

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

T-MOBILE US, INC., AT&T MOBILITY LLC, CELLCO PARTNERSHIP
D/B/A VERIZON WIRELESS, ERICSSON INC. AND
NOKIA OF AMERICA CORPORATION,
Petitioners,

v.

SMART RF INC.,
Patent Owner.

U.S. Patent No. 10,958,296
Issue Date: March 23, 2021

DIGITAL MULTI-BAND PREDISTORTION LINEARIZER
WITH NON-LINEAR SUBSAMPLING ALGORITHM IN THE FEEDBACK
LOOP

Inter Partes Review No.: IPR2025-00691

**DECLARATION OF JAMES PROCTOR IN SUPPORT OF
PETITIONS FOR *INTER PARTES* REVIEW OF
U.S. PATENT 10,958,296**

TABLE OF CONTENTS

I.	INTRODUCTION	1
II.	QUALIFICATIONS	1
III.	COMPENSATION	8
IV.	MATERIALS CONSIDERED	8
V.	RELEVANT LEGAL STANDARDS	8
VI.	OVERVIEW	13
VII.	BACKGROUND	18
A.	State of the Art	18
1.	Power Amplifier Distortion	18
2.	Digital Predistortion (“DPD”).....	22
3.	Direct and Indirect Predistortion	25
4.	Nyquist-Rate Sampling and Subsampling	28
5.	Baseband Signals, Passband Signals, and Modulation.....	33
6.	Complex Envelope Theory	34
B.	Summary of the ’296 Patent	38
C.	Claim Construction.....	43
D.	Priority Date of the Challenged Claims	47
E.	Person of Ordinary Skill in the Art	47
VIII.	IDENTIFICATION OF HOW THE CLAIMS ARE UNPATENTABLE.....	48
A.	Ground 1: Claims 1-7 and 10 are Obvious over Peroulas	48
1.	Peroulas	48

2.	Detailed Application to the Challenged Claims	53
	Claim 1	53
	[1pre] <i>A linearized transmitter comprising:</i>	53
	[1a] <i>a digital signal predistorter block including digital baseband signal predistorters effecting predistortion of concurrent input signals to output concurrent predistorted signals;</i>	54
	[1b] <i>a power amplifier block connected to amplify the predistorted signals; and</i>	58
	[1c] <i>an analyzing and modelling stage receiving first feedback signals taken from an output of the power amplifier, and second feedback signals taken concurrently from the concurrent predistorted signals and using the first feedback and the second feedback signals in the analyzing and modelling stage to model a nonlinearity in the power amplifier, wherein the digital baseband signal predistorters are updated by the analyzing and modelling stage.</i>	59
	Claim 2	64
	[2pre] <i>The linearized transmitter of claim 1, wherein said concurrent digital multi-band predistortion block further comprises:</i>	64
	[2a] <i>a plurality of the digital baseband signal predistorters each corresponding to a respective channel; and</i>	64
	[2b] <i>and a signal observation feedback loop for generating said first feedback signals.</i>	67
	Claim 3	69
	[3pre] <i>The linearized transmitter of claim 2, wherein said plurality of digital baseband signal predistorters further comprises:</i>	69
	[3a] <i>a plurality of inputs, each input corresponding to a single frequency channel; and</i>	69

[3b] <i>a plurality of outputs, each output corresponding to a single frequency channel, and each output connected to an input of a concurrent multi-band transmitter.....</i>	71
Claim 4.....	74
[4pre] <i>The linearized transmitter of claim 2, wherein said analyzing and modeling stage further comprises:</i>	74
[4a] <i>a plurality of outputs connected to update the parameters of said digital baseband signal predistorters; and.....</i>	74
[4b] <i>a plurality of inputs connected to both: (a) outputs of said signal observation feedback loop comprising said first feedback signals, and (b) to outputs of said digital signal predistorter block.</i>	78
Claim 5.....	80
[5pre] <i>The linearized transmitter of claim 2, wherein said analyzing and modeling stage is further adapted to:</i>	80
[5a] <i>perform time alignment of complex baseband signals from sampling said first feedback signals; and.....</i>	80
[5b] <i>perform reconstruction of the complex baseband signals from said sampling.</i>	82
Claim 6.....	84
[6pre] <i>The linearized transmitter of claim 2, ...</i>	84
[6a] <i>said first feedback signals corresponding to a baseband equivalent for all frequency channels and wherein the baseband equivalent signals being extracted from down-converted samples of RF signals output from said power amplifier block.</i>	84
Claim 7.....	87

[7pre]	<i>The linearized transmitter of claim 2, wherein said signal observation feedback loop further comprises a plurality of channels, each channel comprising:</i>	87
[7a]	<i>an RF filter; [7b] a signal down conversion block; and [7c] an analog-to-digital converter (ADC).</i>	88
	Claim 10	89
[10pre]	<i>A method for linearizing a transmitter, said method comprising:</i>	89
[10a]	<i>effecting predistortion of concurrent input signals to output concurrent predistorted signals using a digital signal predistorter block including digital baseband signal predistorters;</i>	89
[10b]	<i>amplifying the predistorted signals using a power amplifier block;</i>	90
[10c]	<i>receiving in an analyzing and modelling stage first feedback signals taken from an output of the power amplifier, and second feedback signals taken concurrently from the concurrent predistorted signals; and using the first feedback and the second feedback signals in the analyzing and modeling stage to model a nonlinearity in the power amplifier, wherein the digital baseband signal predistorters are updated by the analyzing and modelling stage.</i>	90
B.	Ground 2: Claims 8 and 9 are Obvious over Peroulas in View of Cidronali	90
1.	Cidronali	90
2.	Obviousness and Motivation to Combine the Teachings of Peroulas with the Teachings of Cidronali	92
3.	Detailed Application of Peroulas in View of Cidronali	96
	Claim 8	96

[8pre]	<i>The linearized transmitter of claim 2, wherein said signal observation feedback loop further comprises:</i>	96
[8a]	<i>a single subsampling-based receiver to down-convert samples output from said power amplifier block.</i>	96
	Claim 9	98
[9pre]	<i>The linearized transmitter of claim 8, wherein said single subsampling-based receiver further comprises:</i>	98
[9a]	<i>an RF filter; a track and hold (T&H) block; and an analog-to-digital converter (ADC).</i>	98
C.	Ground 3: Claim 1-7, 10 are Obvious over Posti	99
1.	Posti	99
2.	Detailed Application of Posti in View of the Knowledge of a POSA to the Challenged Claims	102
	Claim 1	102
[1pre]	<i>A linearized transmitter comprising:</i>	102
[1a]	<i>a digital signal predistorter block including digital baseband signal predistorters effecting predistortion of concurrent input signals to output concurrent predistorted signals;</i>	103
[1b]	<i>a power amplifier block connected to amplify the predistorted signals; and</i>	106
[1c]	<i>an analyzing and modelling stage receiving first feedback signals taken from an output of the power amplifier, and second feedback signals taken concurrently from the concurrent predistorted signals and using the first feedback and the second feedback signals in the analyzing and modelling stage to model a nonlinearity in the power amplifier, wherein the digital baseband signal predistorters are updated by the analyzing and modelling stage.</i>	107
	Claim 2	111

[2pre]	<i>The linearized transmitter of claim 1, wherein said concurrent digital multi-band predistortion block further comprises:</i>	111
[2a]	<i>a plurality of the digital baseband signal predistorters each corresponding to a respective channel;</i>	112
[2b]	<i>and a signal observation feedback loop for generating said first feedback signals.</i>	113
	Claim 3	115
[3pre]	<i>The linearized transmitter of claim 2, wherein said plurality of digital baseband signal predistorters further comprises:</i>	115
[3a]	<i>a plurality of inputs, each input corresponding to a single frequency channel; and</i>	115
[3b]	<i>a plurality of outputs, each output corresponding to a single frequency channel, and each output connected to an input of a concurrent multi-band transmitter</i>	118
	Claim 4	121
[4pre]	<i>The linearized transmitter of claim 2, wherein said analyzing and modeling stage further comprises:</i>	121
[4a]	<i>a plurality of outputs connected to update the parameters of said digital baseband signal predistorters; and</i>	121
[4b]	<i>a plurality of inputs connected to both: (a) outputs of said signal observation feedback loop comprising said first feedback signals, and (b) to outputs of said digital signal predistorter block.</i>	123
	Claim 5	125
[5pre]	<i>The linearized transmitter of claim 2, wherein said analyzing and modeling stage is further adapted to:</i>	125
[5a]	<i>perform time alignment of complex baseband signals from sampling said first feedback signals; and</i>	125

[5b] <i>perform reconstruction of the complex baseband signals from said sampling.</i>	127
Claim 6.....	131
[6pre] <i>The linearized transmitter of claim 2, ...</i>	131
[6a] <i>said first feedback signals corresponding to a baseband equivalent for all frequency channels and wherein the baseband equivalent signals being extracted from down-converted samples of RF signals output from said power amplifier block.</i>	131
Claim 7	134
[7pre] <i>The linearized transmitter of claim 2, wherein said signal observation feedback loop further comprises a plurality of channels, each channel comprising:</i>	134
[7a] <i>an RF filter; [7.2] a signal down conversion block; and [7.3] an analog-to-digital converter (ADC).</i>	134
Claim 10	136
[10pre] <i>A method for linearizing a transmitter, said method comprising:</i>	136
[10a] <i>effecting predistortion of concurrent input signals to output concurrent predistorted signals using a digital signal predistorter block including digital baseband signal predistorters;</i>	137
[10b] <i>amplifying the predistorted signals using a power amplifier block;</i>	137
[10c] <i>receiving in an analyzing and modelling stage first feedback signals taken from an output of the power amplifier, and second feedback signals taken concurrently from the concurrent predistorted signals; and using the first feedback and the second feedback signals in the analyzing and modeling stage to model a nonlinearity in the power amplifier, wherein the digital</i>	

	<i>baseband signal predistorters are updated by the analyzing and modelling stage.</i>	137
D.	Ground 4: Claims 8 and 9 are Obvious over Posti in View of Cidronali	137
1.	Obviousness and Motivation to Combine the Teachings of Posti with the Teachings of Cidronali.....	137
2.	Detailed Application to the Challenged Claims	142
	Claim 8	142
[8.0]	<i>The linearized transmitter of claim 2, wherein said signal observation feedback loop further comprises:</i>	142
[8a]	<i>a single subsampling-based receiver to down-convert samples output from said power amplifier block.....</i>	142
	Claim 9	142
[9pre]	<i>The linearized transmitter of claim 8, wherein said single subsampling-based receiver further comprises:.....</i>	143
[9a]	<i>an RF filter; a track and hold (T&H) block; and an analog-to-digital converter (ADC).</i>	143
	CONCLUSION AND DECLARATION.....	i

I, James Proctor, declare as follows

I. INTRODUCTION

1. I am over the age of eighteen (18) and otherwise competent to make this Declaration.

2. I have been retained on behalf of T-Mobile USA, Inc., AT&T Mobility LLC, Cellco Partnership d/b/a Verizon Wireless, Ericsson Inc., and Nokia of America Corporation (“Petitioners”) as an independent technical expert in this proceeding before the United States Patent and Trademark Office (“PTO”) regarding U.S. Patent No. 10,958,296 (the “’296 Patent”). I have been asked to consider whether certain references disclose or suggest the features recited in Claims 1-10 of the ’296 Patent (the “Challenged Claims”). My opinions are set forth below

II. QUALIFICATIONS

3. In this section, I summarize some of my relevant educational background, work experience, and other relevant qualifications. A more detailed recitation of my professional qualifications and background is reflected in my Curriculum Vitae, included as EX-1004.

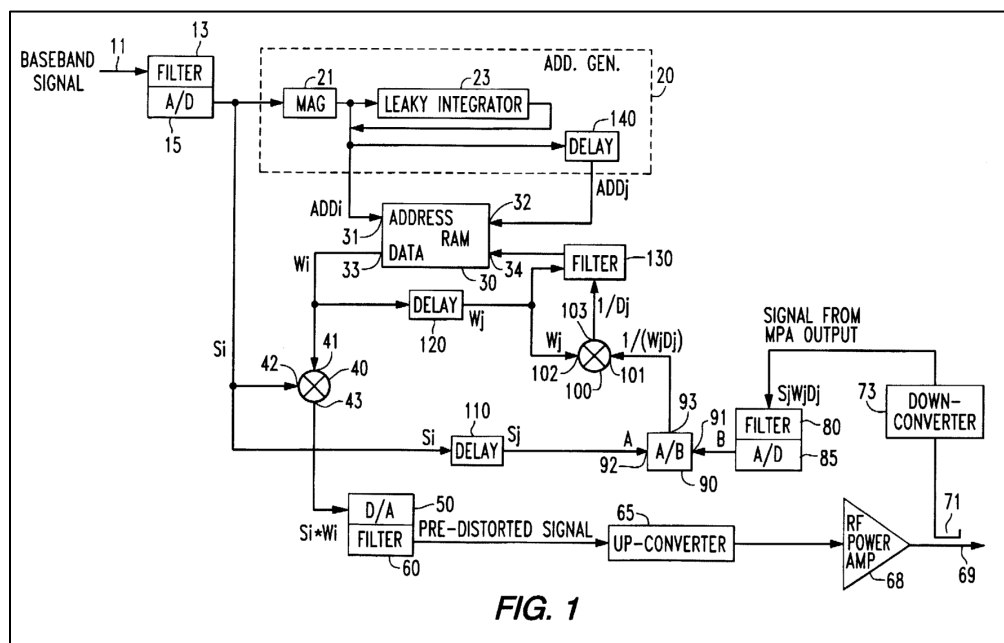
4. I have worked as an engineer and entrepreneur in the field of wireless communications for over 25 years and have been involved with various aspects of wireless communications for the duration of my career.

5. I am currently a named inventor on more than 325 issued U.S. patents, and more than 700 international patent publications in total. A number of these patents and patent applications are related to the subject matter of the patents asserted in this matter. A substantial portion of my work has been focused on wireless communication systems and products. A number of these patents and patent applications are related to the subject matter of the patents asserted in this matter (e.g., Cancellation of intermodulation products in wireless transceivers), or related components (such as correlators and closed loop control for gain and phase in similar systems, and delay alignment). For example, the following patents, for which I am a named inventor, are examples of some of my experience relevant the subject matter of this report:

U.S. Pat. No.	Title	Priority Date
5,898,338	Adaptive digital predistortion linearization and feed-forward correction of RF power amplifier	1996-09-20
5,929,704	Control of RF error extraction using auto-calibrating RF correlator	1998-2-20
6,078,216	Aliased wide band performance monitor for adjusting predistortion and vector modulator control parameters of RF amplifier	1998-03-31
9,306,658	Method and apparatus for a spectrally compliant cellular communication system	1999-12-20
7,272,169	Reverse link correlation filter in wireless communication systems	2000-02-23
7,002,902	Method and system for economical beam forming in a radio communication system	2000-02-24
9,775,115	Antenna control system and method	2000-12-01

6,911,879	Electronic phase shifter with enhanced phase shift performance	2001-01-31
-----------	--	------------

6. For instance, a transmitter which corrects for a power amplifier's intermodulation distortion using both pre-distortion and/or feed-forward (estimation and cancelation of IMDs) is disclosed in U.S. Pat. No. 5,898,338 (the '338 patent), of which I am a named inventor. Fig. 1 of that patent is set forth below:



7. Relevant to the '296 patent, but over 15 years earlier, the '338 discloses many related concepts for power amplifier linearization including a digital pre-distorter utilizing a look up table (30) based upon the magnitude of the input signal (21). The '338 patent and its family have been cited over 115 times during the prosecution of other inventors patents.

8. As another example of my relevant experience is U.S. Patent No. 6,078,216 (the '216 Patent) listed above as well, entitled "Aliased wide band performance monitor for adjusting predistortion and vector modulator control parameters of RF amplifier". Like the '296 patent, it discloses the use of a sub-sampling receiver which aliases the feedback signals for the adaptation of predistortion to linearize a power amplifier. The '338 patent has been cited over 45 times during the prosecution of other inventors patents.

9. My educational background includes a BSEE (Bachelor of Science, Electrical Engineering) from the University of Florida (1991) and MSEE (Master of Science, Electrical Engineering) from the Georgia Institute of Technology (1992) focusing on digital signal processing.

10. From 1986 to 1991, while at the University of Florida, I interned with Harris Corporation in various roles including mechanical design, software development, and digital design. From 1991 to 1992, while at Georgia Institute of Technology, I worked at the Georgia Tech Research Institute (GTRI) as a graduate research assistant, performing software development on classified government programs.

11. From 1993 to 1995, while working for Harris Corporation, I designed various cellular communications systems for voice, data, and tracking/location. Many of these systems I utilized advanced communications technologies, such as those

utilized in the then-developing and future telecommunication standards (such as IS-95, W-CDMA, and aspects of LTE).

12. From 1995 to 1998, I worked at Spectrian in advanced development and technical marketing. At Spectrian, I interfaced with Nortel's and Qualcomm's product management and performed advanced technology development and systems analysis. In this role, I designed IS-95 CDMA and GSM base station power amplifiers and control electronics, and received several patents associated with advanced linearization techniques for the reduction of transmitted intermodulation distortion within multicarrier and single carrier amplifiers and transceivers. These included both analog/RF as well as digital linearization approaches.

13. From 1998 to 2002, I served as the Director of Strategic and Technical Marketing at Tantivy Communications, a venture capital-funded 3G cellular data and chip set company. At Tantivy, I helped to architect and standardize the I-CDMA Spread Spectrum Systems Air Interface Standard (T1P1.4). I also developed both wireless access terminals and base stations that complied with the standard. The base stations utilized various IP protocols, and interfaced with the wire line network utilizing IP over Ethernet. Additionally, I participated in and provided technical contributions to 3GPP/3GPP2 standardization efforts related to the development of CDMA2000 and 1xEV-DO. This work resulted in me being a named inventor on more than 150 pending or issued U.S. patents or applications.

14. From 2002 to 2007, as co-founder of WiDeFi, Inc., I served in various roles including President, CEO, CTO, and board member. As the CEO, my responsibilities included advanced development of platform technologies. I was a named inventor of wireless technology components, including a frequency translating TDD repeater, a same frequency repeater architecture for TDD/FDD-based systems, and physical layer multi-stream MIMO repeater technology. WiDeFi invented and provided wireless home networking products based on WiFi and cellular technologies. While at WiDeFi, I was a named inventor on over 25 issued U.S. patents or patent applications.

15. From 2007 to 2009, I consulted as a principal engineer for Qualcomm Inc. as part of the acquisition of WiDeFi's technology. While at Qualcomm, I worked with its corporate R&D division and developed consumer 3G and 4G cellular coverage enhancement systems utilizing WiDeFi's baseband interference cancellation technologies. My responsibilities included working with international cellular operators on product requirements, detailed W-CDMA simulations, Long Term Evolution ("LTE") systems analysis, and participation in prototype product realization. I am currently a named inventor on roughly 45 issued U.S. patents or patent applications assigned to Qualcomm.

16. From 2010 to the present, I have served as managing director and co-founder of Proxicom Wireless, LLC, which has developed and continues to develop

cloud-based, mobile social networking and mobile payments technology based upon the proximity and location of mobile devices. Proxicom currently holds twelve issued U.S. patents and multiple pending patent applications, of which I am a named inventor. Significant aspects of Proxicom's technology involve a mobile device's use of short-range wireless technologies (802.11, near field communications, Bluetooth) in combination with cellular data links (3G/WCDMA or 4G/LTE, for example) to facilitate frictionless interactions via a wireless networked central cloud server.

17. Since 2007, I also have been the principal of Proctor Consulting, LLC. In this role, I have been a consultant relating to wired, wireless, and cellular communication and technologies, start-up companies and intellectual property. I have also been involved with numerous patent infringement, patent validity, and patent analysis assignments for public and private companies in the wired, wireless, and cellular networking industries.

18. Additionally, I have worked and consulted for both cellular infrastructure and device focused companies (Spectrian, Qualcomm, Fastback Networks), and defense contractors (Harris Corporation), where I developed covert-tracking and location technologies involving CDMA and smart-antenna technologies.

19. In several of the above-detailed roles, I have been responsible for the development of business plans, product development plans, product development budgets, and product bill of materials estimations. I have been responsible for

numerous product development teams, including schedule and costs of the development process at various stages of my career. For example, at Tantivy Communications, I ran a joint development of I-CDMA cellular base stations in Seoul, Korea that were used in a field trial in that country. Additionally, as founder and CEO of WiDeFi, Inc., I was responsible for similar such activities, as required to raise venture capital funding and reporting to the board of directors.

III. COMPENSATION

20. I am being compensated at my standard hourly rate of \$600 per hour for my work performed in connection with this matter. My compensation does not depend in any way upon the outcome of this matter.

IV. MATERIALS CONSIDERED

21. In forming my opinions, I have reviewed and considered the '296 Patent, its corresponding file history, along with all of the documents in the list attached as Appendix A to this declaration.

V. RELEVANT LEGAL STANDARDS

22. I am not an attorney and offer no legal opinions. For the purposes of this Declaration, I have been informed by Counsel about certain aspects of the law that are relevant to my analysis, as summarized below.

23. I have been informed by Counsel that the first step in an invalidity analysis involves construing the claims, as necessary, to determine their scope. I have

also been informed by Counsel that claims are generally given their ordinary and custom meaning as understood by a person of ordinary skill in the art (“POSITA”) at the time of the invention, in light of the patent’s claims, specification and file history. I have additionally been informed by Counsel that claim construction is a matter of law and that the final claim constructions for this proceeding will be determined by the Patent Trial and Appeal Board (“PTAB”).

24. I have further been informed by Counsel that a patent claim is obvious under 35 U.S.C. §103, and therefore invalid, if the claimed subject matter, as a whole, would have been obvious to a POSITA as of the priority date of the patent based on one or more prior art and/or knowledge of a POSITA. I have been further informed by Counsel that a claim is invalid under 35. U.S.C. § 102 if it is anticipated, which requires that every element of a claim is disclosed in a single prior art reference, arranged as in the claim.

25. I have additionally been informed by Counsel that an obviousness analysis must consider (1) the scope and content of the prior art, (2) the differences between the claims and the prior art, (3) the level of ordinary skill in the pertinent art, and (4) secondary considerations, if any, of non-obviousness (such as unexpected results, commercial success, long-felt but unmet need, failure of others, copying by others, and skepticism of experts).

26. I have been informed by Counsel that a prior art reference may be combined with other references to disclose each element of the invention under 35 U.S.C. § 103. I have further been informed by Counsel that a reference may also be combined with the knowledge of a POSITA, and that this knowledge may be used to combine multiple references. I have further been informed by Counsel that a POSITA is presumed to understand the relevant prior art. I have also been informed by Counsel that the obviousness analysis may take into account the inferences and creative steps that a POSITA would employ.

27. In determining whether a prior art reference would have been combined with other prior art or other information known to a POSITA, I have been informed by Counsel that the following principles may be considered:

- a. whether the references to be combined involve non-analogous art;
- b. whether the references to be combined are in different fields of endeavor than the alleged invention in the Patent;
- c. whether the references to be combined are reasonably pertinent to the problems to which the inventions of the Patent are directed;
- d. whether the combination is of familiar elements according to known methods that yields predictable results;

- e. whether a combination involves the substitution of one known element for another that yields predictable results;
- f. whether the combination involves the use of a known technique to improve similar items or methods in the same way that yields predictable results;
- g. whether the combination involves the application of a known technique to a prior art reference that is ready for improvement, to yield predictable results;
- h. whether the combination is “obvious to try”;
- i. whether the combination involves the known work in one field of endeavor prompting variations of it for use in either the same field or a different one based on design incentives or other market forces, where the variations are predictable to a POSITA;
- j. whether there is some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill in the art to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed invention;
- k. whether the combination requires modifications that render the prior art unsatisfactory for its intended use;

- l. whether the combination requires modifications that change the principle of operation of the reference;
- m. whether the combination is reasonably expected to be a success;
and
- n. whether the combination possesses the requisite degree of predictability at the time the invention was made.

28. I have been informed by Counsel that in determining whether a combination of prior art references renders a claim obvious, it is helpful to consider whether there is some teaching, suggestion, or motivation to combine the references and a reasonable expectation of success in doing so. I have further been informed by Counsel that the existence of an explicit teaching, suggestion or motivation to combine known elements of the prior art is a sufficient, but not a necessary, condition to finding of obviousness. This so-called “teaching-suggestion-motivation” test is not the exclusive test and is not to be applied rigidly in an obviousness analysis.

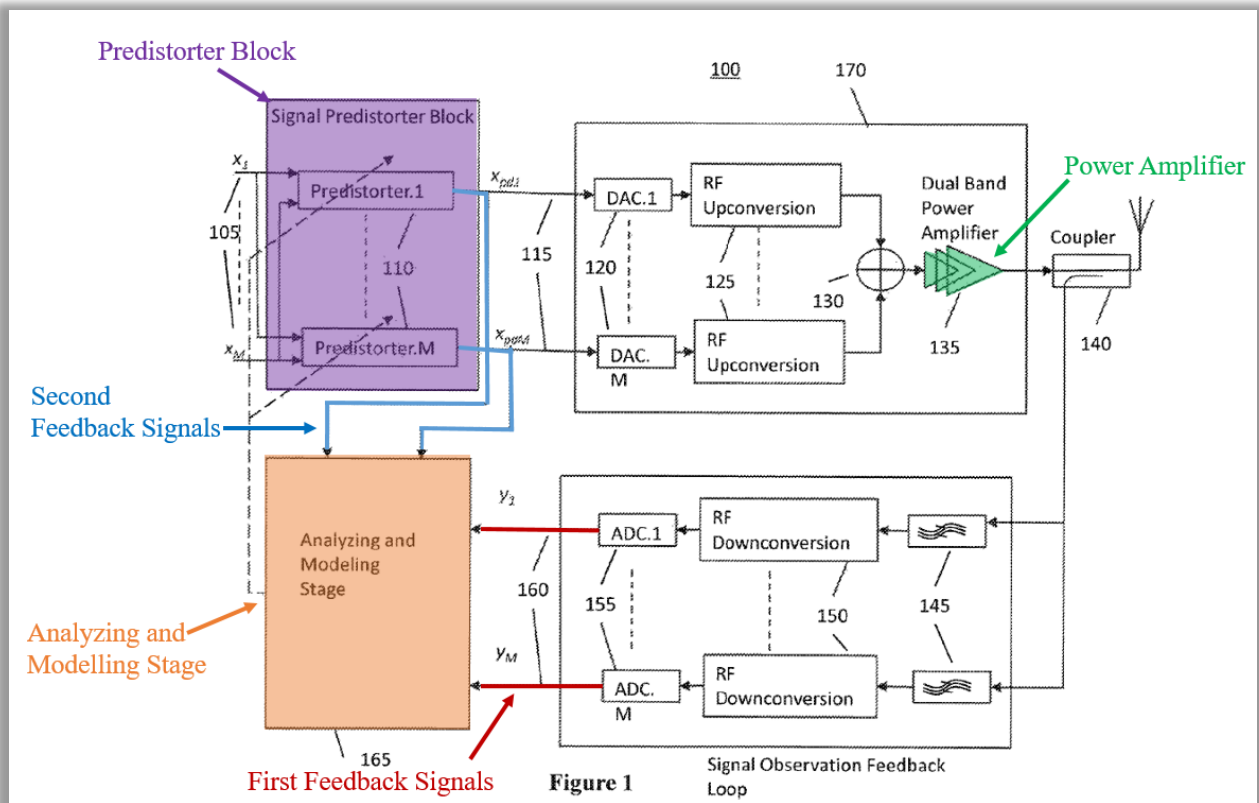
29. I have been informed by Counsel that “a person of ordinary skill in the art” is a hypothetical person to whom an expert in the relevant field could assign a routine task with reasonable confidence that the task would be successfully carried out. I have also been informed by Counsel that evidence of the level of ordinary skill in the art can be found in the patent-in-question.

30. I have been informed by Counsel that a method claim is composed of a series or sequence of steps, each of which state an operation to be performed. I am further informed by Counsel that the sequential arrangement of the steps is not important unless it is essential to the invention itself, and to determine whether the steps recited in a method claim must be performed in the sequence in which they appear in the claim in order, one must look to the nature of the steps themselves and to the written description of the method in the specification.

VI. OVERVIEW

31. The Challenged Claims are unpatentable as obvious over the prior art. When a power amplifier (“PA”), like those used in radio telecommunications, operates in its non-linear region to improve overall efficiency, the output from the PA is distorted relative to its input. Like many others prior to the ’296 Patent, the inventors proposed to mitigate PA nonlinearities by predistorting the signal input to the PA.

32. As shown in the ’296 Patent’s Figure 1, the Patent employs a well-known “indirect learning” approach to predistortion where feedback signals are taken both after predistortion (blue) and after the PA (red) so that nonlinearities introduced by the PA (green) can be analyzed and modeled (orange) and used to update the system’s predistorters (purple):



EX-1001, Fig. 1 (Annotated).

33. More specifically, the '296 Patent's multi-band predistorter block predistorts input signals x_1 to x_M based on an estimate from the analyzing and modelling stage through comparison of first feedback signals (red) and second feedback signals (blue). The first feedback signals (red), y_1 to y_M , are taken from the output of the PA, and the second feedback signals (blue), x_{pd1} to x_{pdM} , are taken from the output of the predistortion block (purple). The analyzing and modelling stage (orange) then updates the predistortion block (purple). The Patent Owner argued during prosecution that this basic architecture where concurrent feedback signals are used in an "indirect learning" approach was novel, but this is simply incorrect.

34. Rather, it was commonplace to compensate for distortion by using concurrent feedback signals taken both after predistortion and after the PA to model the PA's nonlinearity and update the system's predistorters. For example, and as illustrated below, Peroulas (used in Grounds 1 and 2) discloses a near identical architecture for predistortion (shown with common elements annotated in a common color):

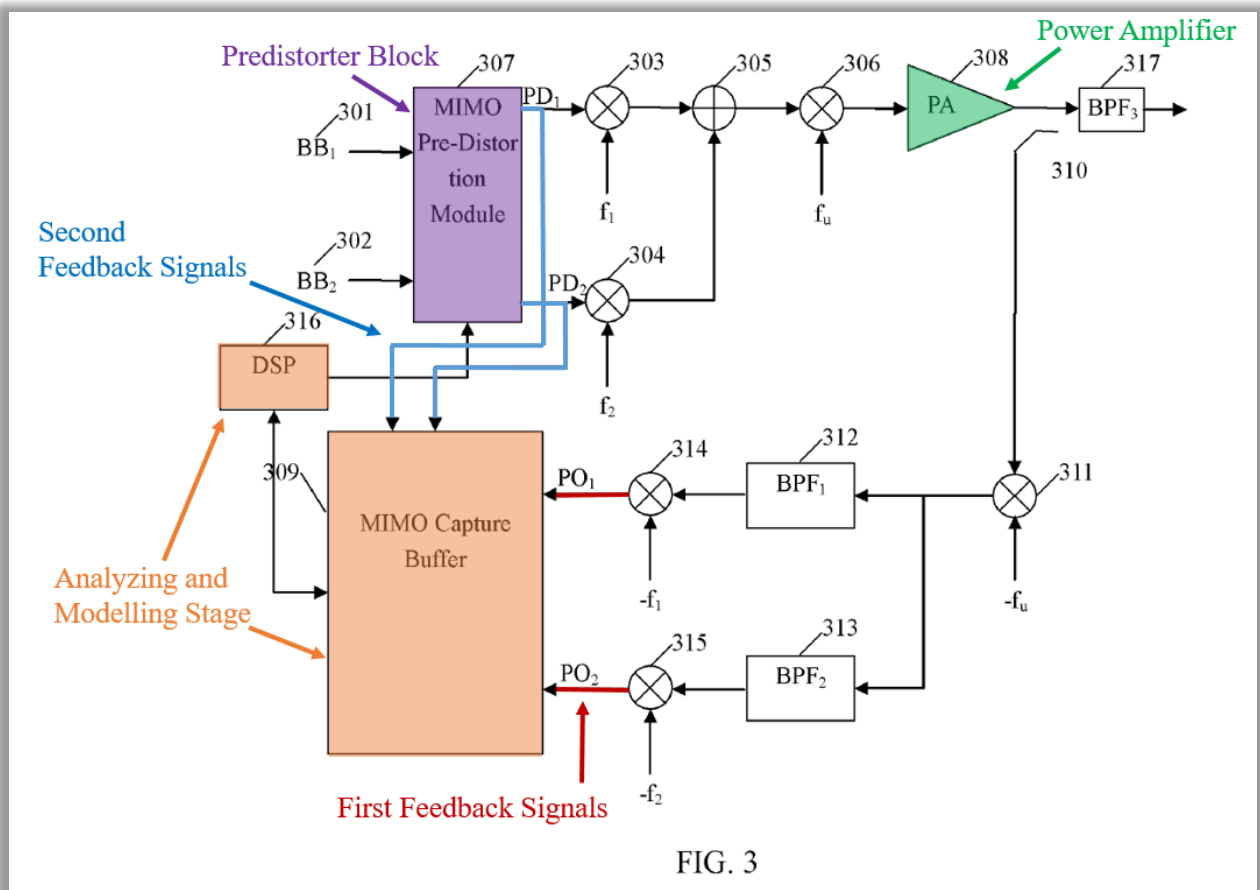


FIG. 3

EX-1005, Fig. 3 (Annotated).

35. Peroulas' MIMO Pre-Distortion Module (purple) predistorts input signals BB_1 and BB_2 based on an estimate from the MIMO Capture Buffer and Digital Signal Processor (DSP) (orange) through comparison of first feedback signals taken from the PA's output (red), and second feedback signals (blue) taken from the predistorters' output. And just like in the '296 Patent, Peroulas' analyzing and modelling stage (orange) then updates its concurrent multi-band predistortion block (purple). Peroulas thus discloses and renders obvious the '296 Patent's independent claims and all but two of the dependent claims, which are separately rendered obvious by Peroulas in view of Cidronali.

36. Grounds 3 and 4 then present an additional basis of unpatentability against each of the Challenged Claims in view of Posti. Posti discloses a multi-frequency carrier transmitter comprising a plurality of input signals, a plurality of digital modulators (purple) for predistortion, and a transmit architecture to amplify (green) the signal. EX-1009, 2:43-60, 4:66-5:5, 5:13-15, 5:41-42; *see, e.g.*:

According to one aspect of the present invention, there is provided a multi frequency carrier transmitter comprising input means for receiving a plurality of different digital signals to be transmitted, said different signals to be transmitted on different carrier frequencies, amplifier means for receiving a composite signal comprising said different signals at the respective carrier frequencies and amplifying said composite signal; and predistortion means for predistorting said plurality of digital signals prior to amplification of the composite signal by said amplification means, said predistortion provided by said predistortion means being subsequently altered in dependence on the

difference between said input signals and the output at Said amplifier means.

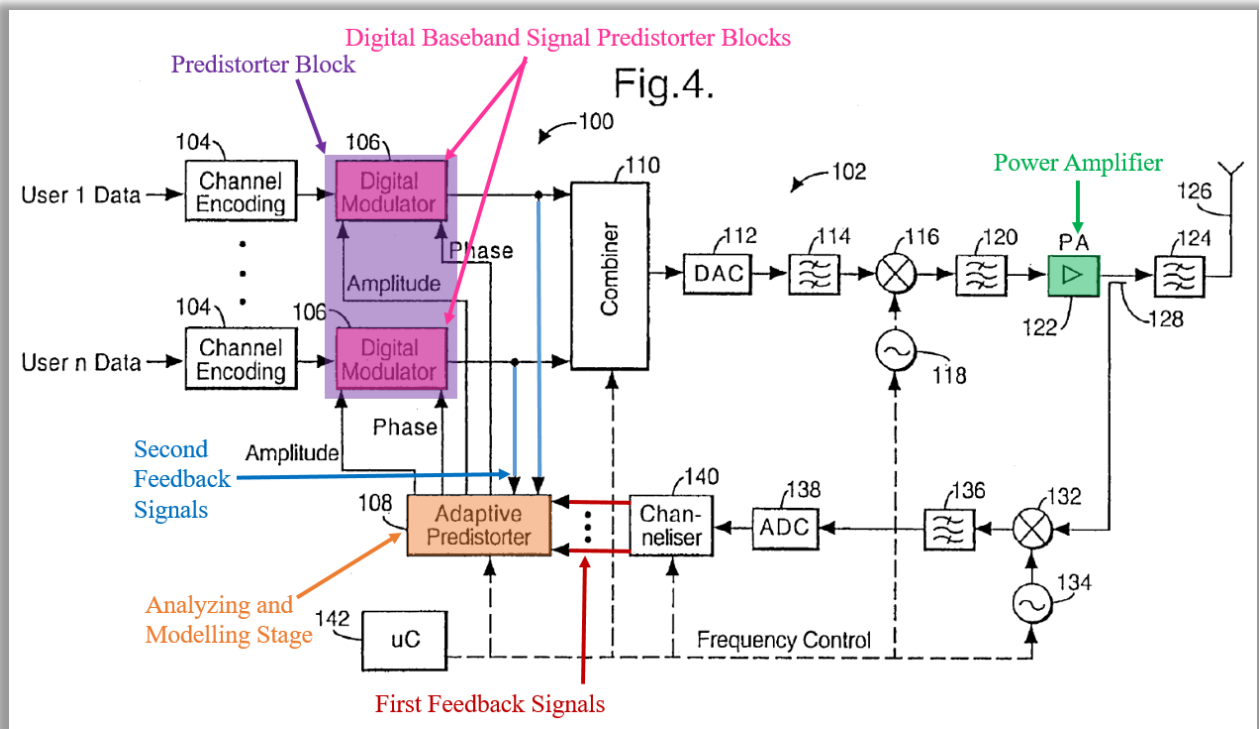
Accordingly, embodiments of the present invention provide a multi carrier transmitter which is able to deal with the problems of nonlinearity by using predistortion. The predistortion can be implemented more simply than the feedback method discussed in the prior art.

EX-1009, 2:43-60. Posti uses indirect learning to estimate and linearize the distortion introduced by the PA, which includes adaptive predistorter 108 (orange) as the claimed “analyzing and modeling stage,” which receives concurrent signals from both the output of the PA (red) and the output of the digital modulators (blue).

EX 1009, 5:50-52, 6:23-31; *See e.g.*:

The adaptive predistorter 108 thus receives for each channel a version of the signal before it passes through the combiner 110 and Subsequent elements of transmit part 102 of the base station 100 (from the respective digital modulator) and a version of the signal after it has passed through the transmit part 102 (from the channelizer 140).

EX 1009, 6:23-31.



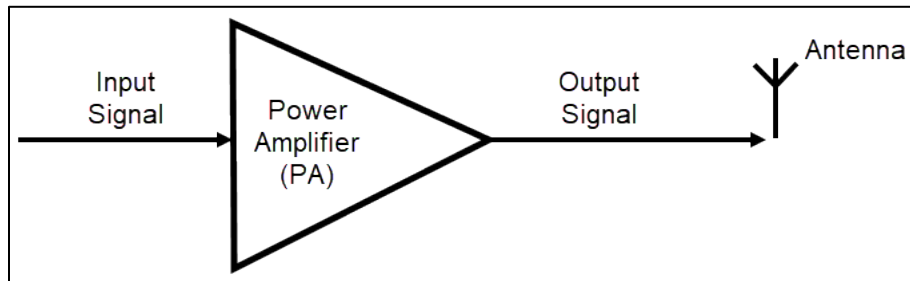
EX-1009, Fig 4 (Annotated). As in Grounds 1 and 2, Posti discloses and renders obvious the '296 Patent's independent claims and all but two of the dependent claims, which are rendered obvious by Posti in view of Cidronali.

