

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of: Xiaodong Li, et al.
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Title: CHANNEL PROBING SIGNAL FOR A BROADBAND
COMMUNICATION SYSTEM

DECLARATION OF DR. R. MICHAEL BUEHRER

I, Dr. R. Michael Buehrer, of Blacksburg, Virginia, declare that:

QUALIFICATIONS AND BACKGROUND INFORMATION

1. I am currently a Professor of Electrical Engineering and the former (2014-2022) Director of Wireless with Virginia Tech. My curriculum vitae is provided as Appendix A.

2. My academic and professional background is in Electrical and Computer Engineering, and I have been working in those fields since the completion of my Ph.D. over 25 years ago. Below, I provide a short summary of my education and experience that I believe to be most pertinent to the opinions I have formed in this case.

3. I received a B.S. in Electrical Engineering from The University of Toledo in 1991, an M.S. in Electrical Engineering from The University of Toledo in 1993, and a Ph.D. in Electrical Engineering from Virginia Polytechnic Institute

and State University in 1996. The focus of my graduate work was wireless communication systems. My Ph.D. thesis involved the application of multiuser detection (an advanced signal processing approach to interference mitigation) to CDMA-based cellular systems.

4. After completion of my Ph.D. in 1996, I joined Bell Laboratories, the research division of Lucent Technologies, where I worked for five years as a Member of Technical Staff and later as a Distinguished Member of Technical Staff. My work there focused on developing advanced technologies for cellular telecommunications, including for 3G cellular standards. For example, while at Bell Labs, I developed and implemented algorithms for intelligent antenna systems which increased the voice capacity (i.e., number of simultaneous phone calls) and data capacity of cellular systems. These algorithms were included in Lucent Technologies' 3G CDMA cellular base station. I also developed techniques known as transmit diversity techniques which increased reliability (i.e., reduced the probability of a dropped call) of cellular systems. These transmit diversity techniques were standardized in the 3GPP2 cellular standard known as cdma2000. During that time, I supported the standardization of my ideas by writing contributions to the working groups developing the standards and attending standards meetings. In particular, I participated in the 3GPP2 standardization

process. During that time, I worked with colleagues to include my ideas on the use of transmit diversity in CDMA systems in the 3GPP2 standard.

5. I am currently a Professor in the Bradley Department of Electrical and Computer Engineering at Virginia Polytechnic Institute and State University, where I have taught and conducted research in the area of wireless communications for nearly 20 years. Specifically, I have taught courses which cover wireless communications and signal processing (including the underlying concepts) at the undergraduate and graduate levels. For example, I teach a sophomore-level course which introduces the concepts of signals and systems, a junior-level course which introduces the basic concepts of communication systems, senior-level and graduate-level courses which cover advanced digital communication topics, and also graduate-level courses which teach the advanced technologies underlying the latest wireless systems, such as Fourth and Fifth Generation (4G/5G) cellular communication standards (e.g., LTE, LTE-Advanced, New Radio) and Wi-Fi. I also teach graduate courses on advanced topics such as Information Theory, Machine Learning Applied to Communication Systems, Spread Spectrum Communications and CDMA.

6. From 2014 until 2022, I also served as the director of *Wireless @ Virginia Tech*, a comprehensive research group focusing on wireless communications which consists of 14 faculty members and approximately 85

graduate students. My specific research focuses on advanced wireless communications and geolocation techniques. This research has examined both advanced theoretical concepts as well as the application of these concepts to the latest wireless standards. As an example of the latter, I (along with my students) have conducted research applying multiuser/multi-antenna signal processing to LTE. I have also applied advanced geolocation techniques to LTE systems.

7. My research work has been funded by national agencies including the National Science Foundation (NSF), the Defense Advanced Research Projects Agency (DARPA), the Office of Naval Research (ONR), the Army Research Lab, the Air Force Research Lab as well as many industrial sponsors.

8. During 2009, I was a visiting researcher at the Laboratory for Telecommunication Sciences (LTS), a Federal Research Lab which focuses on telecommunication challenges for national defense. While at LTS, my research focus was in the area of cognitive radio with a particular emphasis on statistical learning techniques.

9. I have authored and co-authored over 250 publications in my area of expertise, which have been published in the leading journals in my field including *IEEE Transactions on Communications*, *IEEE Transactions on Wireless Communications*, *IEEE Transactions on Information Theory*, *Proceedings of the IEEE*, and *IEEE Transactions on Signal Processing*, and at all of the major

conferences in my field. This research has been cited over 11,000 times. A complete list of my publications over the last 25 years is included in my Curriculum Vitae.

10. I am a Fellow of the IEEE (so named “for contributions to wideband signal processing in communications and geolocation”). I was a co-recipient of the Vanu Bose Award for the best paper at the 2021 Military Communications Conference.

11. In 2010, I was awarded the Ellersick Best Paper Award in the Unclassified Technical Program, at the IEEE Military Communications Conference. I received the SDR Forum Best Paper Award in 2007 and the Outstanding Paper Award at the SDR Forum in 2008. I received the Dean’s Award for Teaching Excellence in April 2014 and the Dean’s Award for Outstanding New Assistant Professor, College of Engineering in 2003. While at Bell Laboratories, I was awarded the Bell Labs President’s Silver Award for outstanding research contributions and the 1999 Best Paper Award in the Bell Labs Technical Journal.

12. As a consultant, I have examined in detail various aspects of the physical layer, MAC layer, RLC layer, and RRC layer including both user data transmission and the control signaling of the standards for 2G, 3G, 4G, and 5G cellular systems. I have also specifically studied the standardization process in

3GPP as it relates to the standardization of a particular aspect of 4G (LTE). I have also taught short-courses in the areas of cellular systems, geolocation and Wi-Fi communications.

13. I also hold 18 issued patents in the area of wireless communications, many of which relate to cellular communication systems.

14. I formerly served as an area editor for *IEEE Transactions on Wireless Communications* supervising a team of 12 editors. I also recently served as a guest editor for a special issue of the *Proceedings of the IEEE*. I was formerly an associate editor for *IEEE Wireless Communications Letters*, *IEEE Transactions on Vehicular Technologies*, *IEEE Transactions on Communications*, *IEEE Transactions on Signal Processing*, and *IEEE Transactions on Education*.

15. Additionally, I formerly served as the guest editor for the *IEEE Journal on Special Topics in Signal Processing*. I served as the Technical Program Chair for the Signal Processing for Communications Symposium at the 2017 IEEE International Conference on Communications. Previously, I was the Organizer and Technical Co-Chair for both the 2015 and 2016 IEEE Global Communications Conference Workshop on Localization and Tracking: Indoors, Outdoors and Emerging Networks (LION). I have also served on the technical program committees of several other conferences and workshops in my field.

16. A complete copy of my curriculum vitae, which includes a list of my publications and contains further details on my education, experience, publications, patents, and other qualifications to render an expert opinion, is attached as Appendix A.

17. I have been retained by Petitioner American Honda Motor Co., Inc. to provide this declaration concerning the technical subject matter relevant to a petition for inter partes review of U.S. Patent No. 10,771,302 (“‘302 patent”).

18. In writing this Declaration, I have considered the following: my own knowledge and experience, including my work experience in the field of wireless communication networks; my experience in teaching those subjects; and my experience in working with others involved in those fields. In addition, I have analyzed the following publications and materials, in addition to other materials I cite in my declaration:

- U.S. Patent No 10,771,302 (HONDA-1001), and its accompanying prosecution history (HONDA-1002)
- IEEE Std. 802.16a-2003, entitled “IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems Amendment 2: Medium Access Control Modifications and Additional Physical Layer Specifications for 2-11 GHz” (“802.16a-2003”) (HONDA-1004)

- IEEE Std. 802.16-2001, entitled “IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems” (“802.16-2001”) (HONDA-1005)
- U.S. Patent Application Publication 2004/0174845 to Koo et al. (“Koo”) (HONDA-1006)
- Itzik Kitroser, Yossi Segal, Yigal Leiba, Zion Hadad, “IEEE 802.16e Mobility System Perspective,” IEEE 802.16 Broadband Wireless Access Working Group, document IEEE C802.16e-03_06 (“Kitroser”) (HONDA-1007)
- Yigal Leiba, Dr. Zion Hadad, Itzik Kitroser, Yossi Segal, Moshe Levinson, “802.16a OFDMA PHY suitability for mobile applications,” IEEE 802.16 Broadband Wireless Access Working Group, document IEEE C802.16sgm-02_23 (“Leiba”) (HONDA-1008)
- U.S. Patent Application Publication 2002/0126650A1 to Hall et al. (“Hall”) (HONDA-1009)
- John Terry and Juha Heiskala, “OFDM Wireless LANs: A Theoretical and Practical Guide,” Sams Publishing, 2002 (“Terry”) (HONDA-1013)

19. Each of these foregoing articles 802.16a-2003, 802.16-2001, Kitroser, Leiba, and Terry indicate on their face that they were published in technical standards, journals, or conference proceedings that I am familiar with, and which

would have been available to and disseminated to members of the general technical community prior to January of 2005.

20. Counsel (Fish & Richardson) has informed me that I should consider these materials through the lens of one of ordinary skill in the art related to the '302 patent at the time of the earliest priority date of the '302 patent to which claims 23, 24, 26, and 27 are entitled to support, and I have done so during my review of these materials. I have been informed by Counsel that the '302 patent claims priority to U.S. provisional application no. 60/540,586, filed on January 30, 2004 (the "'302 Second Provisional") and U.S. provisional application no. 60/540,032, filed on January 29, 2004 (the "'302 First Provisional"), but that claims 23, 24, 26, and 27 are not entitled to these earlier priority dates because the provisional applications do not provide support for, at least, the feature of "*the probing signal with a code sequence **modulated** in the **frequency domain***" recited in claim 23. Therefore, I have been informed by Counsel to use **January 27, 2005** (the filing date of the PCT application of the '302 patent) as the "Critical Date" in my analysis below.

21. My compensation in this matter is not based on the substance of my opinions or the outcome of this matter. I have no financial interest in Petitioner.

OVERVIEW OF CONCLUSIONS FORMED

22. This expert Declaration explains the conclusions that I have formed based on my analysis. To summarize those conclusions:

- Based upon my knowledge and experience and my review of the prior art publications listed above, I believe that claims 23, 24, 26, and 27 of the '302 patent are rendered obvious by 802.16a-2003 and 802.16-2001 (collectively "802.16a") in view of Koo.
- Based upon my knowledge and experience and my review of the prior art publications listed above, I believe that claims 23, 24, 26, and 27 of the '302 patent are also rendered obvious by 802.16a in view of Kitroser.

LEVEL OF ORDINARY SKILL IN THE ART

23. A person of ordinary skill in the art as of the Critical Date of the '302 Patent ("POSITA") would have had at least a Bachelor's degree in an academic area emphasizing electrical engineering, computer engineering, or a similar discipline, and at least two years of experience in the field working with, teaching, or researching wireless communication networks. Superior education could compensate for a deficiency in work experience, and vice-versa.

24. Based on my experiences, I have a good understanding of the capabilities of a POSITA. Indeed, I have taught, mentored, participated in organizations, and worked closely with many such persons over the course of my career. Based on my knowledge, skill, and experience, I have an understanding of the capabilities of a POSITA. For example, from my industry consulting or conference interactions, I am familiar with what a POSITA would have known and found predictable in the art. From teaching and supervising my post-graduate students, I also have an understanding of the knowledge that a person with this academic experience possesses. Furthermore, I possess those capabilities myself.

INTERPRETATIONS OF THE '302 PATENT CLAIMS AT ISSUE

25. I understand that the best indicator of claim meaning is its usage in the context of the patent specification as understood by a POSITA. I further understand that the words of the claims should be given their plain and ordinary meaning unless that meaning is inconsistent with the patent specification or the patent's history of examination before the Patent Office.

BRIEF DESCRIPTION OF THE '302 PATENT

26. The '302 Patent describes a system in which "a spread spectrum signal is intentionally overlapped with an OFDM signal" and is directed to

“methods and techniques to ensure that the mutual interference between the overlapped signals is minimized to have insignificant impact on either signal and that both signals are detectable with expected performance by a receiver”.

HONDA-1001, Abstract.

27. The '302 Patent describes a broadband wireless communication system where both Multi-Carrier (MC) and Direct Sequence Spread Spectrum (DSSS) signals are overlaid together in both time and frequency domains.

HONDA-1001, 2:39-42. The DSSS signal overlaps with the MC signal in the time domain, so that the overlaid signal can be aligned at the boundary of MC slot or MC symbol when they are synchronized. HONDA-1001, 4:30-33. In the frequency domain, the DSSS signal is designed to have spectrum nulls at the MC signal to reduce interference with MC control signals. HONDA-1001, 7:54-8:2.

28. The DSSS signal can be used for various purposes, such as “initial random access, channel probing, and short messaging.” HONDA-1001, 2:46-48. In the context of channel probing, the DSSS signal (which is transmitted by a mobile station to a base station) is used to “assist estimation of channel characteristics” in scenarios where “the mobile station is already synchronized in time and frequency with the base station.” HONDA-1001, 8:65-9:2. Furthermore, channel probing enables the base station to get “an update of the mobile station’s

information such as transmission timing and power from the probing DSSS signal.” HONDA-1001, 9:42-45.

ANALYSIS OF 802.16a and KOO

29. Based on my analysis, 802.16a discloses all features of claims 23, 24, 26, and 27 except for a device that is “mobile.” However, it is clear to me that a POSITA would have understood, prior to the Critical Date, that the relevant teachings of 802.16a are directly applicable to a “mobile” wireless environment, as taught by Koo.

802.16a Overview

30. 802.16a is an IEEE communications standard that specifies an “air interface for fixed broadband wireless access systems.” HONDA-1004, title. The standard is defined in two documents – 802.16a-2003 (HONDA-1004) and 802.16-2001 (HONDA-1005). The 802.16a-2003 document “amends IEEE Std 802.16-2001 by enhancing the medium access control layer and providing additional physical layer specifications in support of broadband wireless access at frequencies from 2-11 GHz.” HONDA-1004, p.3. I will refer to the resulting standard herein simply as “802.16a.”

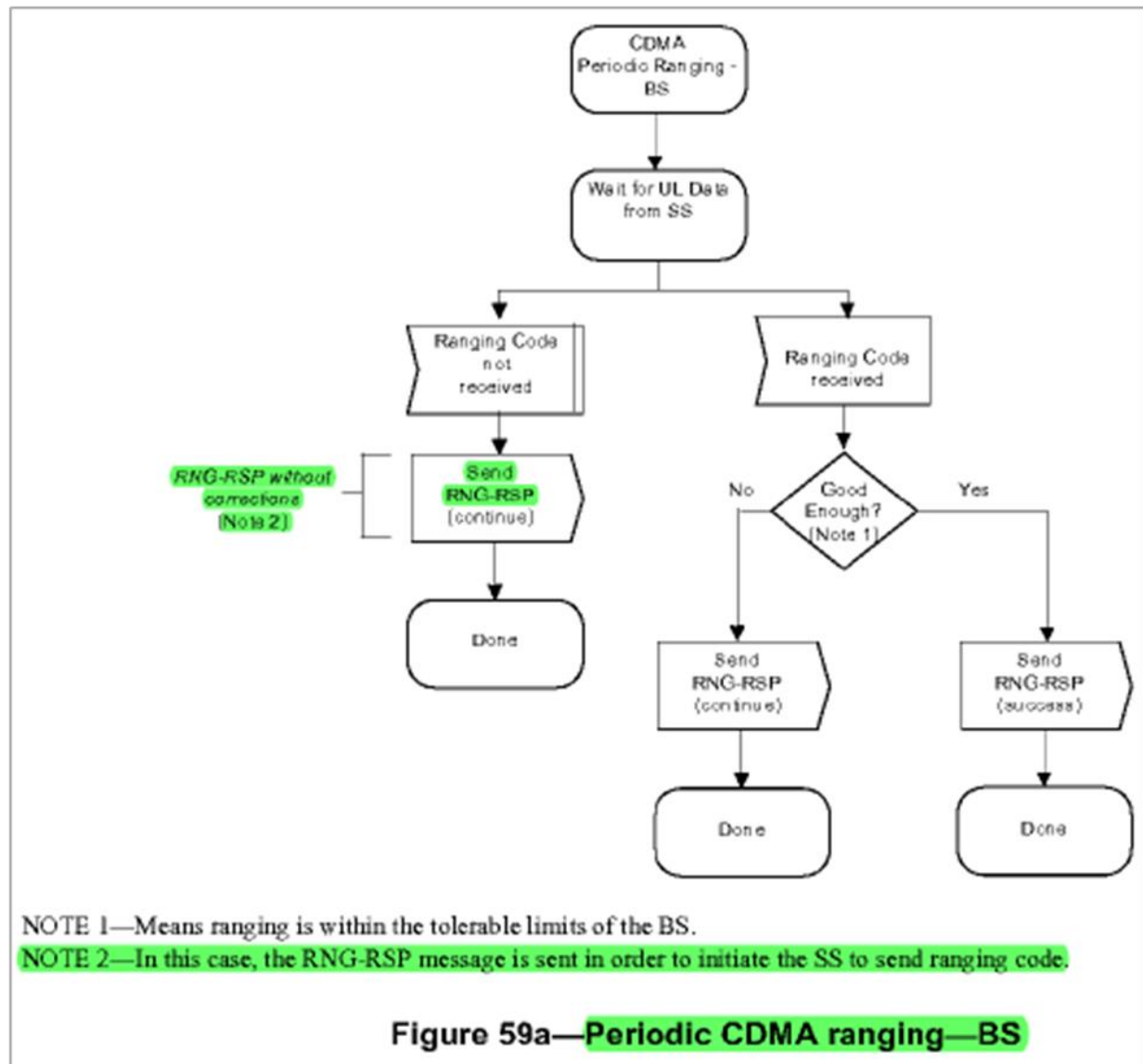
31. 802.16a describes “ranging transmission[s]” (which include a “ranging code”) by a subscriber station (SS) to a base station (BS). HONDA-1004,

Table 63b, FIG. 59c, § 8.5.7. The ranging transmission (including a ranging code) is used for three different purposes, “initial-ranging, periodic-ranging and bandwidth-requests.” HONDA-1004, 8.5.7.3, p.203 (3rd paragraph).

32. In particular, “periodic ranging” enables the SS to periodically adjust its transmission parameters so the SS can communicate with the BS properly. HONDA-1004, § 6.2.10, p.80. To that end, the SS periodically performs a ranging transmission (which includes a ranging code modulating subcarriers in the frequency domain) to the BS, thus allowing the BS to acquire “vast information about the user channel and condition.” HONDA-1004, § 6.2.10, p.80, and § 8.5.7, p.201-203. Based on this channel information, the base station is able to periodically update the SS’s “time and power parameters” and inform the SS of the updated parameters to “ensure changes in the channel can be accommodated.” HONDA-1004, 8.5.10.2. This enables the BS “to adjust transmission parameters so the SSs can communicate with the BS properly.” HONDA-1004, 6.2.10, p. 80.

33. In the OFDMA implementation of 802.16a (which is “based on OFDM modulation”), the periodic ranging process is referred to as “periodic CDMA ranging.” HONDA-1004, 8.5 (p. 179), 6.2.10.2 (p. 84). During periodic CDMA ranging, the BS sends an “RNG-RSP” message to the SS “in order to initiate the SS to send a ranging code.” HONDA-1004, 6.2.10.2, FIGS. 59a and

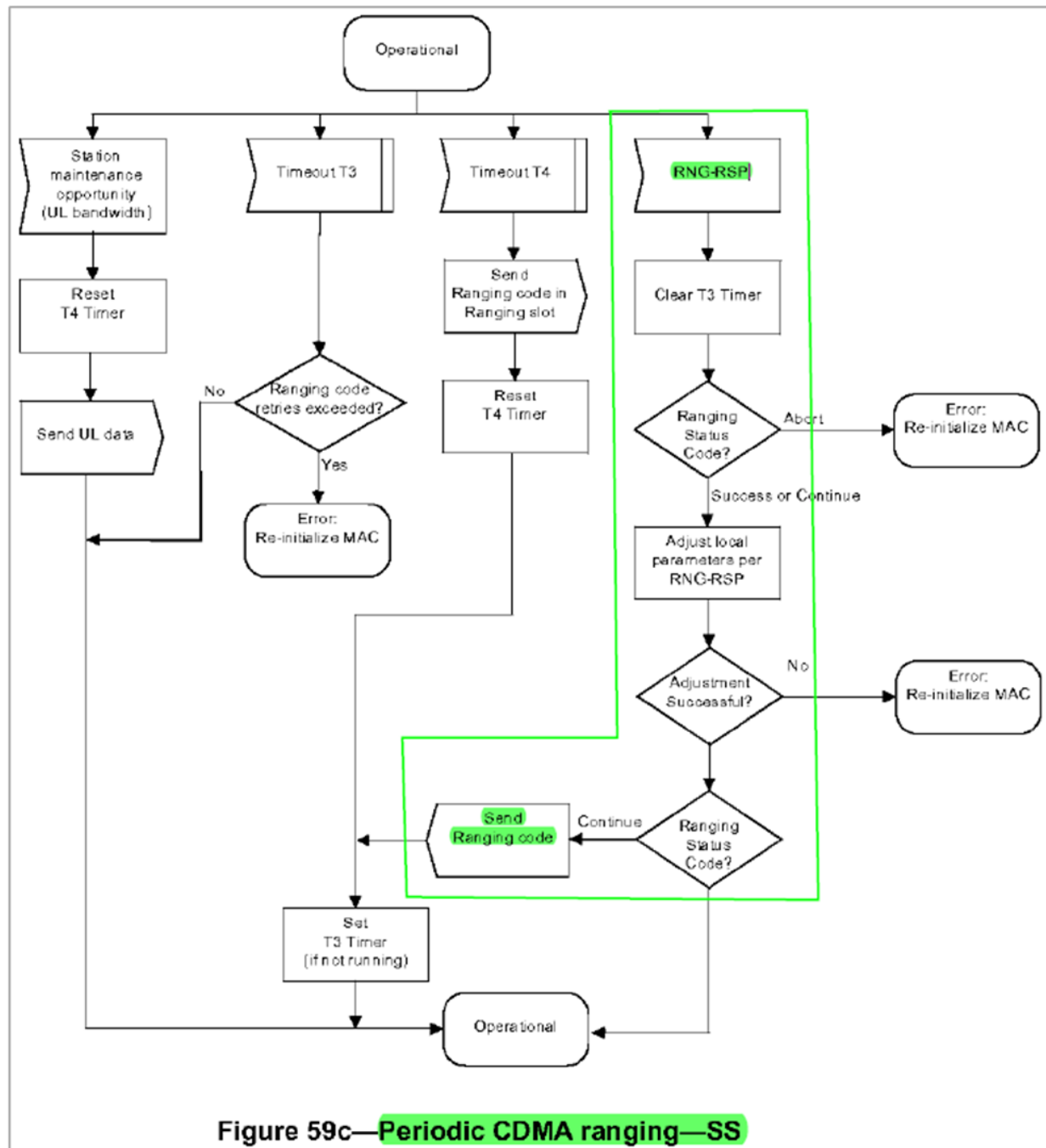
59c (pp. 84-86). An example of the BS sending an RNG-RSP message to the SS is shown in FIG. 59a (below, annotated).



