UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

Intel Corporation
Petitioner

v.

Qualcomm Incorporated
Patent Owner

Case IPR2019-00128
Patent 9,154,356

DECLARATION OF DR. DANIEL FOTY

I declare that all statements made herein on my own knowledge are true and that all statements made on information and belief are believed to be true, and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

By: 

Daniel Foty, Ph.D.

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1. I am making this declaration at the request of Qualcomm Incorporated ("Qualcomm" or "Patent Owner") in the matter of the *Inter Partes* Review of U.S. Patent No. 9,154,356 ("the '356 Patent").

2. I am being compensated for my work in this matter at my standard hourly rate of $475 for consulting services. My compensation in no way depends on the outcome of this proceeding.

3. In preparing this Declaration, I considered all materials cited in the body of this Declaration, which includes but is not limited to the following:

a. The '356 Patent (Ex. 1301) and its file history;

b. Petition for *Inter Partes* Review of U.S. Patent No. 9,154,356, IPR2019-00128 (Paper 3) ("Petition") and materials cited therein;

c. The Declaration of Dr. Patrick Fay (Ex. 1302) and materials cited therein;

d. United States Patent Application Publication No. 2012/0056681 (Ex. 1335) ("Lee")

e. Feasibility Study for Further Advancements for E-UTRA (LTE-Advanced) (3GPP TR 36.912 version 9.1.0 Release 9) (Ex. 1304) ("Feasibility Study")

I. PROFESSIONAL BACKGROUND

4. I have thirty years of experience as an engineer, scientist, and consultant in the electronics industry, including in the areas of integrated circuit (IC) design, layout, structure, and operation, in RF technology for wireless communications, in technology development, and in technical and business development. I have

authored or co-authored four books and some sixty papers (published in refereed journals and refereed conference proceedings), mostly on various aspects of integrated circuit technology and RF/wireless technology. I have also given some eighty lectures and presentations (many of them invited) at various conferences and other similar fora, and have given a number of invited keynote talks on next-generation wireless technologies at a variety of conferences and events throughout the world. I have also served extensively as an expert witness is a wide variety of matters over the past 15+ years.

5. My qualifications to testify as an expert in the field of integrated circuit technology and RF/wireless technology, including my expertise in the structure and operation of RF transceivers and related structures, are described in my *curriculum vitae*, which is attached at Appendix A.

II. RELEVANT LEGAL STANDARDS

6. I have been asked to provide my opinion as to whether claims [insert claims] of the ’356 Patent are anticipated by the alleged prior art or would have been obvious to a person of ordinary skill in the art (“POSITA”) at the time of the alleged invention, in view of the alleged prior art.

7. I am an engineer and scientist by education and profession. The opinions I am expressing in this Declaration involve the application of my engineering knowledge and experience to the evaluation of certain alleged prior art

with respect to the ’356 Patent. Aside from my experience in litigation support, my knowledge of patent law is no different than that of any lay person. Therefore, I have requested that the attorneys from Jones Day, who represent Qualcomm, provide me with guidance as to the applicable patent law in this matter. The paragraphs below express my understanding of how I must apply current principles related to patentability.

8. It is my understanding that in determining whether a patent claim is anticipated or obvious in view of the alleged prior art, the Patent Office must construe the claim by giving the claim its broadest reasonable interpretation consistent with the specification – as it would have been understood by one of ordinary skill in the art as of the filing date of the patent. I understand that the claim language, specification, and prosecution history are relevant to determine the meaning of a claim term. I understand that the prosecution history of a patent provides the record of the examination of a patent application before the U.S. Patent and Trademark Office (PTO). The prosecution history provides evidence of how the patent examiner and the inventors understood the patent application and the claims, and can therefore be instructive on how to interpret the claims. My understanding is that extrinsic evidence may also be used in understanding the meaning of a claim term. Extrinsic evidence includes dictionaries, treatises, expert

testimony, and prior art. But it is my understanding that one should first look to the intrinsic evidence in construing claims.

9. My understanding is that there are at least two circumstances where the words in a patent claim may differ from and not be given their plain and ordinary meaning. One circumstance is when the applicants act as their own lexicographer by clearly setting forth a definition of a claim term that may differ from the plain and ordinary meaning it would otherwise possess. Another circumstance is when the applicant includes or provides an intentional disclaimer, or disavowal, of claim scope. My understanding is that an applicant may act as their own lexicographer, or disclaim or disavow claim scope, in either the specification or the prosecution history of the patent. My understanding is also that the applicant may act as a lexicographer, or disclaim or disavow claim scope, by making amendments to the claims during prosecution, or by making assertions to the PTO about the differences between the claimed inventions and the prior art.

10. It is my understanding that a claim is unpatentable under 35 U.S.C. § 102 if each and every element and limitation of the claim is found either expressly or inherently in a single prior art reference.

11. It is my understanding that a claim is unpatentable under 35 U.S.C. § 103 if the claimed subject matter as a whole would have been obvious to a person of ordinary skill in the art at the time of the alleged invention. I also

understand that an obviousness analysis takes into account the scope and content of the prior art, the differences between the claimed subject matter and the prior art, and the level of ordinary skill in the art at the time of the invention.

12. In determining the scope and content of the prior art, it is my understanding that a reference is considered appropriate prior art if it falls within the field of the inventor's endeavor. In addition, a reference is prior art if it is reasonably pertinent to the particular problem with which the inventor was involved. A reference is reasonably pertinent if it logically would have commended itself to an inventor's attention in considering his problem. If a reference relates to the same problem as the claimed invention, that supports use of the reference as prior art in an obviousness analysis.

13. To assess the differences between prior art and the claimed subject matter, it is my understanding that 35 U.S.C. § 103 requires that the claimed invention be considered as a whole. I also understand that a finding of obviousness requires more than merely demonstrating that each claim element was known in the prior art. Obviousness requires showing that a person of ordinary skill in the art would have been motivated to combine the teachings of the prior art to achieve the claimed invention and would have had a reasonable expectation of success in doing so.

14. It is my understanding that the Supreme Court has recognized several rationales for combining references or modifying a reference to show the obviousness of claimed subject matter. Some of these rationales include: combining prior art elements according to known methods to yield predictable results; simple substitution of one known element for another to obtain predictable results; a predictable use of prior art elements according to their established functions; applying a known technique to a known device (method or product) ready for improvement to yield predictable results; choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success; and some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed invention.

15. It is my further understanding that there are certain limits on combining references in an obviousness determination. One limit is that the combination of references cannot be based on impermissible hindsight. I understand that impermissible hindsight may occur if, for example, different components are selectively culled from the prior art to fit the parameters of the invention, without a teaching or suggestion within the prior art, or within the general knowledge of a person of ordinary skill in the field of the invention, to look to particular sources of information, to select particular elements, and to combine them in the way they were

combined by the inventor. Another limit on combining references is when a reference teaches away from a specific combination. I understand that a first prior art reference may teach away from a second reference if the first reference discourages a person of ordinary skill in the art from following the path set out in the second reference, or would be led in a direction divergent from the path taken by the applicant. Additionally, I understand that even if a reference is not found to teach away, its statements regarding preferences are still relevant to a finding regarding whether a person of ordinary skill in the art would be motivated to combine that reference with another reference.

III. SUMMARY OF CONCLUSIONS

16. It is my opinion that, at the time of filing of the ’356 Patent, a person of ordinary skill in the art would have understood the term “carrier aggregation” to mean “simultaneous operation on multiple carriers that are combined as a single virtual channel to provide higher bandwidth.” I disagree with Petitioner’s proposed construction.

17. It is my opinion that the Petitioner and its expert fail to show by clear and convincing evidence that any of the claims of the ’356 patent are unpatentable as being anticipated and/or obvious.

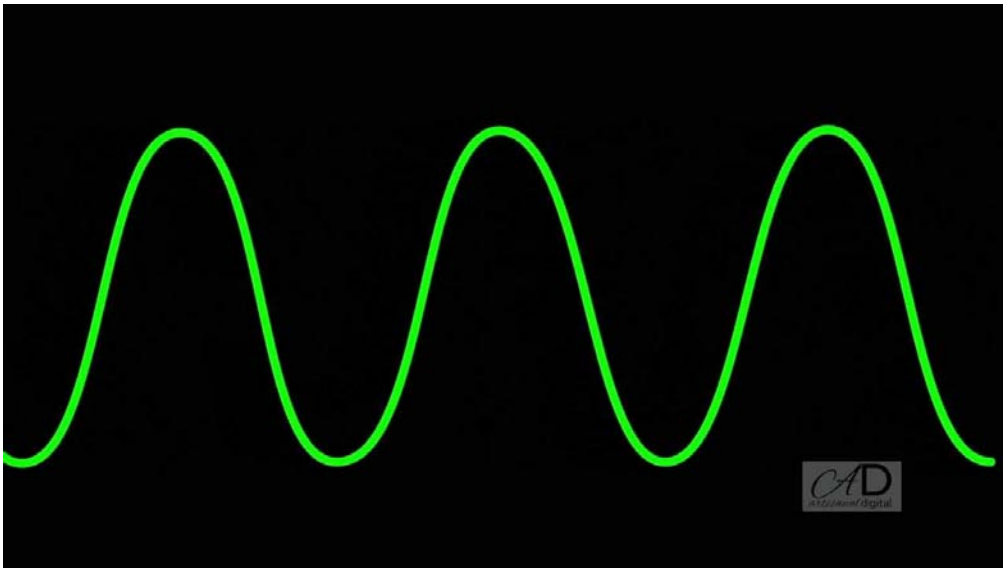
IV. TECHNOLOGY BACKGROUND

A. Overview of the Physics and Mathematics of Bandwidth

18. As will become obvious below (and is also obvious upon review of the material produced in this matter), the term "bandwidth" is central to both the technologies associated with the '356 patent and with other related art – in the generalized field of wireless communications.

19. It also quickly becomes obvious that the term "bandwidth" appears to carry two meanings in this field – on one hand referring to an actual range of spectrum space between a lower frequency limit and an upper frequency limit, while on the other hand referring generically to the rate at which data can be conveyed using some means of communication. However, this *de facto* synonymous use of the same term is neither accidental nor contrived – as the two versions of the term are actually intimately related by the underlying physics and mathematics associated with communications – particularly wireless communications or any other form of communication that is based upon the use of an oscillating, sinusoidal signal.

20. First, consider a simple, perfect sinusoidal signal.



Such a signal is described mathematically as

$$X(t) = A \cdot \sin(w \cdot t),$$

where X is the function at a particular point in time t, A is the amplitude of the signal (as sin(x) varies only between -1 and 1, this factor must be included to describe a real signal), and ω is the radial frequency of the signal. By inspection, it can be seen that this signal is continually repetitive – and it will repeat itself over a span of time known as the *period*, which can be written as t_p. The period is in units of time – and thus the sine wave repeats itself every t_p seconds. For clarity, it is the common practice to treat the sinusoidal signal not in terms of how long one period is – but rather in terms of how many repetitions occur in one second; this is the inverse of the period, and is known as the *frequency* (f);

$$f = \frac{1}{t_p}.$$

As just noted, the frequency is defined as the number of sinusoidal repetitions that occur per second – which was long referred to in radio engineering as "cycles per second"). In more recent decades – reflecting a practice that is common in physics and engineering – this unit of "cycles per second" was given the name "Hertz" (abbreviated in usage as "Hz") – in honor of the early (late 19th century) German radio pioneer Heinrich Hertz. Further, because (when using a scale of radians), one cycle of a sine wave takes a "time" (mathematically) of 2π, the relationship between the actual frequency f and the mathematical expression necessary for use in the equation above (which requires the use of the radial frequency ω) is:

$$\omega = 2\pi f.$$

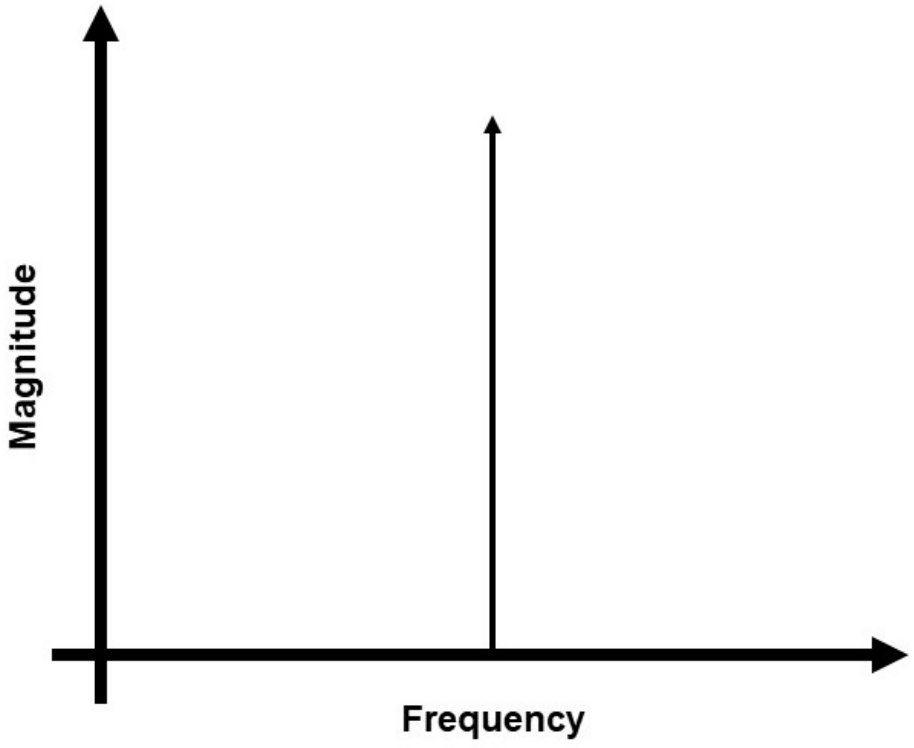
Fortunately, from here, only the frequency f will be used – in terms of signal repetition in some given number of Hz.

21. As noted above, an oscillating, sinusoidal signal will be defined by its particular magnitude (A) and its frequency (f). To describe the nature of both sinusoidal signals and their ability to convey information, only discussion of the frequency f will be necessary.

22. An example of a sinusoidal wave is the auditory (sound) frequency of 440 Hz; this sound frequency is known as "A-440." This particular sound frequency is near the center of a typical piano keyboard – and is of critical importance in the tuning of both pianos and symphony orchestras. This 440 Hz signal simply means

that a vibration is moving through the air – from the source to the end user – at a vibrational frequency of 440 Hz.

23. In time, as described above, this 440 Hz signal is a sine wave. However, one can also look at the signal not in time – but instead with respect to the frequency (or range of frequencies) that the signal occupies. A range of frequencies is usually defined as representing a *spectrum* over which (and within which) a frequency (or multiple frequencies) may be found. In this particular case, the frequency spectrum associated with a clean, pure 440 Hz tone is rather non-descript:



Not surprisingly, the frequency spectrum of a single, pure sinusoidal signal is a single "spike" in the frequency spectrum description – at that single frequency.

24. However, there are some mathematical implications that will become important momentarily. For the frequency spectrum of the signal to be a "spike" (i.e., for the frequency spectrum representation to be infinitely narrow), the sinusoidal signal must continue infinitely in time.

25. In the case of an infinite-in-time sinusoidal 440 Hz auditory signal, that "signal" will convey a continuous note of "A" to the end-user (the listener) – and nothing more; other than its presence, no other information is being conveyed (or even *can* be conveyed). An obvious consequence of this situation is that if such a sinusoidal signal is to convey actual information, it *cannot be infinitely-unchanging with time*. The basic sinusoidal signal will have to be changed in time to convey information.

26. For a simple example of the conveying of information (such as an on/off signaling that will convey the binary 0's and 1's of digital logic/information), consider again the 440 Hz tone. In order for an end-listener to perceive that tone as having a frequency of 440 Hz, that signal must persist for the duration of at least one cycle; as the time of the cycle is the inverse of the frequency (440 Hz), that time is 2.3 milliseconds (ms). Thus, a 440 Hz auditory signal must persist for at least 2.3 ms (at minimum) for the listener to be able to detect it as being a 440 Hz signal. If information is to be conveyed by turning the signal on and off, this represents a form of communication using pulses – and it is necessary that there be enough separation

between the pulses for the separate bits of information to be discernible (in the stream) from each other. If "on" represents "1," then a period of time between the pulses equal to the length of the pulses must be provided – in order to keep the individual pulses separate. Further, if "off" represents "0," then "off pulses" of no signal must still be provided with gaps of the same length between them – in order to be able to keep the 1 and 0 pulses separately-detectable.

27. As a result, the conveyance of a single bit of information requires a time that is twice the period of the underlying sinusoidal signal (in this case, 440 Hz). Thus, to use a 440 Hz tone to convey information, a time of 4.6 ms is required to convey one bit. The inverse of 4.6 ms is (not surprisingly) 220; thus, it can be said that the maximum simple-case theoretical bit rate of the 440 Hz tone is 220 bits per second (bps).

28. It is also obvious that, under this simple description of data rate, the data rate will increase in simple linear proportion to the frequency of the transmitting signal. If this were in fact the precise situation, wireless communication would be a rather simple matter; the achievable data rate would be proportional to the sinusoidal signal frequency, and the ability to pack together single-frequency channels (of the type depicted in the "spike" spectrum above) would only be limited by the ability to differentiate between two very-nearby (in frequency) carriers.

29. However, this is not what happens. As just described, in order to use a sinusoidal signal to convey information, that signal must be altered from that form (with respect to time). If the signal is no longer infinitely-long in time, then *it cannot be infinitely narrow in its frequency spectrum*[1] – as in the depiction shown earlier for the ideal case of a perfect sinusoid which continues infinitely in time. The immediate implication of this statement is that *in order to convey information, more than one frequency must be used*. That is, to convey information, at least some range of frequencies around the central carrier frequency must be used; it is the span of this range of frequencies that defines the *bandwidth* of a channel.

30. Thus, there is an obvious relationship of some sort between the bandwidth of a channel and the ability of that channel to convey data – in particular, it is obvious to ask what data rate can be supported by any particular channel based upon a particular carrier frequency.

31. This relationship is elucidated via what is known as the *bandwidth theorem* (which is also sometimes referred to as the *Fourier limit*).[2] The bandwidth theorem states that:

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[1] This is actually one of several notable contributions made by the late-17th and early-18th century French physicist and mathematician Joseph Fourier – who demonstrated this basic physics and mathematics nearly a century before any serious work on radio communications (such as that done by Hertz) had begun.

[2] Two useful references on this topic can be found at https://farside.ph.utexas.edu/teaching/315/Waves/node59.html and

$$\Delta f \cdot \Delta t \cong 1 ,$$

where *Δf* is the bandwidth and *Δt* is the duration of the pulses that are conveying the information.

32. The implications of the bandwidth theorem become obvious upon simple inspection. First, note that the duration of the pulses (*Δt*) is roughly the inverse of the data rate – that is, a smaller *Δt* corresponds to a higher data rate and a larger *Δt* corresponds to a lower data rate. Thus, according to the bandwidth theorem, *a higher data rate requires a correspondingly-larger bandwidth*. This is the reason for the equivalence (in both word and deed) of "bandwidth" and "data rate" – as the two terms really are two sides of the same coin. As there are two variables, the application of this finding can be interpreted in two ways – for a given desired data rate, a particular minimum bandwidth is required; while conversely, for a given bandwidth, only a particular maximum data rate is achievable.

33. A second implication of the bandwidth theorem is that *it is the bandwidth rather than the carrier frequency that determines the data-conveying ability of a particular signal*. In contrast to the blissfully-simple (and, in fact, overidealized) case first considered, the carrier frequency in use is fundamentally-

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https://physics.stackexchange.com/questions/128882/why-is-bandwidth-range-of-frequencies-important-when-sending-wave-signals-suc .

irrelevant to the data rate – it is instead the bandwidth of the channel that determines the data rate at any particular frequency.

34. Of course, it is not possible to have a bandwidth that is larger than the carrier frequency – which is the prime reason that, *in practice*, higher carrier frequencies allow for higher-bandwidth channels. For example, it can be shown relatively easily that the bandwidth necessary to transmit simple black-and-white television pictures is about 10 MHz; thus, the introduction of broadcast television required radio communications equipment that could operate at frequencies in the tens of MHz – and indeed, the lower band of television channels introduced c. 1945 used a spectrum range of 54 MHz to 88 MHz.

35. In addition, when slices of spectrum are allocated, they tend to be allocated in some range (bottom frequency to top frequency) that has some proportion to the frequencies in question; spectrum allocations at higher frequencies tend to be larger in absolute terms than spectrum allocations at lower frequencies. Thus, if the same number of channels are allocated within two different allocations of spectrum, the channels at the higher frequencies will have larger bandwidths than will the channels at the lower frequencies. However, note that there is also another fundamental trade-off in channel allocation – no matter the frequency involved, if a spectrum allocation tries to slice that spectrum up into more channels, each channel

will have a reduced bandwidth available to it; conversely, if high-bandwidth-channels are desired, then fewer channels can be designated within that allocation.

36. Further, these allocations are not arbitrarily set and cannot be altered at will (either in a static form, or "on the fly" as the network is used). Both the spectrum allocations and the actual channel details (number, frequency, bandwidth, transmission power) are set by regulatory bodies – such as (in the United States) the Federal Communications Commission (FCC). Operators of wireless communication networks must adhere closely to these standards, and all equipment and operations must conform to these rules as well. Obviously, making the best and most-efficient use of both spectrum allocations and particular channels is a critical aspect of wireless communications.

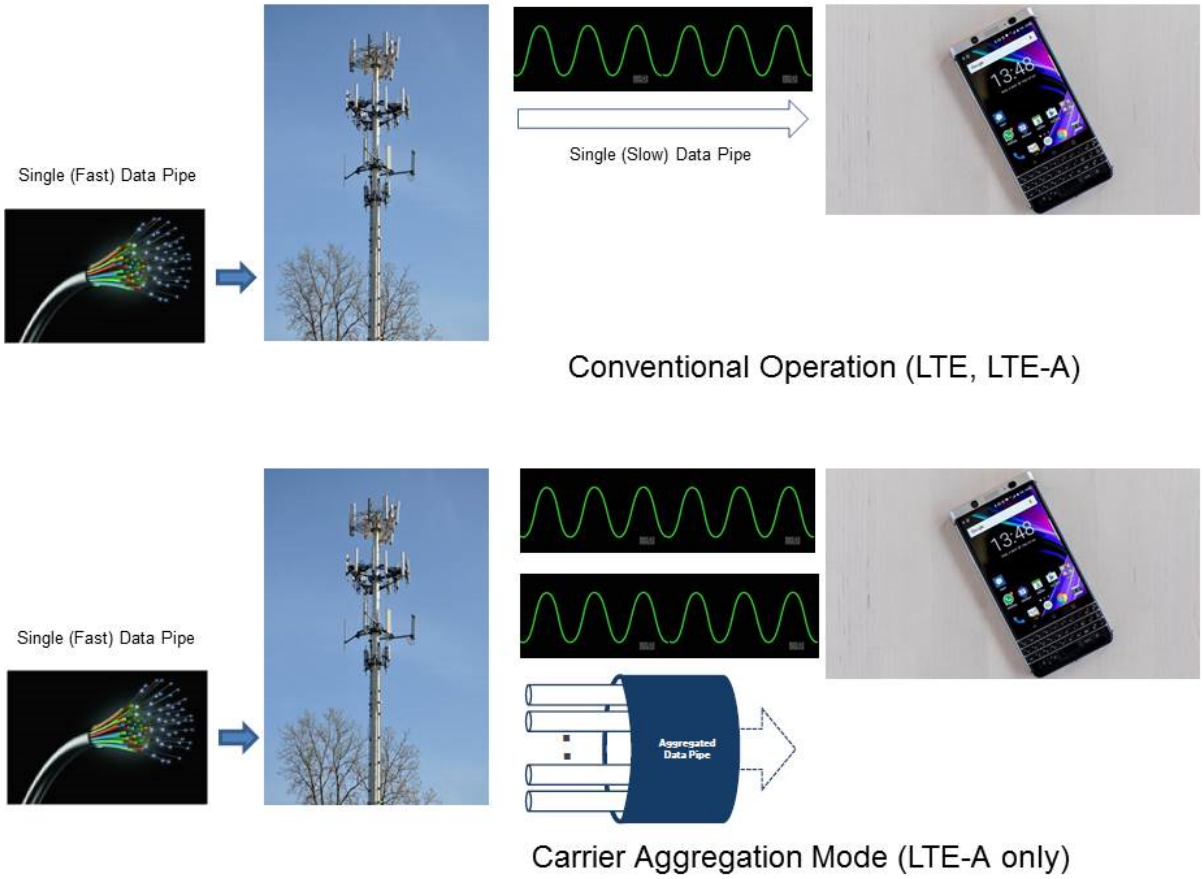
37. This section was not intended to provide an exhaustive description of wireless data communications; but hopefully it has served to clarify the key details surrounding the terms "bandwidth" and "data rate."

