

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

MURATA MANUFACTURING CO., LTD

Petitioner

IPR2025-00384
U.S. Patent No. 7,489,914
PETITION B

**SECOND DECLARATION OF MATTHEW B. SHOEMAKE, PH.D.,
UNDER 37 C.F.R. § 1.68 IN SUPPORT OF PETITION FOR
INTER PARTES REVIEW**

TABLE OF CONTENTS

I.	Introduction.....	5
II.	Qualifications and Professional Experience.....	8
III.	Level of Ordinary Skill in the Art	11
IV.	Relevant Legal Standards	12
V.	Technical Background.....	16
A.	Multi-Band Devices	17
B.	Transceivers.....	21
C.	Packaging	22
VI.	The '914 Patent.....	30
A.	Overview	30
B.	Prosecution History	35
C.	Effective filing date of Application that issued as the '914 Patent	37
VII.	Claim Construction.....	46
VIII.	Identification of How the Claims are Unpatentable.....	47
A.	Ground 1: Claims 1-2 and 4-20 over Yeh and Dalmia	48
1.	Overview of Yeh.....	48
2.	Dalmia.....	49
3.	Reasons to Combine Yeh and Dalmia.....	52
4.	Claim 1	63
5.	Claim 2.....	93
6.	Claim 4.....	97

7.	Claim 11	99
8.	Claim 12.....	100
9.	Claim 13.....	101
10.	Claim 14.....	104
11.	Claim 15.....	105
12.	Claim 16.....	106
13.	Claim 5.....	106
14.	Claim 6.....	115
15.	Claim 7.....	115
16.	Claim 8.....	116
17.	Claim 9.....	117
18.	Claim 10.....	119
19.	Claim 17.....	121
20.	Claim 18.....	121
21.	Claim 19.....	122
22.	Claim 20.....	122
A.	Ground 2 – Claims 1-2 and 4-20 obvious over Dalmia and Hashemi.....	123
1.	Dalmia.....	123
2.	Hashemi	123
3.	Reasons to Combine Dalmia and Hashemi	124
4.	Claim 1.....	128
5.	Claim 2.....	154

6.	Claim 4.....	156
7.	Claim 11.....	157
8.	Claim 12.....	157
9.	Claim 13.....	158
10.	Claim 14.....	158
11.	Claim 15.....	159
12.	Claim 16.....	159
13.	Claim 5.....	160
14.	Claim 6.....	165
15.	Claim 7.....	166
16.	Claim 8.....	167
17.	Claim 9.....	169
18.	Claim 10.....	170
19.	Claim 17.....	172
20.	Claim 18.....	172
21.	Claim 19.....	172
22.	Claim 20.....	173
IX.	Conclusion.....	174

I, Matthew B. Shoemake, do hereby declare as follows:

I. INTRODUCTION

1. I am making this declaration at the request of Murata Manufacturing Co., Ltd in the matter of the *Inter Partes* Review of U.S. Patent No. 7,489,914 (“the ’914 Patent”) to Govind *et al.*

2. I am also being reimbursed for reasonable and customary expenses associated with my work and testimony in this investigation. My compensation is not contingent on the outcome of this matter or the specifics of my testimony, and I have no other interest in this case or the parties thereto.

3. I have been asked to provide my opinions regarding whether Claims 1-2 and 4-20 (“Challenged Claims”) of the ’914 Patent are unpatentable as they would have been obvious to a person having ordinary skill in the art (“POSITA”) at the time of the alleged invention, in light of the prior art. It is my opinion that all of the limitations of the challenged claims would have been obvious to a POSITA.

4. In forming the opinions set forth in this declaration, I have reviewed the documents in the following table:

EX1001	U.S. Patent No. 7,489,914
EX1002	Prosecution History of U.S. Patent No. 7,489,914
EX1005	U.S. Patent No. 6,128,508 (“Francisco”)
EX1006	JP 2001267466 (“JP466”) including original Japanese language document, English translation, and Translator’s certification

EX1007	European Patent Application EP 1 189 345 A2 (“Okubora”)
EX1008	U.S. Patent Appl. Publ. No. 2002/0118067 (“Hirayama”)
EX1009	U.S. Patent No. 5,995,814 (“Yeh”)
EX1010	Design and Implementation of High-Q Passive Devices for Wireless Applications Using System-On-Package (SOP) Based Organic Technologies, Sidharth Dalmia, dated 2002, published March 2003
EX1011	“Concurrent Multiband Low-Noise Amplifiers—Theory, Design, and Applications,” Hossein Hashemi, et al., IEEE Transactions On Microwave Theory And Techniques, Vol. 50, No. 1, January 2002
EX1012	<i>Fundamentals of Microsystems Packaging</i> ; Rao R. Tummula, Table of Contents and Chapter 11
EX1013	<i>Reserved</i>
EX1014	U.S. Patent No. 6,825,818
EX1015	U.S. Patent No. 5,457,734
EX1016	U.S. Patent No. 5,406,615
EX1017	<i>RF Microelectronics</i> , Behzad Razavi, Prentice Hall PTR, 1998
EX1018	U.S. Patent No. 5,821,820
EX1019	US Patent Appl. Pub. No. 2002/0030545
EX1020	EP0851576A2
EX1021	A CMOS RF Bandpass Low Noise Amplifier for Multi-band Wireless Communication Applications, Shouxian Mou et al., IEEE, 2002
EX1022	<i>The Wiley Electrical and Electronics Dictionary</i> , Steven M. Kaplan, 2004, pp. 628, 662, 630,
EX1023	RF Characterization of a low cost multichip packaging technology for monolithic microwave and millimeter wave integrated circuits,”

	Jayaraj, (1995)
EX1024	JP 2001345648 (“JP648”) including original Japanese language document, English translation, and Translator’s certification
EX1025	NIST Technical Note 1520, “Dielectric and Conductor-Loss Characterization and Measurements on Electronic Packaging Materials
EX1026	US Patent Appl. Pub. No. 2004/0127182
EX1027	Embedded Passive Technology Implementation in RF Applications,” John Savic, et al. (2002)
EX1028	US Patent Appl. Pub. No. 2004/0113719
EX1029	US Patent Appl. Pub. No. 2003/0063427
EX1030	<i>Microwave Engineering Second Edition</i> by David M. Pozar was published in 1998 by Wiley (“ <i>Microwave Engineering</i> ”)
EX1031	Datasheet NE38018
EX1032	Characterization of Liquid Crystal Polymer for High Frequency System-in-a-Package Applications, Zou et al., 2002
EX1033	Liquid crystal polymers (LCP) for high performance SOP applications,” 2002 Proceedings. 8th International Advanced Packaging Materials Symposium (Cat. No.02TH8617), Stone Mountain, GA, USA, 2002
EX1034	<i>Microwave Transistor Amplifiers Analysis and Design Second Edition</i> by Guillermo Gonzalez published by Wiley in 1997
EX1037	JPA H06-97315 including original Japanese language document, English translation, and Translator’s certification
EX1040	U.S. Application No. 10/402,313 and applications referred to therein

5. Additionally, I have utilized my own experience and expertise,

including regarding the knowledge and capabilities of a person of ordinary skill in the relevant art in the timeframe of the claimed priority date of the '914 Patent.

6. Unless otherwise noted, all emphasis in any quoted material has been added.

II. QUALIFICATIONS AND PROFESSIONAL EXPERIENCE

7. My qualifications and professional experience are also described in my *Curriculum Vitae*, a copy of which can be found in EX1004. The following is a brief summary of my relevant qualifications and professional experience.

8. I started my career with Texas Instruments as an intern and engineer in their Digital Signal Processing Group. Digital signal processing or (DSP) circuits involve analyzing, modifying, and synthesizing signals using digital processing. Such digital signals to be processed are commonly formed by converting analog signals into digital form via the use of analog-to-digital converters. DSP uses mathematical operations to perform a variety of tasks, such as: compression, decompression, filtering, equalization, modulation, and demodulation including related to wireless communication. In this role, I was responsible for product and applications engineering for Texas Instruments DSP products TMS320C2X and TMS320C3X. This required detailed knowledge of electrical circuits and networks, transistors, semiconductors, passive components (e.g., resistors, capacitors, and inductors), impedance matching, and transmission

lines. This role continued until 1995. I earned a B.S. in Electrical Engineering and a B.S. in Computer Science from Texas A&M University in 1994.

9. I earned a Master's (1997) and then in 1999 a Ph. D. from Cornell University in Electrical Engineering. My graduate work focused on communications systems including wireless systems, algorithms, and architectures.

10. From 1998 to 2000, I worked in the Baseband System Team at Alantro Communications, Inc. In this role, my work centered on wireless communications under IEEE 802.11b (now Wi-Fi 1), a technical standard for wireless communications over local area networks. I developed an 802.11b compliant physical layer. This physical layer operated in the 2.4 GHz ISM band. The solution ultimately shipped in high volume in products such as notebook computers and Wi-Fi access points. At Alantro, I also lead the development of IEEE 802.11a (now Wi-Fi 2) products. These products operated in the 5 GHz U-NII bands. These products also ultimately shipped in high volume. I also participated in the standardization of IEEE 802.11a and IEEE 802.11b and am listed within both standards as a participant in their development. Both IEEE 802.11a and 802.11b were ratified in 1999, thus in 1999 the IEEE 802.11 standard upon which Wi-Fi is based specified operation in both the 2.4 GHz ISM and 5 GHz U-NII bands.

11. Alantro was acquired by Texas Instruments in 2000. Alantro became

Texas Instruments' Wi-Fi business unit. I was at Texas Instruments from 2000 to 2003 where I managed the Wireless Networking branch of the DSP R&D Center and was the Director of Advanced Technology for the Wireless Networking Business Unit. In this role, I worked on numerous activities related to Wi-Fi. I lead the development of Bluetooth and Wi-Fi coexistence technologies. I lead development of very low power Wi-Fi technology for mobile phones. This work resulted in a version of our Wi-Fi chips that were used in the very first smartphone with Wi-Fi, the Nokia 9500 Communicator.

12. Additionally, my role included work to enhance the IEEE 802.11 standards with quality of service extensions.

13. From 2003–2008, I was the founder and CEO of WiQuest Communications, Inc. in Allen, Texas. At WiQuest Communications, I led the development of the world's first 1 Gbps ultrawideband chipset and first wireless VGA/DVI system for notebook computers. WiQuest was a fabless semiconductor company. We developed Wireless USB chipsets including a MAC and baseband processor that were manufactured at TSMC in a silicon process as well as a SiGe radio front-end that were manufactured at IBM. Our technology was integrated into modules that also included a Broadcom Bluetooth chipset. Customers included Dell, Toshiba, Belkin, and Kensington. I personally met with numerous module manufacturers during this period.

14. In 2008 I was first called on to serve as a technical witness in patent litigation. I have been providing technical services related to patent litigation since that time. In 2016, I incorporated my own consulting company, Peritum LLC, and my consulting work continues via Peritum today. My technical consulting services include wireless communications. I provide consulting services for telecommunications engineering, electrical engineering and communication engineering and intellectual property to companies and clients.

15. I am a named inventor on 38 issued US patents. The majority of these patents are directed toward technologies relevant to wireless communications.

III. LEVEL OF ORDINARY SKILL IN THE ART

16. I understand there are multiple factors relevant to determining the level of ordinary skill in the pertinent art, including (1) the levels of education and experience of persons working in the field at the time of the invention; (2) the sophistication of the technology; (3) the types of problems encountered in the field; and (4) the prior art solutions to those problems.

17. As I discuss below, the priority date of the '914 Patent is at the earliest April 23, 2004. I use this date for my analysis of this declaration including the level of A Persons of Ordinary Skill in The Art ("POSITA"). It is my understanding that the earliest alleged priority date for the '914 Patent is March 28, 2003, based on being a continuation-in-part of application No. 10/402,313. For purposes of this

Declaration, in general, and unless otherwise noted, my statements and opinions, such as those regarding my experience and the understanding of a POSITA generally (and specifically related to the references I consulted herein), reflect the knowledge that existed in the field as of the filing date of the provisional application of the '914 Patent (i.e., April 23, 2004), but I have also considered the knowledge that existed as of the earliest possible priority date (i.e., March 28, 2003). My analysis applies to 2003 and 2004 timeframes.

18. A POSITA in April 2004, like in March 2003, would have had a working knowledge of RF communications that is pertinent to the '914 Patent, including RF transceivers. POSITA would have had a bachelor's degree in electrical engineering or an equivalent, and three years of professional experience relating to communication systems.¹ Additional education, such as a master's or doctorate degree, can substitute for professional experience.

IV. RELEVANT LEGAL STANDARDS

19. I am not an attorney. In preparing and expressing my opinions and

¹ As an example, a POSITA may have had knowledge of RF transceivers, physical layer communications systems, antennas, oscillators, low-noise amplifiers, transistors, matching circuits and networks, transmitter and receiver architectures, electro-magnetic wave theory, and electrical properties of materials.

considering the subject matter of the '914 Patent, I am relying on certain basic legal principles that counsel has explained to me. I have become familiar with these principles over the years while serving as a technical expert in patent disputes. These principles are discussed below.

20. I understand that prior art to the '914 Patent includes patents and printed publications in the relevant art that predate the priority date of the alleged invention recited in the '914 Patent.

21. I have been informed that a claimed invention is unpatentable under 35 U.S.C. § 103 if the differences between the invention and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which the subject matter pertains. I have also been informed by counsel that the obviousness analysis takes into account factual inquiries including the level of ordinary skill in the art, the scope and content of the prior art, and the differences between the prior art and the claimed subject matter.

22. I have been informed by counsel that the Supreme Court has recognized several rationales for combining references or modifying a reference to show obviousness of claimed subject matter. Some of these rationales include the following: (a) combining prior art elements according to known methods to yield predictable results; (b) simple substitution of one known element for another to

obtain predictable results; (c) use of a known technique to improve a similar device (method, or product) in the same way; (d) applying a known technique to a known device (method, or product) ready for improvement to yield predictable results; (e) choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success; and (f) some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed invention.

23. I understand that, for any given claim of the '914 Patent, prior art includes patents and printed publications in the relevant art that predate the effective filing date of that claim. I understand that, subject to the next paragraphs, the “priority date” of a patent is the earlier of: (a) the date on which a patent application that later issues as the patent is actually filed; or (b) the date on which an earlier-filed patent application is filed if the patentee properly claims the benefit of priority to the earlier-filed patent application.

24. I understand that merely claiming the benefit of an earlier-filed application is insufficient. In particular, in order for the earlier priority date to be applicable, the prior application must describe the claimed invention and must do so in sufficient detail that one skilled in the art can clearly conclude that the inventor had possession of the claimed invention as of the filing date sought. I am

told that the priority-date analysis is on a claim-by-claim basis. I understand that in order for a patent claim of a later-filed application to be entitled to the filing date of an earlier-filed patent application, the earlier-filed patent application must meet both a written-description and an enablement requirement for that patent claim as of the filing date of the earlier-filed patent application. I also understand that this analysis may be referred to as an analysis of compliance with 35 U.S.C. § 112. I understand that it is not sufficient that the claim would have been obvious from the earlier application, rather the earlier-filed patent application itself must describe the claimed invention.

25. I understand to satisfy the written description requirement the earlier-filed patent application must reasonably convey to those skilled in the art that the inventors had possession of the subject matter of sought to be claimed by the later-filed patent as of the filing date of the earlier-filed patent application. I have been informed that it is disclosures of the earlier-filed patent application that count, and that while the meaning of terms, phrases, or diagrams in the earlier-filed patent application must be interpreted from the vantage point of a POSITA, all of the claimed limitations must be disclosed in the manner later claimed. Further, I understand that this analysis is not a question of whether one skilled in the art *might* be able to construct the later-filed patent application's claimed invention from the teachings of the disclosure or whether that claimed invention is an

obvious variant of that which is actually disclosed in the specification of the earlier-filed patent application; rather, I understand that the earlier-filed patent application must itself describe each of the claim limitations expressly or inherently. I also understand that in order to satisfy the enablement requirement, the earlier application must enable a person of ordinary skill in the art to practice the claimed invention of the later-filed patent application without undue experimentation.

V. TECHNICAL BACKGROUND

26. In its background, the '914 Patent discusses various well-known standards and techniques in wireless communication. EX1001, 1:30-67. The need for radio frequency (RF) components that support multiple frequency bands for communication devices such as mobile phones was well-known. My industry work at the relevant time included working on Wi-Fi which operated in the 2.4 GHz and 5 GHz bands as well as cellular technologies that operated in multiple bands as well such as the 900 MHz, 1.8 GHz, and 1.9 GHz bands. While at Alantro and Texas Instruments, I worked on complete reference designs for modules that were used in products such as notebook computers, smartphones, and access points. This included the development of solutions that operated in multiple frequency bands including Wi-Fi and cellular, two Wi-Fi bands, and even simultaneous use of bands such as the use of the 2.4 GHz band by Bluetooth and Wi-Fi. This work also

included working with module manufacturers that integrated passive components with communications processors. My work also focused on reducing the external components including their quantity, layout area, and cost. My work also included minimizing receiver sensitivity for Wi-Fi solutions which involves the use of low-noise amplifiers with low noise figure. During this period, I also worked on Wi-Fi processors that had support for operation in both the 2.4 and 5 GHz bands, i.e., were multi-band devices.

A. Multi-Band Devices

27. In the first generation of mobile devices (e.g., phones), the communication system operated in a single frequency band – 800 MHz, referred to as cellular band. The first-generation standard was named Advanced Mobile Phone System (AMPS). The system used frequency division duplexing whereby the base station could transmit and receive on two different frequencies at the same time. Uplink transmissions used the 824-849 MHz while downlink transmission used 869-894 MHz.

28. By the 1990s, well before the '914 Patent, additional frequency spectrum was allocated for such communications including the 1800 MHz band, referred to as the personal communication systems (PCS) band. And as additional spectrum was allocated, a need arose for these mobile devices (e.g., personal telephones) to be capable of operating in multiple frequency bands. This is

recognized in the Background of the '914 Patent (EX1001, 1:29-47) and was well understood in the industry. See, e.g., EX1009 (5,995,814, Yeh), 1:13-63

“Demand for cellular telephones and other wireless communications services is continually increasing. As a result, many **wireless systems are now configured to operate in more than one frequency band. ...**”); EX1015 (U.S. 5,457,734), Abstract (“A **dual frequency cellular radiotelephone system**, having different service providers, serving mobile subscribers at **first and second distinct frequency ranges**, uses frequency conversion techniques, to **serve both frequency ranges** with a minimum of equipment duplication.”); EX1016 (USP 5,406,615) Abstract (“A universal wireless radiotelephone communication apparatus is operative in both a first radiotelephone communication system including a first base station having a wide area of coverage, **transmitting radiotelephone signals at a first band of frequencies** and in a second radiotelephone communication system including a second base station having a localized area of coverage, **transmitting radiotelephone signals at a second band of frequencies higher than said first band of frequencies.**”), EX1017 (RF Microelectronics, Razavi), pp. 1-2.

29. Other frequency bands are also discussed in the '914 Patent that were similarly common. One example of bands used in the specification are the 2.5 GHz and 5 GHz bands. EX1001, 21:26-23:8. Related, the description of related art

discusses the 2.4 GHz and 5.2 GHz bands as being used by IEEE 802.11a/b/g protocols at the time. EX1001, 1:34-36. A POSITA would know that the IEEE 802.11a standard (published in 1999 retrospectively referred to as Wi-Fi 2) protocol used the 5 GHz UNII bands and IEEE 802.11b standard (published in 1999 and retrospectively referred to as Wi-Fi 1) used the 2.45 GHz ISM band. Thus, the inventors provide an example of different frequencies as being met when one frequency corresponds to the 2.4 GHz ISM band and the other corresponds to the 5 GHz UNII band.

30. One early technique implemented to provide multi-band functionality relied upon separate sets of components assigned to each band and providing disparate signal paths for each frequency. This is discussed in the background of Yeh, which I discussed in detail below. And also confirmed by various other references such as EX1016 (USP5,406,615), 1:29-44; EX1018, (USP 5,821,820, describing oscillators), 1:10-29, EX1009 (Yeh), 1:38-46 (“For example, application of conventional matching techniques to a low noise amplifier would generally require that both an input and an output **matching network utilize a separate set of at least two or three elements for each of the frequency bands to be matched.** A **separate set of elements** is therefore used to **provide a narrowband input or output match for each of the frequency bands.**”); EX1017 (RF Microelectronics, Razavi), pp. 1-2; EX1005 (Francisco), 1:9-41.

Naturally, providing a path dedicated to a certain frequency led to mobile devices with increased size and cost. Francisco, (“multi-band radiotelephone[s] [] more bulky in size, costly and unreliable.”), 1:33-36; EX1009 (Yeh), 1:29-63 discussing “cost and complexity of the front end radio-frequency (RF) circuitry in these multi-band portable devices[,]”; EX1019 (US Patent Appl. 2002/0030545), FIG. 1-2 [0006]; EX1020 (EP0851576A2), 3:42-53 (“The **high-frequency amplifier 1** according to the **conventional technology** described above **amplifies only** a high-frequency signal **in a single frequency band**. Therefore, to implement a portable telephone which 45 handles a plurality of communication radio waves in different frequency bands (that is, a common portable telephone usable in a plurality of areas), the **portable telephone needs** to be equipped with **a plurality of high-frequency amplifiers 1** each **corresponding to a respective frequency band**. As a result, the portable telephone becomes large, power consumption increases, and cost also increases. Recognizing these challenges, market forces recognized a **need for re-use of components in multi-band devices**.”); EX1018 (USP 5,821,820 (directed to oscillators)), 1:24-29 (“...adds cost and size to the overall circuit.”), EX1011 (Hashemi), Abstract, p. 288.

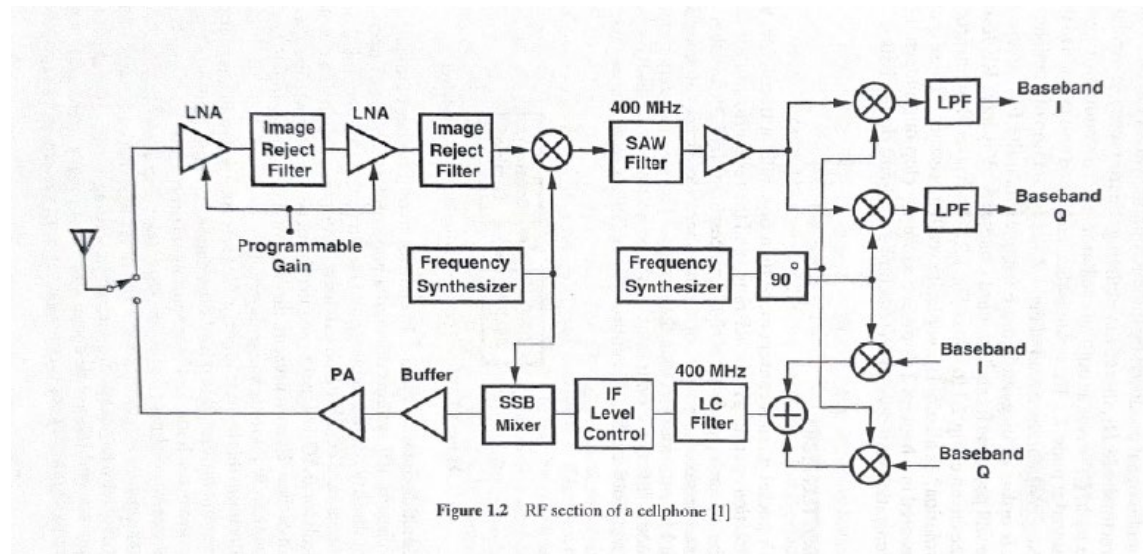
31. Amplifiers were a well-known component for re-use at different frequencies. See EX1005 (Francisco), 1:50-61. See also, EX1009 (Yeh), 1:29-56 (“In order to **minimize** the cost and complexity of the **front end radio-frequency**

(RF) circuitry in these multi-band portable terminals, it would be highly desirable to **provide a single low-noise amplifier** at the front end that can, for example, **amplify both the 900 MHz and 1.8 GHz frequency bands**.”); EX1008 (Hirayama), [0009]; EX1011 (Hashemi), discussed below; EX1021 (Mou) titled “A CMOS RF Bandpass Low Noise Amplifier for Multi-band Wireless Communication Applications”

B. Transceivers

32. The RF circuitry section of a mobile device includes transmit and receive portions, together forming a transceiver, with an antenna for conveying the respective signals. Amplifiers are an important building block of the transceiver coupled with the antenna in each of the transmit and receive paths. The transmit path has a power amplifier (PA) to amplify signals to high power levels prior to being radiated from the antenna. The receive path comprises a low-noise amplifier (LNA) to amplify weak signals received at the antennas without injection of significant noise.

33. Figure 1.2 of RF Microelectronics textbook, EX1017, is illustrative:



34. Amplifiers are comprised of a core amplifying device, typically a transistor, to provide the gain, and passive components to provide for biasing and impedance matching for inputs and outputs of the core amplifying device. The '914 Patent refers to its core amplifying device as an *active device*.

35. The passive components are arranged in a network as there is an interconnection of two or more passive components such as resistors, capacitors, inductors, or transistors. A passive component of an amplifier is one where no gain is introduced. Examples of passive components are resistors, capacitors, inductors, and transformers. Passive components store, dissipate, or transfer energy within a circuit or network.

C. Packaging

36. Similar to market forces driving component reuse, there was a

recognized need for packaging technologies to provide transceiver components with good electrical performance in a small footprint package. Before March 2003, notebook computers and cellular phones were getting smaller. These devices gave one, of many, reasons for RF devices to be provided as an RF module. A module is a component comprising a substrate that incorporates multiple electric components within its footprint. See, e.g., EX1023 (“RF Characterization of a low cost multichip packaging technology for monolithic microwave and millimeter wave integrated circuits,” Jayaraj, (1995)), EX1026 (US Patent Appl. 2004/0127182), [0001], [0005] (“With a still strong demand for making mobile communications devices smaller and lighter in weight, development has been progressing to have common parts and integrated functions into modules.”)

37. There was regulatory reason to integrate into single packages and/or modules as well. The FCC allowed for modular approval for communication systems cards and modules. By obtaining FCC approval at the module level, the larger system, e.g., a notebook computer or cell phone, did not have to be carried through a whole FCC approval cycle due differences in the systems fully unrelated to the wireless subsystem. Thus, the regulatory approval for the communications subsystem could be decoupled from the complete product. This provided time-to-market and cost advantages, and thus also constituted a market force that drove toward reduction of size and component reuse.

38. Integration of the wireless communications system into a single package or module and reduction of component count also helped with yield. Yield is the number of good units manufactured divided by the total number manufactured. During product manufacture, products are tested to see if they are functioning properly. If they are not, they must be discarded and not sold. There is yield at both the component level, e.g., a Wi-Fi module, as well as the final product, e.g., a smartphone. By integrating a communications subsystem into an ever-decreasing package or module size with ever fewer components, the yield tends to increase. Additionally, only known-good modules, e.g., Wi-Fi module, can be installed in the finished product, e.g., cell phone, thereby driving failures of the final product attributable to the communications module to near zero. Said differently, if there is a failure of the communications system module, it is detected by testing the module prior to integration with the cellular phone, thereby making sure that the final product rarely if ever has a defect due to the communications system module. This also constitutes a market force to design integrated communications chips, modules, and solutions with few components.

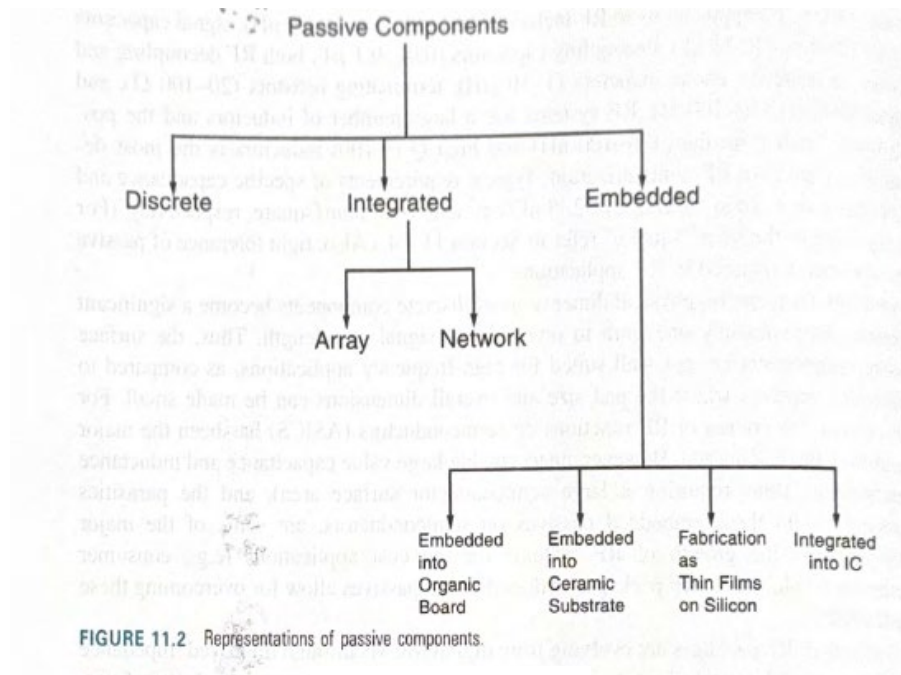
39. Generally, packaging technologies include a substrate that acts as a foundational material providing mechanical support, thermal management, and electrical interconnections. The substrate may ideally have “low permittivity, interconnections made of high-conductive metals, high wiring density, and

embedded passive circuit elements.” EX1025; NIST Technical Note 1520, “Dielectric and Conductor-Loss Characterization and Measurements on Electronic Packaging Materials,” p. 2. The permittivity of the substrate material indicates how easily electrical fields easily pass through the material. Low permittivity materials do not store energy when exposed to an electric field while higher permittivity materials store more energy. High permittivity also lowers the wavelength of signals. Permittivity may also be expressed as the relative permittivity (also called dielectric constant) which is the ratio of the permittivity of a material the ratio of the permittivity of a vacuum. Thus, permittivity is an important design parameter in communications systems that a POSITA would have knowledge of, as it is fundamental to basic theory or propagation of electromagnetic waves through materials.

40. Whether embedded within a substrate or on a substrate, components such as inductors, resistors, and transistors must be connected. Thus, a conductor is needed for these interconnections. These interconnections are formed of a conductive material (metal, such as copper). High wiring density means the ability to include a high density of wires, traces, and vias. This enables more complex and/or compact circuitry to be included in the package.