802.16a-2003, FIG. 59a (annotated)

34. At the receiving end of the RNG-RSP, 802.16a discloses that the SS receives the RNG-RSP message from the BS and transmits the “ranging code” in response to the BS. HONDA-1004, FIG. 59c. An example of the SS receiving the

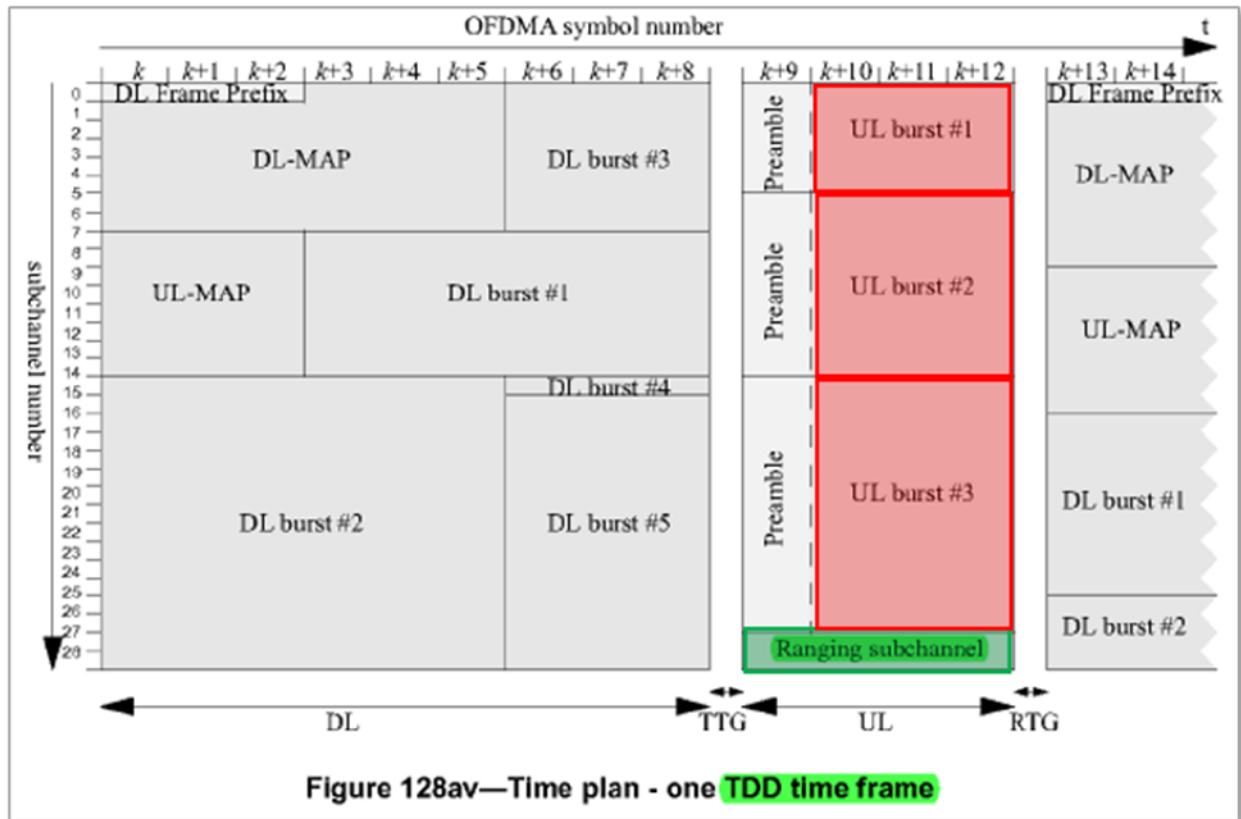
RNG-RSP message and responding by transmitting a ranging code is shown in FIG. 59c (below, annotated).



802.16a-2003, FIG. 59c (annotated)

35. In the periodic CDMA ranging process of 802.16a, the ranging code is a “subsequence” of a “pseudo-noise sequence” whose “bits are used to modulate the subcarriers in a pair of adjacent subchannels” in the frequency domain. HONDA-1004, § 8.5.7.3, pp. 202-203. The CDMA ranging code is used to modulate specific subcarriers in BPSK modulation and is transmitted over a “ranging channel,” which is composed of one or more pairs of adjacent subchannels defined during a particular range of symbol offsets in the time domain. HONDA-1004, 8.5.7, FIG. 128av.

36. 802.16a defines a “frame structure” including both a downlink (“DL”) portion and an uplink (“UL”) portion. HONDA-1004, 8.5.4, FIG. 128av (below, annotated).



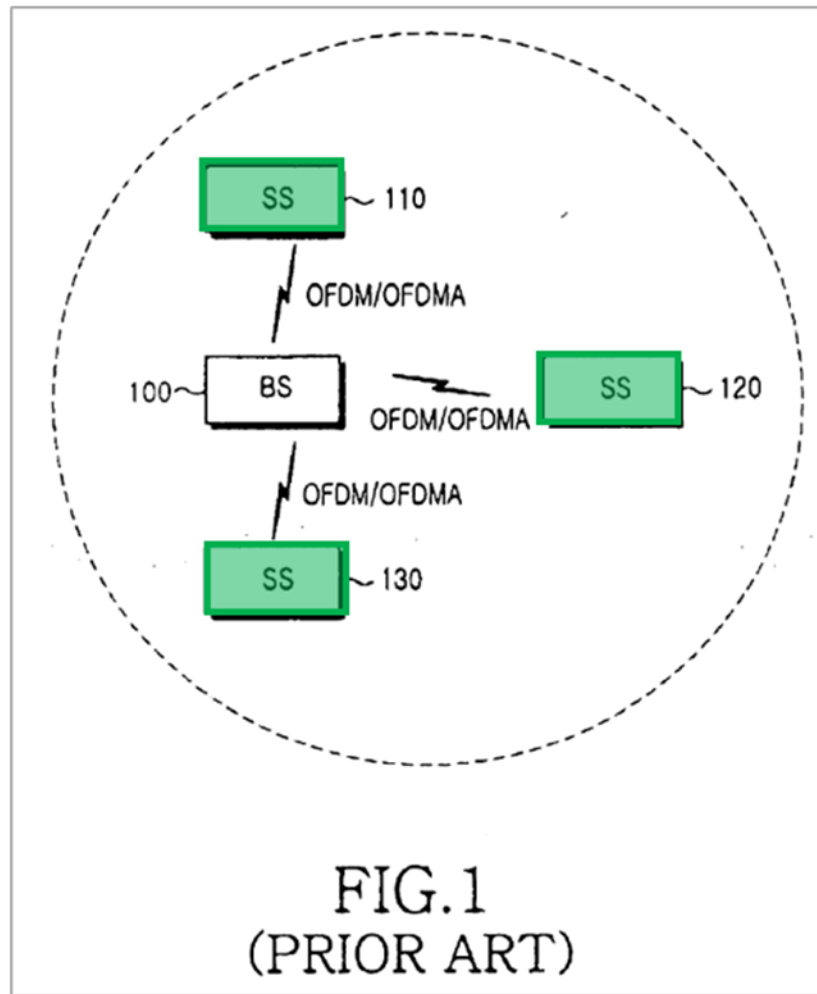
802.16a-2003, 128av (annotated)

37. In the uplink (UL) portion of the frame, the ranging channel is allocated for transmission of the ranging code while the other subchannels are allocated for user transmissions. HONDA-1004, 8.5.4.6. In particular, FIG. 128av above shows a “ranging subchannel” (for ranging code transmissions) and various “UL bursts” (for user transmissions) that are allocated within the uplink (UL) portion of the frame. HONDA-1004, 8.5.4, FIG. 128av.

Koo Overview

38. Koo discloses a communication system using an OFDM/OFDMA scheme. HONDA-1006, [0007]. Koo’s system includes a base station (e.g., “BS

100” in FIG. 1) and subscriber stations (e.g., “SSs 110, 120, and 130” in FIG. 1) that communicate using the OFDM/OFDMA scheme. HONDA-1006, [0006], [0009], FIG. 1 (below, annotated).



Koo, FIG. 1 (annotated)

39. Koo describes two IEEE 802.16 standards that were “currently considered” at the time, namely the “IEEE 802.16a” standard and the “IEEE 802.16e” standard. HONDA-1006, [0006]. Koo explains that the IEEE 802.16a standard is specified for a “fixed state of a current SS” with “no consideration

given to the mobility of the SS.” HONDA-1006, [0026]. With the goal of introducing “mobility” into the IEEE 802.16a standard, Koo discloses that the newer IEEE 802.16e standard “has been defined as a system for considering the SS’s **mobility** in the IEEE 802.16a communication system, such that the IEEE 802.16e communication system must consider the SS’s mobility.” *Id.* However, Koo explains that “there is no detailed specification yet for the IEEE 802.16e communication system” and therefore, to introduce mobility into the IEEE 802.16a standard, Koo discloses that certain “operations modes” of the SS and BS “must be converted into others” to accommodate the “SS’s mobility.” *Id.*

40. In particular, Koo focuses on the “ranging process” of the IEEE 802.16a/ IEEE 802.16e standard. As background, Koo discloses that the “communication system currently considered in IEEE 802.16a and IEEE 802.16e specifications acts as a specific communication system for performing a ranging operation between the SS and a base station (BS).” HONDA-1006, [0006]. Koo describes “three ranging processes for use in the IEEE 802.16a/IEEE 802.16e communication system” namely “an initial ranging process, a maintenance ranging process (also called a period ranging process), and a bandwidth request ranging process.” HONDA-1006, [0019].

41. Among these three types of ranging, Koo describes modifying the “initial ranging process” to implement a “handoff method” so as to guarantee the

SS's "mobility." HONDA-1006, [0027]-[0028]. In particular, Koo explains that "IEEE 802.16e communication system can provide the SS's mobility on the condition that the handoff operation for the SS 430 is supported." HONDA-1006, [0048]. To that end, in order to support the handoff operation, Koo "provides the SS with the handoff-associated information using the DL MAP message for use in the IEEE 802.16a communication system" by adding "the handoff-associated information in an additional field" of the DL-MAP message. HONDA-1006, [0049]. This additional handoff-associated information is then used during a modified initial ranging process to ensure that the mobile SS is able to synchronize with the correct BS as the SS moves between different cells. HONDA-1006, FIG. 5, [0051]-[0058].

42. Therefore, Koo discloses that "mobility" of an SS can be guaranteed by modifying the "initial ranging process" of the IEEE 802.16a standard to utilize additional information provided in the DL-MAP message so that the SS can initially synchronize with the correct BS. Once the initial ranging process is completed, the SS (which has synchronized with a BS to control time offset and power) thereafter periodically performs the traditional "periodic ranging process" specified in the IEEE 802.16a standard to control a channel state. HONDA-1006, [0023].

43. Thus, among the three types of ranging processes in the IEEE 802.16a standard, Koo discloses that only the “initial ranging” process needs to be modified in order to guarantee mobility of an SS. The “periodic ranging process” is described by Koo as being identical in both the IEEE 802.16a standard and the IEEE 802.16e standard. HONDA-1006, [0019], [0023]. Therefore, Koo makes clear that the “periodic ranging process” specified in the IEEE 802.16a standard would remain unchanged even when accommodating “mobility” for SSs in the newer IEEE 802.16e standard.

44. In particular, for both the fixed-wireless IEEE 802.16a standard and the mobile-wireless IEEE 802.16e standard, Koo explains that the “period ranging process is periodically executed” so that the SS “can control a channel state associated with the BS.” HONDA-1006, [0023]. Koo discloses that the IEEE 802.16a and IEEE 802.16e standards define “one ranging channel” that “includes two ranging sub-channels” and explains that “the ranging procedure requires a plurality of ranging sub-channels and a plurality of ranging codes.” HONDA-1006, [0020].

Combination of 802.16a-2003 and 802.16-2001 (collectively “802.16a”)

45. A POSITA would have found it obvious to combine 802.16a-2003 and 802.16-2001 based on explicit statements in 802.16a-2003. For example, 802.16a-2003 explains that it “amends IEEE Std 802.16-2001.” HONDA-1005, i,

iii. 802.16a-2003 also provides editing instructions that “define how to merge the material contained herein into the existing base standard (IEEE Std 802.16TM-2001) to form the comprehensive standard.” *Id.*, 1. These explicit statements would have motivated a POSITA to combine 802.16a-2003 with 802.16-2001 to form a single document/standard, referred to herein as “802.16a.”

The Combination of 802.16a and Koo

46. As discussed above, 802.16a is directed to “fixed broadband wireless access systems” with stationary SSs operating according to the IEEE 802.16a standard. Also as discussed above, Koo shows that, prior to the Critical Date, it was well-known to introduce “mobility” into the IEEE 802.16a standard, resulting in the newer “IEEE 802.16e” standard for mobile wireless communications. Furthermore, as discussed above, Koo teaches that the “periodic ranging process” of the IEEE 802.16a standard would not require any changes for use with mobile SSs in the IEEE 802.16e standard. Therefore, a POSITA would have understood that the “periodic CDMA ranging” process of 802.16a is directly applicable to **mobile** SSs, as taught by Koo.

47. Specifically, as discussed above, Koo discloses that both the fixed-wireless IEEE 802.16a standard and the mobile-wireless IEEE 802.16e systems implement the same “periodic ranging process.” HONDA-1006, [0019]-[0023]. For both the IEEE 802.16a and IEEE 802.16e communication systems, Koo

discloses that “ranging codes” for a “periodic ranging process” are generated by a “pseudorandom noise” sequences over two ranging sub-channels. HONDA-1006, [0021].

48. The details in Koo regarding the “periodic ranging process” are consistent with those in 802.16a. For example, the **structure** of the ranging codes is the same in both Koo and 802.16a. As discussed above, Koo’s ranging codes are created by “segmenting a **PN (Pseudorandom Noise)** sequence” over a “**ranging channel**” that includes up to “**two ranging sub-channels**” such that each of segmented codes has a “length of **106 bits**” with “a maximum of **48 ranging codes** ... assigned to the SS.” HONDA-1006, [0021]. This is consistent with 802.16a’s description that CDMA binary ranging codes are “**pseudo-noise (PN)** codes” and in particular are “**subsequences** of the pseudo-noise sequence” where the “length of each ranging code is **106 bits**” that “modulate the sub-carriers in a **pair** of adjacent **subchannels**” called a “**ranging channel**” and where the “**number** of available codes is **48**.” HONDA-1004, § 8.5.7.3, pp. 202-203.

49. Furthermore, the **usage** of the ranging codes is the same in both Koo and 802.16a. As discussed above, Koo discloses that the “ranging code is differently assigned to the SS according to each objective of the **three ranging processes**.” HONDA-1006, [0021]. For example, Koo explains that “**N** ranging codes are assigned to the SS for the **initial** ranging process ... **M** ranging codes are

assigned to the SS for the **periodic** ranging process ... and **L** ranging codes are assigned to the SS for the **bandwidth request** ranging process.” HONDA-1006, [0022]. This is consistent with 802.16a’s description that the ranging codes are “divided in **three usage groups** (initial ranging, periodic-ranging and bandwidth-request ranging)” and codes are “allocated dynamically to the groups by the BS” such that the “first **N** codes produced are for **initial**-ranging” and the “next **M** codes produced are for **periodic**-ranging” and the “next **L** codes produced are for **bandwidth-requests**.” HONDA-1004, § 8.5.7.3, p. 203. In addition, Koo explains that the periodic ranging process is used so that the SS “can control a **channel state** associated with the BS.” HONDA-1006, [0023]. This is consistent with 802.16a’s description that the periodic ranging process enables the BS to obtain the “**Channel Impulse Response (CIR)**” and acquire “vast information about the user **channel** and **condition**” so as to “ensure **changes in the channel** can be accommodated.” HONDA-1004, § 8.5.7.3, p. 203; § 8.5.10.2, p. 219.

50. Therefore, both 802.16a and Koo describe the same “periodic ranging” process in which an SS periodically transmits a “PN (Pseudorandom Noise) sequence” over a “ranging channel” (comprised of a pair of adjacent subchannels) for the purpose of adapting to changing channel state conditions. Furthermore, Koo makes clear that this “periodic ranging” process is identical for

both the IEEE 802.16a (fixed wireless) and IEEE 802.16e (mobile wireless) communication systems.

51. Based on my experience and knowledge, it is clear to me that applicability of the 802.16a periodic ranging process to mobile environments was well-known in the art prior to the Critical Date. For example, this is evidenced by extensive efforts that were underway to develop the mobile-wireless IEEE 802.16e standard. For example, it was well-known that the development of IEEE802.16e prior to the Critical Date was an effort to support mobility and to fill the gap between fixed wireless local area networks and mobile cellular systems. *See, e.g.,* Jun-Bae Seo, Seung-Que Lee, Nam-Hoon Park, Hyong-Woo Lee and Choong-Ho Cho, "Performance analysis of sleep mode operation in IEEE 802.16e," IEEE 60th Vehicular Technology Conference, 2004. VTC2004-Fall. 2004, Los Angeles, CA, USA, 2004, pp. 1169-1173 Vol. 2, doi: 10.1109/VETECF.2004.1400205. – “Additionally, IEEE802.16e is a standard in progress for BWA in order to support mobility, which may fill the gap between fixed wireless local area networks and mobile cellular systems”). Further, it was well-known that the PHY layer periodic ranging mechanism of the existing IEEE 802.16a standard (for fixed wireless devices) would remain unchanged in a mobile environment. For example, Kitroser discusses the “impact of the mobile environment on the current 802.16a” standard and makes the unequivocal statement that for the “Ranging” process, “[n]o

changes are required in the PHY layer ranging mechanism.” HONDA-1007, p. 3 (§ 3).

52. As a result, a POSITA would have understood, in view of the teachings of Koo and the general knowledge of a POSITA prior to the Critical Date, that the “periodic CDMA ranging” process described in 802.16a would have been directly applicable to **mobile** devices.

Claim 23 is obvious over 802.16a in view of Koo

[23.P] “A mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the mobile device comprising:”

53. To the extent the preamble is deemed limiting, the combination of 802.16a and Koo renders it obvious. As previously discussed, the combination of 802.16a and Koo teaches a mobile subscriber station, or SS (the claimed “*mobile device*”), in a communication system that is based on **OFDM** modulation.

54. Thus, the combination of 802.16a and Koo teaches “*a mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system*” as recited in claim feature [23.P].

[23.1] “a receiver configured to receive a request for a probing signal from a base station in the system;”

55. As described above, 802.16a teaches a “periodic CDMA ranging” process in which the SS performs “periodic **ranging transmissions**” to the BS, where each ranging transmission includes a “ranging code” that enables the BS to

acquire information about the user channel condition. HONDA-1004, § 6.2.10, p. 80, § 8.5.7, p. 201-203. As explained in further detail below, the “ranging transmission” of 802.16a renders obvious the claimed “*probing signal*.”

56. In addition, as explained above and in further detail below, during periodic CDMA ranging, if the BS does not receive the ranging code or if the BS receives a ranging code that is “not good enough,” then the BS sends an “**RNG-RSP** message” with a “ranging status code” that is set to the special status code “**continue**” to the SS “in order to initiate the SS to send a ranging code.” Therefore, as explained further below, the 802.16a “RNG-RSP” message with special ranging status code “continue” renders obvious the claimed “*request*” for the probing signal.

“a probing signal”

57. The ’302 Patent specification does not use the term “*probing signal*.” Instead, the ’302 Patent describes a “Direct Sequence Spread Spectrum (**DSSS**) signal” that can be used for “**channel probing**.” HONDA-1001, 2:40-41, 46-47.

58. A POSITA would have understood that 802.16a’s periodic CDMA “**ranging transmission**” (which includes a “ranging code”) renders obvious the claimed “*probing signal*.” In particular, 802.16a’s description of the ranging code (and how the ranging code is used) is consistent with ’302 Patent’s description of the “Direct Sequence Spread Spectrum (DSSS) signal” which can be

used for “channel probing” (the claimed “*probing signal*”). HONDA-1001, 2:40-41, 46-47.

