 1 proposes a combination that is larger than any of the antennas or devices of Boireau, CN456 and Ciais-Quadband.

72. The Petition characterizes CN456 and Ciais-Quadband as being directed to antennas of “the same type.” This is not the case. CN456 is directed to

single band “**shortened** planar inverted-F antenna (PIFA) units **with respective ground planes**” with length and width constraints that are smaller than those indicated for the radiating planes, as illustrated in FIG. 3 of the reference. Specifically, CN456 limits the size of the radiating plane 2a-2 to lengths and widths that are less than 0.25 times an operating wavelength of the antenna (EX1016 at 1, 4, FIGs. 2(a)-(c), 3, 7(a)-(b)) and limits the ground plane 2a-1 to lengths and widths less than 0.2 times an operating wavelength of the antenna (*Id.* at 1, 4, FIGs. 2(a)-(c), 3, 7(a)-(b)). Further, CN456 discloses that the difference between the length of the radiating plane to the ground plane should be greater than 1/5 the length of the radiating plane, disclosing that “a value obtained by subtracting the length of the conductive ground plane from the length of the conductive radiating plane and then dividing the resulting difference by the length of the conductive radiating plane is greater than 0.2.” *Id.* at 2, 7.

73. These size constraints permit the shortened PIFA antenna units to be arranged in close proximity without substantial coupling between the antenna units. *See, e.g., Id.* at 5 (“the length of the ground plane in which strong current distribution occurs is approximately 0.15 times the wavelength. As a result, the antenna units can be arranged in close proximity to each other, particularly with a spacing within 0.5

times the wavelength, while still maintaining low mutual coupling and high radiation efficiency.”). This decreased size, facilitated by the small ground plane, is what purportedly distinguishes the CN456 arrangement from prior MIMO systems.

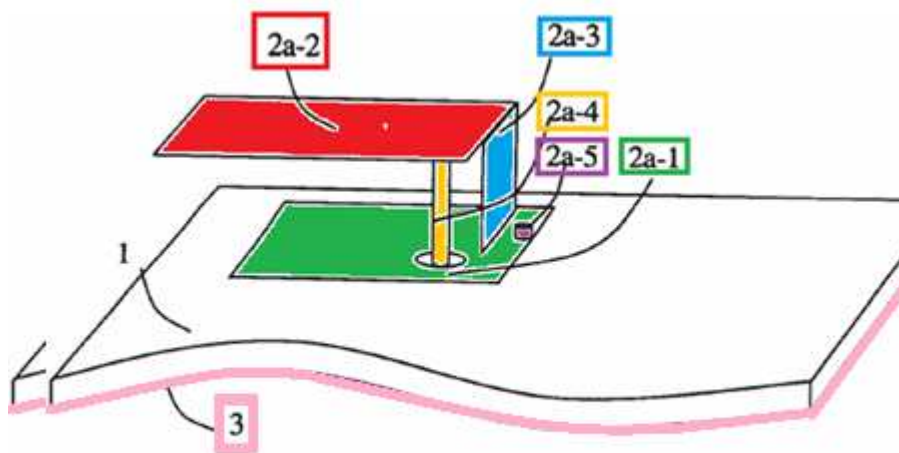
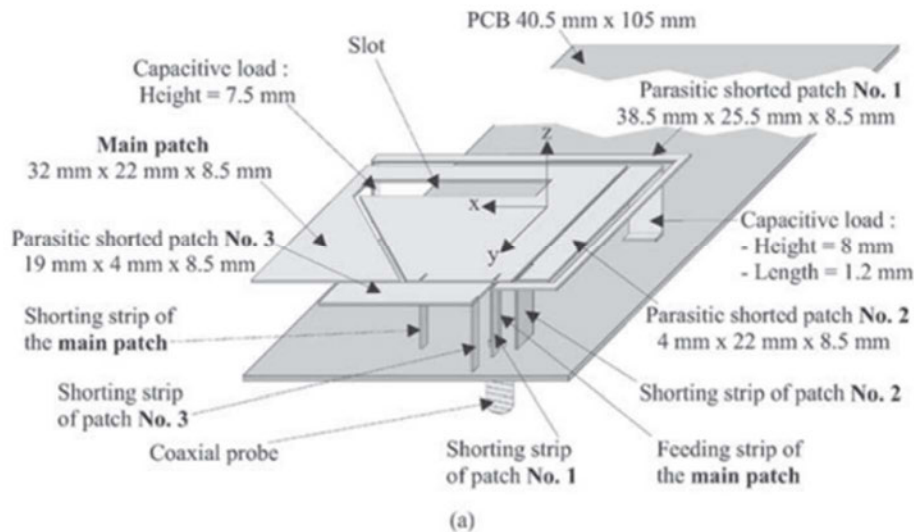