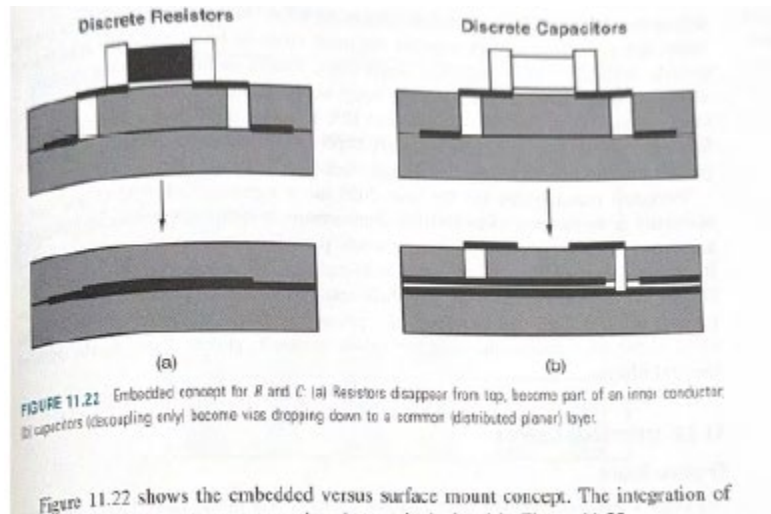
41. Embedded or buried passives means the passive components such as resistors, capacitors, and inductors can be embedded or built directly in the

substrate. For example, a capacitor may be sandwiched between layers of the substrate and connected to the circuit using metal (e.g. copper) traces, which also extend between the layers via interconnects (e.g., vias). “The ability to include components into the modules reduces the number of interconnects which increases reliability and reduces the size and the cost.” EX1025, p. 8. Figure 11.2 of EX1012 is illustrative of the option to embedded passive components:

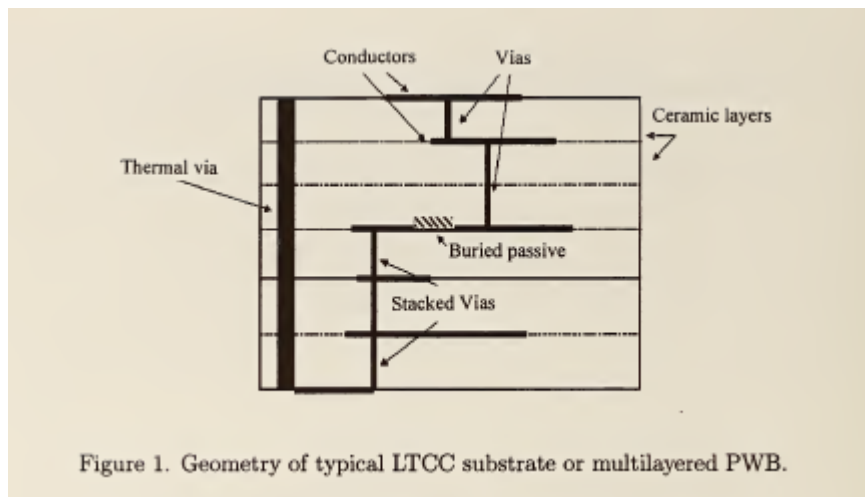


EX1012, p. 426

See also, EX1012, Table 11.3 discussing embedded passives, 11.7 Embedded (Integral Passives) including benefits of integration (p. 254), Figures 11.22 illustrating the embedded passive.

**EX1012, p. 455**

42. A typical configuration of such a substrate is illustrated below. The caption indicates the substrate is made of low-temperature co-fired ceramic (LTCC) or a multi-layer printed wiring board (also referred to as printed circuit board or PCB). The figure below shows six “Ceramic layers” of the substrate. There are multiple metal layers shown comprised of “Conductors.” There are vias that pass through the layers and are typically plated with conductive material to allow signals to pass from one layer to another. Also shown below is a “Buried passive” component such as a resistor or capacitor.

**EX1025, p. 10**

43. The substrate of Figure 1 above illustrates a laminated PWB. A laminate or laminated substrate is one that is formed by bonding multiple layers of dielectric thin films together. In a ceramic technology (LTCC), ceramic layers are laminated or stacked to form the substrate. EX1025, p. 6, Figure 2, p. 10. In organic substrates, layers of organic material are laminated or stacked together. EX1025, p. 9. Conductive material, metal, are formed on the laminate layers as shown by the dark lines of Figure 1 above. Embedding passives has benefits that I discuss below in Section VIII.A. For example, embedding passives allows for shorter interconnects, more compact component arrangement, reduced size including of the component and/or the module, improved quality (including due to the suitable dielectric materials discussed below), and reliability.

44. A POSITA recognizes the use of suitable dielectric materials is

important to minimizing signals loss to heat in the conductors providing interconnections (metal lines and vias) and passive components. The permittivity, ϵ , of a material is complex. It can be written as $\epsilon = \epsilon' + j\epsilon''$. When a material with permittivity, ϵ , is subjected to an electric field, E , the work done on the material corresponding to storage of energy is given by: $W_{\text{stored}} = \frac{1}{2}\epsilon'E^2$. The work done on the material that results in energy dissipation as heat is given by: $W_{\text{dissipated}} = \frac{1}{2}\epsilon''E^2$. The ratio of the imaginary part of the permittivity to the real part is call the *loss tangent*. This associated angle, δ , is known as the *loss angle* and is given by: $\tan \delta = \frac{\epsilon''}{\epsilon'}$. A POSITA recognized that using suitable dielectric materials (e.g., those with a low loss tangent) was desirable to minimize signal distortion and loss.

45. A POSITA also recognized that increasing the permittivity of the substrate makes it easier to build small capacitors, the purpose of which is to store energy in electric fields. A POSITA also recognized that increasing the permittivity can also increase parasitic capacitances in the systems, i.e., undesired capacitances. A POSITA also recognized that high permittivity materials reduce the wavelength thus are conducive to making smaller devices while also recognizing the high permittivity also reduces signal speed and increases latency. A POSITA would thus recognize basic engineering tradeoffs related to the permittivity of the selected substrate.

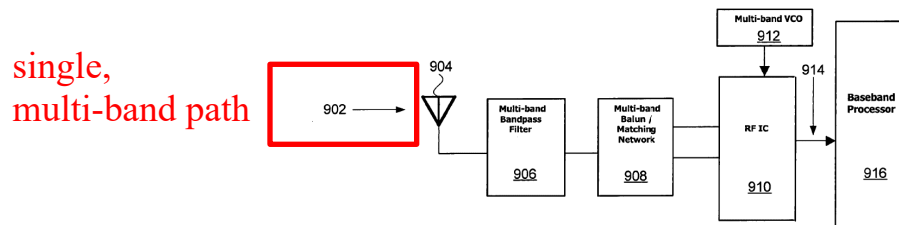
46. A POSITA would also know that the permittivity of a material is a function of frequency. Thus, the selection of material for a desired permittivity would also consider the frequency of the signals being processed. The frequency of the signal being processed would result in a basic and routine engineering design decision to select a material with a permittivity and loss tangent that were acceptable for the application. Numerous substrate materials were known in the prior art. See, e.g., EX1025, Table 6, p. 14. See also, EX1012, p. 456. This included organic substrates such as polyimide-based substrates (e.g., polytetrafluoroethylene (PTFE) or Teflon) and ceramic-based (e.g., aluminum oxide) substrates were well-known options. EX1025, pp. 3-16; EX1012, p. 456 discussing “Organic Board” and “Ceramic Substrates”. *See also*, EX1037 (JP315) using organic substrates for passive components, FIG. 3, [0058], [0016] (“Examples of the organic material that configures the substrate used in the present invention include a glass epoxy resin, BT resin (bismaleimide-triazine resin), polytetrafluoroethylene, and the like.”)

VI. THE '914 PATENT

A. Overview

47. The '914 Patent relates to RF transceivers operable at multiple RF bands, i.e., multi-band transceivers. EX1001, 1:23-27. FIG. 15, below, illustrates a receiver portion using only a single path for multiple band frequencies, which is

contrasted with different paths for each frequency band (see, FIG. 14). EX1001, 17:18-20, 16:53-59.



EX1001, FIG. 15
(annotated)

While FIG. 15 indicates the multi-band *receiver* portion, the '914 Patent recognizes the same applies to the multi-band *transmitter* portion of the transceiver. EX1001, 17:46-47. As discussed above, the receiver portion would comprise a multi-band *low-power* amplifier (LNA) while the transmitter portion would comprise a *power* amplifier (PA).

48. The '914 Patent describes (a) concurrent, multiband oscillators (e.g., Figures 27 and 31A); and (b) a multi-band filter (e.g., Figures 28 and 33). The '914 Patent also suggests multi-band RF transceiver topologies can reuse components at different frequencies and gives examples of a voltage controlled oscillator (VCO) and a low noise amplifier (LNA). EX1001, 2:8-20; see also Figure 27 depicting a concurrent, multiband oscillator.

49. As indicated above, the specification also mentions a multi-band LNA. FIGS. 35 and 36 together describe a single-band LNA. Figure 35 shows the

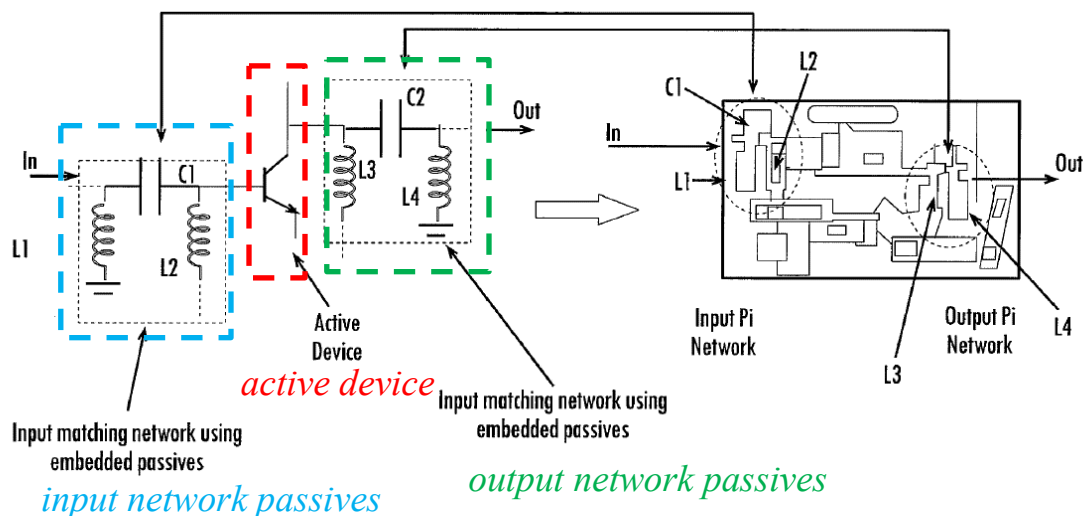
design of the LNA, while Figure 36 shows the performance of the input matching filter. The LNA of Figures 35-36 is designed using an input matching filter at the input of a transistor (marked “Active Device” in FIG. 35). The output of the transistor is connected to another matching network. The “measured gain and input match” for the LNA of FIG. 35 is shown in FIG. 36. FIG. 36 shows the maximum gain and lowest input reflection coefficient are both at approximately 2.45 GHz. There is no inter-band stopband exhibited. There is only one resonant frequency of the input network in FIG. 35, i.e., centered at 2.45 GHz as illustrated by FIG. 36. This can be seen in FIG. 36 as the S21 drops to its lowest point at about 2.45 GHz. The 3 dB bandwidth spans approximately 2.0 GHz to 3.0 GHz, and a 10 dB bandwidth spans from approximately 1.3 GHz to 6.2 GHz.

50. The input and output matching circuits of FIG. 35 are depicted as π networks. This is a configuration known to those in the art. It is called a π network, because there are two downward “shunt” components with an interposed serial component. This makes the general shape of the Greek letter π . Here, the two shunt components are shown as inductors, and the serial component is shown as a capacitor. Low frequency signals will not pass through the capacitor, thus the lowest of frequencies will be blocked. The specification does not provide values for L1, C1, or L2 in Figure 35.

51. While FIGS. 35-36 illustrate a single-band LNA, the specification

says of FIG. 35 that “[a]dditionally, like the VCOs described above, the passives can also be used for implementing multi-frequency resonant circuits, thereby making the LNA operational at multiple frequencies.” EX1001, 24:16-19.

52. Returning to FIG. 35, FIG. 35 illustrates an LNA with an active device (shown as a bipolar junction transistor) and matching networks at its input and output. EX1001, 24:10-27.²

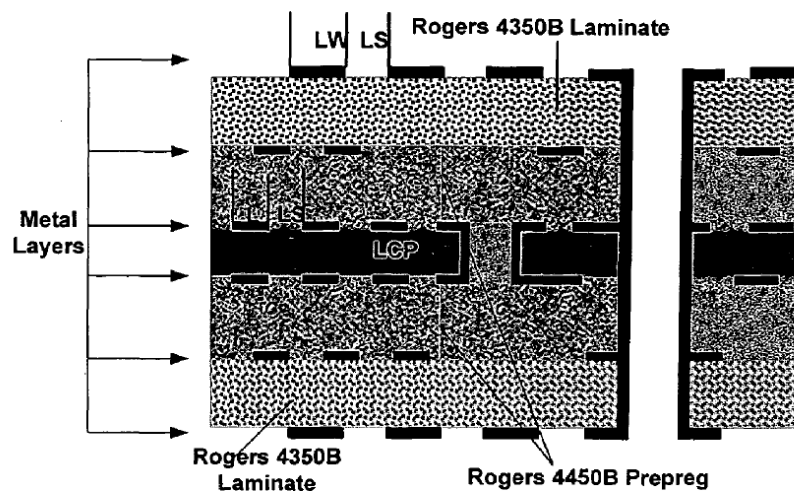


EX1001, FIG. 35
(annotated)

53. The '914 Patent describes embedded passives formed in an organic substrate to reduce the form factor of the module. EX1001, 24:38-46, 58-63. The

² The label of the network including L3, L4, C2 should read an “Output matching network using embedded passives.”

'914 Patent describes "embedded passives can be of microstrip, stripline, co-planar waveguide (CPW) topology, or a hybrid thereof." EX1001, 24:65-67. In some embodiments, the IC may also be embedded. See, e.g., 24:28-63. FIG. 38A illustrates six metal layers (metal being denoted by the dark lines below) where metal layers on each surface of a liquid crystal polymer (LCP) layer may contain passives such as inductors, while the additional metal layers on laminate or additional LCP layers may contain additional components or function as ground shields. EX1001, 25:4-12.



EX1001, FIG. 38A

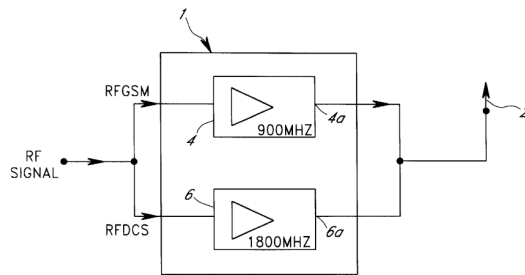
54. Rogers 4350B Laminate is used for outer layers in FIG. 38A, and Rogers 4450 Prepreg is used for inner layers surrounding a liquid crystal polymer (LCP) layer. Rogers 4450B are laminate materials from Rogers Corporation commonly used in the industry. See, e.g., EX1025 NIST Technical Note, pp. 99,

132 (mentioning Rogers).

B. Prosecution History

55. I understand that the Patent Office recognized two different embodiments relative to the originally filed claims (a restriction requirement) that of a “multi-band low noise amplifier [LNA] using active device for RF application, illustrated by Fig. 35” and “multi-band oscillator for use in an RF transceiver, illustrated by Fig. 16A and 27.” EX1002, p. 94 (Restriction Requirement, p. 2). Applicant elected the LNA embodiment. EX1002, p. 88 (RR response, p. 8). I am told that a restriction requirement is a demand by the Examiner for the Applicant to choose one embodiment, here an LNA, of multiple embodiments of the specification/claims, here an LNA and an oscillator, for examination during the patent application.

56. In a subsequent action, the Examiner allowed most claims but rejected then pending claims 1-3 as anticipated by USP 6,075,995 to Jensen. The Examiner alleged Jensen taught a multi-band device operable at GSM and DCS frequencies that included an active device (“power amplifier module 1”) that includes two separate power amplifiers 4, 6 within the module.

**USP 6,075,995, FIG 1**

57. The Examiner pointed to an alleged “first passive network” as that of power amplifier 4 (Fig. 3) adapted to 900 MHz, and separately to an alleged “second passive network” as that of power amplifier 6 (Fig. 4) adapted to 1800 MHz. EX1002, pp. 56-61.

58. In response, Applicant amended pending claim 1 to include dependent claim subject matter that was indicated to be allowable, added new dependent claims, and cancelled non-elected (VCO) claims. EX1002, pp. 44-51. The resulting claim requires that matching networks be at the input and the output of the active device.

1. (Currently Amended) A multi-band RF device operable at a first frequency and a second frequency different from the first frequency, comprising:
 - an active device;
 - a first passive network in communication with the active device, the first passive network comprising a first matching network at an input of the active device;
 - a second passive network in communication with the active device, the second passive network comprising a second matching network at an output of the active device; and
 - an organic-based substrate having at least two metal layers, wherein the two metal layers are patterned to form at least a portion of the first passive network and the second passive network, wherein impedances of the first and second passive networks are different at the first frequency than the second frequency.

EX1002, pp. 44-51. A Notice of Allowance copying each element of the independent claims issued. EX1002, pp. 33-37.

C. Effective filing date of Application that issued as the '914 Patent

59. I understand a continuation-in-part (CIP) patent stems from an application that claims priority to a prior application but adds additional subject matter not disclosed in the prior application. I understand that the face of the '914 Patent, under (63) Related U.S. Application Data, indicates that it is a continuation-in-part (CIP) of U.S. Application No. 10/402,313, filed on March 28, 2003, which issued as U.S. Patent No. 6,900,708 ("the '313 Appl"). I am informed by counsel and note from the front page of the '914 Patent at (60) that the '914 Patent also claims priority to a provisional application No. 60/565,254, filed April 23, 2004. I have not rendered an opinion as to whether the provisional application provides written description support. As explained below, I do not believe the '914

Patent is entitled to a priority date based on the '313 Application. As a result, possible priority dates for the '914 Patent would be April 23, 2004, based on provisional application No. 60/565,254 or April 25, 2005 based on the date of Appl. No. 11/114,733 on April 25, 2005. Again, I have not provided any analysis as to the sufficiency of the disclosure on April 23, 2004 for the purposes of this declaration as all prior art predates April 23, 2004 by over a year.

60. I have reviewed the '313 Application, including those documents it states that it purports to incorporate by reference (including US Provisional Application No. 60/391,742; Serial Nos. 10/402,315, and 10/405,024). No written description exists that provides support for a multi-band RF device, or multi-band low noise amplifier, that comprises an active device and is configured as claimed in the '914 Patent. That is, I find no express, implicit, or inherent disclosure of the multi-band RF/LNA device configured as recited in the '914 Patent in the '313 Application or any of the applications of EX1040.

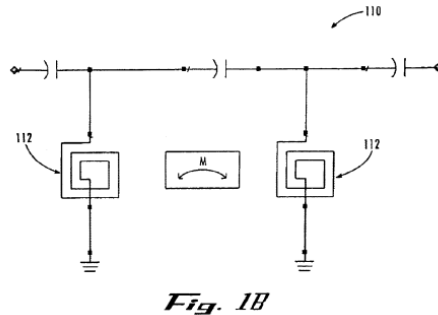
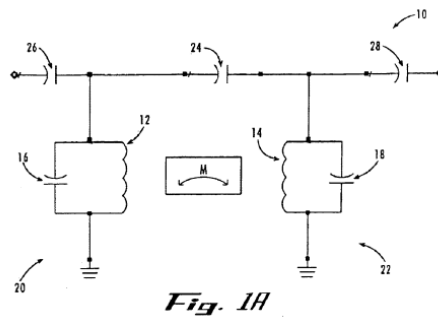
61. The '914 Patent has two independent claims,
- Claim 1 is directed to “[a] **multi-band** RF device operable at a first frequency and a second frequency different from the first frequency, comprising: **an active device**” and continues to recite a first/second passive network (each including matching network) at the input/output of the active device.
 - Claim 5 is directed to “A **multi-band** low noise amplifier for use in an

RF application, comprising: an *active device*” and continues to recite a first/second matching network in communication with the active device.

62. I have reviewed the ’313 Appl. (see EX1040) and no written description exists for these elements or the ’914 Patent claims in general. I have also reviewed documents associated with the serial numbers that are purportedly “incorporated by reference” in the ’313 Appl. (see EX1040) and no written description exists for these elements or the ’914 Patent claims in general. I note that an active device is illustrated in the ’914 Patent as a transistor. And in the context of the RF device and low-noise amplifier, a POSITA would understand that the active device is a component that introduces gain. This is in contrast to a passive component such as a capacitor, resistor or inductor.

63. I note that the ’313 Appl. has a title of “Integrated passive devices fabricated utilizing multi-layer, organic laminates.” EX1040, p. 4.³ FIGS. 1A and 1B of the ’313 Appl. introduces a filter 10 that includes inductors and capacitors. This filter does not include *an active device*. Filter circuit diagrams of the ’313 Appl. (FIGS. 1A and 1B) form the basis of the discussion in the ’313 Appl.; and each shows a dielectric bandpass filter 10/110 made up of passive components (e.g., inductors 12, 14, capacitor 16, 18 or inductors 112).

³ My citations to EX1040 are to the page numbers annotated for this proceeding.

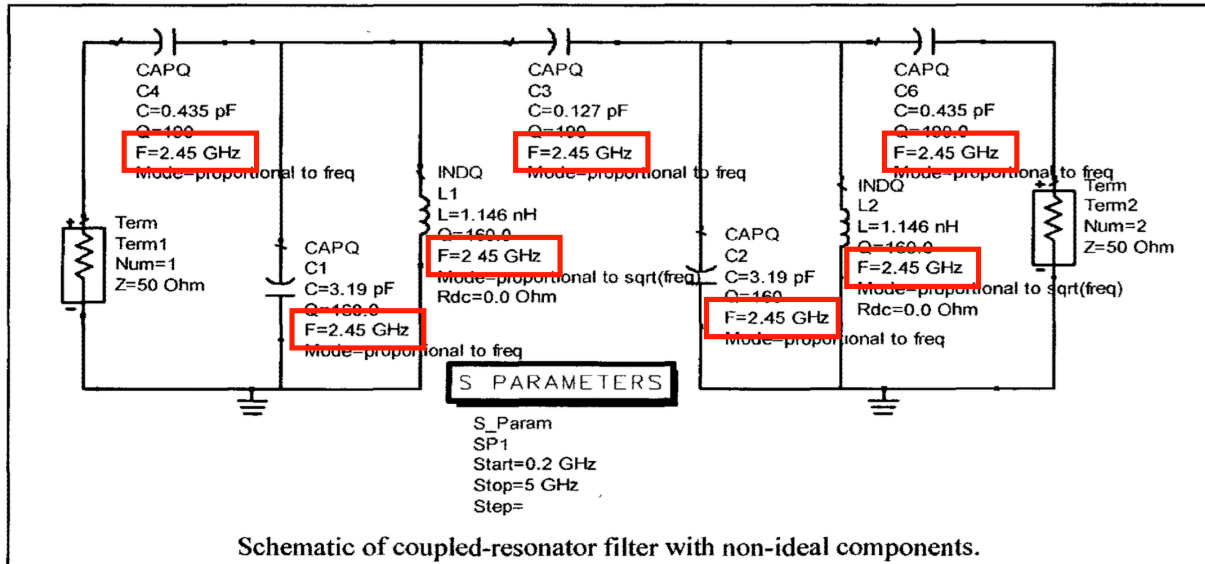
**EX1040, FIGS. 1A, 1B**

There is no active device illustrated in the circuit diagrams at FIGS. 1A and 1B. I note that the claims of the '313 Appl. are also directed to either a "bandpass filter" or "[a] stand-alone organic passive device." EX1040, pp. 34-39. There is no discussion, explicit, implicit or inherent, of an active device or aspects related to such a device such as a transistor or gain. There is similarly no discussion of a multi-band low-noise amplifier or multi-band RF device operation generally. In fact, the '313 Appl. discusses just the opposite, a filter having a single center frequency. The "Bluetooth/WLAN filter" operates at a single frequency of 2.4 GHz. EX1040, p. 29. I also note that Fig. 35 of the '914 Patent illustrates an LNA,

and this figure is not in the '313 Appl. Thus, I conclude there is no written description (express, implicit, or inherent) in the '313 Appl. of a multi-band device, multi-band operation, or multi-frequency resonant circuits providing for operation at multiple frequencies.

64. I have also reviewed Provisional App. No. 60/391,742, which is entitled “Passive Component Architectures in Multi-layer Liquid Crystalline Polymer (LCP) Substrates.” EX1040, p. 156. This application is again directed to filters and stand-alone passive devices. The application mentions its passive architectures can be used for “a portable telephone” that can apply techniques for “integrated passives for high frequency application.” EX1040, p. 160. And that it “provides for passive architectures such as bandpass filters, diplexers, baluns, power combiners and power dividers, low-pass filters and high-pass filters which all use various configurations of Ls, Cs and Ts.” EX1040, p. 160. The document also recognizes “a huge impetus towards the move for sub-systems such as modules (VCOs, LNAs, etc.) which also use a combination of Ls, Cs and Ts for matching and biasing circuits....” EX1040, p. 162. However, there is no suggestion that its integrated passive components be used in conjunction with an active device as claimed in particular in the context of a multi-band RF device / amplifier. Its bandpass filter is taught as passing a single band such as the 2.4 GHz band used by Bluetooth. The schematic of an apparatus (reproduced below with

annotation) shows all center frequencies at 2.45 GHz, thus confirming lack of a dual-band teaching.



EX1040, p. 163 (annotated). Thus, it is my opinion that that there is no written description support for the claims of the '914 Patent in Provisional App. No. 60/391,742, alone or when considered with the applications discussed in this section.

65. I have also reviewed App. No. 10/402,315, which issued as US 7,260,890. This application is entitled "Methods for fabricating three-dimensional all organic interconnect structures" and discloses flip chip wafer level packaging. There is some discussion of active and passive components formed on a substrate,

...The multilayer substrate or module can be used for interconnecting a vast array of active and passive components either through direct attached methods or surface mount technologies.

The multilayer 3D interconnect structure described herein can support the packaging and interconnection of various active and passive components in addition to the passive components embedded in the structure to form functional modules or system boards for digital, RF/wireless, or mixed signal modules. The ability to tailor the expansion of the multilayer circuit, described above, enables the packaging of different active chips such as silicon CMOS, SoI, SiGe, GaAs, and surface mount passive components in a highly reliable platform. For example, FIG. 8 is a schematic representation of a multilayer circuitized structure including various illustrative packaging formats supported by the present invention. Suitable packaging formats include, but are not limited to, flip-chip, wafer level packages (WLP), chip scale packages (CSP), ball grid array (BGA), wire bonded devices and various surface mount devices (SMD or SMT).

The formats illustrated in FIG. 8 include cavity flip chip or wirebond 70, flip chip wafer level packaging 72, BGA/CSP 74, SMD/SMT 76 and wire bond 78.

EX1040, pp. 67-68. However, this does not support the claims of the '914 Patent.

First, there is no written description support for any multi-band functionality or operation for an RF device, much less a low noise-amplifier. Second, there is no written description support for first/second passive networks or matching networks being configured as claimed with respect to the active device. Likewise, the claims are not directed to multi-band devices, matching networks, LNAs or active devices. Thus, it is my opinion that there is no written description support for the

claims of the '914 Patent in App. No. 10/402,315, which issued as US 7,260,890, alone or when considered with the applications discussed in this section.

66. I have also reviewed App. No. 10/405,024, which issued as US 6,987,307. This application is entitled “Stand-alone organic-based passive devices” and is directed to such. EX1040, p. 84. This application recognizes problems associated with discrete stand-alone inductors on a board that also includes active devices.

The present invention avoids the problems associated with modeling ground for a discrete stand-alone inductor mounted to a circuit board of tens to hundreds of other passive and **active electrical components** by providing internal or external shielding, thereby defining ground independent of the inductor's surroundings. An inductor in accordance with the present invention includes a ground reference by having a multi (>2) terminal device, wherein two terminals can be the ground layer and the other two terminals can be the input and output terminals. This helps alleviate the concerns when using a standard two terminal device, such as those described in Table 1. The hybrid topologies of FIGS. 3A–3D also allow for additional shielding on the sides of the device to help restrict the energy within the device. EX1040, p. 100. However, there is no suggestion or indication that the active device and inductor are configured as claimed in the '914 Patent. The application also discusses impedance of an inductor.

The quality determining component of an inductor is the characteristic

impedance, Z_o , of the lines used to comprise the inductor. The conductor loss in an inductor is inversely proportional to Z_o of the line, and represents the dominant loss in the device provided the loss in the dielectric used in the construction is below a certain threshold value of about 0.02. The characteristic impedance of these lines can be determined based on the inductance and capacitance per unit length, which can be computed based on the distance from the reference plane. EX1040, pp. 99-100. Again, there is no suggestion or indication of the inductor being part of a passive network related to an active device according to the configuration claimed in the '914 Patent. The application is focused on the design of integrated passive devices such as inductors using organic materials, not on multi-band devices or LNAs having input and output matching networks for an active device. Moreover, I find no indication in the document of multi-band operation or functionality of an RF device generally or low noise amplifier specifically. Thus, it is my opinion that that there is no written description support for the claims of the '914 Patent in App. No. 10/405,024, which issued as US 6,987,307, alone or when considered with the applications above.

67. Thus, to summarize, it is my conclusion that there is no written description support for the limitations of the '914 Patent claims including a multi-band RF device or low-noise amplifier having an active device.

Serial Number	Title	Disclosure of multi-band RF
---------------	-------	-----------------------------

		device/LNA having active device as configured in the '914 Patent claims
10/402,313	“Integrated Passive Devices Fabricated Utilizing Multi-Layer, Organic Laminates”	none
60/391,742	“Passive Component Architectures in Multi-layer Liquid Crystalline Polymer (LCP) Substrates”	none
10/402,315	“Methods for fabricating three-dimensional all organic interconnect structures”	none
10/405,024	“Stand-alone organic-based passive devices”	none

VII. CLAIM CONSTRUCTION

68. It is my understanding that in order to properly evaluate the '914 Patent, the terms of the claims must first be interpreted. It is my understanding that for the purposes of this *inter partes* review, the claims are to be construed under the so-called *Phillips* standard, under which claim terms are given their ordinary and customary meaning as would be understood by one of ordinary skill in the art

in light of the specification and prosecution history, unless the inventor has set forth a special meaning for a term.

69. For the purposes of my analysis below, I do not believe any claim terms require explicit construction.

VIII. IDENTIFICATION OF HOW THE CLAIMS ARE UNPATENTABLE

70. I have been asked to provide my opinion as to whether the Challenged Claims of the '914 Patent would have been obvious in view of the prior art. The discussion below provides a detailed analysis of how the prior art references identified below teach the limitations of the Challenged Claims of the '914 Patent.

71. As part of my analysis, I have considered the scope and content of the prior art and any differences between the alleged invention and the prior art. I describe in detail below the scope and content of the prior art, as well as any differences between the alleged invention and the prior art, on an element-by-element basis for each of the Challenged Claims of the '914 Patent.

