

IPR2024-00796
U.S. Patent No. 7,483,686
Patent Owner's Response

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

MEDIATEK INC.,
Petitioner,

v.

PARKERVISION, INC.
Patent Owner.

U.S. Patent No. 7,483,686

Issue Date: January 27, 2009

Title: UNIVERSAL PLATFORM MODULE AND METHODS AND
APPARATUSES RELATING THERETO ENABLED BY UNIVERSAL
FREQUENCY TRANSLATION TECHNOLOGY

Inter Partes Review No. IPR2024-00796

DECLARATION OF DR. DAVID RICKETTS

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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 (IPR2024-00796).

2. I have been asked by ParkerVision to provide my expert opinion regarding the validity of claims 1-20 of U.S. Patent No. 7,483,686 (“the ’686 patent”). For the reasons set forth below, it is my opinion that claims 1-20 of the ’686 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. In 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 '686 patent.

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

Exhibit No.	Description
1001	U.S. Patent No. 7,483,686
1002	Declaration of Dr. Lawrence E. Larson
1003	U.S. Patent No. 6,643,522 ("Young")
1004	U.S. Patent No. 6,600,726 ("Nevo")
1005	Estabrook-Thesis
1006	Avitabile
1007	File History of the '686 patent
1008	U.S. Patent No. 6,061,551
1016	Estabrook-1988
1017	Estabrook-1989
2007	Graf
2011	Rofougaran

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.

V. LEVEL OF ORDINARY SKILL IN THE ART

24. 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.

25. In my opinion, a POSITA with respect to the '686 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.

26. 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 '686 patent.

VI. GENERAL OVERVIEW OF WIRELESS TECHNOLOGY

27. 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.

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



29. 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.

30. 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).



31. As shown above, wireless devices use high radio frequency (RF) signals (e.g., above 300 MHz (red) for cellphones) because high frequency signals

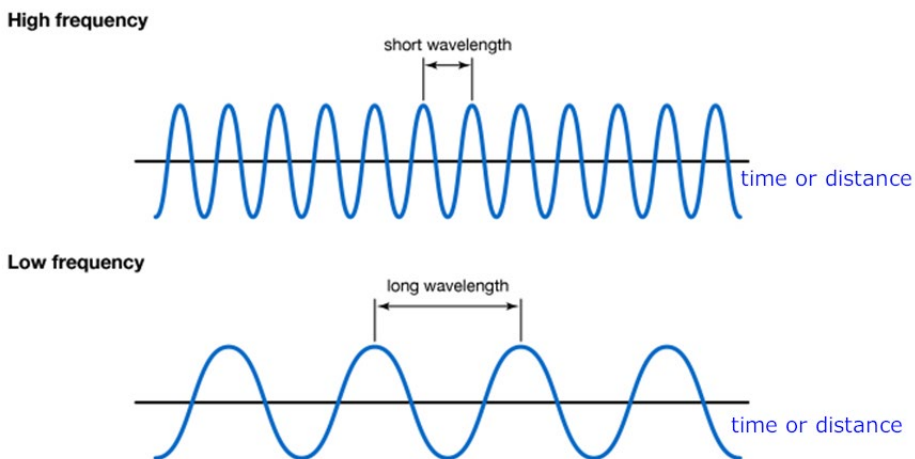
can carry more information and because high frequency antennas can physically fit within small devices such as cellular phones.



32. 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.

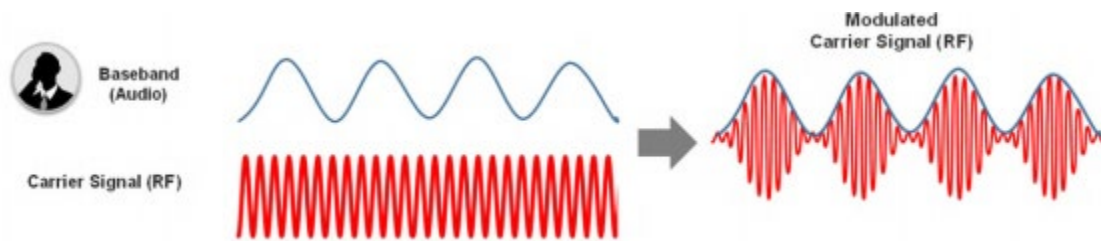
33. Frequency is the number of cycles of a wave per unit time (second).



34. 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.

35. 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.”

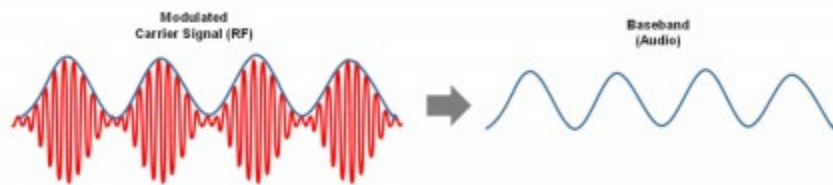


36. In order to transport the baseband (audio) signal, the transmitting wireless device (e.g., Bob’s cell phone) modifies the carrier (RF) signal. As shown above, the baseband signal is impressed upon the carrier signal (above left), thereby modulating/changing the shape of the carrier signal to approximate 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.

37. 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.



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.

38. RF signals are created and processed using electronic circuits. To

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.

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.

39. 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 (−).

40. 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.

41. 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.

42. 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).

43. 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.

44. 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 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.

45. 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.

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

47. 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.

48. 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.

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

50. 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.

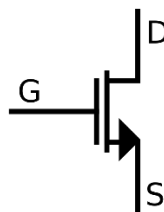
51. A transistor has at least three terminals for connection to an external circuit. Key to the functionality of a transistor is that a controlling voltage or current

at one terminal can control a current between two of the other terminals.

52. 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.

53. 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.

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



55. 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. Diode.

56. A diode is a two-terminal electrical component that allows a circuit to be connected with the flow of current in only one direction. It offers low (negligible) resistance in one direction (to allow current flow) and high resistance in the reverse direction (to prevent current flow).

57. The most common type of diode is made from a combination of p-type semiconductor material and n-type semiconductor material, known as a p-n junction.

58. The symbol for one type of diode is shown below.



59. Current flows through the diode from the anode (positive lead) to the cathode (negative lead). As shown above, the arrowhead points in the direction of the current in conventional flow. When a voltage source is connected to a diode such that the positive terminal of the source is connected to the anode (+) and the negative terminal to the cathode (-), the diode is said to be “forward-biased.” When the voltage across the diode becomes greater than a forward barrier potential, the diode becomes a conductor and allows current to flow.

60. When a voltage source is connected to a diode such that the negative terminal of the source is connected to the (+) anode and the positive terminal to the cathode (-), the diode is said to be “reverse-biased.” In this way, a diode blocks the

flow of current No current will flow until the electric field is so high that the diode breaks down.

3. Resistor.

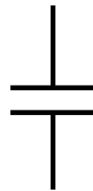
- 61. A resistor is a circuit element that introduces resistance into a circuit.
- 62. The symbol for one type of resistor is shown below.



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

4. Capacitor.

- 64. A capacitor is one type of circuit element used to store (accumulate) energy. A capacitor stores electric energy in an electric field by separating charges over a distance.
- 65. The symbol for one type of capacitor is shown below.



- 66. A capacitor stores energy in an electric field established between two plates.
- 67. The ability of a capacitor to store energy is described by its capacitance.

The capacitance C of a capacitor is equal to the charge Q stored 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.

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

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

69. As such, the energy stored in a capacitor is proportional to (a) the square of the voltage across the capacitor and (b) the capacitance of the capacitor.

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

5. Electrical Load.

71. 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.

72. Connecting a load to a capacitor affects the operation of the capacitor 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.

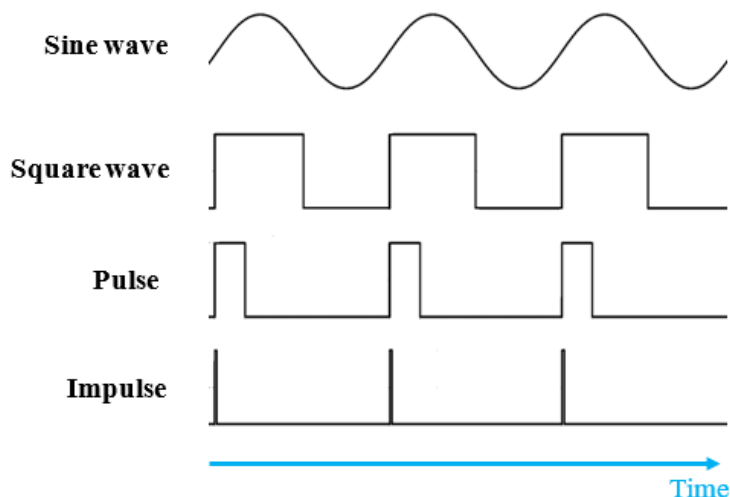
73. Since a load is connected to the output of other circuitry, the circuitry (e.g., capacitor, source, transistors) is said to be driving the load (when substantial current flows from the circuitry to the load). For example, when circuitry is connected to a low impedance load, the circuitry is said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

6. Local Oscillator.

74. An oscillator is “[s]omething that oscillates,” i.e., “repeat[s] a cycle of motions or to pass through a cycle of state with strict periodicity.” Ex. 2007, p. 6. “In particular, [an oscillator is] a self-excited electronic circuit whose output voltage or current is a periodic function of time [and is a] generator of an alternating signal, continuous, sinusoidal or pulsed.” *Id.*

75. 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.” *Id.* at 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.”



76. 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.

77. 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.

78. 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.

79. 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.

C. Wireless Communication Protocols.

80. Wireless communication protocols define the methods and parameters for transmitting data over RF channels.

81. Two widely used protocols are Bluetooth and IEEE 802.11 (commonly known as Wi-Fi). Each of these protocols is optimized for different applications, with specific standard performance factors (e.g., dynamic range, sensitivity, interference) that guide their design and implementation.

1. Dynamic range

82. Dynamic range refers to the range of input signal strengths a receiver can handle without distortion. It is the difference between the weakest desired signal (the smallest signal that can still be distinguished from noise) and the strongest signal that can be received without causing distortion or data loss.

2. Sensitivity

83. Sensitivity determines the minimum RF signal power a receiver can

successfully detect and demodulate in the presence of noise. It is related to the receiver's noise figure and affects its ability to process weak signals. Sensitivity can be expressed as the minimum detectable signal (MDS) plus the minimum specified carrier-to-noise power ratio. Sensitivity dictates the minimum signal strength required for successful data reception, while interference affects the ability to maintain stable communication in the presence of competing signals.

3. Noise Figure

84. The noise figure (NF) of a receiver measures how much noise is added to the received signal during amplification and processing, impacting the receiver's sensitivity.

85. NF is defined as the ratio of input signal-to-noise power ratio (SNR) and output SNR:

$$NF(db) = 10 \log_{10} \left(\frac{SRN_{in}}{SRN_{out}} \right)$$

4. Second order-intercept point (IIP2)

86. The second-order intercept point (IIP2) quantifies a receiver's linearity and its susceptibility to single-tone and two-tone interfering signals. When large signals at two frequencies interact, intermodulation products (additional signals at other frequencies) are produced. High IIP2 values indicate a receiver's ability to handle such interactions without causing unwanted distortion.

5. Third order-intercept point (IIP3)

87. The third order intercept point (IIP3) is another measure of a receiver's linearity. IIP3 specifies the amount of distortion of a desired signal due to the intermodulation products from two interfering signals. IIP3 helps assess the receiver's signal-handling capacity, with higher IIP3 values indicating better linearity and signal separation.

88. Among other criteria, the IIP2 and IIP3 are commonly used in determining the overall dynamic range of a receiver.

89. High IIP2 and IIP3 values generally indicate better performance in handling weak and interfering signals without distortion.

VIII. DOWN-CONVERSION SYSTEMS

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

A. Heterodyning (Non-Sampling)

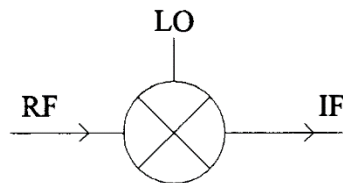
91. From the late 1980s through 2000, the industry was focused on the use of non-sampling mixers and heterodyne receivers for down-conversion. Heterodyne receivers, which used a decades-old RF technology called heterodyning, dominated the cellular/wireless industry for receiving and processing RF signals.

92. 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.

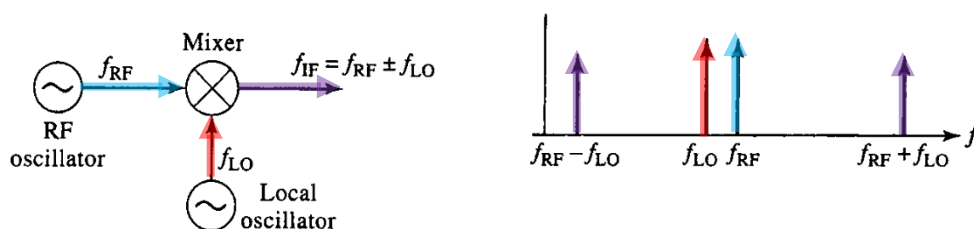
But this technology had problems – the circuitry was large and required significant power. The size and power requirements of heterodyne receivers were, at least in part, the result of the number of components these receivers used in order to perform down-conversion.

93. 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.

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



95. 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.



96. 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).² 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.

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

² 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).

nonlinear device.

98. 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 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.³

99. In the late 1980s through 2000, the dominant type of mixer being used had practical nonlinearity inherent in the process of multiplying an RF signal and an LO signal. In such a mixer, noise and nonlinear distortion generated by the mixer

³ I note that I am not stating that any mixer that multiplies is a non-linear 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. 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 problems.

100. 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.

101. In the late 1980s through 2000, heterodyning mixers 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.

102. The term “mixer” has changed meaning over time and has lost its original meaning. Prior to the time of the invention of the ’686 patent, a “mixer” referred to the configuration set forth above, which was not an energy sampler. After the time of the invention of the ’686 patent, companies began to develop energy samplers and refer to them as “mixers.” As such, the term “mixer” has become a generic term to refer to different configurations that performs down-conversion or up-conversion. As used today, the term “mixer” really says nothing about how a circuit operates or the specific configuration of the circuit. As such, when analyzing a component referred to as a “mixer,” one needs to look at the operation and configuration of the circuit to determine the technology that is being implemented.

103. 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.

104. In the late 1980s through 2000, the 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.

105. ParkerVision's inventions addressed these problems.

106. The technology of the claims of the '686 patent simultaneously a) operates efficiently, b) can be realized in an integrated circuit, c) achieves performance that enables high-performance protocols, d) can be mass produced with excellent yield, and e) eliminates/reduces many expensive and bulky external components (i.e., components (e.g., filters) that device manufacturers (e.g., cellular phone manufacturers) must include in their device external to the RF chip).

B. Sampling

107. 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.

108. Sampling-based down-conversion systems can be further categorized into two distinct types: (1) energy transfer (energy sampling) systems – the technology claimed in the '686 patent, and (2) voltage sampling systems.

1. Voltage sampling.

109. 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).

110. In the late 1990s through March 2000, 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 sample the voltage of the RF signal itself. Such a solution was quite logical – replicate voltage as faithfully as possible and hold the sampled voltage on a capacitor. Holding the voltage level for an interval of time required that there should be no charge leaving (i.e., discharging from) the capacitor. As such, the state-of-the-art at that time was to use a sample-and-hold system to accomplish this.

111. 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.

112. 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.-2011

at p. 5. The above quoted description and analysis applies to voltage sampling in general.

113. 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, without an accurate reading of the voltage, the baseband signal cannot be accurately recreated (the system would not work). 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.

2. Energy Sampling.

114. In the late 1990s through March 2000, 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.

115. 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 '686 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.

116. Only through hindsight (with knowledge of the '686 patent) would a POSITA have looked into using energy sampling instead of voltage sampling.

117. 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 form the down-converted (baseband) signal, i.e., the sampled energy from the input signal makes up/becomes part of the baseband signal itself. In an energy transfer system, energy is integrated on a storage module over multiple samples and a low impedance load is used. This configuration allows energy to continuously flow to the low impedance load and form 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).

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

119. 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).

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

121. 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). And what ParkerVision realized, and others did not, was that accurately capturing the voltage of the RF signal was not critical. ParkerVision realized that using most or all of the available energy was the best way to form the baseband signal. An advantage of ParkerVision's energy sampling system is that the energy stored on the capacitor is accumulated over multiple cycles of the RF signal. 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.

122. 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. U.S. PATENT NO. 7,483,686

A. Overview

123. The '686 patent discloses a system and method to up-convert and down-convert an electromagnetic signal (radio frequency signal). The '686 patent describes a communication system incorporating a universal platform module (UPM) that supports multi-protocol and multi-bearer services. '686 patent, Abstract. The UPM includes universal platform sub-modules (UPSM), each of which includes a universal frequency translation (UFT) module. The UPSMs are connected to different types of networks, such as cellular and WLAN networks. *See, e.g.*, '686 patent, 35:12-38, Fig. 26C.