VII. BACKGROUND

A. State of the Art

1. Power Amplifier Distortion

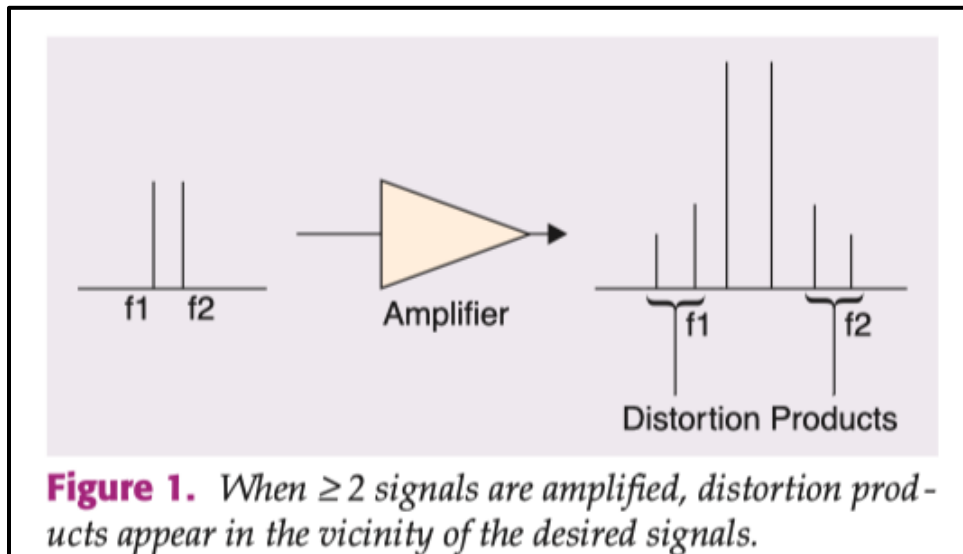
37. Wireless transmitters use PAs to increase the power at which a signal is transmitted. PAs are typically noted as triangles in circuit diagrams, such as the one below:



An input signal's power level is amplified to a higher power level after it passes through the PA to create an output signal. After this amplification, the output signal is transmitted using an antenna.

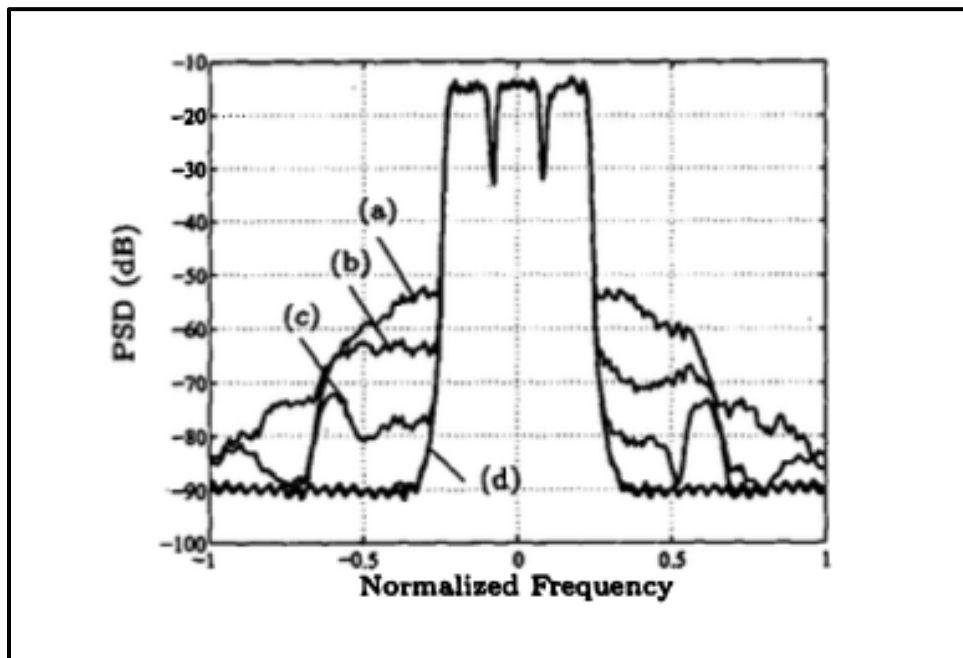
38. All PAs suffer a common problem: when they amplify a signal, they distort that signal to some degree. That distortion may take the form of (1) spectrum spreading or spectral regrowth (i.e., the signal input to the PA is spread across frequencies beyond the channel(s) over which it permitted to be transmitted, which results in so-called adjacent channel interference ("ACI")); or (2) in-band distortion (or more accurately called "in-channel distortion") within the frequencies of the signal itself, which damages the signal's quality.

39. Below is a figure showing spectrum spreading:

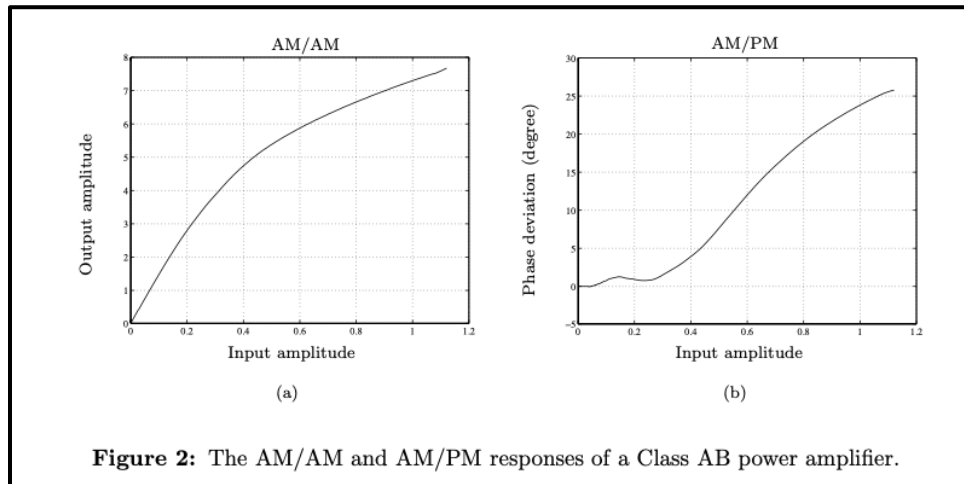


EX-1026, Fig. 1. Above, two signals are input to the power amplifier, which causes distortions: the signals appearing outside of their intended frequency channels.

40. The same effect occurs for modulated input signals composed of multiple frequencies within a given channel, as shown in the following figure:



EX-1027, Fig. 3. In the above figure, the input signal is labeled (d), while the output of the amplifier with distortion is labeled (a).¹ When charted, these distortions can also appear as non-linear curves, where the non-linear curvature represents the distortions that the PAs introduce:



EX-1028, Fig. 2. The above figures depict the relationship of a PA's output to the input signals' amplitude. An ideal PA would proportionally increase the amplitude of a signal, referred to as the amplifier's "gain," to produce a perfectly straight-sloped line in Plot (a), rather than the depicted curved line, which results in different amplification levels depending upon the input level. Such an amplifier might multiply the input amplitude by a factor of ten as a signal changes its amplitude

¹ Plots (b) and (c) show different pre-distortion schemes attempting to compensate for the distortions to "linearize" the amplifier.

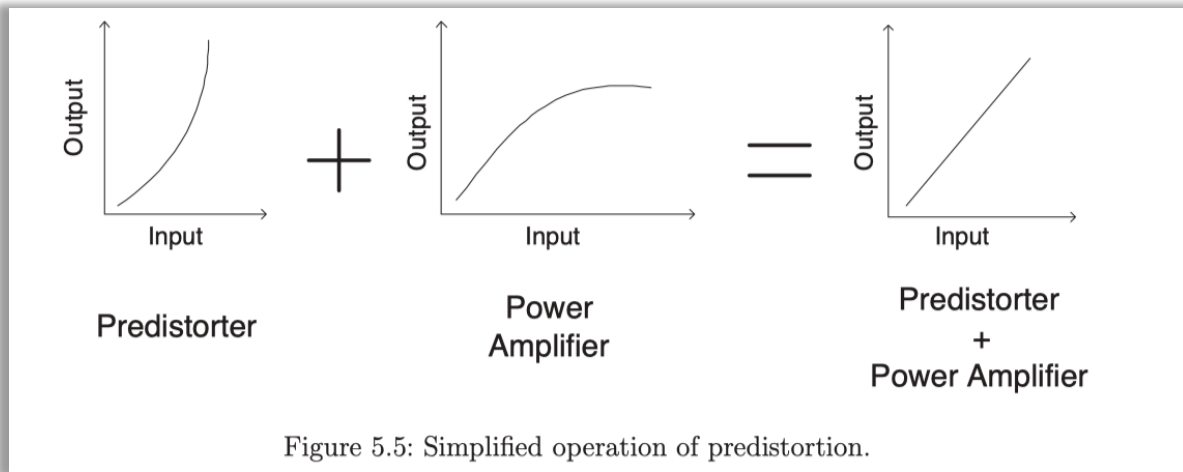
(referred to as “amplitude modulation,” or “AM”). This effect results in a distortion of the output signal that is referred to as “AM to AM.”

41. Plot (b) depicts the phase imparted to the output signal based upon the input signal’s amplitude. Here, an ideal PA would have a flat line such that any additional phase imparted to the output signal would be constant, not depending upon the input level. The depicted curved line indicates that the additional phase added to the signal will change depending on the input signal’s amplitude modulation, causing phase modulation (“PM”) in the output signal, called “AM to PM” distortion.

2. Digital Predistortion (“DPD”)

42. To mitigate unwanted distortions caused by amplification, radios will predistort their input signals before they are sent to the PA. The predistortion begins by “modeling” the PA’s distortion effects. Using knowledge of the kind of distortion a given PA will introduce, a radio can predistort input signals such that the PA’s later distortion is largely canceled. Predistortion is also sometimes called “linearization.”

43. This figure illustrates a predistorter’s operation in a simplified way:



EX-1010, Fig. 5.5; *See, e.g.:*

Fig. 5.5 illustrates predistorter operation in a simplified way. The figure shows AM/AM correction done by the predistorter. In general the similar correction is also done for phase (AM/PM) by adding a phase to the input signal opposite of the phase shift due to the PA.

EX-1010, 53.

44. In a dual or multi-band system, predistortion can mitigate spectral distortion components and intermodulation products (“IMPs”) between the input signals. IMPs arise due to the mixing of signals separated in the frequency domain, and they can appear so close in frequency to the fundamental input signals that they cannot be filtered out. EX-1011, 96, 139, 140. *See, e.g.:*

As discussed in the above paragraphs, the application of digitally modulated signals to a PA, which is considered hereinafter as an nonlinear (NL) dynamic system, causes in-band distortion and spectrum spreading and finally determine a degradation of the signal quality.

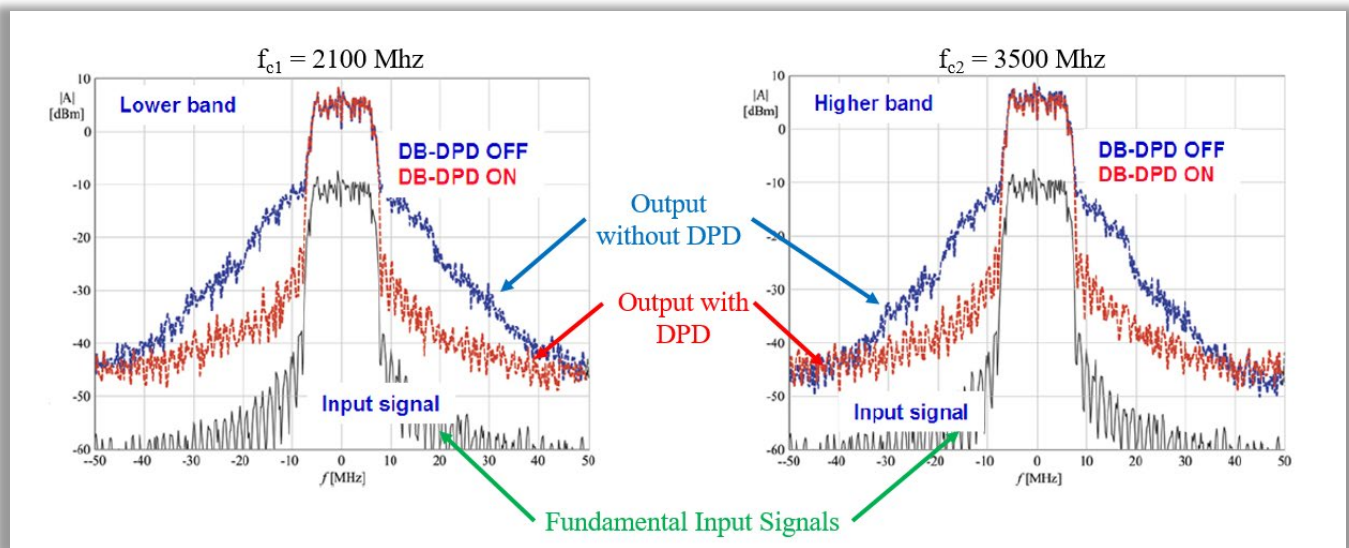
EX-1011, p. 96.

When the input signal is composed of more than one frequency component, that is a multi-tone signal, a new type of distortion will occur. In this case, a new set of spectral components will be generated, in addition to those generated by the nonlinearity on each component considered separately. Such components are called the mixing products or more commonly inter-modulation products.

EX-1011, 139.

[W]e are generally concerned with IMPs around the fundamental frequencies, as they cannot be easily rejected by filters.

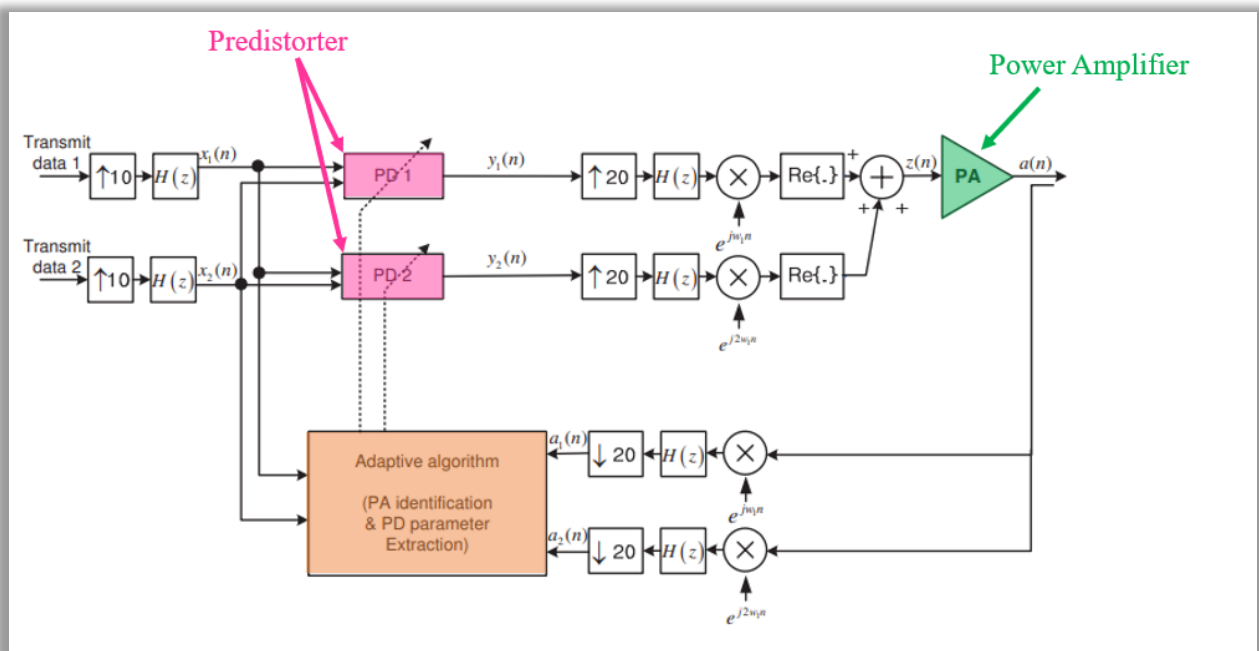
EX-1011, 140. Multi-band predistortion is illustrated in the graphs below, which show that RF signals without predistortion (blue) have an increased power outside the input signal's bandwidth (which is undesirable) as compared to the RF signal with predistortion (red).



EX-1011, Fig. 30 (Annotated).

45. To limit the distortion caused by amplification, a POSA was aware of the many prior architectures and techniques for applying predistortion. For example,

Choi (EX-1021) developed a system using one predistorter per band in a multi-band system such that “[e]ach PD [predistorter] removes the nonlinear cross-products and self-products to mitigate the spectral regrowth for the corresponding band.” EX-1021, 133. Choi also explains that “[s]ince the cross-products between band 1 and band 2 signals appear in both ω_1 and ω_2 , the predistorter also requires $x_1(n)$ and $x_2(n)$ [band 1 and band 2 input signals] for predistortion.” *Id.*, 134.



EX-1021, Fig. 4 (Annotated).

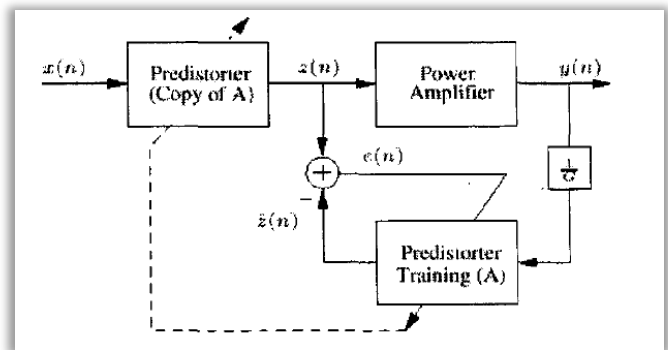
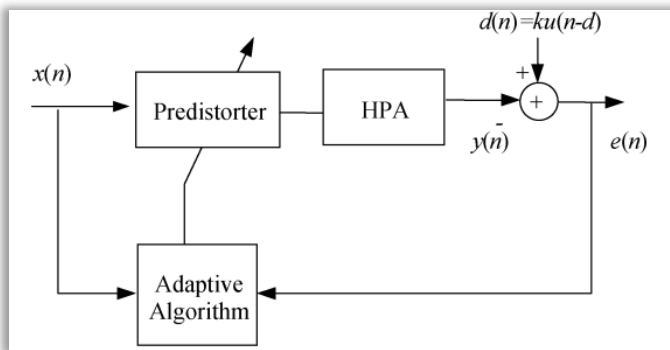
3. Direct and Indirect Predistortion

46. Adaptation or learning architectures for digital predistortion methods were generally categorized as one of two primary types: direct and indirect learning. EX-1012, 1; *See, e.g.:*

Indirect and direct learning architectures are special cases of the inverse control. Additionally, the inverse control is a special case of the self-tuning control. Kalman (1958) has originally proposed the self-tuning controller and its working was later clarified by Åström and Wittenmark (1973) [21]. Direct learning means that the estimate of the input-output relation of the power amplifier is estimated, and the predistortion is obtained directly by “pre-inverting” the PA characteristics. Indirect learning means that a postdistorter first derives a postinverse of the nonlinear model without any predistorter and then the postdistorter is used as a predistorter and the postdistorter is removed.

EX-1012, 1

47. To develop a model of the nonlinearities introduced by the PA, a direct learning architecture uses feedback from the output of the PA and the *input* to the predistorter (prior to predistortion). In contrast, an indirect learning architecture uses the output of the PA and the *output* from the predistorter (prior to amplification). EX-1014, 234, Fig. 2.

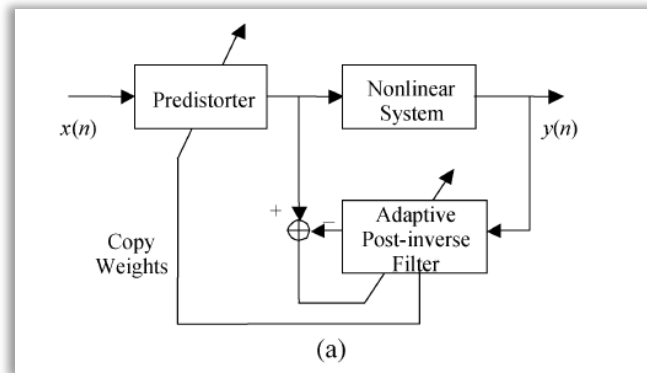


Direct DPD. EX-1013, Fig 2(b).

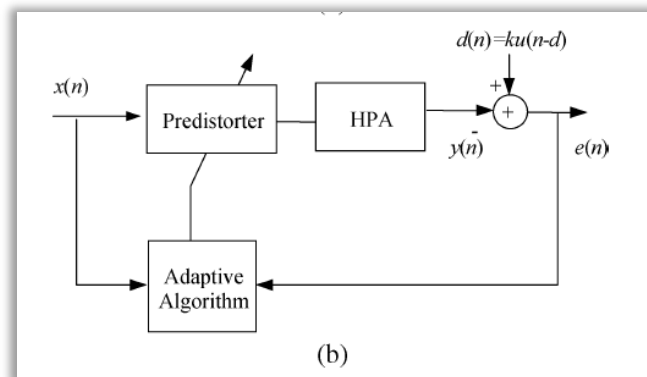
Indirect DPD. EX-1014, Fig. 2.

48. Direct and indirect learning architectures for digital predistortion were widely discussed, and formed the two main feedback mechanisms a POSA would

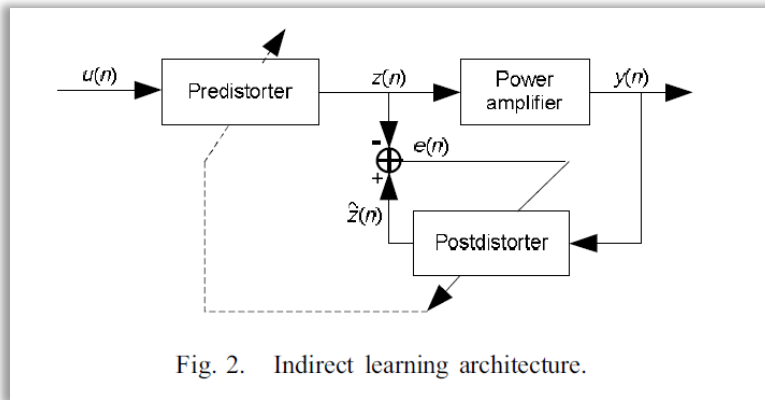
have considered when implementing DPD. *See e.g.*, EX-1005 (indirect); EX-1006 (direct); EX-1011, p. 97 (indirect), EX-1013, Fig. 2(indirect and direct); EX-1012, Figs. 2-3 (indirect and direct respectively); *See, e.g.*:



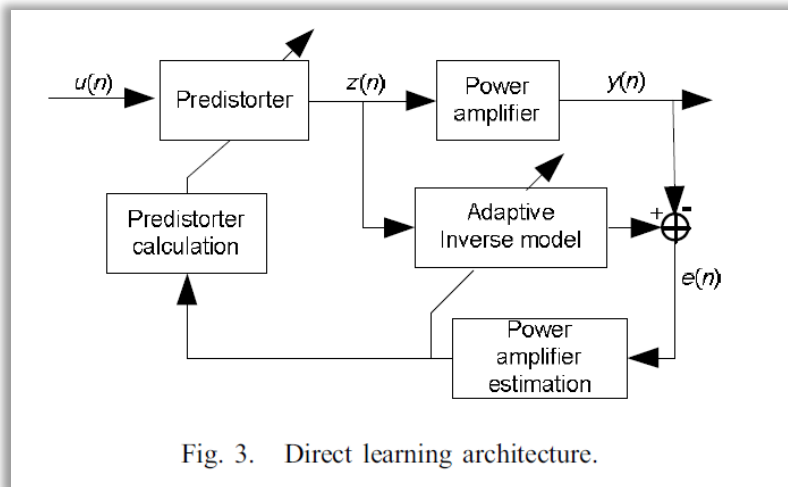
EX-1013, Fig. 2(a) (Indirect).



EX-1013, Fig. 2(b) (Direct).



EX-1012, Fig. 2 (Indirect).



EX-1012, Fig. 3 (Direct).

4. Nyquist-Rate Sampling and Subsampling

49. Analog to digital conversion is the process of sampling an analog waveform, and then transforming the analog information in that sample into a digital representation. EX-1016, 59; *See, e.g.:*

In digital communication systems, the analog information must first be transformed into a digital format. The transform process starts with the sampling process. This process can be implemented by means of

sampling and holding operations. The output of the sampling process is a sequence of pulses with amplitudes derived from the input waveform samples.

EX-1016, 59.

50. To represent an analog signal digitally, this process is repeated at a “sampling rate.” “The classical sampling theorem states that a signal occupying a finite range (band-limited) in the frequency domain can be represented by its samples taken at a finite rate.” EX-1025, 4. Additionally, a band-limited signal can be completely reconstructed if sampled at a rate, f_s , defined as $f_s \geq 2 * f_{max}$, where f_{max} is the highest signal frequency. EX-1016, 59; *See, e.g.:*

A band-limited signal without spectral component beyond frequency f_{max} can be completely reconstructed from a set of uniformly spaced discrete-time samples if the samples are obtained with a sampling rate f_s ,

$$f_s \geq 2 * f_{max}.$$

This particular statement is known as the *uniform sampling theorem*. The sampling rate $f_s = 2f_{max}$ is also referred as the *Nyquist rate*.

EX-1016, 59

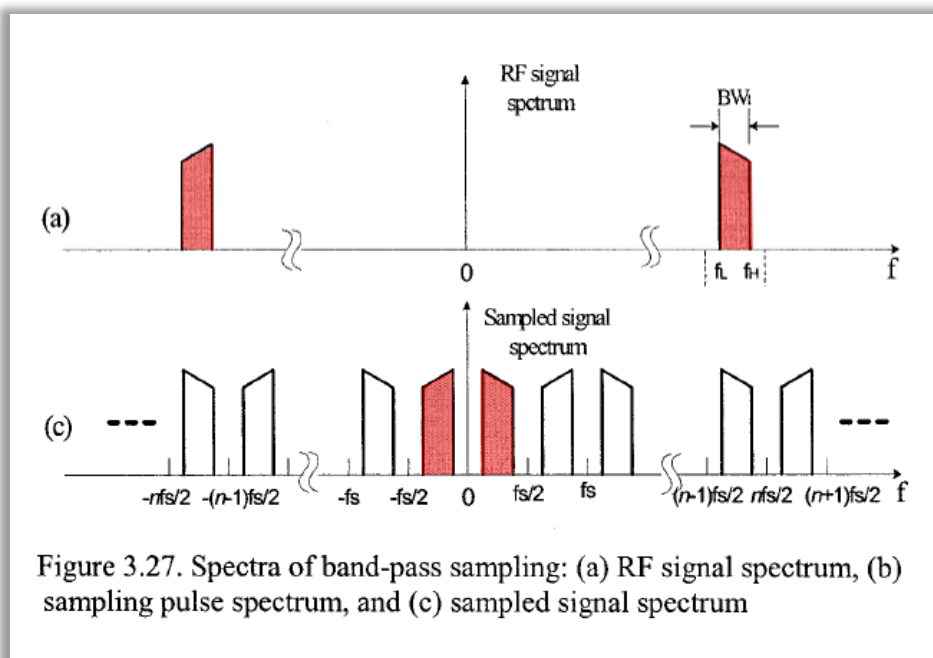
51. In other words, sampling should be done at or higher than twice the highest signal frequency (generally referred to as the Nyquist rate). Sampling at this rate “guarantees no overlaps in the sampled spectrum, and thus allows recovery of the original signal by a low-pass filtering operation.” EX-1024, 2173 (Introduction). But at the same time, it was also known that “[f]or efficient sampling, it is desirable

to attain the lowest sampling rate possible” EX-1025, 4. This is where subsampling, or sampling below the Nyquist rate, comes in. *Id.*, 5;

52. Subsampling or band-pass sampling allows for the entire signal to be reconstructed even though the signal was sampled below the Nyquist sampling rate (illustrated below). EX-1016, 188-189; *See, e.g.*:

The band-pass sampling also referred to as harmonic sampling is the techniques of **sampling at rates lower than the highest frequency of interest to achieve frequency conversion from RF to low IF or base-band through intentional aliasing and to be able to exactly reconstruct the information content of the sampled analog signal** if it is a band-pass signal [19], [20] and [21]. The sampling rate requirement is no longer based on the RF carrier, but rather on the information bandwidth of the signal.

EX-1016, 188-189 (Emphasis added).



EX-1016, Figure 3.27 (Annotated) (Partial). Subsampling, however, was known to create mirror replicas (aliases) of the signal at various frequencies between 0 and f_h , which are dealt with through proper sampling rate, f_s , selection.

53. The widely known equations to determine an acceptable alias-free sample rate are defined below in (1) and (2):

$$\frac{2f_H}{n} \leq f_s \leq \frac{2f_L}{n-1} \quad (1)$$

$$n_{max} = \left\lfloor \frac{f_H}{f_H - f_L} \right\rfloor \quad (2)$$

EX-1016, Equations (3.4.3) and (3.4.4); *see also* EX-1001, 4:48-50; EX-1016, 189; EX-1024, 2173 (Introduction); EX-1025, 1-3. By lowering the required sampling rate, subsampling also reduces the required processing rate, and expensive high-rate components can be replaced with cheaper, low-rate components. Subsampling also reduces the number of down-conversion units and filters. EX-1016, 189; *See e.g.*:

The sampling rate requirement is no longer based on the RF carrier, but rather on the information bandwidth of the signal. Thus the resulting processing rate can be significantly reduced.

EX-1016, 189. Thus, the concept of a “band pass” Nyquist rate, as discussed in the ’296 Patent’s Eq. 2, was well known at the time.

54. Receivers for subsampling were also well-known. As early as 2002, Park (EX-1014) disclosed a subsampling receiver for DPD within an indirect learning architecture to filter, down-convert, and sample the feedback signal:

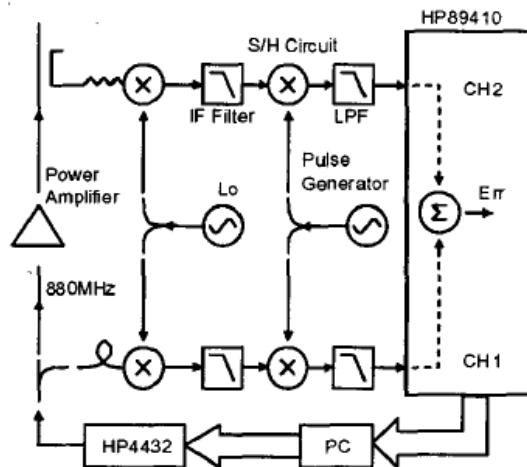


Figure 5: Subsampling Downconverter Test Bed Block Diagram.

EX-1014, Fig. 5. In both direct and indirect architectures for DPD, the feedback path from the PA acts as a receiver and, consistent with any receiver, the feedback path requires filtering, down conversion, and sampling. Further, Mostafa (EX-1019) describes a subsampling receiver that includes filters, a track and hold block, and a single ADC to provide high performance at a reduced manufacturing cost and power. EX-1019, 3:65-67, 4:4-12; *see also* EX-1020 (inventors' own discussion of subsampling receivers at least 3 years prior to the '296 Patent); *See, e.g.:*

It is therefore an object of this invention to provide a radio frequency (RF) receiver that provides high performance at a reduced manufacturing cost and power dissipation.

EX-1019, 3:65-67.

It is a further object of this invention to provide such a receiver in which analog mixers need not be used or reduced in complexity.

It is a further object of this invention to provide such a receiver in which power consumption is also minimized.

It is a further object of this invention to provide such a receiver in which the matching between the I & Q branches is optimized.

EX-1019, 4:4-12.

This paper presents a novel subsampling-based down-conversion topology for multistandard radio receiver design. This receiver topology is based on two subsampling stages. The first stage has a fixed RF subsampling frequency; however, the IF sampling frequency of the second stage is variable and depends on the standard being considered. This approach overcomes various undesirable effects related to the sampling frequencies and noise aliasing. By optimizing the choice of the RF subsampling clock frequency, complete multistandard RF bands are down-converted to the same IF band.

EX-1020, 2901.

Radio receiver design based on the RF subsampling concept offers excellent improvement in terms of integration and power dissipation reduction, compared to analog down-conversion techniques.

EX-1020, 2902.

5. Baseband Signals, Passband Signals, and Modulation

55. A baseband waveform is defined as a signal having a spectral magnitude that is non-zero for frequencies in the vicinity of the origin (i.e., $f=0$) and negligible elsewhere. EX-1030, 203. Baseband signals are typically low-frequency signals that occupy the frequency range starting from zero up to a certain maximum frequency and include the original digital information or data that needs to be transmitted.

56. A bandpass waveform has a spectral magnitude that is non-zero for frequencies in some band concentrated about a frequency $f = \pm f_c$, where $f_c \gg 0$. The

spectral magnitude is negligible elsewhere. f_c is commonly referred to as the carrier frequency. EX-1030, 203. Bandpass waveforms occupy a specific range of frequencies (typically centered around a higher frequency) and are used to facilitate transmission over long distances and through various media. Examples of bandpass signals include radio frequency (RF) and intermediate frequency (IF) signals.

57. Modulation is the process of varying a digital baseband signal in order to create a bandpass waveform with a carrier frequency f_c . EX-1030, 204. This is typically accomplished by combining the baseband signal with a higher frequency carrier signal to create a bandpass waveform. The bandpass signal is often called the modulated signal ($s(t)$), and the baseband source signal is called the *modulating* signal ($m(t)$). In essence, modulation transforms baseband signals representing the original data into bandpass signals for efficient transmission.

6. Complex Envelope Theory

58. A digital baseband signal is expressed by a “complex envelope” consisting of two components: the in-phase (I) component and the quadrature (Q) component. These components combine to form a complex signal, where the I component is the real part and the Q component is the imaginary part.

Theorem. Any bandpass waveform may be represented by

$$v(t) = \text{Re}\{g(t)e^{j\omega_c t}\} \quad (4-1a)$$

where $\text{Re}\{\cdot\}$ denotes the real part of $\{\cdot\}$, $g(t)$ is called the *complex envelope* of $v(t)$, and f_c is the associated carrier frequency, $\omega_c = 2\pi f_c$. Furthermore, two other equivalent representations are[†]

$$v(t) = R(t) \cos[\omega_c t + \theta(t)] \quad (4-1b)$$

and

$$v(t) = x(t) \cos \omega_c t - y(t) \sin \omega_c t \quad (4-1c)$$

where

$$\begin{aligned} g(t) &= x(t) + jy(t) = |g(t)|e^{j\angle g(t)} \\ &\equiv R(t)e^{j\theta(t)} \end{aligned} \quad (4-2)$$

[†]The symbol $\equiv$ denotes an equivalence and the symbol $\triangleq$ denotes a definition.

and

$$x(t) = \text{Re}\{g(t)\} \equiv R(t) \cos \theta(t) \quad (4-3a)$$

$$y(t) = \text{Im}\{g(t)\} \equiv R(t) \sin \theta(t) \quad (4-3b)$$

$$R(t) \triangleq |g(t)| \equiv \sqrt{x^2(t) + y^2(t)} \quad (4-4a)$$

$$\theta(t) \triangleq \angle g(t) = \tan^{-1}\left(\frac{y(t)}{x(t)}\right) \quad (4-4b)$$

The waveforms $g(t)$, $x(t)$, $y(t)$, $R(t)$, and $\theta(t)$ are *all* baseband waveforms and, *except* for $g(t)$, they are all real waveforms. $R(t)$ is a nonnegative real waveform.

EX-1030, 204-205.

59. As shown above, the “complex envelope” of a bandpass signal $g(t)$ may be represented by $x(t) + jy(t)$, which corresponds to the “real” waveform components mapped onto the cosine and sine components of equation 4-1c above. These components represent the in-phase (I) and quadrature (Q) components of the bandpass waveform, respectively. Equations 4-3a and 4-3b show that these components may be demodulated from the carrier frequency by multiplying each by

their in-phase and quadrature carrier frequency components, resulting in two real baseband waveforms that each represent a portion of the bandpass envelope.

60. As discussed above, modulation is the process of converting a baseband signal to its passband counterpart. Modulation varies certain parameters of a carrier signal (e.g. a sinusoid) according to the baseband signal, which may be the in-phase and quadrature signals. For example, in one type of digital modulation called *quadrature amplitude modulation (QAM)*, a passband signal is constructed by impressing separate information bits on each of the quadrature carriers, $\cos(2\pi f_c t)$ and $\sin(2\pi f_c t)$.

$$x_l(t) = x_c(t) + jx_s(t) \quad (2.5.9)$$

$x_c(t)$ and $x_s(t)$ are lowpass signals, called *in-phase* and *quadrature* components of the bandpass signal $x(t)$. Substituting for $x_l(t)$ and rewriting $z(t)$, we obtain

$$\begin{aligned} z(t) &= x(t) + j\hat{x}(t) \\ &= x_l(t)e^{j2\pi f_0 t} \\ &= (x_c(t) + jx_s(t))e^{j2\pi f_0 t} \\ &= (x_c(t) \cos(2\pi f_0 t) - x_s(t) \sin(2\pi f_0 t)) \\ &\quad + j(x_c(t) \sin(2\pi f_0 t) + x_s(t) \cos(2\pi f_0 t)) \end{aligned} \quad (2.5.10)$$

Equating the real and imaginary parts, we have

$$x(t) = x_c(t) \cos(2\pi f_0 t) - x_s(t) \sin(2\pi f_0 t) \quad (2.5.11)$$

EX-1031, 52.

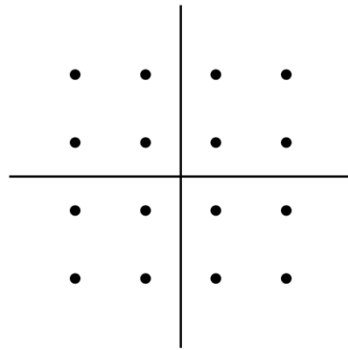


Figure 7.21 $M = 16$ -QAM signal constellation.

