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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
60/535,540	01/12/2004	Mark Webster	088245-2733

CONFIRMATION NO. 7430

POA ACCEPTANCE LETTER



OC00000045977372

23524
FOLEY & LARDNER LLP
150 EAST GILMAN STREET
P.O. BOX 1497
MADISON, WI 53701-1497

Date Mailed: 02/14/2011

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 02/07/2011.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

/hgray/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101



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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
60/535,540	01/12/2004	Mark Webster	56162.000521

CONFIRMATION NO. 7430

POWER OF ATTORNEY NOTICE



OC000000045977357

21967
HUNTON & WILLIAMS LLP
INTELLECTUAL PROPERTY DEPARTMENT
1900 K STREET, N.W.
SUITE 1200
WASHINGTON, DC 20006-1109

Date Mailed: 02/14/2011

NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 02/07/2011.

- The Power of Attorney to you in this application has been revoked by the assignee who has intervened as provided by 37 CFR 3.71. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

/hgray/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(b).

I hereby appoint:

☒ Practitioners associated with the Customer Number:

23524

OR

☐ Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

Name	Registration Number	Name	Registration Number

as attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(b).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(b) to:

☒ The address associated with Customer Number

23524

OR

☐ Firm or Individual Name

Address

City

State

Zip

Country

Telephone

Email

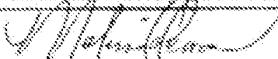
Assignee Name and Address:

XOCYST TRANSFER AG L.L.C.
2711 Centerville Road
Suite 400
Wilmington, DE 19808
USA

A copy of this form, together with a statement under 37 CFR 3.73(b) (Form PTO/SB/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(b) may be completed by one of the practitioners appointed in this form if the appointed practitioner is authorized to act on behalf of the assignee, and must identify the application in which this Power of Attorney is to be filed.

SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee.

Signature		Date	May 24, 2010
Name	Malissa Coleman	Telephone	
Title	Authorized Person for Xocyst Transfer AG L.L.C.		

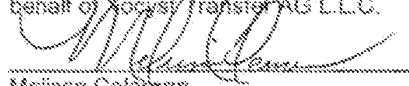
This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. The information is required to obtain or retain a benefit by the public which is in the (and by the USPTO to process) an application. Confidentiality is governed by 36 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FILLS OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2

IAAD_2200389-1

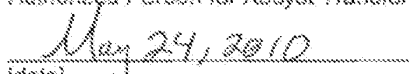
DECLARATION REGARDING AUTHORITY TO SIGN ON BEHALF OF A LEGAL ENTITY
(37 C.F.R. 3.73(b)(2)(i))

I, Melissa Coleman (whose title is supplied below), hereby declare that I am authorized to sign on behalf of Xocyst Transfer AG L.L.C.



Melissa Coleman

Authorized Person for Xocyst Transfer AG L.L.C.



[date]

Electronic Acknowledgement Receipt	
EFS ID:	9385907
Application Number:	60535540
International Application Number:	
Confirmation Number:	7430
Title of Invention:	High-data-rate multi-channel architecture
First Named Inventor/Applicant Name:	Mark Webster
Customer Number:	21967
Filer:	Paul S. Hunter/Ann Laabs
Filer Authorized By:	Paul S. Hunter
Attorney Docket Number:	56162.000521
Receipt Date:	07-FEB-2011
Filing Date:	12-JAN-2004
Time Stamp:	12:04:30
Application Type:	Provisional

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		2733_373b.pdf	489461 c2ce80d075fdbd51dab277815209ac95c0547bc6	yes	3

	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	Assignee showing of ownership per 37 CFR 3.73(b).	1	1
	Power of Attorney	2	3
Warnings:			
Information:			
Total Files Size (in bytes):			489461
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.			

STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: Shearer, Daniel D., Webster, Mark A.

Application No.: 60/535,540 Filed: 01/12/2004

Patent No.: _____ Issue Date: _____

Docket Number: 088245-2733

Entitled: HIGH-DATA-RATE MULTI-CHANNEL ARCHITECTURE

Xocyst Transfer AG L.L.C. Limited Liability Company

(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that it is:

1. ☒ the assignee of the entire right, title, and interest; or
 2. ☐ an assignee of less than the entire right, title, and interest
- The extent (by percentage) of its ownership interest is %

in the patent application/patent identified above by virtue of either:

- A. ☐ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel/Frame ASSMT_REEL_FRAME or for which a copy thereof is attached.

OR

- B. ☒ A chain of title from the inventor(s) of the patent application/patent identified above, to the current assignee as shown below:

1. From: Shearer, Daniel D. et al. To: Conexant Systems, Inc.
The document was recorded in the United States Patent and Trademark Office at
Reel 016506, Frame 0058, or for which a copy thereof is attached.

2. From: Conexant Systems, Inc. To: Xocyst Transfer AG L.L.C.
The document was recorded in the United States Patent and Trademark Office at
Reel 022043, Frame 0587, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet.

☐ Copies of assignments or other documents in the chain of title are attached.

(NOTE: A separate copy (i.e., a true copy of the original document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, if the assignment is to be recorded in the records of the USPTO. See MPEP 302.08)

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/Paul S. Hunter/

February 7, 2011

Signature

Date

Paul S. Hunter (Reg. No. 44,787)

(606) 258-4292

Printed or Typed Name

Telephone Number

Attorney

Title

This collection of information is required by 37 CFR 3.73(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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MADI_2509078.1

011204

13261 U.S. PTO

Attorney Docket Number: 56162.000521

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

MAIL STOP PROVISIONAL PATENT APPLICATION
 COMMISSIONER OF PATENTS
 P.O. Box 1450
 ALEXANDRIA, VA 22313-1450

19587 U.S. PTO
60/535540

011204

THIS IS A REQUEST FOR FILING A PROVISIONAL APPLICATION FOR PATENT UNDER 37 C.F.R. § 1.53(c).

INVENTOR(S)/APPLICANT(S)					
Given Name (first and middle (if any))		Family Name or Surname		Residence (City and Either State or Foreign Country)	
Mark Daniel		Webster Shearer		Indian Harbor Beach, Florida Scottsdale, Arizona	
Additional inventors are being named on page 2 attached hereto.					
TITLE OF THE INVENTION (280 characters max)					
HIGH-DATA-RATE MULTI-CHANNEL ARCHITECTURE					
CORRESPONDENCE ADDRESS					
Please Direct All Correspondence To:					
☒ Customer No.		21967			
☐ Firm Name		Hunton & Williams LLP			
Attorney of Record		Kevin T. Duncan			
Address		Intellectual Property Department			
		1900 K Street, N.W., Suite 1200			
City		Washington		State DC	
Country		U.S.A.		Zip Code 20006-1109	
		Telephone 202-955-1500		Facsimile 202-778-2201	
ENCLOSED APPLICATION PARTS (check all that apply)					
☒ Specification		Number of Pages 93		☐ Small Entity Status Claimed As: ☐ Independent Inventor ☐ Small Business Concern ☐ Nonprofit Organization ☐ Non-Inventor Supporting Claim By Another	
☐ Drawing(s)		Number of Sheets _____		☐ Other (specify) _____	
METHOD OF PAYMENT OF FILING FEE FOR THIS PROVISIONAL APPLICATION					
A check in the amount of ☒ \$ 160.00 ☐ \$ 80.00 is enclosed to cover the filing fee. The Commissioner is hereby authorized to charge any variance between the amount enclosed and the Patent Office charges to Deposit Account No. 50-0206					
☐ The Commissioner is hereby authorized to charge the \$ _____ filing fee or credit any overpayment to Deposit Account No. 50-0206 .					
The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.					
☒ No.					
☐ Yes, the name of the U.S. Government agency and the Government contract number are: _____					

Respectfully submitted,

 By Yisun Song

Date **January 12, 2004**
 Telephone **202-955-1500**
 Registration No. **44,487**



High-Data-Rate Multi-Channel Architecture

High-Data-Rate Expanded-Bandwidth Dual-Channel Tx-Rx: Adaptive Anti-Alias Techniques

Mark Webster
Dan Shearer



Overview

- An embodiment of the present invention is directed to creating very high WLAN data rates that may not supported by IEEE 802.11a/g. For example, the highest data rate for 802.11a/g is 54 Mbps.
- An exemplary technique may include channel concatenation, where multiple 802.11a/g channels are combined thereby expanding bandwidth and data rate.
- In general for conventional systems, a new radio must be designed that up-converts or down-converts the wide signal as a unit.
- An embodiment of the present invention decomposes the signal into separate pieces, up-converting and down-converting the pieces.
- As a result, maximal reuse of existing 802.11a/g radio designs by parallelizing the signals in frequency may be possible without implementing a new transceiver. An embodiment of the present invention provides for extensible channel concatenation, (e.g., one, two, three, ... channels concatenated) and enables concurrent transmissions to two or more devices, such as radios. Further, an embodiment of the present invention meshes cleanly (friendly) with existing networks, such as 802.11a/g networks.
- An exemplary embodiment provides a method and system for achieving very high data rate WLAN operations reusing existing single channel radio designs. A novel technique eliminates aliasing due to adjacent channel waveform.