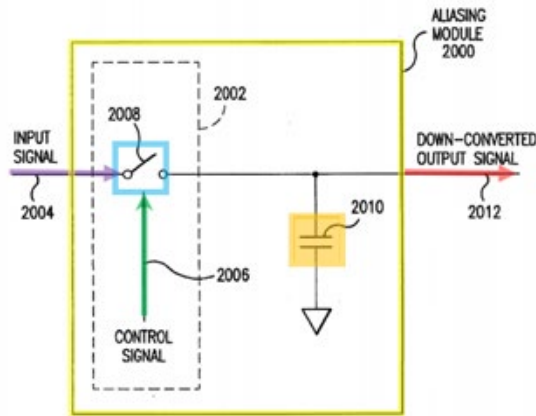


FIG. 20A

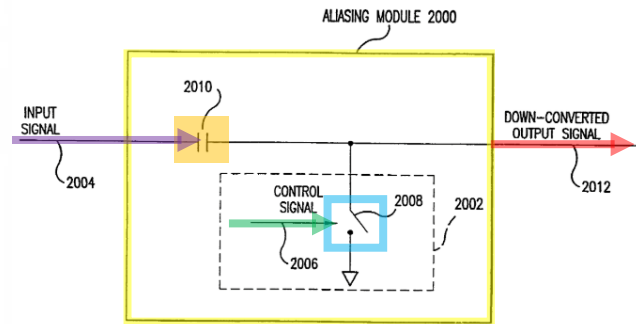


FIG. 20A-1

124. Figure 20A (above left) shows the basic configuration of an aliasing module 2000 for down-conversion. Aliasing module 2000 (yellow) includes (1) a universal frequency translation (UFT) module 2002 (implemented as a switch 2008 (blue) with a control signal 2006 (green) for controlling the switch) and (2) a capacitor 2010 (orange) for storing and discharging energy. The switch receives an input signal 2004 (purple arrow), samples the signal as discussed below, and outputs a down-converted output signal 2012 (red arrow). In this configuration, the switch 2008 is in series with input signal 2004 and capacitor 2010 is shunted to e.g., ground.

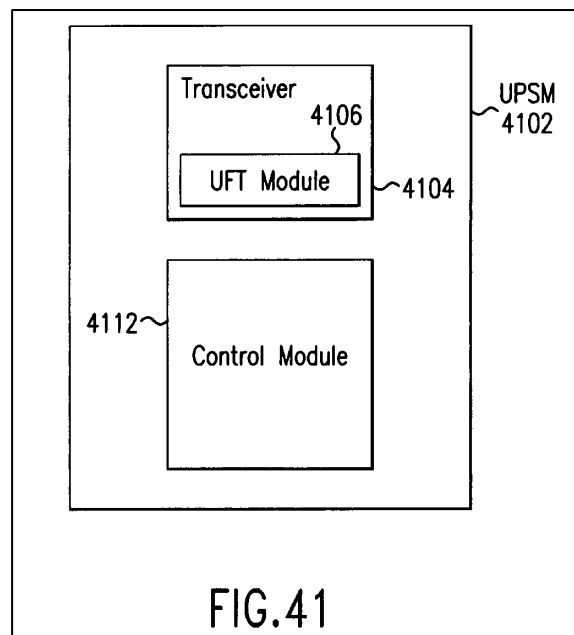
125. Figure 20A-1 shows another configuration of the aliasing module 2000 of Figure 20A. In Figure 20A-1, the capacitor 2010 is in series with input signal 2004 and the switch 2008 is shunted to e.g., ground.

126. The configurations of Figures 20A/20A-1 will operate in the same way.

127. The '686 patent specifies that “[w]hen the pulses of the control signal 2006 have non-negligible apertures, the aliasing module 2000 is referred to

interchangeably herein as an energy transfer module or a gated transfer module, and the control signal 2006 is referred to as an energy transfer signal.” ’686 patent, 13:27-31

128. The ’686 patent discloses various embodiments where the aliasing/UFT modules of Figures 20A/20A-1 can be incorporated, e.g., transceiver 4104 of Figure 41.



129. UPSM 4102 includes a transceiver 4104 with one or more UFT modules 4106.. The UPSM also includes a control module 4112 which enables the UPSM 4102 to operate according to multiple protocol/bearer service combinations (FIG. 39) and/or multiple communication link/types (FIG. 40). *Id.* at 38:63-39:21. The UPSM 4102 operates according to one or more protocol/bearer service combinations and/or communication link/types simultaneously at any given

time. *Id.* This enables the UPSM 4102 to perform simultaneous processing of multiple protocol/bearer service combinations and/or communication link/types. *Id.*

B. The patent disclosure regarding down-conversion systems.

130. U.S. Patent No. 6,061,551 (“the ’551 patent”) (Ex. 1008) is incorporated by reference into the ’686 patent. The disclosure regarding down-conversion is incorporated by reference.

131. The ’686 patent (through its incorporation of the ’551 patent) discloses two systems for down-conversion: (1) energy transfer (energy sampling) and (2) sample and hold (voltage sampling).

132. The claims of the ’686 patent are directed only to energy transfer, because they use the concepts the patentees reserved specifically to connote energy transfer.

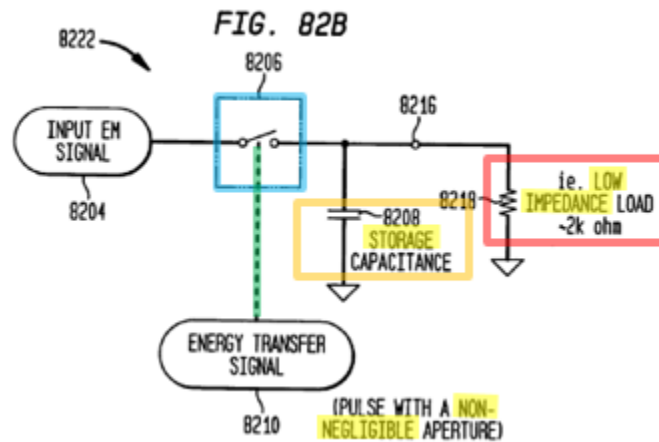
133. Energy transfer and sample/hold are distinctly different technologies. In energy transfer, the down-converted signal includes the energy⁴ from the RF signal; in voltage sampling, the down-converted signal is derived from discrete voltage readings of the RF signal.’551 patent, 66:33-68:15 (energy transfer system); 54:45-55:2 (sample/hold system). While energy transfer and sample/hold both result in down-converted signals, an energy transfer system results in a higher quality

⁴ Energy and voltage are not the same thing. Energy is the product of voltage multiplied by current multiplied by time (i.e., energy = voltage x current x time).

baseband signal and, therefore, allows for wireless devices with fewer components, reduced size and cost, and increased battery life. *Id.*, 62:60-63, 66:34-54.

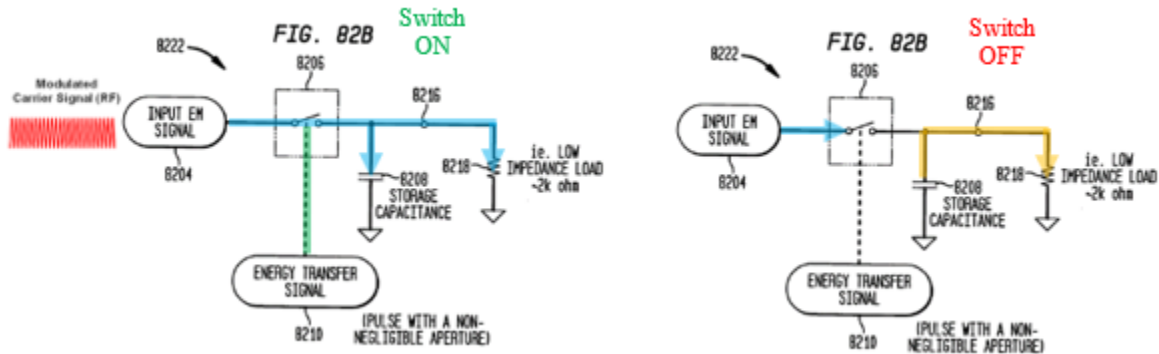
1. Energy Transfer (energy sampling).

134. Figure 82B of the '551 patent (below) illustrates an energy transfer (energy sampling) system, which would be incorporated into a transceiver chip of a wireless device.

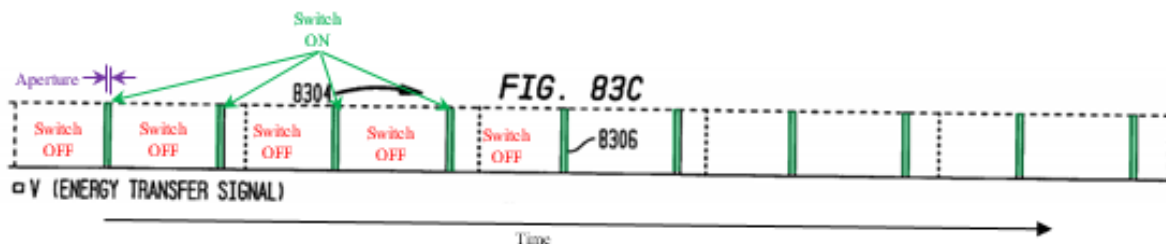


135. The system includes a switch 8206 (blue), an energy transfer signal 8210 (green) for controlling the switch, a “storage” capacitor 8208 (orange) for storing and discharging energy, and a low impedance load (red). Notably, there are several key features (yellow highlights) that distinguish an energy 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.



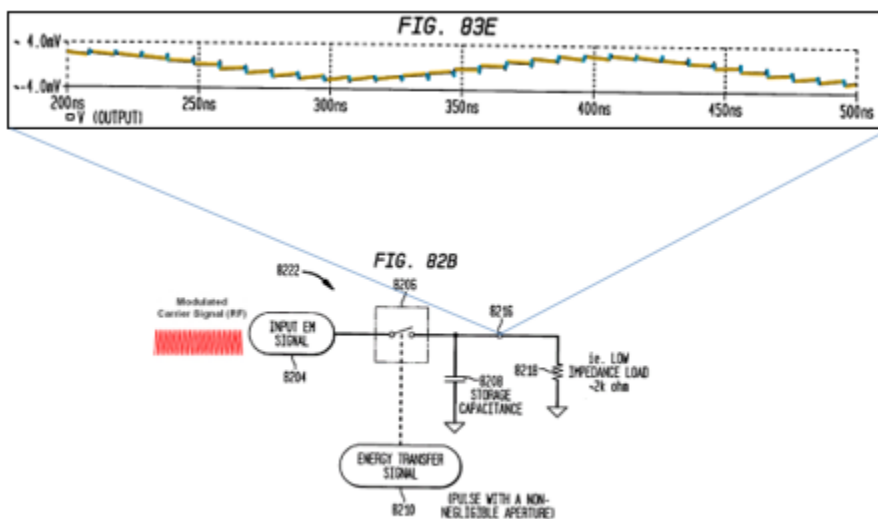
136. The annotations in Figure 82B above illustrate how an energy transfer system down-converts a high frequency input EM signal 8204 (e.g., modulated carrier signal (red)) to a baseband signal. In particular, down-conversion occurs by repetitively opening and closing the switch 8206.



137. 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

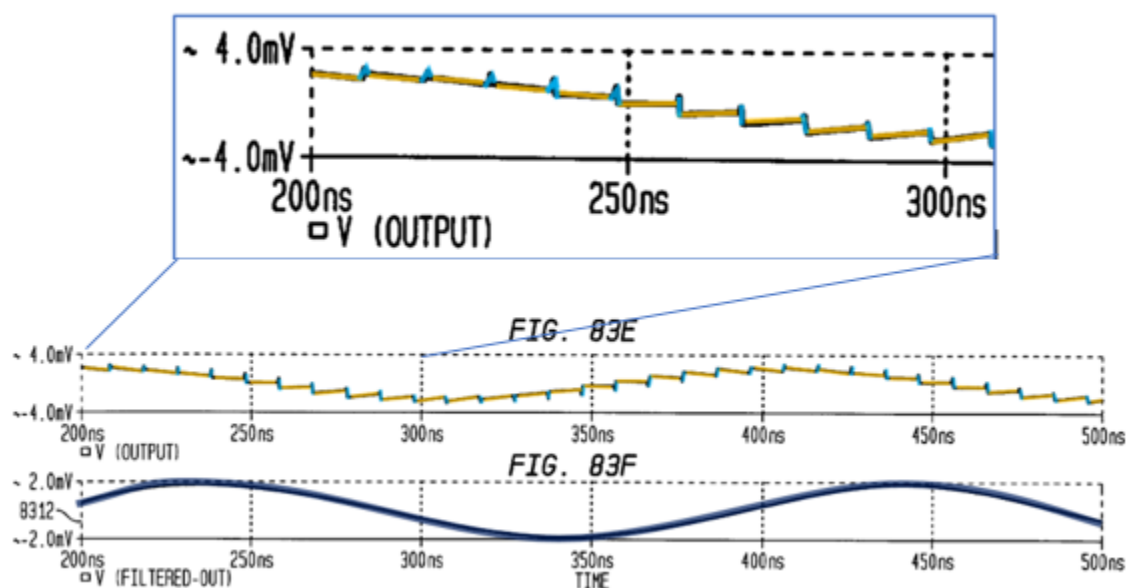
shown by the repetitive pulses 8306, this opening and closing of the switch repeats continuously over time.

138. 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.” ’551 patent, 67:42-46.



139. 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

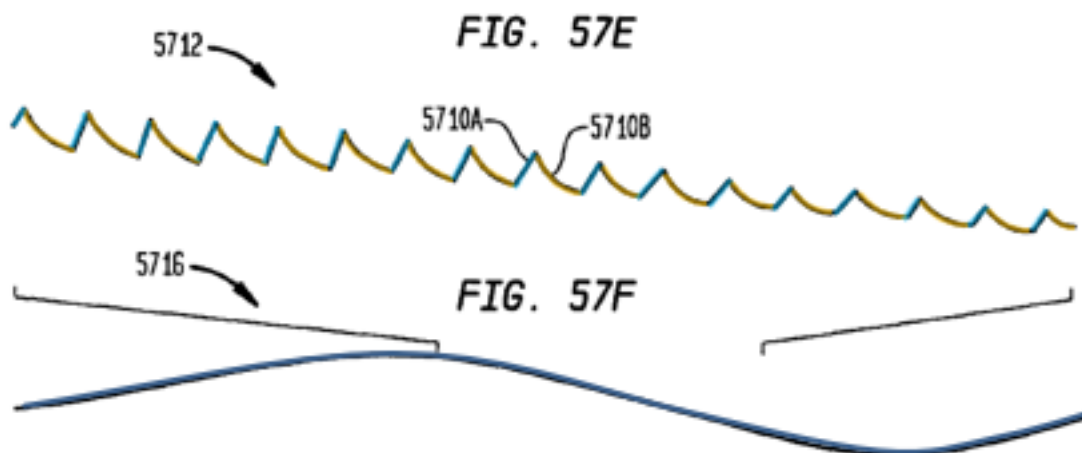
up of energy (blue) from the EM signal and discharged energy (orange) from the “storage” capacitor. Indeed, the discharged energy (orange) from the “storage” capacitor is essential. Without the discharged energy, the waveform of Figure 83E would be incomplete (the orange portions would be missing), thereby producing a degraded and/or unusable signal that could not be properly processed by a receiving wireless device.



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

141. The figures below illustrate a close-up view of another embodiment of

a down-converted signal in an energy transfer system.

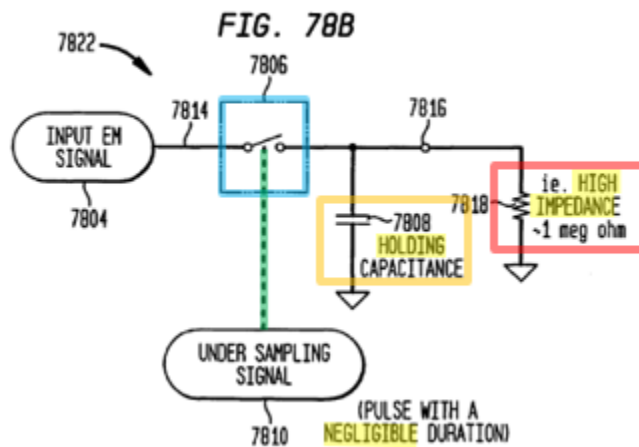


142. FIG. 57E shows a segment 5712 of the down-converted signal 5716 of FIG. 57F. The down-converted signal of FIG. 57E is made up of two portions - portion 5710A (i.e., energy (blue) from the EM signal) and portion 5710B (i.e., discharged energy (orange) from the “storage” capacitor). The baseband signal 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/hold (voltage sampling).

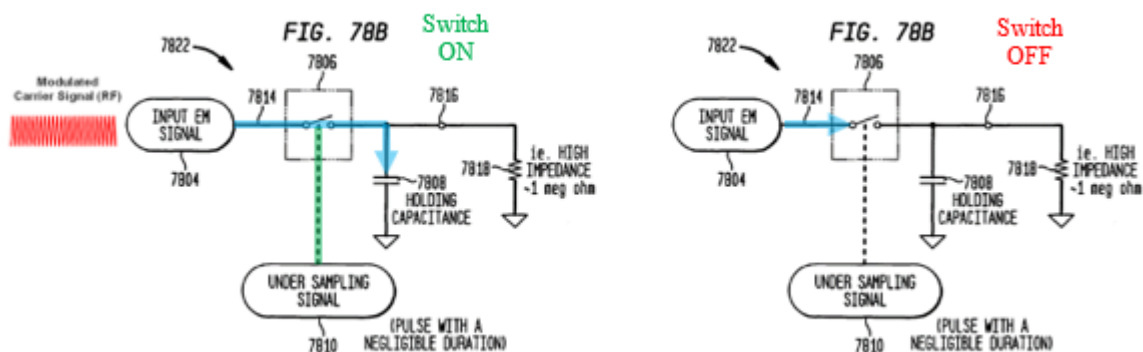
143. Figure 78B of the '551 patent illustrates a sample and hold (voltage

sampling) system.

