

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

MURATA MANUFACTURING CO., LTD

Petitioner

IPR2025-00383
U.S. Patent No. 7,489,914

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

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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 2001-267466 (“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	<i>Reserved</i>
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, 2001, 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	European Patent Application No. EP 0 851 576 A2
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, IEEE, 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., IPC Printed Circuits Expo, 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., IEEE Transactions On Advanced Packaging, Vol. 25, No. 4, 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

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 Processor (DSP) Group. Digital signal processing involves analyzing, modifying, and synthesizing signals using digital processing techniques. Such digital signals to be processed are commonly formed by converting analog signals into digital form via the use of analog-to-digital converters. The DSPs I worked on comprised circuits specifically designed for efficient and fast execution mathematical operations. The capability to efficiently and rapidly perform mathematical operations was used to perform 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. For example, when used in wireless communications systems our DSP processors would interface to RF and analog circuitry. On reception, an antenna would receive a wireless signal which would then be downconverted by radio frequency circuitry such as mixers. The baseband or low-IF (intermediate frequency) would then be sampled by an A/D converter. The DSP would then be used to further process and decode the received signal. Likewise, transmitted signals originate in the DSP where the converted to analog form by a D/A converter and then upconverted to a carrier frequency by RF circuitry. 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 worked focused on communications systems including wireless systems, algorithms, and architectures. This work included techniques for mitigating the effects of noise including noise that originates in the transmission and reception circuitry itself.

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. My team and I were responsible for the overall operation of the physical layer of these systems. This included the whole of the transmit and receiver paths from the antenna through the digital baseband processing and to the interface with the MAC (medium access control) processor. 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 was used in the very first smartphone with Wi-Fi, the Nokia 9500 Communicator. This work required the development of small Wi-Fi modules. During this time period I also worked with Motorola on their RAZR project which also required miniaturization of wireless modules to meet the stringent requirements for height and area.

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 was manufactured at TSMC in a silicon process as well as a SiGe radio front-end that was 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, 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. It is my understanding that the earliest possible priority date for the '914 Patent is March 28, 2003. While not agreeing to this priority date, I have applied this date for the purposes of this declaration as all prior art predates this earliest possible priority date. A Person of Ordinary Skill in The Art ("POSITA") in March 2003 would have had a working knowledge of the 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.

18. For purposes of this present 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 earliest alleged priority date of the '914 Patent (i.e., March 28, 2003). Unless otherwise stated, when I provide my understanding and analysis below, it is consistent with the level of a POSITA as of this earliest alleged priority date of the '914 Patent.

IV. RELEVANT LEGAL STANDARDS

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

¹As an example, 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.

V. TECHNICAL BACKGROUND

23. 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

24. In the first generation of mobile devices, 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.

25. 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 (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.

26. Other frequency bands are also discussed in the '914 Patent and were similarly common for use of personal devices prior to the '914 Patent. 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.

27. 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 Francisco (EX1005), which I discuss 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. Naturally, providing separate

paths each dedicated to a certain frequency led to mobile devices with increased size and cost. See 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.

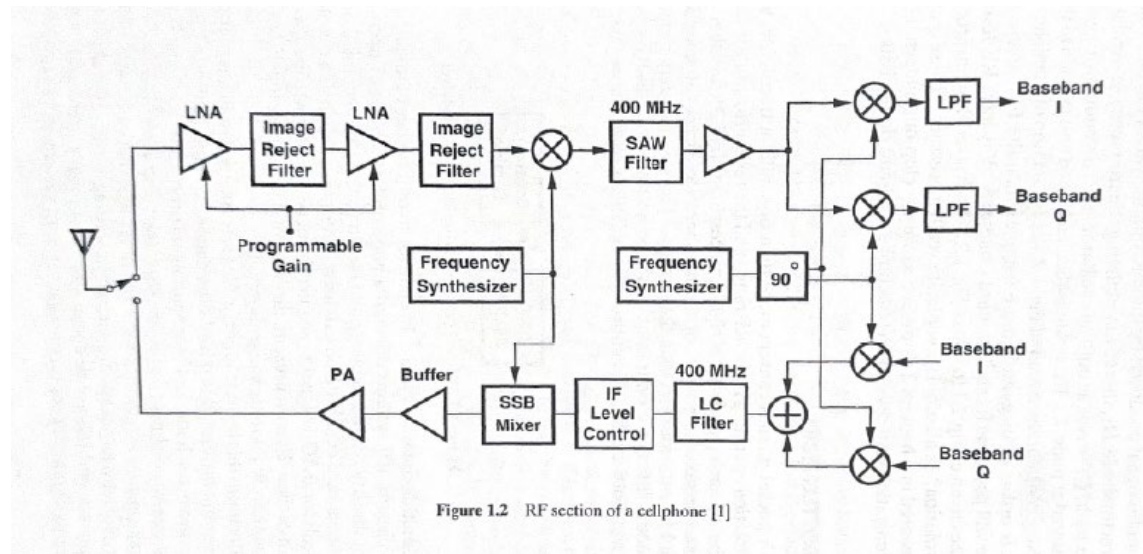
28. Amplifiers were a well-known component for re-use at different frequencies. See Francisco discussed below. *See also*, EX1009 (Yeh), 1:29-56 (“In order to **minimize** the cost and complexity of the **front end radio-frequency**

(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**.”); Hirayama, EX1008 discussed below; EX1021 (Mou) titled “A CMOS RF Bandpass Low Noise Amplifier for Multi-band Wireless Communication Applications.”; EX1011 (Hashemi), p. 288.

B. Transceivers

29. 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.

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



31. 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 in conjunction with the core amplifying device. The '914 Patent refers to its core amplifying device as an *active device*.

32. 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

33. 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 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.”)

34. 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 to a change in 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.

35. 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 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.

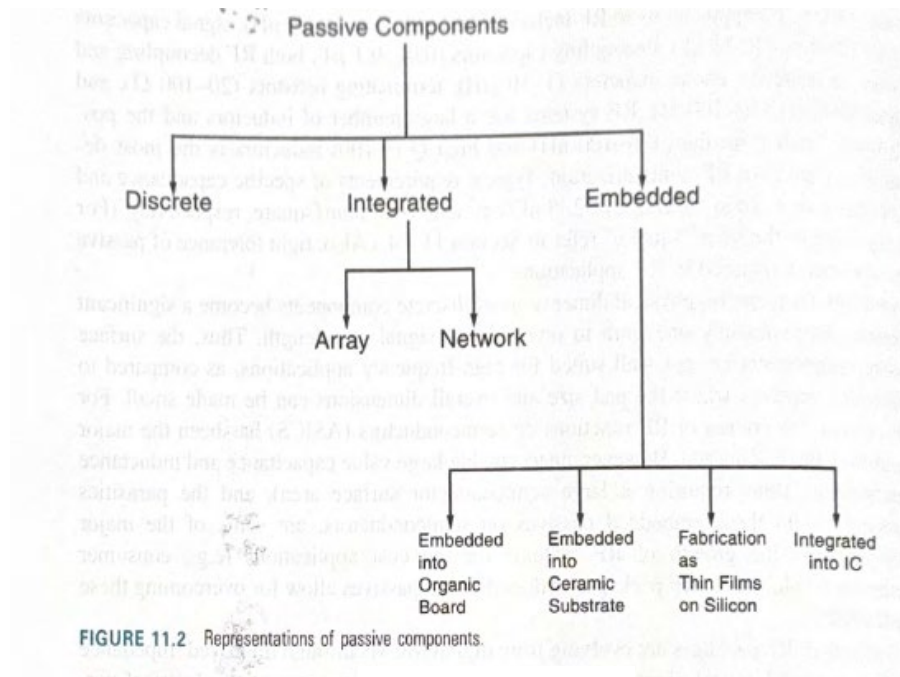
36. Generally, packaging technologies include a substrate that acts as a foundational material providing mechanical support, thermal management, and electrical interconnections. The substrate may ideally have “low permittivity, interconnections made of high-conductive metals, high wiring density, and

embedded passive circuit elements.” EX1025; NIST Technical Note 1520, “Dielectric and Conductor-Loss Characterization and Measurements on Electronic Packaging Materials,” p. 2. The low permittivity means electrical fields easily pass through the material. Likewise, low permittivity materials do not store energy when exposed to an electric field. Permittivity may also be expressed as the relative permittivity (also called dielectric constant) which is the ratio of the permittivity of a material to the permittivity of a vacuum.

37. 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 of 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.

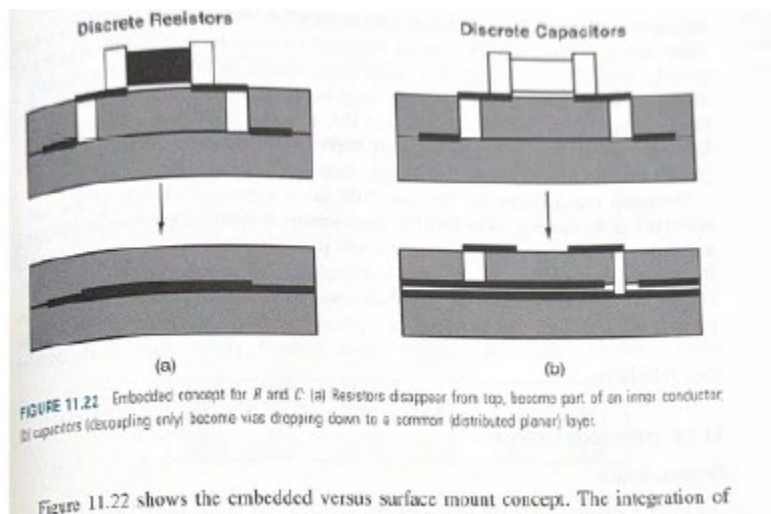
38. Embedded or buried passives means the passive components such as resistors, capacitors, and inductors can be embedded or built directly in the substrate. For example, a capacitor may be sandwiched between layers of the substrate and connected to the circuit using metal (e.g., copper) traces, which 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:

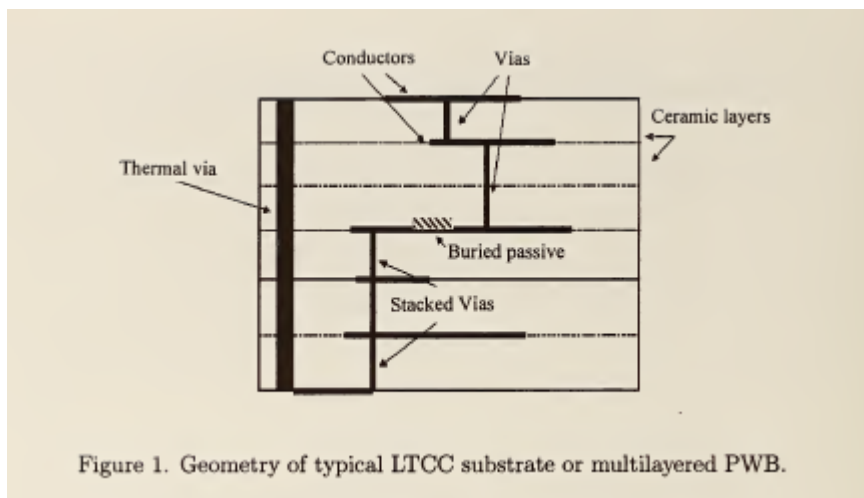


EX1012, p. 426

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.



39. 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 (PWB) (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 signals to pass from one layer to another. Also shown below is a “Buried passive” components such as a resistor or capacitor.



EX1025, p. 10

40. 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 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.4. 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.

41. 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.

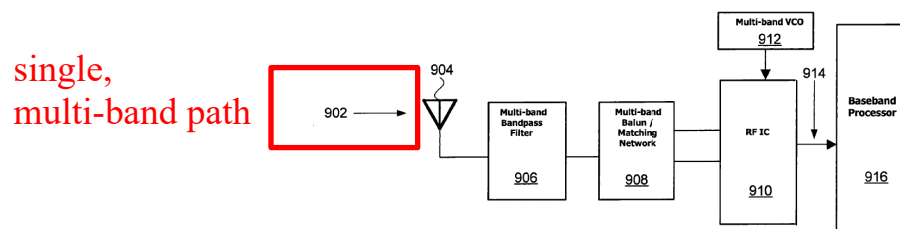
42. A POSITA would also know that the permittivity of a material is a

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 signals 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. 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. *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

43. 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).

44. 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.

45. 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

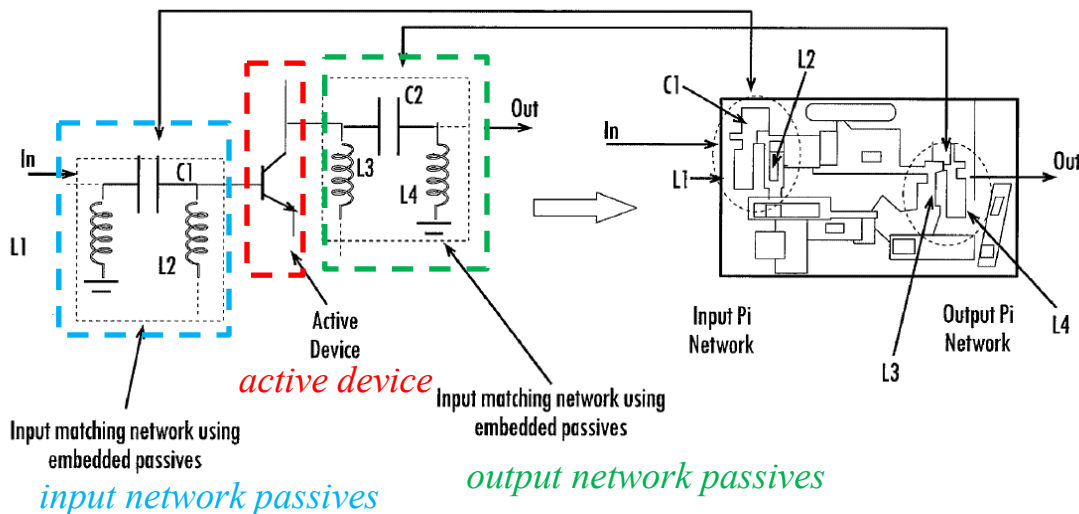
input of a transistor (marked “Active Device” in FIG. 35). The output of the transistor is connected to another matching network. The “measured gain and input match” for the LNA of FIG. 35 is shown in FIG. 36. FIG. 36 shows the maximum gain and lowest input reflection coefficient are both at approximately 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.

46. 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, L2, L3, C2, or L4 in Figure 35.

47. 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.

48. 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

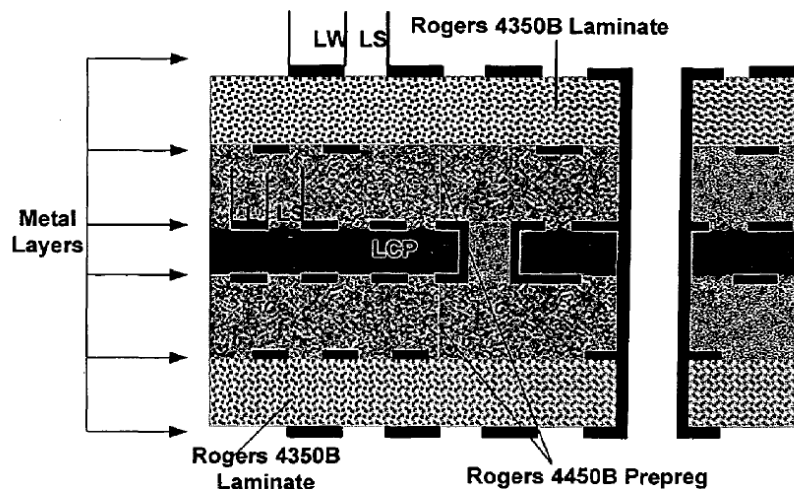


EX1001, FIG. 35
(annotated)

49. 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 '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

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

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

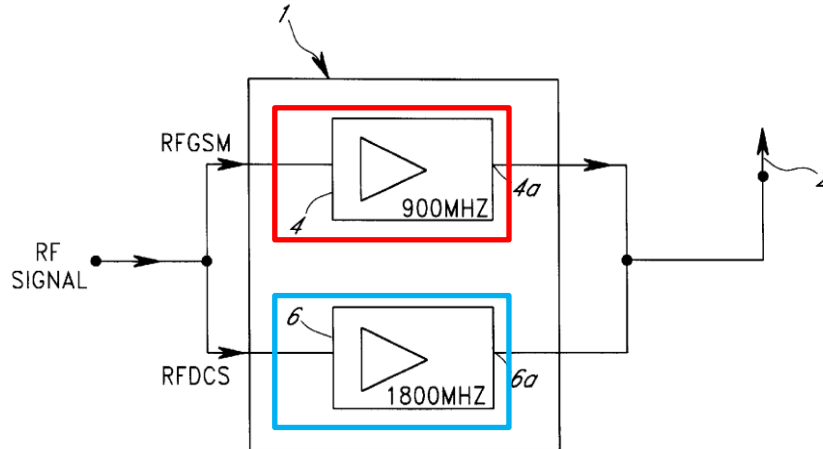
50. Rogers 4350B Laminate is used for outer layers in FIG. 38A, and Rogers 4450 Prepreg is used for inner layers surrounding a liquid crystal polymer (LCP) layer. Rogers 4450B are laminate materials from Rogers Corporation commonly used in the industry. *See, e.g.*, EX1025 NIST Technical Note, pp. 99, 132 mentioning Rogers.

B. Prosecution History

51. 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.

52. 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. EX1002, pp. 56-61. 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
(annotated)**

53. 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.

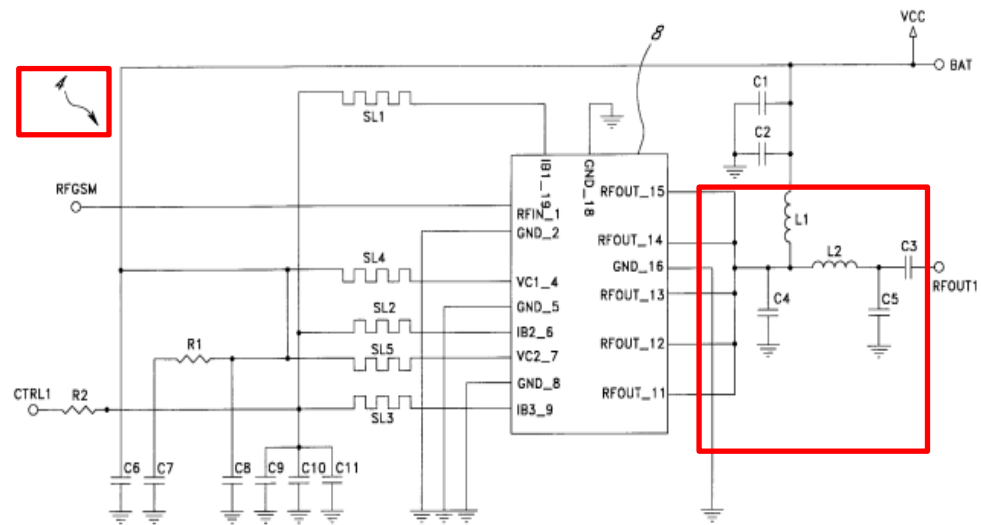


FIG. 3

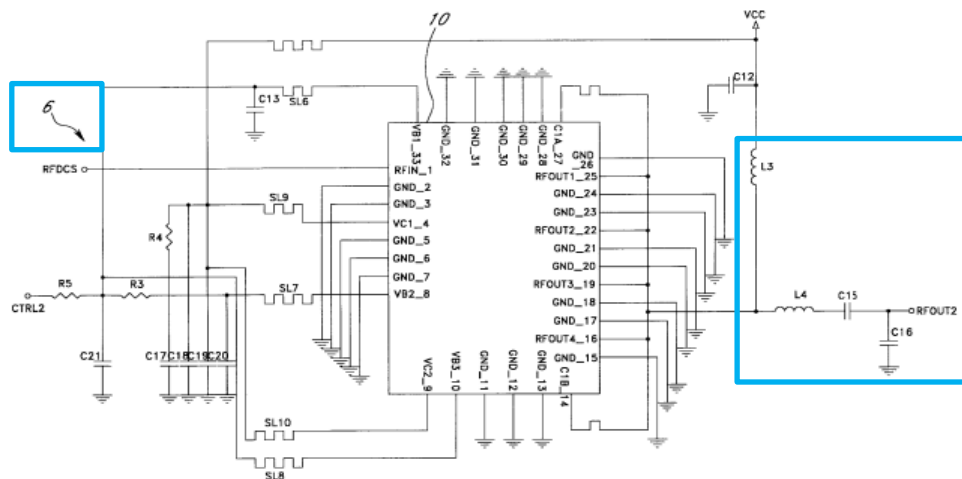


FIG. 4

**USP 6,075,995, FIGS. 3-4
(annotated)**

54. 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.

VII. CLAIM CONSTRUCTION

55. 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.

56. 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

57. 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.

58. 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.

59. 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. I apply the prior art as follows:

Grounds	Claims	Basis
#1	1-2, 5, 12-20	35 U.S.C. § 103 (Pre-AIA) over Francisco and JP466
#2	4, 6	35 U.S.C. § 103 (Pre-AIA) over Francisco and JP466 and Hirayama
#3	7-11	35 U.S.C. § 103 (Pre-AIA) over Francisco and JP466 and Okubora

60. As stated above, I have used the earliest possible priority date – March 2003 – for my analysis of this declaration.

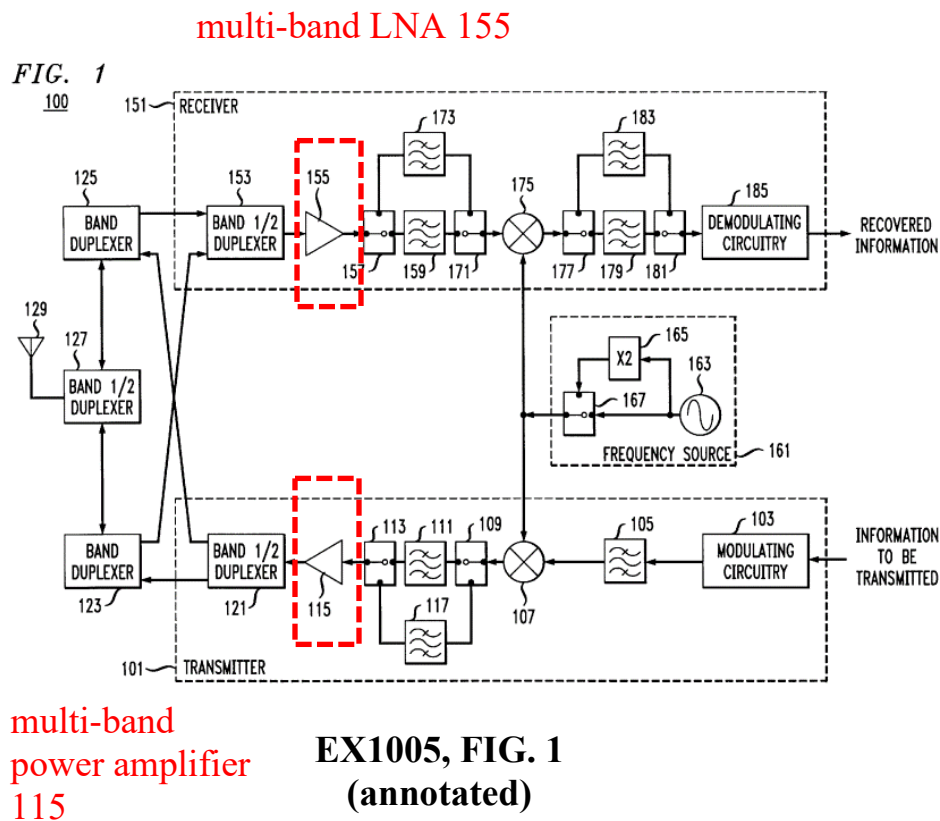
A. Ground 1: Claims 1-2, 5 and 12-20 over Francisco and JP466

1. Overview of Francisco

61. Francisco relates generally to “communications systems, and more particularly to those systems using amplifiers to transmit signals over multiple frequency bands.” EX1005 (Francisco), 1:5-7. Driven by a need to improve “the multi-band radiotelephone, so that the circuit utilizes the space more efficiently, and is less expensive and more reliable,” Francisco describes “multiple prior-art amplifiers each handling communications with only one frequency band” can be replaced with a single amplifier. The single “multi-band amplifier in a communications system [] scale[s] the signal level of a signal communicated over one of multiple frequency bands.” EX1005 (Francisco), 1:50-53.