72. As described in detail below, the alleged invention of the Challenged Claims would have been obvious in view of the teachings of the identified prior art references as well as the knowledge of a POSITA. My obviousness analysis relies on the combined teachings of the references and not on a physical incorporation of elements. I apply the prior art as follows:

Grounds	Claims	Basis(Pre-AIA)
#1	1-2 and 4-20	35 U.S.C. § 103 over Yeh and Dalmia
#2	1-2 and 4-20	35 U.S.C. § 103 over Dalmia and Hashemi

73. As stated above, I have used the priority date – April 23, 2004 – for my analysis of this declaration.

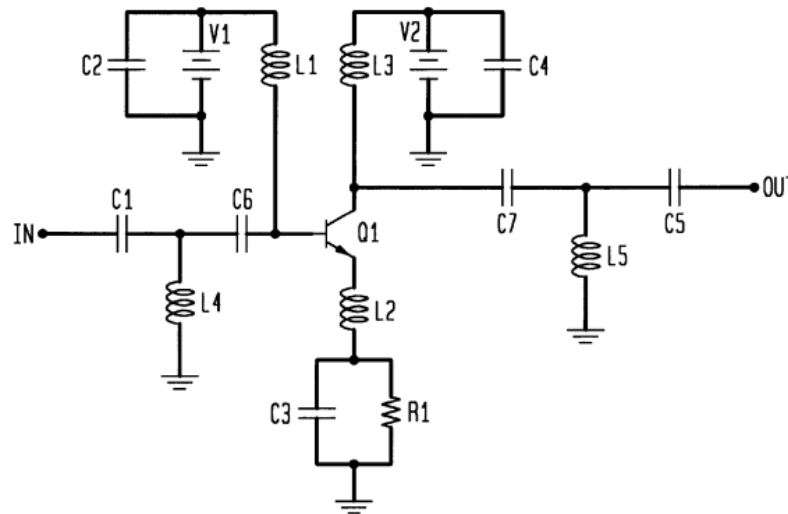
A. Ground 1: Claims 1-2 and 4-20 over Yeh and Dalmia

1. Overview of Yeh

74. Yeh recognizes the desire for cellular telephones and other wireless communication services to operate in more than one frequency band. Yeh, 1:13-28. “In order to minimize the cost and complexity of the front end radio-frequency (RF) circuitry in these multi-band portable terminals, it would be highly desirable to provide a single low-noise amplifier at the front end that can, for example, amplify both the 900 MHz and 1.8 GHz frequency bands.” Yeh, 1:29-34.

75. In response to this desire, Yeh provides “a simple and inexpensive low-noise amplifier which can provide excellent performance in two or more frequency bands...[where] input and output matching networks are used to provide respective input and output matches for the amplifier” in these frequency bands. Yeh, 1:66-2:4. FIG. 1 provides a schematic diagram illustrating such a low-noise amplifier having an input terminal IN and a transistor Q providing a gain and an output terminal OUT; FIG. 5 provides the same amplifier with its input and output

matching networks illustrated.



Yeh, FIG. 5

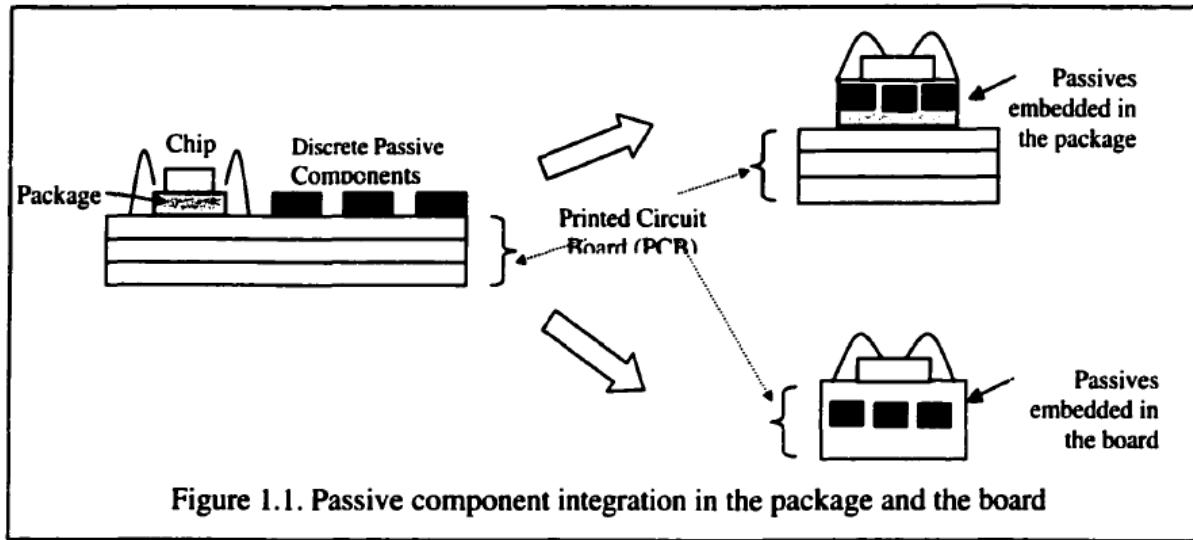
Yeh teaches that the low-noise amplifier of Figure 5 utilizes four elements for the input matching network (C1, L4, C6, L1) and four for the output matching circuit (L3, C7, L5, C5). Yeh teaches that for each of the matching circuits to match at two frequencies (corresponding to two bands) there are two degrees of freedom needed per frequency, and two components provide those two frequencies. Thus, four components allow the degrees of freedom needed to match at two different frequencies. Yeh, 6:1-16.

2. Dalmia

76. Dalmia is an academic Thesis presented by Sidharth Dalmia, a named inventor of the '914 Patent. I understand that Dalmia, the reference, was obtained

from ProQuest® Digital Dissertations and Theses database (PQDT), which indicated that it was publicly available as March 31, 2003. I am aware that it is common for universities to submit theses and dissertations to ProQuest database for publication. It is a typical resource used by a POSITA when searching for teachings in this field.

77. Dalmia recognizes that “[d]iscrete passive components such as inductors, resistors, capacitors, filters, and resonators currently dominate the component count in most RF and mixed signal electronic products. While the cost of discrete passive components may be low, the cost of all the components on total product cost can be significant.” Dalmia, p. 3. “A method for eliminating the surface mount discrete components is by embedding the passive components into the layers of the package or board as shown in Figure 1.1 [below,]” and Dalmia continues to enumerate the numerous benefits of such integration of passive components. Dalmia, p. 4.



78. Dalmia recognizes that embedding passive components had been implemented on various substrate types including ceramic, dielectric films deposited on a base substrate of silicon/glass or alumina, and a “current technology of choice” that is a laminate, organic substrate—each substrate type having respective trade-offs in their implementation. Dalmia, pp. 12-16.

79. The laminate, organic substrate type provides for layers of conductors and organic dielectrics laminated together. Dalmia, pp. 12-15, Appendix A. Dalmia discusses the implementation of embedding passive components for radio frequency (RF) applications including suggesting its use for an amplifier. “The work done in this chapter shows the feasibility of using embedded inductors and capacitors such as those fabricated in previous chapters for their use in LNA and

oscillator applications using organic technology.” Dalmia, p. 133. Fig. 6.4⁴ is illustrative of such an LNA where “[t]he input and output of the transistor are matched [] by using L-C ‘pi’ networks, which are entirely embedded in the package[.]” Dalmia, pp. 136-137.

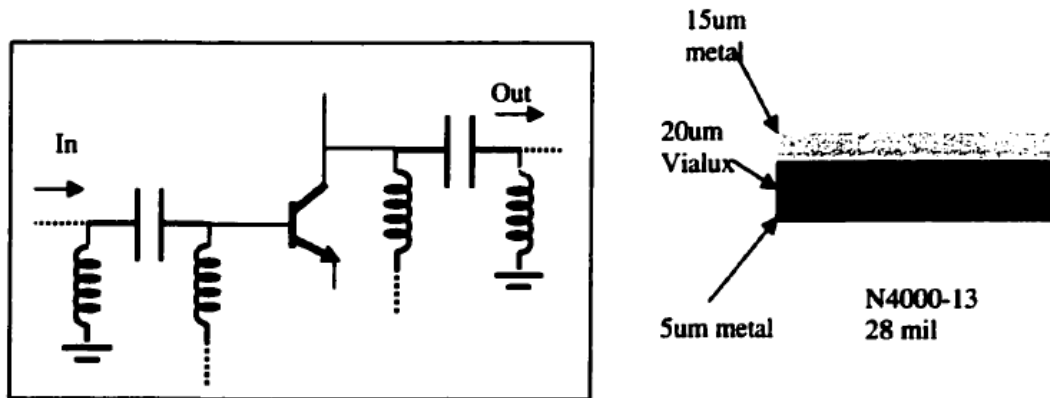


**Fig 6.4. a) Integrated LNA, with impedance transformation networks
b) Cross-section of testbed**

3. Reasons to Combine Yeh and Dalmia

80. A POSITA would have been motivated to combine the teachings of Yeh with Dalmia’s multilayer dielectric substrate having passive components (capacitors and inductors) formed in layers as part of matching and bias circuits coupled at inputs and outputs of its active devices. In particular, a POSITA would

⁴ Vialux™ is an epoxy-glass composite that is an organic substrate. See Dalmia, pp. 12, 15.

have been motivated to combine the teachings of Yeh and Dalmia to produce the obvious, beneficial, and predictable results of utilizing Dalmia's substrate with embedded passive components to form a module implementing Yeh's amplifier circuit. Said differently, a POSITA would have been motivated to implement the novel multi-band amplifier circuits of Yeh using the circuit packaging techniques taught in Dalmia.

81. Yeh and Dalmia are analogous art to the '914 Patent because they are in the same field of endeavor, pertaining to the transmit and receive functionality of RF communication devices such as personal mobile phones. EX1001, 1:29-47; EX1009 (Yeh), 1:5-10; EX1010 (Dalmia), xviii. In particular, each of Yeh, Dalmia and the '914 Patent are directed to configurations of a low noise amplifier for use in a multi-band RF application. EX1001, 2:49; (Yeh), 1:5-10 ("a low-noise amplifier which is capable of operation in multi frequency bands, such as the 900 MHz and 1.8 GHz bands of a personal communication services (PCS) wireless system"); EX1010 (Dalmia), xviii, Chapter VI, 6.1, 6.2 ("Design of Active Modules for multiband applications..."; "Design of a PCS low-noise amplifier"). Further, Yeh and Dalmia are analogous art because each is directed to a same problem faced by the '914 Patent's inventor – decreasing the size of RF devices. EX1010 (Dalmia), p. 3, p. 4 ("Reduction in circuit board area and weight"), EX1009 (Yeh), 1:50-56; EX1001 ('914 Patent), 1:58-62. And a POSITA would

have been motivated to combine the teachings of Yeh and Dalmia for multiple reasons, as discussed below.

82. Yeh suggests forming its passive components are preferably formed with “monolithic integration with the bipolar transistor.” Yeh, 2:30-34; 5:54-57. A POSITA understands that monolithic integration suggests forming the passive components on a semiconductor (silicon) substrate along with the bipolar transistor to form a chip. However, Dalmia cautions against such monolithic integration recognizing “a purely monolithic approach can involve too many performance compromises[.]” Dalmia, p. 1. In particular, losses in the semiconductor (e.g., silicon) substrate and the thin aluminum metallization used in forming the chip limit the performance of inductors and capacitors. Dalmia, pp. 5-6. For example, the Q factor (quality factor) of an inductor is $Q_L = \frac{\omega L}{R}$. EX1012, p. 436. The resistivity of aluminum is higher than copper, thus higher Q inductors can be formed if not constrained to aluminum metallization.

83. Moreover, a “primary disadvantage” of integration on the silicon chip “is that the passive devices such as inductors consume a major part of the expensive silicon area.” Dalmia, p. 5. See also, pp. 131-32 discussing low-noise amplifier implementation with passives embedded in the package providing performance improvements over on-chip integration. EX1012 (Fundamentals of Microsystems Packaging) confirms this: “Integration of passives on the die itself

has been investigated for many years, but in most cases it is not a viable option due to the high real estate costs and limited area on the chip.” EX1012, p. 456.

84. Dalmia teaches an alternative approach to embedding the passives on the silicon chip (referred to as system on a chip) is to embed the inductors and capacitors (passives) in the package substrate or board to achieve a high Q component. This alternative was also recognized by POSITAs. See EX1012, p. 456 discussing “integration options.”

85. Yeh’s amplifier is intended to be used in a wireless communication system such as a mobile phone handset. In particular, as I discuss above, a POSITA would understand that this means one typical manner for Yeh’s circuit to be realized is as a module with a substrate that provides a base on which to configure the circuit components and their interconnections. A POSITA would recognize “[t]he ability to include components into [] modules reduces the number of interconnects which increases reliability and reduces the size and the cost.” EX1025 (NSB technical note), p. 9, USP 2004/0127182, [0005]. And a POSITA would also recognize the other advantages I discuss above. In doing so, providing Yeh’s component(s) as a module based on a substrate was a common, well-known implementation method of such a circuit.

86. Understanding the drawbacks of passive components on a silicon substrate, a POSITA would have been motivated to implement Dalmia’s package

substrate, along its teachings of embedding the passive components within the package substrate. Dalmia details numerous benefits of such a configuration, including those enumerated 1. to 6. on page 4. For example, embedding passive components in a package substrate benefits the design process by reducing system level costs and variables that would otherwise arise from discrete passive components by increasing throughput, reducing inventory, reducing costs, and enhancing ease of design. Dalmia, p. 4. One common way to achieve this reduction was use of system-on-package (SoP) or module configurations typical in the industry prior to the '914 Patent. See, e.g., NIST Technical Note 1520 (2000), p. 8 (“The ability to include components into modules reduces the number of interconnects which increases reliability and reduces the size and cost.”)).

87. As Yeh’s amplifier includes multiple passive components, a POSITA would recognize that providing these components within the substrate of a module, as taught by Dalmia, reduces the need for separate, discrete passive components, which would take up additional area on the system board. A POSITA would readily recognize these benefits from the common configuration of embedding passive components as discussed above in Technology Background.

88. As indicated above, the Q factor (quality factor) of an inductor is $Q_L = \frac{\omega L}{R}$. EX1012, p. 436. Thus, to maximize the quality of an inductor, the resistance must be minimized. By using a material with higher dielectric constant

such as an organic substrate, the wavelength is shortened. This means the trace lengths for inductors can be shorter, thus reducing size. It also means resistance for the trace is lower because of the reduced length, thus increasing the Q factor. To achieve the benefits of the higher dielectric constant substrate, the passive components must be embedded in the substrate so their electric fields are formed in the substrate material. This is merely implementing a known technique of embedding passive components in the substrate to provide to a benefit of efficient use of vertical space. Providing passives embedded within the substrate can also lower manufacturing cost in the sense that the passives can be embedded into a module thereby reducing the number of additional components that must be installed alongside the module. Providing passive components embedded in the substrate also reduces system assembly costs and system level planning. This allows for a reduction in the rest of the bill of materials (RBOM) cost reduction and planning for a device provider. Quality testing may also be performed on a module level. Therefore, there are manufacturing efficiencies that come with the embedding of passives in a module.

89. For example, embedding passive components as taught by Dalmia allows for benefits to the system design process by reducing variables that would otherwise arise from interfaces with discrete components. The system assembly requires meeting tolerances for discrete component placement and would

encounter package and I/O package type variations (i.e., parasitics, resistance) in discrete components. See EX1027 “Embedded Passive Technology Implementation in RF Applications,” John Savic, et al. (2002)). Providing passive components in the module removes these from the system level assembly. A POSITA would also have reason to embed the passive components as suggested by Dalmia in order to reduce circuit board area and weight and increase functionality for a given product size. Dalmia, p. 4.

90. In a substrate, a higher relative permittivity ϵ_r material adjacent to the inductor provides advantages. The wavelength within a substrate of relative permittivity ϵ_r is given by $\lambda = \frac{v}{f} = \frac{c}{f\sqrt{\epsilon_r}}$. Thus, if the permittivity increases by a factor of 4, the wavelength decreases by a factor of 2. This means certain components such as stripline inductors and capacitors can be materially smaller. Permittivity ($\epsilon = \epsilon_r\epsilon_0$) quantifies how well a material can store electrical energy within an electric field. Thus, higher permittivity is directly beneficial in reducing area of passive components such as parallel plate capacitors. The higher permittivity indicates the material, here the substrate of the module, can store more energy in the form of an electric field.

91. A POSITA understands permittivity also determines the speed of

propagation of electromagnetic waves in a medium ($v = \frac{1}{\sqrt{\mu\epsilon}} = c/\sqrt{\mu_r\epsilon_r}$ ⁵). As the permittivity increases, the speed of the wave slows, yet the frequency is the same. Necessarily the wavelength is thus shorter.

92. Thus, providing Yeh's circuit as a module such as in Dalmia allows for embedding of passives in a substrate with many layers, which means an area savings is achieved versus having discrete devices provided on a substrate surface. Further, the electrical performance of the components embedded in the substrate (passives) will correspond to the properties defined by the substrate as discussed above. The increased dielectric constant means capacitors (e.g., stripline or plate) and inductors (e.g., stripline) have smaller area. Further, the electromagnetic fields that go through the substrate are less likely to be altered by foreign material such as dust, humidity changes, etc. Since the dielectric constant of a material is typically a function of frequency, embedding components in a substrate allows for a substrate material to be selected that has desirable dielectric constants at frequencies of interest. Embedding of passives in a substrate means the electrical performance will correspond to the electrical properties of the substrate and the dielectric

⁵ For non-magnetic materials, which is the case generally here, the relative permeability, μ_r , is equal to 1.0 and thus may not be shown in some equations, as a POSITA would understand.

constant of the substrate can be chosen to provide desired functionality.

Embedding also provides for decreased system-level planning (e.g., assembly of surface mount components and allocation of space) that would occur from use of discrete components.

93. A POSITA would have also been motivated to implement Dalmia's teachings with respect to providing such a package substrate as a laminated, organic substrate, which it refers to as MCM-L technology because it was a common option. According to Dalmia, it was "currently the technology of choice." Dalmia, p. 12. Dalmia also recognizes numerous benefits of implementing such as technique such as low cost of materials and "organic/polymer dielectrics offer the benefits of low dielectric constant [], leading to higher signal propagation speeds[.]" Dalmia, p. 13. A POSITA would recognize, like Dalmia, that use of low dielectric polymers as taught by Dalmia is well-suited for high-frequency devices to avoid signal loss as I discuss above.

94. Dalmia teaches the use of low loss tangents which presents signal loss. This low loss tangent is based on the use of LCP. Dalmia, pp. 15, 45. Dalmia also teaches keeping the dielectric constant lower prevents the increase in phase noise. Thus, if, for example, an oscillator is also in a module, using LCP helps maintain signal quality. Dalmia also generally teaches that by keeping the parasitic capacitance low (associated with lower dielectric constant), the parasitic

capacitances can be reduced. Dalmia, p. 9.

95. In particular, Dalmia recognizes benefits of “[a] new breed of polymer laminate dielectrics are emerging to fill the gap between low-cost epoxy dielectrics and high-end, expensive materials like polytetrafluoroethylene (PTFE). These include polyphenyl ether (PPE) based materials, **liquid crystalline polymers (LCP)**, and lower cost polymer and ceramic filled composites.” Dalmia, p. 14. And Dalmia suggests performance benefits in terms of the **quality factor for passives** including for use of Zyvex™, **an LCP material**, that is **greater** than that of other package substrate materials such as ceramic or a thin-film on a base substrate. Dalmia, p. 15.

96. In summary, POSITA would have been motivated to apply Dalmia’s teachings when implementing Yeh’s amplifier (Yeh-Dalmia) because doing so would beneficially (1) minimize the performance compromises by avoiding formation on a silicon substrate, (2) provide benefits with respect to the electrical performance (e.g., Q factor), (3) achieve system-level efficiencies from embedding passive components in a package substrate, and (4) implement a common, cost-effective technology.

97. The results of combining Yeh’s circuit with Dalmia’s substrate would have been predictable and had a reasonable expectation of success given both Yeh and Dalmia relate to substantially similar device types performing the substantially

same function.

98. Each of Yeh and Dalmia is directed to an amplifier circuit with a bipolar transistor and matching circuits (Yeh, FIG. 5, Dalmia, Chapter VI including Fig. 6.4)). Dalmia suggests that it has demonstrated very high-Q “embedded inductors [and capacitors] in epoxy based organic substrates” including those “for RF communication standards such as GSM (900 MHz and 1800 MHz).” Dalmia, pp. 30-31. These passive components and frequency are just like those of Yeh. Moreover, such a configuration for a substrate in RF devices was a common practice. EX1025 (NIST Technical Note 1520), pp. 2-16, EX1029 (US Patent Appl 20030063427), FIG. 1, [0004], inductor 40, capacitor 30, [0041].

99. Yeh’s amplifier is intended for use in wireless communication systems such as a mobile phone handset. POSITA would understand this means one typical manner for Yeh’s circuit to be realized is as a module with a substrate that provides a base on which to configure the circuit components and their interconnections. Module implementation for RF devices was commonplace. EX1026, [0005]; EX1023; EX1012, pp. 438-440 discussing embedded passives and “integrating passive components into a multichip module (MCM) substrate along with other IC chips” and impacts thereof. *See also*, EX1037 (JP315) using organic substrates for passive components, FIG. 3, [0058], [0016] (“Examples of the organic material that configures the substrate used in the present invention

include a glass epoxy resin, BT resin (bismaleimide-triazine resin), polytetrafluoroethylene, and the like.”)

100. It is also noted Dalmia illustrates a test bed at Fig. 6.4b that includes two metal layers. EX1010, p. 137. However, POSITA would understand that the low-noise amplifier (LNA) circuit of Fig. 6.4a could be readily implemented using a substantially similar substrate having any number of metal and dielectric laminate layers in the substrate, including, for example, that of Dalmia’s Fig. 3.14. This is merely applying related substrate teachings of Dalmia to an identified circuit architecture. POSITA would recognize that additional vertically stacked layers provide for further vertical integration and routing paths.

4. Claim 1

[1.0] *A multi-band RF device operable at a first frequency and a second frequency different from the first frequency, comprising:*

101. Yeh discloses this limitation.

102. Yeh “relates generally to **electronic circuits for use in wireless communication systems**, and more particularly to a **low-noise amplifier** which is capable of operation in **multiple frequency bands**, such as the 900 MHz and 1.8 GHz bands of a personal communication services (PCS) wireless system.” EX1009 (Yeh), 1:5-10. See also, Yeh, Abstract (“low-noise amplifier capable of operation in **two or more frequency bands** of a personal communication services (PCS) receiver or other wireless communication system terminal...[operating at]

two distinct frequency bands, such as 900 MHz and 1.8 GHz.”).

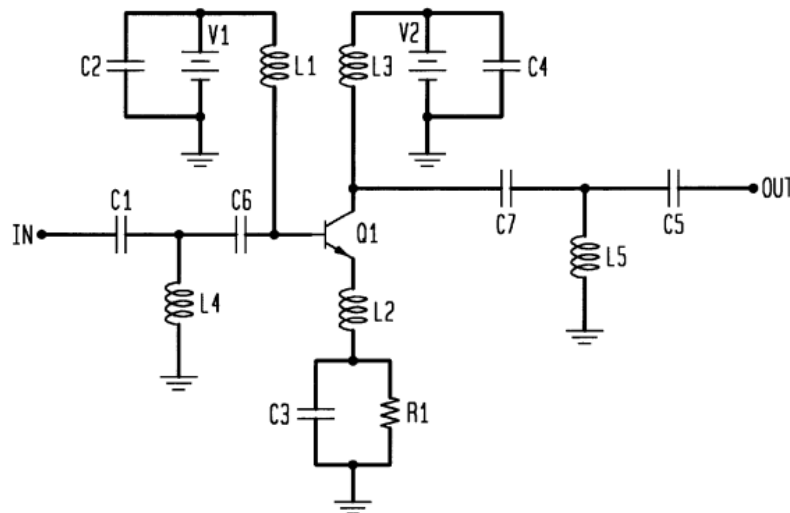
103. Yeh’s low-noise amplifier provides a *multi-band RF device*.⁶ This is because the amplifier receives and provides gain to a signal in two or more distinct operating radio frequency (RF) bands, exemplified by 900 MHz and 1.8 GHz bands. EX1009 (Yeh), 1:24-56, 1:66-2:40, 5:31-46, 9:14-10:15, 10:17-32. In particular, “FIG. 5 shows the low-noise amplifier of FIG. 1 with illustrative input and output matching networks in accordance with the invention. These matching networks each utilize a set of four elements to provide narrowband matches for **both the 900 MHz and 1.8 GHz frequency bands**.” Yeh, 5:32-36.

104. Yeh’s FIG. 1 shows a means for biasing a low noise amplifier. FIG. 2 shows possible gains and associated noise figures for the amplifier of FIG. 1 before the introduction of input and output matching circuits to form a multi-band LNA. FIGS. 3-4 show noise and gain circles for the 900 MHz and 1.8 GHz bands, respectively. For example, in FIG. 3 the small complete dark circle corresponds to a region of lower noise figure while the square at its middle indicates a location of lowest noise figure for the 900 MHz band. Likewise in FIG. 3 the large dark circles indicate regions of higher gain with the highest gain indicates by an upside down

⁶ The amplifier of FIG. 5 is also illustrated in FIG. 1 “without input and output matching networks.” EX1009 (Yeh), 1:60-62.

triangle. These circles allow designers to select an impedance that trades off noise figure and gain. Armed with the information in FIGS. 3-4, a designer can design input and output matching circuits that apply gain to the respective bands, 900 MHz and 1,800 MHz, and minimizes noise figure. As Yeh teaches, the input and output matching circuits are also designed to “suppress the gain outside these frequency bands.” (Yeh), 5:6-31 (“FIG. 2 shows plots of maximum available gain G_{max} and minimum noise figure F_{min} as a function of frequency...at 900 MHz [and] at 1.8 GHz...FIGS. 3 and 4 show noise and gain circles at 900 MHz and 1.8 GHz, respectively, for the transistor Q1 biased in the manner described above.”). See also, Yeh, 6:52–8:2 (“An exemplary optimization of the FIG. 5 low-noise amplifier for operation in the 900 MHz and 1.8 GHz frequency bands will be given below...”). Armed with the noise and gain information of FIGS. 3 and 4, the bias amplifier circuit of FIG. 1 can be modified to form a multi-band LNA as shown in FIG. 5.

105. The amplifier of Yeh’s FIG. 5 is illustrative of a *multi-band RF device*, including an active device and input and output matching networks discussed in the elements that follow.

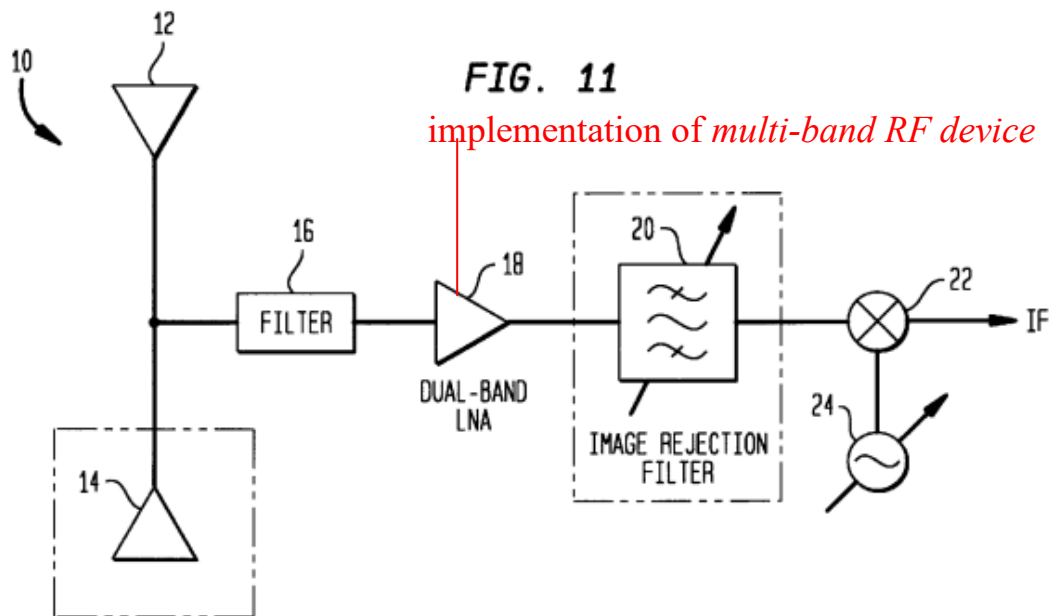
FIG. 5**Yeh, FIG. 5**

106. Frequency bands 900 MHz and 1.8 GHz provide examples of a *first frequency* and a *second frequency* respectively, wherein the second frequency is *different from the first frequency*. However, Yeh's *first frequency* and *second frequency* are not limited to particular bands. EX1009 (Yeh), 3:24-57 discussing different bands and recognizing it "is not limited to use with any particular amplifier type, set of frequency bands or communication system, but is instead more generally applicable to any multi-band wireless application..."

107. Radio frequencies use radio frequency spectrum. The radio frequency spectrum is generally considered to span 3 kHz to 300 GHz which corresponds to wavelengths of about 100 km to 1 mm. See EX1022, *Wiley Electrical and Electronics Dictionary* at radio frequency, RF, and radio spectrum. Yeh's

teachings of the use of 900 MHz and 1.8 GHz are thus within the radio frequency spectrum.

108. FIG. 11 of Yeh is illustrative of an exemplary receiver 10 that receives and downconverts signals at two different bands by providing antennas for each of a *first frequency*, such as 900 MHz, and a *second frequency*, such as 1.8 GHz. Yeh, 9:14-21. The amplifier of FIG. 5, the *multi-band RF device*, is suggested for implementation as amplifier 18 in the receiver 10. Yeh, 9:29-31.



109. This is a largely standard configuration of conventional building blocks as discussed in V.B. For example, to the left of amplifier 18 is a filter 16 that is provided prior to antennas 12, 14, though configured in a multi-band operation.

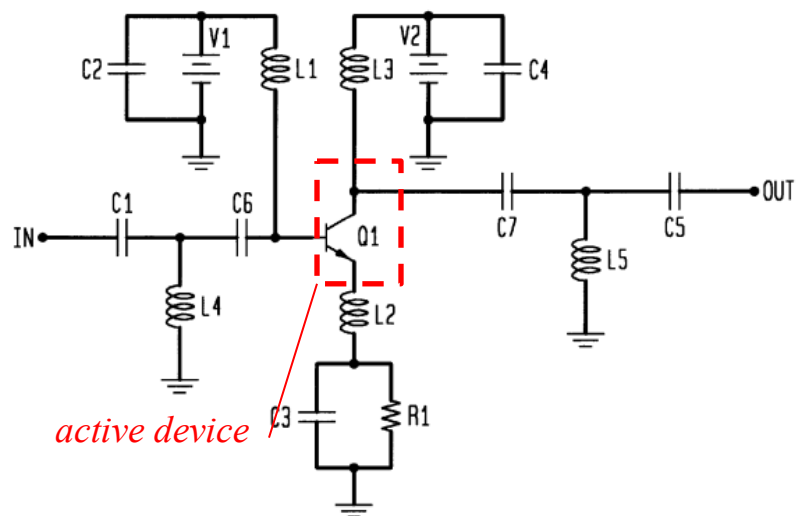
110. Thus, Yeh teaches the *multi-band RF device* of [1.0].