EX-1031, Figure 7.21. A QAM modulator is depicted below:

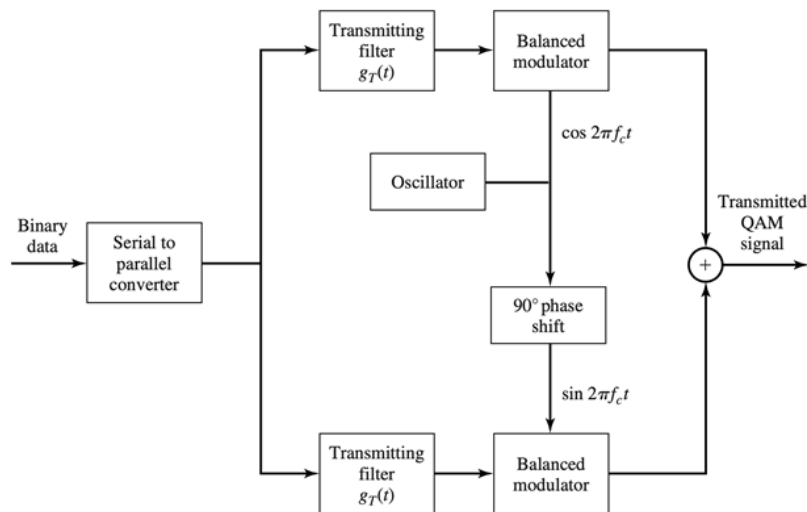


Figure 7.22 Functional block diagram of modulator for QAM.

EX-1031, Figure 7.22. The value mapped on the topmost branch of the QAM modulator of Figure 7.22 results in the real/in-phase component ($x_c(t)$) and the value mapped onto the lower branch results in the imaginary/quadrature component ($x_s(t)$) of equation 2.5.9, forming the QAM constellation of Figure 7.21 above.

61. This complex envelope representation may be utilized for in-phase and quadrature mappings to represent sets of points in a modulation symbol, referred to

as a constellation, utilizing a quadrature modulator as described above. Such signals are passed through a channel, received at a demodulator, and detected.

62. Complex baseband signals have long been used in digital communications systems, such as in the modulation and demodulation processes in systems like QAM, in order to allow processing of the original signal without any modulation to a higher frequency. EX-1030, 203-205; EX-1031, 49-55, 357-360.

B. Summary of the '296 Patent

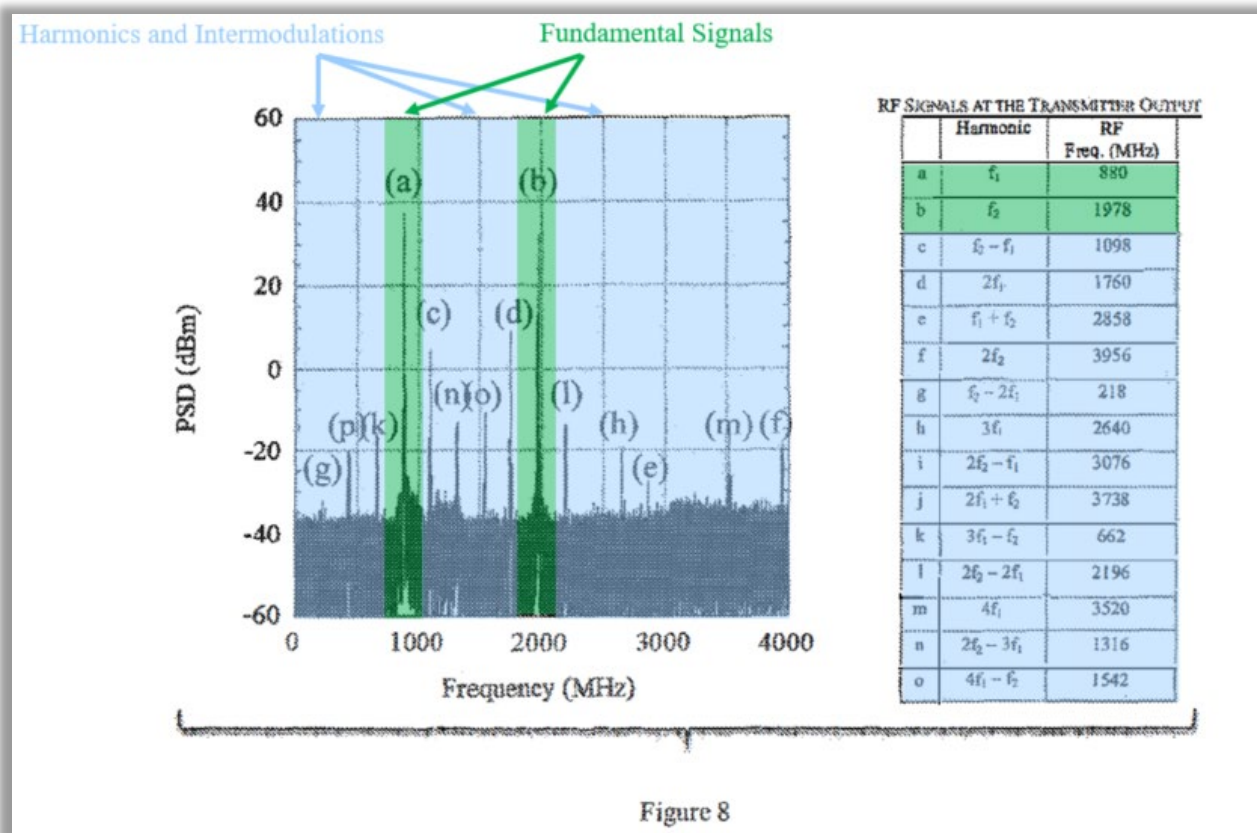
63. The '296 Patent explains that PAs display nonlinear behavior that “introduce unwanted intermodulation distortions into the system, which could significantly degrade the output signal quality.” EX-1001, 1:36-41; *See, e.g.*:

Generally, PAs are the most power consuming and the least power efficient components of the RF chain. Moreover, their nonlinear behavior and non-flat frequency response introduce unwanted intermodulation distortions into the system, which could significantly degrade the output signal quality.

EX-1001, 1:36-41. The '296 Patent further states that in dual-band systems, the PA's nonlinear behavior will further introduce intermodulation, cross-modulation, and harmonic products (blue) caused by interactions between the two fundamental signals (green). *Id.*, 1:51-52; *See, e.g.*:

In dual-band system, the nonlinear behavior of the device will introduce intermodulation, cross modulation, and harmonic products caused by the two fundamental signals. This can be extended to multi-band systems where more than two active signals are transmitted simultaneously.

Id., 1:50-54.

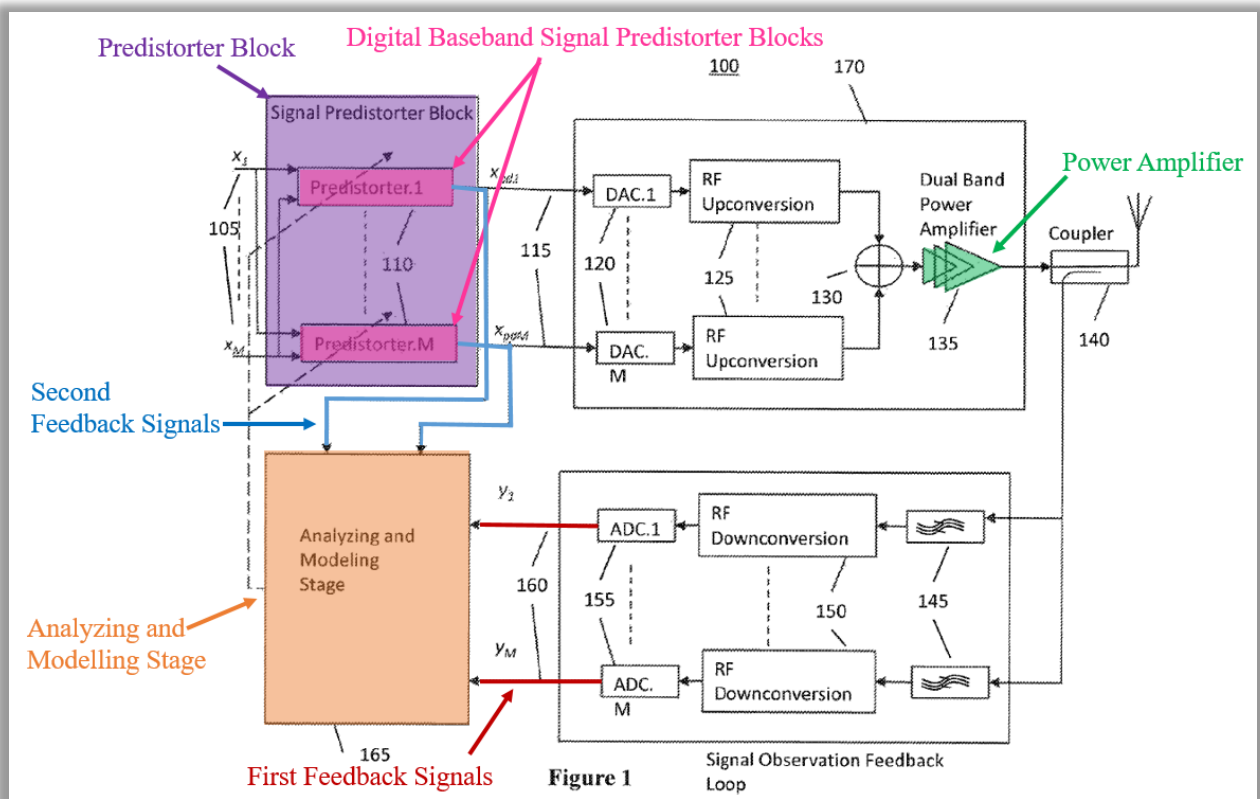


EX-1001 Fig. 8 (Annotated).

64. The '296 Patent purports to provide a solution for this by using a “multiple branch digital predistortion linearization architecture and digital signal processing algorithms for impairments-free operation and linearized multi-band transmitter.” EX-1001, 3:47-50; *See, e.g.*:

Broadly, an embodiment of the present invention provides multiple branch digital predistortion linearization architecture and digital signal processing algorithms for impairments-free operation and linearized multi-band transmitter.

EX-1001, 3:47-50. Fig. 1 (below) illustrates a dual-band linearization architecture 100 including a signal predistorter block (purple), dual-band transmitter 170, signal observation and feedback loop (blue and red), and analyzing and modelling stage (orange).



EX-1001 Fig. 1 (Annotated).

65. The system receives input signals, x_1 to x_m , which are fed into M distinct predistorters 110 (pink) to generate output signals x_{pd1} to x_{pdM} . The digital output signals are converted to analog and ultimately amplified and transmitted. A coupler 140 takes a feedback signal from the output of the PA 135, and then the

system filters, frequency down-converts, digitizes, and passes signals y_1 to y_M to the analyzing and modelling stage (orange). The analyzing and modelling stage receives first feedback signals, y_1 to y_M (red), and second feedback signals, x_{pd1} and x_{pdM} (blue). EX-1001, 3:51-65; *See, e.g.*:

Referring to FIG. 1, the system block diagram of the dual-band linearization architecture 100 is displayed. The input signals, x_1 and x_2 , 105 are fed into two distinct predistorters blocks 110. The predistorted signals 115 are converted from digital to analog 120 and up-converted 125 to RF frequencies. Then the two RF signals are combined 130 and amplified by the power amplifier 135.

For digital predistortion linearization and identify the inverse model, the sample of the RF signal are captured using dual-band coupler 140. Then the RF signals are 60 bandpass filtered 145, frequency down converted 150, digitized using analog-to-digital converters 155. The digital output samples 160, the input signals 105 and predistorted signals 115 are used in the analyzing stage 165 for nonlinear model identification and reverse modeling.

EX-1001, 3:51-65.

66. The specification includes the following equations for prediction and compensation of the nonlinearities created by PA:

$$x_{pd1}(n) = \sum_{m=0}^{M-1} \sum_{k=0}^{K-1} \sum_{j=0}^k c_{1,j,k,m} x_1(n-m) |x_1(n-m)|^{k-j} |x_2(n-m)|^j$$

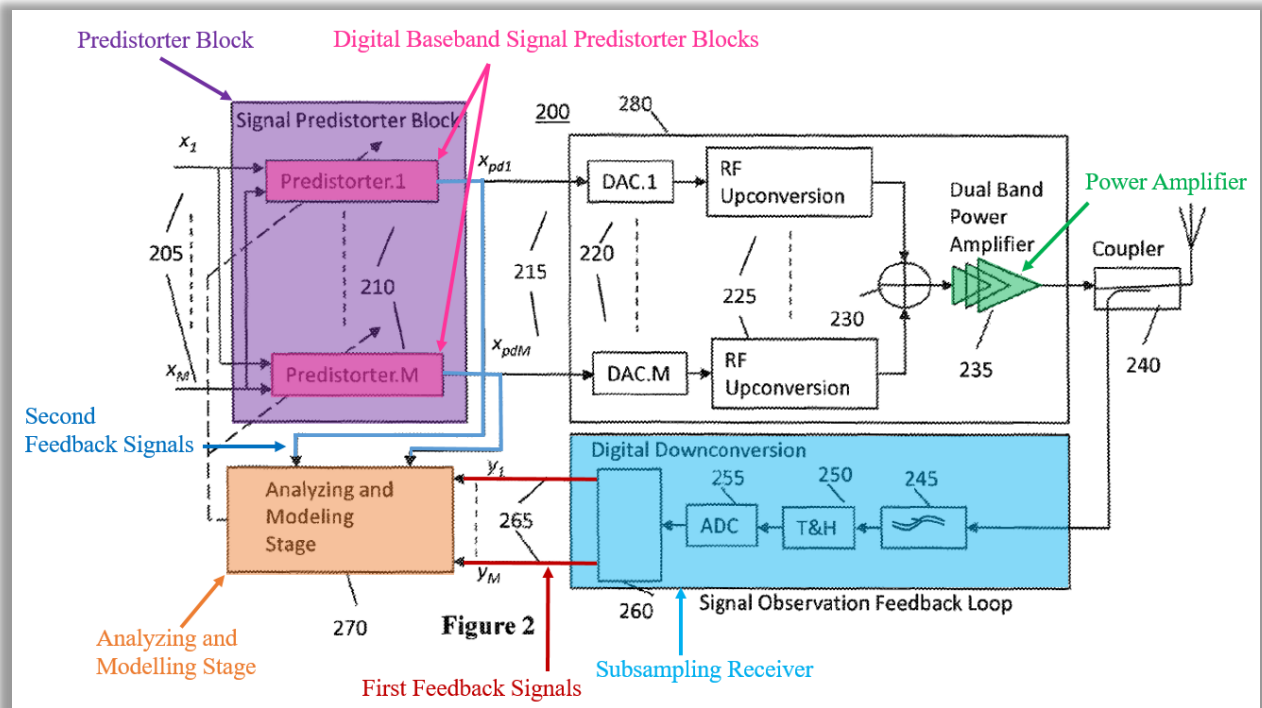
$$x_{pd2}(n) = \sum_{m=0}^{M-1} \sum_{k=0}^{K-1} \sum_{j=0}^k c_{2,j,k,m} x_2(n-m) |x_2(n-m)|^{k-j} |x_1(n-m)|^j$$

Id., 4:10-15.

67. In another embodiment, “subsampling based receiver 300” is used. EX-1001, 4:56-57. Receiver 300 (blue) consists of a singular “RF bandpass filter 305, low-noise amplifier (LNA) 310, subsampling receiver 345 including the track and hold (T&H) 320, and ADC 325 followed by baseband digital signal processing (DSP) unit 330.” *Id.*, 4:56-57; *See, e.g.:*

FIG. 3 shows a general block diagram of subsampling-based receiver 300. It consists of RF bandpass filter 305, low-noise amplifier (LNA) 310, subsampling receiver 345 including the track and hold (T&H) 320, and ADC 325 followed by baseband digital signal processing (DSP) unit 330.

EX-1001, 4:56-61.



EX-1001, Fig. 2 (Annotated).

C. Claim Construction

68. It is my opinion that no specific construction of any claim term is required because the prior art meets each of the claim terms under any reasonable construction.

69. To aid the Board's review, however, I provide additional context surrounding the use of the terms "band" and "channel," which appear in the claims, but are not defined in the specification. For example, dependent claim 2 explains that the "concurrent digital multi-*band* predistortion block further comprises" "a plurality of the digital baseband signal predistorters each corresponding to a respective *channel*."

70. A POSA would have understood "band" and "channel" to correspond to related concepts, with a "band" generally corresponding to a continuous range of frequencies between specified upper and lower limits, and that a "channel" is a particular path (and corresponding signal frequency range) over which signals can be sent. EX-1023 (IEEE Standard 100, 200). Thus, a given "band" may comprise one or more "channels," and if a system is "multi-band," it is comprised of multiple bands with each band containing one or more channels. Likewise, multi-channel systems are comprised of one or more channels within one or more bands. A POSA would have also understood that wireless standards (*i.e.*, 3G, 4G, and 5G) define the

technical requirements around “bands” and the one or more “channels” that make up a particular band.

71. For example, a POSA would have been well aware of 3GPP’s “fragmented carrier aggregation” requirement, which requires transmit equipment to be able to transmit different channels/signals (e.g., LTE and GSM) across different frequency bands without the need for multiple, band-specific PAs. Channels, therefore, encompass the particular signal and frequency range that is going to be transmitted. As another example, in WCDMA (3G standard), a single physical downlink channel is defined within a band to transmit data to user equipment.

72. While none of this is explained in the specification, the ’296 Patent purports to “relate[] to multi-band digital predistortion linearization” (EX-1001, 1:27-28) and, in the patent’s single usage of the word “channel,” the ’296 Patent explains that “out-of-band intermodulation terms” are “usually filtered out before transmission using RF filter to avoid signal quality degradation and interference with signals at the adjacent *channels*.” *id.*, 5:9-14 (emphasis added); *See, e.g.*:

The unwanted intermodulation can be classified into three groups of cross-modulation, in-band intermodulation, and out-of-band intermodulation terms. This latter is usually filtered out before transmission using RF filter to avoid signal quality degradation and interference with the signals at the adjacent channels.

EX-1001, 5:7-14. Thus, the specification appears to suggest that in the aforementioned context, a “channel” is the frequency range corresponding to a signal to be transmitted within a particular band.

73. Similarly, and in the context of the '296 Patent's disclosed “processing model equations of the linearization processing algorithm 165,” “ $x_1(n)$ and $x_2(n)$ are the input signals [and] $x_{pd1}(n)$ and $x_{pd2}(n)$ are the predistorted signals to the input of the dual-band transmitter.” EX-1001, 4:2-21; *See, e.g.:*

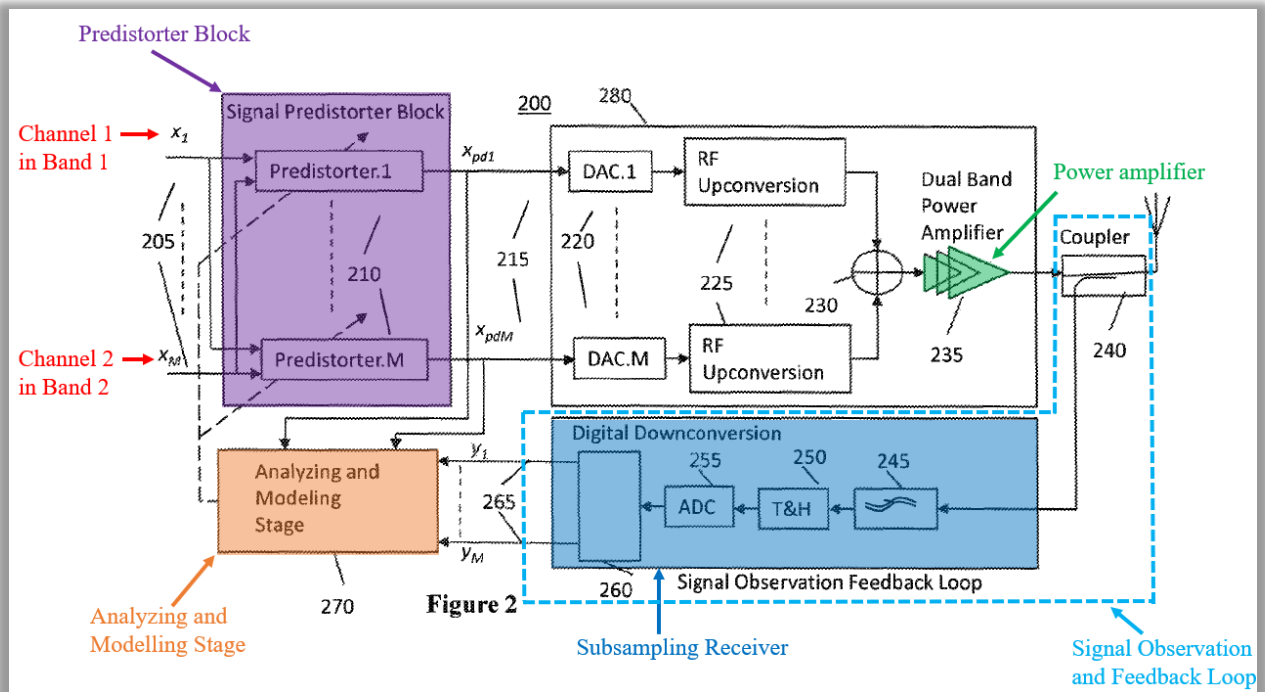
The predistorted inputs, x_{PD1} and x_{PD2} , 115 as well as the output of each band of the PA, y_1 and y_2 , 160 are used to generate the predistorter signal processing model 110. The processing model equations of the linearization processing algorithm 165 for prediction and compensation of the distortions and intermodulations is as follows:

$$\begin{aligned} x_{pd1}(n) &= \sum_{m=0}^{M-1} \sum_{k=0}^{K-1} \sum_{j=0}^k c_{1,j,k,m} x_1(n-m) |x_1(n-m)|^{k-j} |x_2(n-m)|^j \\ x_{pd2}(n) &= \sum_{m=0}^{M-1} \sum_{k=0}^{K-1} \sum_{j=0}^k c_{2,j,k,m} x_2(n-m) |x_2(n-m)|^{k-j} |x_1(n-m)|^j \end{aligned} \quad (1)$$

Where $x_1(n)$ and $x_2(n)$ are the input signals, $x_{pd1}(n)$ and $x_{pd2}(n)$ are the predistorted signals to the input of the dual-band transmitter, $c_{1,j,k,m}$ and $c_{2,j,k,m}$ are the identified model's coefficients, and finally M is the order of the memory effect and K is the order of nonlinearity.

EX-1001, 4:2-21. In other words, and in the context of a “dual-band” transmitter that transmits over two “bands” or frequencies, the paths of the input signals to the predistorter(s), with corresponding frequency ranges, are simply the claimed “channels,” and there will be one channel or signal path corresponding to each

“band” of the transmitter. Thus, each input signal path to a predistorter has a particular frequency range and represents a “channel.” This is also what is depicted in the patent’s architectural layouts, Fig. 1 and 2.



See, e.g., EX-1001, Fig. 2 (Annotated).

74. The prior art relied on herein discloses any reasonable interpretation of “band” and “channel” because both Peroulas and Posti discloses transmitters/PAs that are linearized using predistorters that take, as part of their input, a signal, with a corresponding frequency range (or “channel”), corresponding to each “band” of the transmitter, exactly as described by the ’296 Patent.

D. Priority Date of the Challenged Claims

75. The application that issued as the '296 patent was filed on May 1, 2017, and claims priority through a string of continuations to U.S. Patent No. 8,817,859, filed on October 14, 2011. For the purposes of this declaration, I have been instructed to assume the priority date for the patent is October 14, 2011.

E. Person of Ordinary Skill in the Art

76. I have reviewed the relevant disclosures of the Patent-in-Suit (the '296 Patent) as well as relied on the documents identified above, and on my education and experience, to arrive at my opinions regarding the level of a person of ordinary skill in the art.

77. In my opinion, a person of ordinary skill in the art in the field of the '345 Patent in the relevant time frame would have been someone with at least (1) a bachelor's degree in electrical engineering or a related field, and (2) either (a) a master's degree in electrical engineering or a related field, or (b) two or more years of work or research experience in wireless communications and, in particular, power amplification of radio signals

78. In determining the level of ordinary skill in the art, I considered, for example, the type of problems encountered in the art, prior art solutions to those problems, the rapidity with which innovations were made, the sophistication of the technology, and the educational level of active workers in the field.

79. I met the definition of a POSITA in the relevant time frame. I also had greater knowledge and experience than a POSITA in the relevant time frame. I render my opinions, however, from the perspective of a POSITA, based on my knowledge and research and teaching experience. Indeed, my opinions concerning the '296 Patent and the prior art are from the perspective of a POSITA.

VIII. IDENTIFICATION OF HOW THE CLAIMS ARE UNPATENTABLE

80. In my opinion, the '296 Patent's claims 1-10 are invalid as obvious as summarized in the table below:

Ground	Claims	Basis	References
1	1-7, 10	Obvious	Peroulas
2	8, 9	Obvious	Peroulas in view of Cidronali
3	1-7, 10	Obvious	Posti
4	8, 9	Obvious	Posti in view of Cidronali

81. I understand that Peroulas published on October 4, 2012 (EX-1005), and claims the benefit of a March 28, 2011, International filing date and, therefore, is prior art. Further, I understand Cidronali published on January 9, 2009 (EX-1006) and Posti issued on February 14, 2006 (EX-1009) are both prior art to the '296 Patent.

A. Ground 1: Claims 1-7 and 10 are Obvious over Peroulas

1. Peroulas

82. Peroulas relates to "a method for pre-distorting and a pre-distorter." EX-1005, 1:3-4. Peroulas explains that to improve efficiency, PAs should be driven

into their non-linear region, resulting in higher amounts of distortion. The goal of the pre-distortion function is to create a signal that, when cascaded with the PA, produces an output that is linear overall. EX-1005, 7:25-8:1; *See, e.g.:*

The pre-distorter further comprises:

a bandpass filter, which is configured to connect with a output of the PA, and filter out harmonics of said carrier frequencies introduced by the PA, and transmit the filtered signal;

wherein the cascade of the pre-distortion functions, the PA and the bandpass filter are linear overall.

EX-1005, 7:25-8:1

83. Peroulas' solution, shown in Fig. 3 (below), includes a predistortion module (purple) having a plurality of predistortion units, each corresponding to one predistortion function (not shown, but producing PD₁ and PD₂, respectively). EX-1005, 6:25-27; *see also id.*, Abstract (“pre-distortion module, which is configured to predistort a plurality of baseband input signals by an equal number of pre-distortion functions to obtain equal number of pre-distorted signals... an adder, which is configured to combine all of the pre-distorted signals, ... a power amplifier (PA)”); 6:11-20, 7:1-4, 7:26-27; *See, e.g.:*

In order to solve above technical problem, the present invention provides a pre-distorter, which comprises:

a pre-distortion module, which is configured to pre-distort a plurality of baseband input signals by an equal number of pre-distortion functions to obtain equal number of pre-distorted signals respectively,

wherein all of the baseband input signals input into every pre-distortion function, and each pre-distortion function has one output;

an adder, which is configured to combine all of the pre-distorted signals output from every pre-distortion functions into one combined signal; and

a power amplifier (PA), which is configured to amplify the combined signal,

wherein the cascade of the pre-distortion functions and the PA are linear overall.

Wherein

the pre-distortion module is a multiple input multiple output (MIMO) pre-distortion module, wherein the number of inputs and outputs of the pre-distortion module are equal to the number of baseband input signals, and each output corresponds to one pre-distortion function;

or

the pre-distortion module includes a plurality of pre-distortion units, wherein all of the baseband input signals input into each pre-distortion unit, and each pre-distortion unit corresponds to one pre-distortion function and has one output.

EX-1005, 6:10-27. Peroulas uses indirect learning where feedback is taken from the output of the predistorters and the output of the PA, and concurrently fed into a MIMO Capture Buffer 309 and DSP block 316 (orange) to update the predistortion functions used to linearize the PA. EX-1005, 8:10-15, 9:1-10; *See, e.g.:*

coefficients $h_{i,j,k_1,\dots,k_N}$ are chosen such that the cascade of the MIMO pre-distortion function, and the PA will be linear overall;

BB_i are baseband input signals, and PD_i are the pre-distorted signals,

Wherein the coefficients $h_{i,j,k_1,\dots,k_N}$ are obtained by solving:

$$PD_i(n) = \sum_{j=0}^{M_i-1} \sum_{k_1=0}^{L_{i,1}-1} \sum_{k_2=0}^{L_{i,2}-1} \dots \sum_{k_N=0}^{L_{i,N}-1} \hat{h}_{i,j,k_1,k_2,\dots,k_N} PO_i(n-j) |PO_1(n-j)|^{k_1} |PO_2(n-j)|^{k_2} \dots |PO_N(n-j)|^{k_N}$$

wherein PO_i are captured signals of the pre-distorted signals, which are captured from the output of the PA.

EX-1005, 8:10-15.

a capture buffer, which is configured to obtain PD_i and PO_i , and output the obtained PD_i and PO_i ; to a digital data processor (DSP), and the number of inputs of the capture buffer equals to twice of the number of the baseband input signals; and

a DSP, which is configured to calculate coefficients $h_{i,j,k_1,\dots,k_N}$ by solving equation Eq.2, and output the calculated coefficients $h_{i,j,k_1,\dots,k_N}$ to the pre-distortion module.

EX-1005, 9:1-5.

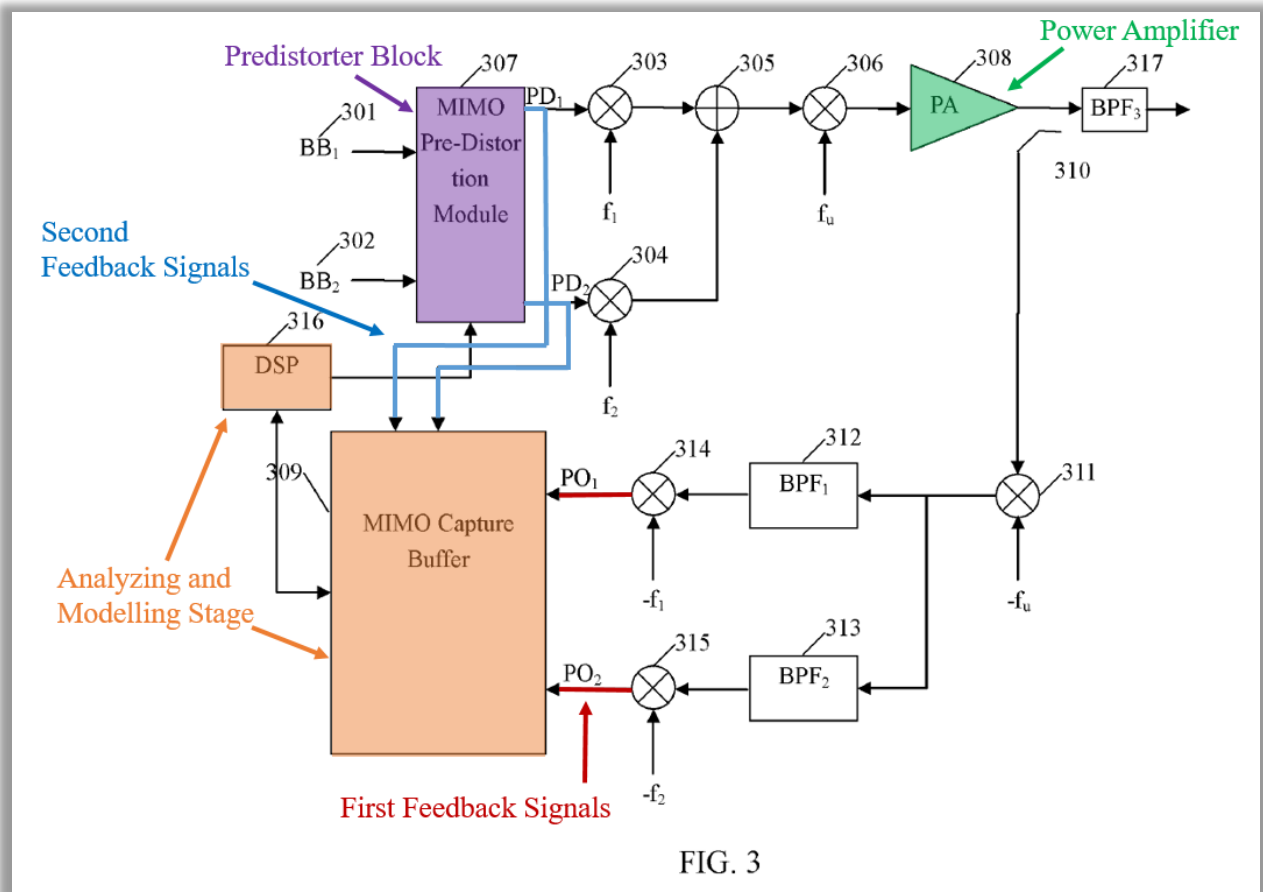


FIG. 3

EX-1005, Fig. 3 (Annotated).

2. Detailed Application to the Challenged Claims

Claim 1

[1pre] *A linearized transmitter comprising:*

84. To the extent the preamble is limiting, Peroulas discloses a “method for pre-distorting and a pre-distorter,” for a *transmitter*, such that the output of the predistorter and power amplifier is linear overall prior to transmission. EX-1005, 6:8-27, 14:17-23; *See, e.g.:*

The problem to be solved in the present invention is to provide a method for pre-distorting

and a pre-distorter, which reduces the implementation cost of a pre-distortion transmitter.

In order to solve above technical problem, the present invention provides a pre-distorter, which comprises:

a pre-distortion module, which is configured to pre-distort a plurality of baseband input signals by an equal number of pre-distortion functions to obtain equal number of pre-distorted signals respectively, wherein all of the baseband input signals input into every pre-distortion function, and each pre-distortion function has one output;

an adder, which is configured to combine all of the pre-distorted signals output from every pre-distortion functions into one combined signal; and

a power amplifier (PA), which is configured to amplify the combined signal,

wherein the cascade of the pre-distortion functions and the PA are linear overall.

Wherein

the pre-distortion module is a multiple input multiple output (MIMO) pre-distortion module, wherein the number of inputs and outputs of the pre-distortion module are equal to the number of baseband input signals, and each output corresponds to one pre-distortion function;

or

the pre-distortion module includes a plurality of pre-distortion units, wherein all of the baseband input signals input into each pre-distortion unit, and each pre-distortion unit corresponds to one pre-distortion function and has one output.

EX-1005, 6:8-27.

The main technical scheme of the present invention is: A plurality of baseband input signals is pre-distorted by an equal number of pre-distortion functions respectively, wherein all of the baseband input signals are input into each pre-distortion function, and each pre-distortion function has one output; the pre-distorted signals are combined into one signal; the combined signal is then power amplified by a PA, and then the PA transmits the processed signal, wherein the cascade of the pre-distortion function and the PA are linear overall, wherein the number of the pre-distortion functions is equal to the number of the baseband input signals

EX-1005, 14:17-23.

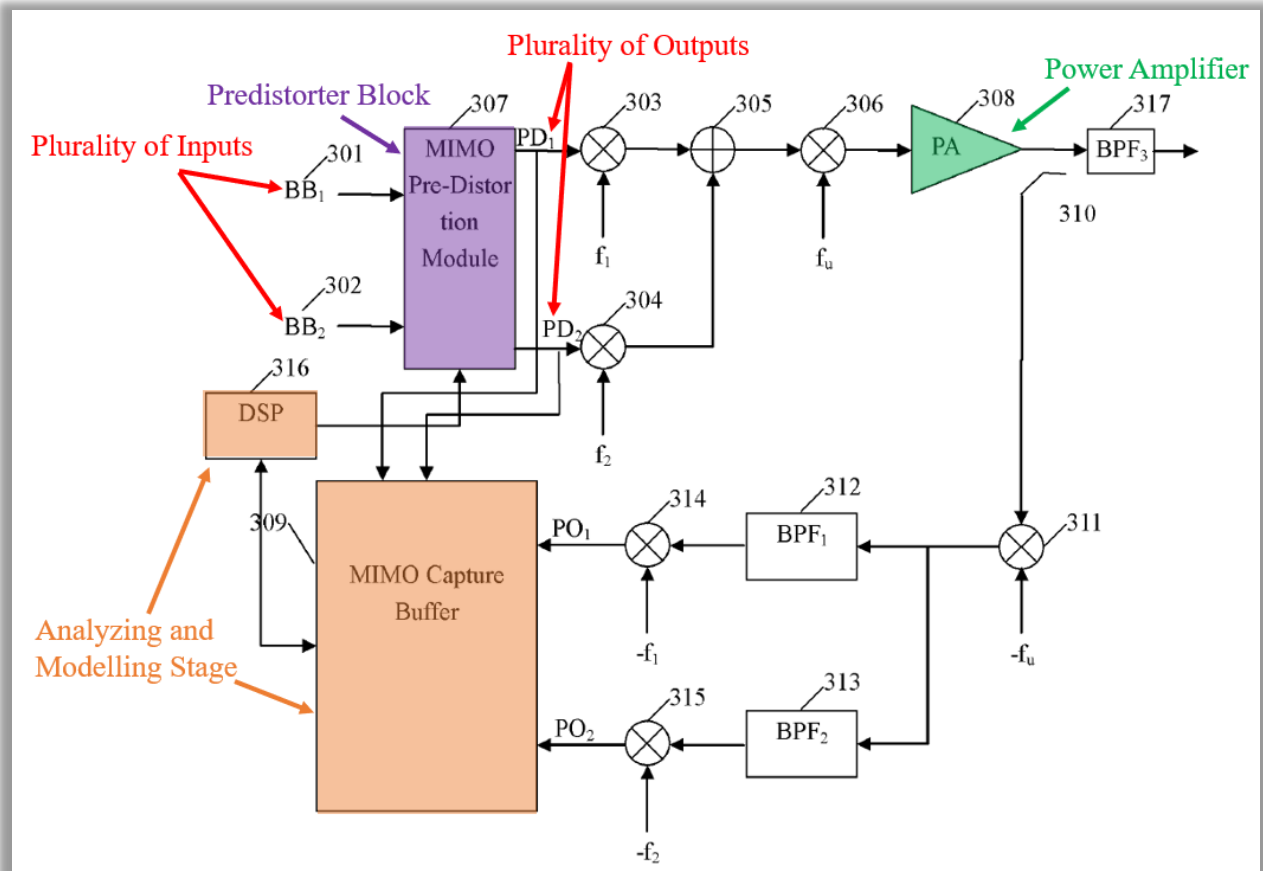
[1a] a digital signal predistorter block including digital baseband signal predistorters effecting predistortion of concurrent input signals to output concurrent predistorted signals;

85. As shown in annotated Fig. 3 (below), Peroulas discloses a MIMO Pre-Distortion Module (purple) (*digital signal predistorter block*) configured to concurrently pre-distort a plurality of baseband signals BB_1 and BB_2 corresponding to a respective channel (*concurrent input signals*), by an equal number of

predistortion functions to obtain an equal number of predistorted output signals, PD_1 and PD_2 (*concurrent predistorted signals*). EX-1005, 8:12-14, 22:26-23:9; *See, e.g.:*

Baseband signals BB1 301 and BB2 302 are sent into a multiple input multiple output (MIMO) pre-distortion module 307 to produce signals PD_1 and PD_2 , and the MIMO pre-distortion module 307 processes baseband signals BB1 301 and BB2 302 with a MIMO predistortion function. Signals PD_1 and PD_2 are sent into frequency shifters 303 and 304 which shift the frequency of the signals PD_1 and PD_2 to f_1 and f_2 respectively. Then these shifted signals are combined by an adder 305. Wherein the MIMO predistortion function includes at least two pre-distortion functions, and each pre-distortion function has two inputs and one output. The number of the inputs for each pre-distortion function is equal to the number of the baseband signals input into the multiband digital pre-distorter, and the number of the predistortion functions is equal to the number of the baseband signals input into the multiband digital pre-distorter.