Overview

- Legacy signals (e.g., one-channel) and wide signals (e.g., multiple-channels) may be arbitrarily interleaved in time (dynamic bandwidth switching) during packet transmission.
- For an exemplary technique of an embodiment of the present invention, no synthesizer frequency-popping exists when bandwidth switching between packets. Synthesizers may stay tuned to legacy channel centers for most or at all times. Further, synthesizer switches that can take 100 usecs to settle are avoided.
- The impact of ADC sample-rate aliasing is examined and adaptive techniques are described for mitigating this impairment.
 - ADC sample-rate aliasing may occur when a wide signal is received by multiple, parallel receive chains designed to receive a single narrow signal.
- For example, operations at 5 GHz are considered (e.g., 20 MHz legacy channel centers). In another example, operations at 2.4 GHz are considered (e.g., 25 MHz legacy channel centers)

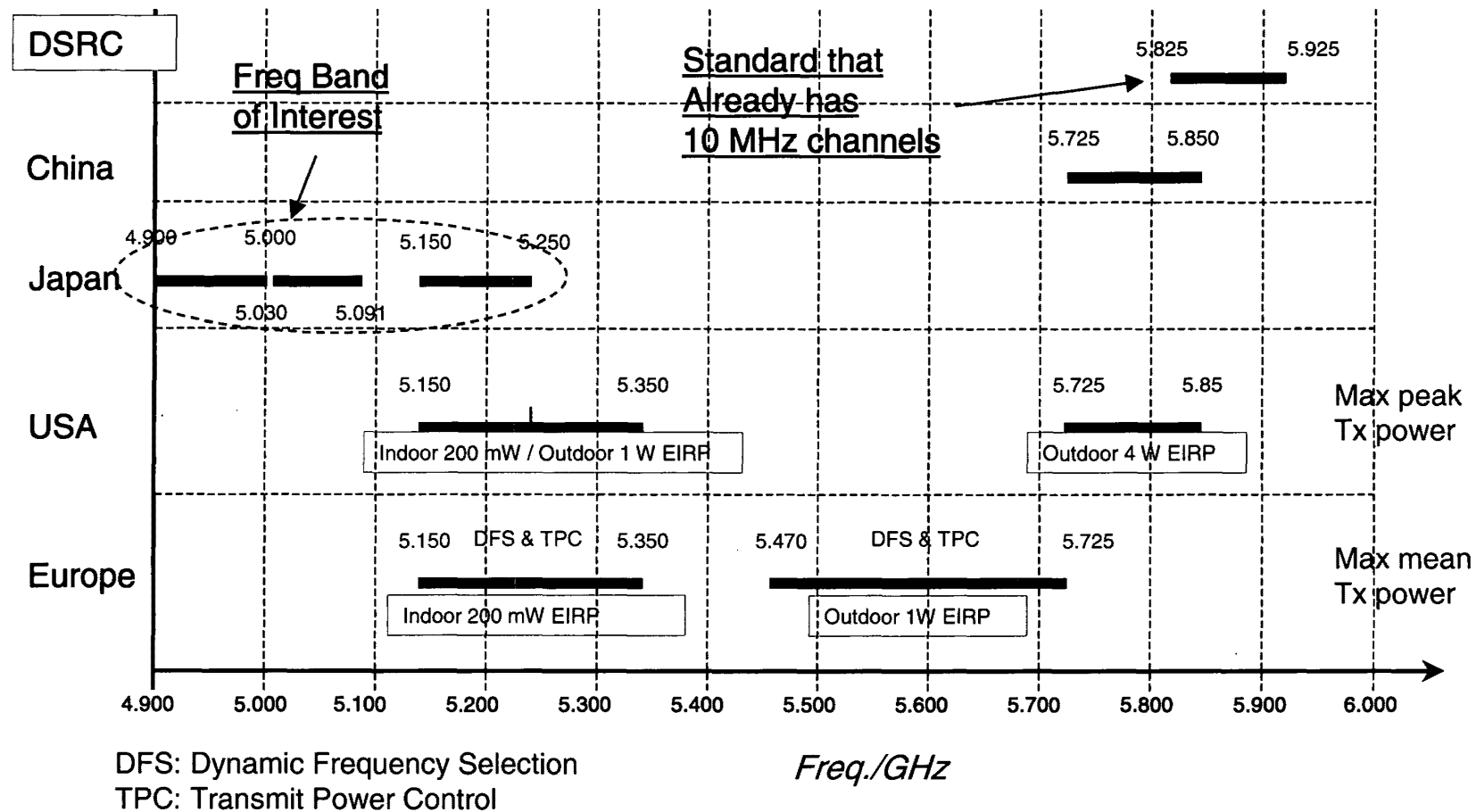


IEEE 802.11n

- The IEEE 802.11a/g WLAN standards currently already exist.
- The new IEEE 802.11n standard (or variations thereof) are being introduced.
- One goal of the 11n standard may involve increasing data rates and data throughput and also to be friendly to existing 802.11 networks.
- An embodiment of the present invention considers ways to increase the data rate using channel bonding with Orthogonal Frequency Division Multiplexing (OFDM) using two or more channels at once.
- Also, a technique for "filling the gap" between two signals with extra OFDM subcarriers is considered, which is extensible to multiple channels.
- Also, a non-11n friendly alternative mode is described which provides higher data rates, but is not friendly to 802.11 because the spectral mask would be violated.
- 20 MHz channels centered with OFDM is considered (pure 802.11a at 5.8 GHz).
- 25 MHz channels centered will be described for 802.11g at 2.4 GHz.