FIG. 3

74. Ciais-Quadband, on the other hand, is directed to a multiband PIFA that includes a ground plane whose length is more than three times the length of the conductive patch that incorporates a slot, three quarter-wavelength parasitic elements, and capacitive loads that create the multiband resonances at four different frequencies. EX1014 at 148.



75. In fact, the large size of the ground plane, and its **length** in particular, is specifically chosen to support the operating frequencies of the antenna:

The PCB size, especially its length, has a strong influence on the performances of mobile phone antennas. In our case, the chosen length is not the best choice for an optimum GSM bandwidth (around 130 mm [9]–[11]) or an optimum DCS bandwidth (around 70 mm [9]–[11]) but it will equally helps in these both bands for an efficient antenna-chassis combination. The dielectric between all patches and the PCB is air and the separation distance is 8.5 mm.

Id. at 148.

76. The Petition, however, ignores these structural and functional differences between the single band shortened PIFA antenna units of CN456 and the

multiband, large ground plane PIFA of Ciais-Quadband and asserts that “[a] POSA would have been motivated to use multiple Ciais-Quadband PIFAs arranged according to CN456’s teachings in the MFWD of Boireau to arrive at an antenna system comprising a ground plane layer and three antenna elements.” Petition at 52. This proposal, however, places the POSITA on the horns of a dilemma: (1) alter the size of the ground plane disclosed in Ciais-Quadband to match the size requirements of CN456, altering the antenna’s operating frequencies and characteristics in the process, or (2) completely disregard the size constraints of CN456 to use appropriately sized ground planes for the antennas, rendering the antennas incapable of being arranged in close proximity without coupling as disclosed in CN456. Neither option is acceptable, which illustrates that the proposed combination is non-obvious.

77. The specific examples of the antennas disclosed in each reference are illustrative. The example of FIGs. 7(a) and 7(b) of CN456 has a ground plane that is 21.6 mm long, substantially shorter than its 27.6 mm long radiating plane, as required by the size constraints. Ciais-Quadband, on the other hand, teaches that the length of the ground plane strongly influences performance of the antenna, and

therefore, provides a ground plane whose length is more than three times that of its radiating element. EX1014 at 148.

78. The Petition, however, makes no mention of the spacing or size requirements disclosed in CN456 for its shortened PIFA antenna units. The Petition makes no mention of the requirement in CN456 that “A spacing between any two adjacent planar inverted-F antenna units ... is within a range of 0.1 to 0.5 times an operating wavelength of the planar inverted-F antenna units,” the Petition makes no mention of the requirement that “a length and a width of the radiating plane are less than 0.25 times an operating wavelength of the antenna,” the Petition makes no mention of the requirement that “a value obtained by subtracting the length of the conductive ground plane from the length of the conductive radiating plane and then dividing the resulting difference by the length of the conductive radiating plane is greater than 0.2,” and the Petition makes no mention of the requirement that “a length and a width of the ground plane are less than or equal to 0.2 times a free-space propagation wavelength corresponding to an operating frequency of the planar inverted-F antenna.” Petition, throughout. The Petition makes no mention that Ciais-Quadband explicitly discloses that the length of the ground plane strongly influences performance of the antenna, and therefore, selected a ground plane whose length is

more than three times that of its radiating element. The Petition omits these disclosures because these structural, spacing and sizing requirements are all fatal to the proposed combination of references in Ground 1.