EX-1005, 22:26-23:9.



EX-1005, Fig. 3 (Annotated).

86. Peroulas states that the Pre-Distortion Module includes “a plurality of pre-distortion units, wherein all of the baseband input signals input into each pre-distortion unit, and each pre-distortion unit corresponds to one pre-distortion function and has one output” (*a digital signal predistorter block including digital baseband signal predistorters effecting predistortion of concurrent input signals*). EX-1005, 6:25-27.

87. Specifically, in Peroulas’ dual-band system, the Pre-Distortion Module includes two predistortion units each outputting PD_1 or PD_2 (*concurrent output*

signals). Both predistortion units receive each of the concurrent input signals, BB₁ and BB₂, as illustrated by the predistortion function in Equation 15 and Eq. 16:

$$(15) PD_1(n) = \sum_{j=0}^{M-1} \sum_{k_1=0}^{L_1-1} \sum_{k_2=0}^{L_2-1} h_{1,j,k_1,k_2} BB_1(n-j) |BB_1(n-j)|^{k_1} |BB_2(n-j)|^{k_2}$$

$$(16) PD_2(n) = \sum_{j=0}^{M-1} \sum_{k_1=0}^{L_1-1} \sum_{k_2=0}^{L_2-1} h_{2,j,k_1,k_2} BB_2(n-j) |BB_1(n-j)|^{k_1} |BB_2(n-j)|^{k_2}$$

88. The use of a common index n, within either Eq. 15 or Eq. 16 confirms that both inputs signals BB₁ and BB₂ are received by each predistortion function. Moreover, both BB₁ and BB₂ are referenced in each of equations 15 and 16. Fig. 3 also depicts concurrent predistorted signals PD₁ and PD₂ being concurrently input into the MIMO Capture Buffer 309 and thus, for any given number of baseband input signals, the output of each predistortion function (PD₁(n) and PD₂(n)) is concurrent.

89. Further, Peroulas' first predistortion unit outputs a predistorted signal PD₁ to frequency shifter 303 and 306 resulting in a predistorted signal centered at f_{c1} and the second predistortion unit would output a predistorted signal PD₂ input to frequency shifter 304 and 306 resulting in a predistorted signal centered at f_{c2} (*to output concurrent predistorted signals*). EX-1001, 22:20-25; *See, e.g.:*

The baseband signals BB₁ 301 and BB₂ 302 are centered at 0Hz and have bandwidths B₁ and B₂ respectively. The intent of the multiband digital pre-distorter is that BB₁ 301 and BB₂ 302 appear on the output of the PA 308 centered at f_{c1} and f_{c2} respectively. Without loss of generality, the discussion here will assume that both signals BB₁ 301

and BB_2 302 are sampled at a rate of f_s and that $f_{c1} < f_{c2}$. Further restrictions on the sampling rate f_s will be presented later in this application.

EX-1001, 22:20-25. Accordingly, Peroulas' MIMO Pre-Distortion Module effects predistortion of concurrent input signals to output concurrent predistorted signals, both as depicted in Peroulas' figures and as further illustrated by Peroulas' predistortion functions/equations.

[1b] a power amplifier block connected to amplify the predistorted signals; and

90. As shown in annotated Fig. 3 (above), Peroulas' system includes a power amplifier 308 (green) and adder 305 to combine and amplify the concurrent predistorted signals PD_1 and PD_2 output from the MIMO Pre-Distortion Module (*a power amplifier block connected to amplify the predistorted signals*). EX-1005, 6:18-19, 10:8-10 ("the combined signal being amplified by a power amplifier (PA)"), 23:10-20 ("combined signal is forwarded to a final frequency shifter 306 ... the output of the final frequency shifter 306 is sent to a power amplifier (PA)"). EX-1005, 14:17-23; *See, e.g.:*

The main technical scheme of the present invention is: A plurality of baseband input signals is pre-distorted by an equal number of pre-distortion functions respectively, wherein all of the baseband input signals are input into each pre-distortion function, and each pre-distortion function has one output; **the pre-distorted signals are combined into one signal; the combined signal is then power amplified by a PA**, and then the PA transmits the processed signal, wherein the cascade of the pre-distortion function and the PA are linear

overall, wherein the number of the pre-distortion functions is equal to the number of the baseband input signals

EX-1005, 14:17-23.

91. Peroulas' disclosure is consistent with the disclosure of the '296 Patent that describes "an RF power amplification block, the RF power amplification block including the concurrent multi-band power amplifier; and an RF power combining network." EX-1001, 2:39-41. Thus, the claimed "block" can include the transmitter's PA and other associated components, which is clearly disclosed in Peroulas.

[1c] an analyzing and modelling stage receiving first feedback signals taken from an output of the power amplifier, and second feedback signals taken concurrently from the concurrent predistorted signals and using the first feedback and the second feedback signals in the analyzing and modelling stage to model a nonlinearity in the power amplifier, wherein the digital baseband signal predistorters are updated by the analyzing and modelling stage.

92. Peroulas's MIMO Capture Buffer 309 (orange) and DSP block 316 (orange) are the claimed *analyzing and modelling stage*. The MIMO Capture Buffer 309 receives PO₁ and PO₂ (red) (*receiving first feedback signals*) "derived from a signal output from a coupler 310 which extracts a small portion (typically less than 1% of the PA output power) of the signal output from the PA 308." EX-1005, 25:17-22; *See, e.g.:*

The other two signals recorded by the MIMO capture buffer 309 are derived from a signal output from a coupler 310 which extracts a small portion (typically less than 1 % of the PA output power) of the signal output from the PA 308. The key property of the coupler 310 is that it produces a signal which is an accurate representation of the actual

output of the PA 308. The output of the coupler 310 is connected to a frequency shifter 311 which shifts the signal down by f_u Hz.

EX-1005, 25:17-22. The MIMO Capture Buffer 309 also receives PD_1 and PD_2 (blue) (*second feedback signals*) that “are produced by the multiple input multiple output (MIMO) Pre-Distortion Module 307” (*receiving . . . second feedback signals taken concurrently from the concurrent predistorted signals*). *Id.*, 25:15-17; *See, e.g.:*

Two of the signals recorded by the MIMO capture buffer 309 in this example are PD_1 and PD_2 , which are produced by the multiple input multiple output (MIMO) pre-distortion module 307.

Id., 25:15-17.

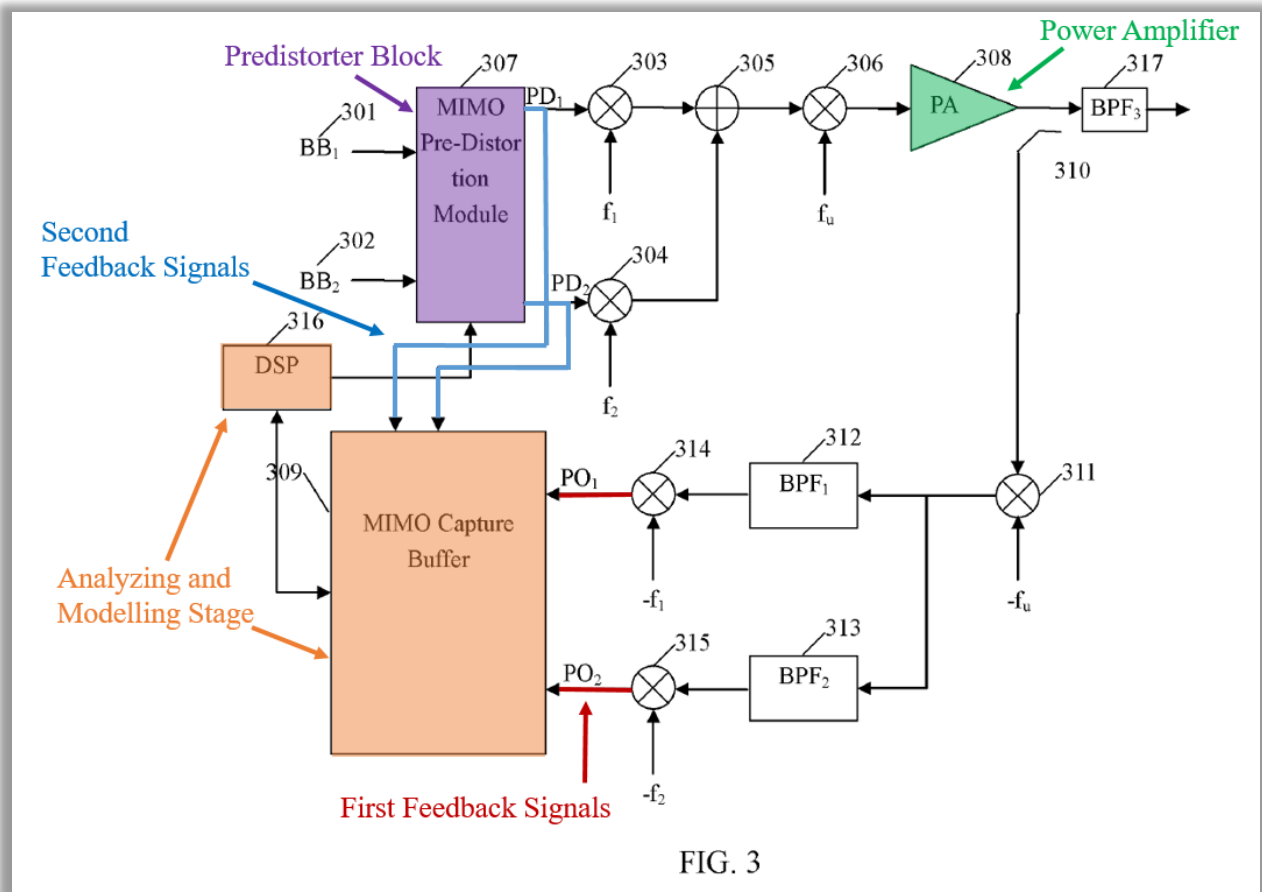


FIG. 3

EX-1005 Fig. 3 (Annotated).

93. In order to use the first and second feedback signals in the analyzing and modelling stage to model a nonlinearity in the power amplifier, Peroulas' DSP Block 316 (*analyzing and modelling stage*) uses the outputs of the MIMO Capture Buffer 309 and least squares minimization to obtain estimates $\hat{h}_{i,j,k_1,k_2}$ for the coefficient values h_{i,j,k_1,k_2} of the pre-distortion functions (*digital baseband signal predistorters*). EX-1005, 26:15-18; *See, e.g.:*

Typically, a DSP 316 is used to read out the values captured in the MIMO capture buffer 309 and based on the captured values PD₁, PD₂,

PO₁ and PO₂, the following equations Eq 19 and Eq 20 are solved by the DSP 316 using least squares minimization to obtain the values of $\hat{h}_{1,j,k_1,k_2}$ and $\hat{h}_{2,j,k_1,k_2}$.

EX-1005, 26:15-18. The estimated coefficients $\hat{h}_{i,j,k_1,k_2}$ are chosen such that “the cascade of the MIMO pre-distortion function, and the PA will be linear overall.”

EX-1005, 11:21-22.

94. After the values $\hat{h}_{i,j,k_1,k_2}$ are calculated, the DSP block 316 (*analyzing and modelling stage*) transmits the values to the Pre-Distortion Module 307 (*digital signal predistortion block*) and each h_{i,j,k_1,k_2} value in the pre-distortion functions (*digital baseband signal predistorters*) is “simultaneously updated and replaced with the $\hat{h}_{1,j,k_1,k_2}$ and $\hat{h}_{2,j,k_1,k_2}$ values”. EX-1005, 28:17-21; *See, e.g.:*

When some samples are captured by the **MIMO** capture buffer 309, the samples are analyzed by the **DSP** so as to produce the vectors $\vec{h}_1$ and $\vec{h}_2$ and all of values in $\hat{h}_{1,j,k_1,k_2}$ and $\hat{h}_{2,j,k_1,k_2}$. After these values have been calculated, the **DSP** transmits these values to the **MIMO** pre-distortion module and all of the h_{1,j,k_1,k_2} and h_{2,j,k_1,k_2} values of the **MIMO** pre-distortion function in the **MIMO** pre-distortion module will be simultaneously updated and replaced with the $\hat{h}_{1,j,k_1,k_2}$ and $\hat{h}_{2,j,k_1,k_2}$ Values.

EX-1005, 28:17-21

95. Similarly, Fig. 3 depicts Peroulas’ predisorted signals PD₁ and PD₂ (*second feedback signals*) being concurrently provided to the MIMO Capture Buffer 309, thereby disclosing *second feedback signals taken concurrently from the*

concurrent predistorted signals, as claimed. To the extent Patent Owner argues that Peroulas' does not expressly state this, despite what is shown in Fig. 3, a POSA would have been motivated to provide predistorted signals PD₁ and PD₂ to MIMO Capture Buffer 309 concurrently to not only avoid delays associated with serial processing, but to fulfill Peroulas' disclosure that its predistorters are "simultaneously updated and replaced with the $\hat{h}_{1,j,k_1,k_2}$ and $\hat{h}_{2,j,k_1,k_2}$ values". EX-1005, 28:17-20. In other words, because both predistorters within Peroulas' MIMO Pre-Distortion Module are "simultaneously updated" and not updated serially, and because Eq. 27 for $\hat{h}_{1,j,k_1,k_2}$ requires PD₁ as an input and $\hat{h}_{2,j,k_1,k_2}$ requires PD₂ as an input (EX-1005, 38:3-7), a POSA would have been motivated to provide PD₁ and PD₂ to MIMO Capture Buffer concurrently to solve all necessary equations within one iteration. EX-1005, 28:22-23; *See, e.g.*:

The process of capturing data, performing calculations, and finally updating the coefficients h_{1,j,k_1,k_2} and h_{2,j,k_1,k_2} can be considered one iteration. Typically, several iterations are performed so as to reach a final optimal solution. Also, if it is known that the characteristics of the PA will be changing in time, iterations may be performed continuously.

EX-1005, 28:22-23.

96. Accordingly, and as recited in claim 1, Peroulas uses its *first and second feedback signals in its analyzing and modelling stage to both model a*

nonlinearity in the power amplifier, and to update Peroulas' digital baseband signal predistorters.

Claim 2

[2pre] *The linearized transmitter of claim 1, wherein said concurrent digital multi-band predistortion block² further comprises:*

[2a] *a plurality of the digital baseband signal predistorters each corresponding to a respective channel; and*

97. As shown in annotated Fig. 3, Peroulas's MIMO Predistortion Module 307 (purple) includes at least two pre-distortion units (*a plurality of digital baseband signal predistorters*) equal in number to the number of bands of Peroulas' multi-band transmitter, and each corresponding to a particular input signal channel pathway and also the frequency range of the respective input signal. EX-1005, 6:25-27 ("the pre-distortion module includes a plurality of pre-distortion units."), 22:26-23:2. More specifically, Peroulas' MIMO Predistortion Module 307 is configured such that it receives "a plurality of baseband input signals being pre-distorted *by an equal*

² Although Claim 2 refers to "said" "concurrent digital *multi-band* predistortion block," Claim 1 only introduces "a digital signal predistorter block." For purposes of this declaration, and so the prior art can be analyzed, I have treated Claim 1 as incorporating a "multi-band" requirement. In other words, because the prior art discloses multi-band transmitters and multi-band predistortion blocks, the prior art can be assessed against Claim 2 and its progeny despite any antecedent basis issues.

number of predistortion functions to obtain [an] equal number of predistorted signal(s) respectively, wherein all of the baseband input signals input into every pre-distortion function, and each pre-distortion function has one output.” EX-1005, 10:4-7 (emphasis added).

98. In the dual-band scenario, each of Peroulas’ predistortion units receives two baseband inputs and outputs one baseband signal (PD₁ or PD₂ respectively, as defined by Eq. 15 and Eq.16). Peroulas describes the predistortion function in Equation 15 and Equation 16 as follows:

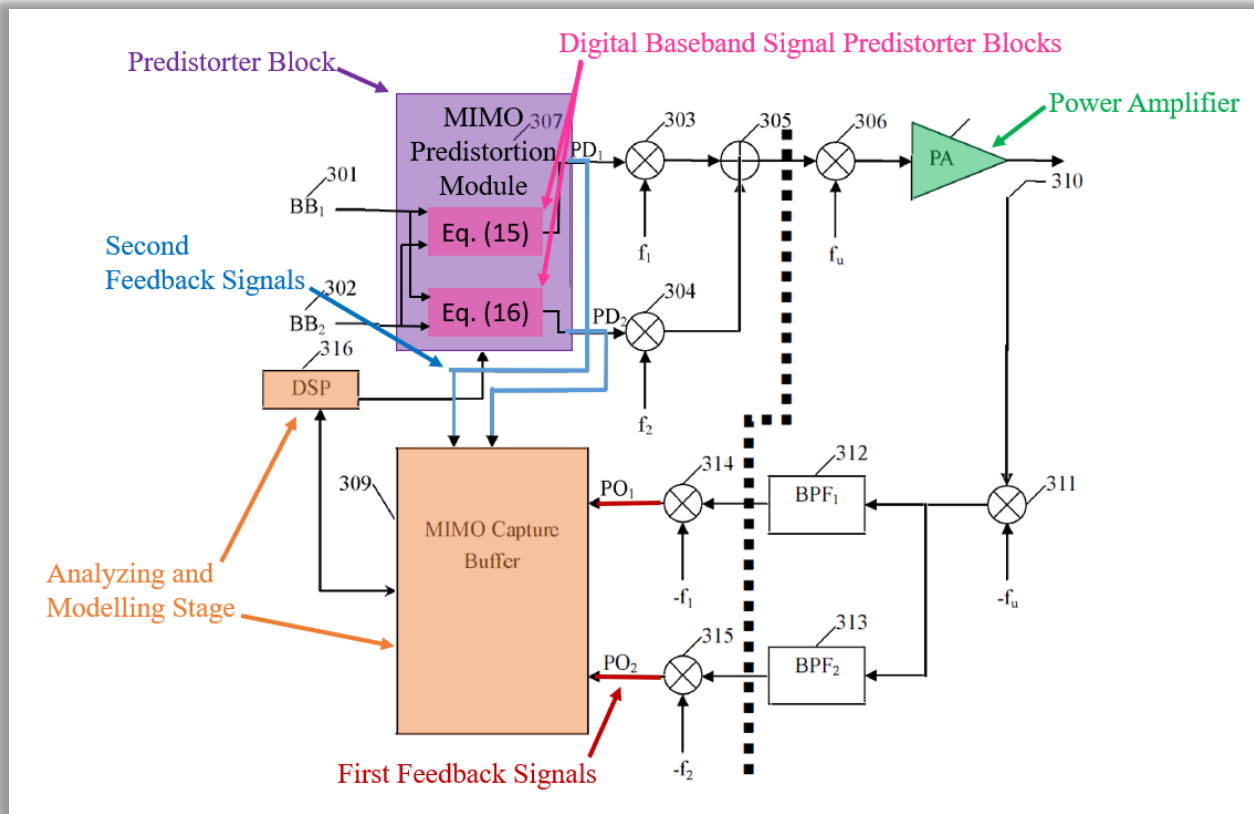
$$(15) PD_1(n) = \sum_{j=0}^{M-1} \sum_{k_1=0}^{L_1-1} \sum_{k_2=0}^{L_2-1} h_{1,j,k_1,k_2} BB_1(n-j) |BB_1(n-j)|^{k_1} |BB_2(n-j)|^{k_2}$$

$$(16) PD_2(n) = \sum_{j=0}^{M-1} \sum_{k_1=0}^{L_1-1} \sum_{k_2=0}^{L_2-1} h_{2,j,k_1,k_2} BB_2(n-j) |BB_1(n-j)|^{k_1} |BB_2(n-j)|^{k_2}$$

EX-1005, 24:12-23. Peroulas’ Eq. 15 effects predistortion of input BB₁ 301 to generate output signal PD₁, using BB₁ and BB₂ input signals. In other words, the predistortion unit corresponding to Eq. 15 is a first of the plurality of digital baseband signal predistorters that corresponds to the input signal BB₁ and BB₁’s occupied frequency range (*i.e.*, “channel”).

99. Likewise, Peroulas’ Eq. 16 effects predistortion of input signal BB₂ 302 to generate output signal PD₂ using both BB₁ and BB₂ input signals. The predistortion unit corresponding to Eq. 16 is a second of the plurality of digital baseband signal

predistorters that corresponds to the channel or input signal BB_2 occupied frequency range. This is graphically illustrated below.



EX-1005, Fig. 4 (Annotated and Modified).

100. Further still, the goal of predistortion functions (15) and (16) in the multi-band transmitter “is to produce signals PD_1 and PD_2 sent to the PA 308 such that the output only contains signals BB_1 301 and BB_1 302 centered at frequencies f_{c1} and f_{c2} .” EX-1005, 24:1-3; *See, e.g.:*

The goal of the MIMO pre-distortion function (which is also a non-linear function) is to produce signals PD_1 and PD_2 sent to the PA 308 such that the output of the BPF₃ 317 only contains signals BB_1 301 and BB_2 302 centered at frequencies f_{c1} and f_{c2} . No system is perfect

and the output of the BPF₃ 317 in this example will also contain some distortions, but the MIMO pre-distortion function in this example attempts to minimize these distortions as much as possible. Although the MIMO pre-distortion function and the PA 308 are individually nonlinear, the cascade of the MIMO pre-distortion function, the PA 308, and BPF₃ 317 produces a system that is linear overall.

EX-1005, 24:1-8. As understood by a POSA, Peroulas' carrier frequencies f_{c1} and f_{c2} each correspond to a single channel located in separate bands. Taken in combination with the fact that each baseband input signal corresponds to a single predistortion unit, Peroulas discloses *a plurality of the digital baseband signal predistorters each corresponding to a respective channel.*

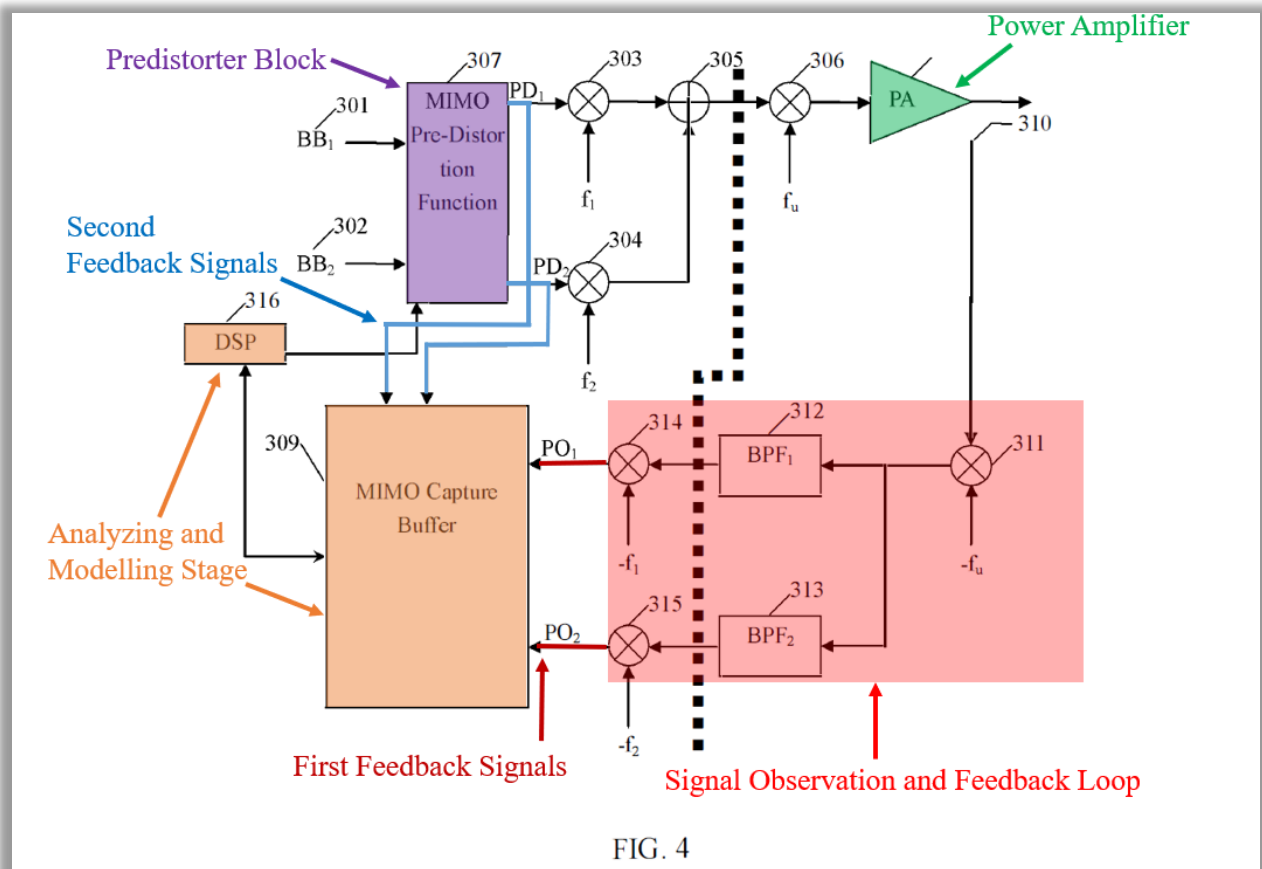
[2b] and a signal observation feedback loop for generating said first feedback signals.

101. Peroulas discloses that “two signals recorded by the MIMO Capture Buffer 309 are derived from a signal output from a coupler 310 which extracts a small portion (typically less than 1% of the PA output power) of the signal output from the PA 308.” EX-1005, 25:15-22. “The output of the coupler 310 is connected to a frequency shifter 311 which shifts the signal down by f_u Hz.” *Id.*, 25:20-22. And as shown in Fig. 4 (dashed line), analog to digital conversion by sampling occurs after BPF₁ 312 and BPF₂ 312. EX-1005, 30:10-18; *See, e.g.:*

For example, the example in FIG 3 of the invention does not explicitly indicate where the digital to analog boundary will appear. The bold dotted line in FIG 4 represents one example of where this boundary may be placed. The bold dotted line represents the boundary between the digital domain and the analog domain in the multiband pre-distorter.

Entities and signals to the left of the bold dotted line are digital and entities and signals to the right are analog. Signal conversion from the digital to the analog domain can be implemented by a D/A converter and signal conversion from the analog to the digital domain can be implemented by an A/D converter. Those skilled in the art will recognize that the digital-analog boundary can be placed in many different locations.

EX-1005, 30:10-18. The cascade of the above components generates feedback signals, PO_1 and PO_2 , and thus constitutes *a signal observation and feedback loop*, as claimed.



EX-1005, Fig. 4 (Annotated).

Claim 3

[3pre] *The linearized transmitter of claim 2, wherein said plurality of digital baseband signal predistorters further comprises:*

[3a] *a plurality of inputs, each input corresponding to a single frequency channel; and*

102. As explained above in [2a], Peroulas' linearized pre-distortion transmitter includes a MIMO Predistortion Module 307 (purple) that has at least two pre-distortion units corresponding to at least two predistortion functions (*digital baseband signal predistorters*). EX-1005, 15:14-17; *See, e.g.,*

the pre-distortion module includes a plurality of pre-distortion units, wherein all of the baseband input signals input into each pre-distortion unit, and each pre-distortion unit corresponds to one pre-distortion function and has one output.

EX-1005, 15:14-17. In the dual band scenario, the two predistortion units, corresponding to Equations (15) and (16), each receive a plurality of inputs BB_1 and BB_2 .

$$(15) PD_1(n) = \sum_{j=0}^{M-1} \sum_{k_1=0}^{L_1-1} \sum_{k_2=0}^{L_2-1} h_{1,j,k_1,k_2} BB_1(n-j) |BB_1(n-j)|^{k_1} |BB_2(n-j)|^{k_2}$$

$$(16) PD_2(n) = \sum_{j=0}^{M-1} \sum_{k_1=0}^{L_1-1} \sum_{k_2=0}^{L_2-1} h_{2,j,k_1,k_2} BB_2(n-j) |BB_1(n-j)|^{k_1} |BB_2(n-j)|^{k_2}$$

EX-1005, 24:12-23; *See, e.g.:*

Although many functions can be used for the MIMO pre-distortion function, one two-input two-output pre-distortion function that can be

used for the MIMO pre-distortion function in this example is given in equations Eq 15 and Eq 16:

$$(15) PD_1(n) = \sum_{j=0}^{M-1} \sum_{k_1=0}^{L_1-1} \sum_{k_2=0}^{L_2-1} h_{1,j,k_1,k_2} BB_1(n-j) |BB_1(n-j)|^{k_1} |BB_2(n-j)|^{k_2}$$

$$(16) PD_2(n) = \sum_{j=0}^{M-1} \sum_{k_1=0}^{L_1-1} \sum_{k_2=0}^{L_2-1} h_{2,j,k_1,k_2} BB_2(n-j) |BB_1(n-j)|^{k_1} |BB_2(n-j)|^{k_2}$$

Wherein, M represents the memory depth of the PA 308. That is, the PA's 308 output is considered to be a function of the current input sample and the previous M-1 input samples. L₁ and L₂ represent the nonlinearity length and the interband crosscorrelation degree of the MIMO pre-distortion model. The actual values used for M, L₁, and L₂ will vary based on the actual PA 308 that is used but typically, M will be a rather small number typically between 1 and 6. The values of L₁ and L₂ will be slightly larger than M and typically between 3 and 15. The coefficients h_{1,j,k_1,k_2} and h_{2,j,k_1,k_2} are chosen such that the cascade of the MIMO pre-distortion function 307, the PA 308, and BPF3 317 will be linear overall. And each equation such as Eq 15 and Eq 16 is called a pre-distortion function.

EX-1005, 24:12-23.

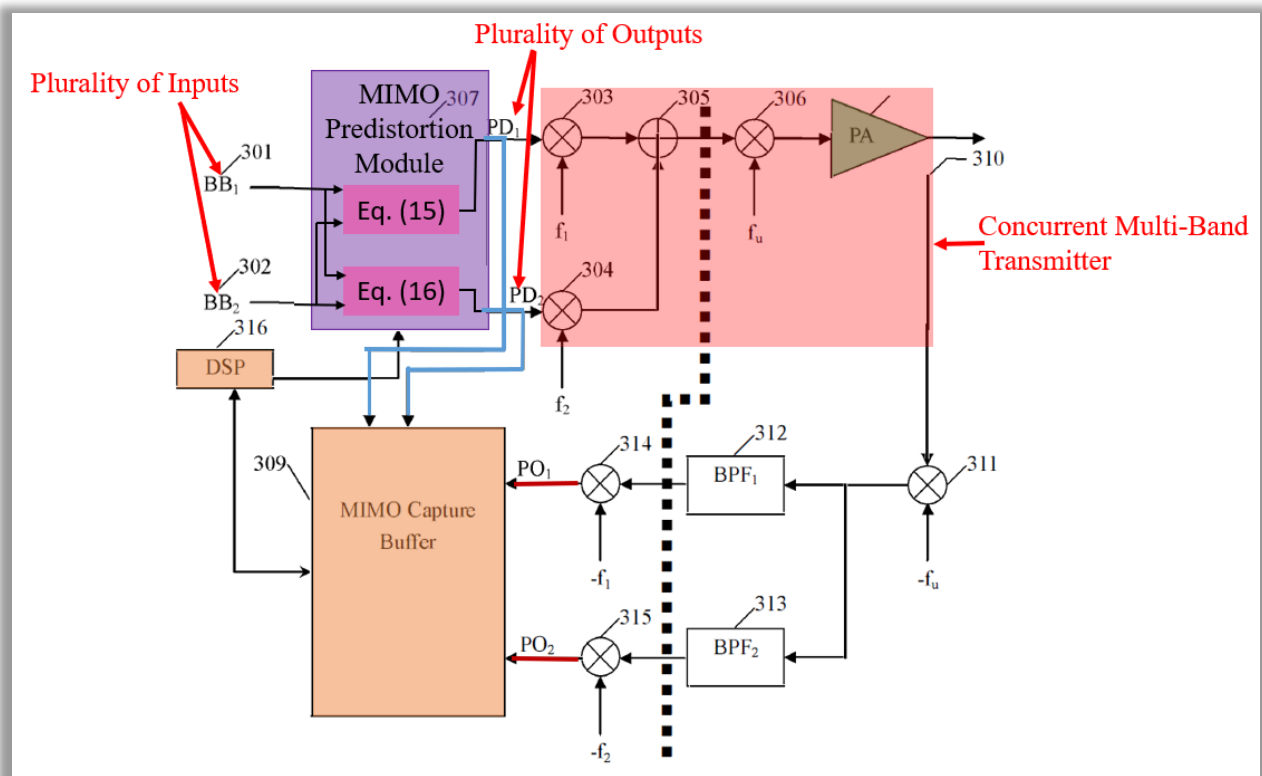
103. Each input signal BB₁ and BB₂ correspond to their own channel/signal frequency range, and each corresponds to a single frequency channel. Indeed, Peroulas explains that “the intent of the multiband digital pre-distorter is that BB₁ 301 and BB₂ 302 appear on the output of the PA 308 centered at f_{c1} and f_{c2} respectively” EX-1005, 22:21-23. In other words, input signals/channels BB₁ and BB₂ correspond to the single frequency channels centered at f_{c1} and f_{c2}.

[3b] a plurality of outputs, each output corresponding to a single frequency channel, and each output connected to an input of a concurrent multi-band transmitter.

104. Peroulas' MIMO Predistortion Module 307 produces a plurality of outputs PD_1 (corresponding to an output at f_{c1}) and PD_2 (corresponding to an output at f_{c2}), as shown in annotated Fig. 3. EX-1005, 22:26-27; *See, e.g.*:

Baseband signals BB_1 301 and BB_2 302 are sent into a multiple input multiple output (MIMO) pre-distortion module 307 to produce signals PD_1 and PD_2 , and the MIMO pre-distortion module 307 processes baseband signals BB_1 301 and BB_2 302 with a MIMO predistortion function.

EX-1005, 22:26-23:2. These are Peroulas' plurality of outputs, each corresponding to a single frequency channel, as claimed.



EX-1005, Fig. 3 (Annotated).

105. More specifically, the signals PD_1 and PD_2 are output from MIMO Predistortion Module 307 at baseband before being shifted to f_1 and f_2 by frequency shifters 303 and 304. EX-1005, 23:2-4; *See, e.g.:*

Signals PD_1 and PD_2 are sent into frequency shifters 303 and 304 which shift the frequency of the signals PD_1 and PD_2 to f_1 and f_2 respectively.

EX-1005, 23:2-4. The signals are then combined via adder 305, and the combined signal is further frequency shifted to f_u by frequency shifters 306 prior to amplification and transmission. EX-1005, 23:3-17.

Then these shifted signals are combined by an adder 305. Wherein the MIMO pre-distortion function includes at least two pre-distortion functions, and each pre-distortion function has two inputs and one output. The number of the inputs for each pre-distortion function is equal to the number of the baseband signals input into the multiband digital pre-distorter, and the number of the predistortion functions is equal to the number of the baseband signals input into the multiband digital pre-distorter.

Preferably, the combined signal is forwarded to a final frequency shifter 306 which shifts the combined frequency by f_u . It should be clear that $f_1+f_2=f_{c1}$ and $f_2+f_2=f_{c2}$. Also, $f_{c2}-f_{c1} = f_2-f_1$. Below the situation to be described is one in which the combined signal is forwarded to a final frequency shifter 306.

If there is the final frequency shifter 306 in the multi band digital pre-distorter, the output of the final frequency shifter 306 is sent to a power amplifier (PA) 308; or if there is no final frequency shifter 306, the output of the adder 305 is sent directly to a power amplifier (PA) 308. The PA 308 produces the final signal which will be transmitted

EX-1005, 23:3-17.

106. Peroulas' frequency shifting architecture results in signals PD_1 and PD_2 shifted to transmitting carrier frequencies f_{c1} and f_{c2} . EX-1005, 24:1-3; *See, e.g.:*

The goal of the MIMO pre-distortion function (which is also a non-linear function) is to produce signals PD_1 and PD_2 sent to the PA 308 such that the output of the BPF₃ 317 only contains signals BB₁ 301 and BB₂ 302 centered at frequencies f_{c1} and f_{c2} .

EX-1005, 24:1-3. Accordingly, the distinct frequency shifters (303 and 304) with distinct center frequencies (f_1 and f_2) for distinct output signals (PD_1 and PD_2) define a plurality of outputs *each corresponding to a single frequency channel*.

107. Finally, claim 3 requires "each output connected to an input of a concurrent multi-band transmitter." The specification explains that " $X_{pd1}(n)$ and $X_{pd2}(n)$ are the predistorted signals to the input of the dual-band transmitter" (EX-1001, 4:19-21), thus claim 3 identifies the components following predistortion as the "concurrent multi-band transmitter." As shown in the annotated figure, above, each output of Peroulas' MIMO pre-distortion module carrying signals PD_1 and PD_2 is *connected to an input of a concurrent multi-band transmitter* at frequency shifters 303 and 304. EX-1005, 23:2-20; *See, e.g.:*

Signals PD_1 and PD_2 are sent into frequency shifters 303 and 304 which shift the frequency of the signals PD_1 and PD_2 to f_1 and f_2 respectively. Then these shifted signals are combined by an adder 305. Wherein the MIMO pre-distortion function includes at least two pre-distortion functions, and each pre-distortion function has two inputs and one output. The number of the inputs for each pre-distortion function is equal to the number of the baseband signals input into the multiband digital pre-distorter, and the number of the predistortion functions is

equal to the number of the baseband signals input into the multiband digital pre-distorter.

Preferably, the combined signal is forwarded to a final frequency shifter 306 which shifts the combined frequency by f_u . It should be clear that $f_1 + f_2 = f_{c1}$ and $f_2 + f_2 = f_{c2}$. Also, $f_{c2} - f_{c1} = f_2 - f_1$. Below the situation to be described is one in which the combined signal is forwarded to a final frequency shifter 306.

If there is the final frequency shifter 306 in the multi band digital pre-distorter, the output of the final frequency shifter 306 is sent to a power amplifier (PA) 308; or if there is no final frequency shifter 306, the output of the adder 305 is sent directly to a power amplifier (PA) 308. The PA 308 produces the final signal which will be transmitted.

The PA 308 is typically a low efficiency device and one method that can be used to improve its efficiency is to drive it into its nonlinear region. The problem is that the more the PA is driven into its nonlinear region, the higher the amount of distortion is introduced by the PA'

EX-1005, 23:2-20.