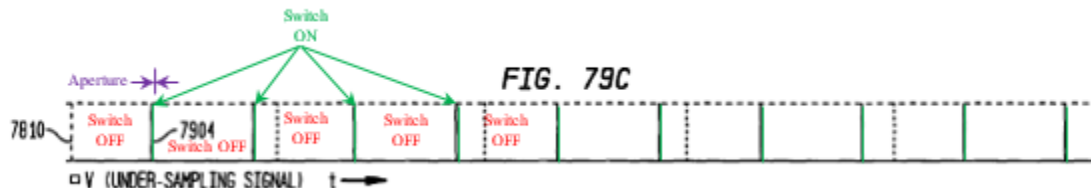


144. The system includes a switch 7806 (blue), a control signal 7810 (green) for controlling the switch, a “holding” capacitor 7808 (orange) for holding a voltage across the capacitor, and a high impedance load (red). Unlike an energy transfer system, a sample and hold system uses (1) a control signal 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).



145. 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.

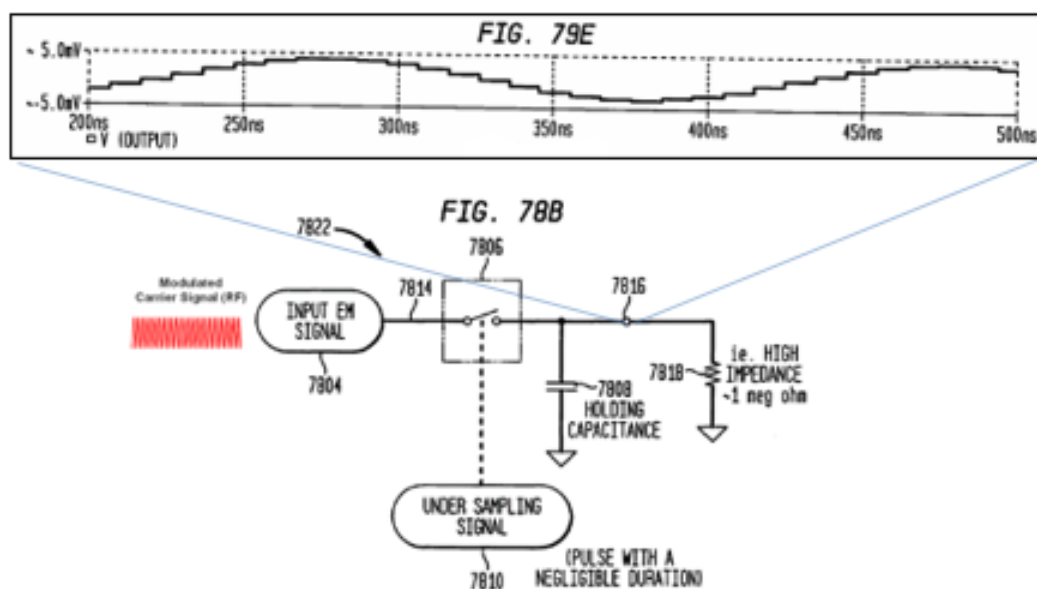


146. As shown in Figure 79C, the switch is turned ON (closed) by sending a pulse 7904 (green vertical line) of an extremely short/negligible duration to the switch. Thus, the aperture (purple) of a pulse is referred to as a negligible aperture because the pulse width “tend[s] toward zero time.” ’551 patent, 63:45-47. As shown by the repetitive pulses 7904, this opening and closing of the switch repeats continuously over time.

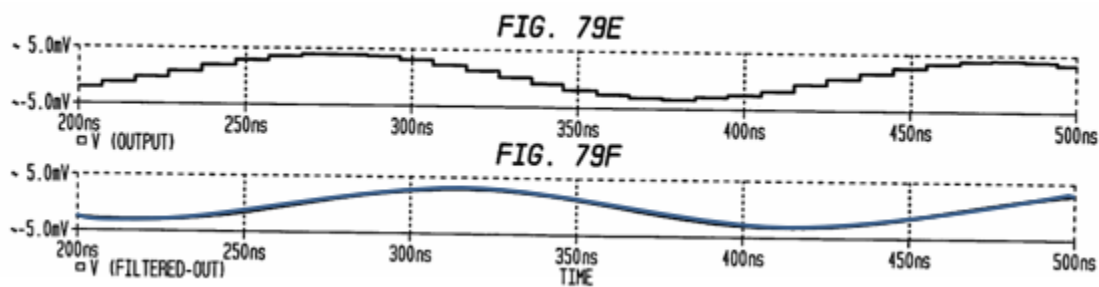
147. As shown in Figure 78B above, when the switch is ON (closed) (during

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.

148. Because there is no significant energy discharge between pulses, the terminal 7816 maintains a constant voltage value until the next pulse. *Id.* at 64:21-26. 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.



149. 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.* at 64:26-30.



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

C. Claims of the '686 patent.

151. The claims of the '686 patent are directed to energy transfer (energy sampling). I noted that the claims use terms that specifically refer to energy transfer systems (energy sampling systems). See Sections VIII.B.2 and IX.B.1

152. Claims 1 and 11 recite “a switch configured to operate according to an energy transfer signal, and to sub-sample and transfer energy from a first

electromagnetic (EM) signal.”⁵

153. Claim 11 recites “a storage module coupled to said switch and configured to *store said transferred energy*, wherein *a second EM signal is generated from said stored energy*.”

154. The language above captures key aspects of energy transfer systems.

X. CLAIM CONSTRUCTION

155. 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. “Switch”

156. Claims 1 and 11 recite a “switch.”

157. I understand that the U.S. Patent Trials and Appeal Board (“PTAB”) in IPR2021-00346 construed “switch” to mean “an electronic device for opening and

⁵ Unless otherwise noted, I have added all emphasis in my declaration.

closing a circuit.”

158. I also understand that Federal Circuit affirmed the PTAB’s construction. *ParkerVision, Inc. v. Vidal*, No. 2022-2173, at 2.

159. I have therefore applied the PTAB’s construction of “switch” in my analysis below.

B. “Energy Transfer Signal”

160. Claims 1 and 11 of the ’686 patent each recite “a switch configured to operate according to an energy transfer signal.”

161. At the time of the invention, a POSITA would have understood that an “energy transfer signal” is “an independent control input of an energy transfer system having pulses with non-negligible apertures.”

162. The ’686 specification states that “[w]hen the *pulses* of the control signal 2006 have *non-negligible apertures*, the aliasing module 2000 is referred to interchangeably herein as an energy transfer module or a gated transfer module, and *the control signal 2006 is referred to as an energy transfer signal.*” ’686 patent, 13:27-31.

163. As shown in Figures 51A-51B, 61 of the ’686 patent (and Figures 46A-46D, 48, 50C, 57C, 63, 64A-64B, 65, 67A-67B, 68G, 69, 74, 76A, 76C, 76D, 82A, 82B, 83C, 85A, 85C, 94A, 95), the ’686 and ’551 patents specifically use the term “energy transfer signal” to exclusively describe the signal in an energy transfer

system. The specification reserves the term “under sampling signal” to be used exclusively to describe the signal in a voltage sampling system.

164. Moreover, the specification discloses that the energy transfer signal is an independent control input – i.e., the signal is a separate input from the signal input into switch and the signal output from the switch. *See* Figures 1A-1C, 2, 19, 20A, 20A-1, 25B, 28, 29, 45A-45D, 47, 51A, 51B, 61; ’551 patent, Figures 28A-28D, 63, 64A, 64B, 65, 66A-66D, 67A, 68G, 69, 74, 76A-76E, 82A, 82B, 94A, 95.

165. The use of an independent control input is not merely an embodiment. It is how the claimed system works. The systems shown in the figures identified above would not work to transfer energy and generate a signal from storage energy without the energy transfer signal being an independent control input.

C. “Storage module”

166. Claim 11 recites a “storage module.”

167. I understand that the PTAB in IPR2020-01265 construed the term “storage element” to mean “an element of a system that stores non-negligible amounts of energy from an input EM signal.”

168. I also understand that the Federal Circuit agreed with the PTAB’s construction. *ParkerVision, Inc. v. Vidal*, 88 F.4th 969, 977 (Fed. Cir. 2023).

169. I have therefore applied the PTAB’s construction of “storage element”

in my analysis below with regard to “storage module.”

D. “Coupled”

170. Claim 11 recites “a storage module coupled to said switch.”

171. I understand that the district court in *ParkerVision, Inc. v. NXP BV et al.* (Case No. 6:23-cv-00389-ADA) construed the term “coupled” in the ’686 patent as plain-and-ordinary meaning wherein “coupled” includes both direct and indirect connections.

172. It is my opinion that the district court’s construction is correct and accurately captures the meaning of “coupled” as understood by a POSITA.

E. “Multi-platform module”

173. Claims 1 and 11 recite “multi-platform module.”

174. I understand that the district court in *ParkerVision, Inc. v. NXP BV et al.*, (Case No. 6:23-cv-00389-ADA) construed the term “multi-platform module” in the ’686 patent as plain-and-ordinary meaning.

175. It is my opinion that the district court’s construction is correct and the term “multi-platform module” should be given its plain and ordinary meaning.

F. “Sub-sample”

176. Claims 1 and 11 each recite “a switch configured to operate according to an energy transfer signal, and to sub-sample and transfer energy from a first electromagnetic (EM) signal.”

177. I understand the parties agree that the term “sub-sample” refers to

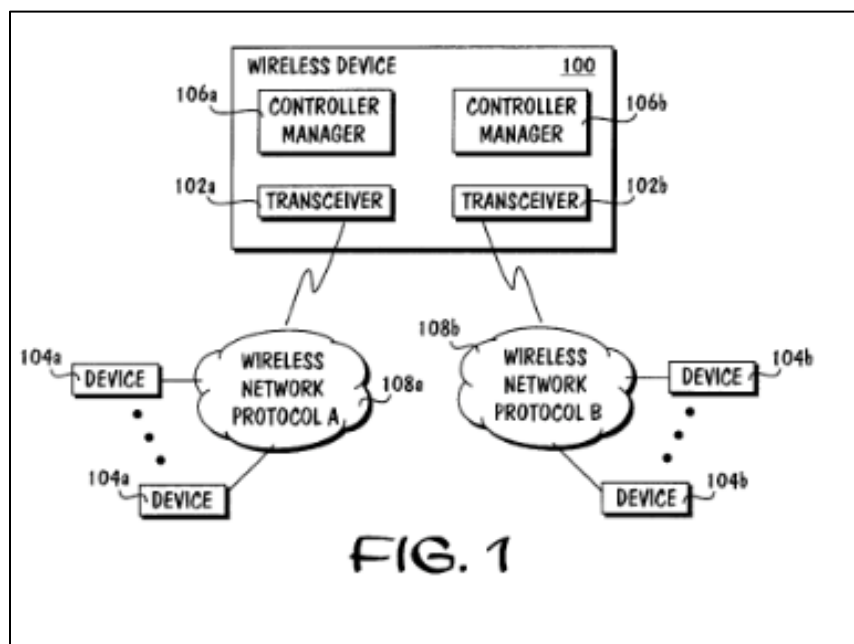
sampling at an aliasing rate. I have therefore applied this construction in my analysis below.

XI. OVERVIEW OF THE ALLEGED PRIOR ART

A. U.S. Patent No. 6,600,726 to Nevo et al. (“Nevo”)

178. Nevo is entitled “Multiple Wireless Communication Protocol Methods and Apparatuses.” Ex. 1004. Nevo discloses a wireless device that facilitates communication across multiple wireless networks. *Id.*, Abstract.

179. Nevo describes a wireless device “with at least one wireless transceiver and at least one controller manager to transmit and receive signals wirelessly to and from network devices of a first and second wireless network, in a coordinated manner, in accordance with a first and a second protocol respectively.” *Id.*



180. Figure 1 of Nevo illustrates a wireless device 100 having controller managers 106a/106b that operate a plurality of transceivers 102a/102b to

communicate with respective communication networks running different wireless network protocols 108a/108b, including Bluetooth, IEEE 802.11, and Home RF. *Id.*, 3:27-35, 4:46-55.

B. Avitabile et al., “S-band digital downconverter for radar applications based on GaAs MMIC fast sample-and-hold” (“Avitabile”)

181. Avitabile describes a sample-and-hold system. Avitabile discloses a “digital downconverter configuration which performs complex detection by means of a *sample-and-hold (SH)* in a single step by using a single-channel configuration.” Ex. 1006, 337. Avitabile explains that “[t]he key element of the down-converter is a very fast sampling circuit directly operating within the S-band.” *Id.*

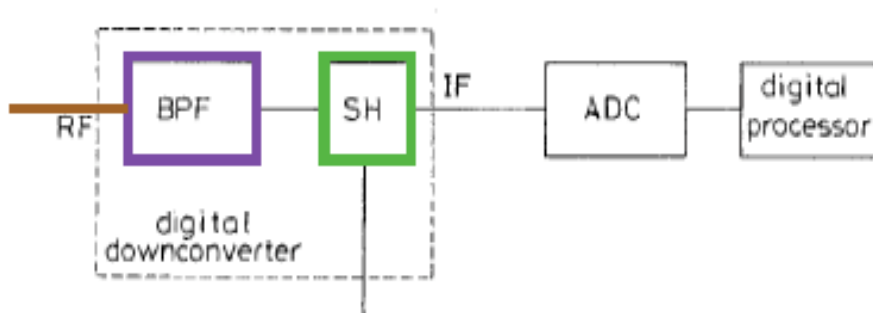


Fig. 1 Schematic diagram

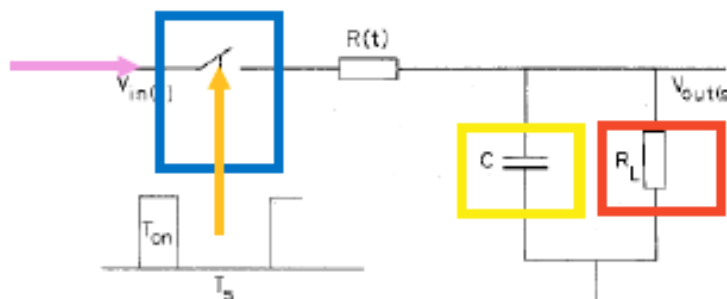
182. As shown in Figure 1, Avitabile shows a block diagram of the digital down-converter configuration, including a bandpass filter (purple) and sample-and-hold (SH) circuit (green). An incoming signal (brown) is filtered through a bandpass filter (purple) and directed to the SH circuit (green) for complex sampling.

183. After sampling, the signal is sent to an A/D converter (ADC) for digital

conversion. “As the digital conversion [at the ADC converter] requires each sample to be held to a fixed value during the conversion interval, it is convenient to perform both *sampling and holding* operations in one step,” which is accomplished by the S/H circuit. Ex. 1006, 338.

184. A POSITA understands that an ADC has a high input impedance so that it can accurately measure the voltage on its input and convert this voltage into a digital signal. *See id.*, 340 (referring to “commercially available A/D converters.”).

185. A POSITA would recognize that no energy flows into the ADC or forms part of the baseband signal.



186. Figure 2 of Avitabile shows a S/H circuit including a switch (blue), a hold capacitor (yellow) and load (implemented as a resistor R_L , red). According to Avitabile, “[i]n the circuit of Fig. 2, C and R_L represent, respectively, the hold capacitor and the load of the buffer stage following the SH circuit.” *Id.*, 338. Resistor R_L is high impedance.

187. A POSITA would understand that R_L is designed to have very high

impedance, as a “buffer stage” following the S/H circuit is intended to buffer the signal. This buffering function isolates the input from the output, ensuring that the signal is not disturbed by downstream components. Moreover, the buffer does not allow energy to flow through it, rather it reads the voltage at its input and then produces that voltage at its output, isolating the output from the input.

188. Avitabile discloses two implementations for voltage sampling: (i) impulse sampling, where “[t]he switch is turned on for a very short time interval t_{on} whose duration is inversely proportional to the RF bandwidth”; and (ii) track-and-hold (TH), where “the input RF signal is sampled after a convenient acquisition time t_{ac} , defined as the time to settling within 1/2 LSB of steady-state at full-speed input signal.” *Id.*, 338-339.

189. [Intentionally Omitted]

190. As shown in Figure 2, in either implementation, an input signal (pink arrow) is received by the switch (blue). The switch is turned ON (closed) by sending a pulse (orange arrow) to the switch. When the switch is ON (closed), the input signal is sent to the “hold” capacitor (yellow). When the switch is OFF (opened) the voltage at the output is held at a constant voltage level so that an ADC can read its value.

191. A POSITA understands that the resistor R_L (red) is a high impedance load, because Avitabile specifically states that “at the time the switch is turned off,

nominally the whole of the input waveform drops across the hold capacitor.” *Id.* at 339. A POSITA also understands that in order to hold voltage on the capacitor, resistor R_L must be a high impedance load. The high impedance load prevents the holding capacitor (yellow) from discharging.

192. Avitabile discloses two different S/H prototypes based on a diode bridge sampling function: SH1 prototype and SH2 prototype.

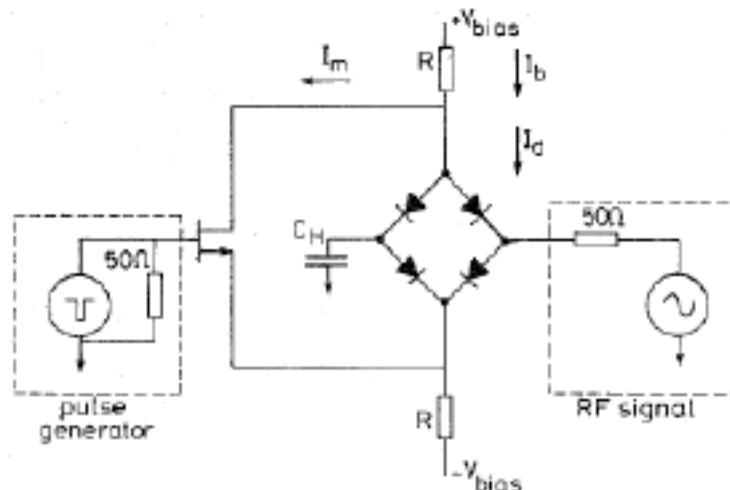


Fig.4 Schematic diagram of SH1 sample-and-hold circuit

193. Figure 4 illustrates the SH1 prototype, which follows the same operation as the S/H circuit above:

In the sample mode, the switching MESFET is turned off and the diodes of the bridge are directly biased, letting the input waveform drop across C_H . In the hold mode, the MESFET is turned on. The voltage difference between drain and source drops to about 0.5V. Consequently the two series-connected diodes in the two arms of the bridge become inversely biased and the hold capacitor is disconnected by the RF source.