79. Highlighting the POSITA's dilemma is the Petition's assertion that "POSAs understood that mobile devices would have to operate in at least the cellular regions of 810–960 MHz, 1710–1990 MHz, and 1900–2170 MHz..." Petition at 39 (emphasis added). These bands correspond to the GSM, DCS, PCS and UTMS bands discussed in Ciais-Quadband. EX1014 at 148. Ciais-Quadband explains that its ground plane length was selected to support operation at these bands. *Id.* The Petition, however, asserts that the POSITA would combine the teachings of CN456, which discloses ground planes shorter than their corresponding radiating elements, with Ciais-Quadband, which specifies a ground plane whose length is more than three times the length of its radiating element, selected so that the antenna can operate at the frequencies at which the POSITA knows that a cellular phone has to operate. CN456 tells the POSITA that the ground planes need to be small to avoid coupling, while Ciais-Quadband tells the POSITA that the ground plane needs to be large to support the required frequencies, frequencies explicitly relied upon in the invalidity ground. These are incompatible teachings.

80. Even ignoring the dilemma placed on the POSITA by the respective size and spacing requirements of the references, it is my opinion that the POSITA would still not have expected to successfully implement the CN456 arrangement of antennas using the Ciais-Quadband antennas for one specific reason: decoupling techniques for single band antennas were not understood as applying to multiband antennas. It was well known in the art, and in the MIMO context in particular, that techniques that decoupled single band antennas would not result in successful operation when using multiband antennas. Consider, for example, the following discussion from a recent paper looking to address antenna-to-antenna coupling for 5G MIMO systems:

Although [decoupling techniques] are effective for decoupling within the single band, achieving multi-band decoupling is challenging. On the other hand, without adding any decoupling elements, filtering antenna elements for single-band operation have been shown to achieve low mutual coupling across two different frequency bands [25,26]. However, when applied to MIMO arrays operating in four bands, four antenna elements are required, which results in occupying more space. In [27], self-decoupling between dual-band patch antennas is realized using hybrid coupling

interfaces. Nonetheless, achieving decoupling across four bands poses considerable design difficulties.

So, how to simply and effectively suppress mutual coupling in a MIMO array operating in dual-band and quad-band remains a significant challenge.

EX12019 at 2 (emphasis added).

81. As indicated above, and as understood by the POSITA, decoupling techniques that are successful for single band operation are not expected to be successful for multiband operation. CN456 provides decoupling techniques for single band antennas. Ciais-Quadband, on the other hand, provides multiband operation in four different frequency bands. The POSITA would not have expected to be able to implement the CN456 single band decoupling techniques to successfully decouple the quadband antennas of Ciais-Quadband.

82. The electrical length of an antenna generally dictates the antenna's resonant frequencies. This is why much of the work in the field of antennas is directed to shrinking antennas while maintaining operation at the desired frequencies. This is the case with Boireau, CN456 and Ciais-Quadband.

83. Specifically, all of the references cited in Ground 1, as well as Ground 2, are directed to decreasing the size of antenna systems for cellular terminals:

Various embodiments may be generally directed to antenna sharing techniques for a wireless device, such as a mobile computing device. A mobile computing device may include multiple transceivers. In an effort to reduce a number of antennas needed for the multiple transceivers, a mobile computing device may use a shared antenna architecture where the transceivers share a single antenna or antenna array. In one embodiment, for example, a mobile computing device may include an antenna, a switch, and multiple transceivers. An 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. **Antenna sharing techniques may provide several advantages for a mobile computing device**, such as decreasing or reducing device power requirements, interference between antennas, **device size**, device shape, device complexity, device component count, and so forth. Antenna sharing techniques may also provide several new use scenarios, as described in more detail below. As a result, a user may realize enhanced products or services. ...

By sharing an antenna among multiple transceivers, mobile computing device 100 may realize reduced device power requirements, interference between antennas, **device size**, device shape, device complexity, device components, and so forth. The shared antenna architecture and corresponding antenna sharing techniques

implemented for mobile computing device 100 may be described in more detail with reference to FIGS. 2-5.

EX1015 at ¶¶ [0016], [0027] (emphases added).

On the other hand, mutual coupling between antenna units increases the correlation between transmitted and received information of the coupled antenna units, thereby undermining the fundamental implementation conditions of MIMO communication, namely that the transmitted and received information on data links associated with different antennas must have low correlation. **This also constitutes a problem in the application of existing MIMO antennas employing PIFA antenna units in small-sized wireless terminals.**

EX1016 at 3 (emphasis added).