Claim 4

[4pre] *The linearized transmitter of claim 2, wherein said analyzing and modeling stage further comprises:*

[4a] *a plurality of outputs connected to update the parameters of said digital baseband signal predistorters; and*

108. Peroulas' uses MIMO Capture Buffer 309 and DSP block 316 (orange) (*analyzing and modelling stage*) to estimate and update the coefficients in the predistortion function (*digital baseband signal predistorters*) such that the cascade of the predistortion function and PA is linear overall. EX-1005, 11:22-22, 25:10-11, 25:15-19, 26:10-12, 26:15-18; *See, e.g.:*

[C]oefficients h_{i,j,k_1,k_2} are chosen such that the cascade of the MIMO pre-distortion function, and the PA will be linear overall;

EX-1005, 11:22-22;

In one example, this model is created by capturing the samples of several signals using a MIMO capture buffer 309.

EX-1005, 25:10-11;

Two of the signals recorded by the MIMO capture buffer 309 in this example are PD₁ and PD₂, which are produced by the multiple input multiple output (MIMO) pre-distortion module 307. The other two signals recorded by the MIMO capture buffer 309 are derived from a signal output from a coupler 310 which extracts a small portion (typically less than 1 % of the PA output power) of the signal output from the PA 308.

EX-1005, 25:15-19;

The capture buffer is typically controlled by a Digital Signal Processor (DSP) 316 which, through the use of a trigger signal, indicates when the capture buffer should begin capturing data.

EX-1005, 26:10-12;

Typically, a DSP 316 is used to read out the values captured in the MIMO capture buffer 309 and based on the captured values PD₁, PD₂, PO₁ and PO₂, the following equations Eq 19 and Eq 20 are solved by the DSP 316 using least squares minimization to obtain the values of $\hat{h}_{1,j,k_1,k_2}$ and $\hat{h}_{2,j,k_1,k_2}$.

EX-1005, 26:15-18.

109. To do this, Peroulas' "DSP 316 is used to read out the values captured in the MIMO Capture Buffer 309 and based on the captured values PD₁, PD₂, PO₁

and PO_2 ,” equations 19 and 20 are solved to obtain the values of $\hat{h}_{1,j,k_1,k_2}$ and $\hat{h}_{2,j,k_1,k_2}$. EX-1005, 26:15-20.

$$(19) PD_1(n) = \sum_{j=0}^{M-1} \sum_{k_1=0}^{L_1-1} \sum_{k_2=0}^{L_2-1} \hat{h}_{1,j,k_1,k_2} PO_1(n-j) |PO_1(n-j)|^{k_1} |PO_2(n-j)|^{k_2}$$

$$(20) PD_2(n) = \sum_{j=0}^{M-1} \sum_{k_1=0}^{L_1-1} \sum_{k_2=0}^{L_2-1} \hat{h}_{2,j,k_1,k_2} PO_2(n-j) |PO_1(n-j)|^{k_1} |PO_2(n-j)|^{k_2}$$

EX-1005, 26:19-20. “After these values have been calculated, the DSP transmits these values to the MIMO pre-distortion module and all of the h_{1,j,k_1,k_2} and h_{2,j,k_1,k_2} values of the MIMO pre-distortion function in the MIMO pre-distortion module will be *simultaneously updated and replaced* with the $\hat{h}_{1,j,k_1,k_2}$ and $\hat{h}_{2,j,k_1,k_2}$ values.” EX-1005, 28:18-21 (emphasis added).

110. To update the pre-distortion function coefficients simultaneously, a POSA understood that Peroulas used a plurality of outputs/traces leading to each predistortion unit. In other words, a POSA would have understood that Peroulas’ disclosure of a single line from DSP 316 to Pre-Distorter Module 307 would include multiple outputs in order to simultaneously update Peroulas’ predistortion units.

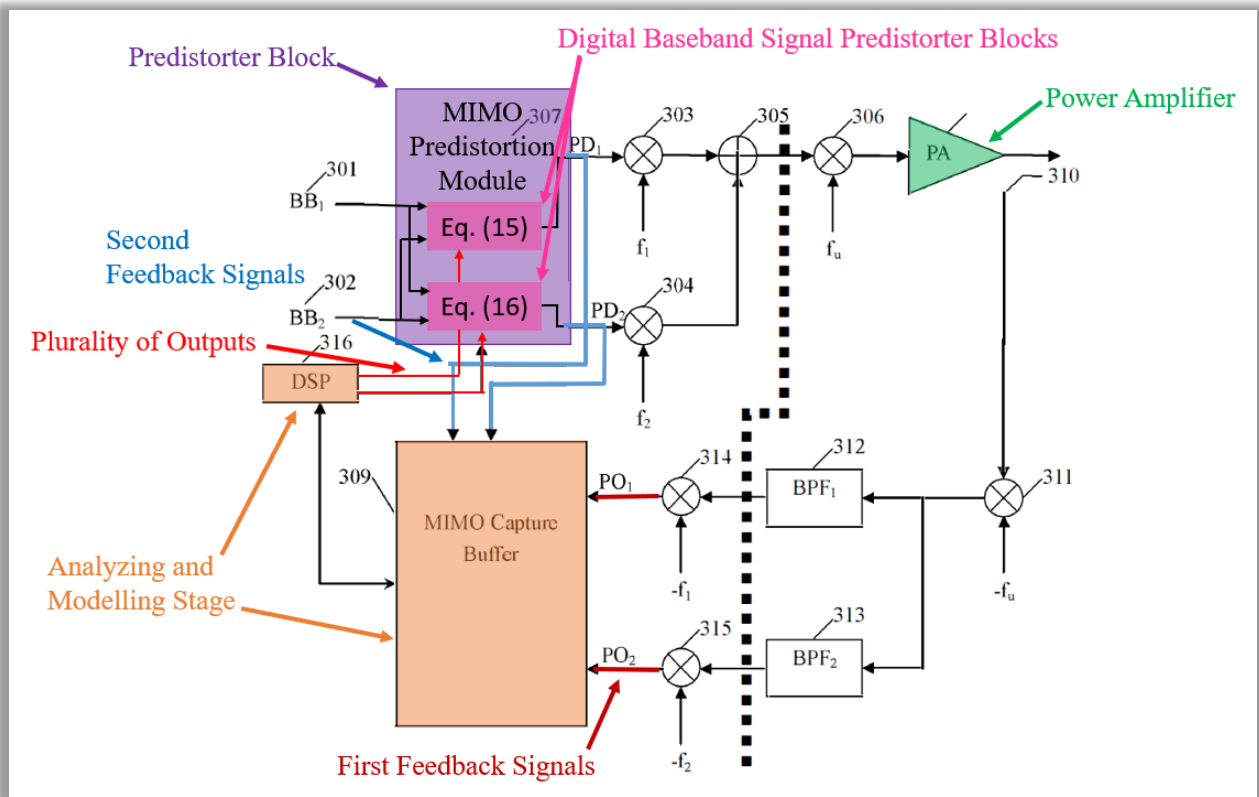
111. To the extent Patent Owner asserts that Peroulas does not state that multiple outputs from the DSP are used, a POSA would be motivated to modify the

teachings of Peroulas to include multiple outputs to simultaneously update Peroulas' predistortion units and avoid delays associated with processing the pre-distortion function coefficients in serial. A POSA understood that one straightforward and obvious way to implement this would be to include two separate wires/traces from DSP 316 going to each individual predistortion unit. EX-1005, 28:16-25; *See, e.g.:*

When some samples are captured by the MIMO capture buffer 309, the samples are analyzed by the DSP so as to produce the vectors $\vec{h}_1$ and $\vec{h}_2$ and all of values in $\hat{h}_{1,j,k_1,k_2}$ and $\hat{h}_{2,j,k_1,k_2}$. After these values have been calculated, the DSP transmits these values to the MIMO pre-distortion module and all of the h_{1,j,k_1,k_2} and h_{2,j,k_1,k_2} values of the MIMO pre-distortion function in the MIMO pre-distortion module will be simultaneously updated and replaced with the $\hat{h}_{1,j,k_1,k_2}$ and $\hat{h}_{2,j,k_1,k_2}$ values.

The process of capturing data, performing calculations, and finally updating the coefficients h_{1,j,k_1,k_2} and h_{2,j,k_1,k_2} can be considered one iteration. Typically, several iterations are performed so as to reach a final optimal solution. Also, if it is known that the characteristics of the PA will be changing in time, iterations may be performed continuously.

EX-1005, 28:16-25.



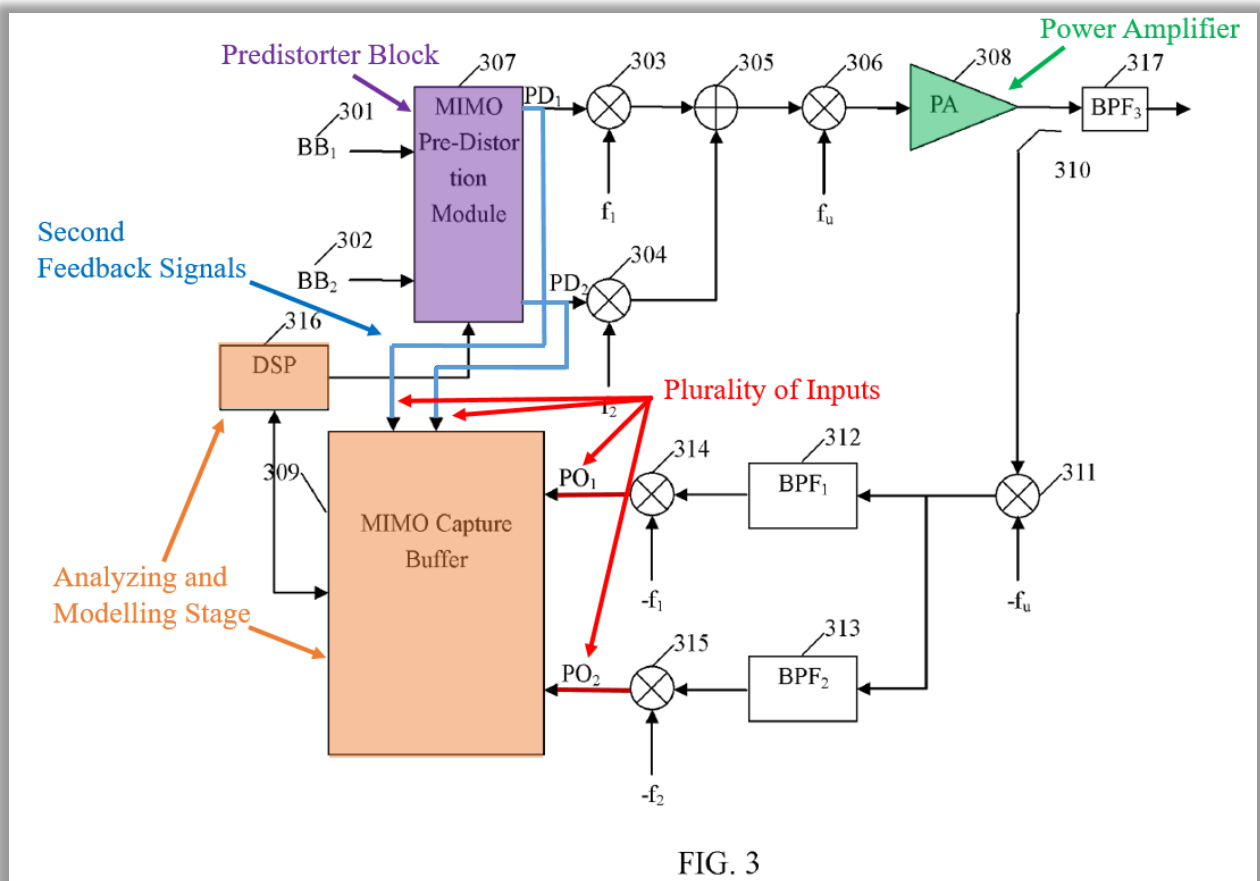
EX-1005, Fig. 3 (Annotated and Modified).

[4b] *a plurality of inputs connected to both: (a) outputs of said signal observation feedback loop comprising said first feedback signals, and (b) to outputs of said digital signal predistorter block.*

112. Peroulas' linearized pre-distortion transmitter uses an indirect learning approach where the system's MIMO Capture Buffer 309 and DSP block 316 (orange) (*analyzing and modelling stage*) are connected to both signals PO_1 and PO_2 (red) (*outputs of signal observation feedback loop*), and signals PD_1 and PD_2 (blue) (*outputs of said digital signal predistorter block*). EX-1005, 25:15-19; §IV.A.3; See, e.g.:

Two of the signals recorded by the MIMO capture buffer 309 in this example are PD_1 and PD_2 , which are produced by the multiple input multiple output (MIMO) pre-distortion module 307. The other two signals recorded by the MIMO capture buffer 309 are derived from a signal output from a coupler 310 which extracts a small portion (typically less than 1 % of the PA output power) of the signal output from the PA 308.

EX-1005, 25:15-19.



EX-1005, Fig. 3 (Annotated). In this way, Peroulas' MIMO Capture Buffer and DSP block (*analyzing and modeling stage*) include at least four inputs, which are connected to both the outputs of a signal observation and feedback loop and the outputs of the digital signal predistorter block, as claimed.

Claim 5

[5pre] *The linearized transmitter of claim 2, wherein said analyzing and modeling stage is further adapted to:*

[5a] *perform time alignment of complex baseband signals from sampling said first feedback signals; and*

113. Peroulas explains that in a real system the propagation delay through components will be nonzero, thus the MIMO Capture Buffer 309 (*analyzing and modelling stage*) can measure and compensate for this by inserting an equivalent delay on the PD₁ and PD₂ signals (*second feedback signals*). EX-1005, 31:1-5; *See, e.g.:*

Another example is that the preferred embodiment assumes that the propagation delay through any one element in the chain is 0. This was done to simplify the description of the invention. It should be clear to one skilled in the art that a real system will have a non-zero delay. This delay can be measured and compensated by inserting an equivalent delay on the PD₁ and PD₂ signals as they enter the MIMO capture buffer 309.

EX-1005, 31:1-5.

114. This delay insertion is time aligning the predistorted signals and feedback signals. And because Peroulas' MIMO Pre-Distortion Function 307 operates at baseband, feedback signals PO₁ and PO₂ are similarly frequency shifted back to baseband so that like signals are compared to one another. This is illustrated by the fact Peroulas MIMO Predistortion Module 307 (purple) outputs signals PO₁ and PO₂ at a baseband frequency. The signals are upconverted or frequency shifted

for transmission to f_{c1} and f_{c2} by the cascaded frequency shifters 303/305 and 306. In the feedback loop, this process is applied in reverse to return the signals at f_{c1} and f_{c2} to baseband in the form of PO_1 and PO_2 . The result of this frequency shifting process ensures that like signals are compared to one another. EX-1005, 12:6-7 (describing frequency shifting back to “zero” or baseband), 30:19-29; *See, e.g.*:

frequency shifting the output signals of each bandpass filters respectively to obtain captured signals PO_i , wherein the center frequency of each frequency shifted signal is zero.

EX-1005, 12:6-7;

As another example, the signal upconversion process (namely, shifting the frequency of the signals PD_1 and PD_2 to f_1 and f_2) was illustrated through the use of two cascaded frequency shifters. The first frequency shifter had a frequency offset of f_1 or f_2 (depending on the band), and the second frequency shifter had an offset of f_u . It should be clear to those skilled in the art that various different frequency shifting architectures are possible, even architectures that use multiple stages and multiple frequency shifters.

The downconversion process (namely, shifting the frequency of the the output of the coupler 310) was similarly illustrated through the use of two cascaded frequency shifters. The first shifted by $-f_u$ and the second shifted by $-f_1$ or $-f_2$ (depending on the band). Again, it should be clear to those skilled in the art that different frequency conversion architectures are possible, even architectures that use multiple stages and multiple frequency shifters

EX-1005, 30:19-29.

115. To the extent Patent Owner argues that Peroulas does not expressly state inserting a delay into either signal PO_1 or PO_2 (*signals from sampling said outputs of said power amplifier*), a POSA would have nonetheless found this either

to be part of Peroulas' disclosure, or an obvious and trivial implementation detail. Indeed, Peroulas already disclosed that time alignment may be required, and a POSA would have understood that different band pass filters (BPFs 312 and 313) will insert non-zero delays into signals PO_1 or PO_2 . And because Peroulas already contemplates inserting delays into the feedback signals, a POSA would have also found it obvious to apply Peroulas' delay insertion technique to time align signals PO_1 and PO_2 (*first feedback signals*) to one another.

[5b] perform reconstruction of the complex baseband signals from said sampling.

116. Because the output of Peroulas' PA 308 is an analog signal at an RF frequency, a POSA would have understood that this signal would be digitized and down converted to baseband (as contemplated by Peroulas) to then be used in modelling distortion.

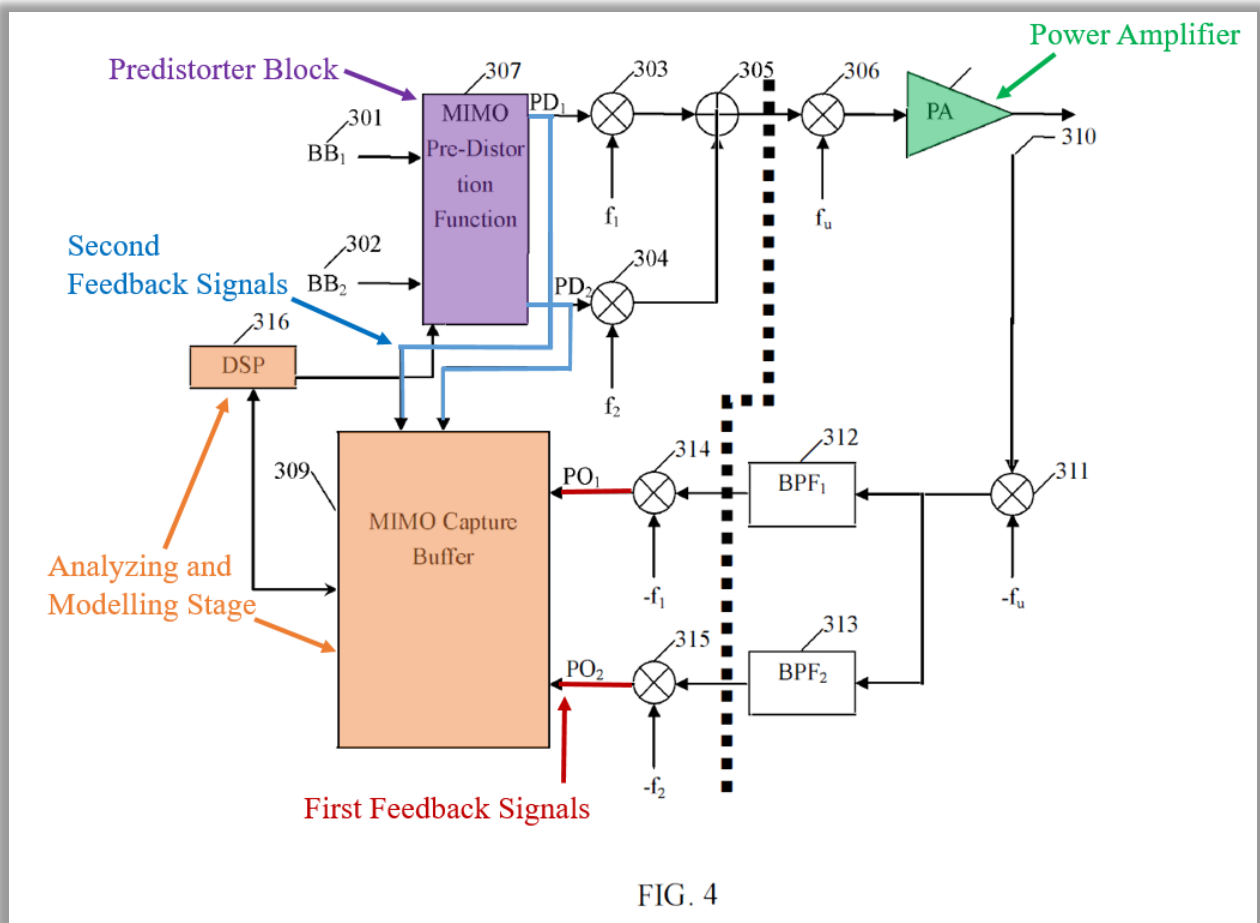
117. Peroulas provides an example where the analog, first-feedback signal is digitized by an ADC after BPF₁ 312 and BPF₂ 313 (as illustrated by the dashed line in annotated Fig. 4, below). EX-1005, 30:10-18; *See, e.g.*:

The bold dotted line in FIG 4 represents one example of where this boundary may be placed. The bold dotted line represents the boundary between the digital domain and the analog domain in the multiband pre-distorter. Entities and signals to the left of the bold dotted line are digital and entities and signals to the right are analog. Signal conversion from the digital to the analog domain can be implemented by a D/A converter and signal conversion from the analog to the digital domain can be implemented by an A/D converter. Those skilled in the art will

recognize that the digital-analog boundary can be placed in many different locations.

EX-1005, 30:10-18.

118. Further, Peroulas includes a two-stage frequency conversion architecture using frequency shifters 311 “which shifts the signal down by f_u Hz” (EX-1005, 25:21-22), and 314/315 “which shift the signals down by f_1 and f_2 , respectively, to produce signals PO_1 and PO_2 , respectively” (EX-1005, 26:6-8; 30:19-29) to down convert the signal output by the PA from an RF frequency to a complex baseband frequency. By filtering, downconverting, and sampling the output of the PA, Peroulas discloses *performing reconstruction of the complex baseband signals from said sampling*, as claimed.



EX-1005, Fig. 4.

Claim 6

[6pre] *The linearized transmitter of claim 2,*

[6a] *said first feedback signals corresponding to a baseband equivalent for all frequency channels and wherein the baseband equivalent signals being extracted from down-converted samples of RF signals output from said power amplifier block.*

119. As shown in Fig. 4 (below), Peroulas down-converts samples taken from the output of the PA through a two-stage frequency conversion process. EX-1005, 25:17-19. *See, e.g.:*

The other two signals recorded by the MIMO capture buffer 309 are derived from a signal output from a coupler 310 which extracts a small portion (typically less than 1 % of the PA output power) of the signal output from the PA 308.

EX-1005, 25:17-19. First, “frequency shifter 311 which shifts the signal down by f_u Hz” (EX-1005, 25:21-22), then the intermediary signals are then band-pass filtered by BPF₁ 312 and BPF₂ 313 (EX-1005, 25:23-24). The signals are next sampled by ADC at the dashed line in Fig. 4. EX-1005, 30:10-18; *See, e.g.*:

For example, the example in FIG 3 of the invention does not explicitly indicate where the digital to analog boundary will appear. The bold dotted line in FIG 4 represents one example of where this boundary may be placed. The bold dotted line represents the boundary between the digital domain and the analog domain in the multiband pre-distorter. Entities and signals to the left of the bold dotted line are digital and entities and signals to the right are analog. Signal conversion from the digital to the analog domain can be implemented by a D/A converter and signal conversion from the analog to the digital domain can be implemented by an A/D converter. Those skilled in the art will recognize that the digital-analog boundary can be placed in many different locations.

EX-1005, 30:11-18.

120. Finally, the signals “are sent into two frequency shifters 314 and 315, which shift the signals down by f_1 and f_2 , respectively, [*all frequency channels*] to produce signals PO₁ and PO₂, respectively.” EX-1005, 26:6-8; *See, e.g.*:

The outputs of BPF₁ 312 and BPF₂ 313 are sent into two frequency shifters 314 and 315, which shift the signals down by f_1 and f_2 , respectively, to produce signals PO₁ and PO₂, respectively.

EX-1005, 26:6-8. The purpose of the above process is “to obtain captured signals PO_i wherein the center frequency of each frequency shifted signal is zero.” EX-1005, 12:6-7; *See, e.g.:*

frequency shifting the output signals of each bandpass filters respectively to obtain captured signals PO_i , wherein the center frequency of each frequency shifted signal is zero.

EX-1005, 12:6-7. In the context of the claim language, signals PO_1 and PO_2 (*first feedback signals*) correspond to a baseband equivalent for all frequency channels (f_1 and f_2), and they were created by extraction from down-converted samples of the RF signals output from the power amplifier block, as claimed and as explained above.

EX-1005, 26:6-8.

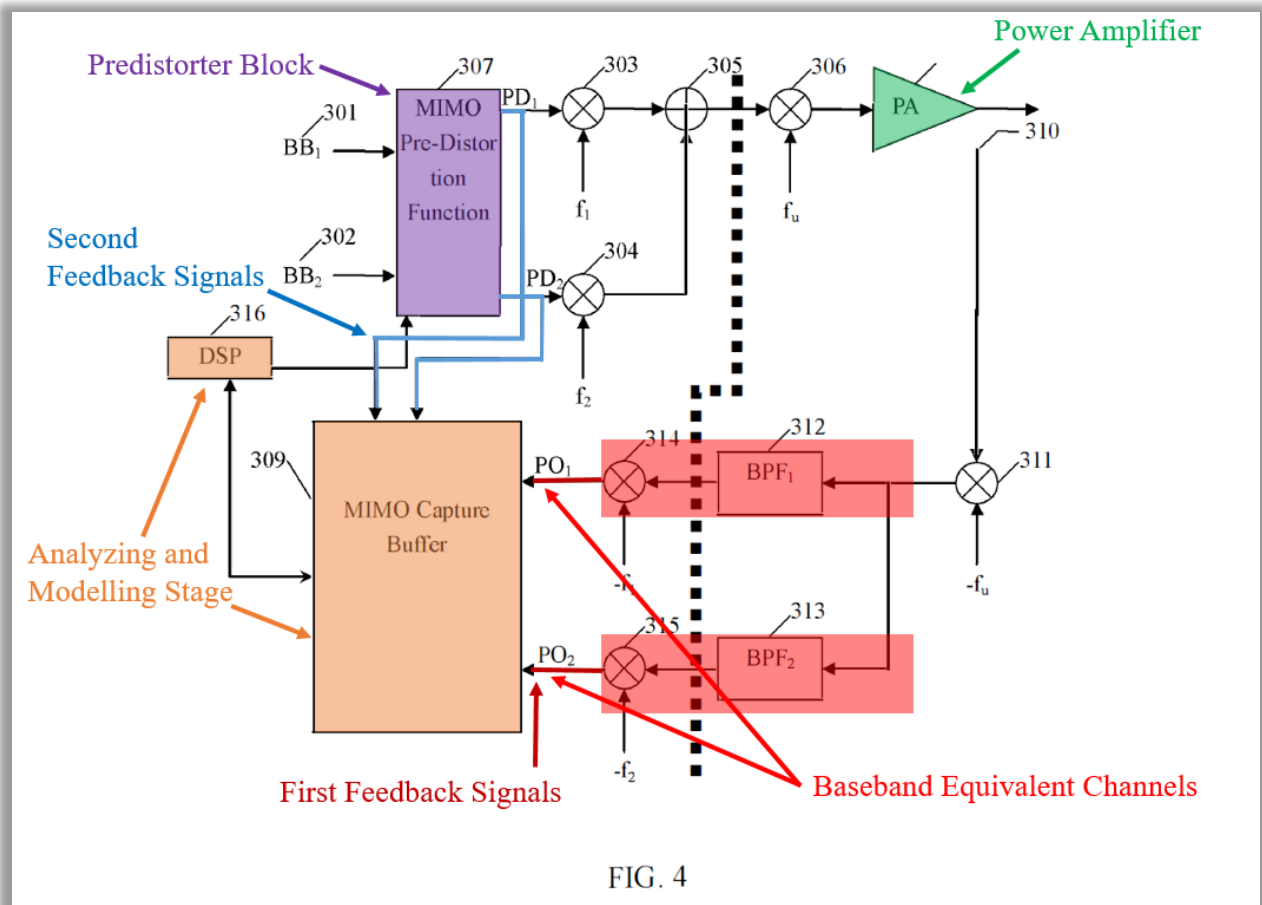


FIG. 4

EX-1005, Fig. 4 (Annotated).

Claim 7

[7pre] The linearized transmitter of claim 2, wherein said signal observation feedback loop further comprises a plurality of channels, each channel comprising:

121. Peroulas' feedback signals PO_1 and PO_2 , which are part of Peroulas' *signal observation feedback loop*, are each inputs into the MIMO Capture Buffer 309, and collectively their paths and associated occupied frequencies comprise a plurality of channels feeding into the MIMO Capture Buffer.

[7a] an RF filter; [7b] a signal down conversion block; and [7c] an analog-to-digital converter (ADC).

122. To generate baseband feedback signals PO_1 and PO_2 , Peroulas' linearized pre-distortion transmitter utilizes an RF filter, a signal down conversion block, and an analog to digital converter (ADC), as claimed. Specifically, Peroulas' *signal observation feedback loop* comprising the channels uses band pass filters BPF_1 312 and BPF_2 313 (*RF filter*), frequency shifter 314 at f_1 and frequency shifter 315 at f_2 (*signal down conversion block*), and an ADC (*an analog-to-digital converter (ADC)*) located along the dotted line in Fig. 4. A POSA would recognize the term frequency shifter as analogous to *signal down conversion block*. EX-1005, 25:23-24, 26:6-8, 30:12-18; *See, e.g.:*

The output of the frequency shifter 311 is connected to two bandpass filters BPF_1 312 and BPF_2 313 respectively.

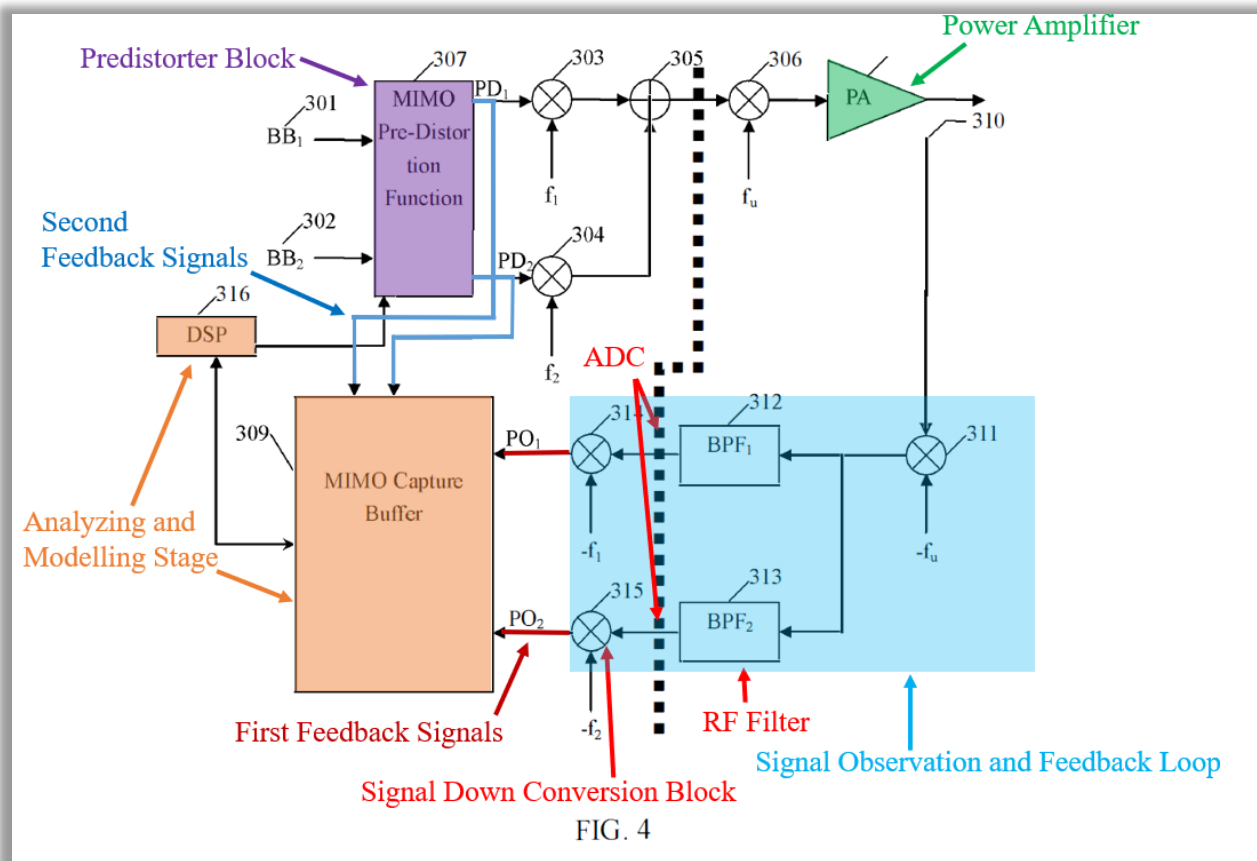
EX-1005, 25:23-24;

The outputs of BPF_1 312 and BPF_2 313 are sent into two frequency shifters 314 and 315, which shift the signals down by f_1 and f_2 , respectively, to produce signals PO_1 and PO_2 , respectively.

EX-1005, 26:6-8;

The bold dotted line represents the boundary between the digital domain and the analog domain in the multiband pre-distorter. Entities and signals to the left of the bold dotted line are digital and entities and signals to the right are analog. Signal conversion from the digital to the analog domain can be implemented by a D/A converter and signal conversion from the analog to the digital domain can be implemented by an A/D converter. Those skilled in the art will recognize that the digital-analog boundary can be placed in many different locations.

EX-1005, 30:12-18.



EX-1005, Fig. 4 (Annotated).

Claim 10

[10pre] *A method for linearizing a transmitter, said method comprising:*

123. *See limitation [1pre].*

[10a] *effecting predistortion of concurrent input signals to output concurrent predistorted signals using a digital signal predistorter block including digital baseband signal predistorters;*

124. *See limitation [1a].*

[10b] *amplifying the predistorted signals using a power amplifier block;*

125. See limitation [b].

[10c] *receiving in an analyzing and modelling stage first feedback signals taken from an output of the power amplifier, and second feedback signals taken concurrently from the concurrent predistorted signals; and using the first feedback and the second feedback signals in the analyzing and modeling stage to model a nonlinearity in the power amplifier, wherein the digital baseband signal predistorters are updated by the analyzing and modelling stage.*

126. See limitation [1c].

B. Ground 2: Claims 8 and 9 are Obvious over Peroulas in View of Cidronali

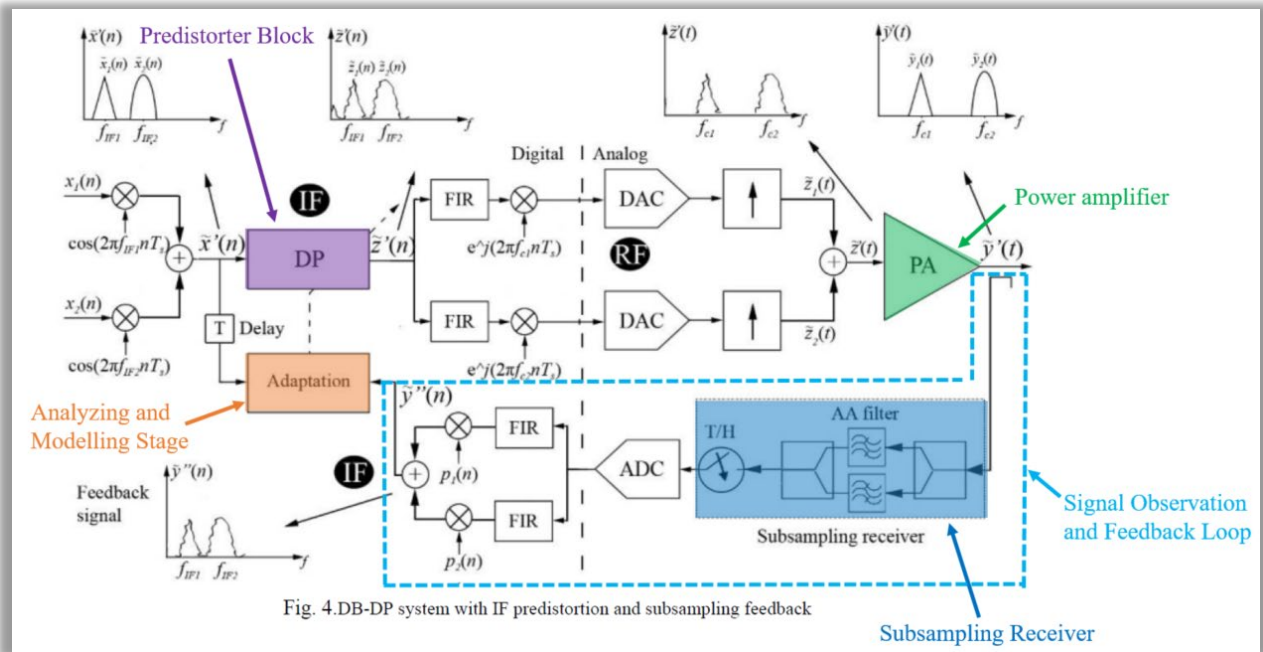
1. Cidronali

127. Cidronali proposes a dual-band DPD system “capable of a simultaneous predistortion of a concurrent dual-band power amplifier at both frequency bands.” EX-1006, 000001; *See, e.g.*:

In this paper we propose a novel method of Dual Band DPD (DB-DPD), capable of a simultaneous predistortion of a concurrent dual-band power amplifier at both frequency bands. The proposed method uses a single band memory polynomial DP for linearization, operating at a proper IF. As feedback path the system adopts a subsampling receiver, which allows extreme flexibility and coherent dual-band down-conversion. With the selection of an appropriate sample rate, the RF channels are translated side-by-side at a low IF with no spectral overlap.

EX-1006, 000001. Cidronali’s system uses a digital IF predistortion block (purple) to generate predistorted signals for the PA (green). For its post-PA feedback, Cidronali uses subsampling and a subsampling receiver (blue) in a signal

observation and feedback loop (light blue) to send this information to an Adaptation block (orange).



EX-1006 Fig. 4 (Annotated). Cidronali's subsampling receiver uses a down-conversion block, filter bank, track and hold block, and ADC sampling according to the widely understood bandpass/subsampling theorem. EX-1006, 000002; *See, e.g.:*

The subsampling adopted in the DB-DPD feedback recalls somehow the receivers adopted in the multiband radios and is based on the bandpass sampling theorem. This principle can be adapted to down-convert two (or more) band-limited signals s_1 and s_2 , located at different centre frequencies.

EX-1006, 000002;

The feedback path proposed in this paper consists of the coherent dual-band subsampling receiver discussed in the previous section. The two bands composing are aliased side-by-side in the baseband, then digitized by a single ADC.

EX-1006, 000002.

2. Obviousness and Motivation to Combine the Teachings of Peroulas with the Teachings of Cidronali

128. As explained previously, Peroulas discloses the signal observation feedback loop of claim 2. It was also known that the sampling rate of Peroulas' feedback loop would either be configured according to the Nyquist rate or subsampled at a rate lower than Nyquist. Indeed, Patent Owner admitted during prosecution of the parent patent to the '296 patent that it "is well known in the art of signal communication that subsampling is the process of sampling at a frequency less than the Nyquist rate." EX-1015, 6.; *See, e.g.*:

The present claims relate in general to subsampling in a feedback loop of modulated concurrent multi-band signals. Applicant submits that it is well known in the art of signal communication that subsampling is the process of sampling at a frequency less than the Nyquist Rate.

EX-1015, 6. Cidronali discloses a single subsampling receiver for use with the very same type of predistorter as disclosed in Peroulas, and a POSA would have been motivated to modify the teachings of Peroulas with Cidronali's subsampling teachings for several reasons.