Ex. 1006, 340.

194. A POSITA understands that in the “hold” mode, the voltage at the output is held at a constant voltage level so that an ADC can read its value: the hold period “is consistent with the acquisition time of several commercially available A/D converters.” *Id.* In other words, in the “hold mode,” the SH1 prototype is designed to prevent discharge from the hold capacitor C_H .

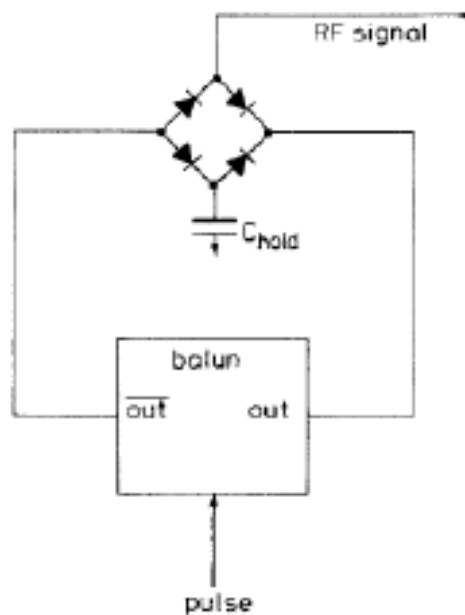


Fig.8 Downconverter schematic diagram

195. Figure 8 illustrates the SH2 prototype. As with SH1 prototype, the SH2 prototype follows the same operation as the SH circuit described above.

196. In a “sample” mode, the balun delivers a current pulse that biases the diode bridge to conduct, sending the input signal to the hold capacitor C_H . In “hold” mode, the balun sends a pulse with the opposite polarity, disconnecting the hold

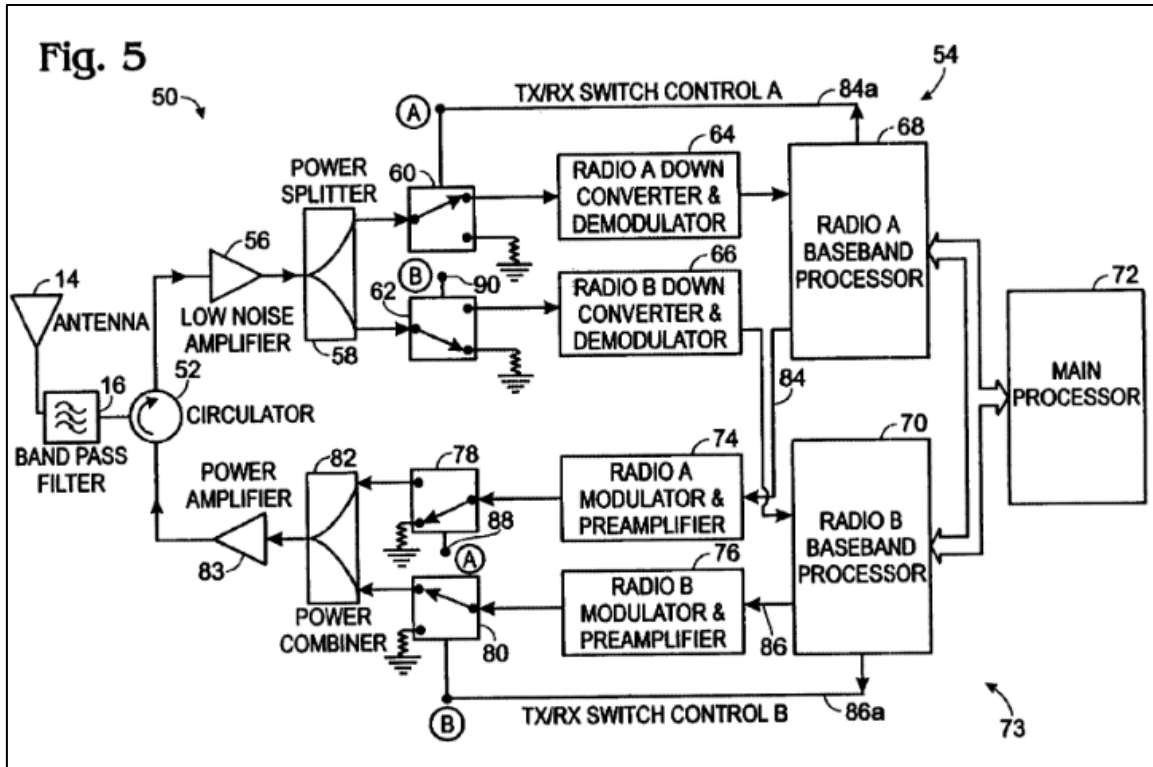
capacitor C_H from the input signal.

197. A POSITA understands that the SH2 prototype is designed to prevent the hold capacitor C_H from discharging in the “hold” mode, allowing the ADC to capture an accurate analog voltage. In the “hold mode,” the SH2 prototype is designed to prevent discharge from the hold capacitor C_H .

C. U.S. Patent No. 6,643,522 to Young (“Young”)

198. Young is entitled “Method and apparatus providing simultaneous dual mode operations for radios in the shared spectrum.” Ex. 1003.

199. Young discloses a system and method for enabling a single wireless device to operate in two different communication modes within the same shared spectrum, specifically addressing interference and desensitization issues when multiple radios operate simultaneously in close proximity. *Id.*, 2:37-67. Young proposes a hardware-based approach that allows two radios, each using a different air interface, to share a common antenna and front-end circuitry while minimizing



200. Figure 5 illustrates the architecture of a wireless transceiver 50 that incorporates two radios—Radio A and Radio B—operating on different air interfaces. *Id.*, 5:66-6:2.

201. Transceiver 50 uses a circulator 52 as part of an isolation mechanism, enabling simultaneous operation of both radios by directing signal flow in a controlled manner to prevent transmitter power from desensitizing the receivers. *Id.*, 6:56-66.

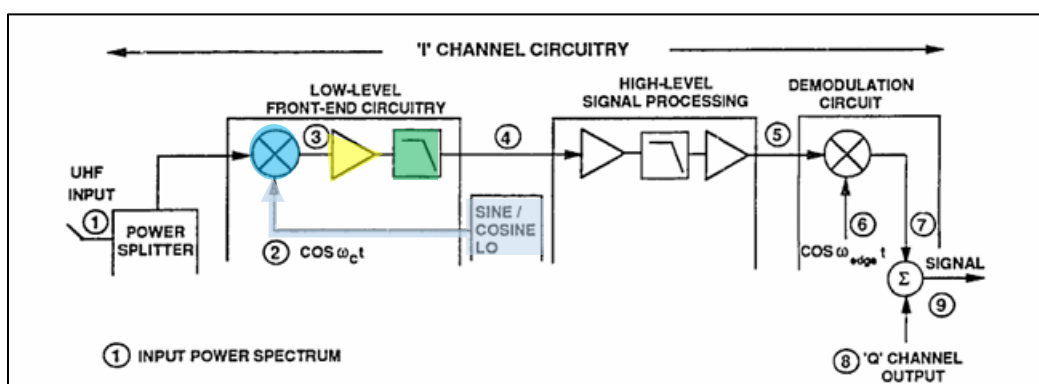
202. The receive chain 54 of transceiver 50 includes a low-pass amplifier 56 and a power splitter 58, which divides incoming signals for processing by both radios. *Id.*, 6:3-6. Each radio's receive path includes a transmit/receive (Tx/Rx)

switch—60 for Radio A and 62 for Radio B—followed by a down converter/demodulator 64, 66 and a baseband processor 68, 70. *Id.*, 6:6-12. A main processor 72 coordinates transceiver functions, managing both radios' operations. *Id.*, 12-13.

D. Estabrook-Thesis

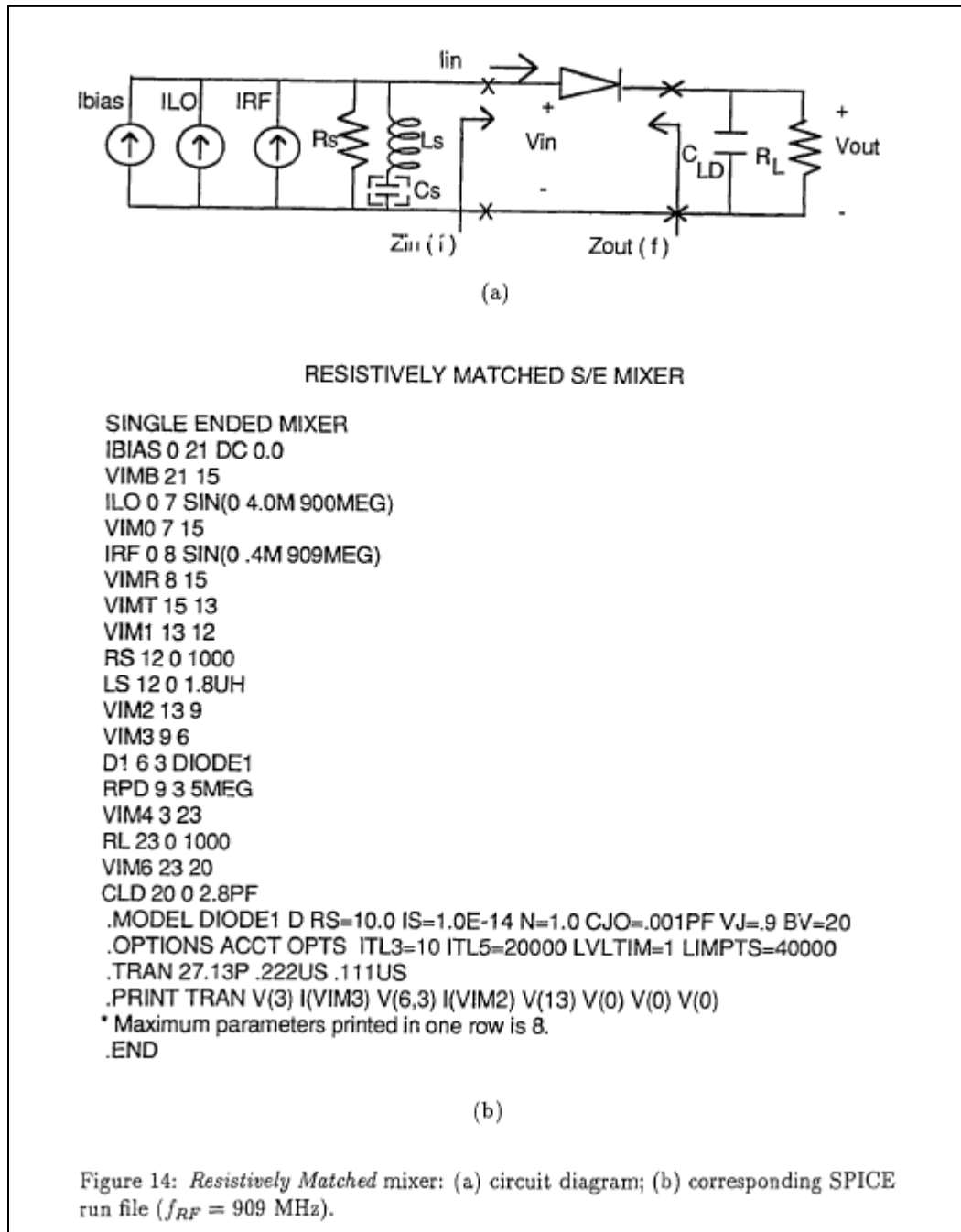
203. Polly Estabrook's dissertation *The Direct Conversion Receiver: Analysis and Design of the Front-End Components* (Ex. 1005, "Estabrook") discusses the design of direct conversion receivers.

204. Estabrook examines how direct conversion techniques can be used for single-channel reception in low-cost, compact transceivers, particularly by eliminating the need for intermediate frequency (IF) stages used in traditional superheterodyne receivers. Ex. 1005, 8-9.



205. Figure 4 illustrates a direct down conversion receiver including a mixer (blue), an amplifier (yellow), a filter (green), and a sinusoidal signal (sine/cosine

LO) (pink) that is input to the mixer.



206. Figure 14(a) illustrates a resistively matched single-ended mixer, featuring a diode-based mixer topology with an input signal processed through a resistive matching network. The SPICE simulation run file (Figure 14(b)) details the

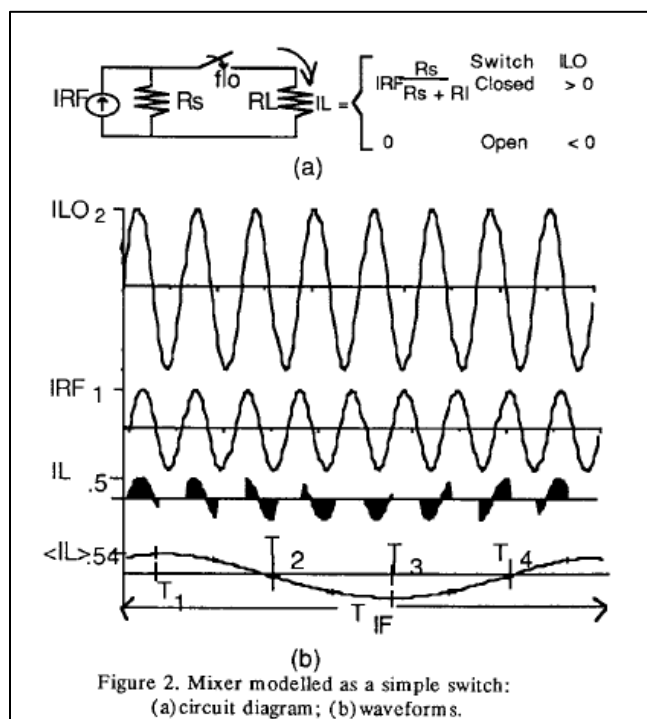
electrical parameters used to simulate the mixer's transient response.

207. Figure 14 includes RF and LO sources shown as current sources with a common source impedance, R_s . Ex. 1005, 57.

E. Estabrook-1988

208. Estabrook-1988 is entitled "A Mixer Computer-Aided Design Tool Based In the Time Domain." Ex. 1016.

209. Estabrook-1988 discloses a time-domain approach to mixer circuit design and presents a computational tool that facilitates analysis of RF mixer circuits.



210. Figure 2(a) of Estabrook-1988 illustrates the theoretical operation of an ideal mixer with a switch driven at a local oscillator frequency f_{LO} . Figure 2(b) plots

the current waveforms of the LO signal (ILO), RF signal (IRF), current in resistor RL (IL) and its value averaged over one LO period(<IL>).

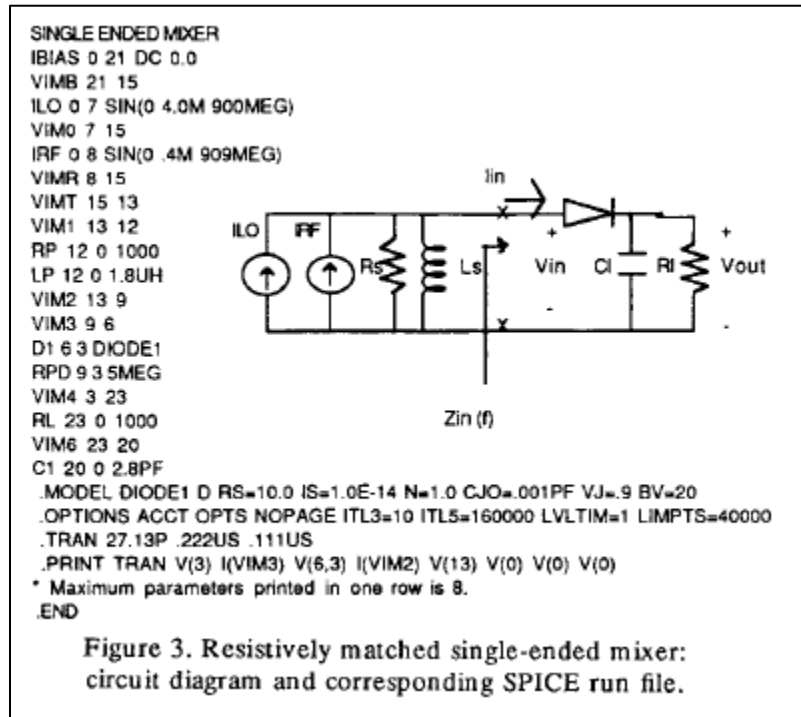


Figure 3. Resistively matched single-ended mixer: circuit diagram and corresponding SPICE run file.

