

IPR2024-00936
U.S. Patent No. 9,118,528
Patent Owner's Response

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

TEXAS INSTRUMENTS INC.,
Petitioner,

v.

PARKERVISION, INC.
Patent Owner

U.S. Patent No. 9,118,528

Issue Date: August 25, 2015

Title: METHOD AND SYSTEM FOR DOWN-CONVERTING AN
ELECTROMAGNETIC SIGNAL, AND TRANSFORMS FOR SAME, AND
APERTURE RELATIONSHIPS

Inter Partes Review No. IPR2024-00936

DECLARATION OF DR. DAVID RICKETTS

TABLE OF CONTENTS

	<u>Page</u>
I. BACKGROUND	1
II. PROFESSIONAL QUALIFICATIONS	1
III. MATERIAL CONSIDERED	4
IV. LEGAL STANDARDS	5
A. Obviousness.....	6
B. Conception and Reduction to Practice	7
V. LEVEL OF ORDINARY SKILL IN THE ART	8
VI. GENERAL OVERVIEW OF WIRELESS TECHNOLOGY	9
A. Wired communications	9
B. Wireless Communications.....	10
C. Frequency	11
D. Up-conversion	12
E. Down-conversion	13
VII. DETAILED TECHNOLOGY BACKGROUND.....	14
A. Basic circuit concepts.....	14
B. Circuit Components.....	16
1. Transistor	16
2. NMOS transistors.....	18
3. Resistor.....	22
4. Capacitor	23
5. Electrical Load	24

6.	Local Oscillator.....	25
7.	Differential Amplifiers.....	26
8.	Low-pass Filter	29
9.	Sampling	31
VIII.	DOWN-CONVERSION SYSTEMS.....	32
A.	Heterodyning (Non-Sampling).....	32
B.	Sampling.....	37
1.	Voltage sampling	38
2.	Energy Sampling.....	40
IX.	OPERATION OF FETS	43
X.	U.S. PATENT NO. 9,118,528	46
A.	Overview	46
B.	The patent’s disclosure regarding down-conversion systems.....	50
1.	Energy Transfer (energy sampling)	51
2.	Sample-and-hold (voltage sampling).....	56
C.	Conception and Reduction to Practice	60
D.	Prosecution history	60
XI.	CLAIM CONSTRUCTION	61
A.	Sampling aperture.....	62
B.	Switch.....	62
C.	Energy storage element	62
XII.	OVERVIEW OF THE ALLEGED PRIOR ART.....	67
A.	U.S. Patent No. 6,600,726 to Tayloe.....	67

B.	Texas Instruments Datasheet for SN74CBT3253 DUAL 1-OF-4 FET MULTIPLEXER/DEMULTIPLEXER.....	82
C.	Razavi.....	83
D.	U.S. Patent No. 7,065,327 to Macnally.....	97
XIII.	VALIDITY OF THE '528 PATENT	99
A.	Tayloe is not prior art.	99
B.	Macnally is not prior art.	99
C.	GROUND 1A: Tayloe, TI Datasheet, Macnally.....	100
1.	The Tayloe/TI Datasheet combination fails to disclose, teach or suggest numerous claimed features of the '528 patent.....	100
a.	Claims 1 and 19	100
b.	Claims 8, 9, 26, and 27	102
2.	Combination of Tayloe, TI Datasheet, Macnally	103
3.	There is no motivation to combine Tayloe, TI Datasheet, and Macnally.....	103
a.	Tayloe teaches away from using Figure 6 with the TI Datasheet multiplexer	106
b.	Tayloe teaches away from creating the integrated circuit that Petitioner suggests	110
c.	Macnally and TI Datasheet are not compatible.....	112
d.	Macnally's teaches a fundamentally different mixer than Tayloe	115
e.	There is no motivation to replace Tayloe's amplifiers with Macnally's biquad two-pole filter	116
4.	Tayloe and Macnally are not compatible.....	123

5.	There is no reasonable expectation of success in combining Tayloe/TI Datasheet and Macnally into an integrated circuit.	124
D.	GROUND 2: Razavi–Macnally	129
1.	Razavi does not disclose, teach, or suggest transferring energy from a modulated carrier signal as an output of a switch when the switch is ON.	129
2.	Razavi does not disclose, teach, or suggest (i) an energy storage element that stores transferred energy from the modulated carrier signal, or (ii) portions of transferred energy from switches are integrated over time to accumulate portions of transferred energy.	136
3.	Razavi does not disclose, teach, or suggest transferring energy from the modulated carrier signal to the storage element during a charging cycle when the switch is ON.	137
4.	Razavi does not disclose, teach, or suggest “energy discharged during any given discharge cycle is not completely discharged, with the remaining undischarged energy from the given discharge cycle becoming an initial condition for the next charging cycle.”	Error! Bookmark not defined.
5.	There is no motivation to combine Razavi and MacNally.	138
a.	Razavi teaches away from the proposed combination.	143
b.	Razavi and Macnally are not compatible.	145
c.	There is no reasonable expectation of success in combining Razavi and Macnally.	147
E.	None of the prior art references teach, disclose, or suggest an energy transfer system.	149
XIV.	SUPPLEMENTATION	150

I have personal knowledge of the facts set forth in this declaration and, if called to testify as a witness, would testify under oath as follows:

I. BACKGROUND

1. I have been retained as an expert on behalf of ParkerVision, Inc. (“ParkerVision”) in the above-captioned matter (IPR2024-00936).

2. I have been asked by ParkerVision to provide my expert opinion regarding the validity of claims 1-5, 8, 9, 11-23, 26, 27, and 29-36 of U.S. Patent No. 9,118,528 (“the ’528 patent”). For the reasons set forth below, it is my opinion that claims 1-5, 8, 9, 11-23, 26, 27, and 29-36 of the ’528 patent are valid.

II. PROFESSIONAL QUALIFICATIONS

3. I am currently Full Professor of Electrical and Computer Engineering at the North Carolina State University. In my position I conduct research and teach undergraduate and graduate students in the area of electrical and computer engineering. The courses I teach include Advanced Analog Integrated Circuit (“IC”) Design, Radio System Design, Analog Circuit Laboratory and Power Management IC Design. I also lead a research group that conducts research and design of electrical and electronic circuits, including millimeter wave and microwave circuits and systems, radio frequency identification (“RFID”) circuits, wireless power transfer circuits, analog circuits, and radio frequency (“RF”) circuits. I lead research in power electronics and power conversion integrated circuits. I also conduct research in

mixed signal RF/digital systems, including microcontroller-based Bluetooth systems. I have served in my current position since 2012.

4. Prior to my current position, I served as an Assistant Professor of Electrical and Computer Engineering and Assistant Professor of Materials Science and Engineering at Carnegie Mellon University from 2006 to 2012.

5. I received my B.S. and M.S. in Electrical Engineering in 1995 and 1997, respectively, from Worcester Polytechnic Institute in Worcester, Massachusetts. I received my Ph.D. in Electrical Engineering from Harvard University in Cambridge, Massachusetts in 2006.

6. Prior to entering academia, I worked as an engineer in private industry holding several engineering and managerial positions where I developed and oversaw the development of electrical and electronic circuits, including those related to power transfer, power conversion, and semiconductor design in wired and wireless circuits and systems.

7. From 1995 to 1999, I held a position as an engineer and senior engineer at American Power Conversion, where I designed AC-DC and DC-DC converters. In 1996, I completed my master's Thesis with Analog Devices on the design of a 622 MHz Frequency Synthesizer.

8. From 1999 to 2001, I held a position as a Principal Consultant at Renaissance Design, Inc., where I designed power management ICs.

9. From 2000 to 2002, I held a position as a Manager of New Product Development at ON Semiconductor Corp., where I was responsible for six product development teams. In that role I oversaw the development of over twenty power management ICs in bipolar, CMOS, and BiCMOS technologies.

10. From 2002 to 2003, I held the position of Advanced System Engineering Manager at ON Semiconductor Corp., where I directed a team of system engineers to develop multi-phase power management ICs for Intel and AMD microprocessors.

11. In 2006, I received my PhD on the topic of advanced oscillator topologies. My work on integrated circuit oscillators was included in the 2008 McGraw-Hill Yearbook of Science and Technology and discussed in Nature, the pre-eminent science journal.

12. I have published at least 52 academic journal papers, as shown in my curriculum vitae, relating to various topics related to millimeter wave and microwave circuits and systems, RFID circuits, wireless power transfer circuits, analog circuits, and RF circuits.

13. I have been the author of at least 81 conference articles, as shown in my curriculum vitae, relating to various topics related to millimeter wave and microwave circuits and systems, RFID circuits, wireless power transfer circuits, analog circuits, and RF circuits.

14. My qualifications forming the opinion set forth in this declaration are summarized here and explained in more detail in my curriculum vitae, which is attached as Appendix A hereto.

15. Based on my experience in the wireless communications industry, I have a detailed understanding of radio frequency circuit design.

III. MATERIAL CONSIDERED

16. In preparing this declaration, I have reviewed the specification, claims, and prosecution history of the '528 patent.

17. I have reviewed and understand the following documents, as well as any other(s) cited herein.

Exhibit No.	Description
Ex-1001	U.S. Patent No. 9,118,528
Ex-1002	Prosecution History of U.S. Patent No. 9,118,528
Ex-1003	Declaration of Dr. Ian Galton
Ex-1004	U.S. Patent No. 6,230,000 (“Tayloe”)
Ex-1005	SN74CBT3253 Dual 1-of-4 FET Multiplexer/Demultiplexer Datasheet
Ex-1017	Razavi, A 900-MHz CMOS Direct Conversion Receiver (“Razavi”)
Ex-1021	U.S. Patent No. US 7,065,327 (“Macnally”)
Ex-1022	U.S. Provisional Patent Application 60/099,723 (“MacNally Provisional”)
Ex.-2006	U.S. Patent No. 6,061,551
Ex.-2007	Joint Claim Construction Statement, ParkerVision, Inc. v. Texas Instruments Inc., 6:23-cv-00384, Dkt. 50 (April 29, 2024)
Ex.-2008	RESERVED
Ex.-2009	UA741 datasheet
Ex.-2010	Boeing Report dated April 29, 1998
Ex.-2011	ParkerVision schematic dated January 20, 1998

Ex.-2012	Eddie chip layout dated March 6, 1997
Ex.-2013	ParkerVision circuit board layout
Ex.-2014	ParkerVision schematic dated August 21, 1997
Ex.-2016	Declaration of David Sorrells
Ex.-2019	ParkerVision Announces Breakthrough in Wireless Radio Frequency Technology
Ex.-2020	Laboratory Tests Verify ParkerVision Wireless Technology
Ex.-2021	Universal Direct Conversion Receiver Evaluation ASIC Contract between ParkerVision and The Boeing Company
Ex.-2022	Notes from Boeing Tests
Ex.-2025	Excerpts from Howe, R. et al., Microelectronics: An Integrated Approach
Ex.-2027	Development Agreement between ParkerVision and TriQuint Semiconductor dated March 4, 1997
Ex.-2029	Spreadsheet showing ParkerVision files
Ex.-2030	Claim Construction Order dated 2/20/13 – No. 3:11-cv-00719 (MDFL)
Ex.-2031	Excerpt of Graf, R., Modern Dictionary of Electronics, Seventh Edition
Ex.-2032	Rofougaran, A., et al., A 1 GHz CMOS RF Front-End IC for a Direct Conversion Wireless Receiver
Ex.-2034	Deposition Transcript of Ian Galton, dated March 12, 2025
Ex.-2035	Sedra, Microelectronic Circuits (4 th ed. 1998)
Ex.-2036	ParkerVision’s Disclosure of Additional Final Infringement Contentions, dated March 31, 2025.
Ex.-2037	CMOS Analog Circuit Design

IV. LEGAL STANDARDS

18. I am not an attorney, and I have not independently researched the law. ParkerVision’s counsel has explained certain legal principles to me that I have relied on in forming my opinions set forth in this declaration. I have applied these legal principles in arriving at my opinions expressed in this declaration.

A. Obviousness

19. I have been informed and understand that an invention cannot be patented if the subject matter as a whole would have been obvious to a person of ordinary skill in the art at the time of the invention. Also, I understand that while the prior art is compared to each claim on an element-by-element basis, the claimed invention as a whole must have been obvious to one of ordinary skill in order for a claim to be invalid.

20. I understand that the fundamental question in analyzing obviousness is whether, at the time of the invention, the subject matter of the claimed invention as a whole would have been obvious to a person of ordinary skill in the art to which the subject matter pertains, taking into account: (a) the scope and content of the prior art; (b) the differences between the prior art and the claims at issue; (c) the level of ordinary skill in the art; and (d) any objective indicia of non-obviousness referred to as secondary considerations.

21. It is my understanding that objective indicia of non-obviousness (secondary considerations) include industry praise, commercial success, long-felt but unresolved need, copying, failure of others, and/or unexpected results. I also understand that there should be a nexus between the objective indicia and the claimed invention.

22. I understand that multiple references can be combined, with one another and/or with the knowledge of a person of ordinary skill in the art, in rendering a claim obvious. I also understand, however, that obviousness cannot be established by simply demonstrating that each element was independently known in the prior art. Rather, it may be necessary to identify a reason, such as a teaching, suggestion, or motivation, that would have prompted a person of ordinary skill in the art to combine the elements in the way the claimed invention does.

23. I also understand that obviousness cannot be established through hindsight. I understand this to mean that the claimed invention cannot be used as a roadmap to combine elements from different pieces of prior art, or different embodiments of a single prior art reference, to create the claimed invention. I understand that the claimed invention as a whole must be compared to the prior art as a whole, and one must avoid aggregating pieces of prior art through hindsight that would not have been combined absent the patent inventor's insight.

B. Conception and Reduction to Practice

24. I have been informed and understand that conception is the formation in the inventor's mind of a definite and permanent idea of the complete and operative invention as it is to be applied in practice.

25. Conception is complete when the idea is so clearly defined in an inventor's mind that, if it were communicated to a person having ordinary skill in

the art, he or she could reduce the invention to practice without undue research or experimentation.

26. Conception must include every feature or limitation of the claimed invention. I further understand that testimony from an alleged inventor regarding conception must be corroborated by other evidence, such as contemporaneous documents from the timeframe of the alleged conception.

27. Because conception is a mental act, it must be proven by evidence showing what the inventor has disclosed to others and what that disclosure means to one of ordinary skill in the art.

28. I have also been informed and understand that a claimed invention is actually “reduced to practice” when it has been constructed, used, or tested sufficiently to show that it works for its intended purpose. Actual reduction to practice of the subject invention means that an actual working embodiment that included all elements of the claim had been built. An invention is also said to be constructively “reduced to practice” if all elements of the claim have been fully described in a filed patent application.

V. LEVEL OF ORDINARY SKILL IN THE ART

29. I have been informed and understand that claims are construed from the perspective of a person of ordinary skill in the art (“POSITA”) at the time of the claimed invention.

30. In my opinion, a POSITA with respect to the '528 patent would have (a) a Bachelor of Science degree in electrical or computer engineering (or a related academic field), and at least two (2) additional years of work experience in the design and development of radio frequency circuits and/or systems, or (b) at least five (5) years of work experience and training in the design and development of radio frequency circuits and/or systems.

31. In view of my qualifications, experience, and understanding of the subject matter of the claimed invention, I believe that I meet the above-mentioned criteria and consider myself a person with at least ordinary skill in the art pertaining to the '528 patent.

VI. GENERAL OVERVIEW OF WIRELESS TECHNOLOGY

32. I have reviewed the declarations of ParkerVision's expert submitted in prior *inter partes* review proceedings and agree with the background information presented therein. Accordingly, I incorporate relevant portions of that background into my declaration, as they accurately describe the relevant technology and concepts.

A. Wired communications

33. Traditional wired communications networks transmit audio signals over wire lines by converting audio signals to electrical signals and back to audio signals.



34. When Bob speaks into a phone, Bob's phone converts his voice (low frequency audio signals) into electrical signals. Electrical signals are transmitted over wires to Alice's phone, which converts the electrical signals back into audio signals so that Alice can hear Bob's voice.

B. Wireless Communications

35. Similar to wired communications, in wireless communications, low frequency audio signals are converted into electrical signals. But instead of travelling through wires, the signals are transmitted through air as radio waves (electromagnetic (EM) waves).



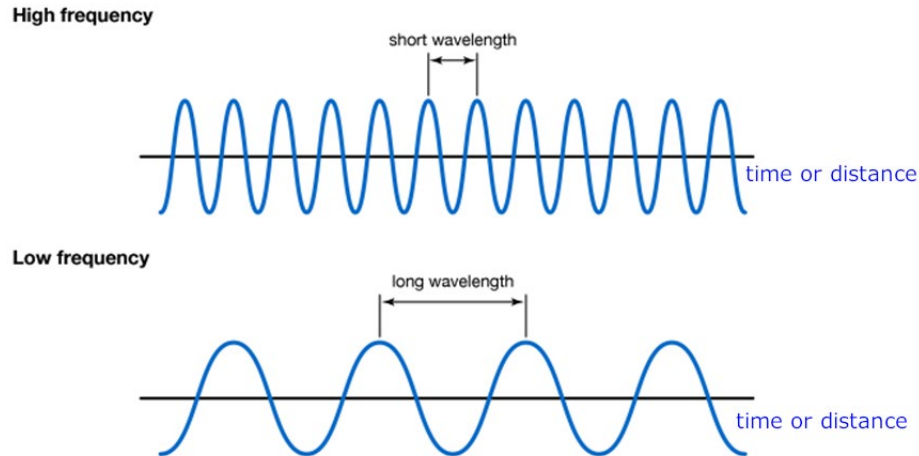
36. As shown above, wireless devices use high radio frequency (RF) signals (e.g., above 300 MHz (red) for cellphones) because high frequency signals can carry more information and because high frequency antennas can physically fit within small devices such as cellular phones.



37. In wireless communication, when Bob speaks into his cell phone, Bob's cell phone converts his voice (low frequency audio signals) into a high frequency RF signal. The RF signal is transmitted over the air to Alice's cell phone. Alice's cell phone then converts the RF signal back into a low frequency audio signal and Alice can hear Bob's voice.

C. Frequency

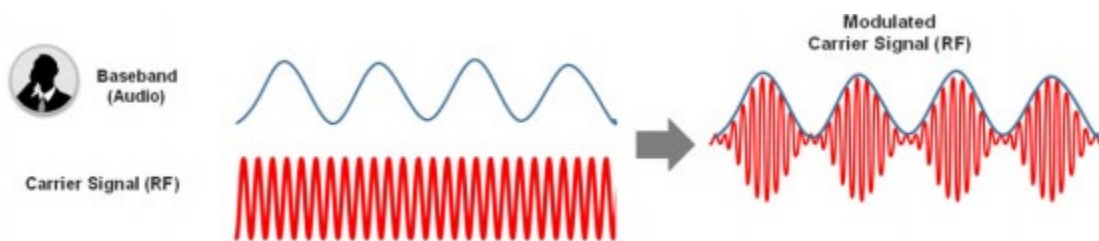
38. Frequency is the number of cycles of a wave per unit time (second).



39. As shown above, a high frequency signal has more cycles of a wave per second than a low frequency signal. Notably, the frequency of an audio wave can be one thousand cycles per second whereas the frequency of a radio wave can be one billion cycles per second.

D. Up-conversion

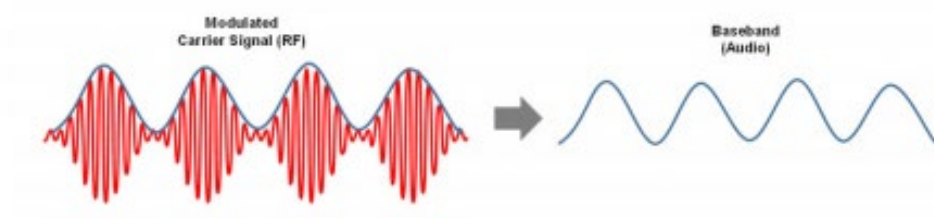
40. In order to transmit an audio signal over air, a wireless device must transform the audio signal to an RF signal. Since the RF signal is used to carry the information in the audio signal, the RF signal is referred to as a “carrier signal.” And since audio waves are at a low frequency, they are referred to as “baseband,” a “baseband signal” or at a “baseband frequency.”



41. In order to transport the baseband (audio) signal, the transmitting wireless device (e.g., Bob's cell phone) modifies the carrier (RF) signal. As shown above, the baseband signal is impressed upon the carrier signal (above left), thereby modulating/changing the shape of the carrier signal to approximate the shape of the baseband (audio) signal (above right).¹ The modified signal is referred to as a "modulated carrier signal." The process is referred to as "up-conversion" because the low frequency signal is being up-converted to a high frequency signal.

E. Down-conversion

42. In order for the receiving wireless device (e.g., Alice's cell phone) to recover the baseband (audio) signal from the modulated carrier signal, the receiving wireless device must transform the modulated carrier signal back to an audio signal. This process is referred to as "down-conversion" because a high frequency signal is being down-converted to a low frequency signal.



¹ This type of modification is referred to as amplitude modulation. But other types of modulation can be used, which involve modifying other properties of the carrier signal, such as frequency or phase.

As shown above, “down-conversion” is the process by which the baseband (audio) signal can be recovered from the carrier signal.

VII. DETAILED TECHNOLOGY BACKGROUND

A. Basic circuit concepts

43. RF signals are created and processed using electronic circuits. To appreciate the operation of such circuits, it is important to understand fundamental electrical concepts, including charge, voltage, current, energy, power, resistance, and impedance. These principles govern the operation of RF wireless receivers and down-conversion systems.

44. Charge: Charge is a fundamental property of matter. There are two physical types of charge: positive and negative. Protons carry a positive charge (+), while electrons carry a negative charge (–).

45. The operation of electrical circuits depends on the movement of electrons (not protons), which in turn facilitates the transfer of energy and information. An electron has potential energy, also called electric potential energy or just electrical energy. When charges move, both energy and charge are conserved and may be converted into other forms, such as heat. The buildup of charge establishes a voltage signal. Here, a voltage signal refers to information that is almost entirely conveyed as a voltage. Alternatively, the movement of charge—measured as current—can itself serve as the signal.

46. Voltage: Voltage represents the difference in electric potential energy per unit charge between two points in a circuit. It quantifies the amount of potential energy available to move charges. Negative charges (electrons) are naturally attracted to higher voltages, while positive charges (protons) are drawn toward lower voltages.

47. Electric current: Electric current is the flow/movement of charge within a circuit (in a conductor or into, out of, or through an electrical component).

48. Electric energy: Electric energy is the capacity to accomplish work based on a quantity of electric charge and its related electric field. Energy can be transferred by the motion of charge and the resulting electric field of the charge. Greater quantities of charge in motion are capable of transferring greater quantities of energy.

49. Energy is not the same as voltage. Energy can be retained as electrical energy or it can be converted to thermal energy. Voltage is the difference in electric potential energy (per unit charge) between two points and there can be a voltage whether or not energy is converted from electrical form to thermal form. Generally, when we are talking about electrical circuits, we are referring to electrical energy only and we talk about energy being dissipated where dissipated is short-hand for electrical energy being converted to thermal energy. Energy and voltage are used in circuits in different ways.

50. Power: Power is the rate at which energy is transferred within a circuit, measured per unit time. In electronic circuits, power quantifies the average rate at which charge carriers deliver energy.

51. Resistance: Resistance is a measure of the difficulty of passing current through a conductor

52. Impedance: Impedance is the measure of the opposition that a circuit presents to a current when a voltage is applied. Impedance is related to, but not the same as, resistance. Resistance is one component of impedance. In addition, impedance describes the ability of a circuit element to store and/or return electrical energy (referred to as reactance). A circuit component with high resistance has high impedance.

B. Circuit Components

53. Circuit designers and engineers use circuit diagrams to illustrate how various circuit elements are connected and interact. Each circuit element affects voltage, current, charge, and energy in a specific way. By combining different circuit elements in various configurations and selecting components with specific values, designers can create circuits that perform a wide range of functions.

1. Transistor

54. A transistor is a semiconductor device used to switch, detect, or amplify electronic signals and electrical power.

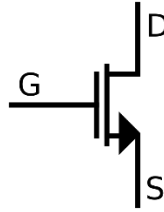
55. A transistor has at least three terminals for connection to an external circuit. Key to the functionality of a transistor is that a controlling voltage or current at one terminal can control a current between two of the other terminals.

56. A transistor has at least three terminals for connection to an external circuit. Key to the functionality of a transistor is that a controlling voltage or current at one terminal can control a current between two of the other terminals.

57. Some types of transistors can be used as a switch. Transistors, however, can also be used to provide other functions (e.g., amplification). Whether a transistor is used as a switch or performs another function depends on the signals applied to the terminals of the transistor, and on the circuit in which the transistor is embedded.

58. A field-effect transistor (FET) is one type of transistor. Most FETs are classified into junction-gate field-effect transistors (JFETs) and metal-oxide-semiconductor field-effect transistors (MOSFETs). One of the characteristics of a FET is that controlling a voltage at one terminal controls a current between two of the other terminals. A JFET or MOSFET can therefore be used as a switch, a continuous time-varying resistor, or can be used in other ways, such as to provide amplification.

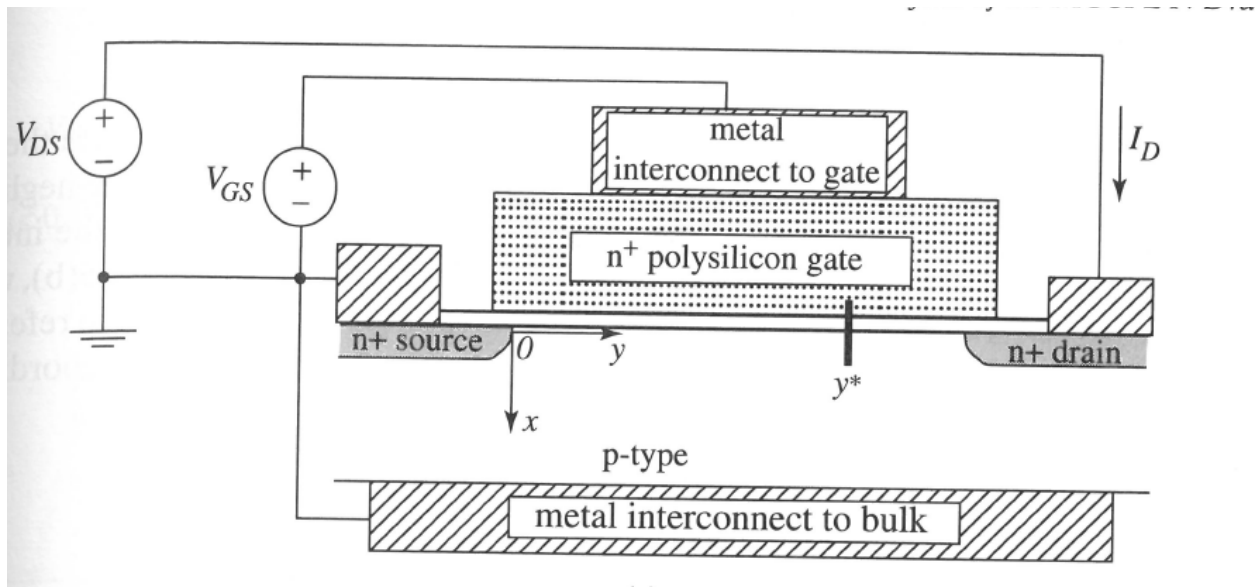
59. The symbol for one type of FET is shown below.



60. A FET has three terminals: (1) source (S), (2) drain (D), and (3) gate (G). In a FET, a voltage at the gate (G) controls the current flow between the drain (D) and source (S).

2. NMOS transistors

61. An NMOS (N-channel Metal-Oxide-Semiconductor) Field-Effect Transistor (FET) consists of three terminals: gate (G), drain (D), and source (S). The electron flow (current) from the drain (D) to the source (S) is controlled by the voltage at the gate (G).

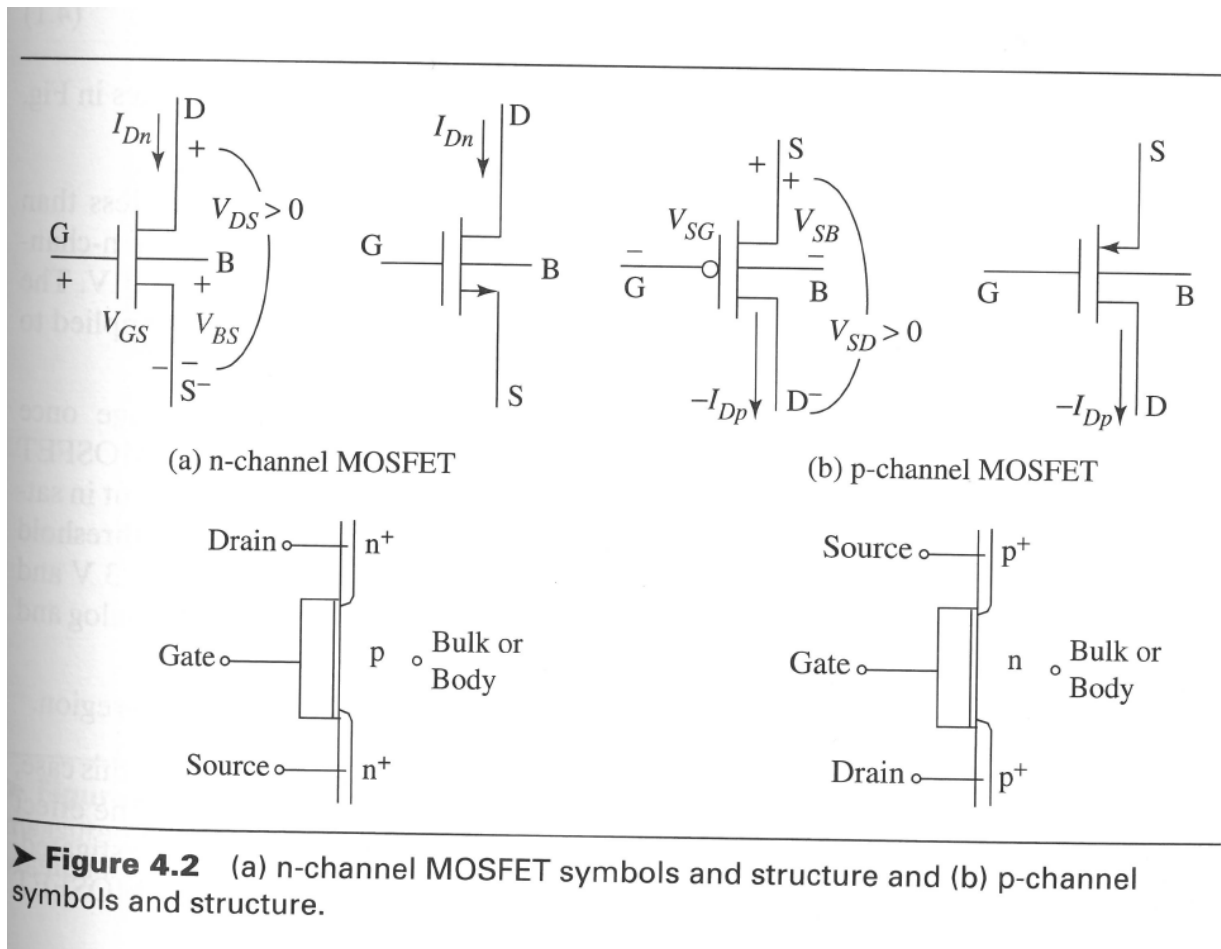


Ex.-2025, at p. 199.

62. When a positive voltage exceeding a fixed threshold² is applied to the gate relative to the source, an inversion layer forms in the p-type substrate, creating a conductive n-channel between the drain and source. This allows current to flow when a voltage difference is applied between the drain and source. The current is controlled by the gate voltage, making NMOS FETs highly efficient for switching and amplification applications.

63. The symbol for a n-channel (and its dual the p-channel) MOSFET is shown below.

² The threshold voltage (V_{Th}) is determined by the fabrication technology of the NMOS transistor and typically ranges between 0.3V and 1V.



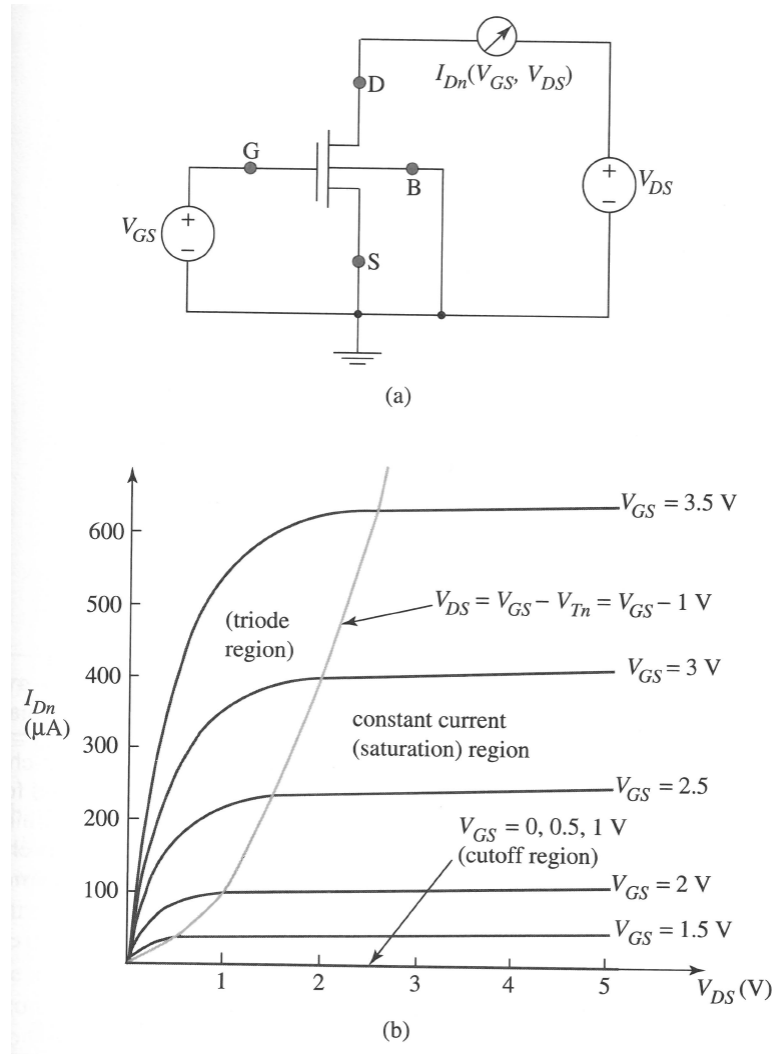
Ex.-2025, at p. 195.

64. As shown by the arrow in Figure 4.2 (a) above, the current I_{Dn} flows from the drain (D) to the source (S).

65. The NMOS MOSFET has two primary regions of operation³: (1) triode region, where the current is proportional to the drain-source voltage (V_{DS}), and (2)

³ There is a third region, called sub-threshold, but is not a region considered in the references discussed in this declaration. This region is used for ultra-low power circuit designs.

saturation region, where the current is constant across all V_{DS} ⁴. These two regions—triode and saturation—are shown in the figure below.



⁴ In practical devices, the current is not perfectly constant but will vary slightly with V_{DS} due to a phenomenon known as channel length modulation. However, to a first-order approximation, the current is considered constant and independent of V_{DS} .

Ex.-2025, at p. 197.

66. The saturation region occurs when the gate-to-source voltage (V_{GS}) exceeds the threshold (voltage V_{Th}) and the drain-to-source voltage (V_{DS}) satisfies: $V_{DS} \geq V_{GS} - V_{Th}$. For example, assuming $V_{Th} = 1\text{ V}$ as shown in the figure above, the minimum required V_{DS} for saturation would be:

If $V_{GS} = 2\text{V}$, then $V_{DS} \geq (2\text{V} - 1\text{V}) = 1\text{ V}$.

If $V_{GS} = 3\text{ V}$, then $V_{DS} \geq 2\text{V}$.

67. In saturation, the current flows only from the drain to the source, and V_{DS} is at least $> V_{Th}$ (usually much greater to allow larger current to flow).

68. An NMOS FET in saturation has a drain voltage of at least the threshold voltage (typically 0.3V to 1V) and supports unidirectional current flow from drain to source.

3. Resistor

69. A resistor is a circuit element that introduces resistance into a circuit.

70. The symbol for one type of resistor is shown below.

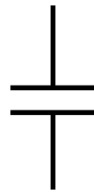


71. Resistors serve various functions, including reducing current, adjusting signal levels, dividing voltages, biasing active elements, and terminating transmission lines.

4. Capacitor

72. A capacitor is one type of circuit element used to accumulate energy. A capacitor accumulates electric energy in an electric field by separating charges over a distance.

73. The symbol for one type of capacitor is shown below.



74. A capacitor accumulates energy in an electric field established between two plates.

75. The ability of a capacitor to accumulate energy is described by its capacitance. The capacitance C of a capacitor is equal to the charge Q accumulated on the plates (with a positive charge $+Q$ on one plate and a negative charge $-Q$ on the other plate) divided by the voltage V between the plates and is calculated using the formula: $C = Q/V$. The capacitance of a capacitor is proportional to plate area and inversely proportional to the distance between the plates.

76. The formula for the energy E accumulated in a capacitor is set forth below (where C is the capacitance of the capacitor and V is the voltage across the capacitor).

$$E_{cap} = \frac{C \times V^2}{2}$$

77. As such, the energy accumulated in a capacitor is proportional to (a) the

square of the voltage across the capacitor and (b) the capacitance of the capacitor.

78. Given that energy accumulated in a capacitor is proportional to its capacitance, a capacitor with a small capacitance cannot accumulate much energy, whereas a capacitor with a larger capacitance can accumulate more energy for a given voltage.

5. Electrical Load

79. An electrical load is an electrical element or portion of a circuit that absorbs power and converts it into a desired form. Whereas a power source supplies energy, a load extracts/uses energy. For example, a resistor (Section VII.B.3 above) is a type of load.

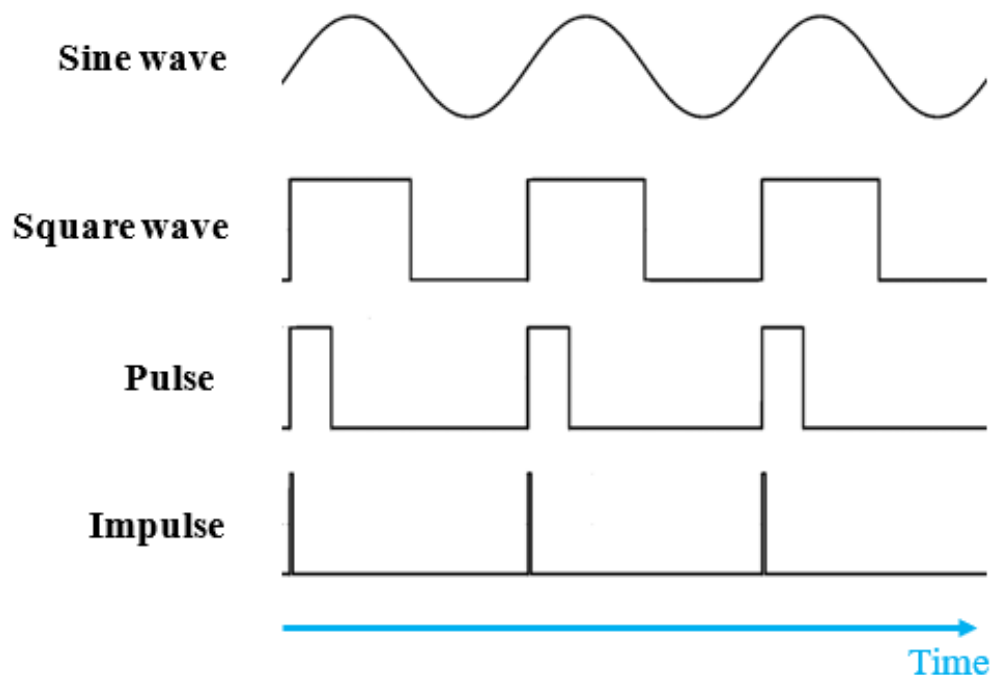
80. Connecting a load to a capacitor affects the amount of potential energy accumulated on the capacitor and how much energy is transferred to the load and, thus, the way the capacitor is used in a circuit. There are high impedance loads and low impedance loads. A high impedance load inhibits current from moving in a circuit and absorbs very little electrical energy. A low impedance load provides little constraint to current moving in a circuit and absorbs electrical energy. Thus, a low impedance load must have a low resistance, whereas a load with a high resistance is a high impedance load. The low impedance load will significantly discharge a capacitor, thereby changing the energy that was previously accumulated.

81. Since a load is connected to the output of other circuitry, the circuitry

(e.g., capacitor, source, transistors) is said to be driving the load (when substantial current flows from the circuitry to the load). For example, when circuitry is connected to a low impedance load, the circuitry is said to be driving a low impedance load.