129. *First*, a POSA would have been motivated to modify the teachings of Peroulas to subsample for the benefit of reducing the complexity and cost of predistorter implementation. As explained in the State of the Art (*see, e.g.*, EX-1019, 3:65-67) and as recognized by Peroulas (EX-1005, Abstract ("[t]he present

invention reduces the implementation cost of a pre-distorter”)), there exists a need to reduce the implementation cost of a dual-band transmitter. EX-1005, 6:2-5; *See, e.g.:*

It would be beneficial if a solution existed to reduce the implementation cost of a dual band pre-distortion transmitter. Furthermore, it would also be beneficial if a solution existed such that the implementation cost of a dual band pre-distortion transmitter would not be a function of $B_{\text{DEADSPACE}}$.

EX-1005, 6:2-5. Cidronali demonstrates that subsampling reduces the number of ADCs thereby minimizing the need for expensive components and reducing cost.

EX-1006, 000002; *See, e.g.:*

The feedback path proposed in this paper consists of the coherent dual-band subsampling receiver discussed in the previous section. The two bands composing are aliased side-by-side in the baseband, then digitized by a single ADC.

EX-1006, 000002. The '296 Patent recognizes this motivation as well, which is nothing more than a restatement of POSA's knowledge and understanding. EX-1001, 2:10-12 (“[u]sing Subsampling technique simplifies the feedback loop topology, requires fewer number of RF components, and reduces the power consumption.”).

130. *Second*, for multiband signals, uniform sampling according to the Nyquist rate can be an inefficient method requiring more components to capture the signal, which increases the complexity of the system. EX-1016, 189; §VII.A.4.

Subsampling addresses this. In fact, Cidronali explains that bandpass/subsampling and its exemplary subsampling receiver “can be adapted to down-convert two (or more) band-limited signals,” making it an ideal choice for multiband implementations. EX-1006, 000002. Thus, a POSA would have been motivated to minimize and simplify Peroulas’ feedback path in a manner that is more efficient with the inclusion of subsampling, “allow[ing] [for] extreme flexibility and coherent dual-band down-conversion.” EX-1006, 000001.

131. *Third*, subsampling allows for direct down conversion from the carrier frequency, which results in cost benefits and performance advantages, further motivating a POSA to use subsampling with Peroulas’ feedback loop. EX-1006, 000002; *See, e.g.*;

The subsampling adopted in the DB-DPD feedback recalls somehow the receivers adopted in the multiband radios and is based on the bandpass sampling theorem. This principle can be adapted to down-convert two (or more) band-limited signals s_1 and s_2 , located at different centre frequencies.

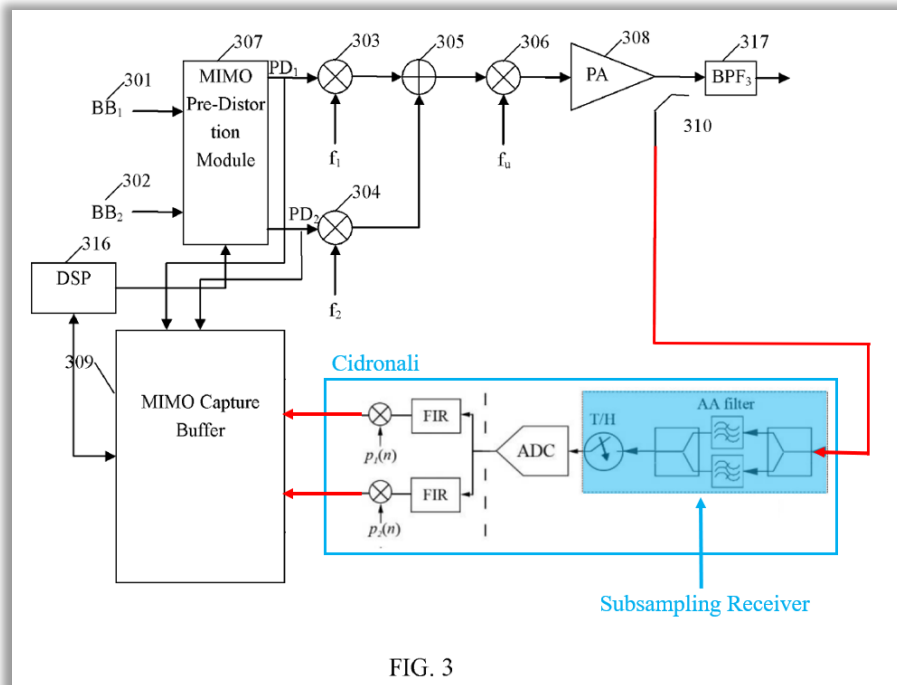
EX-1006, 000002.

132. *Fourth*, due to the down conversion in the digital domain, the system can be more easily designed to accommodate a wide range of frequency bands, and the architecture is more flexible, again motivating a POSA to use subsampling with Peroulas’ feedback loop EX-1006, 000001; *See, e.g.*:

As feedback path the system adopts a subsampling receiver, which allows extreme flexibility and coherent dual-band down-conversion.

EX-1006, 000001.

133. Modifying the teachings of Peroulas to include subsampling and, in particular, a single subsampling-based receiver, was not only obvious, but it would also have been achieved with a reasonable expectation of success. Peroulas' predistortion technique would fundamentally remain unchanged, the only difference being the mechanics of how the PA's feedback signals are fed into Peroulas' MIMO Capture Buffer. Specifically, a POSA would have simply implemented Peroulas' teaching of bandpass filters and ADC with Cidronali's teaching of a single subsampling receiver having filters and an ADC. This modification would have been simple for a POSA to achieve as it requires only using prior art components according to their established functions. A POSA would have also understood that Cidronali's subsampling architecture is not limited to the output of an intermediate frequency (or "IF"), as indicated in Cidronali's Fig. 4, but that the frequency shifters disclosed in both Peroulas and Cidronali are equally capable of returning the signal to baseband (the contemplated input into Peroulas' MIMO Capture Buffer).



EX-1005, Fig. 3 (Annotated and Modified in View of EX-1006, Fig. 4).

3. Detailed Application of Peroulas in View of Cidronali

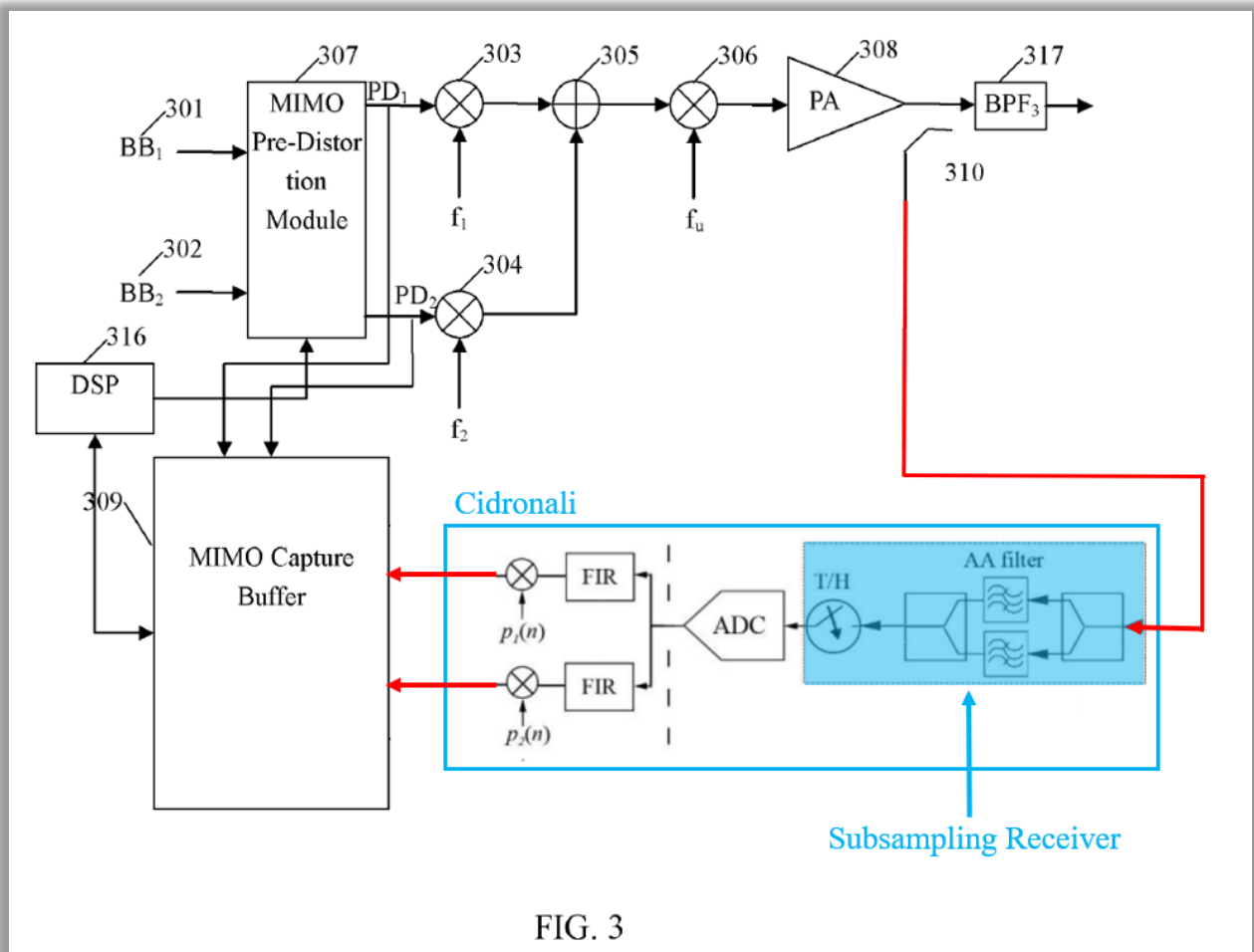
Claim 8

[8pre] *The linearized transmitter of claim 2, wherein said signal observation feedback loop further comprises:*

[8a] *a single subsampling-based receiver to down-convert samples output from said power amplifier block.*

134. As discussed above, it would have been obvious to implement Peroulas' predistortion system using a subsampling-based feedback loop, including the use of *a single subsampling-based receiver*, as disclosed in Cidronali. Cidronali's subsampling receiver "allows [for] extreme flexibility and coherent dual-band down-conversion" (EX-1006, 000001), thus cost-effectively down-converting RF samples

from Peroulas' multi-band transmitter. Accordingly, Peroulas in view of Cidronali discloses *a single subsampling-based receiver to down-convert samples output from a concurrent multi-band transmitter.*



EX-1005, Fig. 3 (Annotated and Modified in View of EX-1006, Fig. 4).

Claim 9

[9pre] *The linearized transmitter of claim 8, wherein said single subsampling-based receiver further comprises:*

[9a] *an RF filter; a track and hold (T&H) block; and an analog-to-digital converter (ADC).*

135. To provide “coherent dual-band down-conversion” (EX-1006, 000001), Cidronali’s single subsampling-based receiver uses an anti-aliasing/AA filter (*rf filter*), T/H component (*track and hold (T&H) block*), and ADC (*an analog-to-digital converter*), as claimed (*id.*, Fig. 4). These commonplace components are further illustrated in the annotated figure below, which a POSA would have immediately understood as corresponding to the claimed components. In other words, because these components are so well-understood, Cidronali had to go no further than to provide a figure depicting an AA filter, T/H, and ADC for a POSA to understand the use of an RF filter, a track and hold (T&H) block, and an analog-to-digital converter (ADC), as claimed.

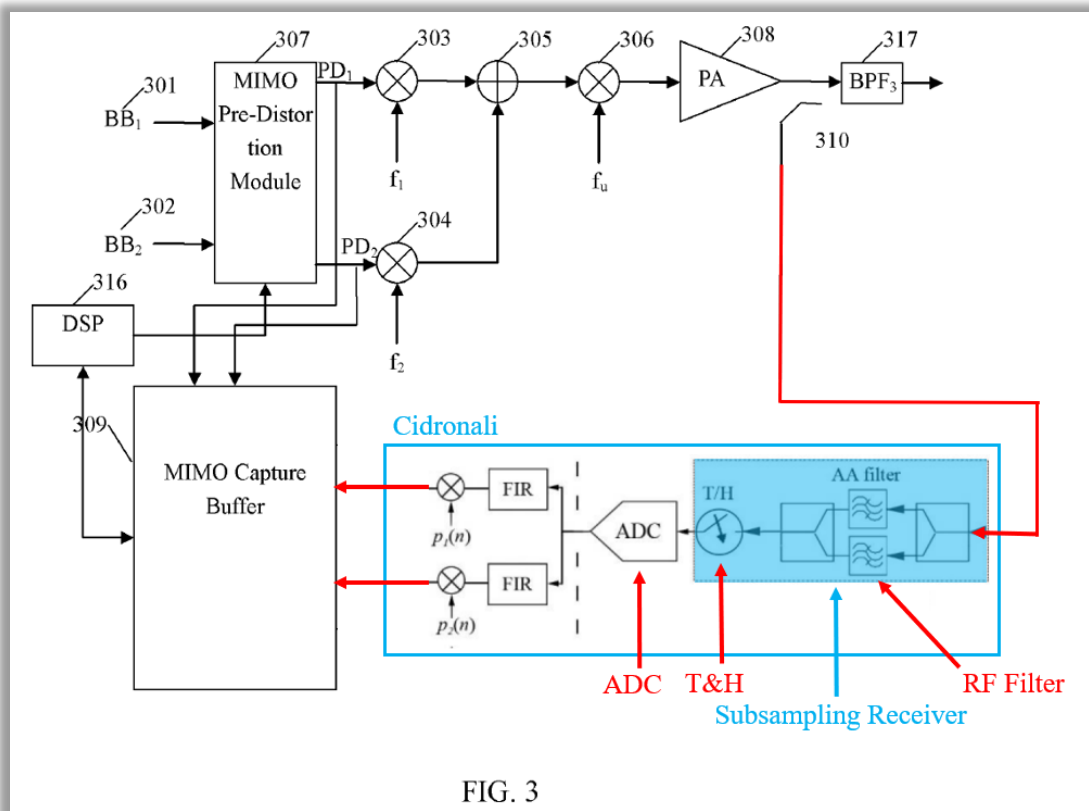


FIG. 3

EX-1005, Fig. 3 (Annotated and Modified in View of EX-1006, Fig. 4).

C. Ground 3: Claim 1-7, 10 are Obvious over Posti

1. Posti

136. Posti discloses a “multi-frequency carrier transmitter,” shown in Fig. 4 (below), including a plurality of input signals each corresponding to a channel (“User 1 Data” through “User N Data”) and a plurality of digital modulators 106 (purple) to predistort these signals before amplification by PA 122 (green). EX-1009, 2:43-60, 4:66-5:5, 5:13-15, 5:41-42; *See, e.g.*:

According to one aspect of the present invention, there is provided a multi frequency carrier transmitter comprising input means for receiving a plurality of different digital signals to be transmitted, said

different signals to be transmitted on different carrier frequencies, amplifier means for receiving a composite signal comprising said different signals at the respective carrier frequencies and amplifying said composite signal; and predistortion means for predistorting said plurality of digital signals prior to amplification of the composite signal by said amplification means, said predistortion provided by said predistortion means being subsequently altered in dependence on the difference between said input signals and the output at said amplifier means.

Accordingly, embodiments of the present invention provide a multi carrier transmitter which is able to deal with the problems of nonlinearity by using predistortion. The predistortion can be implemented more simply than the feedback method discussed in the prior art.

EX-1009, 2:43-60;

In general terms the modulators 106 take the baseband input from the respective channel encoder 104, pass that input through a shaping filter and mix the signal with a carrier signal at an intermediate frequency which is higher than the baseband frequency but less than the frequency at which the signals are transmitted to thereby provide a modulated output.

EX-1009, 4:66-5:5;

The combiner 110 combines the outputs of all of the modulators 106 to provide a single output. That output contains the Signals for each of the frequencies.

EX-1009, 5:13-15;

The output of the second bandpass filter 120 is input to the power amplifier 122 which amplifies the received input.

EX-1009, 5:41-42.

137. Posti uses indirect learning to estimate and linearize the distortion introduced by the PA and includes Adaptive Predistorter 108 (orange) that receives

signals from the output of the PA (red) and the output of the digital modulators (blue).

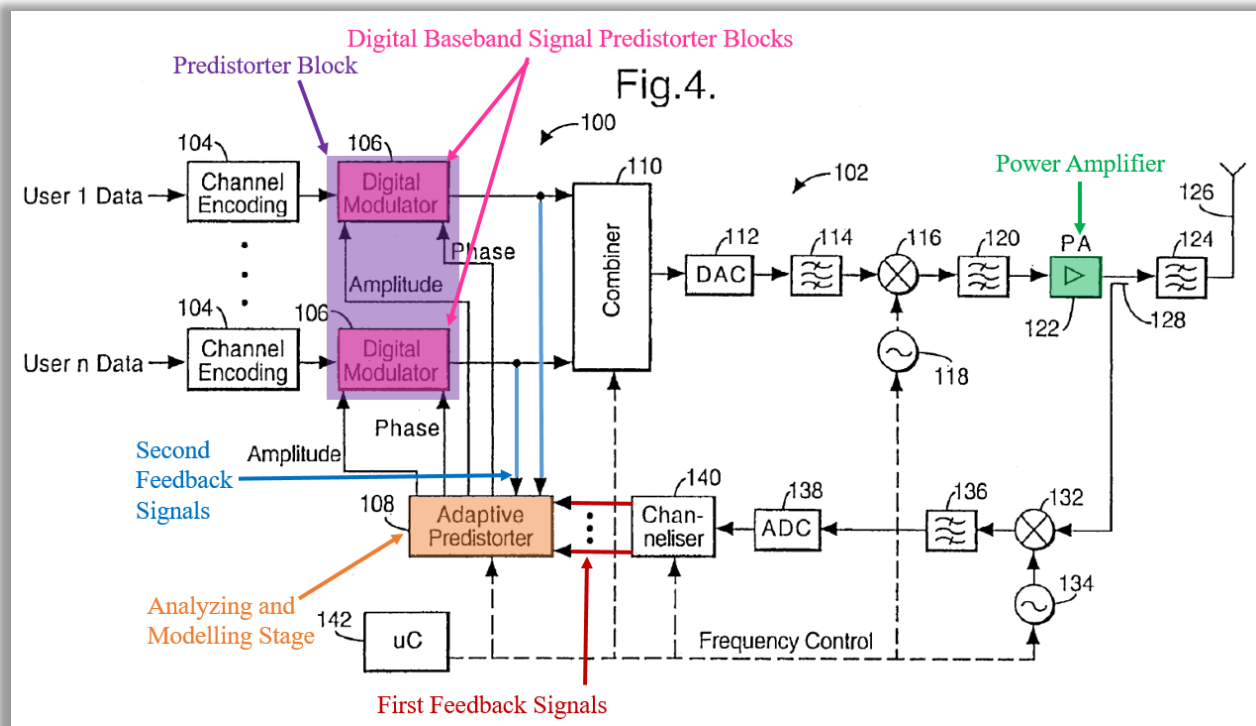
EX 1009, 5:50-52, 6:23-32; *See, e.g.:*

Between the amplifier 122 and the third bandpass filter 124, there is arranged a coupler 128 which is arranged to sample a small part of the signals which are transmitted.

EX 1009, 5:50-52;

The adaptive predistorter 108 thus receives for each channel a version of the signal before it passes through the combiner 110 and Subsequent elements of transmit part 102 of the base station 100 (from the respective digital modulator) and a version of the signal after it has passed through the transmit part 102 (from the channelizer 140). The predistorter 108 thus compares like versions of the same signal eg, both signals will be modulated at the same frequencies. The adaptive predistorter 108 is arranged to compare these signals.

EX-1009, 6:23-32.



EX-1009, Fig 4 (Annotated).

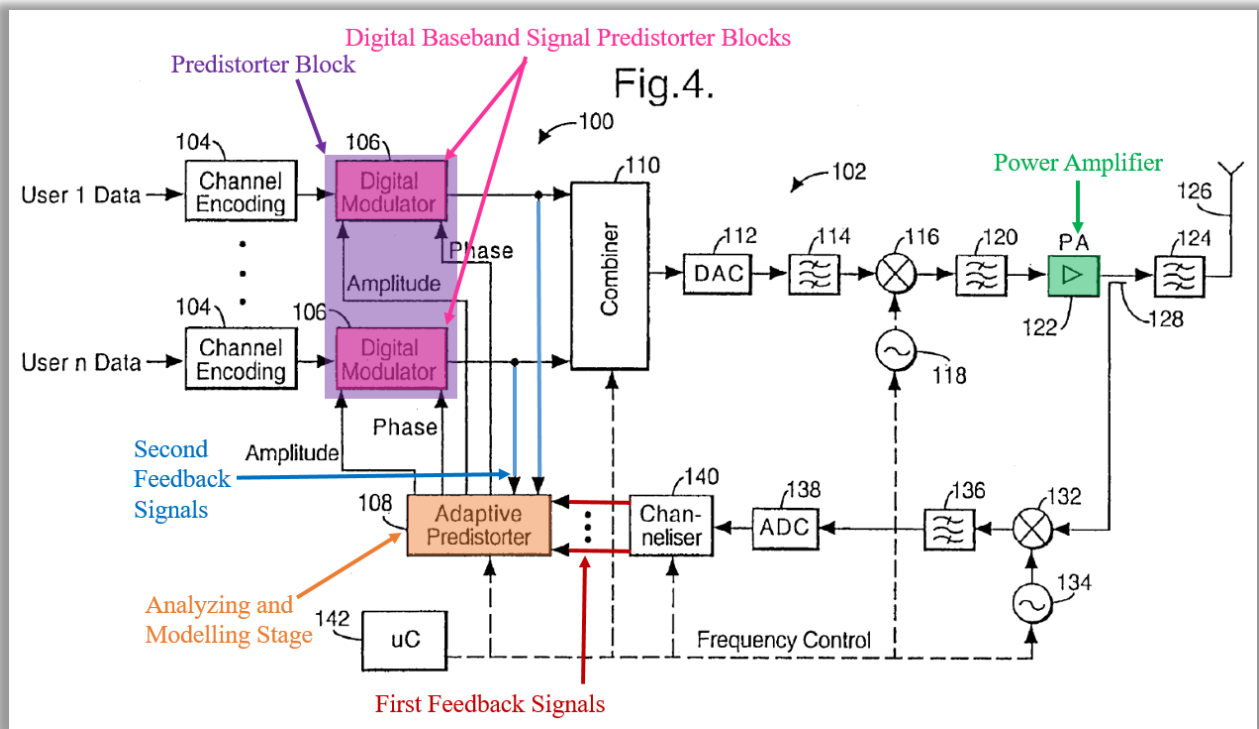
138. Posti explains that “embodiments of the present invention can be used with any suitable transmitter which is sending signals at more than one frequency at the same time” (EX-1009, 9:49-52), directly disclosing and suggesting to a POSA that Posti’s “multi-frequency carrier transmitter” (*id.*, Abstract) is equally applicable to “multi-band” transmission systems. In other words, a POSA understood Posti’s input channels “User 1 Data” through “User n Data” to encompass inputs for the different frequency channels located in the multiple bands used in a multi-band system.

2. Detailed Application of Posti in View of the Knowledge of a POSA to the Challenged Claims

Claim 1

[1pre] *A linearized transmitter comprising:*

139. To the extent that the preamble is limiting, Posti discloses a multi-frequency carrier transmitter using predistortion to “solve[] or at least mitigate[] the problems caused by a nonlinear amplifier.” EX-1009, 2:40-42. Posti’s transmitter is depicted below in annotated Fig. 4.



EX-1009, Fig. 4 (Annotated).

[1a] a digital signal predistorter block including digital baseband signal predistorters effecting predistortion of concurrent input signals to output concurrent predistorted signals;

140. Posti discloses a plurality of digital modulators 106 (pink), shown in Fig. 4 (above), which correspond to a respective channel in Posti's transmitter system and are the claimed *digital baseband signal predistorters* within a *digital signal predistorter block*. EX-1009, 4:49-51; *See, e.g.:*

The output of each channel encoder 104 is input to a respective digital modulator 106. Each digital modulator 106 also receives two outputs from the adaptive predistorter 108.

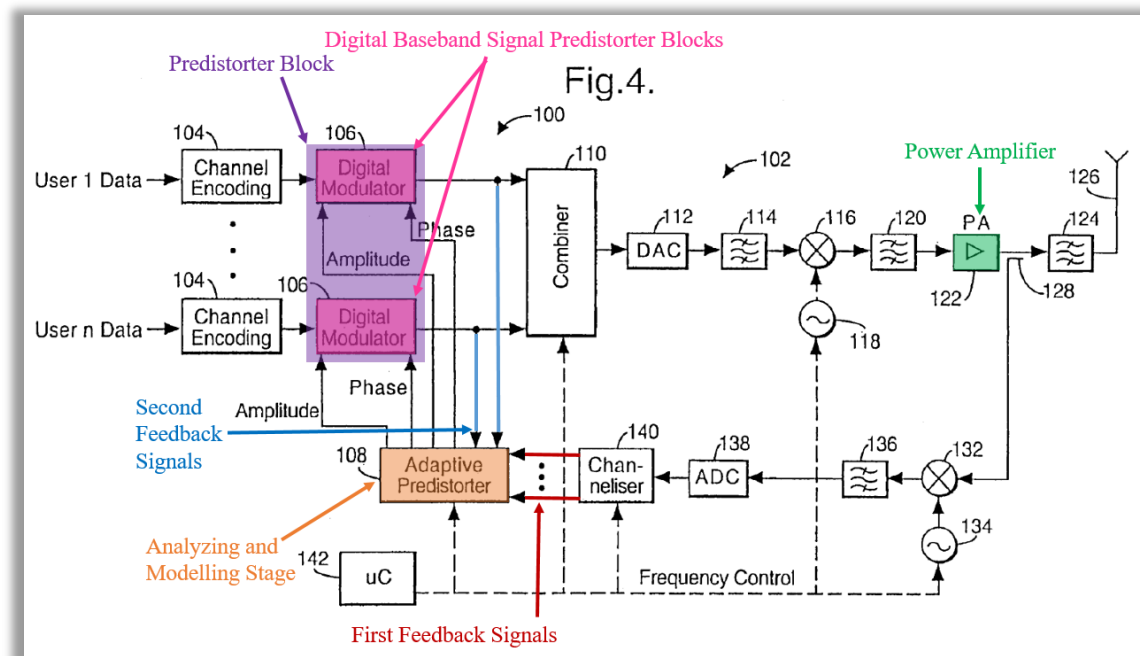
EX-1009, 4:49-51.

141. The digital modulators 106 receive baseband input signals, represented in Posti's figures as "User n Data" (*concurrent input signals*), to be transmitted on particular frequencies from the output of the channel encoding block 104. EX-1009, 4:35-41, 4:43-44 ("As mentioned hereinbefore, each channel is on a different frequency after the modulator."); *See, e.g.:*

The transmit part 102 of the base station 100 comprises N channel encoders 104 where N is the number of different frequencies on which the base station 100 will transmit signals. Each channel encoder 104 receives the data to be transmitted on the particular frequency associated with the given channel encoder 104. The data is placed in a suitable form for transmission. This may include digitising the data, encoding the data, interleaving the data and/or any other step required to be carried out. As mentioned hereinbefore, each channel is on a different frequency after the modulator.

EX-1009, 4:35-44.

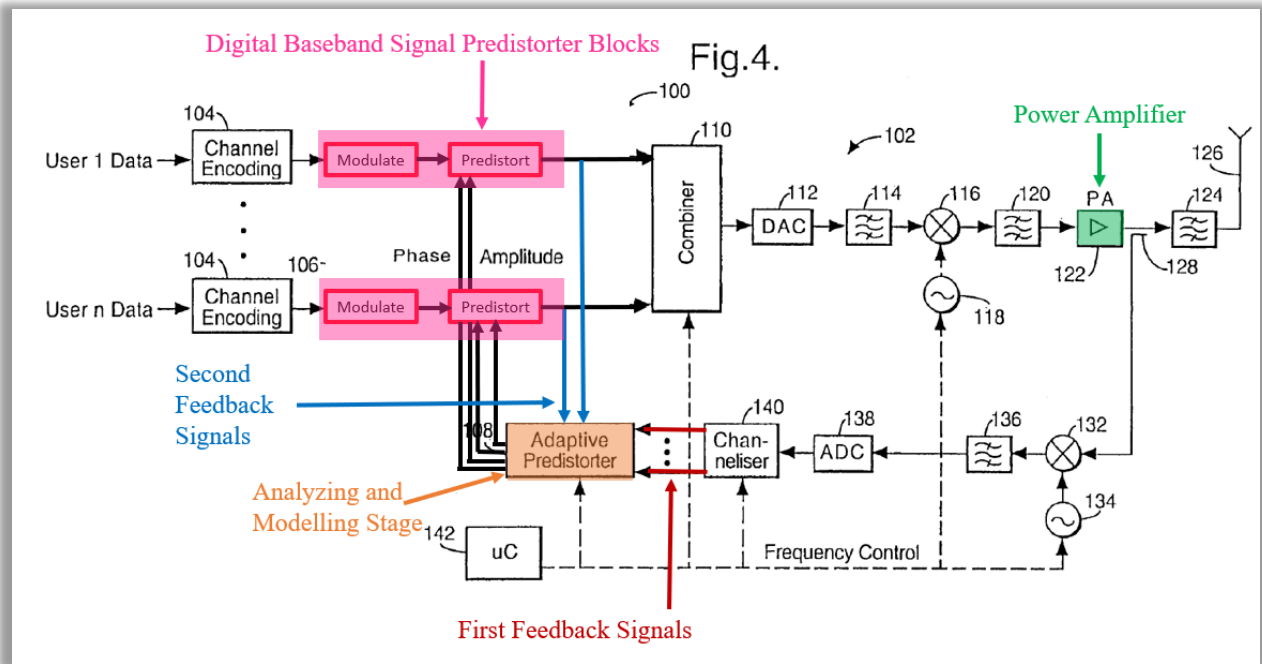
142. The digital modulators are arranged to "modulate the output of the respective channel encoders 104 according to the modulation method use by the telecommunications system," (EX-1009, 4:61-64), "pass that input through a shaping filter and mix the signal with a carrier signal at an intermediate frequency," (*id.*, 4:61-64), and "[apply] predistortion to compensate for the phase and amplitude distortion introduced by the amplifier 122" (*id.*, 5:6-7). The output of digital modulators 106 results in *concurrent predistorted signals*, as shown in the figure below.



EX-1009, Fig. 4 (Annotated).

143. Moreover, Posti explains that “predistortion can be performed during or more preferably after the modulation has been carried out by the modulator” (EX-1009, 5:6-10; *see also id.* 5:2-5), meaning that Posti’s digital modulators can either predistort at baseband frequency—by using, for example, sequential steps for modulation, predistortion, and then upconversion—or at an intermediary frequency after upconversion has occurred. In the first instance when predistorting at baseband, Posti explains that the combiner 110 may instead perform upconversion using an inverse fast Fourier transform (“IFFT”). EX-1009, 7:4-6 (“The combiner 110 requires information on the frequency if an inverse fast fourier transform combining technique is required.”). This is illustrated by modified Fig. 4 (below), which

demonstrates modulation and predistortion in Posti's digital modulators 106, and upconversion in Combiner 110.



EX-1009, Fig. 4 (Annotated and Modified).

144. Either way, Posti's digital modulators are the claimed *digital baseband signal predistorters effecting predistortion of concurrent input signals to output concurrent predistorted signal* because they take incoming concurrent baseband signals and predistort those signals to output concurrent predistorted signals.

[1b] a power amplifier block connected to amplify the predistorted signals; and

145. Posti discloses a power amplifier 122 (green), which “amplifies the received input,” and a signal combiner 110 to “combine the outputs of all of the modulators 106 to provide a single output.” EX-1009, 5:41-42, 5:13-14; *See, e.g.:*

The output of the second bandpass filter 120 is input to the power amplifier 122 which amplifies the received input.

EX-1009, 5:41-42;

The combiner 110 combines the outputs of all of the modulators 106 to provide a single output.

EX-1009, 5:13-14. And in this way, Posti's disclosure is consistent with the disclosure of the '296 Patent that describes "an RF power amplification block, the RF power amplification block including the concurrent multi-band power amplifier; and an RF power combining network." EX-1001, 2:39-41. Thus, the claimed "block" can include the transmitter's PA and other associated components, which is clearly disclosed in Posti.

[1c] an analyzing and modelling stage receiving first feedback signals taken from an output of the power amplifier, and second feedback signals taken concurrently from the concurrent predistorted signals and using the first feedback and the second feedback signals in the analyzing and modelling stage to model a nonlinearity in the power amplifier, wherein the digital baseband signal predistorters are updated by the analyzing and modelling stage.

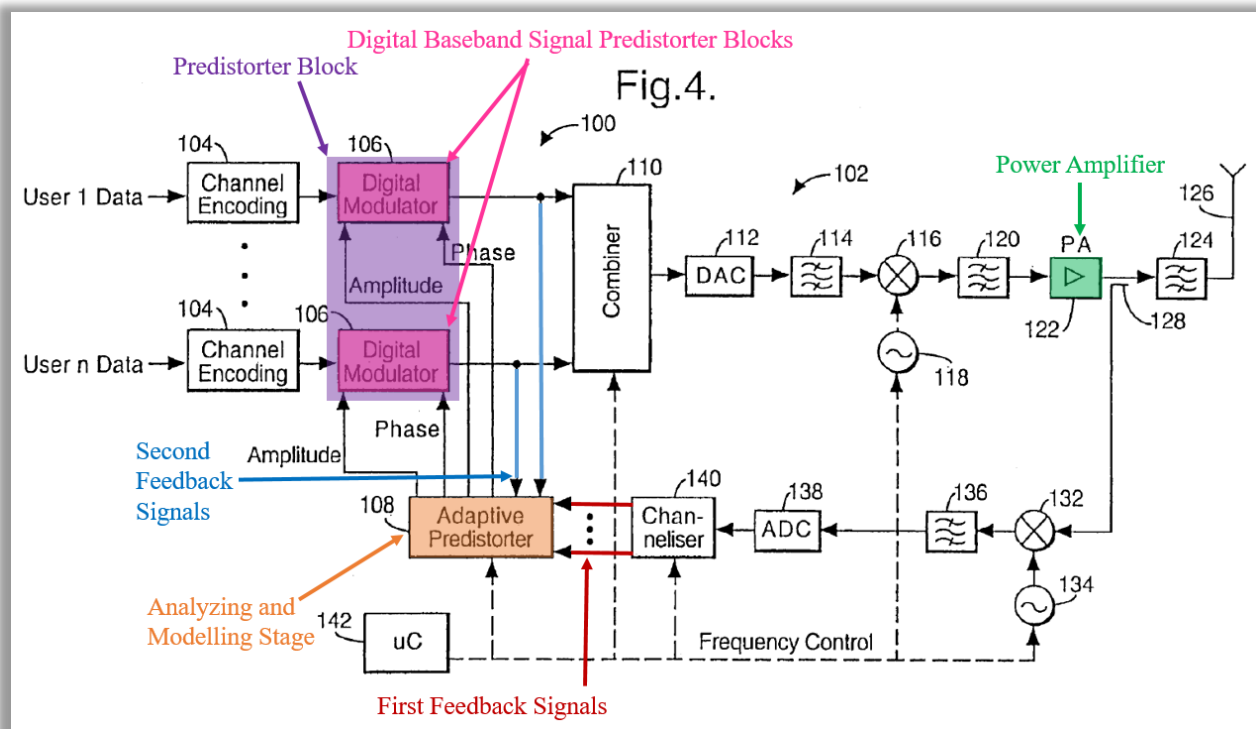
146. Posti uses an indirect learning architecture where adaptive predistorter 108 (orange) (*analyzing and modelling stage*) calculates new predistortion coefficients by comparing feedback signals generated from the output of the PA via channeliser 140 (red) (*first feedback signals*) and concurrent predistorted signals output from the digital modulators 106 (blue) (*second feedback signals*). EX-1009, 5:11-12, 6:19-22; *See, e.g.:*

The output of each of the digital modulators 106 are input to a signal combiner 11 and to the adaptive predistorter 108.

EX-1009, 5:11-12;

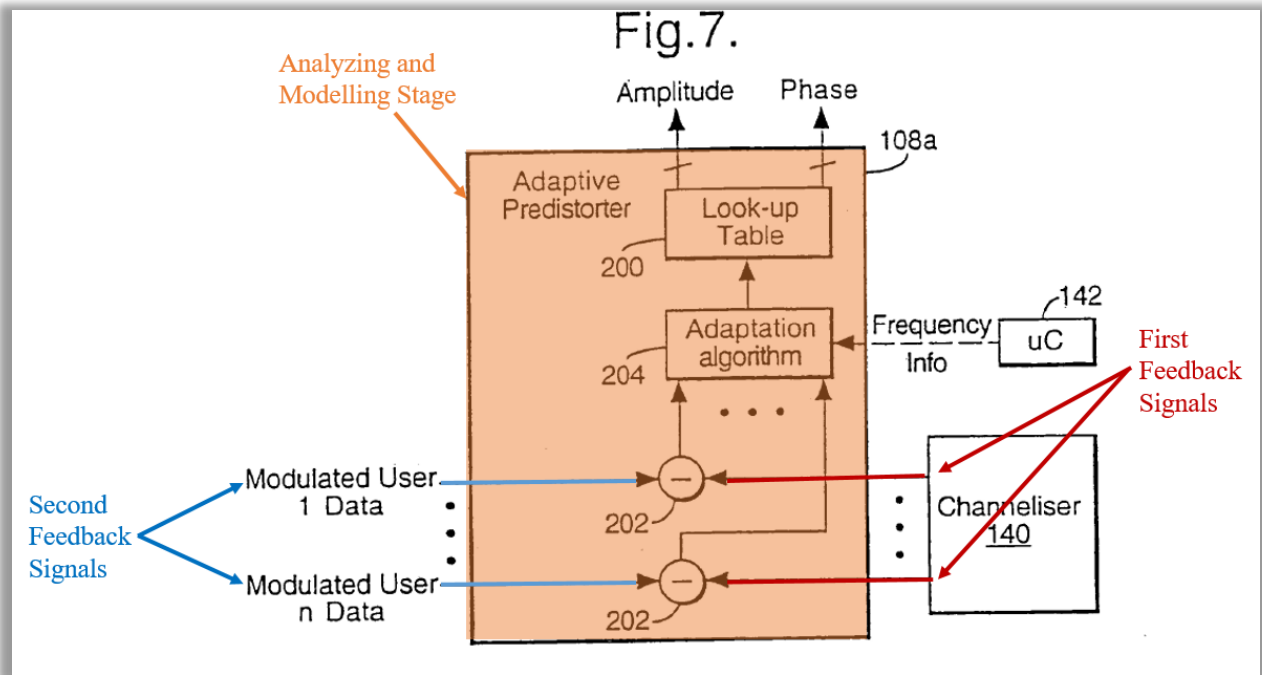
Each of the N outputs provided by the channelizer 140 are input to the adaptive predistorter 108. The channelizer 140 can be provided in any suitable way including a bank of digital downconverters and fast fourier transform circuitry.