59. For example, the **structure** of the 802.16a “ranging transmission” is consistent with the ’302 Patent’s “DSSS signal.” 802.16a describes the process of periodic ranging as “periodic **CDMA** ranging” and describes “periodic ranging codes” as consisting of “periodic ranging **CDMA** codes.” HONDA-1004, FIG. 59c, Table 122. This is consistent with the ’302 Patent which describes the **DSSS** (probing signal) as using “**spreading** codes” (HONDA-1001, col. 1, lines 30-31) and the DSSS signal (probing signal) having a “**spreading** factor” (HONDA-1001, col. 6, lines 6-7). A POSITA would have understood that a “CDMA code” (as taught in 802.16a) is a “spreading code” that has a “spreading factor” (as described in the ’302 Patent). For example, Hall describes a system that provides “synchronous **direct-sequence** code division multiple access (DS-**CDMA**)” and in particular where the “modulation is direct-sequence spread-spectrum (**DS-SS**)”. HONDA-1009, [0041], [0097].

60. As another example, the **purpose** of the 802.16a “ranging transmission” is consistent with the ’302 Patent’s DSSS signal. For example, 802.16a describes “code detection” for periodic ranging, in which the BS can “extract **timing** (ranging) **information** and **power**” from the detected ranging code, and “the BS gets the **Channel Impulse Response** (CIR) of the code, thus

acquiring for the BS vast information about the user **channel** and **condition**.”

HONDA-1004, 8.5.7.3. This is consistent with the '302 Patent which describes that the BS gets “information such as transmission **timing** and **power** from the probing DSSS signal.” HONDA-1001, 9:43-45. The '302 Patent also describes the DSSS signal is used “to derive the **channel information** in the case of channel probing.” HONDA-1001, 5:22-25.

61. As yet another example, the **context** of performing the 802.16a “ranging transmission” is consistent with the context in which the '302 Patent's DSSS signal is used. For example, 802.16a describes that “**periodic-ranging** transmissions” are “sent only by SS that have **already synchronized** to the system.” HONDA-1004, 8.5.7.2. This is consistent with the '302 Patent's description that the “channel **probing**” embodiment of the **DSSS signal** is used in the case where “the mobile station is **already synchronized** in time and frequency with the base station.” HONDA-1001, 8:65-9:4.

62. For these various reasons, a POSITA would have understood that 802.16a's “ranging transmission” renders obvious the claimed “*probing signal*.”

“a request for a probing signal”

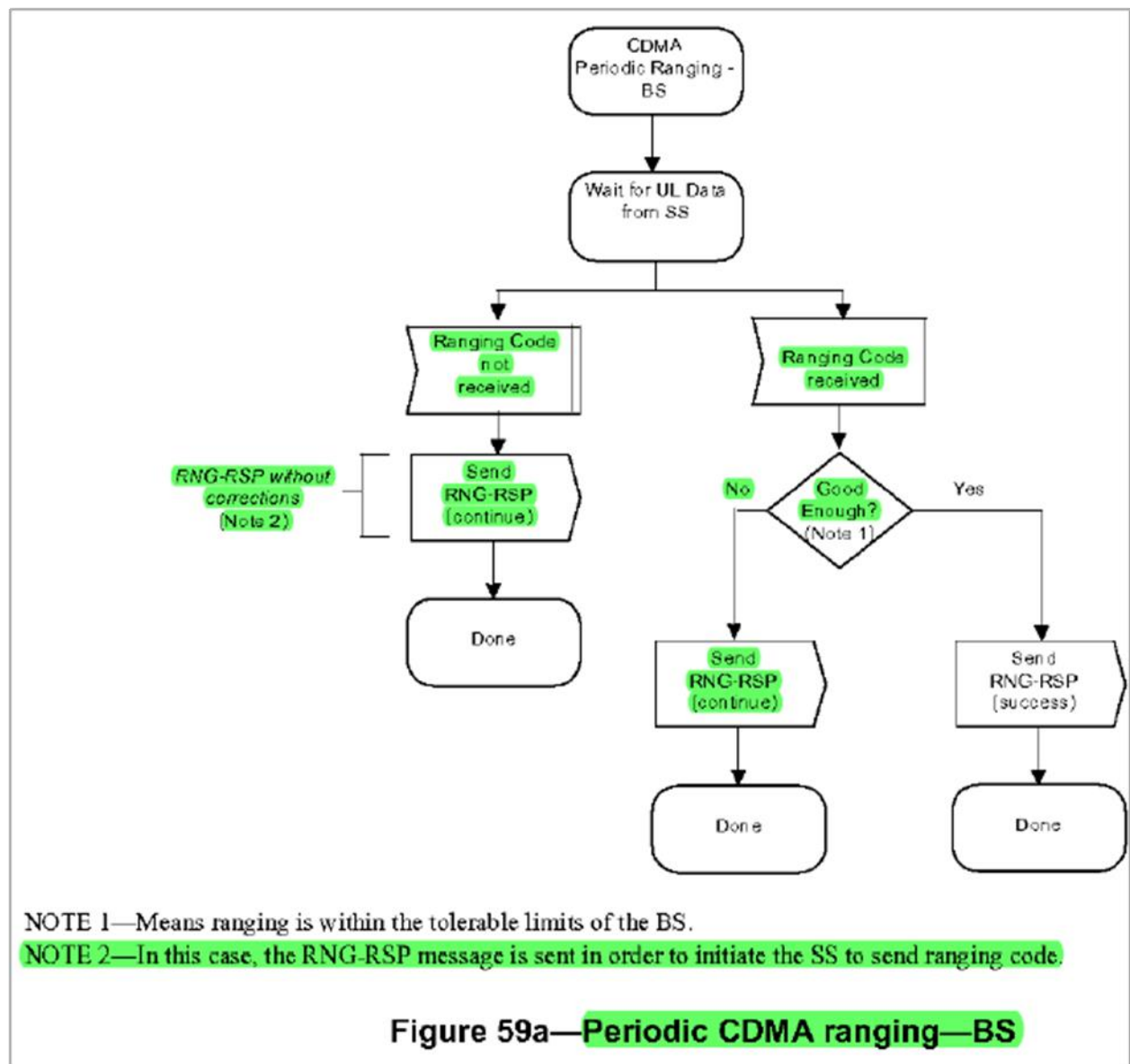
63. The '302 Patent specification does not use the term “*request*” for a probing signal. Instead, the '302 Patent describes that the base station **dictates** the

mobile station to transmit the **channel probing DSSS** when it needs an update of the mobile station's channel characteristics.” HONDA-1001, 9:39-41.

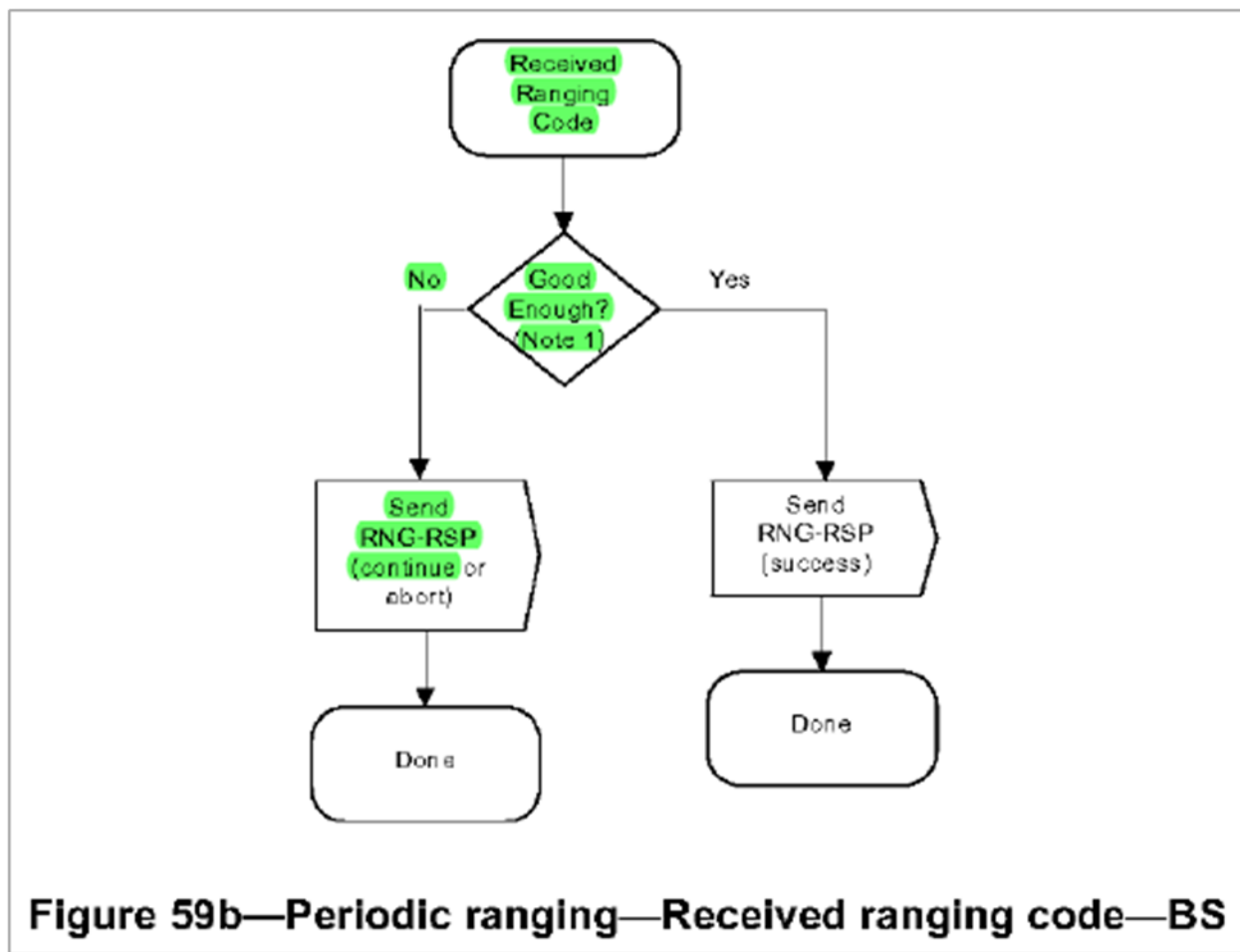
64. A POSITA would have understood 802.16a teaches that the BS sends a **request** for the SS to perform the ranging transmission, and that this is consistent with the description of the '302 Patent and consistent with a POSITA's understanding of the term “request.” For example, as discussed above, during the periodic CDMA ranging process of 802.16a, the SS performs periodic ranging transmissions by periodically sending a “ranging code” to the BS. However, as discussed above, if the BS **does not receive** a ranging code or if the BS receives a ranging code that is **not good enough**, then the BS sends an “**RNG-RSP** message” with a special “ranging status code” of “**continue**” to the SS “in order to **initiate** the SS to send a **ranging code**.” HONDA-1004, FIG. 59a (below, annotated). This is explained in further detail below.

65. In particular, FIG. 59a of 802.16a shows a flow chart of the BS's operations during the periodic CDMA ranging process. *Id.* As shown on the left-hand branch of the flow chart in FIG. 59a, if the BS detects “Ranging Code **not received**” then the BS proceeds to “Send **RNG-RSP (continue)**.” *Id.* As seen in the “NOTE 2” at the bottom of FIG. 59a, 802.16a explains that “In this case, the RNG-RSP message is sent in order to **initiate** the SS to send **ranging code**.” *Id.* Alternatively, as shown on the right-hand branch of the flow chart in FIG. 59a, if

the BS detects “Ranging Code **received**,” then the BS checks whether the ranging code is “Good Enough?” (as explained in Note 1, this means checking whether the “ranging is within the tolerable limits of the BS”). *Id.* If the ranging code is **not** good enough (*i.e.*, “No” in the flow chart), then the BS proceeds to “Send **RNG-RSP (continue)**.” *Id.*, see also FIG. 59b (below, annotated).



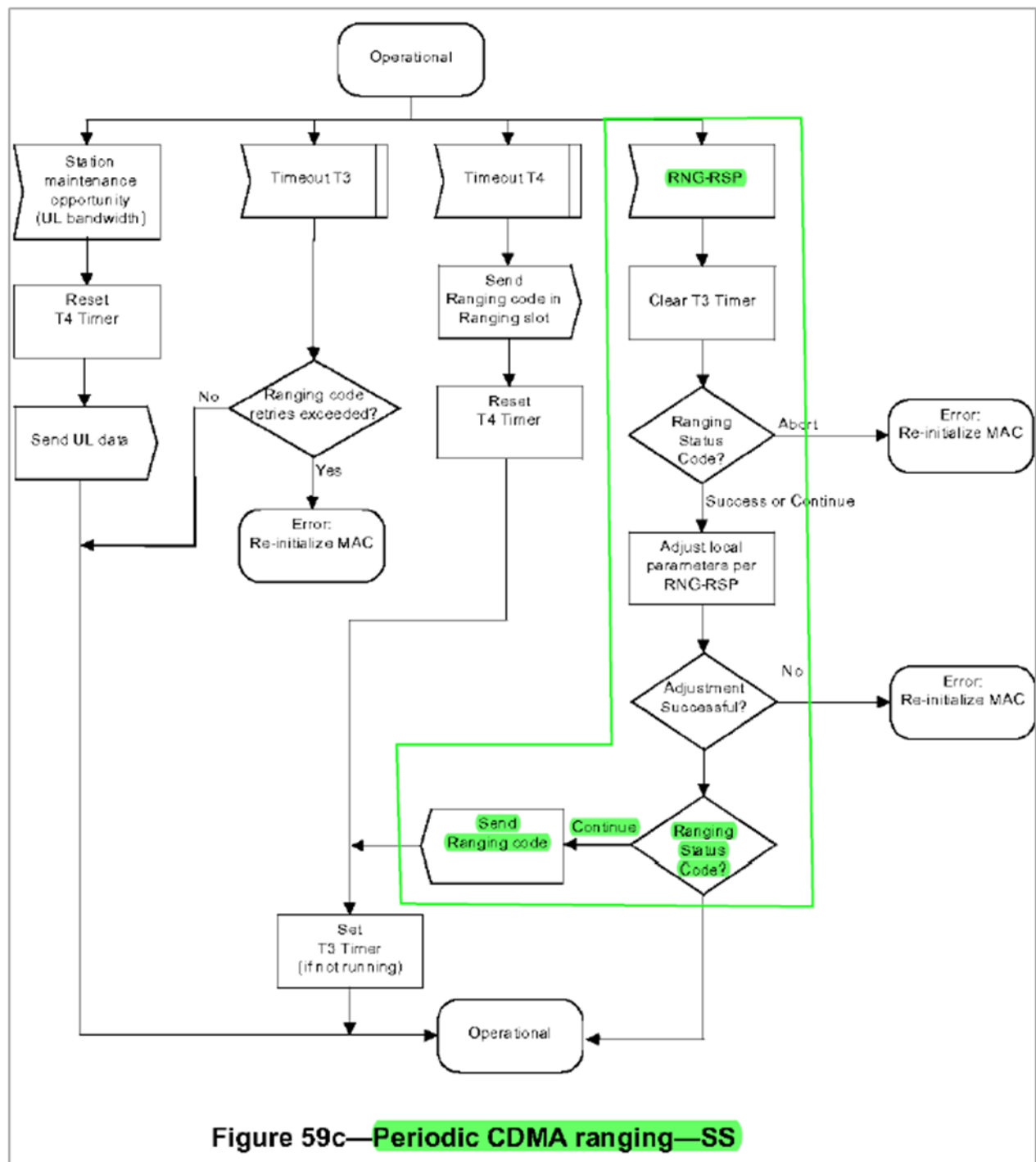
802.16a-2003, FIG. 59a (annotated)



802.16a-2003, FIG. 59b (annotated)

66. Therefore, as seen above, during the periodic CDMA ranging process, if the BS **does not receive** a ranging code or if the BS receives a ranging code that is **not good enough**, then the BS sends an “**RNG-RSP** message” with a special status code “**continue**” to the SS “in order to **initiate** the SS to send a **ranging code**.” This use of the RNG-RSP message with the status code “continue” is consistent with what a POSITA would understand to be a “request for a probing signal”.

67. The corresponding operations of the SS are shown in the flow chart of FIG. 59c of 802.16a (below, annotated). As shown on the left-hand side of the flow chart, the periodic CDMA ranging process involves the SS using various timers (*e.g.*, T3 and T4) to control the periodic ranging transmissions of the ranging code. However, as shown on the right-hand side of the flow chart (annotated), when the SS receives an RNG-RSP message from the BS, then the SS checks whether the “Ranging Status Code” of the RNG-RSP is set to the special status code of “Continue.” HONDA-1004, FIG. 59c (below, annotated). If so, then the SS will “send Ranging code.” *Id.*



802.16a-2003, FIG. 59c (annotated)

68. Therefore, 802.16a discloses that, during the periodic CDMA ranging process, if the SS receives an RNG-RSP message with special status code of

“Continue,” then the SS will send a ranging code to the BS (irrespective of the timers T3 and T4 that are typically used to control the SS’s periodic ranging transmissions).

69. Therefore, because the BS transmits the RNG-RSP message with ranging status code “continue” when the BS fails to receive a ranging code or when the BS receives a ranging code that is not good enough, and because this RNG-RSP message with ranging status code “continue” will “initiate” the SS to send a ranging code, a POSITA would have understood that an SS receives, from a BS, an “RNG-RSP” message with a ranging status code “continue” as a “**request**” for a ranging transmission which includes a ranging code. Furthermore, because the purpose of the BS initiating the SS to send the ranging code is for the BS to acquire “vast information about the user channel and condition” (HONDA-1004, § 6.2.10, p. 80, and § 8.5.7.3, p. 203), this is also consistent with the ’302 Patent’s description that “the base station dictates the mobile station to transmit the channel probing DSSS when it needs an update of the mobile station's channel characteristics.” HONDA-1001, 9:39-41. That is, in both 802.16a and in the ’302 Patent, the base station initiates/dictates the SS/mobile station to send a signal (the “ranging transmission” in 802.16a and the “channel probing DSSS” signal in the ’302 Patent) when the BS needs to acquire a user’s channel information.

70. Moreover, 802.16a teaches that the SS implements a “receiver” for receiving downlink signals from the BS. For example, 802.16a discloses “[i]n the DL, a subchannel may be intended for different (groups of) receivers.” HONDA-1004, 8.5.2.2 (p. 180). 802.16a also specifies various “receiver requirements.” HONDA-1004, 8.5.13. Additionally, a POSITA would understand that the entire 802.16a specification assumes that the signals and processes described require a receiver at each end of the wireless link.

71. Thus, for the various reasons discussed above, the combination of 802.16a and Koo teaches “*a receiver configured to receive a request for a probing signal from a base station in the system*” as recited in claim feature [23.1].

[23.2] “a transmitter configured to form and transmit, in response to the received request, the probing signal with a code sequence modulated in the frequency domain, wherein:”

72. As discussed for claim feature [23.1], 802.16a specifies a “ranging transmission” (the claimed “*probing signal*”) which is sent by the SS in response to an RNG_RSP with status code “continue” received from the BS. In addition, as explained below, 802.16a’s SS forms and transmits the ranging transmission with a code sequence modulated in the frequency domain.

“a transmitter configured to form and transmit, in response to the received request, the probing signal with a code sequence...”

73. As previously discussed, 802.16a specifies that the periodic CDMA “ranging transmissions” include “binary ranging codes” which are “subsequences

of the **pseudo-noise sequence**” generated by a polynomial **generator** shown in Figure 128be. HONDA-1004, 8.5.7.3 (paragraphs 1-2). This description of a “binary ranging code” in 802.16a is consistent with the ’302 Patent’s explanation that “[e]ither **binary** or non binary sequences can be used” for the “DSSS sequence.” HONDA-1001, 7:43-47.

74. Furthermore, as explained with reference to claim feature [23.1](i), above, 802.16a describes “periodic ranging codes” as consisting of “periodic ranging **CDMA** codes.” HONDA-1004, FIG. 59c, Table 122. This is consistent with the ’302 Patent which describes the **DSSS** (probing signal) as using “**spreading** codes” (HONDA-1001, 1:30-31) and the DSSS signal (probing signal) having a “**spreading** factor” (HONDA-1001, 6:6-7). A POSITA would have understood that a “CDMA code” (as taught in 802.16a) is a “spreading code” that has a “spreading factor” (as described in the ’302 Patent). For example, Hall discloses a system that provides “synchronous **direct-sequence** code division multiple access (DS-**CDMA**)” and in particular where the “modulation is direct-sequence spread-spectrum (**DS-SS**)”. HONDA-1009, [0041], [0097].

75. 802.16a further specifies that “[t]o effect a ranging transmission, each user randomly chooses one ranging code from a bank of specified binary codes.” HONDA-1004, 8.5.7 (paragraph 1). Specifically, an SS will “select, with equal probability, one of the codes of the appropriate subset, modulate it onto the

Ranging Subchannel and subsequently **transmit**” the ranging code. HONDA-1004, 6.2.10.2 (paragraph 2).