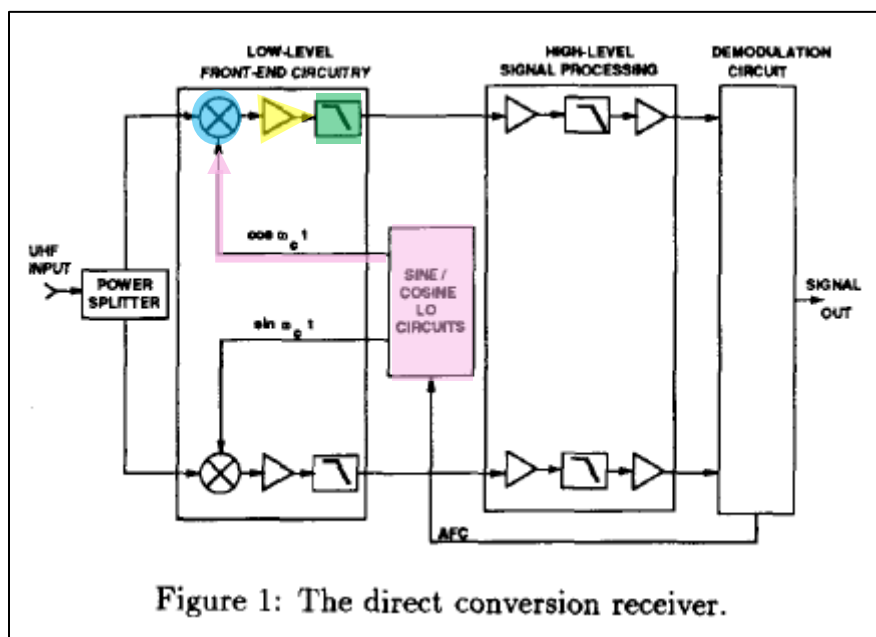
211. Figure 3 illustrates the circuit design of a simple broadband single-ended mixer using a purely resistive diode.

F. Estabrook-1989

212. Estabrook-1989 is entitled “The Design of a Mobile Radio Receiver using a Direct Conversion Architecture.” Ex. 1017.

213. Estabrook-1989 discloses the implementation of a direct conversion receiver (DCR) and explains advantages of using a direct down-conversion

architecture instead of conventional heterodyne receivers.



214. Figure 1 in Estabrook-1989 provides a high-level architecture of the direct conversion receiver, which includes an RF mixer at the front end. Figure 1 includes a mixer (blue), an amplifier (yellow), a filter (green), and a sinusoidal signal (sine/cosine LO) (pink) that is input to the mixer.

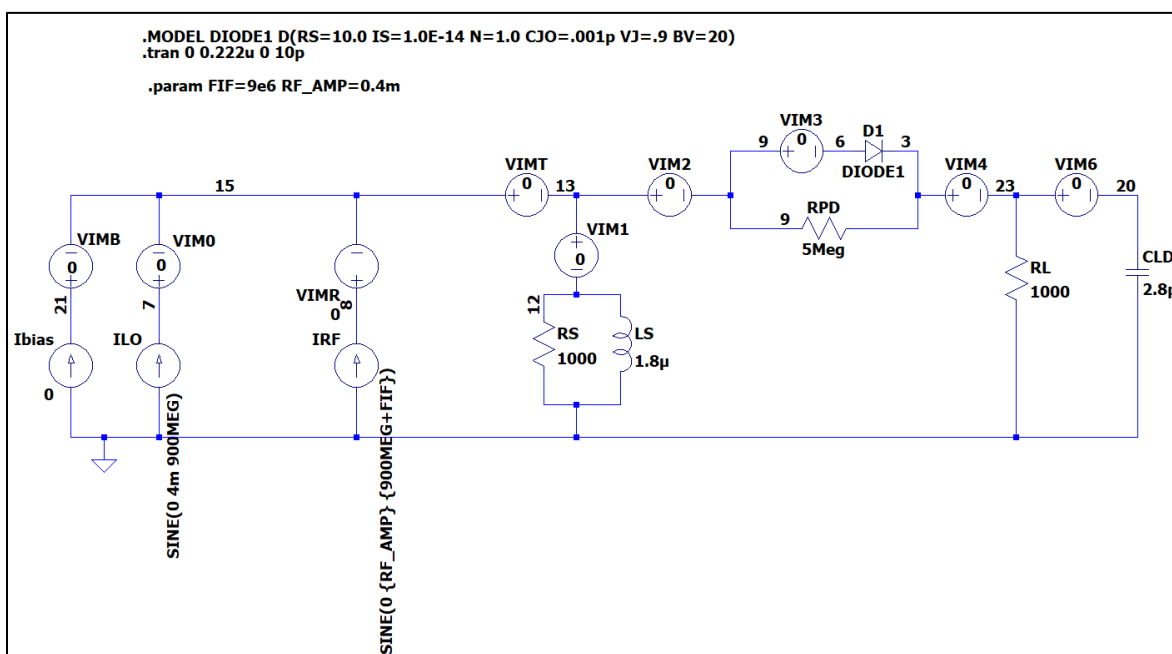
XII. SIMULATIONS

215. My analysis of the Estabrook references includes a simulation of the mixer circuit depicted in Figure 14(a) of Estabrook-Thesis. I note that the SPICE run file provided in Figure 3 of Estabrook-1988 is identical to the SPICE run file in Figure 14(a) of Estabrook-Thesis. Therefore, my analysis applies equally to both references, and I will collectively refer to the circuit as the Estabrook circuit throughout this section.

216. The Estabrook circuit, as described in Estabrook-Thesis and Estabrook-

1988, was implemented and simulated in LTspice 24.1.4 for Windows. The LTspice simulator is a well-known simulator.

217. Below, I provide a screenshot of the schematic along with the corresponding generated netlist. The schematic of the LTSpice simulation has additional components, but these are zero voltage, voltage sources, e.g. VIMT, VIM2, etc. which are for measuring current in the branch of the circuit. As they are zero volts, they do not affect the performance or function. They are just for data capture in the simulation.



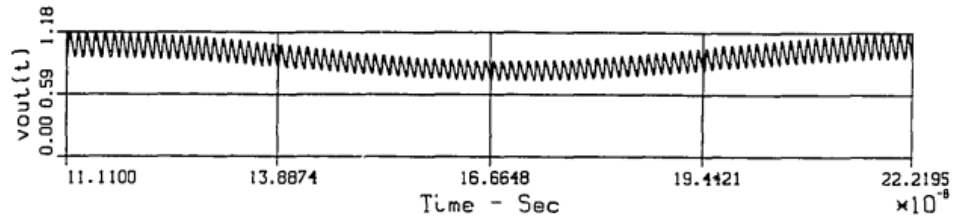
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Ibias 0 21 0
ILO 0 7 SINE(0 4m 900MEG)
IRF 0 8 SINE(0 {RF_AMP} {900MEG+FIF})
VIMB 21 15 0
VIM0 7 15 0
VIMR 8 15 0
VIMT 15 13 0
VIM1 13 12 0
RS 12 0 1000
LS 12 0 1.8μ
VIM2 13 9 0
VIM3 9 6 0
D1 6 3 DIODE1
RPD 9 3 5Meg
VIM4 3 23 0
RL 23 0 1000
VIM6 23 20 0
CLD 20 0 2.8p
.model D D
.lib C:\Users\va5114725\AppData\Local\LTspice\lib\cmp\standard.dio
.MODEL DIODE1 D(RS=10.0 IS=1.0E-14 N=1.0 CJO=.001p VJ=.9 BV=20)
.tran 0 0.222u 0 10p
.param FIF=9e6 RF_AMP=0.4m
.backanno
.end

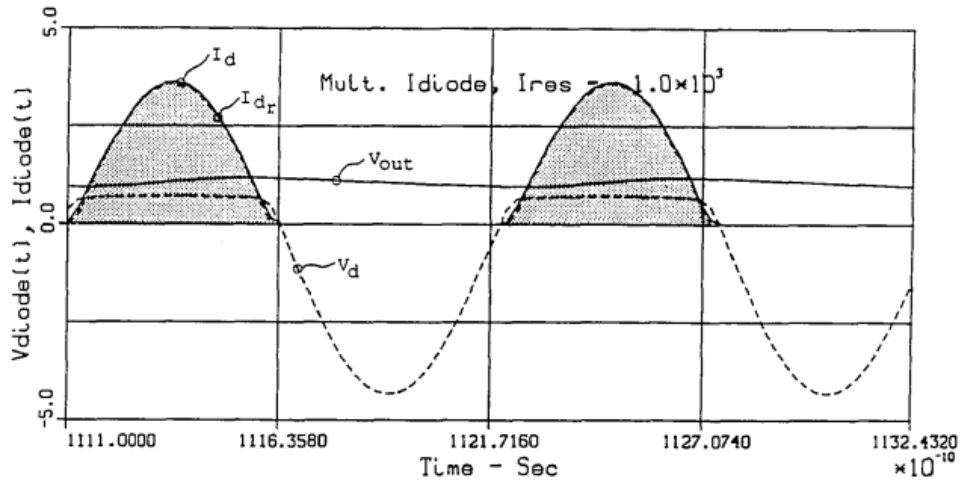
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218. The performance of the simulated mixer was compared to the reported results in Estabrook-Thesis (Ex. 1005, at page 48), as shown below. The comparison confirms that the simulations in the LTSpice match those described by Estabrook.

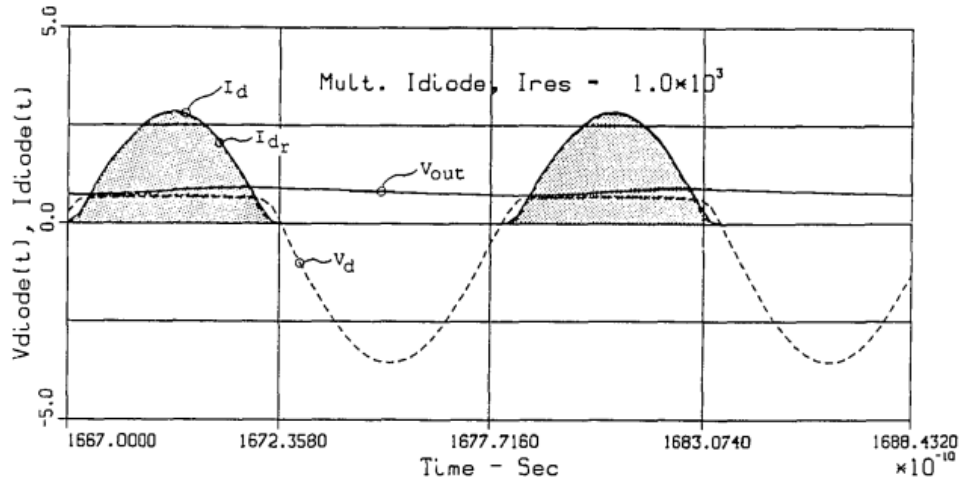
Single Ended Mixer - pdiod5575.dat



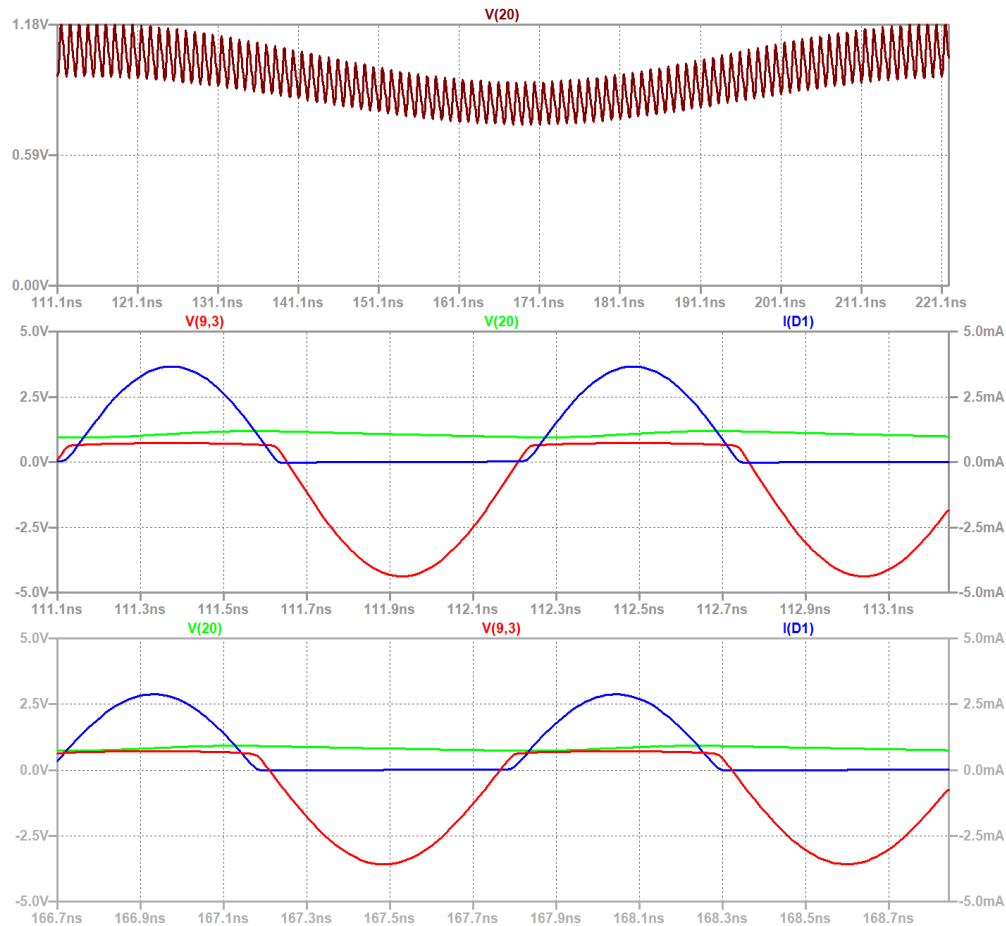
(a) $v_{out}(t)$ plotted for one cycle of the IF frequency



(b) In-phase diode waveforms



(c) 180° out-of-phase diode waveforms



219. I note that Estabrook-Thesis (*See Ex. 1005 at page 40*) mentions that the simulation time was reduced to minimize file storage and memory usage. However, this reduction impacts the resolution bandwidth of the FFT, particularly in intermodulation distortion (IMD) simulations.

220. To ensure accurate frequency resolution, I extended the duration of the transient analysis. This adjustment allows for precise measurement of individual frequency components in intermodulation simulations. The length of the transient simulation does not alter the fundamental operation of the mixer but ensures that

intermodulation artifacts are accurately resolved in the frequency domain.

XIII. VALIDITY OF THE '686 PATENT

A. Ground 1: Nevo in view of Avitabile.

221. Petitioner asserts that claims 1-20 of the '686 patent are obvious over Nevo in combination with Avitabile. I disagree. I note that Nevo discloses a multi-protocol wireless device with transceivers that can operate on various protocols, including Bluetooth and IEEE 802.11. Nevo does not provide the specific circuitry required for frequency translation. MediaTek turns to Avitabile.

1. Nevo/Avitabile do not teach (or suggest) “wherein a second EM signal is generated from said stored energy” (claim 11)

222. Independent claim 11 of the '686 patent recites: “a storage module coupled to said switch and configured to store said transferred energy, wherein a second EM signal is generated from said stored energy.”

223. Petitioner relies on Avitabile for teaching “wherein a second EM signal is generated from said stored energy,” as recited in independent claim 11.

224. But as discussed above in Section XI.B, Avitabile discloses a sample-and-hold (voltage sampling) system.

225. As a sample-and-hold (voltage sampling) system, a POSITA understands that Avitabile seeks to (1) accurately capture the voltage of the input signal at the sampling instant, and (2) hold the voltage reading on the capacitor to

recreate a down-converted signal.

226. A POSITA thus understands that no signal is being generated from the energy stored on the capacitor of Avitabile.

227. Avitabile is configured to hold the charge in the capacitor (and prevent discharge). If the capacitor discharged, the voltage on the capacitor could not be accurately read/reproduced and Avitabile would not work as a sample/hold circuit.

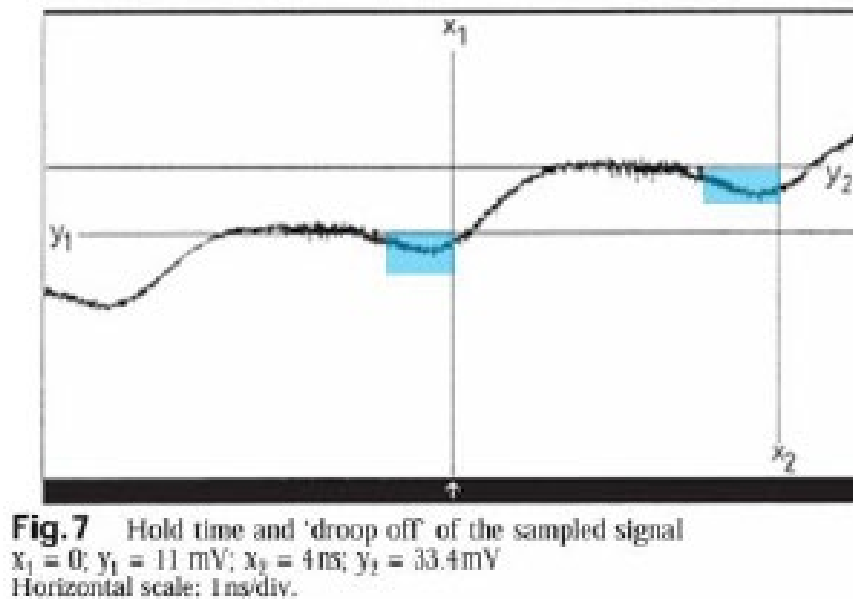
228. The voltage across the capacitor in Avitabile is not accumulated “energy”. A POSITA recognizes that this voltage is not derived from accumulated energy but rather represents the input signal’s instantaneous voltage captured at the sampling instant – a snapshot of the sampled input signal at a discrete moment in time.

229. During a “hold” period, the voltage is held at a constant voltage level so that the ADC can read its value. Avitabile discloses that the system samples and then holds the signal: “The 1.6 ns hold time measured is consistent with the acquisition time of several commercially available A/D converters.” Ex. 1006, 340. In other words, during the hold time, Avitabile is designed to prevent discharge from the hold capacitor.

230. The voltage value serves as the “sample” of a discrete voltage value that the system can then use to recover the baseband signal.