B. Overview of Wireless Network Architecture and Carrier Aggregation

38. When wireless communications networks came to be used for the transmission of data, several challenges immediately appeared. First, the backhaul

capacity (such as fiber optic cable[3]) that delivers content to the transmission facility is much faster (i.e., it has a much higher data throughput rate) than is an over-the-air wireless communications channel. And second, wireless spectrum is a carefully-allocated (by regulation) and scarce resource; while it is relatively easy to add more backhaul capacity (i.e., more fiber), it is difficult (both in terms of regulation and in terms of physics) to add more wireless data capacity-and-speed to the wireless part of the network.

[3] This is the method for the delivery of data to base stations that is most-commonly used in North America; the tower operating companies (such as American Tower, Crown-Castle, and SBC Communications) own and operate large fiber-optic networks for this purpose. In other parts of the world, microwave links are frequently used for the same purpose. However, taken together, the situation is the same – the rate at which a data stream can be sent to a base station (or similar) is much larger than is the data rate that is accessible (for transmission to a receiving device) using a single-frequency over-the-air transmission. This is similar to the situation with in-home networks that use WiFi to transmit to user devices from a WiFi router that is connected to a wired network of some sort, where the wired network provides the connection to the outside world; the data rate attainable using the wired line into the house (be it fiber, cable, or even DSL) is typically much larger than is the data rate attainable with a WiFi connection to the router; the WiFi connection is the data-rate-limiting-step in the connection between the original source of the data and the end-user-device.



39. Referring to the figure above, in conventional operation (as available under the LTE standard), a user device connects to the wireless network over a single carrier frequency. The end user performs tasks using that single carrier; this can include, for example, 1) no particular tasks going on, but the carrier frequency is active in keeping the user connected to the network; 2) one task in progress as the end-user device; 3) two-or more tasks going on simultaneously at the end-user device. As the maximum-available data rate of the single-carrier connection is the rate-limiting step for the end user of the network, if the user makes a request for a large amount of data, that data can only be transferred to the user at the data rate of

that single carrier; if the user requests a large amount of data (or makes a request for an application that requires a very high data rate), the data will be transferred at a rate that is slow for the end-user; in the former situation the end-user will have a long wait for the completion of the delivery of the data, while in the latter situation (of "streaming" data), the data stream will require buffering as well as waiting.

40. It was to relieve this rate-limiting step that carrier aggregation[4] was introduced as part of the LTE-A standard. All of the operations described in the prior paragraph are available in LTE-A – as LTE-A is backward-compatible with LTE. However, LTE-A added the ability for networks to be able to practice carrier aggregation. As the above figure also shows, in an appropriately-equipped LTE-A network and with a suitable end-user device, when an end-user makes a request for a large amount of data (or a situation requiring a high data rate), the network will activate carrier aggregation as a form of "burst mode" to deliver the data more quickly to the end-user. This is done by multiplexing the incoming data stream so that the single data stream (brought to the transmission facility at very high speed

[4] Here, I am providing a general explanation of "carrier aggregation." I realize that "carrier aggregation" is also a presently-disputed term. This description is not meant to address issues of claim construction for purposes of my analysis below, but rather to provide general background regarding carrier aggregation – and related technical concepts in the industry. The characteristics of LTE networks as described here may be found in, for example, the Feasibility Study, while the detailed aspects of carrier aggregation can be found, for example, in the numerous citations provided below in the discussion of Claim Construction.

over the backhaul network) is split up into two separate data streams; these two, multiplexed data streams are then transmitted over two carriers at the same time so that, effectively, the original single data stream is able to reach the end-user device twice as fast as it would have via the use of a single carrier; the two data streams are then demultiplexed (i.e., aggregated) at the end-user device, recreating the single data stream that had been sent over the backhaul network (as described above).

41. When the "burst" (i.e., temporarily-enabled high-data-rate) mode is no longer needed (because the requested data has been delivered to the end user, the need for a large data transfer has been discontinued, etc.), the network will turn off the carrier aggregation operating mode and return to single-carrier operation mode; among other things, this frees up the extra carrier that had been activated for carrier aggregation mode for this particular end-user so that this scarce resource (spectrum) can be freed up for other users of the network.

V. THE '356 PATENT

A. Overview of the '356 Patent

42. United States Patent No. 9,154,356 ("the '356 patent"), "Low Noise Amplifiers for Carrier Aggregation," was issued on October 6, 2015 to Alexsandar Miodrag Tasic and Anosh Bomi Davierwalla. The assignee of this patent is Qualcomm Inc., and the filing date was August 21, 2012. Ex. 1301.

43. The ’356 patent teaches both apparatuses and methods for the reception of signals in a receiving device.

44. When an over-the-air signal is transmitted by a transmitting antenna, there is some level of power (in watts) provided for the signal as it leaves the transmitting antenna. In most situations, that signal propagates outward in an isotropic fashion – that is, the signal propagates uniformly in all directions, without preference of focusing in any particular direction.[5] As such, as an isotropic signal propagates, it spreads out in space and thus the strength of the signal (at a given point at a given distance from the transmitter) decreases the further that signal propagates from the transmitter.

45. These decreasing signal strengths are dictated by the basic physics of the propagation of electromagnetic radiation in free space. In the terrestrial environment, the signal strength can be (and usually is) degraded by interactions with that terrestrial environment – both natural (*e.g.*, precipitation, leafy vegetation, etc.) and man-made (*e.g.*, buildings and building materials, metal objects such as motor vehicles, etc.).

[5] There are a variety of modifications to isotropic transmission that exist and which are frequently under consideration; however, at this time, these sorts of “beam-focusing” technologies are used in specific situations and are not very common. The description being provided at this point is for reference and is not specific to the teachings of the ’356 patent; these teachings apply regardless of the particular nature of the transmissions in use.

46. Thus, a key requirement for any radio-based transmission-and-reception system is technology at the receiver that will be able to detect weakened incoming signals – and then to successfully extract the information these signals are carrying from the transmitter to the receiver.

47. Beyond the specific received signal strength, the main impediment to the successful reception and processing of a weakened incoming signal is noise. "Noise" generally refers to the (constant in magnitude) background electromagnetic radiation present – and to fluctuations in that background; in addition, during operation the receiving electronics will also create noise by being in use. Thus, for successful signal reception, the incoming signal must be strong enough (or must be made to be strong enough) to be detectable over any noise which is present.[6]

48. Thus, in a receiver, a critical priority is the amplification of a received signal, so that there will be sufficient signal strength to allow the downstream electronics in the receive chain[7] to properly process the incoming signal and to extract the desired incoming information.

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[6] A common analogy that is used to explain this situation is to consider a gathering where numerous people are engaged simultaneously in numerous conversations; this constitutes an environment that is "noisy" in an auditory sense. For any specific conversation, the two individuals involved must speak loudly enough to hear each other over the background noise.

[7] The term "receive chain" is common in the industry and refers to the sequence of electronics (and concomitant events) that receive the signal, amplify and filter that signal as necessary, demodulate the signal (to extract the information that

49. The type of amplifier that is used to perform this initial amplification is known as a "low-noise amplifier" (LNA). An amplifier must meet very strict requirements to be a low-noise amplifier. As described above, it is critical that the first amplification not only be able to amplify the incoming signal; that amplification must also be able to extract the signal and separate it from any noise which might be present. Obviously, the amplifier itself must operate at a very low level of intrinsic noise, since otherwise the incoming signal could not be extracted (and amplified). Further, the immediate amplification of the signal is critically-important, as the further downstream circuitry (such as the mixers commonly used for demodulation) tend to be noisy; thus, the incoming signal must be amplified so that a weak signal is not "lost" in the noise of mixer-based demodulation.

50. The teachings of the '356 patent are centered on this need to provide appropriate low-noise amplification of incoming radio signals. However, this focus goes beyond the simple reception of a single incoming signal; the '356 patent specifically teaches apparatuses and methods for use with carrier aggregation.

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has been encoded onto the radio frequency carrier signal), and provide the extracted information to further baseband-processing circuitry. "Filtration" generally refers to the removing of received signals (both transmitted and environmental) that fall outside of a desired frequency range. Filtration can thus remove frequencies that are not desired at the receiver, as well as any noise outside of that frequency range. Both amplification and filtration are done early in the receive chain; these functions can also be repeated further along the receive chain.

51. As described earlier, carrier aggregation is a method used in wireless communications; it is a method for increasing the data rate of a single data stream via what is effectively a form of parallel processing. In wireless communications, a data stream is generally first sent to the transmitting facility (such as a cell tower base station) using a "wired" form of communication – such as via a fiber optic cable. Rather than encoding, transmitting, receiving, and decoding a transmission that is occurring using a single carrier and a single carrier frequency, the information to be transmitted is broken up (at the transmitter) into separate pieces; each piece of the information is encoded onto a separate frequency, those separate frequencies are transmitted independently, received simultaneously at the receiving device, and then the information that has been separated into multiple simultaneous transmissions is reconstituted at the receiver into the single data stream that was sent to the transmitting apparatus via the backhaul network. By using two or more transmissions in parallel, the overall effective data rate (the *aggregated* data rate for the single data stream) is increased; each transmission on each component carrier is a portion of the overall data stream, and the reception of all components is required if the original single data stream is to be constituted (i.e., aggregated)[8]

[8] An analogy can be drawn from the surface-shipping of a small aircraft. This is (and can only be) accomplished by removing the wings of the aircraft and shipping the fuselage and the wings separately. In order to have an aircraft at the other end of the shipping, both the fuselage and the wings must arrive and be reassembled; of

52. The use of multiple carrier frequencies (for the implementation of carrier aggregation) introduces a need for multiple parallel receive chains – to receive the two (or more) parallel signals and to process them (i.e., amplification, down conversion, baseband processing, etc.), so that the two signals can be aggregated and the original single data stream recovered.

53. As detailed earlier (in Section IV.B), carrier aggregation is a type of "burst mode" – in which (with a suitably-equipped network and a suitably-capable mobile device), when an end-user makes a request that would benefit from a higher-data-rate connection for a single data stream, a second (or more) component carrier is activated to provide the single wider virtual data pipe. The '356 patent depicts the non-carrier-aggregation situation in Figure 6C:

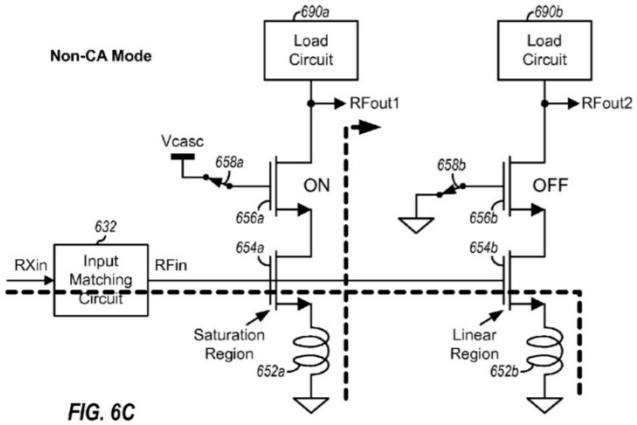


FIG. 6C

particular note, if either the fuselage or the wings arrive while the other does not, then the aircraft cannot be reassembled from the (incomplete) components.

As the specification describes the situation, "FIG. 6C shows operation of CA LNA 640*a* in the non-CA mode. In the non-CA mode, only one amplifier stage is enabled, and the other amplifier stage is disabled." (Ex. 1301 at 8:45-47) The carrier aggregation situation is depicted in Figure 6B:

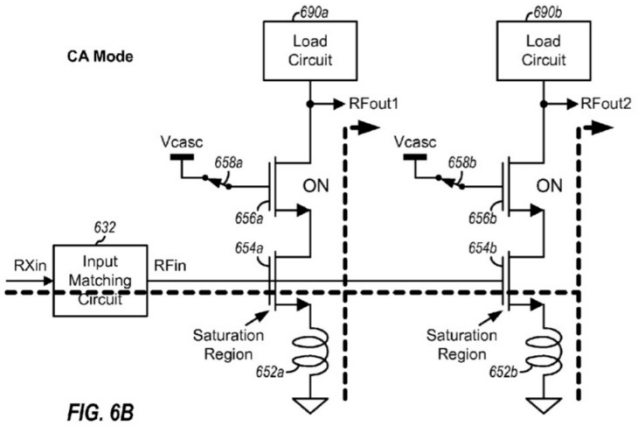
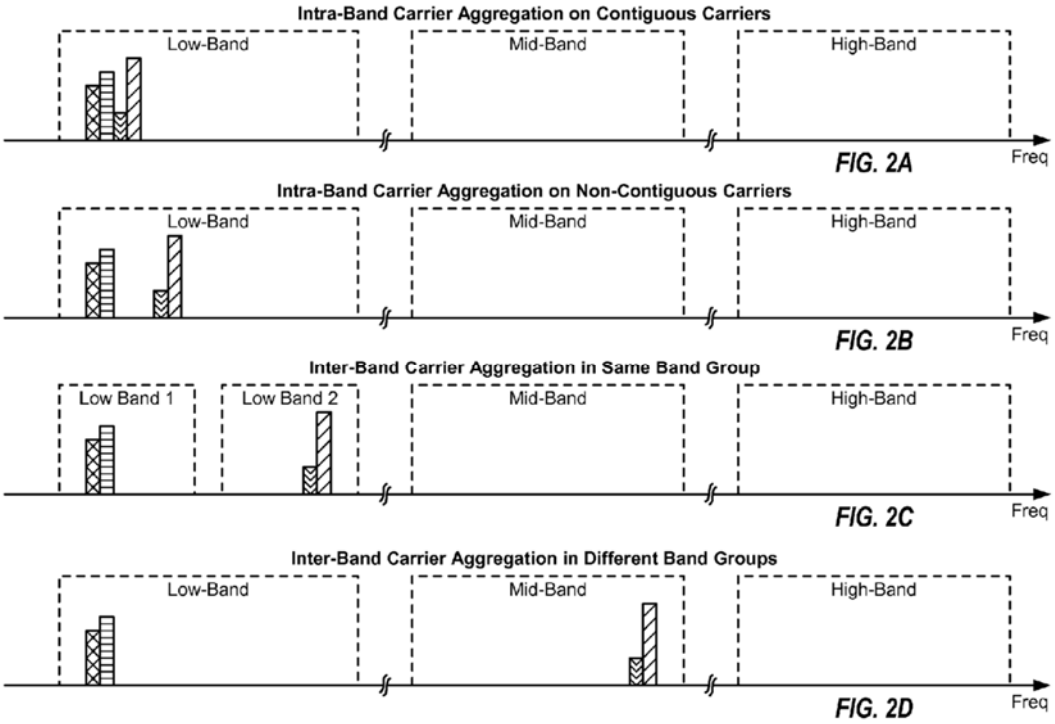


FIG. 6B

As the specification describes this situation, "FIG. 6B shows the operation of CA LNA 640*a* in the CA mode. In the CA mode, both amplifier stages 650*a* and 650*b* are enabled…" (Ex. 1301 at 8:36-38) These descriptions are consistent with the earlier description of carrier aggregation (Section IV.B) – in which there is a regular mode (Figure 6C, with one amplifier stage enabled so as to receive a single carrier) and a carrier-aggregation mode (Figure 6B, where a second amplifier stage is enabled to allow for the reception of a two-component-carrier carrier aggregation signal).

54. The teachings of the '356 patent also address the variety of possible implementations of carrier aggregation - that is, the two-or-more carrier frequencies

that may be used need not be close to each other in frequency. As the '356 patent notes, there is no reason that frequencies used in a carrier aggregation scheme cannot be different and far apart from each other. Ex. 1301 at Fig. 2A-D, 3:6-38.



As described in Figure 2 of the '356 patent, the two or more carriers may be taken from across multiple regions of the frequency spectrum, including so-called low-band (LB), mid-band (MB), and high-band (HB) (where the adjectives "low," "mid," and "high" refer to relative carrier frequency values with respect to each other). *Id*. When, for example, two carriers are used for carrier aggregation, the two carriers can be in the same band (LB, MB, or HB) and next to each other ("contiguous intraband carrier aggregation"), in the same band and not next to each other ("non-

contiguous intraband carrier aggregation"), or in two different bands ("interband carrier aggregation").

55. As long as the receiving apparatus is able to receive all of the incoming carrier aggregation signal components on different carrier frequencies (and then of course be able to demodulate the signals and recombine (i.e., aggregate) the information), carrier aggregation can function properly using a wide range of different individual carrier frequencies. However, the use of widely-differing frequencies requires the design of multiple receive chains in the receiver.

56. In particular, the carriers used for carrier aggregation must (for the reasons detailed above) be routed to low-noise amplifiers (LNAs). Each LNA will amplify a range of carrier frequencies (such as low-band, mid-band, or high band) – which may include one or more carriers. Each of these LNAs requires a supply of power when it is amplifying an incoming signal; this, of course, includes the situations of one carrier or of more-than-one carrier.

57. The power characteristics of analog/RF circuits (such as LNAs) can lead to problems of power consumption. The great success of silicon complementary metal-oxide-semiconductor (CMOS) technology has in large part been due to a technologically-unique feature of CMOS when it is used in the

"digital"[9] realm: When digital logic circuits based on CMOS are quiescent (i.e., holding their digital logic states constant, rather than being involved in switching from one logic state to another), they effectively consume no power. However, the sorts of circuits used to process radio-based sinusoidal signals (and other "non-digital" signals), are not able to operate in such a manner. These types of circuits must be biased so that current is actively flowing; thus, these sorts of circuits must be consuming power when they are placed (as is required) into a state suitable for the processing of an incoming sinusoidal radio signal. Thus, for the circuit to be active and ready to process an incoming signal, it must be biased and consuming power – *even if no incoming signal is being received and processed*.

58. If the host system is connected to main power via the electrical grid, this passive power consumption will not necessarily be problematic, so long as the passive power consumption is not generating excessive heat (and/or is not so large that the cost of maintaining it becomes an issue).

59. However, portable and mobile technologies do not have the luxury of simply ignoring such passive power consumption – because their power is supplied not by direct connection to the electrical grid, but by an onboard battery (or batteries). This situation is obviously of concern on the most basic grounds. But in

[9] For general purposes, "digital" refers to the processing of binary 0s and 1s – as opposed to the sinusoidal electromagnetic-radiation-based signals used in wireless communications.

recent years, portable and mobile technologies have advanced by leaps and bounds – providing users with an astonishing number of high-quality capabilities.

60. Much of this astonishing level of capability is a consequence of "Moore's Law" – the ability of silicon-based integrated circuit (IC) technology to improve at an exponential rate over a number of decades. In portable and mobile devices, Moore's Law has had a direct impact via the development of IC components that allow these many features to be implemented in a small, mobile device at a low cost and an indirect impact via a similar improvement in the size, definition, and brightness of the display screens that can be placed in mobile devices.

61. However, all of these improvements have caused the Achilles' heel of the portable and mobile devices to be painfully exposed: namely, battery technology. Battery technology is still based on the basic "Voltaic pile" that was invented by Alessandro Volta in *1800*. In contrast to the exponential improvements associated with Moore's Law, battery technology has been able to advance (at best) in only small increments over time. Moore's Law applies only to silicon integrated-circuit technology; there is no Moore's Law for batteries.

62. This divergence between the wonders of Moore's Law and the unpleasant realities of the humble battery has provided very strong motivation for the development of power-saving techniques in portable and mobile devices. The '356 patent addresses this general problem in the specific situation of using multiple

LNAs for the purpose of implementing certain modes of carrier aggregation, by teaching apparatuses and methods for reducing the power consumption associated with LNAs that are not needed at particular times for the reception and amplification of incoming signals. More specifically, the '356 patent teaches apparatuses and methods via which LNAs are enabled (for use in certain modes of carrier aggregation) or disabled (when not in use, so that they consume virtually no power). If a single carrier is being received on a single frequency band, the appropriate LNA will be enabled and will receive the signal, while the other LNAs are disabled and thus effectively consume no power. When certain modes of carrier aggregation are activated, multiple LNAs (as appropriate) are enabled and participate in the multi-frequency reception of the signals associated with carrier aggregation.

B. Prosecution History of the '356 Patent

63. I have reviewed the prosecution history of the '356 Patent. Following is a brief summary of key events.

64. The '356 Patent issued from U.S. Patent Application No. 13/590,423 (the "'423 Application"), filed August 21, 2012, and claims priority to U.S. Provisional Application No. 61/652,064, filed May 25, 2012. Ex. 1301. This '423 Application underwent a lengthy and comprehensive examination, spanning five rejections and advisory actions, two requests for continued examination, and hundreds of cited references, including multiple 3rd Generation Partnership Project

("3GPP") standards/articles and an International Search Report ("ISR") and Written Opinion.

65. The initial form of Claim 1 read as:

> 1. An apparatus comprising:
>
> a first amplifier stage configured to receive and amplify an input radio frequency (RF) signal and provide a first output RF signal to a first load circuit when the first amplifier stage is enabled, the input RF signal comprising transmissions sent on multiple carriers at different frequencies to a wireless device; and
> a second amplifier stage configured to receive and amplify the input RF signal and provide a second output RF signal to a second load circuit when the second amplifier stage is enabled.

Ex. 1311 at 30.

66. The first office action was issued on November 14, 2013, and rejected independent claims 1 and 17, among other claims, as obvious over U.S. Patent No. 7,751,513 ("Eisenhut"). Ex. 1312 at 2-5 – on the following grounds:

Regarding claim 1, Eisenhut et al. discloses an apparatus (see FIG. 1) comprising:

a first amplifier stage configured to receive and amplify an input radio frequency (RF) signal and provide a first output RF signal to a first load circuit when the first amplifier stage is enabled (signal path 6 including an amplifier and an analog/digital conversion; column 5 lines 27-35. Eisenhut et al. further discloses the two signal paths 6 and 7 can be individually activated or disconnected by a corresponding activation signal at their associated inputs 62 and 72. The signal paths 6 and 7 can thus both be active, both be disconnected, or one of them be active and the other be disconnected; column 5 lines 20-23);

and a second amplifier stage configured to receive and amplify the input RF signal and provide a second output RF signal to a second load circuit when the second amplifier stage is enabled (signal path 7 including an amplifier and an analog/digital conversion; column 5 lines 27-35. Eisenhut et al. further discloses the two signal paths 6 and 7 can be individually activated or disconnected by a corresponding activation signal at their associated inputs 62 and 72. The signal paths 6 and 7 can thus both be active, both be disconnected, or one of them be active and the other be disconnected; column 5 lines 20-23).