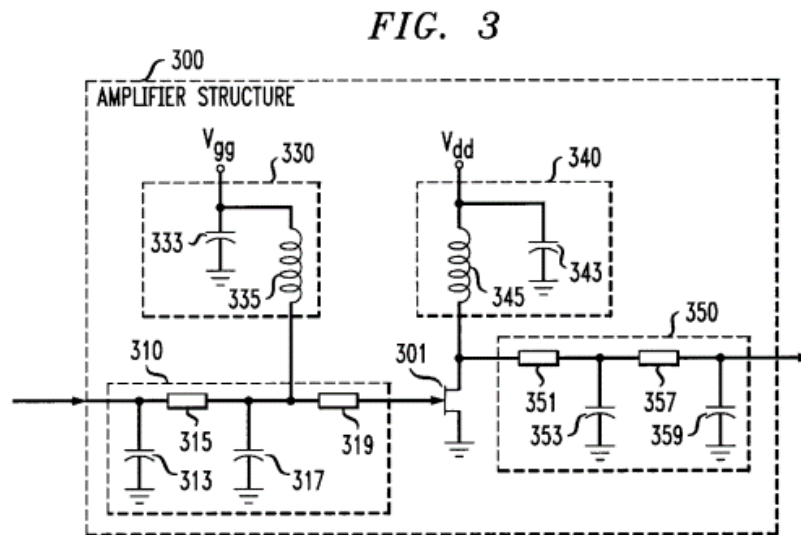
62. FIG. 1 illustrates system 100 including transmitter 101 and receiver

151 suitable for receiving multiple sets of frequency bands such as a cellular (~800 MHz) band and a PCS band (~1800 MHz). EX1005 (Francisco), FIG. 2, 2:20-26, 2:48-49, 1:11-24, 7:45-52. Francisco illustrates each of the transmitter 101 and the receiver 151 include a multi-band amplifier (115 and 155, respectively) to provide gain to the relevant signal. EX1005 (Francisco), FIG. 1, 3:41-47, 4:38-46. Again, POSITAs recognize that in the transmit circuit the amplifier is a power amplifier (PA) and in the receive transmit circuit the amplifier is a low-noise amplifier (LNA)).



63. FIG. 3 illustrates an amplifier structure 300 that can be used for each

of the amplifiers, the power amplifier 115 and the multi-band LNA 155. EX1005 (Francisco), 5:24-29. Each of the power amplifier 115 and the multi-band LNA 155 are “[advantageously...with respect to its prior art counterpart, [] less expensively and bulky, and more reliable due to use of at least fewer [] amplifiers.” EX1005 (Francisco), 3:66-4:2, 4:43-46. The amplifier structure 300 includes field effect transistor (FET) 301, having a gate terminal connected to input matching network 310 and coupled gate bias circuit 330 as well as a drain terminal connected to drain bias circuit 340 and output matching network 350. EX1005 (Francisco), FIG. 3, 5:30-36.



EX1005, FIG. 3

64. Francisco also teaches that the passive components illustrated in FIG. 3 are illustrative and will be changed to meet the goals of an amplifier. Francisco,

5:65-6:65. Thus, Francisco's disclosure is not limited to the circuit configuration in networks 310 and 350 in Francisco. See, e.g., EX1009 (Yeh), Abstract, Fig. 5; and EX1008 (Hirayama), Abstract, Fig. 1; each showing input and output matching networks; EX1014 (Toncich), 1:44-50. To the contrary, a POSITA would design the matching networks requirements to meet the requirements taught in Francisco that are specific to the desired performance.

2. JP2001267466 (JP466)

65. Like Francisco, JP466 is directed to signal amplification in communications systems. Like Francisco, JP466's interest motivation relates to circuitry "used in a communication equipment transmitter of a mobile phone, or the like." EX1006 (JP466), [0001]. However, JP466 is directed to implementation of communications circuits in efficient, small modules. JP466 suggests improvements of the power amplifier by reducing size of its passives (particularly inductors) and by mitigating the generation of a standing wave depending on wavelength of a signal. EX1006 (JP466), [0011]-[0022].

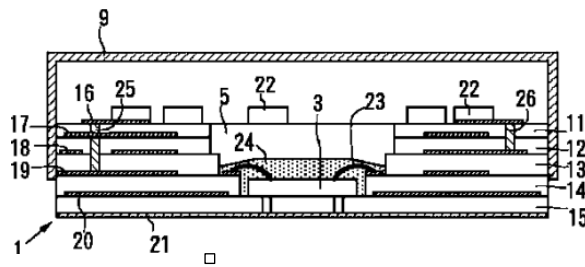
66. The teachings of JP466 are provided to amplifiers in the context of a power amplifier, however, they are equally as applicable to low noise amplifiers. JP466's teachings include using substrates with higher dielectric constants thereby shortening the wavelength thereby reducing component size such as conductor lengths. A POSITA would understand that the teaching of using substrates with

higher dielectric constant to shorten the wavelength is equally as applicable to transmitted and received signals, because (a) the wavelengths are the same or similar; (b) components such as inductors and capacitors are need in both; and (c) elimination of unwanted standing waves is applicable to both. Moreover, the stack-up of layers as shown in Figure 5 is equally as applicable to low noise amplifiers as power amplifiers. For example, as Francisco teaches, both power and low noise amplifiers both require an active element such as a transistor with input and output matching circuitry, which is the same as taught in JP466's Figure 2 and 3 where bias circuitry along with input and output matching circuitry is taught for the active element(s), transistors. See Francisco, 5:23-29 ("The structure of multi-band power amplifier 115 and that of multi-band LNA 155 will now be described. Although the values of the components may vary according to their specific applications, the structures of amplifiers 115 and 155 are similar. FIG. 3 illustrates amplifier structure 300 in accordance with the invention suitable for [power] amplifier 115 and LNA 155.")

67. JP466, like Francisco, focuses on size reduction in amplifiers for communications systems. Francisco focuses on design of a multi-band amplifier that results in a "circuit of the communications system ... [that] utilizes the space efficiently, and is inexpensive and reliable." EX1005, 1:62-67. JP466 focuses on an amplifier *module* that is stable with a form that is significantly smaller than

conventional approaches. EX1006, (56) Abstract. Thus, both Francisco and JP466 are in the fields of wireless communications system, and more narrowly the design of amplifiers. Additionally, they are both focused on size efficiency, they do so in two complimentary ways: Francisco via an innovative multi-band low noise amplifier, and JP466 via the design of modules with higher dielectric constant thereby reducing wavelength and size of the module. EX1006 at [0022] (“[T]he effective wavelength [] becomes shorter as the relative dielectric constant ... becomes higher. ... [T]he pattern length of the conductor pattern can be made shorter than a conventional one. This allows a ... module with ... smaller external form to be obtained.”), [0080] (“A polyvinyl benzyl ether compound may be used as the **organic resin material**.” (emphasis added)), [0081] (“It is preferable to use a polyvinyl benzyl ether compound with relative dielectric constant in the range 2.5 to 3.5 and a dielectric loss tangent in the range 0.0025 to 0.005.”).

68. To form the amplifier of JP466, a dielectric substrate is used and its semiconductor amplifying element such as a FET is mounted directly on the substrate, while passive components such as “a matching circuit...[and] part of an FET bias circuit (resistor, capacitor)...and the like, are arranged on each layer of the dielectric substrate.” EX1006 (JP466), [0006]. Fig. 5 is illustrative:

**EX1006, Fig. 5**

69. The substrate, by using a dielectric material having a high relative permittivity ϵ_r , obtains an amplification module in which the length of the conductor pattern is reduced and the outer shape of the dielectric substrate is reduced and electromagnetic coupling between patterns is suppressed. EX1006 (JP466), [0018]-[0022]. The dielectric substrate (1) includes multiple, stacked dielectric substrates (11 to 15), which are also referred to as “layer[s].” EX1006 (JP466), [0006], [0051]-[0053], FIG. 5. Passive circuit components such as resistors, capacitors, and other impedance elements may be mounted or formed as conductor patterns on the surface of dielectric substrates/layers 11 to 15. EX1006 (JP466), [0053]. For example, conductor patterns for portions of capacitors (e.g., C1, C3) may be formed on a dielectric substrate 13. *See* EX1006 (JP466), [0054]-[0055], FIGs. 5-7. Likewise, strip lines form inductors (e.g., L4, L5, L6) on dielectric substrate 15. *See* EX1006 (JP466), [0057], FIGs. 5, 9. In other words, the passive components, or portions thereof, are formed embedded within the substrate 1 on conductive (metal) layers.

70. Further, a POSITA would understand that parallel plates can be used to form a capacitor, and the capacitance is given by $C = \epsilon_r \epsilon_0 \frac{A}{d}$, where A is the area of the plates, d is the distance between plates, ϵ_0 is the permittivity of vacuum, and ϵ_r is the relative permittivity that JP466 teaches to increase. Thus, by increasing the relative permittivity, the ability to make a capacitor with smaller plates is achieved. If the permittivity is 3.0 (e.g., using organic material as taught by JP466) as opposed to 1.0 (air or foam), then the area of the capacitor can be reduced by a factor of three as without change the capacitance. This noted by JP466 at [0088] when it is taught to form a capacitor by “forming a capacitor electrode **between** the layers of the first ... to fourth dielectric substrates”

3. Reasons to Combine Francisco and JP466

71. A POSITA would have been motivated to combine the teachings of Francisco, which is silent as to the physical implementation of its amplifier circuits and architecture, with JP466’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 have been motivated to combine the teachings of Francisco and JP466 to produce the obvious, beneficial, and predictable results of utilizing JP466’s teachings of substrates having high dielectric constant and embedded passive components to form a module implementing Francisco’s amplifier circuit.

Said differently, a POSITA would have been motivated to implement the multi-band amplifier circuits of Francisco using the package techniques taught in JP466.

72. Francisco and JP466 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; EX1005 (Francisco), 1:11-25; EX1006 (JP466), [0003]. In particular, each of Francisco, JP466 and the '914 Patent are directed to configurations of an amplifier component of such an RF device. EX1001, 2:14-16; EX1006 (JP466), [0003]; EX1005 (Francisco), 1:5-61. Further, Francisco and JP466 are analogous art because each is directed to a same problem faced by the '914 Patent's inventor—decreasing the size of RF devices. EX1006 (JP466), [0007]-[0016]; EX1005 (Francisco), 1:42-46; EX1001 ('914 Patent), 1:58-62. And a POSITA would have been motivated to combine the teachings of Francisco and JP466 for multiple reasons, as discussed below.

73. **First**, Francisco's amplifier is intended to be used in a system such as a mobile phone. Thus, a POSITA is faced with design question of implementation of Francisco's circuit to provide its circuit components and their interconnections for such an application. Due to Francisco's silence, a POSITA would turn to substantially similar circuits and their implementation to provide Francisco's amplifier circuit. In particular, as I discussed above in Section V.C., implementing

components as a module was a common method of implementation of a circuit or portion thereof. 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 discussed above. In doing so, providing Francisco’s component(s) as a module based on a substrate was a common, well-known implementation method of such a circuit. JP466 provides an example of such as a “module” in the context of an amplifier. JP466, Title, Abstract.

74. Further, providing communication circuits as a module was a common technique to recognize the benefits provided by the substrate. In particular, providing Francisco’s components as a module such as in JP466 allows for embedding of passives in a substrate with many layers, which means an area savings is achieved versus having to form all components on one layer. Further, the electrical performance of the components will correspond to the properties defined by the substrate. The increased dielectric constant means capacitors (e.g., stripline or plate) and inductors (e.g., stripline) have smaller area. The electromagnetic fields that go through the substrate are less likely to be altered by foreign material such as dust, humidity changes, etc., when the passive devices are embedded in the substrate as opposed to being mounted on the substrate as discrete surface-mount

devices (SMDs). 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.

75. **Second**, a POSITA would have been motivated to implement JP466's module, along with its teachings of embedding the passive components (such as inductors and capacitors) within its substrate, in order to recognize a benefit of reducing device size. EX1006 (JP466), [0011], [0014], [0094]. There was a well-recognized motivation to decrease the size of the circuit, as well as the components thereof, when implementing an RF device. EX1006 (JP466), [0007], EX1005 (Francisco), 1:41-46. 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.")). As Francisco's amplifier includes multiple passive components, a POSITA would recognize that providing these components within the substrate of a module, as taught by JP466, reduces the need for separate, discrete passive components, which would take up additional area on the system board. Importantly, to achieve the benefits of the higher dielectric constant substrate taught by JP466, the passive components must be embedded in the substrate so their electric fields are formed in the substrate rather

than some other material such as air that surrounds the module and has relative permittivity of 1.0. 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.

76. A POSITA would also recognize a benefit of implementing JP466's teachings allow for a reduction in device size and passive component size. By forming a passive component of an inductor embedded in a dielectric substrate, JP466 teaches the length of an inductor (which it refers to as pattern length), and thus its size, is decreased. EX1006 (JP466), [0064]. This is because, within the substrate, a higher relative permittivity ϵ_r material adjacent to the inductor allows it to be made smaller than, for example, a surface mount inductor. EX1006 (JP466), [0011]. 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 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, can store more energy in the form of an electric field. JP466, [0064], [0070], [0075].

77. A POSITA understands permittivity also determines the speed of propagation of electromagnetic waves in a medium ($v = \frac{1}{\sqrt{\mu\epsilon}} = c/\sqrt{\mu_r\epsilon_r}$). As the permittivity increases, the speed of the wave slows, yet the frequency is the same. Necessarily the wavelength is thus shorter. Thus, when implementing passive devices such as capacitors and inductors with quarter-wavelength strips, the size becomes smaller because the wavelength is shorter because the permittivity is higher because the dielectric constant is higher as JP466 prescribes. JP466, [0019].

³ 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.

78. **Third**, a POSITA would have been motivated to implement JP466's teachings and the configuration of the passive components embedded therein for benefits in the electrical performance of the device. As discussed above, JP466's substrate provides a high dielectric constant material surrounding the passive components, which provides for shorter wavelength and higher energy storage, both benefits to implementation of certain passive components. This can provide a benefit of smaller passive components.

79. JP466 teaches that the shorter conductive striplines that form the passive component prevent the signal from "leaking out," i.e., radiating from the striplines as with an antenna. A POSITA would recognize that unintentional radiation from striplines is not desirable at least because there is a loss of energy, loss of signal quality, and such unintentional radiation is limited by regulatory bodies and may cause the product to fail regulatory rules. See EX1006 at [0063].

80. JP466 recognizes that its suggested configuration can allow for prevention of standing waves. See EX1006 (JP466), [0066] preventing standing wave). These standing waves are prevented by making the module smaller which is aided by the multiple layers of substrate and higher dielectric constant.

81. Further, the embedding of components within JP466's substrate material makes it possible for a "high Q value [to] be acquired." A high Q value means lower losses and better high frequency performance. See, e.g., EX1006

(JP466), [0080]. JP466 specifically teaches the use of an organic substrate that has a low loss tangent. This means that signal loss due to resistance is low. JP466, [0080-81] (“It is preferable to use a polyvinyl benzyl ether compound” “as the organic resin material” “with a relative dielectric constant in the range of 2.5 to 3.5 and a **dielectric loss tangent in the range of 0.0025 to 0.005.**” For example, a POSITA would recognize that to have a high Q inductor, the resistance within the inductor must be low, and a low loss tangent correspond to low resistance. In other words, a high Q value means as lower losses and better high frequency performance.

82. And further, embedding passive components as taught by JP466 allows for benefits to the system design process by reducing variables that would otherwise arise from interfaces with discrete components. The system assembly of discrete components 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.

83. Further, there is an additional benefit to the shorter wavelengths achieved by embedding passives in a high dielectric substrate. Since component sizes are smaller, there is less possibility for a trace to a passive to act as an

antenna and thereby unintentionally receive undesired radiation from the environment which would then be injected as noise into the circuit.

84. **Fourth**, a POSITA would have been motivated to implement JP466's teachings to achieve the benefits of the quality and reliability of JP466's substrate material. JP466 teaches its substrate "[u]nlike conventional ones formed using ceramic material...is less prone to cracking and layer delamination during processing and has superior mechanical strength, and thus has superior reliability as a product. In addition, such a dielectric substrate is convenient for forming a capacitor since an insulating resistor between layers is not degraded by cracking." EX1006 (JP466), [0026], [0079]. Dielectric materials in a substrate also provide recognized benefits such as weight. See, e.g., EX1028 (US Appl 2004/0113719) illustrating resin substrates, dual band VCO, substrate advantages of resin being lighter [0099].

85. In summary, a POSITA would have been motivated to apply JP466's teachings when implementing Francisco's amplifier because doing so would beneficially (1) provide details as to the implementation of Francisco's circuit suitable for its intended use in a communication system as an integrated module comprising Francisco's amplifier circuit; (2) provide benefits to the size of Francisco's amplifier circuit via use of multiple layers in the module with a substrate with high dielectric constant; (3) provide benefits with respect to

electrical performance such as (a) low noise and signal loss via the use of an organic dielectric substrate with low resistivity (low loss tangent); and (b) enhanced energy storage in electric fields; and (4) provide a robust module with a substrate that avoids delamination and cracking issues.

86. The results of combining Francisco's device with JP466's substrate would have been predictable and had a reasonable expectation of success given both Francisco and JP466 relate to substantially similar device types performing the substantially same function. Each device includes an amplifier circuit with a central device of a FET or the like, a matching circuit, a drain bias circuit, a gate bias circuit, etc., forming a circuit block. JP466, [0003], Francisco, FIG. 3, 4.

87. Further, Francisco's teaching of the dual band circuitry is clearly specified. Francisco's low noise amplifier is constructed from the same types of components used by JP466's amplifier, i.e., capacitors, inductors, transistors. Compare JP466 at Figures 2 and 3 with Francisco's low noise amplifier at Figure 3. Thus, the JP466 teaches the exact types of components needed to implement Francisco's low noise amplifier. Further, the results are predictable because JP466's module is designed with a substrate that was selected for high frequency applications.

88. Additionally, JP466 describes an amplifier implemented as a power amplifier, which means there is more thermal energy to dissipate relative to

implementation as a low-noise amplifier. When using Francisco's low noise amplifier, there will be less power to dissipate, which means there will be no issues with power dissipation. This indicates there will be predictable performance with respect to thermal issues.

89. Both JP466 and Francisco teach the use of a field effect transistor (FET) as the transistor in the amplifier. The use of the same type of transistor makes the performance of the combination predictable. Both JP466 and Francisco mention processing waves of similar frequency, e.g., 900 MHz and 1,800 MHz. See JP466 at [0015], [0018], and [0019]; see Francisco at Figure 2 showing 800 MHz and 1,900 MHz frequency bands. Thus, the fact that the circuits can operate on signals in the same frequency ranges also makes the combination predictable.

90. Moreover, such applying JP466's techniques related to a substrate for RF devices including embedding passives in a dielectric material 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]; EX1037, (JP315) using organic substrates for passive components, FIG. 3, [0037], [0058], [0016], Fig. 3; EX1012, Chapter 11, discussing embedded passives.

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:*

91. Francisco discloses this limitation.

92. As discussed above, Francisco introduces a communication system 100, which in an embodiment is a portable radiotelephone for wireless communications over multiple frequency bands (i.e., multi-band). EX1005 (Francisco), 2:19-26, 1:14-16. The communication system 100 includes an antenna 129 coupled with transmitter 101 and receiver 151, each of which includes components of filters, oscillators, switches, and amplifiers to effectuate the processing of RF signals at multiple bands. EX1005 (Francisco), 2:48-49, 2:63-3:55, FIG. 1.

93. This is a largely standard configuration of conventional transceiver building blocks as discussed in V.B. For example, to the left of amplifiers 115 and 155 in FIG. 1, duplexers are used to allow simultaneous transmission and reception using a single antenna. Duplexers contain frequency-selective filters that direct signals based on their frequency. The duplexer configuration at left of the amplifiers directs radio frequency signals between the receiver, transmitter, and antenna based on frequency. For example, FIG. 2 shows a band for cellular transmit and receiver near 850 MHz as well as PCS transmit and receiver near 1,900 MHz. These duplexers couple the antenna to the transmit and receive channels at the proper frequencies. The duplexer structure is not the focus of the invention of Francisco.

94. In FIG. 1 to the right of amplifiers 115 and 155 are also conventional

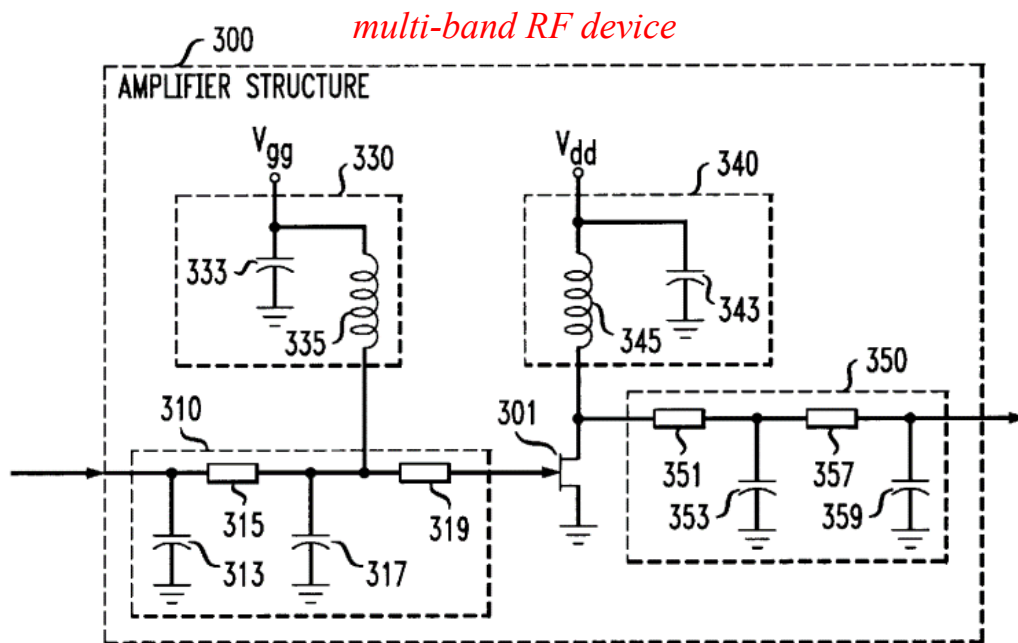
processing components. For example, to the right of LNA 115, there is a switch that directs the received signal to one of two bandpass filters 159 or 173 based on whether the received signal corresponds to the “Cellular” or “PCS” bands, which are two different frequencies. That is followed by a mixer 175 that frequency-shifts the received signal to a lower frequency, which is followed by additional filter at 179 and 183 that is also based on whether the received signal is Cellular or PCS. Traditional demodulating follows. Conventional processing also occurs to the right of power amplifier 115. This processing to the right of amplifiers 155 and 115 is also not the focus of Francisco. Francisco discloses a frequency source 161, an oscillator, which can generate two output frequencies, i.e., a frequency for use when transmitting or receiving in the Cellular band and another frequency for use when transmitting or receiving in the PCS bands. This is achieved by using a frequency double 165. Thus, two frequencies are generated and presented at the inputs two switch 167. Francisco focus, however, is the architecture of amplifiers including both low noise (e.g., unit 155) and power (e.g., unit 115) amplifiers that have multi-band capabilities.