EX-1009, 6:19-22. More specifically, Posti explains that the adaptive predistorter 108 receives “for each channel a version of the signal before it passes through the combiner 110 and subsequent elements of transmit part 102 of the base station 100 (from the respective digital modulator) and a version of the signal after it has passed through the transmit part 102 (from the channelizer 140).” EX-1009, 6:23-28.



EX-1009, Fig. 4 (Annotated).

147. Fig. 7, below, shows an enhanced view of the adaptive predistorter 108.



EX-1009, Fig. 7 (Annotated).

148. The signals output from the channeliser 140 (red) (*first feedback signals*) and concurrent predistorted signals output from the digital modulators 106 (blue) (*second feedback signals*) are applied to the adaptation algorithm 204. This process is explained by Posti:

The predistorter 108a comprises n subtracters 202 each of which receives a respective one of the outputs from the digital modulators 106. Each subtracter also receives a input from the channeliser 140. Each subtracter 202 receives the output from the modulator 106 corresponding to a given user and the output from the channeliser 140 which also corresponds to that user. The subtracter 202 subtracts one of the outputs from the other to thus determine the difference between those signals. The output of each subtracter 202 thus constitutes a difference signal which is input to an adaption algorithm block 204 which on the basis of the input received from the subtractor 202

calculates, if necessary, new amplitude and phase predistortion coefficients.
EX-1009, 7:12-24.

149. So that the subtractors 202 can determine the difference signal between Posti's first and second feedback signals, a POSA would have understood, as shown in Figs. 4 and 7, for example, that Posti's second feedback signals are being provided to the adaptive predistorter concurrently. To the extent Patent Owner argues that Posti does not expressly state that second feedback signals are provided concurrently, a POSA would have been motivated to do so in order to, at a minimum, allow for concurrent processing across bands and the concurrent updating of each of Posti's digital modulators.

150. Posti's adaptation algorithm 204 then calculates the amplitude and phase coefficients to "compensate for non-linearity with respect to amplitude and also phase distortion." EX-1009, 4:51-59, 6:49-56; *See e.g.*:

The first output from the predistorter 108 provides one or more amplitude coefficients which are used to predistort the signal which is output by the digital modulator to compensate for the non linearity of an amplifier 122 with respect to amplitude. The second output from the predistorter 108 provides one or more phase coefficients which are used to predistort the signal which is output by the modulator 106 to compensate for phase distortion provided by the amplifier 122.

EX-1009, 4:51-59;

The predistortion coefficients are arranged to compensate for non-linearity with respect to amplitude and also phase distortion. The phase and amplitude of the signals of the digital modulators 106 are altered in

accordance with these coefficients. How these coefficients are used will depend on the modulation method. In the simplest cases, the coefficients could be added to the Signal or used as multipliers.

EX-1009, 6:49-56.

151. The amplitude and phase coefficients calculated by adaption algorithm 204 are output to look-up table 200 where they are stored (EX-1009, 7:21-26), and then “supplied, as shown in FIG. 4, to the respective digital modulators 106 (*id.*, 7:26-28). In this way, Posti’s adaptive predistorter 108 (*analyzing and modelling stage*) models the power amplifier’s nonlinearity (*using the first feedback and the second feedback signals in the analyzing and modelling stage to model a nonlinearity in the power amplifier*) and then updates Posti’s digital modulators 106 (*wherein the digital baseband signal predistorters are updated by the analyzing and modelling stage*). Accordingly, the ’296 Patent’s claim 1 is rendered obvious in view of Posti.

Claim 2

[2pre] *The linearized transmitter of claim 1, wherein said concurrent digital multi-band predistortion block further comprises:*

152. As discussed previously, Posti explains that its teachings are suitable for any transmitter that sends “signals at more than one frequency at the same time” (EX-1009, 9:49-52), which is true of multi-band transmitters, meaning that a POSA understood Posti’s input signals “User 1 Data” through “User n Data” to encompass inputs for the different frequency channels used in a multi-band system. *See, e.g.:*

Embodiments of the present invention can be used with any suitable transmitter which is sending signals at more than one frequency at the same time in both wireless and wired environments.

EX-1009, 9:49-52. In other words, and in the context of a single PA that can transmit signals located in different frequency bands, a POSA understood that Posti's plurality of digital modulators 106 would apply predistortion across a first channel within a first band, and a second channel within a second band.

[2a] a plurality of the digital baseband signal predistorters each corresponding to a respective channel;

153. Posti discloses that “base station 100 comprises N channel encoders 104 where N is the number of different frequencies on which the base station 100 will transmit signals” and that each channel encoder 104 “receives the data to be transmitted on the particular frequency associated with the given channel encoder 104.” EX-1009, 4:35-41; 4:43-44 (“As mentioned hereinbefore, each channel is on a different frequency after the modulator.”); *See, e.g.:*

The transmit part 102 of the base station 100 comprises N channel encoders 104 where N is the number of different frequencies on which the base station 100 will transmit signals. Each channel encoder 104 receives the data to be transmitted on the particular frequency associated with the given channel encoder 104. The data is placed in a suitable form for transmission. This may include digitising the data, encoding the data, interleaving the data and/or any other step required to be carried out. As mentioned hereinbefore, each channel is on a different frequency after the modulator.

EX-1009, 4:35-44. Each channel encoder 104 outputs a signal corresponding to that respective channel to be “input to a respective digital modulator 106.” EX-1009,

4:48-49. Accordingly, the connection from each channel encoder 104 to a digital modulator 106 demonstrates that each digital modulator 106 (*digital baseband signal predistorters*) corresponds to a respective channel, and thus Posti discloses a plurality of the digital baseband signal predistorters each corresponding to a respective channel, as claimed.

[2b] and a signal observation feedback loop for generating said first feedback signals.

154. As explained previously, Posti's adaptive predistorter 108 (*analyzing and modelling stage*) receives, *inter alia*, signals output from the channeliser 140 (*first feedback signals*). EX-1009, 5:11-12, 6:19-20; *See, e.g.*:

The output of each of the digital modulators 106 are input to a signal combiner 11 and to the adaptive predistorter 108.

EX-1009, 5:11-12;

Each of the N outputs provided by the channelizer 140 are input to the adaptive predistorter 108.

EX-1009, 6:19-20. Before those feedback signals are passed from the channeliser 140 to the adaptive predistorter 108 (*analyzing and modeling stage*), the feedback first passes through coupler 128, mixer 132, band pass filter 136, and ADC 138, which taken together with the channeliser 140 comprise a *signal observation feedback loop*, as illustrated in annotated Fig. 4. EX-1009, 5:50-6:16; *See, e.g.*:

Between the amplifier 122 and the third bandpass filter 124, there is arranged a coupler 128 which is arranged to sample a small part of the signals which are transmitted. In other words, the coupler 128 allows a

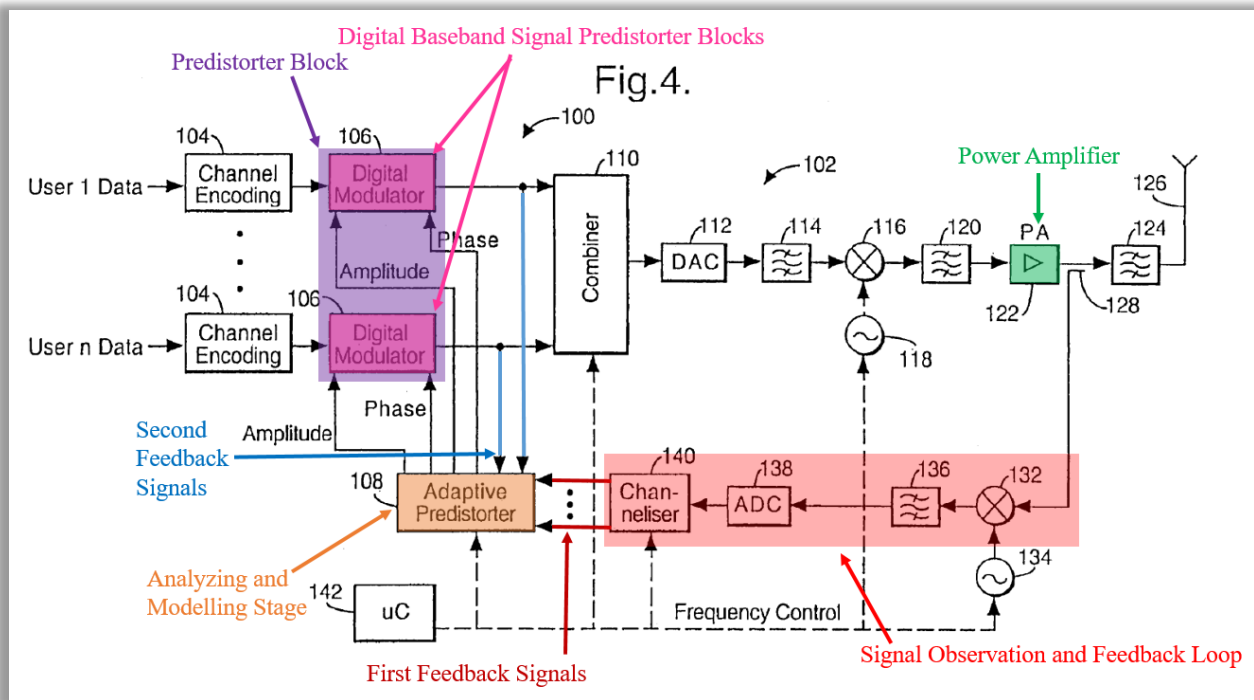
small proportion of the signals to be transmitted to be sampled. The coupler 128 outputs an analogue sample of the output signal which is typically below the power of the input to the third bandpass filter 124.

The output of the coupler 128 is input to a second mixer 132 which receives a signal from a second local oscillator 134. The signals which are received from the coupler 128 are in the radio frequency band. The signal from the second local oscillator 134 is at a frequency such that when the signals from the coupler 128 are mixed with signal from the local oscillator 134, the output of the second mixer 132 consists of the signals which were transmitted but at the intermediate frequencies. The intermediate frequencies output by the second mixer 132 may but not necessarily be the Same as the intermediate frequencies input to the first mixer 116. Accordingly, the frequency of the Signals provided by the first and second oscillators 118 and 134 may be the same. In that case, a single oscillator may be provided.

The output of the second mixer 132 is input to a fourth bandpass filter 136 which filters out any signal components introduced by the second mixer 132 which are outside the intermediate frequency band. The output of the fourth band pass filter 136 is input to an analogue to digital converter 138 which is arranged to convert the analogue signals to digital form.

The digital signals are output by the analogue to digital converter 138 to a channelizer 140. The channelizer 140 divides the signals into the N different frequencies corresponding to the frequencies on which those signals were transmitted.

EX-1009, 5:50-6:16.



EX-1009, Fig. 4 (Annotated).

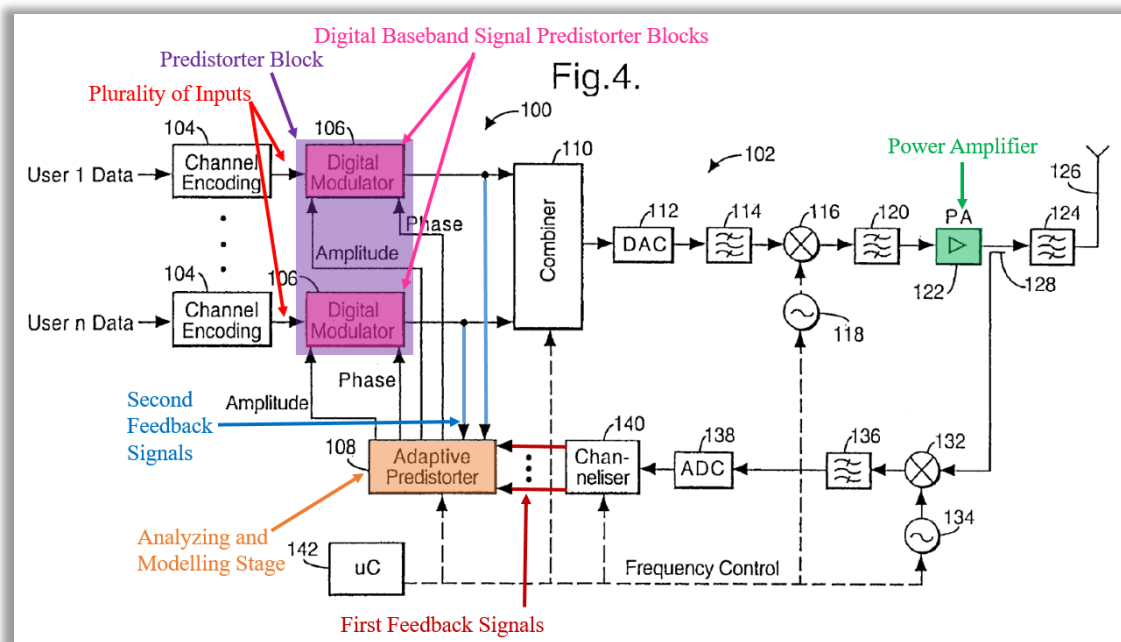
Claim 3

[3pre] *The linearized transmitter of claim 2, wherein said plurality of digital baseband signal predistorters further comprises:*

[3a] *a plurality of inputs, each input corresponding to a single frequency channel; and*

155. Posti's transmitter (or base station 100) uses a plurality of digital modulators 106 (said *digital baseband signal predistorters*) (see, e.g., EX-1009, 4:49-51), which receive input signals from N channel encoders 104 where "*each channel encoder 104* receives the data to be transmitted on the particular frequency associated with the given channel encoder 104." EX-1009, 4:38-40 (emphasis added). Further, Posti explains that the transmit portion 102 of the base station 100

“comprises N channel encoders 104 where *N is the number of different frequencies on which the base station 100 will transmit signals.*” EX-1009, 4:35-38 (emphasis added). In other words, each “user data” input in Posti’s transmitter corresponds to a single frequency channel, as claimed. And taken together, Posti’s plurality of digital modulators 106 (*plurality of digital baseband signal predistorters*) receive a plurality of inputs with each input corresponding to a single frequency channel (*i.e., the “N” number of different frequencies on which the base station 100 will transmit signals*). And while not claimed, a POSA would have also understood to implement Posti such that each digital modulator receives as inputs each user input channel to more effectively deal with intermodulations or cross-products between the different bands of a multi-band signal. *See, e.g.,* EX-1005, 10:4-7; EX-1021, 134.



EX-1009, Fig. 4 (Annotated).

156. In this way, Posti's predistorter includes an equal number of digital modulators to the number of bands of the multi-band transmitter, with each input corresponding to a single frequency channel. For example, in a dual-band implementation, Posti's multi-frequency transmitter would receive user data 1 and user data 2, each corresponding to a single frequency channel to be transmitted at respective frequencies in band 1 and band 2.

157. Further, because "each of the individual channels are input to the adaptive predistorter on the input side and the individual channels are received from a channeliser on the output side," Posti's pre-distortion coefficient are "calculated by the adaptive predistorter [] based on all of the carriers, [which] allows [for] optimal performance to be obtained since all the information is available." EX-1009, 6:63-7:3; *See, e.g.*:

The embodiment of FIG. 4 has the advantage that each of the individual channels are input to the adaptive predistorter on the input side and the individual channels are received from a channeliser on the output Side. Therefore, the predistortion coefficients that are calculated by the adaptive predistorter are based on all of the carriers. This allows optimal performance to be obtained since all the information is available.

EX-1009, 6:63-7:3. Tellingly, this is no different than the '296 Patent's explanation that the "predistorted inputs, X_{pd1} and X_{pd2} , 115 as well as the output of each band

of the PA, y_1 and y_2 , 160 are used to generate the predistorter signal processing model 110.” EX-1001, 4:2-5.

[3b] a plurality of outputs, each output corresponding to a single frequency channel, and each output connected to an input of a concurrent multi-band transmitter.

158. Posti’s plurality of digital modulators 106 (*plurality of digital baseband signal predistorters*) each output a signal on a single frequency channel (as explained for limitation [3a]) to frequency combiner 110, and thus disclose a *plurality of outputs, each output corresponding to a single frequency channel*. EX-1009, 4:49-51, 5:11-12; *See, e.g.:*

The output of each channel encoder 104 is input to a respective digital modulator 106. Each digital modulator 106 also receives two outputs from the adaptive predistorter 108.

EX-1009, 4:49-51.

The output of each of the digital modulators 106 are input to a signal combiner 11 and to the adaptive predistortor 108.

EX-1009, 5:11-12; The combiner 100 then provides a composite signal to first band pass filter 114, mixer 116, second band pass filter 120, power amplifier 122, and third band pass filter 124. EX-1009, 5:22-25, 5:25-26, 5:37-40, 5:41-46.; *See, e.g.:*

The output of the digital to analogue converter 112 is input to a first bandpass filter 114 which removes signal components generated by the digital to analogue converter 112 which are outside the intermediate frequency band. The output of the first bandpass filter 114 is input to a first mixer 116.

EX-1009, 5:22-26;

The output of the first mixer 116 is input to a second bandpass filter 120 which removes any signal components introduced by the first mixer 116 which are outside the radio frequency band of the Signals to be transmitted.

EX-1009, 5:37-40;

The output of the second bandpass filter 120 is input to the power amplifier 122 which amplifies the received input. The output of the amplifier 122 is input to a third bandpass filter 124 which is arranged to filter out any Signal components introduced by the amplifier 122 which fall outside the radio frequency band of the Signals to be transmitted.

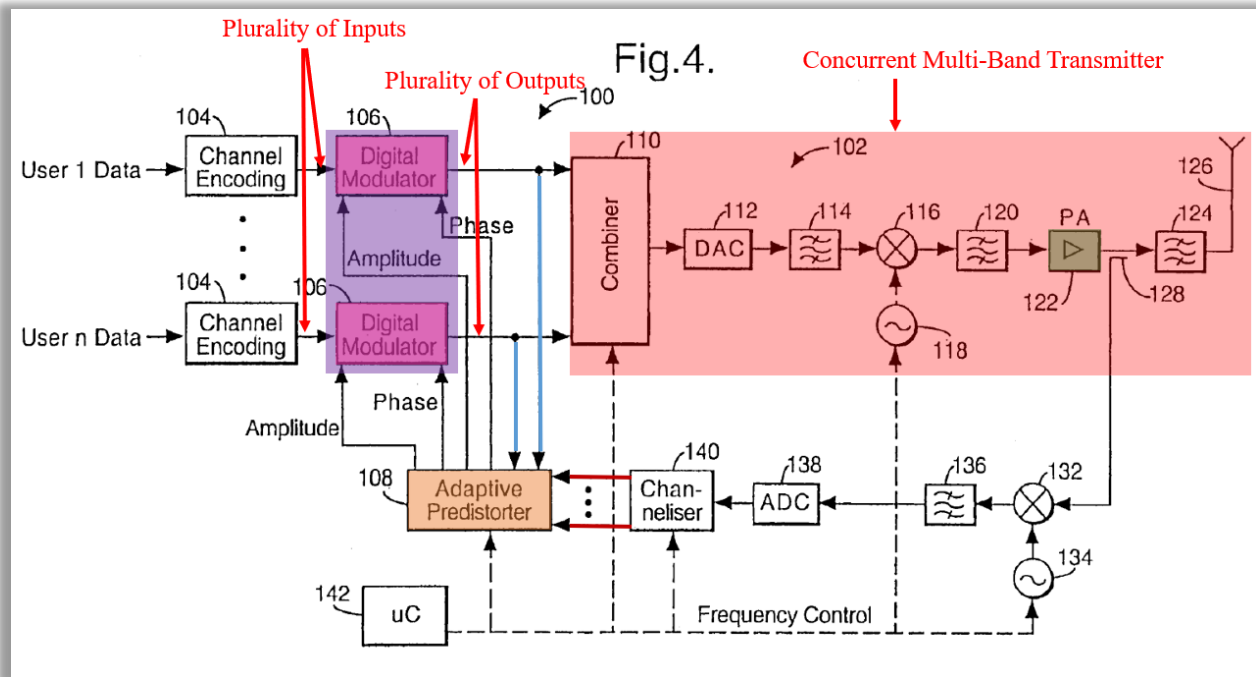
EX-1009, 5:31-46. The signal is then transmitted via antenna 126. EX-1009, 5: 46-49; *See, e.g.:*

The output of the third bandpass filter 124 is passed to an antenna 126 which transmits the signals to the terminals in the cell associated with the base Station.

EX-1009, 5:46-49. Accordingly, and as shown in Fig. 4, below, each output of Posti's predistortion distortion block is connected to an input of Posti's concurrent multi-band transmitter through the aforementioned components.

159. This limitation also requires "each output connected to an input of a concurrent multi-band transmitter." The specification explains that " $X_{pd1}(n)$ and $X_{pd2}(n)$ are the predistorted signals to the input of the dual-band transmitter" (EX-1001, 4:19-21), thus Claim 3 identifies the components following predistortion as the "concurrent multi-band transmitter." As shown in the figure below, each output from

Posti's digital modulators is *connected to an input of a concurrent multi-band transmitter* at combiner 110.



EX-1009, Fig. 4 (Annotated).

160. Further, a POSA would have also understood the above processing chain (*i.e.*, signal combiner 110, first band pass filter 114, mixer 116, second band pass filter 120, power amplifier 122, and third band pass filter 124) to constitute a *concurrent multi-band transmitter* because “N” different frequencies are being transmitted by antenna 126. And as previously discussed, a POSA understood that Posti’s teaching are equally applicable to a transmitter configured to predistort and transmit across multiple channels in multiple bands.

Claim 4

[4pre] *The linearized transmitter of claim 2, wherein said analyzing and modeling stage further comprises:*

[4a] *a plurality of outputs connected to update the parameters of said digital baseband signal predistorters; and*

161. As explained above, Posti uses adaptive algorithm block 204 within adaptive predistorter 108 (*analyzing and modeling stage* (orange)) to calculate, and store, new amplitude and phase coefficients, and ultimately provide those updated predistortion coefficients to each respective digital modulator. *See, e.g.:*

The first output from the predistorter 108 provides one or more amplitude coefficients which are used to predistort the signal which is output by the digital modulator to compensate for the non linearity of an amplifier 122 with respect to amplitude. The second output from the predistorter 108 provides one or more phase coefficients which are used to predistort the Signal which is output by the modulator 106 to compensate for phase distortion provided by the amplifier 122. The amplifier 122 will be described in more detail hereinafter.

EX-1009, 4:51-60;

Thus, the predistorter 108 compares for each frequency the signal which was transmitted with the signal output by the respective digital modulator 106. For each frequency it is determined if the current predistortion coefficients are acceptable and if not calculates new coefficients to be used for that channel. Predistortion is thus performed individually for each frequency prior to signal combining. The predistortion coefficients for each frequency are determined based on feedback from the corresponding frequency as transmitted. The predistortion coefficients are arranged to compensate for non-linearity with respect to amplitude and also phase distortion. The phase and amplitude of the Signals of the digital modulators 106 are altered in accordance with these coefficients. How these coefficients are used will

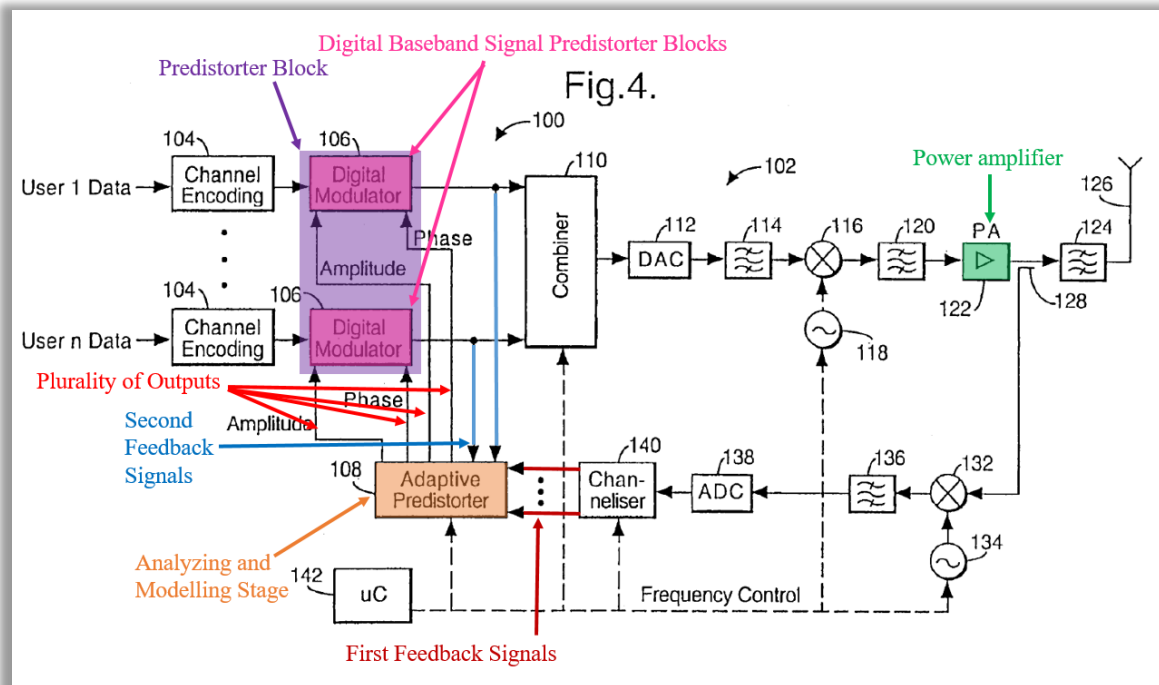
depend on the modulation method. In the simplest cases, the coefficients could be added to the signal or used as multipliers.

EX-1009,6:40-56;

The output of each subtracter 202 thus constitutes a difference Signal which is input to an adaption algorithm block 204 which on the basis of the input received from the subtractors 202 calculates, if necessary, new amplitude and phase predistortion coefficients. These amplitude and phase coefficients are output to a look-up table 200 where they are stored. The values from the look-up table 200 are supplied, as shown in FIG. 4, to the respective digital modulators 106.

EX-1009, 7:20-28.

162. “Each digital modulator 106 [] receives two outputs from the adaptive predistorter 108” (pink) via direct path for the amplitude and phase coefficients. EX-1009, 4:49-51. Thus, Posti’s analyzing and modeling stage has *a plurality of outputs connected to update the parameters of a digital baseband signal predistorter*, as claimed.



EX-1009, Fig. 4 (Annotated).

[4b] a plurality of inputs connected to both: (a) outputs of said signal observation feedback loop comprising said first feedback signals, and (b) to outputs of said digital signal predistorter block.

163. Posti's adaptive predistorter 108 (*analyzing and modelling stage*) receives signals output from the channeliser 140 (*first feedback signals*), and therefore has a plurality of inputs connected to the outputs of the signal observation feedback loop. The adaptive predistorter 108 also receives signals output from the digital modulators 106 (*second feedback signals*), and therefore has a plurality of inputs connected to the outputs of the claimed digital signal predistorter block. EX-1009, 5:11-12, 6:13-28; *See, e.g.:*

The output of each of the digital modulators 106 are input to a signal combiner 11 and to the adaptive predistorter 108.

EX-1009, 5:11-12;

The digital signals are output by the analogue to digital converter 138 to a channelizer 140. The channelizer 140 divides the signals into the N different frequencies corresponding to the frequencies on which those signals were transmitted. The channelizer 140 is able to distinguish the N signals as they are all at different frequencies. The channel izer 140 provides N outputs, one for each of the frequencies. Each of the N outputs provided by the channelizer 140 are input to the adaptive predistorter 108. The channelizer 140 can be provided in any suitable way including a bank of digital downconverters and fast fourier transform circuitry.

The adaptive predistorter 108 thus receives for each channel a version of the signal before it passes through the combiner 110 and subsequent elements of transmit part 102 of the base station 100 (from the respective digital modulator) and a version of the signal after it has passed through the transmit part 102 (from the channelizer 140).

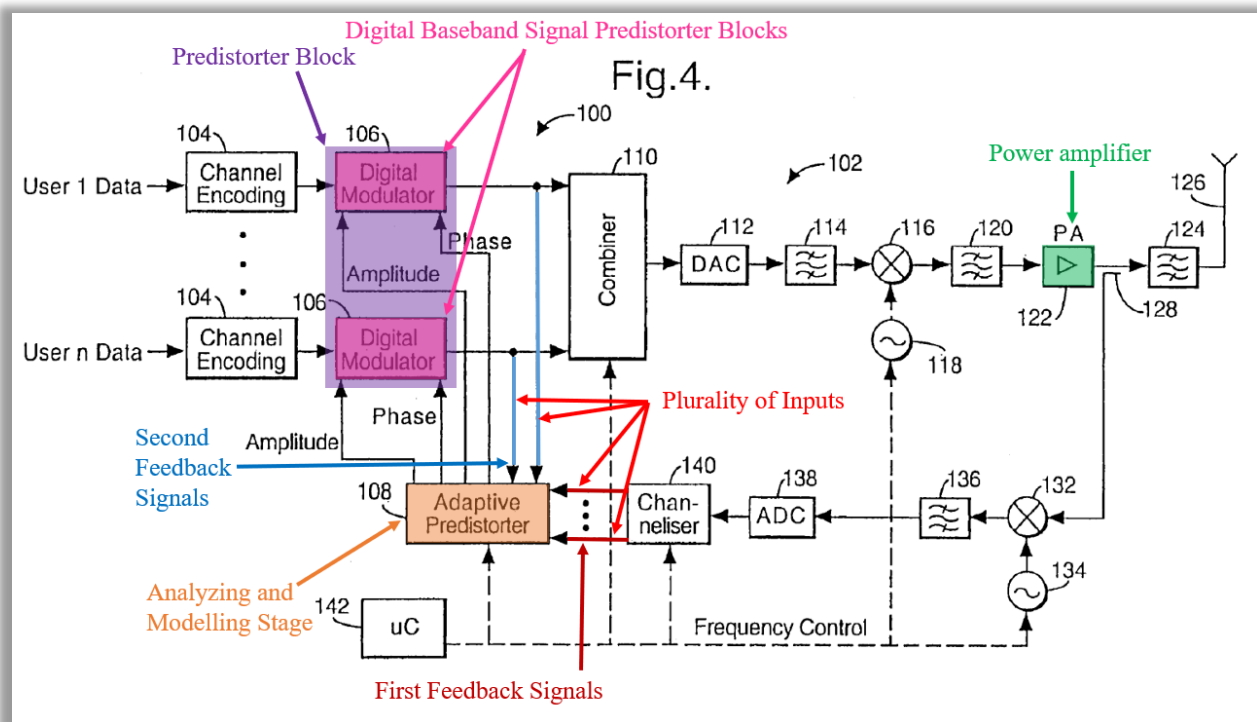
EX-1009, 6:13-28.

164. More specifically, Posti explains that “each of the individual channels are input to the adaptive predistorter on the input side and the individual channels are received from a channeliser on the output side,” such that Posti’s pre-distortion coefficient are “calculated by the adaptive predistorter [] based on all of the carriers, [which] allows [for] optimal performance to be obtained since all the information is available.” EX-1009, 6:63-7:3; *See, e.g.:*

The embodiment of FIG. 4 has the advantage that each of the individual channels are input to the adaptive predistorter on the input side and the individual channels are received from a channeliser on the output Side. Therefore, the predistortion coefficients that are calculated by the

adaptive predistorter are based on all of the carriers. This allows optimal performance to be obtained since all the information is available.

EX-1009, 6:63-7:3



EX-1009, Fig. 4 (Annotated).

Claim 5

[5pre] *The linearized transmitter of claim 2, wherein said analyzing and modeling stage is further adapted to:*

[5a] *perform time alignment of complex baseband signals from sampling said first feedback signals; and*

165. Posti's adaptive predistorter 108 (*analyzing and modeling stage*) includes "n" subtractors 202 "each of which receives a respective one of the outputs from the digital modulators 106 [and each] subtracter also receives a input from the

channeliser 140. EX-1009, 7:12-16. The subtractors create a composite signal that is supplied to adaptation algorithm 204 for calculation of amplitude and phase coefficients (EX-1009, 6:31-40), and all of this is coordinated timewise so that the adaptive predistorter 108 is comparing “like versions of the same signal.” EX-1009, 6:29-31; EX-1009, 6:29-40; *See, e.g.*:

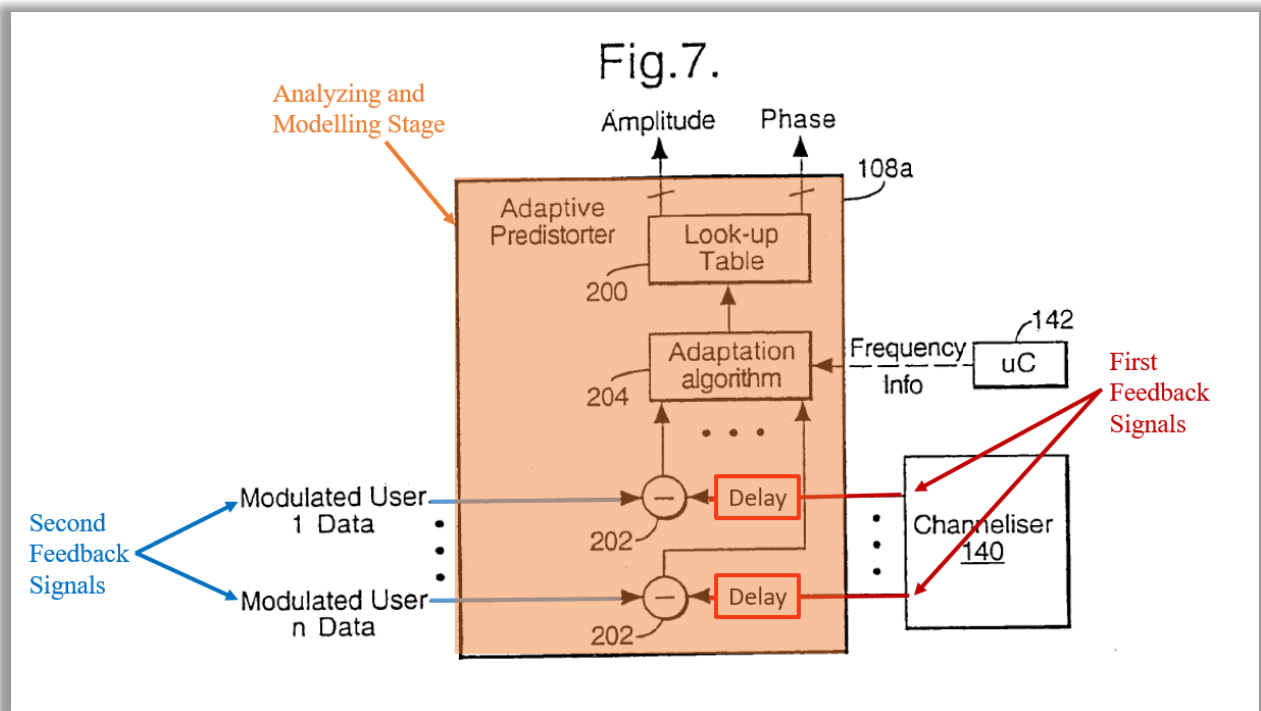
The predistorter 108 thus compares like versions of the same signal eg, both signals will be modulated at the same frequencies. The adaptive predistorter 108 is arranged to compare these signals. If the coefficients which the predistorter 108 outputs to the given digital modulator are good then the signal which is transmitted should be the same as the respective signal which is input to the combiner 110. Ideally the only differences should be in scale of the signals. If the signals differ, the predistorter 108 arranged to calculate new predistortion coefficients which take into account the results of the comparison.

EX-1009, 6:29-40.

166. Posti’s comparison of “like versions of the same signal” (EX-109, 6:29-31) means that Posti’s adaptive predistorter performs *time alignment of the signals*, as claimed. To implement this, Posti explains that the channelizer is “provided in any suitable way” (EX-1009, 6:21-22), and a POSA understood that one well-understood and routine way to implement time alignment is to insert a delay block after the channeliser 140 to time align the signals.

167. To the extent Patent Owner asserts that Posti does not expressly state that Posti’s analyzing and modeling stage is configured to perform time alignment, a POSA would have understood and been motivated in view of Posti’s instruction to

compare “like versions of the same signal” (EX-1009, 6:29-31) to implement the teachings of Posti with a delay block after channeliser 140 to ensure that the composite signal supplied to adaptation algorithm 204 is, in fact, time aligned. I address Posti’s use of complex baseband signals in element 5[b], below.



EX-1009, Figure 7 (Annotated and Modified to show Delay Blocks).

[5b] perform reconstruction of the complex baseband signals from said sampling.

168. Because the output of Posti’s PA 122 is an analog signal at an RF frequency, a POSA would have understood that this signal would be digitized and down converted to an intermediate frequency or baseband before use in modeling.

To do this, Posti discloses a feedback path from coupler 128 including mixer 132, band pass filter 136, ADC 138, and channeliser 140. EX-1009, 5:57-6:17; *See, e.g.:*

The output of the coupler 128 is input to a second mixer 132 which receives a signal from a second local oscillator 134. The signals which are received from the coupler 128 are in the radio frequency band. The signal from the second local oscillator 134 is at a frequency such that when the signals from the coupler 128 are mixed with signal from the local oscillator 134, the output of the second mixer 132 consists of the signals which were transmitted but at the intermediate frequencies. The intermediate frequencies output by the second mixer 132 may but not necessarily be the same as the intermediate frequencies input to the first mixer. Accordingly, the frequency of the signals provided by the first and second oscillators 118 and 134 may be the same. In that case, a single oscillator may be provided.

The output of the second mixer 132 is input to a fourth bandpass filter 136 which filters out any signal components introduced by the second mixer 132 which are outside the intermediate frequency band. The output of the fourth band pass filter 136 is input to an analogue to digital converter 138 which is arranged to convert the analogue signals to digital form.

The digital signals are output by the analogue to digital converter 138 to a channelizer 140. The channelizer 140 divides the signals into the N different frequencies corresponding to the frequencies on which those signals were transmitted. The channelizer 140 is able to distinguish the N signals as they are all at different frequencies.

EX-1009, 5:57-6:17. The resulting signals output from the channeliser 140 correspond to the frequencies of transmission and have both I and Q components.