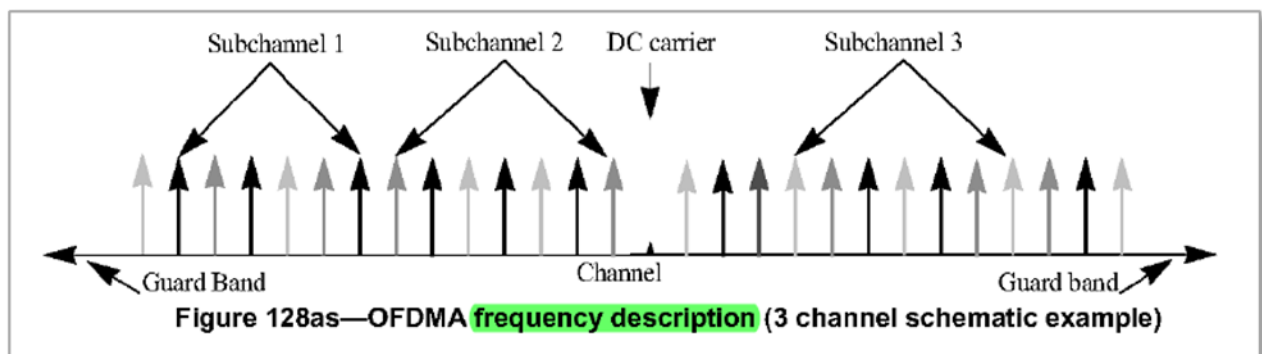
76. Therefore, 802.16a teaches that the SS is configured to form and transmit the “ranging transmission” (the claimed “*probing signal*”) with a “ranging code” consisting of a subsequence of the **pseudo-noise sequence** (the claimed “*code sequence*”). Similarly, Koo teaches that the “ranging codes are created by segmenting a PN (**Pseudorandom Noise**) **sequence** ... into predetermined units” and performs the “performs the period[ic] ranging process using the ranging codes.” HONDA-1006, [0021], [0023]. As a result, a POSITA would have understood that both 802.16a and Koo disclose “*a transmitter configured to form and transmit, in response to the received request, the probing signal with a code sequence...*” as recited in claim feature [23.2].

“...modulated in the frequency domain”

77. Furthermore, as explained in detail below, 802.16a teaches that bits of the binary ranging code are used to modulate carriers in the frequency domain. In particular, 802.16a teaches that when the SS transmits the ranging code, the SS shall “**modulate** it onto the Ranging Subchannel and subsequently transmit in a with equal probability selected (pair of) OFDM symbol(s) within the appropriate UL allocation.” HONDA-1004, 6.2.10.2 (paragraph 2). To perform the modulation, 802.16a explains that the codes are “**BPSK modulated** onto the

carriers in the ranging channel, one bit per carrier.” HONDA-1004, 8.5.7 (paragraph 1). Specifically, 802.16a discloses that the “length of each ranging code is 106 bits” and these “bits are used to **modulate** the **sub-carriers** in a pair of adjacent **subchannels**.” HONDA-1004, 8.5.7.3 (paragraph 2). In more detail, 802.16a describes a particular formula for “BPSK modulation on the ranging transmissions” in which the “*k*th carrier of the Ranging Channel” is modulated by the “*k*th bit of the code bits of the ranging code sequence.” HONDA-1004, 8.5.9.4.3.2. Therefore, 802.16a discloses that a particular modulation scheme (BPSK, or Binary Phase Shift Keying) is used to modulate each bit of the ranging code onto a respective carrier in the ranging channel.

78. Furthermore, 802.16a describes that the “carriers” are grouped into “subchannels” a part of the “**frequency domain** description” of OFDMA. HONDA-1004, 8.5.2.2, FIG. 128as (below, annotated).



802.16a-2003, FIG. 128as (annotated)

79. Therefore, 802.16a teaches that the bits of the “ranging code” which is a “subsequence of the pseudo-noise sequence” (the claimed “*code sequence*”) in

the “ranging transmission” (the claimed “*probing signal*”) are modulated onto “carriers” in the “ranging subchannel” (the claimed “*in the frequency domain*”).

80. Moreover, 802.16a teaches that the SS implements a “transmitter” for transmitting uplink signals to the BS. For example, 802.16a discloses “in the UL, a transmitter may be assigned one or more subchannels, several transmitters may transmit in parallel.” HONDA-1004, 8.5.2.2 (p. 180). 802.16a also specifies various “transmitter requirements.” HONDA-1004, 8.5.12.

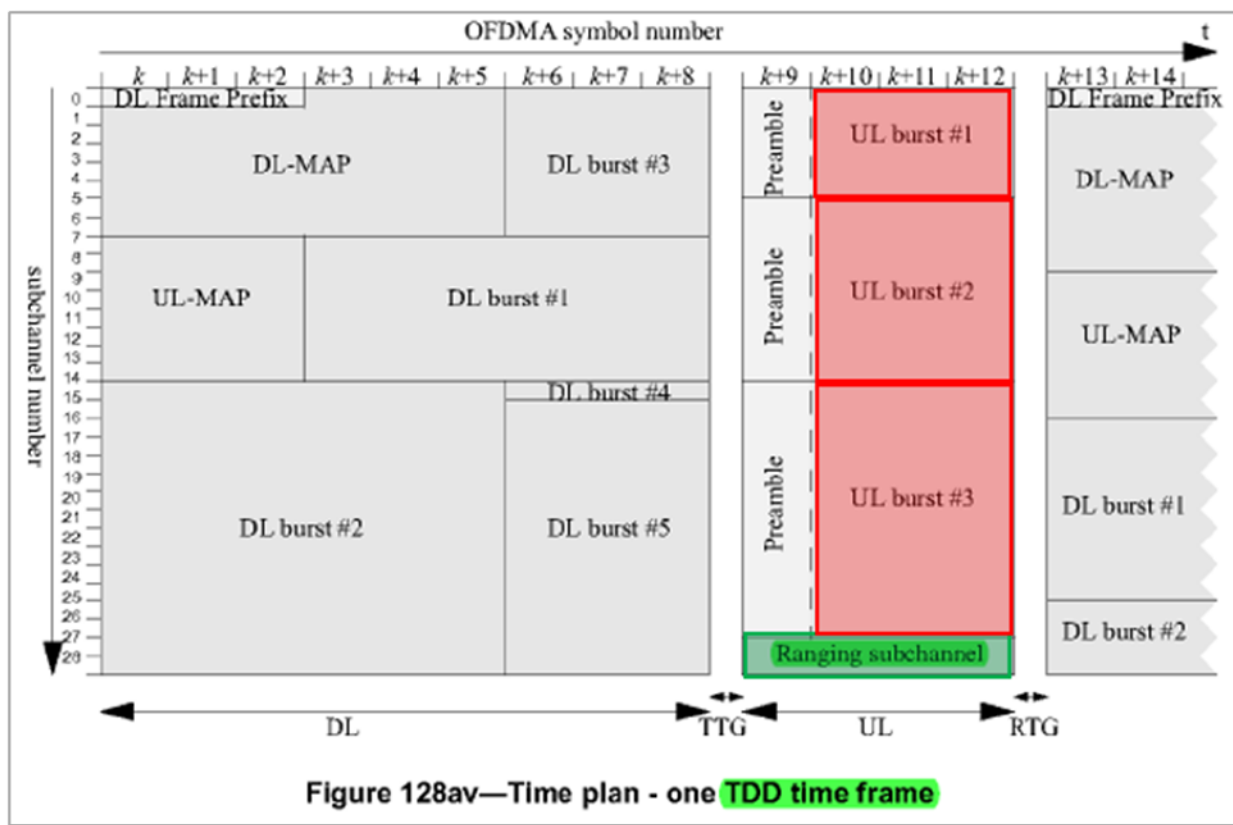
81. As a result, a POSITA would have understood that the combination of 802.16a and Koo discloses “*a transmitter configured to form and transmit, in response to the received request, the probing signal with a code sequence modulated in the frequency domain*” as recited in claim feature [23.2].

[23.3] “the probing signal is configured to overlap, in the time domain, with uplink signals transmitted over an uplink frequency band by other mobile devices in the system; and”

82. The combination of 802.16a and Koo discloses at least two different types of “*uplink signals transmitted by other mobile devices*” that overlap with a ranging transmission (the claimed “*probing signal*”). As one example, 802.16a discloses that the ranging transmission overlaps with “payload of MAC PDUs” which are transmitted by other SSs. As another example, the ranging transmission of 802.16 overlaps with ranging transmissions transmitted by other

SSs, resulting in users colliding on the ranging channel. Both of these examples are described in detail below.

83. As discussed above, 802.16a defines a “frame structure” in which the “ranging subchannel” and various “UL bursts” are allocated within an uplink (“UL”) portion of the frame. HONDA-1004, 8.5.4, FIG. 128av (below, annotated).

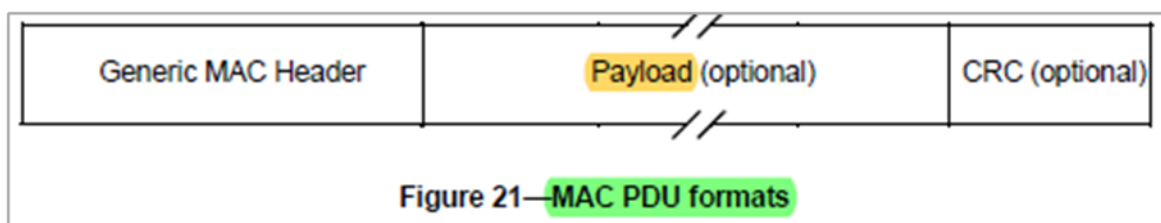


802.16a-2003, FIG. 128av (annotated)

84. As seen above, the “ranging subchannel” overlaps, in a time domain, with the “UL bursts” over OFDMA symbol numbers $k+10$, $k+11$, and $k+12$. As evident from the horizontal axis of FIG. 128av marked “ t ”, these OFDMA symbol numbers enumerate units of time in the time domain. Also, as seen in FIG. 128av,

in the frequency domain, the “UL bursts” are transmitted over an uplink frequency band, such as a frequency band that includes subchannel numbers 0 through 31 along the vertical axis in FIG. 128av. Because this band of frequencies is used for uplink transmissions during the “UL” period, it is an uplink frequency band. The fact that the same band of frequencies is sometimes used for downlink transmissions (during the “DL” period) does not change the fact that it is used for uplink transmissions during the “UL periods.” As such, in 802.16a, the “UL bursts” are transmitted over a band of frequencies (e.g., a band of frequencies that includes subchannel numbers 0 through 31 in FIG. 128av) which is an uplink frequency band during the “UL” periods.

85. Furthermore, each “UL burst” includes multiple “MAC PDUs” and each MAC PDU has a “MAC payload.” HONDA-1005, 6.2.3.2 and FIG. 26, 6.2.2, FIG. 21 (below, annotated).



802.16-2001, FIG. 21 (annotated)

86. Therefore, 802.16a discloses that the “ranging subchannel” overlaps in time with the “MAC payloads” that are transmitted in the “UL bursts.”

87. Furthermore, 802.16a discloses that the UL bursts can be allocated to different SSs. For example, 802.16a discloses that a “PHY burst in OFDMA is allocated a group of contiguous subchannels” and “can be assigned in the UL to a specific SS.” HONDA-1004, 8.5.3.1. Moreover, “in the uplink, each subchannel may be transmitted from a different SS.” HONDA-1004, 8.5.6. Therefore, 802.16a discloses that different UL bursts (each consisting of subchannels) can be transmitted from different SSs.

88. Therefore, the combination of 802.16a and Koo teaches that a user’s “ranging transmission” (the claimed “*probing signal*”) overlaps over a certain number of OFDMA symbols in time (the claimed “*overlap, in the time domain*”) with “MAC payloads” in UL bursts that are transmitted by other SSs (the claimed “*uplink signals transmitted over an uplink frequency band by other mobile devices in the system*”).

89. As another example, 802.16a also discloses that different SSs transmit “ranging transmissions” that collide (and therefore overlap in time) on the single ranging channel. In particular, 802.16a teaches that for the Wireless MAN-OFDMA PHY implementations, “the MAC shall define a single ranging channel” and “[u]sers are allowed to collide on this ranging channel.” HONDA-1004, 8.5.7 (paragraph 1). When transmissions of these different ranging transmissions (which include different “ranging codes”) by multiple users collide on the ranging

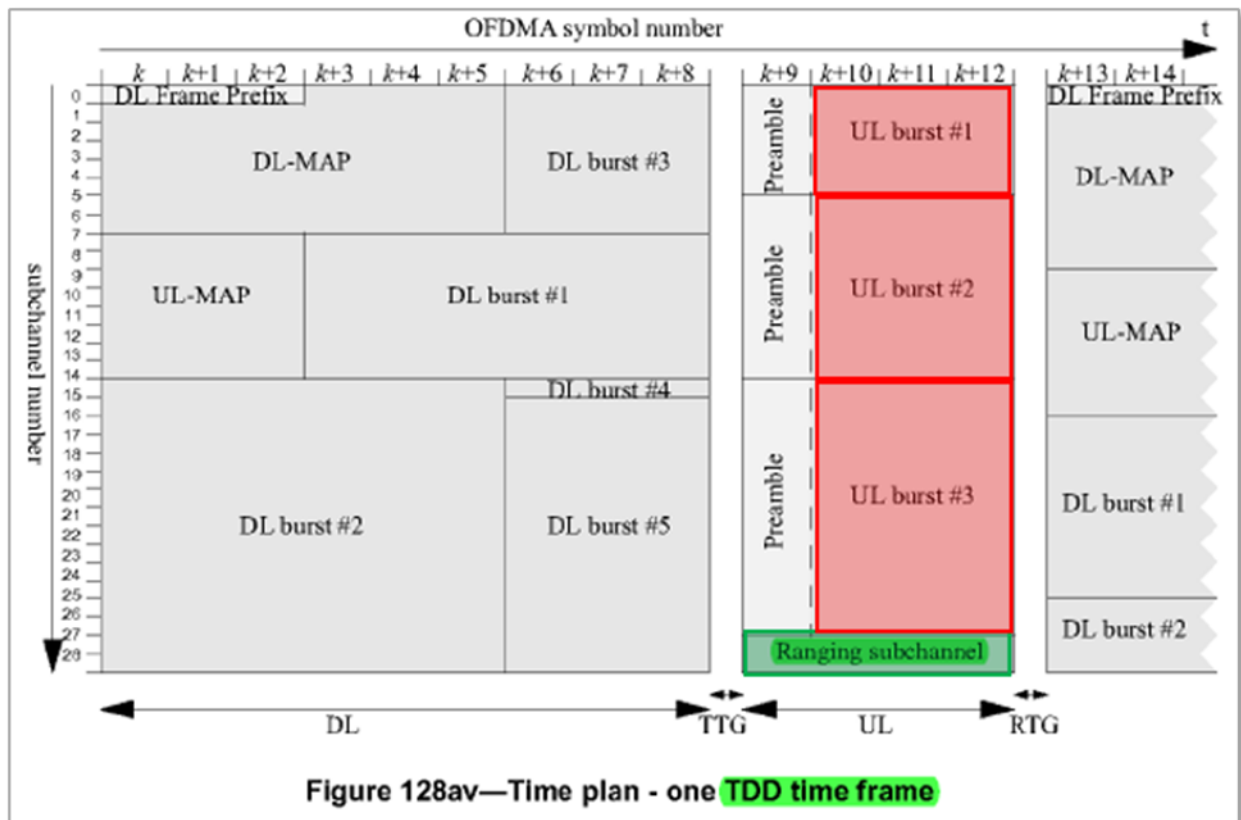
channel, “the BS can separate colliding codes and extract timing (ranging) information and power” for a particular user, which is referred to as “the process of user code detection.” HONDA-1004, 8.5.7.3 (paragraph 8).

90. Therefore, the combination of 802.16a and Koo teaches that a user’s “ranging transmission” (the claimed “*probing signal*”) is configured to “collide” during the “period of one OFDM symbol” on the ranging channel (the claimed “*overlap, in the time domain*”) with “colliding codes” in “ranging transmissions” that are transmitted by other users in the ranging subchannel (the claimed “*uplink signals transmitted over an uplink frequency band by other mobile devices in the system*”).

91. As a result, for the various reasons discussed above, a POSITA would have understood that the combination of 802.16a and Koo discloses “*the probing signal is configured to overlap, in the time domain, with uplink signals transmitted over an uplink frequency band by other mobile devices in the system*” as recited in claim feature [23.3].

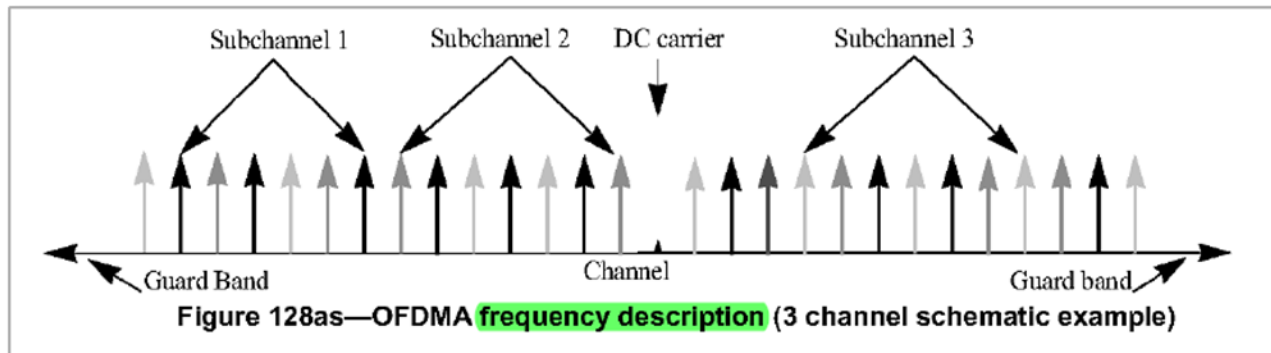
[23.4] “the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system.”

92. As discussed above, 802.16a defines a “frame structure” in which **uplink** (UL) transmissions include “UL bursts” and a “ranging subchannel.” HONDA-1004, FIG. 128av (below, annotated).



802.16a-2003, FIG. 128av (annotated)

93. As seen above, UL bursts are allocated in different frequency subchannels (along the vertical axis of FIG. 128av) which are distinct from the ranging subchannel. Furthermore, as discussed above, 802.16a describes “subchannels” as a fundamental part of the “**frequency domain** description” of OFDMA. HONDA-1004, 8.5.2.2, FIG. 128as (below, annotated).



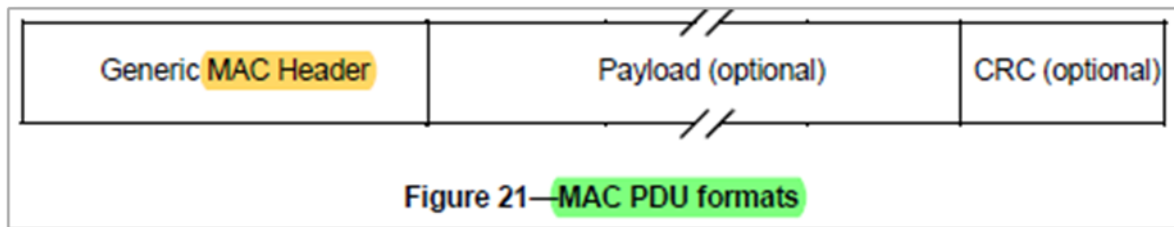
802.16a-2003, FIG. 128as (annotated)

94. Therefore, a POSITA would have understood that the “ranging transmission” of 802.16a occupies a portion of spectrum in the uplink frequency band (e.g., in FIG. 128av, the ranging transmission occupies the “ranging subchannel” in the last two frequency subchannels of the uplink frequency band from subchannel numbers 0 through 31) which is not designated for transmission of the UL bursts.

95. This is further confirmed by 802.16a disclosing a technique for “UL transmission allocations” which involve “the **allocation of ranging subchannels** within the OFDMA symbols, while the **rest of the subchannels** are used for **users transmission.**” HONDA-1004, 8.5.4.6. Therefore, 802.16a clearly distinguishes the (frequency-domain) subchannel allocation of “ranging subchannels” which is distinct from the “rest of the subchannels” that are allocated for user transmissions. Accordingly, a POSITA would have understood that the “ranging transmission” of 802.16a occupies a portion of spectrum in the uplink frequency band not designated for transmission of the “UL bursts.”

96. In addition, a POSITA would have understood that the UL bursts of 802.16a include **uplink control** signals. For example, as discussed in regard to claim feature [23.3], above, each UL burst includes multiple “MAC PDUs.”

HONDA-1005, 6.2.3.2, FIG. 26. Further, 802.16a specifies that each MAC PDU has a “**MAC header**.” HONDA-1005, 6.2.2, FIG. 21 (below, annotated).



802.16-2001, FIG. 21 (annotated)

97. The MAC header can be a “Generic MAC Header” (which can include a “MAC management message” or “CS data”) or the MAC header can be a “Bandwidth Request Header used to request additional bandwidth.” HONDA-1005, 6.2.2. In each case, a POSITA would have understood that the “MAC header” includes numerous fields with parameters, identifiers, and descriptors that convey control information about the uplink MAC PDU transmitted in the UL burst. HONDA-1005, Tables 3 and 6. For example, the “Generic MAC header” includes a field “CI” which is a 1-bit indicator of whether CRC is appended to the MAC PDU, and a field “CID” which is a 16-bit connection identifier, and a field “EC” which is a 1-bit “Encryption Control” flag indicating whether the payload of the uplink MAC PDU is encrypted. HONDA-1005, Table 3 (below, annotated).

Table 3—Generic MAC header fields

Name	Length (bits)	Description
CI	1	CRC Indicator 1 = CRC is appended to the PDU 0 = No CRC is appended
CID	16	Connection Identifier
EC	1	Encryption Control 0 = Payload is not encrypted 1 = Payload is encrypted
EKS	2	Encryption Key Sequence The index of the Traffic Encryption Key and Initialization Vector used to encrypt the payload. This field is only meaningful if the Encryption Control field is set to 1.
HCS	8	Header Check Sequence An 8-bit field used to detect errors in the header. The generator polynomial is $g(D)=D^8 + D^2 + D + 1$.
HT	1	Header Type. Shall be set to zero.
LEN	11	Length The length in bytes of the MAC PDU including the MAC header.
Type	6	This field indicates the payload type, including presence of subheaders.