Eisenhut et al. differs from the application claim in that Eisenhut et al. does not discloses the input RF signal comprising transmissions sent on multiple carriers at different frequencies to a wireless device as set forth in the application claim.

Because the application claim recites the signal input being an input RF signal, therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made that one recognizes Eisenhut et al. would apply to the input RF signal as claimed.

67. To overcome the rejection, the Applicant amended claim 1 as follows:

1. An apparatus comprising:

> a first amplifier stage configured to receive and amplify an input radio frequency (RF) signal and provide a first output RF signal to a first load circuit when the first amplifier stage is enabled, the input RF signal comprising transmissions sent on multiple carriers at different frequencies to a wireless device, the first output RF signal including at least a first carrier of the multiple carriers; and
> a second amplifier stage configured to receive and amplify the input RF signal and provide a second output RF signal to a second load circuit when the second amplifier stage is enabled, the second output RF signal including at least a second carrier of the multiple carriers different than the first carrier.

Ex. 1313 at 2. The Applicant made a similar amendment to claim 17. *Id*. at 6. The Applicant additionally included arguments that Eisenhut does not teach or suggest at least the elements added by this amendment. *Id*. at 7-9.

68. The Patent Office then issued a final office action on April 18, 2014, rejecting claims 1 and 17 (among others) as anticipated by U.S. Patent No. 7,317,894 ("Hirose"). Ex. 1314 at 2-5 on the following grounds:

Regarding claim 1, Hirose discloses an apparatus (FIG. 6 digital broadcast receiver) comprising:

a first amplifier stage configured to receive and amplify an input radio frequency (RF) signal and provide a first output RF signal to a first load circuit when the first amplifier stage is enabled (variable gain amplifier 15, corresponding to the claimed first amplifier stage, receiving input RF signal (e.g. satellite wave signal and ground wave signal) and providing an output to intermediate frequency demodulation stage (for ground wave), which corresponds to the claimed first load circuit (see column 5 lines 1-30 and FIG. 6) ;

the input RF signal comprising transmissions sent on multiple carriers at different frequencies to a wireless device, the first output RF signal including at least a first carrier of the multiple carriers (as recited above, the input RF signal comprising satellite wave signal and ground wave signal (column 5 lines 1-4) and the output to intermediate frequency demodulation stage for ground wave, corresponding to the claimed first carrier of the multiple carriers);

and a second amplifier stage configured to receive and amplify the input RF signal and provide a second output RF signal to a second load circuit when the second amplifier stage is enabled (variable gain amplifier 25, corresponding to the claimed second amplifier stage, receiving input RF signal (e.g. satellite wave signal and ground wave signal) and providing an output to intermediate frequency demodulation stage (for satellite wave), which corresponds to the claimed second load circuit (see column 5 lines 1-30 and FIG. 6), the second output RF signal including at least a second carrier of the multiple carriers different than the first carrier (as recited above, the input RF signal comprising satellite wave signal and ground wave signal (column 5 lines 1-4) and the output to intermediate frequency demodulation stage for satellite wave, corresponding to the claimed second carrier of the multiple carriers).

Note: the rejection is based on the assumption that both first and second amplifier stages are enabled.

69. In response, the Applicant amended claims 1 and 17 as follows

1. (Currently amended) An apparatus comprising:

a first amplifier stage configured to receive and amplify an input radio frequency (RF) signal and provide a first output RF signal to a first load circuit when the first amplifier stage is enabled, the input RF signal employing carrier aggregation comprising transmissions sent on multiple carriers at different frequencies to a wireless device, the first output RF signal including at least a first carrier of the multiple carriers; and

a second amplifier stage configured to receive and amplify the input RF signal and provide a second output RF signal to a second load circuit when the second amplifier stage is enabled, the second output RF signal including at least a second carrier of the multiple carriers different than the first carrier.

17. (Currently amended) A method comprising:

amplifying a first input radio frequency (RF) signal with a first amplifier stage to obtain a first output RF signal when the first amplifier stage is enabled, the first input RF signal employing carrier aggregation comprising transmissions sent on multiple carriers at different frequencies to a wireless device, the first output RF signal including at least a first carrier of the multiple carriers; and

amplifying the first input RF signal or a second input RF signal with a second amplifier stage to obtain a second output RF signal when the second amplifier stage is enabled, the second output RF signal including at least a second carrier of the multiple carriers different than the first carrier.

Ex. 1315 at 2, 6.

70. The Applicant further argued that Hirose did not utilize an input RF signal employing carrier aggregation. *Id*. at 7-9 Of particular note, this is the point in the history of the '356 patent where the term "carrier aggregation" was introduced into the claims; the term "carrier aggregation" was added specifically to overcome Hirose; Hirose teaches the use of two-or-more independent data streams which are *not* aggregated together for the purpose of providing a higher data rate for a single stream of data. This is in contrast to carrier aggregation – where, as detailed earlier,

a single data stream is split up at the transmitter, the separate pieces are transmitted on separate carriers to the receiving device, and the pieces are aggregated together at the receiving device to recover the original data stream. As the Applicant noted in the reply, "Applicant's amended independent claims 1 and 17 recite, *inter alia*, 'the [] input RF signal employing ***carrier aggregation***,' which is **not** disclosed in Hirose. Generally, Applicant's claimed invention recites 'carrier aggregation' which results in an ***increased aggregated*** data rate. In contrast, Hirose transmits the same signals over different paths which results in ***redundant*** data at a ***common*** data rate." (Emphases in the original.) The Applicant was obviously drawing the distinction between the increased data rate associated with carrier aggregation and the independent (and non-aggregated) data rates in the three separate-and-independent data streams described by Hirose. The Applicant thus distinguished quite clearly between Hirose ("a common data rate") and carrier aggregation ("an increased aggregated data rate").

71. The Patent Office then issued an advisory action indicating that the claim amendments raised new issues that would require additional searching. Ex. 2001. Accordingly, on July 17, 2014, the Applicant filed a request for continued examination ("RCE") that included the aforementioned amendments and arguments. Ex. 2002.

72. The Patent Office next issued a non-final office action on August 1, 2014, rejecting claims 1 and 17 as anticipated by U.S. Patent No. 8,442,473 ("Kaukovuori"). Ex. 1316 at 2-5 – on the following grounds:

> Regarding claim 1, Kaukovuori et al. discloses an apparatus (FIG. 15 embodiment) comprising:
>
> a first amplifier stage configured to receive and amplify an input radio frequency (RF) signal and provide a first output RF signal to a first load circuit when the first amplifier stage is enabled, the input RF signal employing carrier aggregation comprising transmissions sent on multiple carriers at different frequencies to a wireless device, the
>
> first output RF signal including at least a first carrier of the multiple carriers (Kaukovuori et al. teaches ***a method of receiving data*** transmitted via a combination of at least a plurality of radio frequency signals ***using carrier aggregation*** (see column 2 lines 44-49). FIG. 15 discloses a Radio Frequency Integrated Circuit (RFIC1) 1 including first amplifier stage LNA to provide a first output RF signal to a digital data path. The two clusters are each received with different bandwidth filter (see column 10, lines 22-53).
>
> and a second amplifier stage configured to receive and amplify the input RF signal and provide a second output RF signal to a second load circuit when the second amplifier stage is enabled, the second output RF signal including at least a second carrier of the multiple carriers different than the first carrier (similarly, FIG. 15 further discloses a Radio Frequency Integrated Circuit (RFIC1) 1 including second amplifier stage LNA to provide a second output RF signal to a digital data path. The two clusters are each received with different bandwidth filter (see column 10, lines 22-53)).

73. In response, the Applicant presented arguments as to why Kaukovuori does not teach or suggest "[a first amplifier stage configured to ... amplify/

amplifying ... with a first amplifier stage] ... when the first amplifier stage is enabled ... and [a second amplifier stage configured to ... amplify/ amplifying ... with a second amplifier stage] ... when the second amplifier stage is enabled," as recited in claims 1 and 17. Ex. 1317 at 6-9.

74. On December 26, 2014, the Patent Office issued a second final office action, again rejecting claims 1 and 17 as anticipated by Kaukovuori. Ex. 1318 at 7-9.

75. After an Examiner Interview discussing possible claim amendments, the Applicant amended independent claims 1, 17, and 19 to recite

> 1. (Currently amended) An apparatus comprising:
>
> a first amplifier stage configured to be independently enabled or disabled, the first amplifier stage further configured to receive and amplify an input radio frequency (RF) signal and provide a first output RF signal to a first load circuit when the first amplifier stage is enabled, the input RF signal employing carrier aggregation comprising transmissions sent on multiple carriers at different frequencies to a wireless device, the first output RF signal including at least a first carrier of the multiple carriers; and
>
> a second amplifier stage configured to be independently enabled or disabled, the second amplifier stage further configured to receive and amplify the input RF signal and provide a second output RF signal to a second load circuit when the second amplifier stage is enabled, the second output RF signal including at least a second carrier of the multiple carriers different than the first carrier.

17. (Currently amended) A method comprising:

amplifying a first input radio frequency (RF) signal with a first amplifier stage to obtain a first output RF signal when the first amplifier stage is enabled, the first amplifier stage configured to be independently enabled or disabled, the first input RF signal employing carrier aggregation comprising transmissions sent on multiple carriers at different frequencies to a wireless device, the first output RF signal including at least a first carrier of the multiple carriers; and

amplifying the first input RF signal or a second input RF signal with a second amplifier stage to obtain a second output RF signal when the second amplifier stage is enabled, the second amplifier stage configured to be independently enabled or disabled, the second output RF signal including at least a second carrier of the multiple carriers different than the first carrier.

19. (Currently amended) An apparatus comprising:

first means for amplifying configured to amplify a first input radio frequency (RF) signal and provide a first output RF signal when the first means for amplifying is enabled, the first means for amplifying configured to be independently enabled or disabled, the first input RF signal employing carrier aggregation comprising transmissions sent on multiple carriers at different frequencies to a wireless device, the second output RF signal including at least a second carrier of the multiple carriers different than the first carrier; and

second means for amplifying configured to amplify the first input RF signal or a second input RF signal and provide a second output RF signal when the second means for amplifying is enabled, the second means for amplifying configured to be independently enabled or disabled, the second output RF signal including at least a second carrier of the multiple carriers different than the first carrier.

Exs. 1319; 1320 at 2, 5-6. In light of this amendment, the Examiner allowed claims 1 and 17. Ex. 1321 at 2, 5.

76. Prior to paying the issue fee, the Applicant filed a second request for continued examination in order to permit the Patent Office to consider additional

prior art disclosed in an Information Disclosure Statement. Ex. 2003. After reviewing the references, the Examiner again issued a Notice of Allowance, and the '423 Application issued on October 6, 2015 as the '356 Patent. Ex. 1322.

VI. LEVEL OF SKILL IN THE ART

77. I understand that Petitioner has proposed that a person of ordinary skill in the art ("POSITA") relevant to the '356 Patent would have had at least an M.S. degree in electrical engineering (or equivalent experience) and would have had at least two years of experience with the structure and operation of RF transceivers and related structures (or the equivalent). Petition at 32.

78. For the purpose of this proceeding, I do not dispute Petitioner's proposed level of ordinary skill in the art.

79. It is my understanding that when interpreting the claims of the '356 Patent, I must do so based on the perspective of one of ordinary skill in the art at the relevant priority date. I understand that the Petitioner alleges the '356 Patent is entitled to a priority date no earlier than May 25, 2012. Petition at 5. For the purpose of this proceeding, I will consider May 25, 2012 to be the relevant date to ascertain the perspective of one of ordinary skill in the art.

VII. CLAIM CONSTRUCTION

80. I understand that the Petitioner applied an interpretation of the term "carrier aggregation" to mean "simultaneous operation on multiple carriers." *See* Petition at 28-32. I disagree.

81. Independent claims 1 and 17 of the '356 Patent recite "an input RF signal employing carrier aggregation." The broadest reasonable interpretation of this claim element in light of the '356 patent specification and file history is ***simultaneous operation on multiple carriers that are combined as a single virtual channel to provide higher bandwidth***. The interpretation proposed by the Petitioner, on the other hand, is unreasonably broad and it is not consistent with the amendment made during prosecution to overcome the examiner's rejection based on the Hirose prior art reference.

82. It is my understanding that all grounds in the Petition depend on this definition for carrier aggregation. However, the Petitioner's proposed construction of "carrier aggregation" is improper for a number of reasons.

A. The Patent Owner's Construction Is The Ordinary And Customary Meaning, As Would Be Understood By A Skilled Artisan In The Context Of The Entire Disclosure.

83. While it is true that "simultaneous operation on multiple carriers" is an attribute of carrier aggregation, Ex. 1301 at 1:32–33, a person of ordinary skill would have further understood the term to mean that the multiple carriers are combined

(aggregated) as a single virtual channel. This understanding is consistent with the objective of aggregating carriers to provide a combined higher bandwidth channel for communications. *Id*. at 2:63–67. This construction is confirmed by the specification and the file history, and is further supported by extrinsic evidence.

1. The Specification Supports the Patent Owner's Proposed Construction

84. The specification states that the term "carrier may refer to a range of frequencies … and may be associated with certain characteristics." *Id*. at 1:33–35. Each of the multiple carriers "may also be referred to as a "***component carrier***." *Id*. at 1:37–40.[10] The plain meaning of the adjective "component" indicates that a "component carrier" constitutes a part of something larger. In particular, the component carriers are components that are combined to form a single aggregated carrier.

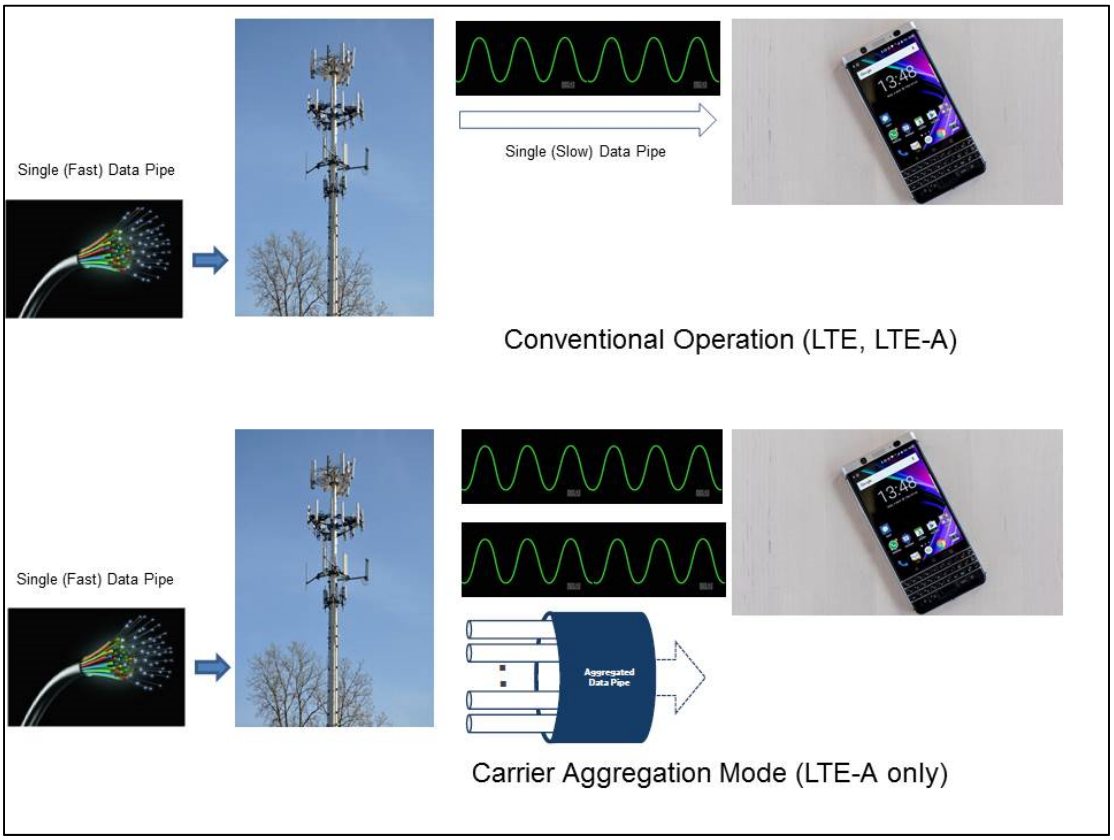
85. The specification depicts the aggregation of component carriers in Figures 2A to 2D. *Id*. at 3:6–38, Figs. 2A–2D. Each figure illustrates that by aggregating four component carriers, the system is capable of delivering data using a single virtual channel that has the equivalent of four times the bandwidth of a single non-aggregated carrier.

[10] Emphasis and highlighting added throughout this Declaration unless otherwise noted.

86. Thus, for example, while earlier LTE systems were limited to single channels with a maximum-available bandwidth of 20 MHz, LTE-Advanced (LTE-A) can be configured to aggregate up to five of these 20 MHz channels as component carriers of a single virtual channel having a bandwidth capacity of up to 100 MHz. Ex. 1301 at 2:63–67. The specification explains that LTE carriers may be aggregated from frequency bands listed in the 3GPP TS (Technical Specification) 36.101. *Id.* at 2:63–67. The applicant also identified 3GPP TS 36.101 during prosecution in an Information Disclosure Statement. Ex. 2015 at 12 (considered by examiner Nov. 4, 2013). In 3GPP TS 36.101, carrier aggregation is described as an "Aggregation of two or more component carriers in order to support wider transmission bandwidths." Ex. 2026 at 14.

87. The figure below illustrates carrier aggregation as implemented in LTE-Advanced (LTE-A). In earlier LTE systems, a user device connects to the wireless network over a single carrier (with a maximum possible bandwidth, depending on the exact band allocations, of 20 MHz). Ex. 1301 at 2:63–67. As the maximum-available data rate of the single-carrier wireless connection is the rate-limiting step for the end user, requests for a large amount of data (e.g., a video) data can only be received at the data rate of that single carrier. To relieve this rate-limiting step, LTE-Advanced added the ability for network equipment to practice carrier aggregation. Ex. 1301 at 2:63–67. When an end user requests a large amount

of data, the network will activate carrier aggregation to deliver that data more quickly. This is done by multiplexing the incoming data stream, which is illustrated by the "single (fast) data pipe", so that the incoming data stream is separated into multiple streams that are transmitted over multiple component carriers at the same time. The user device receives and de-multiplexes (aggregates) the multiple streams to recreate the original incoming data stream. The result is that the incoming data stream is received more quickly because it was transmitted in a higher bandwidth virtual channel.



2. The File History Supports Patent Owner's Proposed Construction

88. The file history of the '356 patent further supports this interpretation of carrier aggregation.

89. One of the references provided by the Applicant (and included in the file history is WO 2012/008705 – which includes the following description of carrier aggregation:

> [7] LTE-Advanced (LTE-A) system, which is one of systems following three generation wireless communication systems, is undergoing a standardization work for a terminal, which can support not only the MIMO system but also a Carrier Aggregation (CA), which is a scheme for transmitting more data to a terminal or User Equipment (UE) using different multiple carriers. The LTE-A is a technology for aggregating a plurality of unit carriers, which are used in the conventional LTE release-8/9, to be used simultaneously. Such technology aims to extending a bandwidth up to 100 MHz.
>
> [8] In other words, a carrier, which was defined fully up to 20 MHz in the conventional LTE release-8/9, is redefined as a component carrier, and one terminal is allowed to use maximum 5 component carriers by the carrier aggregation (CA) technology. Hereinafter, a terminal is referred to as User Equipment (UE).
>
> [9] The CA is a way to get high throughput by aggregating a used band for each component carrier. There are three types of carrier aggregations which are intra-band contiguous aggregation, intra-band non-contiguous aggregation and inter-band non-contiguous aggregation for LTE-Advanced CA.

Ex. 2016 at 4.

This is consistent with the various detailed descriptions already presented regarding carrier aggregation. Conventional LTE (release 8/9) uses a defined set of individual carriers – each with a bandwidth of up to 20 MHz, and each of which must be used one-at-a-time for any particular end-user device. In contrast, in LTE-A, these individual carriers are redefined as being able to serve as *component carriers*; the

use of the word "component" is significant, as this word is defined as "being or serving as an element (in something larger); composing; constituent."[11] Thus, two-or-more component carriers are used as constituent elements of a larger whole – in which the multiple component carriers are used together to create a single virtual data pipe, with a higher effective bandwidth for a single data stream.

90. A second reference provided by the Applicant (and included in the file history is GB2472978 – which includes the following descriptions of carrier aggregation:

(57) A multi-antenna receiving terminal can be switched between a receiver diversity mode (Fig. 1), in which the same data is received at each of a plurality of different antenna, and a carrier aggregation mode (Fig.2). In the carrier aggregation mode data has data been multiplexed across multiple carrier frequencies and each carrier is received by a different respective antenna. A network element (e.g.eNodeB) decides whether to switch between modes based on a network parameter, such as load, or a channel quality indication and instructs the receiving terminal accordingly. Carrier aggregation mode is also known as spectrum aggregation mode, dual carrier mode and dual cell mode.

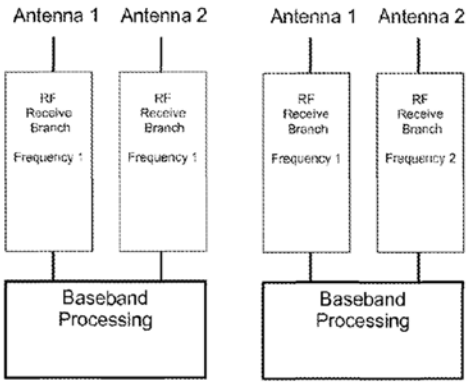


Fig 1 *Fig 2*

GB 2472978 states that "[i]n the carrier aggregation mode ***data has [] been multiplexed*** across multiple carrier frequencies . . . ." Ex. 2017 at 1.

[11] https://www.dictionary.com/browse/component .

> A known technique for increasing the capacity of a cellular telecommunications network such as HSDPA, LTE, WiFi or WiMAX is to bond together two parallel carriers. This approach is called carrier or spectrum aggregation.

Id. at 5.

The use of the term "bond" ("bond together two parallel carriers") is particularly significant as this is a specific term-of-the-art in communications. This term ("bond") refers to what is done in a situation where there is a low-data-rate segment of the chain between the data source and the end-target of that data; to overcome (or at least to reduce the detrimental effect of) the low-data-rate segment, the data stream from the data source is split up into two (or more) independent components, the split-up single-data-stream is sent in parallel over two (or more) paths that use the technology of the low-data-rate segment, and then the multiple components are assembled together at the other end of the low-data-rate segment as a method of increasing the overall data rate through the otherwise low-data-rate-technology segment. A prominent example of (and implementation) of this type of technology is what is known as "bonded" DSL service.[12] In much of the less-densely-populated regions of the United States, DSL ("digital subscriber line") is the only viable

[12] See, for example, https://evolving.net.uk/bonded-adsl/what-is-bonded-adsl/ and https://speedify.com/blog/combining-internet-connections/bond-two-dsl-lines-one-faster-connection/ .

method of providing data access at a reasonable data rate; DSL is a method of providing digital data signals over the standard "twisted pair" telephone lines that have been the default telephone wires for decades. DSL is limited to a distance of no more than some three miles from the appropriate network hub, but is able to provide a data rate of about 3 Mbps without any modifications to the existing telephone lines. However, these standard telephone line installations provided (to the end user) not one twisted-pair, but two. Bonded DSL service makes use of both of these twisted pairs – in concert – to increase the data rate to the end user of such service; this is done by splitting up the data stream before the data stream reaches the twisted pairs, transmitting the two component signals in concert (i.e., they are independent wires but the two data streams are not independent – they are *bonded* together) over the two twisted pairs, and then aggregating the two bonded signals together at a special modem (designed to serve this purpose). This basically doubles the data rate available at the modem – to some 6 Mbps. This is essentially the same technology as that used in carrier aggregation – as this UK patent application plainly states. Note also that, as detailed earlier, the network must be enabled and configured to support bonded DSL service – and that the end-user device (a bonded-DSL-capable modem) must be present to recombine the two components.[13]

[13] Note that even if the modem then distributes the incoming data stream around the premises using WiFi, contemporary WiFi is much faster than even

> In accordance with one aspect of the present invention, there is provided a network element in a cellular telecommunications network for increasing network capacity, the network including at least one mobile data terminal equipped with a plurality of receivers, the terminal being operable to communicate with the network element in a receiver diversity mode and in a carrier aggregation mode, the network element including: a decision making unit that instructs the terminal to switch from receiver diversity mode to carrier aggregation mode in dependence upon at least one input parameter.