95. Francisco’s system 100 operates “over **a first set of frequency bands pursuant to the AMPS cellular standard**, and a **second set of frequency bands for personal communications system (PCS) use.**” EX1005 (Francisco), 2:20-26. *See also*, EX1005 (Francisco), FIG. 2, 2:27-47. These specific frequency bands are

exemplary and not limited by Francisco. EX1005 (Francisco), 7:45-52. Thus, Francisco teaches a system, and RF devices therein (such as the amplifier) as discussed below, *operable at a first frequency band* (e.g., cellular, ~800 MHz) and *a second frequency band* (e.g., PCS, ~1800MHz), which is *different from the first frequency band*. EX1005 (Francisco), 1:10-25.

96. 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 *Wiley Electrical and Electronics Dictionary* at radio frequency, RF, and radio spectrum. Francisco's teachings of the use of 0.9 GHz and 1.9 GHz are thus within the radio frequency spectrum.

97. The amplifier structure 300 of FIG. 3, which as discussed below is implemented in the system 100 in both the transmit and receive paths, receives and processes signals of these multiple bands and as such is *a multi-band RF device*. Francisco (EX1005), 5:23-28.



EX1005, FIG. 3
(annotated)

See also, EX1005 (Francisco), FIG. 4 (“a multi-band amplifier structure comprising a concatenation of circuits of FIG. 3”) that increases the gain of the amplifier structure; 6:66-7:4.

98. One instance where the amplifier structure 300 provides a *multi-band RF device* is as low noise amplifier (LNA) 155 in the receive path of the system 100, and a second instance of the amplifier structure 300 providing a *multi-band RF device* is as a power amplifier 115 in the transmit path of the system 100. A POSITA understands that low-noise amplifiers, such as Francisco’s LNA 155, and power amplifiers, such as Francisco’s PA 115, are typically used on the receive and transmit sides of transceivers, respectively. Both types of amplifiers perform a

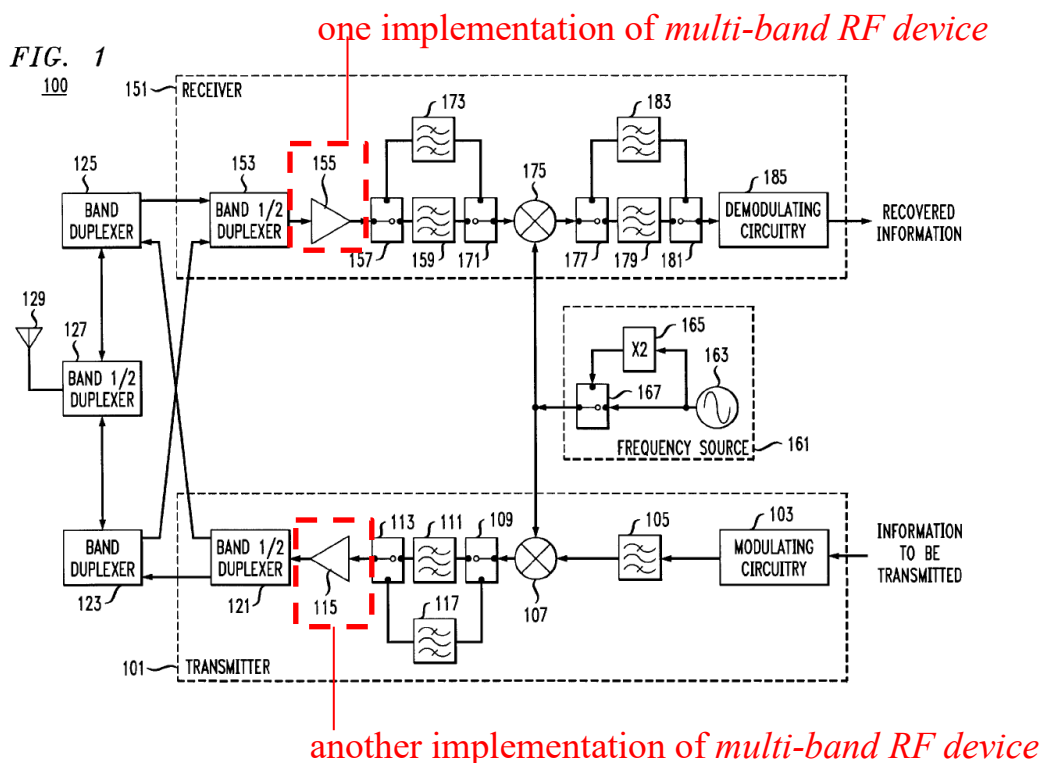
similar function, just in different places in the signal chain and have different values of components to emphasize different aspects, for example noise minimization in the LNA and gain maximization in the power amplifier. Likewise each type of amplifier may be designed to reject different types of signals as well. For example, the LNA may have its components selected to reject out-of-band signals received at the antenna, while the power amplifier may be designed to reject unwanted harmonics or images generated in the transmit processing itself.

99. Francisco recognizes “[a]lthough the values of the components may vary according to their specific applications, the structures of amplifiers 115 and 155 are similar.” EX1005 (Francisco), 5:23-29. *See also*, EX1005 (Francisco), 5:66-6:3. In each configuration, the amplifier operates to achieve a designed gain to signals in *first and second frequency band[s]* and thus, is a *multi-band RF device*.

100. Francisco explains that “unlike a prior art power amplifier which provides a desired gain to a signal within only a particular transmit band, amplifier 115 provides, in an efficient manner, a **desired gain to a signal within any one of the many discrete transmit bands.**” EX1005 (Francisco), 3:56-62. Similarly, “the received signal, either a cellular receive signal or PCS receive signal, [is delivered] to multi-band low-noise amplifier (LNA) 155.” EX1005 (Francisco), 4:48-51. An amplifier is the same device as described in ’914 Patent as one

example of a “multi-band RF device.” See EX1001, dependent claim 4, 2:14-16 (“low noise amplifier”), see also, 23:60-24:36.

101. FIG. 1 is illustrative of the system implementation of *multi-band RF device[s]*:



See also, EX1005 (Francisco), 3:36-55.

102. Francisco explains the benefits of using each amplifier to produce signal gain at multiple bands is reduction in components in the multi-band system. “[A]mplifier 115 replaces two prior art power amplifiers which would otherwise be employed to handle signals within cellular Xmt band 201 and PCS Xmt band 205 separately. Advantageously, with multi-band power amplifier 115, the circuit of

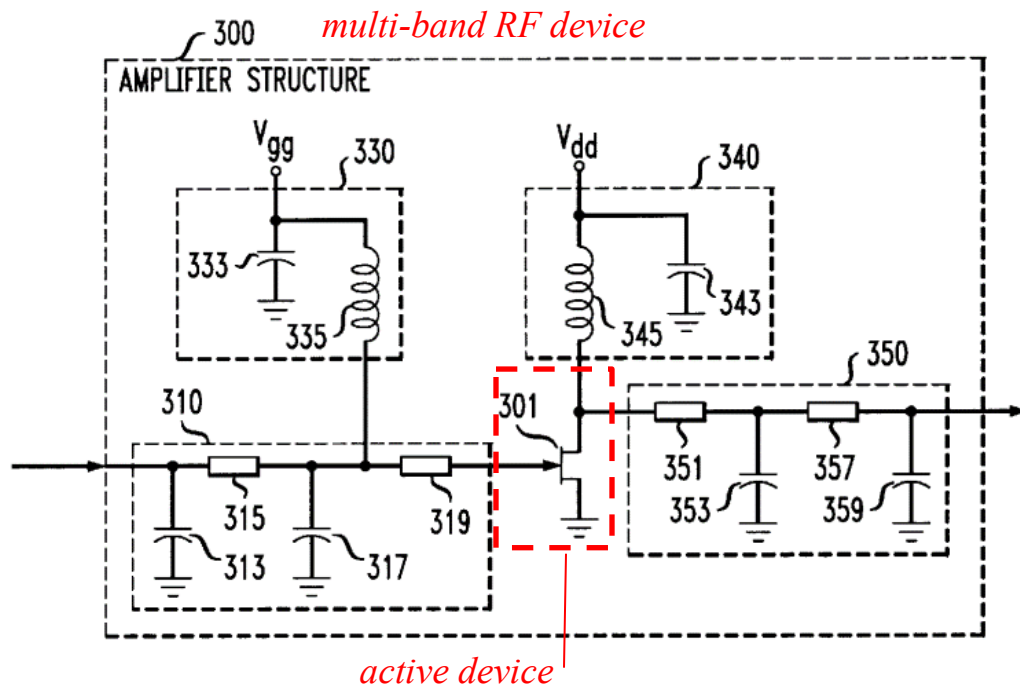
the system 100, with respect to its prior art counterpart, is less expensive and bulky, and more reliable due to the use of at least fewer power amplifiers.”

EX1005 (Francisco), 3:62-4:2. “Like amplifier 115, LNA 155 replaces two prior art LNAs which would otherwise be employed to handle cellular receive signals and PCS receive signals separately.” EX1005 (Francisco), 4:43-46. This is the same advantage recognized by the ’914 Patent. *See* EX1001, 2:8-16 (“in certain circumstances, can be reused at different frequency ranges, thereby reducing the number of components required.”)

103. Thus, Francisco teaches the *multi-band RF device* of [1.0].

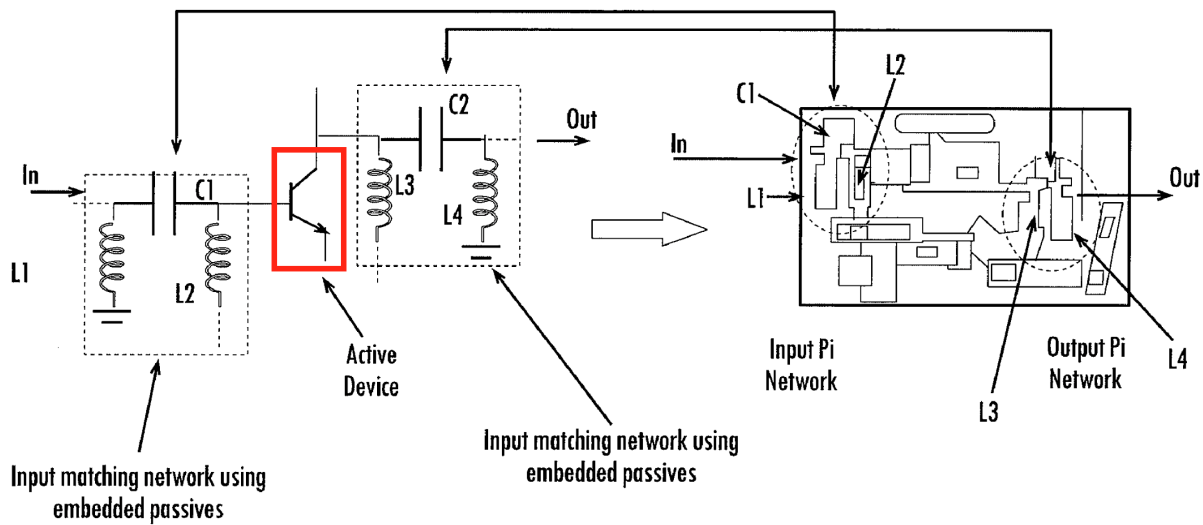
[1.1] *an active device*;

104. As discussed above, the amplifier structure 300 of Francisco illustrates the *multi-band RF device* and it includes a transistor (field effect transistor (FET) 301), which is *an active device*. “As shown in FIG. 3, central to amplifier structure 300 is **field effect transistor (FET) 301**.” EX1005 (Francisco), 5:30-31. The transistor in Francisco’s Figure 3 is shown as a field effect transistor (FET). The unit 301 uses a symbol for a FET, as a POSITA would readily recognize.



EX1005, FIG. 3
(annotated)

105. This configuration of an active device is the same as recognized in the '914 Patent. EX1001 ('914 Patent), 27:20-21 ("wherein the active device is a field effect transistor"). Namely, the '914 Patent teaches the use of a transistor as the active device. FIG. 35 of the '914 Patent reaches the use of an LNA as the "active device" position with matching circuits at its input and output.

**Fig. 35**

EX1001 ('914 Patent) at FIG 35.

106. The transistor shown in '914 Patent's Figure 35 is a bipolar junction transistor (BJT). A BJT is a commonly used type of transistor. Another commonly used transistor type is the field-effect transistor ("FET"). The '914 Patent specifically claims a "field effect transistor" as a type of active device that is within the bounds of certain claims of the '914 Patent. Claim 12 of the '914 Patent depends on claim 1 and specifies that the "active device is a field effect transistor". '914 Patent, 27:20-21.

107. In FIG. 3 of Francisco, the source terminal (bottom of transistor 301) is connected to ground. The gate is connected to an input matching network 310. There is a gate bias circuit 330. 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 Francisco patent that there is a “gate bias circuit 330” which a POSITA would know contributes to setting the operating point of the transistor. The “input matching circuit 310” is then “coupled” to the gate as well to allow a small alternating signal to be applied to the gate. Likewise, the drain terminal (top of transistor 301) is connected to a drain bias circuit 340 which contributes to setting the operating point of the transistor, and the output matching circuit 350 also connects to the drain.

108. Said differently, the operating point of the transistor is set by (a) the gate bias circuit 330; (b) connection of the transistor’s source terminal to ground; and (c) the drain bias circuit 340. A small signal from matching network 310 is then coupled into the gate. The transistor amplifies the small signal. The amplified small signal appears at the drain of the transistor which is coupled to output matching circuit 350.

109. Finally, a POSITA would understand the transistor of Francisco is an *active device*. The ’914 Patent provides one example of an “active device” but of a transistor. The purpose of the transistor in Francisco, like the ’914 Patent, is to introduce gain. The purpose of biasing the transistor in Figure 3 of Francisco 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 Francisco is an active device because it is a transistor that is introducing gain and amplifying the signal that is input from the input matching network 310 and the transistor is providing an amplified version of that signal at the drain (output) which is connected to the input of output matching network 350. Just as in the '914 Patent. See above at VI.A.

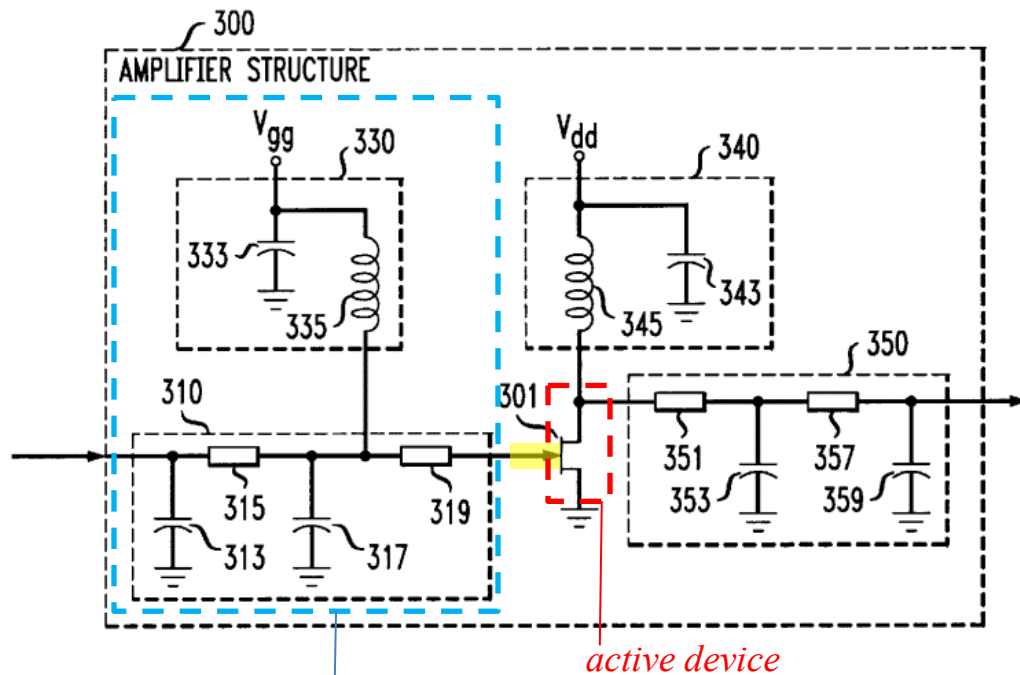
110. Thus, Francisco teaches *an active device* of [1.1].

[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;*

111. Francisco teaches its *RF multi-band device* as illustrated by amplifier structure 300 includes *a first passive network* as recited in this element.

112. Francisco describes an “input matching network 310” and coupled “gate bias circuit 330” that together provide *a first passive network*. EX1005 (Francisco), FIG. 3, 5:31-40. This is the same 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. The *active device* of Francisco, FET, also performs the same function of receiving a signal input received from a matching network (e.g., input matching network 310), producing

gain and amplifying the signal, which is output to another matching network (e.g., output matching network 350).



first passive network

**EX1005, FIG. 3
(annotated)**

113. The input matching network 310 and gate bias circuit 330, together the *first passive network*, is *in communication* with the FET 301, *active device*. In particular, the matching network 310 is connected to one of the FET terminals (i.e., the gate). EX1005 (Francisco), FIG. 3, 5:32-34 (“**gate terminal** [of FET 301] **connected to input matching network 310** coupled to **gate bias circuit 330**.”), 5:44-45 (“[t]ransmission line 319 connects both capacitor 317 [component of matching network 310] and circuit 330 to the gate terminal of transistor 301.”) This connection is for *communication* of a signal to the FET 301.

114. Francisco's *first passive network* comprises a *first matching network* of at least "input matching network 310." A matching network, such as in Francisco's amplifier structure 300, refers to an impedance matching network. EX1005, 1:53-56; EX1001, 24:11-14. And this is the exact functionality of Francisco's "input matching network 310," which "provides an optimum input **impedance match** over the multiple bands of interest (in this instance the cellular and PCS transmit bands for amplifier 115, or the cellular and PCS receive bands for LNA 155)." EX1005 (Francisco), 6:57-61. *See also*, EX1005 (Francisco), 5:65-6:65 discussing the values of the passive networks for application as LNA 155 and power amplifier 115.

115. The *first passive network*, including the gate bias circuit 330 and matching network 310, is *at an input of the active device* illustrated (1) by the arrow highlighted in FIG. 3 above providing connection to the gate terminal of the active device without intervening components, (2) by Francisco's description of the network as an "**input** matching network," and (3) by a POSITA's understanding of functionality of this network in the context of an amplifier, which I discuss below.

116. As I discussed above, the gate of the central component, the FET (*active device*) is connected to an input matching network 310 and a gate bias circuit 330. 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 Francisco patent that there is a “gate bias circuit 330,” which a POSITA recognizes contributes to setting the operating point of the transistor 301. The input matching circuit 310 is coupled at the gate of the FET 301, as well to allow a small alternating signal to be applied to the gate. Likewise, the drain of FET 301 is connected to a drain bias circuit 340, which contributes to setting the operating point of the transistor, and the output matching circuit 350 also connects to the drain. Providing circuitry to bias a transistor to an operational or quiescent point has been a fundamental topic in undergraduate in electrical engineering courses since at least the 1990s.

117. This is the same as in FIG. 35 of the '914 Patent. The '914 Patent does not illustrate the bias network. See, e.g., EX1001 at 20:23-24 (“For simplicity, the bias and decoupling circuitry are not shown in FIG. 21.”); 23:13-14 (“The bias network is not shown for simplicity.”).

118. 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. Consistent with the understanding of a

POSITA, the '914 Patent identifies capacitors, inductors and resistors as “passives.” EX1001, '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. Francisco likewise teaches the use of capacitors and inductors in a network in bias and matching circuitry of amplifier 300. EX1005 (Francisco), FIG. 3, 5:30-64.

119. Francisco teaches that the values of passives in the amplifier structure 300 including those of the *first passive network* are set differently when implemented as a multi-band LNA than as a power amplifier. See, Francisco, 5:65 – 6:65.

120. More specifically when implemented as the LNA 155, the input matching network 310 is taught to be synthesized using well-known techniques in the field such that “the source impedance of band half-duplexer 153” is transformed to “ Γ_{OPT} .” In the field and in this context, Γ is used to represent a reflection coefficient. The reflection coefficient is a key parameter 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. Francisco suggests that the input matching circuit 310 should be set such that an optimal reflection coefficient is achieved. Specifically, Francisco says the input matching circuit “transform[s]”

the “source impedance” such that an optimal reflection coefficient is achieved. The value Γ_{OPT} “represents the source reflection coefficient **giving the minimum noise in Rcv bands 203 and 207.**” Francisco, 6:1-9. Francisco also teaches that this optimal reflection coefficient is “provided by the manufacturer of transistor 301.” Francisco, 6:6-7.

121. A POSITA would understand that minimizing noise and maximizing power transfer are two different conditions. When the goal is to maximize power transfer, a *first passive network* with an input matching network having impedance that is the conjugate of the source impedance is optimal. However, when the goal is noise minimization, other impedance matching techniques are used for the first passive network. This is discussed further in [1.4b].

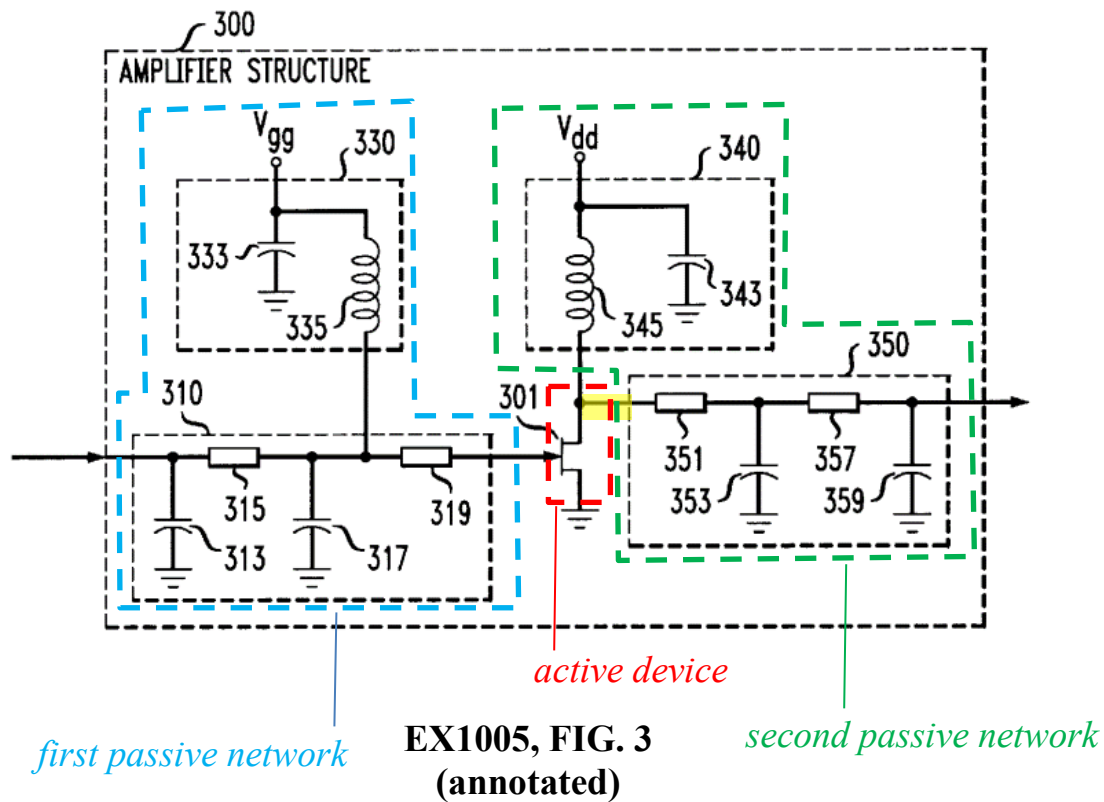
122. Thus, Francisco teaches the *first passive network* of [1.2].