With the rapid progress in new communication standards, miniature multiband internal antennas are needed for modern mobile handsets [1]–[3]. **Several techniques applied simultaneously are thus necessary to reduce the size of these antennas** while maintaining good multiband/wideband performance.

EX1014 at 1 (emphasis added).

In particular, the dual band 802.11a/b and HIPERLAN/2 antennas are **required toward a small size** and high gain while retaining the high efficiency. Internal PIFAs are very suitable in WLAN

applications since they are compact, low profile and easy to manufacture [3].

EX1026 at 1 (emphasis added).

84. The proposed combination of Ground 1, ignoring all size and space requirements from the references to provide a “best case scenario” regarding a size of the antenna system, results in an antenna system that would not fit in the handheld devices disclosed in Boireau.

85. Reproduced below is a scale mock-up of four Ciais-Quadband antennas placed substantially closer together than required in CN456 and lacking the ground plane disclosed in Ciais-Quadband. Specifically, the spacing between the Ciais-Quadband antennas is smaller than the “0.1 to 0.5 times an operating wavelength” spacing required in CN456. The Ciais-Quadband antennas are arranged next to a Palm Treo handheld device, an embodiment of the handheld devices disclosed in Boireau and relied upon in the Petition. EX1015 at ¶ [0019] (“Examples of smart phones include, for example, Palm® products such as Palm® Treo™ smart phones.”); Petition at 49 *citing* EX1015 at ¶ [0019]. As clearly illustrated, the four antenna elements would not fit within the handheld device.



86. It bears repeating – the mock-up provided above includes **only the Ciais-Quadband radiating elements**, it does not include the ground planes from either CN456 or Ciais-Quadband, it does not space the radiating elements as

disclosed in CN456, and it does not arrange the radiating elements on the short side of ground planes as disclosed in Ciais-Quadband. In other words, even ignoring the structural and operational requirements of both references relating to ground planes (something that would completely destroy the operation of the antennas), the **radiating elements of the proposed combination alone are prohibitively large.**

A POSITA looking to reduce the size of antenna systems and handheld devices would not implement the Ciais-Quadband antenna in a MIMO system that would end up being substantially larger than the handset itself.

87. These size considerations become significantly worse when implemented in conjunction with either the Ciais-Quadband ground plane, or the CN456 spacing requirements. As indicated in FIGs. 1(a) and 1(b) from Ciais-Quadband, its ground plane is more than triple the length of the radiating element. Incorporating the Ciais-Quadband ground plane into the MIMO system would result in a *substantially* larger arrangement.

88. Similarly, CN456 requires “A spacing between any two adjacent planar inverted-F antenna units is equal to a perpendicular distance between the respective ground planes thereof, and such distance is within a range of 0.1 to 0.5 times an operating wavelength of the planar inverted-F antenna units.” EX1016 at 4. The

lowest frequency of Ciais-Quadband's antenna is 870 MHz. EX1014 at 149. The wavelength λ corresponding to a frequency of 870 MHz is 344.8 mm (based on the relationship between frequency and wavelength provided by $\lambda = c/v$, where λ is the wavelength, v is the frequency, and c is the speed of light), and a tenth of this wavelength – the minimum spacing specified by CN456 – is 34 mm. Therefore, implementing CN456's spacing requirements would introduce *at least* an additional 34 mm of size to the MIMO structure illustrated above.

89. Implementing an antenna system in a handset that would require expanding the size of the handset would not have been obvious to the POSITA given all of the cited references were seeking to decrease the size of antenna systems and handsets.

VII. Ground 2

90. The Petition alleges in Ground 2 that dependent claims 5 and 11 would have been obvious over the combined teachings of Boireau, CN456, Ciais-Quadband, and Cho. It is my opinion that Cho does nothing to remedy the deficiencies of the combination of Boireau, CN456, Ciais-Quadband proposed in Ground 1 of the Petition, a POSITA would not have combined Boireau, CN456,

Ciais-Quadband, and Cho for substantially the same reasons explained in Section VI, *supra*.

I declare under penalty of perjury that the foregoing is true and correct.

Date: 7/22/2026

By: 
Hossein Hashemi, Ph.D.