802.16-2001, Table 3 (annotated)

98. Therefore, because the MAC header of the MAC PDU includes various flags, identifiers, and indicators that control or identify features regarding the uplink transmission of the MAC PDU (such as encryption and CRC of the MAC PDU) in the uplink UL burst, a POSITA would have understood that these various fields of the MAC header convey uplink control information. Therefore, a POSITA would have understood that the “MAC header” of the uplink “MAC PDU” which is transmitted in the “UL burst” of 802.16a is an “uplink control signal.”

99. Therefore, at least because of the reasons discussed above, 802.16a teaches the “ranging transmission” (the claimed “*probing signal*”) is configured to

occupy the “ranging subchannel” (the claimed “*a portion of spectrum in the uplink frequency band*”) which is not designated for transmission of the “MAC headers” which include various uplink control information (the claimed “*transmission of uplink control signals in the system*”).

100. As a result, a POSITA would have understood that the combination of 802.16a and Koo discloses “*the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system*” as recited in claim feature [23.4].

Claims 24, 26, and 27 are obvious over 802.16a in view of Koo

Claim 24

[24.0] “The mobile device of claim 23, wherein the probing signal provides information for the base station to estimate a channel profile in the frequency domain.”

101. As discussed above, when the base station in 802.16a receives a ranging transmission from the SS, the BS performs a process of “code detection” in which the BS detects the “ranging code” of the user and obtains a “**Channel Impulse Response (CIR)**” to acquire information about “the user **channel and condition.**” HONDA-1004, 8.5.7.3. Furthermore, a POSITA would have understood that the base station uses the “Channel Impulse Response (CIR)” of 802.16a to estimate a channel profile in the frequency-domain. For example, 802.16a discloses a “Fourier transform” representation of “channel impulse

responses.” HONDA-1004, 8.3.3.1.2. Although this particular description in 802.16a is in the context of the single-carrier (“SCa”) implementation, a POSITA would have understood that, in general, it was fundamentally well-known that a “Fourier transform” is an extremely common frequency-domain representation of a time-domain sequence (in this case, the time-domain sequence of a “channel impulse response”).

102. Based on my experience and knowledge, it was well-known prior to the Critical Date that a receiver in an OFDM wireless system can estimate the frequency response of a channel by using a Fourier transform of the channel impulse response. For example, Terry describes “[c]hannel estimation is the task of estimating the frequency response of the radio channel” where the “frequency response of the channel is the Fourier transform of the channel impulse response” and “the channel estimation process outputs ... an estimate of the channel frequency response for each subcarrier”. HONDA-1013, p.77 (“Channel Estimation”).

103. Furthermore, I note that this description in 802.16a of a base station obtaining a “channel impulse response” from which the base station obtains a frequency-domain channel response is consistent with the ’302 Patent’s description that “by estimating the peaks of a channel response in the time domain ... the

channel profile in the frequency domain ... can be obtained.” HONDA-1001, 9:18-26.

104. Therefore, because 802.16a discloses the “ranging transmission” (the claimed “*probing signal*”) provides a “channel impulse response” (the claimed “*information*”) which the base station uses to estimate the channel frequency response (the claimed “*channel profile in the frequency domain*”), a POSITA would have understood that the combination of 802.16a and Koo discloses “*the probing signal provides information for the base station to estimate a channel profile in the frequency domain*” as recited in claim 24.

Claim 26

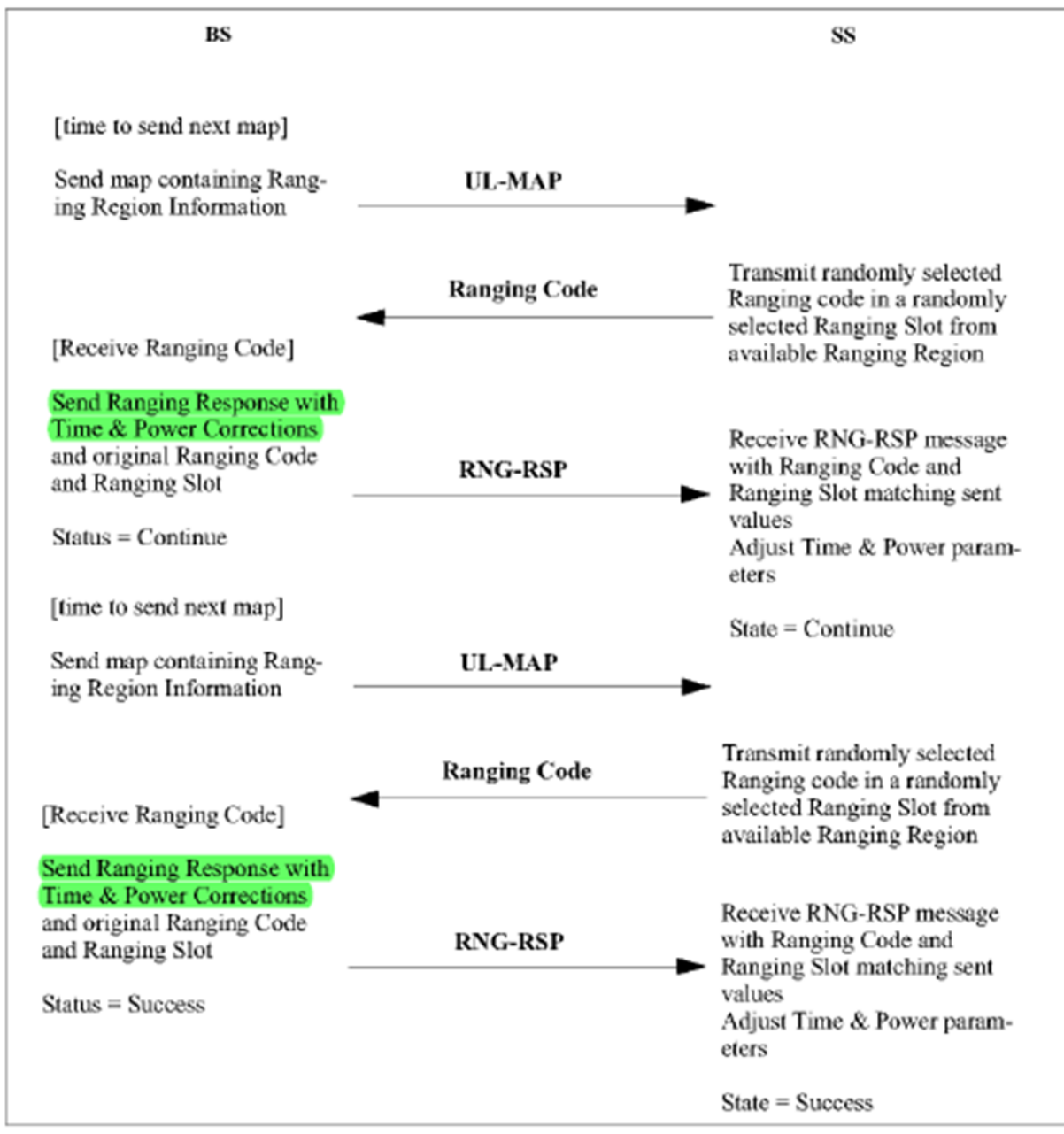
[26.0] “The mobile device of claim 23, wherein the probing signal provides information for the base station to determine a transmission format for a subsequent transmission.”

105. As discussed above, 802.16a discloses that a periodic CDMA “ranging transmission” (the claimed “*probing signal*”) by the SS allows the BS to acquire information “about the user channel and condition.” HONDA-1004, 8.5.7.3, p. 203. By acquiring this information, the “time (ranging) and power measurements allow the system to compensate for the near/far user problems and the propagation delay.” *Id.* In particular, the “time and power parameters” are “monitored, measured, and stored **at the base station**, and transmitted to the subscriber unit.” HONDA-1004, 8.5.10.2. Thus, at the base station, “the stored

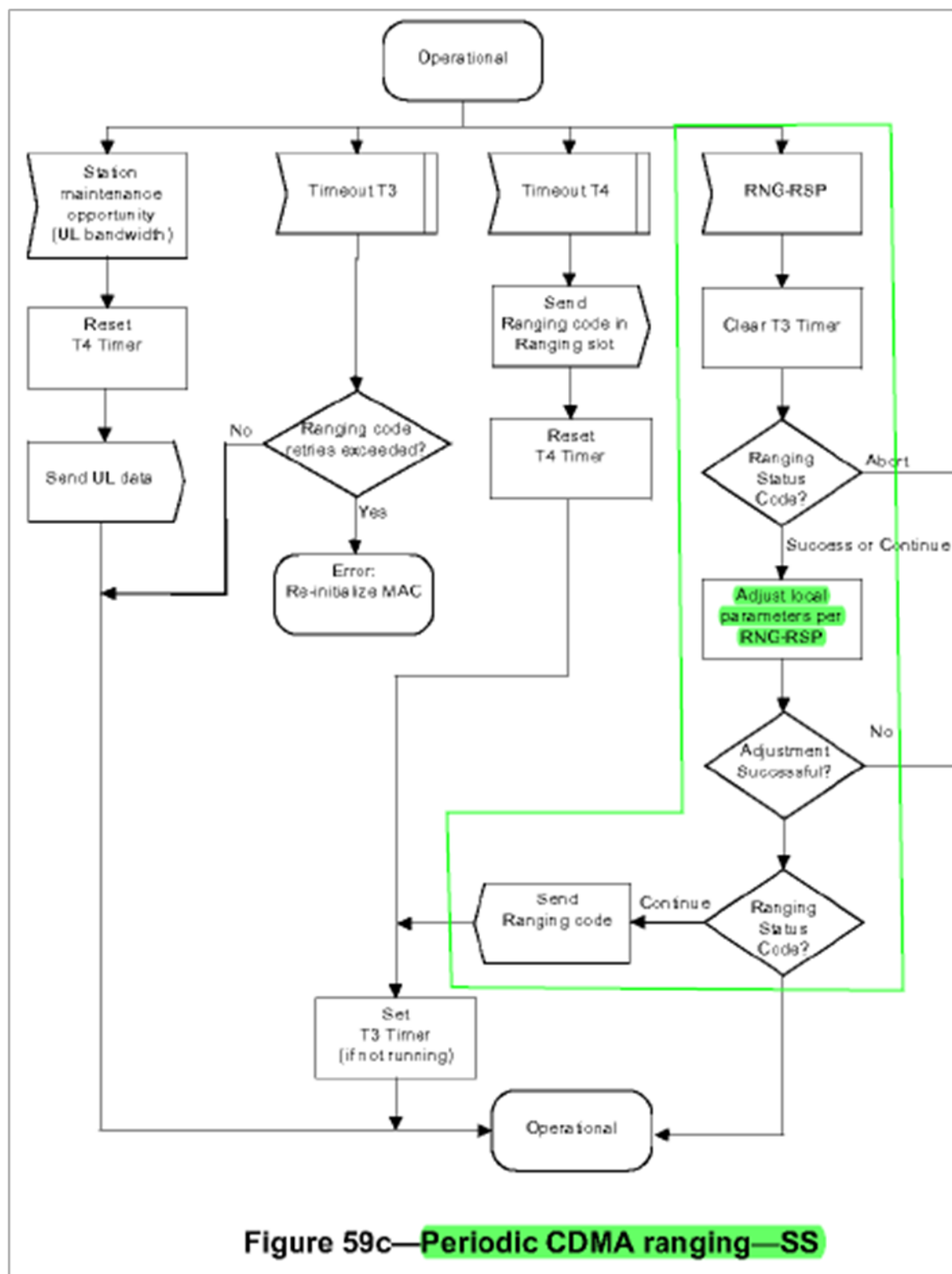
parameters are updated in a periodic manner based on configurable update intervals to ensure changes in the channel can be accommodated.” *Id.* This enables the BS “to adjust transmission parameters so the SSs can communicate with the BS properly.” HONDA-1004, 6.2.10, p. 80.

106. In particular, after updating the stored transmission parameters, the BS transmits the adjusted transmission parameters to the SS through the “RNG-RSP” and thereby sends the “Ranging Response with Time & Power Corrections.” HONDA-1004, Table 63b (below, annotated). At the SS, the adjusted parameters in the received RNG-RSP allows the SS to “adjust local parameters per RNG-RSP.” HONDA-1004, FIG. 59c (below, annotated).

Table 63b—Ranging and automatic adjustments procedure



802.16a-2003, Table 63b (annotated)



802.16a-2003, FIG. 59c (annotated)

107. Therefore, as seen above, the BS monitors, measures, and stores the SS's transmission parameters, updates the parameters periodically based on the periodic CDMA ranging transmissions received from the SS, and transmits the adjusted transmission parameters to the SS through the "RNG-RSP" message, which allows the SS to adjust its local parameters. 802.16a explains that the "Ranging Response message contains all the needed adjustment (e.g., time, power and possibly frequency corrections)." HONDA-1004, 6.2.10.2 (4th paragraph).

108. This periodic adjustment of the SS's transmission parameters by the BS enables the uplink to "support different modulation schemes for each SS based on the MAC burst configuration messages coming from the Base Station." HONDA-1004, 8.5.9.4.1. In particular, 802.16a provides various examples of different modulation schemes that are based on constellation mappings of "Gray-mapped QPSK," "16-QAM," and "64-QAM." HONDA-1004, 8.5.9.4.1 (1st paragraph). A POSITA would understand that the fundamental difference between these supported modulation schemes is that they trade bandwidth efficiency for energy efficiency. Specifically going from QPSK to 16-QAM to 64-QAM allows for higher data rates to be supported, but at the cost of higher power requirements. Thus, a POSITA would understand that as part of performing adaptive modulation, some measurement of received signal power is needed. Furthermore, 802.16a explains that the constellation is "normalized by multiplying the constellation point

with the indicated factor c to achieve equal average power.” *Id.* As such, a POSITA would have understood that the modulation scheme of 802.16a can be adapted (e.g., the constellation and average power of the modulation constellation can be adjusted) based on adjustments of transmission power that the BS determines based on the received CDMA ranging code. In general, this process of “adaptive modulation” enables a system to “**subsequently communicate** with multiple systems using different burst profiles.” HONDA-1004, p. 4 (definition 3.57).

109. Therefore, 802.16a discloses that the periodic CDMA ranging transmission (the claimed “*probing signal*”) provides the BS with information such as a “channel impulse response (CIR)” and “information about the user channel and condition” (the claimed “*information*”) so that the BS can monitor, measure, store, and update the SS’s transmission parameters and adaptively determine a “modulation scheme” (the claimed “*for the base station to determine a transmission format*”) for a subsequent transmission.

110. Accordingly, for at least the reasons discussed above, a POSITA would have found obvious that the combination of 802.16a and Koo discloses “*the probing signal provides information for the base station to determine a transmission format for a subsequent transmission*” as recited in claim 26.

Claim 27

[27.0] “The mobile device of claim 26, wherein the transmission format comprises a modulation/coding or pilot pattern.”

111. As discussed in regard to claim 26, above, 802.16a discloses that the CDMA ranging transmission (the claimed “*probing signal*”) enables the base station to adaptively determine a “modulation scheme” (the claimed “*transmission format*”) for a subsequent transmission. For example, as discussed above, 802.16a provides various examples of different modulation schemes that are based on constellation mappings of “Gray-mapped QPSK,” “16-QAM,” and “64-QAM.” HONDA-1004, 8.5.9.4.1 (1st paragraph).

112. Furthermore, as discussed above, based on channel information acquired from the periodic ranging transmissions, the base station is able to periodically update the SS’s “time and power parameters” and inform the SS of the updated parameters to “ensure changes in the channel can be accommodated.” HONDA-1004, 8.5.10.2. This enables the BS “to adjust transmission parameters so the SSs can communicate with the BS properly.” HONDA-1004, 6.2.10, p. 80

113. As such, a POSITA would have understood that the modulation scheme of 802.16a can be adapted (e.g., the timing and power of the modulation constellation can be adjusted) based on adjustments of transmission parameters that the BS determines from the received CDMA ranging transmission. In addition, 802.16a describes “modulation” and the adaptive use of “different

modulation schemes” as part of the overall process of “channel coding.” HONDA-1004, 8.5.9 (heading), 8.5.9.4 (heading), 8.5.9.4.1 (2nd paragraph).

114. Therefore, a POSITA would have understood that the combination of 802.16a and Koo disclose “*the transmission format comprises a modulation/coding or pilot pattern.*”

ANALYSIS OF 802.16a and KITROSER

115. As I have previously mentioned above, 802.16a discloses all features of the Challenged Claims except for a device that is “mobile.” However, a POSITA would have understood that the relevant teachings of 802.16a (e.g., as relating to the “ranging process”) are directly applicable to a “mobile environment” as taught by Kitroser.

116. Moreover, because Kitroser predates even the earlier filing date of the ’302 First Provisional, Kitroser shows that a POSITA would have known the applicability of the 802.16a “ranging process” to a “mobile environment” even as far back as the filing date of the ’302 First Provisional.

Kitroser Overview

117. Kitroser shows that a POSITA would have known, even prior to the ’302 First Provisional filing date, that the teachings of 802.16a relating to the “ranging process” were directly applicable to mobile environments.

118. Kitroser is directed to “IEEE 802.16e Mobility System Perspective.” HONDA-1007, title. Kitroser explains “[t]his contribution presents some notes on reference system deployment scenario and impact of the mobile environment on the current 802.16a, and answers some of the points presented in the call for contributions IEEE 80216e-02_01.” HONDA-1007, p. 1 (Abstract); p. 2 (§ 1).

119. In particular, Kitroser discusses the “impact of the mobile environment on the current 802.16a” standard. HONDA-1007, p. 1 (§ 1), p. 3 (§ 3). In discussing the impact of a mobile environment on the existing IEEE 802.16a standard, Kitroser makes the unequivocal statement that for the “Ranging” process, “[n]o changes are required in the PHY layer ranging mechanism.” HONDA-1007, p. 3 (§ 3). As such, Kitroser clearly discloses that the PHY layer ranging mechanism of the existing IEEE 802.16a standard (for fixed wireless devices) would remain unchanged in a mobile environment.

The Combination of 802.16a and Kitroser

120. As mentioned above, 802.16a is directed to “fixed broadband wireless access systems” in which subscriber stations are stationary. HONDA-1004, p. 3. Nonetheless, a POSITA would have known, even prior to the ’302 First Provisional filing date, that the periodic CDMA ranging process described in 802.16a could also be used in a “mobile environment,” as taught by Kitroser.

121. As discussed above, Kitroser was a contribution to the IEEE 802.16 Broadband Wireless Access Working Group which was tasked with developing the IEEE 802.16e standard for mobile wireless broadband communication. HONDA-1007, p. 1. Kitroser discusses the “impact of the mobile environment on the current 802.16a” standard and therefore specifically contemplated modification of 802.16a to mobile environments. HONDA-1007, p. 1 (§ 1), p. 3 (§ 3). Specifically, for the “Ranging” process of 802.16a, Kitroser unequivocally states that “[n]o changes are required in the PHY layer ranging mechanism” of 802.16a. HONDA-1007, p. 3 (§ 3). As such, Kitroser clearly shows a POSITA would have known, even prior to the ’302 First Provisional filing date, that the teachings of 802.16a relating to the “ranging process” were directly applicable to a mobile environment.

122. Even before the ’302 First Provisional filing date of January 2004, there was extensive discussion on how to modify the IEEE 802.16a standard to mobile environments (as evidenced by the IEEE 802.16 Broadband Wireless Access Working Group which began work in early 2003, for which Kitroser was one of many contributions). For example, Leiba was another contribution to the same IEEE 802.16 Broadband Wireless Access Working Group. HONDA-1008, p.1. Like Kitroser, Leiba studied “802.16a OFDMA PHY suitability for mobile applications” prior to the ’302 First Provisional filing date, and specifically

described “[i]n a mobile environment ranging has to be more frequent because of the existence of fast fading effects in the channel” and that the existing IEEE 802.16a standard could accommodate these changes (e.g., “OFDMA PHY can support the fast power control loop necessary in a mobile environment”).
HONDA-1008, pp.1, 2.

123. As a result, in view of the teachings of Kitroser and the general knowledge of a POSITA, a POSITA would have understood even before the ’302 First Provisional filing date that the “periodic CDMA ranging” process described in 802.16a would have been directly applicable to **mobile** devices.

Claim 23 is obvious over 802.16a in view of Kitroser

[23.P]“A mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system, the mobile device comprising:”

124. To the extent the preamble is deemed limiting, the combination of 802.16a and Kitroser renders it obvious. As previously discussed, the combination of 802.16a and Kitroser teaches that an SS operating in an OFDM communication system that can be implemented in a “mobile environment.”

125. Thus, the combination of 802.16a and Kitroser teaches “*a mobile device in an Orthogonal Frequency Division Multiplexing (OFDM) communication system.*”

[23.1] “a receiver configured to receive a request for a probing signal from a base station in the system;”

126. As I previously discussed in regards to 802.16a and Koo, above, for claim feature [23.1], 802.16a discloses that an SS includes a receiver configured to receive an “RNG-RSP message” with the special status code of “Continue” (the claimed “*request*”) which initiates the SS to send a “ranging code” in a “ranging transmission” (the claimed “*probing signal*”).

127. For at least this reason, the combination of 802.16a and Kitroser teaches “*a receiver configured to receive a request for a probing signal from a base station in the system*” as recited in claim feature [23.1].