[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

123. Francisco’s amplifier structure 300, *an RF multi-band device*, includes a second passive network as recited in this element.

124. Francisco describes a “drain bias circuit 340” and “output matching circuit 350” that together provide a *second passive network*. EX1005 (Francisco), FIG. 3, 5:34-36. This is the same configuration of a passive network, a matching network comprising inductors and capacitors and providing matching functionality,

as provided in the '914 Patent's exemplary embodiment of an amplifier as an RF device. EX1001, Fig. 35, 24:20-35.



125. The *second passive network*, including drain bias circuit 340 and output matching circuit 350, is *in communication* with the *active device* of [1.1], FET 301. EX1005 (Francisco), 5:34-36 (“The drain terminal of the transistor [FET 301] is **connected** to drain bias circuit 340 and also to output matching network 350.” EX1005 (Francisco), 5:58-59 (“[t]ransmission line 351 in network 350 **connects** the drain terminal of transistor 301 to capacitor 353 [of output matching network 350].”) This connection is for *communication* of a signal from the FET

301.

126. The *second passive network* comprises output matching circuit 350, which is a *second matching network*. Just as described in [1.2], Francisco describes “output matching network 350 provides an **optimum output impedance match** over the same bands [e.g., cellular and PCS]” and thus, provides a *second matching network*. See EX1005 (Francisco), 6:61-65, 5:65-6:65, EX1001, 24:11-14.

127. Francisco’s *second passive network* of the drain bias circuit 340 and output matching network 350 is *at an output of the active device* (FET 301) as illustrated (1) by the yellow highlighted interconnection above in FIG. 3 from the drain terminal of the FET 301 without intervening components, (2) by Francisco’s description of the network as an “**output** matching network,” and (3) by a POSITA’s understanding of functionality of this network in the context of an amplifier, which I discuss below.

128. As I discuss in [1.2], the drain of the active device, FET, is connected to a drain bias circuit 340 which contributes to setting the operating point of the transistor, and the output matching circuit 350 also connects to the drain. The amplified small signal appears at the drain of the transistor, FET 301, which is coupled to output matching circuit 350. 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.

129. Said differently, the *second matching network* of Francisco has an input impedance that matches the output impedance of the active device (FET). The matching network transforms the impedance that would otherwise be presented by the next network component, switch 157, to an impedance matched to the output of the transistor thereby maximizing power transfer. EX1005 (Francisco), 6:12-20 (“Output matching network 350 in LNA 155 is synthesized such that the load impedance (Z_{L155}) at band switch 157 presented to transistor 301 is transformed according to the following expression $Z_{L155} = Z_{output}^*$ where Z_{output}^* represents the complex conjugate of the output impedance of transistor 301.... Again, the values of the individual components within network 350 to realize such a transformation can be readily determined by well-known methods”).

130. FIG. 3 of Francisco also shows transmission lines such as units 315, 319, 351, and 357. These components are used as part of the input and output matching circuits, respectively. Transmission lines may be used to connect other components such as inductors and capacitors. Transmission lines exhibit impedances themselves in that they have resistance. Transmission lines are passive devices in that they only dissipate, store, and/or transfer energy.

131. Thus, Francisco 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,*

132. Francisco in combination with JP466 discloses this element.

133. Francisco suggests that its amplifier structure 300, *RF multi-band device*, be implemented in a system that provides multi-band functionality for “radiotelephones.” EX1005 (Francisco), 1:25-45. The common way of providing circuit components is on a substrate that is mounted in the radiotelephone, commonly referred to as cell phone or mobile phone. I discuss this above in the reasons to combine including that providing the amplifier as a module was a known technique. And as also discussed in the reasons to combine above, a POSITA would have reason to turn to the teachings of JP466, which describes a similar circuit, to implement the circuits of Francisco.

134. Just like Francisco, JP466 teaches an amplifier with an active device in communication with passive networks at its input and output. JP466 also teaches an implementation of an amplifier in the form of a module including passive networks in communication with the active device (e.g., a FET). And JP466 details implementing the amplifier using a dielectric substrate, which includes multiple, stacked layers, where passive components of the amplifier are provided on metal layers embedded within its substrate.

To create a power amplifying module with the circuit configuration described above using a **multi-layer dielectric substrate**, a matching circuit, a secondary harmonic countermeasures circuit, part of an FET bias circuit (resistor, capacitor), a bias circuit with a ($\lambda/4$) pattern, and

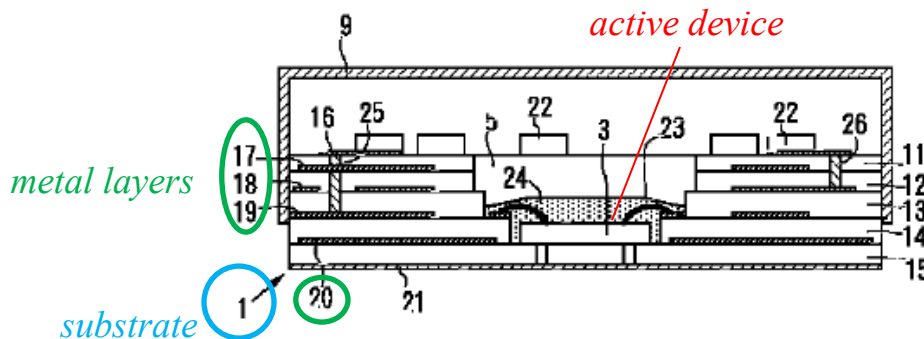
the like, are arranged on each layer of the dielectric substrate. ... An **inductance element is formed on a layer of the dielectric substrate as a conductor pattern**. The semiconductor amplifying element of FET, or the like, is mounted directly on the dielectric substrate as a bare chip, or packaged using a resin mold and then mounted on the dielectric substrate.

EX1006 (JP466), [0006]. FIG. 5 of JP466 is illustrative of a cross-sectional view of JP466's power amplifier module having a dielectric substrate 1 and an active device of semiconductor chip 3 (e.g., a FET) mounted on the substrate. The dielectric substrate 1 has a stacked configuration including first to fifth dielectric substrates/layers 11 to 15 adhered together. EX1006 (JP466), [0051]-[0052]. Each layer of substrate 1 (e.g., dielectric substrates 15-11 as illustrated) has a *metal layer*, shown by conductor patterns 20, 19, 18, 17, and 16, respectively, from bottom to top.

135. 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

136. A POSITA would readily understand that each vertically stacked layer of a “conductor pattern” of JP466 provides a *metal layer*. Use of metal as a conductor pattern was standard practice. See, e.g., EX1007 discussing copper, EX1025 NIST

pp. 7-11 including metal and copper foils to form conductors; EX1006 (JP466), Figs. 6-9); EX1037, Abstract, FIG. 3 discussing metal. Thus, JP466's dielectric substrate 1 provides *at least two metal layers*. In fact, in JP466's exemplary embodiment there appear to be six metal layers, i.e., 16, 17, 18, 19, 20, and 21.



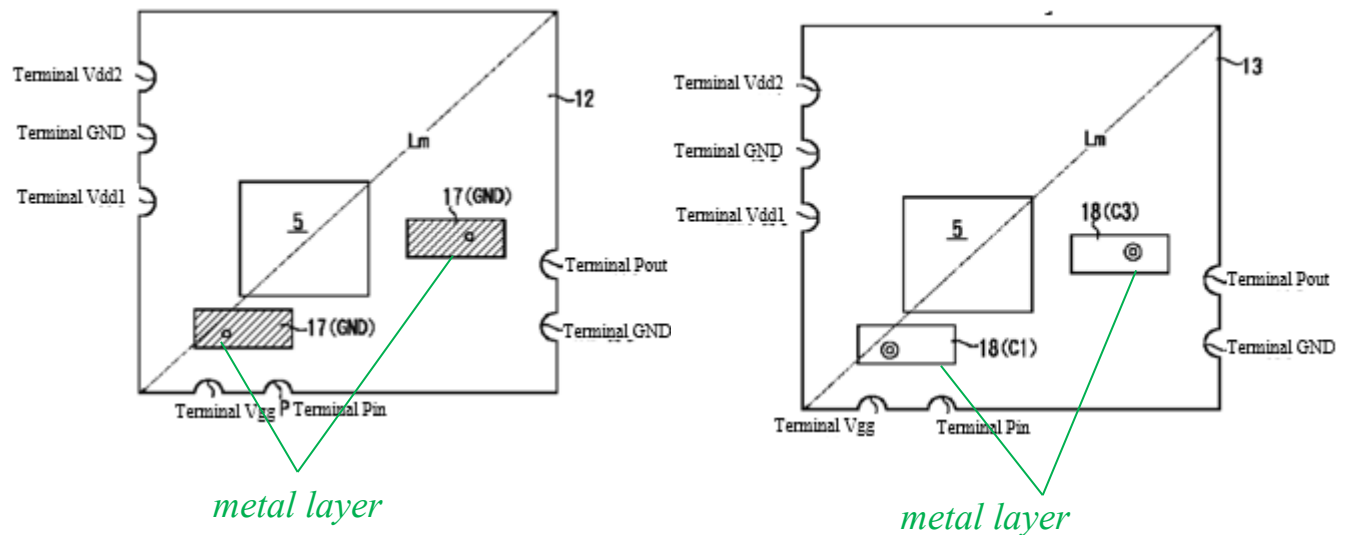
**EX1006, FIG. 5
(annotated)**

137. JP466's conductor patterns provided by these metal layers are *patterned to form at least a portion* of the passive networks of its amplifier. See, EX1006 (JP466), [0053]-[0055].

138. A POSITA would understand that these metal layers can be used to form different passive elements such as transmission lines, inductors, capacitors, and resistors. For example, see 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 stub to provide shunt capacitance, or a single gap or interdigital step of gaps can be used to form capacitors. EX1030, *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.

139. As one example of providing a passive component formed by a pattern of *at least two metal layers*, JP466 illustrates in its Fig. 7, one substrate layer (13) having conductor pattern (18) (a first metal layer). And this patterned metal layer along with conductor pattern (17) (a second metal layer) of an adjacent substrate layer (12) forms a capacitor (C1 and C3) of the amplifier's passive network.



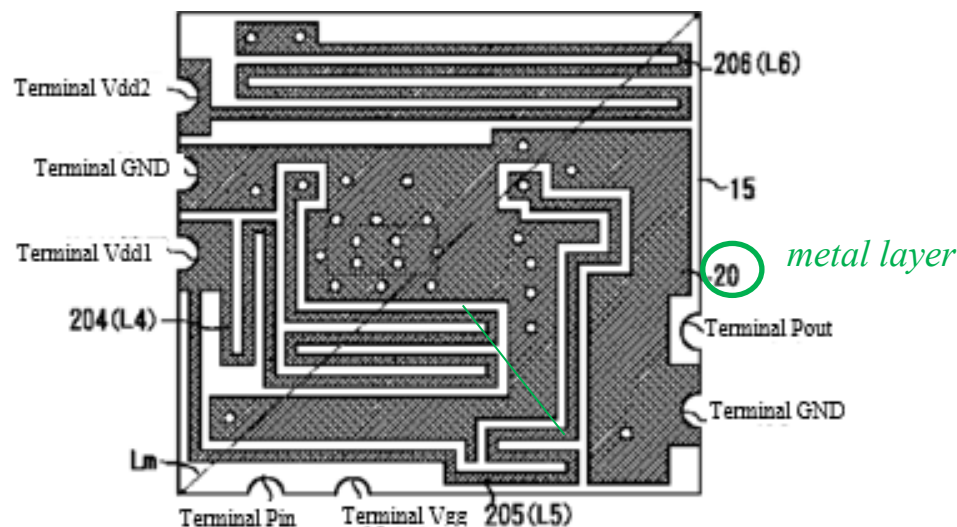
at least two metal layers patterned to form passives (capacitors)

EX1006, FIGs. 6 and 7 (annotated)

140. The *first passive network* of Francisco discussed above in [1.2] includes a similar capacitor - “[c]apacitor 313 in network 310 at one end is connected to ground, and at the other end to an input to structure 300 and transmission line 315.” EX1005 (Francisco), 5:38-40. And the *second passive network* of [1.3] also includes capacitors. EX1005 (Francisco), 8:51-64 (e.g., capacitors 343, 353, 359). Thus, a POSITA would have readily recognized forming one or more of these substantially similar passive components using Francisco’s technique.

141. As another example, JP466’s Fig. 9 illustrates a substrate layer (15) having conductor pattern (20) (*metal layer*) *patterned* into strip lines 204, 205 and

206 that form inductors (inductance elements L4, L5 and L6) of the amplifier's passive network. EX1006 (JP466), [0055], [0057].



a metal layer patterned to form a passive (inductor)

**EX1006, FIG. 9
(annotated)**

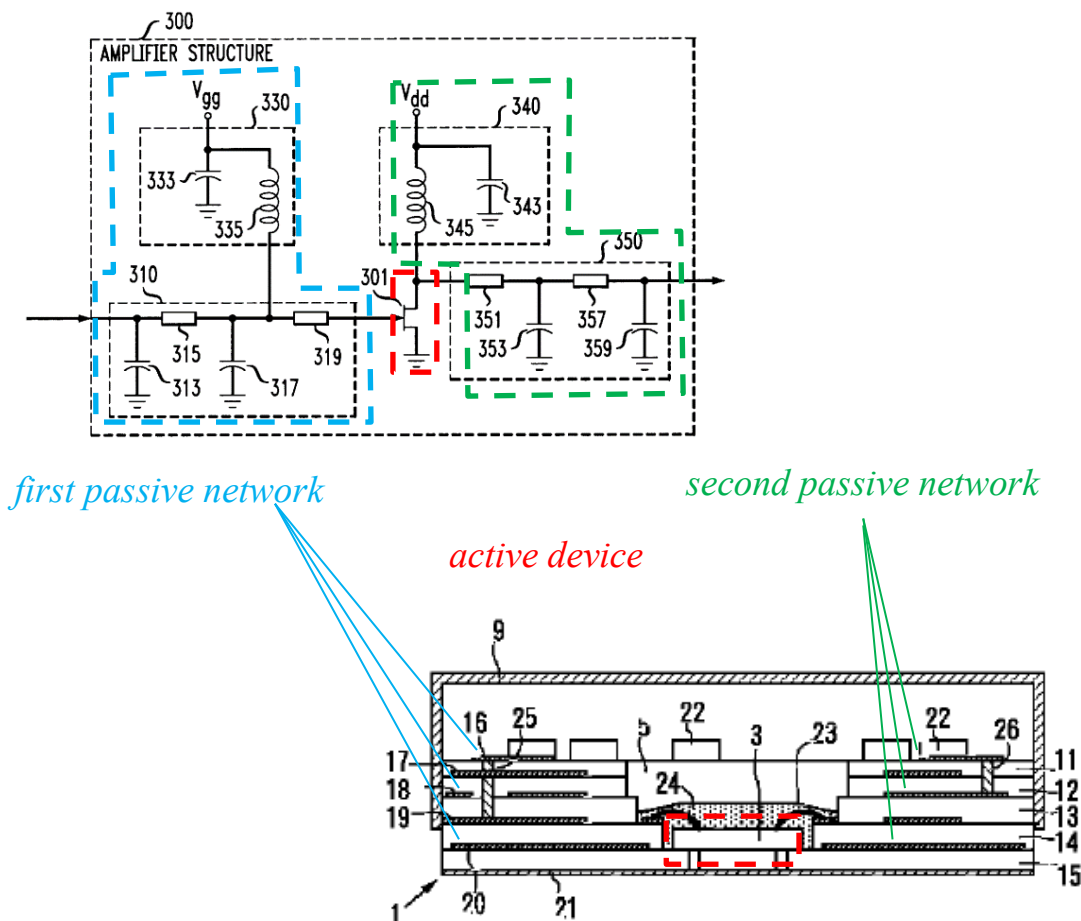
See also, EX1006 (JP466) [0093] (“When the impedance elements Z1 to Z7 (see FIG. 2) that configure the matching circuit are configured of striplines, ... the striplines 204, 205, and 206 [] configure the drain bias inductance elements L4, L5, and L6...”)

Francisco’s passive networks, see [1.2], [1.3], similarly include inductance elements such as inductor 335, 345 and transmission lines 315, 319, 351, 357. EX1005 (Francisco), 5:40-64. Thus, a POSITA would have readily recognized forming this substantially similar component using Francisco’s technique.

142. JP466 describes that these examples of patterned metal layers forming passive components are just that, non-limiting examples. EX1006 (JP466), [0053] There are no particular limitations to how the circuit components are arranged, but one possible example is shown below.”) A POSITA would recognize that one location on the dielectric substrate 1 for a component of the *first* or *second passive network* would be adjacent to the input or output of the active device respectively as the first passive network is connected to an input (gate) of the active device and the second passive network is connected to the drain for the active device. Placing the component near the respective input/output of the transistor would tend to reduce loss due to resistance, reduce exposure to noise and undesired coupling of signals, and maximize routing efficiency, as a POSITA would realize. Similarly, the use of varying layers of metal (e.g., at least two layers) was also a known design technique. 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. POSITA would recognize that each of the passive networks of Francisco are readily formed using the metal layers. Any number of metal layers may be implemented providing additional positions for components and interconnects, while increasing vertical height.

143. In light of JP466’s teachings, POSITA would have reasons to *form at least a portion* of the *first passive network* and the *second passive network* of

Francisco, such as the capacitors and inductors of the biasing and matching networks, by providing a 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* as shown in JP466.



EX1005, FIG. 3

EX1006, FIG. 5

(annotated)

144. JP466's dielectric substrate 1 discussed above is an *organic-based substrate*. JP466 describes that “[u]nlike conventional [substrates] formed using ceramic material,” its dielectric substrate includes an “**organic resin material**.”

EX1006 (JP466), [0026], [0079]. JP466 describes an example material forming its substrate 1 of a polyvinyl benzyl ether compound. EX1006 (JP466), [0080]. A polyvinyl benzyl ether compound is an organic material. I note polyvinyl benzyl ether is a polymer made up of repeating benzyl vinyl, which has the molecular formula $C_9H_{10}O$, in a chain; $C_9H_{10}O$ being an organic material. In one example, JP466 provides a content rate of the polyvinyl benzyl ether compound (organic material) as a 70% by volume of a composite material. EX1006 (JP466), [0083]. See also, EX1007 recognizing a substrate including a mixture of ceramic on a base organic material, [0035] “The core substrate 5 is comprised of a substrate material of low dielectric constant and low $\tan\delta$, that is of superior high frequency characteristics, such as polyphenylethylene (PPE), bis maleido triazine (BT-resin), polytetrafluoroethylene (trade mark: Teflon), polyimide, liquid crystal polymer (LCP), polynorbornene (PNB), ceramics or a mixture of ceramics with an organic substrate.” This is just as discussed in the '914 Patent, discussing an LCP-based substrate also including “alternate materials include other low loss organic laminates like PPE, PTFE composites, hydrocarbon ceramic composites, BT resin composites (e.g., Speedboard C), and thermosets (e.g., Hitachi MCL-LX-67F).” EX1001, 11;1-4. Thus, JP466’s substrate is an *organic-based substrate*.

145. Moreover, the use of this organic compound is taught to provide a desired dielectric constant (relative permittivity) and low loss tangent. EX1006

(JP466) at [0080-81] (“A polyvinyl benzyl ether compound may be used as the organic resin material. ... It is preferable to use a polyvinyl benzyl ether compound with relative dielectric constant in the range 2.5 to 3.5 and a dielectric loss tangent in the range of 0.0025 to 0.005.”).

146. Thus, Francisco in combination with JP466’s teachings directed to organic substrate and formation of passive network on metal layers within that substrate, Francisco in view of JP466 renders obvious [1.4a].

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

147. Francisco teaches this element.

148. **First**, as I discussed above, Francisco’s passive networks are circuits comprising inductors (L) and capacitors (C), commonly known as LC circuits—or more generally, RLC circuits when including resistance (R). LC and RLC circuits present different impedances to signals having different frequencies.

149. As discussed in the elements above, Francisco 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], Francisco’s multi-band amplifier structure, *RF multi-band device*, is used to “scale the signal level of a signal communicated over one of multiple frequency bands.” EX1005 (Francisco), 1:50-54.

In accordance with the invention, the multi-band amplifier uses **an input network to achieve a selected input impedance**, and an **output**

network to achieve a selected output impedance. The values of the input and output impedances are selected such that the **gain values afforded** by the multi-band amplifier to the components of the communication signal within the **multiple frequency bands** are significantly higher than the gain values to the signal components outside those bands.

EX1005 (Francisco), 1:53-61. Thus, Francisco's passive networks perform the same function as the '914 Patent that 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.**"). Francisco, EX1005, 5:65-6:65, which describes in the context of its LNA implementation minimizing NF at the input and maximizing power gain at the output.

150. 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 Francisco as discussed above, it necessarily follows, under basic laws of physics, that the impedances of the passive networks at each frequency are different. More specifically, the impedance of passive components of the passive networks have frequency dependent impedances, which means the overall networks also have impedances that are functions of frequency, i.e. are different at different frequencies.

151. The first and second passive networks of Francisco each include

capacitors and inductors as discussed above in regards to passive networks 310, 320, 340, 350 of FIG. 3. 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.

152. 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.

153. 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, $X_C = 1/(\omega C) = 1/(2\pi f C)$. And inductors have reactance that is also a function

of frequency, namely, $X_L = \omega L = 2\pi fL$.⁴

154. Thus, the *first passive network* of Francisco, 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 Francisco 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., $Z_B(f2)$.

155. 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.**”)

156. **Second**, a POSITA would have had reason and motivation to select the components of the *first passive network* and the *second passive network* so that their impedances vary at different frequencies. Having different impedances of each of the first passive network and the second passive network are different at

⁴ These facts are taught in introductory electrical engineering classes. The principles have been known since the mid-1800s and such knowledge of a POSITA was in use in the mid-1900s in AM radio systems.

different frequencies provides for the LNA to function with good performance in each of the different frequencies. This variation enables the LNA to maintain good performance at each frequency. In particular, a POSITA would aim to match impedance with the subsequent component in the system, a principle that applies to both the first and second passive networks in Francisco. Since the impedance of the components matched by the first and second passive networks varies with frequency, a POSITA would design these networks to provide different impedances at the first and second frequencies to achieve proper matching. I detail this below.

157. Francisco specifically discusses using the basic amplifier structure of Figure 3 as an LNA. Francisco, 5:65-67. Francisco teaches for example, a first passive network including an input matching network to match the source impedance of an upstream component to the input impedance of an amplifying transistor so as to minimize noise. Francisco, 6:1-25. Francisco teaches this matching is performed by achieving the optimal amount of reflection (Γ_{opt}); this necessarily means that the first passive network including an input matching network will have two different impedances at the two different frequencies to have the required reflection coefficients. The reflection coefficient Γ is a key parameter in RF engineering, quantifying how much of a signal is reflected due to an impedance mismatch--that is, a point in the circuit where the impedance

changes. In Francisco's design, impedance matching in the input network aims to minimize noise by optimizing signal reflection (Γ) for each frequency band, considering that Γ is a frequency dependent characteristic of the transistor. Given the known relationship between input impedance (Z_A) and Γ , a POSITA would configure Francisco's *first passive network* (at transistor input) to provide a frequency-dependent impedance (Z_A) to achieve the desired matching.