[1.1] *an active device;*

111. The amplifier of Yeh provides a *multi-band RF device* and includes a transistor Q1, which is *an active device*. “The low-noise amplifier includes a single amplification stage comprising in this example an n-p-n bipolar junction **transistor Q1**...other suitable transistors, including...field effect transistors (FETs)...could also be used for transistor Q1[.]” Yeh, 3:64-66. Yeh’s suggested *active device* configurations—bipolar junction transistor (BJT) or FET—are the same as in the ’914 Patent. EX1001 (’914 Patent), 27:1-2, 20-21. FIG. 5 illustrates a BJT as drawn, which a POSITA would readily recognize.

multi-band RF device

FIG. 5



**EX1009, FIG. 5
(annotated)**

112. Namely, the ’914 Patent describes the use of a transistor as the active

device. FIG. 35 of the '914 Patent shows an LNA with a BJT transistor as the “active device” with matching circuits at its input and output.

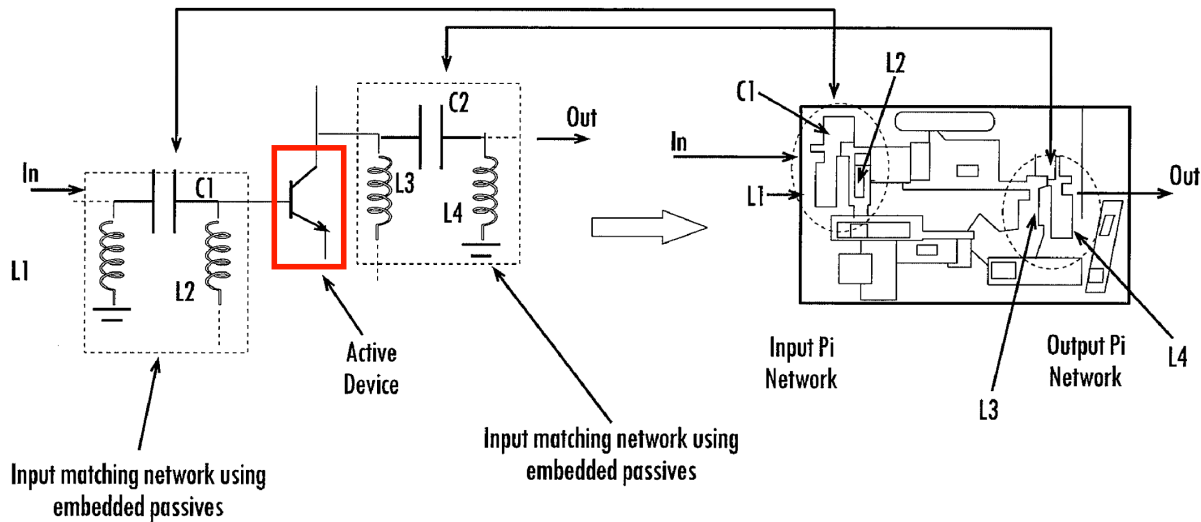


Fig. 35

EX1001 ('914 Patent) at FIG 35.

113. The transistor shown in '914 Patent's Figure 35 is a bipolar junction transistor (BJT), like FIG. 5 of Yeh. A BJT is a commonly used type of transistor. Another commonly used transistor type is the field-effect transistor ("FET"). In each, one terminal is connected to ground and another terminal is connected to the passive network.

114. A POSITA would understand that bias circuits set the operating point of a transistor which is also called the quiescent point or Q-point. This biasing ensures proper functioning in the desired region of operation of the transistor. A small signal may then be injected or coupled into the transistor for purposes such

as signal amplification. This is consistent with the teaching of the Yeh patent that there is a “biasing of a transistor described with respect to FIG. 1 which is then modified to have input and output matching circuits couple small signals into the biased transistor (active device) to perform signal amplification. Said differently, the operating point of the transistor Q1 is set by the biasing circuitry shown explicitly in FIG. 1 and repeated in FIG. 5 of Yeh. In FIG. 1 a small signal is then coupled in via capacitor C1. The small signal is output at FIG. 1 via the capacitor C5. In FIG. 5 input and output matching circuits tuned to multi-frequencies are used to achieve a multi-band LNA. Those input and output matching circuits are frequency-selective but still couple small signals into and out of the active device.

115. Finally, a POSITA would understand the transistor of Yeh is an *active device*. The '914 Patent provides one example of an “active device” of a transistor. This is consistent with a POSITA’s understanding. Further, a POSITA would understand the biasing of transistor Q1 as taught in Yeh causes the transistor Q1 to act as an active device that amplifies small signals provided at its input. The purpose of the transistor in Yeh, like the '914 Patent, is to introduce gain. The purpose of biasing the transistor in Figure 5 of Yeh to a quiescent point is to achieve an operating point in which a small change at the input to the transistor results in a large gain at the output. Thus, a POSITA would understand the transistor taught in Yeh is an active device because it is a transistor that is

introducing gain and amplifying the signal that is input from the matching network formed by passive components C1, C6, L4, and L1 and providing an amplified version of that signal at its output to the matching network formed by passive components L3, C7, L5, and C5.

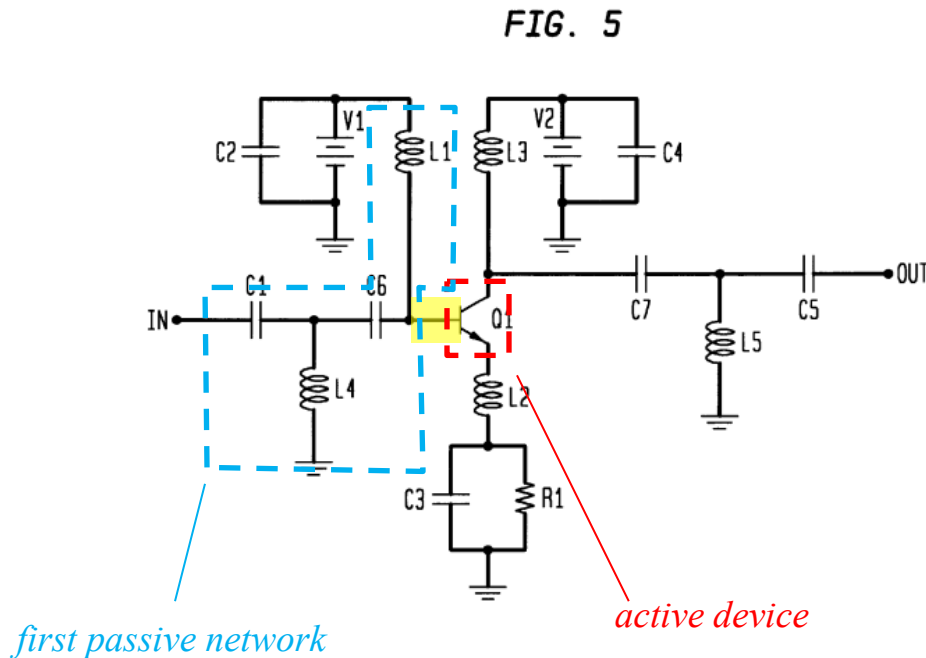
116. Thus, Yeh teaches *an active device* of [1.1].

[1.2] *a first passive network in communication with the active device, the first passive network comprising a first matching network at an input of the active device;*

117. Yeh teaches its *RF multi-band device* as illustrated by the amplifier of FIG. 5 includes *a first passive network* as recited in this element.

118. In particular, passive components of capacitors C1, C6 and inductors L1, L4 and their interconnections provide a *first passive network*. Yeh, 4:14-31, 6:1-47. This is the same general configuration of a passive network, a network comprising inductors and capacitors and providing a matching functionality, as provided in the '914 Patent's exemplary embodiment of an amplifier as an RF device. EX1001, Fig. 35, 24:20-35. Indeed, Yeh provides more specificity of the input and output matching networks than the '914 Patent. The '914 Patent in Fig. 35 shows an input and output matching circuit that as I discuss above shows a single band operation (see, e.g., Fig. 36) and simply asserts "passives can also be used for implementing multi-frequency resonant circuits, thereby making LNAs operational at multiple frequencies." EX1001, 24:16-19. Yeh on the other hand

provides specific teachings of how to design the passive input and output matching circuits to match to two distinct bands.



EX1009, FIG. 5
(annotated)

119. Yeh describes its *first passive network* includes a *first matching network*. “FIG. 5 shows the low-noise amplifier [] with illustrative **input** and output **matching networks** in accordance with the invention. These **matching networks** each utilize a set of **four elements** to provide narrowband matches for both the 900 MHz and 1.8 GHz frequency bands.” Yeh, 5:32-36. “The **input matching network** includes **capacitors C1 and C6, and inductors L1 and L4**...This embodiment utilizes a set of four elements for the matching networks of

both input and output because two frequencies need to be matched.” Yeh, 6:2-8.

Yeh, when describing its matching networks, is, like the '914 Patent (EX1001, 24:11-14), referring to an impedance matching network. EX1021, pp. 225-226.

This claim term – first passive network – does not require constituents other than a *first matching circuit*. Nonetheless, if the claim is construed to include some additional circuit/element is necessary, a POSITA would have recognized that inductor L1 (and thus the *first passive network*) also participates in a larger biasing circuit. EX1009, 6:43-47.

120. The first passive network is in *communication* with transistor Q1, *active device*, and the *first matching network* (passive components C1, C6, L1, L4) of the *first passive network* is at an *input* of the transistor Q1, *active device*. This is illustrated by the schematic of FIG. 5 (see yellow highlight), by Yeh’s description of the passive components as an “**input** matching network.”

121. Yeh describes components of its first passive network/first matching network including capacitor C1 and inductor L1 are connected to and thus are in communication with its active device transistor Q1. Yeh, 4:14-20 (“an **input series capacitor C1 connected between an input terminal IN of the amplifier and the base terminal of transistor Q1 [active device]**. The capacitor C1 serves as a direct current (DC) isolation capacitor, which approximates an open circuit at DC and a short circuit at RF frequencies. **The base of Q1 [active device] is connected**

via an inductor L1 to a voltage supply V1.”); 6:18-25 (“[T]he DC bias for the base of Q1 [active device] is provided through inductor L1 of the input matching network...DC isolation for the amplifier input is provided using capacitor C1 of the input matching network[.]”). Yeh also recognizes that “[t]he input and output matching networks thus each utilize four elements to provide narrowband matches at 900 MHz and 1.8 GHz, with certain elements of the matching networks also serving DC isolation and bias functions.” Yeh, 6:43-47. POSITA would recognize DC isolation and bias are functions are associated with communication with the transistor Q1. Through the superposition principles well known to a POSITA, such elements can serve multiple functions, e.g., being part of a DC isolation and biasing functions as well as acting as part of an impedance matching and resonant networks. These functions are provided by communication with the active device.

122. And a POSITA would understand of Yeh’s passive network’s function in the context of the amplifier is to be in *communication* with the transistor Q1, active device. A POSITA would understand that bias circuits set the operating point of a transistor which is also called the quiescent point or Q-point. This biasing ensures proper functioning in the desired region of operation of the transistor. A small signal may then be injected or coupled into the transistor for purposes such as signal amplification. Providing circuitry to bias a transistor to an

operational or quiescent point based on basic circuits has been taught to undergraduates in electrical engineering since at least the 1990s. For example, based on my firsthand knowledge, courses EE 325 and 326 have been taught to undergraduates in electrical engineering at Texas A&M University since the 1990s and includes teaching of input and output impedance for BJTs as well as high-frequency transistor models with DC and AC analysis of such circuits.

123. Yeh's low-noise amplifier also illustrates a similar configuration of the passives, a network comprising inductors and capacitors and providing a matching functionality, as provided in the '914 Patent's exemplary embodiment of an amplifier as an RF device. See EX1001, Fig. 35, 24:20-35. The passive components L4, C6, L1 of Yeh form an LC circuit as do passive components L1, C1 and L2 of Fig. 35 of the '914 Patent. Yeh's input network also includes C1 which gives four degrees of freedom thus allowing Yeh's input circuit to fully match to two input frequencies, one associated with each of two bands to form the matching network for a multi-band LNA.

124. A POSITA would also understand that devices such as capacitors, inductors, and resistors are passive components. As can be seen above, the amplifier shown in Figure 35 of the '914 Patent shows input and output matching circuits of inductors and capacitors. The '914 Patent does not set forth any definition for passive component. However, the '914 Patent identifies capacitors,

inductors and resistors as “passives.” ’914 Patent, e.g., 18:41-45, FIG. 35, 24:64-67. Passive components including capacitors, inductors and resistors only dissipate (e.g., resistor) or store or transfer (e.g., capacitor via electric field or inductor via magnetic field) energy. This is the same component and function as in Yeh’s capacitors and inductors of Figure 5.

125. Yeh also describes “[c]onventional matching techniques, in contrast, generally either utilize separate sets of two of three elements to provide a match for each frequency band, or attempt to provide a wideband match which covers both frequency bands. These conventional approaches now only fail to provide acceptable gain and noise figure performance in many important applications, but can also increase the size, complexity and cost of the low-noise amplifier.” Yeh, 5:37-44. In contrast, Yeh’s input matching network (first passive network) “can provide a narrowband match for two frequency bands utilizing a single set of elements, thereby improving the amplifier performance while reducing its cost and complexity.” Yeh, 5:44-48. This is the same as the “passive reuse” suggested by the ’914 Patent. EX1001, Title, 2:8-13.

126. More specifically when implementing the matching network its design is determined using well-known techniques in the field. See, Yeh, 5:49-7:20. Yeh describes “[t]he input and output matching networks of the low-noise amplifier of FIG. 5 may be optimized in accordance with a **particular set of design goals** using

optimization tools such as an optimization function available in software packages from EESOF or MMICAD.” Yeh, 6:48-52. Yeh describes “It should again be emphasized that the above values are for a particular illustrative embodiment, and should not be construed as limiting the invention to any particular embodiment or class of embodiments. The values selected in a given application will depend on the particular design goals, the particular configuration of the matching networks, the type of transistor used as well as other factors.” Yeh, 7:48-54.

127. Figure 6 of Yeh illustrates a Smith chart plot of the input and output impedances of the low-noise amplifier of FIG. 5 at two frequencies. The Smith chart illustrates the change in impedance caused by the selected passive element values. Yeh, 7:55-58. Smith chart plot illustrates the input reflection coefficient and shows that it is close to the locations indicated in FIGS. 3-4, i.e., there is demonstration of matching to impedances that minimize the noise figure and increase the gain at specific frequencies. Yeh, 7:55-67. The reflection coefficient Γ is a well-known parameter in the art. The reflection coefficient is a key parameter in RF engineering, as it describes how much of a signal is reflected back at an impedance mismatch, i.e., a point in the circuit where the impedance changes. Thus, Yeh teaches selection of the passive component values to impedance match to preferred impedance to achieve adequate gain and low noised figure for the specific active device (transistor) under the specific biasing conditions. See also,

EX1014, 1:18-61 (“Matching circuits are widely used to transform the impedance of the various components within a circuit to a target impedance....The **impedances of the components** and the matching circuits are **frequency dependent.**”) This is discussed further in [1.4b].

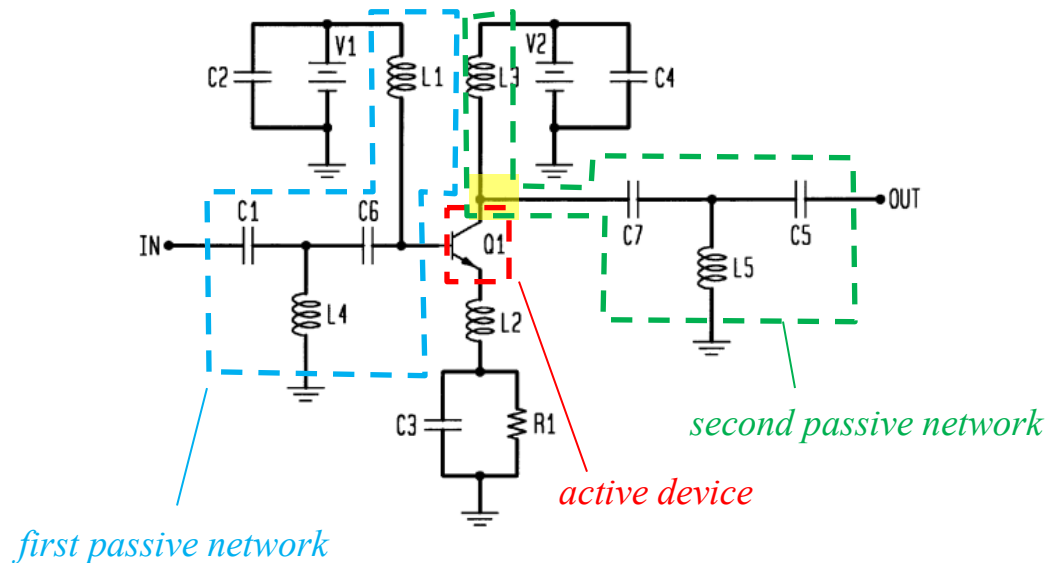
128. Thus, Yeh teaches the *first passive network* of [1.2].

[1.3] *a second passive network in communication with the active device, the second passive network comprising a second matching network at an output of the active device; and*

129. Yeh teaches its *RF multi-band device* as illustrated by the amplifier of FIG. 5 includes a *second passive network* as recited in this element.

130. Passive components such as capacitors C5, C7 and inductors L3, L5 and their interconnections provide a *second passive network*. Yeh, 4:22-48, 6:4-47.

FIG. 5

EX1009, FIG. 5
(annotated)

131. Yeh describes its *second passive network* includes a *second matching network*. “FIG. 5 shows the low-noise amplifier [] with illustrative input and **output matching networks** in accordance with the invention. These matching networks each utilize a **set of four elements** to provide narrowband matches for both the 900 MHz and 1.8 GHz frequency bands.” Yeh, 5:32-36. “The **output matching network** includes **capacitors C5 and C7, and inductors L3 and L5**. This embodiment utilizes a set of four elements for the matching networks of both input and output because two frequencies need to be matched.” Yeh, 6:4-8. Again, a matching network is referring to an impedance matching network. See EX1001, 24:11-14. This claim term does not require constituents other than a *second*

matching circuit. Nonetheless, if the claim is construed to include some additional circuit/element is necessary, a POSITA would have recognized that inductor L3 (and thus the *second passive network*) also participates in a larger biasing circuit. EX1009, 6:43-47.

132. The *second passive network* is in *communication with* transistor Q1, *active device*, and the *second matching network* (passive components C5, C7, L3, L5) of the *second passive network* is *at an output of the* transistor Q1, *active device*. This is illustrated by the schematic of FIG. 5 (see yellow highlight). This is also recognized by Yeh's description of the passive components as an “**output matching network**.”

133. Yeh describes components of its *second passive network* and *second matching network* including capacitor C5 and inductor L3 are connected to and in communication with its active device transistor Q1. Yeh, 4:38-40 (“[a]n output DC blocking capacitor C5 is **connected between the collector of transistor Q1** and an output terminal OUT of the amplifier.”), 6:20-25 (“the **DC bias** for the collector of **Q1** is **provided through inductor L3** of the output matching network...DC isolation for the amplifier output is provided using capacitor C5 of the output matching network.”). Yeh also recognizes that “[t]he input and output matching networks thus each utilize four elements to provide narrowband matches at 900 MHz and 1.8 GHz, with certain elements of the matching networks also serving

DC isolation and bias functions.” Yeh, 6:43-47. A POSITA would recognize that DC isolation and bias are functions associated with communication with the transistor Q1.

134. The collector of the active device, BJT at Q1, is connected to the second passive network. The inductor L3 contributes to both setting the operating point of the transistor and the impedance matching functionality of the second passive network. The amplified small signal appears at the collector of the transistor, which is coupled to the output matching circuit. The purpose of the output matching circuit is to match to the output impedance of the active device, thereby maximizing power transmission from the active device to the second matching network.

135. Said differently, the *second matching network* of Yeh has an input impedance that matches the output impedance of the active device (BJT). The output matching network provides impedance matching in two distinct frequencies. This is discussed in Yeh, see 2:4-8, 2:45-48. The output matching circuit also contributes to maximizing gain and minimizing noise in the respective bands. Yeh, 5:16-21. A POSITA would understand that the output matching filter would provide an impedance match to circuitry connected to the output of the matching circuit to thereby maximize power transfer and gain in the two distinct frequency bands.

136. The passive networks of Yeh's low-noise amplifier are a network comprising inductors and capacitors and providing a matching functionality, which are the same component types as in the '914 Patent's exemplary embodiment of an amplifier as an RF device. EX1001, Fig. 35, 24:20-35. Yeh's disclosure continues to describe the use of four components in each matching network to control match to two distinct frequencies. The embodiment of Figure 35 of the '915 Patent only has three components, which as Yeh suggests is not enough to affect a matching for two distinct frequencies. Yeh also suggests specific values of the four passive components in embodiments, where Figure 35 of the '915 Patent is silent. See also, EX1014, 1:18-61 ("Matching circuits are widely used to transform the impedance of the various components within a circuit to a target impedance....The **impedances of the components** and the matching circuits are **frequency dependent.**") This is further discussed in [1.4b].

137. Thus, Yeh teaches *the second passive network* of [1.3].

[1.4a] *an organic-based substrate having at least two metal layers, wherein the two metal layers are patterned to form at least a portion of the first passive network and the second passive network,*

138. Yeh and Dalmia disclose this element.

139. As discussed in the reasons to combine above, a POSITA would have reason to implement Yeh's low-noise amplifier circuit on Dalmia's substrate having embedded passive components.

140. Dalmia describes implementing an RF device on an *organic-based substrate*, which it refers to as laminated multi-chip module (MCM-L). This module configuration is used to provide the RF device with its passive components embedded in the substrate. See Dalmia, p. xviii, pp. 3-4 discussing embedding passive components, pp. 12-16 discussing MCM-L, pp. 30-31 discussing implementing MCM-L technology in RF devices including amplifiers, which is discussed further in Chapter VI. In particular, Dalmia's MCM-L substrate is an *organic-based substrate* with an organic core laminate and a plurality of organic material laminates (layers) each with copper line patterns formed thereon:

A thick copper-cladded (9um-35um) FR-4 **organic substrate (epoxy-glass fiber composite)** is used as the core laminate. Etching copper, which is **cladded on the laminates** or using electroplating baths, forms the **line patterns. Each copper level is insulated from the other using thin-film epoxy-glass composites** (25um-100um). **The layers of conductors and organic dielectrics are laminated together** using vacuum pressure type laminators and then heat cured.

Dalmia, pp. 12-13. As “[e]ach copper level” is formed in the laminated substrate, the organic substrate provides *at least two metal layers*. See also, p. xviii “multi-layer sequential build-up (SBU) technology.” See also, Figure 3.14 illustrating an exemplary multi-layer substrate with at least two metal layers (e.g., Metal 1B, 1A, 2A, 3A), Figure 3.15 illustrating a test vehicle with a patterned metal layer forming

inductors, Appendix A discussing multiple metal layers.

141. This is the same configuration as the '914 Patent which states “[t]he term ‘substrate’... consists of a multilayer stackup, including Hydrocarbons like Rogers 4350B, single or multiple layers of LCP, single or multiple layers of high-K materials or any combination of the above.” EX1001, 24:49-52. See EX1001, FIGS. 28

142. Dalmia details this substrate formation in its Appendix A. *See* Dalmia, pp. 155-156 describing “**organic** substrate...[t]he first conductor layer is then patterned...and a thin dielectric laminate dry film is laminated using the same method to insulate the conductor layers; the following films were chosen for this work: DuPont’s Vialux™, Asahi PPE™ and Rogers Zyvex™.” Each of these suggested films for the dielectric laminate layers of the organic substrate are themselves organic. For example, Dalmia, Table 1.2 on p. 15, describes Rogers Zyvex™ is liquid crystal polymer (LCP) based, which is a same organic material as suggested and claimed in the '914 Patent. EX1001, 2:18-20, claim 11. And the '914 Patent also describes PPE and DuPont’s Vialux™ as “organic dielectric substrate” material. '914 Patent, 6:25-27, 8:10-13, 10:1, 11:1-2, 15:17-21.

143. A cross-section for an exemplary multi-layer substrate is provided at Figure 3.14, where the shaded areas represent *at least two metal layers* (metal 1A-metal 3A) and each of Vialux and FR-406 are *organic* materials. Dalmia, pp. 12.

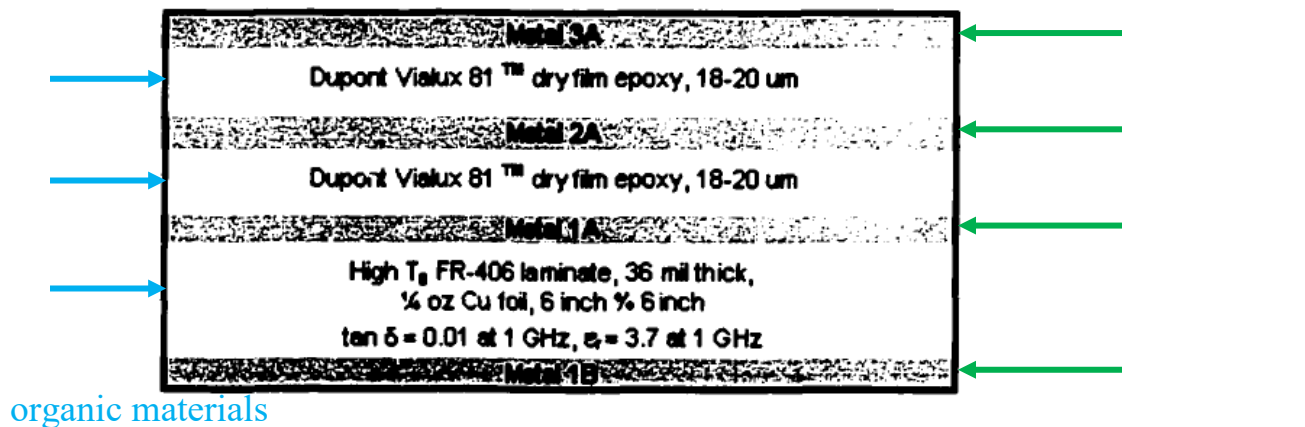


Figure 3.14 Cross-section for Multi-layer Substrate *at least two metal layers*
EX1010, p. 12

144. Dalmia uses the patterned of the copper layers (*the two metal layers*) to provide for “embedded passives such as inductors, capacitors, filters and resonators.” Dalmia, p. xviii. See also, e.g., Dalmia p. 2 discussing system-on-package, pp. 3-5 and Figure 1.1 illustrating embedded passive components.

145. A POSITA would understand that Dalmia’s suggested use of metal layers to form different passive elements such as transmission lines, inductors, capacitors, and resistors was a well-known practice. For example, EX1030 *Microwave Engineering Second Edition* by David M. Pozar was published in 1998 by Wiley (“*Microwave Engineering*”). It explains that passive elements such as resistors, inductors and capacitors can be “realized at microwave frequencies” using metal layers. Inductors can be formed from short length or loop of transmission line. Capacitors can be formed by short transmission line stubs to provide shunt capacitance, or a single gap or interdigital step of gaps can be used

to form capacitors. *Microwave Engineering* at pp. 257-258. Thus, it was well known by a POSITA that passive devices can be formed at microwave frequencies by using structures defined from patterns on metal layers. See also, EX1025, NIST, p. 10, Figure 1. EX1024 illustrates, see, e.g., FIGS. 9, 10, 11, 12 that inductors of passive networks can be formed on multiple metal layers indicated by L* components.

146. A POSITA would *form at least a portion of the first passive network and the second passive network* of Yeh's amplifier embedded in the patterned copper layers of Dalmia's substrate as this is just what Dalmia teaches. Like Yeh, Dalmia describes a low-noise amplifier with passive matching networks at the input and output of a transistor including "high Q **embedded** inductors and capacitors." Dalmia, pp. 136-137. "The input and output of the transistor are matched to 50Ω by using L-C [inductor-capacitor] 'pi' networks, which are **entirely embedded** in the package[.]" Dalmia, p. 136. Passives are formed on multiple (at least two) metal layers of laminate substrates. This makes use of the vertical space of the substrate. EX1010, p. 4.22 at pg. 102, Figure 2.3, p. 36, Figure 3.14 p. 66, p. 156. See EX1026, FIG. 17, [0157], [0161], [0163]; EX1027, S09-3-2; EX1028 discussing modules (e.g., FIG. 8 illustrating multiple metal layers forming passives); FIGS. 1-4; EX1025 (NIST Technical Note 1520), pp. 2-16, EX1029 (US Patent Appl 20030063427), FIG. 1, [0004], inductor 40, capacitor

30, [0041]; EX1037, (JP315) using organic substrates for passive components, FIG. 3, [0037], [0058], [0016], Fig. 3; EX1012, Chapter 11, discussing embedded passives; EX1006, FIG. 5, dielectric layers 11-15, each having a conductor pattern 16-20 used to form passive components; EX1027, Figures 1-2.

147. Further, both of Yeh and Dalmia's matching networks include capacitors, which are typically and in a best practice formed in two metal layers with interposing dielectric and thus, *at least a portion* of the networks are formed on *at least two metal layers*. See, e.g., EX1029, FIG. 4(a), 4(b). EX1010 at Figure 4.22 at pg. 102 illustrates capacitors in a testbed comprising a first metal layer and a second metal layer (ground) with interposing dielectric.

148. Yeh in combination with Dalmia's teachings directed to organic substrate and formation of passive network by metal layers embedded within that substrate teaches [1.4a].

[1.4b] wherein impedances of the first and second passive networks are different at the first frequency than the second frequency.

149. Yeh discloses this element.

150. First, as I discuss above, Yeh's passive networks are circuits comprising inductors (L) and capacitors (C), which are commonly referred to as LC circuits. LC circuits present different impedance to signals having different frequencies. I discuss this in greater detail below.

151. First, Yeh illustrates a multi-band amplifier that has *first and second*

passive network[s]. See [1.0]-[1.3]. And as detailed in element [1.0], Yeh provides a multi-band amplifier structure, *RF multi-band device*, operable at a first and second frequency. EX1009, Abstract (“These four elements [of input/output matching networks] are used to provide...output matches in two distinct frequency bands...The amplifier may be configured to provide a minimum gain of 15dB and a maximum noise figure of 2dB over 100 MHz-wide bands centered at 900 MHz and 1.8 GHz.”); EX1009, 5:49-6:65. Thus, Yeh’s passive networks perform the same function purported to be provided in the ’914 Patent of minimizing noise and maximizing power gain over multiple frequency bands. ’914 Patent, EX1001, 24:10-14 (“These **matching networks** provide impedance transformation for **minimum NF at the input** and **maximum power gain at the output**.”).

152. Understanding that signals at each of a first frequency and differing second frequency (e.g., ~800 MHz and ~1800 MHz) are each provided to the passive networks of Yeh as discussed above, it necessarily follows, under basic laws of physics, that the impedances of the passive networks at each frequency are different. As well understood in the art and explained in detail below, the impedance of a capacitor and the impedance of an inductor are strict functions of frequency. Since the impedances of the components of the networks are a function of frequency, the overall impedances are as well. This means the overall impedances are different at different frequencies.

153. The *first* and *second passive networks* of Yeh each include capacitors and inductors as discussed above and illustrated in Figure 5 and discussed in Yeh, 5:32-7:54. Thus, with each different frequency, there is a different impedance for the *first passive network*. And likewise, with each different frequency, there is different impedance for the *second passive network*. This is because impedance of an inductor varies (i.e., increases) with frequency and impedance of a capacitor varies (i.e., decreases) with frequency. I discuss this in detail below.