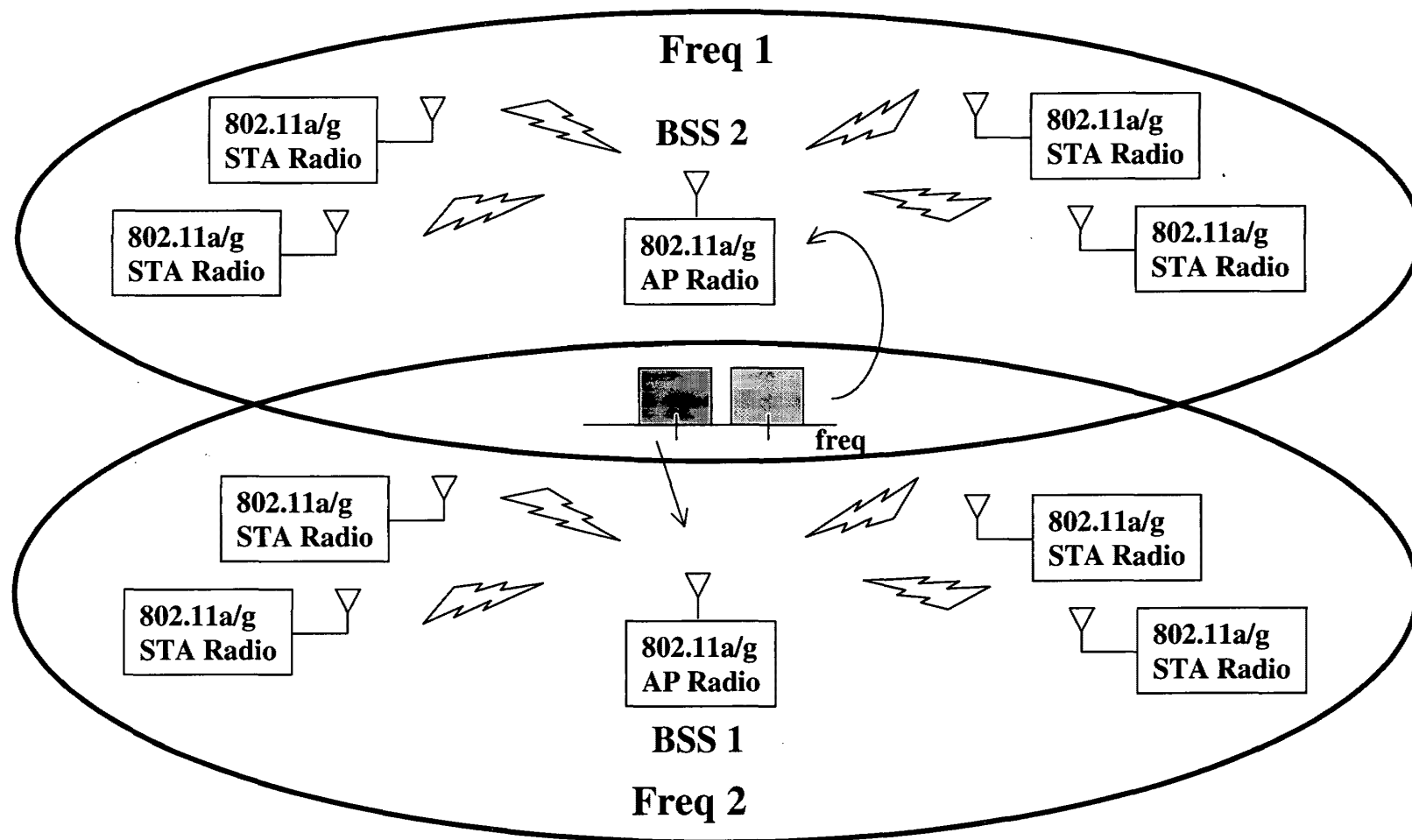


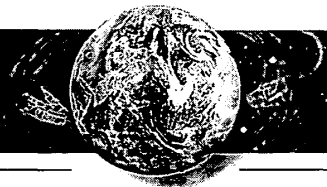
World-Wide 5 GHz Frequency Allocations



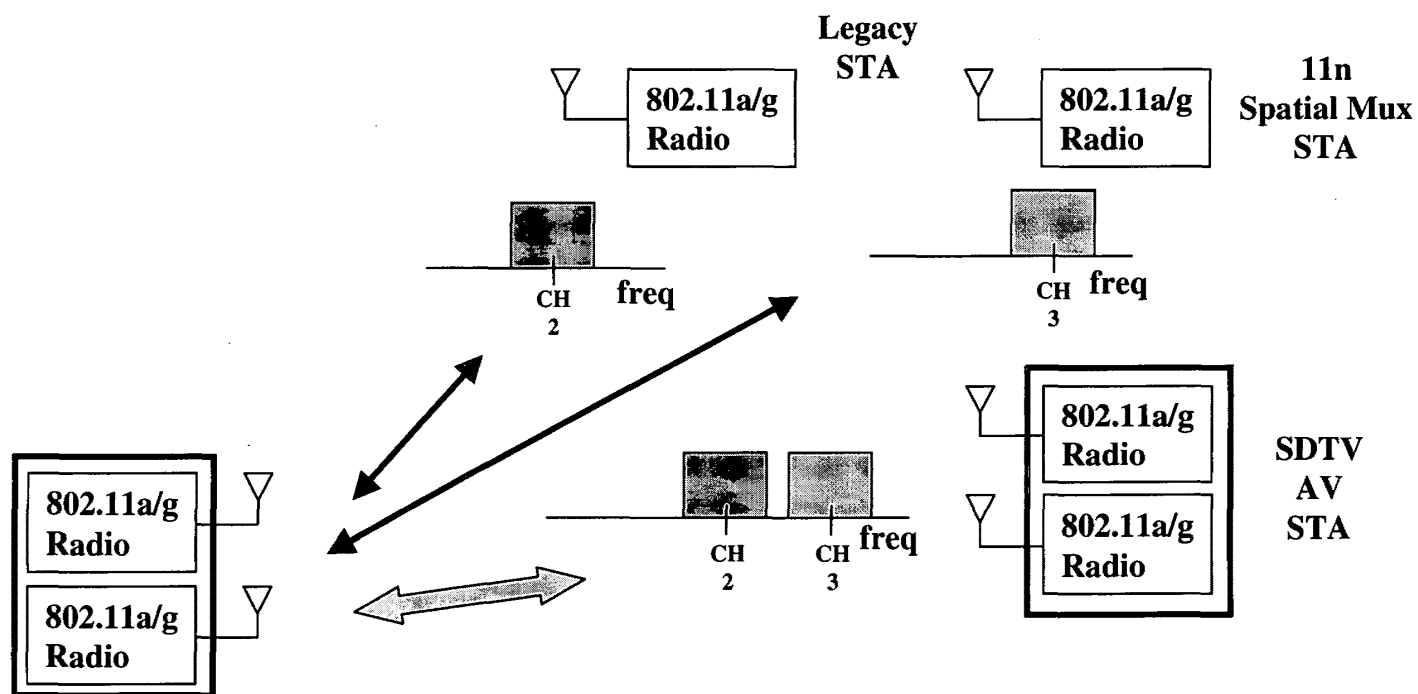


The Current 802.11a/g Situation: Single Channel Radio's





What Will IEEE 802.11n Want?



- **Service multiple signals in parallel.**
- **Transmit to two separate radios**
- **Or, to a single radio**
- **Make this capability extensible to more channels**



Exemplary Innovations

- An embodiment of the present invention is directed to concatenation of two (or more) channels using parallel transceivers at the transmit and/or receive end.
- Another embodiment of the present invention is directed to transmitting and/or receiving two channels to two different radios, or to a single radio thereby increasing data rate to the single radio.
- Another embodiment of the present invention is directed to being extensible to multiple channels.
- Another embodiment of the present invention is directed to an adaptive anti-aliasing function in the receiver.
 - In general, ADC's must run fast to ingest a total signal.
 - Here, the signal is allowed to alias and to run ADC's slow.
 - Preamble techniques are proposed to ease anti-aliasing.
- Another embodiment of the present invention uses a Power Amplifier (PA)/antenna for each channel or single PA/antenna for all channels, at the transmit and/or receive end.



*OFDM with
20 MHz Channel Centers
(Situation with 802.11a 5 GHz)*

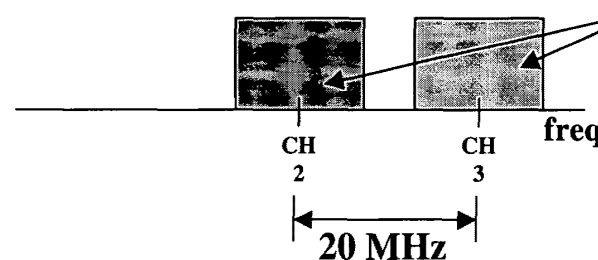


Three Signal Cases Under Consideration

3 Spectrums

CASE 1 Two 802.11a

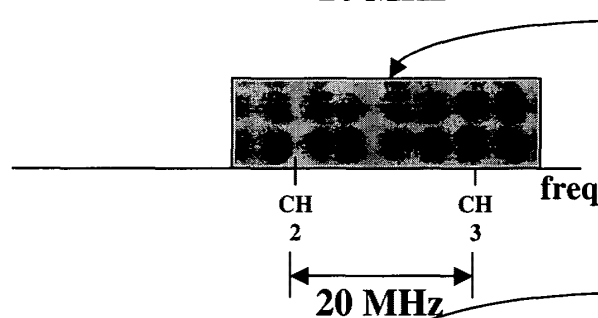
Two 1x chan's



Each Waveform

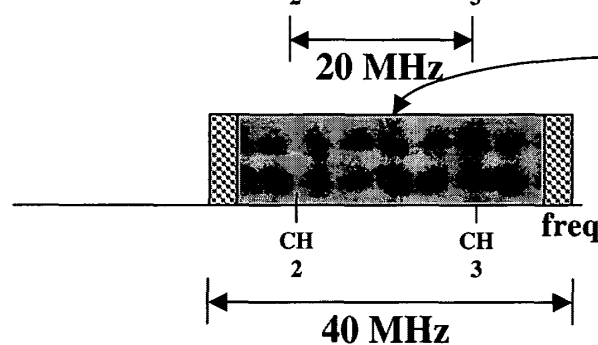
- 52 OFDM Subcarriers
- = 48 Data Subcarrier
- + 4 Pilot Subcarriers

CASE 2 Filled-Gap OFDM



Fill gap between
2 "normal" OFDM
channels

CASE 3 Alternative Mode OFDM



Use all usable
Points in FFT
Across 2 channels



This Exemplary Method Uses No Synthesizer Frequency Popping

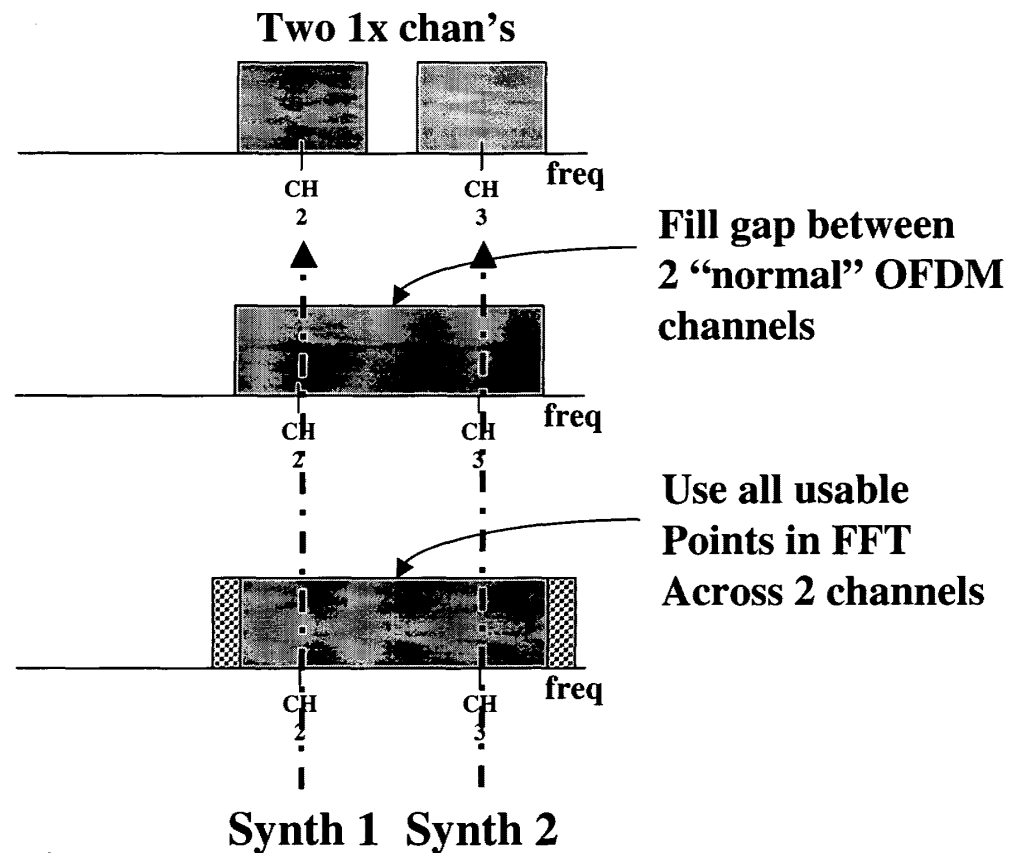
3 Spectrums

CASE 1
Two 802.11a

CASE 2
Filled-Gap
OFDM

CASE 3
Alternative Mode
OFDM

**Each synthesizer stays
Tuned to its individual
Channel when mode switching**





Filled-Gap OFDM Mode ~120 Mbps



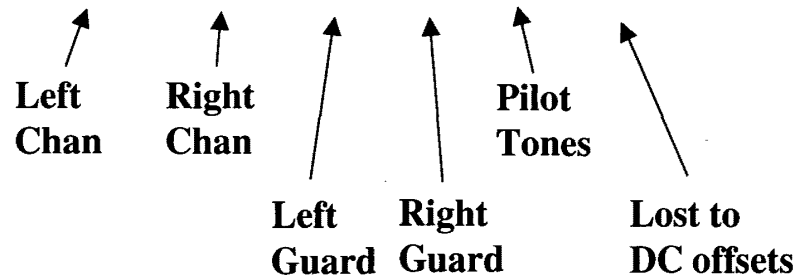
Filled-Gap Data Rate Increase

Dual-channel w/o gap fill → 108 Mbps

- $(96 \text{ sc}) / (48 \text{ sc}) = 2\times$ data rate factor
- $2 * 48$ data subcarriers = 96 data subcarriers

Dual-channel w/ gap fill → 121.5 Mbps

- $(108 \text{ sc}) / (48 \text{ sc}) = 2.25\times$ data rate → 121.5
- $64 + 64 - 6 - 5 - 4 - 5 = 108$ data subcarriers





*An Alternative Mode for Retail
~135 Mbps*



Alternative Mode

- An embodiment of the present invention is directed to an alternative mode that is not defined in 11n. The interference level will be a little higher than 11n would like.
- An attractive feature is the alternative mode will still allow fast switching between normal 802.11a and the alternative mode packet using 11g-like mechanisms.