158. Continuing my explanation above, the input matching network would match the source impedance of the previous component (band half-duplex 153) to the input impedance of the transistor to minimize noise. Francisco teaches this matching is performed by achieving the optimal amount of reflection (Γ_{opt}) ("value is provided by the manufacturer of the transistor 301") at the input to the transistor for each of the two receive bands 203 and 207. Francisco, 5:65-6:65. This necessarily means that the input matching filter will have two different impedances at the two different frequencies ("Rcv bands 203 and 207") to meet the requirements to have the required reflection coefficients at the input of the active device for each of the two bands.

159. For example, an exemplary transistor is NE38018, a field-effect transistor (FET) designed for use in a low-noise amplifiers, as suggested in Francisco. See EX1031, pg. 1, Datasheet NE38018. This transistor is intended for operational frequencies the same as those in Francisco. See EX1031, Noise Figure

& Associated Gain vs. Frequency, p. 1 including frequencies of 0.9 GHz and 1.9 GHz. I note that JP466 has a cavity for the transistor provided as a semiconductor chip, just like the NE38018. 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. I note that JP466 includes a cavity for the transistor, provided as a semiconductor chip, just like the NE38018. 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. At 0.9 GHz, the transistor 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 $0.65 \angle 25.1^\circ$. This demonstrates that the optimal reflection coefficient (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

160. A POSITA would understand that the reflection coefficient (Γ), which

the input matching network must achieve, corresponds to an impedance that minimizes the noise figure. This desired impedance is often specified in data sheets as the optimal reflection coefficient, Γ_{opt} . The normalized reflection coefficient, Γ , is mathematically related to the normalized source impedance by the equation:

$$Z_{\text{normalized}} = \frac{1+\Gamma}{1-\Gamma}.$$

Thus, when given an optimal Γ that minimizes the noise figure, the corresponding normalized source impedance can be easily calculated to achieve optimal noise performance.

161. As an example, the NEC NE38018 (EX1031) data sheet lists 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 yields $Z_{\text{normalized}} = \frac{1+\Gamma}{1-\Gamma} = \frac{1+(0.5886+j0.2757)}{1-(0.5886+j0.2757)} = 2.355 + j2.248$. This is the normalized impedance that is required of the input matching network at 0.9 GHz to minimize the noise figure.

162. At the second frequency of about **1.9 GHz**, for the same transistor (EX1031), the datasheet indicates the optimal reflection coefficient is $\Gamma_{\text{opt}} = 0.48 \angle 58.0^\circ = 0.2544 + j0.4071$. 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*.

163. 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.

164. 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 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.

165. 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 in

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 the desired transformation. 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 Francisco, implementing such a matching network one would consider not only 0.9 GHz but other frequencies such as 1.9 GHz. Francisco discloses its first matching network uses capacitors and inductors to form the specified impedance at two different frequencies. 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.

166. 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:

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

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.

167. The S22 parameter indicates the ratio of the reflected signal at the output port of the transistor. Reflectivity is caused by a 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 downstream devices in Francisco, e.g., switch 157 as shown in Figure 1. This means the *second passive network* (including output matching network) must also have a different impedance at the *first frequency* and *second frequency*.

168. In summary, in Francisco the LNA 155, the input matching network 310 is taught to be synthesized (designed) using well-known techniques in the field such that “the source impedance of band half-duplexer 153” is transformed to “ Γ_{OPT} .” Francisco, 5:65-6:25. In the field and in this context, Γ is used to represent a reflection coefficient as discussed above. And Francisco suggests an optimal reflection coefficient Γ_{OPT} is achieved. Specifically, Francisco says the input matching circuit 310 “transform[s]” the “source impedance” such that an optimal reflection coefficient Γ_{OPT} is achieved. *Id.* The value Γ_{OPT} “represents the source reflection coefficient **giving the minimum noise in Rcv bands 203 and 207.**” *Id.* Francisco also teaches that this optimal reflection coefficient is “provided by the manufacturer of transistor 301.” *Id.* Said more simply, 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 mathematical relationship between Z and Γ .

169. A POSITA would understand that minimizing noise and maximizing power transfer are two different performance conditions. When the goal of component in the system is to maximize power transfer, a matching impedance that is the conjugate of the source impedance is optimal. However, when the goal of the component in the system is noise minimization, other impedance matching techniques are used. This impedance to minimize noise is a characteristic of the transistor 301 and can be obtained from the data sheet for the transistor (as Z_{opt} or Γ_{opt}). There is a relationship between the optimal impedance to minimize the noise and the reflection coefficient. That relationship is, where Z_0 is the characteristic impedance of the system:

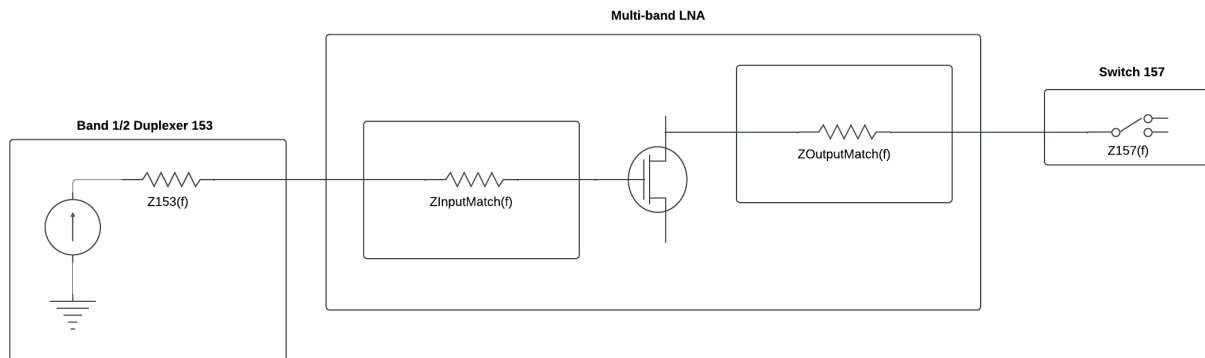
$$\Gamma_{OPT} = \frac{Z_{OPT} - Z_0}{Z_{OPT} + Z_0}$$

170. Thus, by specifying Γ_{OPT} the optimal impedance of the source is specified. For example, if the optimal reflection coefficient to reduce noise is provided, then the optimal source impedance can be calculated as:

$$Z_{OPT} = Z_0 \cdot \frac{1 + \Gamma_{OPT}}{1 - \Gamma_{OPT}}$$

171. The diagram below shows the impedances related to the input and output of the transistor. The half-band duplexer 153 presents a source current with

an associated impedance shown as $Z_{153}(f)$. The input matching network is shown to have an impedance $Z_{\text{InputMatch}}(f)$. The ideal source impedance for the transistor is Z_{OPT} . Thus, $Z_{OPT} = Z_{153}(f) + Z_{\text{InputMatch}}(f)$. This means that the input match filter should have an impedance of $Z_{\text{InputMatch}}(f) = Z_{OPT} - Z_{153}(f)$.



172. Likewise, impedance matching in the output network involves configuring Francisco's *second passive network* (at transistor output) to present a load that is the complex conjugate of the transistor's output impedance, thereby matching impedance and maximizing power transfer across for each of the frequency bands. Francisco has, and a POSITA would readily recognize, a desire for an impedance over bands 203 and 207 that corresponds to the complex conjugate of transistor output impedance. Francisco teaches that the "[o]utput matching network 350" is designed such that "the load impedance (Z_{L155}) at band switch 157 presented to transistor 301 is transformed according to the" equation $Z_{L155} = Z_{\text{output}}^*$. Francisco, 6:12-25. The output impedance of the transistor is Z_{output} . *Id.* This means that the "load impedance ... presented to the transistor 301" should

be equal to Z_{output}^* . *Id.* This is also equal to the series combination of the impedances of the output matching filter and the input to the switch 157. This results in the requirement:

$$Z_{L155} = Z_{output}^* = Z_{OutputMatch}(f) + Z_{157}(f)$$

173. This means the output match should be set to:

$$Z_{OutputMatch}(f) = Z_{output}^* - Z_{157}(f)$$

174. Setting the load impedance to the complex conjugate of the transistor's output impedance indicates that the optimization criterion at the transistor's output is the maximization of power transfer, a fact that a POSITA would readily recognize. See Francisco, 5:65-6:25.

175. The first passive network at the input matching network has an impedance set, according to the teachings of Francisco, such that the minimum noise for each frequency band is achieved in the low noise amplifier. Since the optimal impedance is a function of frequency, as a POSITA would understand and the above data sheet confirms, the impedance at the *first frequency* (first band) and the *second frequency* (second band) will necessarily be different.

176. The impedances for the second passive network of Francisco are also different at different frequencies because Francisco requires that the output matching network present a load to the output of the transistor that is match for power transfer on each of the two bands ("over bands 203 and 207"). Francisco

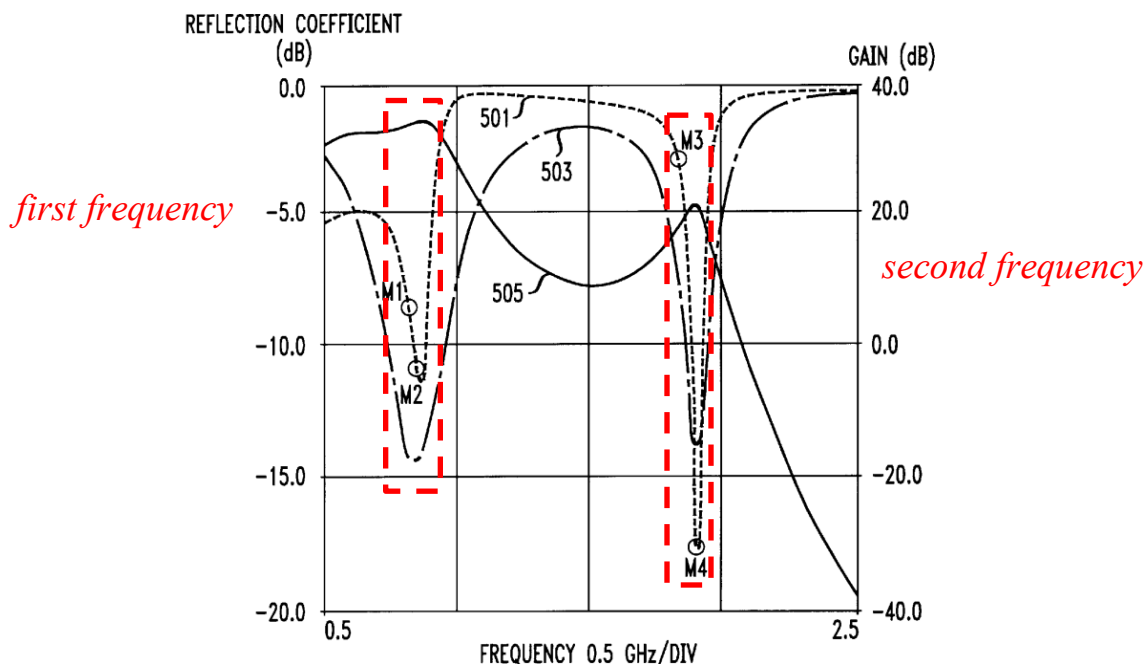
specifically teaches that the output matching network should match to the impedance of transistor 301 over bands 203 and 207.

177. Thus, for the reasons discussed above, to achieve the desired impedance matching in the *first passive network* (at transistor input) and the *second passive network* (at transistor output), a POSITA would understand that impedances at the *first frequency* (first band) and the *second frequency* (second band) will necessarily be different.

178. **Third**, Francisco illustrates the performance of a multi-band power amplifier in the transmitter portion of the system (i.e., amplifier 115) in the graph of FIG. 5. FIG. 5 is in the context of a low-noise amplifier. Figure 5 shows the performance of a preferred multi-band power amplifier such as the amplifier 115. Although the performance is shown for an amplifier configuration (e.g., FIG. 3) implemented as a power amplifier, the performance also informs a POSITA as to how the corresponding low-noise amplifier would function. This is at least because the amplifier of FIG. 5 is designed with respect to the amplifier structure of 400 which is based on the structure of Figure 3 which is common to the low-noise and power amplifiers taught by Francisco.

179. The graph illustrates differences in reflection coefficients between frequencies for the amplifier circuit. EX1005 (Francisco), 7:5-19. FIG. 5 shows the return loss at the input of the amplifier with a dashed line 501. The return loss is

minimized at the AMPS bands around 850 MHz and the PCS bands around 1.9 GHz. Likewise, the reflection coefficient for AMPS and PCS bands at the output of the transistor is also relatively low as shown by the dash-dotted line. Francisco, 7:5-19. The gain provided by the power amplifier is shown with a solid line. It can be seen there are local maxima around the 850 MHz bands (AMPS) and the 1.9 GHz bands (PCS). Further, the gain outside these bands tends to be significantly lower. EX1005 (Francisco), 7:20-35. This gain shaping in the LNAs that use the same design techniques results in less interference from mixing products of out-of-band signals entering the receiver chain. EX1005 (Francisco), 7:36-38.



**EX1005, FIG. 5
(annotated)**

180. Thus, FIG. 5 illustrates reduced (and different) return loss at the input and reflection coefficients at the output at the 850 MHz and 1.9 GHz bands and

that gain shaping presents local maxima around the 850 MHz and 1.9 GHz bands. Moreover, these illustrated characteristics are further evidence that different impedances are presented by the matching networks for the different frequency bands. In particular, different impedances are being used in the input matching filter for the different frequency bands, otherwise a POSITA would not expect to see the gain peak independently for the two different bands and the reflection coefficients also have local minima.

181. Therefore, Francisco teaches [1.4b].

182. Thus, Francisco's amplifier structure 300 in combination with JP466's suggestion to use an organic substrate with embedded passive networks 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.*

183. Francisco in combination with the teachings of JP466 rendered obvious claim 1 and Francisco further teaches this element.

184. As discussed in [1.2] and [1.3], Francisco provides *first* and *second passive networks*, each including inductors and capacitors. As a fundamental matter, inductors and capacitors are electronic components that contribute

reactance, i.e., the imaginary⁵ component of a complex impedance, in an interconnected network of components that forms an electrical circuit. The presence of inductors and/or capacitors in the first and second passive networks of Francisco demonstrates that impedances of the first and second networks comprise reactance.

185. Moreover, inductors and capacitors are common components of *resonant circuits*—indeed, what makes a circuit resonant. A resonant circuit is designed to oscillate at one or more frequencies, and it is the inductive and capacitive components of a complex impedance that contribute to resonance as I discuss below. A 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 resonant when the inductance and capacitance sum to near zero. This

⁵ A POSITA would have understood impedance (Z) to be mathematically expressed as a complex (real and imaginary number) quantity, $Z = R + jX$, consisting 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.

condition occurs when $\omega_0 = \frac{1}{\sqrt{LC}}$.

186. As discussed above at [1.2] and [1.3], Francisco provides *first* and *second passive network[s]*, each including inductors and capacitors. Inductors and capacitors are each common components of *resonant circuits*.

187. 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. It is fundamentally true that LC, π or T, transmission line matching (e.g., quarter-wave transformer), and stub matching all involved resonance.

188. 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 Francisco's circuit, a POSITA would understand that the input and output matching networks must each be designed to be resonant in the two pass bands and to avoid resonance in the stop bands. Francisco's teaching of achieving conjugate source and load impedances for the transistor is a teaching of resonance for the pass bands. For example, Francisco teaches the output load on the transistor should be matched to the conjugate of the output impedance of the transistor. EX1005, 6:15-17. 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 Francisco is clearly see in Figure 5 which shows local maxima in gain at both 900 MHz (cellular) and 1.85 MHz (PCS). These peaks indicate resonant behavior. The fact that the reflections are low at the same frequencies also indicates resonance, as the imaginary parts of the impedances are canceling and thus minimizing the overall impedance. As shown in FIG. 5, Francisco includes a stop band between the 900 MHz and 1.8 GHz bands. The gain, represented by line 505, dips to approximately 10 dB at 1.5 GHz—a

reduction of over 20 dB compared to the gain at 900 MHz and more than 10 dB compared to the gain at 1.8 GHz. Additionally, the high reflection coefficient between the 900 MHz and 1.8 GHz passbands further indicates the presence of a stop band in Francisco's design.

189. Thus, the input matching circuit 310 in Francisco is a *resonant circuit*, as evidenced by the teaching to match the transistor's input impedance at the two desired frequency bands and the resulting resonant behavior shown in Figure 5. Likewise, the output matching filter 350 functions as a *resonant circuit* because it is designed to present a load impedance that is the complex conjugate of the transistor's output impedance—a resonant condition that maximizes power transfer.

190. Similarly, the impedances of Francisco'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. Francisco's passive networks of [1.2] and [1.3] include inductors and capacitors and thus *comprise reactance*. A POSITA would understand impedance of a capacitor is purely reactive and impedance of an inductor is purely reactive.

191. 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. It is not possible to arbitrarily meet the

requirement of the data sheet of a transistor to meet an Γ_{opt} value without reactance. As for the output matching circuit, it is taught to meet a conjugate requirement which is meaningless in practice unless there is reactance, thus it also discloses reactance.

192. Thus, Francisco in view of JP466 render obvious claim 2.

6. Claim 12

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

193. Francisco and JP466 render obvious claim 1, and Francisco also teaches this element.

194. As discussed above in [1.1], Francisco describes an active device that is a field effect transistor. “As shown in FIG. 3, central to amplifier structure 300 is **field effect transistor (FET) 301.**” EX1005 (Francisco), 5:30-31. *See also*, EX1006 (JP466), FIG. 3, [0003] (“FET”), [0006], [0032].

195. Thus, claim 12 is rendered obvious by Francisco in view of JP466.

7. 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.*

196. Francisco and JP466 render obvious claim 1, and the combination also teaches this element.

197. As discussed above in [1.4a], JP466 provides a dielectric substrate

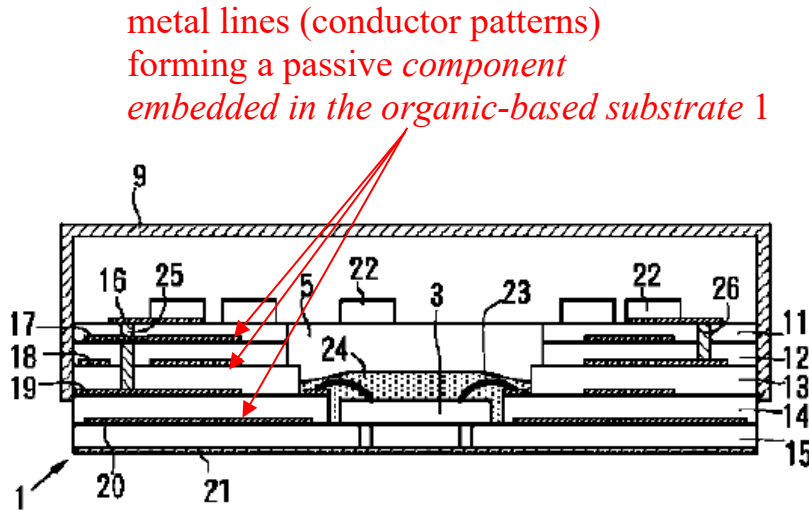
that is an *organic-based substrate* of an amplifier module. EX1006 (JP466), [0003], [0093]. JP466 describes *embedd[ing]* components of its amplifier's passive network, such as capacitors or inductors, in its *organic-based substrate*. That is, JP466 forms passive components in patterned conductor layers disposed within a stack of dielectric layers making up the substrate. *See* EX1006 (JP466), FIG. 5, 6-9, [0053].

198. A POSITA would recognize that the passives are embedded in the substrate to obtain the desired effects provided by the organic substrate. The electric field associated with the device formed by the conductive metal layers, e.g., a capacitor, must have its relevant electric fields (e.g., electric field between two plates of the capacitor) go through the dielectric material. JP466 shows metal layers (e.g., 16-21) layered so the components formed by them are embedded within the substrate.

199. 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.”). Roberts 4350B is organic, since it is a hydrocarbon, meaning it is comprised of hydrogen and carbon atoms. LCP is liquid crystal polymer. LCPs are also organic. See EX1001, 2:19 (“organic substrates such as LCP (liquid crystalline polymer”).

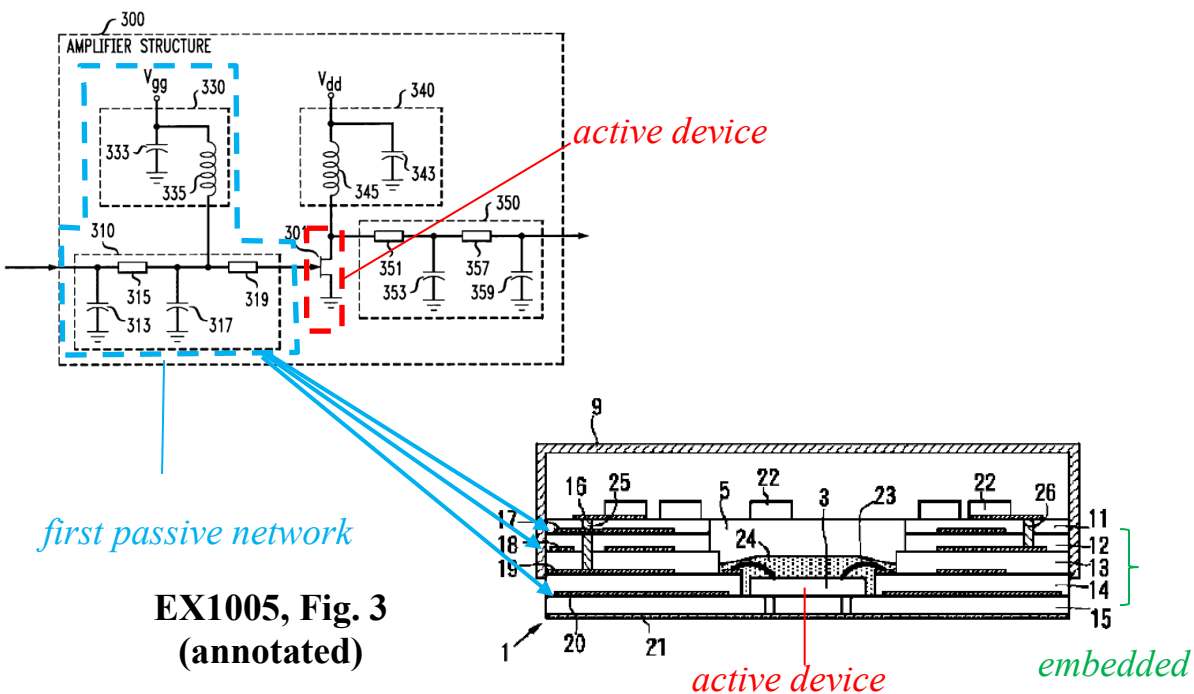
200. FIG. 5 is illustrative of JP466’s substrate 1 having dielectric layers 11-15, each having a conductor pattern 16-20 used to form passive components. And at least those conductor patterns 17-20 are *embedded* within the substrate 1. Further, those conductors form passive components such as capacitors, inductors, resistors, and transmission lines that are also embedded in the substrate. Indeed, JP466 specifically shows a capacitor being embedded in the substrate at FIGS. 6 and 7 via the use of a ground element 17 on the top of organic substrate layer 12 (top capacitor plate) and element 18 on metal layer 13 at the bottom of organic substrate layer 12 (bottom capacitor plate). Further, substrate layer 15 in FIG 9. is shown to have a metal layer on top used to form an inductor 204 (L4). Thus, the inductors are also taught to be embedded in the substrate. For example, the inductor 204 (L4) is sandwiched between organic substrate layers 14 and 15 and thus embedded within organic substrate.