6. Local Oscillator

82. A local oscillator is “[a]n oscillator used in a ... circuit to reproduce a sum or difference frequency equal to the intermediate frequency of the receiver. This is done by mixing its output with the received signal.” Ex.-2031, p. 5. The terms “local oscillator,” “LO,” or “LO circuit” are used to refer to the local oscillator circuit. The output signal of a local oscillator is commonly referred to as the “LO,” “LO signal,” or “local oscillator signal.”



83. The diagram above shows different types of signals that can be

generated by a local oscillator. The signal can be (1) a sine or sinusoidal wave, (2) a square wave, (3) a pulse, or (4) an impulse. A square wave, pulse and impulse are each periodic repetition of pulses.

84. A sine or sinusoidal wave is “a wave that can be expressed as the sine of a linear function of time, space, or both.” *Id.* at p. 8. In the context of circuits, a sine wave is a voltage or current that varies sinusoidally with time. The sine wave is a continuous signal with a value that changes smoothly over time.

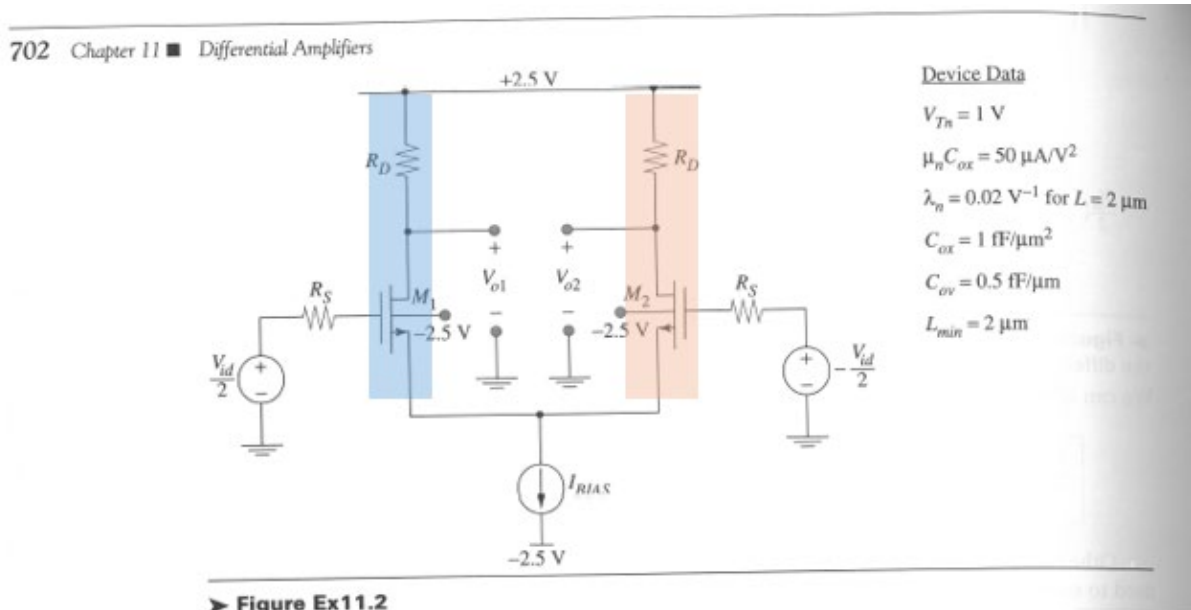
85. A square wave is a “square- or rectangular-shaped periodic wave that alternately assumes two fixed values for equal lengths of time, the transition time being negligible in comparison with the duration of each fixed value.” *Id.* at p. 9. A square wave is a signal that has two values, and unlike a sine wave, has abrupt transitions between those values.

86. A pulse is defined by “[a] sudden and abrupt jump in an electrical quantity from its usual level to a higher or lower value, quickly followed by an equally abrupt return.” *Id.* at p. 7. In other words, a local oscillator producing a pulse is actually producing a train of pulses, which repeat periodically in time. A train of pulses is a signal that has two values, and unlike a sine wave, has abrupt transitions between those values.

7. Differential Amplifiers

87. A differential amplifier circuit amplifies a differential input signal

using a “differential pair,” which consists of a pair of transistors connected as shown in the diagram below.



Ex.-2025, at p. 702.

88. As shown above, the differential amplifier circuit operates with a constant current bias (I_{BIAS}), which provides the bias, or operating point (quiescent point), for both transistors M_1 and M_2 . A differential input voltage, V_{id} , which is split into its differential components (a positive component and a negative component), is applied to the gates of M_1 and M_2 .

89. The bias current I_{BIAS} is divided between the two branches: (i) transistor M_1 and resistor R_D (blue) and (ii) transistor M_2 and resistor R_D (red). The differential output voltage is composed of V_{o1} and V_{o2} , where the voltages at these nodes are determined by the current through M_1 (for V_{o1}) or M_2 (V_{o2}) and the resistor R_D ,

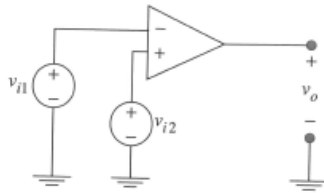
following Ohm's Law: $V = I \times R$.

90. The differential input voltage (V_{id}) steers the current I_{BIAS} between the two branches (blue and red).

91. For large input differential input signals, the current may be entirely steered into either the blue branch or the red branch, resulting in the maximum possible output voltage swing.

92. For example, if the differential input voltage is such that all of I_{BIAS} is directed through M1, then: $V_{o1} = 2.5 \text{ V} - R_D \times I_{M1}$ and $V_{o2} = 2.5 \text{ V}$. The differential output would then be: $V_{o1} - V_{o2} = -R_D \times I_{M1} = -R_D \times I_{BIAS}$, since the maximum current through either transistor is I_{BIAS} .

93. Operational amplifiers (op-amps) use a differential pair as their input.



► **Figure 11.19** Many operational amplifiers require a differential-to-single-ended conversion.

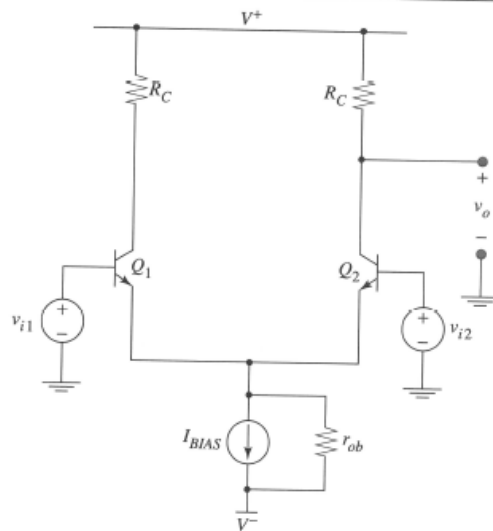
where $a_{dm} = -g_m R_C$ and $a_{cm} = \frac{-g_m R_C}{1 + 2g_m r_{ob}}$.

Using Eq. (11.38) the differential-mode gain for a purely differential input signal for this single-ended amplifier is

$$\frac{v_o}{v_{id}} = -\frac{a_{dm}}{2} = \frac{g_m R_C}{2} \quad (11.39)$$

The common-mode gain for a purely common-mode input signal is

$$\frac{v_o}{v_{ic}} = a_{cm} = \frac{-g_m R_C}{1 + 2g_m r_{ob}} \quad (11.40)$$



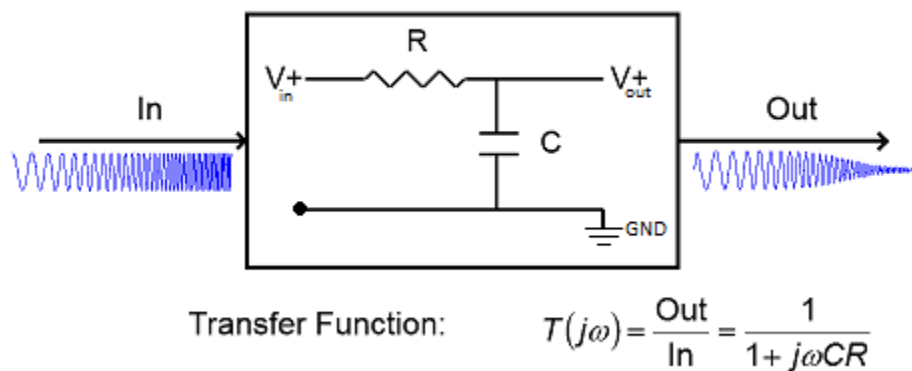
► **Figure 11.20** Differential amplifier with single-ended output.

Ex.-2025, at p. 709.

8. Low-pass Filter

94. A low pass filter is a circuit that attenuates high-frequency signals while allowing low-frequency signals to pass through. Typically, a low-pass filter shunts

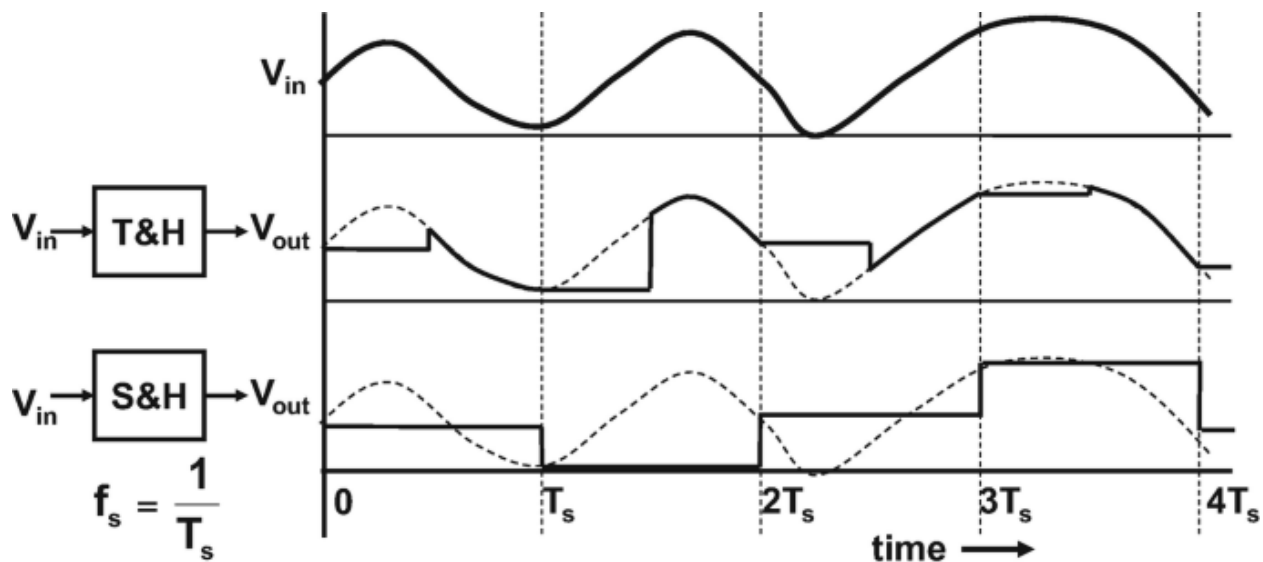
high-frequency components to ground. An example implementation of a low-pass filter is the RC filter, as shown below. In such a circuit, low frequencies pass through the filter (as illustrated by the left portion of the blue waveform), whereas the high frequencies are attenuated (i.e., not passed through).



95. A low-pass filter can be implemented in various ways. In the simple RC filter above, filtering is achieved due to the frequency-dependent impedance of the capacitor, C . The impedance of a capacitor decreases as frequency increases. When the frequency is low, the impedance of the capacitor C is high, and the voltage divider formed by R and C is such that $V_{\text{out}} \approx V_{\text{in}}$. However, as the frequency increases, the impedance of the capacitor C decreases, causing more of the input signal to be dropped across the capacitor rather than appearing at V_{out} . At sufficiently high frequencies, the capacitor C behaves as a short circuit ($\sim 0\Omega$ impedance), and essentially all of the input signal is dissipated across R , leading to V_{out} approaching $0V$.

9. Sampling

96. Sampling is the process of taking a continuous time signal and converting it to a discrete time signal. There are two common, traditional voltage sampling techniques. The first is a sample-and-hold, where a sample at a time instance, t , is taken and that value is held for a period of time T . During this time, typically the value is measured by an analog to digital converter (ADC) and converted to a digital representation. The second is a track-and-hold, where the signal is tracked and then at time T , it is held at the value it was at T . This also produces a discrete representation of the analog signal. The diagram below shows the two types of sampling.



97. A track- and-hold is typically easier to implement in practical circuits than a sample and hold. Both types of sampling are voltage sampling, that preserve the voltage of the waveform during the hold period. Any error to the held voltage

results in an error in the system. As such, a voltage sampler is measured with a very high-impedance measurement system so as to not affect the held voltage.

VIII. DOWN-CONVERSION SYSTEMS

98. There are two fundamentally different categories of down-conversion: (1) non-sampling/heterodyning; and (2) sampling-based down-conversion.

A. Heterodyning (Non-Sampling)

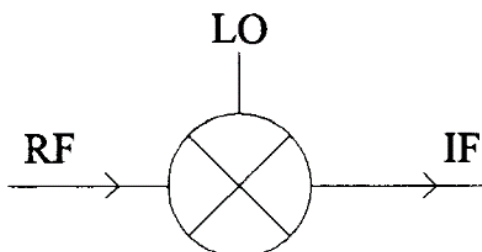
99. From the late 1980s through 2000, the industry was focused on the use of non-sampling mixers and heterodyne receivers for down-conversion. Heterodyne receivers, which used a decades-old RF technology called heterodyning, dominated the cellular/wireless industry for receiving and processing RF signals.

100. This technology used nonlinear and time-varying elements (e.g., transistors or diodes) in a nonlinear or time-varying mixer to effect translation of information centered at one frequency to information centered at another frequency. But this technology had problems – the circuitry was large and required significant power. The size and power requirements of heterodyne receivers were, at least in part, the result of the number of components these receivers used in order to perform down-conversion.

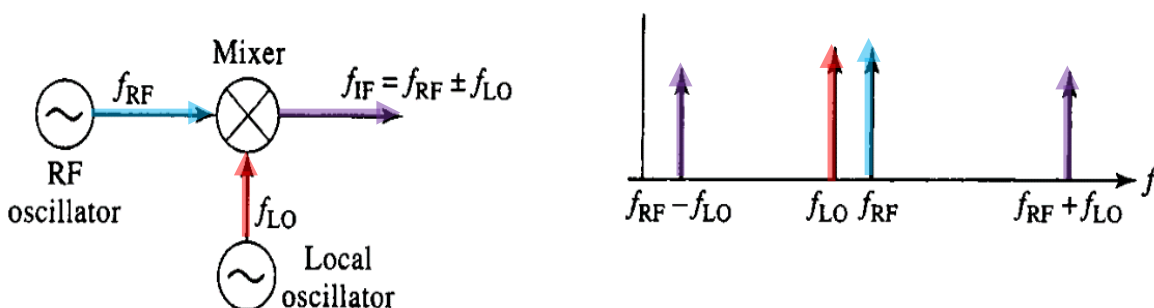
101. A non-sampling mixer operates by continuously multiplying two sinusoidal signals—an incoming RF signal with a local oscillator (LO) signal—resulting in an output spectrum governed by the equation: $f_o = mf_{RF} \pm nf_{LO}$, where f_{RF}

is the frequency of the RF signal, f_{LO} is the frequency of the local oscillator, and m and n are integers.

102. The typical symbol for a mixer is shown below.



103. The function of a mixer is to convert a signal received at one frequency to another frequency. As shown above, an input signal (here, an RF signal (modulated carrier signal)) enters a mixer and an output signal (here, an intermediate frequency (IF) signal) leaves the mixer. A component referred to as a local oscillator (LO) sends a signal to the mixer to effect down-conversion by the mixer.



104. As shown in the diagrams above, an RF signal is down-converted by frequency shifting the RF signal (blue arrow) to an IF signal (purple arrows). The frequency shift is accomplished by using a local oscillator to send a signal with a

frequency f_{LO} (red arrow) to the mixer. The mixer mixes the RF signal having a frequency f_{RF} and the LO signal having a frequency f_{LO} to produce an IF signal having frequencies at $f_{RF} - f_{LO}$ and $f_{RF} + f_{LO}$. As shown in the frequency domain (above right), down-conversion by the mixer replicates the RF signal frequency (blue arrow) at two frequencies: $f_{RF} - f_{LO}$ and $f_{RF} + f_{LO}$ (purple arrows).⁵ The circuitry after the mixer filters out the higher frequency $f_{RF} + f_{LO}$ signal, thus, leaving just the lower frequency $f_{RF} - f_{LO}$ signal. The mixer exploits the non-linearity of circuit elements to achieve the multiplication, i.e., mixing, of the RF and LO signals.

105. In view of the foregoing, the mixer described above is inherently a nonlinear circuit exploiting the nonlinear current-voltage characteristic of a nonlinear device.

106. Despite its widespread adoption, conventional receivers and mixers had significant drawbacks. The circuits were large, required substantial power, and introduced unwanted signals at undesired frequencies due to practical nonlinearities. This led to excessive noise and interference in direct down-conversion systems, requiring additional filtering and circuit components. Moreover, direct conversion

⁵ The mixer described in this section is an ideal mixer/multiplier. As such, while not shown, in practice there will be many other unwanted frequency components in the RF signal leaving the mixer (i.e., there will be noise).

schemes using heterodyning struggled to accommodate modern communication protocols with wide variations in baseband characteristics, including large amplitude variations. Furthermore, continuously time-varying elements consumed considerable battery power, reducing device efficiency and battery life. There are significant disadvantages to using mixers with continuously time-varying resistance (e.g., Gilbert cell analog multiplier). Because of practical nonlinearities inherent to their operation, they create unwanted signals at frequencies other than the desired frequency. Because of non-linearity, mixers have traditionally been the limiting factor in the performance of radio receivers.⁶

107. In non-sampling mixers, noise and nonlinear distortion generated by the mixer become significant. A consequence of the noise generated is that the RF signal level needs to be much higher than it would otherwise be for the mixer to output a down-converted signal level that is more than the noise level. This high level of noise means that the down-converted signal cannot be distinguished from noise for low RF input signal levels. Once noise is produced at frequencies corresponding to the down-converted signal, it cannot be removed without loss of desired information. A consequence of this is that more battery power is required by the LNA before the mixer to boost the RF signal level, which causes additional

⁶ I note that I am not stating that any mixer that multiplies is a non-linear mixer.

problems.

108. The nonlinearity in the process of multiplying an RF signal and an LO signal using practical hardware results in nonlinear distortion which is made worse with larger RF signal levels input to the mixer. A result is that no matter what is done, the minimum RF input signal level received by a receiver, e.g., the receiver in a cell phone, must be much larger than it would be if the mixer was ideal with no non-linearity and no noise injection. The distance the receiver (e.g., a phone) can be from a transmitter (e.g., base station) is much less than it would be if the mixer had lower noise and nonlinear distortion levels.

109. Mixers used in heterodyne receives could not efficiently handle baseband signals that varied widely in amplitude such as the range of amplitudes used in advanced communication protocols. In addition, with mixers, there was a problem of too much noise and interference being inserted into the down-converted signal. Addressing this noise and interference required many additional circuit components such as filters to eliminate unwanted signals. But no component could remove noise near the frequency of the down-converted signal without removing part of the down-converted signal. There was yet another problem with mixers in that the non-sampling and time-varying elements consumed considerable battery power, thus reducing battery lifetime. As a result, research and design of mixers based on a nonlinear mixing was pursued extensively in order to address these issues.

110. Another type of down-converter is a direct down-converter, where the RF and LO frequencies are the same, such that the purple arrow would be near or around 0 Hz. This would put the information signal at baseband.

111. Direct conversion schemes used non-sampling or time-varying devices to effect conversion. But these schemes had difficulty handling signals (RF or baseband) that varied widely in amplitude. With direct down-converters, there was a problem of too much noise and interference being inserted into the down-converted signal. These problems required many additional circuit components and also resulted in direct conversion schemes that could not be used with advanced communication protocols that have wide variations in the baseband characteristics such as having large amplitude variations.

B. Sampling

112. In contrast to heterodyning, sampling-based down-conversion uses pulsed LO signals rather than continuous sinusoidal signals. These systems use switches to capture discrete samples of the RF signal at specific time intervals, leveraging aliasing effects for frequency translation.

113. Sampling-based down-conversion systems can be further categorized into two distinct types: (1) voltage sampling systems, and (2) energy transfer (energy sampling) systems – the technology claimed in the '528 patent.

1. Voltage sampling

114. In the late 1980s through 2000, a technology being considered for direct down-conversion (to recover the baseband signal directly from the RF signal without using IF) was sample-and-hold (a type of voltage sampling).

115. In the late 1990s through the early 2000s, the radio (cellular/wireless) industry was exploring direct down-conversion solutions that replicated the voltage of the RF signal and introduced as little voltage distortion as possible. At this time, it was thought that the best (and most accurate) way to accomplish this was to use the held voltage of the RF signal itself or its envelope, at a particular instant in time. Such a solution was quite logical – replicate voltage as faithfully as possible and hold the sampled voltage on a capacitor, until the next sampling instance. Holding the voltage level for an interval of time required that there should be no charge leaving (i.e., discharging from) the capacitor. *See Ex.-2037, pp. 523-524.* As such, the state-of-the-art at that time was to use a sample-and-hold system to accomplish this.

116. One implementation of sample-and-hold was based on sampling the RF signal using an impulse sampling concept. Impulse sampling attempts to replicate the voltage of the RF signal at the sampling instant with as little distortion as possible. The sampled voltage of the RF signal, in turn, is a representation of the original baseband signal sent from a transmitting device. The technique that was

being explored at the time was impulse sample-and-hold. A switch was used to connect the RF signal to a small holding capacitor which held the sampled voltage long enough for its value to be read. It was critical that the holding capacitor was small so that relatively few charges were transferred during sampling so that the source RF voltage signal was not distorted.

117. Another implementation of sample-and-hold is track-and-hold. In track-and-hold, the same or equivalent circuit configuration to an impulse sample-and-hold circuit is used. In track-and-hold, the switch is connected to the holding capacitor for a tracking interval and the voltage that is sampled (and held on the holding capacitor) is the voltage at the end of the tracking interval. Thus, the sampling aperture is the instant, i.e., negligible aperture, at the end of the tracking interval. Track-and-hold is a type of voltage sampling because track-and-hold uses readings of voltage across a capacitor in order to down-convert, and energy is not discharged from the capacitor to form the down-converted signal. A track-and-hold voltage sampling mixer circuit “fundamentally suffers from a large noise figure, because while tracking the narrowband signal, it also tracks and aliases wideband noise. This, and the difficulty of buffering such a switched mixer to the inductive load of an integrated LNA, make it inappropriate in a sensitive receiver.” Ex.-2032 at p. 5. The above quoted description and analysis applies to voltage sampling in general.

118. In a voltage sampling system, the system captures discrete voltage readings on a capacitor and recreates the baseband signal based on those voltage readings. A high impedance load is used to hold the voltage on a capacitor during each sample. The high impedance load prevents the capacitor from discharging so that an accurate reading of voltage can be taken. Without a high impedance load, the voltage on the capacitor would fluctuate, thereby preventing an accurate reading of the voltage and defeating the fundamental purpose of voltage sampling. And, without an accurate reading of the voltage, the baseband signal cannot be accurately recreated (the system would not work). Transferring any energy out of the capacitor does not allow for an accurate reading of the voltage, thereby defeating the entire purpose of the system. Each sample of a voltage sampling circuit is independent from the previous sample. Energy does not become part of the baseband signal; instead, energy is effectively thrown away and wasted. In other words, in voltage sampling, energy from the input signal is not integrated nor does it make up/become part of the baseband signal itself. *See Ex.-2037, pp. 523-524.*

2. Energy Sampling

119. In the late 1990s through early 2000s, a POSITA was not looking into energy sampling as an alternative to voltage sampling in order to perform down-conversion. Nor was sampling the only solution being considered. So, a POSITA would not look at the problems with sample-and-hold/voltage sampling and turn to

energy sampling for a solution. On the contrary, using energy sampling to form a baseband signal was counter-intuitive and against the thinking in the radio (cellular/wireless) industry at the time.

120. Energy transfer (energy sampling) was/is a fundamentally different and competing method to voltage sampling. Energy samplers do not attempt to replicate or sample the voltage of an RF signal. As such, at the time of the invention of the '528 patent, a POSITA would not simply substitute or consider using an energy transfer (energy sampling) system in place of a sample-and-hold/voltage sampling system and vice versa.

121. In ParkerVision's energy transfer system, non-negligible amounts of energy from an input signal (a radio frequency (RF) signal) pass through the switch and the energy transferred itself to a load forms the down-converted (baseband) signal. In an energy transfer system, energy is integrated in a storage module and a low impedance load is used. The low impedance load allows energy to be transferred through the system. This configuration allows energy to continuously flow to the low impedance load and forms the baseband signal. In particular, the RF signal drives the low impedance load when the switch is closed (ON), and the storage module continues to drive the low impedance load when the switch is opened (OFF). So energy flows from the switch when the switch is closed (ON) and from the storage module when the switch is opened (OFF).

122. If the capacitor did not continue to drive the low impedance load, there would be gaps in the output signal. As such, the energy transfer system would not work properly, and information would be lost.

123. Whereas the high impedance load in voltage sampling (e.g., sample-and-hold) causes a capacitor to hold energy (i.e., prevent energy in the capacitor from being discharged to form the down-converted signal), the low impedance load in energy sampling has the opposite effect, enabling a capacitor to store energy and then discharge the stored energy in between samples to form the down-converted signal (i.e., the discharged energy is conveyed in the down-converted signal).

124. The technique used in energy sampling enables direct down-conversion with advantages over other techniques including voltage sampling/sample-and-hold.

125. Energy sampling is an accurate way to form a baseband signal (which is a representation of the original baseband signal sent from a transmitting device). In energy sampling, unlike voltage sampling, accurately capturing the voltage of the RF signal is not critical. An advantage of an energy sampling system is that the energy stored on the capacitor is accumulated. This accumulation enabled the random noise fluctuations on the RF signal to average out even further than would be obtained by averaging out over just one sampling aperture. Moreover, the baseband signal carries significant power because non-negligible energy is discharged from the capacitor for driving a low impedance load.

126. There are significant advantages to using energy sampling instead of voltage sampling. For example, use of energy sampling to down-convert an RF signal improves RF receiver performance, lowers power consumption, reduces size of integrated circuits/devices and has other integration benefits. In other words, by using energy sampling, RF receivers can be built smaller, cheaper and with improved performance.

IX. OPERATION OF FETS

127. A FET is a type of transistor that can amplify, oscillate, or switch the flow of current between two terminals by varying the current or voltage at a third terminal. The specific function a FET performs depends on how it is configured within a circuit.

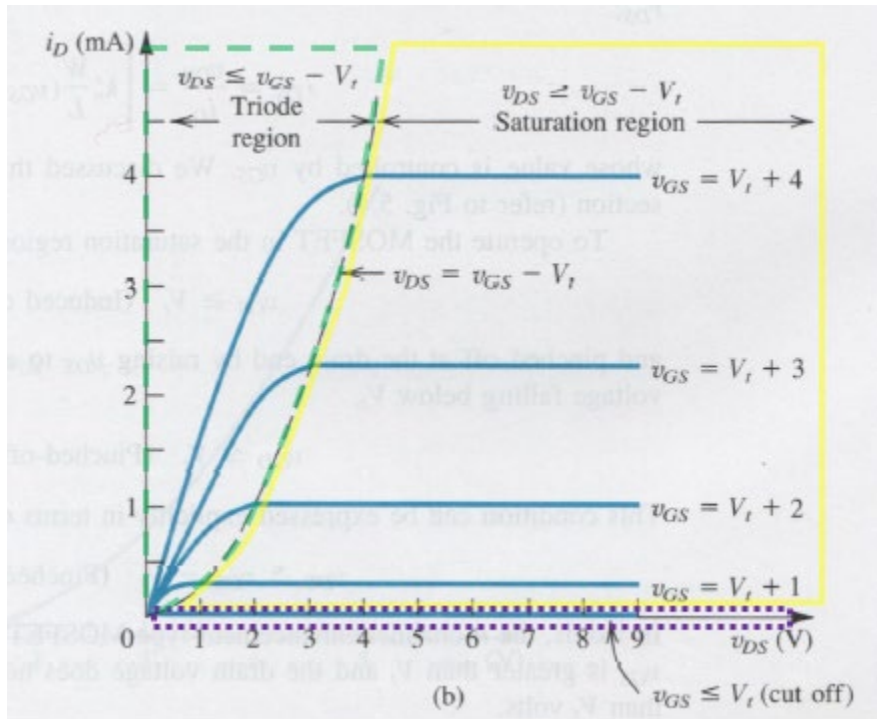
128. In electronics, “biasing” refers to setting a device’s operating conditions—such as its current or voltage—to achieve a desired mode of operation. FETs are non-linear devices, meaning their electrical characteristics change in response to variations in voltage and current. Because of this, a FET can behave differently depending on how it is biased and how it interacts with the surrounding circuit.

129. The behavior of a FET is primarily determined by three factors: the input signal applied to the gate (e.g., LO signal), the biasing conditions of the FET, and the overall circuit configuration.

130. Even if the same exact FET is used in the same exact circuit, applying different input signals at the gate can cause the FET to function in entirely different ways.

131. When a FET receives a moderate amplitude sinusoidal input signal at its gate, it modulates the current flowing between its output terminals in a continuous manner. The FET behaves as a continuous time-varying resistor. This mode of operation is referred to as time-varying transconductance—where a change in voltage at one terminal affects the conductance (ease of current flow) elsewhere in the circuit.

132. If that same exact FET receives a high-amplitude, rapidly changing input signal (e.g., square wave or a pulse train) it operates as a switch. In this mode, the FET alternates between an “on” state (allowing current to flow) and “off” state (blocking current flow), effectively opening and closing the circuit at defined intervals.



Ex.-2035, 367.

133. In order to explain how a FET works, a current-voltage characteristic graph for a MOSFET is shown above. The figure shows several current-voltage (I-V) curves (blue lines) of an enhancement-type NMOS transistor (a type of MOSFET). Each blue line corresponds to a different controlling voltage, i.e., gate to source voltage (V_{GS}). The vertical axis is the current (I_{DS}) that flows between the drain (D) and source (S) terminals, and the horizontal axis is the voltage (V_{DS}) between the drain and source.

134. A MOSFET has distinct regions of operation: (i) cutoff region (dotted purple box); (ii) triode region (dashed green box); and (iii) saturation region (yellow box). When operating in different regions, a MOSFET (and FETs in general)

exhibits different behaviors and, thus, the MOSFET will act as different devices.

135. **Cutoff Region**: When V_{GS} is below a critical voltage, which is the threshold voltage of the transistor V_t , the conductive channel is closed, and no current flows between the drain and source ($I_{DS} = 0$).

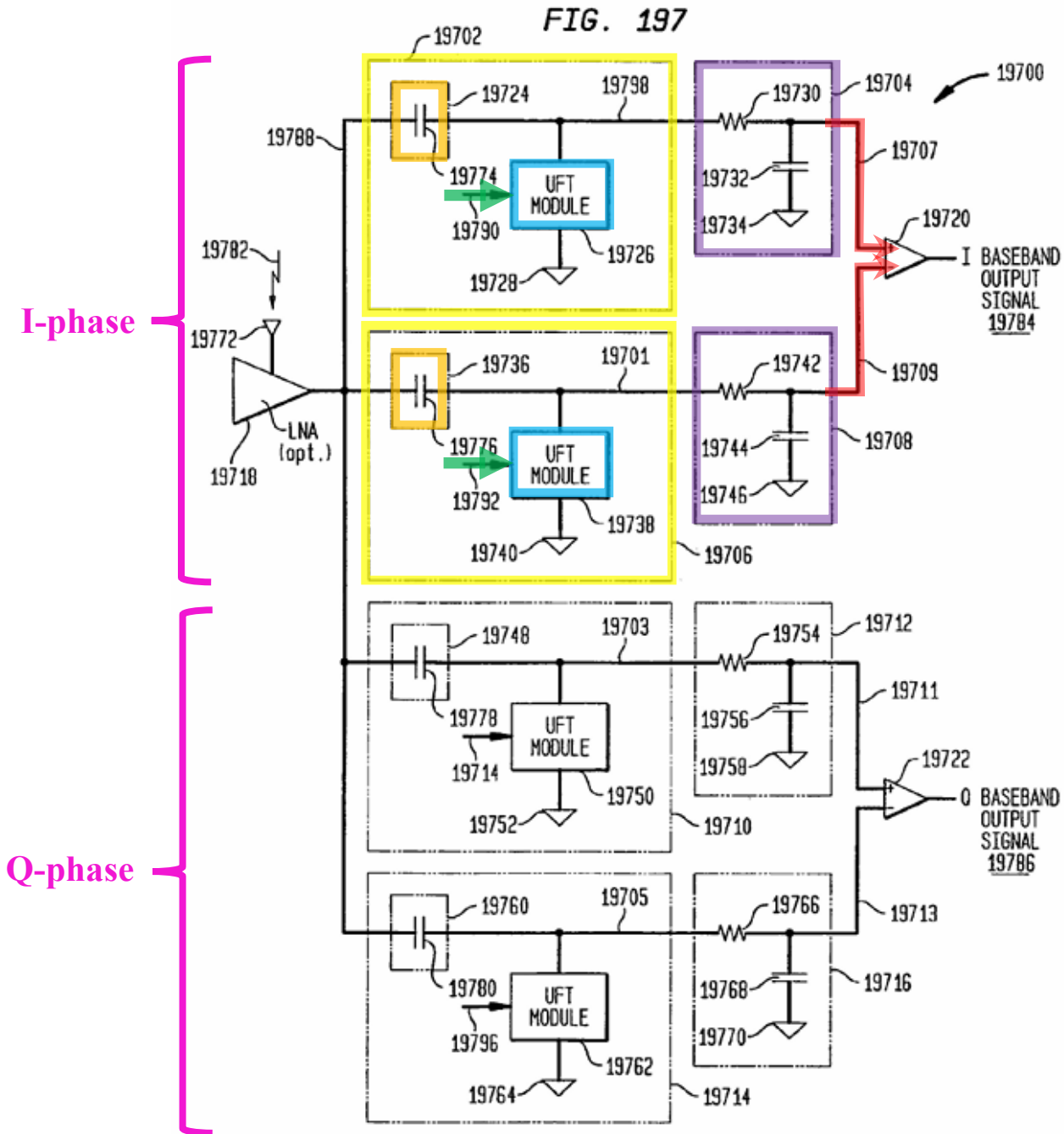
136. **Triode (Transconductance) Region**: When V_{GS} exceeds the threshold voltage and V_{DS} is less than the saturation voltage of the MOSFET, the MOSFET behaves like a voltage-controlled resistor. The relationship between I_{DS} and V_{DS} is roughly linear.

137. **Saturation (Non-Linear) Region**: When V_{DS} exceeds a certain saturation voltage, I_{DS} remains relatively constant despite increases in V_{DS} . In this mode, the MOSFET functions as a voltage-controlled current source, with a non-linear response to changes in voltage.

X. U.S. PATENT NO. 9,118,528

A. Overview

138. The '528 patent discloses a system and method for down-converting an electromagnetic signal.



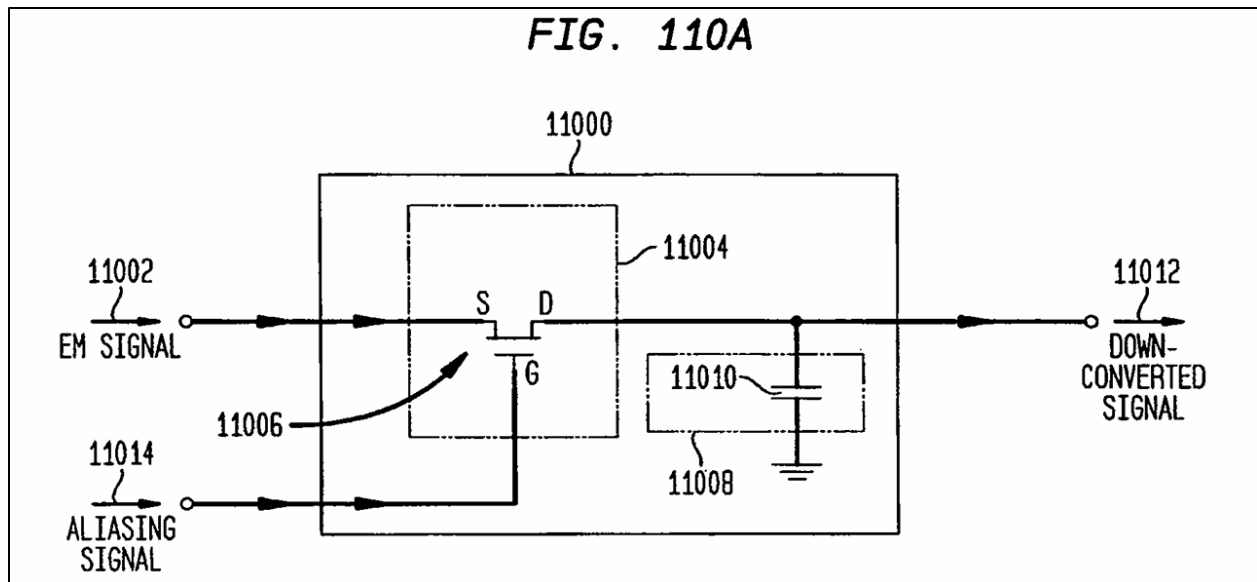
139. Figure 197 (shown above) of the '528 patent illustrates an exemplary I/Q modulation receiver 19700. Ex.-1001, 176:38-39. The receiver 19700 receives, down-converts, and demodulates an I/Q modulated RF input signal 19782 to I and Q baseband output signals 19784, 19786, respectively. *Id.*, 176:47-50.

140. Antenna 19772 receives I/Q modulated RF input signal 19782. *Id.*, 176:56-57. RF input signal 19782 comprises a first and second information signal that are I/Q modulated onto an RF carrier signal. *Id.*, 176:50-52. RF input signal 19782 is received by a low noise amplifier (LNA) 19718. *Id.*, 176:57-58. The LNA 19718 amplifies I/Q modulated RF input signal 19782 and outputs the amplified I/Q signal 19788 to UFD modules 19702, 19706 and UFD modules 19710, 19714. *Id.*, 176:59-60. As shown above by the pink, modules 19702, 19706 (yellow) handle the I-phase signal and modules 19710, 19714 handle the Q-phase signal.

141. Other than processing signals with different phases, modules 19702, 19706 and modules 19710, 19714 operate the same. Accordingly, I explain the operation of Figure 197 in the context of modules 19702, 19706 and their associated circuitry.

142. Modules 19702, 19706 (yellow) include UFT modules 19726, 197238 (blue), respectively. UFT modules 19726, 19738 each include a switch.

143. For example, Figure 110A shows that a UFT module has a switch. In particular, Figure 110A illustrates exemplary module 11000 that down-converts electromagnetic signal 11002. The module 11000 includes a UFT module 11004 made up of an n-channel FET that functions as a switch. *Id.*, 108:23-33.



144. Moreover, modules 19702, 19706 include storage modules 19724, 19736 (orange), respectively. The specification specifically refers to and identifies storage modules 19724, 19736 as having capacitors 19774, 19776, respectively. *Id.*, 176:61-177:15, 177:31-54.

145. A switch in the UFT module 19726, 19738 is turned ON (closes) and OFF (opens) based on a control signal 19790, 19792, respectively (green). As the switch opens and closes, a down-converted signal (I output signal 19798 and inverted I output signal 19701) is formed. *Id.*, 177:3-7, 42-46.

146. The I output signal 19798 is input to filter 19704 (purple), which filters the signal. The inverted I output signal 19701 is input to filter 19708 (purple), which filters the signal. *Id.*, 177:16-30, 177:55-178:2.

147. As shown by the red arrows, filtering results in a filtered I output signal 19707 and filtered inverted I output signal 19709 (both in red). *Id.*, 177:16-30,

177:55-178:2.

148. Regardless of whether a filter is used, the I output signal and inverted I output signal are sent to a differential amplifier 19720. The differential amplifier 19720 subtracts the inverted I output signal from the I output signal, amplifies the result, and outputs I baseband output signal 19784. *Id.* 178:3-25.

149. The Q-phase portion of the circuit works the same way as the I-phase portion of the circuit. *Id.*, 178:26-179:52. The differential amplifier 19722 subtracts the inverted Q output signal from the Q output signal, amplifies the result, and outputs Q baseband output signal 19786. *Id.* 179:34-52.

150. The '528 patent discloses that the differential amplifier 19720 can have a differential baseband signal/differential output. *See id.*, Figures 76A-C, 76E; 119:10-120:55.

B. The patent's disclosure regarding down-conversion systems

151. U.S. Patent No. 6,061,551 ("the '551 patent") (Ex.-2006) is incorporated by reference into the '528 patent.

152. The '528 patent (similar to the '551 patent) discloses two systems for down-conversion: (1) energy transfer (energy sampling) and (2) sample and hold (voltage sampling).