Ex. 2017 at 7.

Note again that, as described earlier, that a hallmark of carrier aggregation is that the network must be configured to support-and-allow carrier aggregation – and must work in tandem with a suitably-enabled end-user device to make carrier aggregation available to that end user.

> It is well-known that carrier aggregation has more benefits for bursty data traffic (such as web-browsing). A simple estimation of the burstiness or the index of the predominant traffic class may be used as a further input to the decision making unit.

Id. at 12.

The invocation of "bursty data" and "burstiness" is also a clear confirmation of the nature of carrier aggregation as properly understood. Carrier aggregation need not be active perpetually; instead, it is invoked as needed – to, among other things, allow

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bonded DSL service – maintaining even the bonded DSL as the rate-limiting part of the chain between the data source and the ultimate end-user device.

as much spectrum as possible to remain as fully-available to the network as is possible. Instead, when an end-user has made a request that the network deems to be sufficiently data-intensive, the network will activate carrier aggregation mode – and will make another component carrier (or more than one additional component carrier) available to the end user, and then activate that addition component carrier at the end-user device so as to provide a higher aggregated data rate for what appears to the end user to be a single data stream. As also described earlier, when the need for "burst mode" has ended, the additional component carriers that had been activated for carrier aggregation mode are deactivated – and returned to the control of the network so that they can be made available (as needed) for other users.

> In a further embodiment, the decision to switch between receive diversity mode and carrier aggregation mode is made by the terminal, with assistance from the network.

Id. at 13. Once again, it is made plain that carrier aggregation is a technology that must be implemented in both the network and in the end-user device – and is called into operation on an as-needed basis.

91. A third intrinsic reference is provided by the Kaukovuori patent (U.S. Patent No. 8,442,473) – which was the basis of a rejection of the (eventual) '356 patent, as detailed earlier in the discussion of the File History. The specification of Kaukovuori includes a detailed description regarding the essence of carrier aggregation:

> Long Term Evolution (LTE) Advanced is a mobile telecommunication standard proposed by the 3rd Generation Partnership Project (3GPP) and first standardised in 3GPP Release 10. In order to provide the peak bandwidth requirements of a 4th Generation system as defined by the International Telecommunication Union Radiocommunication (ITU-R) Sector, while maintaining compatibility with legacy mobile communication equipment, LTE Advanced proposes the aggregation of multiple carrier signals in order to provide a higher aggregate bandwidth than would be available if transmitting via a single carrier signal. This technique of Carrier Aggregation (CA) requires each utilised carrier signal to be demodulated at the receiver, whereafter the message data from each of the signals can be combined in order to reconstruct the original data. Carrier Aggregation can be used also in other radio communication protocols such as High Speed Packet Access (HSPA).

Ex. 1425 at 1:19-35.

92. Kaukovuori describes carrier aggregation as "the aggregation of multiple carrier signals in order to provide a higher *aggregate* [emphasis mine] bandwidth than would be available if transmitting via a single carrier signal." That carrier aggregation involves the use of these "multiple carrier signals" to provide a single, aggregated data stream (originating in the backhaul network) at the end-user device is made clear by: "This technique of Carrier Aggregation (CA) requires each utilised carrier signal to be demodulated at the receiver, whereafter the message data from each of the signals can be *combined* [emphasis mine] in order to *reconstruct* [emphasis mine] the original data." As per the earlier discussion of wireless network architecture and carrier aggregation (Section IV.B), a single data stream arrives at the wireless communications system via the (much-faster) backhaul network, and is split up into separate components which are transmitted in parallel over multiple carriers; these multiple carriers are received at (the suitably-capable and suitably-

enabled) end-user device, where they are combined together to reconstruct the original, single data stream that was originated in the backhaul network. Of particular note, if carrier aggregation were to encompass mere concurrent operation using two-or-more completely independent data streams, there would be no need to "combine" or "reconstruct" anything. Kaukovuori is describing carrier aggregation as it is understood in the art and as described at numerous points throughout this declaration.[14]

3. Extrinsic Evidence Supports Patent Owner's Proposed Construction

93. Further, there is also an extensive amount of extrinsic evidence that also supports this interpretation of carrier aggregation and what follows is only a representative sample of the available extrinsic evidence.

94. The 3GPP organization also published a document entitled "Carrier Aggregation Explained,"[15] which further described the nature of carrier aggregation:

> Carrier aggregation is used in LTE-Advanced in order to increase the bandwidth, and thereby increase the bitrate.

[14] It must again be noted that Kaukovuori explicitly references the LTE release 10 (i.e., LTE-A) standard and that the Petitioner has produced no evidence – from either that standard or anywhere else – which describes concurrent operation as being a form of "carrier aggregation."

[15] http://www.3gpp.org/technologies/keywords-acronyms/101-carrier-aggregation-explained

This single sentence affirms that carrier aggregation was introduced as part of LTE-A, and that it was developed to increase the data rate (bit rate) for an end-user.

95. Another example is provided from a book authored by Erik Dahlman and others, of Ericsson.[16] A figure from this book (p. 26) depicts the multiplexing which occurs as part of carrier aggregation (as explained earlier in Section IV.B):

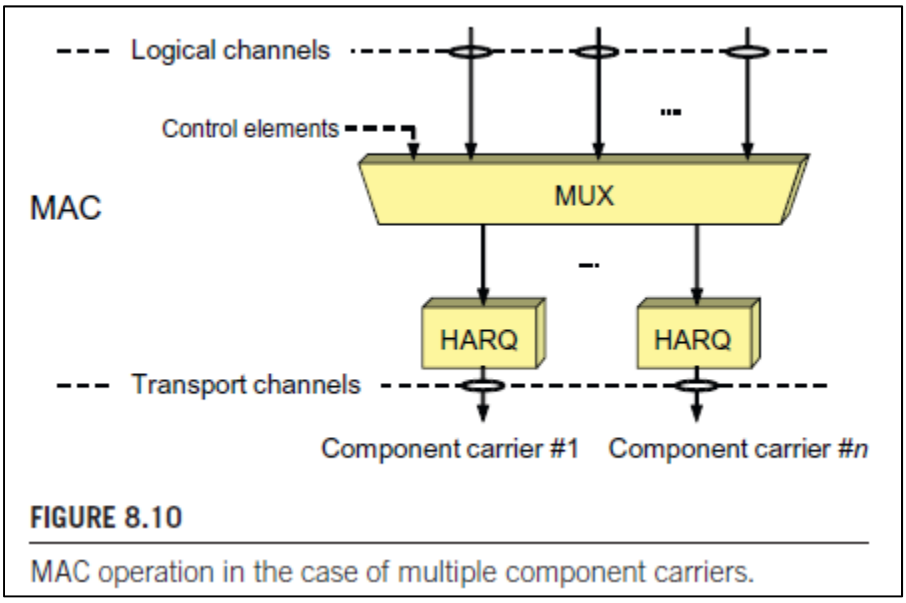


FIGURE 8.10

MAC operation in the case of multiple component carriers.

As noted earlier in the overview of carrier aggregation (Section IV.B), multiplexing of the data streams is a key aspect of carrier aggregation. In addition, this figure is nearly identical to one that appears in the 2009 3GPP Feasibility Study, Ex. 1304 at 10, which is a document that the Petitioner has submitted as constituting primary prior art in their Petition.

[16] Ex. 2021, E. Dahlman et al., "4G LTE/LTE-Advanced for Mobile Broadband," (Academic Press, 2011).

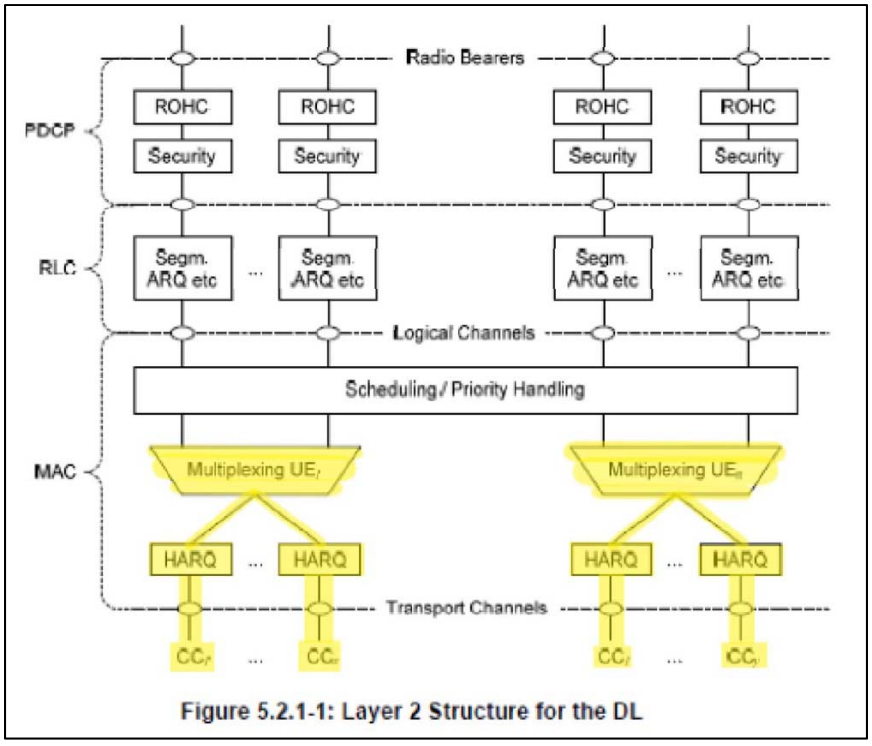


Figure 5.2.1-1: Layer 2 Structure for the DL

(Highlighting added.)

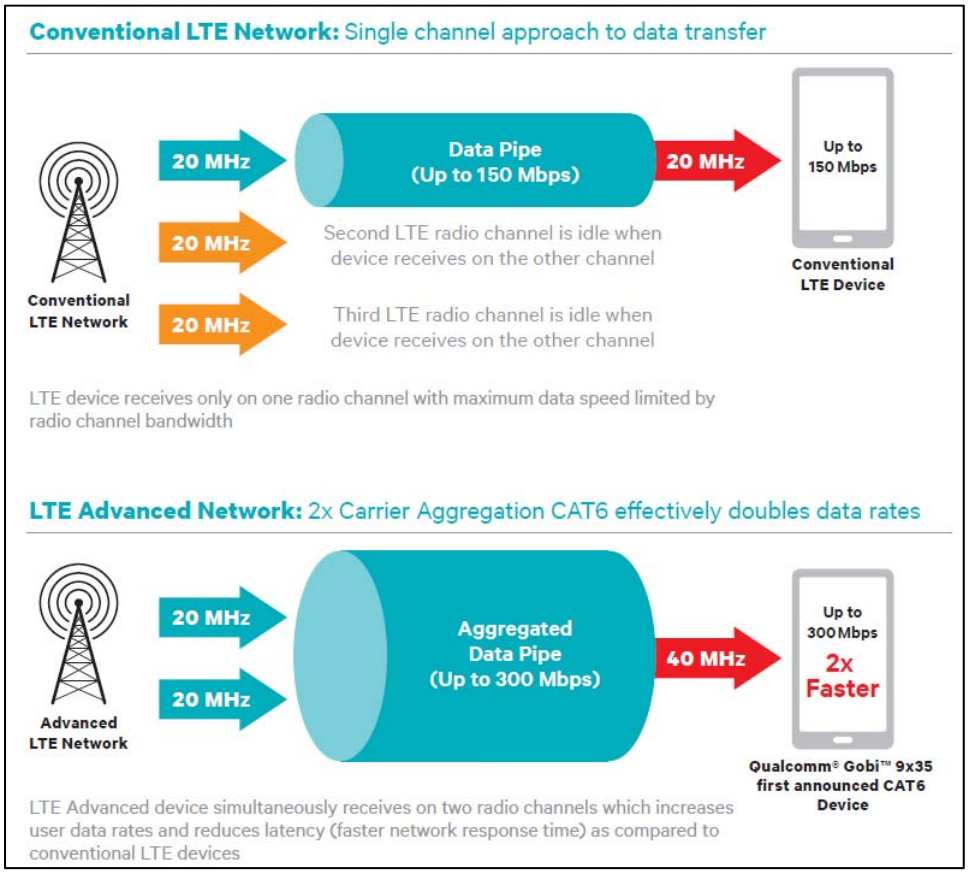
96. Thus, the 3GPP Feasibility Study agrees with the Dahlman textbook and with the earlier descriptions – that carrier aggregation employs the ***multiplexing*** of ***user data*** for transmission to each user device (i.e., UE_1 – UE_n), using multiple ***component carriers*** (i.e., CC_1 – CC_n) for each such device (when carrier aggregation mode is active for each device and for the network supporting those devices. Carrier aggregation delivers multiplexed data to the user, in order to provide an aggregated higher bandwidth channel (i.e., a single virtual channel) – so that data demanding a higher data rate (e.g., video) than is available using only a single carrier can be delivered at the aggregated data rate. This also demonstrates that a person of skill in the art, reading the Feasibility Study, would be fully aware that "carrier

aggregation" is describing the combining of multiple component carriers into a single virtual channel with a higher data rate. A 2013 U.S. Patent Application (U.S. Pat. Pub. No. 2013/0217398) is also quite plain regarding the structural nature of carrier aggregation: "Carrier aggregation provides an increase in data throughput capability by allowing different parts of the frequency spectrum to be ***combined logically to form a single channel*** (e.g. over-the-air interface between a base station and a user equipment). The technique of carrier aggregation thus allows an expansion of the effective bandwidth which can be utilized in wireless communication by concurrent utilization of radio resources across multiple carriers. ***Multiple component carriers are aggregated to form a larger overall transmission bandwidth***." Ex. 2020 ¶ [0003]. The use of the phrase "combined logically" is salient as it refers *not* to independent carriers used concurrently, but to component carriers that are combined together (i.e., aggregated) to produce a single data pipe with a higher data rate.

97. A 2013 Qualcomm document[17] states that "Carrier aggregation, as the name suggests, ***combines multiple carriers (a.k.a. channels) at the device to provide a bigger data pipe*** to the user." Ex. 2019 at 6. In addition, a 2014

[17] Ex. 2019, *Strategies to win in LTE and evolve to LTE Advanced* (2013), https://www.qualcomm.com/documents/wireless-networks-strategies-win-lte-and-evolve-lte-advanced .

Qualcomm document[18] clearly describes the basic nature of carrier aggregation, including the differences (discussed earlier) between conventional LTE and the carrier-aggregation-capabilities included in LTE-A:



Of particular note is the consistency of this publicly-available 2014 description of carrier aggregation with the earlier detailed descriptions of carrier aggregation. Under the conventional LTE standard, only a single carrier can be used at a time to connect to a mobile device; as this single carrier has a defined (by the standard)

[18] Ex. 2022, Qualcomm Carrier Aggregation Infographic, https://www.qualcomm.com/media/documents/files/carrier-aggregation-infographic.pdf .

bandwidth of up to 20 MHz, the amount of data that can be transmitted over this link is limited (by the basic physics, as described earlier in Section IV.A). As is noted in the text accompanying the conventional LTE figure (and as just described), "The LTE device receives only on one radio channel with maximum data speed limited by radio channel bandwidth." Only one radio channel is available for communication with the end-user device; the other channels are depicted as being idle and unavailable to the end-user – and, as described earlier, remain available to the network for allocation to other users on a similar (one-radio-channel-only) basis. Consistent with the earlier discussion of the nature of bandwidth (Section IV.A), the data speed is limited by the bandwidth of the single 20 MHz channel (the largest single-channel-bandwidth available) that is in use. In contrast, with carrier aggregation available as part of LTE-A, the network and an appropriately-equipped end-user device can use more than one component carrier in a parallel form, in which the component carriers are combined into a virtual single carrier with a much-larger bandwidth, allowing for a higher data rate for a single data stream (as shown). As shown in the figure, the use of two 20 MHz component carriers, aggregated together into a single data pipe, allows for a doubling of the bandwidth (to the end user) to 40 MHz – and thus a doubling of data rate for a single data stream.

98. Furthermore, the Petitioner's own patent portfolio contains instances of the term "carrier aggregation," and it is clear from reading these references that the

Petitioner demonstrates an understanding of the meaning of the term "carrier aggregation" that is consistent with the one provided in this Declaration.

99. An example is provided by U.S. Patent No. 9,161,254, which describes carrier aggregation as the "***aggregation of multiple smaller bandwidths to form a virtual wideband channel*** at a wireless device (e.g., UE)." Ex. 2013 at 3:20-22. The specification of this patent further states that "Carrier aggregation provides a broader choice to the wireless devices, enabling more bandwidth to be obtained. The greater bandwidth can be used to communicate bandwidth-intensive operations, such as streaming video or communicating large data files." (*Id.* at 3:49-53). This makes it clear that carrier aggregation is used to move a single data stream (rather than parallel independent streams) to an end-user device. The text of the specification also serves to solidly connect carrier aggregation to the component carriers available under the LTE-A standard:

One technique for providing additional bandwidth capacity to wireless devices is through the use carrier aggregation of multiple smaller bandwidths to form a virtual wideband channel at a wireless device (e.g., UE). In carrier aggregation (CA) multiple component carriers (CC) can be aggregated and jointly used for transmission to/from a single terminal. Carriers can be signals in permitted frequency domains onto which information is placed. The amount of information that can be placed on a carrier can be determined by the aggregated carrier's bandwidth in the frequency domain. The permitted frequency domains are often limited in bandwidth. The bandwidth limitations can become more severe when a large number of users are simultaneously using the bandwidth in the permitted frequency domains.

FIG. 1 illustrates a carrier bandwidth, signal bandwidth, or a component carrier (CC) that can be used by the wireless device. For example, the LTE CC bandwidths can include: 1.4 MHz 210, 3 MHz 212, 5 MHz 214, 10 MHz 216, 15 MHz 218, and 20 MHz 220. The 1.4 MHz CC can include 6 resource blocks (RBs) comprising 72 subcarriers. The 3 MHz CC can include 15 RBs comprising 180 subcarriers. The 5 MHz CC can include 25 RBs comprising 300 subcarriers. The 10 MHz CC can include 50 RBs comprising 600 subcarriers. The 15 MHz CC can include 75 RBs comprising 900 subcarriers. The 20 MHz CC can include 100 RBs comprising 1200 subcarriers.

Carrier aggregation (CA) enables multiple carrier signals to be simultaneously communicated between a user's wireless device and a node. Multiple different carriers can be used. In some instances, the carriers may be from different permitted frequency domains. Carrier aggregation provides a broader choice to the wireless devices, enabling more bandwidth to be obtained. The greater bandwidth can be used to communicate bandwidth intensive operations, such as streaming video or communicating large data files.

Another Intel patent (U.S. Patent No. 10,044,613) also provides the same details regarding carrier aggregation: "carrier aggregation of multiple smaller bandwidths ***to form a virtual wideband channel at a wireless device.***" (Ex. 2018 at 3:27-62.)

100. Further, a trade press article from 2015[19] clearly describes the origins and key aspects of carrier aggregation:

[19] https://www.eetimes.com/author.asp?section_id=36&doc_id=1327340 .

> The thirst for more entertainment videos, streaming music, videoconferencing, interactive games, and higher data speeds in general are pushing cellular carriers to enhance their service offerings.
>
> That requires greater channel bandwidth for higher-speed down links and, increasingly, up links as well (think videoconferencing like Skype and Apple's Face Time).
>
> CA is the leading feature of LTE-Advanced (LTE-A). Unfortunately, the spectrum available to the operator is often a patchwork of several different bands, so to achieve higher-speed operation means of stitching together two or more bands is necessary through CA.
>
> Aggregation of carriers enables combining two or more bands to provide a single channel whose bandwidth is, theoretically, the sum of all of them.
>
> In November 2014, Qualcomm was the first cellphone chip vendor to announce a category 10 (Cat 10) LTE-A modem supporting global CA for down link speeds of up to 450 Mbps, up link speeds of up to 100 Mbps, and CA across both TDD and FDD spectra.

101. From a journal article:[20]

> In carrier aggregation, two or more smaller bands are compounded to form a wider band for supporting higher data rates in the broadband systems.

102. From a 2018 trade press article:[21]

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[20] https://www.researchgate.net/publication/332267848_On_the_Spectral_Content_of_Nonlinear_Carrier_Aggregated_Windowed_OFDM_Systems

[21] http://www.mpdigest.com/2018/07/24/gans-role-in-5g/

> Carrier aggregation combines radio channels within the same frequency band (intraband) or over different frequency bands (interband) to increase wireless data rates and lower latency.

103. From a 2017 article produced by a supplier of base station equipment that supports carrier aggregation, describing both carrier aggregation in LTE-A and the differences as compared with the older LTE:[22]

> Carrier aggregation in LTE offers successively higher peak data rates as well as better broadband experience across the coverage area.
>
> The date rates scale with the amount of spectrum allowing 3GPP Rel 10 to support up to 5 carriers with up to 100 MHz of spectrum and commercial solutions to support up to 3 carriers with peak data rates up to 450 Mbps (Cat 5).
>
> LTE Advanced offers considerably higher data rates than even the initial releases of LTE. While the spectrum usage efficiency has been improved, this alone cannot provide the required data rates that are being headlined for 4G LTE Advanced.
>
> To achieve these very high data rates it is necessary to increase the transmission bandwidths over those that can be supported by a single carrier or channel. The method being proposed is termed carrier aggregation, CA, or sometimes channel aggregation. Using LTE Advanced carrier aggregation, it is possible to utilise more than one carrier and in this way increase the overall transmission bandwidth.
>
> The target figures for data throughput in the downlink is 1 Gbps for 4G LTE Advanced. Even with the improvements in spectral efficiency it is not possible to provide the required headline data throughput rates within the maximum 20 MHz channel.
>
> To an LTE terminal, each component carrier appears as an LTE carrier, while an LTE-Advanced terminal can exploit the total aggregated bandwidth.

[22] https://www.cablefree.net/wireless-technology/cablefree-4g-lte-advanced-carrier-aggregation/

104. All of these descriptions are consistent with the description of carrier aggregation that was provided in the technology overview sections – that is, as a single carrier frequency is limited (by basic considerations of the bandwidth of that channel) in the data rate that it can intrinsically support, the overall data rate to the end user is increased via a form of parallel processing – in which the data stream is split up into two (or more) separate streams, the two streams are sent to the end-user device on separate carrier frequencies, and then the two streams are reassembled (at the end-user device) into the original, single data stream. In this way, the use of parallel transmissions allows the effective data rate for the single stream to be much higher than that attainable using a single carrier frequency. Of particular note, carrier aggregation is a feature that was included with LTE-A; it is not available in LTE, and it will not work in LTE.