EX1006, Fig. 5
(annotated)

201. As also discussed above, a POSITA would have had reason to, and recognized benefits from, forming the similar components of the *first passive network* of Francisco, discussed above in [1.3], using JP466's technique of patterning a metal layer (patterned conductors 17-20) on a dielectric layer (dielectric substrates 15-11) to embed the component within the substrate. It is noted that the components of the first and second passive networks are not limited to any specific location on the substrate 1. JP466 recognizes "first to fifth dielectric boards mount a passive circuit component of the circuit components included in the circuit diagram depicted in FIG. 1, and connect the passive circuit component to form a required circuit configuration. There are no particular limitations to how the circuit components are arranged, but one possible example is shown below." EX1006 (JP466), [0053]. A POSITA would recognize that one location on the

dielectric substrate 1 for a component of the *first passive network* would be adjacent to the input of the active device. Placing the component near the input of the transistor would tend to reduce loss due to resistance, reduce exposure to noise and undesired coupling of signals, and maximize routing efficiency, as a POSITA would realize.



EX1005, Fig. 3
(annotated)

EX1006, Fig. 5
(annotated)

202. The analysis of [1.4a] provides further detail as to the exemplary passive components (e.g., capacitors and inductors) formed of these patterned conductor layers. In one particular example, JP466 forms inductors of its passive network on conductor pattern 20 of layer 15 thereby forming the inductor

embedded in the dielectric substrate 1. EX1006 (JP466), FIG. 9, [0051], [0057].

And JP466 recognizes advantages to forming the inductor *embedded* within the substrate including prevention of signal leakage to the outside and efficient signal transmission. EX1006 (JP466), [0062]-[0063]. Further, “the use of a dielectric material with the high relative dielectric constant ϵ_r shortens the pattern length of the striplines 204, 205, and 206, which makes it possible to make the external form of the dielectric substrate smaller.” EX1006 (JP466), [0064]. A POSITA would recognize these same advantages to forming an inductor component, such as inductor 335, of Francisco’s *first passive network* similarly embedded within JP466’s dielectric substrate 1, an *organic-based substrate*. An “inductive choke 335” is a type of inductor. For example, the Q factor (quality factor) of an inductor is $Q_L = \frac{\omega L}{R}$. 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.

203. As discussed in the reasons to combine JP466, a POSITA would recognize benefits to embedding passive components in a dielectric substrate. For example, embedding of passives in a substrate means the electrical performance will correspond to the electrical properties of the substrate and the dielectric

constant of the substrate can be chosen to provide desired functionality. In doing so, electromagnetic fields that go through the substrate are not altered by foreign material such as dust, humidity changes, etc. experienced by a surface mount component. Embedding also provides for decreased system-level planning (e.g., assembly of surface mount components and allocation of space). Embedding also provides for traces between components to be decreased. Embedding shortens the wavelength of signals thus fundamentally reducing the size of components whose implementation is dependent on wavelength.

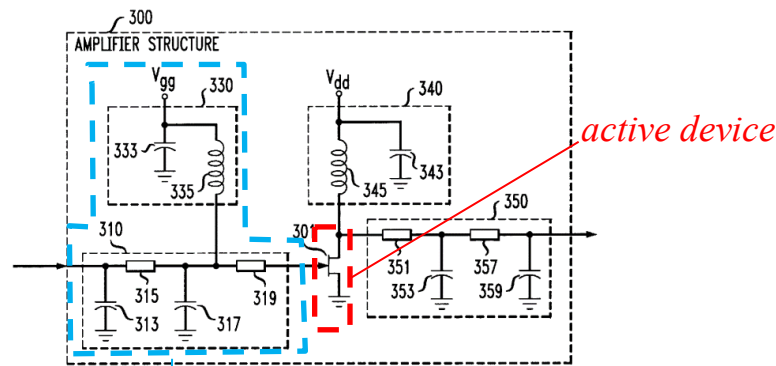
204. Thus, claim 13 is rendered obvious by Francisco in view of JP466.

8. 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.*

205. Francisco and JP466 render obvious claim 1, and the combination also teaches this element.

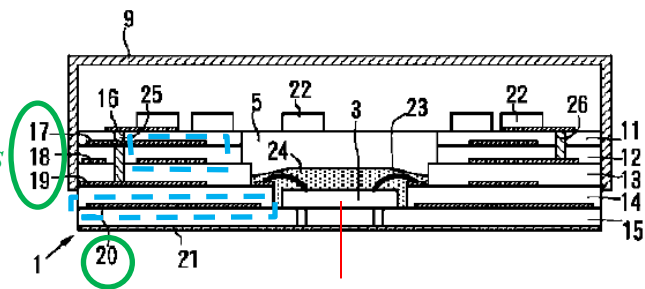
206. JP466 teaches forming conductor patterns (16-20), one or more of which provides *at least one of the metal layers that is patterned*, to form *at least a portion of a component* of its passive network as discussed above in [1.4a] and [13]. And for the reasons also discussed above, a POSITA would have had reason and recognized benefit to providing *at least a portion of a component* of Francisco's *first passive network* of [1.1] using JP466's technique.



first passive network

metal layers

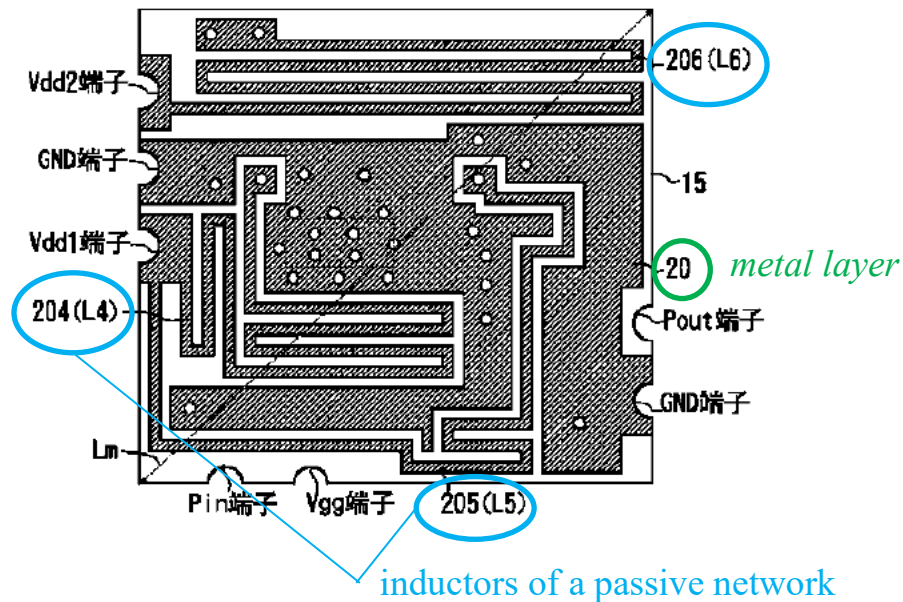
EX1005, Fig. 3
(annotated)



active device

EX1006, Fig. 5
(annotated)

207. In one example, JP466 describes strip lines 204, 205 and 206 of conductor pattern 20, which is a *metal layer* that is *patterned* to form inductors, a *component* of a *passive network*. “Further, as shown in FIG. 9, the fifth dielectric substrate 15 is formed with **strip lines 204, 205 and 206** which form the inductance elements L4, L5 and L6 included in the drain bias circuit.” EX1006 (JP466), [0057]. Figure 9 is illustrative.



EX1006, Fig. 9
(annotated)

See also, EX1006 (JP466), FIGS. 6, 7 having conductor patterns 17, 18 forming capacitors of a passive network. It would have been obvious to form a similar component (e.g., capacitor and/or inductor) of the first passive network of Francisco using JP466's technique for the reasons discussed in claim 1.

208. Thus, claim 14 is rendered obvious by Francisco and JP466.

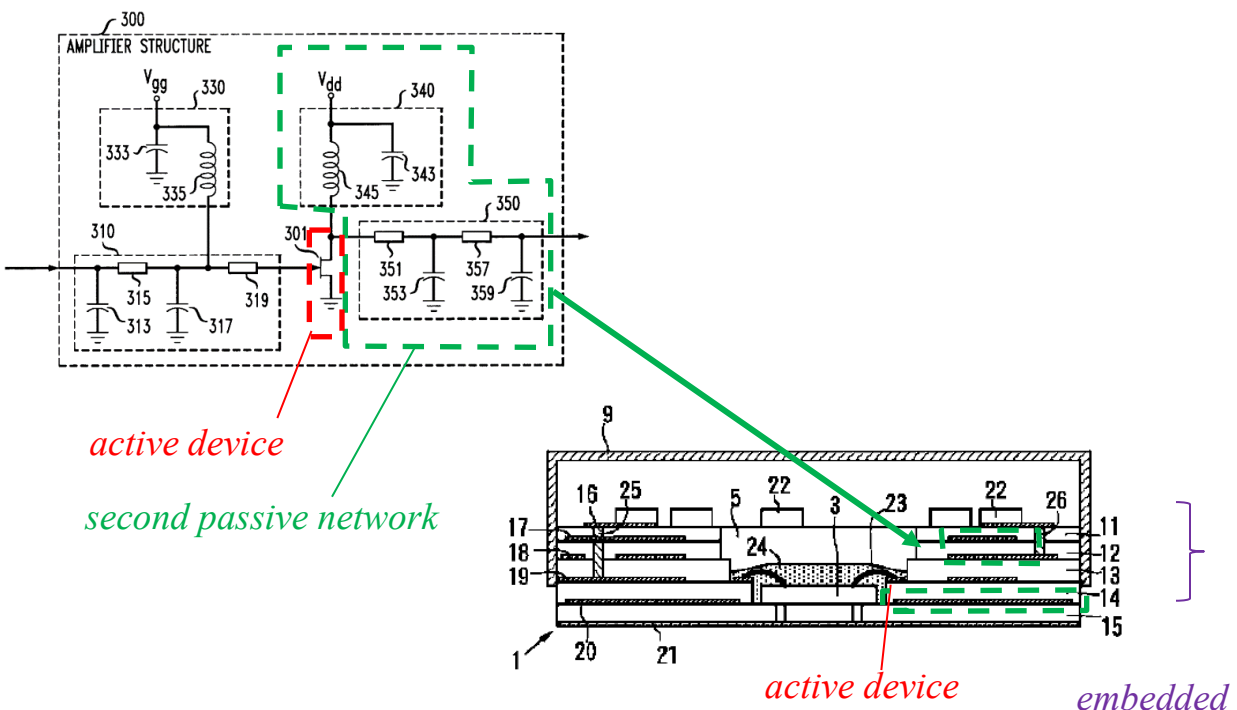
9. Claim 15

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

209. Francisco and JP466 render obvious claim 1, and the combination also teaches this element.

210. As discussed above in [1.4a], JP466 describes use of a dielectric

substrate and conductor patterns embedded therein to provide a component of a passive network; the substrate is an *organic-based substrate*. EX1006 (JP466), [0093]. The analysis of claim 13 with respect to the *first passive network* applies equally to the *second passive network* of this claim; Francisco-JP466 provide a component such as a capacitor or inductor of the *second passive network* of [1.3] *embedded* in JP466's organic-based substrate.



211. It is noted that the components of the first and second passive networks are not limited to any specific location on the substrate 1. JP466 recognizes “first to fifth dielectric boards mount a passive circuit component of the circuit components included in the circuit diagram depicted in FIG. 1, and connect the passive circuit component to form a required circuit configuration. There are no

particular limitations to how the circuit components are arranged, but one possible example is shown below.” EX1006 (JP466), [0053]. A POSITA would recognize that one location on the dielectric substrate 1 for a component of the *second passive network* would be adjacent to the output of the active device as the second passive network is connected to the drain for the active device. Placing the component near the output of the transistor would tend to reduce loss due to resistance, reduce exposure to noise and undesired coupling of signals, and maximize routing efficiency, as a POSITA would realize.

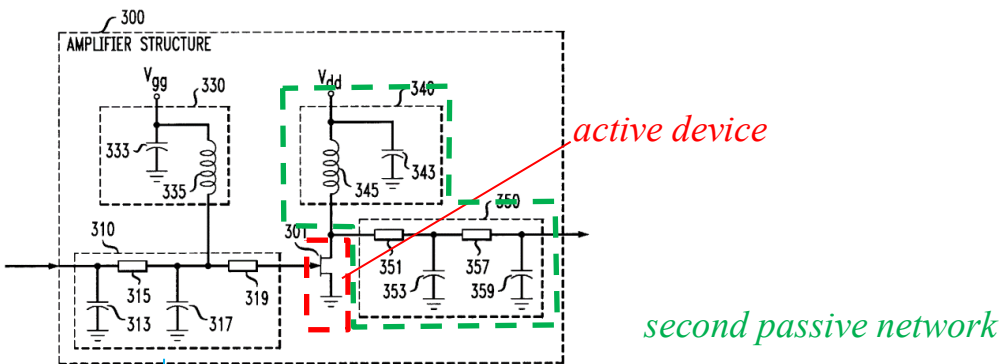
212. Thus, claim 15 is rendered obvious by Francisco in view of JP466.

10. Claim 16

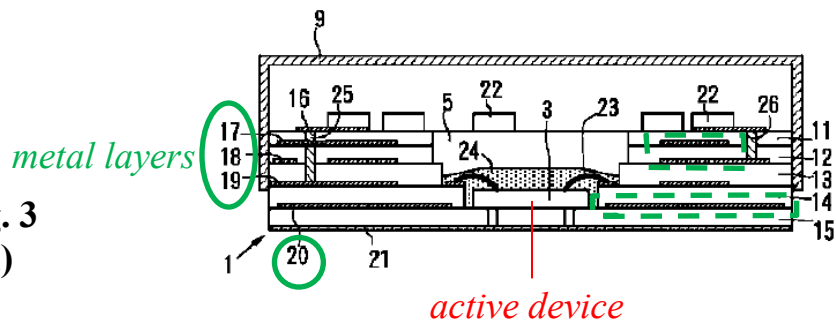
[16] *The multi-band R[F] device of claim 1, wherein at least one of the metal layers is patterned to form at least a portion of a component included in the second passive network.*

213. Francisco in view of JP466 renders obvious claim 1 and in light of the JP466 teachings in the context of the second passive network of Francisco teaches this element.

214. As discussed above in [1.4a] and [14], JP466 suggests that at least one metal layer, illustrated by conductor patterns formed on layers of its dielectric substrate 1, is patterned to form a component of its passive network. It would have been obvious to apply this technique is providing to the *second passive network* of Francisco discussed above in [1.3].



EX1005, Fig. 3
(annotated)



EX1006, Fig. 5
(annotated)

215. The formation of the components of the *second passive network* is the same as those of the *first passive network* discussed above in claim 13. Again it is noted that the components of the first and second passive networks are not limited to any specific location on the substrate 1. EX1006 (JP466), [0053]. A POSITA would recognize that one location on the dielectric substrate 1 would be adjacent the output of the active device as the second passive network is connected to the drain for the active device.

216. Thus, claim 16 is rendered obvious by Francisco and JP466.

11. Claim 5

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

217. Francisco teaches a multi-band low noise amplifier for use in an RF application.

218. Francisco's amplifier structure 300, as discussed above in [1.0], is described as being applicable to the multi-band low-noise amplifier 155 of the communication system 100, teaches *a multi-band low noise amplifier*. This communication system 100 uses the amplifier for *an RF application* as shown with respect to the application of the first and second frequencies (e.g., cellular and PCS frequency bands), also discussed in [1.1].

219. 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. Francisco's teachings of the use of 0.9 GHz and 1.9 GHz are thus within the radio frequency spectrum. Further, the RF applications taught by Francisco include at least the applications of mobile phones. This is supported by Francisco's discussion of radiotelephones. EX1005 (Francisco) at 1:11-24.

220. Thus, Francisco teaches [5.0].

[5.1] *an active device*;

221. Francisco teaches a transistor 301 of the multi-band amplifier structure 300 that provides *an active device* as shown in [1.1] above and thus,

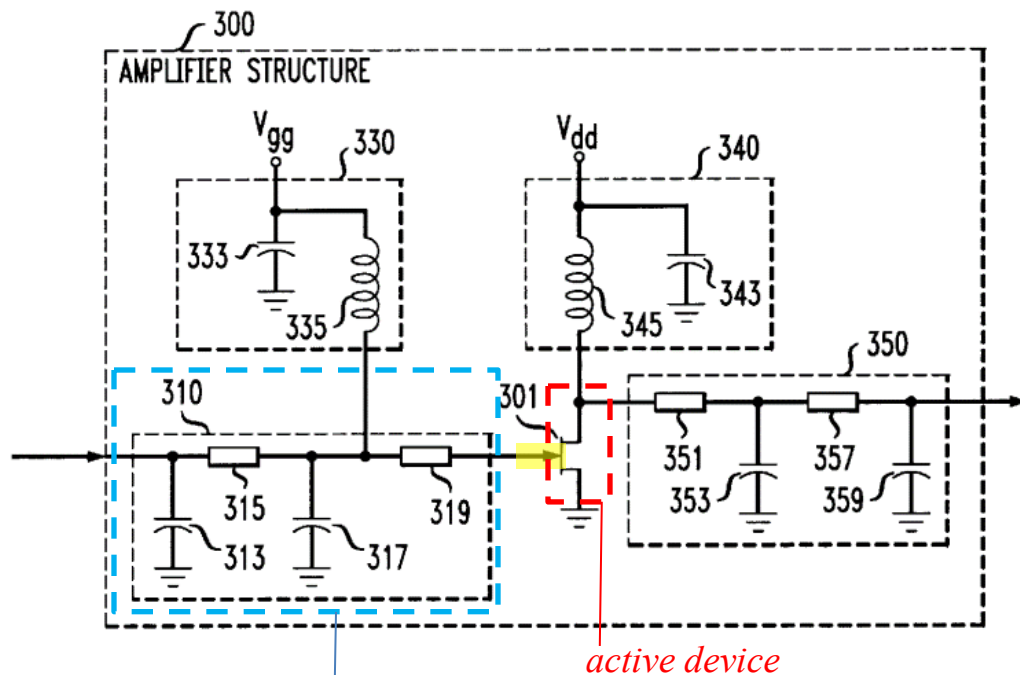
teaches this element.

[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;

222. Francisco describes an “input matching network 310” that provides a *first matching network*. EX1005 (Francisco), 8:30-36. *See also* [1.2] above.

Francisco describes this portion of the passive network as a “matching network” and describes its function of matching impedances of adjacent components.

EX1005 (Francisco), 6:1-9, 6:26-27, 6:43-56.



first matching network **EX1005, FIG. 3**
(annotated)

223. The input matching network 310 is *in communication* with the FET 301, the *active device*. In particular, the matching network 310 is connected to one

of the FET terminals (i.e., the gate). EX1005 (Francisco), FIG. 3, 5:32-34 (“**gate terminal [of FET 301] connected to input matching network 310** coupled to **gate bias circuit 330.**”), 5:44-45 (“[t]ransmission line 319 connects both capacitor 317 [component of matching network 310] and circuit 330 to the gate terminal of transistor 301.”) This is discussed above in [1.2].

224. And as also discussed above, the impedance of the network, which includes reactance, is different at a *first frequency* (e.g., cellular) than a *second frequency* (e.g., PCS) as discussed in [1.4b].

225. Francisco specifically discusses using the basic amplifier structure of Figure 3 as an LNA. Francisco, 5:65-67. Francisco teaches that the input matching circuit should match to the optimal reflection coefficient for the transistor, which is available in transistor data sheets as recognized by Francisco at column 6. I explain this above in [1.4b].

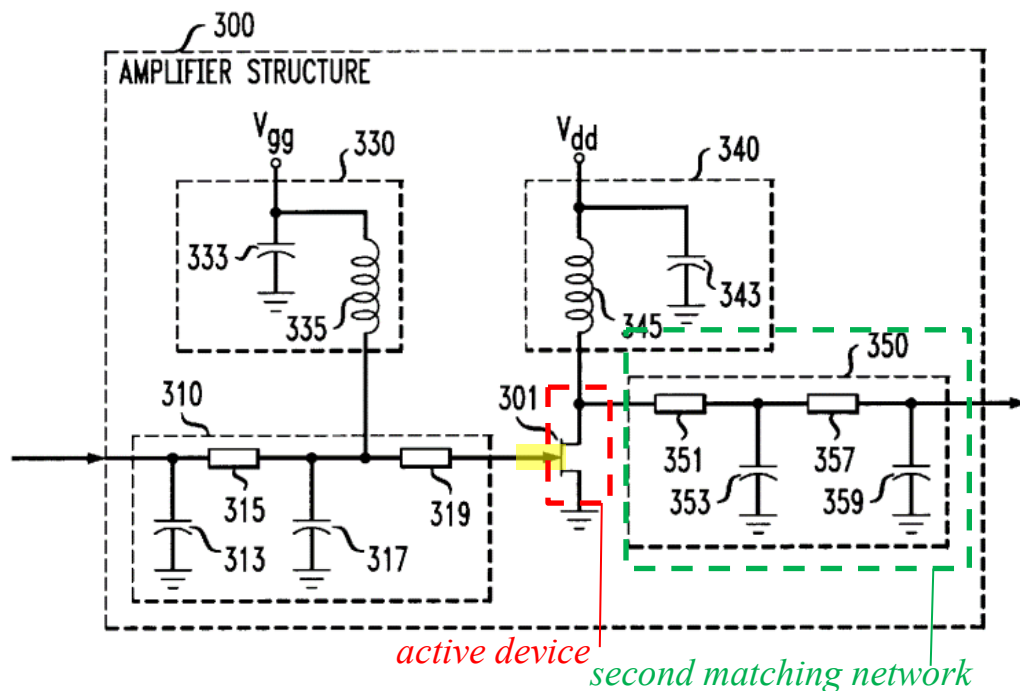
226. Thus, Francisco teaches this element.

[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

227. Francisco describes an “output matching network 350” that provides a *second matching network*. EX1005 (Francisco), 8:30-36. *See also* [1.3] above.

Francisco describes this portion of its passive network as a “matching network” and describes its function of matching impedances of adjacent components.

EX1005 (Francisco), 6:12-23, 6:26-40. The *second passive network*, including drain bias circuit 340 and output matching circuit 350, is *in communication* with the *active device* of [1.1], FET 301. EX1005 (Francisco), 5:34-36 (“The drain terminal of the transistor [FET 301] is **connected** to drain bias circuit 340 and also to output matching network 350.” EX1005 (Francisco), 5:58-59 (“[t]ransmission line 351 in network 350 **connects** the drain terminal of transistor 301 to capacitor 353 [of output matching network 350].”) This connection is for *communication* of a signal from the FET 301.



EX1005, FIG. 3
(annotated)

228. Francisco describes an “output matching network 350” that provides a *second matching network* as described in [1.3] above. And as also discussed above,

the impedance of the network, which includes passives such as capacitors and transmission lines, is different at a *first frequency* (e.g., cellular) than a *second frequency* (e.g., PCS) as discussed in [1.4b].

229. I discuss the S22 parameter of the active device of a transistor above in [1.4b], which indicates the ratio of the reflected signal at the output port of the transistor. A POSITA would know that the S22 parameter of a transistor is a function of frequency. EX1031. This means the output matching circuit must modify its impedance with frequency to properly match to downstream devices in Francisco, e.g., switch 157 as shown in Figure 1. This means the second matching network must also have a different impedance at the *first frequency* and *second frequency* as I detail above in [1.4b].