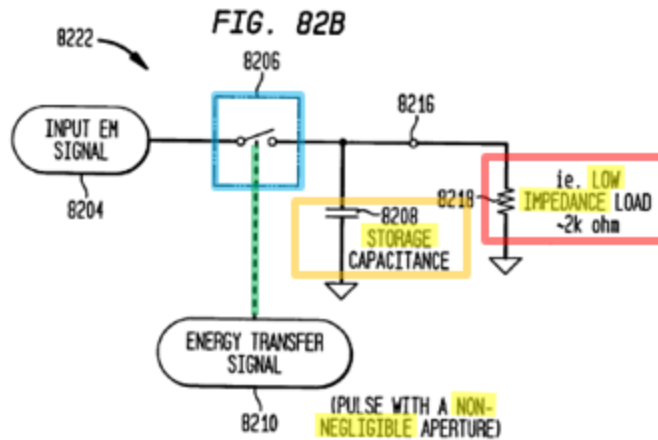
153. The claims of the '528 patent are directed to energy transfer. *See, e.g.*, Section XI.C.

154. Energy transfer and sample/hold are distinctly different technologies. In energy transfer, the down-converted signal includes the energy⁷ from the RF signal; in voltage sampling, the down-converted signal is derived from discrete voltage readings of the RF signal. Ex. 1001, 72:55-74:35 (energy transfer system); 60:23-61:52 (sample/hold system). While energy transfer and sample/hold both result in down-converted signals, an energy transfer system results in a higher quality baseband signal and, therefore, allows for wireless devices with fewer components, reduced size and cost, and increased battery life. Id., 69:18-21, 72:55-73:8.

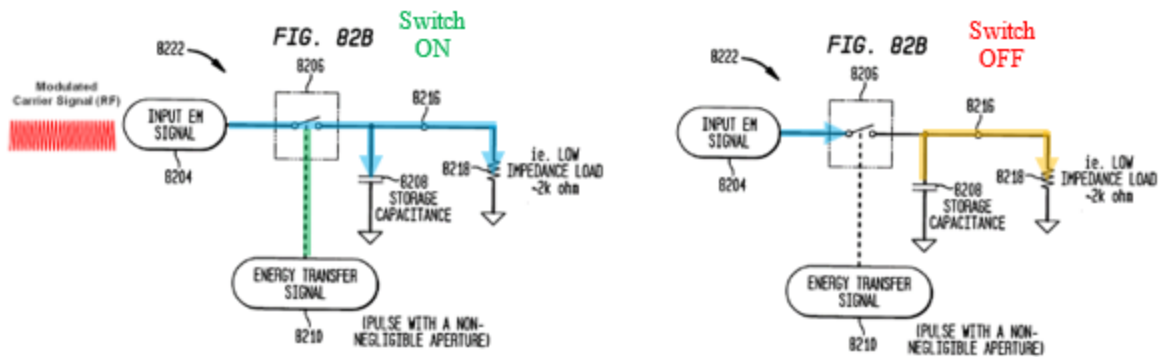
1. Energy Transfer (energy sampling)

155. Figure 82B of the '528 patent (below) illustrates an energy transfer (energy sampling) system, which would be incorporated into a transceiver chip of a wireless device.

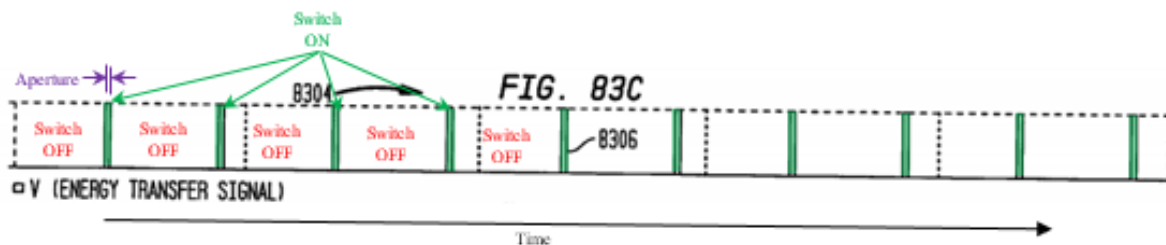
⁷ Energy and voltage are not the same thing. Energy is the total amount of work a circuit or component can deliver, i.e. $\text{energy} = \text{Power} \times \text{time}$.



156. The system includes a switch 8206 (blue), an energy transfer signal 8210 (green) for controlling the switch, a “storage” capacitor 8208 (orange) for storing and discharging energy, and a low impedance load (red). Notably, there are several key features (yellow highlights) that distinguish an energy transfer system from sample and hold. In particular, an energy transfer system uses (1) a control signal having a pulse with a non-negligible aperture/duration, and (2) a “storage” capacitor for storing and discharging non-negligible amounts of energy for driving a low impedance load. Indeed, low impedance is what enables a storage capacitor to discharge its energy when the switch is OFF (open). If the impedance were high, the “storage” capacitor could not discharge sufficient energy for the system to perform energy transfer (energy sampling) and form a down-converted signal from energy transferred to the low impedance load.



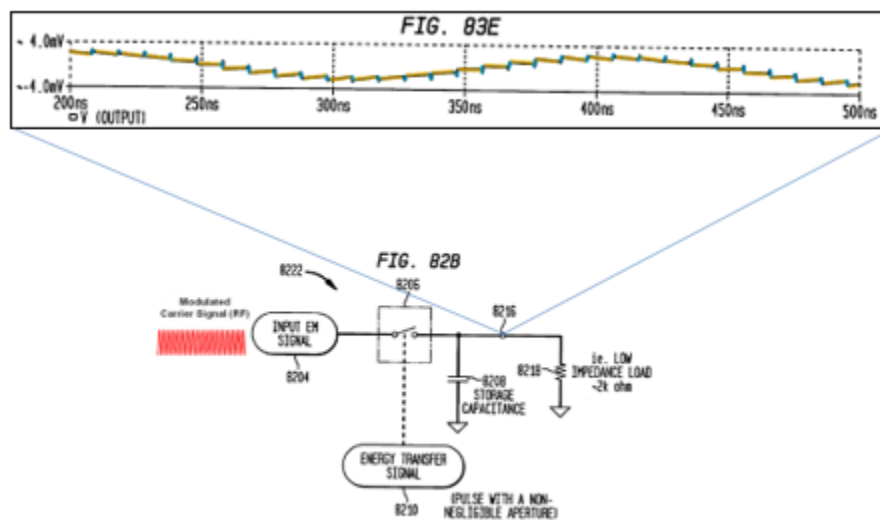
157. The annotations in Figure 82B above illustrate how an energy transfer system down-converts a high frequency input EM signal 8204 (e.g., modulated carrier signal (red)) to a baseband signal. In particular, down-conversion occurs by repetitively opening and closing the switch 8206.



158. As shown in Figure 83C above, the switch is turned ON (closed) by sending a pulse 8306 (green) to the switch. The switch is kept ON (kept closed) for the duration of the pulse (i.e., a non-negligible aperture (purple) of the pulse). As shown by the repetitive pulses 8306, this opening and closing of the switch repeats continuously over time.

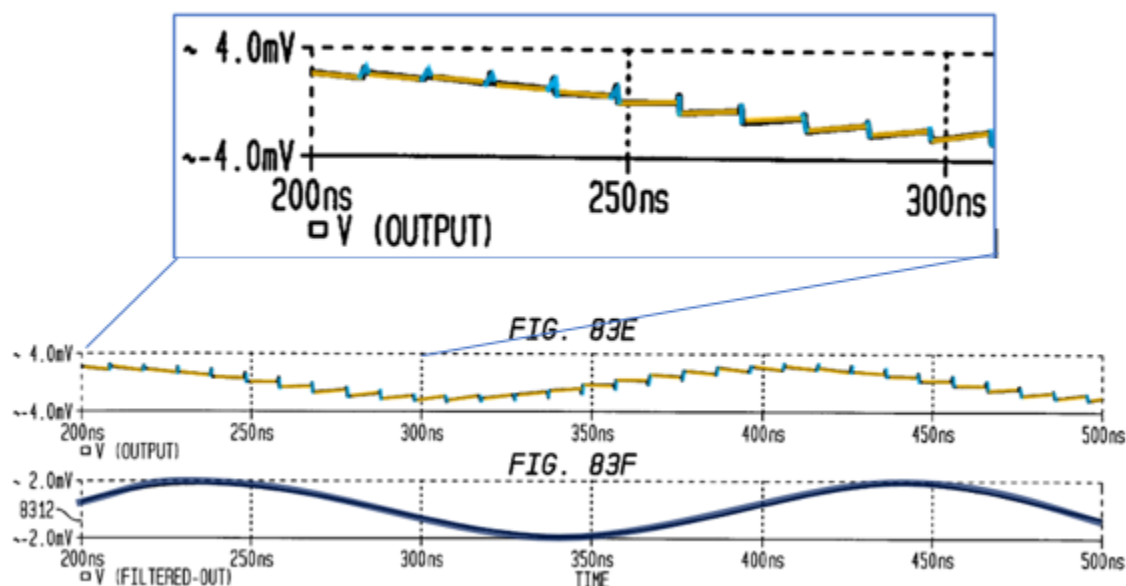
159. As shown in Figure 82B above (left), when the switch is ON (during the aperture), a portion of the input EM signal 8204 (blue) passes to the “storage”

capacitor 8208 and the low impedance load 8218. When the pulse 8306 (green) stops, the switch is turned OFF (opened), and the input EM signal is prevented from passing through the switch. Since the load is low impedance, when the switch is OFF (opened), as shown in Figure 82B above (right), energy (orange) stored in the “storage” capacitor 8208 is discharged to the low impedance load 8218. For this reason, the “storage” capacitor is said to “drive the load.” Ex.-1001, 73:65-74:2.



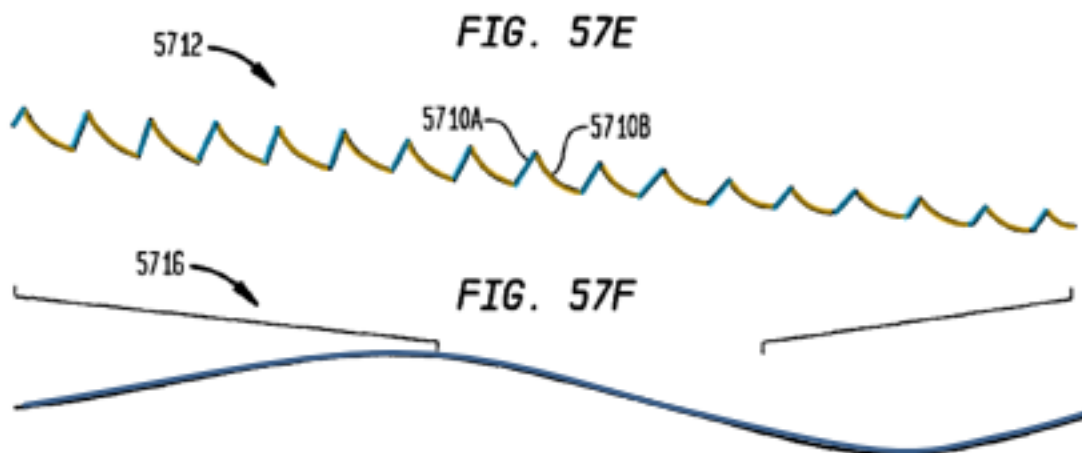
160. The repetitive opening and closing of the switch results in the waveform (blue/orange) shown above in Figure 83E at terminal 8216. The waveform is made up of energy (blue) from the EM signal and discharged energy (orange) from the “storage” capacitor. Indeed, the discharged energy (orange) from the “storage” capacitor is essential. Without the discharged energy, the waveform of Figure 83E would be incomplete (the orange portions would be missing), thereby producing a degraded and/or unusable signal that could not be properly processed by a receiving

wireless device.



161. As shown above, the waveform of Figure 83E is filtered to create a smooth waveform (dark blue) as shown in Figure 83F.

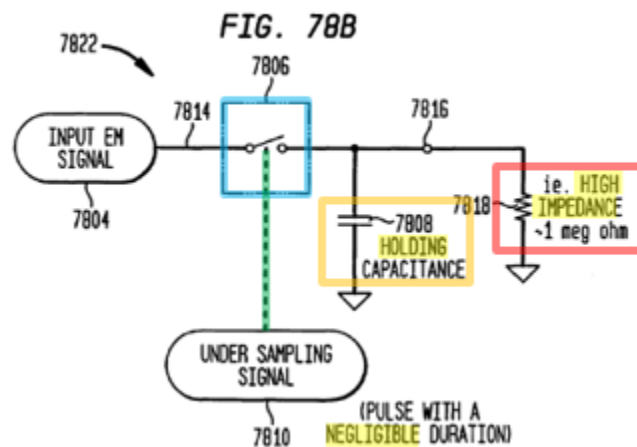
162. The figures below illustrate a close-up view of another embodiment of a down-converted signal in an energy transfer system.



163. Figures 57E shows a segment 5712 of the down-converted signal 5716 of Figure 57F. The down-converted signal of Figure 57E is made up of two portions - portion 5710A (i.e., energy (blue) from the EM signal) and portion 5710B (i.e., discharged energy (orange) from the “storage” capacitor). The baseband signal is derived from an accumulation function (e.g., integration) in which the energy transferred from the current cycle is combined with previously accumulated energy left in the storage module from preceding cycles. Thus, the energy transfer occurs and is accumulated, or “integrated,” over multiple apertures.

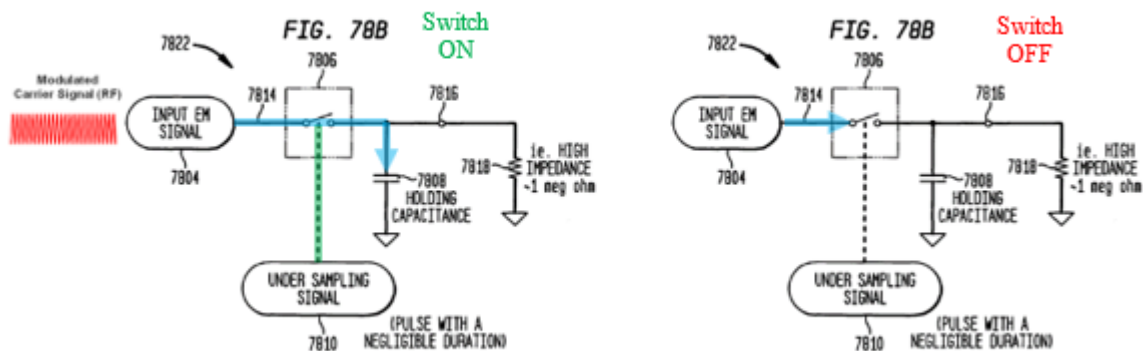
2. Sample-and-hold (voltage sampling)

164. Figure 78B of the '528 patent illustrates a sample and hold (voltage sampling) system.

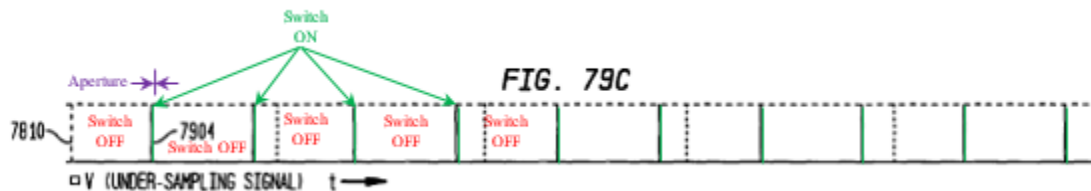


165. The system includes a switch 7806 (blue), a control signal 7810 (green) for controlling the switch, a “holding” capacitor 7808 (orange) for holding a voltage across the capacitor, and a high impedance load (red). Unlike an energy transfer

system, a sample and hold system uses (1) a control signal having a pulse with a negligible aperture/duration, (2) a “holding” capacitor for holding a constant voltage across the capacitor and (3) a high impedance load (yellow highlights). The capacitor is referred to as a “holding” capacitor because, unlike the “storage” capacitor in an energy transfer system, a “holding” capacitor does not discharge any significant energy to the load. Indeed, the high impedance load is specifically included to prevent the holding capacitor from discharging energy, which would degrade the discrete voltage measurements and adversely affect the system performing sample and hold (voltage sampling).



166. The annotations in Figure 78B illustrate how a sample and hold system down-converts a high frequency input EM signal 7804 (e.g., modulated carrier signal (red)) to a baseband signal.

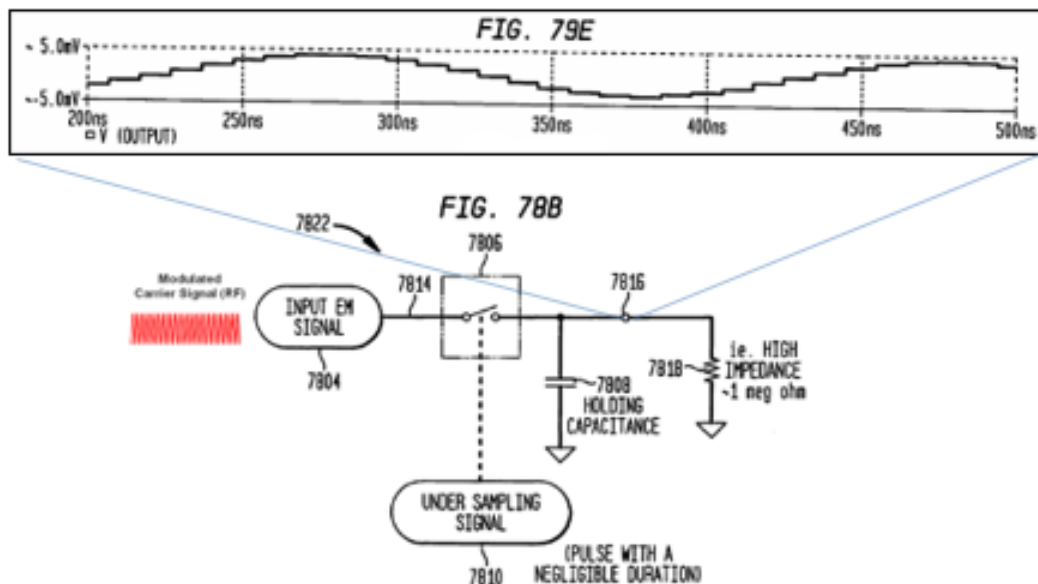


167. As shown in Figure 79C, the switch is turned ON (closed) by sending a pulse 7904 (green vertical line) of an extremely short/negligible duration to the switch. Thus, the aperture (purple) of a pulse is referred to as a negligible aperture because the pulse width “tend[s] toward zero time.” Ex.-1001, 70:2-4. As shown by the repetitive pulses 7904, this opening and closing of the switch repeats continuously over time.

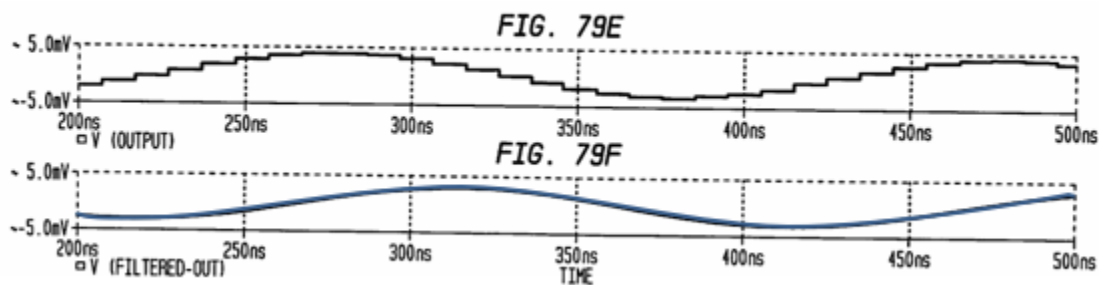
168. As shown in Figure 78B above, when the switch is ON (closed) (during the aperture), the EM signal 8204 (blue) is sent to the “holding” capacitor 7808. When the pulse 7904 (green) stops, the switch is turned OFF (opened). But unlike energy transfer (energy sampling), since sample and hold uses a high impedance load, when the switch is OFF (opened), there is high resistance to the flow of current and, thus, the “holding” capacitor holds a constant voltage value.

169. Because there is no significant energy discharge between pulses, the terminal 7816 maintains a constant voltage value until the next pulse. Ex.-1001, 70:43-48. The voltage value serves as the “sample” of a discrete voltage value that the system uses to recover the baseband signal. In particular, the system uses each discrete change (increase/decrease) in the voltage value over time to recover the

baseband. This is unlike energy transfer (energy sampling) which uses the energy from the input EM signal provided to a low impedance load to recover the baseband.

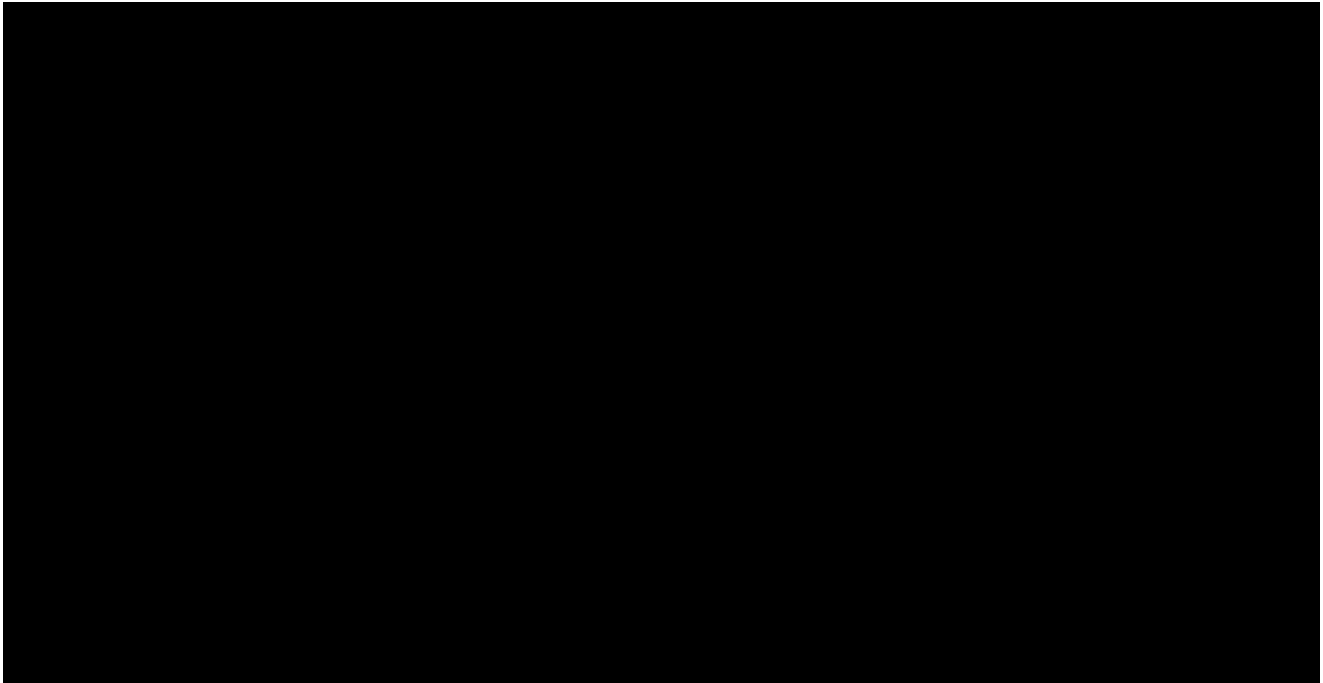


170. As shown in Figure 79E, sample and hold produces a voltage wave with a stair step pattern. The vertical part of the step represents the “sample” of the voltage value which occurs at the time of pulse 7904. The horizontal portion of the step represents the “holding” of that voltage value until the next pulse when the next sample of voltage is taken. Id., 70:48-52.



171. As shown above, the waveform of Figure 79E is filtered to create a smooth waveform (dark blue) as shown in Figure 79F.

C. Conception and Reduction to Practice



D. Prosecution history

173. The '528 patent was filed February 4, 2014 as U.S. Patent Application No. 14/172,392 (“the '392 Application”). The '392 application claims priority back to the '551 patent, filed on October 21, 1998.

174. On August 27, 2014, the USPTO rejected the then-pending claim 1 under 35 U.S.C. ¶102(b).

175. On February 27, 2015, the applicants cancelled claim 1 and added new claims. The applicants explained the claimed technology and argued that the prior art (Arpaia) reference discloses a direct conversion (homodyne) receiver. The

applicants asserted:

Arpaia does not mention any kind of sampling signal that, as applied to a switch, *serves to provide energy of the modulated carrier signal [that] is sampled and differentially applied to the respective integration modules and energy storage elements at the frequency of the respective control signal's aperture* as set forth in the claims (e.g., claim 2 “a first switch

Nor is there any teaching or suggestion in Arpaia with respect to “the portions of transferred energy from each of the first and second switch [being] integrated over time to accumulate said portions of transferred energy from which said down-converted in-phase baseband signal portion and said down-converted inverted in-phase baseband signal portion are derived.” Claim 2.

176. On March 12, 2015, the USPTO allowed the claims without further amendment, noting that the prior art fails to disclose the combination of claim elements.

177. On March 27, 2015, the applicants had an interview with the examiner and discussed a terminal disclaimer and several prior art references.

XI. CLAIM CONSTRUCTION

178. I understand that claim construction is the process of determining the meaning of words used in a patent claim in order to understand the meaning of the claim. I have been informed that claim construction is a matter of law and that claim construction will be determined by the Patent Trial and Appeal Board. I understand that the proper construction of a term is how a POSITA, at the time of the invention, would have understood the term based on its use in the claims, specification, and prosecution history of the patent. I further understand that the claims are not to be

reviewed in this proceeding under the “broadest reasonable interpretation” standard.

A. Sampling aperture

179. In the Texas District Court litigation between ParkerVision and Texas Instruments, the parties agreed that “sampling aperture” means “a period of time during which the switch is in its closed (i.e., on) state.” Ex.-2007. I have used this construction with regard to the challenged claims.

B. Switch

180. The PTAB has previously construed the term “switch” in IPR2021-00346 related to U.S. Patent No. 8,190,108 to mean “an electronic device for opening and closing a circuit.” *Intel Corp. v. ParkerVision, Inc.*, IPR2021-00346, Paper 33, at 25-26 (PTAB Jun. 30, 2022). The Federal Circuit affirmed this construction in a Rule 36 judgment. *ParkerVision, Inc. v. Vidal*, No. 2022-2173, at 2 (Fed. Cir. 2024). I have used this construction with regard to the challenged claims.

C. Energy storage element

The PTAB has previously construed the term “storage element” in IPR-2020-01265 related to U.S. Patent No. 7,110,444 to mean “an element of a system that stores non-negligible amounts of energy from an input EM signal.” *Intel Corp. v. ParkerVision, Inc.*, IPR2020-01265, Paper 44 (PTAB Jan. 21, 2022). The Federal Circuit affirmed this construction. *ParkerVision, Inc. v. Vidal*, No. 2022-1548, slip op. at 14 (Fed. Cir. 2023).

181. The term used in the claims of the ’528 patent, however, is “energy

storage element,” not just “storage element.” A POSITA reading the patents understands that an “energy” storage element is a particular type of storage element – one that is used in an energy transfer system.

182. Unlike the claims of the ’444 patent, the claims of the ’528 patent specifically recite transferring energy and recite various elements that are specific to an energy transfer system.

183. For example, claims 1 and 19 recite: “a portion of energy *that is distinguishable from noise* is transferred from the modulated carrier signal as an output of said [first/second/third/fourth] switch during the sampling aperture of the [first/second/third/fourth] control signal,” “energy storage element that *stores the transferred energy* from the modulated carrier signal,” “the *portions of transferred energy* from each of the [first and second/third and fourth] switch are *integrated over time to accumulate said portions of transferred energy* from which said down-converted in-phase baseband signal portion and said down-converted inverted in-phase baseband signal portion are derived.”

184. Further, claims 8 and 26 recite “portion of energy *that is distinguishable from noise is transferred* to the ... storage element *when the ... switch is on during the charging cycle*, and a *portion of the transferred energy* is discharged during the *discharging part of the cycle* for each ... switching device *when the [] switching device is off*.”

185. Claims 9 and 27 recite “the *energy* discharged during any given discharge cycle *is not completely discharged*, with the *remaining undischarged energy from the given discharge cycle becoming an initial condition for the next charging cycle.*”

186. Claims 10 and 28 recite: “*energy storage element [outputs/generates]* respectively, said differential *down-converted in-phase baseband signal portion and said down-converted inverted in-phase baseband signal portion* of said modulated carrier signal [*as a result of/from*] *the alternate charging and discharging applied to the respective energy storage elements.*” Claim 28 recites”

187. Claims 17 and 35 recites “*portions of transferred energy* from each of the ... switch which are *integrated over time to accumulate* said portions of transferred energy *are integrated by a separate integration module* coupled to the output of each said ... switch.”

188. Claim 18 recites “*portions of transferred energy are integrated* by the capacitive storage circuits as they *accumulate charge during successive sampling apertures.*” Claim 36 recites “*portions of transferred energy from each ... switch which are integrated over time to accumulate said portions of transferred energy are integrated* by the capacitive storage circuits of the ... storage elements as they *accumulate charge during successive sampling apertures.*”

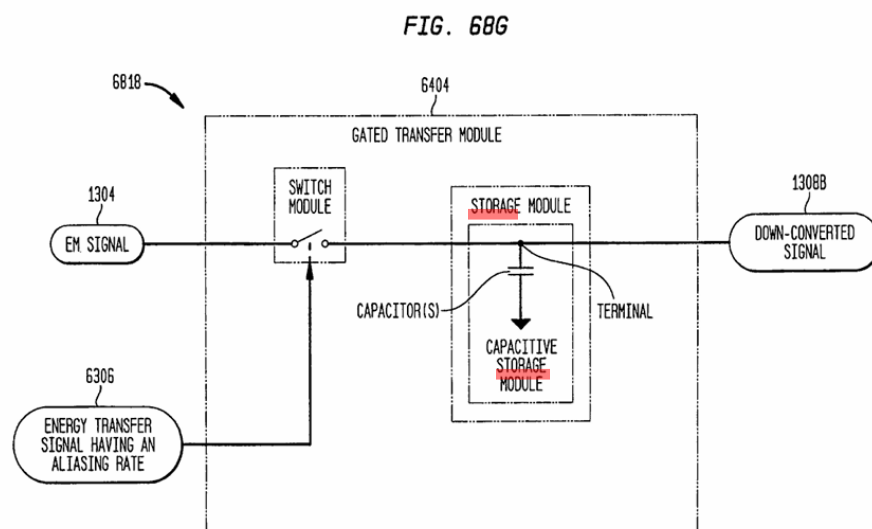
189. I note that the construction of “storage element” in IPR-2020-01265

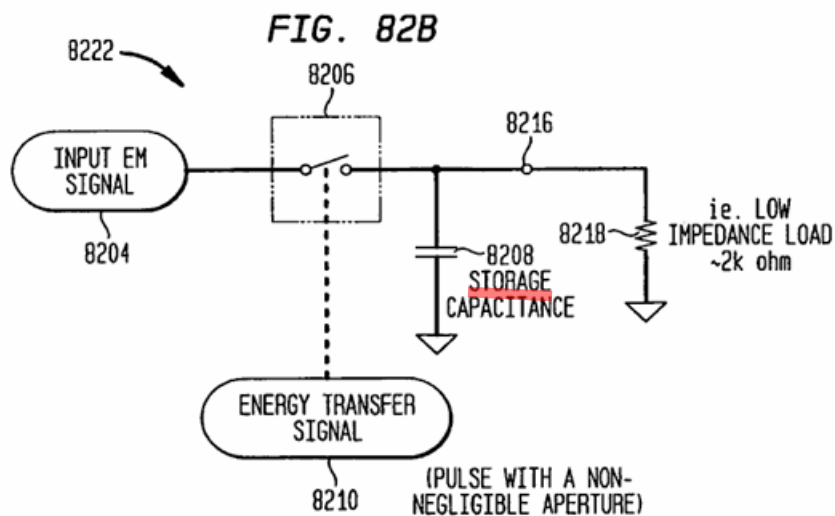
already includes the conception of “non-negligible amounts of energy.” Thus, a POSITA would understand that an “energy storage element” must be something more than just an element that stores energy otherwise the term “energy” before “storage element” would be meaningless.

190. There are only two types of systems disclosed in the '528 patent – an energy transfer system and a voltage sampling system. I discuss these two distinct types of systems in Section X.B.

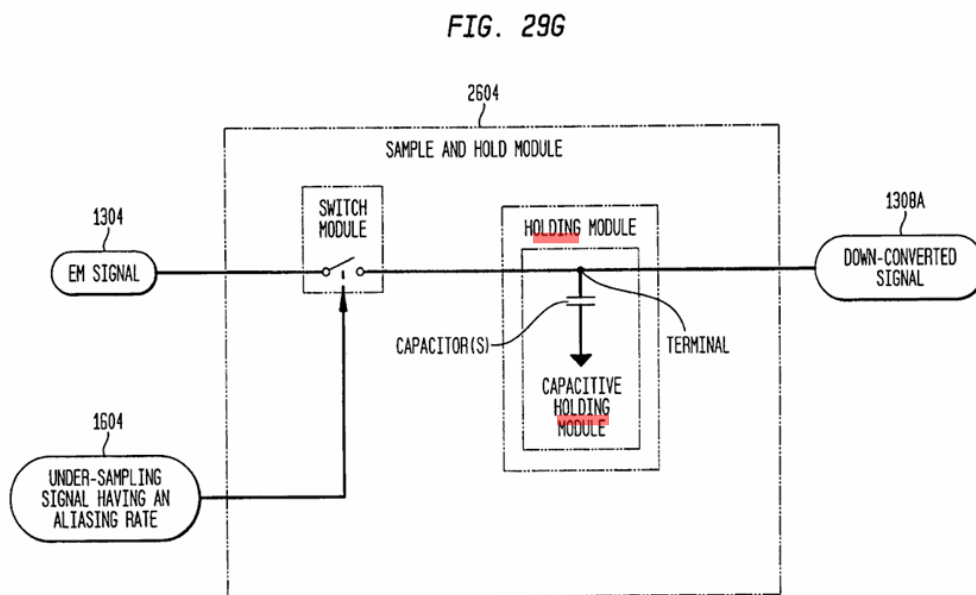
191. An “energy storage element” is a term used in the patent for a component of an energy transfer (energy sampling) system. This is unlike a “holding” element which the patent refers to a component of a sample-and-hold (voltage sampling) system.

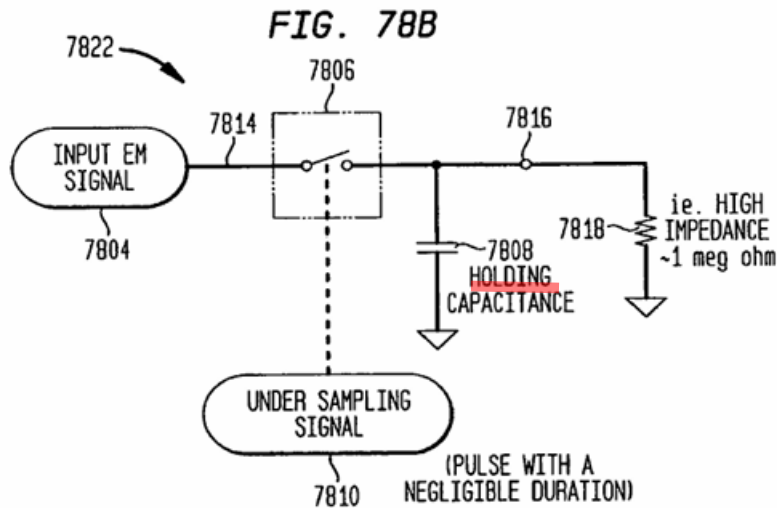
192. Notably, the distinction between an “energy storage element” and a “holding” element can be seen in the patent figures shown below.





193. Figures 68G and 82B (above) show energy transfer systems and use the term “storage” module.





194. On the other hand, Figures 29G and 78B (above) show sample-and-hold systems and use the term “holding” module.

195. With regard to the challenged claims, I have used the construction of “storage element” from IPR-2020-01265 as well as the construction of “energy storage element” in my analysis set forth Section XIII below.

XII. OVERVIEW OF THE ALLEGED PRIOR ART

A. U.S. Patent No. 6,230,000 to Tayloe⁸

196. Tayloe was filed October 15, 1998 and is entitled “Product Detector and Method Therefor.”

⁸ I have considered the declaration of Dr. Michael Steer in a previous IPR involving Tayloe. In my analysis, I have adopted certain portions and figures from Dr. Steer’s analysis.

197. As discussed above in Section VIII, as of October 1998, other than non-sampling mixing, the radio (cellular/wireless) industry was focused on voltage sampling solutions for direct down-conversion of RF input signals.

198. Consistent with the direction of the industry in the late 1990s, Tayloe discloses a voltage sampling system for direct down-converting an input signal.

199. Because Tayloe is a voltage sampling system, Tayloe does not transfer energy to a load. Voltage and energy sampling are fundamentally different and competing technological solutions for down-conversion.

200. All discussion in Tayloe refers only to voltage. There is no mention of “energy,” “current,” or “power.” *See e.g.*, Ex.-1004, Abstract (“The samples are integrated over time to produce an average *voltage* at 0 degrees, 90 degrees, 180 degrees and 270 degrees. The average *voltage* at 0 degrees is the baseband in-phase signal, and the average *voltage* at 90 degrees is the baseband quadrature signal.”); 2:28-42; 3:40-56; 4:2-4, 46-57; 5:37 46.

201. Notably, the word “voltage” is used throughout the Tayloe specification to describe how the circuits disclosed in Tayloe operate. Indeed, a POSITA would understand that all of the concepts taught in Tayloe relate to the use of voltage and voltage sampling to perform down-conversion of an input signal. A POSITA does not understand that Tayloe discloses, teaches or suggests the use of energy or energy sampling to perform down conversion of an input signal.

202. The “Background of the Invention” section of Tayloe discusses direct down-conversion of RF signals and the problem associated with existing solutions. Ex.-1004, Figures 1, 2; 1:10-45. Tayloe proposes a solution that purportedly solves the problem.

203. Tayloe discloses a product detector (part of a down-converter) for converting an RF signal to a baseband signal using a switch, which samples an RF signal (waveform) during periods of the RF signal. *Id.*, Abstract. “The samples are integrated over time to produce an average voltage” *Id.* According to Tayloe, the “average voltage” is the baseband (down-converted) signal. *Id.*

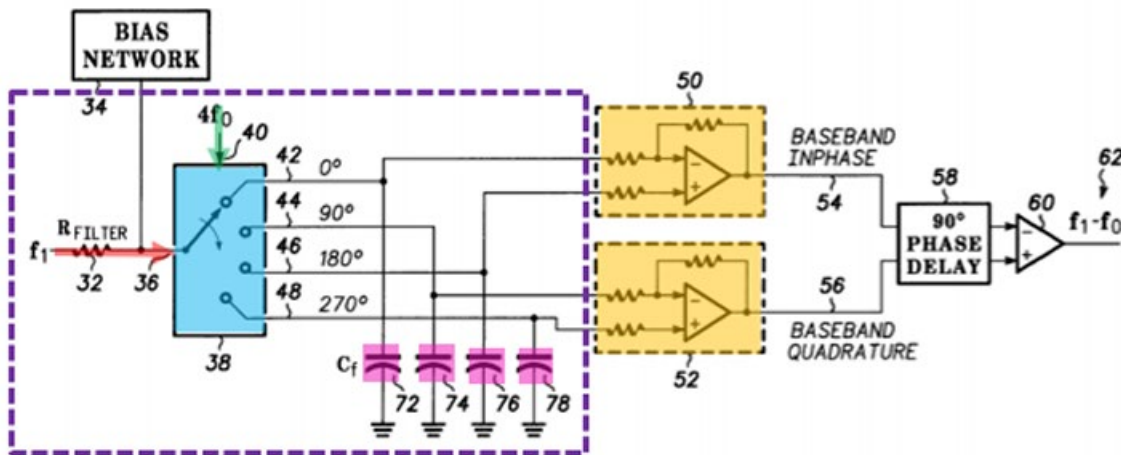


FIG. 3

204. Figure 3 discloses a receiver 30 having a commutating switch 38 (blue), capacitors 72, 74, 76, 78 (pink), and summing amplifiers 50, 52 (orange). *Id.*, 2:6-12. Tayloe “product detector” or “Tayloe Product Detector” is shown in the purple dashed box. *Id.* at 3:1-4. 8.

205. A RF or IF signal f1 (red arrow) is received at the resistor R_{FILTER} 32, which forms a filter when combined with the capacitors 72, 74, 76, 78. *Id.*, 2:13-15. Tayloe touts this filter as being an important part of his work. *Id.*, 2:13-15, 3:21-39.