154. A POSITA understands passive components and networks of passive components have *impedances*. Impedance is a measurement of the total opposition to the flow of alternating current (AC) and is given by the ratio of the voltage to the current in the circuit. Impedance is expressed as a complex quantity ($Z = R + jX$), which consists of a real part (R), where R is the resistance, and an imaginary part ($+jX$ or $-jX$), where X is the reactance. A positive reactance ($+jX$) corresponds to inductance while a negative reactance ($-jX$) corresponds to capacitance.

155. Impedance is a function of frequency and is typically written as $Z(f)$ or $Z(\omega)$, where f is frequency, ω is the angular frequency of the applied signal. Impedance is a function of frequency because capacitors and inductors contribute to the reactance of the impedance, and their reactance is frequency dependent. Specifically, capacitors have reactance, that is a function of frequency, namely, $X_C = 1/(\omega C) = 1/(2\pi f C)$. See EX1012 p. 432. And inductors have reactance

that is also a function of frequency, namely, $X_L = \omega L = 2\pi fL$. See EX1012 p. 432.

156. Thus, the *first passive network* of Yeh, which includes capacitors and inductors, has a first impedance at a first frequency ($f1$) (see [1.0]), i.e., $Z_A(f1)$. And the *first passive network* of Yeh has a second impedance at a second frequency ($f2$), i.e., $Z_A(f2)$. Similarly, the *second passive network* of Yeh, which includes capacitors and inductors, has a first impedance at a first frequency ($f1$) (see [1.0]), i.e., $Z_B(f1)$. And the *second passive network* of Yeh has a second impedance at a second frequency ($f2$), i.e., $Z_B(f2)$.

157. See also, EX1014, 1:18-61 (“Matching circuits are widely used to transform the impedance of the various components within a circuit to a target impedance....The **impedances of the components** and the matching circuits are **frequency dependent.**”)

158. **Second**, Yeh recognizes that its *first* and *second passive networks* (input and output respectively) each have a different impedance at the *first frequency* than at the *second frequency*. “An embodiment of the FIG. 5 low-noise amplifier optimized for the design goals given above had the following lumped element values in the input and output matching networks:

Element	Value	Z or Y at 900 MHz	Z or Y at 1.8 GHz
C1	9.07 pF	$Z = -j\ 0.39$	$Z = -j\ 0.20$
C6	3.69 pF	$Z = -j\ 0.96$	$Z = -j\ 0.48$
L1	7.60 nH	$Y = -j\ 1.16$	$Y = -j\ 0.58$
L4	4.79 nH	$Y = -j\ 1.84$	$Y = -j\ 0.92$

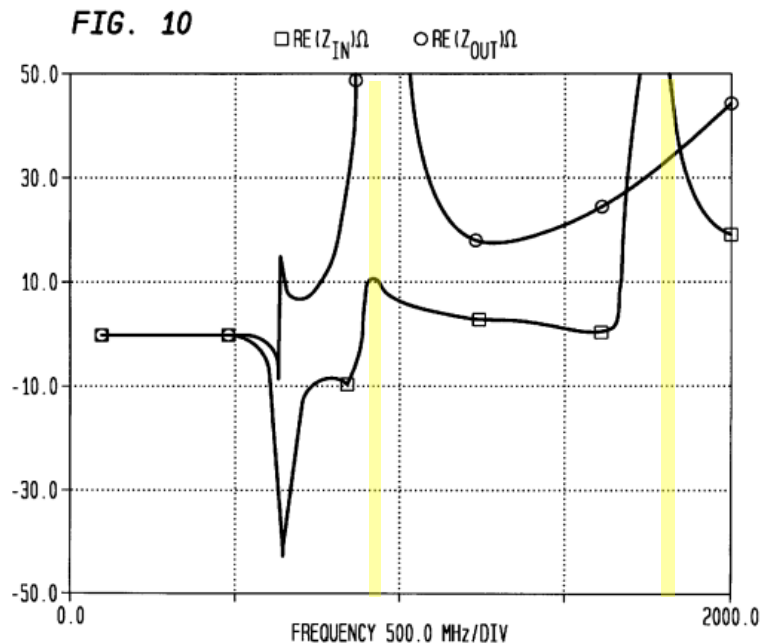
Input Matching Network

Element	Value	Z or Y at 900 MHz	Z or Y at 1.8 GHz
C5	0.80 pF	$Z = -j\ 4.42$	$Z = -j\ 2.21$
C7	1.46 pF	$Z = -j\ 2.53$	$Z = -j\ 1.26$
L3	8.16 nH	$Y = -j\ 1.05$	$Y = -j\ 0.52$
L5	10.0 nH	$Y = -j\ 0.88$	$Y = -j\ 0.44$

Output Matching Network

Yeh, 6:66-7:20. Admittance (Y) determines how easily a circuit or device allows current to flow and is defined as the reciprocal of impedance ($1/Z$). Since the impedances of the input and output matching network components vary with frequency, the overall impedances of these networks are also frequency-dependent. In other words, the frequency-dependent impedances of individual circuit elements result in a frequency-dependent impedance for the entire matching network.

159. **For example**, Yeh illustrates in FIG. 10, which shows “the real parts of the input impedance Z_{IN} and the output impedance Z_{OUT} of the exemplary low-noise amplifier from about 100 MHz to 2.0 GHz,” that the impedance is different at the first and second frequency. Yeh, 8:31-57.



Yeh, FIG. 10 with annotated 900 MHz and 1.8 GHz bands

160. This clearly shows the impedance of each network is different at the two different frequencies – which are highlighted in yellow. First, the input impedance is shown via the curve with the squares. At a frequency of about 900 MHz the real part of the impedance is about 10 Ω. But at a frequency of 1.8 GHz, the value of the real part of the impedance is more than 50 Ω. Thus, the impedance of the input matching network is different at 900 MHz and 1.8 GHz. The real part of the impedance for the output matching network is shown via the curve with the circles. At 900 MHz the impedance is substantially more than 50 Ω. At 1.8 GHz the impedance is moderately less than 50 Ω. Thus, the impedance of the second matching network is also different at 900 MHz and 1.8 GHz.

161. Further, Yeh specifically teaches that the impedances should be

different at different frequencies. Yeh provides Figures 3 and 4 that show the target impedances for the different frequency bands. For example, to minimize noise figure in the 900 MHz band, the impedance needs to be match to the impedance at the square which is about $1.5+j0.6$. However, to minimize noise figure in the 1.8 GHz band, the impedance needs to be matched to the square in Figure 4 which is at $0.8+j0.5$. Thus, Yeh explicitly teaches that matching should be based on the impedance matching at different frequencies and shows the impedance varies with frequency for a device like transistor, Q1, which both the input and output matching circuits are connected to.

162. Therefore, Yeh teaches [1.4b].

163. Thus, Yeh's low-noise amplifier in combination with Dalmia renders obvious claim 1.

5. Claim 2

[2.0] The multi-band RF device of claim 1, wherein the first and second passive networks comprise resonant circuits, and wherein the impedances of the first and second networks comprise reactance.

164. Yeh in combination with the teachings of Dalmia rendered obvious claim 1 and Yeh further teaches this element.

165. A given circuit is generally considered to be resonant if the inductive and capacitive components balance each other resulting in maximum energy transfer or specific behavior such as amplification, oscillation, or selective filtering

at a particular frequency, the resonant frequency. For example, a classical LC circuit will be resonant when the inductance and capacitance sum to near zero.

This condition occurs when $\omega_0 = \frac{1}{\sqrt{LC}}$. In this claim, the *first passive network* comprises a resonant circuit. And the *second passive network* comprises a resonant circuit.

166. As discussed above at [1.2] and [1.3], Yeh provides *first* and *second passive networks*, each separately including inductors and capacitors. Inductors and capacitors are each common components of *resonant circuits*.

167. Resonance is a condition existing when an oscillatory circuit responds with maximum amplitude to a periodic driving force so that a relatively small amplitude of the driving force produces a large amplitude of oscillation. Resonance is achieved when the driving force coincides with the natural undamped frequency of the oscillatory system. A simple resonance network may be comprised of an inductor and capacitor and are thus referred to as LC circuits (or RLC if resistive components are also present). When the capacitor and inductor are placed in series, the resonance occurs when the impedance is at its minimum. This occurs when the reactive components cancel, i.e., $X_L - X_C = 0$. In a circuit comprised of a capacitor and inductor in parallel, another form of LC circuit, resonance occurs when the combined impedance of the circuit is at the maximum. Either way, the frequency of resonance is $\omega_0 = 1/\sqrt{LC}$. This is basic knowledge of a POSITA, as it has been

taught to electrical engineers by at least the sophomore year since the 1990s. See, e.g., *Electrical Circuits Third Edition* by James W. Nilsson published by Addison-Wesley Publishing company in 1990 at Chapter 15 Series and Parallel Resonance. It is fundamentally true that LC, π or T, transmission line matching (e.g., quarter-wave transformer), and stub matching all involved resonance.

168. As a POSITA would recognize, to have gain in the desired respective multiple bands, the reactance of the input matching network must cancel thereby enabling the lowest power dissipation via resistance and oscillatory behavior between inductive and capacitive components in the network. In Yeh's circuit, a POSITA would understand that the input and output matching networks must each, individually, be designed to be resonant in the two pass bands and to avoid resonance in the stop bands.

169. The conjugate of a complex value is the same value with the sign of the imaginary part changed. When added together, the imaginary parts thus cancel which causes resonance. As for the input matching circuit, a POSITA would understand that the matching circuit is also designed to be resonant while also minimizing noise. That the input circuit is designed to be resonant in Yeh is clearly see in Figure 10 as the input impedance becomes large at 900 MHz and 1.8 GHz. which shows local maxima at both 900 MHz and 1.8 MHz. These peaks indicate resonant behavior.

170. Thus, the input matching circuit in Yeh is a *resonant circuit* due to the use of a network of inductors and capacitors. These components are energy storage mechanisms. Their impedances are a function of frequency as previously discussed. An inductor has a positive reactance, and a capacitor has a negative reactance. With two inductors and two capacitors, there will generally be resonances to two frequencies.

171. Yeh also discusses resonance in the context of avoiding oscillations. Yeh suggests that “[i]f the real part of the input or output impedance is negative and is greater in magnitude than the corresponding source or load resistance, a negative resistance results and oscillations may begin.” Yeh, 8:44-47. This discussion is of the overall transfer function of the LNA itself and not of the passive input and output matching networks in isolation. Indeed, a passive network by itself cannot have a negative resistance. Thus, Yeh’s teaching of a certain resonance to be avoided has to do with not resonance of the input and output matching circuits but resonance of the LNA itself that could cause it to act like an oscillator instead of an LNA. Yeh, e.g., 8:33-57. Yeh teaches that the passive networks may be adjusted to avoid this resonance between the input and output of the LNA. Yeh, 8:53-57. A POSITA would not confuse these teachings regarding avoiding oscillations between the output and input of the LNA with resonance built into the input and output passive networks themselves for the purpose of achieving

matching at multiple frequencies.

172. The impedances of Yeh's passive networks *comprise reactance*. As discussed above, reactance is the opposition to the flow of alternating current in a circuit due to the presence of inductance and capacitance. Yeh's passive networks at the input and output of the LNA of Figure 5 include inductors and capacitors and thus *comprise reactance*. Yeh specifically lists the reactance of the components of the passive networks in the tables near the top of column 7. Further, Figure 6 shows how the impedance of the overall networks is changed based on the reactance of the individual components, i.e., capacitors and inductors. A POSITA would understand impedance of a capacitor and an inductor are both purely reactive.

173. Further, the input matching network to the transistor is taught as needing to meet a reflection coefficient requirement. This requirement necessarily requires the ability to have reactance. Figures 3 and 4 of Yeh, e.g., show target impedances to match to, and those impedances have reactive components which means the matching networks must as well.

174. Thus, Yeh in view of Dalmia renders obvious claim 2.

6. Claim 4

[4.0] *The multi-band RF device of claim 1, wherein the active device is a bipolar junction transistor and wherein the multiband device is a low noise amplifier operable for providing power gain at the first frequency and the second frequency.*

175. Yeh in view of Dalmia renders obvious claim 1 and Yeh further teaches this element.

176. Yeh's "low-noise amplifier includes a single amplification stage comprising in this example an n-p-n **bipolar junction transistor** Q1. The transistor Q1 may be an HP Avantek 1400 bipolar junction transistor configured in a chip package.... Other suitable transistors, including, but not limited to, p-n-p **bipolar junction transistors**...could also be used for transistor Q1 in alternative embodiments of the single-stage low-noise amplifier." Yeh, 3:64-4:13. See also, FIG. 5 illustrating a BJT.

177. As discussed in [1.0] above, Yeh's multi-band device is *a low noise amplifier operable for providing power gain at the first frequency and the second frequency*. Yeh's amplifier provides a "narrowband match" in which refers to "a match which provides a desired gain, noise figure or other performance measure over one band of an amplifier operating in two or more bands, while suppressing gain between the bands." Yeh, 3:49-53. Yeh, 6:47-65 illustrating gain at various frequencies, 8:6-8 ("the gain is about 18 dB in the 900 MHz band and about 15 dB in the 1.8 GHz band, while the noise figure is 2 dB or less in both bands."). A POSITA would understand that "gain" performance in the context of a low noise amplifier is *power gain*. Gain is the ratio of output power to input power.

178. Thus, Yeh in view of Dalmia renders obvious claim 4.

7. Claim 11

[11.0] *The multi-band R/F device of claim 1, wherein the organic-based substrate comprises liquid crystalline polymer.*

179. Yeh in view of Dalmia renders obvious claim 1, and Dalmia also teaches its organic-based substrate comprises *liquid crystalline polymer*.

180. As discussed above in [1.4a] and Summary of Dalmia, Dalmia teaches providing the multi-band RF device of Yeh with an organic-based substrate. “[L]iquid crystalline polymers (LCP)” is one of Dalmia’s suggested organic materials. Dalmia, p. 14. Table 1.2 of Dalmia is illustrative:

Table 1.2. Common Low Dielectric Polymers and their Electrical Properties		
Material	ϵ_r (1 GHz)	$\tan\delta$ @ 1 GHz
Dupont Vialux™(epoxy-glass based))	3.3-3.7	0.015-0.025
Asahi A-PPE™ (PPE based)	3.5	0.007
Rogers Zyvex™ (LCP based)	2.95	0.002
Polymer ceramic composites	10.75	0.08-0.1

181. Dalmia continues to describe benefits of Zyvex™, which is a commercially available LCP based material, including benefits of its comparable low loss nature, quality factor for capacitors formed embedded therein, lower-cost, and desirable dielectric constant. *Id.* pp. 14-15. Dalmia in particular suggests LCP

based material for high quality (Q) passive devices for RF systems. Dalmia, p. 16. Thus, a POSITA would implement Dalmia's LCP based material to obtain high quality (Q) passive devices for RF systems.

182. LCP was also a well-known choice for dielectric materials of substrates in general, and RF devices in particular. See, e.g., EX1032 "Characterization of Liquid Crystal Polymer for High Frequency System-in-a-Package Applications" Zou et al., 2002, p. 503 ("LCP was introduced for multilayer PCBs in 1995") and throughout recognizing LCP for high frequency use due to its relative dielectric constant and loss tangent, IV. Conclusion p. 507; EX1023 "RF Characterization of a Low Cost Multichip Packaging Technology for Monolithic Microwave and Millimeter Wave Integrated Circuits," K. Jayaraj, 1995, including "multilayer LCP"; EX1033 "Liquid crystal polymers (LCP) for high performance SOP applications," 2002 Proceedings. 8th International Advanced Packaging Materials Symposium (Cat. No.02TH8617), Stone Mountain, GA, USA, 2002, pp. 249-253.

183. Thus, Yeh and Dalmia render obvious claim 11.

8. Claim 12

[12.0] *The multi-band R/F device of claim 1, wherein the active device is a field effect transistor.*

184. Yeh and Dalmia render obvious claim 1, and Yeh also teaches this element.

185. As discussed above in [1.1], Yeh describes a suitable transistor for implementing its active device of its low noise amplifier is *a field effect transistor* (FET). Yeh, 4:1-13.

186. BJT and FETs are both common for implementation in amplifiers, and both FETs and BJTs are three-port devices. One port controls the resistance seen between the other two ports. No matter what type of transistor is selected, the bias point must be set based on the specific characteristics of the transistor. This does not change when switching from an FET to a BJT. BJTs tend to have higher linearity. Higher linearity results in increase performance (less noise from non-linearity) but does not require any specific adjustment in design when using an BJT instead of a FET. FETs may be commonly manufactured and can include lower cost processes. See also, EX1017 discussing “Bipolar LNAs” and “CMOS LNAs” as known alternatives.

187. Thus, claim 12 is rendered obvious by Yeh and Dalmia.

9. Claim 13

[13] *The multi-band RF device of claim 1, wherein the first passive network comprises a component embedded in the organic-based substrate.*

188. Yeh and Dalmia render obvious claim 1, and the combination also teaches this element.

189. As discussed above in [1.4a], Dalmia describes an *organic-based substrate* and embedding passive components, such as capacitors or inductors,

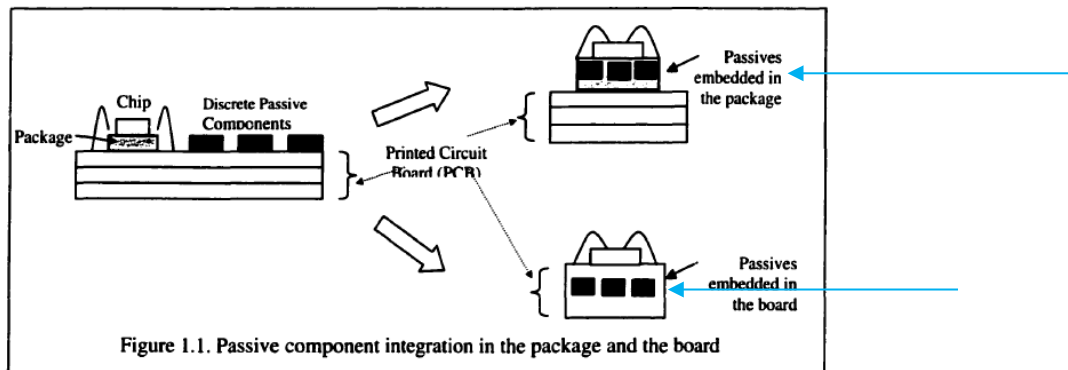
within its *organic-based substrate*. The passive components are *embedded* as they are formed of patterned copper layers disposed within the laminated stack of dielectric, organic layers making up the substrate. *See* [1.4a].

190. This is the same configuration as the '914 Patent. EX1001, 24:49-53 (“The term “substrate in each of the above diagrams consists of a **multilayer stackup**, including hydrocarbons like Rogers 4350B, single or multiple layers of LCP single or multiple layers of high-K materials or any combination of the above.”), 24:64-68 (“FIGS. 38A-38F provide exemplary multi-layer stackups according to an embodiment of the present invention. The embedded passives can be of microstrip, stripline, co-planar waveguide (CPW) topology, or a hybrid thereof.”).

191. Dalmia suggests an input matching network of a low-noise amplifier be “**entirely embedded** in the package[.]” Dalmia, p. 136. Thus, a POSITA would form at least *a component* of Yeh’s *first passive network*, which includes input matching network passive components (see [1.2]), on a patterned metal layer *embedded* in Dalmia’s organic-based substrate for the reasons discussed above. Further, embedding the components leads to numerous benefits such as for ease and cost of assembly and board area (size). Dalmia, p. 4. See also, Figure 6.15, p. 146.

192. Dalmia suggests that its passives are formed on embedded metal

layers within the substrate as illustrated below. These metal layers are patterned to define the passive components (e.g., inductor/capacitor). Dalmia, Appendix A discusses the patterning.



*example embedded metal layers
patterned to form passives*

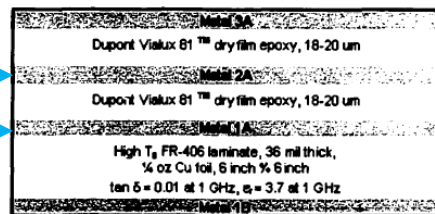


Figure 3.14 Cross-section for Multi-layer Substrate

193. And this embedding is a common technique for forming passives. See, e.g., EX1025 (NIST Technical Note 1520), pp. 2-16, EX1029 (US Patent Appl 20030063427), FIG. 1, [0004], inductor 40, capacitor 30, [0041]; EX1037, (JP315) using organic substrates for passive components, FIG. 3, [0037], [0058], [0016], Fig. 3; EX1012, Chapter 11, discussing embedded passives; EX1006, FIG. 5, dielectric layers 11-15, each having a conductor pattern 16-20 used to form passive components.

194. Thus, claim 13 is rendered obvious by Yeh in view of Dalmia.

10. Claim 14

[14] *The multi-band R[F] device of claim 1, wherein at least one of the metal layers is patterned to form at least a portion of a component included in the first passive network.*

195. Yeh and Dalmia render obvious claim 1, and the combination also teaches this element.

196. As discussed in [1.4a] and [13], Dalmia describes forming a plurality of *patterned* copper layers (*metal layers*) within its laminated substrate *to form* passive components. A POSITA would have had reason and recognized benefit to providing *at least a portion of a component* of Yeh's *first passive network* of [1.2] using Dalmia's patterned metal layers. This is because Dalmia teaches the "entirety" of a matching network on the metal layers patterned. Dalmia, p. 136. Thus, a POSITA would have recognized forming *at least a portion of a component* (e.g., capacitor or inductor) of Yeh's *first passive network* as taught by Dalmia for the reasons discussed above. Dalmia describes depositing the metal on a substrate layer and then etching "line patterns" to form the component. Dalmia, p. 13. See also, Appendix A, p. 155 discussing use of patterning material and selective etching to form the patterned copper.

197. Thus, claim 14 is rendered obvious by Yeh and Dalmia.

11. Claim 15

[15] *The multi-band R[F] device of claim 1, wherein the second passive network comprises a component embedded in the organic-based substrate.*

198. Yeh and Dalmia render obvious claim 1, and the combination also teaches this element.

199. As discussed above in [1.4a] and [13], Dalmia describes an *organic-based substrate* and embedding passive components, such as capacitors or inductors, within its *organic-based substrate*. The passive components are *embedded* as they are formed of patterned copper layers disposed within a laminated stack of dielectric, organic layers making up the substrate. *See* [1.4a]. This is the same configuration as the '914 Patent. (see [13]).

200. Dalmia suggests an output matching network of a low-noise amplifier be “**entirely embedded** in the package[.]” Dalmia, p. 136. Thus, a POSITA form at least *a component* of Dalmia’s *second passive network*, which includes an output matching network (see [1.3]), on a patterned metal layer of an organic-based substrate as taught by Dalmia for the reasons discussed above. See also, Dalmia, p. 4. This is a common technique for forming passives. See, e.g., EX1012, p. 438 which discusses general Passive component nomenclature including “Embedded Passives.”

201. Thus, claim 15 is rendered obvious by Yeh in view of Dalmia.

12. Claim 16

[16] *The multi-band R[F] device of claim 1, wherein at least one of the metal layers is patterned to form at least a portion of a component included in the second passive network.*

202. Yeh and Dalmia render obvious claim 1, and the combination also teaches this element.

203. As discussed in [1.4a] and [14], Dalmia describes forming a plurality of *patterned* copper layers (*metal layers*) within its laminated substrate *to form* passive components and a POSITA would have had reason and recognized benefit to providing *at least a portion of a component* of Yeh's *second passive network* of [1.3] using Dalmia's patterned metal layers. Dalmia teaches the "entirety" of a matching network be embedded in a substrate on patterned metal layers. Dalmia, p. 136. Thus, a POSITA would have recognized forming at least a portion of a component (e.g., capacitor or inductor) of Yeh's second passive network, which similarly includes a matching network, as taught by Dalmia for the reasons discussed above.

204. Thus, claim 16 is rendered obvious by Yeh and Dalmia.

13. Claim 5

[5.0] *A multi-band low noise amplifier for use in an RF application, comprising:*

205. To the extent this element is limiting, Yeh teaches it.

206. Yeh "relates generally to **electronic circuits for use in wireless**

communication systems [RF application], and more particularly to a **low-noise amplifier** which is capable of operation in **multiple frequency bands**, such as the 900 MHz and 1.8 GHz bands of a personal communication services (PCS) wireless system [an RF application].” EX1009 (Yeh), 1:5-10. Thus, Yeh’s low noise amplifier is *a multi-band low noise amplifier* and is discussed in further detail at element [1.0]. See, e.g., Yeh, FIG. 5, 5:32-6:65.

207. Thus, Yeh teaches [5.0].

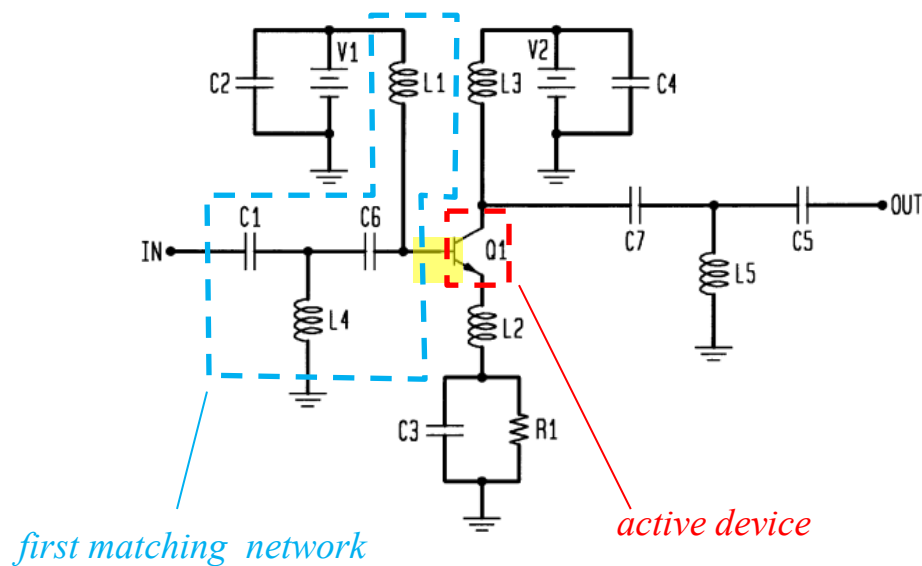
[5.1] *an active device;*

208. Yeh teaches a transistor Q1 of the multi-band amplifier structure of FIG. 5 that provides *an active device* as shown in [1.1] above and thus, teaches this element. See, e.g., Yeh, 3:60-4:13.

[5.2] *a first matching network in communication with the active device, wherein an impedance of the first matching network at a first frequency is different than the impedance of the first matching network at a second frequency;*

209. Yeh teaches its *multi-band low noise amplifier* as illustrated by amplifier structure of FIG. 5 includes *a first matching network* as recited in this element. “FIG. 5 shows the low-noise amplifier [] with illustrative **input** and output **matching networks** in accordance with the invention. These matching networks each utilize a set of four elements to provide narrowband matches for both the 900 MHz and 1.8 GHz frequency bands.” Yeh, 5:32-36. In particular, “[t]he **input matching network** includes capacitors C1 and C6, and inductors L1 and L4...This

embodiment utilizes a set of four elements for the matching networks of both input and output because two frequencies need to be matched.” Yeh, 6:2-8. See also, Yeh, 4:14-31, 6:1-47 and the discussion at [1.2].



EX1009, FIG. 5
(annotated)

210. The *first matching network* (passive components C1, C6, L1, L4) is *in communication* with transistor Q1, *active device*. This is illustrated by the schematic of FIG. 5 (see yellow highlight). It is also illustrated by Yeh’s description of the passive components as an “**input** matching network” and a POSITA’s understanding of the passive network’s function in the context of the amplifier. I discuss this above in [1.2].

211. Yeh describes components of its *first matching network* including capacitor C1 and inductor L1 are connected to and thus are *in communication with* its active device transistor Q1. Yeh, 4:14-20 discussing capacitor C1 connected to the base terminal of transistor Q1, which is connected via inductor L1 to a voltage V1, 6:18-25, 6:43-47. A POSITA would recognize these functions are associated with communication with the transistor Q1. I detail this in [1.2].

212. Yeh also teaches an impedance of *the first matching network at a first frequency is different than the impedance of the first matching network at a second frequency* as shown in [1.4b]. As I discussed above, Yeh's *first matching network* operates on signals at two distinct frequencies. See [5.0], [1.0]. A POSITA recognize an inductor-capacitor (LC) network such as the *first matching network* has a different impedance at different frequencies; and Yeh describes this in its Table at column 7, FIGS. 3-4, 10. Further, as I discuss above a POSITA would have had a desire to ensure that the impedance of the first matching network is different at a first and second frequency to provide a benefit to the noise figure performance. See my discussion above of Yeh's Figures 3-4 at [1.4b].

213. Thus, Yeh teaches this element.

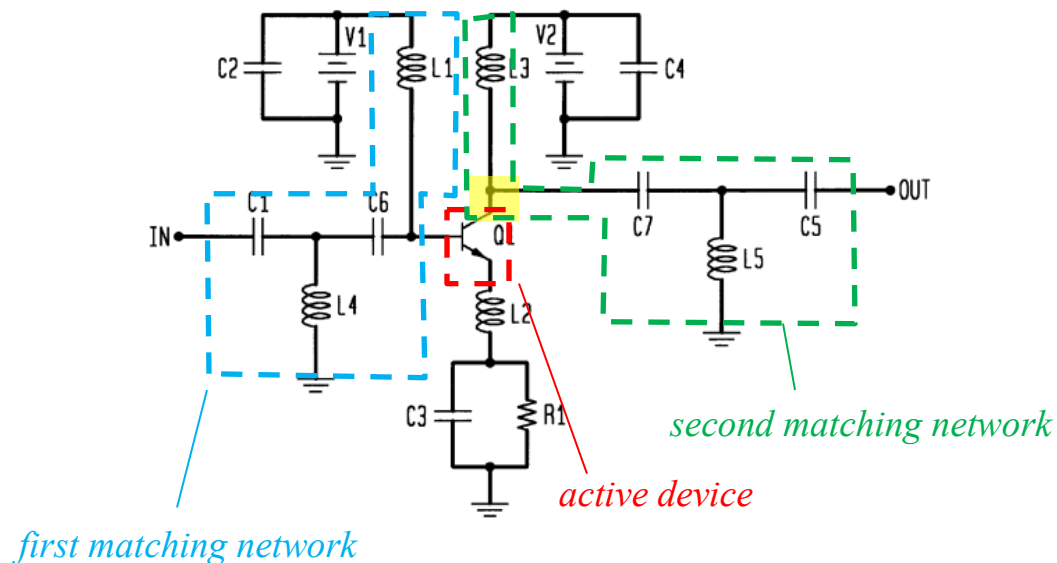
[5.3] *a second matching network in communication with the active device, wherein an impedance of the second matching network at the first frequency is different than the impedance of the second matching network at the second frequency; and*

214. Yeh teaches its low-noise amplifier of FIG. 5 includes a *second*

matching network as recited in this element. “FIG. 5 shows the low-noise amplifier [] with illustrative input and **output matching networks** in accordance with the invention. These matching networks each utilize a set of four elements to provide narrowband matches for both the 900 MHz and 1.8 GHz frequency bands.” Yeh, 5:32-36. In particular, “[t]he **output matching network** includes capacitors C5 and C7, and inductors L3 and L5. This embodiment utilizes a set of four elements for the matching networks of both input and output because two frequencies need to be matched.” Yeh, 6:4-8. See also, Yeh, 4:22-48, 6:4-47, discussion at [1.3].