105. As such, the implementation of carrier aggregation requires something that would *not* be required for the implementation of concurrent operation. Unlike in the case of concurrent operation, the implementation of carrier aggregation requires modifications-and-additions to the network itself. In particular, the network operators must upgrade their network infrastructure to support carrier aggregation; the implementation of carrier aggregation features in an end-user mobile device is insufficient if that end-user is to be able to actually make use of carrier aggregation. This is made clear by examining information from both suppliers of equipment to,

e.g., mobile network operators, and the announcements regarding carrier aggregation made by those network operators themselves.

106. For example, the base station supplier CableFree announced that its base station would, after receiving a software upgrade for the purpose, support carrier aggregation.[23]

> CableFree LTE-A Base Stations include full support for CA with latest Release 12 LTE-A software.

This announcement also describes the use of carrier aggregation for situations demanding "burstiness" – in a manner similar to that described above as found in the reference GB 2472978 (Ex. 2017):

> Higher capacity for bursty applications
>
> Increased data rates of carrier aggregation can be traded off to get higher capacity for bursty applications, such as web browsing, streaming, social media apps and others, meaning operators can choose a higher capacity for the same user experience, better user experience for the same capacity, or both.

107. Carrier aggregation, which was implemented as part of LTE-A, requires infrastructure and network upgrades – such as the base station software upgrade just described.[24] But to again be clear, carrier aggregation is a stated part

[23] https://www.cablefree.net/wireless-technology/cablefree-4g-lte-advanced-carrier-aggregation/

[24] This critical linkage between carrier aggregation and the network infrastructure is further elucidated by examining a possible scenario that is described in document from the 3GPP organization that was cited earlier, "Carrier Aggregation

of the LTE-A standard; there is nothing in the LTE-A standard that describes any implementation of concurrent operation.

108. Further, these upgrades are the responsibility of the network operator – as the network operator's infrastructure must be able to support carrier aggregation if end-user devices (if they are able to use carrier aggregation) are going to be able to make use of carrier aggregation. For example, earlier this year, the Polish subsidiary of Orange (a network operator in Europe) announced that their networks had been upgraded to support carrier aggregation.[25]

Explained" (http://www.3gpp.org/technologies/keywords-acronyms/101-carrier-aggregation-explained) – a scenario in which an end-user is using carrier aggregation via two carriers – but with each carrier coming from a different base station transmitter. In wireless communications networks, a user typically is virtually linked to a particular transmitting base station at a particular time – with the particular base station that is being used changing as the user moves around. In that simple situation, the network must be monitoring to which base station the user is linked – so that all communications to-and-from that user can be routed by the backhaul network (usually optical fiber connections running to the base stations) to the appropriate base station at the appropriate time. For a user employing carrier aggregation via a single base station, somewhere between the main backhaul data link and the transmitter, the original data stream must be split up so that it can be transmitted to the user over two component carriers. In the two-base-station carrier aggregation scenario just described, the importance of the infrastructure to carrier aggregation becomes even clearer – as in this possible situation, the network infrastructure must split up the data stream into two sub-streams before that data stream reaches the base station, and then route each sub-stream individually to each of the two base-stations. Carrier aggregation is indeed defined by the need for extensive infrastructure upgrades.

[25] https://www.telecompaper.com/news/orange-poland-applies-carrier-aggregation-on-7000-base-stations--1284659 .

> Orange Poland reports that it has 7,000 base stations using carrier aggregation. The operator provides LTE on 15 MHz in the band 2600 MHz and 10 MHz in each of the bands 800 MHz, 1800 MHz and 2100 MHz. In its tests, the operator used carrier aggregation to reach the maximum bandwidth of 100 MHz for LTE, resulting in a speed of 1.91 Gbps.

Note again that the implementation of carrier aggregation requires implementation into the network infrastructure by the network operator. Also note that, as detailed above, carrier aggregation serves to use multiple carriers in parallel to achieve a much higher data rate for what, to the user, is a single, enhanced data pipeline (here, with a single-stream data rate of 1.91Gbps); in particular, this identification of "the maximum bandwidth of 100 MHz" is consistent with the 2009 3GPP Feasibility Study (Ex. 1304) describing the maximum-available carrier aggregation implementation in LTE-A as being the aggregating together of five 20 MHz channels – to provide a single aggregated data pipe with a virtual bandwidth of 100 MHz.

109. All this history makes it clear that carrier aggregation is not merely a happenstance – or something that the mobile end-user can take advantage of solely by acquiring a suitably-enabled mobile device. Carrier aggregation is a newer technology that was introduced as part of the LTE-A network standard. It is clearly intended to use multiple carriers in parallel for the express purpose of creating what the user perceives as a single data stream that has a much higher data rate. Also, carrier aggregation requires not just an appropriately-enabled mobile device; it also requires the presence of upgrades to the wireless infrastructure, as made by the

equipment makers and the network operators. All of this effort (in both infrastructure and in end-user mobile devices) is undertaken to provide the user with higher effective data rates – higher than would be possible using a single component carrier.

B. The Petitioner's Proposed Construction Should Be Rejected

1. The Petitioner's Proposed Construction Is Unreasonably Broad

110. The Petitioner proposes the same unreasonably broad construction adopted by the ITC. Petition at 31. In the ITC proceeding, the Patent Owner proposed that "carrier aggregation" should mean "simultaneous operation on multiple carriers to increase the bandwidth for a user." Ex. 1336 at App. A, p. 20 of 46. The Patent Owner continues to maintain that is a correct construction, but seeks to further clarify it here because that construction merely serves to shift the parties' dispute to the meaning of the phrase "increase the bandwidth."

111. Specifically, the Petitioner argues that "receiving data over two 20 MHz carriers increases bandwidth to 40 MHz." Petition at 46. As explained above, two 20 MHz carriers operating independently do not provide a single virtual channel with an increased ***aggregated*** bandwidth. The bandwidth of any one channel remains 20 MHz – and, as explained earlier, it is the bandwidth which sets the maximum capacity of that channel. But by aggregating two 20 MHz carriers as a single virtual channel, the network and the user device may operate using an

aggregated 40 MHz channel that has a combined bandwidth equal to the sum of the bandwidths of the component carriers.

2. The Amendment To Add "Carrier Aggregation" To Overcome Hirose Precludes Petitioner's Proposed Construction

112. As I described earlier in the overview of the File History of the '356 patent, during the patent's prosecution, the term "carrier aggregation" was specifically added by the Applicant to overcome the Hirose reference (U.S. Patent No. 7,317,894). Ex. 1315. Hirose teaches an apparatus for a satellite digital radio broadcast, in which data are transferred wirelessly from a data source to a "mobile station" (such as a moving vehicle). Ex. 1324. As Hirose describes, this is a challenging task – as not only is the mobile terminal frequently moving, but that movement also will cause the receiving terminal to be moving through a variety of level-of-quality environments with respect to the ability of the mobile terminal to receive the intended data. Thus, Hirose teaches a system in which the data are sent to the receiver (at the mobile terminal) via two separate methods – via "ground waves" (depicted as progressing from the studio to a geostationary[26] satellite to a

[26] A geostationary satellite is placed in orbit at a distance (from the Earth) of about 22,000 miles, over the equator. At this distance, the satellite orbital speed is equal to the speed of the rotation of the Earth; thus, the satellite remains fixed at a single point in the sky from the perspective any spot on the Earth below where the satellite is visible.

ground repeater and the mobile terminal (the final destination)) and "satellite waves" (depicted in Figure 1 as progressing from the studio to a ground station to a satellite in a "Figure 8" orbit[27] and to the mobile terminal). This two-fold approach provides redundancy, thus increasing the chances that the intended data will successfully reach the mobile terminal.

113. Thus, Hirose is teaching "simultaneous operation on multiple carriers" – and as just noted, the Applicant added the term "carrier aggregation" to the claim terms in order to overcome Hirose. As the Petitioner's proposed construction clearly does *not* overcome Hirose, it is obviously insufficient as a construction for "carrier aggregation." Thus, "simultaneous operation on multiple carriers" is a requirement for the use of carrier aggregation; however, it is a necessary-but-not-sufficient requirement.

114. The Petitioner acknowledges this deficiency by then attempting to argue that the only distinction provided by the addition of "carrier aggregation" to the claim terms is the overcoming of Hirose's use of redundant data – that is, they argue that the introduction of "carrier aggregation" overcomes the use of multiple

[27] This is the apparent pattern that the satellite will traverse when viewed from a fixed point on the Earth below; in this case, the satellite is orbiting at the same rate at which the Earth is turning, but the orbit is not on the plane of the equator (as is the case with a geostationary satellite).

carriers for redundant data but does *not* overcome the use of multiple carriers for non-redundant, independent data streams (i.e., concurrent operation).

115. The Petitioner's sole grounds for attempting to impose this distinction is the discussion which the Applicant supplied as part of their reply to the Examiner which accompanied the submission of their revised claim language that includes the phrase "carrier aggregation." In that reply, the Applicant pointed out that Hirose teaches the use of redundant data – whereas "carrier aggregation" does not involve redundant data. Ex. 1315 at 7-8.

116. First, this attempt fails as a matter of simple logic. The Applicant was pointing out a limiting factor specifically associated with Hirose – that as Hirose teaches the transmission of redundant data, that alone is sufficient to demonstrate that Hirose is not teaching carrier aggregation; however, that does not, *a priori*, mean that this is the only difference between Hirose's teachings and carrier aggregation – or that the Applicant was using this observation to define "carrier aggregation." In fact, as detailed above, the applicant specifically noted that carrier aggregation differed from Hirose by more than the mere non-use of redundant data: "Applicant's amended independent claims 1 and 17 recite, *inter alia*, 'the input RF signal employing ***carrier aggregation'***, which is **not** disclosed in Hirose. Generally, Applicant's claimed invention recites 'carrier aggregation' which results in an ***increased aggregated*** data rate. In contrast, Hirose transmits the same signals over

different paths which results in ***redundant*** data at a ***common*** data rate." The "redundant data" is an adder to the explanation that Hirose describes "the same signals over different paths … at a common data rate." That is, each of Hirose's independent data streams has its own data rate – and these streams are never aggregated together to create a single data pipe and a corresponding higher data rate.

117. The Petitioner's proposed construction would permit the claims to read on the multiple carriers disclosed by Hirose, which transmit "redundant data at a common data rate." Thus, "carrier aggregation" cannot have the meaning the Petitioner proposes.

3. Petitioner's Proposed Construction Is Not Indicative Of How A Skilled Artisan Understood the Term

118. The Petitioner's proposed construction is also incorrect because it reads out the word "aggregation." The proposed construction fails to impart any meaning to the word aggregation, e.g., what is aggregated, why is it aggregated, how is it aggregated, etc. As explained above, it is the component carriers that are aggregated into a single virtual channel to provide higher bandwidth. A proper construction must reflect that "aggregation" is an essential characteristic of carrier aggregation. Furthermore, a person of ordinary skill in the art would have understood that "carrier aggregation" is not equivalent to any "simultaneous operation on multiple carriers." A person of ordinary skill would have recognized "carrier aggregation" as a term of art in the context of the '356 patent specification and the file history.

119. The Petitioner's proposed construction also adds little, if any, additional meaning beyond the surrounding claim language. The claim recites "multiple carriers" in the same phrase that the term "carrier aggregation" appears: "the input RF signal employing carrier aggregation comprising transmission sent on multiple carriers . . ." Substituting the Petitioner's proposed construction would result in a claim that recited "the input RF signal employing *simultaneous operation on multiple carriers* comprising transmissions sent on multiple carriers." Indeed, if "carrier aggregation" were equivalent to multiple carrier operation, the applicant would have had no reason to separately distinguish terms such as "multiple bands" and "multiple radio technologies," which also implicate multiple carrier operation. Ex. 1301 at 3:43–49.

120. Thus, in my opinion, the Petitioner's construction of "simultaneous operation on multiple carriers" should be rejected. Not only does it fail to properly describe the nature of carrier aggregation (as just described) – it also fails to overcome the prior art reference which caused the term "carrier aggregation" to be included in the claim terms in the first place.

121. To conclude this section, several final summary points need to be made.

- The Petitioner provides no support at all (either intrinsic or extrinsic) for their attempt to use their proposed construction to expand the definition of "carrier aggregation" to include concurrent

operation on multiple independent carriers; the Applicant could have discussed concurrent operation – but did not. In addition, nothing regarding concurrent operation appears in the file history; further, the Petitioner has provided not a single extrinsic reference describing either concurrent operation or that concurrent operation is identified (by anyone) as another form of carrier aggregation; this contention is of their own making, with absolutely no support.

- In fact, as noted earlier, the Petitioner's own cited extrinsic reference (the 3GPP Feasibility Study) contradicts their construction and associated contentions as it specifically discusses the multiplexing of data streams, which is something that is required for carrier aggregation but which would *not* be needed for concurrent operation.

- As a person of ordinary skill in the art would understand the earlier, fundamental discussion of the meaning of bandwidth (Section IV.A), bandwidth would not be interpreted as the Petitioner has proposed – and again, the Petitioner provides no supporting evidence (either intrinsic or extrinsic) to show otherwise. As detailed in Section IV.A, the reason that "bandwidth" and "data rate" have come to be used synonymously in wireless communications is due to

fundamental physics – in particular, that the width of a channel (no matter its actual frequency) limits the data rate that said channel can provide. In particular, as the channels under the LTE standard are defined (by the standard) as each having a bandwidth of up to 20 MHz, the ability of a single such channel to transfer data is limited by that 20 MHz – and the standard does not include any wider channel bandwidths. A person of skill in the art would further understand that carrier aggregation provides a method of using multiple such channels to transmit a single incoming data stream (coming from the backhaul network) over those multiple channels as a way of creating a virtual single data pipe with the aggregated data capacity of those multiple channels – and that this is the circumstance under which it is appropriate to add bandwidth numbers together – as the addition together of (e.g.) two 20 MHz channels using two LTE-A component carriers is a method of creating the equivalent of a single 40 MHz channel – something that the LTE carriers, on their own, do not allow. This serves to increase the data rate available in the wireless network to more quickly move a single data stream from the much-faster backhaul network over the slower wireless network (the rate-limiting step), and thus deliver that data to the end-user at a

faster rate than would be possible using a single LTE channel. This Declaration has provided a very large amount of clear evidence – both intrinsic and extrinsic – for this interpretation of carrier aggregation. In stark contrast, the Petition provides no corroborating evidence for their attempt (as noted above) to expand the definition of carrier aggregation to include independent, concurrent operation. A person of skill in the art would not add the total bandwidths of two-or-more channels under some form of concurrent operation – and the Petitioner has not provided a single example of this being done. Further, the Petition attempts to claim that concurrent operation amounts to an "increased data rate" because two independent data streams amount to the total provision of a larger amount of data.[28] Once again, a person of skill in the art would not adopt such an interpretation – as an "increased data rate" means that something is being delivered more quickly (from the backhaul network to the end user); while this Declaration has (as noted above)

[28] Note again that this also forces the Petitioner into the odd circumstance of trying to impose a requirement that the content of the data streams in concurrent operation be a discriminant between carrier aggregation and not-carrier-aggregation – in which different data in the streams *is* carrier aggregation but redundant data *is not* carrier aggregation. Given that carrier aggregation is a network functionality and an end-user-device feature, this unsupported contention makes little sense.

provided extensive evidence for this interpretation of carrier aggregation and "increased data rate," the Petitioner has provided no corroborating evidence for this interpretation of "increased data rate." In addition, as was also noted earlier, the conventional LTE standard allowed only single carrier operation, while the LTE-A standard describes the use of multiple component carriers specifically for carrier aggregation as per the Applicant's proposed construction for the term. The Petitioner has produced no evidence that concurrent operation is part of the LTE-A standard, is contemplated by the LTE-A standard, or is even allowed under the LTE-A standard; therefore, there is no way via which a person of skill would consider concurrent operation in association with either the 3GPP Feasibility Study or the LTE-A standard.

VIII. OVERVIEW OF THE CITED REFERENCES

A. Overview of Lee

122. U.S. Patent Publication No. 2012/0056681 ("Lee") proposes an apparatus in which "a low-noise amplifier (LNA) of the multi-radio device can be configured to commonly amplify a plurality of radio-frequency signals … such as the Bluetooth connection and the WiFi connection" to "reduce the hardware cost and the chip size of the multi-radio device." Ex. 1335 at [0002].

123. At the time of Lee's invention, both WiFi and Bluetooth used only the 2.4GHz "ISM" (Industrial-Scientific-Medical) band.[29]

124. Lee describes a series of "signal amplification circuits," each of which includes one or more "input stages" for receiving a signal, one or more "output stages" coupled to one or more output ports, and one or more "selecting stage[s]" for coupling input and output stages. Ex. 1335 at Abstract.

125. The stated basis for Lee's invention(s) is one that is well-known in the art – regarding the commonality of operating frequency (noted above) between the WiFi and Bluetooth protocols. When they were introduced during the latter part of the 1990s, both WiFi (i.e., 802.11b[30]) and Bluetooth used the unlicensed[31] 2.4 GHz ISM (Industrial-Scientific-Medical) band of the radio spectrum. While 802.11b and Bluetooth used different power levels, different data rates, different ranges, and

[29] Today, Bluetooth still only uses the 2.4 GHz ISM band; in contrast, WiFi has more-recently expanded (via a variety of new standards) to also use other bands, such as the 5 GHz band. However, as discussed, at the time of Lee's invention, both Bluetooth and WiFi used only the 2.4 GHz ISM band, which is consistent with both the specification and the claims of Lee.

[30] At that time, the 802.11a standard was also introduced which operated in the 5 GHz band. Despite the higher frequency's promise to offer higher bandwidth (i.e., higher data rates), this frequency suffered from propagation and attenuation problems, particularly in situations involving building materials; thus, it quickly fell into disuse – and, as just noted, the use of the 5 GHz band in WiFi standards has only recently been revived. Further, the 802.11g standard offers faster data rates than does 802.11b but it still uses only the 2.4 GHz ISM band.

[31] The term "unlicensed" means that as long as transmissions remain below certain power levels, no license is required for operation in this band.

different encoding schemes, the commonality of the transmission frequencies led to obvious interest in finding ways to share components between a WiFi receive chain and a Bluetooth receive chain to reduce the total number of components, so that the size, complexity, cost, etc., of the 2.4 GHz radio system inclusions can be reduced. Lee states this goal quite clearly in Ex. 1335 at Paragraph [0002]: "For example, if a low-noise amplifier (LNA) of the multi-radio device can be configured to commonly amplify a plurality of radio-frequency signals, the LNA shared between different radio connections, such as the Bluetooth connection and the WiFi connection, would reduce the hardware cost and the chip size of the multi-radio device." This is embodied in Figure 1 of Lee – where a single LNA provides signals to multiple output stages.

126. As Lee's circuitry is based upon the use of MOS transistors as LNAs,[32] these LNAs are being used as transconductance amplifiers – that is, the input is a voltage signal on the gate of the transistor, the output is the current coming out of the transistor's current path, and the relationship between that gate voltage and the output current (the change in the output current divided by the change in the input voltage) is known as the transconductance. As Lee notes, a possible problem arises

[32] As Lee notes, the use of multiple transistors in parallel as an LNA is the equivalent of using a single transistor of the combined channel width; "It should be noted that the parallel connection of transistors can be regarded as a single transistor with an equivalent size." (At [0018].)

if a single LNA may be driving a non-fixed number of outputs; as the output current supplied by the LNA will be a fixed function of the input gate voltage, that current will all be supplied to the output if only one output is active – but will be reduced (by simple division) if more than one output is active. In this latter situation, the current at each output will be reduced (and provide less current to the output); in addition, as the characteristics of the LNA are determined by the bias current (as described earlier, in Section V.A), if the current through the LNA were to change, its radio-signal-receiving behavior of that LNA would be altered.

127. It is for these current-related reasons that Lee developed the complex structure of the disclosed output stages. Lee describes two possible operating modes – a "shared" mode (in which only one output stage is active) and a "combo" mode (in which more than one output stage is active). In shared mode, only one type of RF input signal (e.g., just a WiFi signal or just a Bluetooth) signal is being received; in that situation, the output signal is routed to only one of the outputs – and the transistors of the output stages are used to provide the appropriate current level (for both the output and the LNA bias current) to one of the outputs. In combo mode, multiple types of RF input signals (e.g., both a WiFi signal and a Bluetooth signal) are being received; in that situation, the output signal is routed to the same number of outputs as there are input signals (e.g., both a WiFi signal and a Bluetooth signal) – and the transistors of the output stages are used (in a different manner as compared

to shared mode) to ensure that the same appropriate current levels are provided at the outputs, and also to maintain the LNA bias current.

128. For completeness, it should be noted that Lee discloses no separation of incoming signals, and no circuitry for doing so. If a multi-signal input is provided to the circuitry of Lee, the same multi-signal content will appear at all of the outputs that are active in "combo" mode.

129. Lee was considered by the Examiner during prosecution and is cited on the face of the '356 patent. In particular, during the prosecution of the '356 Patent, Qualcomm submitted an Information Disclosure Statement (IDS) listing Lee. Ex. 2004 at 3. The Examiner subsequently considered Lee, and provided his initials on a signed-and-dated "List of References cited by applicant and considered by Examiner" and as a result, as noted above, Lee appears in the specification of the '356 patent, in the list of "References Cited."

130. Further, Lee was not merely buried in a large stack of such "References Cited." The Examiner also considered an International Search Report and Written Opinion of the International Searching Authority which provided a detailed discussion of how Lee allegedly reads on the claims. Ex. 2005. The Lee reference was one of only four references cited in this ISR and Written Opinion – and thus, as noted above, was not just one reference listed in a very long list of references. The Examiner considered these documents and initialed, signed, and dated the IDS. Ex.

2004 at 6. In allowing the claims of the '356 Patent, the Examiner thus considered Lee as well as the ISR and Written Opinion discussing Lee.

B. Overview of "The Feasibility Study"

131. The "Feasibility Study" is more formally entitled "LTE; Feasibility study for Further Advancements for E-UTRA (LTE-Advanced) (3GPP TR 36.912 version 9.1.0 Release 9)" ("3GPP TR 36.912"); it is a 2009 technical report produced by the (somewhat-anachronistically-named[33]) 3rd Generation Partnership Project ("3GPP"). Ex. 1304.

132. The opening "Scope" section describes the purpose of this document: "This document [was] intended to gather all technical outcome[s] of the study item, and draw a conclusion on [the] way forward. In addition this document includes the results of the work supporting the 3GPP submission of "*LTE Release 10 & beyond (LTE-Advanced)*" to the ITU-R as a candidate technology for the IMT-Advanced." *Id*. at 7.

133. Further, as the "Introduction" section states: "At the 3GPP TSG RAN #39 meeting, the Study Item description on 'Further Advancements for E-UTRA (LTE-Advanced)' was approved. The study item covers technology components to be considered for the evolution of E-UTRA, e.g. to fulfil the requirements on IMT-Advanced." *Id*. at 8.

[33] This is certainly the case today, but was also the case even in 2009.

134. The key part of the Feasibility Study is that it describes detailed high-level implementation possibilities for (as per the title of Section 5) "Support of wider bandwidth" which, as described earlier, is the same as stating that LTE-A is intended to support higher data rates for the moving of data (over the wireless network and to an end-user device). *Id*. As the section begins, "LTE-Advanced extends LTE Rel.-8 [i.e., "conventional" LTE] with support for *Carrier Aggregation* [emphasis in the original], where two or more *component carriers* [emphasis in the original] (CCs) are aggregated in order to support wider transmission bandwidths up to 100MHz and for spectrum aggregation." *Id*. Again, among other things, this sentence clearly links carrier aggregation with the introduction of LTE-A. As also noted earlier, Figure 5.2.1-1 on page 10 depicts the proposed downlink layer structure – depicting the inclusion of multiplexing in the end-user devices (UE). As described earlier, multiplexing is a requirement in such systems, which are multiplexing two-or-more component carriers together into a single, aggregated data stream. The study further states (*id*. at 9) that as LTE-A is envisioned, "It is possible to configure a [user equipment] to aggregate a different number of component carriers originating from the same [base station] and of possibly different bandwidths in the [uplink] and the [downlink]" communication paths.