231. Avitabile is not using energy (integrated or otherwise) to generate the

claimed second signal. This is fundamentally different than an energy transfer (energy sampling) system, which uses the energy from the input signal provided to a low impedance load to generate a second signal (i.e., the sampled energy makes up/becomes part of the second signal).



232. Figure 7 of Avitabile (shown above) illustrates the capacitor in Avitabile holding a voltage at y_1 and again at y_2 .

233. A POSITA understands that the “droop off” (shown in blue) is not the result of energy transfer to the baseband from the capacitor, but rather the effect of parasitics on the capacitor.⁶ Energy from the capacitor dissipates through these

⁶ In real-world implementations, however, parasitics (such as leakage to ground) may cause minor energy dissipation, which Avitabile refers to as “droop off.”

parasitics. The dissipated energy is not transferred to the baseband signal or anywhere else in the down-conversion chain; it remains isolated and does not flow beyond capacitor 30. This “droop off” does not contribute to the formation of the baseband signal.

234. The sample-and-hold circuit in Avitable takes a sample of the input signal by turning the switch ON (closing the switch) and OFF (opening the switch). When the switch is turned ON, “the input waveform drops across the hold capacitor.” Ex. 1006, 339. When the switch is turned OFF, the switch opens and the hold capacitor maintains a constant voltage value until the next pulse (which is what is shown in Figure 7 above). The voltage is held on the capacitor by using a high impedance load.

235. A POSITA understands that the high impedance load causes the capacitor to hold the voltage so that an accurate voltage across the capacitor could be determined. The ADC can read its value. Avitable discloses that the system samples and then holds the signal: “The 1.6 ns hold time measured is consistent with the acquisition time of several commercially available A/D converters.” Avitable, 340. During the hold time, Avitable is designed to prevent discharge from the hold capacitor.

236. A POSITA understands that the high impedance load causes the capacitor to hold charge so that an accurate voltage across the capacitor could be

determined. This is the basis upon which ADC sampling is dependent. An accurate capture of the input waveform voltage. Droop or error not the capacitor would cause errors in the ADC processing of the input signal, leading to noise and distortion. Without a high impedance load, energy would be discharged from the capacitor toward the load and the system could not accurately determine the voltage (i.e., the system would not work properly). Because the sample-and-hold system of Avitable use a high-impedance load, no energy from the RF signal is conveyed with the baseband signal. A POSITA understands that voltage and energy are distinct concepts: voltage is the potential difference between two points, while energy involves the transfer and accumulation of power over time. The voltage value serves as the “sample” of a discrete voltage value that the system can then use to recover the baseband signal. Thus, Avitable is not using energy (stored or otherwise) to generate the claimed second signal. This is fundamentally different than an energy transfer (energy sampling) system, which uses the *energy* from the input signal provided to a low impedance load to generate a second signal (i.e., the sampled energy makes up/becomes part of the second signal). *Id.*

237. Because sample-and-hold system of Avitable uses a high-impedance load, no energy (stored or otherwise) from the RF generates a second signal, i.e., no

energy from the RF signal makes up/becomes part of the second signal.

238. [Intentionally Omitted]

239. Therefore, Nevo and/or Avitabile does not teach or suggest generating a second EM signal from stored energy.

2. Nevo/Avitabile do not teach (or suggest) “a switch configured to operate according to an energy transfer signal” (claims 1 and 11)

240. Claims 1 and 11 recite “a switch configured to operate according to an energy transfer signal.”

241. An energy transfer signal is “an independent control input of an energy transfer system having pulses with non-negligible apertures.” See Section X.B.

242. Petitioner relies on Avitabile for teaching “a switch configured to operate according to an energy transfer signal.”

243. As discussed in Section XI.B above, Avitabile is a sample-and-hold system.

244. I understand that the Federal Circuit specifically found that ParkerVision’s energy transfer (energy sampling) technology is different from voltage sampling: “ParkerVision’s down-converting system uses a technique called ‘energy sampling,’ which differs from the technique of ‘voltage sampling,’ which was used in conventional down-converting systems.” *ParkerVision*, 116 F.4th 1345

(Fed. Cir. 2024).

245. Therefore, Nevo and/or Avitable does not teach or suggest an energy transfer signal as specified in claims 1 and 11.

3. Nevo/Avitable do not teach (or suggest) “a plurality of protocol/standard sub-modules” or “operating a [first/second] transceiver in conformance with a [first/second] protocol/standard combination” (claims 1 and 11)

246. Claims 1 and 11 recite an apparatus comprising “at least one *multi*-platform module” including “a plurality of transceivers” that communicates with “at least one of a plurality of communication links” using a control module “having a *plurality of protocol/standard sub-modules*.” A POSITA would understand that, in order for the multi-platform module to communicate with protocol/standard sub-modules, the transceivers must comply with/meet protocols/standards. Claim 11 recites a method comprising “operating a [first/second] transceiver in conformance with a [first/second] protocol/standard combination.” A POSITA understands this to mean that the transceivers must comply with/meet protocols/standards. The first and second transceivers are part of the claimed “plurality of transceivers” having a “frequency translation module” comprising the claimed switch and storage module.

247. Petitioner asserts that because Nevo describes using several well-known protocols (including Bluetooth and IEEE 802.11) and acknowledges the need for down-converters, a POSITA would have been motivated to look to Avitable for

the required circuitry. Pet., 25. I disagree.

248. Because Petitioner relies on Avitable of the claimed frequency translation module, Avitable's circuitry (incorporated into Nevo) is what must comply with a "plurality of protocols/standards" and operate "in conformance with a [first/second] protocol/standard combination."

249. [Intentionally Omitted]

250. Avitable is directed to an S-band digital downconverter designed for radar applications. It does not account for the protocol-specific modulation, error correction, and synchronization requirements necessary for Bluetooth or IEEE 802.11 operation.

251. Even if combined with Nevo, Avitable does not disclose how it would meet fundamental performance requirements in terms of dynamic range, sensitivity, and interference tolerance, which are essential for Bluetooth and IEEE.11 compliance:

252. Dynamic Range: Bluetooth and IEEE 802.11 require transceivers to support a wide range of signal levels from strong (-10 dBm) to weak (-90 dBm) signals. Avitable's sample-and-hold (SH) circuit lacks automatic gain control (AGC) or any adaptive mechanism to maintain dynamic range. Nevo is also silent on AGC or any equivalent mechanism for controlling gain, meaning that a POSITA

would not find a solution in the proposed combination.

253. Instead, Avitable is designed for a radar environment, where input signal levels are typically high and stable. Bluetooth and IEEE 802.11, however, require handling of widely varying signal strengths due to real-world conditions like multipath fading, attenuation, and interference.

254. Sensitivity: Wireless transceivers must have high sensitivity to detect weak signals in noisy environments. Bluetooth and IEEE 802.11 set strict minimum sensitivity levels (e.g., -70 dBm for Bluetooth and -90 dBm for IEEE 802.11n at MCS0). Notably Avitable has 26dB of loss, which would any receiver further into the noise floor.

255. [Intentionally Omitted]

256. [Intentionally Omitted]

257. [Intentionally Omitted]

258. Therefore, Petitioner's combination of Nevo and Avitable does not teach or suggest "a plurality of protocol/standard sub-modules" or "operating a [first/second] transceiver in conformance with a [first/second] protocol/standard combination" as set forth in claims 1 and 11.

4. A POSITA would not be motivated to combine Nevo and Avitable to arrive at the claimed invention.

259. A POSITA reading Nevo would understand that the transceivers need to be configured in order to operate in compliance with the specific protocols

identified in Nevo

260. A POSITA would not understand that any transceiver configuration could be used as Nevo's transceiver, which is a black box.

261. A POSITA understands that wireless communication protocols, such as Bluetooth and IEEE 802.11, define not only the frequency ranges but also specific methods and parameters for transmitting data over RF channels.

262. These protocols are designed with critical performance factors, such as dynamic range, sensitivity, and interference tolerance, which ensure reliable communication in real-world environments. As discussed in Section XIII.A.3 above, a POSITA would understand that Avitabile does not address these performance factors and, thus, would not combine Avitabile with Nevo.

263. [Intentionally Omitted]

264. A POSITA recognizes that these factors must be considered when designing circuitry for these protocols and, therefore, would not consider Avitabile's design as a solution for Nevo's transceivers.

265. A POSITA understands that operating on the same frequency range is not the same as being compatible with protocol standards, such as Bluetooth and IEEE 802.11.

266. A POSITA would understand that merely incorporating Avitabile's down-converter into Nevo's transceiver would fail to meet the protocol-specific

requirements, and the resulting system would not function as intended.

267. Though Avitabile's down-converter operates within the frequency range of Bluetooth and IEEE 802.11 (2.4 GHz), it does not provide any details on how it would address the complex protocol-specific signal processing required by these systems. Bluetooth and IEEE 802.11 rely on sophisticated modulation, demodulation, and signal processing techniques that Avitabile's down-converter does not address. A POSITA would understand that merely incorporating Avitabile's down-converter into Nevo's transceiver would fail to meet the protocol-specific requirements, and the resulting system would not function as intended. Thus, combining Nevo and Avitabile would require significant redesign and protocol-specific signal processing far beyond just adding a down-converter circuit.

268. Given the absence of protocol-specific processing in Avitabile's design, a POSITA would not consider it a plug-and-play solution for Nevo's protocol-specific transceivers. Though Avitabile may demonstrate its circuit works for frequency conversion, it does not show how this design can interface with or supports the specific modulation, demodulation, and signal processing required by Bluetooth or IEEE 802.11.

269. In view of the foregoing, a POSITA would not be motivated to combine

Nevo and Avitabile.

5. Claims 2-10 and 12-20.

270. Claims 2-10 depend from independent claim 1, and claims 12-20 depend from independent claim 11. For the same reasons set forth above as to why Nevo in combination with Avitabile does not invalidate claims 1 and 11, claims 2-10 and 12-20 are not obvious for at least the same reasons that claims 1 and 11 are not obvious.

B. Ground 2A: Young in view of Estabrook-Thesis

271. Petitioner asserts that claims 1-20 of the '686 patent are unpatentable as obvious over Young and Estabrook-Thesis. I disagree. I note that Young discloses a two-protocol transceiver with separate transmit and receive chains for each protocol. Each of Young's transceivers includes an associated "down converter and demodulator." But Young does not provide the specific circuitry required for frequency translation. MediaTek turns to Estabrook.

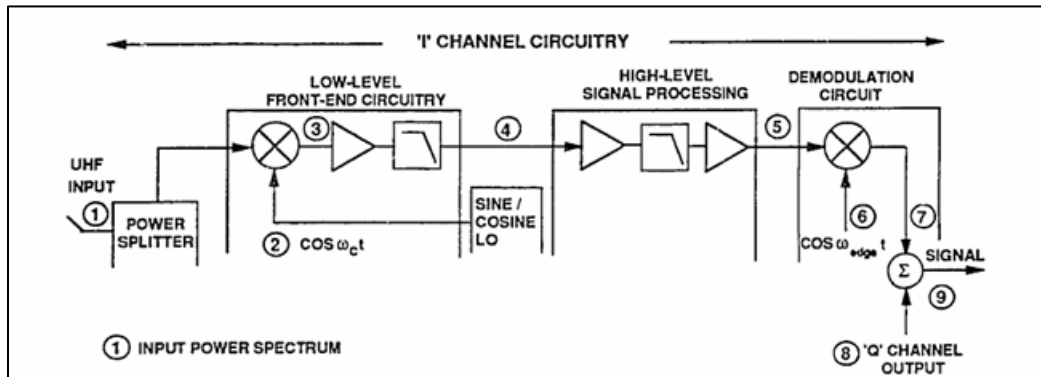
1. Estabrook does not teach (or suggest) "a switch configured to operate according to an energy transfer signal" (claims 1 and 11)

272. Claims 1 and 11 of the '686 patent recite "a switch configured to operate according to an energy transfer signal." Petitioner identifies the diode in Estabrook-Thesis's Figure 14(a) as the claimed "switch" and ILO signal as the claimed "energy transfer signal." Pet., 70.

273. An energy transfer signal is "an independent control input of an energy

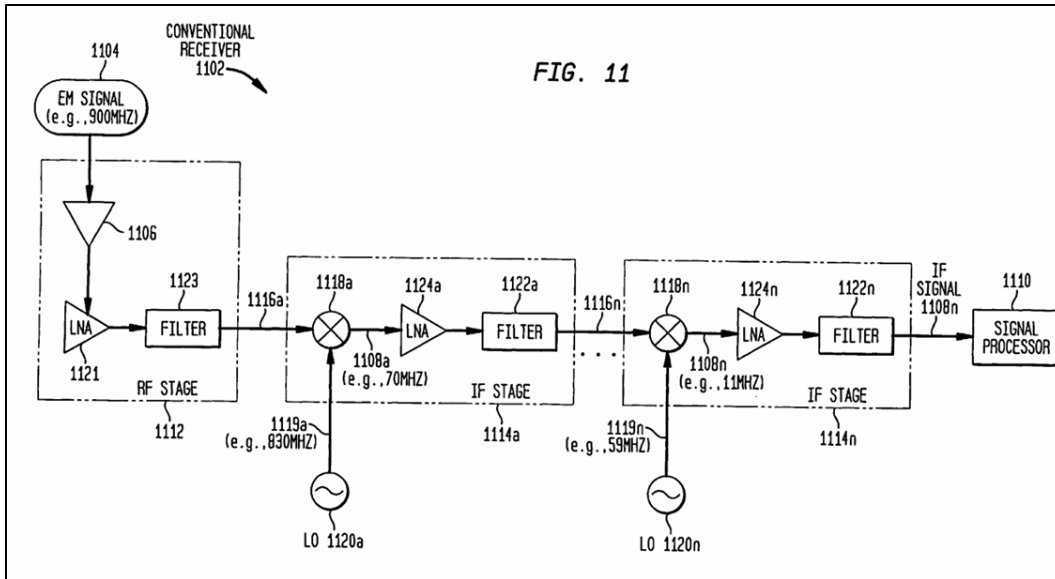
transfer system having pulses with non-negligible apertures.”

274. The ILO signal in Estabrook-Thesis is not (1) an input of an energy transfer system, (2) an independent control input, or (3) a signal having pulses with non-negligible apertures.



275. As discussed in Section XI.D, a POSITA reading Estabrook-Thesis would understand that Estabrook-Thesis discloses a heterodyning (non-sampling) system – a fundamentally different and competing technology to energy transfer (energy sampling).

276. Thus, the ILO signal is not a signal/input of an energy transfer system.

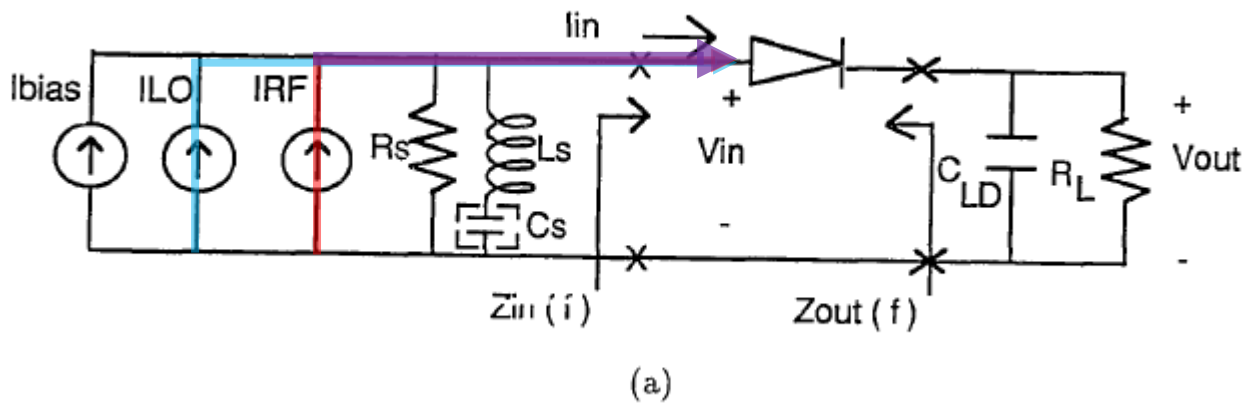


277. As shown above, the '551 patent specifically illustrates and discusses a conventional heterodyne receiver (Figures 1, 11; 24:3-25:56) and distinguishes the patented/claimed technology from this type of receiver.

278. As a non-sampling mixer, a POSITA recognizes that Estabrook-Thesis uses the diode in a nonlinear or time-varying mixer to effect translation of information centered at one frequency to information centered at another frequency. Estabrook-Thesis classifies Figure 14 as a “Resistively Matched (‘RM’) mixer circuit.” Ex. 1005, 57.

279. The mixer exploits the non-linearity of the diode to achieve the

multiplication, i.e., mixing, of the RF and LO signals.