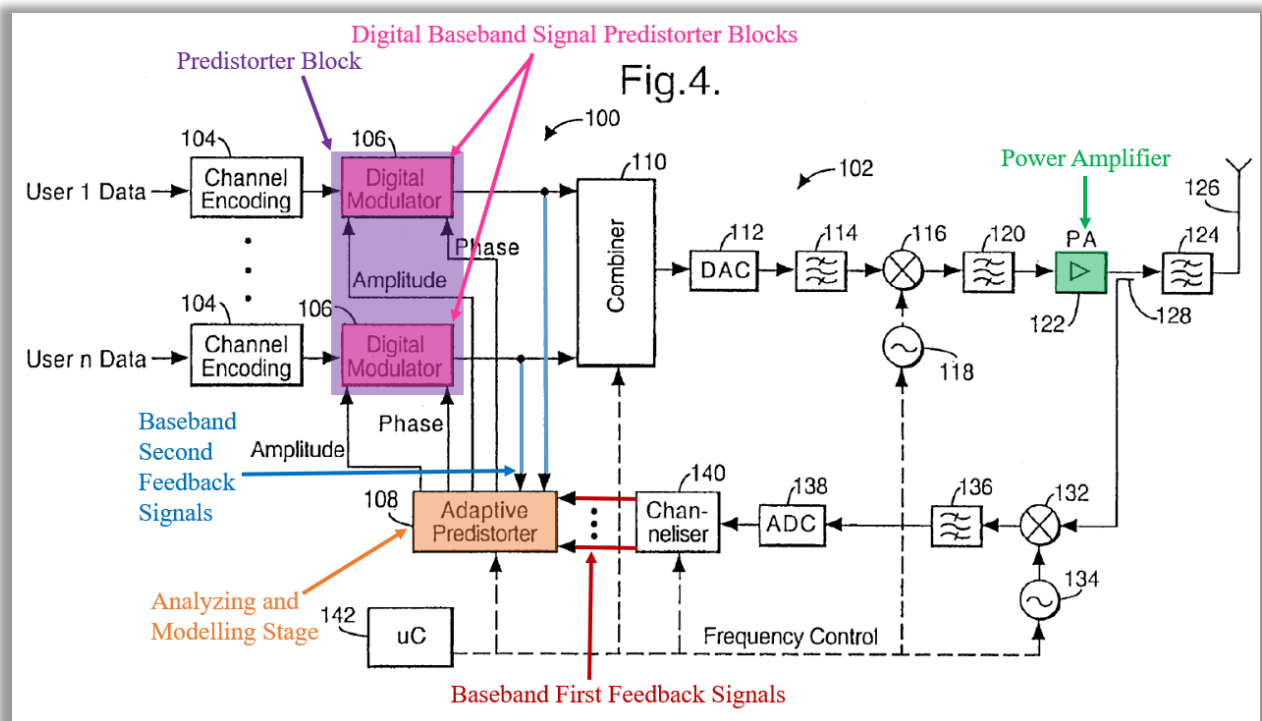
EX-1009, 6:12-20 (channelizer 140 “provides N outputs, one for each of the frequencies [on which the signals were transmitted].”), 8:34-36 (channelizer 140

provides I and Q components “for each frequency”). By having both I and Q component, the channelizer’s output is a “complex” sampled signal.

169. And while Posti provides an example where the represented first feedback signals are at an intermediate frequency, Posti’s teachings are not limited to this. Rather, Posti explains that its “channelizer 140 can be provided *in any suitable way* including a bank of digital downconverters and *fast fourier transform circuitry* [“FFT”].” EX-1009, 6:20-22 (emphasis added). As was well known as early as 1996, A POSA understood (Fast Fourier Transform) FFT circuitry in channelizing to be used for down-conversion of intermediate frequency signals to baseband signals. The FFT techniques in channelizing takes a composite signal (itself a baseband signal comprising parallel frequency channels at discrete frequency offsets) and separates the signal into parallel baseband signals. Conversely, a POSA understood that the inverse fast Fourier transform (IFFT) would be used for taking parallel baseband signals and combining them into a composite signal with discrete frequency offsets in a combiner. EX-1029, Fig. 7.1, 290. Thus, Posti discloses reconstruction of the first feedback signals to *complex baseband signals*.

170. Further, for Posti’s adaptive predistorter 108 to compare like versions of (1) the predistorted signal to (2) the PA’s output, a POSA would have understood that the predistorted signals from digital modulators 106 would also need to be provided to the adaptive predistorter 108 at baseband (so a predistorted baseband

signal is being compared to a baseband signal from the post-PA feedback path). This too is addressed by Posti. Namely, Posti explains that frequency upconversion (from baseband) is not limited to digital modulators 106, but that the combiner 110 may instead perform upconversion using an inverse fast Fourier transform (“IFFT”). EX-1009, 7:4-6 (“The combiner 110 requires information on the frequency if an inverse fast fourier transform combining technique is required.”). In this scenario where upconversion from baseband is done in combiner 110, the predistorted signal output from the digital modulators 106 is output at baseband and provided to both the adaptive predistorter 108 and combiner 110.



EX-1009, Fig. 4 (Annotated).

171. Further confirming this operation, Posti explains that “[t]he algorithm performed by the adaptive predistorter 108 may also, as discussed hereinbefore utilize frequency information when calculating the predistortion coefficients.” EX-1009, 7:4-9. A POSA understood that when working with complex baseband signals, such frequency information is needed to associate the respective first and second (complex baseband) feedback signals to each other in determining the predistortion coefficients on a per-channel basis. Posti additionally discusses the microprocessor as controlling these components (“A microcontroller **142** is provided which provides control signals to the predistorter **108**, the combiner **110**, the channelizer **140** and the first and second local oscillators **118** and **134**.” EX-1009, 6:60-62).

172. Accordingly, for at least the reasons set forth above, a POSA would have understood Posti’s disclosure to include reconstructing the first feedback signals using *complex baseband signals*.

Claim 6

[6pre] *The linearized transmitter of claim 2,*

[6a] *said first feedback signals corresponding to a baseband equivalent for all frequency channels and wherein the baseband equivalent signals being extracted from down-converted samples of RF signals output from said power amplifier block.*

173. Posti’s feedback signals are taken from the output of the PA by coupler 128 before being processed by mixer 132, band pass filter 136, ADC 138, and channeliser 140. EX-1009, 5:57-6:17; *See, e.g.:*

The output of the coupler 128 is input to a second mixer 132 which receives a signal from a second local oscillator 134. The signals which are received from the coupler 128 are in the radio frequency band. The signal from the second local oscillator 134 is at a frequency such that when the signals from the coupler 128 are mixed with signal from the local oscillator 134, the output of the second mixer 132 consists of the signals which were transmitted but at the intermediate frequencies. The intermediate frequencies output by the second mixer 132 may but not necessarily be the same as the intermediate frequencies input to the first mixer. Accordingly, the frequency of the signals provided by the first and second oscillators 118 and 134 may be the same. In that case, a single oscillator may be provided.

The output of the second mixer 132 is input to a fourth bandpass filter 136 which filters out any signal components introduced by the second mixer 132 which are outside the intermediate frequency band. The output of the fourth band pass filter 136 is input to an analogue to digital converter 138 which is arranged to convert the analogue signals to digital form.

The digital signals are output by the analogue to digital converter 138 to a channelizer 140. The channelizer 140 divides the signals into the N different frequencies corresponding to the frequencies on which those signals were transmitted. The channelizer 140 is able to distinguish the N signals as they are all at different frequencies.

EX-1009, 5:57-6:17.

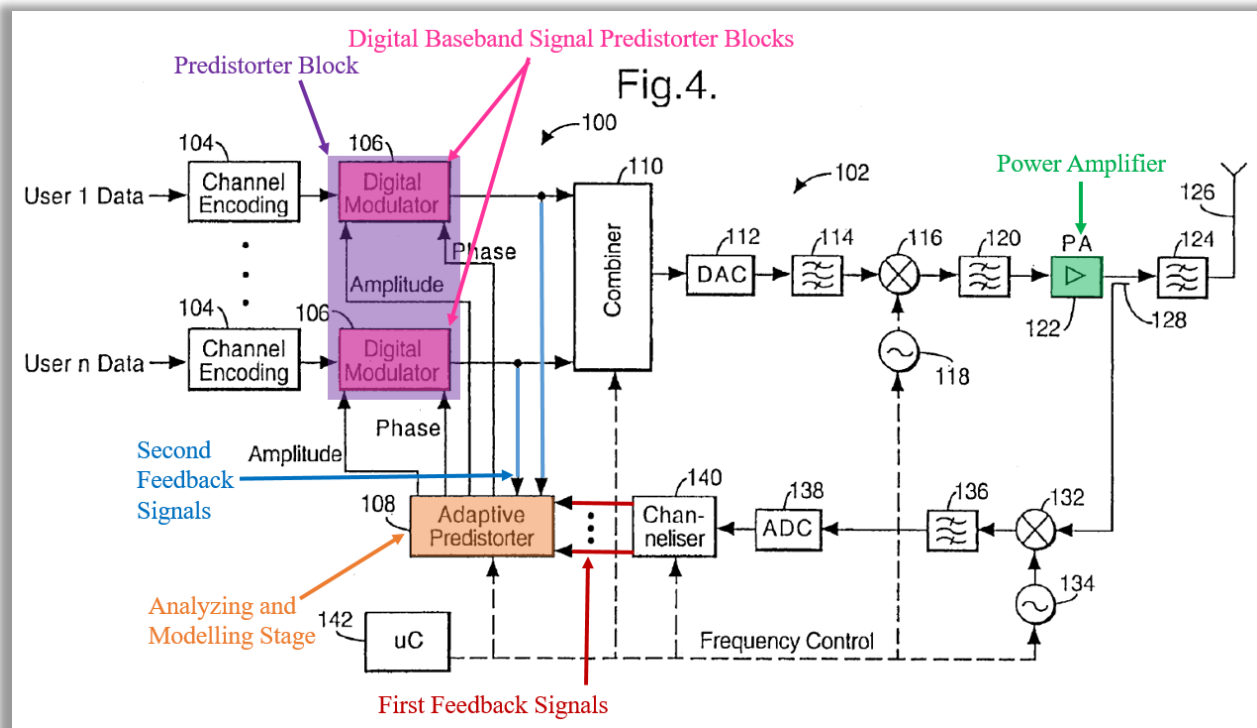
174. The mixer 132 down-converts to an intermediate frequency and ADC 138 digitizes the signal. The channeliser 140, which is provided as “a bank of digital downconverters,” “provides N outputs, *one for each of the frequencies*” (EX-1009, 6:16-22 (emphasis added)), and therefore discloses *for all frequency channels down-converting samples of RF signals output from said power amplifier block. See* limitation 5[b]; EX-1009, 4:66-5:5, 6:20-22; *See, e.g.:*

In general terms the modulators 106 take the baseband input from the respective channel encoder 104, pass that input through a shaping filter and mix the signal with a carrier signal at an intermediate frequency which is higher than the baseband frequency but less than the frequency at which the signals are transmitted to thereby provide a modulated output.

EX-1009, 4:66-5:5;

The channelizer 140 can be provided in any suitable way including a bank of digital downconverters and fast fourier transform circuitry.

EX-1009, 6:20-22.



EX-1009, Fig. 4 (Annotated).

175. As explained in limitation 5[b], Posti discloses complex baseband feedback signals, and therefore likewise discloses claim 6's "baseband equivalent signals." Thus, Posti's first feedback signals correspond to baseband equivalent

signals extracted from down-converted samples of RF signals output from said power amplifier block for all frequency channels.

Claim 7

[7pre] *The linearized transmitter of claim 2, wherein said signal observation feedback loop further comprises a plurality of channels, each channel comprising:*

[7a] *an RF filter; [7.2] a signal down conversion block; and [7.3] an analog-to-digital converter (ADC).*

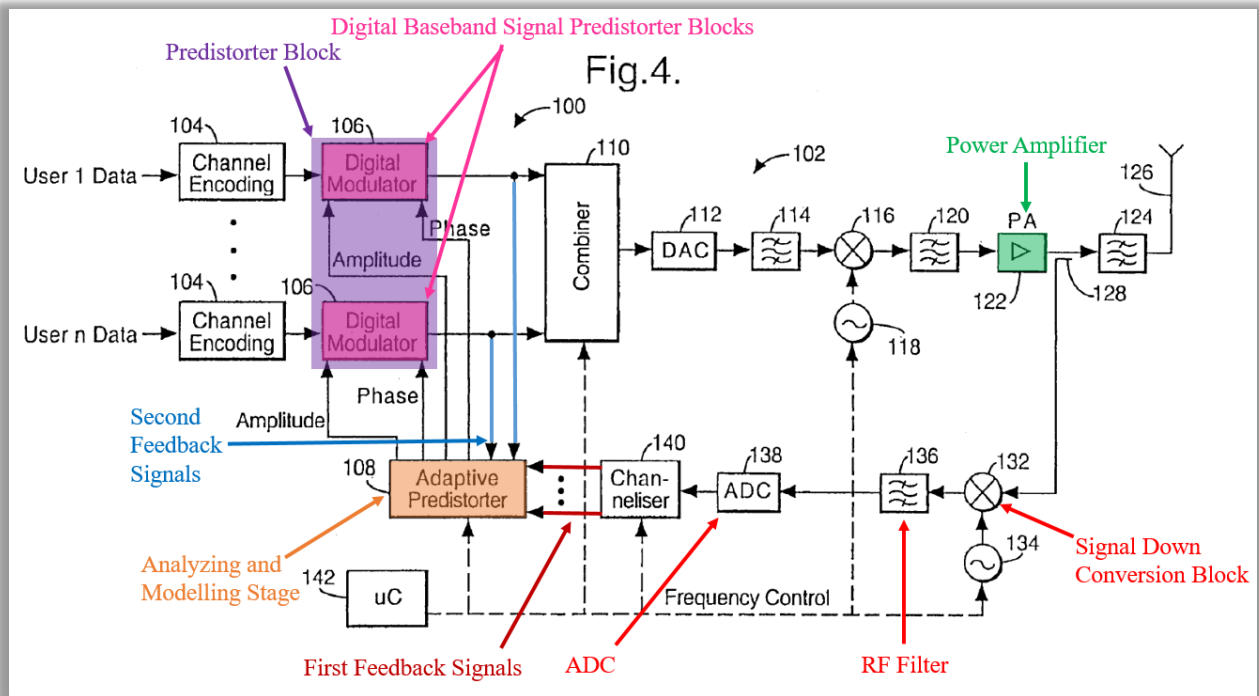
176. Posti's adaptive predistorter 108 receives signals output from the channelizer 140 (EX-1009, 5:11-12, 6:19-20) and "[t]he channelizer 140 provides N outputs, one for each of the frequencies" (*id.*, 6:16-18). As each channel is on a different frequency (*id.*, 4:43-45), Posti's signal observation feedback loop therefore also comprises a plurality of channels.

177. Specifically, Posti's first feedback signals forming the signal observation and feedback loop are taken from the output of power amplifier 122 using coupler 128. EX-1009, 5:50-54; *See, e.g.*:

Between the amplifier 122 and the third bandpass filter 124, there is arranged a coupler 128 which is arranged to sample a small part of the signals which are transmitted. In other words, the coupler 128 allows a small proportion of the signals to be transmitted to be sampled.

EX-1009, 5:50-54. The signals pass from coupler 128 to mixer 132 (*i.e., signal down conversion block*) (EX-1009, 5:50-60), the mixer 132 passes the signals to a band pass filter 136 (*i.e., an RF filter*) (*id.*, 6:5-8), and then the output of band pass filter

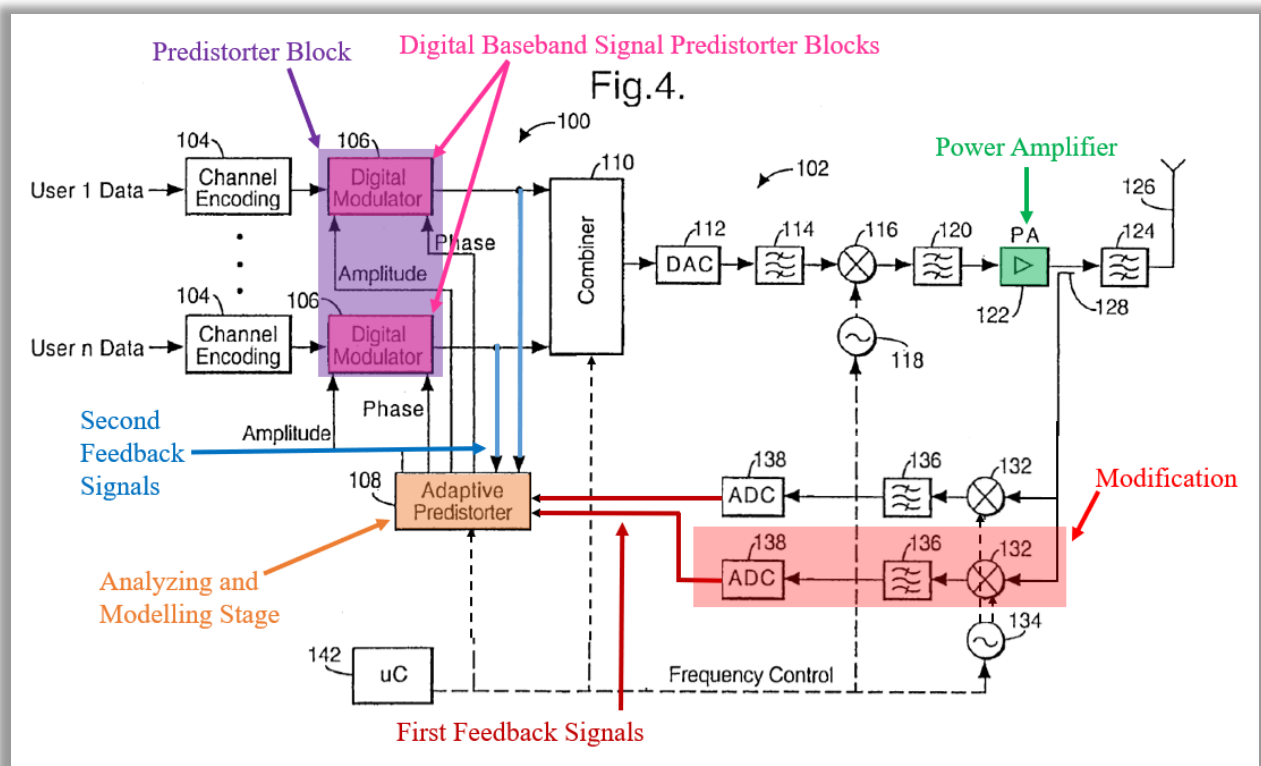
136 is provided to ADC 138 (i.e., *analog to digital converter*) (*id.*, 6:8-11). Accordingly, the components recited in limitation [7a] are expressly included in Posti's feedback loop.



EX-1009, Fig. 4 (Annotated).

178. To the extent Patent Owner argues that Claim 7 requires multiple parallel feedback paths for each plurality of channels, this would have been well within the understanding of a POSA and a trivial implementation detail. A POSA understood that to do so, all that would be required is to replace Posti's channelizer with parallel versions of the already disclosed feedback path including mixer 132 (*i.e.*, *signal down conversion block*) (EX-1009, 5:58-60), band pass filter 136 (*i.e.*, *an RF filter*) (*id.*, 6:5-8), and ADC 138 (*i.e.*, *analog to digital converter*) (*id.*, 6:8-11). This

implementation would provide a feedback path for each channel, and the mixer 132 would advantageously be used to convert each channel directly down to baseband in its respective signal path. A POSA would have been motivated to apply this implementation detail and option to reduce the number of down-conversion stages and to obviate the need for channelizer 140.



EX-1009, Fig. 4 (Modified).

Claim 10

[10pre] *A method for linearizing a transmitter, said method comprising:*

179. See limitation [1pre].

[10a] *effecting predistortion of concurrent input signals to output concurrent predistorted signals using a digital signal predistorter block including digital baseband signal predistorters;*

180. See limitation [1a]

[10b] *amplifying the predistorted signals using a power amplifier block;*

181. See limitation [1b].

[10c] *receiving in an analyzing and modelling stage first feedback signals taken from an output of the power amplifier, and second feedback signals taken concurrently from the concurrent predistorted signals; and using the first feedback and the second feedback signals in the analyzing and modeling stage to model a nonlinearity in the power amplifier, wherein the digital baseband signal predistorters are updated by the analyzing and modelling stage.*

182. See limitation [1c].

**D. Ground 4: Claims 8 and 9 are Obvious over Posti in View of
Cidronali**

**1. Obviousness and Motivation to Combine the Teachings of
Posti with the Teachings of Cidronali**

183. Posti discloses the claimed linearized transmitter, including an analyzing and modeling stage and signal observation feedback loop as recited in Claims 1 and 2. It was also known that the sampling rate of Posti's feedback loop would either be configured according to the Nyquist rate, or subsampled at a rate lower than Nyquist. Indeed, Patent Owner admitted during prosecution of the parent patent to the '296 patent that it "is well known in the art of signal communication that subsampling is the process of sampling at a frequency less than the Nyquist rate."

EX-1015, 6.; See, e.g.:

The present claims relate in general to subsampling in a feedback loop of modulated cocurrent multi-band signals. Applicant submits that it is well known in the art of signal communication that subsampling is the process of sampling at a frequency less than the Nyquist Rate.

EX-1015, 6. Cidronali discloses a single subsampling receiver for use with the very same type of predistorter as disclosed in Posti, and a POSA would have been motivated to modify the teachings of Peroulas with Cidronali's subsampling teachings.

184. *First*, a POSA would have been motivated to modify the teachings of Posti to subsample for the benefit of reducing the complexity and cost of predistorter implementation. Posti itself recognizes the desirability of reducing transmitter costs (EX-1009, 1:60-61), and the proposed combination achieves cost reduction by minimizing the need for expensive components. *See* §VII.A.4; EX-1019, 3:65-67; EX-1001, 2:7-13; *See, e.g.*:

It is therefore an object of this invention to provide a radio frequency (RF) receiver that provides high performance at a reduced manufacturing cost and power dissipation.

EX-1019, 3:65-67;

The subsampling receiver architecture is designed to concurrently down-convert the multiple RF signals through single receiver chain. Using subsampling technique simplifies the feedback loop topology, requires fewer number of RF components, and reduces the power consumption.

EX-1001, 2:7-13.

185. *Second*, for multiband signals, uniform sampling according to the Nyquist rate can be an inefficient method requiring more components to capture the signal, which increases the complexity of the system. EX-1016, 189; §VII.A.4. Subsampling addresses this. In fact, Cidronali explains that bandpass/subsampling and its exemplary subsampling receiver “can be adapted to down-convert two (or more) band-limited signals,” making it an ideal choice for multiband implementations. EX-1006, 000002. Thus, a POSA would have been motivated to minimize and simplify Posti’s feedback path in a manner that is more efficient with the inclusion of subsampling, “allow[ing] [for] extreme flexibility and coherent dual-band down-conversion.” EX-1006, 000001. Similarly, Posti itself suggests that the disclosed invention would be obvious to implement with different frequency conversion architectures (EX-1009, 9:30-33), and that only a “small part” of Posti’s amplified signal needs to be captured as feedback (EX-1009, 5:50-57). All of this would have suggested the use of subsampling to a POSA. *See, e.g.:*

However in alternate embodiments of the present invention, there may be a further stage where the frequencies of the signals at a first set of intermediate frequencies may be upconverted to a second Set of intermediate frequencies which are greater than the first set of intermediate frequencies but less than the radio frequency.

EX-1009, 9:30-35;

Between the amplifier 122 and the third bandpass filter 124, there is arranged a coupler 128 which is arranged to sample a small part of the signals which are transmitted. In other words, the coupler 128 allows a

small proportion of the signals to be transmitted to be sampled. The coupler 128 outputs an analogue sample of the output signal which is typically below the power of the input to the third bandpass filter 124.

EX-1009, 5:50-57.

186. *Third*, a POSA would have understood that by subsampling, Posti's post-PA feedback architecture would allow for direct down conversion from the carrier frequency to an intermediate frequency, resulting in cost savings by reducing the number of components and increasing PA performance. These advantages would have provided a POSA with further motivation to use subsampling. EX-1006, 000002; *See, e.g.*;

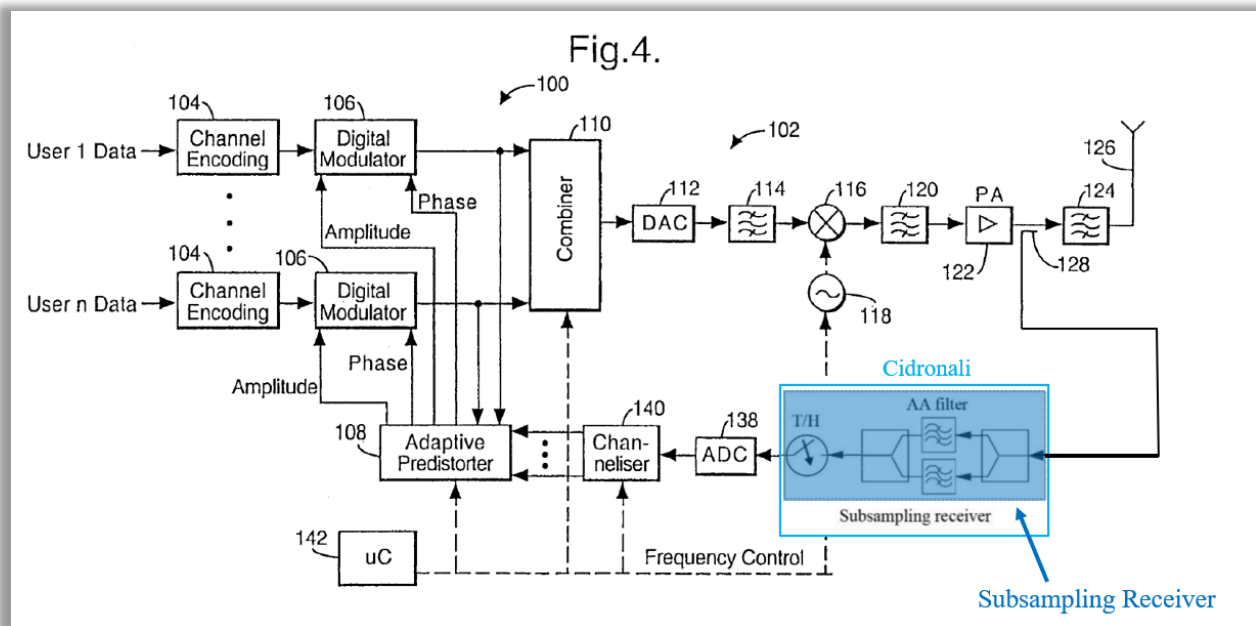
The subsampling adopted in the DB-DPD feedback recalls somehow the receivers adopted in the multiband radios and is based on the bandpass sampling theorem. This principle can be adapted to down-convert two (or more) band-limited signals s_1 and s_2 , located at different centre frequencies.

EX-1006, 000002;

187. *Fourth*, by subsampling and down-converting in the digital domain, such as done in Cidronali, Posti's system would more easily accommodate a wide range of frequency bands. This additional architectural flexible would have provided further motivations to subsample as part of Posti's feedback loop.

188. Modifying the teachings of Posti to include subsampling and, in particular, a single subsampling-based receiver, was not only obvious, but it would also have been achieved with a reasonable expectation of success. Posti's

predistortion technique would fundamentally remain unchanged, the only difference being the mechanics of how the PA's feedback signals are fed into Posti's adaptive predistorter. Specifically, a POSA would have simply implemented Posti's feedback path with Cidronali's subsampling receiver in the place of RF filter 136 and mixer 132. Further, Posti's channelizer 140 and ADC 136 would not need any modification to support Cidronali's subsampling components. This modification would have been simple for a POSA to achieve as it requires only using prior art components according to their established functions.



EX-1009, Fig. 4 (Annotated and Modified in View of EX-1006, Fig. 4).

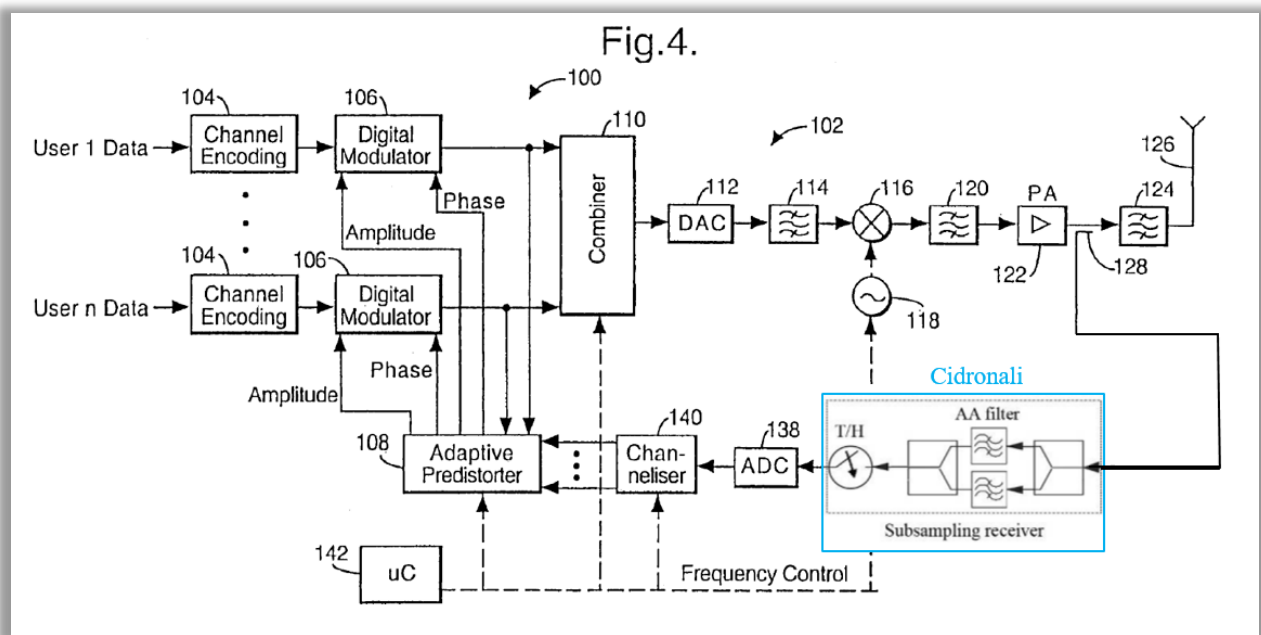
2. Detailed Application to the Challenged Claims

Claim 8

[8.0] *The linearized transmitter of claim 2, wherein said signal observation feedback loop further comprises:*

[8a] *a single subsampling-based receiver to down-convert samples output from said power amplifier block.*

189. Cidronali's single subsampling receiver "allows [for] extreme flexibility and coherent dual-band down-conversion" (EX-1006, 000001), thus cost-effectively down-converting RF samples from a PA. As combined with Posti, therefore, the claimed *single subsampling-based receiver to down-convert samples output from a concurrent multi-band transmitter* is rendered obvious.



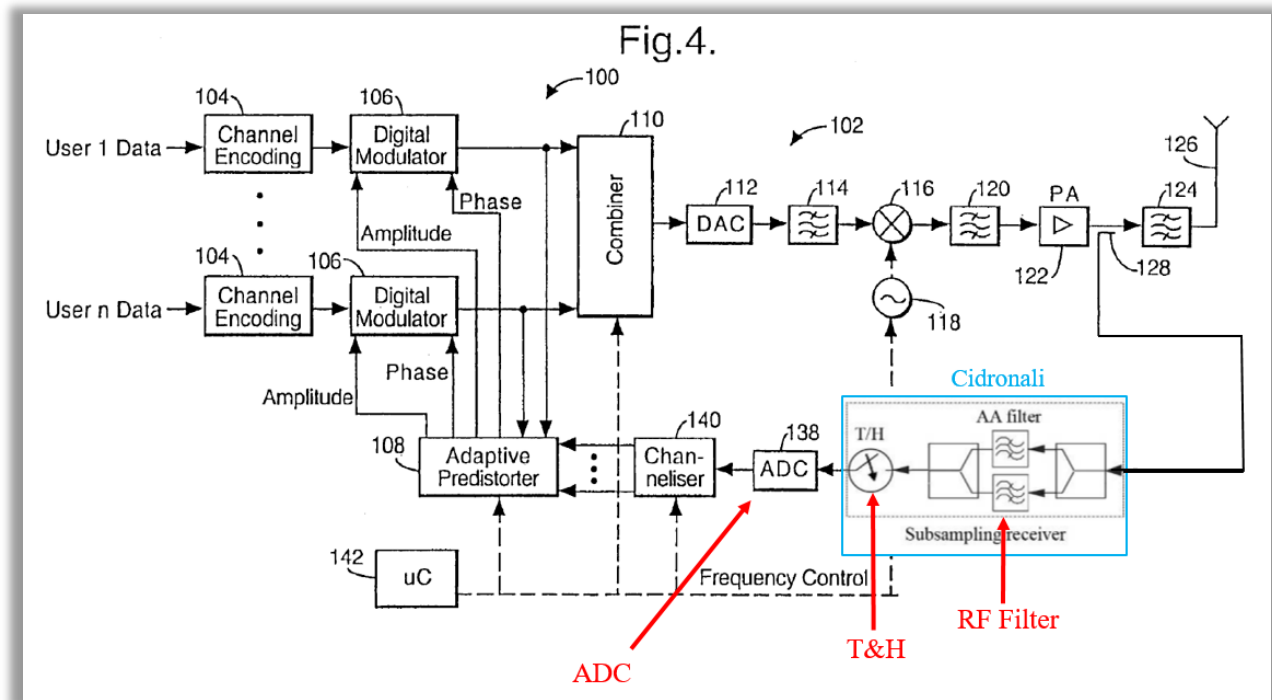
EX-1009, Fig. 4 (Annotated and Modified in View of EX-1006, Fig. 4).

Claim 9

[9pre] The linearized transmitter of claim 8, wherein said single subsampling-based receiver further comprises:

[9a] an RF filter; a track and hold (T&H) block; and an analog-to-digital converter (ADC).

190. To provide “coherent dual-band down-conversion” (EX-1006, 000001), Cidronali’s single subsampling-based receiver shown in Fig. 4 uses an anti-aliasing/AA filter (*RF filter*), T/H component (*track and hold (T&H) block*), and ADC (*an analog-to-digital converter*) (*id.*, Fig. 4). These commonplace components recited in claim 9 are further illustrated in the annotated figure below, which a POSA would have immediately understood as corresponding to the claimed components.



EX-1009, Fig. 4 (Annotated and Modified in View of EX-1006, Fig. 4).

CONCLUSION AND DECLARATION

My findings and opinions set forth in this Declaration are based on my work and examination to date. I may continue my examinations in view of additional documents or other factual evidence over the course of this proceeding that may necessitate supplementing and/or refining my opinions. I reserve the right to add to, alter, or delete my opinions and my Declaration upon discovery of additional information. I reserve the right to make such changes as necessary.

In signing this Declaration, I understand that the Declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I acknowledge that I may be subject to cross-examination in this case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

I declare that all statements made herein of my knowledge are true, and that all statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001, of Title 18 of the United States Code.

[SIGNATURE ON FOLLOWING PAGE]

Date: 3/17/2025

By: 

APPENDIX A – MATERIALS RELIED UPON

Ex. No.	Brief Description
1001	U.S. Patent No. 10,958,296 (“the ’296 Patent”)
1002	File History for U.S. Patent No. 10,958,296
1003	<i>Reserved</i>
1004	<i>Curriculum Vitae</i> of James Proctor
1005	World Intellectual Property Organization International Publication No. WO 2012/129768 to James Peroulas, Filing Date of March 28, 2011 and Publication Date October 4, 2012 (“Peroulas”).
1006	Alessandro. Cidronali, “A New Approach for Concurrent Dual-Band IF Digital PreDistortion: System Design and Analysis,” 2008 Workshop on Integrated Nonlinear Microwave and Millimetre-Wave Circuits (January 2009), (“Cidronali”)
1007	Declaration of Julie Ann Munford
1008	Dennis Morgan, “A Generalized Memory Polynomial Model for Digital Predistortion of RF Power Amplifiers,” IEEE Transactions on Signal Processing, vol. 54, no. 10, (October 2006), (“Morgan”)
1009	U.S. Patent No. 6,999,523 (“Posti”)
1010	Nazim Ceylan, “Linearization of Power Amplifiers by Means of Digital Predistortion” (2005) (“Ceylan”)
1011	Excerpts from Zhurbenko <i>et al.</i> , Advanced Microwave Circuits and Systems (2010), (“Zhurbenko”)
1012	Henna Paaso, “Comparison of Direct Learning and Indirect Learning Predistortion Architectures,” 2008 IEEE International Symposium on Wireless Communication Systems (2008), (“Paaso”)
1013	Dayong Zhou, “Novel Adaptive Nonlinear Predistorters Based on the Direct Learning Algorithm,” <i>IEEE Transactions on Signal Processing</i> , vol. 55, no. 1, (Jan. 2007), (“Zhou”)
1014	Youngcheol Park, “Adaptive Predistortion Linearization of RF Power Amplifiers Using Lookup Tables Generated from Subsampled Data,” 2002 IEEE Radio and Wireless Conference (2002), (“Park”)

Ex. No.	Brief Description
1015	Excerpts from the File History for U.S. Patent No. 9,641,204
1016	Excerpts from Qizheng Gu, RF System Design of Transceivers for Wireless Communications (Springer 2005), (“Gu”)
1017	Docket Control Order, <i>Smart RF Inc. v. AT&T Mobility LLC et al.</i> , Case No. 2:24-cv-00195-JRG, Dkt. No. 41 (E.D. Tex. June 21, 2024)
1018	Federal Court Management Statistics - Profiles, June 30, 2024, available at https://www.uscourts.gov/sites/default/files/2024-11/fcms_na_distprofile0630_2024.pdf
1019	U.S. Patent No. 7,110,732 (“Mostafa”)
1020	Rim Barrak, “Optimized Multistandard RF Subsampling Receiver Architecture,” IEEE Transactions on Wireless Communications (2009), (“Barrak”)
1021	Sungho Choi, “Design of Digital Predistorters for Multi-Band Signals,” Proceedings of the Second APSIPA Annual Summit and Conference (2010), (“Choi”)
1022	Letter to Smart RF re: <i>Sotera</i> Stipulation
1023	Excerpts from IEEE Std 100-2000, The Authoritative Dictionary of IEEE Standards Terms, Seventh Edition (2000)
1024	R. Venkataramani and Y. Bresler, "Perfect reconstruction formulas and bounds on aliasing error in sub-Nyquist nonuniform sampling of multiband signals," in IEEE Transactions on Information Theory, vol. 46, no. 6, pp. 2173-2183, (Sept. 2000)
1025	R. Venkataramani, “Sub -Nyquist multicaset and MIMO sampling: Perfect reconstruction, performance analysis, and necessary density conditions,” University of Illinois at Urbana-Champaign ProQuest Dissertations & Theses (2001).
1026	Allen Katz, “Linearization: Reducing Distortion in Power Amplifiers,” IEEE Microwave Magazine (2001), (“Katz”)
1027	Lei Ding, Raviv Raich, <i>et al.</i> , “A Hammerstein Predistortion Linearization Design Based on the Indirect Learning Architecture,” 2002 IEEE International Conference on Acoustics, Speech, and Signal Processing (2002), (“Raich”)

Ex. No.	Brief Description
1028	Lei Ding, “Digital Predistortion of Power Amplifiers for Wireless Applications”, A Thesis Presented to the Academic Faculty, School of Electrical and Computer Engineering, Georgia Institute of Technology (2004), (“Ding”)
1029	Excerpts from Ronald Crochiere, Multirate Digital Signal Processing (Prentice Hall 1983), (“Crochiere”)
1030	Excerpts from Leon Couch, Digital and Analog Communication Systems (Macmillan Publishing 1987), (“Couch”)
1031	Excerpts from John Proakis, Communication Systems Engineering (Prentice Hall 2002), (“Proakis”)