135. The remainder of the study provides details on the network architecture and high-level-operating functions of the network and suitable end-user devices.

However, the study provides no circuit-level design concepts for the implementation of any form of LTE-A deployment and/or usage.

IX. GROUND 1: LEE DOES NOT ANTICIPATE CLAIMS 1, 7, 8, 11, 17, OR 18

136. The first ground of the petition – that Lee anticipates Claims 1, 7, 8, 11, 17, and/or 18 of the '356 patent – fails in that assertion. Even though the term "carrier aggregation" was a known term of the art at the time of Lee, neither this phrase nor any derivative forms of it appear anywhere in Lee. The Petitioner attempts to create a remedy for this deficiency by proposing an overly-broad construction for the term "carrier aggregation"; however, as discussed extensively above, this construction is inconsistent with both the File History of the '356 patent and with the generally-understood meaning of the term "carrier aggregation" in the art. The petition fails to show that Lee discloses the "carrier aggregation" limitation of independent claims 1 and 17 in accordance with the meaning of the term "carrier aggregation" as it would have been properly understood by a person of ordinary skill in the art. In addition and for at least this reason, dependent claims 7, 8, 11, and 18 also fail to be anticipated by Lee.

A. Claim 1

137. Claim 1 recites a first amplifier stage configured to receive and amplify an "input RF signal employing carrier aggregation;" Lee fails to disclose this claim limitation.

138. First, as a matter of fact (and as discussed above), the phrase "carrier aggregation" does not appear in Lee, nor does any derivative form of this term appear; this is particularly notable, as the term is one that was known in the art at the time of Lee.

139. Further, the Petitioner asserts (incorrectly) that Lee's "VIN" signal comprises "a Bluetooth and a WiFi signal" that teaches "the input RF signal employing carrier aggregation." (Petition at 45–46.) Lee never describes the VIN signal (or anything else) as "employing carrier aggregation." Instead, Lee consistently refers throughout to two separate and distinct input signals "(e.g., a Bluetooth signal and a WiFi signal) received by a single antenna." Ex. 1335 at [0017]. These two input signals originate from two separate-and-distinct radio systems – even if both of those systems happen to be implemented in the same host system; thus, the input signal(s) disclosed by Lee represent separate and distinct "wireless connections" (*id*. at [0002]) – as WiFi and Bluetooth are indeed separate radio protocols with distinctly-different characteristics and which support distinctly-different activities. Lee does not disclose the "aggregation" of these separate (WiFi and Bluetooth signals) in any way – and the Petitioner cites no evidence to the contrary. In fact, Lee is clear that a key goal of his invention is to provide outputs of the WiFi and Bluetooth inputs that are kept separate; one of skill in the art would readily understand that the eventual goal is to feed these outputs to further processing

in further circuitry (not disclosed or discussed by Lee) that would extract the *separate and individual* information that has been encoded (on the transmit side) into the (separate) WiFi and Bluetooth signals.

140. The Petitioner attempts to overcome this obvious deficiency in Lee's disclosure by proposing an unreasonably broad construction of the term "carrier aggregation." As explained above, "carrier aggregation" means more than just "simultaneous operation on multiple carriers." The mere presence of both a Bluetooth signal and a WiFi signal cannot, on its own, establish "carrier aggregation." Lee describes no such aggregation, the Petitioner provides no evidence that Lee discloses such aggregation and one of skill in the art would not only not find any such aggregation, but would further not expect anyone to attempt to aggregate together a WiFi signal and a Bluetooth signal. Standing alone, the disclosure of two unrelated carrier signals is not evidence of an "aggregation" – because it ignores the plain-and-ordinary meaning of the word "aggregation" – that one-or-more things are aggregated together. In addition, the amendment that was added to Claim 1 during prosecution which added the term "carrier aggregation," to overcome the Hirose reference was specifically defined as referring to the creation of an "increased aggregated rate"; this further confirms that Lee does not disclose an "input RF signal employing carrier aggregation."

141. The Petitioner further argues that Lee's Bluetooth signal and WiFi signal "increases bandwidth." (Petition at 46–47.) According to the Petitioner's expert, "receiving data over two 20 MHz carriers increases bandwidth to 40 MHz." *Id*. First, as noted repeatedly throughout this Declaration, neither the Petitioner nor the Petitioner's expert cite any evidence (intrinsic or extrinsic) to support this assertion that independent operation on two different channels can be described via the mathematical addition of the bandwidth of the two channels – and thus as "increasing bandwidth." Second, as detailed earlier (particularly in Section IV.A), the bandwidth of a channel has a direct, specific relationship with the maximum data rate that such a channel can support; in particular, the only way to increase that maximum data rate is to increase the bandwidth of that channel for a single signal – something that does not occur with two independent channels. The term "bandwidth" applies (see Section IV.A) to a single channel not to the numbers associated with two independent channels; mathematically adding together the bandwidths of two independent channels simply does not make physical sense – any more than does the adding together of the temperatures in two adjacent rooms. Finally, as was also noted earlier, the LTE-A standard documents (such as the Feasibility Study cited by the Petitioner) describe the multiplexing of data so that two-or-more channels can be used together to create a higher effective data rate; as per the discussion in Section IV.B, this higher data rate is the virtual equivalent of a

single channel with a larger bandwidth because, as explicitly explained in Section IV.A, to achieve a larger data rate, a larger bandwidth for a single channel is required. This is what is being done using "carrier aggregation" – as that termed is described in this Declaration and as it was understood in the art by a person of ordinary skill.

142. From this (incorrect) premise, the Petitioner's expert then asserts that "Lee therefore teaches carrier aggregation." *Id*. However, once again, the Petitioner's expert cites no evidence or authority to support that opinion. As discussed above, carrier aggregation has a specific meaning – in which two-or-more channels are combined (i.e., aggregated) together to form a single data pipe with a higher effective data rate. Not only does Lee not describe such an occurrence, Lee describes circuitry in which a WiFi signal and a Bluetooth signal are explicitly kept separate from each other. The Petitioner's expert does not argue that Lee combines (aggregates) the WiFi and Bluetooth connections together into a single virtual channel.

143. The Petitioner's expert further argues – again without citing any evidence – that "Lee uses multiple carriers to send different data." Petition at 49 (citing Ex. 1302 ¶ 83). However, this assertion is simply incorrect – as Lee is completely silent on the data content of the WiFi and Bluetooth signals that will be entering his disclosed circuitry. This should not be a surprise as Lee is teaching

circuitry to receive signals, and this circuitry is not dependent on the specific data content of those signals. Once again, it must be noted that the Petitioner is trying to assert that whether or not "carrier aggregation" is being practiced is dependent on the specific content of the data streams. But an instance of different data on the two signals does not establish that the input signal employs carrier aggregation.

144. Further, the Petitioner fails to cite any examples in which WiFi and Bluetooth signals are aggregated together; in addition, the Petitioner also fails to suggest any reasons that one of skill in the art might attempt to do so. At the time of the invention of the '356 Patent, WiFi, which was developed as a multi-megabit (e.g., 11 Mbps and greater), medium-range wireless networking technology, employed channels with a bandwidth of 22 MHz – with the ability to increase the bandwidth to 40 MHz. Bluetooth, which was originally developed for short-range, low-power, low-data-rate (e.g., c. 1 Mbps) applications (e.g., wireless headsets) employed channels with a bandwidth of 1 MHz. Even if one applies the Petitioner's (incorrect) reasoning, an aggregated WiFi and Bluetooth signal would result in increasing the bandwidth from either 22 MHz to 23 MHz, or from 40 MHz to 41 MHz. It is obvious to one of skill in the art that if using such signals (WiFi and Bluetooth) for "carrier aggregation" (under either the proper definition of the term or even the Petitioner's incorrect interpretation of the term), the benefits from such an aggregation are at best negligible.

145. For these reasons – in conjunction with the background discussions provided earlier – at the time of the invention of the '356 patent, a person of ordinary skill in the art would not have understood Lee to disclose a VIN signal "employing carrier aggregation." Accordingly, Lee fails to anticipate claim 1 and each of its dependent claims.

B. Claim 7

146. As explained above, Lee fails to disclose "the input RF signal employing carrier aggregation" limitation of claim 1. Because claim 7 depends from claim 1, Lee fails to anticipate claim 7 for the same reason.

147. Lee also fails to anticipate claim 7 for an additional reason. It is my understanding that anticipation requires that the prior art reference disclose each of the elements of the claim "arranged as in the claim" and Lee fails to disclose each of the elements of claim 7 in that manner. Whereas the Petitioner relies on circuit 200 in Lee's Figure 2 for claim 1, the Petitioner then switches to the embodiment disclosed as circuit 400 in Figure 4 for claim 7. (Petition at 56.) However, even within the framework of circuit 400, the Petitioner improperly mixes different embodiments to set forth their anticipation argument. For some limitations, the Petitioner asserts that the anticipating circuit operates in a "shared mode," and for other limitations asserts that the anticipating circuit operates in a "combo mode." However, Lee does not disclose an instance in which circuit 400 operates in both

modes in a single embodiment. It is my understanding that "anticipation is not proven by multiple, distinct teachings that the artisan might somehow combine to achieve the claimed invention." Therefore, Lee fails to anticipate Claim 7 for this reason as well.

1. "a first amplifier stage configured to be independently enabled or disabled"

148. The Petitioner argues that the "transistor M'_1 and output stage 304_1" of circuit 400 in Figure 4 are "configured to be independently enabled or disabled." Petition at 56–57 (citing Lee ¶ 37 (describing circuit 300)). In paragraph 36, Lee explains that, in a "shared mode," the "output stages 304_1-304_N are enabled in a time-division manner." Ex. 1335 at [0036]. When the output stage 304_1 is enabled, the output stage 304_N is disabled. *Id*. When the output stage 304_1 is disabled, the output stage 304_N is enabled. *Id*.; *see also id*. at [0037] ("If the ***output stages 304_1 and 304_N are enabled alternately under the mode***, the signal amplification circuit 300 refers to the input signal VIN to generate the processed signal VOUT_1 for WiFi connection and the other processed signal VOUT_N for Bluetooth connection alternately."). Thus, Lee fails to disclose that output stage 304_1 is enabled or disabled independent of output stage 304_N.

149. The Petitioner further argues in the same paragraph that "circuit 400 may also operate in combo mode." Petition at 57 (citing Ex. 1335 ¶¶ 41, 42, 33). However, that "alternative design" refers to a different embodiment than the "shared

mode" described above in the context of circuit 300. Ex. 1335 ¶¶ 36–37. Lee fails to disclose circuits that simultaneously embody both a time-division "shared mode" and a "combo mode." Thus, Lee fails to anticipate claim 7.

2. **"the first amplifier stage further configured to receive and amplify an input radio frequency (RF) signal and provide a first output RF signal to a first load circuit when the first amplifier stage is enabled"**

150. The Petitioner contends that this limitation is satisfied by an embodiment where the output stages are enabled in a time-division manner as discussed above. Petition at 57–58 (citing Ex. 1335 ¶ 37 ("the output stages 304_1 and 304_N are enabled alternately"). But, as explained above, circuit 400 cannot be "independently enabled or disabled" in a "shared mode." To the extent that the limitation above is satisfied by the "combo mode," which is a different embodiment, circuit 400 could not also operate in a "time-division" "shared mode." Thus, Lee fails to anticipate claim 7.

3. **"the input RF signal employing carrier aggregation comprising transmissions sent on multiple carriers at different frequencies to a wireless device"**

151. Lee fails to disclose "the input RF signal employing carrier aggregation" for the same reasons explained above with respect to claim 1. Thus, Lee fails to anticipate claim 7.

4. **"a second amplifier stage configured to be independently enabled or disabled"**

152. The Petitioner argues that the "transistor M'_N and output stage 304_N" of circuit 400 in Figure 4 are "configured to be independently enabled or disabled." Petition at 58–59. The Petitioner's argument fails for the same reasons explained above with respect to the first amplifier stage. Thus, Lee fails to anticipate claim 7.

5. **"the second amplifier stage further configured to receive and amplify the input RF signal and provide a second output RF signal to a second load circuit when the second amplifier stage is enabled"**

153. The Petitioner contends that this limitation is satisfied by an embodiment where the output stages are enabled in a time-division "shared mode" as discussed above. Petition at 59–60 (citing Ex. 1335 ¶ 37 ("the output stages 304_1 and 304_N are enabled alternately"). The Petitioner's argument fails for the same reasons explained above with respect to the first amplifier stage. Thus, Lee fails to anticipate claim 7.

* * * *

154. For all of the reasons stated above, Lee fails to anticipate claims 1 and 7; further, Lee fails to anticipate dependent claims 8, 11, 17, and 18 for the same reasons.

X. GROUND 2: LEE DOES NOT RENDER OBVIOUS CLAIMS 7 OR 8

155. Recognizing that claims 7 and 8 are not anticipated by Lee, the Petitioner includes an obviousness challenge which is based on a combination of

different embodiments disclosed by Lee. As explained above, Lee fails to disclose "the input RF signal employing carrier aggregation." For at least this reason, Lee does not render obvious either claim 7 or claim 8.

156. Furthermore, the Petitioner fails to sufficiently articulate why someone of skill in the art would have been motivated to combine these embodiments. The Petitioner disparages Lee's circuit 200 of Figure 2 as a "circuit ready for improvement" that needs "improved input matching performance." Petition at 71. Yet, the embodiment of Figure 2 already includes "matching network 210" in order to "meet the impedance matching requirements." Ex. 1335 at [0026]. The Petitioner fails to sufficiently explain why Lee included a "matching network 210" that needed "improvement." If it was obvious that "matching network 210" needed improvement, as Petitioner argues, then that begs the question of why Lee did not simply include the "feedback circuit" of Figure 4 in circuit 200 of Figure 2. The Petitioner's stated reason is that "input matching performance can be improved greatly." Petition at 70. However, the Petitioner's conclusory assertions are insufficient and lead to hindsight bias.

157. For the reasons stated above, Lee fails to render obvious claims 7 and 8.

XI. GROUND 3: LEE AND THE FEASIBILITY STUDY DO NOT RENDER OBVIOUS CLAIMS 1, 7, 8, 11, 17, OR 18

158. The Petitioner argues that claims 1, 7, 8, 11, 17, and 18 are obvious over Lee and the 3GPP Feasibility Study. The Petition, however, fails to sufficiently articulate a motivation to combine these two disparate references. Indeed, one of skill in the art would not have had a reason to select these two references – which are not directed to the problems addressed by the claimed inventions of the '356 patent.

159. Lee is directed to a "signal amplification circuit" having an input signal that is "shared between different radio connections, such as" Bluetooth and WiFi. Ex. 1335 at [0002]; as noted earlier, WiFi and Bluetooth are indeed different radio connections – with different data rates, different ranges, and different power-consumption characteristics. Lee does not disclose that his circuitry may be shared between the same type of radio connections – such as the various (numerous) bands that are encompassed within the LTE standard. Further, as detailed above, Lee does not disclose carrier aggregation. In addition, Lee's teachings are at the circuitry level – more specifically, his teachings are at the transistor-circuitry level.

160. The Feasibility Study is a high-level, network-functionality document – and is directed to "Further Advancements" for LTE-Advanced (also known as LTE-A), an industry standard for mobile communications. Ex. 1304 ("Further Advancements for E-UTRA [Evolved Universal Terrestrial Radio Access]"). Thus, the Feasibility Study discloses numerous details regarding the operation of network-

level functions for LTE-A; it does not describe any particular circuitry for implementing LTE-A (in whole or in part). The level of detail in the Feasibility Study does not go any deeper than block diagrams; it certainly does not go into the transistor-level circuit descriptions which are found in Lee.

161. As such, while the Feasibility Study describes how LTE-Advanced offers "support for *Carrier Aggregation*, where two or more [LTE] *component carriers* (CCs) are aggregated," (Ex. 1304 ¶ 5.1), the Feasibility Study does not disclose any amplifier circuitry (or any other circuitry) associated with carrier aggregation.

A. The Petitioner Fails To Sufficiently Articulate A Motivation To Combine

162. The Petitioner fails to sufficiently articulate why someone of skill in the art would have been motivated to combine these two distinctly different references (Lee and the Feasibility Study).

163. In particular, the Petitioner fails to explain why someone of skill in the art would combine Lee (which is directed to "***different kinds of radio connections***," Ex. 1335 at [0002]) and the Feasibility Study (which is directed to the ***same type of radio connections*** (e.g., LTE-A), Ex. 1304 ¶ 5.1.) The Petitioner also fails to explain why someone of skill in the art would combine Lee (which is directed to Bluetooth and WiFi) and the Feasibility Study (which is directed to LTE/LTE-A cellular communications). The Petitioner also fails to explain why someone of skill in the

art would combine Lee (which does not disclose carrier aggregation) and the Feasibility Study (which does not even disclose any amplifier circuit or any circuitry at all).

164. According to the Petitioner, the "motivation to combine Lee with the teachings of the Feasibility Study ***arises from the references themselves***." Petition at 74. To support this argument, the Petitioner relies in particular on a statement in the Feasibility Study that, for certain aggregation scenarios, a receiver "would have multiple RF front-ends." *Id*. at 73 (citing Ex. 1304 at 26 ("separate RF front end[s] are necessary")). The Petitioner's argument is insufficient. Indicating that "separate RF front end[s] are necessary" is nothing more than the statement of a problem. The Petitioner fails to articulate a reason that a person of skill in the art would – among a vast possible sea of references describing separate, multiple RF front ends – find Lee as the particular reference for addressing that posed challenge; even this alone is an insufficient motivation to combine the two references. For example, a Google Patents search identified "About 24,933 results" in response to a search for "low noise amplifiers" with a priority date before May 25, 2012. Ex. 2023. But further, while the Feasibility Study involves the LTE standard and its very wide range of frequency bands, Lee only addresses a single frequency band – the 2.4 GHz ISM band in which both WiFi (at the time of Lee) and Bluetooth operate; in this sense, Lee actually teaches *away* from the Feasibility Study.

165. The Petitioner also asserts that a person of ordinary skill would have been motivated to combine the references "to use the input RF signal employing carrier aggregation of the Feasibility Study with the amplification blocks of Lee in order to ***achieve the[ ] benefits*** [of carrier aggregation] and ***unlock the features*** of LTE-Advanced." Petition at 74. But this assertion from the Petitioner's expert is unsupported. As detailed above, the Feasibility Study relates to LTE/LTE-A, mobile communications frequencies, and a very large range of radio communications bands; in contrast, Lee discusses two independent communications protocols which operate in the same band (the 2.4 GHz ISM band), and which are not aggregated together (in either Lee's teachings or anywhere else that has been identified). Since (as noted above), these two references are both dissimilar and divergent, that would not have provided a motivation for a person of skill in the art to combine them.

B. A Person of Skill In The Art Would Not Have Combined Lee And The Feasibility Study

166. I disagree with Petitioner's alleged "motivation to combine" Lee with the Feasibility Study – for the reasons just discussed above, and for further reasons to be discussed here.

167. The '356 Patent is directed to circuitry with two (or more) amplifier stages that separately amplify the two (or more) component carriers of an input RF signal that is employing carrier aggregation. The specification discloses, for example, an input RF signal using carrier aggregation with up to five LTE carriers

from among the 35 different frequency bands in the LTE/LTE-A standard (Ex. 1301 at 2:63–67); this is consistent with the LTE-A standard's formulation for carrier aggregation, which allows up to five LTE component carriers to be aggregated together into a single virtual data pipe (with up to five times the data rate of a single LTE-A component carrier channel.)

168. In sharp contrast, Lee is directed to signals from "different radio connections" – that is, WiFi and Bluetooth. Ex. 1335 at [0002]. Lee does not disclose a signal employing "carrier aggregation" – either explicitly (as noted earlier, the term appears nowhere in Lee, even though it was a term of the art at the time) or by inference. Further, at the time of Lee, WiFi and Bluetooth signals were both transmitted and received in the same frequency band (the 2.4 GHz "ISM" (Industrial-Scientific-Medical) band). Lee would not have been selected to address a need for an amplifier for input signals carrying aggregated LTE component carriers, which would have been chosen (over a potentially very wide frequency range) from among a plurality of frequency bands. This is because WiFi and Bluetooth are wireless communication standards that are unrelated to LTE. Bluetooth was developed for use in short-range, ultra-low-power, low-data-rate personal area communications, and WiFi was developed for medium-range, low-power, high-data-rate local area communications – while LTE was developed for use in long-range, high-power, wide-area wireless mobile communications. Further,

WiFi and Bluetooth employ signals in different frequency bands than does LTE. In addition, Lee describes input signals from "different" radio connections – whereas the '356 Patent discloses embodiments where input signals are aggregated using the same type of radio connections. A person of ordinary skill in the art would have had no reason to select Lee to design an amplifier for LTE carrier aggregation applications.

169. The Feasibility Study is directed to LTE-Advanced (LTE-A), a cellular communication technology. However, it does not even disclose an amplifier circuit (or any other circuitry) – and amplifier circuits are the subject of the claimed invention. Ex. 1301 at 20:43-61 ("a first amplifier stage," "a second amplifier stage"). Nor does the Feasibility Study disclose key limitations of the claimed invention – such as "amplifier stage[s]" that are "independently enabled or disabled." Indeed, the Petitioner contends that the only element of the challenged claims that the Feasibility Study discloses is "carrier aggregation." (Petition at 72.) Thus, a person of ordinary skill in the art would have had no reason to select the Feasibility Study to design an amplifier for carrier aggregation – or to even provide guidance for the design of an amplifier for carrier aggregation.

170. Contrary to the Petitioner's assertion, a person of skill in the art would not have been motivated to combine Lee and the Feasibility Study merely because the Feasibility Study taught that "[i]t is possible to configure a UE [user equipment]

to aggregate a different number of component carriers originating from the same eNB [e.g., base station] and of possibly different bandwidths in the UL [uplink] and the DL [downlink]." In my opinion, the mere generalized possibility that a wireless device can be configured for carrier aggregation would not motivate a person of ordinary skill in the art to combine the Lee and the Feasibility Study references specifically – for the reasons discussed above. In a similar way, a person of skill in the art would not have been motivated to combine Lee and the Feasibility Study on the grounds that such a person "would have found it obvious to turn to the amplification circuit of Lee in order to process the carrier aggregated input RF signal of the Feasibility Study and would have been motivated to combine those references." As noted above, the Petitioner has provided no support for the assertion that Lee in particular would stand out from a variety of possible references – particularly as the use of multiple RF front ends is not unique to either Lee or the Feasibility Study. And once again, the mere generalized possibility that a wireless device can be configured for carrier aggregation would not motivate a person of ordinary skill in the art to combine the Lee and the Feasibility Study references specifically.

171. Further, the Petition references page 26 of the Feasibility Study, which shows a table (Table 11.3.3.1-1) which lists "Possible UE Architecture for the three carrier aggregation scenarios" and indicates that a multiple RF front end architecture

is appropriate for contiguous intra-band, non-contiguous intra-band, or inter-band carrier aggregation. In my opinion, the generalized description of "Possible UE Architecture" for different carrier aggregation scenarios would not provide motivation to combine the Lee and Feasibility Study references specifically. The criterion of having multiple RF front ends is vague and would broadly apply to a wide range of circuit designs; as noted above, as someone of skill in the art would understand the existence of this wide range of settings for the use of multiple RF front ends, there is nothing in the Feasibility Study that would cause such a person to fix on Lee as a particular amplifier to choose. Therefore, this description in the Feasibility Study does not provide any reason to combine carrier aggregation with Lee in particular –- and in fact, as also noted earlier, the discrepancies between (on the one hand) the LTE-A standard and carrier aggregation and (on the other hand) Lee are such that the Feasibility Study actually teaches away from Lee (and vice-versa).