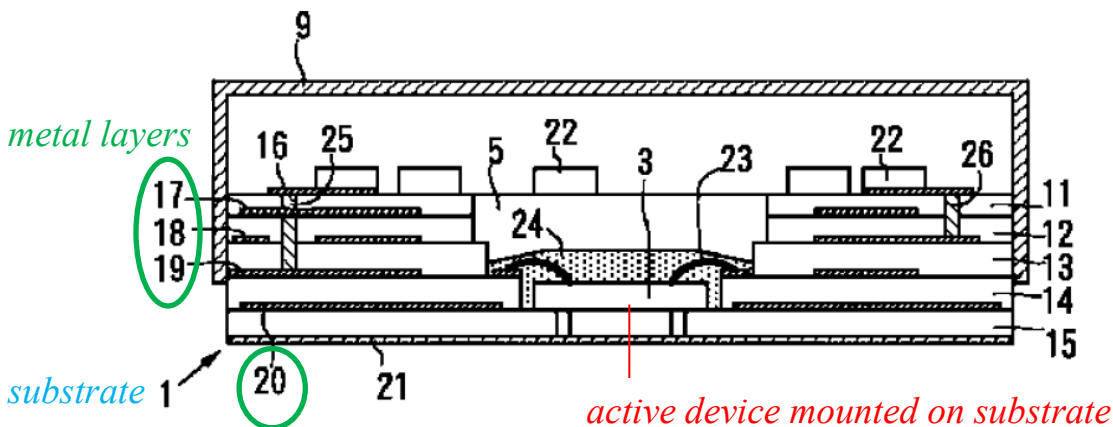
230. Thus, Francisco teaches this element.

[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,

231. **First**, as discussed above in [1.4a], [14], [16], JP466 describes a substrate 1, *a multi-layer organic-based substrate*, having at least one metal layer illustrated by conductor patterns 16-20, where is input and output passive network components are formed on the metal layer(s). As discussed above, it would have been obvious to form Francisco's passive components, including those of the *first matching network* and the *second matching network*, on the metal layer(s) that are

the conductor patterns formed embedded in JP466's substrate 1.

232. **Second**, JP466 also describes "[t]he semiconductor amplifying element of FET, or the like, is mounted directly on the dielectric substrate as a bare chip, or packaged using a resin mold and then mounted on the dielectric substrate." EX1006 (JP466), [0006]. The chip 3 mounted on the multi-layer organic substrate 1 in Fig. 5 is illustrative. *See also*, EX1006 (JP466), [0052], [0060]; FIGS. 4, 5.



EX1006, FIG. 5
(annotated)

233. As JP466 illustrates forming a FET mounted on the multi-layer organic substrate, it would have been obvious to implement the same configuration and form the FET 301 of Francisco, the *active device*, mounted on the multi-layer organic substrate of JP466.

[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.*

234. Francisco in view of JP466 *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 [1.4b]), Francisco illustrates a multi-band amplifier (including an active device and matching networks), which it uses to “scale the signal level of a signal communicated over one of multiple frequency bands.” EX1006 (Francisco), 1:50-54. *See also*, EX1006 (Francisco), Abstract, 3:56-4:2, 4:37-46, 6:57-65 discussing the amplifiers, and thus the passive networks thereof, handling multiple frequency bands to provide the amplifier’s function of providing *desired power gains*.

235. 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 the passive networks at each frequency are different. See [2].

236. Moreover, as I showed above the matching networks necessarily have complex impedances to achieve the objectives taught in Francisco. The so-called imaginary part of the impedance corresponds to the reactance. Thus, my previous analysis with respect to claim 2 limitations above supports that the first and second

matching network have different a reactance at the first and second frequencies.

This flows from the fact that the matching objectives taught by Francisco for the input (Γ_{opt}) and output matching networks (convert load on transistor to conjugate of output impedance which is a function of frequency as evidenced by S22 varying with frequency) must have different reactance.

237. Thus, claim 5 is rendered obvious by Francisco in view of the teachings of JP466 of embedding passive components in an organic-based substrate.

12. Claim 17

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

238. Claim 5 is rendered obvious by Francisco in view of JP466 and the combination further teaches this element as discussed above with reference to claim 13 including JP466's teachings of embedding a component of the input matching network 310, *first matching network*, amplifier structure 300 of Francisco in an organic-based substrate. Thus, claim 17 is obvious in light of Francisco and JP466.

13. 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.*

239. Claim 5 is rendered obvious by Francisco in view of JP466 and the combination further teaches this element as discussed above with reference to

claim 14, which illustrates JP466's conductor patterns 16-20 are *metal layers patterned to form at least a portion of a component* of passive network such as a component of the input matching network 310 of Francisco, *the first matching network*.

240. Thus, claim 18 is obvious in light of Francisco and JP466.

14. Claim 19

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

241. Claim 5 is rendered obvious by Francisco in view of JP466 and the combination further teaches this element .

242. As discussed above with reference to claim 15, it would have been obvious to use JP466's technique of forming passive components using conductor patterns 17-20 of dielectric substrates 12-15 to form components of the output matching network 350 of Francisco, *second matching network*. In doing so, passive components are *embedded* in substrate 1, an *organic-based substrate*. Thus, claim 19 is obvious in light of Francisco and JP466.

15. 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.*

243. Claim 5 is rendered obvious by Francisco in view of JP466 and the combination further teaches this element.

244. As discussed above with reference to claim 16, it would have been obvious to use JP466's conductor patterns 16-20, which are patterned *metal layers*, to form *at least a portion of a component* of the output matching network 350 of Francisco, *second matching network*. Thus, claim 20 is obvious in light of Francisco and JP466.

B. Ground 2 - Claims 4, 6 over Francisco, JP466, and Hirayama

1. Hirayama

245. Hirayama is entitled "Analog Amplifier Circuit" and describes circuits "which can be suitably applied to an amplifier circuit for a dual band" mobile terminal such as a mobile telephone. EX1008 (Hirayama), (54), [0002], [0004]. Hirayama recognizes previous dual band implementations used "two amplifiers (i.e., transistors 1501 and 1502) which are matched according to [separate] frequencies[,]" which "increases the area of a chip, and further, induc[es] an increase in cost." EX1008 (Hirayama), [0005]-[0006]. In contrast, with a goal of reducing cost and size, Hirayama's amplifier "can be used at two frequency bands" to "enable[] the impedance to be converted at both of two frequencies." EX1008 (Hirayama), [0007], [0071]. Hirayama describes its multi-band amplifier can "be applied to the case where an active element constituting the amplifier is either a bipolar transistor or a field effect transistor in the same manner, thus providing the matching circuit for converting the impedance into an optimum impedance at

either of the two frequencies.” EX1008 (Hirayama), [0072].

246. Hirayama also provides specific configurations of input and output matching circuits for a transistor-based amplifier circuit. The input and output matching circuits are designed with dual resonant frequencies to enable the resulting amplifier to have multi-band operation. Hirayama explicitly mentions that such input and output matching circuits match to two frequencies is applicable to “mobile telephone[s].” Hirayama, [0004]. Hirayama provides specific details on how to design the matching circuits to match at two different frequencies. For example, Hirayama provides specific design techniques and circuits to match a 50Ω line to the input impedance, Z_s , at the input of the transistor. Hirayama teaches specific circuits to use based on region of the Smith chart in which the input impedance of the transistor resides. For example, the input impedance of the example NEC38018 transistor discussed in Ground 1 was $2.355+j2.248$. This impedance falls within region 801 of Hirayama’s Figure 8. Thus, for that example, the matching filter of Hirayama’s Seventh Embodiment would be used. EX1008 (Hirayama) at [0093-0097], FIGS. 6, 7A-C, 8. Hirayama exclusively teaches the use of passive components in its matching filters, specifically, inductors, capacitors, and transmission lines. Said simply, Hirayama provides specific instances of circuits to use for input and output matching to two frequencies that would be one implementation a POSITA would recognize in light of the teachings

of Francisco.

247. Additionally, Hirayama teaches certain tradeoffs. For example, Hirayama teaches that the transistor type may be an FET to minimize cost, or a bipolar transistor (e.g., BJT) for high gain. EX1008 (Hirayama) at [0128]. Thus, Hirayama explicitly teaches a basic engineering tradeoff decisions when selecting the type of transistor. A POSITA would have already been aware of such basic selection between these two options, however, Hirayama states the tradeoff decision explicitly.

2. Reasons to combine Francisco and JP466 (Francisco-JP466)

248. Reasons to combine Francisco and JP466 are above in Challenge 1.

3. Reasons to combine Francisco-JP466 and Hirayama

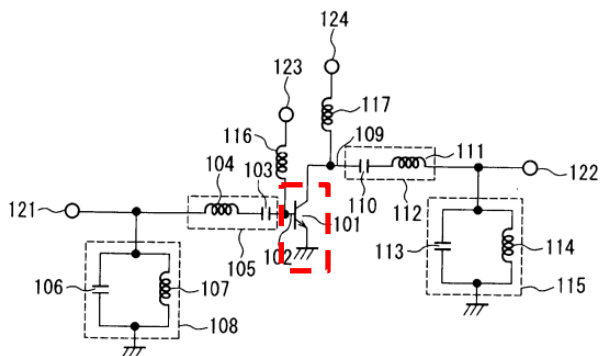
249. A POSITA would have been motivated to combine the teachings of Francisco-JP466 and Hirayama for multiple reasons, including to produce the obvious, beneficial, and predictable results of providing a bipolar junction transistor (BJT) as an active device of the amplifier of a RF communication system.

250. Francisco-JP466 and Hirayama are in the same field of endeavor as the '914 Patent as they are related to RF devices suitable for personal communication devices and moreover are particularly directed to amplifier circuits for those devices. EX1008 (Hirayama), [0004], [0002]; EX1005 (Francisco), 1:5-7,

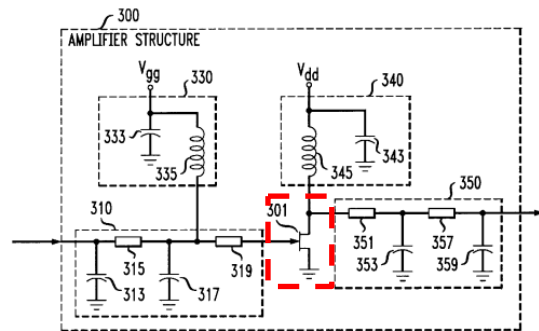
1:36-46; EX1001, 1:23-27, 2:14-16. Not only are Francisco-JP466, Hirayama and '914 Patent in the same field of endeavor, but they are reasonably pertinent to a problem faced by the inventor of the '914 Patent of avoiding duplication of components for multi-band frequency systems through component reuse. EX1008 (Hirayama), [0006]-[0007]; EX1001, 1:48-61, 2:8-13; EX1005 (Francisco), 1:24-46, 1:62-67.

251. That Francisco, JP466, and Hirayama all pertain to amplifier design for wireless communications systems that operate in multiple bands also indicates that their respective works were driven by market dynamics. Indeed, as a POSITA would know, as those patent discussion, and as I am personally aware based on industry experience in the relevant period, in the late 1990s and early 2000s, before the priority date of the '914 Patent, both cellular and wireless LAN (IEEE 802.11 aka Wi-Fi) standards were specifying the use of multiple bands. I believe this increases the likelihood that the techniques used to enable of amplifier operation in multiple bands were driven by a POSITA's application of fundamental skills to a problem arising from market dynamics. Indeed, Francisco shows that it was known to have input and output matching circuits for an LNA that are tuned to multiple frequencies. JP466 shows that integration of those circuits into modules was known. Hirayama shows specific techniques to design input and output matching circuits to two different frequencies.

252. Francisco and Hirayama describe a substantially similar structure – a multi-band amplifier having a three-terminal active device (i.e., a transistor) with passive components at its input and output, wherein the amplifier functions to obtain gain in signal level at multiple bands. Compare, Francisco at FIG. 3 and Hirayama at FIG. 1, each having an active device with a first terminal connected to an input network of passive components, a second terminal connected to an output network of passive components, and a third terminal connected to ground.



EX1007, FIG. 1
(annotated)



EX1005, FIG. 3
(annotated)

253. Providing Francisco's transistor 301 with Hirayama's transistor 101, suggested as a bipolar junction transistor, is merely applying a known technique illustrated in Hirayama (forming an active device of an amplifier as a BJT) to a substantially similar active device of a multi-band amplifier device (Francisco's amplifier structure 300) ready for improvement (e.g., improvement in gain as discussed below).

254. The choice of the type of active device for RF devices was well understood by system designers. Based on my experience with this technology, and as would be known to POSITA, transistors are selected according to established characteristics such as noise figure, cost, power consumption, size, and transition frequency (maximum bandwidth capability). For example, FETs could be used in a low-cost CMOS process to reduce cost, but this may come with higher noise figure and lower transition frequency. CMOS processes are commonly optimized for FETs, thus are the natural choice when having an available CMOS process. On the other hand, bipolar transistors such as the BJT are commonly used in SiGe processes and are accompanied by higher gain and lower noise figure which typically comes at higher cost. As an example, at WiQuest we used a SiGe front-end with a BJT because low noise figure and gain was very important to Wireless USB, which had very limited transmit power. On the other hand, in Wi-Fi which has higher transmit power, in my experience it has been common for some period of time to use amplifiers built in CMOS that use FETs. See also, EX1019, [0043] discussing concurrent multi-band LNA's with an NFET transistor that "apply equally to other types of three terminal active devices, such as bipolar, MESFET, PHEMT [] etc"; EX1011 ("Concurrent Multiband Low-Noise Amplifiers—Theory, Design, and Applications"), pp 288-289 discussing bipolar and FET implementations. Hirayama itself recognizes this option of transistor type

suggesting that its transistor 101 can be a BJT or FET. EX1008 (Hirayama), [0128]. Further, it was generally recognized that amplifiers can implement bipolar LNAs or CMOS LNAs (i.e., FETs). See EX1017, RF Microelectronics, Behzad Razavi, Section 6.1.3 entitled Bipolar LNAs, Section 6.1.4 entitled CMOS LNAs, pp. 166-180.

255. Further, the fundamental theory of a transistor, whether a BJT or FET, is the same. It is a three-terminal device in which one terminal controls the resistance between the other two terminals. Characteristics such as gain, noise figure, cost, size, power consumption, input impedance, output impedance, etc., vary from one specific transistor to another. However, the fundamental operation of the transistor does not change when using different types. For example, whether using a BJT or FET the transistor in an amplifier is commonly biased to an operation point (quiescent point) and input and output circuitry is used to couple small AC signals into the amplifier's input and extract the amplified AC signal from the output.

256. Further, a POSITA would recognize that there are only a limited number of choices for a transistor structure, with BJT and FET being two common choices. Implementations of amplifiers with bipolar junction transistors (BJT) were well-known. EX1019 (US20020030545), [0043]; EX1020 (EP0851576A2) 24:44-46; EX1009, Yeh (USP 5,995,814), 4:8-13. A POSITA would recognize the

known design choice between BJTs and FETs in the context of amplifiers include implementing a BJT can provide a higher gain. EX1008 (Hirayama) [0128], (“[T]he bipolar transistor has been used as the amplifier device [in the embodiments], [but] a field effect transistor may be used instead. The amplifier circuit of a high gain can be achieved in the case of the use of the bipolar transistor; an amplifier circuit of a low cost can be achieved in a silicon-based device in the case of the field effect transistor[.]”) That is, for applications where amplifier figures of merit—such as gain, noise figure, and linearity—are critical, a POSITA would have been motivated to choose BJTs due to their advantageous characteristics. Compared to MOSFETs, BJTs typically offer higher gain, superior linearity, and a higher transition frequency (f_T), making them well-suited for high-frequency and low-noise applications. These factors can be important in RF and microwave amplifiers, where maintaining signal integrity and minimizing distortion are key. Thus, a POSITA would recognize the benefit of using a BJT as the active device in an amplifier when the need for higher gain outweighs cost considerations. Likewise, a POSITA would recognize that when some loss of performance versus a BJT is acceptable, the cost savings of a MOSFET can be enjoyed.

257. In summary, a POSITA would have been motivated to apply Hirayama’s teachings when implementing Francisco’s amplifier because doing so

would beneficially (1) provide specific circuits topologies for the input and output matching circuits that are designed for two distinct frequencies; and/or (2) increase gain of the amplifier by using a BJT. Additionally, a POSITA would know that BJTs are commonly implemented in lower noise processes such as SiGe whereas FETs are commonly implemented in CMOS. Thus, a POSITA would also recognize the benefit of choosing a BJT in a process such as SiGe which has a higher transition frequency, higher gain, and commonly more linearity. High gain, low noise, and linearity are key metrics for an amplifier; thus these primary metrics are in favor of BJTs. Each of these reasons separately and together would have motivated a POSITA.

258. The results would have been predictable and there would have been a reasonable expectation of success in the combination because Francisco and Hirayama describe similar amplifiers for use in similar systems. Any modification needed to the teachings of Francisco, including implementing changes to the passive networks, to accommodate the teachings of Hirayama, would have been within the level of ordinary skill in the art. See Francisco, 6:7-56 discussing (“[t]he values of the individual components...can be readily determined by well-known methods.”), 6:20-23, 7:39-44; EX1017, RF Microelectronics, pp. 173-177; EX1001, 24:28-36 (“One of ordinary skill in the art would recognize that many other embodiments of the LNA are also possible. For instance, instead of an

explicit matching network...”), EX1029 (US20030063427A1) at FIG. 6 illustrates an amplifier implementing a BJT. And again, Hirayama itself suggests the interchangeability of the transistors in an amplifier are within the skills of a POSITA. EX1008 (Hirayama), [0128]. Further, Francisco and Hirayama use the same type of passive components, namely, inductors, capacitors, and transmission lines. This makes the implementation of Hirayama’s specific teachings regarding the input and output matching networks highly predictable, as the only changes are to topology and component values and not to the fundamental types of components.

4. 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.

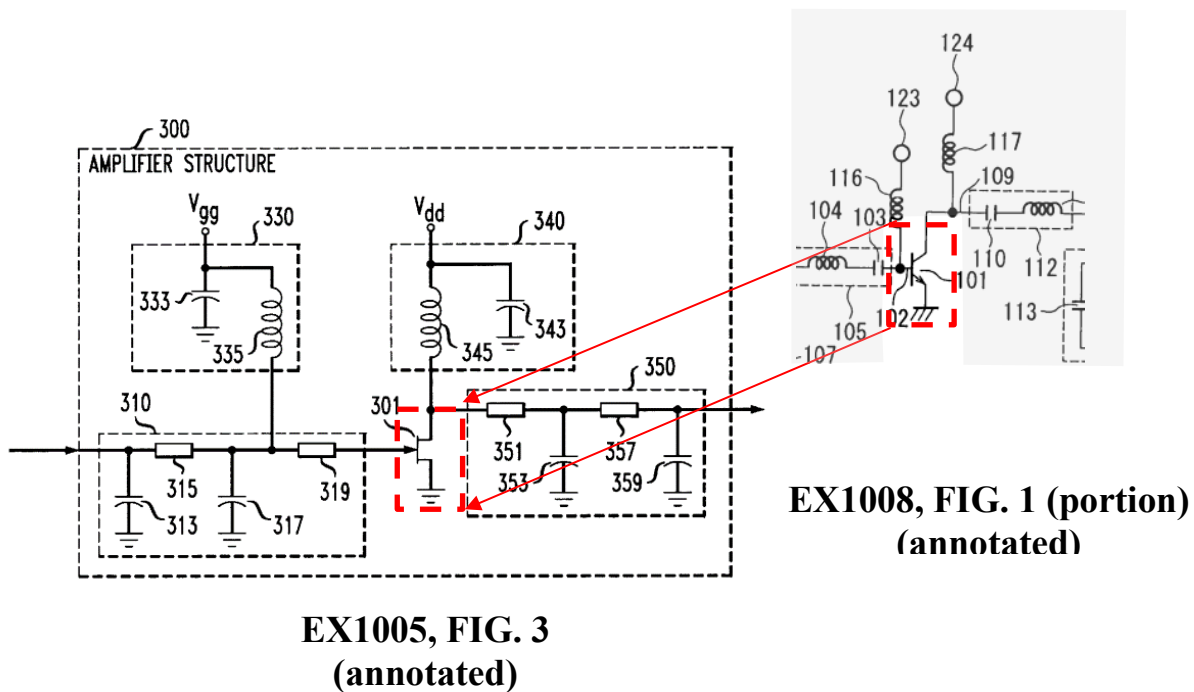
259. Francisco in combination with the teachings of JP466 renders obvious claim 1 and Francisco in view of Hirayama further teaches this element.

260. **First**, Francisco teaches that its active device is “a transistor.” EX1005, 8:8-9. While Francisco’s specification discusses a field-effect transistor (FET) configuration of its transistor, Francisco does not limit its disclosure to a FET. *See* Francisco) 8:30-54 (“As shown in FIG. 3, central to amplifier structure 300 is field effect transistor (FET) 301.”), claims 1-3 reciting “amplifying element,” which is narrowed to “a transistor,” and further narrowed “said transistor

is a field effect transistor (FET).” Thus, a POSITA would understand Francisco does not limit the configuration of its transistor to a FET.

261. Further, as discussed above in the reasons to combine Hirayama, it would have been obvious to provide the transistor of Francisco as a bipolar junction transistor (BJT) as shown in Hirayama. Hirayama describes that an amplifier can use an active device of a “bipolar transistor or a field effect transistor.” EX1008 (Hirayama), [0014]. In particular, Hirayama describes its techniques to allow use at multiple frequencies “can be applied to the case where an active element constituting the amplifier is **either a bipolar transistor or a field effect transistor** in the same manner, thus providing the matching circuit for converting the impedance into an optimum impedance at either of the two frequencies.” EX1008 (Hirayama), [0072].

262. Hirayama suggests design trade-offs between gain performance and cost would motivate a POSITA to use a BJT device in the amplifier: “The amplifier circuit of a **high gain** can be achieved in the **case of the use of the bipolar transistor** ... The optimum device can be appropriately selected according to the specifications required for the system.” EX1008 (Hirayama), [0128]. Thus, it would have been obvious to provide the active device of Francisco as a bipolar transistor as suggested by Hirayama.



263. As previously mentioned, both the FET and BJT 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. In sum, while a BJT has certain superior qualities such as higher gain, more linearity, and lower noise figure, these fundamental design principles are the same as when using other transistor types including FETs. This makes the use of a BJT instead of an FET highly predictable.

264. **Second**, as discussed in [1.0] above, Francisco teaches its amplifier structure 300 provides “multi-band **low noise amplifier (LNA) 155**” in the system 100. EX1005 (Francisco), 4:48-56, 5:27-29. The LNA 155 provides a *low noise amplifier* and is *operable for providing power gain at the first frequency and the second frequency*. EX1005 (Francisco), 4:47-48 (“**multi-band** LNA 155 provides an appropriate **gain** to the received signal.”), 7:57-58. The referred to gain is a *power gain* and as discussed above, the signals received by multi-band LNA 155 are of both the first and second frequency. Thus, Francisco teaches is amplifier structure operates as an LNA that receives and provides power gain for both the *first frequency* (e.g., cellular) and the *second frequency* (e.g., PCS). *See also*, EX1005, FIGS. 3, 5, 7:54-8:8, Abstract. Said differently, Francisco teaches that gain is desirable in the amplifier, and Hirayama’s usage of a BJT will tend to increase the gain as compared to an FET. For example, BJTs tend to have higher transconductance (g_m) which leads to better voltage gain.⁶

265. Thus, Francisco in view of JP466 and Hirayama renders obvious

⁶ In the basic model for a transistor, the output current is the transconductance, g_m , times the input voltage. Thus, a higher transconductance leads to higher output currents and/or voltages. Higher transconductance is fundamentally linked to higher gain.

claim 4.