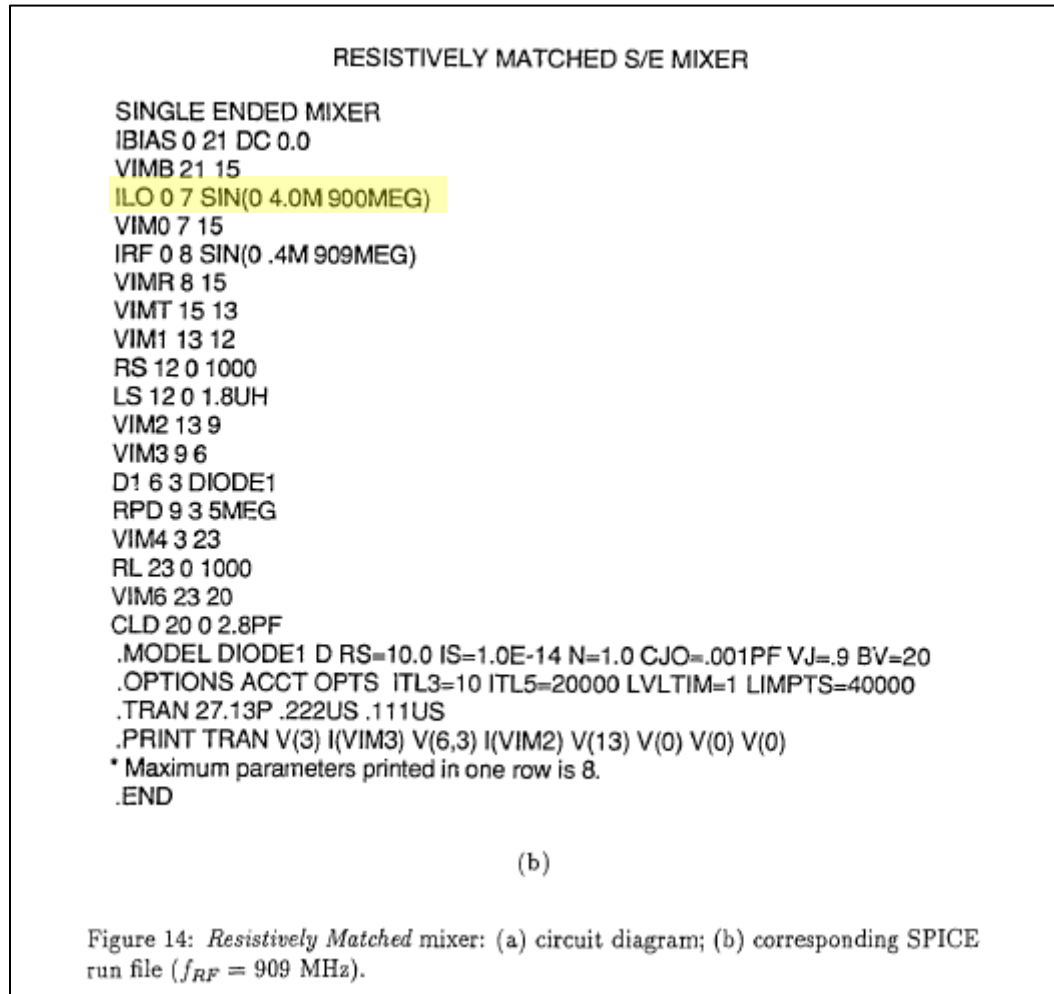


280. As shown above in Figure 14(a) of Estabrook, IRF (red) and ILO (blue) are “mixed” or “combined” at the anode terminal of the diode, which serves as an input (purple). The combined signal is then passed through the diode. Thus, the diode in Estabrook’s circuit does not operate according to an “energy transfer signal.” Instead, the diode’s operation is dictated by the combined influence of the RF and LO signals.

281. The operation of Estabrook-Thesis’s diode is part of a heterodyne mixing process where the LO signal modulates the RF input. The diode does not receive an independent control input that controls its operation as a switch. Rather, the diode’s conduction state is passively dictated by the instantaneous voltages of the combined RF and LO signals at the input of the diode. Thus, the ILO is not an independent control input.

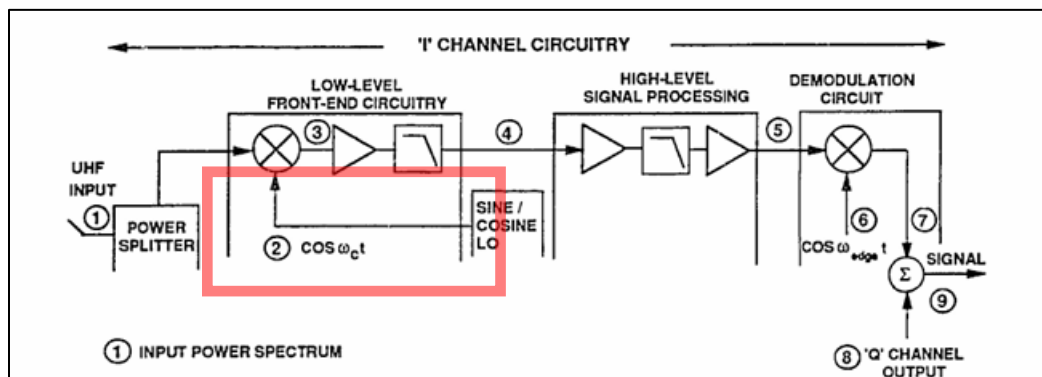
282. Further, Estabrook’s ILO signal is sinusoidal rather than pulsed, as

evidenced by the corresponding SPICE run file in Figure 14(b) (below), which defines the ILO signal as: 0 7 SIN (0.1M 900MEG) (yellow highlight). A POSITA recognizes that SIN in SPICE stands for sinusoid.



283. As shown in the red box below, Figure 4 of Estabrook specifically

discloses that the LO is a sinusoidal wave (sine/cosine LO).



284. As discussed in Section VII.B.6 above, a POSITA understands that a sine wave is a continuous signal that varies smoothly over time. In contrast, a pulse is a non-sinusoidal waveform with abrupt transitions and a defined width. Therefore, the ILO signal in Estabrook-Thesis is not a pulse having non-negligible apertures.

285. [Intentionally Omitted]

286. [Intentionally Omitted]

287. [Intentionally Omitted]

288. [Intentionally Omitted]

289. [Intentionally Omitted]

290. [Intentionally Omitted]

291. [Intentionally Omitted]

292. [Intentionally Omitted]

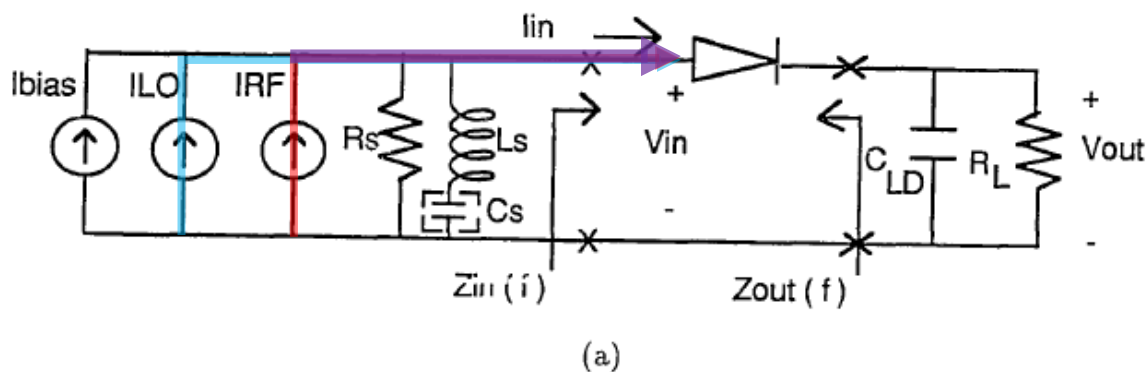
2. Estabrook does not teach (or suggest) “a switch configured ... to sub-sample and transfer energy” (claims 1 and 11)

293. Claims 1 and 11 of the '686 patent recite “a switch configured ... to sub-

sample and transfer energy from a first electromagnetic (EM) signal.”

294. Petitioner points to the diode in Figure 14(a) Estabrook-Thesis as “sub-sampl[ing]” energy from the IRF because it passes energy from the IRF at an aliasing rate driven by ILO (900 MHz), which is less than twice the frequency of the signal (IRF) being sampled (909 MHz).” Pet., 74-75.

But as explained in Section XI.D above, a POSITA reading Estabrook-Thesis would understand that Estabrook-Thesis discloses a non-sampling mixer system— a fundamentally different and competing technology to sampling. Estabrook-Thesis does not describe, teach, or suggest a sampling system. The diode in Estabrook does not function as a periodic switch that sub-samples an electromagnetic signal. Instead, it behaves as a continuously conducting nonlinear element in a heterodyne mixing. This can be understood by the mixing of two sinusoids, ILO and IRF, to create a down converter frequency. This is clearly understood from the trigonometry of two cosines as in Esterbrook: $\cos w_1 t * \cos w_2 t = 0.5 \cos(w_1 - w_2)t + 0.5 \cos(w_1 + w_2)t$



295. I disagree with Petitioner's assertion that Estabrook's diode "sub-samples" based on a 50% duty cycle. In Estabrook's resistive diode mixer, the RF (red) and LO (blue) signals are always present at the diode junction, and their interaction occurs constantly rather than in discrete switching events.

296. A POSITA would recognize that sub-sampling requires a switch that momentarily connects and disconnects to sample discrete portions of RF energy. In contrast, a non-sampling mixer like Estabrook's relies on the nonlinearity of the diode for continuous frequency translation rather than discrete-time sampling.

297. The 50% duty cycle that MediaTek refers to merely reflects the periodicity of a continuous conduction process in a mixer circuit, i.e., that a cosine has a 50% positive cycle and a 50% negative cycle. The use of 50% duty cycles does not mean that Estabrook's diode performs sub-sampling. In a sub-sampling system, the switch would turn on and off in discrete intervals, sampling the signal at specific times—which does not happen in Estabrook's system.

298. Sub-sampling requires controlled switching that enables periodic energy transfer from the input to the output. Estabrook's circuit lacks any independent switching mechanism capable of performing periodic energy transfer.

299. The diode in Estabrook does not operate independently on the IRF signal, nor does it perform energy transfer via periodic switching. Instead, the diode processes a combined signal composed of the RF signal, LO signal, resistor R_s ,

inductor-capacitor pair (Ls/Cs), and bias signal I_{bias} .

300. Because the diode does not selectively sample the IRF signal but instead responds passively to the combined effect of multiple continuously applied inputs, the IRF is not being “sub-sampled” as required by the claims. Therefore, Young and/or Estabrook does not teach or suggest “a switch configured . . . to sub-sample and transfer energy” as set forth in claims 1 and 11

3. Young/Estabrook do not teach (or suggest) “a plurality of protocol/standard sub-modules” or “operating a [first/second] transceiver in conformance with a [first/second] protocol/standard combination” (claim 11)

301. Claim 1 recites an apparatus comprising “a plurality of protocol/standard sub-modules.” The protocol/standard sub-modules are part of the control module that is incorporated into the frequency translation module of the claimed transceiver. A POSITA would understand that, in order for modules to be protocol/standard sub-modules, the modules must comply with/meet protocols/standards. Claim 11 recites a method comprising “operating a [first/second] transceiver in conformance with a [first/second] protocol/standard combination.” A POSITA would understand this to mean that the transceivers must comply with/meet protocols/standards. The first and second transceivers are part of the claimed “plurality of transceivers” having a “frequency translation module” comprising the claimed switch and storage module.

302. Petitioner asserts that because Young acknowledges the need for a

“down-converter and demodulator,” a POSITA would have been motivated to look to Estabrook-Thesis for the required circuitry. Pet., 61. I disagree.

303. Because Petitioner relies on Estabrook for the circuitry of the downconverter and demodulator in Young’s transceivers, Estabrook’s circuitry (incorporated into Young) is what must comply with a plurality of protocols/standards and operate “in conformance with a [first/second] protocol/standard combination.”

304. The petition has not shown that the circuit in Estabrook would operate in conformance with protocols/standards - Bluetooth or IEEE 802.11. standards.

305. [Intentionally Omitted]

306. Young, however, describes a multi-band receiver operating on communication standards such as Bluetooth or WiFi. These standards operate by dividing a frequency band into multiple closely spaced channels. For example, Bluetooth operates in the 2.4 GHz ISM band (2400–2483.5 MHz). It consists of 79 channels. Bluetooth uses Gaussian Frequency Shift Keying (GFSK) modulation with a bit rate of 1 Mbps.

307. Petitioner suggests that the block labeled “RADIO A DOWN CONVERTER AND DEMODULATOR” in Young corresponds to Estabrook’s single-ended diode mixer. However, a POSITA would recognize that Estabrook’s mixer lacks the necessary signal processing capabilities to conform to these wireless

communication standards.

308. Wireless receivers must contend with blocker signals—unwanted signals within the same band. Estabrook’s mixer does not provide sufficient rejection of in-band and out-of-band interferers. As demonstrated by the simulation results below, Estabrook’s mixer exhibits significant intermodulation distortion, leading to spectral artifacts and signal degradation. A POSITA would recognize that these deficiencies render Estabrook’s circuit non-compliant with Bluetooth. Because the Bluetooth standard/protocol is significantly easier to comply with than the IEEE802.11 (i.e., 802.11 has more stringent standards for compliance), there is no evidence that Estabrook will meet the 802.11 standard/protocol.

309. [Intentionally Omitted]

310. [Intentionally Omitted]

311. Simulations confirm that Estabrook’s single-ended mixer does not provide inherent image rejection, making it unsuitable for the receiver in Case 1.

312. Furthermore, Estabrook’s mixer exhibits second-order nonlinearities, which degrade signal integrity and violate Bluetooth. These nonlinearities generate

unwanted frequency components that interfere with the desired signal.

313. [Intentionally Omitted]

314. [Intentionally Omitted]

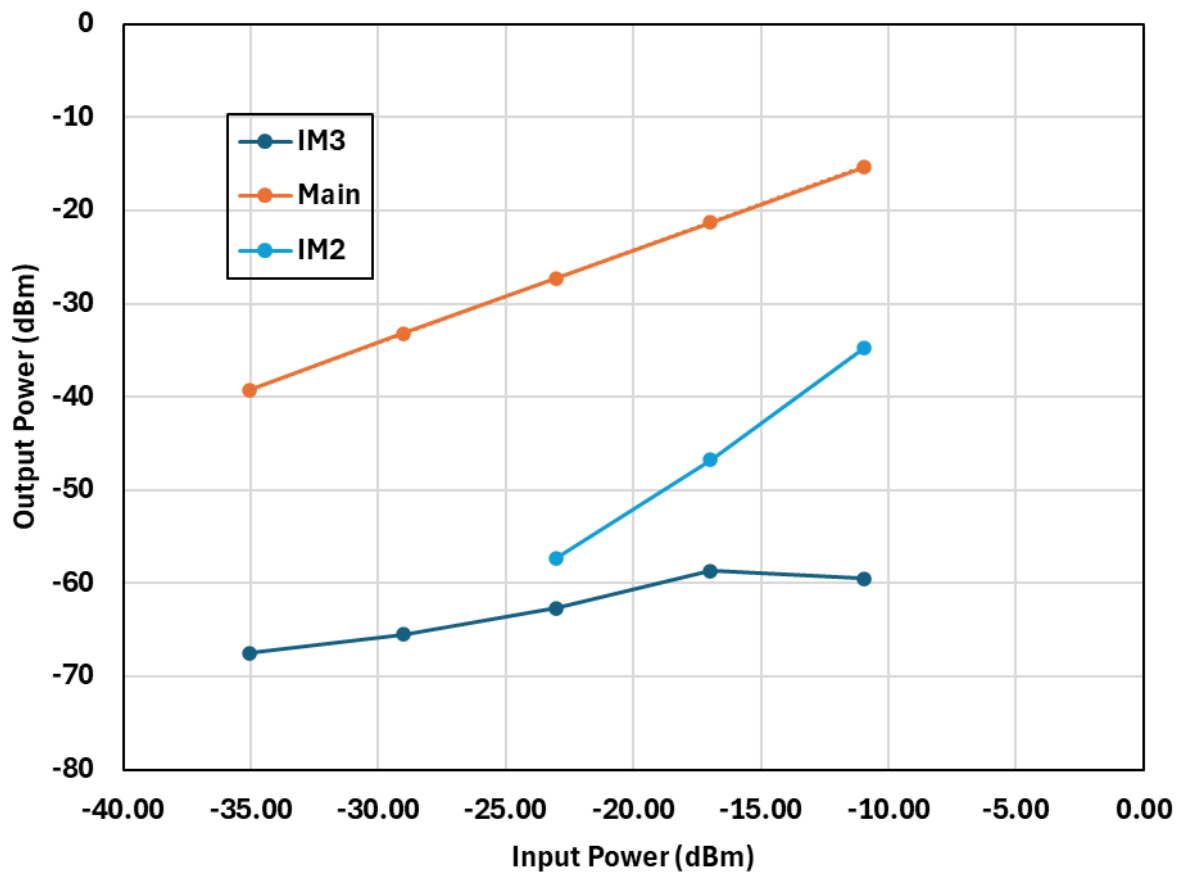
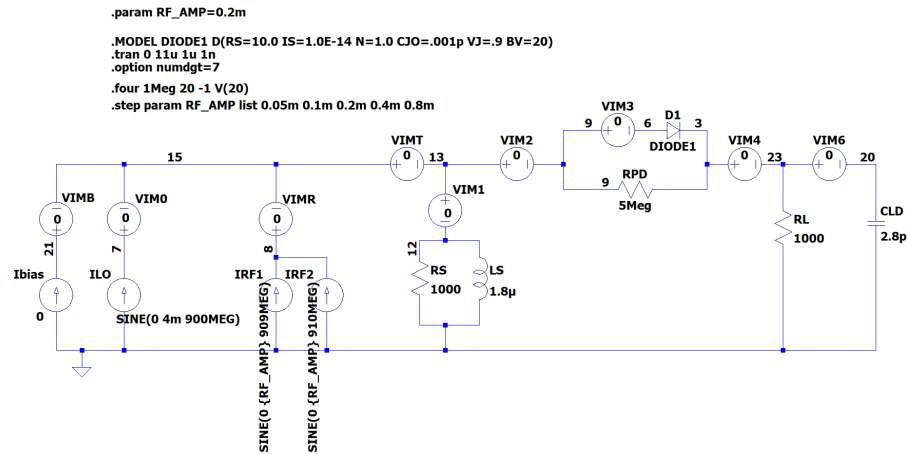
315. [Intentionally Omitted]

316. In particular, I conducted simulations of Estabrook's single-ended resistive mixer to evaluate its image rejection and second-order intermodulation (IM2) performance.