215. At least in view of Yeh’s teachings, a POSITA would recognize that two elements are needed to match to a specific frequency on the Smith Chart. One element can be used to move along a reactive curve and the other can be used to move along a constant admittance curve thus allowing an impedance at a particular frequency to be change via the matching circuit to a different frequency. Two do this for two frequencies, four elements are needed as Yeh illustrates in FIG. 6. FIG. 5 is illustrative of the two matching networks with four components each and the active device. The second matching network is connected at the output of the transistor Q, is capable of matching two different frequencies using its four elements L3, C7, L5, and C5, and is capable of matching to an impedance of a device connected to the output port (“OUT”) at far right:

FIG. 5

EX1009, FIG. 5
(annotated)

216. The *second matching network* (passive components C5, C7, L3, L5) is in *communication* with transistor Q1, *active device*. This is illustrated by the schematic of FIG. 5 (see yellow highlight). This is also illustrated by Yeh’s description of the passive components as an “output matching network,” and a POSITA’s understanding of the passive network’s function in the context of the amplifier and for performance considerations. I discuss this above in [1.3].

217. Yeh also describes components of its *second matching network* including capacitor C5 and inductor L3 are connected to and thus are *in communication with* its active device transistor Q1. Yeh, 4:38-40, 6:20-25 discussing capacitor C5 connected to collector terminal of transistor Q1, which is

connected to inductor L3 to DC bias, 6:43-47.

218. Yeh also teaches *an impedance of the second matching network at the first frequency is different than the impedance of the second matching network at the second frequency* as shown in [1.4b]. As I discussed above, Yeh's *second matching network* operates on signals of at distinct first and second frequencies. See [5.0], [1.0]. A POSITA recognizes an inductor-capacitor (LC) network such as the *first matching network* has a different impedances at different frequencies; and Yeh describes this in its Table at column 7, FIGS. 3-4, 10.

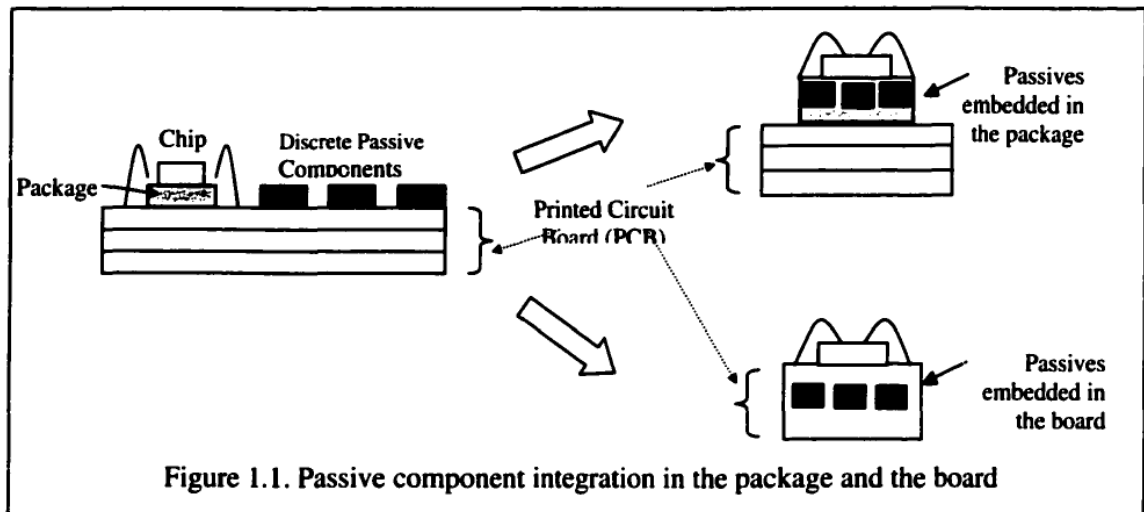
219. Thus, Yeh teaches this element.

[5.4a] a multi-layer organic-based substrate having at least one metal layer, wherein the first matching network and the second matching are formed on the at least one metal layer and wherein the active device is mounted on the multi-layer organic substrate,

220. **First**, as discussed above in [1.4a], [14], [16], Dalmia describes a *multi-layer organic-based substrate having at least one metal layer* illustrated patterned copper layers formed on organic, dielectric layers that are laminated together, where input and output passive network components are formed on the metal layers. As detailed above, it would have been obvious to form Yeh's passive components, including those of the *first matching network* and the *second matching network*, on the patterned copper layers (*at least one metal layer*) that are the patterned copper layers formed embedded in Dalmia's organic-based substrate.

221. **Second**, Dalmia also describes a chip is mounted on the multi-layer

organic substrate. Figure 1.1 of Dalmia is illustrative.



222. Yeh describes that its transistor Q1 is “configured in a chip package.” Yeh, 3:66-4:1. Thus, a POSITA would recognize to place Yeh’s transistor Q1, active device, *mounted on the multi-layer organic substrate* as illustrated in Dalmia.

[5.4b] thereby allowing the an [sic] output of the multi-band low noise amplifier to have desired power gains at the first frequency and the second frequency based at least in part on each of the first and second matching networks having the different reactance at the first frequency and the second frequency.

223. Yeh also teaches *allowing an output of the multi-band low noise amplifier to have desired power gains at the first frequency and the second frequency based at least in part on each of the first and second matching networks having the different reactance at the first frequency and the second frequency.*

224. As discussed above (see [1.4b]), Yeh illustrates a multi-band

amplifier (including an active device and matching networks), which “can provide a narrowband match for two frequency bands utilizing a single set of elements, thereby improving the amplifier performance while reducing its cost and complexity.” EX1009 (Yeh), 5:44-48. “The term ‘narrowband match’ as used herein refers to a match which provides a **desired gain, noise figure** or other performance measure over one band of an amplifier operating in **two or more bands**, while suppressing gain between the bands.” EX1009 (Yeh), 3:49-53. *See also*, EX1009 (Yeh), Abstract, FIGS. 2-4, 6; 5:16-21. This “gain” in each of multiple bands for an LNA is a *power gain*. Gain is the ratio of output power to input power.

225. A POSITA would understand that the amplifier’s function (power gains) is *based at least in part on each of the first and second matching networks having the different reactance at the first frequency and the second frequency*. Understanding that the first frequency and the second frequency band signals are each provided to the first and second passive networks and that the frequency bands are different from one another, it necessarily follows that the *reactance* of the passive networks at each frequency are different. See Claims [1.4b], [2] where I explain this in detail. Further, Yeh’s LNA’s *desired power gain* is *based on different reactance* as the power gain is *based* on the matching networks and their reactance, which is the frequency-dependent opposition to the flow of alternating current in a circuit due to the presence of inductance and capacitance.

226. Thus, claim 5 is rendered obvious by Yeh in view of the teachings of Dalmia of embedding passive components in an organic-based substrate.

14. Claim 6

[6] *The multi-band amplifier of claim 5, wherein the active device is a bipolar junction transistor.*

227. Yeh in view of Dalmia renders obvious claim 5, Yeh also discloses the active device, Q1, is a *bipolar junction transistor*. “The low-noise amplifier includes a single amplification stage comprising in this example an n-p-n **bipolar junction transistor Q1**...” Yeh, 3:64-66. See also, Dalmia, pp. 136-137.

228. Thus, claim 6 is rendered obvious by Yeh and Dalmia.

15. Claim 7

[7] *The multi-band amplifier of claim 5, wherein the multi-layer organic-based substrate comprises at least one of hydrocarbon and liquid crystalline polymer.*

229. Yeh and Dalmia render obvious claim 5, Dalmia also teaches this element.

230. As discussed above in [1.4a] and [11], it would have been obvious to provide multi-band low-noise amplifier of Yeh with an organic-based substrate as taught by Dalmia. Dalmia provides an example material of its substrate of liquid crystalline polymer (LCP).

231. To the extent that this claim requires both at least one a hydrocarbon and at least one LCP, it would have been obvious for the organic

substrate to include a hydrocarbon **and** LCP. Dalmia describes that multiple of its insulating compositions can be used together in a laminate configuration. See, Figure 3.14. LCP and hydrocarbons (e.g., Rogers 4350B named in the '914 Patent at 24:51-52 as a hydrocarbon) were well-known substrate materials. See, EX1025, NIST technical note noting Roger's RO4350 as substrate ("PWB") material, p. 99 and Dalmia, p. 150 describing use of organic materials generally to form laminate "PWB." EX1033, p. 250 ("The lamination press is used to bond LCP as a dielectric layer onto carbon and FR-4 substrates..."), EX1007, [0035] Thus, a POSITA would have recognized a common design choice of a hydrocarbon material such as Rogers 4350B as the organic material suggested by Dalmia. This is merely using a known material for its known function. Further, using multiple material types allows trade-offs between electrical properties, thermal properties, structural properties, and cost, as a POSITA would recognize

232. Thus, claim 7 is obvious in light of Yeh and Dalmia.

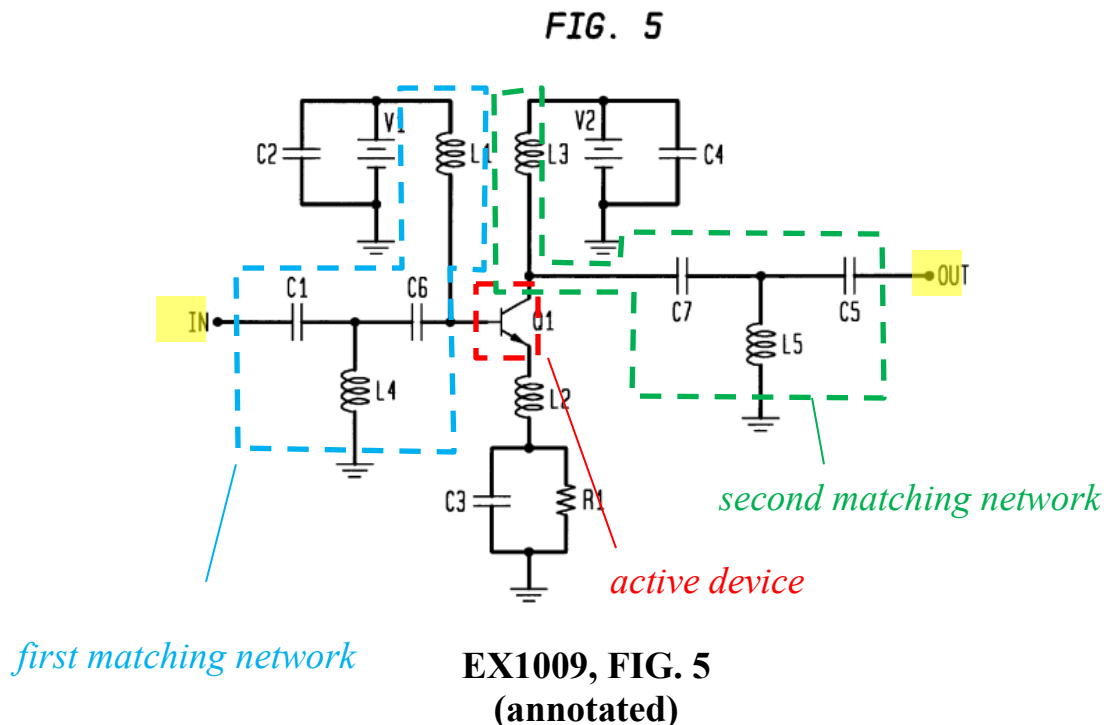
16. Claim 8

[8] *The multi-band amplifier of claim 7, wherein the first matching network is positioned at an input of the multi-band amplifier and the second matching network is positioned at an output of the multi-band amplifier.*

233. Yeh in view of Dalmia renders obvious claim 7, and Yeh also teaches this element.

234. Yeh illustrates an input matching network, the *first matching*

network as in [5.2] above, which is positioned at *an input* of the low-noise amplifier of FIG. 5 illustrated as “IN.” EX1009 (Yeh), FIG. 5, 5:32-6:15. Yeh also illustrates output matching circuit, which provides the *second matching network* as in [5.3] above, positioned at *an output* of the low-noise amplifier of FIG. 5 (“OUT”). EX1005 EX1009 (Yeh), FIG. 5, 5:32-6:15.



235. Thus, claim 8 is rendered obvious by Yeh and Dalmia.

17. Claim 9

[9] *The multi-band amplifier of claim 8, wherein the first matching network minimizes the noise figure for the multi-band amplifier at the input at both the first frequency and the second frequency.*

236. Claim 8 is rendered obvious by Yeh and Dalmia and Yeh also

teaches this element.

237. Yeh describes that its input matching network, the *first matching network* of [5.2], *minimizes the noise figure for amplifier of FIG. 5 at the input at both the first frequency and the second frequency*. First, a POSITA would recognize the goal of the input matching network of a low noise amplifier is to minimize the noise at the operation frequency at the input.

238. Here, Yeh's device has multiple operation frequencies and thus, a POSITA would minimize the noise figure at each. The noise factor is minimized in the context of the design goals, that is considering competing performance factors such as gain. Second, Yeh discloses that its input matching network, *first matching network*, of the amplifier of FIG. 5 operates with narrowband matches for two frequencies, which means the networks provide "a match which provides a **desired gain, noise figure** or other performance measure over one band of an amplifier **operating in two or more bands**, while suppressing gain between the bands." Yeh, 3:49-53, 5:31-47. *See also*, Yeh, 2:1-8, 5:16-21 describing the performance minimizing a noise figure (i.e., defining a maximum noise figure) for both bands for the matching networks; FIG. 2, 5:6-21 discussing "minimum noise figure F_{min} as a function of frequency" for each of 900 MHz and 1.8 GHz; FIGS. 3-4 illustrating noise at two frequencies; 5:47-65 discussing design goals of the matching network including minimizing noise figure. POSITA recognize design factors for an LNA

include considering competing gain and noise figure performance. The '914 Patent recognizes this. EX1001, 24:11-14.

239. Thus, claim 9 is rendered obvious by Yeh and Dalmia.

18. Claim 10

[10] *The multi-band amplifier of claim 9, wherein the second matching network maximizes the desired power gains for the multi-band amplifier at the output at both the first frequency and the second frequency.*

240. Claim 9 is rendered obvious by Yeh and Dalmia and Yeh also teaches this element.

241. Yeh describes that its output matching network, the second matching network of [5.3], *maximizes the desired power gains for its amplifier at the output at both the first frequency and the second frequency.* First, a POSITA would recognize that the performance goal of the output matching network of a low-noise amplifier is to maximize power transfer from its input to its output through impedance matching. Since power gain is defined as the ratio of output power to input power, maximizing power transfer inherently maximizes the power gain. The claim language refers to maximizing “power gains ... *at the output.*” A POSITA would understand to mean maximizing the power gains for the multi-band amplifier at its output by maximizing power transfer in the second matching network at the amplifier’s operating frequencies, i.e. the first frequency and the second frequency.

242. To be sure, maximizing the gain is in the context of other

performance and design factors for the device (e.g., noise). When designing an amplifier and a circuit comprising an amplifier, a POSITA would understand that there is an optimization of performance that includes the competing factors of gain and noise, which are prioritized based on specific application needs. Here, Yeh describes multiple operating frequencies for its amplifier, so a POSITA would have known to maximize power transfer and thus “powers gains ... at the output” for each of the frequencies. Moreover, Yeh discusses matching extensively. A POSITA would know that at the output of the multi-band amplifier where the second matching network is located the primary goal of matching would be maximizing power transfer unlike the input matching network which operates on a signal before any amplification, the output matching network operates on a signal that has already been amplified and thus maximizing the power gain at the output is thus the primary goal and is conveyed in Yeh via repeated teachings of “matching.” Second, the matching networks of Yeh’s amplifier of FIG. 5 operate as narrowband matches for multiple frequencies, which means the networks provide “a match which provides a **desired gain**, noise figure or other performance measure over one band of an amplifier **operating in two or more bands**, while suppressing gain between the bands.” Yeh, 3:49-53, 5:31-47. See also, Yeh, Abstract, 2:1-9, 5:16-21 describing the performance setting a minimum gain (i.e., maximizing desired power gains) for both bands for the matching networks; FIG. 2, 5:6-21 discussing maximum available

gain Gmax” for each of 900 MHz and 1.8 GHz; FIGS. 3-4 illustrating gain at two frequencies; 5:47-65 discussing design goals of the matching network including desired power gains. Again, this “gain” in each of multiple bands for an LNA is a *power gain*. Gain is the ratio of output power to input power.

243. Thus, claim 10 is rendered obvious by Yeh and Dalmia.

19. Claim 17

[17] *The multi-band amplifier of claim 5, wherein the first matching network comprises a component embedded in the organic-based substrate.*

244. Claim 5 is rendered obvious by Yeh and Dalmia and the combination further teaches this element as discussed above with reference to claim 13 including Dalmia’s suggestion of embedding a component of the input matching network, *first matching network*, of the amplifier of Yeh in an organic-based substrate. Dalmia, pp. 136-137 including input match is “entirely embedded in the package.” EX1010, pp. 136-137 describing an input matching network is “entirely embedded in the package.” See also, EX1010, pp. 3-4 discussing embedded passives.

245. Thus, claim 17 is obvious in light of Yeh and Dalmia.

20. Claim 18

[18] *The multi-band amplifier of claim 5, wherein at least one of the metal layers is patterned to form at least a portion of a component included in the first matching network.*

246. Claim 5 is rendered obvious by Yeh and Dalmia and the

combination further teaches this element as discussed above with reference to claim 14, which illustrates the obviousness of using Dalmia technique of *patterned* metal layers *form[ing] at least a portion of a component* of passive network such as a component (e.g., capacitor, inductor) of the input matching network of Yeh, *the first matching network*. EX1010, pp. 136-137 describing an input matching network is “entirely embedded in the package[,]” pp. 13, 155 discussing metal patterns.

247. Thus, claim 18 is obvious in light of Yeh and Dalmia.

21. Claim 19

[19] *The multi-band amplifier of claim 5, wherein the second matching network comprises a component embedded in the organic-based substrate.*

248. Claim 5 is rendered obvious by Yeh and Dalmia and the combination further teaches this element. As discussed above with reference to claim 15, it would have been obvious to use Dalmia’s technique of forming passive components using metal layers of the organic-based substrate (e.g., laminate of organic layers) to form components of the output matching network of Yeh, *second matching network*. In doing so, passive components are *embedded* in the *organic-based substrate*. EX1010, pp. 136-137 describing an output matching network is “entirely embedded in the package.”

249. Thus, claim 19 is obvious in light of Yeh and Dalmia.

22. Claim 20

[20] *The multi-band amplifier of claim 5, wherein at least one of the metal*

layers is patterned to form at least a portion of a component included in the second matching network.

250. Claim 5 is rendered obvious by Yeh and Dalmia and in combination teach this element. As discussed above with reference to claim 16, it would have been obvious to implement Dalmia's metal layers of its organic-based laminate substrate, which provide *patterned metal layers*, to form *at least a portion of a component* of the output matching network of Yeh, *second matching network*. EX1010, pp. 136-137 describing an output matching network is "entirely embedded in the package[,]” pp. 13, 155 discussing metal patterns.

251. Thus, claim 20 is obvious in light of Yeh and Dalmia.

A. Ground 2 – Claims 1-2 and 4-20 obvious over Dalmia and Hashemi

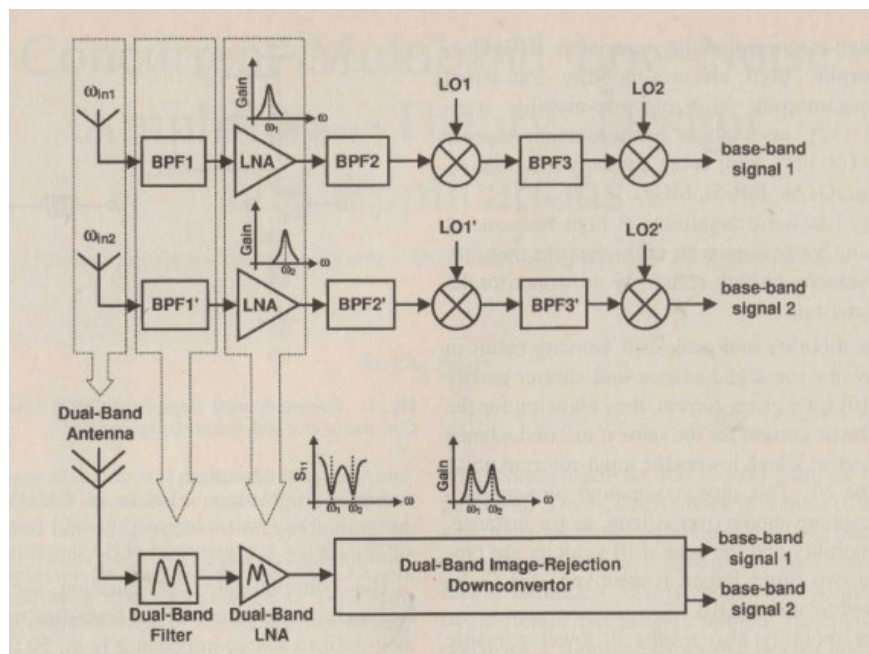
1. Dalmia

252. Dalmia is summarized above.

2. Hashemi

253. Hashemi recognizes that historically standard receiver architectures have a narrow-band operation at a single input frequency forcing operation at different frequency bands to be achieved by building multiple independent signal paths with an inevitable increase in the cost, footprint, and power dissipation. EX1011 (Hashemi), p. 288. In contrast, Hashemi discloses a "concurrent dual-band receiver architecture" capable of simultaneous operation at two-different

frequencies. EX1011 (Hashemi), p. 288. In particular, Hashemi is directed to “multiband [low noise amplifiers] LNAs [that] provide simultaneous narrow-band input matching and gain at multiple frequency bands, while maintaining low noise.” Id. FIG. 2 of Hashemi is an illustrative process of moving from two parallel receiver paths to a dual-band receiver including a dual-band low-noise amplifier (LNA).



Hashemi, FIG. 2, p. 288

3. Reasons to Combine Dalmia and Hashemi

254. A POSITA would have been motivated to combine the teachings of Dalmia with Hashemi’s technique of providing multiband functionality to an LNA architecture for operation at two different frequencies by one LNA device. In particular, a POSITA would have been motivated to combine the teachings of

Dalmia and Hashemi to produce the obvious, beneficial, and predictable results of utilizing Hashemi's suggestion of achieving simultaneous impedance matching for multiple distinct frequencies in the low noise amplifier module substrate having embedded passive components of Dalmia.

255. Dalmia and Hashemi are analogous art to the '914 Patent because they are in the same field of endeavor, pertaining to the transmit and receive functionality of RF communication devices such as personal mobile phones. EX1001, 1:29-47; EX1010 (Dalmia), xviii, Hashemi, p. 288. In particular, each of Hashemi, Dalmia and the '914 Patent are directed to configurations of a low noise amplifier of such an RF device. EX1001, 2:14-16; EX1011 (Hashemi), p. 288; EX1010 (Dalmia), xviii, Chapter VI, 6.1, 6.2. Further, Hashemi and Dalmia are analogous art because each is directed to a same problem faced by the '914 Patent's inventor – decreasing the size of RF devices. EX1010 (Dalmia), p. 3, p. 4 (“Reduction in circuit board area and weight”), EX1011 (Hashemi), p. 288 (discussing footprint); EX1001 ('914 Patent), 1:58-62. And a POSITA would have been motivated to combine the teachings of Dalmia and Hashemi for multiple reasons, as discussed below.

256. **First**, Dalmia recognizes the existence of multi-bands for wireless communications and the desirability to implementing high quality components for such bands including “RF communication standards such as GSM (900 MHz and

1800 MHz), Bluetooth (2.4 GHz) and Hyperlan (5.1-5.8 GHz).” Dalmia, p. 30. See also, Dalmia, e.g., p. 121 discussing PCS (1.9 GHz), Bluetooth/802.11b (2.4 GHz). Dalmia invites modification of its amplifier by suggesting it is to be used in “**multiband applications** with embedded passives in organic substrates.” Dalmia, p. 131, Chapter VI, title.

257. **Second**, Hashemi describes the benefits of using an amplifier for processing signals at multiple bandwidths. This allows for dual-band receiver architecture to reuse components (i.e., LNA) without requiring two separate transceiver paths for each band. Hashemi, pp. 288, 290 Figure 2. Thus, the single concurrent multiple band functionality for the LNA allows for “simultaneous operation at two-different frequencies without dissipating twice as much power[.]” Hashemi, p. 288. Thus, a POSITA would have reason to implement Hashemi’s techniques to gain improvements in power dissipation and component reuse.

258. **Third**, just as discussed with respect to reduction in power dissipation by implementing a concurrent dual-band receiver architecture rather than two separate paths, implementing Hashemi’s concurrent multiband LNA rather than two separate LNAs also saves on “cost and footprint.” Hashemi, p. 288; see also, p. 291. Saving on footprint means that the area taken by the components is reduced. This allows smaller devices such as multiband cellular telephones, which were under market pressures to be smaller and lighter. This was well-recognized in the art before

the '914 Patent. See, e.g., EX1005 (Francisco), 1:25-46, EX1009 (Yeh), 1:29-64, and my discussion above in the Technology Background, Section V.A.

259. In summary, a POSITA would have been motivated to apply Hashemi's teachings when implementing Dalmia's amplifier because doing so would beneficially (1) allow for multiband functionality, (2) reduce the power consumption relative to use of two separate transceiver paths, (3) allow for component reuse, and (4) provide benefits with respect to cost and footprint.

260. The results of combining Dalmia and Hashemi would have been predictable and had a reasonable expectation of success given both Dalmia and Hashemi relate to substantially similar device types — LNAs — performing the substantially same function in an RF communication system. In particular, the LNA's are in the receiver path of the RF device increasing the signal gain while minimizing noise. And dual band LNAs were well-known in the art. See, e.g., EX1005 (Francisco), Abstract, FIG. 3; EX1009 (Yeh), Abstract, FIG. 5; EX1021 (Mou), Abstract. To the extent Hashemi suggests one implementation of its LNA is through the use of CMOS technology, it does not require such implementation and Dalmia details why a POSITA would choose to form passive components as it illustrates — embedded in a package substrate — rather than within a silicon chip (i.e., CMOS technology). I discuss this above in Section V.C. with respect to modules and Section VIII.A.3 with respect to disadvantages of semiconductor substrate (e.g.,

CMOS) use.

261. It is also noted Dalmia illustrates a test bed at Fig. 6.4b that includes two metal layers. EX1010, p. 137. However, a POSITA would understand that the low-noise amplifier (LNA) circuit of Fig. 6.4a could be readily implemented using a substantially similar substrate having any number of metal and dielectric laminate layers in the substrate, including, for example, that of Dalmia's Fig. 3.14. This is merely applying related substrate teachings of Dalmia to an identified circuit architecture. A POSITA would recognize that additional vertically stacked layers provide for further vertical integration and routing paths.

4. Claim 1

[1.0] *A multi-band RF device operable at a first frequency and a second frequency different from the first frequency, comprising:*

262. To the extent the preamble is limiting, Dalmia and Hashemi discloses it.

263. Dalmia teaches an *RF device* of a low-noise amplifier. "In any wireless architecture, the first active device of the RF frontend is the [low-noise amplifier] LNA. This amplifier circuit needs to be extremely sensitive to detect the incoming signal, as well as having a good input impedance matching circuit." Dalmia, p. 133. "The basic LNA architecture consists of an active device with impedance transformation networks at the input and output." Dalmia, p. 134. Dalmia illustrates in Figure 6.4 the design of its *RF device* of an LNA.

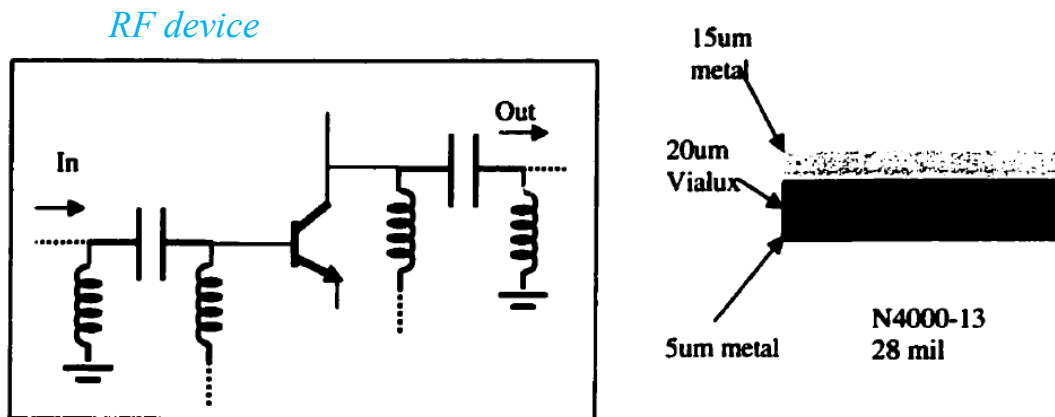


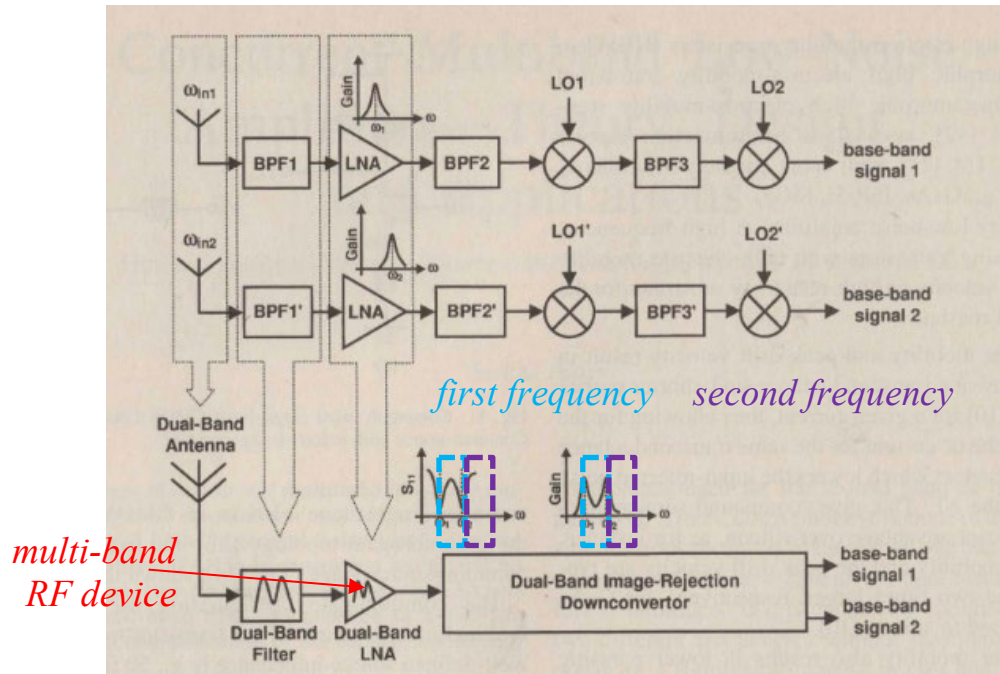
Fig 6.4. a) Integrated LNA, with impedance transformation networks
b) Cross-section of testbed

EX1010, p. 137

264. Dalmia presents this LNA under a heading suggesting dual-band functionality, titling the chapter: “DESIGN OF ACTIVE MODULES FOR **MULTIBAND** APPLICATIONS WITH EMBEDDED PASSIVES IN ORGANIC SUBSTRATES” p. 131. However, Dalmia continues to state that the design of Fig. 6.4 itself is for “PCS (1.9GHz) applications.” Dalmia, p. 133. However, a POSITA would have had reason to provide Dalmia’s LNA with functionality for dual-band operation at *a first frequency* and *a second frequency different from the first frequency* for the reasons discussed above; Hashemi’s teachings are addressed below.