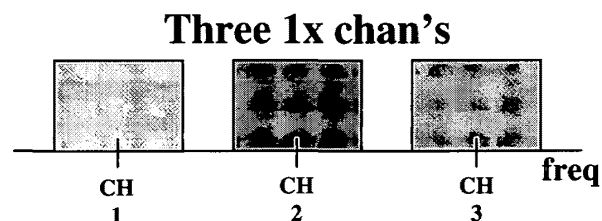
- An embodiment of the present invention is directed to increasing the data rate even more without increase the analog and mixed signal requirements. This may be accomplished by using a FULL spectral synthesis capability of the Inverse Fast Fourier Transform/Fast Fourier Transform (IFFT/FFT).
- All the subcarriers across 2 channels for carrying data except 4 pilot tones and 2 DC notches at legacy locations may be utilized.
- This is like the filled-gap OFDM presented in the preceding section, where the gaps on the outer edges are also filled. As a result, the guard band on each end is filled with data. This increases Adjacent Channel Interference (ACI) beyond 11a levels.



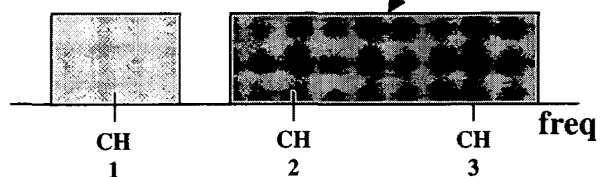
Alternative Mode

- **Key Idea:**
 - For dual channel bandwidth Tx to single STA (radio station in a wireless LAN cell), fill gap
 - For triple channel bandwidth Tx to single STA, fill 2 gaps

Now

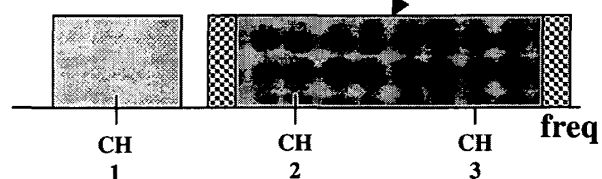


**Filled-Gap
OFDM**



**Fill gap between
2 “normal” OFDM
channels**

**Alternative Mode
OFDM**



**Use all available
Points in FFT
Across 2 channels**



Filled-Gap Data Rate Increase

- Dual-channel w/o gap fill → 108 Mbps
 - $(96 \text{ sc}) / (48 \text{ sc}) = 2 \times 54 \text{ Mbps} = 108 \text{ Mbps}$
 - $2 \times 48 \text{ data subcarriers} = 96 \text{ data subcarriers}$
- Dual-channel w/ gap fill → 121.5 Mbps
 - $(108 \text{ sc}) / (48 \text{ sc}) = 2.25 \times 54 \text{ Mbps} \rightarrow 121.5 \text{ Mbps}$
 - $64 + 64 - 6 - 5 - 4 - 5 = 108 \text{ data subcarriers}$

↑ ↑ ↑ ↑ ↑ ↑
 Left Right Left Right Pilot Lost to
 Chan Chan Guard Guard Tones DC offsets

- Alternative mode
 - Dual channel w/ all gaps filled → 135 Mbps
 - $(120 \text{ sc}) / (48 \text{ sc}) = 2.5 \times 54 \text{ Mbps} \rightarrow 135 \text{ Mbps}$
 - $64 + 64 - 4 - 4 = 120 \text{ data subcarriers}$

↑ ↑ ↑ ↑
 Left Right Pilot Lost to
 Chan Chan Tones DC offsets



Even more

- **Extra FEQ (Frequency Domain Equalizer) taps may be needed.**
- **Extra soft-decisions may need to be generated.**
- **Viterbi decoder may run faster.**



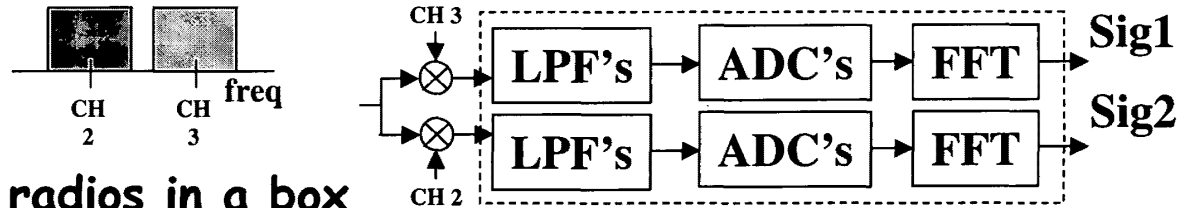


Overview

- The obvious radio for a wide signal built from 2 narrower signals is a wide-channel transceiver with faster Digital-to-Analog Converters (DAC's) and Analog-to-Digital Converters (ADC's) (e.g., 40 MHz wide instead of 20 MHz wide).
- However, there are problems associated with this implementation.
 - There is cost/power increase for 40 MHz channels.
 - Only 20 MHz channel doubling is feasible with current technology.
 - More than two channels is too difficult.
 - 25 MHz channel doubling at 2.4 GHz is too difficult.
 - E.g., 50 MHz frontend is a lot harder than 40 MHz.
 - More Power Amplifier (PA) back-off is required to meet the spectral mask, especially at 2.4 GHz.
 - ADC and DAC's must run much faster.
 - Receive filter requirements are very difficult.
 - Filter must be wide and have very sharp skirts to reject adjacent channel interference.
 - There may be synthesizer retuning issues.
- An embodiment of the present invention is directed to avoiding the 40 MHz transceiver (XCVR) by re-using existing 20 MHz XCVR's.

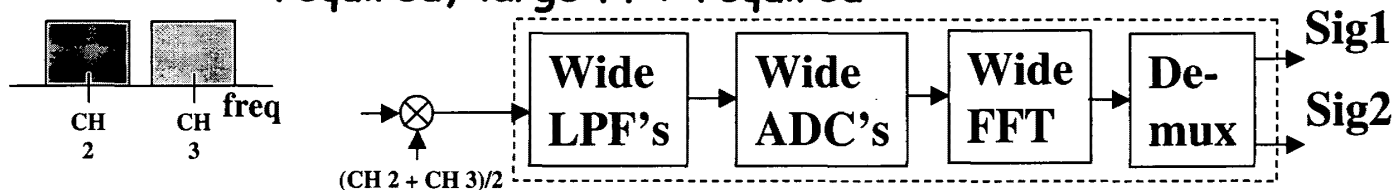
Expensive

- Multiple radios in a box
 - Multi-chain radio each with single bandwidth
 - Multiple FFT's, multiple converters, multiple analog filters
- When channel bonding
 - Use common synthesizer
 - Use common AGC with receiving



Lower expense

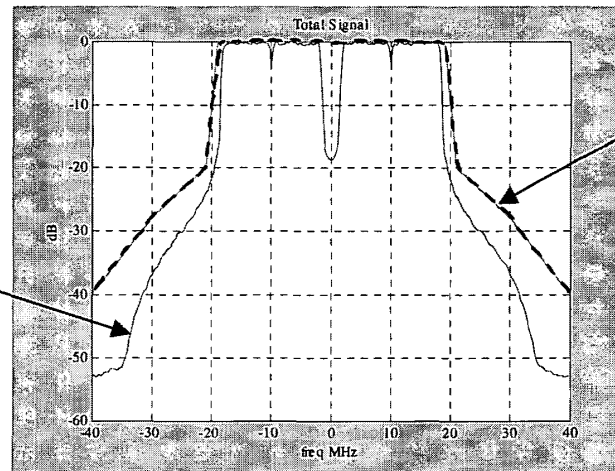
- Build one radio that implements multi-channel capability
 - Single chain with programmable bandwidth expansion
 - High speed converters required, bandwidth switched filters required, large FFT required





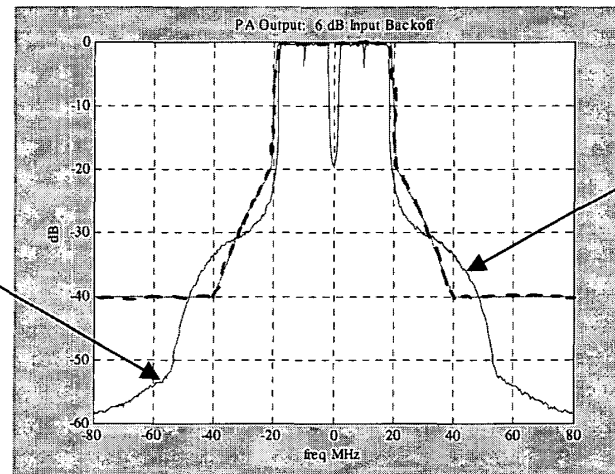
Satisfying Spectral Mask is More Difficult with Single Chain