206. The input signal f1 (red arrow) is subsequently received by the commutating switch 38 (blue). *Id.*, 2:16-17. 9. The commutating switch 38 has one input 36 and four outputs 42, 44, 46, 48. *Id.*, 2:17-18. Upon receiving a control signal (green) at control input 40, the commutating switch 38 can move to one of four different positions: (1) time T1, the commutating switch 38 connects input 36 to output 42, (2) time T2, the commutating switch 38 connects input 36 to output 44; (3) time T3, the commutating switch 38 connects input 36 to output 46, and (4) time T4, the commutating switch 38 connects input 36 to output 48. *Id.*, 2:18-26. 10.

207. The input 36 is switched to each of the four outputs 42, 44, 46, 48 substantially once during each period of the input signal f1. *Id.*, 2:24-26. The commutating switch 38 remains closed at each of the four outputs for 90 degrees or less of the input signal f1. *Id.*, 3:27-31.

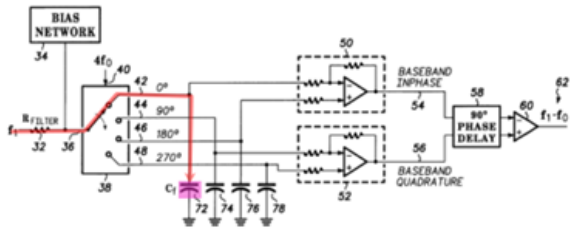


FIG. 3

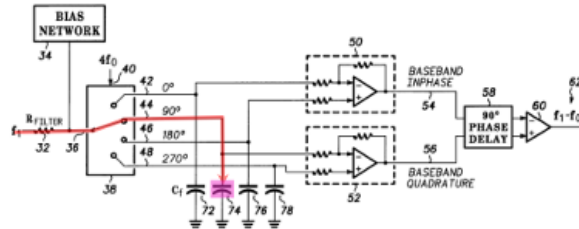


FIG. 3

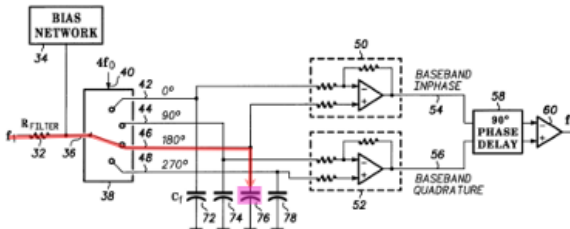


FIG. 3

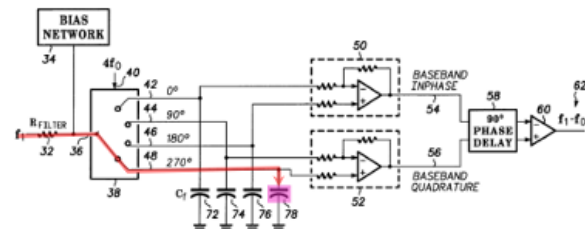
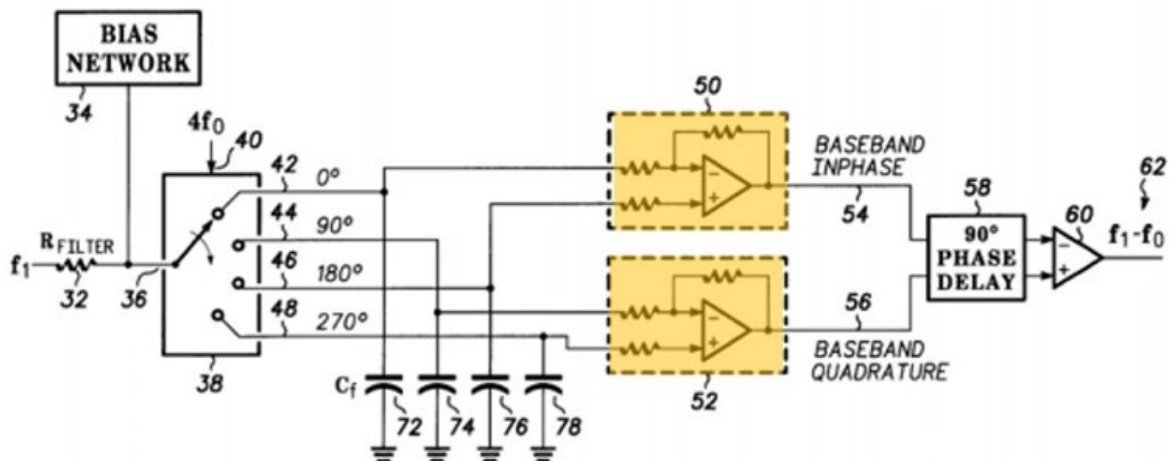


FIG. 3

208. “As commutating switch 38 cycles through the four outputs, capacitors 72-78 charge to voltage values substantially equal to the average value of the input signal during their respective quadrants.” *Id.*, 2:38-41. As shown above, during the time that the commutating switch 38 connects input signal 36 to output 42 (top left), charge builds up on capacitor 72. When the commutating switch 38 connects input signal 36 to output 44 (top right), charge builds up on capacitor 74. When the commutating switch 38 connects input signal 36 to output 46 (bottom left), charge builds up on capacitor 76. When the commutating switch 38 connects input signal 36 to output 48 (bottom right), charge builds up on capacitor 78. *Id.*, 2:32-38.

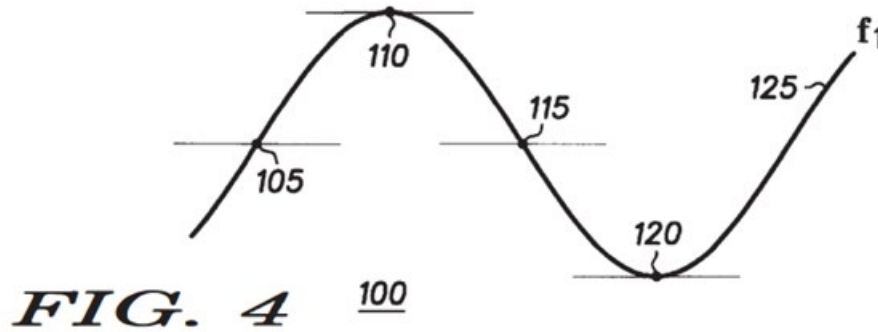
209. According to Tayloe, each of the capacitors operate as a separate averaging component, which average a separate quarter wave of the input signal f_1 . *Id.*, 2:40-43.



30 **FIG. 3**

210. As shown above in Figure 3, “the outputs of commutating switch 38 are input to summing amplifiers 50 and 52. Summing amplifier 50 differentially sums the 0 degree output and the 180 degree output, thereby producing baseband in-phase signal 54. Summing amplifier 52 differentially sums the 90 degree output and the 270 degree output, thereby producing baseband quadrature signal 56.” *Id.*, 2:56-61.

211. The summing amplifiers are used to increase gain: “to increase gain, the 0 degree average can be differentially summed with the 180 degree average to form the baseband in-phase signal.” *Id.* Abstract. Thus, the goal of the summing amplifier is to increase gain. A single ended signal provides a baseband signal. A differential summing of 0 degree and 180 degree (or 90 degree and 270 degree) is for increasing the gain, since the difference of the respective signals has twice the amplitude of any one phase alone.



212. Figure 4 above illustrates how the system uses the input signal f_1 to determine the voltage to which each capacitor charges. Figure 4 shows a waveform 100 that includes a signal 125 corresponding to input signal f_1 . *Id.* at 40-42.

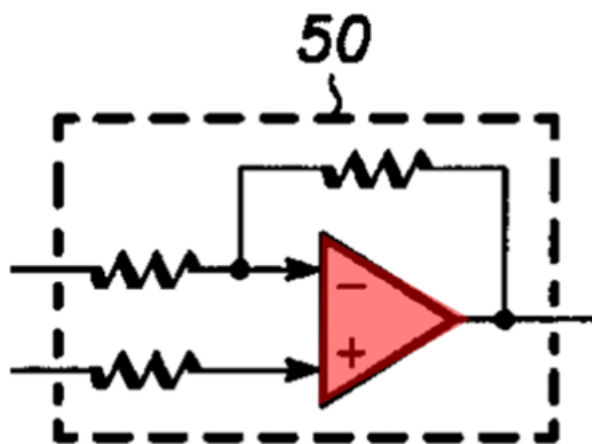
213. Tayloe's discussion of Figure 4 makes it clear that Tayloe is using a high impedance load (i.e., amplifiers 50, 52 are high impedance) and capacitors are not discharging to that load. Specifically, Tayloe states that the voltage on the capacitors charges to points 105, 110, 115, 120. *Id.*, 3:40-48. In order for the voltage on the capacitors to charge to these points, there cannot be any discharge from the capacitors to a load. Otherwise, the voltage on the capacitors could not charge up to those points. Any charge in the capacitor (if discharged) would flow back to the RF input.

214. As shown in Figure 4: "Point 105 represents the voltage to which capacitor 72 (FIG. 3) charges. Likewise, point 110 represents the voltage to which capacitor 74 charges, point 115 represents the voltage to which capacitor 76 charges, and point 120 represents the voltage to which capacitor 78 charges." *Id.*, 3:43-48.

215. According to Tayloe, outputs 42, 44, 46, 48 represent average values of the input signal f1 during quarter waves of a period.

Output 42 represents the average value of the input signal during the first quarter wave of the period, and is termed the 0 degree output. Output 44 represents the average value of the input signal during the second quarter wave of the period, and is termed the 90 degree output. Output 46 represents the average value of the input signal during the third quarter wave of the period, and is termed the 180 degree output. Output 48 represents the average value of the input signal during the fourth quarter wave of the period, and is termed the 270 degree output.

Id., 2:45-54. In other words, the points 105, 110, 115, 120 in Figure 4 represent the average value of voltage at 0°, 90°, 180°, 270°, respectively, of the input signal f1. Thus, the capacitors 72, 74, 76, 78 are charging to the average voltage as shown by points 105, 110, 115, 120, respectively.



216. As shown above in the excerpt from Figure 3, Tayloe discloses an op-amp (red triangle).

217. A POSITA understand that the “+” and “-” inputs are connected to the gates of FETs. Ex.-2034, 72:9-73:6, 127:4-19. A POSITA understands that this

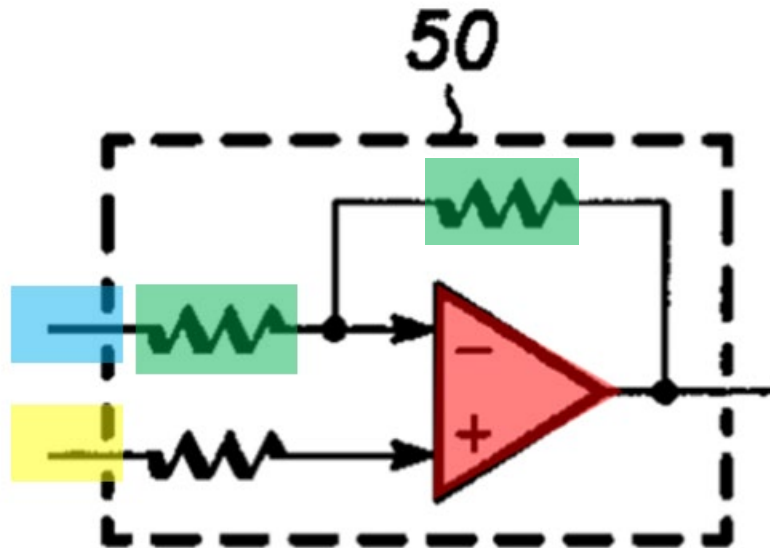
results in very high impedance/high resistance. Dr. Galton admits this. *Id.*, 72:14-73:6, 85:1-7 (“when you look into the -- in a typical op amp that you build in a CMOS process, what you said before, of it -- of the inputs feeding into the gates of MOSFETs is true. And *gates of MOSFETs* are almost purely capacitive, meaning they've got an *exceedingly high resistive component*.”).

218. A POSITA understands that if one input is high impedance/resistance, the other input must also be high impedance/resistance. As shown above, there is no feedback loop around the lower portion of the amplifiers 50, 52. The input goes into the gate of a FET which would be very high impedance/resistance. Thus, the “+” input will be high impedance/resistance. Dr. Galton admits this. Ex.-2034, 122:18-123:10, 126:7-127:1. The “+” input cannot be low impedance because there is no circuitry shown in Tayloe that would be able to compensate for the fact that, as shown, it has a high impedance. Therefore, because the “+” input is high impedance/resistance, the “-” input must also be high impedance/resistance.

219. Another reason why the “-” input must be high impedance/resistance is because a POSITA also understands that there cannot be a significant mismatch between the resistance/impedance of the “+” and “-” inputs. As discussed above, a POSITA would understand that the “+” input would have a very high

resistance/impedance—millions of ohms.⁹ Dr. Galton’s assertion that the input resistance of 50 and 52 would have a very low resistance (kilo-ohms or less) cannot be correct. *See* Ex.-1003, ¶96. This is because the input resistance for both inputs of amplifier 50 (and for both inputs of amplifier 52) would need to be matched or nearly matched to each other so as to preserve the balance of the 0 and 180 degrees capacitors and the balance of the 90 and 270 degree capacitors. As discussed above, the “+” input is extremely high impedance (e.g., 2 meg ohm or $2\text{M}\Omega$) and, thus, the impedance looking into the resistor of 50, 52 connected to the “+” input must also be extremely high impedance (e.g., $2\text{M}\Omega$). Therefore, to keep the inputs of 50 or 52 balanced, the input resistance of the resistor connected to the “–” input must also be very high impedance.

⁹ Indeed, the most common/widely sold op-amp at the time of the patent and Tayloe was the 741 Series op-amp, which had a high input resistance of typically 2,000,000 ohms (2 meg ohm ($\text{M}\Omega$)). Ex.-2009; *See* Ex.-2034, 125:15-126:6. I note that the ’551 patent uses a 1 meg ohm resistor in Figure 78B as the load and identifies 1 meg ohm as a high impedance load.



220. In other words, as shown above, the input resistance of the yellow input must be matched with the input resistance of the blue input. Because the input resistance of the yellow input will be very high (the input is connected to the “+” input which is very high impedance), the input resistance of the blue input must also be very high. Thus, resistors (green) must be very high resistance/high impedance. If the input impedances of blue/yellow do not match, the voltage measurements will not be symmetric, and an error will occur in the voltage measurement.

221. The “+” and “-” inputs cannot be substantially mismatched. Notably, Dr. Galton admitted that an op amp circuit would never be built with such a significant mismatch (it “literally would never happen”), these circuits are built as “symmetrical as possible,” and he has “never” purposefully designed an op amp circuit that had a significant mismatched impedance/resistance at its inputs. Ex.- 2034, 82:17-86:5, 87:5-88:6, 92:22-93:16, 96:11-21, 97:20-100:21, 101:2-20.

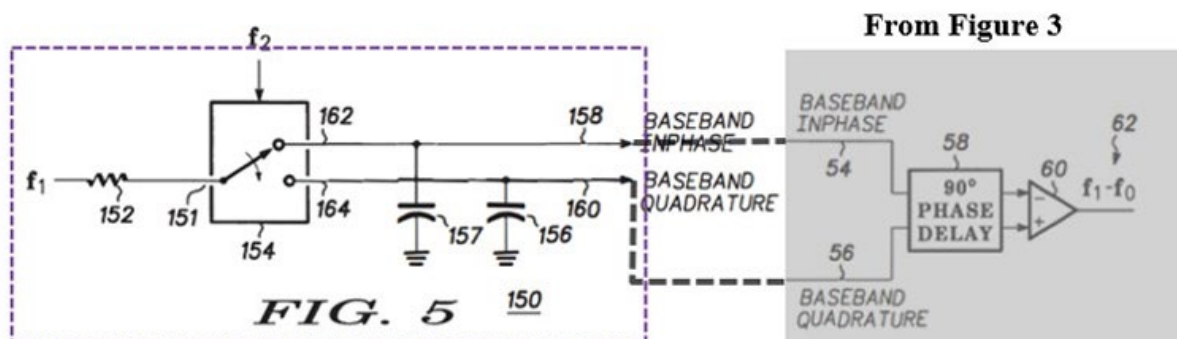
222. Dr. Galton asserts that at higher frequency, impedance is lower; and low frequencies, impedance is higher. Ex.-2034, 116:21-118:9, 126:7-127:1. Tayloe specifically discloses using a frequency of 1kHz centered at 7MHz. Ex.-1004, 5:49-50. This is a low frequency. Thus, under Dr. Galton's own logic, that Tayloe uses a low frequency input further supports that the "+" input of the op amp is high impedance.

223. In view of the foregoing, a POSITA would understand that both the non-inverting "+" and inverting "-" inputs of Tayloe's op-amp present high impedance loads.

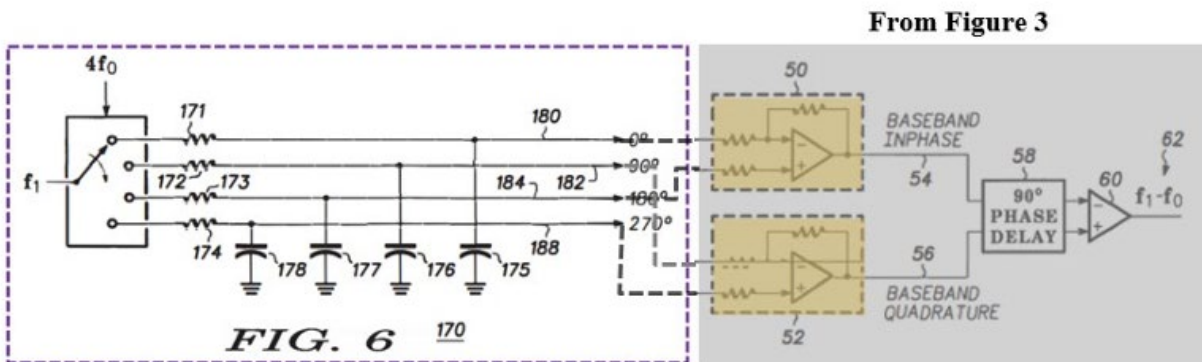
224. In view of the above and as further shown below, a POSITA would understand that Tayloe is a voltage sampling system, which uses a high impedance load. The high impedance load causes each capacitor of Tayloe to hold charge (i.e., prevent charge in the capacitor from being discharged to form the down-converted signal) when it is not connected to input 36, so that an accurate voltage across each capacitor can be determined.

225. As the charge is being held, the system determines the voltage across the capacitor (i.e., the voltage level). At the next sampling interval (i.e., when the capacitor is again connected to input 36), the voltage on the capacitor will change to the next average voltage value. Using multiple voltage readings, the system recreates a baseband signal (which is a representation of the original baseband signal sent from

the transmitting device).



226. As shown above, Figure 5 of Tayloe discloses an alternative embodiment of a product detector 150 (purple dashed box). Ex.-1004, 4:9-15, 42-44. According to Tayloe, “[p]roduct detector 150 can be substituted into direct conversion receiver 30 (FIG. 3)” (*id.* at 4:42-44) and the only difference between Figure 3 and Figure 5 is that Figure 5 only has two outputs. *Id.* at 4:13-15. The circuit of Figure 5 works the same as the circuit of Figure 3 with regards to holding the average voltages on the capacitors and my analysis of Figure 3 above would apply to Figure 5. Tayloe does not disclose any load in Figure 5, which a POSITA would understand because Tayloe is a voltage sampling system, which requires a high impedance load. A POSITA would understand that the baseband in quadrature would be recombined as illustrated in Figure 3, which only provides a phase delay (and infinite impedance) on the output of Figure 5. In view of the foregoing and for the same reasons as set forth with regard to Figure 3, Figure 5 of Tayloe is operating as a voltage sampling system, not as an energy transfer (energy sampling) system.



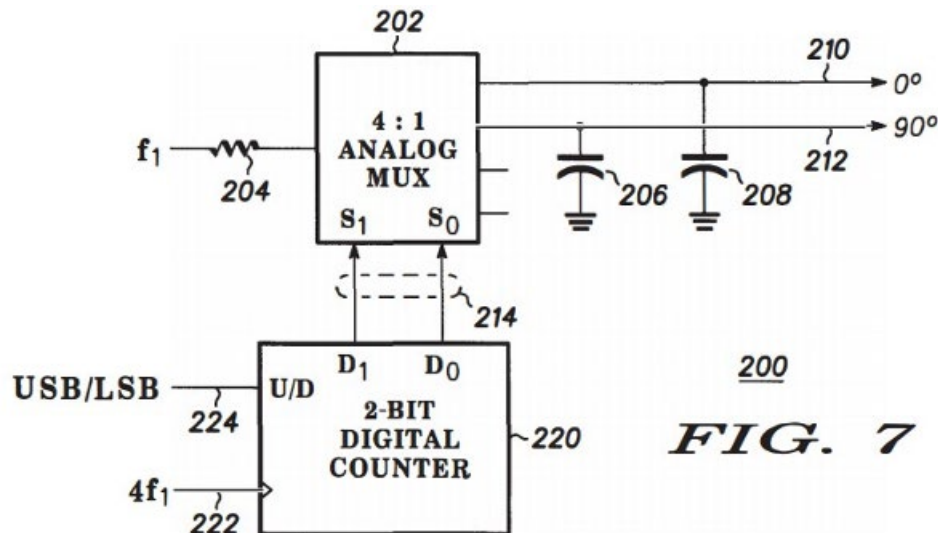
227. As shown above, Figure 6 of Tayloe discloses another alternative embodiment of a product detector 170 (purple dashed box) where the single resistor before the commutating switch of Figure 3 is replaced by four single resistors 171, 172, 173, 174 after the commutating switch (each capacitor has its own resistor). Ex.-1004, 4:46-49. As such, as shown above, a POSITA would understand that Figure 6 would be connected to the summing amplifier 50, 52 just like the product detector of Figure 3.

228. In Figure 6, with the R_{FILTER} removed and replaced with separate resistors after the switch 38, the radio frequency source is connected directly to the commutating switch 38. The circuit of Figure 6 works the same as Figure 3 with regard to holding the average voltages on the capacitors 175, 176, 177, 178 and my analysis of Figure 3 above applies to Figure 6.

229. Moreover, with regard to Figure 6, Tayloe clearly focuses only on voltage and how only voltage is controlled by the combination of the capacitor and resistor:

0 degree output 180 has a voltage controlled by the combination of capacitor 175 and resistor 171. Likewise, 90 degree output 182 has a voltage controlled by the combination of capacitor 176 and resistor 172, 180 degree output 184 has a voltage controlled by the combination of capacitor 177 and resistor 173, and 270 degree output 188 has a voltage controlled by the combination of capacitor 178 and resistor 174.

Ex.-1004, 4:49-57. The statement that the voltage of the outputs are controlled by the capacitor and resistor means that the voltage across each capacitor is not affected by the circuitry to the right of the capacitor. This demonstrates that the summing amplifiers 50, 52 and/or other circuitry to the right of the capacitors 175, 176, 177, 178 is a high impedance load to each capacitor, which is a well-known characteristic of any voltage sampling system. In view of the foregoing, Figure 6 of Tayloe is operating as a voltage sampling system, not as an energy transfer (energy sampling) system.



230. As shown above, Figure 7 of Tayloe discloses another alternative embodiment of a product detector. Ex.-1004, 5:1-2. An analog multiplexer (MUX)

202 is used instead of commutating switch 38 of Figure 3; a digital counter 220 provides control signals to the analog MUX 202. Id. at 5:1-16. Tayloe refers to Figure 7 as the product detector and Tayloe explains that the receiver design of Figure 7 is “the same as direct conversion receiver 30 (FIG. 3)” (other than the analog MUX 202 and a digital counter 220) (id. at 5:31-34).

231. Moreover, a POSITA would understand that if output 210, output 212, as well as 180 degree and 270 degree outputs are being used, Figure 7 would be connected to the amplifiers 50, 52 just like the product detector of Figure 3.

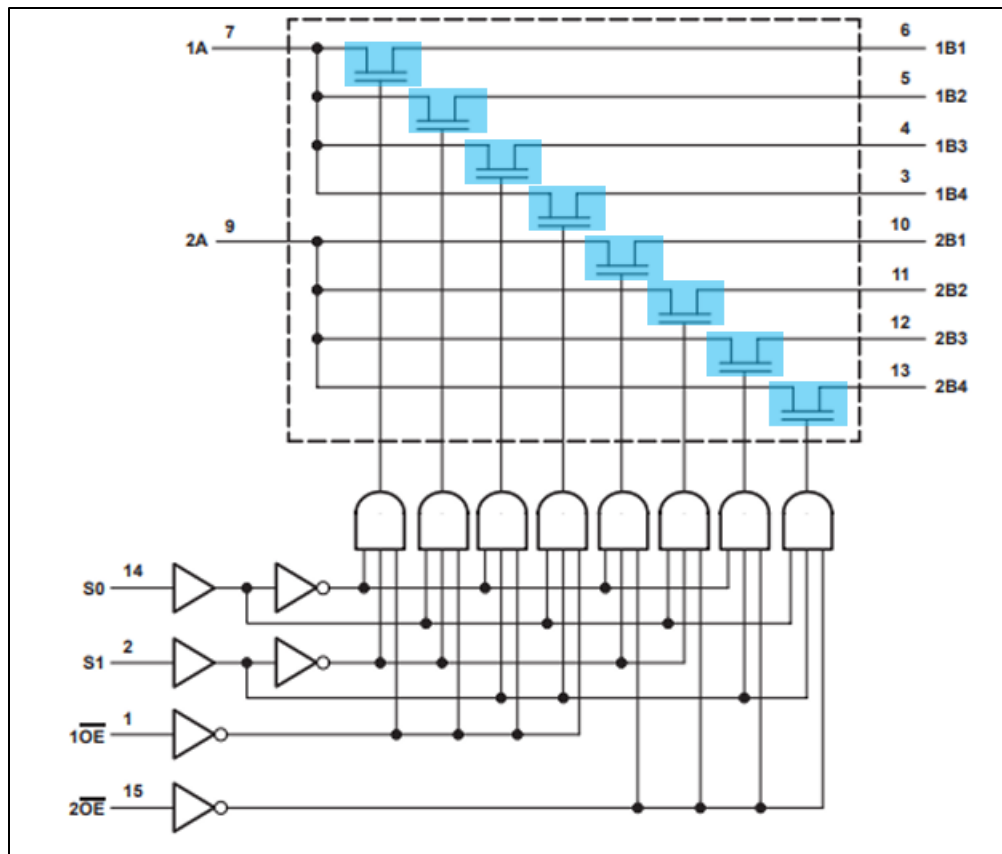
232. The circuit of Figure 7 works the same as Figures 3 and 5 (depending on how many outputs are used) with regard to holding the average voltages on the capacitors 206, 208 (as well as capacitors for the 180 and 270 degree paths) and my analysis of Figures 3 and 5 above applies to Figure 7.

233. In view of the foregoing, Figure 7 of Tayloe is operating as a voltage sampling system, not as an energy transfer (energy sampling) system.

B. Texas Instruments Datasheet for SN74CBT3253 DUAL 1-OF-4 FET MULTIPLEXER/DEMULTIPLEXER

234. The TI Datasheet is the product specification for Texas Instrument’s SN74CBT3253. Texas Instruments relies on the TI Datasheet for its switch configuration.

235. The TI Datasheet discloses a dual 1-of-4 high-speed TTL-compatible FET multiplexer/demultiplexer. Ex.-1005.



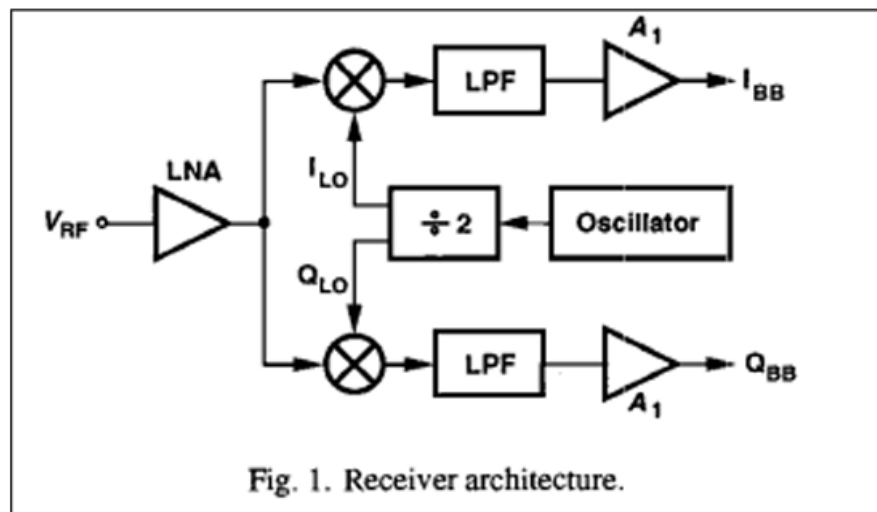
236. As shown above, the multiplexer/demultiplexer includes multiple FETs (blue above) which are used as switches.

C. Razavi

237. Razavi is a paper entitled “A 900-MHz CMOS Direct Conversion Receiver” (DCR) and on its face indicates that it was published in the 1997 Symposium on VLSI Circuits Digest of Technical Papers. Ex.-1017.

238. Razavi’s mixer was a research project. I am unaware of the Razavi system ever being implemented in any commercial system. Razavi is a voltage-based system that does not transfer energy from the RF input signal to the output of the mixer.

239. Razavi describes the design of a single-chip 900-MHz CMOS direct conversion receiver (DCR) fabricated in digital 0.6- μm technology. *See* Ex.-1017, 113. A block diagram of a general DCR architecture is shown in Figure 1 (below). Dr. Razavi explains how he proposes modifying this circuit to create a different type of direct downconverter.



240. As shown in Figure 1, the DCR consists of a low-noise amplifier (LNA), in-phase and quadrature mixers, low-pass filters (LPFs), and baseband amplifiers A_1 . This down-converter was already known at the time Razavi wrote his paper. The in-phase and quadrature-phase mixers are driven by local oscillator (LO) signals offset by 90-degrees. Razavi notes that “[a]n important goal in the design has been to achieve a relatively high gain (approximately 35 dB) in the RF section so as to minimize the effect of the $1/f$ noise contributed by the baseband amplifiers. For this reason, passive mixers have been avoided even though they provide potentially higher linearity than do their active counterparts.” Ex.-1017, 113. Accordingly,

Razavi discloses a DCR using active mixers with high gain.

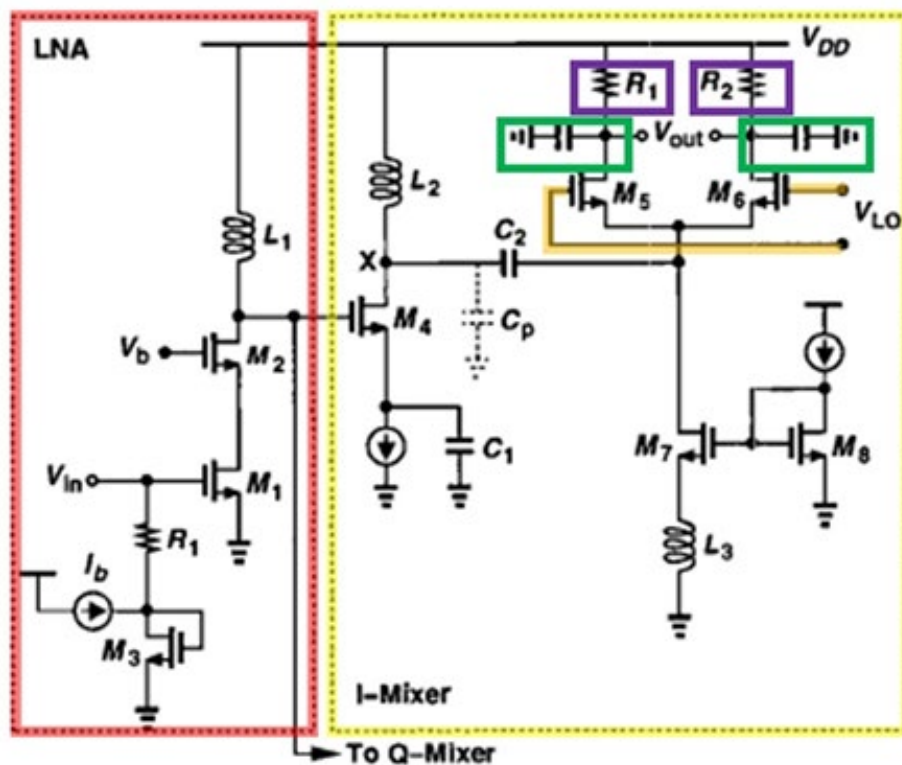


Fig. 2. LNA/mixer implementation.

241. Figure 2 from Razavi (above) illustrates the LNA (shown in the red box) and I-mixer (shown in the yellow box) of Razavi's proposed circuit. As shown above, the RF signal passes through the LNA and is subsequently received by the I-mixer. "The mixer employs a single-balanced topology consisting of an input transistor M_4 and a switching pair M_5 - M_6 ." Ex.-1017, 113. A POSITA would understand that a single-balanced topology means that the local oscillator (LO) signal is differential, and the RF input signal is single-ended.

242. Razavi uses an active mixer (shown in yellow) with high gain. Razavi

is not transferring the RF input signal or its energy to the output of the mixer. Rather, Razavi creates a new output signal based on the input signal and its modulation information and adds gain to create a copy of that information signal at the output of the mixer. Razavi is using energy from a power supply (represented by VDD) to accomplish this. In other words, unlike an energy sampling (transfer) system, the output signal energy in Razavi comes from a power supply, not from sampled energy of the RF input signal itself.

243. Razavi characterizes transistors M5 and M6 as a “switching pair” because they commute the signal current. Transistors M5 and M6 are NMOS field-effect transistors (FETs). Ex.-2034, 203:9-12. The RF input signal is applied to the common node of the source terminals of M5 and M6, and the drain node of M7. The drain terminals of M5 and M6 are connected to VDD through resistors R1 and R2. *Id.*, 214:4-7.

244. A POSITA would recognize that transistors M5 and M6 form a well-known circuit topology known as a differential pair. A POSITA would also recognize that M5 and M6 pass a DC current that flows from VDD to ground and is controlled by transistor M7.

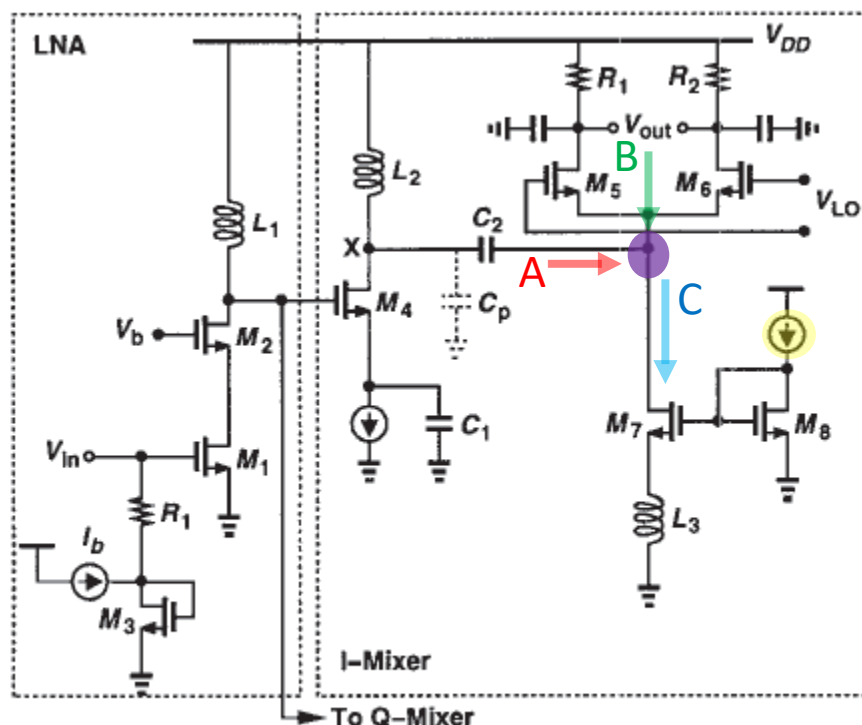


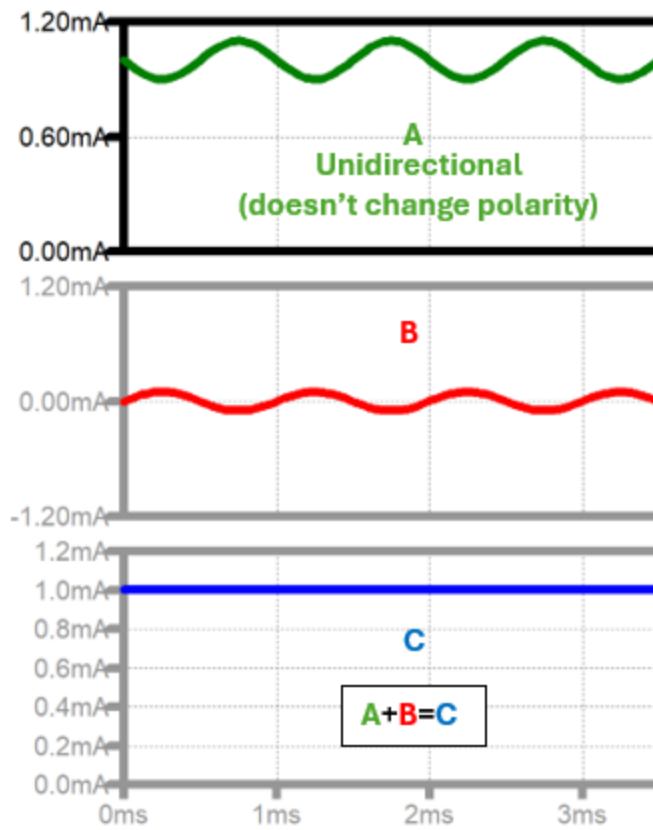
Fig. 2. LNA/mixer implementation.

245. A POSITA would recognize from fundamental circuit theory that the current flowing through M7 must be direct current (DC). DC is the non-time varying (non-RF) current that provides the bias and operating points for M5 and M6. A POSITA would understand that a DC current is mirrored from M8 to M7, as shown by the yellow-highlighted DC current symbol above. Thus, a POSITA would recognize that the current in M7 is also a DC current.

246. Current B (shown by the green arrow above) represents the combined current from the differential pair M5 and M6, and can be determined from Kirchhoff's Current Law, which states that the sum of the currents into a node must equal the current out of a node.

247. At the purple node, current A (shown by the red arrow) represents the RF input signal flowing into the node (purple). Current C (shown by the blue arrow) represents the current flowing out of the node through M7. Thus, current B (represented by the green arrow) can be found using Kirchoff's Current Law: $A + B = C$. Rearranging, therefore, $B = C - A$. In other words, current B is determined as the difference between current C (the total current flowing through M7) and current A (the current from capacitor C2, representing the RF input signal).

248. As an example, for a current $C = 1\text{ mA}$ and current $A = 100\text{ }\mu\text{A}$ (which are typical values in an integrated circuit such as disclosed in Razavi). Then, current $B = 1\text{ mA} - 100\text{ }\mu\text{A} = 900\text{ }\mu\text{A}$. This is shown by the figures below.



249. As shown above, current B—the total current flowing through the differential pair M5 and M6—is always a positive number. Since B is always positive, current is always flowing from VDD to M7. Current B increases or decreases such that when combined with current A (the AC current in C2), it forms a constant current that flows through M7.

250. M5 and M6 operate by steering current from VDD through either R1 and M5 or R2 and M6, depending on the local oscillator (LO) signal applied to their gates. As the LO signal varies, it modulates the gate voltages of M5 and M6, which in turn affects the flow of current through them. When the gate voltage of M5 is

substantially greater than that of M6, current flows from VDD, through R1 and M5, and down to M7. Conversely, when the gate voltage of M6 is substantially greater than that of M5, current flows from VDD, through R2 and M6, and down to M7. Therefore, M5 and M6 simply serve as a current-steering mechanism that routes current from VDD through either R1 or R2 before reaching M7.

251. Furthermore, Razavi explicitly states that “[t]o achieve a high conversion gain, M5 and M6 must remain in saturation.” Ex.-1017, 113. A POSITA understands that for an NMOS transistor to remain in saturation, the drain-to-source voltage must be positive, meaning current can only flow from the drain to the source. *See* Section VII.B.2. Therefore, a POSITA would understand that, in the NMOS transistors used in Razavi,¹⁰ current flows from the drain to the source, not in the

¹⁰ Dr. Galton stated that current can move in both directions in an NMOS transistor when the transistor is used as a transconductor. Ex.-2034, 245:5-15. However, he later admitted that M5 and M6 are not used as transconductors. *Id.*, 251:13-15. In Razavi’s circuit, current through M5 and M6 can only flow in one direction—down; current from the RF input signal cannot flow up through M5 and M6. Razavi clearly states that the transistors operate in the saturation region, which is distinct from transconductance-mode operation in the triode region. *See* Section VII.B.2.

opposite direction. This means that current cannot flow from the RF input signal (current in C2) (at the source of transistors M5 and M6) upward through the NMOS transistors, *i.e.*, current cannot flow from the source to the drain.