172. Furthermore, the assertion that "Lee thus teaches the exact type of receiver that the Feasibility Study recognizes would work with signals employing carrier aggregation" is simply factually incorrect. The explanation of "Option A" on p. 26 of the Feasibility Study (Ex. 1304) provides a description of an RF front end as containing "mixer, AGC, ADC." The Petitioner details this description as "The Feasibility Study characterizes an 'RF front end' as having its own gain control

(amplifier), mixer, and analog-to-digital conversion. See *id*. at 73-74 ('RF front end (i.e., mixer, AGC [Automatic Gain Control], ADC [Analog to Digital Conversion)')." The second part of this excerpt is correct – "AGC" is clearly "Automatic Gain Control," and "ADC" is clearly "Analog-to-Digital Conversion." *Id*. at 74. However, the first part of the excerpt incorrectly refers to "gain control" as being an amplifier; this is simply incorrect, as AGC is a feature that an amplifier may be designed to *include*, but it is *not* an amplifier. Thus, taken together, Lee teaches *none* of these three items – neither ADC, nor AGC, nor mixers. Lee teaches an amplifier circuit and only an amplifier circuit. Thus, not only is it not correct that "Lee thus teaches the exact type of receiver that the Feasibility Study recognizes would work with signals employing carrier aggregation" – Lee actually teaches *not one* of these items. Therefore, contrary to the Petitioner's assertion, this listing of terms in the Feasibility Study provides no motivation to combine these two references.

173. In addition, a person of ordinary skill in the art would not have been motivated to combine Lee with the Feasibility Study merely because the Feasibility Study teaches that "carrier aggregation may provide benefits, such as wider transmission bandwidths and spectrum aggregation" or to "unlock the features of LTE-Advanced." In my opinion, these describe generalized benefits that are not directed with any particularity at the amplifier circuit of Lee (or any other particular

circuitry); thus, they do not provide any motivation to combine these two references specifically.

174. Finally, I disagree with the Petitioner's contention that a person of ordinary skill in the art "would have been motivated to use the input RF signal employing carrier aggregation of the Feasibility Study with the amplification blocks of Lee" and "would have had a reasonable expectation of success" in that implementation. Ex. 1302 ¶¶ 135, 136. Lee relates to an amplification circuit capable of receiving and amplifying multiple signals (WiFi and Bluetooth); these signals are used for purposes other than achieving faster data rates. In particular, Lee discloses an "LNA shared between different radio connections, such as the Bluetooth connection and the WiFi connection" in order to "reduce the hardware cost and the chip size of the multi-radio device." Ex. 1335 at [0002]. One of skill in the art at the time of Lee (2012) would understand that as WiFi and Bluetooth were using the same frequency band (the 2.4 GHz ISM band), some way of sharing components (as opposed to providing two completely-independent radio receivers) would be desirable – for the exact reasons that Lee cites (to "reduce the hardware cost and chip size of the multi-radio device"). *Id*. Nothing in Lee suggests that his circuitry can be reused for purposes that are not disclosed in Lee - such as carrier aggregation (which, again, is a term that does not appear in Lee).

175. Furthermore, the "different radio connections" taught by Lee refer to separate signals with separate data streams, which the amplifier circuit of Lee is designed to receive alternately or simultaneously – while specifically teaching circuitry that will keep the output current at either output at the same level, regardless of whether one or both output paths are active. A person of ordinary skill in the art would not have combined Lee with carrier aggregation, which, as discussed above, uses different parts of the frequency spectrum to provide an increased data rate for a single data stream; this would also defeat the purpose of Lee – which is ultimately about *separation* rather than *aggregation.*

176. Thus, the Petitioner has failed to sufficiently articulate why a person of skill in the art would have been motivated to combine Lee and the Feasibility Study – as these are distinctly different references. As explained above, someone of skill in the art would not have had any reason to select these references for a combination that would allegedly render the claims obvious.

XII. CONCLUSION

177. Accordingly, the Petitioner has not shown that the claims are unpatentable as either anticipated or obvious over these two references – either individually (in the case of Lee alone) or in the case of the combination (Lee and the Feasibility Study).

Appendix A

DANIEL FOTY, Ph.D.

SUMMARY

Dr. Foty has more than 25 years of engineering and management experience in the mainstream of the technology industry. During this time, he has worked in semiconductor physics, device design, process integration, modeling/simulation (process, device, and circuit), circuit design/analysis, and wireless communications. After seven years at the microelectronics unit of IBM, he founded his own consulting firm, Gilgamesh Associates, LLC, which works in very demanding areas of technology design and development such as analog, mixed-signal, RF, signal processing, wireless communications, and ultra-low-power design.

Dr. Foty is also an advisor to the Tallinn University of Technology (Estonia) and the University of Pretoria (South Africa). He is also the author of *MOSFET Modeling with SPICE: Principles and Practice*, the more-recent *Moore's Law: The Untold* Story, and several other books. He has also authored well over 100 journal articles and conference presentations, and is a frequent plenary (keynote) speaker at major international conferences throughout the world. He is also a licensed pilot, who possesses both an instrument rating and a seaplane rating.

Expertise

- Analog/Mixed-Signal/RF CMOS
- CMOS Integrated Circuit Design
- IC Modeling/Simulation
- CMOS Technology and Process Integration
- Semiconductor Manufacturing/Fabrication
- Nanotechnology
- Design Automation (CAD) Software
- Semiconductor Memory (DRAM, SRAM, Flash)
- Semiconductor Physics
- RF/Radio Technology and Wireless Communications
- Power Management
- Cryogenic Electronics
- Technology, Economics and Public Policy
- Prior Art Search – Patents/Literature

PROFESSIONAL EXPERIENCE

1994 to Present **Gilgamesh Associates, LLC**
President

- Analysis of analog/mixed-signal/RF CMOS circuits
- New technologies in high-speed wireless data communications
- Specialized process-design-kits (PDKs) for circuit design/simulation
- Foundry interfacing for fabless IC design companies
- Professional education via short courses and lectures
- Litigation support in various aspects of the integrated circuit industry

1988 to 1994 **IBM Microelectronics Division**
Scientist/Engineer

- Process integration, device design, semiconductor/IC physics
- Process and device simulation; circuit simulation
- Process and device integration for memory and logic technologies
- Process-design-kits (PDKs) for circuit simulation
- Spearheaded initial IBM foray into OEM foundry market; responsible for all "external customer" PDKs and support/interfacing; business grew from nothing to $66M in revenue in first year.

EDUCATION

Ph.D., Materials Science, University of Vermont, 2001
MS, Electrical Engineering, University of Illinois, 1985
BS, Physics and Chemistry, Bates College, 1983

LITIGATION RELATED EXPERIENCE

Dr. Foty has served as a testifying expert, and provided declarations, expert reports, trial testimony, and arbitration-hearing testimony for cases that have touched on the complete spectrum of semiconductor/electronics engineering issues, electronic design automation software, wireless technology, contract interpretations and business processes, and prior art searches in both patents and the public-domain literature. He has also served as a consulting expert. Dr. Foty has been deposed more than twenty times, and has testified at trial five times. Below are matters in which he has written expert reports and given testimony either at deposition, trial, or before an arbitration panel.

Type of Matter:	*Inter Partes* review involving wireless/RF technology
Law Firm:	Jones, Day LLP, Cleveland, Ohio
Case Name:	Intel v. Qualcomm
Represented:	Patent holder
Disposition:	Ongoing.
Date:	June 2019 – present.

Type of Matter:	Patent infringement involving integrated circuit technology (ITC matter)
Law Firm:	Pepper Hamilton LLP, Boston, Massachusetts
Case Name:	Tela v. Intel
Represented:	Patent holder
Disposition:	Prepared several declarations; ongoing.
Date:	March 2018 – present.

Type of Matter:	Patent infringement involving RF/wireless technology (ITC matter)
Law Firm:	Quinn Emanuel Urquhart & Sullivan LLP, New York, New York
Case Name:	Qualcomm v. Apple
Represented:	Patent holder
Disposition:	Prepared two expert reports regarding RF-IC/wireless technology; deposed; testified at the hearing/trial in September 2018.
Date:	January 2018 – September 2018.

Type of Matter:	Patent infringement involving integrated circuit technology and printed-circuit board technology
Law Firm:	Dovel and Luner, LLP, Santa Monica, California
Case Name:	X2Y v. Intel
Represented:	Patent holder
Disposition:	Ongoing.
Date:	June 2017 – present.

Type of Matter:	Patent infringement involving integrated circuit technology
Law Firm:	Jones, Day LLP, San Francisco, California, and Slater Matsil LLP,

	Dallas, Texas
Case Name:	IPBridge v. Xilinx
Represented:	Respondent
Disposition:	Ongoing.
Date:	February 2017 – present.
Type of Matter:	Patent infringement involving analog circuits
Law Firm:	Covington & Burling LLP, San Diego, California
Case Name:	Tessera v. Broadcom
Represented:	Patent holder
Disposition:	Settled.
Date:	December 2016 – December 2017.
Type of Matter:	Patent infringement involving integrated circuit design methods and integrated circuit design-automation software
Law Firm:	Jones, Day LLP, Cleveland, Ohio
Case Name:	Synopsys v. ATopTech
Represented:	Patent holder
Disposition:	Prepared an expert report; deposed; matter was suspended when ATopTech filed for Chapter 11 bankruptcy.
Date:	June 2016 – March 2017.
Type of Matter:	Patent infringement involving integrated circuit process/manufacturing technology for wireless communications
Law Firm:	McKool Smith, LLP, Dallas, Texas
Case Name:	Ericsson v. TCL
Represented:	Plaintiff
Disposition:	Prepared an expert report regarding the costs and timelines associated with the development of integrated circuits for wireless communications, and the related difficulties encountered.
Date:	November 2015 – present.
Type of Matter:	*Inter Partes* review involving integrated circuit design methods and integrated circuit design-automation software
Law Firm:	Jones, Day LLP, Cleveland, Ohio
Case Name:	ATopTech v. Synopsys
Represented:	Patent holder
Disposition:	Prepared two declarations; deposed.
Date:	November 2014 – January 2016.
Type of Matter:	*Inter Partes* review involving a semiconductor flash memory technology patent
Law Firm:	Aka Chan LLP, Santa Clara, California
Case Name:	Silicon Motion Technology Corp. v. Phison Electronics Corp.
Represented:	Petitioner
Disposition:	Prepared a declaration; deposed; hearing before the PTAB in September 2014, PTAB ruled completely in Petitioners' favor

Date:	May 2014 – September 2014.
Type of Matter:	Patent infringement involving integrated circuit design
Law Firm:	Bragalone, Conroy, PC, Dallas, Texas
Case Name:	HSM v. Elpida Memory et al. (was HSM v. Fujitsu et al.)
Represented:	Plaintiff
Disposition:	Prepared numerous declarations and two expert reports; deposed; all respondents eventually settled.
Date:	February 2012 – February 2016.
Type of Matter:	Patent infringement involving integrated circuit process/manufacturing technology (ITC matter)
Law Firm:	McKool Smith, LLP, Dallas, Texas
Case Name:	Samsung v. Ericsson
Represented:	Defendant
Disposition:	Was assigned one patent in a larger matter, having done much original engineering work on the technology in question; produced extensive background prior art (having created much of it), demonstrated that the accused technology clearly did not practice the teachings of the patent, and clearly showed that the aforementioned prior art would call the patent's validity seriously into question; plaintiff dropped that patent from the action.
Date:	January 2013 – May 2013.
Type of Matter:	Patent infringement involving integrated circuit design, with a focus on RF-ICs for wireless communications
Law Firm:	Antonelli, Harrington, & Thompson, LLP, Houston, Texas
Case Name:	Semiconductor Ideas to the Market, BV v. Texas Instruments et al.
Represented:	Plaintiff
Disposition:	Prepared a declaration for pre-hearing; major defendant (Qualcomm) settled following this expert's examination of their Confidential Business Information (CBI) in June, 2012; other defendants settled shortly thereafter.
Date:	May 2012 – August 2012.
Type of Matter:	Bond forfeiture proceeding (ITC matter)
Law Firm:	Adduci, Mastriani, & Schaumberg, LLP, Washington, D.C.
Case Name:	Tessera v. Freescale
Represented:	Plaintiff
Disposition:	Following unfavorable ITC ruling, respondent argued that posted bond (pending final disposition) should be returned to them; prepared a declaration for hearing; ITC ruled against respondent, who then agreed to cease litigation and forfeit the bond.
Date:	April 2012 – October 2012.
Type of Matter:	Theft of trade secrets involving integrated circuit design, manufacturing, and characterization technology

Law Firm:	Shore, Chan, Bragalone, and DePumpo, LLP, Dallas, Texas
Case Name:	Xicor v. SST
Represented:	Plaintiff
Disposition:	Prepared a declaration for hearing regarding plaintiff's identification of its trade secrets; following favorable ruling on this, defendant agreed to settle on terms favorable to the plaintiff
Date:	February 2012 – September 2012.
Type of Matter:	Patent infringement in integrated circuit substrates (ITC matter)
Law Firm:	Alston + Bird, LLP, Atlanta, Georgia
Case Name:	X2Y v. Intel
Represented:	Plaintiff
Disposition:	Consulted on technology involved
Date:	August 2011 – August 2012.
Type of Matter:	Theft of trade secrets involving design of power management integrated circuits (ITC enforcement proceeding)
Law Firm:	Alston + Bird, LLP, Menlo Park, California
Case Name:	Richtek v. uPI, and Sapphire Technology
Represented:	Plaintiff
Disposition:	Prepared an expert report and a supplemental expert report; deposed; testified at hearing/trial; subsidiary respondent Sapphire settled and exited the case shortly before trial.
Date:	June 2011 – March 2012; follow-on district/superior court cases temporarily stayed, but pending.
Type of Matter:	Patent infringement in switching power supplies
Law Firm:	McDermott, Will & Emery, LLP, Miami, Florida
Case Name:	Power Integrations, Inc. v. Fairchild Semiconductor International, Inc.
Representing:	Defendant
Disposition:	Presented the tutorial at the Markman hearing in San Jose, California (Northern District of California) in March; matter ongoing, but no longer involved.
Date:	December 2010 – March 2011.
Type of Matter:	Patent infringement in the power management methodologies of portable/mobile device (ITC matter)
Law Firm:	Finnegan, Henderson, Farabow, Garrett & Dunner, LLP, Washington, D.C.
Case Name:	HTC v. Apple
Represented:	Plaintiff
Disposition:	Deposed in March; testified at trial/hearing (ITC) in May; outcome pending.
Date:	November 2010 – May 2011.

Type of Matter:	Theft of trade secrets involving design of power management integrated circuits (ITC matter)
Law Firm:	Alston + Bird, LLP, Menlo Park, California
Case Name:	Richtek v. uPI, AMD, Sapphire Technology, Diamond Multimedia, and XFX Technology
Represented:	Plaintiff
Disposition:	Prepared an expert report and a supplemental expert report; deposed twice (three days total); subsidiary respondents settled and exited the case during May 2010 – July 2010; main respondent uPI agreed on 21 July 2010 to a Consent Order that included a ten-year ban on importation of the accused products to avoid an ITC hearing.
Date:	January 2010 – July 2010; ITC enforcement proceeding opened against uPI and Sapphire, June 2011 – March 2012 (see above); follow-on district/superior court cases temporarily stayed, but pending.

Type of Matter:	Patent infringement and theft of trade secrets involving integrated circuit manufacturing
Law Firm:	Keker and Van Nest, LLP, San Francisco, California
Case Name:	TSMC v. SMIC
Represented:	Plaintiff
Disposition:	Deposed; testified at trial September 2009; jury returned guilty verdict on all 18 counts; parties settled during damages phase of trial.
Date:	July 2007 – September 2009.

Type of Matter:	Theft of Trade Secrets
Law Firm:	Baker & McKenzie, LLP, San Diego, California
Case Name:	Neology Inc. v. B. Roesner et al.
Represented:	Plaintiff
Disposition:	Reviewed materials produced during discovery and found considerable facially-labeled trade secret material in the possession of the defendant. Case Settled
Date:	April 2007 – May 2007

Type of Matter:	Theft of Trade Secrets
Law Firm:	Weil, Gotshal, and Manges, LLP, New York, New York
Case Name:	Synopsys v. Nassda
Represented:	Defendant
Disposition:	Wrote an expert report on behalf of defendant but was not deposed. Case Settled
Date:	September 2003 - August 2004

Type of Matter:	Theft of Trade Secrets
Law Firm:	Howrey, Simon, Arnold & White, LLP, Menlo Park, California

Case Name:	Silvaco, Inc. v. Circuit Semantics, Inc.
Represented:	Defendant
Disposition:	Wrote an expert report on behalf of defendant and was deposed. Case Settled
Date:	February 2003 - September 2003
Type of Matter:	Contract dispute, Copyright Infringement, and Theft of Trade Secret matter involving integrated circuit design tools
Law Firm:	Russo & Hale, LLP, Palo Alto, California
Case Name:	Virtual Silicon Technology, Inc. v. Library Technologies, Inc.,
Represented:	Plaintiff
Disposition:	On behalf of plaintiff, wrote an expert report, was deposed and testified at arbitration hearing. Decision of binding arbitration released in November 2003; all findings-of-fact in favor of the plaintiff.
Date:	December 2002 - November 2003

PUBLICATIONS

Books

1. D. Foty, "Moore's Law: The Untold Story," August 2017.

2. D. Foty, "The Rise and Fall of Classical Athens: A Short History," January 2018.

3. D. Foty, "Thomas Seebeck: His Life and Science," September 2018.

4. D. Foty, "Essential Digital, Analog, and Semiconductor Electronics Technology," Chapter 19 in *Concise Higher Electrical Engineering* (ed. by E. Chikuni, M. Khan, and O. Okoro), Juta Academic, 2008.

5. D. Foty, *MOSFET Modeling with SPICE: Principles and Practice*, Prentice-Hall (now Pearson Education), 1997 (now in its third printing; Vietnamese-language edition published in 2006).

6. Proceedings of the Symposium on Low Temperature Electronics and High Temperature Superconductors (ed. by S. Raider, C. Claeys, D. Foty, T. Kawai, and R. Kirschman) (published in October 1993).

7. Proceedings of the Symposium on Low Temperature Electronic Device Operation (ed. by D. Foty) (published in December 1991).

Guest Journal Editor

1. Guest editor, special issue on Low Voltage/Low Power Design, Analog Integrated Circuits and Signal Processing, December 1999.

Refereed Journal Publications

1. D. Foty, "Nanoscale Electron Devices: Difficulties, Granularities, and Applications" (Invited Paper), Romanian Journal of Information Sciences and Technology, (published by the Romanian Academy of Sciences), January 2009, vol. 12(3), pp. 317 – 338.

2. D. Foty, "An Evaluation of Deep-Submicron CMOS Design Optimized for Operation at 77K" (Invited Paper), Analog Integrated Circuits and Signal Processing vol. 49, pp. 97 – 105 (2006).

3. D. Foty and K. Runge, "What's Ahead in High-Speed Wireless Data Communications? The Future Will Be Better Tomorrow – And Different Than What We've Been Expecting" (Invited Paper), the African Journal of Information and Communications Technology (online publication).

4. S. Terry, J. Rochelle, D. Binkley, B. Blaylock, D. Foty, and M. Bucher, "Comparison of a BSIM3V3 and EKV MOST Model for a 0.5μm Process and Implications for Analog Circuit Design," IEEE Transactions on Nuclear Science vol. NS-50, pp. 915 - 920 (2003).

5. D. Binkley, C. Hopper, S. Tucker, B. Moss, J. Rochelle, and D. Foty, "A CAD Methodology for Optimizing Transistor Current and Sizing in Analog CMOS Design," IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems vol. CAD-22, pp. 225 – 237 (2003).

6. D. Foty, "Perspectives on Analytical Modeling of Small Geometry MOSFETs in SPICE for Low Voltage/Low Power CMOS Circuit Design" (Invited Paper), Analog Integrated Circuits and Signal Processing vol. 21, pp. 229 – 252 (1999).

7. D. Foty, "Taking a Deep Look at Analog CMOS," IEEE Circuits and Devices, March 1999, pp. 23 – 28.

8. D. Foty, "MOSFET Modeling for Circuit Simulation: Where Do We Go From Here?," IEEE Circuits and Devices, July 1998, pp. 26 – 31.

9. G. Gildenblat and D. Foty, "Low Temperature Models of Metal-Oxide-Semiconductor Field-Effect Transistors" (Invited Paper), The International Journal of High Speed Electronics and Systems vol. 6, pp. 317 - 373 (1995).

10. D. Foty and E. Nowak, "MOSFET Technology for Low Voltage/Low Power Applications" (Invited Paper), IEEE Micro, June 1994, pp. 68 - 77.

11. D. Foty, P. Wyns, and K. Oughstun, "On the Propagation of Short Optical Pulses in a Linear Dispersive Medium," IEEE Journal of Quantum Electronics vol. 28, pp. 1619 - 1622 (1992).

12. E. Farrell, P. Appino, D. Foty, and T. Linton, "Visual Interpretation of Multi-Dimensional Computations and Transistor Design," IBM Journal of Research and Development vol. 35, pp. 26 - 44 (1991).

13. D. Foty, "Impurity Ionization in MOSFETs at Very Low Temperatures," Cryogenics vol. 30, pp. 1056 - 1063 (1990).

14. D. Cole, E. Buturla, S. Furkay, K. Varahramyan, J. Slinkman, J. Mandelman, D. Foty, O. Bula, A. Strong, J. Park, T. Linton, J. Johnson, M. Fischetti, S. Laux, P. Cottrell, H. Lustig, F. Pileggi, and D. Katcoff, "The Use of Simulation in Semiconductor Technology Development" (Invited Paper), Solid State Electronics vol. 33, pp. 591 - 623 (1990).

15. K. Oughstun, P. Wyns, and D. Foty, "Numerical Determination of the Signal Velocity in Linear Dispersive Pulse Propagation," Journal of the Optical Society of America A vol. 6, pp. 1430 - 1440 (1989).

16. P. Wyns, D. Foty, and K. Oughstun, "Numerical Analysis of the Precursor Fields in Dispersive Pulse Propagation," Journal of the Optical Society of America A vol. 6, pp. 1421 - 1429 (1989).

17. D. Foty, "Thermal Effects in p-Channel MOSFETs at Low Temperatures," IEEE Transactions on Electron Devices vol. 36, pp. 1542 - 1544 (1989).

18. D. Foty and S. Titcomb, "Thermal Effects in n-Channel Enhancement MOSFETs Operated at Cryogenic Temperatures," IEEE Transactions on Electron Devices vol. 34, pp. 107 - 114 (1987).

Refereed Conference Proceedings

1. D. Foty, "Amplification, Feedback, and Sub-Biasing: Applying Analog Techniques to High-Speed, Low-Power Digital CMOS Circuits," *Invited Conference Plenary Lecture,* Proceedings of the 13th International Symposium on Signals, Circuits, and Systems, pp. 123 - 128 (published July 2017).

2. D. Foty, "The Future of 'Moore's Law' – Does It Have One?" *Invited Conference Plenary Lecture,* Proceedings of the 11th International Symposium on Signals, Circuits, and Systems, pp. 1 - 8 (published July 2013).