Dual Chain Transmitter Spectrum With 6 dB PA Back-off



Spectral Mask

Single Chain Transmitter Spectrum With 6 dB PA Back-off

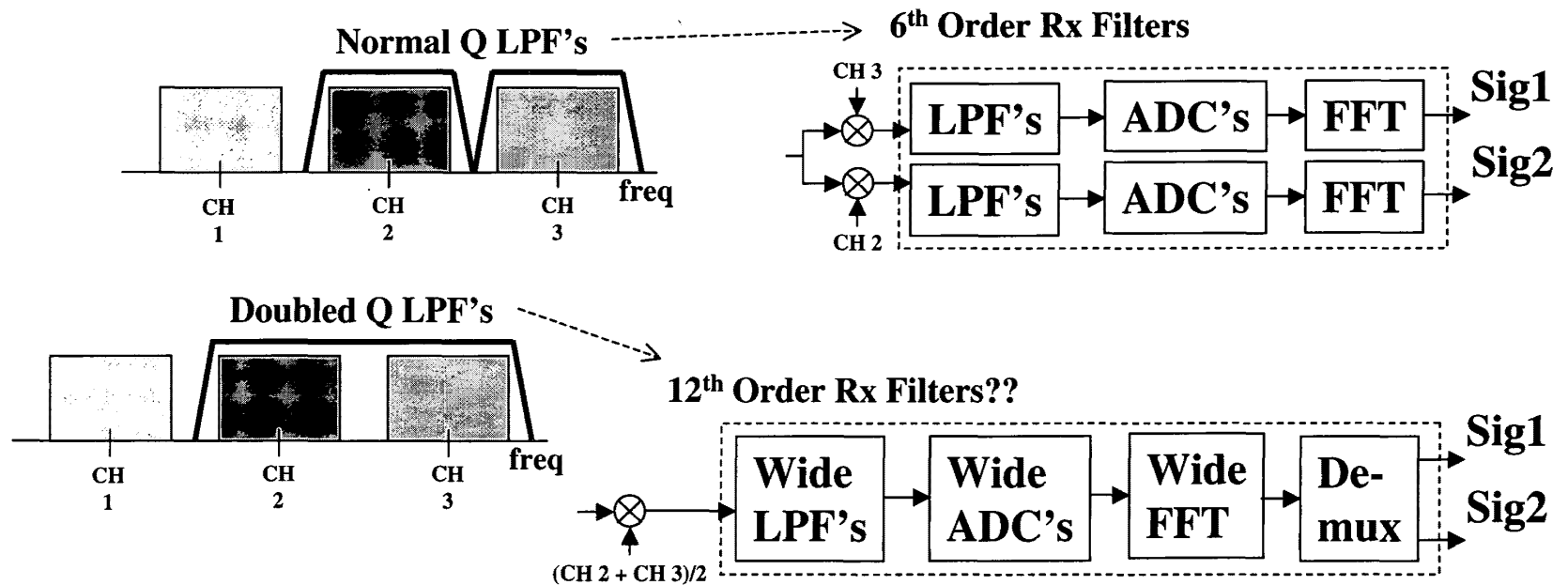


Spectral Mask Violated



PHY Issues with Single Channel Approach

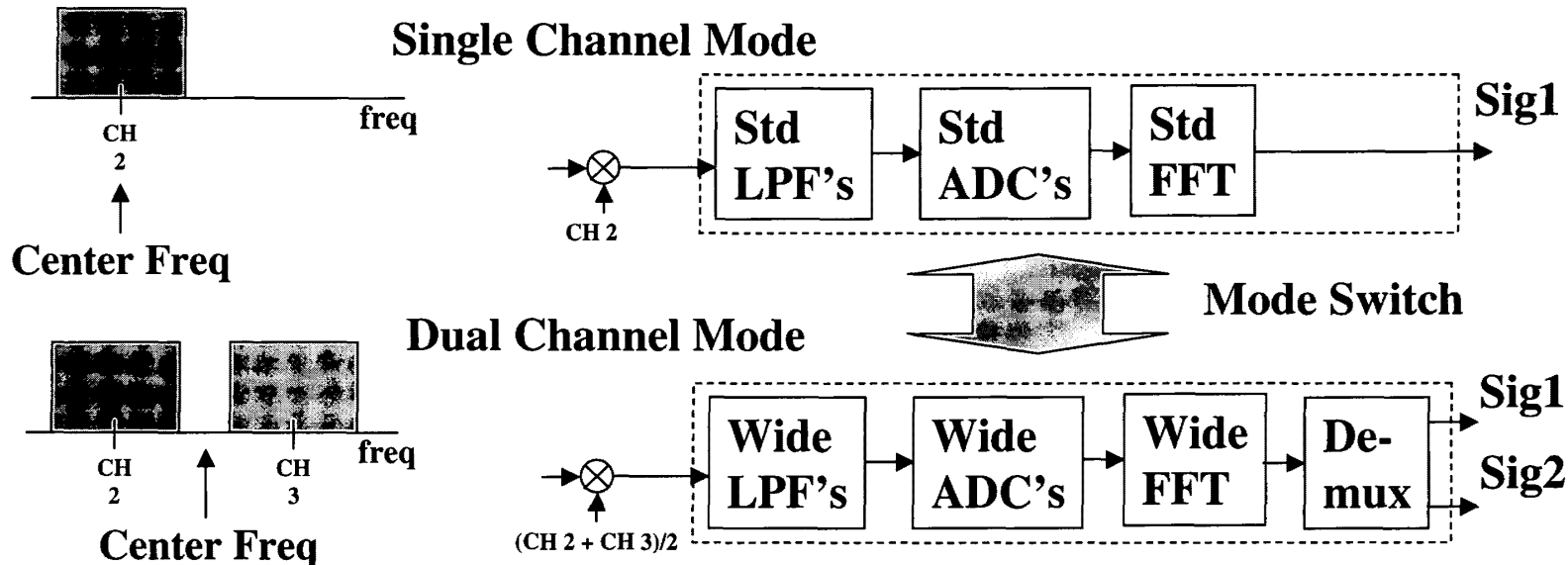
- Analog Transmit (Tx)/Receive (Rx) filter-Q issue ^{Adjacent channel interference}
 - Must meet 11a/g spectral mask and ACI requirements
 - Single channel receiver doubles Tx/Rx filter Q requirements, where Q refers to how narrow a filter is (higher Q is more narrow).
 - Dual channel receiver still uses single channel filters





PHY Issues with Single Channel Approach

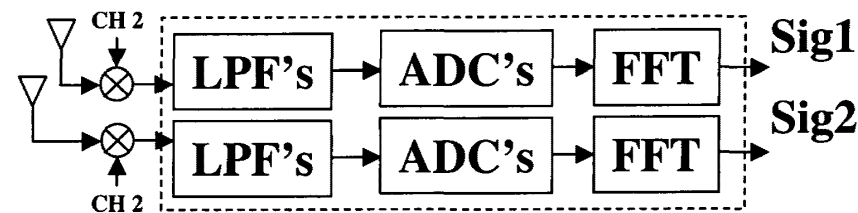
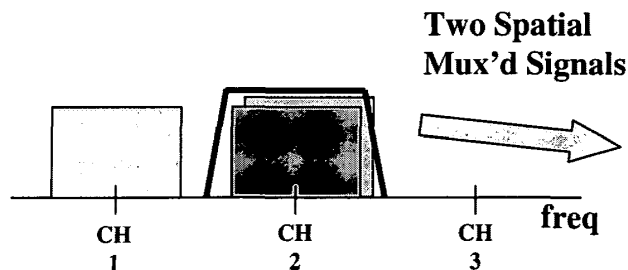
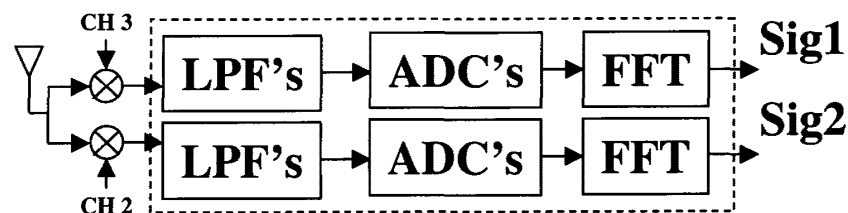
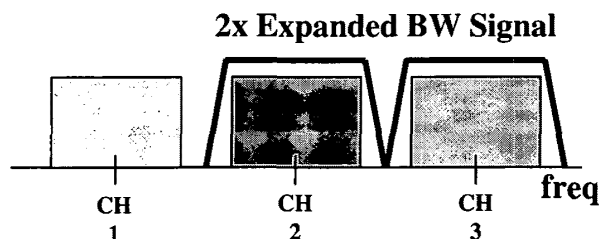
- Synthesizer (and BW) switching issue
 - Marketing has asked for 11g-like switching
 - Single channel receiver must jump synthesizer frequency when switching between wide and normal packets if tight receive filtering is needed (sensitivity and interference robustness)
 - Dual channel requires does not jump frequency
 - Requires 2 synthesizer LO (Local Oscillator) frequencies, though