5. Claim 6

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

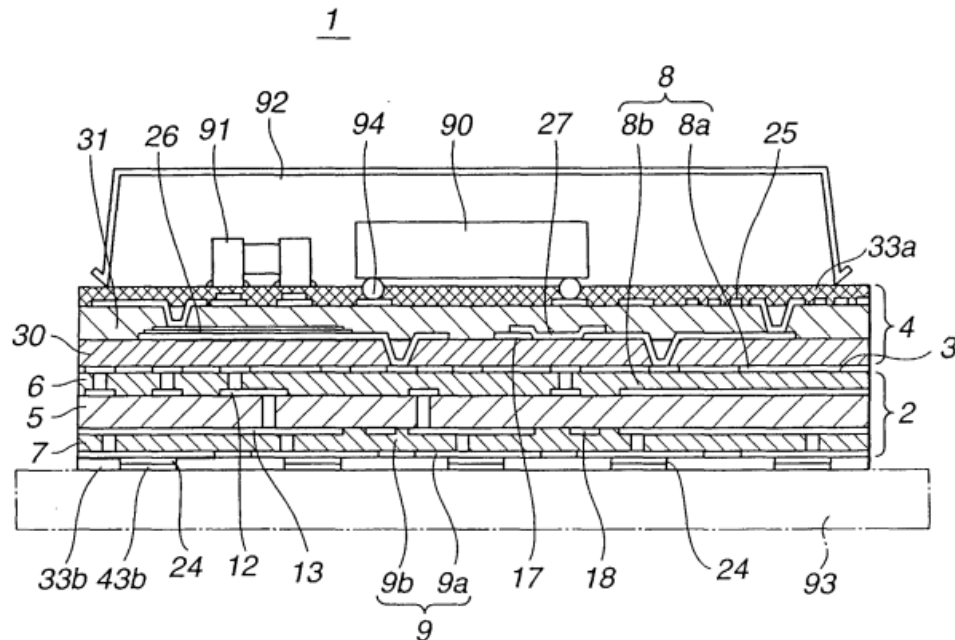
266. Francisco in view of JP466 renders obvious claim 5, and in light of Hirayama's teaching it would have been obvious to implement Francisco's active device as a bipolar junction transistor as discussed above in claim 4. Thus, claim 6 is rendered obvious by Francisco, JP466 and Hirayama.

C. Ground 3 - Claims 7-11 over Francisco, JP466, and Okubora

1. Okubora

267. Okubora is entitled "[h]igh frequency module device and method for its preparation," and describes devices for electronic equipment such as portable telephones. EX1007 (Okubora), (54), [0001]. Okubora also recognizes that communication systems for such equipment are reliant on various high frequency bands. EX1007 (Okubora), [0002]-[0005]. When implementing RF transmission/reception circuits, Okubora recognizes challenges to using silicon and glass substrates and in response provides "an object of the present invention to provide a high frequency module in which [] high precision passive elements...is formed on a base substrate formed on inexpensive organic resin to improve the function, as well as to reduce the thickness and size and to lower the production cost." EX1007 (Okubora), [0025].

268. Okubora illustrates a module that includes a high frequency integrated circuit (IC) 90 on core substrate 5, which also has a high frequency device layer 4 including first and second insulating layers 30 and 31 with passive elements, such as an inductor 25, a capacitor 26 and a resistor 27. *See* EX1007 (Okubora), Fig. 7, [0059]-[0075], method of fabricating in Fig. 8 with corresponding cross-sectional views in Figs. 9-21.



EX1007, FIG. 7

269. The substrate, including core substrate 5 and layers 30 and 31 each are formed of a material of low dielectric constant and low $\tan \delta$ (loss tangent).

EX1007 (Okubora), [0035], [0048], [0054]. A POSITA would readily appreciate the properties of the dielectric material of the substrate having embedded passive

components as discussed in claim 1, affects the structural and electrical properties of the module. The properties of dielectric materials that a POSITA would readily consider include $\tan \delta$ of the material, which is a measure of the inherent energy dissipation within a dielectric material when subjected to an alternating electric field. More specifically the loss tangent quantifies how much energy is lost as heat compared to how much energy is stored in an electric field within the dielectric material. This measure is expressed as a ratio, i.e., ratio of energy lost to heat divided by the energy stored in the electric field. Thus, a low loss tangent is preferred, as it means less energy is lost in the form of heat. One of the preferred materials with low loss tangent that is suggested by Okubora is liquid crystal polymer (LCP). *Id.*

2. Reasons to combine Francisco and JP466 (Francisco-JP466)

270. Reasons to combine Francisco and JP466 are above in Challenge 1.

3. Reasons to combine Francisco-JP466 and Okubora

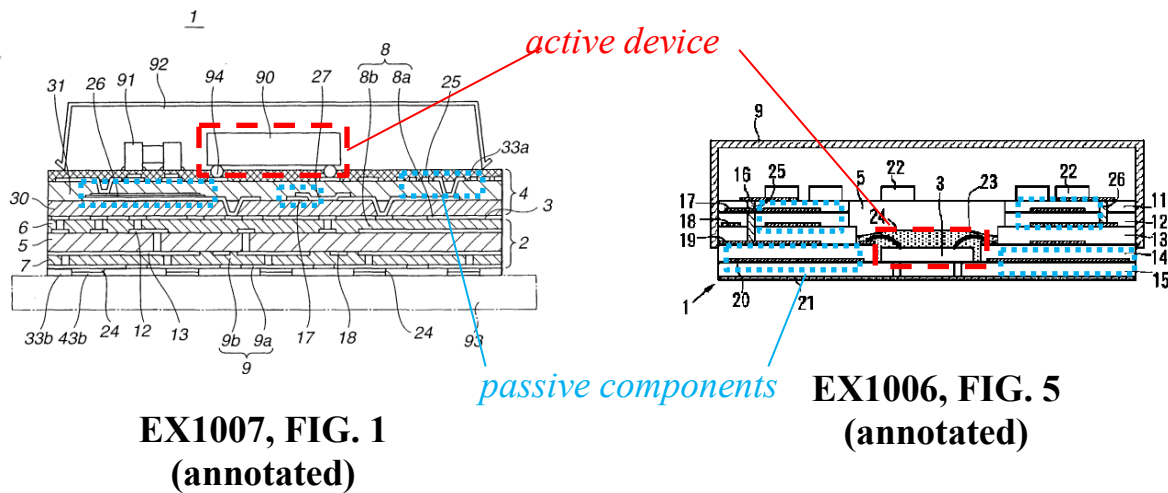
271. A POSITA would have been motivated to combine the teachings of Francisco-JP466 and Okubora for multiple reasons, including to produce the obvious, beneficial, and predictable results of providing JP466's insulating substrate in Francisco-JP466 device as comprising liquid crystalline polymer (LCP).

272. Francisco-JP466 and Okubora are in the same field of endeavor as the

'914 Patent as they are related to transmit and receive circuits including amplifiers and related passive components for radio frequency devices suitable for personal communication devices. EX1007 (Okubora), [0001]-[0006], FIG. 1; EX1005 (Francisco), 1:5-7, 1:36-46; EX1001, 1:23-27, 2:14-16. Not only are Okubora and '914 Patent in the same field of endeavor, but Okubora is reasonably pertinent to a problem faced by the inventor of the '914 Patent pertinent to reducing cost and size of packages of such devices. EX1001, 2:8-20, 24:37-46; EX1007 (Okubora), Abstract, [0006].

273. Further, Okubora is directed to implementation of circuitry in modules, as is the focus of JP466. Okubora is titled “High frequency module device and method for its preparation.” Okubora, like JP466 is focused on the reduction of “size and the cost of the package” by the use of “substrate” designed for “high frequency” operation. EX1007 (Okubora) at (57).

274. Francisco-JP466 and Okubora describe a substantially similar structure – RF transmit and receive circuitry each having a core device (Francisco’s transistor 101 or Okubora’s IC 90) disposed on a multi-layer, organic insulating material substrate having passive components (e.g., resistors, capacitors, inductors) embedded *within* its organic layers. Compare, Okubora at FIG. 7 and JP466 at FIG. 5.



275. Providing the JP466 substrate's dielectric substrate 1 with Okubora's dielectric material similarly configured in a substantially similar substrate is merely implementing a known material to perform its known function. A POSITA would recognize that there are a limited number of choices for dielectric material, with LCP being 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 multi[]layer 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, 249 (“LCP as a dielectric layer for system-on-package process”).

276. A POSITA would also appreciate the benefits of implementing LCP material. LCP is a thermoplastic providing an ease of use and fabrication. See Okubora, [0048]. As discussed below, LCP has an advantageous (e.g., low) loss tangent, which allows for maintain signal integrity and reduced generation of heat. And LCP has a benefit of being stable in the presence of moisture and exhibiting advantageous hermetic properties. See EX1023, p. 444 (“The need for a hermetic package is eliminated due to the highly impermeable characteristics of the LCP, which results in tremendous cost and weight savings.”) See also, EX1033, p. 249 (“LCP’s have high modulus, high melting temperatures, and good impact strength as a result of the fibrous nature of liquid crystal morphology.” LCP was also recognized as a cost-conscious material choice. EX1023, p. 444.

277. In summary, a POSITA would have been motivated to apply Okubora’s teachings when implementing the Francisco-JP466 device because doing so would beneficially (1) continue JP466’s goal of providing an organic dielectric material suitable for embedding high-quality passive components; (2) provide material that allows to maintain coating uniformity or thickness controllability as discussed in Okubora ([0048]), (3) provide benefits of LCP

including moisture resistance and (4) provide a low cost option. Each of these reasons separately and together would have motivated a POSITA.

278. The results would have been predictable and there would have been a reasonable expectation of success in the combination because Francisco-JP466 and Okubora describe similar RF devices for use in similar systems. JP466 describes an example using a polyvinyl benzyl ether compound as its organic resin material, which has a relative dielectric constant between 2.5 and 3.5 and a dielectric loss tangent in the range of 0.0025 to 0.005 (EX1006 (JP466), [0081].) The relative dielectric constant of LCP is about 3.0 and the value of the loss tangent of LCP is below 0.0045. *See* EX1032, “Characterization of Liquid Crystal Polymer for High Frequency System-in-a-Package Applications” Zou et al., 2002, p. 507. Thus, a POSITA would recognize that the wavelength reduction and higher dielectric constant benefits taught by JP466 are achieved via the use of LCP material of Okubora. The higher dielectric constant results in shorter wavelength and thus smaller elements such as inductors. The higher dielectric constant also allows capacitors to store more energy per area and thus become smaller. The low loss tangent avoids thermal dissipation, signal loss, and enables high-Q (quality) components such as inductors and capacitors. The structure of LCP and the polyvinyl benzyl ether compound are similar in that they are both organic polymer compounds.

279. Any modification needed to the teachings of Francisco-JP466 to accommodate the teachings of Okubora's material would have been within the level of ordinary skill in the art. JP466 does not limit its teaching to any particular material. See, JP466 [0079] ("The dielectric substrate is preferably made..."). And Okubora itself suggests the interchangeability of the suitable dielectric materials. Okubora, claim 4 describing "an organic material, **such as** benzocyclobutene, polyimide...**liquid crystal polymer**...exhibiting high frequency characteristics, thermal resistance, resistance against chemicals, uniform coating characteristics and thickness controlling characteristics." Okubora also illustrates the interchangeability of substrate materials including "liquid crystal polymer (LCP)" and "a mixture of ceramics with an organic substrate." Okubora, [0036].

4. Claim 11

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

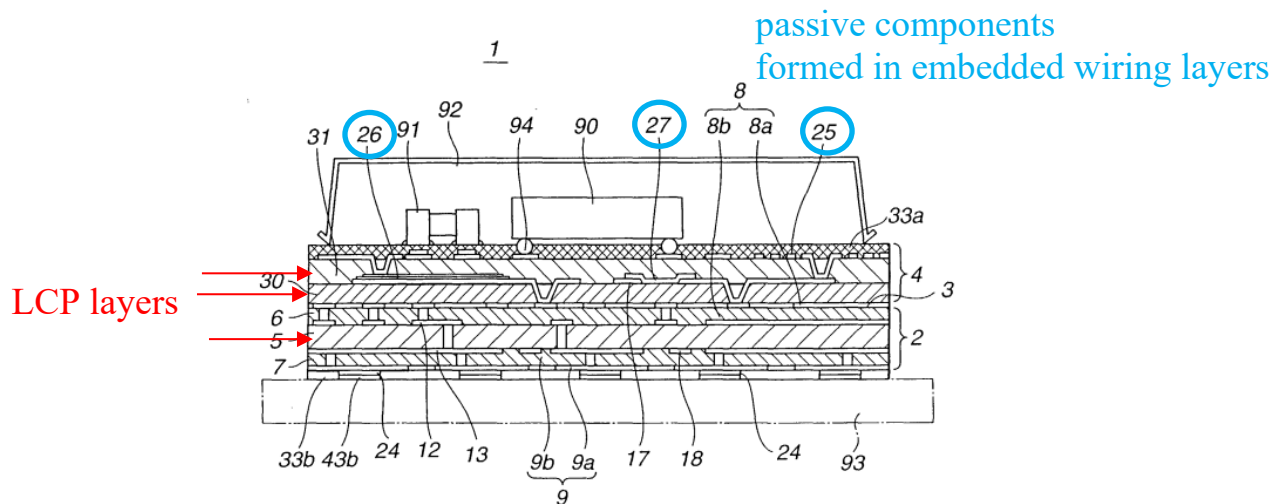
280. Francisco and JP466 render obvious claim 1, and in light of Okubora this element would have been obvious.

281. As discussed above in [1.4a], JP466 teaches that providing the multi-band RF device of Francisco with a dielectric, organic-based substrate. It would have been obvious for the substrate to comprise a liquid crystalline polymer (LCP) in light of the teachings of Okubora.

282. First, as discussed above in the reasons to combine Okubora above,

LCP is a dielectric organic material known for use in substrates including RF devices well before the '914 Patent and it would have been obvious on the suggestion of Okubora to use LCP in JP466's dielectric substrate 1. This is a simple substitution of one exemplary organic dielectric material for another where the materials have similar properties and are described as performing similar functions as discussed above and below.

283. Okubora describes a multi-layer substrate including multiple layers comprising liquid crystalline polymer (LCP). In particular, Okubora's "core substrate 5 is comprised of a low dielectric constant and low $\tan \delta$, that is of superior high frequency characteristics, such as....liquid crystal polymer (LCP)[.]" EX1007 (Okubora), [0063]. And Okubora continues that its insulating layers 30, 31 formed on core substrate 5 also comprise LCP. EX1007 (Okubora), [0076], [0082]. Passive elements such as resistor 27, capacitor 26, and inductor 25 are formed on wiring layers on these LCP layers. EX1007 (Okubora), [0079], [0084].



**EX1007, FIG. 7
(annotated)**

284. Okubora's FIGS. 8-23 are illustrative of the details of the formation the mobile device 1 of FIG. 7. A POSITA would have recognized using LCP in JP466's substrate for one or more of its layers (12, 13, 14, and/or 15), which are similarly configured, have similar dielectric properties, also include patterned conductors forming passives thereon.

285. Thus, Francisco, JP466, and Okubora render obvious claim 11.

5. 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.

286. Francisco and JP466 render obvious claim 1, and in light of Okubora this element would have been obvious.

287. As discussed above in [1.4a], it would have been obvious to provide

multi-band RF device of Francisco with an organic-based substrate as taught by JP466. JP466 provides an example of polyvinyl benzyl ether compound, which is a chlorinated hydrocarbon. To the extent that this claim is met by the use of a hydrocarbon alone, it is rendered obvious by Francisco and JP466.

288. Additionally, as discussed in claim 11 above, it would have been obvious for this substrate to comprise liquid crystalline polymer (LCP) in light of the teachings of Okubora. Thus, to the extent that this claim is construed as requiring 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. Okubora describes that multiple of its insulating compositions can be used together. *See also*, JP466, [0084]-[0088]. Okubora, claim 2 “substrate formed of **one or more** materials selected from the group consisting of **polyphenyl ethylene**, bismaleidotriazine, polyimide, **liquid crystal polymer**, **polynorbornene**, ceramics and mixtures of ceramics and organic materials.” At least polyphenyl ethylene and polynorbornene are hydrocarbons.

289. Thus, claim 7 is obvious in light of Francisco, JP466 and Okubora.

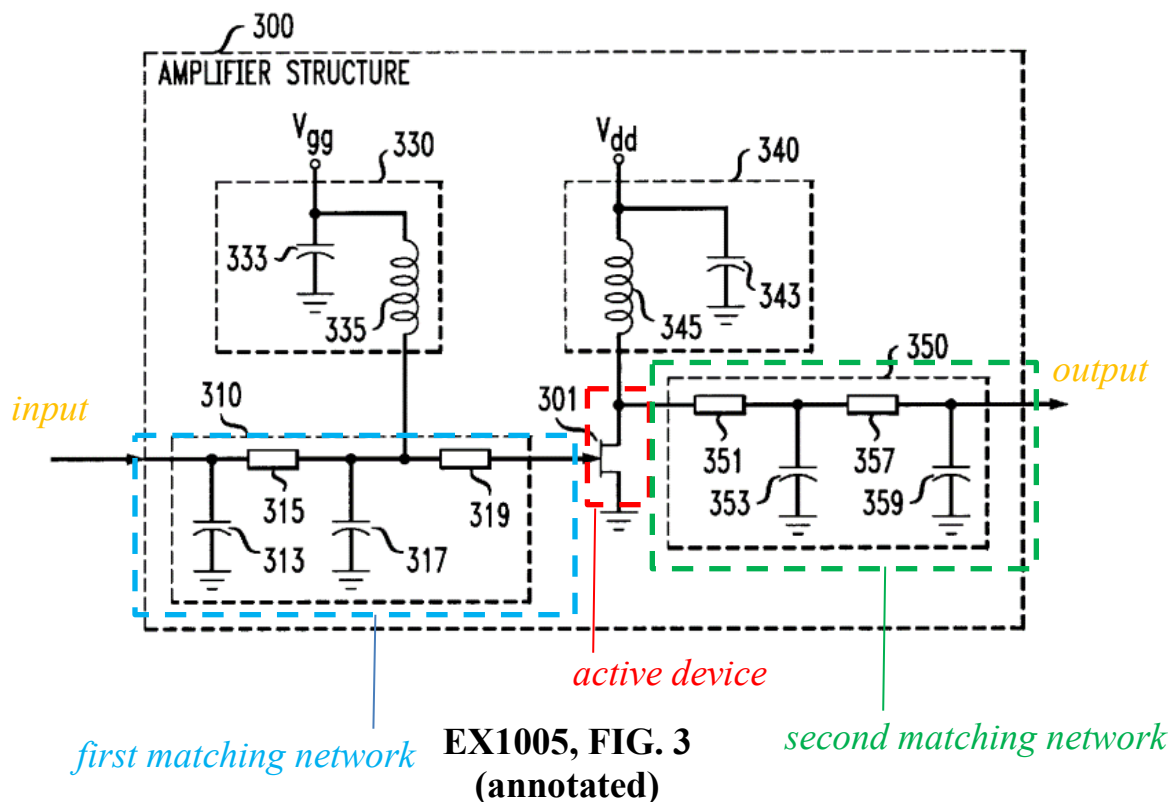
6. Claim 8

[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.*

290. Francisco in view of JP466 and Okubora renders obvious claim 7, and

Francisco also teaches this element.

291. Francisco illustrates the input matching circuit 330, which provides the *first matching network* as in [5.2] above, is positioned at an *input* of the amplifier structure 300 (*multi-band amplifier*). EX1005 (Francisco), FIG. 3, 5:30-45. And Francisco illustrates output matching circuit 350, which provide the *second matching network* as in [5.3] above, positioned at an *output* of the amplifier structure 300. EX1005 (Francisco), FIG. 3, 5:30-64. FIG. 3 is illustrative.



292. Francisco confirms:

In accordance with the invention, the **multi-band amplifier** uses an **input network** to achieve a selected input impedance, and an

output network to achieve a selected output impedance. The values of the input and output impedances are selected such that the gain values afforded by the multi-band amplifier to the components of the communication signal within the multiple frequency bands are significantly higher than the gain values to the signal components outside those bands.

EX1005 (Francisco), 1:50-61. I also discuss this above at claim elements [1.2], [1.3], [5.2], [5.3].

293. Thus, claim 8 is rendered obvious by Francisco, JP466 and Okubora.

7. 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.*

294. Claim 8 is rendered obvious by Francisco, JP466, and Okubora and Francisco also teaches this element.

295. Francisco teaches that its multi-band amplifier, illustrated by amplifier structure 300 of FIG. 3, receives and amplifies signals at multiple frequencies including the first frequency (e.g., cellular) and the second frequency (e.g., PCS) as discussed in [1.0] and [5.0]. The input matching network 310, *the first matching network*, minimizes the noise figure at each of these frequencies. A POSITA would recognize this to be the function of amplifier structure 300 functioning as low noise amplifier as in LNA 155. Francisco explicitly describes this in the context of its communication system 100. “In **LNA 155, input matching network 310** is

synthesized such that the source impedance of band half-duplexer 153 of FIG. 1 is transformed to T, which represents the source reflection coefficient giving **minimum noise in Rcv bands 203 [cellular] and 207 [PCS]**, and whose value is provided by the manufacturer of transistor 301.” EX1005 (Francisco), 6:1-7; *see also*, 2:27-74 discussing Rcv bands 203 and 207.

296. 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. Thus, claim 9 is rendered obvious by Francisco, JP466 and Okubora.

8. 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.

297. Claim 9 is rendered obvious by Francisco, JP466 and Okubora, and Francisco also teaches this element.

298. Francisco teaches that its multi-band amplifier, illustrated by amplifier structure 300 of FIG. 3, receives and amplifies signals at multiple frequencies including the first frequency (e.g., cellular) and the second frequency (e.g., PCS) as discussed in [1.0] and [5.0]. The output matching network 350, *the second matching network*, maximizes the desired power gains at each of these frequencies. A POSITA would recognize this to be the function of amplifier structure 300 functioning as power amplifier as in amplifier 115. Francisco explicitly describes this. “It suffices to know for now that unlike a prior art power amplifier which provides a **desired gain** to a signal within only a particular transmit band, amplifier 115 provides, in an efficient manner, **a desired gain** to a signal within **any one of the many discrete transmit bands.**” EX1005 (Francisco), 3:56-62, *see also*, 3:62-4:2. This is also described with respect to the amplifier structure 300 functioning as LNA 155 in the system 100. The system “...feeds the received signal, either a **cellular receive signal or PCS receive signal**, to multi-band low-noise amplifier (LNA) 155 ... Like amplifier 115, LNA 155 replaces two prior art LNAS which would otherwise be employed to handle cellular receive signals and PCS receive signals separately. In any event, multi-band LNA 155 provides an **appropriate gain** to the **received signal.**” EX1005 (Francisco), 4:40-48.

299. Francisco also explicitly suggests that the power gains be *maximize[d]*. “The **maximum power transfer** in the multiple bands of interest is thus achieved by amplifier structure 300 in accordance with the invention.” EX1005 (Francisco), 6:63-65.

300. Thus, claim 10 is rendered obvious by Francisco, JP466, and Okubora.

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: 7 February 2025A handwritten signature in black ink, appearing to read "Matthew B. Shoemake", written over a horizontal line.Matthew B. Shoemake