252. A POSITA further understands that in Razavi, current flows from VDD downward towards M5 and M6—from a higher potential to a lower potential. Ex.-2034, 152:19-22, 164:13-166:7, 203:13-19. The current does not flow upward from M5 or M6 to VDD.

253. While M5 and M6 can modulate the amount of current flowing downward from VDD (Ex.-2034, 167:13-22), they do not reverse the current flow direction. No current flows upward through M5 or M6 toward VDD. Therefore, the RF input signal cannot propagate from the input (at the source of M5 and M6) to the capacitors or resistors R1 and R2 (which Petitioner/Dr. Galton allege to be the loads).

254. To circumvent this fact, Dr. Galton attempts to distinguish between absolute current and signal current (“signal component”) and asserts that signal current flows upward in the circuit. Ex.-2034, 152:19-153:14, 165:21-167:12. However, Dr. Galton is incorrect. While current through M5 and M6 is affected by the RF signal as discussed above in connection with my analysis of Kirchoff’s Current Law, the current remains unidirectional—always flowing downward to ground. There is never a scenario in which current from the RF input signal flows

from the source of M5 and M6 toward VDD, as Dr. Galton suggests.

255. The mixers in Razavi require a local oscillator. Local oscillators are typically sinusoidal waveforms or near-sinusoidal waveforms due to filtering by parasitics when generated at high frequencies (900MHz at the date of Razavi would be considered a high frequency).

256. In Razavi, transistors M5 and M6 in Figure 2 are driven by a differential LO signal (labeled VLO and shown along the orange paths in Figure 2 above) from the LO/divider circuit shown in Figure 3 (below).

257. A POSITA understands that Razavi uses a 50% duty cycle LO because the oscillator is symmetric—i.e., it generates a periodic signal with equal high and low phases. This symmetry is characteristic of sinusoidal oscillators, where the output waveform spends equal time in the high and low states.

to form the down-converted signal, as is done in an energy transfer system. In fact, in the configuration of Razavi, no energy from the RF input signal is integrated/accumulated in the capacitors. This is because, as discussed above, current only flows downward from VDD to M5/M6. Current from the RF input signal cannot pass through transistors M5 and M6 upward toward the capacitors.

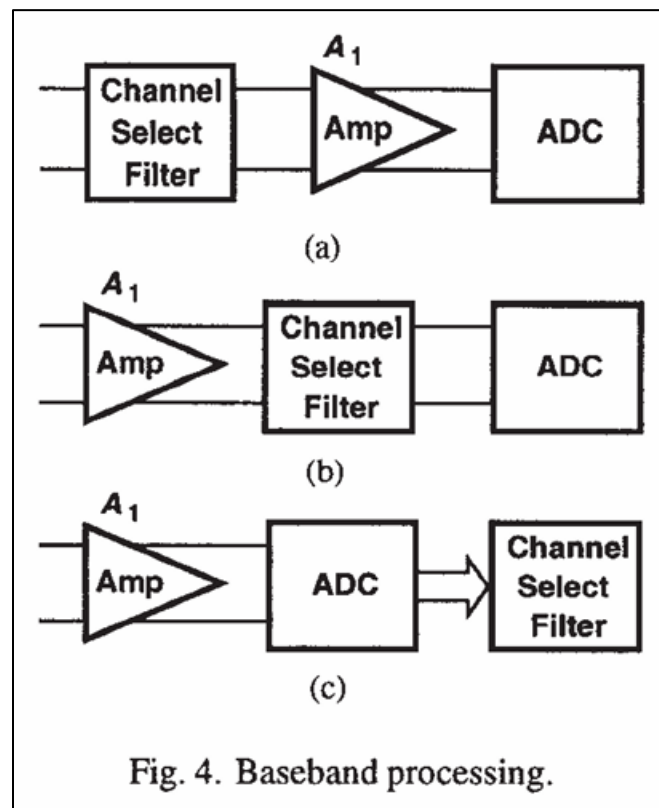
260. In Razavi, the capacitors are connected to resistors R1 and R2 (shown in the purple boxes in Fig. 2 above). Razavi notes that to achieve high conversion gain, in addition to the transistors being in saturation, “and more importantly, the voltage drop across R1 and R2 must be maximized.” Ex.-1017, 113. A POSITA would understand that the voltage drop across any resistor depends upon the magnitude of the resistance of that resistor. According to Ohm’s law ($V=IR$), the higher the magnitude of resistance, the greater the voltage drop across the resistor. In other words, resistor R1 and R2 would need to be as high resistance/impedance as possible.

261. The down-converted signal in Razavi’s circuit is a voltage, not current (or energy). Figure 2 of Razavi identifies the output of the mixer as a voltage, labeled V_{out}. Dr. Galton admits this. Ex.-2034, 161:6-16.

262. Razavi specifically teaches to use the configurations shown in Figures 4(b) and 4(c). The output of the mixer (the connection identified as V_{out} in Figure 2) is connected directly to the input of baseband amplifiers. A POSITA would

recognize that baseband amplifiers have high input impedance as their inputs are directly into the gates of MOSFETs. As a result, the signal at V_{out} is a voltage and no energy is transferred from capacitors in Figure 2.

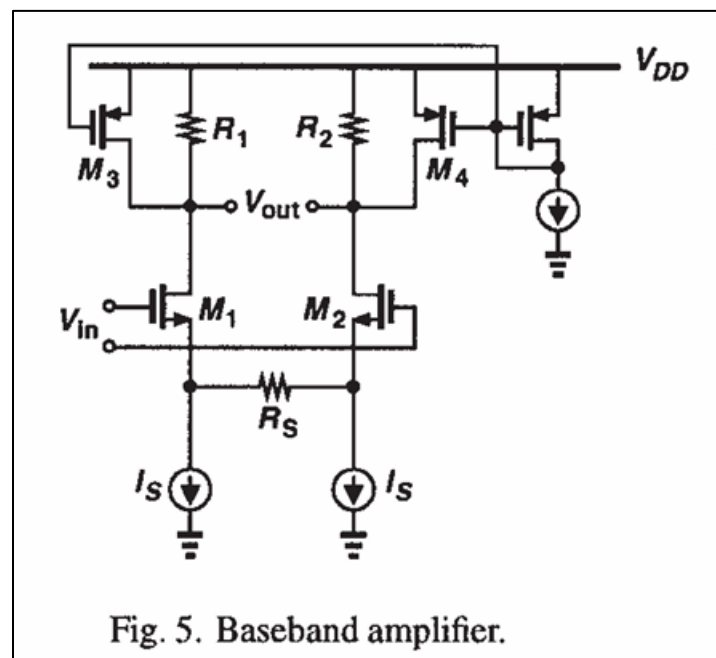
263. Figure 4 (below) shows three permutations considered by Dr. Razavi for the circuit following the mixer. Each permutation includes a channel select filter, baseband amplifier A_1 and analog-to-digital converter (ADC).



264. Razavi specifically teaches not to use the permutation shown in Figure 4(a). Razavi explains that “a low-pass filter suppresses out-of-channel interferers, allowing A_1 , to be a nonlinear, high-gain amplifier and the analog-to-digital converter (ADC) to have a moderate dynamic range (roughly 4 to 8 bits depending

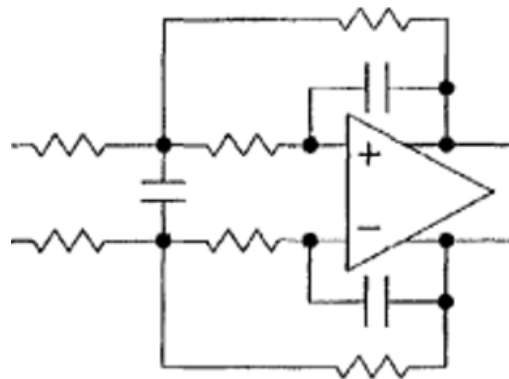
on the gain control in the RF domain and the type of modulation).” Ex.-1017, 113. However, Razavi criticizes (and teaches away from) this permutation because “the low-pass filter design entails severe noise-linearity-power tradeoffs.” *Id.* Indeed, Razavi specifies that “[t]he present design is intended for permutations in Figs. 4(b) and (c).” *Id.*

265. In the configurations of Figures 4(b) and 4(c), the mixer stage is followed by a baseband amplifier A1. Dr. Galton admits this. Ex.-2034, 201:5-11. The baseband amplifier is shown in Figure 5 (below).



266. As shown in Figure 5 above, the input of the amplifier (V_{in}) is applied to the gates of transistors M1 and M2. A POSITA understands that the gate of a FET presents a high input impedance and does not draw current. *See* Ex.-2034, 202:17-203:5. Accordingly, a POSITA would understand that the amplifier A1 is a high

traditional Gilbert cell double-balanced mixer. Ex.-1021, 7:8-10; Ex.-2034, 57:17-58:5. “The mixer’s conversion gain is 14.3 dB.” Ex.-1021, 7:8. The circuit includes a differential RF input signal (R_{FP} , R_{FN} , shown along the red paths), differential LO signal (LO_p , LO_n , shown path the orange paths), transistors M1, M2, M5, M6, M7, and M8 (shown in the purple boxes), and an antialias filter (shown in the blue box).



270. The antialias filter is made up of two biquad two-pole filters (one filter is shown above). Ex.-1021, 7:17-29; Ex.-2034, 56:14-57:5, 288:9-14 (explaining that the antialias filter is made up of biquad circuits (differential biquads) that perform amplification).

271. As shown in Figure 3, signals R_{FP} and R_{FN} are applied to the gates of transistors M1 and M2, respectively. The LO signals LO_p and LO_n are applied to the gates of transistors M5, M8, and transistors M6, M7, respectively.

272. Macnally’s disclosure is notably limited, as it does not provide component values for any of the elements shown in Figure 3. However, Macnally

does disclose that “[t]he mixer uses a double-balanced structure without a tail current source to increase headroom,” and the “[b]iasing for the RF input transistors is performed by a replica circuit that suppresses transconductance variations with process and temperature.” Ex.-1021, 7:8-12. Additionally, Macnally states that “[t]he output of the mixer is fed to a four-pole Butterworth antialias filter with a cut-off frequency of 2.4 MHz.” *Id.* at 7:14-16.

273. Notably, MacNally specifies that the mixer's conversion gain is 14.3 dB. *Id.* at 7:8. Because Macnally's mixer circuit provides gain, a POSITA would understand that the mixer is an active non-sampling mixer, using the FETs as voltage-controlled current sources, thereby allowing the circuit to amplify the signal while performing frequency conversion. *See* Section IX above.

XIII. VALIDITY OF THE '528 PATENT

A. Tayloe is not prior art.

274. Tayloe was filed on October 15, 1998. As discussed in Section X.C, claims 1, 3, 5, 8-9, 11-18 of the '528 patent were conceived of and diligently reduced to practice months before the filing of Tayloe. Accordingly, Tayloe is not prior art and, thus, Tayloe alone or when combined with the TI Datasheet/Macnally cannot invalidate claims 1, 3, 5, 8-9, 11-18 of the '528 patent.

B. Macnally is not prior art.

275. Macnally was a PCT filed on September 10, 1999. As discussed in Section X.C, claims 1, 3, 5, 8-9, 11-18 of the '528 patent were conceived of and

diligently reduced to practice months before the filing of Macnally. Accordingly, Macnally is not prior art and, thus, Macnally alone or when combined with the Tayloe/TI Datasheet or Razavi cannot invalidate claims 1, 3, 5, 8-9, 11-18 of the '528 patent.

C. GROUND 1A: Tayloe, TI Datasheet, Macnally

1. The Tayloe/TI Datasheet combination fails to disclose, teach or suggest numerous claimed features of the '528 patent.

276. Petitioner/Dr. Galton rely on the *combined teachings of three references*—Tayloe, the TI Datasheet, and Macnally—to satisfy the limitations of claims 1, 5, 8, 9, 11–19, 23, 26, 27, and 29–36 of the '528 patent. *See, e.g.*, Galton Decl. ¶¶ 153, 160, 173 (asserting that it is the “combination system” that allegedly discloses the claimed feature). Petitioner never contends that Tayloe alone—or Tayloe together with the TI Datasheet—discloses these features.

a. Claims 1 and 19

277. Claims 1 and 19 of the '528 patent recite “energy storage element[s]” that “store[] the transferred energy from the modulated carrier signal and output[] a down-converted [] baseband signal portion.”

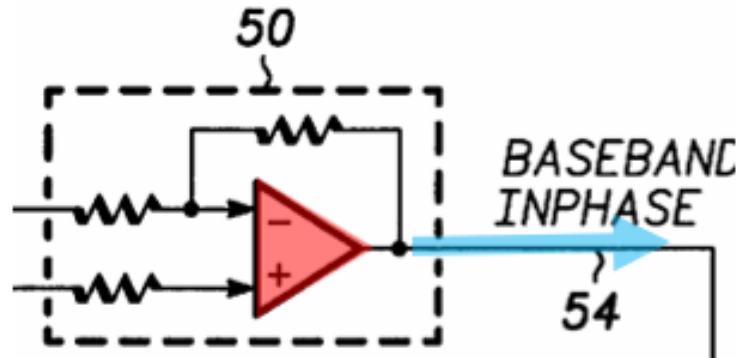
278. Claims 1 and 19 further recite that the baseband signal portions are “derived” from accumulated portions of transferred energy.

279. But, as discussed in Section VII.A above, the alleged energy storage elements in Tayloe (capacitors 72, 76 of Figure 3; or capacitors 175, 177 in Figure

6) do not discharge energy to generate the baseband signal and thus cannot output any baseband signal portion, as required by the claims. Tayloe explicitly states that the voltage on the capacitors charge to voltage points 105, 110, 115, and 120. Ex.-1004, 3:40–48. A POSITA would understand that in order for the capacitors to maintain those voltage level, the capacitors must retain charge and cannot discharge energy to form an output signal. Because there is no discharge of energy from the capacitors to the load in Tayloe, the baseband signal portion cannot be derived from the accumulated transferred energy.

280. Claims 1 and 19 further recite “differential amplifier circuit that combines” down-converted baseband signal portions and “outputs a [] down-converted differential [] baseband signal.”

281. A differential amplifier that outputs a differential signal—i.e., two outputs representing opposite signal phases—is typically called a fully-differential amplifier. A “down-converted differential [] baseband signal” in the claims, thus, means that there are *two* outputs from the amplifier circuit. Ex.-2034, 106:10-107:19 (stating that Tayloe does not disclose fully-differential amplifier where the output signal is represented by two wires).



282. But, as shown above, the op-amp (red) in Tayloe’s amplifier 50 (as well as amplifier 51) provides a *single-ended* (non-differential) output (blue arrow). Thus, Tayloe by itself does not disclose, teach, or suggest outputting a *differential* baseband signal from a differential amplifier circuit. And because Tayloe fails to disclose any output of baseband signal portions from energy transferred from the RF input in the first place, it necessarily also fails to disclose, teach, or suggest a differential amplifier circuit that combines baseband signal portions formed from energy transferred from the RF input signal to form a differential output.

b. Claims 8, 9, 26, and 27

283. Claims 8 and 26 of the ’528 patent recite “a portion of the transferred energy is discharged during the discharging part of the cycle for each respective switching device when the switching device is off.” Claims 9 and 27 further recite “energy discharged during any given discharge cycle.”

284. As discussed in Section VII.A above, the capacitors identified in Tayloe—whether 72 and 76 in Figure 3 or 175 and 177 in Figure 6—do not discharge

to form a baseband signal when the associated switches are OFF. Tayloe's circuit instead holds the voltage steady during this portion of the cycle. A POSITA would understand that this indicates the capacitors do not discharge energy into a load. As a result, Tayloe fails to disclose, teach, or suggest any energy discharge during the discharging part of the switching cycle (i.e., when the switching device is off).

2. Combination of Tayloe, TI Datasheet, Macnally

285. Because neither Tayloe nor the Tayloe/TI Datasheet combination disclose, teach, or suggest any of the elements disclosed in Section XIII.C.1 above, Petitioner turns to Macnally's biquad filter to change how Tayloe's circuit operates to accurately read voltage.

286. But as explained below, a POSITA would not have been motivated to combine Tayloe, the TI Datasheet, and Macnally, nor would there have been a reasonable expectation of success in doing so.

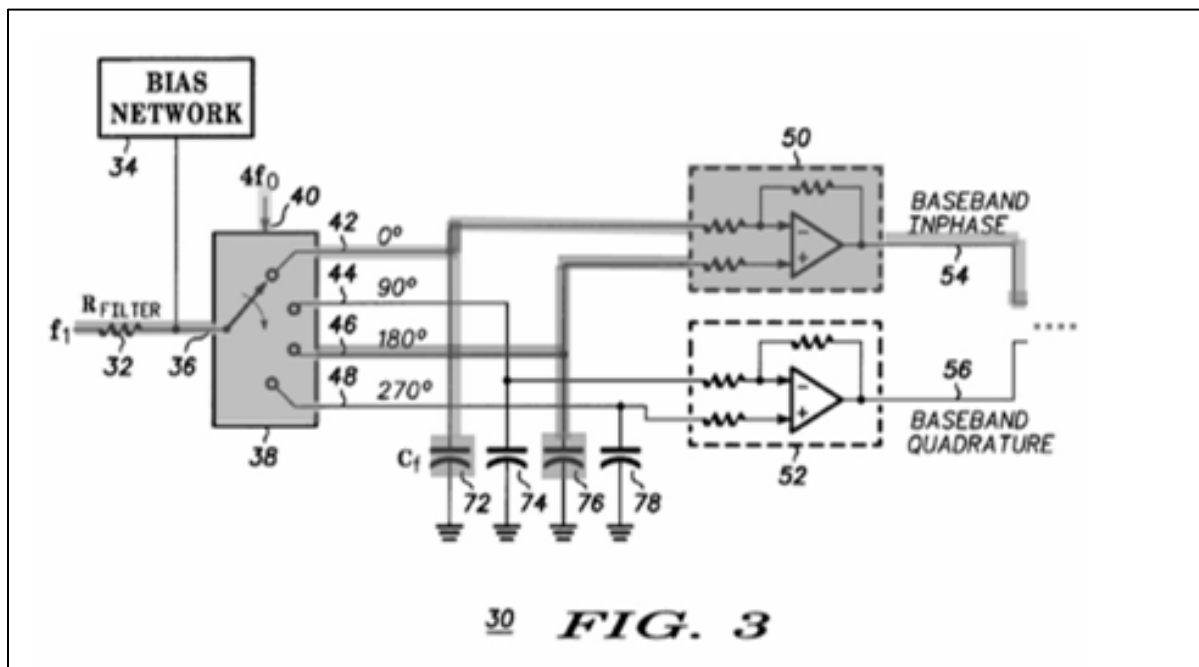
3. There is no motivation to combine Tayloe, TI Datasheet, and Macnally.

287. Petitioner/Dr. Galton¹¹ alleges that a POSITA would have found it obvious to combine the teachings Tayloe, TI Datasheet, and Macnally to arrive at the claims of the '528 patent. Pet., 1. I disagree.

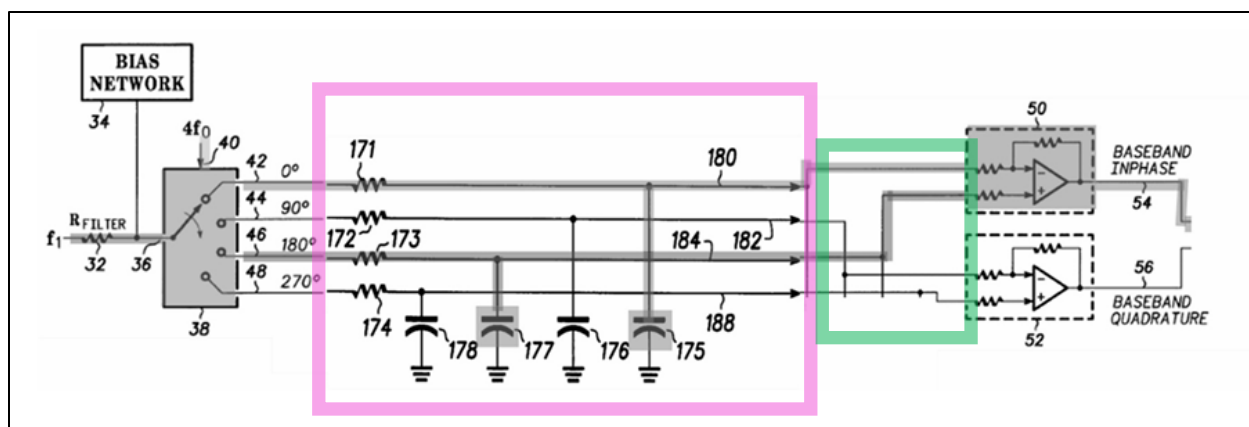
¹¹ When I refer to Petitioner in my analysis below, I am also referring to Dr. Galton.

288. Petitioner uses Figure 3 of Tayloe—described as a “direct conversion receiver”—and proposes modifying it as follows:

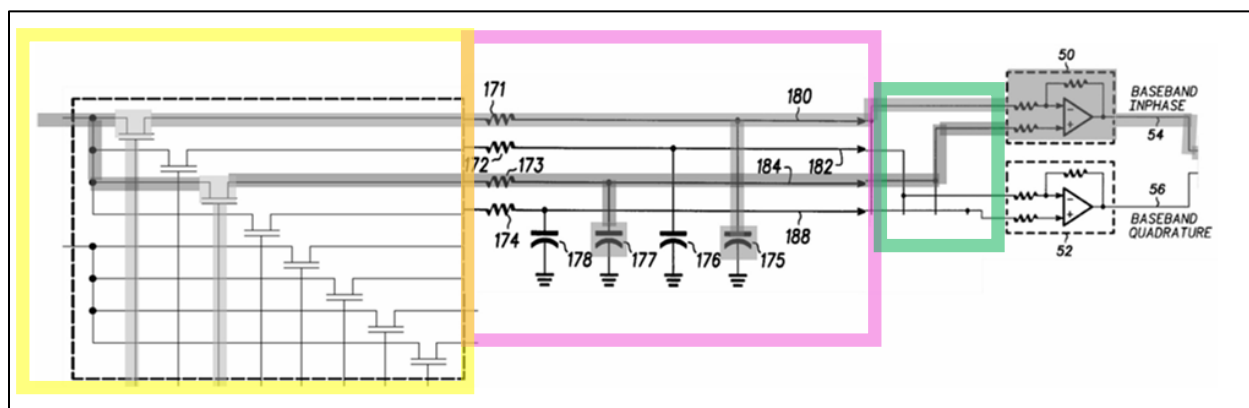
- (1) replacing the product detector of Figure 3—which includes commutating switch 38, a single resistor 32, and four capacitors 72, 74, 76, 78—with the product detector of Figure 6—which includes a commutating switch, four resistors 171-174, and four capacitors 175-178;
- (2) replacing commutating switch 38 with a multiplexer from the TI Datasheet; and
- (3) replacing each of Tayloe’s amplifiers 50, 52 with the biquad two-pole filter from Figure 3 of Macnally.



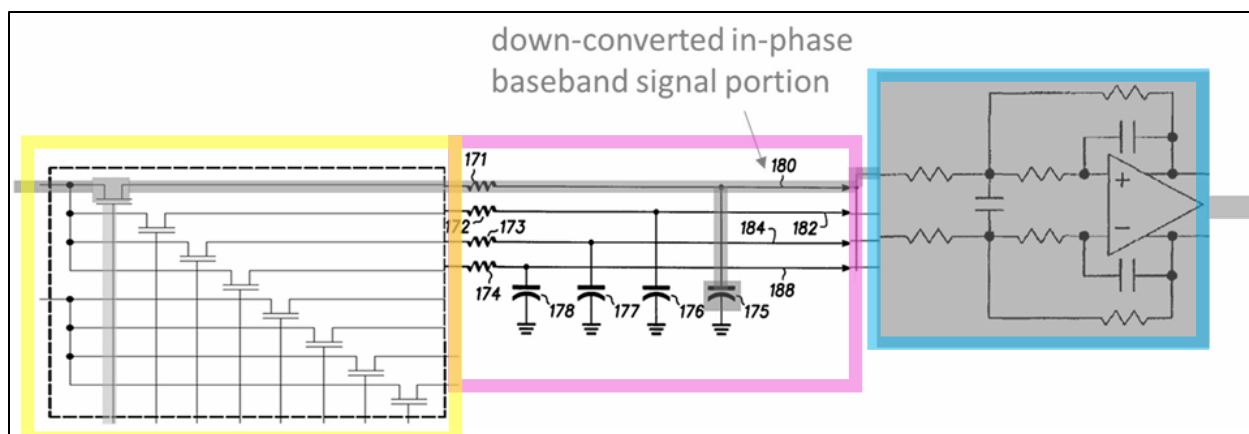
289. First, Petitioner begins to build an entirely new circuit starting with Figure 3 above. Ex.-1003, p. 71.



290. Second, as shown above, Petitioner replaces the middle portion of Figure 3 with Figure 6 (pink box). *Id.* Third, Petitioner creates new circuit connections (green) to connect lines 180, 182, 184, 188 of Figure 6 to the amplifiers 50, 52 of Figure 3. *Id.* Ex.-1003, p. 71.



291. Fourth, as shown above, Petitioner then replaces Figure 3's commutating switch 38 with the multiplexer of the TI Datasheet (yellow box). *Id.*



292. Finally, as shown above, Petition replaces the amplifier 50 with Macnally's biquad two-pole filter (blue box). *Id.*, pp. 73, 81.

293. The resulting proposed circuit combination shown above has no resemblance whatsoever to what is actually disclosed in Tayloe, TI Datasheet, or Macnally. Rather, Petitioner uses the patented invention as a roadmap to reconstruct a completely new circuit. Petitioner does so without analyzing how each substitution would affect circuit functionality or offering a reasoned motivation for why a POSITA would be inclined to pursue these specific modifications.

294. It is clear that this mocked up circuit is driven by hindsight based on the '528 patent. Only using the '528 patent as a template would such a combination be created. There is no teaching, suggestion, or motivation in Tayloe, TI Datasheet or Macnally that would lead a POSITA to make this combination.

a. Tayloe teaches away from using Figure 6 with the TI Datasheet multiplexer

295. It would not be obvious for a POSITA to use Figure 6 of Tayloe in

combination with the TI Datasheet multiplexer as proposed by Petitioner.

296. Tayloe only discloses using a multiplexer—such as the one disclosed in the TI Datasheet—in the context of Figures 3 and 7. Ex.-1004, 5:31-37. Nowhere does Tayloe disclose or suggest using a multiplexer in the context of the circuit architecture shown in Figure 6.

297. In order to get to the combination of Figure 6 and the TI Datasheet multiplexer, Petitioner asserts that (1) Tayloe “expressly teaches using an analog multiplexer,” (2) the TI Datasheet multiplexer “is a suitable analog multiplexer....” (Pet. 24), and (3) Figure 6 is an “alternate embodiment” which a POSITA would purportedly know to substitute Figure 6 for the product detector portion of Figure 3 (Pet. 26). But Petitioner’s assertions ignore critical distinctions among the embodiments.

298. The configuration of Figures 3 and 7 is different than that of Figure 6. And Tayloe specifically chose not to disclose using the TI Datasheet multiplexer with Figure 6. Unlike Figure 6, Figures 3 and 7 use a *shared* resistor configuration — a *single* resistor *before* the switch (204 in Fig. 7; 32 in Fig. 3) and individual capacitors at each output (206, 208 in Fig. 7; 72, 74, 76, 78 in Fig. 3). In contrast, Figure 6 uses a *per-path* resistor configuration, with four separate resistors (171-174), each placed *after* the switching element. Tayloe’s only disclosed multiplexer-based implementation is expressly tied to the shared-resistor configuration in Figures

3 and 7. Tayloe never discloses, teaches, suggests combining the multiplexer with the more complex and component-heavy configuration of Figure 6.

299. Petitioner does not provide any reason for departing from Tayloe’s disclosed design choice and replacing the shared resistor 204 of Figures 3 and 7 with the multiple resistors (171, 172, 173, 174) of Figure 6. In fact, doing so undermines the very design tradeoffs Petitioner claims would motivate a POSITA to adopt the proposed Tayloe-Macnally-TI Datasheet combination in the first place.

300. If, as Petitioner contends, a POSITA is considering “size, packaging advantages, and low unit cost” (Ex.-1003, ¶141; Pet. 28) of an IC, then the shared-resistor configuration of Figure 3 is more suitable than the more complex per-path resistor architecture of Figure 6. A POSITA seeking a single-chip IC would prefer the simpler architecture of Figure 3—which uses fewer components, reduces layout complexity, and minimizes die area and power consumption— compared to Figure 6’s per-path resistor structure—which introduces greater component count, routing complexity, and cost.

301. Figure 6 also introduces substantial practical complications. In an integrated circuit context, using Figure 6 would require precise matching of the four resistors (171–174) in order to maintain equal time constants across signal paths which is necessitated by Petitioner’s proposed combination. This level of matching is difficult to achieve due to variation in IC fabrication processes. A mismatch would

introduce distortion or imbalance in the signals. Achieving such matching would necessitate larger resistors (increasing die area) and/or post-fabrication calibration—both of which run counter to the alleged design goals of cost and simplicity. But these burdens are not present in Figure 3’s shared-resistor design, which does not require matched per-path resistors. That Petitioner instead relies on Figure 6 contradicts the very design tradeoffs Petitioner alleges would motivate the combination with Macnally.

302. Contrary to Dr. Galton’s implication, it is not as simple as just substituting Figure 6 for Figure 3. Using Figure 6 in Petitioner’s proposed combination with the TI Datasheet multiplexer introduces complexities that Figure 3 does not have. Whereas Figure 3 uses a single resistor R_{FILTER} before the switch, Figure 6 uses four separate resistors after the switch. This distinction has meaningful consequences for signal timing, die layout, and implementation in silicon. Petitioner offers no evidence or reasoning to support that a POSITA would willingly introduce these complexities—especially when doing so undermines Petitioner’s own rationale for compactness and cost-efficiency.

303. Accordingly, Tayloe does not teach or suggest using the Figure 6 architecture with the TI Datasheet multiplexer. Doing so would increase design complexity, die area, and implementation cost—contrary to the motivations Petitioner claims would drive a POSITA.

b. Tayloe teaches away from creating the integrated circuit that Petitioner suggests

304. Petitioner asserts that a POSITA would be motivated to adapt Tayloe's circuit as an integrated circuit "to meet relentless market demand for improved product size/performance, and decreased unit cost." Pet., 28. I disagree.

305. Tayloe provides no motivation for a POSITA to develop an integrated circuit incorporating Tayloe's product detector. In fact, Tayloe already discloses use of an integrated circuit —specifically, the analog multiplexer of the TI Datasheet. But Tayloe never discloses, teaches, or suggests integrating its product detector (whether the implementation of Figure 3 or 6) into the integrated circuit of the TI Datasheet or any other integrated circuit. A POSITA would not have been motivated to develop an entirely new integrated circuit around Tayloe's product detector.

306. To the contrary, a POSITA would understand that Tayloe specifically teaches away from implementing its product detector in an integrated circuit. For example, Dr. Galton proposed mock-up circuit includes Tayloe's capacitors. But a POSITA would recognize that Tayloe's capacitors would not be suitable for integration due to their extremely large size. Specifically, a POSITA understands that capacitances larger than 1 pico-Farad are difficult/generally impractical due to integrated on-chip space and process limitations. Yet, the embodiment disclosed in Tayloe's Experimental Results section uses a 0.3 microfarads capacitor – 300,000 times larger than what is considered feasible (1 pico-Farad) in an IC. *See* Ex.-1004,

5:50-51. Thus, a POSITA would recognize Tayloe's capacitors would be off chip, not integrated. Notably, Dr. Galton ignores this and offers no rationale as to how Tayloe's large capacitors could be implemented in silicon. Instead, he simply states that "[a] POSITA would have been motivated to adapt Tayloe's *system* as a single-chip (i.e. integrated circuit known as an IC) ..." (Ex.-1003, ¶141, emphasis added), without addressing this fundamental incompatibility. Dr. Galton's proposal of adapting Tayloe's entire system, including the large capacitors, into an integrated circuit does not work, given the large size of Tayloe's capacitors.

307. Moreover, Tayloe specifically states that a "*prototyped* direct conversion receiver" was built using the circuit of Figure 3. Ex.-1004, 5:49-50. However, Tayloe admits that, as of the time of the patent, the prototype could not handle higher frequency signals (the types of signals that would be used for cellular/WiFi communications) which were "many orders of magnitude greater than the prototyped unit." *Id.*, 5:34-59. While Tayloe states that higher-frequency receivers were possible to build, it provides no example or guidance on how to achieve this with its disclosure. Critically, the TI Datasheet multiplexer cannot support higher frequencies because it cannot switch fast enough, as discussed further below.

308. Thus, a POSITA would recognize that building an integrated circuit with Tayloe's product detector and the TI Datasheet would require redesigning the

circuit architecture, abandoning the TI multiplexer, and developing new switching components capable of operating orders of magnitude faster than those disclosed in Tayloe or the TI Datasheet. Doing so would require undue experimentation, well beyond routine skill in the art.

309. For these reasons, Tayloe does not provide any motivation to create an integrated circuit based on Tayloe's product detector/TI Datasheet. Rather, Tayloe teaches away from such a design by disclosing large, off-chip components that are fundamentally incompatible with IC implementation. Petitioner's proposal relies on hindsight and ignores real-world engineering constraints that a POSITA would not overlook.

c. Macnally and TI Datasheet are not compatible

310. A POSITA would not combine the TI Datasheet and Macnally in an integrated circuit.

311. Petitioner's stated motivation for relying on Macnally is the desire to realize the entire system as a single integrated circuit.

312. Macnally is realized in integrated circuit technology, in part, because it operates at high frequencies, e.g., 915 MHz, which enables the use of smaller component values (and thus, physically smaller sized components), making it feasible for an integrated circuit.

313. Indeed, Macnally's circuit operates at 915 MHz (Ex.-1021, Figs. 6 and

10). At this frequency, the signal period is approximately 1.09 nanoseconds. The TI Datasheet multiplexer, however, cannot switch quickly enough to function at that rate.¹² The switches in the TI Datasheet cannot turn ON and OFF fast enough to handle 915 MHz.

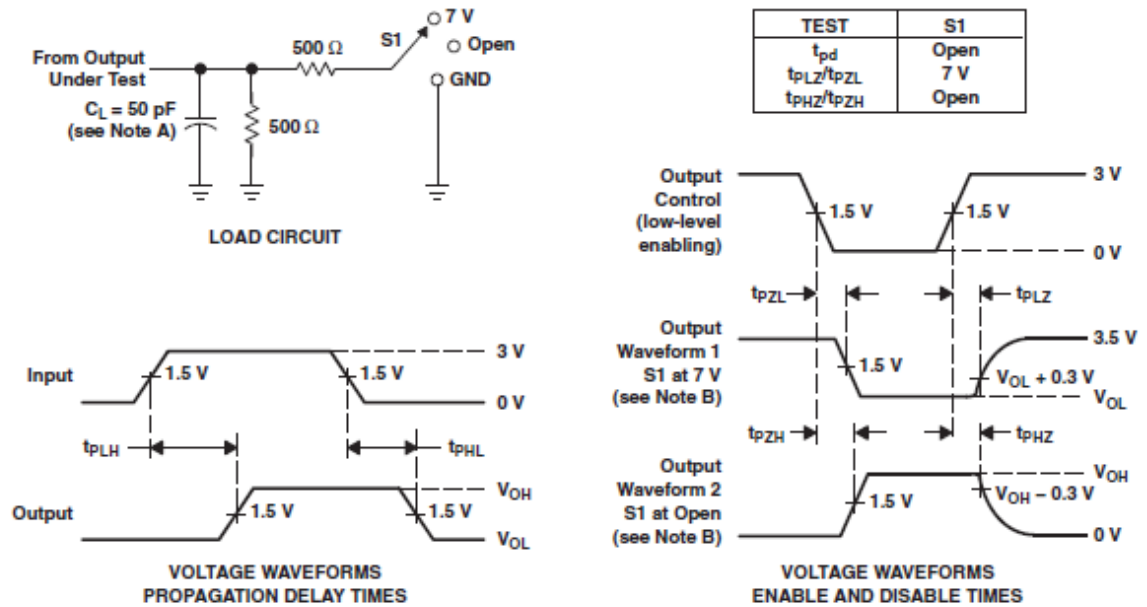
314. In particular, Tayloe describes the commutating switching being ON for one-quarter ($\frac{1}{4}$) of a full cycle. At 915 MHz, that would be 273 picoseconds. For the circuit to function, the switches in the TI Datasheet multiplexer would need to turn ON, allow current to flow through it, and then turn OFF all within 273 ps. To be practical, the switch transition time (time it takes for the switch to turn ON and OFF) must be only a small fraction of this—typically on the order of 10%—or 27.3 ps. The TI Datasheet shows that the response time of the switches is much slower than this, at least an order of magnitude slower.

¹² Tayloe's prototype circuit that used the TI Datasheet multiplexer operated at 7 MHz. Ex.-1004 5:49-50. The TI Datasheet multiplexer only worked because it operated at 7MHz which is more than two orders of magnitude lower than the frequency disclosed in Macnally.

SN74CBT3253 DUAL 1-OF-4 FET MULTIPLEXER/DEMULTIPLEXER

SCDS0180 – MAY 1995 – REVISED JANUARY 2004

PARAMETER MEASUREMENT INFORMATION



- NOTES:
- C_L includes probe and jig capacitance.
 - Waveform 1 is for an output with internal conditions such that the output is low except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high except when disabled by the output control.
 - All input pulses are supplied by generators having the following characteristics: PRR $\leq 10 \text{ MHz}$, $Z_O = 50 \Omega$, $t_r \leq 2.5 \text{ ns}$, $t_f \leq 2.5 \text{ ns}$.
 - The outputs are measured one at a time with one transition per measurement.
 - t_{PLZ} and t_{PHZ} are the same as t_{dis} .
 - t_{PZL} and t_{PZH} are the same as t_{en} .
 - t_{PHL} and t_{PLH} are the same as t_{pd} .
 - All parameters and waveforms are not applicable to all devices.

Figure 1. Load Circuit and Voltage Waveforms

switching characteristics over recommended operating free-air temperature range, $C_L = 50 \text{ pF}$ (unless otherwise noted) (see Figure 1)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	$V_{CC} = 4 \text{ V}$		$V_{CC} = 5 \text{ V} \pm 0.5 \text{ V}$		UNIT
			MIN	MAX	MIN	MAX	
$t_{pd}^{(1)}$	A or B	B or A	0.35		0.25		ns
t_{pd}	S	A or B	6.6	1.6	6.2		ns
t_{en}	S	A or B	7.1	1.3	6.3		ns
	$\overline{OE}$		7.3	1.4	6.4		
t_{dis}	S	A or B	7.9	1.1	7.4		ns
	$\overline{OE}$		7.3	2.3	7		

⁽¹⁾ The propagation delay is the calculated RC time constant of the typical on-state resistance of the switch and the specified load capacitance, when driven by an ideal voltage source (zero output impedance).

315. As shown in the table of parameters in Figure 1 above, the propagation

delay through a single switch is 0.25 ns (250 ps) (shown in blue), which nearly consumes the entire allowable ON time. Even worse, the turn ON delay from the command signal (signal to turn ON the switch) is t_{plz} which is equal to t_{dis} (Note E., Figure 1). This is 1.1 ns at the minimum and can vary as large as 7.4 ns (shown in yellow). These values (shown in yellow) are all substantially longer than the 1.09 ns full cycle of a 915 MHz signal and far exceed the 27.3 ps transition time noted above.

d. Macnally's teaches a fundamentally different mixer than Tayloe

316. Dr. Galton focuses on incorporating the Macnally's biquad two-pole filter with Tayloe's product detector and the TI Datasheet multiplexer. But Dr. Galton ignores that another way to look at this is that he is replacing Macnally's mixer with Tayloe's product detector and the TI Datasheet multiplexer. Dr. Galton fails to show any motivation for replacing Macnally's mixer, which achieves significant gain (14.3dB), with Tayloe and the TI Datasheet multiplexer to form a new circuit.

317. Macnally discloses a high-performance mixer, namely an active double balanced mixer that achieves high gain. Ex.-1021, 7:8-10 ("The mixer's conversion gain is 14.3 dB. The mixer uses a double balanced structure without a tail current source to increase headroom..."); *see also* Section XII.D. Tayloe, on the other hand, discloses a mixer with a -1 dB conversion loss, which is 15 dB less gain (worse) than Macnally. Ex.-1004, 1:65; 3:5-6, 9-11. I note that the gain achieved in Macnally is

not due to the biquad two-pole filter. signal.

e. There is no motivation to replace Tayloe's amplifiers with Macnally's biquad two-pole filter

318. Petitioner asserts that a POSITA would be “inspired by several known advantages of using fully differential amplifiers and Macnally’s topology for baseband processing on an IC.” Pet. 28; Ex.-1003, ¶141. Based on this, Petitioner asserts that a POSITA would be motivated to replace Tayloe’s amplifiers 50, 52 with Macnally’s biquad two-pole filters.¹³ I disagree.