265. Hashemi teaches providing the architecture of an LNA to form “a concurrent **dual-band LNA** that provides simultaneous gain and matching two bands.” Hashemi, p. 290. Fig. 2 of Hashemi is illustrative of the evolution of design

from a single-band LNA such as Dalmia's, to a dual-band LNA, a *multi-band RF device*.



Hashemi, p. 290

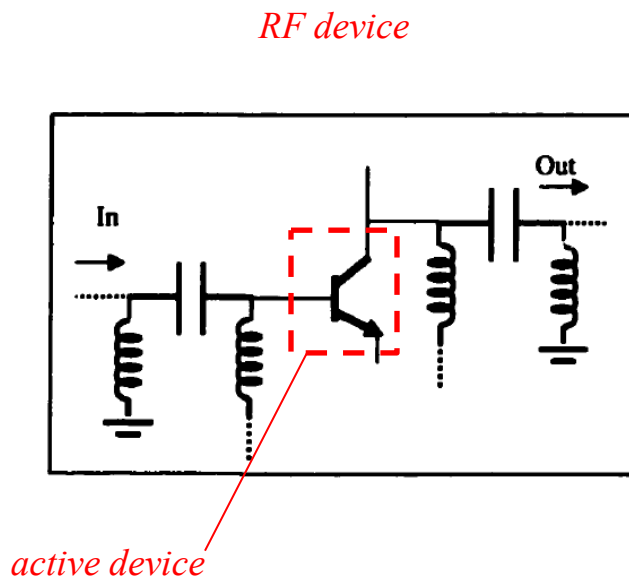
266. Hashemi recognizes an active device of the LNA, the transistor discussed in [1.1] below, inherently “can be used at multiple frequencies simultaneously.” Hashemi, p. 291. However, generally in the single-band LNAs “passive networks are used to shape the response...of the active device in the [single] frequency domain to achieve gain and matching at the [single] frequency of interest.” *Id.* Hashemi recognizes the RF engineering principles that allow for instead implementing these passive networks so there is power gain and “matching at **multiple distinct frequencies.**” p. 292. It is noted that while Hashemi details the

principals (e.g., equations and design parameters) to implement dual band LNAs, it recognizes that “numerous topologies” could achieve such functionality. Hashemi, p. 292. Of note, the ’914 Patent makes mention of a supposed dual-band nature of its LNA in a single sentence in its disclosure. See EX1001, 24:16-18.

267. Thus, Dalmia in view of Hashemi teaches the *multi-band RF device* of [1.0].

[1.1] *an active device*;

268. Dalmia illustrates an LNA includes a transistor that is *an active device*.



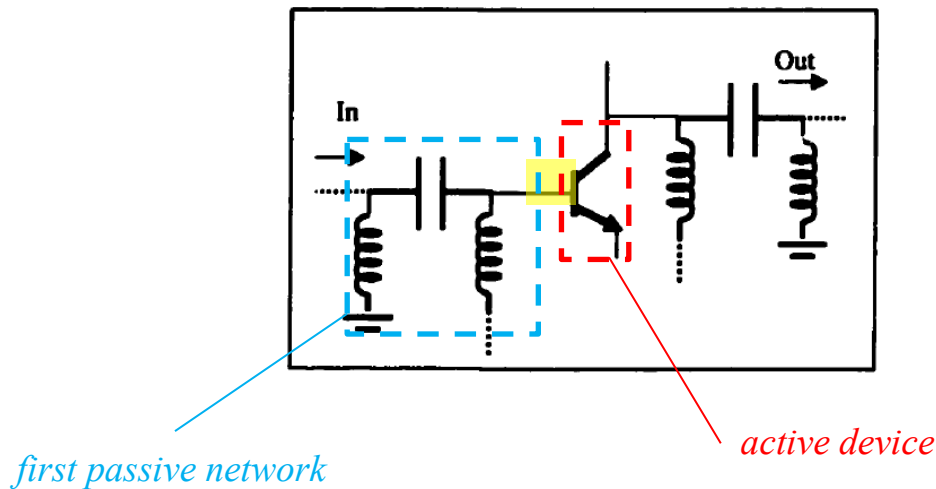
**EX1010, FIG. 6.4 (portion
(annotated))**

269. Dalmia discloses a “discrete HBFP-0420 dual emitter transistor,” which is a bipolar junction transistor (BJT). Dalmia, p. 136. Hashemi also recognizes

the LNA has an active device of a transistor in either BJT or field effect transistor (FET). Hashemi, pp. 289-290. Thus, Dalmia in view of Hashemi provides a multi-band RF device with *an active device* of a transistor.

[1.2] *a first passive network in communication with the active device, the first passive network comprising a first matching network at an input of the active device;*

270. Dalmia in view of Hashemi teaches its *multi-band RF device* includes *a first passive network* as recited in this element. Dalmia illustrates the architecture of the LNA with the *first passive network* of “high Q embedded inductors and capacitors.” Dalmia, p. 136. The *first passive network* includes a *first matching network*. “The input and output of the transistor are **matched** to 50Ω by using L-C **‘pi’ networks**.” Dalmia, p. 136. This is the same matching network as described in the ’914 Patent. FIG. 35 of the ’914 Patent describes the same “Pi” network. Dalmia illustrates the matching network while omitting the bias circuit, which also would comprise passive components in communication with the active device. Dalmia, p. 136. If Patent Owner alleges some additional circuit/element is necessary in a first passive network, POSITA would have recognized passive components in the larger biasing circuit.



EX1010, Figure 6.4 (portion)
(annotated)

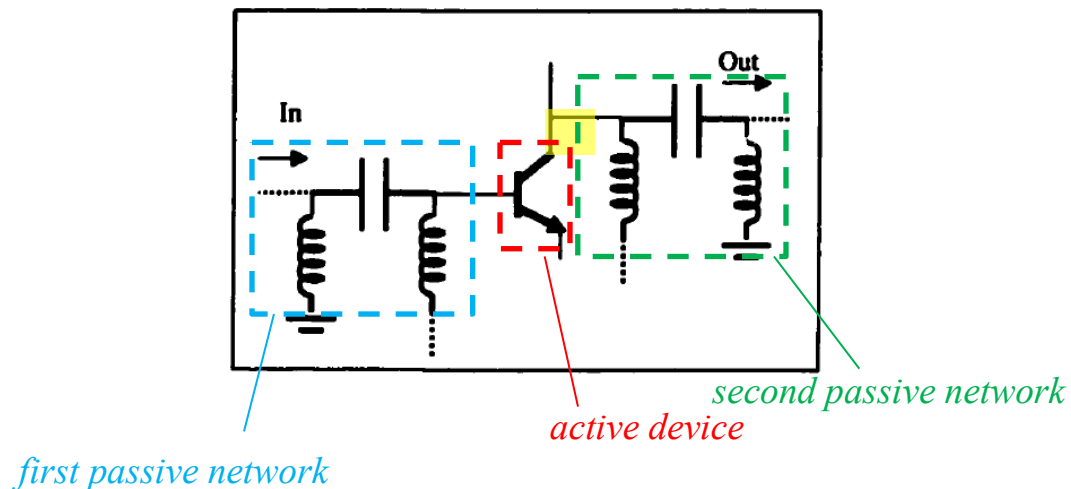
271. The *first passive network* is in *communication with* the transistor (active device), and *the first matching network at an input of the active device*. This is illustrated in Figure 6.4 (including the highlighted connection and the “In” annotation, Dalmia’s description of the matching as being at the “input [] of the transistor” (p. 136), and a POSITA’s understanding of the function of the matching network, which is to create matched impedance between a source and a load. Dalmia recognizes that the function of the matching network in the context of an LNA is to provide a low noise figure. Dalmia, p. 22.

272. Hashemi recognizes single-band LNA’s have “passive networks are used to shape the response...of the active device in the frequency domain to achieve gain and matching at the frequency of interest.” p. 291. Hashemi describes techniques for “design [of] multiband input matching networks.” p. 292. While the

impedance design may change, the first passive network including inductors and capacitor passive components continues to be perform the matching functionality and is in communication with and at the input of the active device. Thus, Dalmia in view of Hashemi teaches this element.

[1.3] *a second passive network in communication with the active device, the second passive network comprising a second matching network at an output of the active device; and*

273. Dalmia in view of Hashemi teaches its *multi-band RF device* includes *a second passive network* as recited in this element. Dalmia illustrates the architecture of the LNA with the *second passive network* of “high Q embedded inductors and capacitors.” Dalmia, p. 136. The *second passive network* includes a *second matching network*. “The input and **output** of the transistor are **matched** to 50Ω by using L-C ‘**pi**’ **networks**.” Dalmia, p. 136. As discussed above, these are the same type of components that form the matching circuit in the ’914 Patent. See EX1001, FIG. 35, pi network. If Patent Owner alleges some additional circuit/element is necessary in a first passive network, POSITA would have recognized passive components in the larger biasing circuit. Dalmia, p. 136.



**EX1010, Figure 6.4 (portion)
(annotated)**

274. The *second passive network* is in *communication with* the transistor (*active device*), and *the second matching network* is at an output of the active device. This is illustrated in Figure 6.4 (including the highlighted connection and the “Out” annotation, Dalmia’s description of the matching as being at the “output of the transistor” (p. 136), and a POSITA’s understanding of the function of the matching network is to create matched impedance between a source and a load, thereby maximizing power transfer.

275. As discussed above, Hashemi designs the output passive network, including the output matching network, to perform impedance matching for multiple frequencies. Hashemi, p. 296. While the impedance design may change, the second

passive network including inductors and capacitor passive components continues to be perform the matching functionality and is in communication with and at the output of the active device. The output matching network of Dalmia's *second passive network*, is merely designed using Hashemi's teachings and RF principals to provide for matching at multiple frequency bands. Thus, Dalmia in view of Hashemi teaches *the second passive network* of [1.3].

[1.4a] *an organic-based substrate having at least two metal layers, wherein the two metal layers are patterned to form at least a portion of the first passive network and the second passive network,*

276. Dalmia discloses this element.

277. As discussed in Ground 1 above, Dalmia teaches this element. I detail this in element [1.4b] above, which applies equally here.

278. Dalmia describes one RF device that is fabricated using its module having an organic-based substrate is a low-noise amplifier with passive matching networks at the input and output of a transistor. Dalmia, pp. 136-137. The LNA is formed by the matching networks, the first passive network and second passive network of [1.2], [1.3] are formed “**entirely embedded** in the package[.]” Dalmia, p. 136. This means that the passive components (e.g., inductors and capacitors) of each of the *first* and *second passive network[s]* are formed by patterns in at least two *metal layers* embedded within the substrate.

[1.4b] *wherein impedances of the first and second passive networks are different at the first frequency than the second frequency.*

279. First, as I discuss above, Hashemi and Dalmia's passive networks, alone and in combination (Dalmia-Hashemi), comprise inductors (L) and capacitors (C), which are commonly referred to as LC circuits. EX1010, pp. 136-137, Fig. 6.4; EX1011, pgs. 290-292, Fig. 1. LC and RLC circuits present different impedances to signals having different frequencies. And as discussed in the elements above, Hashemi illustrates a desire to provide the multi-band amplifier such that Dalmia's *first and second passive networks* are operable at a first frequency and a second frequency. *See* [1.0]-[1.3]. Thus, Dalmia in view of Hashemi's input and output passive networks perform the same function as the '914 Patent of minimizing noise and maximizing power gain over multiple frequency bands. '914 Patent, EX1001, 24:10-14 ("These matching networks provide impedance transformation for minimum NF at the input and maximum power gain at the output.").

280. Dalmia's low-noise amplifier in combination with Hashemi's technique to provide for dual band operation of the amplifier renders obvious claim 1. Understanding that signals at each of a first frequency and differing second frequency are each provided to the passive networks of Dalmia in view of Hashemi's multi-band operation as discussed above, it necessarily follows, under basic laws of physics, that the impedances of the passive networks at each frequency are different.

281. The first and second passive networks of Dalmia in view of Hashemi each include capacitors and inductors. See Dalmia, pp. 136-137, Fig. 6.4; Hashemi, pgs. 290-292, Fig. 1. Thus, with each different frequency, there is a different impedance for the *first passive network*. And likewise, with each different frequency, there is different impedance for the *second passive network*. This is because impedance of an inductor varies (i.e., increases) with frequency and impedance of a capacitor varies (i.e., decreases) with frequency. I discuss this in detail below.

282. A POSITA understands passive components and networks of passive components have *impedances*. Impedance is a measurement of the total opposition to the flow of alternating current (AC) and is given by the ratio of the voltage to the current in the circuit. Impedance is expressed as a complex quantity ($Z = R + jX$), which consists of a real part (R), where R is the resistance, and an imaginary part ($+jX$ or $-jX$), where X is the reactance. A positive reactance ($+jX$) corresponds to inductance while a negative reactance ($-jX$) corresponds to capacitance.

283. Impedance is a function of frequency and is typically written as $Z(f)$ or $Z(\omega)$, where f is frequency, ω is the angular frequency of the applied signal. Impedance is a function of frequency because capacitors and inductors contribute to the reactance of the impedance, and their reactance is frequency dependent. Specifically, capacitors have reactance, which is a function of frequency, namely,

$X_C = 1/(\omega C) = 1/(2\pi fC)$. And inductors have reactance that is also a function of frequency, namely, $X_L = \omega L = 2\pi fL$.

284. Thus, the *first passive network* of Dalmia in view of Hashemi, which includes capacitors and inductors, has a first impedance at a first frequency ($f1$) (see [1.0]), i.e., $Z_A(f1)$. And the *first passive network* of Dalmia in view of Hashemi has a second impedance at a second frequency ($f2$), i.e., $Z_A(f2)$. Similarly, the *second passive network* of Francisco, which includes capacitors and inductors, has a first impedance at a first frequency ($f1$) (see [1.0]), i.e., $Z_B(f1)$. And the *first passive network* of Francisco has a second impedance at a second frequency ($f2$), i.e., $Z_B(f2)$.

285. See also, EX1014, 1:18-61 (“Matching circuits are widely used to transform the impedance of the various components within a circuit to a target impedance....The **impedances of the components** and the matching circuits are **frequency dependent.**”)

286. **Second**, POSITA would have had reason and motivation to select the components of the *first passive network* and the *second passive network* such that the impedances of each of the first passive network and the second passive network are different at different frequencies. Hashemi recognizes passive networks must provide matching with respect to neighboring components within the signal path. Hashemi describes “In any case, the impedance looking into the input of the

LNA should be power matched (i.e., complex conjugate matched)[] to the impedance of the preceding stage for maximum signal power transfer.”

EX1011, p. 291. Note that this is a maximum gain condition, as it transfers the maximum amount of power from the input matching network to the active device, i.e., the transistor.⁷

287. The maximum amount of power is transferred by the complex conjugate match because such a match is defined such that the reactances cancel leaving only a real part of the impedance. This is the minimum impedance; thus, it corresponds to maximum power transfer. The impedances of the matching network must be different at different frequencies because the input impedances to transistors are a function of frequency. See, e.g., EX1031, discussed below. Hashemi teaches to match to these frequencies, which means the impedance of the matching network must necessarily be different to match to different impedances of the transistor at

⁷ This teaching of Hashemi maximizes gain. I note that a POSITA would recognize that there are two different impedances for maximizing gain and minimizing noise figure, and one can select an impedance that balances the maximization of gain and minimization of noise. A POSITA would fully understand this basic tradeoff, and Hashemi explicitly teaches a matching that maximizes power transfer and gain, i.e. a most basic of impedance matchings.

different frequencies. Thus, it is necessary that under Hashemi's matching criteria to be "complex conjugate matched" that the impedances must be different at different frequencies because the transistors themselves are known to a POSITA to have different impedances at different frequencies. See also Yeh at Fig. 3 and 4 also showing what a POSITA would know: input impedance of transistors varies with frequency. I discuss this above at [1.4b] also.

288. Hashemi focuses on designing the first and second matching networks to optimize their impedances differently at the first and second frequencies. In other words, the matching networks are designed to have distinct impedances at different frequencies to achieve specific goals, such as low noise and/or maximum power transfer.

289. For example, in the introductory section, Hashemi teaches that **"new concurrent multiband LNAs provide simultaneous narrow-band input matching and gain at multiple frequency bands while maintaining low noise."** Hashemi emphasizes the significance of the low-noise amplifier (LNA), noting that it is the **"first active element in the receiver chain"** and, therefore, plays a **"significant role in the overall NF [(noise figure)] of the receiver"** while also **"control[ling] its sensitivity and output signal-to-noise ratio (SNR)."** Furthermore, Hashemi explains that in a multi-band LNA, noise sources behave differently at different frequencies, which is crucial for achieving both noise and

power matching at the amplifier's input. This suggests an optimization of the matching circuitry on a per-frequency-band basis. See Hashemi at p. 289.

290. Hashemi also teaches that in a dual-band concurrent architecture, it is **“a very important observation”** that a transistor is inherently wideband and can therefore be **“used to provide gain and matching at other frequencies without any penalty in power dissipation.”** In other words, Hashemi suggests using a single matching network to cover two frequency bands. Indeed, he states explicitly that his approach **“does not need any dual-band switch or diplexer because simultaneous reception at both bands is desired.”** He illustrates this in **Fig. 2**, which shows a circuit designed for **matching at two bands**.

291. Hashemi further teaches that the **input of the LNA** may be fed directly by an antenna or connected via a **bandpass filter, a diplexer/duplexer, or both**. Regardless of the connection method, the impedance seen at the LNA's input should be power-matched to the preceding stage's impedance (**i.e., complex conjugate matched**) to maximize signal power transfer. Hashemi explicitly states that power matching may be used to **“achieve simultaneous impedance matching at multiple distinct frequencies.”** However, he also teaches that matching at different frequencies may be necessary to minimize noise, explaining: **“In an LNA, it is also necessary to achieve noise match at the input for the frequency(ies) of interest to minimize NF.”** Thus, Hashemi discloses impedance

matching across multiple frequency bands using criteria such as **noise minimization and power transfer maximization.**

292. Additionally, Hashemi emphasizes that such impedance matching **“can only be achieved using lossless passive components,”** which a POSITA would recognize as referring to inductors and capacitors. He further explains that **different passive topologies may be used to provide impedance matching at multiple frequency bands.** A POSITA would understand that this extensive discussion of multi-band impedance matching is necessary because the source and load impedances of the first and second passive networks **vary with frequency.** Consequently, the matching networks themselves must also have different impedances at different frequencies, regardless of whether the matching criterion is **maximum power transfer (complex conjugate matching), noise minimization, or a combination of both.**

293. Hashemi provides an example of this approach in **Section V: LNA Design Examples and Measurement Results,** specifically for the **2.45 GHz and 5.25 GHz bands.** He explains that passive components fabricated **on a silicon substrate are typically lossy,** and having them at the amplifier’s input **degrades the NF of the LNA.** This suggests using passive networks **external to the active device (i.e., the transistor), rather than integrating them within the same fabrication process (e.g., CMOS process).** This is visually represented in **Fig. 11,**

where a **“Pad”** shows the matching network connected externally to the active component.

294. Finally, Hashemi teaches that the impedances of the two frequency bands are designed to **resonate at different frequencies**, stating: **“The parallel LC of Z_g is designed to resonate with $Z_g + Z_s$ at both the frequency bands of interest.”** In other words, the first passive network is designed to have **different impedances at different frequencies** to create two resonances in separate frequency bands and thus achieve gain. This is illustrated in **Fig. 12**, which shows gain at both **2.45 GHz and 5.25 GHz**, with a deep null around **3.1 GHz** acting as a stop band. Likewise, the **matching network at the LNA’s output consists of inductors and capacitors, whose impedances vary with frequency**. Following Hashemi’s teaching on **power transfer maximization (complex conjugate matching)**, the second matching network must also have different impedances at different frequencies.

295. Transistor datasheets confirm the device impedances as seen by the first and second matching networks vary with frequency and thus require the passive networks to have different impedances at different frequencies to meet Hashemi’s matching criteria. For example, one exemplary transistor is NE38018, which is a field effect transistor (FET) for use in a low noise amplifier as suggested in Dalmia and Hashemi. See EX1031, pg. 1, Datasheet NE38018. This transistor is targeted

for operational frequencies of approximately 1-3 GHz. See EX1031, at Description on p. 1 (“..make it an ideal low noise medium power amplifier in the 1-3 GHz frequency range.”) and Noise Figure & Associated Gain vs. Frequency, p. 2 including frequencies of 0.9 GHz and 1.9 GHz. The datasheet includes a table comprising $\Gamma_{\text{opt}}(f)$ as shown below. Γ_{opt} has magnitude and angle, thus it is a complex value. The reflection coefficient Γ is a key parameter in RF engineering, as it describes how much of a signal is reflected back at an impedance mismatch, i.e., a point in the circuit where the impedance changes. Γ_{opt} is the optimum reflection coefficient to minimize noise.

296. At a frequency of 0.9 GHz, it can achieve a noise figure of 0.41 dB and gain of 21.1 dB when the input matching circuit achieves a reflection coefficient of $0.65 \angle 25.1^\circ$. That is, this datasheet shows optimal amount of reflection (Γ_{opt}) varies by frequency.

TYPICAL NOISE PARAMETERS (TA = 25°C)

FREQ. (GHz)	NF _{OPT} (dB)	GA (dB)	Γ _{OPT}		Rn/50
			MAG	ANG	
V _{DS} = 2 V, I _{DS} = 5 mA					
0.9	0.41	21.1	0.65	25.1	0.18
1.0	0.42	20.3	0.63	27.2	0.18
1.5	0.48	16.9	0.55	42.4	0.17
1.9	0.54	15.0	0.48	58.0	0.16
2.0	0.55	14.7	0.46	62.1	0.15
2.5	0.62	13.4	0.38	81.3	0.13
V _{DS} = 2 V, I _{DS} = 10 mA					
0.9	0.37	22.0	0.59	29.2	0.13
1.0	0.38	21.8	0.50	38.0	0.12
1.5	0.44	17.6	0.50	39.6	0.12
1.9	0.49	15.6	0.38	45.1	0.11
2.0	0.50	15.5	0.39	54.4	0.11
2.5	0.56	13.9	0.38	70.3	0.10
V _{DS} = 3 V, I _{DS} = 5 mA					
0.9	0.41	21.8	0.67	24.9	0.18
1.0	0.42	20.8	0.65	26.9	0.18
1.5	0.48	16.9	0.54	42.1	0.17
1.9	0.54	14.8	0.47	57.8	0.16
2.0	0.55	14.4	0.45	61.8	0.15
2.5	0.62	13.3	0.38	80.7	0.13

297. A POSITA would know the input matching network needs to transform to a source impedance that achieves a low noise figure performance. This desired source impedance is often conveyed in data sheets via a desired reflection coefficient that is optimal, Γ_{opt} . The normalized reflection coefficient, Γ , is mathematically related to the normalized source impedance by $Z_{\text{normalized}} = \frac{1+\Gamma}{1-\Gamma}$. Thus, when given an optimal Γ that minimizes the noise figure, the normalized source impedance that achieves such noise minimization is easily calculated.

298. As an example, the NEC NE38018 (EX1031) data sheet for listed the optimal reflection coefficient to minimize the noise figure **at 0.9 GHz** as $\Gamma_{\text{opt}} = 0.65 \angle 25.1^\circ = 0.5886 + j0.2757$. Solving for the optimal normalized source

impedance results in $Z_{\text{normalized}} = \frac{1+\Gamma}{1-\Gamma} = \frac{1+(0.5886+j0.2757)}{1-(0.5886+j0.2757)} = 2.355 + j2.248$. This

is the normalized impedance that is required of the input matching network at 0.9 GHz to minimize the noise figure.

299. At the second frequency of about **1.9 GHz**, for the same transistor (EX1031), the datasheet indicates the optimal reflection coefficient is $\Gamma_{\text{opt}} = 0.48 \angle 58.0 = 0.2544 + j0.4071$. Solving for the normalized impedance of the first matching network at this second frequency yields $Z_{\text{normalized}} = \frac{1+\Gamma}{1-\Gamma} = \frac{1+(0.2544+j0.4071)}{1-(0.2544+j0.4071)} = 1.066 - j1.128$. Thus, the impedance of the first passive network including the input matching network at the *first frequency* is different than the impedance of the first passive network including the input matching network at a *second frequency*.

300. It is worth noting that at the first frequency, the matching filter is inductive (has positive reactance) and at the second frequency is capacitive (has a negative reactance). This indicates that the realization of the matching filter will utilize both inductors and capacitors. Even if the signs were the same, the matching network would still be created with inductors and capacitors, i.e., lossless elements.

301. That the impedances at the two frequencies are different is not happenstance, as a POSITA would recognize. The optimal reflection coefficient is complex and varies with frequency. Because the reflection coefficient determines the impedance of the matching filter, the matching filter impedance is generally complex as well. Since the optimal reflection coefficient varies with frequency, the

impedance at the two different frequencies will also be different, as shown above.

302. A POSITA would recognize there are many ways to design a network with each required impedance. To provide explanation of the basic approach, I used an L network as an example. See EX1034 *Microwave Transistor Amplifiers Analysis and Design Second Edition* by Guillermo Gonzalez published by Wiley in 1997 (*Microwave Amplifier Design*) at pp. 112-124. In the 0.9 GHz band, the matching network needs a normalized impedance of $2.355+j2.248$. As shown on at Figure 2.4.7 on p. 119 shunt and series capacitors and inductors can be used to move around circles of constant conductance or resistance to achieve. This allows the characteristic impedance to be transformed to a different impedance at a particular frequency by the combination of a capacitor and an inductor. Figure 2.4.2 shows various L networks. To transform from the characteristic impedance to $2.355+j2.248$, a series inductor would be used (clockwise on constant resistance curve) and then a shunt capacitor would be used to move along a constant conductance curve. Compare EX1034 with Figure 2.4.8 of *Microwave Amplifier Design* showing how to follow such curves to change from the characteristic impedance. In the case of Dalmia-Hashemi, with Hashemi's dual band LNA teachings, implementing such a matching network one would consider not only 0.9 GHz but other frequencies such as 1.9 GHz. Since the first matching network must match to two different reflection coefficients for the first and second frequencies as

discussed above, respectively, the impedance of the matching network must be different at the different frequencies.

303. Further, with respect to the *second passive network* including the output matching network, again the output impedance of the transistor is not constant with frequency, as POSITA also would understand. A POSITA would know that the output impedance of the transistor is related to the S22 parameter. See, EX1031 at pg. 4 which lists the S22 parameter and its variation with frequency.

V_{DS} = 2 V, I_{DS} = 5 mA

FREQUENCY (GHz)	S ₁₁		S ₂₁		S ₁₂		S ₂₂		K	MAG ¹ (dB)
	MAG	ANG	MAG	ANG	MAG	ANG	MAG	ANG		
0.10	0.992	-2.50	6.847	175.44	0.009	86.79	0.642	-7.96	0.05	28.63
0.20	1.027	-10.20	6.717	171.01	0.017	84.51	0.626	-11.36	-0.16	25.95
0.30	0.999	-17.98	6.698	165.35	0.025	79.74	0.632	-13.98	0.00	24.23
0.40	0.981	-24.47	6.640	160.28	0.033	76.53	0.632	-17.71	0.06	22.99
0.50	0.964	-29.81	6.518	154.91	0.041	72.59	0.623	-21.83	0.12	22.03
1.00	0.876	-56.41	5.830	131.52	0.073	56.83	0.561	-40.01	0.28	19.04
1.50	0.773	-79.57	5.119	111.75	0.096	44.71	0.493	-54.94	0.42	17.28
2.00	0.686	-100.40	4.506	94.58	0.114	35.02	0.430	-67.65	0.54	16.01
2.50	0.604	-120.28	4.005	78.97	0.127	26.80	0.370	-79.24	0.67	15.02
3.00	0.542	-140.30	3.590	64.57	0.138	19.51	0.314	-90.98	0.77	14.18
3.50	0.496	-160.84	3.239	50.93	0.147	12.72	0.263	-103.80	0.87	13.45
4.00	0.472	178.65	2.941	38.00	0.155	6.47	0.219	-118.63	0.94	12.80
5.00	0.476	141.84	2.464	13.65	0.169	-5.34	0.167	-156.15	1.04	10.46
6.00	0.506	112.81	2.109	-8.88	0.183	-16.40	0.154	164.89	1.09	8.79
7.00	0.548	87.17	1.833	-30.86	0.199	-28.79	0.161	124.93	1.11	7.60
8.00	0.603	62.70	1.600	-52.62	0.212	-42.18	0.207	82.05	1.13	6.59
9.00	0.677	40.36	1.382	-74.07	0.223	-56.42	0.307	53.73	1.10	6.03
10.00	0.750	21.52	1.184	-94.38	0.229	-71.03	0.422	35.57	1.03	6.04
11.00	0.800	5.69	1.011	-113.63	0.231	-85.60	0.511	19.76	0.98	6.43
12.00	0.829	-9.17	0.873	-132.22	0.232	-100.40	0.571	2.76	0.95	5.78

Note:

1. Gain Calculations:

$$MAG = \frac{|S_{21}|}{|S_{12}|} \left(K \pm \sqrt{K^2 - 1} \right). \text{ When } K \leq 1, \text{ MAG is undefined and MSG values are used. } MSG = \frac{|S_{21}|}{|S_{12}|}, K = \frac{1 + |\Delta|^2 - |S_{11}|^2 - |S_{22}|^2}{2 |S_{12}| |S_{21}|}, \Delta = S_{11} S_{22} - S_{21} S_{12}$$

MAG = Maximum Available Gain

MSG = Maximum Stable Gain

See also, EX1031, NEC NE38018 transistor data sheet at p. 4 where the S22 parameter is shown on a Smith Chart (left) to be a function of frequency.

304. The S22 parameter indicates the ratio of the reflected signal at the

output port of the transistor. Reflectivity is caused by discontinuity in the impedance. As previously discussed, reflection coefficients are directly related to impedance changes. Thus, if the S22 parameter changes with frequency, the output impedance of the transistor (active device) changes with frequency. As the output impedance of the active device changes with frequency, the *second passive network* including the output matching circuit must have a different impedance at different frequencies. This is because the output matching circuit must modify its impedance with frequency to properly match to the components in the path. This means the *second passive network* (including output matching network) must also have a different impedance at the *first frequency* and *second frequency*. Said simply, a POSITA would recognize there is an ideal source impedance at the input to the transistor to minimize the noise. That source impedance is a function of frequency, and it is found in the data sheets for transistors used for low-noise amplifiers. The data sheet may present optimal source impedance, Z_{opt} , or equivalently provide the optimal reflection coefficient, Γ_{opt} . A POSITA would understand this because a POSITA would know the relationship between Z and Γ .