317. The second order and third order intercept points can be simulated with the two-tone test. The two-tone test was performed by applying two equal-amplitude signals separated by 1 MHz to the RF port of the mixer. The power of the input tones was incrementally increased, and the output power of the intermodulation products was measured. A 10 μ s transient simulation was performed, followed by an FFT with 4096 points, providing a resolution bandwidth of 1 MHz, which is sufficient to distinguish the intermodulation products.

318. In the simulation, the main tones were down-converted to 9 MHz and 10 MHz, while the IM2 product appeared at 1 MHz, and the IM3 products were

located at 8 MHz and 11 MHz.



319. As shown above, the third order intermodulation products are very

low— almost in the noise level of the simulator for all input power levels. This suggests that the simplified model of the diode may not include third-order effects.

320. However, second-order intermodulation products were clearly visible, and their power followed the expected 1:2 growth slope.

321. In another simulation, I tested Estabrook's single-ended mixer against multiple RF frequencies.

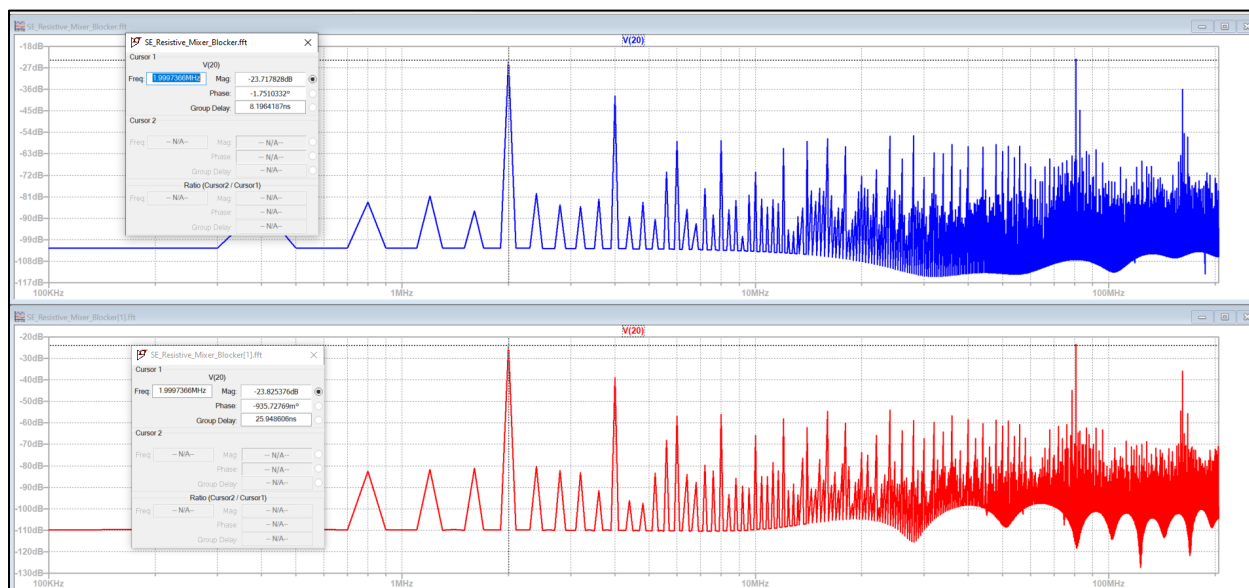
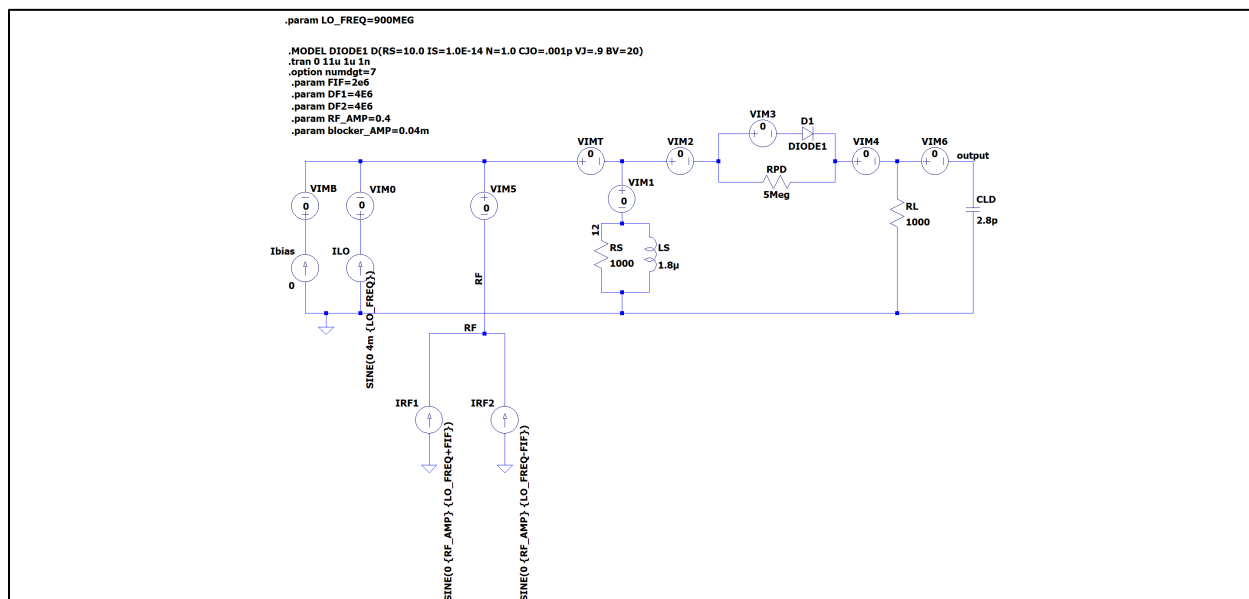
322. [Intentionally Omitted]

323. In another simulation, response of Estabrook's single-ended mixer is examined to multiple RF frequencies each 2MHz spaced. These RF tones represent different channel.

324. Although Estabrook's thesis states that its circuit components could be scaled for different frequencies, the mixer was not originally designed for 2.4 GHz operation. To analyze Estabrook's linearity performance, in particular, with respect to Bluetooth standard, I conducted simulations on the original 900 MHz design as it was disclosed in Estrabrook.

325. The first simulation set the LO frequency to 900 MHz and the desired channel to 902 MHz, then repeated the test with another signal at 898 MHz

(representing the image channel).



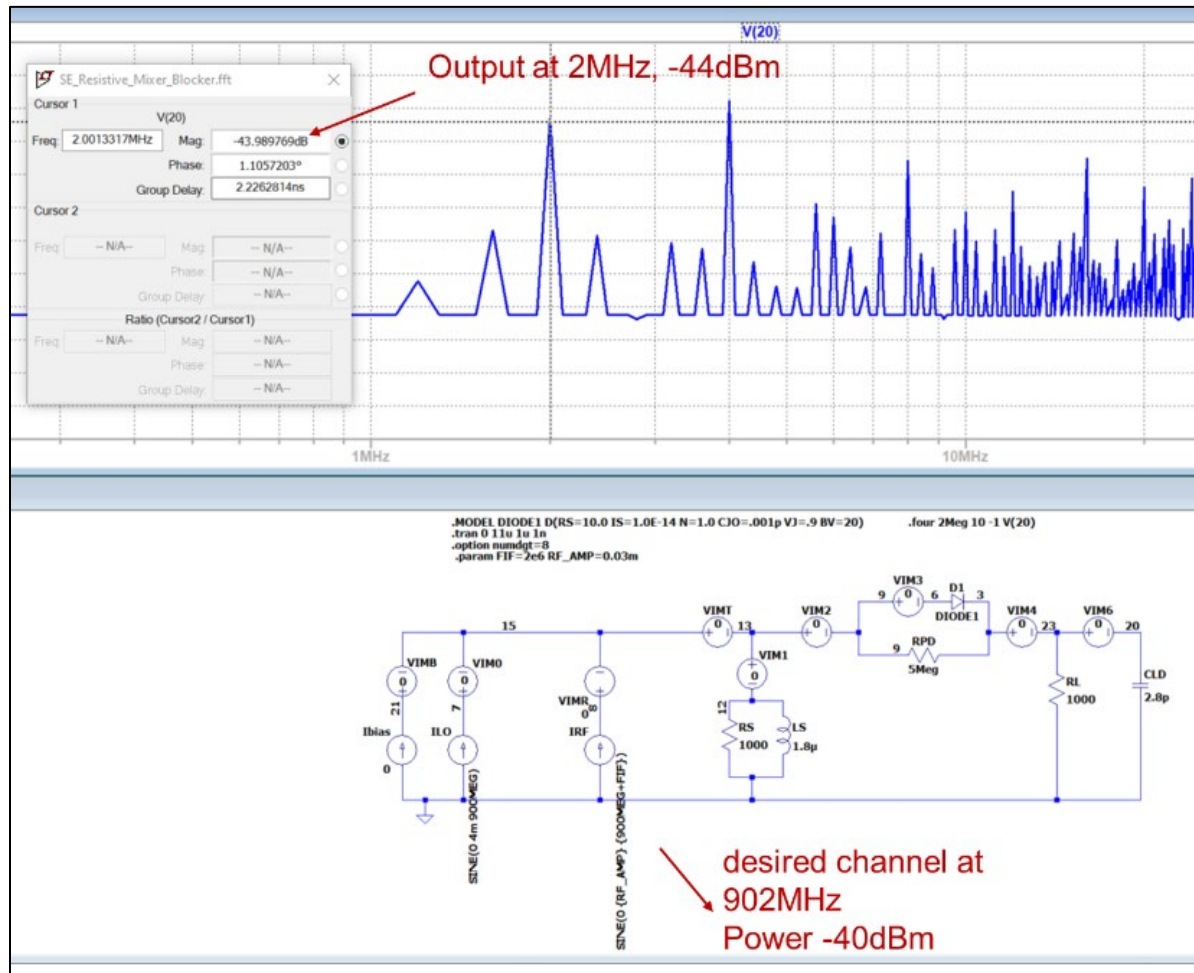
326. Esterbrook incorrectly down converts both 902 MHz and 898 MHz to 2 MHz. As shown above, the output spectrum from both cases confirms that Estabrook's single-ended mixer does not provide image rejection, which is required for modern protocols.

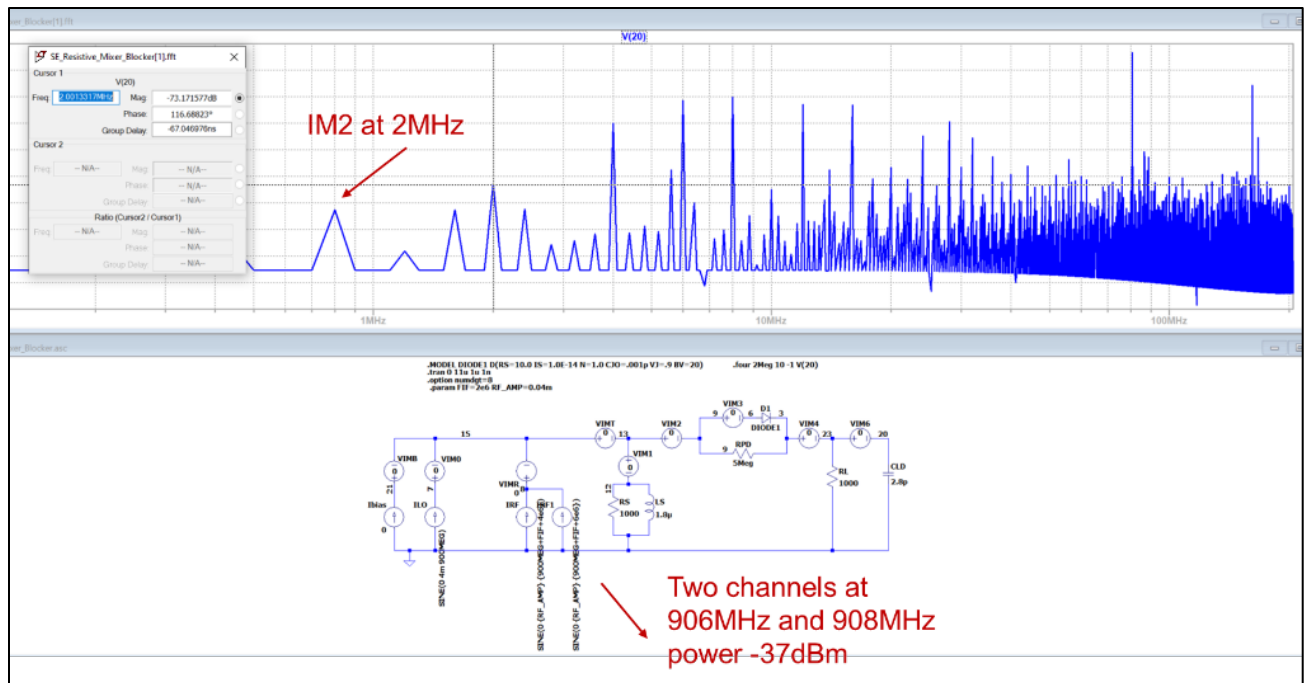
327. Carrier-to-Interference (C/I) Ratio Validation: The Bluetooth Core

Specification defines the reference sensitivity level as -70 dBm. To validate C/I ratio compliance, I assumed a low-noise amplifier (LNA) in front of the mixer with 30 dB gain and simulated the mixer's response to a -40 dBm signal on the main channel.

328. In the following simulation, the desired channel was set to 902 MHz (-40 dBm), with interfering signals at 906 MHz and 908 MHz (-37 dBm). The interfering signals were more than 3MHz away and thus were 3dB above sensitivity. (-70dBm + 30 dB of amplification). The output was at 2 MHz from the desired input was -44 dBm. The adjacent signals at 906 MHz and 908 MHz were then simulated and the measured signal at 2 MHz (where the normal signal would appear) was -73

dBm.





329. The simulated C/I value is $(-73.1\text{dBm}) - (-44\text{dBm}) = -31\text{dB}$ which does not meet the -40dB requirements for the $(\text{C/I}) > 3\text{MHz}$.

330. Estabrook's mixer (1) lacks image rejection and (2) exhibits high second-order intermodulation distortion (IM2), and (3) inadequate C/I ratio performance. Even if integrated into Young's receiver, Estabrook's circuit would not operate in conformance with a protocol/standard combination as required by claim 11.

331. Therefore, Young and/or Estabrook do not teach or suggest "a plurality of protocol/standard sub-modules" or "or "operating a [first/second] transceiver in conformance with a [first/second] protocol/standard combination" as set forth in the

claimed invention.

4. A POSITA would not be motivated to combine Young and Estabrook to arrive at the claimed invention.

332. Petitioner asserts that “[a] POSITA would have been motivated to combine Young and Estabrook-Thesis because references are in the same field, because both describe RF receivers.” Pet. 61. I disagree.

333. A POSITA reading Young would understand that the transceivers need to be configured in order to operate in compliance with the specific protocols identified in Young. In particular, Young teaches spread spectrum radio protocols. Esterbrook teaches single-side-band radios.

334. A POSITA would not understand that any transceiver configuration could be used as Young’s transceiver, which is a black box.

335. A POSITA understands that wireless communication protocols, such as Bluetooth and IEEE 802.11, define not only the frequency ranges but also specific methods and parameters for transmitting data over RF channels.

336. These protocols are designed with critical performance factors, such as dynamic range, sensitivity, and interference tolerance, which ensure reliable communication in real-world environments. As discussed in Section XIII.B.3 above, a POSITA would not understand Estabrook as meeting these requirements.

337. A POSITA recognizes that these factors must be considered when designing circuitry for these protocols and, therefore, would not consider

Estabrook's design as a solution for Young's transceivers.

338. A POSITA recognizes that Estabrook being a down converter and demodulator does not demonstrate that Estabrook's circuitry could actually be used Bluetooth and IEEE 802.11. Reliance on Estabrook-Thesis being a down converter, receiver, and demodulator does not demonstrate that Estabrook-Thesis's circuitry could actually be used for Bluetooth or IEEE 802.11

339. A POSITA understands that merely incorporating Estabrook's down-converter into Young's transceiver would not meet the protocol-specific requirements.

340. Thus, combining Young and Estabrook would require significant redesign and protocol-specific design, analysis, and additional circuitry far beyond merely adding Estabrook's down-converter circuit to Young.

341. [Intentionally Omitted]

342. In view of the foregoing, a POSITA would not be motivated to combine Young and Estabrook-Thesis.

5. Claims 2-10 and 12-20.

343. Claims 2-10 depend from independent claim 1, and claims 12-20 depend from independent claim 11. Claims 2-10 and 12-20 are not obvious in view of Young and Estabrook-Thesis for at least the same reasons that claims 1 and 11

are not obvious.

C. Ground 2B: Young in view of Estabrook-1988 and Estabrook-1989

344. Petitioner asserts that claims 1-20 of the '686 patent are unpatentable as obvious over Young, Estabrook-1988, and Estabrook-1989.

345. Petitioner fails to cite any evidence from Estabrook-1988 or Estabrook-1989 that is not already disclosed in Estabrook-Thesis.

346. Therefore, the same reasons why claims 1-20 are not obvious over Young and Estabrook-Thesis, as explained in Section XIII.D above, apply equally here to Young in combination with Estabrook-1988 and Estabrook-1989.

SUPPLEMENTATION

347. 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: March 11, 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).

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- 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)

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- 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.

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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)

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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)

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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.

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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.

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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.

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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.

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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

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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.

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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.

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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"

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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.

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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.

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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

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- 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