319. Petitioner lists a few purported benefits of using a fully differential amplifier (i.e., an amplifier having a differential input and a differential output). Pet., 28-30. But there is no reason for a POSITA to even consider using a fully differential amplifier in the first place.

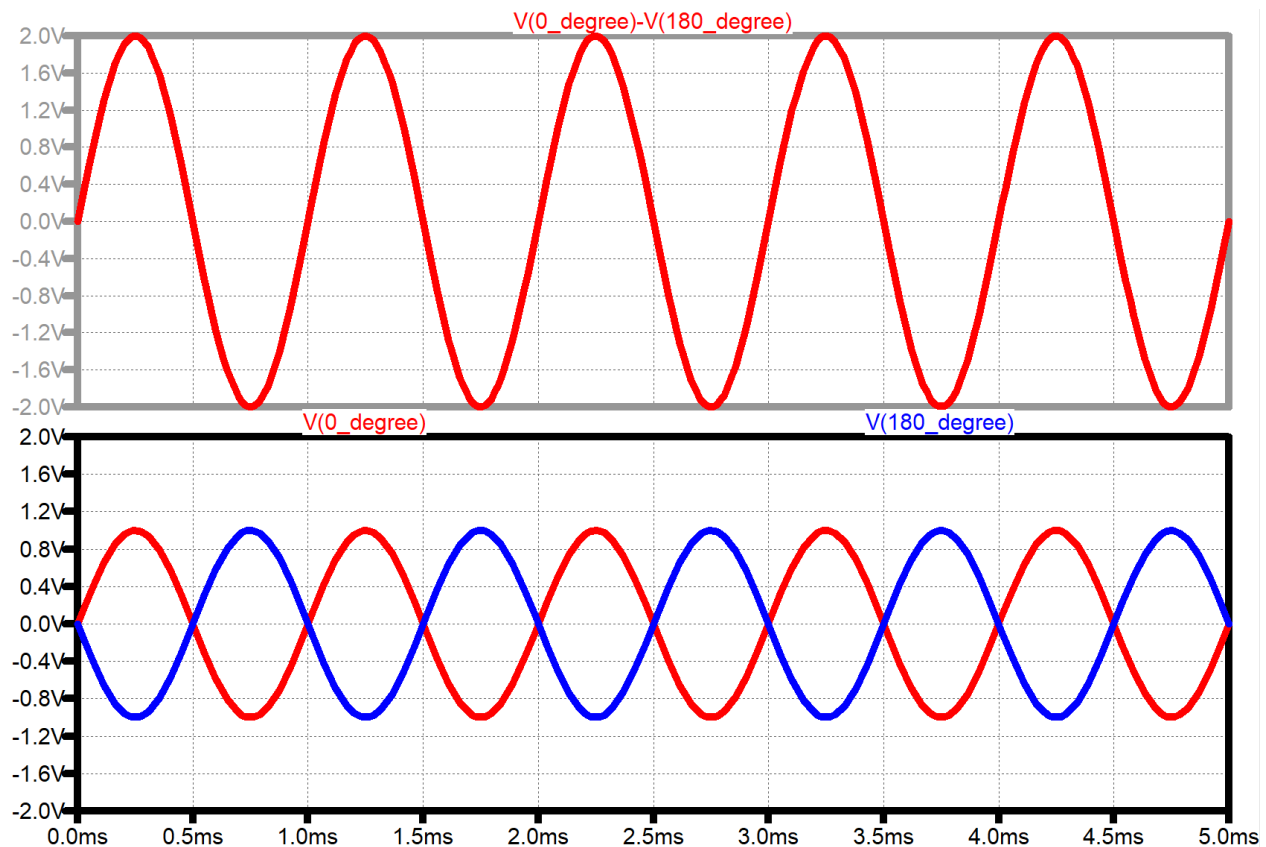
320. First, Tayloe specifically teaches using a summing amplifier with a differential input and signal-ended output for a specific goal, namely gain. Tayloe explains that “to increase gain, the 0 degree average can be differentially summed with the 180 degree average to form the baseband in-phase signal, and the 90 degree

¹³ Macnally discloses a “biquad four-pole filter,” (Ex.-1021, 7:17-19), however a POSITA would recognize that there are two filters that make up the circuit in Macnally and that each circuit, the proposed substitution by Petitioner/Dr. Galton, has two poles. Two two-pole filters are the four-pole filter disclosed in Macnally.

average can be differentially summed with the 270 degree average to produce the baseband quadrature signal.” Ex.-1004, Abstract.

321. Tayloe’s amplifier 50, 52 are used to amplify the signal and provide gain. In particular, Tayloe’s amplifiers 50, 52 receive two inputs and produce a single-ended, amplified output. Because Tayloe’s amplifiers already accomplish the intended goal of providing gain, a POSITA would not have any reason to replace Tayloe’s amplifiers with a different type of circuit. Thus, a POSITA would not be motivated to look to Macnally and use Macnally’s biquad two-pole filter to perform amplification.

322. Below I show this gain increase. Taking the difference between 0 degree and 180 degree components (both a 1V sinewave) results in a 2 V single-ended output—twice the amplitude of either input.



323. Yet, Petitioner inexplicably proposes replacing Tayloe’s amplifiers with Macnally’s biquad two-pole filters—an entirely different type of circuit. Unlike Tayloe’s design, which provides a single-ended output, Macnally’s biquad two-pole filter produces a differential output. The difference is significant, as Tayloe deliberately uses a single-ended output to extract the gain from complementary signals. Petitioner’s proposed substitution undermines Tayloe’s intended functionality.

324. Second, Macnally’s biquad two-pole filter acts as a low-pass (anti-alias) filter. Ex.-1021, 7:17-19; Ex.-1003, ¶143; Ex.-2034, 56:5-57:16. An anti-aliasing filter removes aliased signals from the band of operation. Tayloe, however,

already achieves low-pass filtering using RC time constants created by resistor 32 and capacitors 72–78 in Figure 3 (or resistors 171-174, capacitors 175-178 in Figure 6). Ex.-1004, 2:14-15, 3:21–27; Ex.-2034, 145:2-9.

325. Tayloe does not identify or discuss any need for any additional filtering or anti-aliasing components. This is because Tayloe’s existing design already performs the function of an anti-aliasing filter—removing aliasing artifacts. Thus, a POSITA would not be motivated to look at filtering technology such as Macnally’s biquad two-pole filters to incorporate into Tayloe’s circuit. And a POSITA would certainly not look to replace an amplifier with a filter, regardless of whether that filter also happens to amplify a signal.

326. Notably, Petitioner simply provides no rationale for why an additional low-pass filter is needed when there is a low-pass filter that is already part of Tayloe’s product detector.

327. Third, Petitioner attempts to justify replacing Tayloe’s amplifiers with Macnally’s biquad two-pole filters by suggesting problems with Tayloe’s circuit that are already addressed in Tayloe. Petitioner identifies linearity, noise, and power consumption as alleged issues to address. Pet. 28, 29.

328. In particular, Petitioner asserts that by taking the difference between “two complementary signal components,” Macnally’s biquad two-pole filter offers advantages such as cancelling interference, minimizing harmonic distortion, and

improving linearity Pet. 28. But Tayloe's amplifiers 50, 52 already process complementary inputs and achieve the same results. Tayloe's configuration (without Macnally's biquad two-pole filters) accomplishes these benefits without Macnally's filter. Thus, there is no motivation to replace Tayloe's amplifiers with Macnally's biquad two-pole filters. There is no technical reason a POSITA would look to Macnally for Petitioner's alleged improvements.

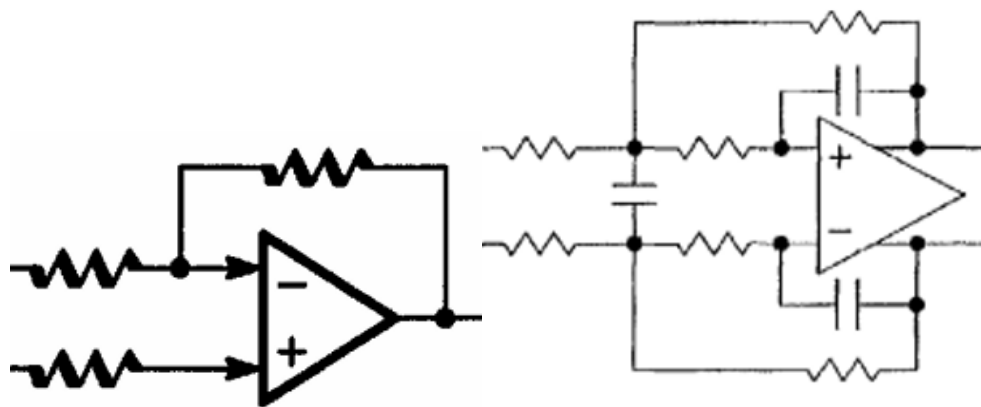
329. Petitioner also asserts that fully differential amplifiers provide symmetrical layouts in ICs, which can minimize noise. *Id.* But Tayloe already addresses the issue of noise. Tayloe explains that its design reduces conversion loss and significantly improves noise performance. Ex.-1004, 3:4-13 ("The Tayloe Product Detector can exhibit less than 1 dB of conversion loss, which is 6-7 dB improvement over the typical conversion loss of 7-8 dB in the prior art. This 6-7 dB conversion loss improvement translates into a 6-7 dB improvement in overall receiver noise figure. The noise figure improvement results in substantial receiver performance gains, in part because a pre-amplifier may become unnecessary as a result. The use of a pre-amplifier, while improving receiver noise figure by overcoming front end receiver loss."). These are precisely the performance concerns Petitioner claims would motivate a POSITA to seek alternatives. But Tayloe already solves them. A POSITA would not be motivated to look for a solution to something that was already addressed. Accordingly, a POSITA would not think to look to

Macnally's biquad two-pole filter.

330. Petitioner further suggests that Macnally's biquad filter uses a "Rauch biquad topology known for reducing the number of operational amplifiers on an IC." Ex.-1003, ¶141; Pet. 28. But this is misleading.

331. In fact, using Macnally's biquad two-pole filter in Tayloe's circuit would require more components (not fewer) than Tayloe's existing amplifier design.

332. Petitioner proposes a one-for-one replacement of Tayloe's amplifiers with biquad two-pole filters. Thus, at the very least, Petitioner's proposal uses the same number of op-amps already disclosed in Tayloe.



333. But, as shown above, Tayloe's amplifiers (above left) has significantly fewer components than Macnally's biquad two-pole filter (above right).

334. Moreover, Tayloe's amplifier produces a single-ended output, while Macnally's biquad two-pole filter produces a differential output. Macnally's differential output would therefore require additional subsequent circuitry (that

Tayloe's amplifier does not need) to achieve Tayloe's final, single-ended signal of interest 62. Indeed, to get to a single-ended output using Macnally would require additional op-amps that Tayloe does not require. Thus, a POSITA would not be motivated to use Macnally's biquad two-pole filter to reduce the number of components or op-amps.

335. Thus, Petitioner fails to provide any reason why a POSITA would substitute Macnally's biquad two-pole filter for Tayloe's amplifier. The circuits are not functionally equivalent, and the substitution would increase complexity without offering meaningful benefits.

336. Fourth, Petitioner asserts that, in developing an integrated circuit, a POSITA would consider "size, packaging advantages, and low unit cost" (Ex.-1003, ¶141; Pet. 28) of an IC. Using Tayloe Figure 6 and Macnally's biquad two-pole filter, however, would significantly increase (not decrease) the number of components need to achieve the same result. For example, Figure 6 uses more resistors than Figure 3 and Macnally's biquad two-pole filter requires many more components than Tayloe's amplifier as well as additional subsequent components to process the differential signal to a single-end output.

337. Fifth, Tayloe describes the invention as "a simple and inexpensive product detector," with performance benefits such as "low conversion loss" and "substantial receiver performance gains." Ex.-1004, 1:65; 3:5-6, 9-11. These

performance characteristics address the very issues that Petitioner alleges would drive a POSITA to incorporate Macnally.

338. Finally, a POSITA would not look to Macnally for components to substitute into Tayloe's circuit. Tayloe and Macnally are two fundamentally different systems. Tayloe is a sampling system whereas Macnally discloses a traditional Gilbert cell double-balanced mixer (non-sampling mixer). See Ex.-2034, 102:11-14, 104:7-18, 57:17-58:5. Sections IV; VIII.A, D. Tayloe uses a 25% duty cycle mixer whereas Macnally uses a nominal 50% duty cycle mixer. Ex.-2034, 59:3-16, 59:17-60:12, 104:21-105:3.

4. Tayloe and Macnally are not compatible.

339. A POSITA would not be motivated to replace Tayloe's summing amplifiers with Macnally's biquad two-pole filters, as alleged by Petitioner/Dr. Galton, because the two circuits are fundamentally incompatible.

340. As explained in Section XII.A above, Tayloe's amplifiers (summing amplifiers 50 and 52 in Figure 3) operate as *high* impedance loads. This high input impedance is critical to the operation of Tayloe's circuit—it ensures Tayloe's capacitors retain charge during the sampling cycle and establish a stable voltage that represents the down-converted signal.

341. Petitioner and Dr. Galton, however, propose replacing Tayloe's summing amplifiers with Macnally's biquad two-pole filter. But according to

Petitioner, Macnally's filter presents a *low impedance* load— “typically in the kilo-ohm range.” *See* Pet. 35, 70, 72; Ex.-1003 ¶ 240. A POSITA would understand that substituting a low impedance load in place of a high impedance load would fundamentally alter the operation of Tayloe's circuit. In particular, a low impedance load would draw current from Tayloe's capacitors during the sampling cycle, altering voltage levels in the capacitors, thereby corrupting the sampled voltage.

342. This is not a minor or superficial difference. High and low impedance loads produce materially different effects in analog circuits. A high impedance load is required to preserve charge on the capacitors and maintain accurate voltage representations. A low impedance load, on the other hand, prematurely discharges stored charge, distorting the intended signal output and corrupting the sampled signal. Making this substitution would not only alter the behavior of the circuit but would defeat the very function Tayloe's architecture is designed to serve.

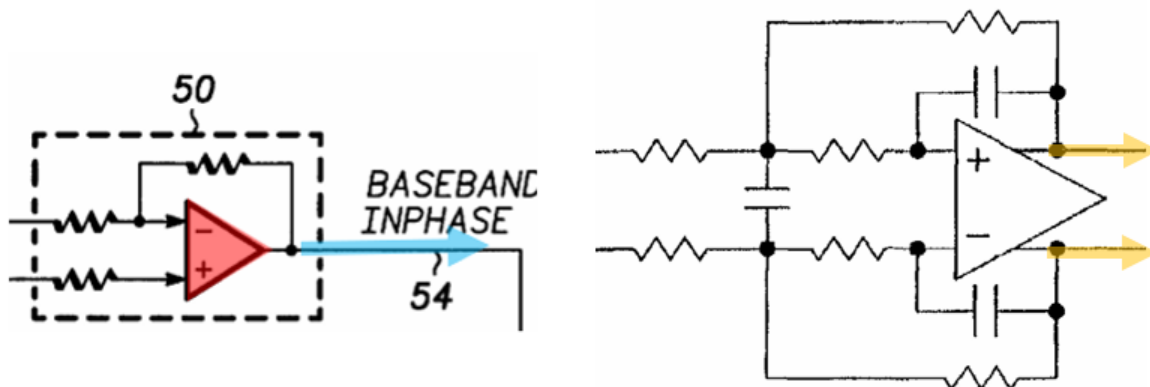
343. The incompatibility between Tayloe's high impedance amplifier and Macnally's low impedance biquad filter would therefore dissuade, not encourage, a POSITA from making Petitioner's proposed substitution.

5. There is no reasonable expectation of success in combining Tayloe/TI Datasheet and Macnally into an integrated circuit.

344. Petitioner alleges that replacing Tayloe's amplifiers with Macnally's biquad two-pole filters is “a simple substitution of one known element (fully

differential amplifier circuit of Macnally) for another (summing amplifier circuit of Tayloe) to obtain predictable results (e.g., improved linearity and reduced power consumption for on-chip performance), and hence would have had a reasonable expectation of success.” Pet., 29-30; Ex.-1003, ¶143. I disagree.

345. Replacing Tayloe’s single-ended amplifiers with Macnally’s biquad two-pole filter requires fundamental restructuring of Tayloe’s circuit that will not produce predictable results or have a reasonable expectation of success.

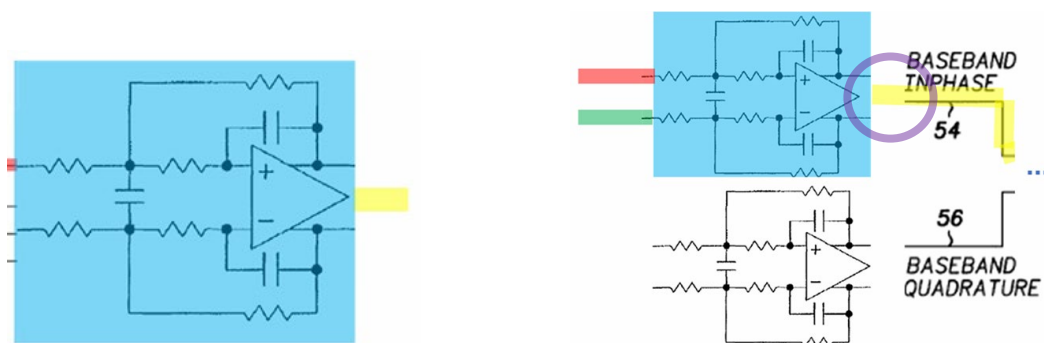


346. First, Tayloe’s amplifiers 50, 52 (above left) use a differential input and a *single-ended* output. In contrast, Macnally’s filters (above right) use differential inputs and *differential* outputs. Incorporating Macnally’s biquad two-pole filter into Tayloe’s circuit would fundamentally change the signal paths and negate the gain benefits that Tayloe describes.

347. Implementing Macnally’s differential output in place of Tayloe’s single-ended output would require redesigning the rest of Tayloe’s signal chain to accommodate Macnally’s differential output configuration. Even Petitioner

acknowledges that a POSITA would need to adapt all subsequent on-chip components (circuitry after Macnally's biquad two-pole filter) to match Macnally's differential configuration, including phase shifters and amplifiers. Pet., 29.

348. Those changes to such a number of components would not lead to predictable results or a reasonable expectation of success. Petitioner is proposing replacing a simple amplifier of Tayloe with a complicated Rauch biquad two-pole filter of Macnally (as well as additional subsequent circuitry). Further, adding a Rauch biquad two-pole filter into Tayloe's system, which makes no mention of such a filter, would also require considerable experimentation to figure out how to design Tayloe with a complicated circuit – a Rauch biquad two-pole filter. A POSITA would need to engage in substantial experimentation to determine how (or whether) such a filter could function in Tayloe's circuit. And there is no guarantee that the newly designed circuit would have improved linearity and reduced power consumption for on-chip performance compared to using Tayloe's amplifier and subsequent circuitry.

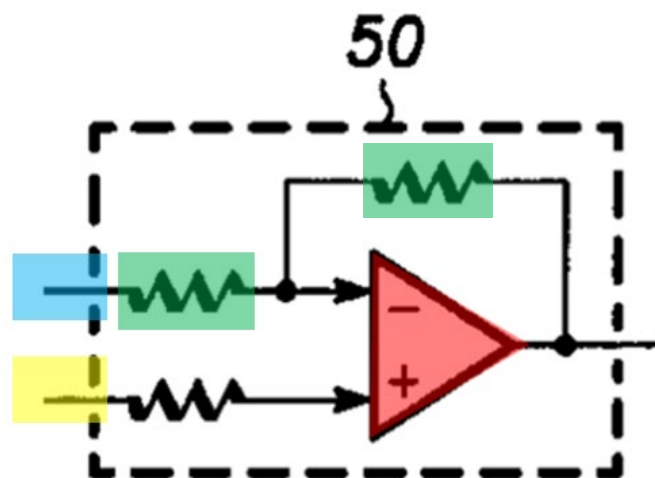


349. Notably, as shown above, Dr. Galton did not even provide any

indication of what circuitry would exist after Macnally's biquad two-pole filter or how it is configured or would operate. Instead, he merely draws in some yellow lines. Ex.-1003, ¶¶153, 167. As shown above right in the purple circle, instead of showing how the *two* outputs (differential output) are actually connected to subsequent circuitry, Dr. Galton just leaves a space and shows a yellow line going into a *single* line. A differential output does not just connect to a single line as shown.

350. Second, replacing Tayloe's single-ended amplifier with Macnally's filter amplifier would alter the fundamental operation of Tayloe's circuit.

351. Tayloe specifically chose its configuration to so that the circuit operates in a specific way. Tayloe specifically shows a differential amplifier with a single-ended output to improve gain. Using Macnally's biquad two-pole filter with a differential output changes that configuration considerably. Moreover, as discussed in Section VIII.A, Tayloe's amplifiers 50, 52 are *high impedance loads*.



352. In particular, a POSITA understands that the yellow and blue inputs

(above) of amplifiers 50, 52 exhibit very high resistance/impedance. These amplifiers cause capacitors to hold charge so that a voltage can be read in order to recreate the baseband signal. On the other hand, according to Petitioner, the biquad two-pole filter of Macnally provides “*low impedance load* typically in the kilo ohm range.” Pet., 35, 70. As explained in Sections III.B.5 and VI.B, high and low impedance loads have very different effects on a circuit. A low impedance load in Tayloe would lead to an inaccurate measurement of the voltage average and Tayloe would not be able to accurately reproduce the baseband signal.

353. A POSITA would therefore not be motivated to replace Tayloe’s high impedance load amplifiers 50, 52 with the alleged low impedance biquad two-pole filter of Macnally. Such a modification would ignore all of the disclosure in Tayloe, abandon all of the teachings and suggestions of Tayloe and go in the opposite direction, and fundamentally change the Tayloe’s circuit.

354. Third, Petitioner asserts that “a POSITA would have recognized that the lowpass filtering function of the Macnally differential amplifier is beneficial in the Tayloe’s circuits as lowpass filtering of the baseband signals in direct conversion receives is beneficial.” Ex.-1003, ¶143. As discussed above, Tayloe already incorporates a low-pass filter and achieves low-pass filtering. There is no additional benefit to using Macnally’s biquad two-pole filters. Petitioner never explains how adding a second filtering stage—or replacing Tayloe’s RC filtering with Macnally’s

filters—would affect the circuit’s frequency response

355. In view of the foregoing, there is no reasonable expectation of success in combining Tayloe/TI Datasheet and Macnally.

D. GROUND 2: Razavi–Macnally

356. The challenged claims are not obvious over Razavi in combination with Macnally.

1. Razavi does not disclose, teach, or suggest transferring energy from a modulated carrier signal as an output of a switch when the switch is ON.

357. Claims 1 and 19 recite “wherein the [] switch is on and a portion of energy that is distinguishable from noise is transferred from the modulated carrier signal as an output of said [] switch during the sampling aperture...”

358. The parties agree that a “sampling aperture” means “a period of time during which the switch is in its closed (i.e., on) state.” Ex-2030.

359. A POSITA understands that sampling, in this context, refers to reducing a continuous-time signal to a discrete-time signal. *See* Ex.-2030; Sections III.B.9, IV.B, VI.B. Notably, as discussed in Sections III.B.9, IV.B, and VI.B, in sampling systems such as the ’528 patent, there is a continuous current from the RF input signal at the input of a switch. When the switch is ON (closed), current from the RF input signal can pass through. When the switch is OFF (open), current cannot pass through. Turning the switch ON and OFF creates gaps in the RF signal current at the

output of the switch. Thus, in a sampling system, the RF input signal must physically pass through a switching element in a way that breaks the continuous signal into discrete-time samples. This is not how Razavi works.

360. Dr. Galton points to transistors M5 and M6 in Razavi's mixer as the alleged "switches" and the RF input signal as the modulated carrier signal. Ex.-1003, ¶¶231-232, 236-237. Dr. Galton asserts that Razavi's mixer performs sampling and transfers energy from the modulated carrier signal because the LO signal opens and closes transistors M5 and M6. Ex.-1003, ¶¶231-232. Neither M5 nor M6, however, transfers energy from the modulated carrier signal as an output even if M5 or M6 is ON. Dr. Galton's explanation of how Razavi's mixer works is incorrect.

361. As explained in Section VIII.C above, Razavi's mixer does not sample the RF input signal. The RF input signal does not—and cannot—physically pass through transistors M5 or M6. And because the RF input signal cannot physically pass through transistors M5 and M6, energy is never transferred as an output of M5 or M6 even if they are ON.

362. As Dr. Galton admits, M5 and M6 are NMOS transistors that do not operate as transconductors. Ex.-1034, 203:9-12; 251:13-15. Instead, as explained in Sections VIII.C above and as Razavi explicitly states, transistors M5 and M6 operate in saturation. A POSITA understands that in the configuration set forth in Razavi, current can only flow through M5 to M6 in one direction—downward from the drain

flows downward toward M7—it never passes through M5 or M6. As such, the RF input signal remains a continuous-time signal throughout the circuit. Nothing in Razavi’s mixer changes this fact.

365. Even assuming, as Dr. Galton asserts, that transistors M5 and M6 are switches that open and close, this would not change the fact that no current from the RF input signal passes through M5 or M6 from the source to the drain. Therefore, there is no energy being transferred as an output of M5 or M6 even if M5 or M6 are ON.

366. The fact that Razavi’s mixer does not sample and transfer energy from the modulated carrier signal is also evident to a POSITA based on how the mixer actually works.

367. A POSITA understands that current flows from a higher potential to a lower potential. Dr. Galton admits this. Ex.-2034, 152:19-22. In Figure 2 of Razavi (shown below), VDD is the highest potential in the circuit. Consequently, current flows downward from VDD, through resistors R1 and R2, transistors M5, M6, and M7, and ultimately to ground.

368. Even assuming transistors M5 and M6 turn ON and OFF (as Petitioner/Dr. Galton asserts), the only direction of current flow remains downward from VDD to ground. Dr. Galton admits this. *Id.*, 164:13-21.

369. Figure 2 of Razavi (annotated below) illustrates the actual current flow

in two scenarios: (1) when M5 is closed and M6 is open, and (2) when M5 is open and M6 is closed.

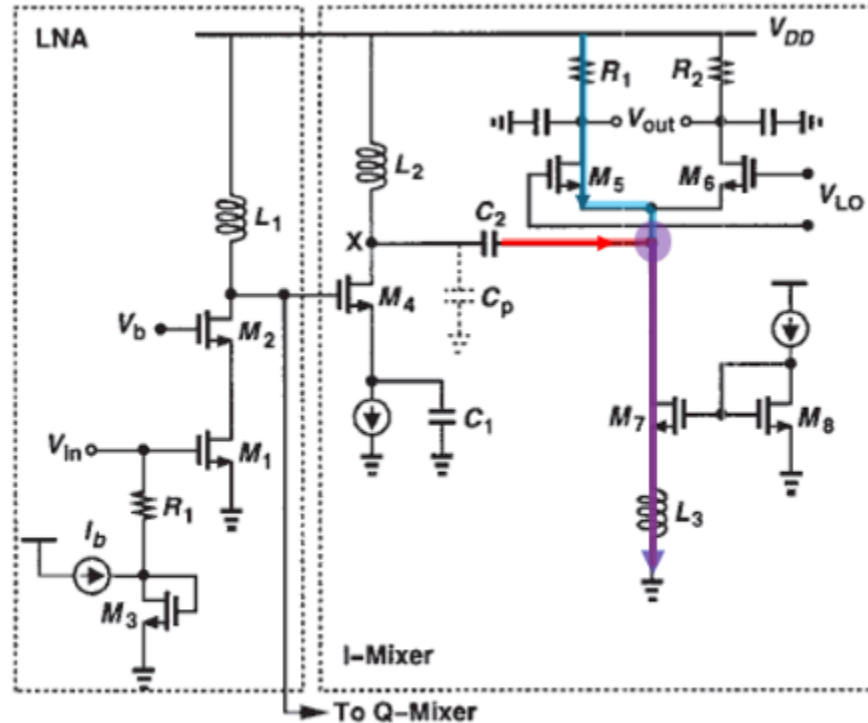


Fig. 2. LNA/mixer implementation.

370. In the first scenario, as shown in the figure above, transistor M5 is closed and transistor M6 is open. As shown above, current from VDD (blue arrow) flows downward through R1 and M5 to the common node (highlighted in purple). The RF input signal current (red arrow) flows from capacitor C2 to the same common node (purple). These currents combine and flow through M7 toward ground (purple arrow).

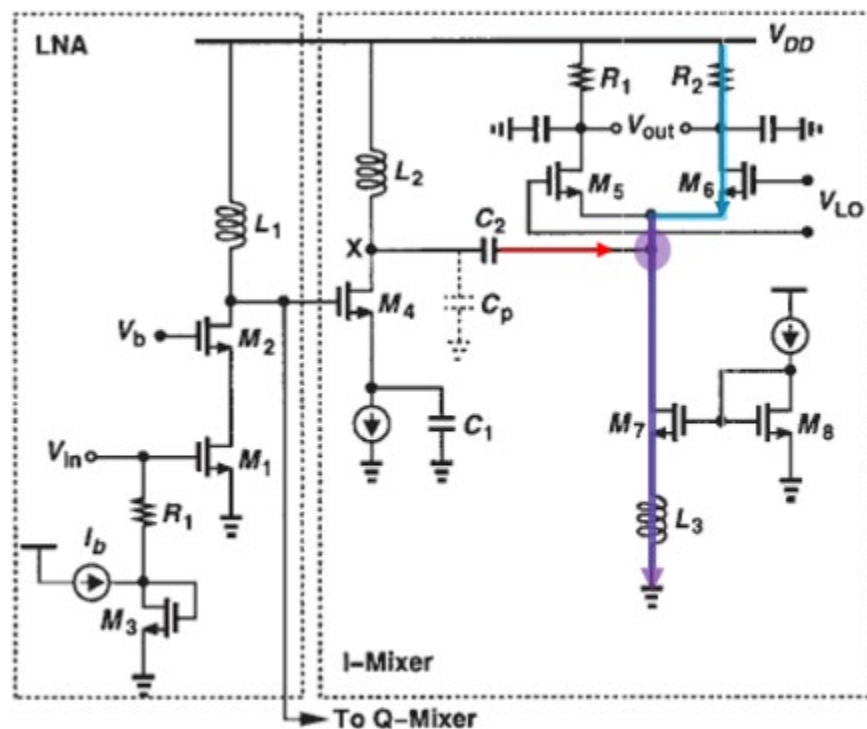


Fig. 2. LNA/mixer implementation.

371. In the second scenario, as shown in the figure above, transistor M5 is open and transistor M6 is closed. As shown above, current from VDD (blue arrow) flows downward through R2 and M6 to the common node (highlighted in purple). The RF input signal current (red arrow) flows from capacitor C2 to the same common node (purple). These currents combine and flow through M7 toward ground (purple arrow).

372. A POSITA would recognize, as illustrated in the annotated figures above, that M5 and M6 function as a current-steering circuit, directing VDD-supplied current downward through M7. This is not sampling the RF input signal.

373. Even if transistors M5 and M6 open and close as Dr. Galton suggests,

this action only affects the amount of current flowing downward from VDD. Ex.- 2034, 167:16-22. When the RF signal is stronger, more current is supplied through C2, reducing the amount of current that must come from VDD. Conversely, when the RF signal is weaker, the current from VDD increases to maintain the total current through M7. The alleged opening and closing of M5 or M6, does not affect the RF input signal in any way.

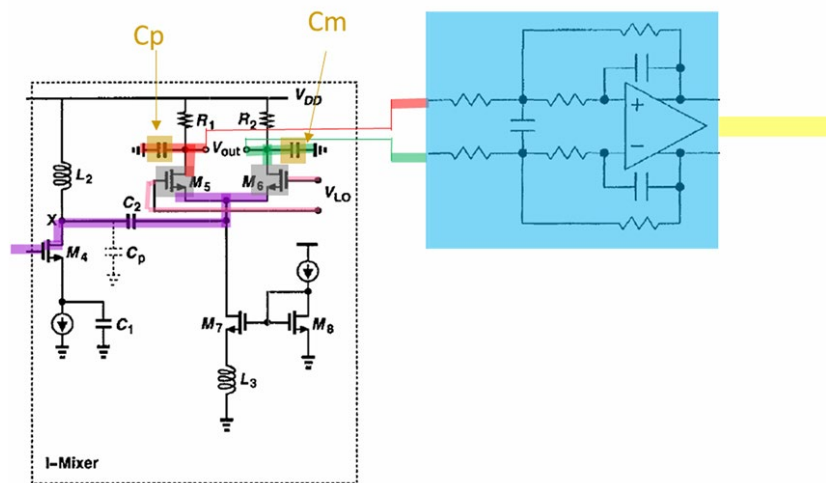
374. During his deposition, Dr. Galton attempted to distinguish between absolute or total current from VDD (which he agreed moves downwards) and “signal current” or “signal component” (which he claims moves both upwards and downwards). However, this distinction is incorrect. There is only one physical current in the circuit—the absolute current from VDD. The “signal component” Dr. Galton refers to is not an independent current that flows separately but merely describes how the RF input signal affects the current flow from VDD. The entire current, including any signal variations, flows downward. No portion of the RF input signal current moves upward. Thus, Dr. Galton’s reliance on a so-called “signal current” does not change that the current always flows downward. Thus, regardless of his interpretation, the RF input signal is not sampled and no energy is transferred from the RF input signal as an output of M5 or M6.

375. For the foregoing reasons, Razavi fails to disclose, teach, or suggest “the [] switch is on and a portion of energy that is distinguishable from noise is

transferred from the modulated carrier signal as an output of said [] switch during the sampling aperture....”

2. **Razavi does not disclose, teach, or suggest (i) an energy storage element that stores transferred energy from the modulated carrier signal, or (ii) portions of transferred energy from switches are integrated over time to accumulate portions of transferred energy.**

376. Claims 1 and 19 recites “energy storage element that stores the transferred energy from the modulated carrier signal” and “wherein the portions of transferred energy from each ... switch are integrated over time to accumulate said portions of transferred energy.”



377. As shown in Dr. Galton’s annotated figure above, Dr. Galton incorrectly alleges capacitor C_p/C_m store and accumulate/integrate portions of transferred energy from the modulated carrier signal (RF input signal). Ex.-1003, ¶¶233-235, 239, 243.

378. But, as explained above in Section IX.C.1 above, no current—and

therefore no energy—from the RF input signal passes through M5 or M6 towards the capacitors C_p/C_m . Thus, no energy from the RF input signal can ever make its way to the capacitors to be stored and accumulated/integrated.

3. Razavi does not disclose, teach, or suggest transferring energy from the modulated carrier signal to the storage element during a charging cycle when the switch is ON.

379. Claims 8 and 26 recite “said portion of energy that is distinguishable from noise is transferred to the respective storage element when the switch is on during the charging cycle.” In context, the “said” portion of energy being transferred refers to energy from the modulated carrier signal (RF input signal).

380. Razavi does not work this way. According to Petitioner and Dr. Galton, the capacitors C_p and C_m in Razavi function as the alleged storage elements. But in Razavi, capacitors C_p/C_m do not charge when M5 or M6, respectively, is ON. Rather, they would charge when M5 or M6, are OFF—the opposite of what the claims require.

381. Specifically, when M5 or M6 is ON, the respective capacitor is connected through to M7 and ultimately to ground, forming a discharge path. As discussed in Section XIII.C above, when the switch is ON, current only flows down through M5 or M6 and into M7. Conversely, when M5 or M6 is OFF, the capacitor is disconnected from the signal path to ground and only connected to VDD through R1 or R2. When either M5 or M6 is OFF, the respective capacitor is isolated from

ground (via M7) and instead is connected only to VDD, allowing it to only charge from VDD.

382. Critically, Razavi's capacitors do not receive any energy from the modulated carrier signal (RF input signal identified by Petitioner/Dr. Galton). The capacitors receive current/energy only from VDD. As discussed above in Section IX.C.1, no current— and therefore no energy—flows from the RF input signal upward through M5 or M6 toward C_p or C_m .

383. Accordingly, Razavi fails to disclose, teach, or suggest the transferring energy from the RF input signal to a storage element when the switch is ON during the charging cycle.

4. There is no motivation to combine Razavi and MacNally.

384. Petitioner contends that a POSITA would have found it obvious to incorporate Macnally's biquad two-pole filter in Razavi's receiver to process the down-converted signal. Pet., 65-; Ex.-1003, ¶¶227-229. I disagree.

385. First, Razavi does not simply identify a generic amplifier circuit or use a generic symbol for an op-amp. Instead, as shown in Figure 5, Razavi discloses a fully realized amplifier design (including the length and width of transistors) tailored to meet specific performance goals: to achieve “high gain,” improve linearity, and reduce noise. Ex.-1017, 113 (discussing adding PMOS current sources to provide about 75% of the drain current of M_1 and M_2 thereby allowing a large value for R_1

and R_2 ; discussing increasing the length of transistors M_3 and M_4 and using wide transistors). Petitioner inexplicably removes Razavi's carefully designed amplifier and replaces it with Macnally's biquad two-pole filter.

386. Second, Macnally's biquad two-pole filter acts as a low-pass filters—anti-alias filter. Ex.-1021, 7:17-19; Ex.-1003, ¶143; Ex.-2034, 56:5-57:16. An anti-aliasing filter removes aliased signals from the band of operation. Razavi, however, already discloses on-chip RC low-pass filters: the output of each mixer branch includes a resistor and capacitor (R_1 and C_p / R_2 and C_m) . Ex.-1017, 113 (“The output nodes of the mixer are loaded with on-chip capacitors to suppress high-frequency components.”)

387. Razavi makes no mention of the need for additional filtering or bandwidth narrowing beyond these RC filters at the mixer output. This is because Razavi's architecture is already designed to handle high-frequency content and suppress out-of-band signals. A POSITA would recognize that the existing RC filters found in Razavi already perform the anti-aliasing function—Razavi's RC filters serve the role of aliasing suppression. Thus, a POSITA would not be motivated to add another filtering stage such as Macnally's biquad two-pole filters at the output of the mixer.

388. Dr. Galton suggests that because Razavi states “channel-selection filtering is not included,” this suggests the desire for channel-select filtering and

need to turn to Macnally. Ex. 1003, ¶228. But Dr. Galton misrepresents what Razavi actually teaches. The full sentence Dr. Galton cites actually states: “The output nodes of the mixer are loaded with on-chip capacitors to suppress high-frequency components, but channel-selection filter is not included here.” Ex.-1017, 113. In context, Razavi is simply clarifying that the on-chip capacitors do not perform channel selection. This is not an admission that Razavi’s receiver lacks channel filtering altogether.

389. Indeed, Figures 4(b) and 4(c) of Razavi expressly show a channel-select filter block located *after* the amplifier (i.e., after the Figure 5 amplifier). This indicates that Razavi intentionally places the channel-select filter downstream of the amplifier—not within it. As discussed in Section XIII.4.a below, Razavi’s architecture reflects deliberate staging, in which amplification and filtering are handled in separate circuit blocks. A POSITA would recognize that inserting Macnally’s filter at the amplifier stage would contradict Razavi’s specific design intent.

390. Third, according to Petitioner, Macnally’s biquad two-pole filter offers advantages such as cancelling interference, minimizing harmonic distortion, and improving linearity. Pet. 28. But Razavi already addresses these very issues.. Just like Macnally, Razavi’s amplifier (Figure 5) uses differential inputs and differential outputs and operates on complementary signal components. Razavi (without

Macnally's biquad two-pole filters) already achieves the advantages that Dr. Galton identifies as advantages of Macnally's biquad two-pole filter.

391. Further, Razavi also addresses noise, improving linearity, and distortion. Ex.-1017 ("In order to improve the linearity..."), ("The problem with noise differential [] is overcome by allowing..."), ("suppressing low-frequency beat signals that are generated if two input interferers experience [distortion]..."). Thus, a POSITA would not be motivated to look for a solution to these issues. Accordingly, a POSITA would not think to look to Macnally's biquad two-pole filter.

392. Finally, Macnally's biquad two-pole filter includes additional op-amps, resistors, and capacitors that significantly increase the component count over Razavi's amplifier. Using Macnally's biquad two-pole filter would actually require many more components (not fewer components) than using Razavi's amplifier. In particular, Petitioner proposes a one-for-one substitution of Razavi's amplifier with Macnally's biquad filter, yet the latter requires more circuitry, not less. Thus, at the very least, Petitioner's proposal uses the same number of op-amps as already disclosed in Razavi – not less.