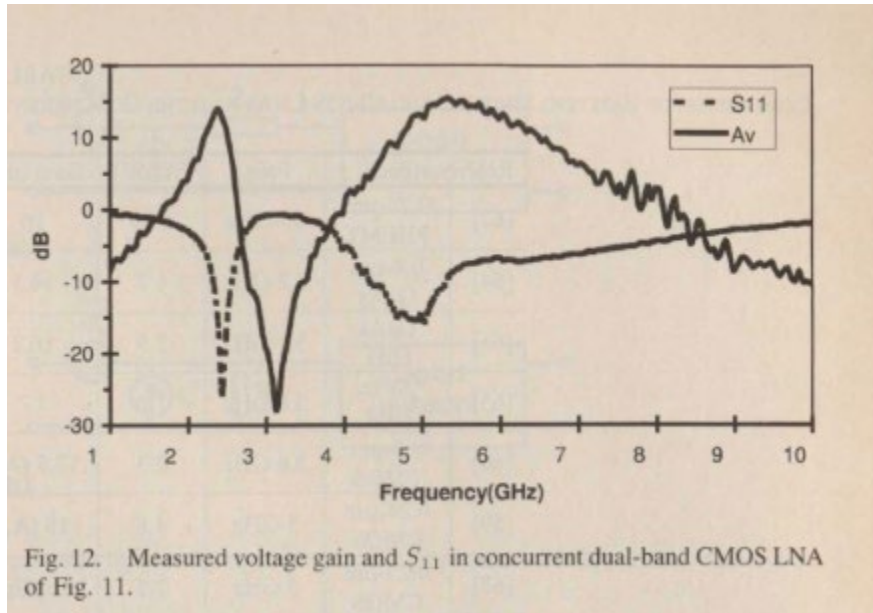
305. Hashemi focuses on design of the first and second matching networks to optimize their impedances at the first frequency than the second frequency, i.e. to make them different toward some goal such as low noise and/or maximum power transfer. For example in the introductory section Hashemi teaches the “new

concurrent multiband LNAs provide simultaneous narrow-band input matching and gain at multiple frequency bands, while maintaining low noise.” EX1011, Hashemi, p. 288. Hashemi notes the importance of the LNA due to it being the “first active element in the receiver chain” thereby playing a “significant role in the overall NF [(noise figure)] of the receiver” and “control[ing] its sensitivity and output signal to noise ratio (SNR).” EX1011, Hashemi, p. 288. Further, Hashemi teaches that in designing a multi-band LNA the noise sources behave differently at different frequencies which is important to noise and power matching the input to the amplifier. Thus, Hashemi teaches suggests optimization of matching circuitry on a per frequency-band basis. Hashemi at p. 289. Hashemi teaches with a dual-band concurrent architecture it is “a very important observation” that the transistor is inherently wideband and can thus be “used to provide gain and matching at other frequencies without any penalty in power dissipation,” i.e. Hashemi is teaching to use a single matching circuit for two bands. Hashemi at p. 290. Indeed, Hashemi teaches “matching at two bands, as shown at the bottom of Fig. 2.” Hashemi at p. 289. Hashemi notes that his approach “does not need any dual-band switch or diplexer, because simultaneous reception at both bands is desired.” Hashemi at p. 289. Hashemi teaches the “input of the LNA is either fed directly by the antenna or is connected to the antenna through a bandpass filter, a diplexer/duplexer, or both. In any case, the impedance looking into the input of the LNA should be power

matched (i.e. complex conjugate matched) to the impedance of the preceding stage for maximum signal power transfer.” Hashemi at p. 291. Thus, Hashemi teaches using complex conjugate matching at the input of the LNA to maximize power transfer and this power matching may be used to “achieve simultaneous impedance matching at multiple distinct frequencies.” See Hashemi at p. 292. However, Hashemi also teaches matching at the different frequencies for noise. (“In an LNA, it is also necessary to achieve noise match at the input for the frequenc(ies) of interest to minimize NF.”) Hashemi at p. 292. Thus, Hashemi discloses matching in two different frequencies bands using criteria such as noise minimization and power transfer maximization. Hashemi also teaches this matching “can only be achieved using lossless passive components” which a POSITA would understand to refer to components such as inductors and capacitors. Hashemi at p. 292. Hashemi teaches that differing passive topologies may be used to “provide impedance matching at multiple frequency bands.” *Id.*

306. A POSITA recognizes that this extensive discussion in Hashemi of impedance matching in multiple frequency bands is because the source and load of to the first and second passive networks have impedances that vary with frequency. This means the matching provides by the first and second passive networks must also have different impedance at different frequencies no matter if the matching criteria is maximum power transfer (complex conjugate matching), matching to

minimize noise, or some combination thereof. Hashemi produces an example for the 2.45 and 5.25 GHz bands in its section V. LNA Design Examples and Measurement Results. Hashemi at p. 297. Hashemi teaches that realization of passive components “on a silicon substrate are normally very lossy, [and] having them at the input of the amplifier degrades the NF of the LNA.” Hashemi at p. 297. This is suggesting using passive networks realized separate from the active device, i.e. the transistor. This can be seen as well via the “Pad” in Fig. 11 which shows the matching network connected to the active component externally rather than being fabricated in the same process as the active device, e.g. CMOS process. Hashemi teaches that the impedances of the two frequency bands are designed to cause resonance at two different frequencies. (“The parallel LC of Z_g is designed to resonate with $Z_{gs} + Z_s$ at both the frequency bands of interest.”) Hashemi at p. 297. In other words, the impedances of the first passive network are designed such that passive network has different impedances at different frequencies to achieve two resonances in the two frequencies bands and thus gain. See Fig. 12 of Hashemi showing gain at both 2.45 GHz and 5.25 GHz with a stop band in between with a deep null around 3.1 GHz.



Hashemi at Fig. 12

307. Likewise, the matching network at the output of the LNA is comprised of inductors and capacitors which have impedances that vary with frequency. Applying Hashemi's teaching of maximizing for power transfer maximization (complex conjugate) thus necessarily results in different the second matching network having different impedances at different frequencies.

308. For the reasons stated, limitation [1.4b] is met by Dalmia in view of Hashemi. And claim 1 is rendered obvious by Dalmia and Hashemi.

5. Claim 2

[2.0] *The multi-band RF device of claim 1, wherein the first and second passive networks comprise resonant circuits, and wherein the impedances of the first and second networks comprise reactance.*

309. Dalmia as modified by Hashemi renders obvious claim 1 and further teaches this element.

310. Dalmia in view of Hashemi teaches this element. First, the first and second passive networks comprise resonant circuits. This is because they comprise inductors and capacitors (e.g., L-C circuits), which are resonant circuits. And Hashemi confirms that, see p. 296, “To achieve highest gain and selectivity at the frequencies of interest, it is desirable to use a multiresonant load at the **output** whose impedance is maximum at the frequencies of interest.”), p. 297. The parallel LC network of Hashemi is designed to be resonant at both frequency bands of interest. Hashemi, p. 297, e.g., at Figure 12 showing S11 (input reflection coefficient) being low at two different frequencies (2.45 GHz and 5.25 GHz) with amplitude gain being high. This indicates the circuit is resonant at two distinct frequencies. The reason an impedance matching criteria as taught in Hashemi corresponds to resonance is because when the reactances cancel, i.e. positive reactances provided by inductors are of the same magnitude as negative reactances provided by capacitors and thus sum to zero, the capacitors store energy in electric fields while the inductors are discharging energy from magnetic fields and the capacitors release energy from electric fields at the same time the inductors are storing energy in magnetic fields. This is why the matching condition taught by Hashemi corresponds to resonance. Further, there must be reactance due to the use of capacitors and inductors.

311. Thus, Dalmia and Hashemi renders obvious claim 2.

6. Claim 4

[4.0] *The multi-band RF device of claim 1, wherein the active device is a bipolar junction transistor and wherein the multiband device is a low noise amplifier operable for providing power gain at the first frequency and the second frequency.*

312. Dalmia as modified by Hashemi renders obvious claim 1 and further teaches this element. Dalmia and Hashemi both recognize the *active device* of a low-noise amplifier as a *bipolar junction transistor*. pp. 136-137 dual emitter transistor, which illustrates a BJT, and Fig. 6.4, pg. 140 (“Figure 6.9 shows a fabricated LNA with embedded passives, discrete passives and a discrete BJT”); Hashemi, pp. 288-289 discussing “[t]he bipolar junction transistor” for use in LNAs, FIG. 1, p. 291.

313. Further, Dalmia in view of Hashemi teaches the amplifier is *operable for providing power gain at the first frequency and the second frequency*. Providing power gain is the standard function of an amplifier. See [4.0] Ground 1. And implementing the teachings of Hashemi to provide a multiband LNA, means that this function is provided at the *first frequency and the second frequency*. Hashemi explains “[t]hese new concurrent multiband LNAs provide simultaneous narrow-band input matching and **gain at multiple frequency bands**, while maintaining low noise.” Hashemi, p. 288.

314. Thus, Dalmia in view of Hashemi renders obvious claim 4.

7. Claim 11

[11.0] *The multi-band R/F device of claim 1, wherein the organic-based substrate comprises liquid crystalline polymer.*

315. Dalmia in view of Hashemi renders obvious claim 1, and Dalmia also teaches its organic-based substrate comprises *liquid crystalline polymer* as discussed in Ground 1, [11.0].

316. Thus, Dalmia and Hashemi render obvious claim 11.

8. Claim 12

[12.0] *The multi-band R/F device of claim 1, wherein the active device is a field effect transistor.*

317. Dalmia and Hashemi render obvious claim 1, and Hashemi also teaches this element.

318. Hashemi recognizes the use of a bipolar transistor, as in Dalmia, for the active device of a low-noise amplifier was a common choice. And Hashemi also recognizes as alternative that “field-effect transistors (FETs)” are a common choice. Hashemi pp. 288-289. Hashemi recognizes that its analysis can be readily applied to either active device. Hashemi, p. 291, fn. 2.

319. Field effect transistors (FETs) are the most common type of transistor formed in CMOS processes, and CMOS is a lower-cost process. BJTs are common in silicon-germanium (SiGe) processes, which can come with a higher cost. Hashemi recognizes that FETs (e.g., formed in CMOS) could be used an alternative

to the BJT. Hashemi pp. 288-289. A POSITA would have thus been motivated to use a FET instead of a BJT for the cost savings that accompanies it. I know firsthand based on experience at Texas Instruments in the 2000-2003 timeframe in which we were selling wireless solutions to companies like Nokia and Blackberry that there were market pressures to reduce cost in the high-volume cellular and Wi-Fi spaces. One way to reduce cost was to use lower-cost processes such as CMOS, which is used to form FETs, instead of BJTs. See also, EX1017 discussing “Bipolar LNAs” and “CMOS LNAs” as known alternatives.

320. Thus, claim 12 is rendered obvious by Dalmia and Hashemi.

9. Claim 13

[13] *The multi-band RF device of claim 1, wherein the first passive network comprises a component embedded in the organic-based substrate.*

321. Dalmia in view of Hashemi renders obvious claim 1, and the combination also teaches this element. As discussed above in [1.4a] and as in [13] of Ground 1, Dalmia describes an *organic-based substrate* and embedding passive components, such as capacitors or inductors, within its *organic-based substrate*.

322. Thus, claim 13 is rendered obvious by Dalmia in view of Hashemi.

10. Claim 14

[14] *The multi-band R[F] device of claim 1, wherein at least one of the metal layers is patterned to form at least a portion of a component included in the first passive network.*

323. Dalmia in view of Hashemi renders obvious claim 1, and the

combination also teaches this element. As discussed in [1.4a], as well as [14] of Ground 1, Dalmia describes metal layer(s) formed on dielectric layers within its *organic-based substrate* form at least a portion of passive components, such as capacitors or inductors, of the *first passive network* of its amplifier. Dalmia, pp. 136-137.

324. Thus, claim 14 is rendered obvious by Dalmia and Hashemi.

11. Claim 15

[15] *The multi-band R[F] device of claim 1, wherein the second passive network comprises a component embedded in the organic-based substrate.*

325. Dalmia and Hashemi render obvious claim 1, and the combination also teaches this element. As discussed above in [1.4a] and also in Ground 1, [15], Dalmia describes an *organic-based substrate* and embedding passive components, such as capacitors or inductors, of the second passive network within its *organic-based substrate* as they are formed of patterned copper layers disposed within a laminated stack of dielectric, organic layers making up the substrate.

326. Thus, claim 15 is rendered obvious by Dalmia and Hashemi.

12. Claim 16

[16] *The multi-band R[F] device of claim 1, wherein at least one of the metal layers is patterned to form at least a portion of a component included in the second passive network.*

327. Dalmia and Hashemi render obvious claim 1 and teach this element.

328. As discussed in [1.4a], [14] and the analysis for [16] in Ground 1,

Dalmia teaches *patterned* copper layers (*metal layers*) within its laminated substrate *to form* passive components and suggests embedding the *second passive network* in the substrate [1.3] using these patterned metal layers.

329. Thus, claim 16 is rendered obvious by Dalmia and Hashemi.

13. Claim 5

[5.0] *A multi-band low noise amplifier for use in an RF application, comprising:*

[5.1] *an active device;*

330. Dalmia in view of Hashemi teaches a multi-band RF device of a low noise amplifier with an active device of a transistor, which is used in RF communications as discussed in [1.0]-[1.1]. Thus, Dalmia in view of Hashemi teaches these elements.

[5.2] *a first matching network in communication with the active device, wherein an impedance of the first matching network at a first frequency is different than the impedance of the first matching network at a second frequency;*

331. Dalmia in view of Hashemi teaches a *first matching network* of passive components *in communication with* its transistor (*active device*) as discussed above in [1.2].

332. Further, the combination teaches that *an impedance of the first matching network at a first frequency is different than the impedance of the first matching network at a second frequency* as the matching network of Dalmia as

modified by Hashemi receives and operates on signals of each of the *first frequency* and the *second frequency*. As the matching network includes inductors and capacitors, the impedance of the input matching network will be different at the two frequencies. The impedance at the two different frequencies will also be different because the impedances of devices that are being matched to also vary as a function of frequency when operating at radio frequencies. For example, the input impedance required to maximize the gain or lower noise figure of a transistor varies with frequency, as explained. Also, the output impedance of the transistor will vary with frequency at least because the biasing circuitry is comprised of inductors and/or capacitors whose impedance varies with frequency. Further, downstream devices like RF switches or mixers will also have impedance that varies as a function of frequency.

[5.3] *a second matching network in communication with the active device, wherein an impedance of the second matching network at the first frequency is different than the impedance of the second matching network at the second frequency; and*

333. Dalmia in view of Hashemi teaches a *second matching network* of passive components *in communication with* its transistor (*active device*) as discussed above in [1.2].

334. Further, the combination teaches that *an impedance of the second matching network at the first frequency is different than the impedance of the second matching network at the second frequency* as the matching network of Dalmia-

Hashemi receives and operates on signals of each of the first frequency and the second frequency. As the output matching network (*second matching network*) includes inductors and capacitors, the impedance of the output matching network will be different at the two frequencies.

335. Further still, the output matching network connects to an output node that is biased with capacitors and inductors. That means the source impedance from the output of the transistor varies with frequency. The downstream devices that represent the load impedance to the second matching network (such as an RF switch, filter, or mixer) also have impedances that vary with frequency. Thus, the source impedance and load impedance seen by the second matching network will vary with frequency.

[5.4a] *a multi-layer organic-based substrate having at least one metal layer, wherein the first matching network and the second matching are formed on the at least one metal layer and wherein the active device is mounted on the multi-layer organic substrate,*

336. **First**, as discussed above in [1.4a], [14], [16], Dalmia describes *a multi-layer organic-based substrate having at least one metal layer*; the metal layers are shown by patterned copper layers each formed on a respective dielectric layer that are laminated together to form the substrate that provides the multi-layer organic-based substrate. The input and output passive network components are formed on the metal layers. And Dalmia suggests forming the input and output matching networks (*first matching network* and the *second matching network*, on the

patterned copper layers (*at least one metal layer*) that are the patterned copper layers embedded in Dalmia's organic-based substrate.

337. **Second**, Dalmia also describes a chip is mounted on the multi-layer organic substrate. Figure 1.1 of Dalmia is illustrative.

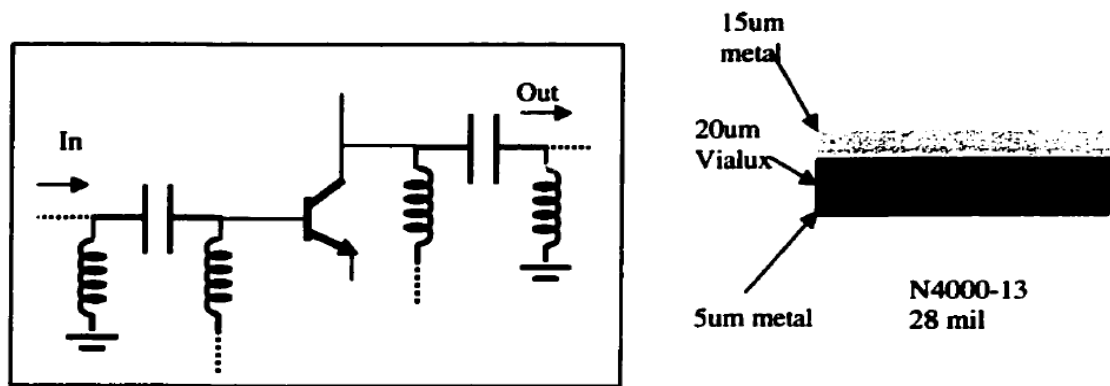


**Fig 6.4. a) Integrated LNA, with impedance transformation networks
b) Cross-section of testbed**

POSITA would recognize to place Dalmia's transistor, active device, *mounted on the multi-layer organic substrate*. Dalmia suggests that the active device (BJT) of the LNA is a discrete component. Dalmia, pp. 140, 149.

[5.4b] *thereby allowing the an [sic] output of the multi-band low noise amplifier to have desired power gains at the first frequency and the second frequency based at least in part on each of the first and second matching networks having the different reactance at the first frequency and the second frequency.*

338. Dalmia in view Hashemi teaches *allowing an output of the multi-band low noise amplifier to have desired power gains at the first frequency and the second frequency*. As discussed above (see [1.0]-[1.4b]), Dalmia in view of Hashemi

teaches a multi-band low noise amplifier (including an active device and matching networks), which it uses to achieve power and noise matching in multiple bands. “This equivalent circuit will be used to achieve simultaneous **power** and noise matching in a concurrent multiband LNA.” EX1011 (Hashemi), p. 291. *See also*, Hashemi at p. 296 discussing gain: “To achieve the highest gain and selectivity at the frequencies of interest, it is desirable to use a multiresonant load at the output whose impedance is maximum at the frequencies of interest.” Thus, Hashemi describes the amplifier performing its function of providing *desired power gains* at multiple frequencies.

339. A POSITA would understand that the amplifier’s function (power gains) is *based at least in part on each of the first and second matching networks having the different reactance at the first frequency and the second frequency.*

Understanding that the first frequency and the second frequency are each provided to the first and second passive networks and that the frequency bands are different from one another, it necessarily follows that the *reactance* of each of the passive networks at each frequency are different. See [2].

340. Moreover, as I showed above, the matching networks necessarily have complex impedances to achieve the objectives taught in Hashemi. See, p. 291. The imaginary part of the impedance corresponds to the reactance. Thus, my previous analysis of the claim 2 limitations supports the conclusion that the first and

second matching networks have different reactances at the first and second frequencies. This follows from the fact that the impedance matching objectives taught by Hashemi for the input and output matching networks necessarily result in different reactances at the two frequencies. Simply put, the matching networks of Dalmia-Hashemi comprise capacitors and inductors which are purely reactive components. The reactance of those components fundamentally varies with frequency. Furthermore, Hashemi describes that maximum power gain is achieved by matching the frequency-dependent impedance of components in the signal path. A POSITA would understand that this is accomplished by matching reactances (*e.g.*, to the transistor at its input and output, as well as upstream and downstream components). The frequency dependence of the circuit or component being matched, the frequency-dependent reactance of the components in the first and second matching networks, and the fundamental requirement of impedance matching itself—which necessitates selecting appropriate reactances—all dictate the frequency dependency of the matching network reactances. Thus, this claim term is met. I discuss this in [1.4b], [2.0].

341. Thus, claim 5 is rendered obvious by Dalmia in view of the multi-band techniques of Hashemi.

14. Claim 6

[6] *The multi-band amplifier of claim 5, wherein the active device is a bipolar junction transistor.*

342. Dalmia in view of Hashemi renders obvious claim 5, Dalmia (as well as Hashemi) also discloses the active device, Q1, is a *bipolar junction transistor*.

343. Dalmia at pp. 136-137 discusses a dual emitter transistor, which is a BJT, and Fig. 6.4, pg. 140 (“Figure 6.9 shows a fabricated LNA with embedded passives, discrete passives and a discrete BJT.”) This is also confirmed by Hashemi. See pp. 288-289 discussing “[t]he bipolar junction transistor” for use in LNAs, FIG. 1, p. 291. As discussed previously, there are design choices between BJT and FETS. A POSITA would have reason to choose a BJT when higher gain or lower noise is desired.

344. Thus, claim 6 is rendered obvious by Dalmia and Hashemi.

15. Claim 7

[7] *The multi-band amplifier of claim 5, wherein the multi-layer organic-based substrate comprises at least one of hydrocarbon and liquid crystalline polymer.*

345. Dalmia as modified by Hashemi renders obvious claim 5, Dalmia also teaches this element. As discussed above in [1.4a], Dalmia provides a multi-layer organic-based substrate and as discussed in [11], liquid crystalline polymer is one of the compositions of that substrate.

346. To the extent that this claim requires both at least one a hydrocarbon and at least one LCP, it would have been obvious for the organic

substrate to include a hydrocarbon **and** LCP. Dalmia describes that multiple of its insulating compositions can be used together in a laminate configuration. See, Figure 3.14. LCP and hydrocarbons (e.g., Rogers 4350B named in the '914 Patent) were well-known substrate materials. See, EX1025, NIST technical note noting Roger's RO4350 as substrate ("PWB") material, p. 99, Dalmia, p. 150 describing use of organic materials generally to form laminate "PWB". Thus, POSITA would have recognized a common design choice of a hydrocarbon material such as Rogers 4350B as the organic material suggested by Dalmia. This is merely using a known material for its known function.

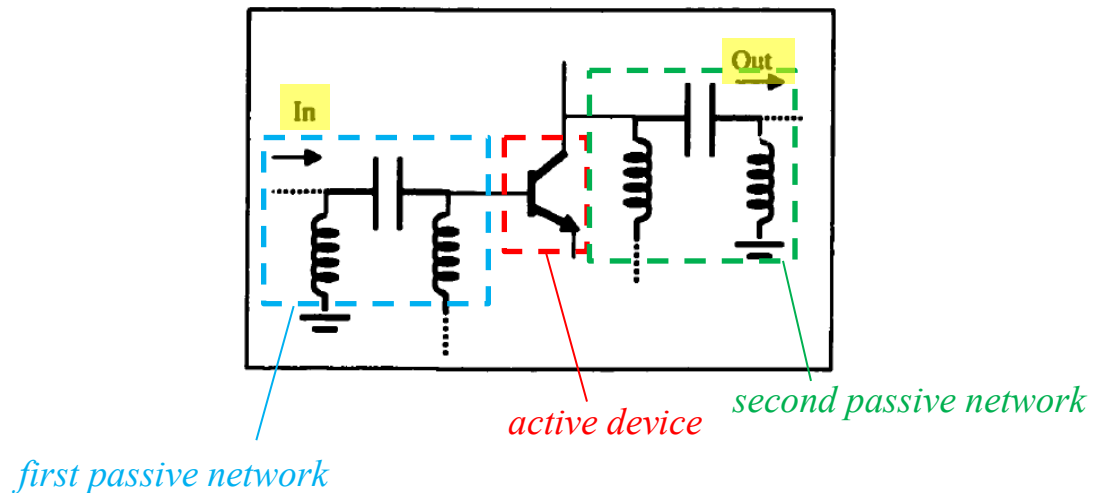
347. Thus, claim 7 is obvious in light of Dalmia and Hashemi.

16. Claim 8

[8] *The multi-band amplifier of claim 7, wherein the first matching network is positioned at an input of the multi-band amplifier and the second matching network is positioned at an output of the multi-band amplifier.*

348. Dalmia as modified by Hashemi renders obvious claim 7, and also teaches this element.

349. The *first matching network*, as in [5.2] above, which is positioned at *an input* illustrated the low-noise amplifier. And the output matching circuit, which provides the *second matching network* as in [5.3] above, is positioned at *an output* of the low-noise amplifier. Figure 6.4 is illustrative of the matching networks at the "In" (*input*) and "Out" (*output*) of the LNA.



EX1010, Figure 6.4 (portion)
(annotated)

350. This configuration, i.e., positioning of the input and output matching circuits with respect to the active device, does not change because of modifications taught by Hashemi. See Hashemi, pp. 291-295 sections “B. Input Matching” and “C. Noise Matching” of IV. Concurrent Multiband LNA, “**The input of the LNA** is either fed directly by the antenna or is connected to the antenna through a bandpass filter, a diplexer/duplexer, or both. In any case, the impedance **looking into the input of the LNA should be power matched...**to the impedance of the preceding stage for maximum signal power transfer.”) See Hashemi, p. 296 (“D. Load Circuit, Output Matching, and Gain” of IV. Concurrent Multiband LNA, “To achieve highest gain and selectivity at the frequencies of interest, it is desirable

to use a multiresonant load at the **output** whose impedance is maximum at the frequencies of interest.”)

351. Thus, claim 8 is rendered obvious by Dalmia and Hashemi.

17. Claim 9

[9] *The multi-band amplifier of claim 8, wherein the first matching network minimizes the noise figure for the multi-band amplifier at the input at both the first frequency and the second frequency.*

352. Claim 8 is rendered obvious by Dalmia as modified by Hashemi, which also teaches this element.

353. Dalmia as modified by Hashemi describes input matching network, the first matching network of [5.2], that *minimizes the noise figure for the multi-band amplifier at the input at both the first frequency and the second frequency*. First, POSITA would recognize the goal of the input matching network of a low noise amplifier is to minimize the noise at the operational frequency. Second, Hashemi recognizes for LNAs, it is “desirable to have a low NF [noise factor also referred to as noise figure] *while* maintaining high gain.” p. 292 (emphasis in original). And implementing Hashemi’s techniques provides an architecture including a concurrent dual-band LNA that provides for “simultaneous narrow-band gain and input matching which offering low NF in concurrent multiband LNAs” that an implementation of which demonstrated “superior NF” performance. Hashemi, p. 298.

354. It would have been an obvious design choice to match to minimize noise figure. Indeed, noise figure is a key figure of merit of a low noise amplifier, and it is common to even sacrifice some gain to minimize noise figure. The low noise amplifier is commonly the key component that determines how much self-induced noise a receiver injects into the desired signal. The noise figure of the LNA commonly sets the noise floor of a receiver, as the noise figure adds to the inherent thermal noise within a system (kT where k is Boltzmann's constant and T is temperature). Thus, a POSITA is well aware of the desired to minimize the noise figure of an LNA in a communications system and is thus motivated to make design decisions to do so. LNA data sheets typically have a noise figure as a key figure of merit.

355. Thus, claim 9 is rendered obvious by Dalmia and Hashemi.

18. Claim 10

[10] The multi-band amplifier of claim 9, wherein the second matching network maximizes the desired power gains for the multi-band amplifier at the output at both the first frequency and the second frequency.

356. Claim 9 is rendered obvious by Dalmia as modified by Hashemi, which also teaches this element.

357. Dalmia as modified by Hashemi describes that an output matching network, the second matching network of [5.3], *maximizes the desired power gains for the multi-band amplifier at the output at both the first frequency and the second*

frequency. First, POSITA would recognize the goal of the output matching network of a low noise amplifier is to maximize the gain at the operational frequency, i.e., at the passband of the system. Second, Hashemi recognizes for LNAs, it is “desirable to have a low NF [noise factor] *while* maintaining high gain.” p. 292 (emphasis in original). And implementing Hashemi’s techniques provides an architecture including a concurrent dual-band LNA that provides simultaneous **gain...at two bands.**” p. 290. See also, Hashemi, FIG. 10, FIG. 12, pp. 297-298.

358. Further, Hashemi explicitly teaches the use of conjugate matching of impedances. Conjugate matching achieves the maximization of power transfer and thus power gains. Hashemi teaches “conjugate match[ing]” at the input of the LNA at p. 291, which has to do with the input matching circuit. Thus, at minimum Hashemi’s teaching of using conjugate matching at the input matching filter teaches a POSITA to use conjugate matching at the output matching network as well. Further, a POSITA would be inclined to match using a conjugate matching at the output of the LNA because any self-induced noise caused by the LNA has already been injected, thus the basic teaching of matching with conjugate matching to avoid reflections and maximize power transfer via maximizing power gains would be to implement. Moreover, there is no noise figure-gain tradeoff decision at the output matching network, so matching for maximum power gain would be an obvious choice.

359. Thus, claim 10 is rendered obvious by Dalmia and Hashemi.

19. Claim 17

[17] *The multi-band amplifier of claim 5, wherein the first matching network comprises a component embedded in the organic-based substrate.*

360. Claim 5 is rendered obvious by Dalmia as modified by Hashemi, which also teaches this element as discussed in [13] including Dalmia's teachings of embedding *a component* of the input matching network, *first matching network*, of the amplifier of Dalmia as modified by Hashemi in an organic-based substrate. Thus, claim 17 is obvious in light of Dalmia and Hashemi.

20. Claim 18

[18] *The multi-band amplifier of claim 5, wherein at least one of the metal layers is patterned to form at least a portion of a component included in the first matching network.*

361. Claim 5 is rendered obvious by Dalmia as modified by Hashemi and the combination further teaches this element as discussed above in [14], which illustrates Dalmia's metal layers of its organic-based substrate are *patterned to form at least a portion of a component* of the input matching network.

362. Thus, claim 18 is obvious in light of Dalmia and Hashemi.

21. Claim 19

[19] *The multi-band amplifier of claim 5, wherein the second matching network comprises a component embedded in the organic-based substrate.*

363. Claim 5 is rendered obvious by Dalmia as modified by Hashemi

and the combination further teaches this element. As discussed above with reference to claim 15, Dalmia teaches forming passive components using metal layers *embedded* in the *organic-based substrate* (e.g., laminate of organic layers) to form components of the output matching network, *second matching network*. Thus, claim 19 is obvious in light of Dalmia and Hashemi.

22. Claim 20

[20] *The multi-band amplifier of claim 5, wherein at least one of the metal layers is patterned to form at least a portion of a component included in the second matching network.*

364. Claim 5 is rendered obvious by Dalmia and Hashemi and the combination further teaches this element. As discussed in [16], POSITA would have known to use Dalmia's metal layers of its organic-based laminate substrate to form *at least a portion of a component* of the Dalmia's LNA output matching network including as modified by Hashemi to provide dual-band functionality. Thus, claim 20 is obvious in light of Dalmia and Hashemi.

IX. CONCLUSION

This declaration and my opinions herein are made to the best of my knowledge and understanding, and based on the material available to me, at the time of signing this declaration. I declare that all statements made herein on my own knowledge are true and that all statements made on information and belief are believed to be true, and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 or Title 18 of the United States Code.

Date: 9 February 2025

Matthew B. Shoemake