[23.2] “a transmitter configured to form and transmit, in response to the received request, the probing signal with a code sequence modulated in the frequency domain, wherein:”

128. As I previously discussed in regards to 802.16a and Koo, above, for claim feature [23.2], 802.16a teaches that **(i)** the SS transmits the “ranging transmission” (the claimed “*probing signal*”) with a “ranging code” that is a “subsequence of the pseudo-noise sequence” (the claimed “*code sequence*”), and that **(ii)** the bits of this code sequence are modulated onto “carriers” in the “ranging subchannel” (the claimed “*in the frequency domain*”).

129. For at least this reason, a POSITA would have understood that the combination of 802.16a and Kitroser discloses “*a transmitter configured to form and transmit, in response to the received request, the probing signal with a code sequence modulated in the frequency domain*” as recited in claim feature [23.2].

[23.3] “the probing signal is configured to overlap, in the time domain, with uplink signals transmitted over an uplink frequency band by other mobile devices in the system; and”

130. As I previously discussed in regard to 802.16a and Koo, above, for claim feature [23.3], 802.16a discloses at least two different types of “uplink signals” transmitted by other SSs that overlap with a ranging transmission.

131. As one example, discussed above, 802.16a teaches that a user’s “ranging transmission” (the claimed “*probing signal*”) overlaps over a certain number of OFDMA symbols in time (the claimed “*overlap, in the time domain*”) with “MAC payloads” in UL bursts that are transmitted by other SSs over a band of frequency subchannels used for uplink transmission (the claimed “*uplink signals transmitted over an uplink frequency band by other mobile devices in the system*”).

132. As another example, discussed above, 802.16a teaches that a user’s “ranging transmission” (the claimed “*probing signal*”) is configured to “collide” during the “period of one OFDM symbol” on the ranging channel (the claimed “*overlap, in the time domain*”) with “colliding codes” of ranging transmissions that are transmitted by other users over the ranging subchannel (the claimed “*uplink signals transmitted over an uplink frequency band by other mobile devices in the system*”).

133. For at least these reasons, a POSITA would have understood that the combination of 802.16a and Kitroser discloses “*the probing signal is configured to*

overlap, in the time domain, with uplink signals transmitted over an uplink frequency band by other mobile devices in the system" as recited in claim feature [23.3].

[23.4] “the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system.”

134. As I previously discussed in regard to 802.16a and Koo, above, for claim feature [23.4], 802.16a teaches the “ranging transmission” (the claimed “*probing signal*”) is configured to occupy the “ranging subchannel” (the claimed “*a portion of spectrum in the uplink frequency band*”) which is not designated for transmission of the “MAC headers” which include various control information (the claimed “*transmission of uplink control signals in the system*”).

135. For at least this reason, a POSITA would have understood that the combination of 802.16a and Kitroser discloses “*the probing signal is configured to occupy a portion of spectrum in the uplink frequency band not designated for transmission of uplink control signals in the system*” as recited in claim feature [23.4].

Claims 24, 26, and 27 are obvious over 802.16a in view of Kitroser

Claim 24

[24.0] “The mobile device of claim 23, wherein the probing signal provides information for the base station to estimate a channel profile in the frequency domain.”

136. As I previously discussed in regard to 802.16a and Koo, above, for claim 24, the “ranging transmission” of 802.16a (the claimed “*probing signal*”) provides a “channel impulse response” (the claimed “*information*”) for the base station to estimate a Fourier transform representation of the channel response (the claimed “*channel profile in the frequency domain*”).

137. For at least these reasons, a POSITA would have understood that the combination of 802.16a and Kitroser discloses “*the probing signal provides information for the base station to estimate a channel profile in the frequency domain*” as recited in claim 24.

Claim 26

[26.0] “The mobile device of claim 23, wherein the probing signal provides information for the base station to determine a transmission format for a subsequent transmission.”

138. As I previously discussed in regard to 802.16a and Koo, above, for claim 26, the ranging transmission of 802.16a (the claimed “*probing signal*”) provides the BS with information such as a “channel impulse response (CIR)” and “information about the user channel and condition” (the claimed “*information*”) so that the BS can monitor, measure, store, and update the SS’s transmission parameters and adaptively determine a “modulation scheme” (the claimed “*for the base station to determine a transmission format*”) for a subsequent transmission.

139. Therefore, a POSITA would have found obvious that the combination of 802.16a and Kitroser discloses “*the probing signal provides information for the base station to determine a transmission format for a subsequent transmission*” as recited in claim 26.

Claim 27

[27.0] “The mobile device of claim 26, wherein the transmission format comprises a modulation/coding or pilot pattern.”

140. As I previously discussed in regard to 802.16a and Koo, above, for claim 27, and also as discussed in regard to claim 26, above, the CDMA ranging transmission of 802.16a (the claimed “*probing signal*”) enables the base station to adaptively determine at least a transmission power and a “modulation scheme” (the claimed “*transmission format*”) for a subsequent transmission. In addition, 802.16a describes “modulation” and the adaptive use of “different modulation schemes” as part of the overall process of “channel coding.” HONDA-1004, 8.5.9 (heading), 8.5.9.4 (heading), 8.5.9.4.1 (2nd paragraph).

141. For at least these reasons, a POSITA would have understood that the combination of 802.16a and Kitroser disclose “*the transmission format comprises a modulation/coding or pilot pattern.*”

LEGAL PRINCIPLES

Anticipation

142. I have been informed that a patent claim is invalid as anticipated under 35 U.S.C. § 102 if each and every element of a claim, as properly construed, is found either explicitly or inherently in a single prior art reference. Under the principles of inherency, if the prior art necessarily functions in accordance with, or includes the claimed limitations, it anticipates.

143. I have been informed that a claim is invalid under 35 U.S.C. § 102(a) if the claimed invention was known or used by others in the U.S., or was patented or published anywhere, before the applicant's invention. I further have been informed that a claim is invalid under 35 U.S.C. § 102(b) if the invention was patented or published anywhere, or was in public use, on sale, or offered for sale in this country, more than one year prior to the filing date of the patent application (critical date). And a claim is invalid, as I have been informed, under 35 U.S.C. § 102(e), if an invention described by that claim was described in a U.S. patent granted on an application for a patent by another that was filed in the U.S. before the date of invention for such a claim.

Obviousness

144. I have been informed that a patent claim is invalid as "obvious" under 35 U.S.C. § 103 in light of one or more prior art references if it would have been obvious to a POSITA, taking into account (1) the scope and content of the prior art, (2) the differences between the prior art and the claims, (3) the level of ordinary

skill in the art, and (4) any so called “secondary considerations” of non-obviousness, which include: (i) “long felt need” for the claimed invention, (ii) commercial success attributable to the claimed invention, (iii) unexpected results of the claimed invention, and (iv) “copying” of the claimed invention by others. For purposes of my analysis above and because I know of no indication from the patent owner or others to the contrary, I have applied a date of January 29, 2004, as the date of invention in my obviousness analyses, although in many cases the same analysis would hold true even at an earlier time than January 29, 2004.

145. I have been informed that a claim can be obvious in light of a single prior art reference or multiple prior art references. To be obvious in light of a single prior art reference or multiple prior art references, there must be a reason to modify the single prior art reference, or combine two or more references, in order to achieve the claimed invention. This reason may come from a teaching, suggestion, or motivation to combine, or may come from the reference or references themselves, the knowledge or “common sense” of one skilled in the art, or from the nature of the problem to be solved, and may be explicit or implicit from the prior art as a whole. I have been informed that the combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. I also understand it is improper to rely on hindsight in making the obviousness determination.

ADDITIONAL REMARKS

146. I currently hold the opinions set expressed in this declaration. But my analysis may continue, and I may acquire additional information and/or attain supplemental insights that may result in added observations.

147. I declare that all statements made herein of 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.

Dated: 3/29/23

By: _____

Dr. R. Michael Buehrer



APPENDIX A

R. Michael Buehrer, FIEEE

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Education

June 1996	Virginia Polytechnic Institute and State University, The Bradley Department of Electrical and Computer Engineering, Bradley Fellowship, Ph.D.
August 1993	The University of Toledo, Department of Electrical Engineering and Computer Science, M.S.
June 1991	The University of Toledo, Department of Electrical Engineering and Computer Science, B.S.

Employment

Aug. 2012 - Present	Professor, Virginia Polytechnic Institute and State University, Bradley Department of Electrical and Computer Engineering, Director of <i>Wireless @ Virginia Tech</i>
Aug. 2006 – Aug. 2012	Associate Professor, Virginia Polytechnic Institute and State University, Bradley Department of Electrical and Computer Engineering, Mobile and Portable Radio Research Group.
Aug. 2009 – Dec. 2009	Visiting Researcher at the Laboratory for Telecommunication Sciences (LTS) a federal research lab which focuses on telecommunication challenges for national defense.
Aug. 2001 – Aug. 2006	Assistant Professor, Virginia Polytechnic Institute and State University, Bradley Department of Electrical and Computer Engineering, Mobile and Portable Radio Research Group.
Aug. 2001 – Present	Independent Consultant, self-employed.
Aug. 1996 – Aug. 2001	Member Technical Staff, Bell Laboratories, Lucent Technologies, promoted to Distinguished Member of Technical Staff in September 2000.
Sep. 1993 – Jun. 1996	Graduate Research Assistant, Virginia Polytechnic Institute and State University, Bradley Department of Electrical and Computer Engineering, Mobile and Portable Radio Research Group.
May 1994 – Aug. 1994	Senior Engineer, Stanford Telecommunications, Advanced Programs.
Sep. 1991 – Aug. 1993	Graduate Research Assistant, The University of Toledo, Department of Electrical Engineering and Computer Science, Communications Research Group.

Honors and Recognitions

- Fellow of the IEEE (So named “for contributions to wideband signal processing in communications and geolocation”)
- Vanu Bose Best Paper Award *IEEE Military Communications Conference (MILCOM)* 2021.
- Dean’s Award for Teaching Excellence - April 2014.
- Ellersick Best Paper Award in the Unclassified Technical Program, *IEEE Military Communications Conference (MILCOM)* 2010.
- SDR Forum Best Paper Award, 2007.
- Outstanding Paper Award, SDR Forum, 2008.
- Dean’s Award for Outstanding New Assistant Professor, College of Engineering, 2003.
- Dean’s List for Teaching Effectiveness (teaching evaluation greater than 3.6) 16 out of 18 semesters list was published.
- Nominated for Teaching Certificate, College of Engineering, Spring 2004 and Spring 2005.
- Bell Labs President’s Silver Award for outstanding research contributions.
- 1999 Best Paper Award for *Bell Labs Technical Journal*.

Patents

- S. D. Gordon, R.M. Vaghefi, and R.M. Buehrer, “Estimating the Location of a Wireless Terminal Based on Cooperative Measurements,” *US Patent No. 10,527,708*, January 7, 2020.
- S. D. Gordon, R.M. Vaghefi, and R.M. Buehrer, “Estimating the Location of a Wireless Terminal Based on Radio-Frequency Pattern Matching and Cooperative Measurements,” *US Patent No. 9,989,620 B1*, June 5, 2018.
- S. D. Gordon, R.M. Vaghefi, and R.M. Buehrer, “Estimating the Location of a Wireless Terminal Based on Radio-Frequency Pattern Matching and Cooperative Measurements,” *US Patent No. 9,596,571 B1*, March 14, 2017.
- R.M. Buehrer, R.A. Soni, and J.A. Tsai, “Methods and Apparatus for Downlink Diversity in CDMA Using Walsh Codes,” *U.S. Patent No. 7,400,614 B2*, July 15, 2008.
- R. D. Benning, R. M. Buehrer, Mark H Kramlm, and P. A. Polakos, “Space-Time Spreading and Phase Sweep Transmit Diversity”, *US Patent No. 7,042,955 B2*, May 9, 2006.
- R.D. Benning, R.M. Buehrer, and R.A. Soni, “Biased Phase Sweep Transmit Diversity”, *US Patent No. 7,035,599 B2*, April 25, 2006.
- R. D. Benning, R. M. Buehrer, P. A. Polakos, and R. A. Soni, “Split Shift Phase Sweep Transmit Diversity, ” *US Patent No. 6,980,778 B2*, December 27, 2005.
- R.D. Benning, R.M. Buehrer, and R.A. Soni, “Symmetric Sweep Phase Sweep Transmit Diversity”, *US Patent No. 6,920,314*, July 19, 2005.
- R.M. Buehrer, S.P. Nicoloso, R.A. Soni, and D. Uptegrove, “Cellular Communications System And Related Methods”, *US Patent No. 6,801,791*, October 5, 2004.

- R.M. Buehrer, S.-C. Liu, S.P. Nicoloso, and D. Uptegrove, “Method of channel estimation and compensation based thereon,” *U.S. Patent No. 6,542,560*, April 1, 2003.
- R.M. Buehrer and S.-C. Liu, “Code division multiple access system and method of operation with improved signal acquisition and processing,” *U.S. Patent No. 6,549,565*, April 15, 2003.
- R.D. Benning, R.M. Buehrer, and R.A. Soni, “Apparatus and method of enhancing transmit diversity,” *U.S. Patent No. 6,594,226*, July 15, 2003.
- R.M. Buehrer, S.-C. Liu, S.P. Nicoloso, and D. Uptegrove, “Iterative channel estimation and compensation based thereon,” *U.S. Patent No. 6,614,857*, September 2, 2003.
- R.M. Buehrer and R.A. Soni, “Methods And Apparatus For Downlink Diversity In CDMA Using Walsh Codes”, *U.S. Patent No. 6,515,978*, February 4, 2003.
- R.M. Buehrer, S. Gollamudi, and S.P. Nicoloso, “Multistage interference cancellation for CDMA applications using M-ary orthogonal modulation,” *US Patent No. 6,363,103*, March 26, 2002.
- S.A. Allpress, R.M. Buehrer, and R.A. Soni, “Receiver Architecture Employing Space Time Spreading and Orthogonal Transmit Diversity Techniques,” *US Patent No. 6,317,410 B1*, November 13, 2001.
- S.A. Allpress, R.M. Buehrer, Quinn Li, Ramesh Nallepilli, and R.A. Soni, “Transmitter Architecture Employing Space Time Spreading and Orthogonal Transmit Diversity Techniques,” *US Patent No. 6,392,988*, May 21, 2001.
- R.M. Buehrer, M.D. Hahm, S.C. Liu, and S.P. Nicoloso, “Base Station System Including Parallel Interference Cancellation Processor,” *US Patent No. 6,157,847*, December 5, 2000.

Teaching

Undergraduate Courses

- Engineering Exploration
- Electric Circuits
- Signals and Systems
- Introduction to Communications
- Digital Communications
- Analog and Digital Communication Laboratory – *developed this course with \$70k grant from the State of Virginia.*

Graduate Courses

- Spread Spectrum Communications – *developed this course for the ECE department. It is now a permanent offering.*
- Advanced Digital Communications
- Multi-Channel Communications (Course covers the fundamentals of OFDM and MIMO techniques the underlying technologies for 4G cellular communications) – *developed this course for the ECE dept.*
- Information Theory
- Machine Learning for Communication Systems

Teaching Evaluations (through Spring 2011)

- Average student evaluation – 3.8/4.0 (17 courses, 450 students)
- Dean’s List (student evaluation > 3.6) in 16 of 18 semesters of teaching

Short Courses Given

- Position Location
- Position Location using Ultra-Wideband Signals
- Radio Resource Management in CDMA Systems
- WiFi – An introduction to WLANs
- OFDM – Multicarrier transmission for high data rate systems; Application to 4G (LTE) cellular and Wi-Fi
- Ultra Wideband Communications
- Multi-Input Multi-Output (MIMO) Communication Systems; Application to 4G (LTE/LTE-Advanced) cellular and Wi-Fi

Advising

Current

- Charlie Thornton, “Distributed Cognitive Radar,” Ph.D. candidate, expected graduation May 2023.
- William Howard, “Distributed Learning Approached for Cognitive Radar and Radio,” Ph.D. candidate, expected graduation December 2023.
- Don-Roberts Emenonye, ”Machine Learning Approaches to Remote Rehabilitation,” Ph.D. candidate, expected graduation December 2023.
- Sam Shebert, ”Automatically Classifying Modern Communication Waveforms,” Ph.D. candidate, expected graduation May 2024.
- Megan Moore, “Machine Learning in Wireless Communications,” Ph.D. candidate, expected graduation May 2025.
- Haozhou Hu, “Geolocation via Landmarks,” Ph.D. candidate, expected graduation May 2025.
- Gaurav Duggal, “Combined Radar and Communications Signals for Geolocation,” Ph.D. candidate, expected graduation May 2025.
- Harish Dureppagari, “Emergency Localization using UAVs and Collaborative Localization,” Ph.D. candidate, expected graduation May 2026.

Former

- Jianyuan Yu, “Wireless Sensing and Fusion using Deep Neural Networks,” Ph.D., August 2022.
- Yue Xu, “Deep Recurrent Q Networks for Dynamic Spectrum Access in Dynamic Heterogeneous Environments with Partial Observations,” Ph.D. , August 2022.
- Chris O’Lone, “Statistical Analysis of Geolocation Fundamentals Using Stochastic Geometry,” Ph.D. December 2020.
- Jeff Poston, “ILoViT: Indoor Localization via Vibration Tracking,” Ph.D. March 2018.
- Mahi Abdelbar, “Applications of Sensor Fusion in Classification, Localization and Mapping,” Ph.D. February 2018.
- Mico Woolward, “SUPPLEMENTING LOCALIZATION ALGORITHMS FOR INDOOR FOOTSTEPS,” Ph.D., July 2017.
- Daniel Jakubisin, “Advances in Iterative Probabilistic Processing for Communication Receivers,” Ph.D., April, 2016, *currently employed by The Hume Center*.
- Jeannette Nounagnon “Using Kullback-Leibler Divergence to Analyze the Performance of Collaborative Positioning,” Ph.D., April, 2016, *currently employed by ComSat*.
- SaiDhiraj Amuru, “Intelligent Approaches for Communication Denial,” Ph.D., September, 2015, *currently employed by Samsung*.
- Javier Schloemann, “Fundamental Analyses of Collaborative and Noncollaborative Positioning,” Ph.D., August, 2015, *currently employed by Northrup-Grumman*.
- Reza Vaghefi, “Cooperative Positioning in Wireless Sensor Networks Using Semidefinite Programming,” Ph.D., December 2014, *currently employed by Blue Danube Labs*.
- Jeong-heon Lee, “Physical Layer Security for Wireless Position Location in the Presence of Location Spoofing,” Ph.D., March 2011, *currently employed by Samsung*.
- Haris I. Volos, “Cognitive Radio Engine Design For Link Adaptation,” Ph.D., September 2010, *currently employed by the University of Arizona*.
- Tao Jia, “Collaborative Position Location for Wireless Networks in Harsh Environments,” Ph.D., March 2010, *currently employed by Qualcomm, Inc.*
- Heba Shaban, “A Novel Highly Accurate Wireless Wearable Human Locomotion,” Ph.D., April 2010, *currently employed by Arab Academy of Science and Technology*.
- Haesoo Kim, “Cooperative Communications,” Ph.D., August 2008, *currently employed by LG Electronics*.
- Rekha Menon, - “Interference Avoidance based Underlay Techniques for Dynamic Spectrum Sharing,” Ph.D., April 2007, *currently employed by Tyco Electronics*.
- Swaroop Ventkatesh, “The Design and Modeling of Ultra-Wideband Position-Location Networks,” Ph.D., February 2007, *currently employed by Marvel Semiconductor*.
- Jihad Ibrahim, “Algorithms and Architectures for UWB Receiver Design,” Ph.D. January 2007, *currently employed by MathWorks*.
- Chris Anderson, “A Software Defined Ultra Wideband Transceiver Testbed for Communications, Ranging, or Imaging,” Ph.D., September 2006, *currently an Associate Professor at the US Naval Academy*.
- Samir Al-Ghadhban - “Multi-layered Space Frequency Time Codes,” Ph.D. October, 2005, *currently an associate professor at King Fahd University*.