11n Spatial Multiplexing Ready

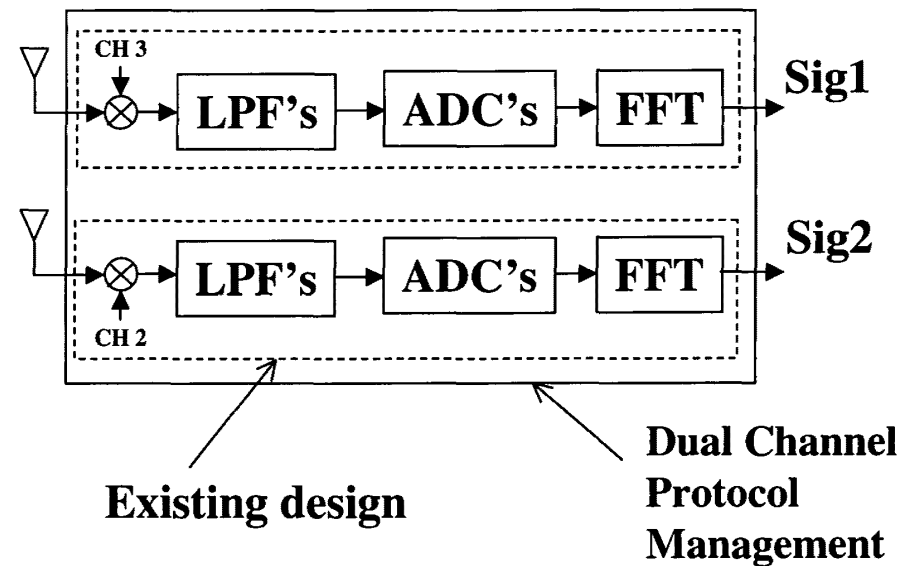
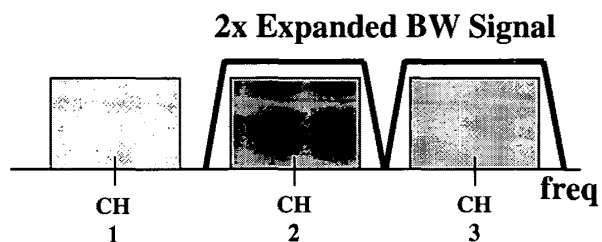
- Multi-channel radio architecture may be implemented for spatial multiplexing.
- Hence, implementing bandwidth expansion using the multi-channel radio architecture makes a system more 11n ready
 - With the penalty of added expense and power draw





Is a New Design Needed?

Simply double existing chips and plug into prime power.



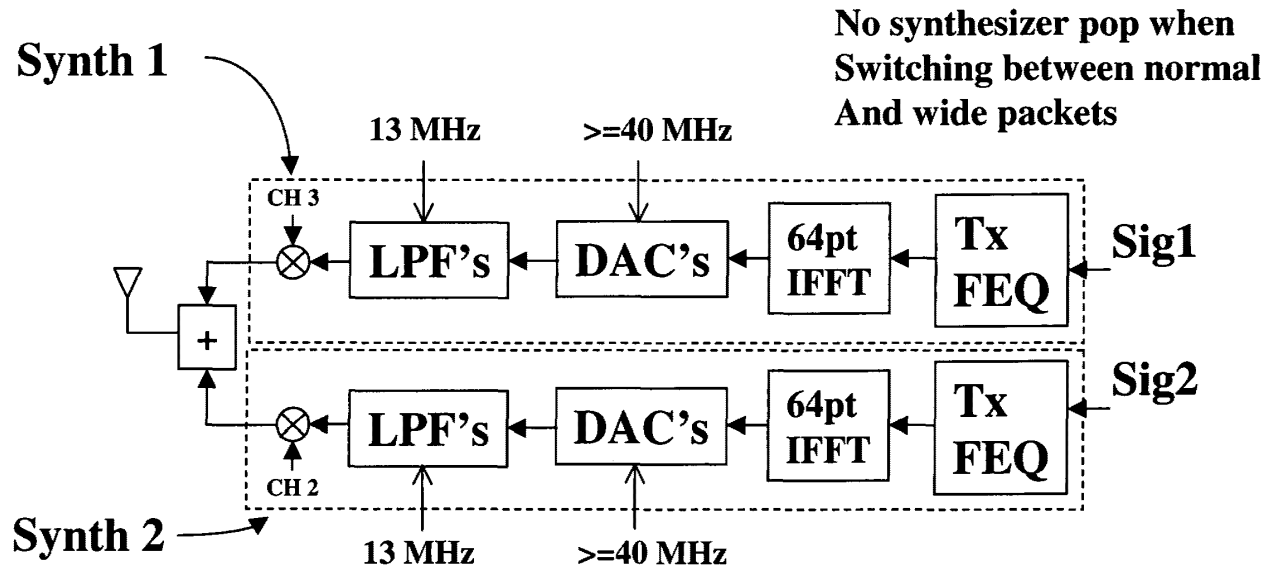


Multi-Chain Transmitter with 20 MHz Channels



Two-Channel Transmitter

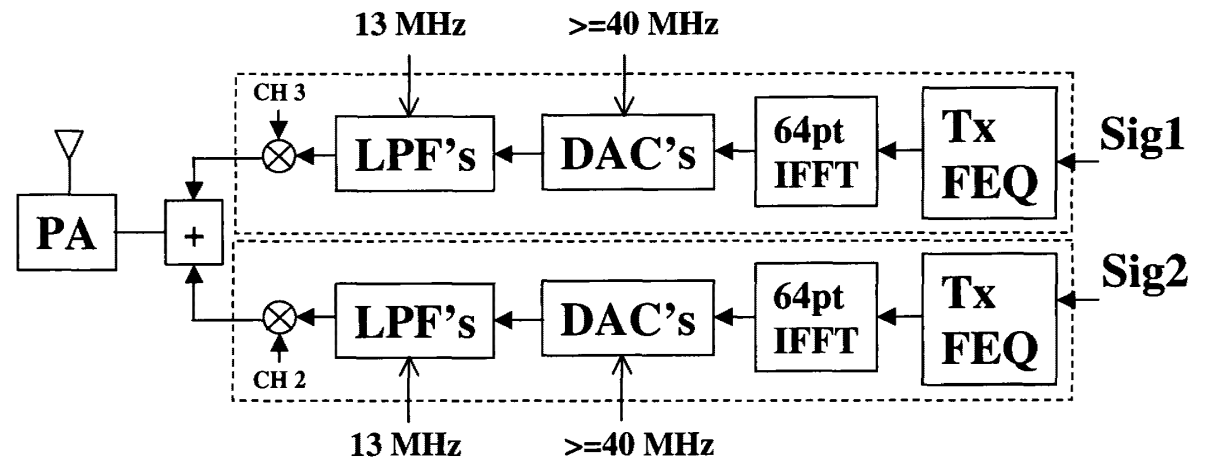
- Expanded Bandwidth (BW) signal may be decomposed into sub-components.
 - Frequency-concatenate two Tx signal components at RF (Radio Frequency).
 - A synthesizer may be used to realize the exact two LO offsets needed related to subcarrier spacing (both can have same part per million (PPM) error).
 - Use expanded bandwidth station (XBW STA) (e.g., 40 MHz instead of 20 MHz) to phase-align 2 chains thru feedback packet, if desirable. This is not viewed as necessary.
 - Use Tx DAC sample rate that allows clean digital synthesis of two Tx signal components with simple reconstruction low pass filter (LPF's).