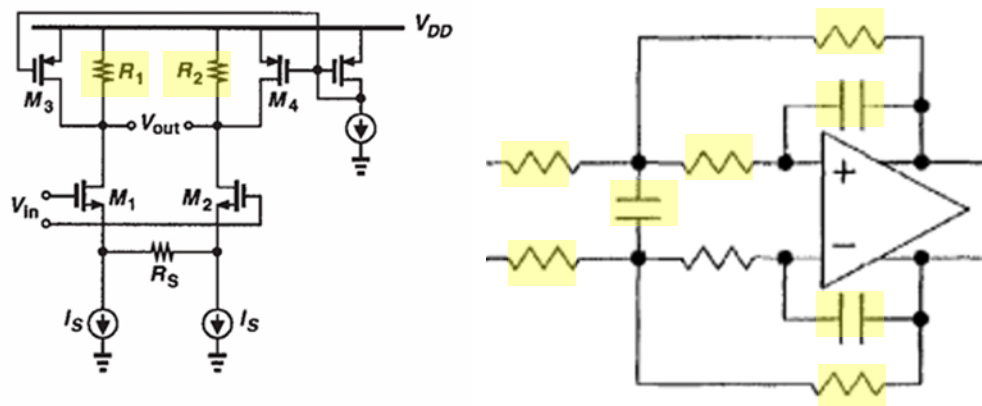


Fig. 5. Baseband amplifier.

393. The components highlighted above show the equivalent gain setting components. As shown above, Razavi's amplifier (above left which shows the configuration of the op-amp) has significantly fewer components than Macnally's biquad two-pole filter (above right, which has additional resistors and capacitors around the op-amp). Thus, Petitioner's substitution would increase die area, power consumption, and circuit complexity.

394. A POSITA seeking Razavi's stated objective of a "single-chip receiver"—and concerned with IC design factors like area, simplicity, and power—as Dr. Galton claims (*see* Ex. 1003 ¶¶228; *see also id.* at ¶¶144) would prefer Razavi's amplifier because it's already an integrated circuit and Razavi teaches it as the explicit design solution. There is no reason a POSITA would replace Razavi's amplifier with Macnally's biquad two-pole filter, especially when the claimed benefits (linearity, noise, filtering) are already addressed. Thus, a POSITA would not be motivated to use Macnally's biquad two-pole filter to reduce the number of

components or op-amps.

395. Thus, there is no reason why a POSITA would substitute Razavi's amplifier for Macnally's biquad two-pole filter. The proposed combination is not only unnecessary, but also contradicts the very design Razavi teaches.

a. Razavi teaches away from the proposed combination.

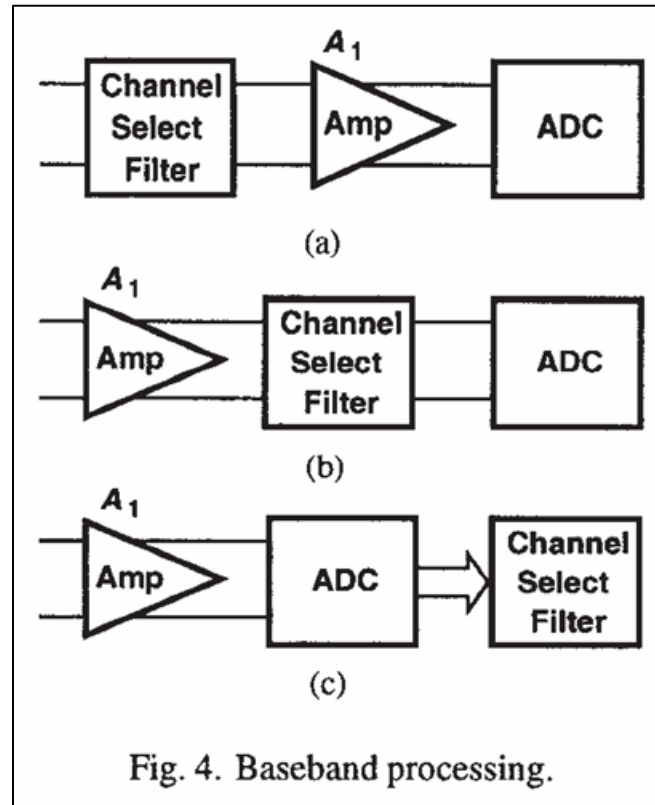
396. A POSITA would not have been motivated to incorporate Macnally's biquad two-pole filter in Razavi's receiver after Razavi's mixer, as Petitioner proposes. In fact, Razavi expressly teaches against the very design Petitioner relies on.

397. Razavi explicitly discourages (teaches away from) the use of channel select filtering—such as that performed by Macnally's biquad two-pole filter—after the mixer in its receiver architecture.

398. Dr. Galton states that “[a] POSITA would have recognized the benefits of applying the example circuit of Macnally to complement Razavi's receiver design and achieve both amplification and ‘channel-selection filtering’ at baseband. Ex.-1003, ¶228. Petitioner/Dr. Galton relies on this property to justify inserting Macnally's biquad two-pole filter after Razavi's mixer. But Razavi specifically cautions against this approach.

399. Razavi describes the design of a single-chip 900-MHz CMOS direct conversion receiver (DCR) fabricated in digital 0.6- μm technology. Ex.-1017, 113.

Razavi proposes modifications to general DCR architecture to create a different type of direct downconverter.



400. In particular, Figure 4 of Razavi (below) illustrates three permutations of a baseband processing for the circuit following the mixer. Each permutation includes a channel select filter, baseband amplifier A_1 and analog-to-digital converter (ADC).

401. Petitioner's proposed combination aligns with the permutation in Figure 4(a), which involves low-pass filtering using Macnally's biquad two-pole filter. Indeed, Petitioner acknowledges that a POSITA would understand "channel-select filtering" as low-pass filtering in the context of Razavi and "using Macnally's

fully differential amplifier circuit, a known low-pass filter, [is] consistent with one design option disclosed by Razavi.” Pet., 66-67.

402. But Razavi specifically teaches against the use of the permutation depicted in Figure 4(a). Razavi notes that “a low-pass filter suppresses out-of-channel interferers, allowing A1, to be a nonlinear, high-gain amplifier and the analog-to-digital converter (ADC) to have a moderate dynamic range (roughly 4 to 8 bits depending on the gain control in the RF domain and the type of modulation).” Ex.-1017, 113. Razavi criticizes (and teaches away from) this permutation because “the low-pass filter design entails severe noise-linearity-power tradeoffs.” *Id.* Indeed, Razavi specifies that “[t]he present design is intended for permutations in Figs. 4(b) and (c),” thereby excluding Figure 4(a) from consideration. *Id.*

403. Petitioner fails to address the conflict between Razavi’s teachings and the proposed combination, which undermines its obviousness argument.

b. Razavi and Macnally are not compatible.

404. A POSITA would not be motivated to replace Razavi’s amplifier with Macnally’s biquad two-pole filter, as alleged by Petitioner and Dr. Galton, because the two circuits are fundamentally incompatible.

405. As explained in Section XII.C above, Razavi’s amplifier (Figure 5) operates as a *high impedance* load. In Razavi’s architecture, the outputs of the mixer—Vout—are connected directly to the gates of NMOS transistors M1 and M2

in Figure 5. This configuration provides high input impedance, which is critical to ensuring accurate baseband voltage representation.

406. Petitioner and Dr. Galton, however, propose replacing Razavi’s high impedance amplifier with Macnally’s biquad two-pole filter. But according to Petitioner, Macnally’s filter presents a *low impedance* load— “typically in the kilo-ohm range.” See Pet. 35, 70, 72; Ex.-1003 ¶ 240. A POSITA would understand that substituting a low impedance load in place of a high impedance load would alter the operation of Razavi’s circuit. In particular, a low impedance load would draw current, compromising the baseband signal accuracy.

407. This is not a minor or superficial difference. High and low impedance loads produce materially different effects in analog circuits. In Razavi’s circuit, a high impedance amplifier is essential to preserving the voltage signal developed at the output of the mixer. Moreover, Razavi specifically states, “to achieve a high conversion gain...R1 and R2 must be maximized.” A low impedance load, like Macnally’s filter, would distort this signal. Replacing Razavi’s amplifier with a low impedance circuit would not simply modify the circuit—it would defeat its intended design goals.

408. The incompatibility between Razavi’s high impedance amplifier and Macnally’s low impedance biquad filter would therefore dissuade, not encourage, a POSITA from making Petitioner’s proposed substitution.

c. There is no reasonable expectation of success in combining Razavi and Macnally.

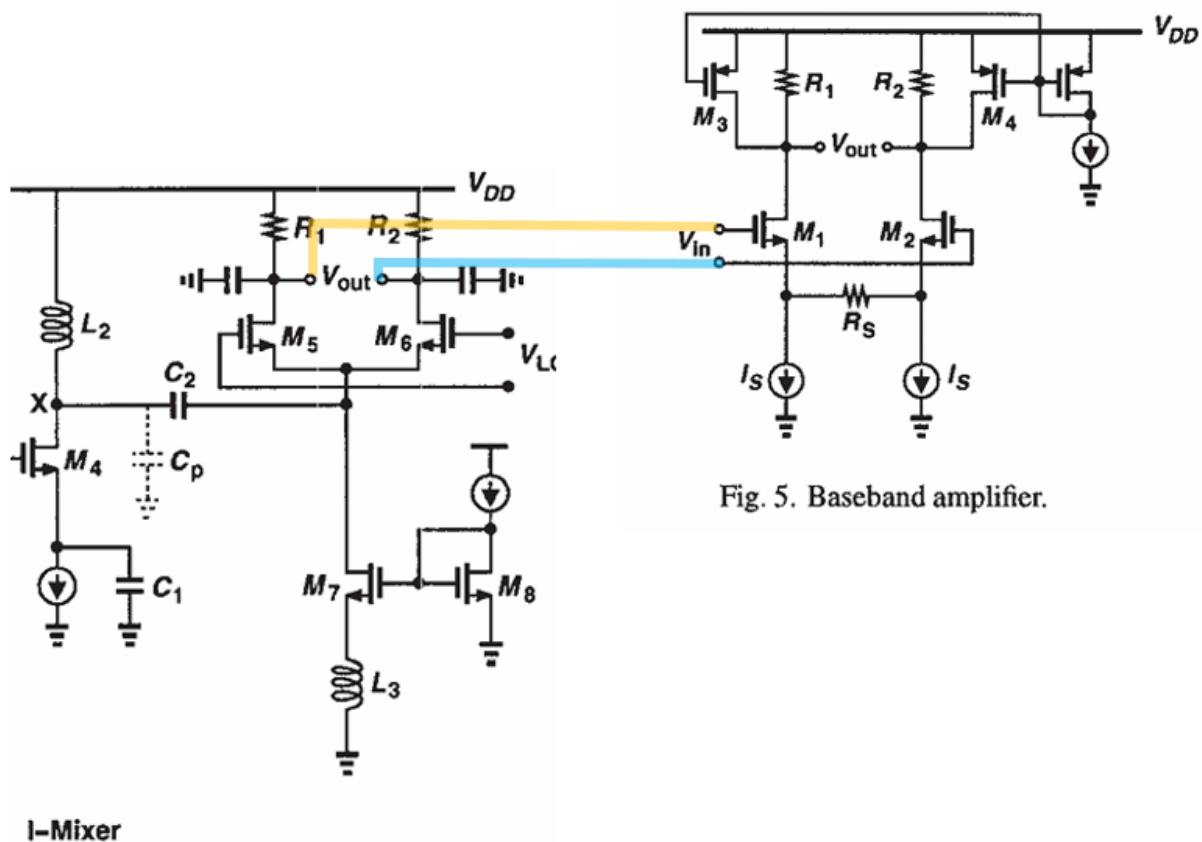
409. Petitioner/Dr. Galton asserts that replacing Razavi’s amplifier with Macnally’s biquad two-pole filter “would have had a reasonable expectation of success because it would have been a combination of prior art elements according to known methods to yield predictable results (using Macnally’s fully differential amplifier circuit... consistent with one design option disclosed by Razavi).” Pet., 66-67; Ex.-1003, ¶229. I disagree. Petitioner and Dr. Galton provide no basis for this.

410. Replacing Razavi’s amplifier with Macnally’s biquad two-pole filter requires fundamental restructuring of Razavi’s receiver architecture. The proposed substitution would not yield predictable results and, as such, cannot support a reasonable expectation of success.

411. First, Razavi itself demonstrates why there is no reasonable expectation of success. As discussed above, Razavi explicitly criticizes the design permutation shown in Figure 4(a)—which is structurally analogous to Petitioner’s proposed combination—because that architecture introduces “severe noise-linearity-power tradeoffs.” Ex.-1017, 113. A POSITA would not ignore Razavi’s express warning and adopt the very design Razavi cautions against.

412. Adding Macnally’s Rauch biquad two-pole filter into Razavi’s system would also require considerable experimentation to figure out how to design Razavi

413. Second, replacing Razavi's amplifier with Macnally's biquad two-pole filter would alter the fundamental operation of Razavi's circuit.



148

M2 in the Figure 5 amplifier configuration. This is a voltage-mode design that depends on a high impedance load. As discussed in Section VIII.C, Razavi's amplifier (Figure 5 above right) is a *high impedance load*. On the other hand, according to Petitioner, Macnally's biquad two-pole filter provides "*low impedance load* typically in the kilo ohm range." Pet., 35, 70, 72; Ex.-1003, ¶240. As explained in Sections III.B.5 and VI.B, high and low impedance loads have very different effects on a circuit. Razavi specifically states, "to achieve a high conversion gain...R1 and R2 must be maximized." Moreover, a low impedance load in Razavi would lead to an inaccurate measurement of the voltage and Razavi would not be able to accurately reproduce the baseband signal. Specifically, the low impedance would draw current away from the mixer output, disrupting the voltage levels intended to represent the baseband signal.

415. A POSITA would therefore not be motivated to replace Razavi's high impedance load amplifier with the alleged low impedance biquad two-pole filter of Macnally. Such a modification would ignore all of the disclosure in Razavi, abandon all of the teachings and suggestions of Razavi, and fundamentally change the Razavi's circuit.

E. None of the prior art references teach, disclose, or suggest an energy transfer system.

416. Claim 1 recites a first and second "energy storage element." As discussed in Section VII.C above, a POSITA would understand "energy storage

element” to mean “an element of an energy transfer system that stores non-negligible amounts of energy from an input EM signal.” Neither Tayloe nor Razavi disclose, teach, or suggest an energy transfer system.

417. As discussed in Section VIII.A, Tayloe uses a high impedance load (amplifier 50, 52) and does not transfer energy to a load. Tayloe is a voltage sampling system. As discussed in Sections VIII.C, Razavi does not perform sampling, does not transfer energy from an input electromagnetic signal, does not accumulate or discharge transferred energy from the input signal to a load. Razavi uses a non-sampling mixer.

418. Moreover, by using an active mixer with high gain, Razavi is not transferring the RF input signal or its energy to the output of the mixer. Rather, Razavi is copying the input modulated signal and adding gain to create a copy of that modulated signal at the output of the mixer. Razavi is using energy from a power supply (represented by VDD) to accomplish this. In other words, unlike an energy sampling (transfer) system, the output signal in Razavi comes from a power supply, not from sampled energy from the RF input signal itself.

XIV. SUPPLEMENTATION

419. I reserve the right to supplement the opinions set forth in this declaration to (a) respond to any arguments that Petitioner or its expert raise and/or (b) consider new information that becomes available to me from Petitioner, its

expert or otherwise.

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge.

Dated: April 4, 2025

David Ricketts

Dr. David Ricketts

APPENDIX A

David S. Ricketts

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1. EDUCATION

Harvard University

Ph.D., 2006.

Thesis: Electrical Soliton Modelocking.

Advisor: Donhee Ham.

Worcester Polytechnic Institute

M.S.E.E., 1997.

Thesis: AD6509, A 622 MHz Frequency Synthesizer.

Advisor: John A. McNeill

Worcester Polytechnic Institute

B.S.E.E., 1995, with *High Distinction*.

Thesis: Development methodology and control systems in a NASA GASCAN project.

2. REASEARCH INTERESTS

- Mm-wave and Microwave circuits and systems
- RFID
- Wireless Power Transfer
- Analog and RF circuits

3. AWARDS & FELLOWSHIPS

- Best Paper Award, IEEE Asia-Pacific Microwave Conference 2016.
- Certificate of Teaching Excellence, Derek Bok Center, Harvard University, 2013
- NSF CAREER Award, 2011
Spin-torque Oscillator Arrays. 13 % funding rate in 2011.
- Wimmer Teaching Fellow, Carnegie Mellon University, 2009
One of five fellows selected per year on a university wide bases. Award is for development of educational content for new courses.
- George Tallman Ladd Research Award 2009
Awarded to the two junior faculty in the College of Engineering at CMU for outstanding research.
- National Academy of Engineers Frontiers of Engineering Education Recipient, 2009.
Visualization of E&M for undergraduate course.
- DARPA Young Faculty Award, 2008
Spin-torque oscillators for agile RF systems.
- McGraw-Hill Yearbook of Science and Technology, 2008
Research on solitons selected as top research highlight for 2008.

David S. Ricketts

4. PROFESSIONAL EXPERIENCE

Full Professor of Electrical and Computer Engineering, North Carolina State University, 2012-

My research centers on the application of physical phenomena to electrical devices, circuits and systems, covering a range of areas in electrical engineering. I focus on ultra-fast electronics and microwave systems.

Visiting Researcher (Research Scientist), Massachusetts Institute of Technology, 2012-2013
(On leave from NCSU)

I am working with a team of 13 members on the DARPA ELASTx program. I am focusing on developing state-of-the-art power amplifier (PA) and power combining systems for mm-wave applications (Q-W band).

Innovation Fellow and Visiting Associate Professor (2012), School of Engineering and Applied Science, Technology and Entrepreneurship Center, Harvard University, 2010-

Research with graduate students at the School of Engineering and Applied Science and the Harvard Business School on Innovation in Science and Creativity, specifically the role of the individual in the creation of new knowledge. This work supports both scholarly research in this area as well as the development of educational material for courses taught at Carnegie Mellon and Harvard.

Assistant Professor of Electrical and Computer Engineering, Assistant Professor (Courtesy) of Materials Science and Engineering, Carnegie Mellon University 2006-2012

I was the PI of a successful 15 member DARPA team on Tip-directed Field-emission Assisted Nanofabrication, where we developed arrays of MEMS cantilevers to write nanoscale features (< 10 nm) on Si and Ti surfaces with application in quantum electronic devices. In addition, I received my NSF CAREER award for my work on a nanoscale magnetic device, the spin-torque oscillator, where I am pursuing fundamental research on its ultimate performance and application into wider electronic systems. I also investigated many other interdisciplinary programs in circuits, systems and sensing, including a large DARPA program on high-speed circuits & energy with MIT. I received the NSF CAREER award, the DARPA Young Faculty Award and the George Tallman Ladd Research Award. I have also developed/redesigned several new courses at CMU in device physics, circuit design and innovation in science and have developed a new outreach program with Disney Animal Kingdom on animal conservation. I am a 2008 Wimmer Teaching Fellow and an invited participant in the 2009 NAE, Frontiers of Engineering Education Symposium.

Research Assistant (Ph. D), Ham Group, Harvard University, 2004 – 2006.

Doctoral research in Ultrafast electronics, nonlinear wave and soliton based electronics and nanowire based circuits. Developed the first electrical soliton modelocked oscillator and also the first chip-scale modelocked oscillator in any field. Through collaboration with the Lieber group,

David S. Ricketts

helped to develop the fastest integrated nanowire circuit to date. Other projects included phase noise analysis and stochastic resonance.

Staff Research Assistant, Harvard University, 2003 – 2004.

Supported research efforts in high-speed electronics.

Advanced System Engineering Manager, ON Semiconductor, 2002-2003.

Directed a highly skilled team of system engineers to develop next generation technology for multi-phase power management ICs for Intel and AMD microprocessors. Initiated 10 new products in first 12 months and generated eight new patent/IP disclosures in first 6 months. Responsible for the development of new IP for the product line and the investigation of emerging technologies for acquisition.

Manager of New Product Development, ON Semiconductor, 2000-2002.

Responsible for 6 product development teams consisting of technical members across design, test, application engineering and layout. Oversaw the development of over 20 power management ICs in bipolar, CMOS and BiCMOS technologies. Responsible for ensuring technical excellence in design and system engineering as well as mentoring engineering staff.

Principal Consultant, Renaissance Design, Inc. 1999-2001.

Provided design and system engineering services for the power management semiconductor industry. Led the system architecture and transistor level design of a custom 2-stage dc-ac inverter. Used Verilog to develop an all-digital controller which enhanced controller functionality and robustness. Designed system supervisory circuitry and peripherals, including a 5V LDO, ac line sense, current sense and protection, etc.

IC Technology Unit Manager/Staff IC Designer, APC, 1995-1999.

Responsible for the development of custom power management ICs for uninterruptible power supplies (UPS). Developed a custom controller for push-pull dc-ac inverters, an 8-bit A/D supervisory IC for sine wave inverters, and a next generation sine-wave inverter controller. Designs utilized bipolar, CMOS and BiCMOS technologies.

David S. Ricketts

5. Consulting

Nuvotronics, Durham, NC 2015- 2019

RF Circuits & Systems

bMuse, New York, New York, 2015-16

Magnetoquasistatic Positioning

General Motors, Herzlia, Israel 2012-2015

Wireless Power.

Cadence Corporation, Porto Alegre, Brazil, August 2008-July 2009

Co-taught RF design course as part of technology infrastructure initiative by Brazilian government.

ALTRAN Corporation, Paris, France, May 2006, May 2007

Lecturer for “Innovation in Science and Engineering”, course offered to consortium of top engineering schools in Paris vicinity (Ecole Polytechnique, SUPELEC, etc.).

Sparktronics, Inc., Torrence, CA, 2008

System design and modeling for Soliton/NLTL based EMP system development.

SigmaTel Corp, Burlington MA, 2005

Consulting on the development of high power audio driver IC.

Apogee Technologies, Norwood MA, 2004

Consulting on IC controller for DC-DC power conversion.

David S. Ricketts

6. Teaching and Education

U- undergraduate, G – graduate

North Carolina State University (2013-)

ECE714	Advanced Analog IC Design
ECE424/524	Radio System Design
ECE734	Power Management IC

Harvard University (F2012, 2006+)

Taught (F12) and Co-Taught (2006+) course on innovation for scientists

ES139/239 Innovation in Science and Engineering (U/G)

Massachusetts Institute of Technology (S2013)

6.775 Design of Analog MOS Circuits (Co-Taught with H.S. Lee)

Carnegie Mellon University (2006-)

18-623	Analog Circuit Design (G)
18-310	Fund Devices Physics (U)
18-610	Modern CMOS Devices (G)
18-513	RF Circuits and Antennas for Wireless Systems (U - capstone)
18-605	Innovation in Science and Engineering: Theory (G - interdisciplinary)
18-606	Innovation in Science and Engineering: Application (G - interdisciplinary)

Educational Contributions

Applied Physics

- Curriculum development of AP undergraduate and graduate courses with AP faculty.
- Introduced new graduate device physics course, 18-610, Modern Device Physics
- Redeveloped 18-310, Fundamentals of Semiconductor Devices, including development of 5 virtual labs for web deployment
- Development of discovery based learning tools in conjunction with J. Bain and Eberly center via Wimmer Fellow, “IEMFE: Intuitive Electromagnetic Fields Education”

E&M and Circuits

- Curriculum development for undergraduate courses with circuits faculty, including proposal for reorganizing 300 level circuits courses into 18-320 (introductory analog/digital), 18-422 (advanced digital) and 18-423 (advanced analog).

David S. Ricketts

- Collaborated with D. Stancil to re-design 18-513 into an interdisciplinary, wireless course: Wireless System Design, to include RF circuit content, enabling an analog circuit's capstone while broadening the AP antennas capstone.
- ECE 592 Analog-to-digital Converters: (NCSU) Fall 2013
Developing new course for ADCs as part of ECS circuit's curriculum. Developed 4 Verilog A labs for course. Developed ADC design project for course
- ECE 492(592) Radio Systems Design: (NCSU) Spring 2014
Developing new experiential undergraduate course in radio system design. Included final 2.4 GHz QAM design project. Developed 8 experimental labs
- ECE 792 Advanced Analog IC Design (ADCs): (NCSU) Fall 2015
Developing new course for advanced analog IC design. Adds synergistic course to ECE511 and complements ECE712

Interdisciplinary

- Developed a new interdisciplinary/interdepartmental course between ECE and EPP: 18-605/6 & 19-685/6: Innovation in Science and Technology, which explores the role of scientists and engineers in developing technological innovations. These courses focus on the development of technical solutions to a variety of scientific/engineering problems.

Outreach

- Collaboration with Disney Animal Kingdom
 - Developed nest positioning systems for conservation monitoring of sea turtles on Florida beaches
 - Developed dolphin identification and location instrumentation for monitoring dolphin activity
- Participated in Carnegie Science Museum Engineers Week symposium, demonstrating engineering and science concepts to children ages 3-18.
- International outreach:
 - Taught courses in innovation and discovery in science in France (2005-2008)
 - Taught RF electronics in Brazil as part of a governmental program to develop engineering talent and infrastructure in Brazil.
-

Analog to Digital Converter Executive Education, Analog Devices, 2023.

- ADC course based on my university course taught to Analog Devices engineering students..

NSCAD - Instituto de Informática – UFRGS/ Cadence Design Systems, Porto Alegre, Brazil (July-August 2008)

David S. Ricketts

- BA03 RF IC Design – Full time intense course (40 hrs/week) as part of Brazilian government initiative to increase high-tech infrastructure in Brazil.

Lecturer (2002-2006)

- Teaching Fellow, ES139 Innovation in Science and Engineering , (G, U), Harvard University, 2004 & 2005
- Guest Lecturer, ES 272 RF and High Speed Circuits, (G), Harvard University, 2005
- Invited Lecturer, Innovation in Science & Technology (G, U), Paris University Consortium, Paris, France, 2005
- Guest Lecturer, EE2799 Electrical and Computer Engineering Design, (G) Worcester Polytechnic Institute (WPI), 2002
- Guest Lecturer, ELE535 BiCMOS Integrated Circuit Design, (G), University of Rhode Island, 2002.

David S. Ricketts

7. Research Supervision

GRADUATE STUDENT SUPERVISION NCSU

1. Prya Darshni (PhD Canddiate, 2026)
2. Hongtao Zhong (PhD Candidate, 2025)
3. Shian Su (PhD Candidate, 2025)
4. Joe Zhou (PhD Candiate 2023)
5. Karan Maru F20-S21 RA
6. Sriraj Kandala, Summer 2020 RA
7. Bhaumik Jain Summer-Fall 2020 RA
8. Matt Dwyer Summer-Fall 2020. RA
9. William Harris (PhD candidate, 2019)
10. Junyu Shen (PhD candidate, 2019)
11. Hangjin Liu (PhD Candidate, 2021)
12. You Zhou (PhD Candidate, 2021)
13. Deeksha Lal (PhD 2018)
14. Samyak Parakh (MS, 2018)
15. Rafael de Silva (PhD candidate, 2020)
16. Michael Aiken (MS 2017, PhD Candidate)
17. Viswanath Ramesh (Initial PhD work 2015-2016)

GRADUATE STUDENT SUPERVISION CMU

1. Emre Karagozler, PhD 2013
2. Wei Tai, PhD 2012
3. Darmin Arumugam, PhD 2012
4. Weihua Hu, PhD 2012
5. Chongzhe Li, MS 2012
6. Zacherias George, MS 2012
7. En Shi, MS 2010
8. Qianyu Liu, MS 2009

GRADUATE COMMITTEES

1. Yongduk Oh (PhD Candidate 2023)
2. Jaewoo Kim (MS 2021)
3. Sarah Colebaugh
4. Weifu Li (PhD Candidate 2019)
5. Kirti Bhanushali (PhD candidate 2018)
6. Weihua Wang (PhD candidate 2018)
7. Yunjia Zhu (MS candidate Textiles 2017)
8. Junan Zhu (PhD candidate 2016)
9. Yunjia Zhu (MS candidate 2016)
10. Anirban Sarkar, (PhD candidate 2016)
11. Sandeep Hari, (PhD candidate 2018)
12. Kevin Green (PhD candidate 2016)

David S. Ricketts

13. Ying Yi Tang, PhD 2015 (CMU)
14. Mohammad Noman, PhD 2013 (CMU)
15. Erkan Alpman, PhD 2007 (CMU)

UNDERGRADUATE STUDENT SUPERVISION

1. Maya Clinton F22-S23 (MechE)
2. Cole Contos F22
3. Jason Abell F22-S23
4. Landon Calton F22
5. Frank di Lustro S21
6. Alan Davila Summer 2020
7. Casey Crouse Spring 2020-Summer 2020
8. Jacob Abramow Spring 2020
9. Jeremy Peterson Spring 2020-Summer 2020
10. Laura Walker Spring 2020
11. Ryan Hardy REU Spring 2020-Spring 2021
12. Matt Dwyer Connor Walker REU Fall/Spring 2019
13. Matt Dwyer REU 2019 Summer.
14. Casey Crouse REU 2019 Summer.
15. Zack Miller, Felix Chamielec, Danny Krafft, Grason Humphrey, Sufian Ahmad (NCSU UG Senior Design: Qi Charger, 2019)
16. Matt Dwyer, S19 (NCSU, Undergrad Research)
17. Shakti Reddy, F18/S19 (NCSU, Undergrad Research)
18. Shane Reagan, Zach Cline, Daniel Robson, Andrew Cragg, (NCSU UG Senior Design: Pringles Radar 2017/18)
19. Christian Burke, F17/S18 (NCSU, Undergrad Research)
20. Bill Zhou (BSEE) Fall 2016 (NCSU, Undergrad Research)
21. Akshay Iyer, Stephen Kerr, William Stepp, Kirk Weston, (NCSU UG Senior Design: Magnetic Sports Tracking, 2015/16)
22. Shaunak Turaga (BSEE), Fall/Spring 2014/15 (NCSU, Undergrad Research)
23. Mathew Briley (BSEE), Fall/Spring 2014/15 (NCSU, Undergrad Research)
24. Adeola Salu (BS), Spring 2013 (Harvard, Independent Study)
25. Zackary Hamad (BS), Spring 2011 (Harvard, independent Study)
26. Andrew Hillenius (BS), Summer/Fall, 2011 (CMU, Independent Study)
27. Chongzhe Li (BS), Spring 2010 (CMU, Independent Study)
28. Christopher Heidelberger (BS), Summer 2009, (CMU) NSF REU
29. Yue Lu (BS), Summer 2007 (CMU Independent Study)

SPECIAL STUDENT ADVISING

1. Karan Maru, S20 (NCSU MSEE Research)
2. Bhaumik Jain, F19 (NCSU, MSEE Research)
3. Sriraj Kandala, F19 (NCSU, MSEE Research)

David S. Ricketts

4. Sandesh Shanmukha, S19 (NCSU, MSEE Research)
5. Shubhankar Patwardham F17/S18/F18 (NCSU, Ind. Study)
6. Amrutha Anantha S18 (NCSU, Ind. Study)
7. David Philpott S2017 (NCSU, Ind. Study)
8. Shenoy Akshat S2017 (NCSU, Ind. Study)
9. Sayan Das Fall 2016 (NCSU, Ind. Study)
10. Rounak Lokare Spring 2016 (NCSU, Ind. Study)
11. Swaroop Mohapatra Spring 2016 (NCSU, Ind. Study)
12. Ganapati Pai Spring 2016 (NCSU, Ind. Study)
13. Mahmoud Metwally 2015 (NCSU, MS research)
14. Ashwin Thyagarajan Spring 2015 (NCSU Ind. Study)
15. Reza Chavoshisani 2015 (PhD – 1 year visiting scholar)
16. Abhishek Malhotra (MS), Spring/Summer, 2013 (NCSU, Independent Study)
17. Syed Saad (MS), Summer 2011 (CMU, Independent Study)
18. Brian Lee (MS), Summer 2011 (CMU, Independent Study)
19. Ashwath Krishnan (MS), Summer 2010 (CMU, Independent Study)
20. Akshat Gupta (MS), Fall 2009 (CMU, Independent Study)
21. Heer Ghandi (MS), Fall 2007 (CMU, Independent Study)

Publications

1.1 Books

Radio System Design, **D. S. Ricketts**, Ingram Spark, 2015.

Electrical Solitons: Theory, Design and Applications, **D. S. Ricketts** and D. Ham, CRC Press, 2010.

The Designers Guide to Jitter in Ring Oscillators, J. A. McNeill and **D. S. Ricketts**, Springer Verlag, 2009.

1.2 Books Chapters/Sections

D. S. Ricketts, Xiaofeng Li, and Donhee Ham, "Soliton Electronics," in *Circuits for Emerging Technologies - CMOS and beyond*, CRC Press 2008.

X. Li, **D. S. Ricketts**, and D. Ham, "Solitons in electrical networks," *McGraw-Hill 2008 Yearbook of Science and Technology*, McGraw-Hill, 2008.

1.3 Journal Articles (51 papers)

1. W. C. Harris and D. S. Ricketts, "Maximum Gain Enhancement n Wireless Power Transfer using Anisotropic Metamaterials," Scientific Reports, 2023.
2. J. Shen and D. S. Ricketts, "Compact W-Band "Swan Neck" Turnstile Junction Orthomode Transducer Implemented by 3-D Printing," in IEEE Transactions on Microwave Theory and Techniques, vol. 68, no. 8, pp. 3408-3417, Aug. 2020
3. **M. Dwyer** and D. S. Ricketts, "The North Carolina state university rabbit radar: Build a frequency-modulated continuous-wave radar in a day [application notes]," IEEE Microwave Magazine, vol. 21, no. 5, pp. 136–145, 2020..[Invited]
4. D. S. Ricketts, "A modern 16-qam digital radio you can design and build at home [application notes]," IEEE Microwave Magazine, vol. 21, no. 7, pp. 10–22, 2020.

David S. Ricketts

5. **W. C. Harris**, D. D. Stancil, and David S. Ricketts, "Improved wireless power transfer efficiency with non-perfect lenses," *Applied Physics Letters* 114:14, April 2019.
6. D. S. Ricketts, E. Shi, X. Li, N. Sun, O. O. Yildirim and D. Ham, "Electrical Solitons for Microwave Systems: Harmonizing Nonlinearity and Dispersion with Nonlinear Transmission Line," in *IEEE Microwave Magazine*, vol. 20, no. 4, pp. 123-134, April 2019 [**Invited**].
7. **J. Shen** and D. S. Ricketts, "Additive Manufacturing of Complex Millimeter-Wave Waveguides Structures Using Digital Light Processing," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 67, no. 3, pp. 883-895, March 2019.
8. D. S. Ricketts, **J. Shen**, J. Dunn, "Expanding the Antenna Frontier With Antenna Synthesis and 3D Printing", (Cover article), *Microwave Engineering Europe*, Sept. 2018.
9. **D. Lal**, A. M. A. Ali and D. S. Ricketts, "Analysis and Comparison of High-Resolution GS/s Samplers in Advanced BiCMOS and CMOS," in *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 65, no. 5, pp. 532-536, May 2018.
10. J. Besnoff, M. Abbasi and D. S. Ricketts, "Ultrahigh-Data-Rate Communication and Efficient Wireless Power Transfer at 13.56 MHz," in *IEEE Antennas and Wireless Propagation Letters*, vol. 16, pp. 2634-2637, 2017.
11. M. Abbasi, B. Wang, S. Tamaru, H. Kubota, A. Fukushima and D. S. Ricketts, "Accurate De-Embedding and Measurement of Spin-Torque Oscillators," in *IEEE Transactions on Magnetics*, vol. 53, no. 11, pp. 1-4, Nov. 2017.
12. **V. Pasku** et al., "Magnetic Field-Based Positioning Systems," in *IEEE Communications Surveys & Tutorials*, vol. 19, no. 3, pp. 2003-2017, thirdquarter 2017.
13. W. Tai, M. Abbasi and D. S. Ricketts, "Analysis and design of high-power and efficient, millimeter-wave power amplifier systems using zero degree combiners," *IET J. of Electronics*, pp. 1-11, Jul. 2017.
14. M. Chabalko, J. Besnoff, M. Laifenfeld and D. S. Ricketts, "Resonantly Coupled Wireless Power Transfer for Non-Stationary Loads With Application in Automotive Environments," in *IEEE Transactions on Industrial Electronics*, vol. 64, no. 1, pp. 91-103, Jan. 2017.
15. Abbasi M, Ricketts DS. A high-power, broadband 245-285 GHz balanced frequency doubler in 45 nm SOI CMOS *Microwave and Optical Technology Letters*. 58: 423-426, 2016.
16. M. E. Karagozler, S. C. Goldstein and D. S. Ricketts, "Scalable self-assembly process for the fabrication of sub-millimetre three-dimensional cylindrical tubes," in *IET Micro & Nano Letters*, vol. 11, no. 1, pp. 4-8, 1 2016.
17. M. Abbasi, D. S. Ricketts, "A 275 GHz-285 GHz Balanced Frequency Quadrupler in 45nm SOI CMOS," *Electronic Letters*, vol. 51, no. 18, pp. 1424-1426, Sept 2015.
18. J. Besnoff, M. Abbasi and D. S. Ricketts, "High Data-Rate Communication in Near-Field RFID and Wireless Power Using Higher Order Modulation," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 64, no. 2, pp. 401-413, Feb. 2016.
19. J. Besnoff, M. Chabalko and D. S. Ricketts, "A Frequency-Selective Zero-Permeability Metamaterial Shield for Reduction of Near-Field Electromagnetic Energy," in *IEEE Antennas and Wireless Propagation Letters*, vol. 15, pp. 654-657, 2016.
20. M. J. Chabalko, J. Besnoff and D. S. Ricketts, "Magnetic Field Enhancement in Wireless Power With Metamaterials and Magnetic Resonant Couplers," in *IEEE Antennas and Wireless Propagation Letters*, vol. 15, pp. 452-455, 2016.
21. M. Chabalko and D. S. Ricketts, "Experimental characterization of Fabry-Perot resonances of magnetostatic volume waves in near-field metamaterials", *Applied Physics Letters*, 106, 062401 (2015).
22. **Ozcan, O.; Weihua Hu**; Sitti, M.; Bain, J.; Ricketts, D.S., "Investigation of tip current and normal force measured simultaneously during local oxidation of titanium using dual-mode scanning probe microscopy," *Micro & Nano Letters*, IET , vol.9, no.5, pp.332,336, May 2014
23. Ricketts, D.S.; Chabalko, M.; **Hillenius, A.**, "Tri-Loop Impedance and Frequency Matching With High- Q Resonators in Wireless Power Transfer," *Antennas and Wireless Propagation Letters*, IEEE , vol.13, no., pp.341,344, Jan. 2014.
24. **D. Arumugam**, J. Griffin, D. Stancil and D. S. Ricketts, "Three-Dimensional Position and Orientation Measurements using Magnetoquasistatic Fields and Complex Image Theory," *Antennas and Propagation Magazine*, IEEE, vol.56, no.1, pp.160,173, Feb. 2014
25. Williams, D.F.; Corson, P.; Sharma, J.; Krishnaswamy, H.; **Tai, W.**; George, Z.; Ricketts, D.S.; Watson, P.M.; Dacquay, E.; Voinigescu, S.P., "Calibrations for Millimeter-Wave Silicon Transistor Characterization," *Microwave Theory and Techniques*, IEEE Transactions on , vol.62, no.3, pp.658,668, Mar. 2014.
26. **Tai, W.**; Ricketts, D.S., "A compact, 36 to 72 GHz 15.8 dBm power amplifier with 66.7% fractional bandwidth in 45 nm SOI CMOS," *Microw. And Opt. Tech Lett.* ,vol. 56, pp.1098-2760, Nov. 2013.
27. J. Xu and D. S. Ricketts, "An Efficient, Watt-Level Microwave Rectifier Using an Impedance Compression Network (ICN) With Applications in Outphasing Energy Recovery Systems," *Microwave and Wireless Components Letters*, IEEE , vol.23, no.10, pp.542,544, Oct. 2013.