- Jing Jiang – “Increasing the Capacity of Wireless Data Systems - A Cross Layer Perspective,” Ph.D., July 2004, *currently employed by Texas Instruments.*
- Jiann-An Tsai – “Overloaded Array Processing Using Interference Cancellation,” Ph.D., May 2002. *Currently employed by Samsung.*
- Sebastian Rodriguez, “Value of Machine Learning and Cognition on Target Tracking,” M.S., June 2022.
- C. Tanner Fredieu, “Spectrum Awareness: Deep Learning and Isolation Forest Approaches for Open-set Identification of Signals,” M.S. May 2022.
- Dhwan Wanjara, “A Python Software Library to Improve the Accessibility of the Apple Watch as a Research Tool,” M.S. May 2022.
- Daniel Tait, “Electromagnetic Vector-Sensor Direction-of-Arrival Estimation in the Presence of Interference,” M.S. August 2020.
- Don-Roberts Emenonye, “Application of Machine Learning to Multi-Antenna Transmission and Machine Type Resource Allocation,” M.S. July 2020.
- Charlie Thornton, “Learning Schemes for Adaptive Spectrum Sharing Radar,” M.S. May 2020.
- Mark Kozy, “Creation of a Cognitive Radar with Machine Learning: Simulation and Implementation,” M.S., May 2019.
- Bryse Flowers, “Adversarial RFML: Evading Deep Learning Enabled Signal Classification,” M.S., June 2019.
- Parker White, “Constrained Clustering for Frequency Hopping Spread Spectrum Signal Separation,” M.S., August 2019.
- Ersin Selvi, “Cognitive Radar Applied To Target Tracking Using Markov Decision Processes,” M.S. December 2017, *currently employed by Raytheon.*
- Ali Gaber Mohamed, “Navigating via Discrete Astronomical Radio Sources: Geolocation Using Fringe Rates,” M.S. April 2017, *currently employed by Alexandria University.*
- Eric Sollenberger, “Iterative Leakage-Based Precoding for Multiuser-MIMO Systems,” M.S., May, 2016, *currently employed by Qualcomm, Inc..*
- Kevin McDermott, “On the Improvement of Positioning in LTE with Collaboration and Pressure Sensors,” M.S., May, 2015, *currently employed by Northrup Grumman*
- Tori Jewell, “Use of GIS in Radio Frequency and Positioning Applications,” M.S. June 2014.
- Jacob Overfield, “The Impact of MIMO on Signal Localization,” MS, May 2013, *currently employed by n-ask, inc.*
- Zachary Biskaduros, “Collaborative GPS,” MS, June 2013, *currently employed by n-ask, inc.*
- Hunter DeJarnette, “Measuring Noise in the VHF Band and Its Effect On Low SNR Signal Detection,” MS Thesis, September 26, 2012, *currently employed by Johns Hopkins Applied Physics Lab.*
- Benton Thompson, “Characterization and Improvement of the Collaborative and Non-Collaborative Position Location Problems,” MS, August 2011, *currently employed by G3, Inc.*
- Corey Cooke, “Attenuation Field Estimation using Radio Tomography,” MS, August 2011, *currently a Ph.D. student at Georgia Tech.*
- Harpreet Dhillon, “The Optimal Sum-Rate of Multi-Band MIMO Interference Channel,” MS, July 2010, *currently an Assistant Professor at Virginia Tech.*

- Justin Kelly, “The Value of Collaboration in Dynamic Spectrum Access,” MS, July 2009, *currently employed by the Department of Energy.*
- Matthew Roney, “Dual-Channel Direction Finding in Multipath Channels,” M.S. candidate, *currently employed by DRS Signal Solutions.*
- Jesse Reed, “Approaches to Multiple-source Localization and Signal Classification,” MS, May, 2009, *currently employed by Arinc, Inc.*
- Chang Li, “Non-contact Estimation of Respiration and Heartbeat Rate using Ultra Wideband,” MS, August 20, 2008, *currently employed by Qualcomm, Inc.*
- Arjun Bhupathi Raju, “Characterization of Uplink Transmit Power and Talk-Time in WCDMA Networks”, MS, July 15, 2008, *currently employed by Qualcomm, Inc.*
- Rajaraman Parameswaran – “Effects of user and spatial diversity on high data rate wireless systems,” M.S., August 2005, *currently employed by Qualcomm Inc.*
- Nathan Harter, “Single Channel Direction Finding in Multipath Channels,” M.S., April 2007, *currently employed by IO-Max.*
- John Keaveny – “The Implementation of Single-Channel Direction Finding,” M.S., February 2005. *Currently employed by Boeing.*
- Brian Donlan, “Ultra-wideband Narrowband Interference Cancellation and Channel Modeling for Communications,” M.S., January 2005, *currently employed by IOMAX USA.*
- Vivek Baradwaj, “Ultra-Wideband for Communications: Spatial Characteristics and Interference Suppression,” M.S., April 2005. *Currently employed by Qualcomm, Inc.*
- Liu Yang, “On the Applicability of the Tap-delay Line Model to UWB Channel Modeling,” M.S., August 2004, *currently employed by Microsoft.*
- Dan Hibbard, “The Impact of Bandwidth on Indoor Communication System Performance,” M.S., May 2004. *Currently employed by Raytheon.*
- Nishant Kumar – “MAC and Physical Layer Design for Ultra-Wideband Communications,” M.S., May 2004. *Currently employed by Staccato Communicaitons.*
- Samir Ginde – “A Game-theoretic Analysis of Link Adaptation in Cellular Radio Networks,” M.S., May 2003. *Currently employed by Qualcomm, Inc.*
- Rahul Mahajan – “Cross Layer Optimization: System Design and Simulation Methodologies,” M.S., December, 2003. *Currently employed by Qualcomm, Inc.*
- Aaron Orndorf, “Transceiver Design for Ultra Wideband Communications,” M.S., completed May 2004.
- David McKinsty – “Channel Models and Receivers for Ultra Wideband Communications,” M.S., May 2003. *Currently employed by Johns Hopkins Applied Physics Lab.*
- Venkatasubramanian Ramasamy – “MC-CDMA/OFDM and Adaptive Antennas,” M.S., June 2002. *Currently employed by Apple.*
- Ray Chan – “Link Adaptation for Public Safety Wireless Information Networks,” M.S., June 2003. *Currently employed by Northrup Grummond Corp.*
- Payal Jain – “Software Radio Implementation of Adjustable High Data Rate Receivers,” M.S., November 2002. *Currently employed by Digital Receiver Technology, Germantown, MD.*

Funded Research

1. Title: “Development of Machine Learning Methodologies for Radar Signal Classification,”
Sponsor: Alion,
Funding: \$118,000,
Period of Performance: January 26, 2023 – December 31, 2024
Percent: 100
2. Title: “Prototyping 5G-enabled Indoor Geolocation System for Fire Fighters using UAVs,”
Sponsor: National Institutes of Standards and Technology (through George Mason University),
Funding: \$849,994,
Period of Performance: June 1, 2022 – May 31, 2025
Percent: 34
3. Title: “SWIFT: Electronically-Reconfigurable Surfaces for Improved Coexistence Between Radio Astronomy and Satellite Communications Systems,”
Sponsor: National Science Foundation,
Funding: \$748,463,
Period of Performance: September 1, 2021 - August 31, 2024.
Percent: 50%.
4. Title: “Collaborative Research: CNS Core: Medium: Localization in Millimeter Wave Cellular Networks: Fundamentals, Algorithms, and Measurement-inspired Simulator,”
Sponsor: National Science Foundation,
Funding: \$635,000,
Period of Performance: October 2021 – September 2025.
Percent: 33%.
5. Title: “SWIFT: SMALL: Interference Canceling for Improved Coexistence for Passive and Active Radio Systems,”
Sponsor: National Science Foundation,
Funding: \$499,999,
Period of Performance: January 2021– January 2024.
Percent: 50%.
6. Title: “SCH:INT: Collaborative Research: Semi-Automated Rehabilitation in the Home,”
Sponsor: National Science Foundation,
Funding: \$1.1M
Period of Performance: August 2020 – July 2024,
Percent: 10%
7. Title: “Vector Sensor Processing in the Presence of Multipath”
Sponsor: Applied Signals Intelligence
Funding: \$170,000
Period of Performance: April 2020 - April 2021.
Percent: 90%
8. Title: “Machine Learning Approaches to Optimize Army Radar, Communication and EW Systems”
Sponsor: Army Research Lab
Funding: \$975,000
Period of Performance: May 11, 2020 - May 10, 2024.
Percent: 100%
9. Title: “Vector Sensor Processing in the Presence of Interference”
Sponsor: Applied Signals Intelligence
Funding: \$232,193

Period of Performance: December 20, 2018 - April 30, 2019.
Percent: 60%

10. Title: "Digital Beamforming and Interference Mitigation for MIMO Systems"
Sponsor: GIRD Systems
Funding: \$1,575,398
Period of Performance: October 17, 2018 - October 16, 2021.
Percent: 50%
11. Title: "Cognitive Radar for C-SCoRE: Enhancing Radar Functionality through Interference Analysis and Avoidance,"
Sponsor: Georgia Tech Research Institute (AFRL)
Funding: \$285,000
Period of Performance: December 15, 2018 – May 30, 2022
Percent: 100%
12. Title: "Collaborative Learning for Harmonious Coexistence of Heterogeneous Wireless Networks"
Sponsor: Defense Advanced Research Projects Agency
Funding: \$1,999,994
Period of Performance: January 1, 2017 - December 30, 2019.
Percent: 25%
13. Title: "MU-MIMO Channel Characterization"
Sponsor: GIRD Systems
Funding: \$117,712
Period of Performance: April 1, 2017 - March 31, 2019.
Percent: 100%
14. Title: "Cognitive Radio Approaches to Optimize Army Radar Systems"
Sponsor: Army Research Lab
Funding: \$250,000
Period of Performance: January 1, 2018 - December 30, 2020.
Percent: 100%
15. Title: "Cognitive Radio Approaches to Optimize Army Radar and Communication Systems"
Sponsor: Army Research Lab
Funding: \$190,282
Period of Performance: January 1, 2017 - December 30, 2017.
Percent: 50%
16. Title: "Hyper-wideband Communications"
Sponsor: Defense Advanced Research Projects Agency
Funding: \$182,451
Period of Performance: May 1, 2015 - April 30, 2016.
Percent: 50%
17. Title: "IUSE: Gamification of Wireless Communication Testbeds for Authentic STEM Learning"
Sponsor: National Science Foundation
Funding: \$626,665
Period of Performance: Sept. 1, 2014 - Aug. 31, 2017.
Percent: 20%
18. Title: "Advanced Cognitive Radio Design using SDRs"
Sponsor: Lockheed Martin Advanced Technologies
Funding: \$494,600
Period of Performance: April 1, 2014 – Sept. 30, 2015
Percent: 100%

19. Title: "SDR Technology Development Support"
Sponsor: DoD
Funding: \$375,000
Period of Performance: 5/1/14 – 4/30/14
P.I.: J.H. Reed
Percent: 30%
20. Title: "Improving Cellular Positioning through Collaboration"
Sponsor: Polaris Wireless
Funding: \$82,813
Period of Performance: 11/01/2013 - 10/31/2014
Percent: 100%
21. Title: "Advanced Wireless Systems and Technologies"
Sponsor: DoD
Funding: \$3,883,320
Period of Performance: 07/01/2012 - 06/30/2014
P.I. R.W. McGwier
Percent: 10%
22. Title: "Cognitive Radio Development"
Sponsor: Lockheed Martin – Advanced Technologies Lab
Funding: \$325,000
Period of Performance: 7/1/2012 – 12/31/2013
P.I. R.M. Buehrer
Percent: 50%
23. Title: "Next Generation Secure, Scalable Communication Network for the Smart Grid"
Sponsor: Oak Ridge National Labs
Funding: \$626,671
Period of Performance: 1/1/2011-10/31/2012
PI – R.M. Buehrer
Co-PI: J.H. Reed
Percent: 50%
24. Title: "Software Defined Radio Waveform and Device Development And Component Deployment Using Ossie"
Sponsor – DoD (Maryland Procurement Office)
PI – RM Buehrer
Period of Performance: Aug. 1, 2010 – July 31, 2013
Funding: \$299,227
Percent: 100%
25. Title: "SDR Technology Development Support"
Sponsor – DoD (Maryland Procurement Office)
PI – R.M. Buehrer and J.H. Reed
Funding: \$638,653
Period of Performance: 9/30/2010 – 4/30/2014
Percent: 75%
26. Title: "Signal Processing Research"
Sponsor: Aerospace Corp.
PI: T.C. Clancy
Co-PI: R.M. Buehrer
Period of Performance: 1/1/2011 – 10/31/2011
Funding: \$130k
Percent: 50%

27. Title: "IHCS: Proactive Cross-Layer Adversary Localization for Hostile or Harsh Wireless Environments"
Sponsor: National Science Foundation
Funding: \$494,788
Period of Performance: 5/1/08 – 4/30/11
PI: Y. Yang
Co-PI's: R.M. Buehrer and J.M. Park
Percent: 33%
28. Title: "A Fundamental Analysis of Spectrum Sharing"
Sponsor: Qualcomm, Inc.
Funding: \$120,000
Period of Performance: 5/1/08 – 4/30/10
PI: Buehrer
Co-PI's: Y. Yang
Percent: 85%
29. Title: "Reasoning and Learning in Adaptive Wireless Networks"
Sponsor: BBN/DARPA
Funding: \$605,000
Period of Performance: 10/1/07 – 3/31/10
PI: L. DaSilva
Co-PI's: R.M. Buehrer, C. Bostian, A. MacKenzie, and J.H. Reed
Percent: 25%
30. Title: DRS Graduate Fellowship
Sponsor: DRS Signal Solutions
Funding: \$76,000
Period of Performance: 9/01/07 – 8/30/09
PI: R.M. Buehrer
Percent: 100%
31. Title: U-PoLo Nets – Position Location in Harsh Environments
Sponsor: National Science Foundation
Funding: \$175k
Period of Performance: 8/1/05 – 7/30/08
PI: R.M. Buehrer
Percent: 100%
32. Title: NeTS ProWiN: An Open Systems Approach for Rapid Prototyping Waveforms for Software Defined Radio
Sponsor: National Science Foundation
Funding: \$1M
Period of Performance: 8/1/05 – 7/30/09
PI: J.H. Reed (lead), R.M. Buehrer, and W.H. Tranter
Percent: 33%
33. Title: Node and Network Benefits of Improved RF Characteristics in CDMA Cellular Networks
Sponsor: ParkerVision
Funding: \$131,474
Period of Performance: 11/1/07 – 10/31/08
PI: R. M. Buehrer
Percent: 100%
34. Title: UWB Propagation in Office Environments
Sponsor: Freescale Semiconductor
Funding: \$35,000
Period of Performance: 5/1/05 – 4/30/06

- PI: R. M. Buehrer
Percent: 100%
35. Title: Networking Issues for Peer-to-Peer VoIP Link for Radio Interoperability, Fire Management and Security
Sponsor: Catalyst Communications
Funding: \$67,500
Period of Performance: 1/1/05 – 5/15/05
PI: S.M. Midkiff (lead) and R.M. Buehrer
Percent: 33%
36. Title: AWINN: Advanced Wireless Networking for the Navy
Sponsor: ONR
Funding: \$3M
Period of Performance: 12/20/04 – 6/19/06
PI: Warren Stutzman
Co-PI's: J.H. Reed, Scott Midkiff, R. M. Buehrer, W.H. Tranter, Peter Athanas, Tom Hou, Binoy Ravindran, Rick Habayeb
Percent: 10%
37. Title: Ultra Wideband Communications Systems
Sponsor: ASPIRES
Funding: \$118,360
Period of Performance: 7/1/03 – 6/30/04
PI: R. M. Buehrer
Percent: 100%
38. Title: UWB Communications
Sponsor: Motorola
Period of Performance: 12/15/03 – 12/14/04
Funding: \$35,000
PI: Buehrer
Percentage: 100%
39. Title: Simulation of Ultra Wideband Communications
Sponsor: ITRI
Funding: \$10,000
Period of Performance: 9/1/03 – 12/31/03
PI: R.M. Buehrer
Percent: 100%
40. Title: Receiver Design for Ultra Wideband Communications
Sponsor: ITRI
Funding: \$15,000
Period of Performance: 9/1/03 – 12/31/03
PI: R.M. Buehrer
Percent: 100%
41. Title: Indoor Propagation
Sponsor: Qualcomm, Inc.
Funding: \$14,000
Period of Performance: 12/1/03 – 5/15/04
PI: R.M. Buehrer
Percent: 100%
42. Title: Single Channel Direction Finding
Sponsor: DRS Technologies
Funding: \$91,000

Period of Performance: 10/18/02 – 10/17/05
PI: R. M. Buehrer
Percent: 100%

43. Title: Flexible High Data Rate Transmission for Wireless Data Applications

Sponsor: BAE Systems
Funding: \$29,000
Period of Performance: 10/18/01 – 10/17/02
PI: R. M. Buehrer
Percent: 100%

44. Title: UWB Propagation Measurements, Modeling, and Communication System Enhancements

Sponsor: Defense Advanced Research Projects Agency
Funding: \$688,620
Period of Performance: 5/13/02-5/12/03
PI: R.M. Buehrer
Co-PI: A.S. Safaai-Jazi, W. Davis, D. Sweeney
Percentage: 35%

45. Title: Modeling and Simulation for the FCS Development Environment

Sponsor: Boeing
Funding: \$127,022
Period of Performance: 5/1/02 - 4/1/03
PI: W. H. Tranter
Co-PI: R. M. Buehrer, A. Annamalai
Percentage: 33%

46. Title: The Benefits of Multiple Antennas at the Handset for Cellular CDMA

Sponsor: e-Tenna Corporation
Funding: \$15,000
Period of Performance: 5/15/02 – 8/14/02
PI: R. M. Buehrer
Percent: 100%

47. Title: MPRG Affiliates Program

Sponsor: Analog Devices, ARO, Cingular, DRS Technologies, General Motors, General Dynamics, Huawei Technologies, Hughes, Lucent Technologies, Motorola, Qualcomm, Raytheon, Samsung, SW Bell, Texas Instruments, et. al.
Funding: \$2M
Period of Performance: 8/25/01 – 5/15/11
PI: J.H. Reed
Co-PI's: R.M. Buehrer, W.H. Tranter, S.W. Ellingson, others
Percent: 20%

Book Publications

S. Zekavat and R.M. Buehrer, editors, Position Location - Theory, Practice and Advances, Second Ed., Wiley-IEEE, 2019.

S. Zekavat and R.M. Buehrer, editors, Position Location - Theory, Practice and Advances, Wiley-IEEE, 2011.

J.H. Lee and R.M. Buehrer, "Security Issues in Position Location," Chapter 3 in Position Location - Theory, Practice and Advances, Wiley-IEEE, 2011.

R. M. Buehrer and S. Venkatesh, “Fundamentals of Time-of-Arrival-based Position Location,” Chapter 6 in Position Location - Theory, Practice and Advances, Wiley-IEEE, 2011.

J.H. Lee and R.M. Buehrer, “Fundamentals of Received Signal Strength Based Position Location,” Chapter 11 in Position Location - Theory, Practice and Advances, Wiley-IEEE, 2011.

T. Jia and R.M. Buehrer, “Collaborative Position Location,” Chapter 23 in Position Location - Theory, Practice and Advances, Wiley-IEEE, 2011.

R.M. Buehrer, An Introduction to Code Division Multiple Access (CDMA), Morgan-Claypool Publishers, 2007.

R.A. Soni and R.M. Buehrer, “Multiple Antenna Techniques in 3G Wireless Systems,” Chapter 25 in Space-Time Wireless Systems: From Array Processing to MIMO Communications, H. Bolecskei, D. Gesbert, C. Papadias, and A.J. vander Veen, editors, Cambridge University Press, 2005.

R.M. Buehrer, “Channel Modeling,” Chapter 3 in An Introduction to Ultra Wideband Communication Systems, Jeff Reed, editor, pp. 73-158, Prentice-Hall, 2005.

A.F. Molisch, J. Kunisch, R. Qiu, D. Cassioli, M. Buehrer, M. Pendergrass, I.Z. Kvac, G.F. Pedersen, P.C.F. Eggers, S. Roy and I. Ramachandran, “UWB Propagation Channels,” Chapter 2 in UWB Communication Systems – A Comprehensive Overview, M.-G. Di Benedetto, T. Kaiser, A.F. Molisch, I. Oppermann, C. Politano, and D. Porcino, editors, pp.21-142, Hindawi Publishing Company, 2006.

M. Dohler, J. Liu, S. Venkatesh, R.M. Buehrer and B. Allen, “Large- and Medium-Scale Propagation Modelling,” Chapter 14 in Ultra-wideband Antennas and Propagation for Communications, Radar and Imaging, B. Allen, et. al., editors, pp. 283-308, John Wiley and Sons, 2006.

S. Venkatesh, R.M. Buehrer, J. Liu, and M. Dohler, “Small-Scale Ultra-wideband Propagation Modelling,” Chapter 15 in Ultra-wideband Antennas and Propagation for Communications, Radar and Imaging, B. Allen, et. al., editors, pp. 309-330, John Wiley and Sons, 2006.

R. Muhamed, R.M. Buehrer, A. Doradla, and T.S. Rappaport, “Mobile and Portable Radio Communications,” Chapter 139 in The Engineering Handbook, Second Ed., R.C. Dorf, Editor, pp. 139-1 - 139-19, CRC Press, 2004.

T.S. Rappaport, R. Muhamed, M. Buehrer, and A. Doradla, “Mobile and Cellular Radio Systems,” The Engineering Handbook, R. C. Dorf Editor, CRC Press, 1996.

R.M. Buehrer and B.D. Woerner, “Spread Spectrum for Wireless Communications,” Wireless Personal Communications: Research Developments, B.D. Woerner, T.S. Rappaport, and J.H. Reed editors, Kluwer Academic Press, 1995.

H. Shaban, M. A. El-Nasr, and R. M. Buehrer, “A Full-Body Wireless Wearable UWB-Based Human Motion Capture and Gait Analysis System,” Chapter 20 in E-Healthcare Systems and Wireless Communications: Current and Future Challenges, pp. 434-459, Prof. Mohamed K. Watfa, Editor.

Journal Publications

S.W. Ellingson and R.M. Buehrer, “Coherent Time-Domain Canceling of Interference for Radio Astronomy,” *Publications of the Astronomical Society of the Pacific*, to be published, 2022. doi:10.1088/1538-3873/ac9b92

W.W. Howard, A.F. Martone, and R.M. Buehrer, “Distributed Online Learning for Coexistence in Cognitive Radar Networks,” *IEEE Transactions on Aerospace and Electronic Systems*, 2022, doi: 10.1109/TAES.2022.3198038.