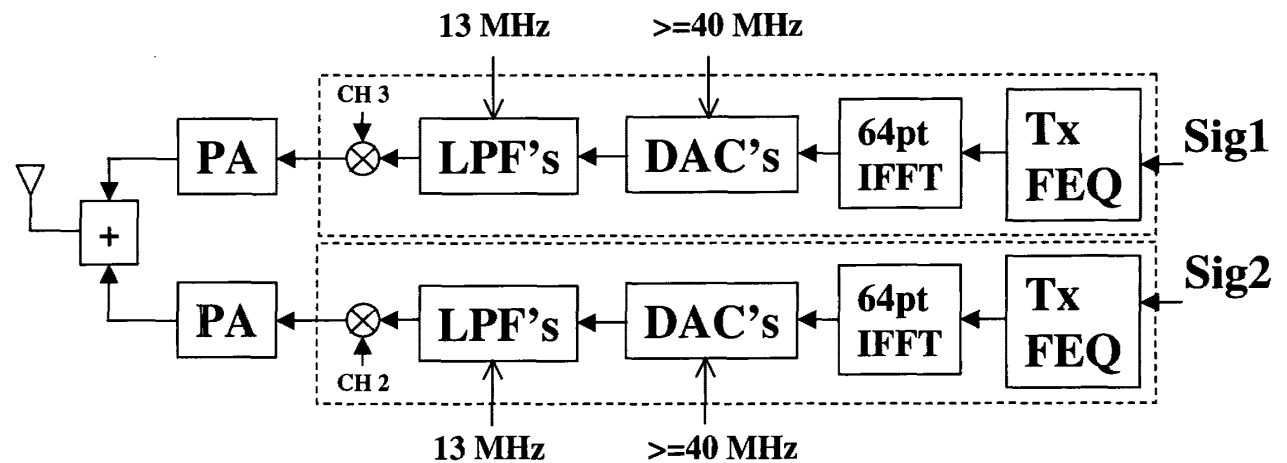


Two Variations: Pre- and Post- PA Summation

Pre-PA Summation



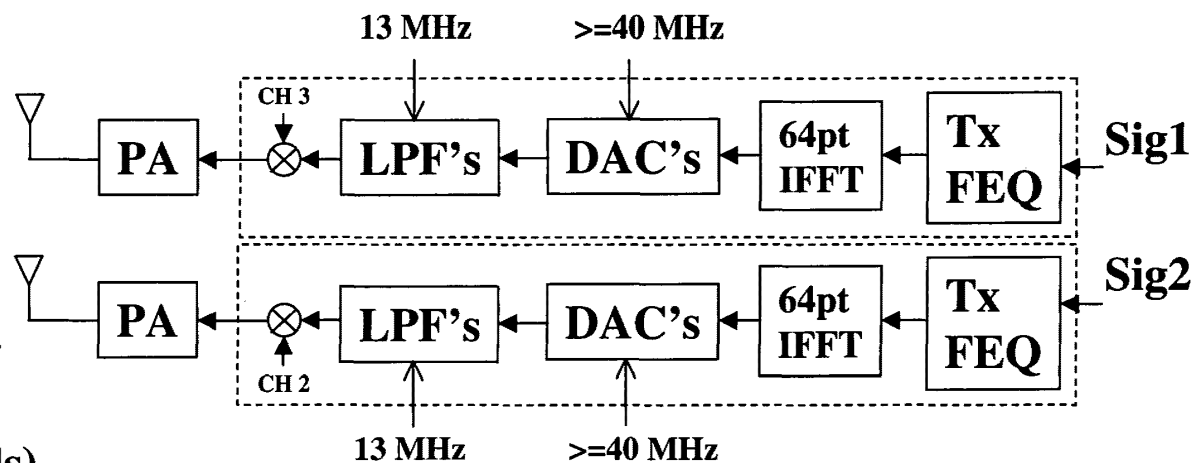
Post-PA Summation





Third Variation: Post Antenna Summation

**Post-Antenna
Summation of
Signal in the
Ether (e.g., the air
or other medium
which radio travels)**

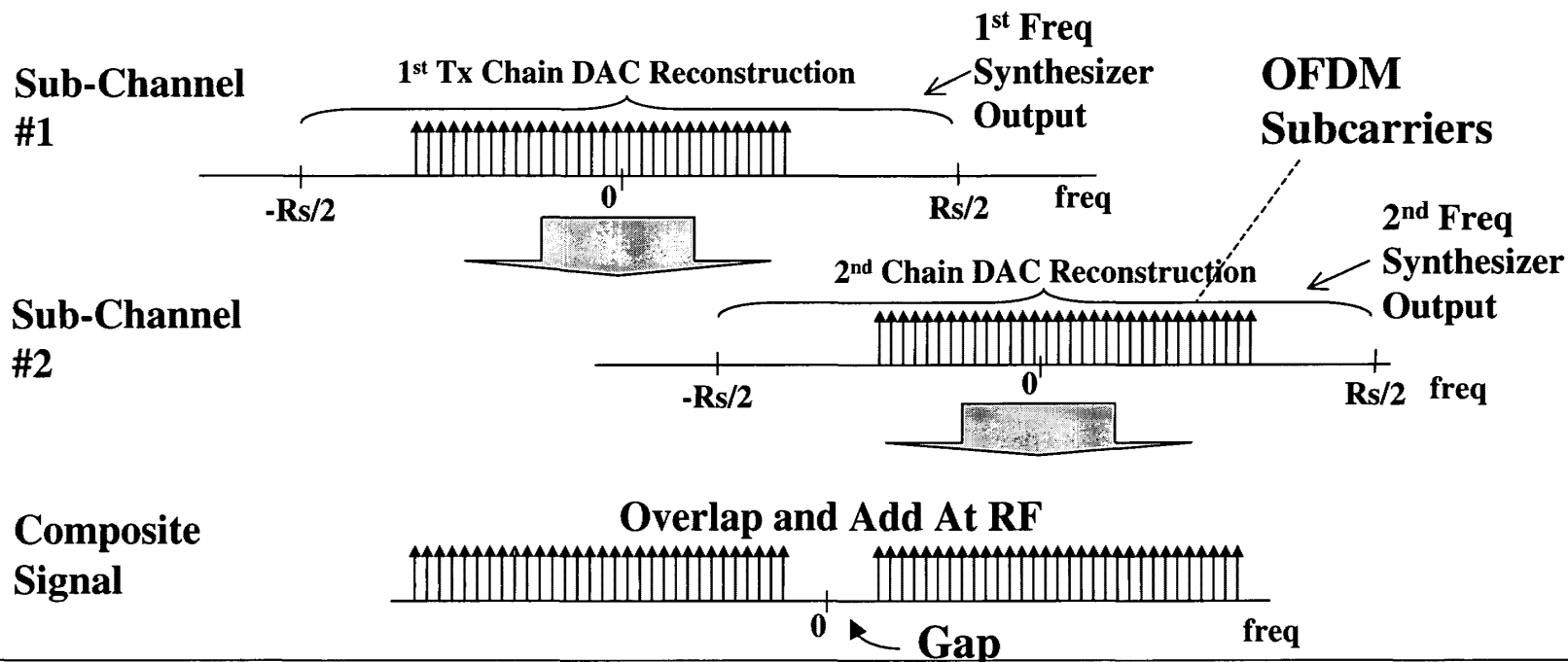




Two 802.11a Signals with Two-Channel Transmitter?

Overlap-and-add at RF

- Generate lower $\frac{1}{2}$ spectrum in 1st Tx chain
- Generate upper $\frac{1}{2}$ spectrum in 2nd Tx chain
- Add to signal at RF
 - Either pre-single-PA or post-two-PA's



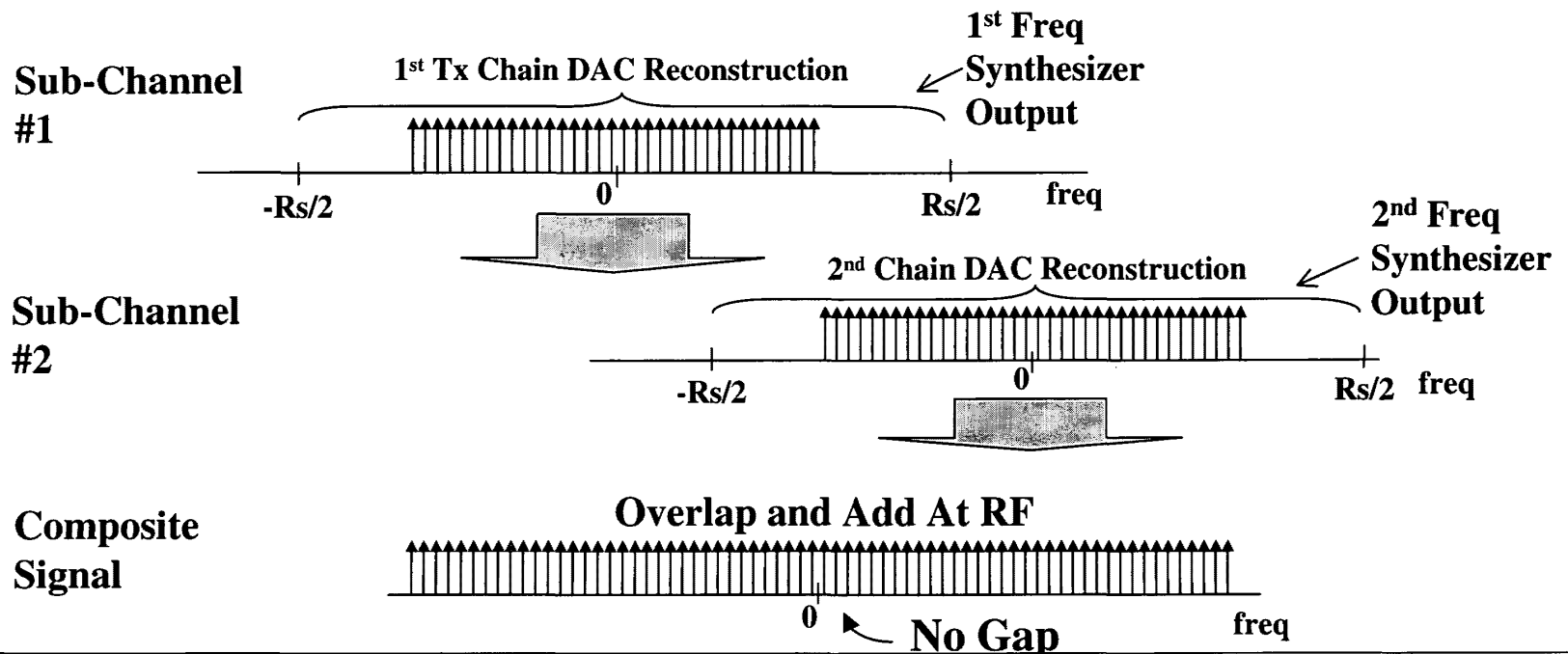


How Can Gap Be Filled With Two-Channel Transmitter?