David S. Ricketts

28. Arumugam, D.D.; Ricketts, D.S., "Passive orientation measurement using magnetoquasistatic fields and coupled magnetic resonances," *Electronics Letters* , vol.49, no.16, pp.999,1001, Aug. 2013.
29. Williams, D.F.; Corson, P.; Sharma, J.; Krishnaswamy, H.; **Wei Tai**; George, Z.; Ricketts, D.; Watson, P.; Dacquay, E.; Voinigescu, S.P., "Calibration-Kit Design for Millimeter-Wave Silicon Integrated Circuits," *Microwave Theory and Techniques, IEEE Transactions on* , vol.61, no.7, pp.2685,2694, July 2013.
30. **Tai, W.**; Ricketts, D.S., "74 GHz, 17.2 dBm power amplifier in 45 nm SOI CMOS," *Electronics Letters* ,vol.49,no.12,pp.758,759, June 2013.
31. S. Tamaru and D. S. Ricketts, "Measurement of ultra-low power oscillators using adaptive drift cancellation with applications to nano-magnetic spin torque oscillators," *Rev. of Scien. Instr.*, vol. 84, p. 054704-7, May 2013.
32. Arumugam, D.D.; Ricketts, D.S., "Passive Magnetoquasistatic Position Measurement Using Coupled Magnetic Resonances," *Antennas and Wireless Propagation Letters, IEEE* , vol.12, no., pp.539,542, Apr. 2013
33. Arumugam, D.D.; Griffin, J.D.; Stancil, D.D.; Ricketts, D.S., "Magneto-Quasistatic Tracking of an American Football: A Goal-Line Measurement," *Antennas and Propagation Magazine, IEEE* , vol.55, no.1, pp.138,146, Feb. 2013.
34. D. S. Ricketts, M. Chabalko and **A. Hillenius**, "Experimental demonstration of the equivalence of inductive and strongly coupled magnetic resonance wireless power transfer," *Applied Physics Letters*, vol. 102, no. 5, Feb. 2013.
35. C. Li and D. S. Ricketts, "Loss minimization in $\lambda/4$ impedance transformers using multiple $\lambda/4$ segments," *Electronic Letters*, vol.49, no.4, pp.274,276, Feb. 14 2013
36. **W. Hu**, J. Bain and D. S. Ricketts, "An AFM/STM multi-mode nanofabrication approach allowing in situ surface modification and characterization," *Micro and Nano Letters*, Vol. 8, p. 43-46, Jan 2013.
37. **Arumugam**, J. Griffin, D. Stancil and D. S. Ricketts, "Error Reduction in Magnetoquasistatic Positioning Using Orthogonal Emitter Measurements," *Antennas and Wireless Propagation Letters, IEEE*, vol.11, no., pp.1462,1465, 2012
38. R. Birt, K. An, M. Tsoi, S. Tamaru, D. Ricketts, K. L. Wong, P. K. Amiri, K. L. Wang, and X. Li, "Deviation from exponential decay for spin waves excited with a coplanar waveguide antenna," *Applied Physics Letters*., vol. 101, no. 25, 2012.
39. S. Tamaru and D. S. Ricketts, "Experimental Study of the Variation in Oscillation Characteristics of Point-Contact-Based Spin-Torque Oscillators." *IEEE Trans. on Magnetics*, vol.3, no., pp.3000504, 2012
40. **M. E. Korogozlar**, S. Goldstein and D. S. Ricketts, "Analysis and modeling of capacitive power transfer in microsystems," *Circuits and Systems I: Regular Papers, IEEE Transactions on* , vol.59, no.7, pp.1557,1566, July 2012
41. **W. Hu**, J. A. Bain and D. S. Ricketts "In-Situ quantification of electrical isolation in STM-fabricated TiOx nanostructures," *Micro and Nano Letters*, vol. 7, no. 4, pp. 334-36, Apr. 2012.
42. S. Tamaru, J. A. Bain, M. H. Kryder and D. S. Ricketts, "Theory for calculating the Green's function of magnetostatic surface waves and its application to the study of spatial diffraction patterns," *Physical Rev. B*, 84, pp.064437 (2011).
43. D.S. Ricketts, J. A. Bain, Y. Luo, S. Blanton, K. Mai and G. K. Fedder, "Enhancing CMOS using nanoelectronic devices, a perspective on hybrid integrated systems," *Proc. of the IEEE* vol.98, no.12, pp.2061,2075, Dec. 2010.
44. **R. Evarts**, L. Cao, D. S. Ricketts, N. D. Rizzo, J. A. Bain, and S. A. Majetich, "Characterization of conducting atomic force microscopy for use with magnetic tunnel junctions," *IEEE Trans. on Magnetics*, vol.46, no.6, pp.1741,1744, June 2010
45. **E.R. Evarts**, L. Cao, D. S. Ricketts, N. D. Rizzo, J. A. Bain, and S. A. Majetich, "Spin transfer torque switching of magnetic tunnel junctions using a conductive atomic force microscope," *Applied Physics Letters* 95, 132510 (2009).
46. **O. O. Yildirim**, D. S. Ricketts, and D. Ham, "Reflection soliton oscillator," *IEEE Transactions on Microwave Theory and Technique* , vol. 57, no. 10, pp. 2344-2353, Oct. 2009.
47. D. S. Ricketts, X. Li, N. Sun, K. Woo, and D. Ham, "On the self-generation of electrical soliton pulses," *IEEE J. Solid-State Circuits (JSSC)*, vol. 42, no. 8, pp. 1657-1668, Aug. 2007.
48. D. Ham, X. Li, S. A. Denenberg, T. H. Lee, and D. S. Ricketts, "Ordered and chaotic electrical solitons: communication perspectives," (Invited) *IEEE Communications Magazine*, vol. 44, no. 12, pp. 126-135, December 2006.
49. D. S. Ricketts, X. Li, and D. Ham, "Electrical Soliton Modelocking," (Invited cover article) *IEEE LEOS Newsletter*, vol. 20, no. 3, pp. 4-11, June 2006.
50. D. S. Ricketts, X. Li, and D. Ham, "Electrical Soliton Oscillator," *IEEE Trans. on Microwave Theory and Tech.*, vol. 54, no. 1, pp. 373-382, Jan. 2006.
51. R. S. Friedman, M. C. McAlpine, D. S. Ricketts, D. Ham, C. M. Lieber, "High-speed integrated nanowire circuits," *Nature*, vol. 434, p.1085, Apr. 2005.

David S. Ricketts

1.4 Archival Conference Articles (79 Papers)

1. H. Zhaong and D. S. Ricketts, "14dB Active Gain Magnetic Negative Permeability Metamaterial Cell with Self-coupling Compensation," European Microwave Conference, Sept., 2023.
2. J. Besnoff and D. S. Ricketts, "Teaching 100 remote students hands-on microwave design: Building a 16 QAM radio at home by hand," 2021 51st European Microwave Conference (EuMC), London, United Kingdom, 2022, pp. 1-4
3. J. Shen and D. S. Ricketts, "Advances in 3D additive manufacturing for complex mm-wave components and sub-systems," IEEE Radio Wireless Week, Jan 2020. **Invited**.
4. **M. Aiken** and D. S. Ricketts, "Simple Laminated PCB Artificial Dielectrics for mm-Wave Quasioptical Lenses," 2019 49th European Microwave Conference (EuMC), Paris, 2019, Submitted.
5. J. Besnoff, Y. Buchbut, K. Scheim and D. S. Ricketts, "A 50% Fractional Bandwidth, Wireless Power Communication System Achieving 6.78 Mbps at 13.56 MHz Carrier," 2018 48th European Microwave Conference (EuMC), Madrid, 2018, pp. 178-181.
6. J. Besnoff, Y. Buchbut, K. Scheim and D. S. Ricketts, "Dynamic Impedance Matching of Multiple Loads in Wireless Power Transfer using a Genetic Optimization Approach," 2018 IEEE/MTT-S International Microwave Symposium - IMS, Philadelphia, PA, 2018, pp. 1272-1274.
7. **J. Shen, D. P. Parekh**, M. D. Dickey and D. S. Ricketts, "3D Printed Coaxial Transmission Line Using Low Loss Dielectric and Liquid Metal Conductor," 2018 IEEE/MTT-S International Microwave Symposium - IMS, Philadelphia, PA, 2018, pp. 59-62.
8. **J. Shen**, M. Abbasi, and David S. Ricketts, "3D Printed Antennas: Enabling Complex Antenna Structures," USNC-URSI, Jan 2018.
9. J. Besnoff, D. S. Ricketts, Y. Buchbut, G. Castillo, M. Laifendfeld and K. Scheim, "Smart wireless power: A wireless power and bi-directional LIN communication system," 2017 IEEE International Conference on Microwaves, Antennas, Communications and Electronic Systems (COMCAS), Tel-Aviv, 2017, pp. 1-3.
10. **J. Shen, M. Aiken**, M. Abbasi, **D. P. Parekh, X. Zhao**, M. D. Dickey, David S. Ricketts, "Rapid prototyping of low loss 3D printed waveguides for millimeter-wave applications," 2017 IEEE MTT-S International Microwave Symposium (IMS), Honolulu, HI, 2017, pp. 41-44.
11. D. S. Ricketts, "Analog limitations for high-speed digital radios: Where the bits stop working," 2017 IEEE 60th International Midwest Symposium on Circuits and Systems (MWSCAS), Boston, MA, 2017, pp. 37-40. (**Invited**)
12. M. Abbasi, B. Wang, S. Tamaru, H. Kubota, A. Fukushima and D. Ricketts, "Precision power measurement of spin-torque nano-oscillators using an accurate de-embedding structure and analysis," 2017 IEEE International Magnetism Conference (INTERMAG), Dublin, 2017, pp. 1-1.
13. D. Ricketts and M. Abbasi, "Analytical limits to maximum RF performance of spin torque nano-oscillators," 2017 IEEE International Magnetism Conference (INTERMAG), Dublin, 2017, pp. 1-1.
14. **J. Shen, M. Aiken**, C. Ladd, M. Dickey and D. S. Ricketts, "A Simple Electroless Plating Solution for 3D Printed Microwave Components," *IEEE Asia Pacific Microw. Conf.*, Dec 2016. (**Best paper award**)
15. **W. Harris**, T. Nichols, M. Abbasi and D. S. Ricketts, "A Simple Electroless Plating Solution for 3D Printed Microwave Components A Versatile mm-Wave Micromachined Anti-Reflective Layer," *IEEE Asia Pacific Microw. Conf.*, Dec 2016.
16. M. Abbasi and D. S. Ricketts, "W-Band Conical and Corrugated Horn Antennas Using Stereolithography 3D-Printing Technology," *IEEE Asia Pacific Microw. Conf.*, Dec 2016.
17. M. Abbasi and D. S. Ricketts, "mm-Wave and THz Multipliers: Advances and Opportunities," *IEEE Asia Pacific Microw. Conf.*, Dec 2016. (**Invited**)
18. **D. Lal**, M. Abbasi and D. S. Ricketts, "A broadband, compact 140–170GHz double side-band receiver in 90nm SiGe technology," 2016 46th European Microwave Conference (EuMC), London, 2016, pp. 687-690.
19. **Lal, D.**; Abbasi, M. and D. S. Ricketts, "A Compact, High Linearity 40GS/s Track-and-Hold Amplifier in 90nm SiGe Technology," IEEE Custom Integrated Circuits Conf., Sept. 2015.
20. Besnoff, J. and D. S. Ricketts, "Wide bandwidth for high-speed communication in mid-range, resonant WPT and RFID systems," Microwave Conference (EuMC), 2015 European.
21. Besnoff, J.; Ricketts, D.S., "Near field wireless power transfer and quadrature amplitude modulated (QAM) communication link," in Wireless Power Transfer Conference (WPTC), 2015 IEEE , vol., no., pp.1-4, 13-15 May 2015.
22. Besnoff, J.; Ricketts, D., "Quadrature amplitude modulated (QAM) communication link for near and mid-range RFID systems," in RFID (RFID), 2015 IEEE International Conference on , vol., no., pp.151-157, 15-17 April 2015.
23. **Wei Tai**; Ricketts, D.S., " A Compact, High-gain Q-Band Stacked Power Amplifier in 45nm SOI CMOS With 19.2dBm Psat and 19% PAE, IEEE PAWR Conference, Jan 2015," IEEE PAWR Conference, Jan 2015.

David S. Ricketts

24. M. J. Chabalko, **W. C. Harris**, D. D. Stancil and D. S. Ricketts, "Experimental Characterization of Volume-mode Waves in Near-field Anisotropic Metamaterials with Application to Wireless Power Transfer," Asia-Pacific Microwave Conference, Nov 2014.
25. Junfeng Xu; Ricketts, D.S., "Broadband W-band On-Chip Yagi Antenna Using Superstrate for High Efficiency and Endfire Radiation" Asia Pacific Microwave Conference, Nov. 2014
26. Chabalko, M.J.; Laifenfeld, M.; Buchbut, Y.; Ricketts, D.S., "Resonantly-coupled wireless powered seat locomotion in automotive applications," European Microwave Conference (EuMC), 2014 44th , vol., no., pp.421,424, 6-9 Oct. 2014.
27. Chabalko, M.J.; Ricketts, D.S., "The effects of magneto-static resonances in metamaterials on the quality factor of coils in near field applications," Antennas and Propagation Society International Symposium (APSURSI), 2014 IEEE , vol., no., pp.426,427, 6-11 July 2014.
28. Chabalko, M.; Alarcon, E.; **Bou, E.**; Ricketts, D.S., "Optimization of WPT efficiency using a conjugate load in non-impedance matched systems.," Antennas and Propagation Society International Symposium (APSURSI), 2014 IEEE , vol., no., pp.645,646, 6-11 July 2014
29. Chabalko, M.J.; Ricketts, D.S., "Low-frequency metamaterial permeability retrieval for near-field applications," Antennas and Propagation Society International Symposium (APSURSI), 2014 IEEE , vol., no., pp.233,234, 6-11 July 2014
30. **Wei Tai**; Ricketts, D.S., "A W-band 21.1 dBm power amplifier with an 8-way zero-degree combiner in 45 nm SOI CMOS," Microwave Symposium (IMS), 2014 IEEE MTT-S International , vol., no., pp.1,3, 1-6 June 2014
31. **Wei Tai**; Ricketts, D.S., "Watt-Level, All-Silicon mm-Wave Power Amplifiers Using Zero-Degree Combiners" GOMACTech (Government Microcircuit Applications and Critical Technology) Conference, April 2014
32. **Wei Tai**; Ricketts, D.S., "A Q-band power amplifier with high-gain pre-driver and 18.7 dBm output power for fully integrated CMOS transmitters," Power Amplifiers for Wireless and Radio Applications (PAWR), 2014 IEEE Topical Conference on , vol., no., pp.34,36, 19-23 Jan. 2014
33. **Chen, M.W.**; Carley, L.R.; Ricketts, D.S., "A process-technology-scaling-tolerant pipelined ADC architecture achieving 6-bit and 4 GS/s ADC in 45nm CMOS," Silicon Monolithic Integrated Circuits in Rf Systems (SiRF), 2014 IEEE 14th Topical Meeting on , vol., no., pp.16,18, 19-23 Jan. 2014
34. M. Trotter, J. D. Griffin, D. S. Ricketts, "Enhanced Accuracy for a Complex Image Theory Position Estimator using Frequency Diversity," Wireless Sensors and Sensor Networks, IEEE Topical meeting on, Feb. 2014.
35. Junfeng Xu; **Wei Tai**; Ricketts, D.S., "Microwave watt-level rectifiers for power recycling applications," Microwave Integrated Circuits Conference (EuMIC), 2013 European, pp.516,519, 6-8 Oct. 2013.
36. Ricketts, D.S.; Chabalko, M.J.; **Hillenius, A.**, "Optimization of wireless power transfer for mobile receivers using automatic digital capacitance tuning," Microwave Conference (EuMC), 2013 European , vol., no., pp.515,518, 6-10 Oct. 2013.
37. M. Chabalko and D. S. Ricketts, "The Effects of Magneto-static Surface Resonances in Metamaterials on the Quality Factor of Coils in Near Field Applications," Antennas and Propagation Society International Symposium (APSURSI), July, 2014.
38. Trotter, M.S.; Ricketts, D.S.; Griffin, J.D., "Experimental demonstration of complex image theory for vertical magnetic dipoles with applications to remote sensing and position tracking," Electromagnetics in Advanced Applications (ICEAA), 2013 International Conference on , vol., no., pp.1248,1251, 9-13 Sept. 2013.
39. **O. Ozcan, W. Hu**, M. Sitti, J. A. Bain and D.S. Ricketts, "Experimental Investigation of Force, Conduction and Growth in Nano-oxidation using scanning probe microscopy," Enabling Nanomanufacturing for Rapid Innovation, Aug. 2013. [Best Poster]
40. D. S. Ricketts and M. Chabalko, "Distributed Resonant Coil Systems for Efficient Wireless Power Transfer," Progress in Electromagnetics Research Symposium (PIERS), Aug. 2013.
41. J. Xu and D. S. Ricketts, "A Transmission line based resistance compression network (TRCN) for microwave applications," Microwave Symposium Digest (IMS), 2013 IEEE MTT-S International , vol., no., pp.1,3, 2-7 June 2013
42. D. S. Ricketts and M. Chabalko, "On the efficient wireless power transfer in resonant multi-receiver systems," Circuits and Systems (ISCAS), 2013 IEEE International Symposium on , vol., no., pp.2779,2782, 19-23 May 2013
43. **Arumugam, D.D.**; **Sibley, M.**; Griffin, J.D.; Stancil, D.D.; Ricketts, D.S., "An active position sensing tag for sports visualization in American football," RFID (RFID), 2013 IEEE International Conference on , vol., no., pp.96,103, April 30 2013.
44. **W. Tai**, L. R. Carley and D. S. Ricketts, "A 0.7W Fully Integrated 42GHz Power Amplifier with 10% PAE in 130nm SiGe BiCMOS," Solid-State Circuits Conference Digest of Technical Papers (ISSCC), 2013 IEEE International , vol., no., pp.142,143, 17-21 Feb. 2013

David S. Ricketts

45. **M. W. Chen, D. Tian, S. Phatak**, L. R. Carley, D. S. Ricketts, "A 4GHz-Bandwidth Op-Amp Free Track-and-Hold and 6-bit Flash ADC in 45nm SOI CMOS" Silicon Monolithic Integrated Circuits in RF Systems (SiRF), 2013 IEEE 13th Topical Meeting on , vol., no., pp.126,128, 21-23 Jan. 2013
46. **D. Birt, K. An, M. Tsoi**, S. Tamaru, D. Ricketts, K.L. Wong, P.K. Amiri, K.L. Wang and X. Li," Oscillatory Spatial Intensity Pattern for Spin Waves Excited with a Coplanar Waveguide Antenna," Conference on Magnetism and Magnetic Materials, Chicago, IL, paper EC-02, Jan. 2013.
47. **C. Li** and D. S. Ricketts, "A low-loss, compact, $\lambda/4$ power combiner architecture," Microwave Integrated Circuits Conference (EuMIC), 2012 7th European , vol., no., pp.147,150, 29-30 Oct. 2012
48. D. S. Ricketts and **A. Hillenius**, "Equivalence of inductive coupling and strongly coupled Magnetic resonance in wireless power transfer," Progress in Electromagnetics Research Symposium (PIERS), Aug. 2012.
49. **D. Arumugam**, J. Griffin, D. Stancil and D. S. Ricketts, "Experimental study on the effects of groups of people on magnetoquasistatic positioning accuracy," Antennas and Propagation Society International Symposium (APSURSI), 2012 IEEE , vol., no., pp.1,2, 8-14 July 2012
50. D. S. Ricketts, "A dispersion-tapered reflection soliton oscillator," Microwave Symposium Digest (MTT), 2012 IEEE MTT-S International , vol., no., pp.1,3, 17-22 June 2012
51. **D. Tian**, L. R. Carley and D. S. Ricketts, "Frequency Scaling of Power Reclamation Networks in Outphasing PA Architectures," Circuits and Systems (ISCAS), 2012 IEEE International Symposium on , vol., no., pp.1058,1061, 20-23 May 2012
52. S. Tamaru and D. S. Ricketts, "Origin of variation in the oscillation characteristics of point contact based spin torque oscillators," Magnetism Letters, IEEE , vol.3, no., pp.3000504,3000504, 2012
53. **W. Hu** J. A. Bain and D. S. Ricketts, "In-situ characterization using AFM probes in multiple modes," Int. Conf. Electron, Ion, Photon Beam Technology and Nanofabrication, May, 2012.
54. **Lee, B.J.; Hillenius, A.**; Ricketts, D.S., "Magnetic resonant wireless power delivery for distributed sensor and wireless systems," Wireless Sensors and Sensor Networks (WiSNet), 2012 IEEE Topical Conference on , vol., no., pp.13,16, 15-18 Jan. 2012.
55. **D. Arumugam**, J. Griffin, D. Stancil and D. S. Ricketts, "A wireless orientation sensor using magnetoquasistatic fields and complex image theory," Radio and Wireless Symposium (RWS), 2012 IEEE , vol., no., pp.251,254, 15-18 Jan. 2012
56. **W. Tai**, L. R. Carley and D. S. Ricketts, "A Q-band SiGe Power Amplifier with 15.5 dBm Saturated Output Power and 26% Peak PAE," Bipolar/BiCMOS Circuits and Technology Meeting (BCTM), 2011 IEEE , vol., no., pp.146,149, 9-11 Oct. 2011
57. **D. Arumugam**, D. Stancil and D. S. Ricketts, "Proximity and Orientation Sensing Using Magnetoquasistatic Fields and Complex Image Theory" Vehicular Technology Conference (VTC Fall), 2011 IEEE , vol., no., pp.1,5, 5-8 Sept. 2011
58. **W. Hu**, J. Gu, **Z. George** and D. S. Ricketts, "Directed scanning probe nanomanufacturing of lateral Ti-TiO₂-Ti junctions for low capacitance MIM rectenna diodes," Micro and Nano Engineering Conf., Berlin, Sept. 2011.
59. **D. Arumugam**, J. Griffin, D. Stancil and D. S. Ricketts, "2-Dimensional Position Measurement using Magnetoquasistatic Fields," Antennas and Propagation in Wireless Communications (APWC), 2011 IEEE-APS Topical Conference on , vol., no., pp.1193,1196, 12-16 Sept. 2011
60. **W. Hu**, **Y. Tang**, **Y. Zhang**, J. Gu, S. Tamaru, J. A. Bain, L. R. Carley, R. F. Davis, G. K. Fedder and D. S. Ricketts, "Ti/TiO₂ nanodevice fabrication using compliant probes and CMOS probe-arrays," Technologies for Future Micro-Nano Manufacturing, Napa Valley, CA, Aug. 2011.
61. **D. Arumugam**, J. Griffin, D. Stancil and D. S. Ricketts, "Higher Order Loop Corrections for Short Range Magnetoquasistatic Position Tracking," Antennas and Propagation (APSURSI), 2011 IEEE International Symposium on , vol., no., pp.1755,1757, 3-8 July 2011
62. **M. E. Karagozler, A. M. Thaker**, S. Goldstein and D. S. Ricketts, "Electrostatic-actuation generation and control of micro robots in a post-processed HV SOI CMOS," Circuits and Systems (ISCAS), 2011 IEEE International Symposium on , vol., no., pp.2509,2512, 15-18 May 2011
63. **W. Hu**, S. Tamaru, J. A. Bain and D. S. Ricketts, "High Current Pulse Generation for Thermal Surface Modification using Standard STM," Int. Conf. Electron, Ion, Photon Beam Technology and Nanofabrication, May. 2011.
64. J. R. Smith, D. S. Ricketts and J. A. Bain, "Localized thermal modification of surfaces via pulsed electron bombardment from an STM tip," Int. Conf. Electron, Ion, Photon Beam Technology and Nanofabrication, May. 2011.
65. **D. Arumugam**, J. Griffin, D. Stancil and D. S. Ricketts, "Long Range Magnetoquasistatic Position Tracking using a Simple Active RFID Tag," IEEE Int. Conf. RFID, Apr. 2011.
66. S. Tamaru and D. S. Ricketts, "Influence of the bias field orientation on the interaction strength between two closely formed spin torque oscillators," Int. Magnetism Conf., paper CO-05, Taiwan, Apr 2011.

David S. Ricketts

67. **E.R. Evarts, R.A. Booth, L.R. Shah, Y. Tang**, S. Tamaru, D.S. Ricketts, J.A. Bain, S.A. Majetich, "Sub-30 nm Magnetic Tunnel Junction and Spin Valve Nanopillar Analysis Using Conductive Atomic Force Microscopy," Int. Magnetism Conf., paper BB-03, Taiwan, Apr 2011.
68. J. R. Smith, **W. Hu, Y-Y Dang, O. Ozcan**, M. Sitti, J. A. Bain, D. S. Ricketts, R. Davis, "Scanning Probe Nanomanufacturing on Si: Surface Characterization of the Process Technique," Materials Research Symposium, paper G1.5, Nov. 2010
69. **E. R. Evarts**, M. Moneck, R. A. Booth, C. Hogg, D. S. Ricketts, J-G Zhu, J.A. Bain, and S. A. Majetich, "Spin Torque Switching of 26 nm Diameter Magnetic Tunnel Junction Using a Conductive Atomic Force Microscope," Conference on Magnetism and Magnetic Materials, Atlanta, GA, paper FC-13, Nov. 2010.
70. **E. R. Evarts, T.T. Farkas, B. Tsukerman**, L. Cao, D. S. Ricketts, G. Markovich, J.A. Bain, and S.A. Majetich, "Noise Measurements on Magnetic Tunnel Junction Nanopillars using Conductive Atomic Force Microscopy," Conference on Magnetism and Magnetic Materials, Atlanta, GA, paper CB-10, Nov. 2010.
71. **M. W. Chen** and D. S. Ricketts, "An 8.6GHz 42ps Pulse-Width Electrical Mode-Locked Oscillator," International Solid-State Circuits Conference (ISSCC), pp. 500-501, Feb. 2010.
72. D. S. Ricketts, L. Cao and S. Tamaru, "Spin-torque oscillator arrays as a solution for line width reduction in RF applications", Conference on Magnetism and Magnetic Materials, paper EY-01, Washington D.C., Dec. 2009.
73. D. S. Ricketts, T. Schlesinger, Y. Luo and J. Bain, "Materials and Devices for Hybrid CMOS Circuits: Expanding the Functionality of Nanoscale CMOS," Nano-DDS Conference, Ft. Lauderdale, FL, Oct. 2009 (Invited).
74. D. S. Ricketts and S. Bruck, "Stochastic Logic", NRI-MIND, Architectures for post-CMOS switches (Invited), Notre Dame, IN, Oct. 2009.
75. D. S. Ricketts, X. Li and D. Ham, "Soliton Electronics," (Invited) CMOS Emerging Technology Workshop, Whistler, Canada, 2007. (invited)
76. W. F. Andress, D. S. Ricketts, X. Li, and D. Ham, "Passive & active control of regenerative standing & soliton waves," (Invited) Proc. of the IEEE Custom Integrated Circuits Conference, pp. 29-36, Sept. 2006.
77. D. S. Ricketts, X. Li and D. Ham, "Taming the electrical soliton: A new direction in picosecond electronics," Radio Frequency Integrated Circuits (RFIC) Symposium, 2006 IEEE , vol., no., pp.4 pp.,24, 11-13 June 2006
78. D. S. Ricketts and D. Ham, "A chip-scale electrical soliton modelocked oscillator," IEEE International Solid-State Circuits Conference (ISSCC), pp. 432-433, Feb 2006.
79. D. S. Ricketts, X. Li, M. DePetro, and D. Ham, "A self-sustained electrical soliton oscillator," Microwave Symposium Digest, 2005 IEEE MTT-S International , vol., no., pp.4 pp., 12-17 June 2005
80. D. Ham, W. Andress, and D. S. Ricketts, "Phase noise in oscillators," (Invited) Int. Workshop on Sip/SoC Integration of MEMS and Passive Components with RF-ICs, March 2004.

1.5 Papers in Symposium or Conference Proceedings (No archival paper)

1. M. Abbasi and D. S. Ricketts, "100 Gb/s All-electronic Radios: Opportunities and Challenges", GomacTech, Mar. 2014
2. **W. Tai, C. Li, Z. Li, G. Yahalom**, D.S. Ricketts, V. Stojanovic and J. Dawson, "A 45 GHz Asymmetric Multilevel Outphasing Transmitter in 45nm SOI CMOS," Student Research Int. Solid-State Circuits Conf, IEEE, Feb. 2012.
3. J.R. Smith, **W. Hu, Y.Y. Dang, O. Ozcan**, M. Sitti, J. Bain, R. Davis and D. S. Ricketts, "Writing Si nanowires on Si (100) with an STM tip: surface preparation and initial results," Materials Research Symposium, M11.50, Boston, MA, Nov. 2009
4. R. S. Friedman, M. C. McAlpine, D. S. Ricketts, D. Ham, C. M. Lieber, "Fully integrated high frequency nanowire ring oscillators," Materials Research Symposium, Mar. 2005.
5. D. S. Ricketts, "Current sensing and accuracy for CPU multi-phase DC-DC converters: the sub 20 mV challenge," IBM Power Delivery Symposium, 2002.

1.6 ACADEMIC WORKSHOPS and SHORT COURSES (Chair or Co-Chair)

1. 12th Tom Brazil Doctoral School of microwaves "Build a Frequency Modulated Continuous Wave Radar in 1-day" IEEE European Microwave Week, Milan, Italy, Sept 2022.
2. 11th Tom Brazil Doctoral School of microwaves "Build a modern digital radio" IEEE European Microwave Week, London, UK, June 2021.
3. "Build a NIST Atomic Clock Radio" International Microwave Symposium, Denver, Co June, 2022.
4. "5th European Microwave Student and Doctoral Schools: Build a modern digital radio," IEEE , IEEE European Microwave Week, Paris, France, Oct 2019.

David S. Ricketts

5. "Build a 950 MHz radar in a day," IEEE Int. Microwave Symposium, Boston, MA, June 2019.
6. "Design, Fab and Test Your Own Microwave Component," Industry Workshop, IEEE Int. Microwave Symposium, Boston, MA, June 2019..
7. "From Bits to Waves: Building a Modern Digital Radio in 1 Day – Hand-on Workshop," IEEE Asia Pacific Microwave Conference, Kyoto, Japan, 2018.
8. "4th European Microwave Student and Doctoral Schools: Build a modern digital radio," IEEE ,," IEEE European Microwave Week, Madrid, Spain, Sep 2017.
9. "Build a 16 QAM Radio – Student Design Competition," IEEE Int. Microwave Symposium, Philadelphia, PA, June 2018.
10. "Design, Fab and Test Your Own Microwave Component," Industry Workshop, IEEE Int. Microwave Symposium, Philadelphia, PA, June 2018.
11. "3rd European Microwave Student and Doctoral Schools: Build a modern digital radio," IEEE ,," IEEE European Microwave Week, Nuremberg, Germany, Oct 2017.
12. "Build a Modern Digital Radio in a day," Int. Microwave Symposium, Honolulu, HI, June 2017.
13. "From Bits to Waves: Building a Modern Digital Radio in 1 Day – Hand-on Workshop," IEEE Asia Pacific Microwave Conference, New Delhi, India, Nov 2016.
14. "From Bits to Waves: Building a Modern Digital Radio in 1 Day – Hand-on Workshop," IEEE European Microwave Week, London, UK, Oct 2016.
15. "From Bits to Waves: Building a Modern Digital Radio in 1 Day – Hand-on Workshop," EDICON, Boston, MA, Sep. 2016.
16. "Emerging devices for Microwave Circuits and Systems," IEEE Int. Microwave Symposium, San Francisco CA,, May 2016.
17. "Build a Modern Digital Radio in a day," IEEE Int. Microwave Symposium, San Francisco, CA, May 2016.
18. "Build a Modern Digital Radio in a day," IEEE Radio Wireless Week, Austin, Texas, Jan, 2016.

1.7 Discussion PI's Work

Nature, News & Views article by Thomas H. Lee, "Electrical solitons come of age," *Nature*, vol. 440, 36-37, Mar. 2006.

1.8 Patents

Ricketts, *et.al* U.S. Patent No. 8,154,354 "Nonlinear pulse oscillator methods and apparatus".

Ricketts, *et. al* U.S. Patent No. 7,339,440 "Nonlinear pulse oscillator methods and apparatus"

Arumugam, *et. al* U.S. Patent No. 9,625,247 "Systems and methods for position tracking using magnetoquasistatic fields"

David S. Ricketts

8. Invited and Contributed Talks (65)

1. "Live from Faraday's Lab": An Intuitive and Historical Perspective on Electromagnetism" IEEE MTT Webinar, May 2022.
2. "NCSU Rabbit Radar: Design, Simulation & Building your own Frequency Modulated Continuous Wave Radar at Home," IEEE MTT-S Virtual Lecture, Sept, 2020
3. "From Bits to Waves - Building a Modern Digital Radio," Cadence Live, August 2020.
4. "Data, Sensors and New Technologies for Smart Cities," RMIT, Melbourne Australia, Mar 2019.
5. "New Approaches to IoT in Smart Cities," Western Sydney University, Sydney, Australia, Mar 2019.
6. "Enhancing, Shaping and Steering WPT Fields," WPT NSF ERC Industry Workshop, Alexandria, VA, Dec 2018.
7. "High-speed GaN RF DC-DC Converter design," Power America Webinar, NCSU, Oct. 2018.
8. "High-speed Communication & Field Enhancement Using Artificial Materials," Pennsylvania State University, Oct 2018.
9. "Modern Digital Radios," EuMW Microapp Lecture, Madrid Sept. 2018.
10. "Sensors and Networks for Smart Cities," City of San Diego, CA, Apr 2018.
11. "Emerging Technologies in Sensors for Smart Cities," Facebook, Dublin, Feb 2018.
12. "Science in Microwaves," NSF Workshop at IMS2017, June 2017.
13. "Magic with Magnetic Fields: NFL Football Tracking", Raleigh Engineers Club, Raleigh, NC, June 2017.
14. "Maximum power and phase noise in spin-torque oscillators," AIST Dec 2016.
15. "High-power, broadband multipliers for high-speed microscale radios," IEEE IMS invited workshop presentation, May 2016.
16. "Advances in wireless power transfer research: challenges and opportunities," General Motors, Feb. 2016.
17. "Magic with magnetic fields: NFL football tracking and advances in wireless power transfer & communication," Univ. of Washington, Feb, 2015.
18. "State of the art and future of high-speed wireless transceivers: Opportunities and challenges for near-THz communication," CMOS Emerging Technologies Conference, PLENARY, May 2015.
19. "Advances in wireless power transfer research from academia: Challenges and opportunities," Wireless Power Summit, INVITED, Berkeley, CA, Nov 2014.
20. "Advances in high-speed integrated and nanoelectronics," AIST Nov 2014.
21. "Watt-level, Highly Efficient, Fully Integrated all-Silicon Linear Power Amplification for mm-Wave Radar and Communications," Berkeley Nov. 2014.
22. "High-speed integrated circuits: From water waves to optical sampling," Analog Devices, Oct 2014.
23. "Advanced RF substrates: Applications in mm-wave electronics," DuPont 2014.
24. "Advanced mm-wave Circuits and Systems," Nuvotronics, 2014.
25. "Watt-level, Highly Efficient, Fully Integrated all-Silicon Linear Power Amplification for mm-Wave Radar and Communications," University of Delft, Netherlands, 2014
26. "Watt-level, Highly Efficient, Fully Integrated all-Silicon Linear Power Amplification for mm-Wave Radar and Communications," University of Pavia, Italy, 2014
27. "Magnetoquasistatics: Emerging Applications in Sports Visualization and Enhanced Wireless Power Transfer," University of Perugia, Italy, 2014
28. "Power, Sensing and Communication: Opportunities for a wireless world," General Motors Research, Herzlia Israel, Oct. 2013.
29. "Enabling Rapid Innovation in Nanomanufacturing," ENRI NSF workshop keynote, Napa, CA. Aug. 2013.
30. "Watt-level, Highly Efficient, Fully Integrated Linear Power Amplification for mm-Wave Radar and Communications," MIT, Boston Ma, May 2013.
31. "Watt-level, Highly Efficient, Fully Integrated Linear Power Amplification for mm-Wave Radar and Communications," Qualcomm, San Diego, CA, Jan 2013.
32. "Impedance Matched Magnetoquasistatic Wireless Power: On the equivalence of inductive and strongly coupled magnetic resonance and the challenges of multiple and mobile receivers" Qualcomm, San Diego, CA, Jan 2013.
33. RF from Kilometer to Millimeter Waves: NFL Football Tracking and High-power mm-Wave Circuits and Systems," POSTECH, Korea Aug 2012 (Distinguished Lecturer)
34. "Watt-level, Highly Efficient, Fully Integrated Linear Power Amplification for mm-Wave Radar and Communications," Jet Propulsion Laboratory, Pasadena, CA, Jul 2012.
35. "NFL Football Tracking, Microrobots and Nanoelectronics: Novel applications of Analog Circuits, E&M and MEMS," University of FL, Apr 2012.
36. "RF devices, circuits & systems: from nanometers to kilometers," University of Illinois, Urbana Champagne, Apr 2012.

David S. Ricketts

37. "Applications of Analog Circuits and Electromagnetics in mm-wave RF and μ Robots," NCSU Mar 2012.
38. "RF from Kilometer- to Millimeter-waves: NFL Football Tracking and Power Amplifier Circuits & Systems," UMich. Mar 2012.
39. "RF devices, circuits and systems: from nanometer to kilometer" University of Utah, Feb 2012
40. "NFL Football Tracking and Microrobots: Novel Applications of Analog Circuits, MEMS and E&M," Harvard University, Feb 2012
41. "RF devices, circuits and systems: from nanometer to kilometer," Duke Univ, Jan 2012
42. "At the boundaries of high-frequency analog & RF ICs: Speed, energy and uncertainty", Univ. NC State, NC, Dec 2011, (Distinguished Lecturer)
43. "Quasistatics in E&M: Sports Visualization, Wireless Power and Microrobots," Ga Tech, GA Nov. 2011.
44. "RF devices, circuits and systems: from nanometer to kilometer," Univ. of Texas, Austin, Oct 2011
45. "RF devices, circuits and systems: from nanometer to kilometer," Princeton Univ., Oct 2011
46. "High-speed PA and ADCs," Univ. Wisconsin, Oct. 2011
47. "At the boundaries of high-frequency analog & RF ICs: Speed, energy and uncertainty", GA Tech, GA, May 2011
48. "RF PA's and spin-torque oscillators for RF," University of FL, Mar, 2011
49. "Tip-directed, Field-assisted Nanofabrication," NIST, Mar 2011.
50. "Extending the boundaries of analog and RF electronics," Brown Univ., Mar, 2011.
51. "Nanoscale magnetics for integrated power conversion and RF," ARL, Jan, 2011.
52. "Ultimate limitation of conversion in conventional ADCs," ONR Superconducting Electronics Program, San Diego, Jan. 2011.
53. "Tip-assisted, field emission nanofabrication," Zyvex Corp., Apr., 2010.
54. "Tip-assisted Nanofabrication," Worcester Polytechnic Institute, MA, Mar. 2010.
55. "Spin Torque Oscillators for Agile RF," DARPA YFA Program, Oct. 2009.
56. "Perspectives on electrical oscillators," IBM Research, NY, Apr., 2009
57. "Electrical oscillators and phase noise," NIST, Boulder, CO, Oct. 2008
58. "Creativity in science and engineering," Innovation in Science and Engineering, Harvard University, Oct. 2008
59. "The Double Helix, a case study in scientific discovery," Innovation in Science & Technology, Paris University Consortium, Paris France, 2008.
60. "Creativity in science and engineering," Innovation in Science & Technology, Paris University Consortium, Paris France, 2008.
61. "New directions : soliton mode-locking and nanowire circuits," CMU, Sept. 2006
62. "Electrical soliton oscillators" University of Michigan, Mar, 2006
63. "Electrical soliton oscillator and nanowire Circuits," University of California, Berkeley, Apr. 2006
64. "Electrical soliton oscillators," Cornell University, Mar 2006.
65. "Electrical solitons," The Cooper Union, Feb. 2006.

David S. Ricketts

9. Professional Activities

Societies

- **Chair**, IEEE Chapter ACME (Joint chapter of Antennas and Propagation (AP), Electronic Packaging Society (EP), Microwave Theory and Techniques (MTT), and Electron Devices (ED) 2019-
- Technical Committee **Vice-chair** for IEEE T-MTT TC-9 Society 2015-2019, **Chair** 2019-2021
-
- Technical Program **Chair**: Enabling Nanomanufacturing for Rapid Innovation, TRC/NSF Workshop, Aug. 2013
- Technical Program Committee (member) – IEEE International Microwave Symposium 2014-;
- Technical Program Committee IEEE BioWireless 2012-2015.
- Session Chair - Nanotechnology, CMOS Emerging Technologies Conf., Banff, Canada 2009; NANO-DDS, Chemically-Synthesized, Biomimetic Systems and Biologically-Inspired Architectures Session, August 2011.

10. Editorial Roles on Publications, Major Activities in Professional

Meetings

- Track Editor, T-MTT Oct 2019 -
- Session Chair, *BioWireless*, Energy Scavenging and Remote Patient Monitoring, Jan. 2012.
- Session Chair, *NANO-DDS*, Chemically-Synthesized, Biomimetic Systems and Biologically-Inspired Architectures Session, August 2011.
- Session Chair, *Nanotechnology*, CMOS Emerging Technologies Conf., Banff, Canada 2009.
- Harvard College Innovation Challenge Reviewer/Judge (2012, 2013)
- Guest Editor for:
 - Journal of Solid State Circuits special issue of the JSSC on ISSCC 2009
- Reviewer for:
 - ACS Nano Letters
 - Journal of Solid State Circuits (IEEE)
 - Electron Device Letters (IEEE)
 - Transactions on Circuits and Systems (IEEE)
 - Proceedings of the National Academy of Sciences
 - MacArthur Foundation (Fellows program)
 - Nano Letters

David S. Ricketts

- Sensors
- Journal of Applied Physics
- Journal of Emerging and Selected Topics in Power Electronics
- IET Circuits, Devices & Systems
- IEEE Transactions on Power Electronics
- IEEE AP-S
- IEEE Transaction on Antennas and Propagation