J. Yu, P. Wang, T. Koike-Akino, Y. Wang, P. V. Orlik and R. M. Buehrer, “Multi-Band Wi-Fi Sensing with Matched Feature Granularity,” *IEEE Internet of Things Journal*, vol. 9, no. 23, pp. 23810-23825, 2022, doi: 10.1109/JIOT.2022.3190826

- M. O. Moore, R. M. Buehrer and W. C. Headley, "Decoupling RNN Training and Testing Observation Intervals for Spectrum Sensing Applications," *Sensors* 2022, 22(13), *Special Issue on Radio Frequency Machine Learning (RFML) Applications* 4706; doi: 10.3390/s22134706.
- C.E. Thornton, R.M. Buehrer, H.S. Dhillon, and A.F. Martone, "Universal Learning Waveform Selection Strategies for Adaptive Target Tracking," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 58, no. 6, pp. 5798-5814, Dec. 2022. doi: 10.1109/TAES.2022.3181554
- A. Sarker, D.R. Emenonye, A. Kelliher, T. Rikakis, R. M. Buehrer, A. Asbeck, "Capturing Upper Body Kinematics and Localization with Low-cost Sensors for Rehabilitation Applications," *Sensors* 2022 , 22 , 2300. <https://doi.org/10.3390/s22062300>.
- D.R. Emenonye, C. Dietrich, and R.M. Buehrer, "Differential Modulation in Massive MIMO With Low-Resolution ADCs," *IEEE Transactions on Wireless Communications*, vol. 21, No. 6, pp. 4482-4496, June 2022, DOI: 10.1109/TWC.2021.3130499
- C. E. Thornton, R. M. Buehrer, and A. F. Martone, "Constrained Contextual Bandit Learning for Adaptive Radar Waveform Selection," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 58, no. 2, pp. 1133-1148, April 2022, Digital Object Identifier: 10.1109/TAES.2021.3109110.
- L.J. Wong, W. H. Clark IV, B. Flowers, R. M. Buehrer, A. J. Michaels, and W. C. Headley, "An RFML Ecosystem: Considerations for the Application of Deep Learning to Spectrum Situational Awareness," *IEEE Open Journal of the Communications Society*, vol. 2, pp. 2243-2264, 2021, doi: 10.1109/OJCOMS.2021.3112939.
- C.E. O'Lone, H.S. Dhillon, and R.M. Buehrer, "Characterizing the First-Arriving Multipath Component in 5G Millimeter Wave Networks: TOA, AOA, and Non-Line-of-Sight Bias", *IEEE Transactions on Wireless Communications*, vol. 21, no. 3, pp. 1602 - 1620, March 2022, Digital Object Identifier: 10.1109/TWC.2021.3105641.
- A. F. Martone, J. A. Kovarskiy, C. E. Thornton, B. H. Kirk, J. W. Owen, B. Ravenscroft, A. Egbert, A. Goad, R. M. Buehrer, R. M. Narayanan, S. Blunt, C. Baylis, and K. D. Sherbondy, "Closing the Loop on Cognitive Radar for Spectrum Sharing", *IEEE Aerospace and Electronic Systems Magazine*, vol. 36, no. 9, pp. 44-55, September 2021, Digital Object Identifier: 10.1109/MAES.2021.3072698.
- S. R. Zekavat, R. M. Buehrer, G. D. Durgin, L. Lovisolo, Z. Wang, S.T. Goh, and A. Ghasem, "An Overview of Position Location: Past, Present, Future," *International Journal of Wireless Information Networks*, vol. 28, pp. 45-76, March 2021, Digital Object Identifier: 10.1007/s10776-021-00504-z.
- C.E. Thornton, M. Kozy, A. F. Martone, K. Sherbondy, and R.M. Buehrer, "Deep Reinforcement Learning Control for Radar Detection and Tracking in Congested Spectral Environments," *IEEE Transactions on Cognitive Communications and Networking*, Vol. 6, No. 4, pp. 1335-1349, December 2020, Digital Object Identifier: 10.1109/TCCN.2020.3019605.
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S.V. Hum, S.W. Ellingson, and R.M. Buehrer, "Toward Electronically Reconfigurable Rims for Reflectors in Radio Astronomy," accepted for presentation at *URSI General Assembly and Scientific Symposium 2023*.

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W.H. Howard and R.M. Buehrer, "Timely Target Tracking in Cognitive Radar Networks," accepted for presentation at *2023 IEEE Radar Conference*, San Antonio, Texas, May 1-5, 2023.

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J. Tsai, R.M. Buehrer, and B.D. Woerner, "Performance of Transmit Beamforming in Rician Fading Channels: Robustness of Quantization Error and Feedback Error," *IEEE Vehicular Technology Conference – Fall 2002*, Vancouver, British Columbia, Canada, pp. 1792-1795, September 24-29, 2002.

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N.A. Kumar and R.M. Buehrer, "Application of Layered Space-Time Processing to Ultra-Wideband Communication,"

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P. Jain and R.M. Buehrer, "Implementation of Adaptive Modulation on Sunrise Software Radios," *45th IEEE Midwest Symposium on Circuits and Systems*, Tulsa, OK, pp. 405-408, August 4-7, 2002.

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R.M. Buehrer, "On the Convergence of Multistage Interference Cancellation," *33rd IEEE Conference on Signals, Systems and Computers - Asilomar*, Pacific Grove, CA, vol. 1, pp. 634-638, October 1999.

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J.-A. Tsai and R.M. Buehrer, "Frequency Reuse Reduction for IS-136 Using a Four Element Adaptive Array," *8th Virginia Tech Symposium on Wireless Personal Communications*, Blacksburg, VA, pp. 11-22, June 10-12, 1998.

N.S. Correal, R.M. Buehrer, and B.D. Woerner, "Real-Time DSP Implementation of a Coherent Partial Interference Cancellation Multiuser Receiver for DS-CDMA," *IEEE International Conference on Communications - ICC*, Atlanta,

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R.M. Buehrer and B.D. Woerner, "The Asymptotic Multiuser Efficiency of M -Stage Interference Cancellation Receivers," *8th IEEE International Symposium on Personal, Mobile, and Indoor Radio Conference*, Helsinki, Finland, vol. 2, pp. 570-574, September 1997.

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N. Correal, R.M. Buehrer, and B.D. Woerner, "DSP Implementation of Parallel Interference Cancellation," *Symposium on Interference Rejection and Signal Separation in Wireless Communications*, George Washington University, Washington, D.C., (proceeding pages unnumbered), March 1997.

R.M. Buehrer, N.S. Correal, and B.D. Woerner, "A Comparison of Multiuser Receivers for Cellular CDMA," *IEEE Global Telecommunications Conference '96*, London, England, pp. 1571-1577, November 11-18, 1996.

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J. Feil, L. Ippolito, M. Buehrer, G. Feldhake, and S. Horan, "First Year Propagation Experiment Results from the New Mexico ACTS Receiver Terminal at 20.185 and 27.505 GHz," *16th AIAA International Communications Satellite Systems Conference*, Washington, D.C. pp. 1-11, February 1996.

R.M. Buehrer and B.D. Woerner, "Performance of CDMA Multistage Interference Cancellation with Phase and Timing Errors," *1995 IEEE Conference on Universal Personal Communications – UPC'95*, Tokyo, Japan, pp. 153-157, November 6-9, 1995.

R.M. Buehrer and B.D. Woerner, "Analysis of Adaptive Multistage Interference Cancellation for CDMA Using an Improved Gaussian Approximation," *1995 IEEE Military Communications Conference*, San Diego, CA, vol. 3, pp. 1195-1199, November 5-8, 1995.

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R.M. Buehrer and B.D. Woerner, "Spread Spectrum for Wireless Communications," *4th Virginia Tech Symposium on Wireless Personal Communications*, Blacksburg, VA, pp. 3-1 – 3-20, June 1994.

R.M. Buehrer, S.C. Kwatra, and J. Kim, "A Satellite/Terrestrial Hybrid System for the National Research and Education Network," *15th AIAA International Communications Satellite Systems Conference*, San Diego, CA, March 1994.

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R. M. Buehrer, W.A. Davis, A. Saffai-Jazi, and D. Sweeney, “Ultra-wideband Propagation Measurements and Modeling - Final Report,” submitted to DARPA as part of the NETEX Program.

R. M. Buehrer, A. Saffai-Jazi, W. A. Davis, D. Sweeney, “Path Loss Calculations for Ultra-wideband Signals in Indoor Environments,” invited contribution to the International Telecommunications Union, Document Number USWP 3K-1, October 26, 2003.

15 technical memoranda in the areas of multiuser detection, intelligent antennas, and OFDM for Bell Labs – Lucent Technologies. Titles and abstracts are proprietary information.

Professional Affiliations

- *Fellow*, Institute of Electrical and Electronics Engineers (IEEE)
- Member, IEEE Communications Society
- Member, IEEE Vehicular Technologies Society
- Member, IEEE Signal Processing Society
- Member, Eta Kappa Nu
- Member, Tau Beta Pi
- Member, Pi Mu Epsilon

Selected Professional Activities

- Area Editor, *IEEE Transactions on Wireless Communications*, 2017 - present.
- Guest Lead Editor, *IEEE Journal on Special Topics in Signal Processing*, special issue on non-cooperative position location networks.
- Guest Editor, *Proceedings of the IEEE*, special issue on cooperative localization.
- Associate Editor, *IEEE Wireless Communications Letters*, 2010 - 2014
- Associate Editor, *IEEE Transactions on Communications*, 2009 - 2014
- Associate Editor, *IEEE Transactions on Wireless Communications*, 2005 - 2012, 2015 - 2017
- Associate Editor, *IEEE Transactions on Vehicular Technologies*, 2005 - 2009
- Associate Editor, *IEEE Transactions on Signal Processing*, 2006-2007
- Associate Editor, *IEEE Transactions on Education*, 1997-2000
- Organizer and Technical Co-Chair, 2015 IEEE Global Communications Conference Workshop on Localization and Tracking: Indoors, Outdoors and Emerging Networks (GC - LION '15), December 6, 2015.
- “Signal Processing for Communications” symposium co-chair for IEEE ICC 2017

- Symposium co-chair for IEEE ICC 2017 Signal Processing for Communications Symposium
- Technical Program Co-Chair, WPNC 2013.
- Technical Program Chair for UWBST2003.
- Technical Program Committee, 2008-2016 IEEE Global Communications Conference
- Technical Program Committee, 2007-2016 IEEE International Conference on Communications
- Technical Program Committee, IEEE RWS 2006
- Technical Program Committee, IEEE 2006 International Conference on Ultra Wideband
- Technical Program Committee, IEEE Vehicular Technology Conference 2006 - Fall
- Technical Program Committee, 2004 IEEE International Workshop on Ultra Wideband Systems / Ultra Wideband Systems and Technologies.
- Technical Program Committee, 2004 IEEE Radio and Wireless Conference (RAWCON), September 2004.
- Technical Program Committee, 2005 Wireless Communications and Networking Conference.
- Reviewer for *IEEE Journal on Selected Areas in Communications*, *IEEE Transactions on Communications*, *IEEE Transactions on Vehicular Technology*, *IEEE Communications Letters*, *IEEE Transactions on Signal Processing*, *ETRI Research Journal*, *Army Research Office*, *State of Tennessee*
- Session Chair, IEEE Vehicular Technology Conference – Fall 2002

Selected Consulting

- Lutron Electronics
 - Provided recommendations on the design and testing of indoor wireless networks, August - Sept. 2019.
 - Evaluated RF coexistence plan, March 2020.
 - Evaluated RF coverage and planning techniques for 2.4GHz indoor networks, September - October 2021.
- Polaris Wireless - Provided an evaluation of Z-axis estimation algorithm, Sept-Oct 2018.
- ENSCO, Inc. – Provided an evaluation of spread spectrum ranging system. March 2011.
- FCC – Delivered short courses on various topics in wireless communications including WiFi, spread spectrum, and 3G technologies. Summer 2004, Summer 2005.

Selected Expert Witness Experience

- Ericsson vs. Apple
 - Law firm: Fish and Richardson
 - Represented: Apple
 - Analyzed technical aspects of various patents to aid validity/invalidity and infringement/non-infringement analysis. Included both Inter Partes Review proceedings and ITC case. **Was deposed multiple times. Testified at trial.**
 - Dates: September 2021 - December 2022

- Godo Kaisha IP Bridge vs. Nokia
 - Law firm: Alston & Bird
 - Represented: Nokia (defendant)
 - Served as expert witness for non-infringement and invalidity.
 - Case No. 2:21-CV-215-JRG
 - Technology: Sounding Reference Signal, RACH, ACK/NACK and CQI reporting in cellular networks. **Was deposed.**
 - Dates: September 2021 - November 2022
- Honeywell, Int'l., Inc., et. al. vs. Sisvel International
 - Law firm: K&L Gates
 - Represented: Honeywell (Petitioner)
 - Served as expert in Inter Partes Review proceedings. Wrote declaration supporting petitioner. **Was deposed.**
 - IPR2021-00640
 - Technology: Cell selection and reselection in Radio Resource Control
 - Dates: December 2021 - Current
- Thales, et. al. vs. Sisvel International
 - Law firm: AddyHart
 - Represented: Thales (Petitioner)
 - Served as expert in Inter Partes Review proceedings. Wrote declarations supporting petitioner. **Was deposed.**
 - IPR2021-00639
 - Technology: Data connection management.
 - Dates: December 2021 - Current
- ZTE, et. al. vs. Sisvel International
 - Law firm: Banner-Witcoff
 - Represented: ZTE (Petitioner)
 - Served as expert in Inter Partes Review proceedings. Wrote declarations supporting petitioner.
 - IPR2021-00639, IPR2021-00640
 - Technology: Cell selection and reselection in Radio Resource Control; Data connection management.
 - Dates: January 2021 - April 2021
- HP, Inc. vs. Ozmo
 - Law firm: DLA-Piper
 - Represented: HP
 - Served as testifying expert
 - 6:21-cv-00383-ADA
 - Technology: Wireless local area and personal area networks (WLANs and WPANs)
 - Dates: August 2021 - October 2021
- Samsung vs. Ericsson

- Law firm: Fish & Richardson
- Represented: Samsung
- Wrote declarations for IPR filings.
- IPR2021-00615, IPR2021-00685
- Technology: Cellular communications
- Dates: January 2021 - April 2021
- Tesla, Inc. vs. Optis
 - Law firm: Munger, Tolles, & Olson
 - Represented: Tesla (defendant)
 - Case 2:20-cv-00310
 - Served as testifying expert witness
 - Technology: Control channels/information in cellular systems
 - Dates: November 2020 - March 2021
- Apple, Inc.
 - Law firm: Wilmer-Hale
 - Wrote declaration in support of request for ex parte reexamination
 - Reexam Control Number 90/014,653
 - Technology: Control information in cellular systems
 - Dates: November 2020 - January 2021
- Phillips vs. Garmin
 - Law firm: Alston-Bird
 - Represented: Garmin (defendant)
 - Served as testifying expert witness for Federal Trade Commission proceedings
 - Technology: Local and Cellular Wireless Connections in Personal Emergency Response Systems
 - District: FTC
 - Dates: June - July 2020
- ZTE vs. Sisvel International
 - Law firm: Banner-Witcoff
 - Represented: ZTE (Petitioner)
 - Served as expert in Inter Partes Review proceedings. Wrote declarations supporting petitioner. **Was deposed.**
 - IPR2020-01070, IPR2020-01071
 - Technology: Radio Resource Control
 - Dates: March 2020 - May 2021
- Apple, Inc. vs. Optis
 - Law firm: Wilmer-Hale
 - Represented: Apple (Plaintiff)
 - Served as testifying expert witness for litigation. **Was deposed. Testified at trial.**
 - Case 2:19-cv-66 (E.D. Tex.)

- Technology: Control information in cellular systems
- District: Eastern District of Texas
- Dates: July 2019 - August 2020.
- Apple, Inc. vs. Wi-LAN
 - Law firm: DLA Piper
 - Represented: Apple (Plaintiff)
 - Served as testifying expert witness for litigation. **Was deposed. Testified at trial.**
 - Technology: Resource Allocation in Wireless Systems
 - District: Southern District of California
 - Dates: January '19 - January '20
- TELUS Communications, Bell Mobility, and Rogers Communications vs. WiLAN, Inc.
 - Law firm: Torys, LLP.
 - Represented: TELUS Communications, Bell Mobility, and Rogers Communications
 - Served as testifying expert. Analyzed certain patents (and the prior art) and provided technical reports on sufficiency, validity and potential double-patenting.
 - Technology: Resource allocation in wireless networks
 - Dates: January 2019 - November 2019
- Samsung vs. Sharp
 - Law firm: Fish and Richardson
 - Represented: Samsung
 - Analyzed technical aspects of patent to aid validity/invalidity analysis.
 - Technology: Feedback in MIMO-OFDM systems
 - Dates: April 2019 - July 2019
- American Patents, LLC vs. HP, Inc.
 - Law firm: DLA Piper
 - Represented: HP, Inc.
 - Analyzed technical aspects of two patents to aid validity/invalidity analysis.
 - Case 18-cv-700 (E.D. Tex.)
 - Technology: MIMO/OFDM synchronization in cellular systems
 - Dates: June 2019
- Blackberry vs. Uniloc, LLC.
 - Law firm: Oblon
 - Represented: Blackberry (Petitioner)
 - Wrote declaration to the USPTO concerning the disclosure of certain features of two patents in previous references.
 - Technology: Traffic mapping between logical channels and transport channels in wireless systems
 - Dates: June 2019.
- Apple, Inc. vs. Wi-LAN
 - Law firm: DLA Piper

- Represented: Apple (Plaintiff)
- Served as testifying expert witness for litigation (non-infringing alternatives). **Was deposed. Testified at trial.**
- Case 3:14-cv-2235-DMS-BLM
- Technology: Resource Allocation in Wireless Systems
- District: Southern District of California
- Dates: November '17 - July '18
- Apple, Inc., LG Electronics Inc., Samsung Electronics Co., Ltd., and Samsung Electronics America, Inc. vs. Uniloc, LLC.
 - Law firm: Fish and Richardson
 - Represented: Apple, Inc., LG Electronics Inc., Samsung Electronics Co., Ltd., and Samsung Electronics America, Inc. (Petitioner)
 - Wrote declarations to the USPTO concerning the disclosure of certain features of two patents in previous references.
 - IPR2019-00219, IPR2019-00222
 - Technology: Traffic mapping between logical channels and transport channels in Wireless Systems; Multi-mode transceivers
 - Dates: September 2018 - November 2019.
- CCE vs. Apple, Inc.
 - Law firm: DLA Piper
 - Represented: Apple (Defendant)
 - Served as testifying expert witness for litigation (infringement analysis). **Was deposed.**
 - 2:15-cv-00576-RWS-RSP
 - Technology: Power Headroom Reporting in Cellular Systems
 - District: Eastern District of Texas
 - Dates: January 2017 - July 2017
- Nokia Technologies vs. Apple, Inc.
 - Law firm: Wilmer-Hale
 - Represented: Apple (Defendant)
 - Served as testifying expert witness for litigation (infringement analysis)
 - Technology: antennas for handheld mobile devices
 - District: Eastern District of Texas
 - Dates: January 2017 - June 2017
- Core Wireless vs. Apple, Inc.
 - Law Firm: Wilmer-Hale
 - Represented: Apple (Defendant)
 - Role: Served as testifying expert witness for litigation (infringement and validity analysis). **Was deposed. Testified at trial.**
 - Case 5:15-cv-5008
 - Technology: Control Channels and Frame Stealing in 2G (GSM) cellular networks.
 - District: The US District Court for the Northern District of California

- Dates: May 2015 - December 2016.
- AMERICAN SYSTEMS vs. US Navy
 - Law Firm: Miles and Stockbridge
 - Represented: AMERICAN SYSTEMS (Plaintiff)
 - Role: Served as testifying expert witness for litigation (case settled prior to expert reports being filed).
 - Technology: Wireless mesh networks.
 - Dates: Nov. 2014 - June 2015.
- TruPosition, Inc. vs. LM Ericsson Telephone Company, et. al.
 - Law Firm: Constantine-Cannon LLP
 - Represented: TruePosition (Plaintiff)
 - Role: Served as testifying expert witness for litigation. Case settled prior to depositions being taken.
 - Case 2:11-cv-04574-RK
 - Technology: Cellular-based geolocation for 4G (LTE) cellular networks.
 - District: The US District Court for the Eastern District of Pennsylvania
 - Dates: March 2013 - July 2014.
- Andrew, LLC vs TruPosition, Inc.
 - Law Firm: Patterson Belknap Webb & Tyler LLP
 - Represented: Andrew, LLC (Plaintiff)
 - Role: Served as testifying expert witness for patent litigation. **Was deposed.**
 - Civil Action 09-669
 - Technology: Cellular-based (2G, 3G) geolocation.
 - District: The US District Court for the District of Delaware
 - Dates: Nov. 2009 - March 2010.
- TCL vs. Ericsson
 - Law Firm: Sheppard Mullin
 - Provided Services for: TCL (Plaintiff)
 - Role: Served as consulting expert witness for essentiality analysis.
 - Technology: digital communications in 2G, 3G, and 4G cellular systems.
 - District: The US District Court for the Central District of California
 - Dates: March 2015 - December 2015.
- Univ. of Minnesota vs. Sprint
 - Law Firm: McGuire-Woods
 - Provided Services for: Sprint (Defendant)
 - Role: Served as consulting expert for validity analysis.
 - Technology: 4G cellular networks.
 - Dates: October 2015 - January 2016.
- Eon Corp, IP Holdings, LLC vs Research In Motion Corporation, et. al.
 - Law Firm: Sidley-Austin

- Provided Services for: Research in Motion Corporation (Defendant)
- Served as consulting expert for patent litigation
- Technology: Cellular technologies
- Dates: March 2012
- InterDigital vs. Nokia
 - Law Firm: Alston-Bird LLP
 - Provided Services for: Nokia
 - Served as a consulting expert
 - Technology: Cellular CDMA and power control
 - Date: Oct. 2011 - Dec. 2011.
- SPH America, LLC vs Acer, Inc.
 - Law Firm: Spotts Fain PC
 - Provided Services for: UT Starcomm
 - Role: Served as a consulting expert for patent litigation
 - Technology: CDMA (spread spectrum) and 3G cellular technologies.
 - Dates: Jan. 2011 - March 2011

References

Available upon request.