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Co-Authored Conference Presentations

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2. B.C. Mabuza, S. Sinha and D. Foty, "On-chip Impedance Tuning for mm-Wave Applications," presented at the South African Conference on Semiconductor and Superconductor Technology, Stellenbosch, South Africa 8 April 2009.

3. S. Terry, J. Rochelle, D. Binkley, B. Blaylock, D. Foty, and M. Bucher, "Comparison of a BSIM3V3 and EKV MOST Model for a 0.5µm Process and Implications for Analog Circuit Design," presented at the IEEE Nuclear Science Symposium, Norfolk, Virginia, 15 November 2002.

4. M. Bucher, D. Kazazis, F. Krummenacher, D. Binkley, D. Foty, and Y. Papananos, "Analysis of Transconductances at All Levels of Inversion in Deep Submicron CMOS," presented at the 9th International Conference on Electronics, Circuits, and Systems, Dubrovnik, Croatia, 18 September 2002.

5. D. Binkley, M. Bucher, and D. Foty, "Design-Oriented Characterization of CMOS Over the Continuum of Inversion Level and Channel Length," presented at the 7th International Conference on Electronics, Circuits, and Systems, Kaslik, Lebanon, 18 December 2000.

6. G. Gildenblat, M. Bradford, and D. Foty, "A New MOS C-V Simulator for Low Temperature Applications," presented at the Symposium on Low Temperature Electronics and High Temperature Superconductors, Honolulu, Hawaii, 20 May 1993.

Conference Panel Participation

1. Member of Panel Discussion, 2nd Regional African Conference of the International Telecommunications Society, Lusaka, Zambia, 15 March 2018.

2. Member of Panel Discussion, 12th International Conference on Synthesis, Modeling, Analysis, and Simulation Methods and Applications to Circuit Design, Istanbul, Turkey, 7 September 2015.

3. Member of Panel Discussion, Future Wireless Telecommunications, "Telecosm," Lake George, New York, 16 October 2007.

4. Moderator of Panel Discussion, International Workshop on System-on-Chip, Banff, Alberta, Canada, 22 July 2005.

5. Member of Panel Discussion, Custom Integrated Circuits Conference, San Jose, California, 23 September 2003.

6. Co-moderator of Panel Discussion, Fabless Semiconductor Association Modeling Workshop, Santa Clara, California, 9 September 2002.

7. Member of Panel Discussion, Workshop on Compact Modeling, International Conference on the Modeling and Simulation of Microsystems, San Juan, Puerto Rico, 23 April 2002.

8. Member of Panel Discussion, "Vermont's High-Tech Future – Does it Have One?," Room 11, the Statehouse, Montpelier, Vermont, 26 April 2001.

9. Member of Panel Discussion, Fabless Semiconductor Association Quarterly Meeting, San Jose, California, 5 September 1999.

10. Member of Panel Discussion, Fabless Semiconductor Association Modeling Workshop, San Jose California, 24 May 1999.

11. Member of Panel Discussion, Symposium on Low Voltage-Low Power Integrated Circuits at the 1993 European Solid State Device Research Conference, Grenoble, France, 16 September 1993.

12. Member of Panel Discussion, Symposium on Low Temperature Electronics and High Temperature Superconductors, Honolulu, Hawaii, 19 May 1993.

Invited Seminars/Lectures

1. "Digital Semiconductor Electronics: Why It Happened, And Where It's Going," short course hosted by the University of Pretoria, Pretoria, South Africa, 15 August 2011.

2. "The Untold Story of 'Moore's Law': *Why* It Happened," short course hosted at the summer school of the Universitatea Politehnica Bucureşti, held in Iaşi, Romania, 4 – 5 July 2011.

3. "Some Background Thoughts On mm-Wave Radio Technology," seminar presented at the University of Pretoria, Pretoria, South Africa, 17 August 2010.

4. "Digital Semiconductor-Based Electronics: Why It Became A Juggernaut," short course hosted by the University of Pretoria, Pretoria, South Africa, 16 August 2010.

5. “Some Thoughts On mm-Wave Radio Technology,” short course hosted at the summer school of the Universitatea Politehnica Bucureşti, held in Oradea, Romania, 13 July 2010.

6. “Silicon-Based Semiconductor Electronics – How It Came To Dominate,” short course hosted at the summer school of the Universitatea Politehnica Bucureşti, held in Oradea, Romania, 12 July 2010.

7. “The Powerful Entropy Challenge: Dealing With Power Consumption,” presented at the IEEE South Africa Section Meeting, Pretoria, South Africa, 18 August 2009.

8. "Digital CMOS Electronics: The Background Story," short course hosted by the University of Pretoria, Pretoria, South Africa, 17 August 2009.

9. “An Overview of mm-Wave Radio Technology,” short course hosted at the summer school of the Universitatea Politehnica Bucureşti, held in Iaşi, Romania, 13 July 2009.

10. “Modern Electronics: How We Got Here,” short course hosted at the summer school of the Universitatea Politehnica Bucureşti, held in Iaşi, Romania, 13 July 2009.

11. “Prospects for mm-Wave Radio Technology: An Overview,” short course hosted at the summer school of the Universitatea Politehnica Bucureşti, held in Oradea, Romania, 22 July 2008.

12. “Into the NanoSmall: The Unexpected Challenges,” short course hosted at the summer school of the Universitatea Politehnica Bucureşti, held in Oradea, Romania, 22 July 2008.

13. “A Concise History of Modern Electron Devices,” short course hosted at the summer school of the Universitatea Politehnica Bucureşti, held in Oradea, Romania, 22 July 2008.

14. "Issues In mm-Wave Radio Systems: Prospects and Challenges," short course hosted by the University of Pretoria, Pretoria, South Africa, 8 May 2008.

15. "Prospects for mm-Wave Radio Technology: An Executive Summary for Decision-Makers," presented at the IEEE Region 8 meeting, University of Pretoria, Pretoria, South Africa, 8 May 2008.

16. “The MOS Transistor, On a Tourist Visa,” short course hosted at the summer school of the Universitatea Politehnica Bucureşti, held in Iaşi, Romania, 16 July 2007.

17. "Semiconductor Electronics: Some Fundamental Background," short course hosted at the summer school of the Universitatea Politehnica Bucureşti, held in Iaşi, Romania, 16 July 2007.

18. "The MOS Transistor and CMOS Technology: Past, Present, and Future," short course hosted by Tallinn University of Technology, Tallinn, Estonia, 13 – 14 November 2006.

19. "New Directions in Technology for High-Speed Wireless Data Communications," seminar presented at the Universitatea Politehnica Bucureşti, Bucharest, Romania, 28 July 2006.

20. "The MOS Transistor and CMOS Technology: History as a Guide to the Future," short course hosted at the summer school of the Universitatea Politehnica Bucureşti, held in Braşov, Romania, 25 July 2006.

21. "The Underpinnings of the MOS Transistor and CMOS Technology in the 21st Century - Scaling Theory and New Methods in Analog/RF Design," short course hosted by l'École Polytechnique de Montréal, Montréal, Québec, Canada; sponsored by ReSMiQ and the local IEEE Solid State Circuits Society chapter, 27 October 2005.

22. "The Underpinnings of the MOS Transistor and CMOS Technology in the 21st Century – Scaling Theory and New Methods in Analog/RF Design," short course hosted by the Department of Electrical, Electronic, and Computer Engineering, University of Pretoria, Pretoria, South Africa, and sponsored by the IEEE South Africa Section, 9 – 10 May 2005.

23. "What's Ahead in High-Speed Wireless Data Communications? The Future Will Be Better Tomorrow – And Different Than What We've Been Expecting," seminar presented at the Department of Electrical Engineering, University of Cape Town, Cape Town, South Africa, 7 May 2005.

24. "Low Temperature CMOS: A Bad Idea Whose Time Has (Finally) Come?", seminar presented at the Department of Computer-Aided Design, L'viv Polytechnic National University, L'viv, Ukraine, 28 February 2005.

25. "The Underpinnings of the MOS Transistor and CMOS Technology in the 21st Century – Scaling Theory and New Methods in Analog/RF Design," Full-day "Eurotraining" course, held at the Danish Technical University, Lyngby, Denmark, 27 October 2004.

26. "The Underpinnings of the MOS Transistor and CMOS Technology in the 21st Century – Scaling Theory and New Methods in Analog/RF Design," Full-day "Eurotraining" course, held at the Politechnico di Torino, Turin, Italy, 25 October 2004.

27. "CMOS Scaling and Low Temperature CMOS: A Bad Idea Whose Time Has Come?", seminar presented at the Department of Electrical and Computer Engineering, Oakland University, Auburn Hills, Michigan, 25 March 2004.

28. "Modernizing the Interpretation of the MOS Transistor for the 21st Century: Generalized Methods and Their Extension to Nanotechnology," presented at the IEEE Southeast Michigan Spring Section Meeting, Auburn Hills, Michigan, 24 March 2004.

29. "Re-Interpreting the MOS Transistor for the 21st Century: Generalized Methods and Their Extension to Nanotechnology," seminar presented at Tallinn Technical University, Tallinn, Estonia, 13 November 2003.

30. "Re-Interpreting the MOS Transistor for the 21st Century: Generalized Methods and Their Extension to Nanotechnology," seminar presented at Helsinki University of Technology, Espoo, Finland, 7 November 2003.

31. "A Practical Examination of MOS Transistor Model 'Accuracy' in Modern CMOS Technology," presented at the MOS Arbeitskreis Meeting, Crolles, France, 5 May 2003.

32. "Building a New Framework for Deep Submicron Analog/RF CMOS Design – and Beyond," invited seminar presented at the Department of Electrical Engineering, Columbia University, New York, New York, 25 April 2003.

33. "A New Framework for Deep Submicron Analog/RF CMOS Design – and Beyond," seminar presented at the Department of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, Georgia, 20 March 2003.

34. "Starting Over: Modernizing the Framework for Deep Submicron Analog CMOS Design," seminar presented at the Nokia Research Center, Helsinki, Finland, 29 November 2002.

35. "Modernizing the Framework for Deep Submicron Analog CMOS Design," Distinguished Guest Lecturer, IEEE Baltic Region Meeting (sponsored by Tallinn Technical University), Sagadi, Estonia, 19 – 20 August 2002.

36. "Modernizing the Framework for Deep Submicron Analog CMOS Design," seminar presented at Helsinki University of Technology, Espoo, Finland, 16 August 2002.

37. "gm/Id-Based MOSFET Modeling and Modern Analog Design," presented at the MOS Arbeitskreis Meeting, Ünterpremstatten, Austria, 19 November 2001.

38. "MOS Modeling and Analog Circuit Design," lecture as part of "Practical Aspects of Analog Design," professional short course sponsored by Mead Microelectronics, San Francisco, California, 13 November 2001.

39. "MOS Modeling and Analog Circuit Design," lecture as part of "Transistor-Level Analog IC Design," professional short course sponsored by Mead Microelectronics, Lausanne, Switzerland, 10 October 2001.

40. "Please Stop Imitating Us!' – An Engineer Looks at the (Unstable) State of the Humanities," presented at a meeting of the National Association of Scholars, Burlington,Vermont, 14 July 2001.

41. "Introduction to the Fabless Semiconductor Association (FSA) and the Modeling Committee Activities," presented at the MOS Arbeitskreis Meeting, Munich, Germany, 5 March 2001.

42. "The EKV MOSFET Model: A MOS Model of, by, and for Analog Designers," presented at Broadcom Corp., Irvine, California, 30 November 2000.

43. "Modeling and Simulation for Mixed-Signal IC Design," lecture as part of "Transistor-Level Analog IC Design," professional short course sponsored by Mead Microelectronics, Lausanne, Switzerland, 27 September 2000.

44. "MOS Models as a Factor in the Quality of Electronic Design," presented at the Rockwell Scientific Center, Thousand Oaks, California, 17 March 2000.

45. "MOS Models as a Factor in the Quality of Electronic Design," presented at Micron Technology, Inc., Boise Idaho, 4 March 2000.

46. "Modeling and Simulation for Mixed-Signal IC Design," lecture as part of "Practical Aspects of Analog and Mixed-Signal ICs," professional short course sponsored by Mead Microelectronics, Monterey, California, 3 February 2000.

47. "Modeling and Simulation for Mixed-Signal IC Design," lecture as part of "Transistor-Level Analog IC Design," professional short course sponsored by Mead Microelectronics, Lausanne, Switzerland, 30 September 1999.

48. "AC Simulation Aspects of MOS Modeling," presented at the Fabless Semiconductor Association Modeling Workshop, San Jose, California, 25 May 1999.

49. D. Foty, M. Bucher, and C. Enz, "The EKV MOSFET Model – A MOS Model for the Analog Designer," presented at the Fabless Semiconductor Association Modeling Workshop, San Jose, California, 25 May 1999.

50. Several lectures on MOS device physics, modeling, and analog design, presented at Mentor Graphics, Heliopolis, Cairo, Egypt, 5 – 8 May 1999.

51. "A Brief History of MOS Modeling (or, How We Got In This Mess In the First Place)," presented at Philips Research Laboratories, Eindhoven, The Netherlands, 24 March 1999.

52. "An Overview of MOS Modeling for SPICE Circuit Simulation," presented at Mitel Corporation, Bromont, Québec, Canada, 2 February 1999.

53. "Modeling and Simulation for Mixed-Signal IC Design," lecture as part of "Practical Aspects of Analog and Mixed-Signal ICs," professional short course sponsored by Mead Microelectronics, Monterey, California, 12 December 1998.

54. "MOS Modeling Challenges for Deep Submicron CMOS," lecture presented as part of "Deep Submicron CMOS Design," professional short course sponsored by Mead Microelectronics, Lausanne, Switzerland, 12 October 1998.

55. "Modeling the Temperature-Dependent Characteristics of MOSFETs for Circuit Simulation," presented at the Electronic Parts Selection and Management Workshop, Center for the Analysis of Life-Cycle Engineering, University of Maryland, College Park, Maryland, 17 June 1998.

56. "A Primer on Trench Isolation Technology (or, Why Do Process Engineers Hate Circuit Designers?)," presented at the Fabless Semiconductor Association Modeling Subcommittee Meeting, Opti, Inc., Milpitas, California, 12 May 1998.

57. C. Enz, M. Bucher, and D. Foty, "The EKV MOSFET Model for Analog and Mixed-Mode Circuit Design," satellite broadcast class, National Technological University (hosted by North Carolina State University, Raleigh, North Carolina), 30 April 1998.

58. "MOS Modeling Challenges for Deep Submicron CMOS Circuit Simulation," presented at Digital Equipment Corporation, Hudson, Massachusetts, 13 April 1998.

59. "Challenges for 0.25µm CMOS Circuit Design: Scaling, MOS Modeling, and Complexity," presented at CERN, Geneva, Switzerland, 6 February 1998.

60. "MOS Modeling Challenges for Deep Submicron CMOS," lecture presented as part of "Deep Submicron CMOS Design," professional short course sponsored by Mead Microelectronics, Monterey, California, 11 December 1997.

61. C. Enz, M. Bucher, and D. Foty, "The EKV MOSFET Model for Analog and Mixed-Mode Circuit Design," one-day short course sponsored by the Fabless Semiconductor Association, San Jose, California, 8 November 1997.

62. "MOS Modeling Issues in the Emerging Analog and Low Power Era," presented Taiwan Semiconductor Manufacturing Company, Hsinchu, Taiwan, 27 August 1997.

63. "Current Problems in MOSFET Modeling for Analog Circuit Simulation," presented at Level One Communications, Inc., Sacramento, California, 9 August 1997.

64. Guest lecturer, Centre National pour les Récherches Scientifique (CNRS) Summer Lecture Series, La Londe des Maures, France, 23 – 28 June 1997.

65. "MOSFET Modeling and Analog Circuit Design," presented at the Centre National pour les Récherches Scientifique (CNRS) Summer Lecture Series, La Londe des Maures, France, 27 June 1997.

66. "Benchmarking and Pre-Screening SPICE FET Models for Circuit Simulation Usage," presented at the Fabless Semiconductor Association Modeling Subcommittee Meeting, Adaptec, Inc., Milpitas, California, 6 May 1997.

67. "Benchmarking and Pre-Screening SPICE FET Models for Circuit Simulation Usage," presented at Cirrus Logic, Inc., Fremont, California, 6 May 1997.

68. "MOSFET Modeling and SPICE: Are You an Educated Model Consumer?," presented at Cirrus Logic, Inc., Fremont, California, 6 May 1997.

69. "MOS Modeling and SPICE: Are You an Educated Model Consumer?," satellite broadcast class, National Technological University (hosted by North Carolina State University, Raleigh, North Carolina), 21 April 1997.

70. "An Overview of the SPICE FET Modeling Infrastructure" lecture presented as part of "Modeling and Simulation of MOS Analog ICs," professional short course sponsored by Mead Microelectronics, Lausanne, Switzerland, 18 February 1997.

71. "An Overview of the SPICE FET Modeling Infrastructure" lecture presented as part of "Modeling and Simulation of MOS Analog ICs," professional short course sponsored by Mead Microelectronics, Monterey, California, 12 December 1996.

72. "Analytical MOSFET Modeling and SPICE - Past, Present, and Future", seminar presented at the Department of Electrical Engineering, Ohio State University, Columbus, Ohio, 9 May 1995.

73. "Constraints on CMOS Technology for Low Voltage/Low Power Applications", seminar presented at the Department of Electrical Engineering, Ohio State University, Columbus, Ohio, 8 May 1995.

74. "Submicron FET Design: Physical Considerations and Technological Choices", seminar presented at the Electrical Engineering Department, University of Hawaii, Honolulu, Hawaii, 24 May 1993.

75. "Aspects of the Design of Deep Submicron FETs for CMOS Operation at 300K and 77K", seminar presented at the Department of Electrical Engineering, Pennsylvania State University, University Park, Pennsylvania, 10 November 1992.

PROFESSIONAL AFFILIATIONS & AWARDS

Honorary Member of the Applied Radio Electronics Science Academy of Ukraine

Senior Member, The Institute of Electrical and Electronic Engineers (IEEE); and of the Electron Devices, Lasers and Electro-Optics, Circuits and Systems, and Communications Societies of the IEEE.

Reviewer/evaluator of funding proposals, Natural Science and Engineering Research Council of Canada, 1991 - present.

Reviewer/evaluator of funding proposals, California MICRO program, 2001 - present.

Reviewer/evaluator of funding proposals, National Research Foundation of South Africa, 2007- present.

Industrial and Academic Mentoring

Member of the Advisory Board, Department of Electrical, Electronic & Computer Engineering, University of Pretoria, South Africa, 2012 – present.

Advisor to the Tshwane University of Technology, Pretoria, South Africa, 2007 - present.

Advisor to the University of Pretoria, Pretoria, South Africa, 2005 – present.

Advisor to the Tallinn University of Technology, Tallinn, Estonia, 2004 – present.

Industrial Mentor for "Development and Applications of a New MOS C-V Simulator for the 2 - 300K Temperature Range" (Professor Gennady Gildenblat, Principal Investigator, Department of Electrical Engineering, Pennsylvania State University, University Park, Pennsylvania), funded by the IBM Shared University Research Contract program, calendar year 1992.

Committees/Conferences

1. Member of the Organizing Committee, and Chair of the Track on Electromagnetics and Antennas, Africon 2011, Victoria Falls, Zambia, September 2011.

2. Member of the Organizing Committee, and Chair of the Track on Electron Devices and Circuits, Africon 2009, Nairobi, Kenya, September 2009.

3. Session Chair, 31st International Conference on Semiconductor Physics, Sinaia, Romania, 14 October 2008.

4. Session Chair, Africon 2007, Windhoek, Namibia, 27 September 2007.

5. Session Chair, 13th International Conference on the Mixed Design of Integrated Circuits and Systems, Gdynia, Poland, 24 June 2006.

6. Session Chair, International Workshop on System-on-Chip, Banff, Alberta, Canada, 22 July 2005.

7. Session Chair, 7th International Symposium on Signals, Circuits, and Systems, 4Iaşi, Romania, 15 July 2005.

8. Member of the Scientific Committee, European Conference on Circuit Theory and Design (ECCTD), 2005.

9. Special Session Organizer, 12th International Conference on the Mixed Design of Integrated Circuits and Systems, Krakow, Poland, 22 - 25 June 2005.

10. Special Session Organizer, International Symposium on Industrial Electronics, Dubrovnik, Croatia, 20 – 23 June 2005.

11. Session Chair, 12th International Conference on Telecommunications, Cape Town, South Africa, 4 – 6 May 2005.

12. Session Chair, 11th International Conference on Electronics, Circuits, and Systems, Tel Aviv, Israel, 13 - 15 December 2004.

13. Session Chair, the 12th International Symposium on Electron Devices for Microwave and Optoelectronic Applications, Berg-en-Dal, Kruger National Park, South Africa, 8 - 9 November 2004.

14. Member of the International Program Committee, International Conference on Mixed Design of Integrated Circuits and Systems, 2004 – present.

15. Member of the Technical Program Committee, International Symposium on Signals, Circuits, and Systems, 2004 – present.

16. Special Session Organizer, 11th International Conference on Electronics, Circuits, and Systems, Tel Aviv, Israel, 13 – 15 December 2004.

17. Session Chair, 4th Electronic Circuits and Systems Conference, Bratislava, Slovakia, 11 – 12 September 2003.

18. Member of the Scientific Committee, European Conference on Circuit Theory and Design (ECCTD), 2003.

19. Session Chair, 9th International Conference on Electronics, Circuits, and Systems, Dubrovnik, Croatia, 16 - 18 September 2002.

20. Member, Analog Signal Processing Technical Committee, IEEE Circuits and Systems Society, 2002 – present.

21. Member, Program Committee, Analog Circuits and Signal Processing, International Symposium on Circuits and Systems (ISCAS), 2002 – present.

22. Session Chair, International Symposium on Quality Electronic Design, San Jose, California (ISQED), 18 – 20 March 2002.

23. Chairman, Modeling Subcommittee, Fabless Semiconductor Association, 2001 – 2003.

24. Chairman, Fabless Semiconductor Association Modeling Workshop, 2001 – present.

25. Member of Technical Program Committee, European Conference on Circuit Theory and Design (ECCTD), 2001.

26. Member, IEEE Advisory Committee, 2001 – present.

27. Member of the Organizing Committee, International Symposium on Quality Electronic Design (ISQED), 2000 – 2002.

28. Member of the Modeling Committee, International Symposium on Quality Electronic Design (ISQED), 2000 – 2002.

29. Chairman of the Modeling Committee, International Symposium on Quality Electronic Design (ISQED), 2001.

30. Session Chair, International Symposium on Quality Electronic Design, San Jose, California (ISQED), 26 – 28 March 2001.

31. Lead Organizer, Fabless Semiconductor Association Workshop, 2000 – present.

32. Member of the MOS Arbeitskreis, 2000 – present.

33. Co-Chairman, Modeling Subcommittee, Fabless Semiconductor Association, 1999 – 2000.

34. Member of the Executive Committee, Modeling Subcommittee, Fabless Semiconductor Association, 1998 – present.

35. Member, Modeling Subcommittee, Fabless Semiconductor Association, 1996 – present.

36. Organizer, Symposium on Low Temperature Electronics and High Temperature Superconductors, Honolulu, Hawaii, 16 - 21 May 1993.

37. Organizer, Symposium on the Physics and Fabrication of Semiconductor Nanostructures, Washington DC, 5 - 10 May 1991.

38. Lead Organizer, Symposium on Low Temperature Electronic Device Operation, Washington DC, 5 - 10 May 1991.

39. Co-Chaired the Symposium on Low Temperature Electronics, Materials, and Processing, Hollywood, Florida, 17 October 1989.