• Overlap-and-add at RF

- Generate lower $\frac{1}{2}$ spectrum in 1st Tx chain
- Generate upper $\frac{1}{2}$ spectrum in 2nd Tx chain
- Add to signal at RF
 - Either pre-single-PA or post-two-PA's

Filled-Gap OFDM



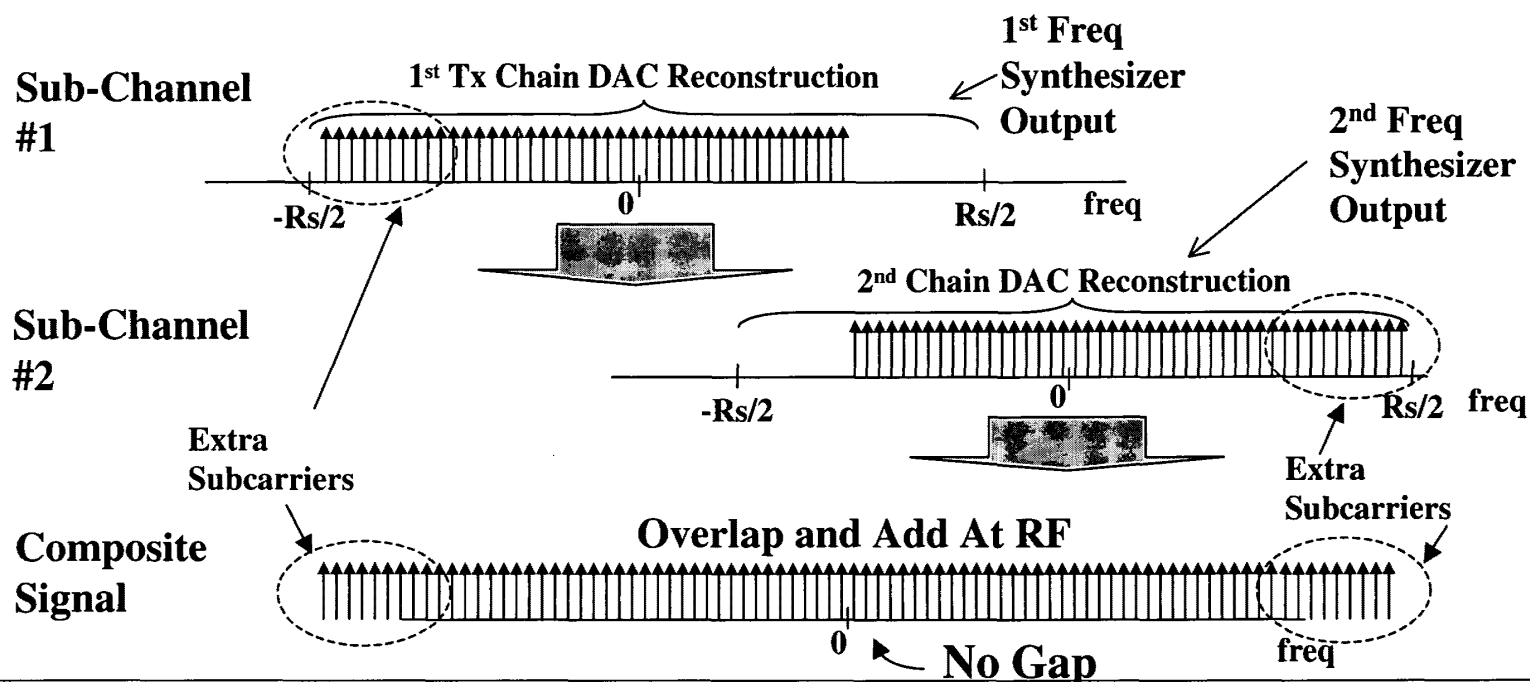


Alternative Mode With Two-Channel Transmitter?

Overlap-and-add at RF

- Generate lower $\frac{1}{2}$ spectrum in 1st Tx chain
- Generate upper $\frac{1}{2}$ spectrum in 2nd Tx chain
- Add to signal at RF
 - Either pre-single-PA or post-two-PA's

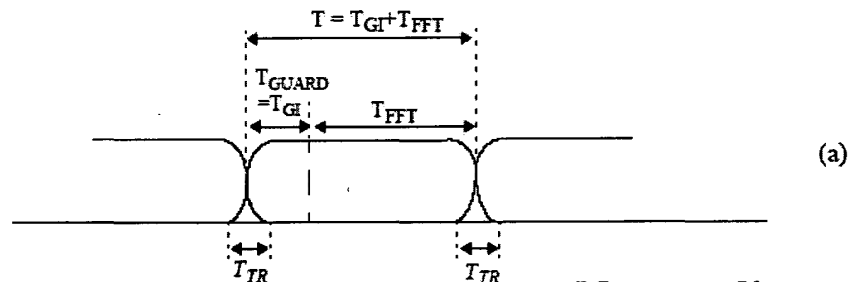
Filled-Gap OFDM





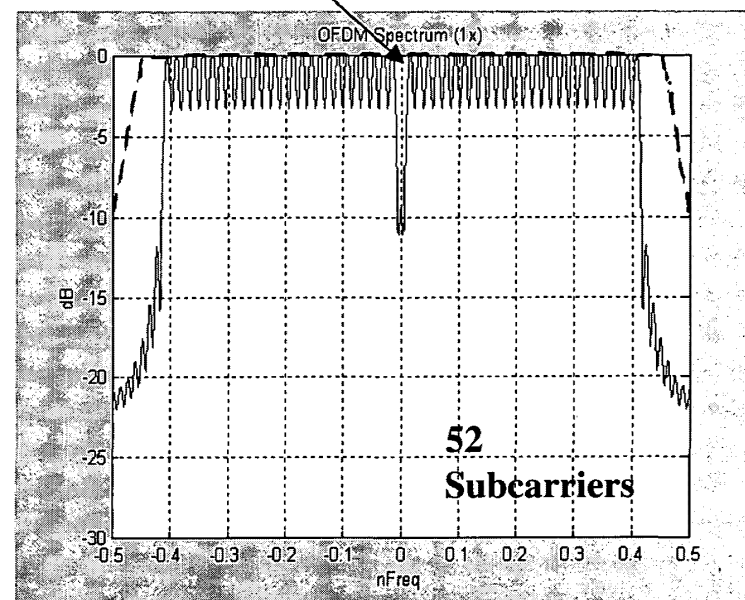
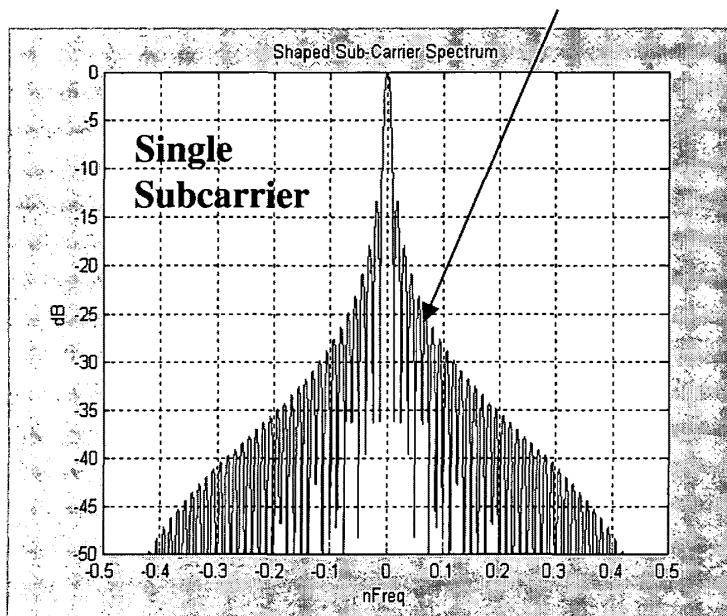
802.11a Subcarrier Windowing Per Informative Method

$$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \leq t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t-T)/T_{TR})\right) & (T - T_{TR}/2 \leq t < T + T_{TR}/2) \end{cases}$$



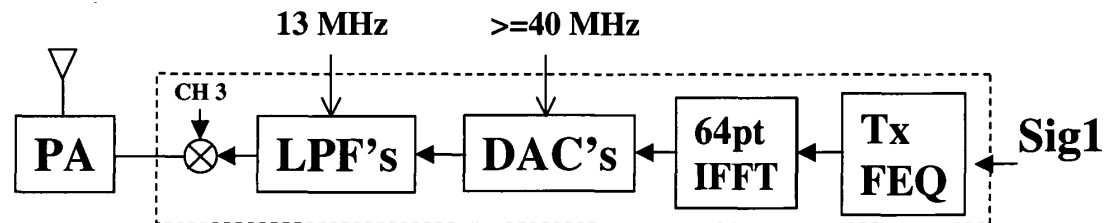
**This type of overlap is not a problem.
Each subcarrier is still orthogonal at FFT.**

**No non-linear
Distortion**

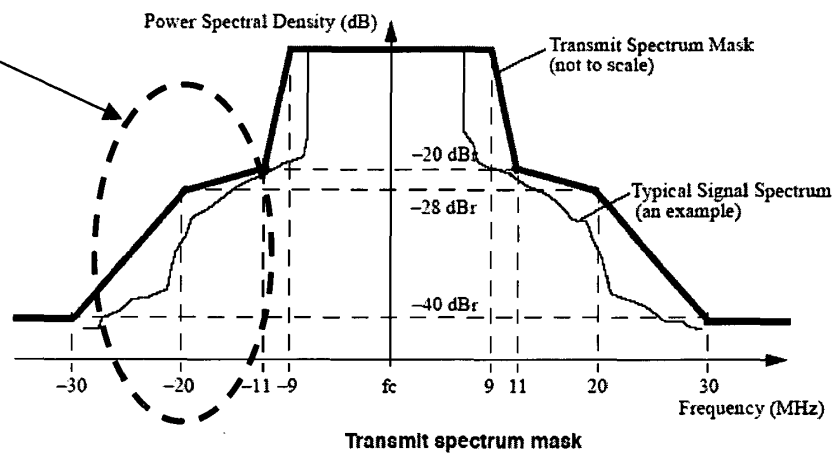




Single Channel with PA: 802.11a Spectral Mask



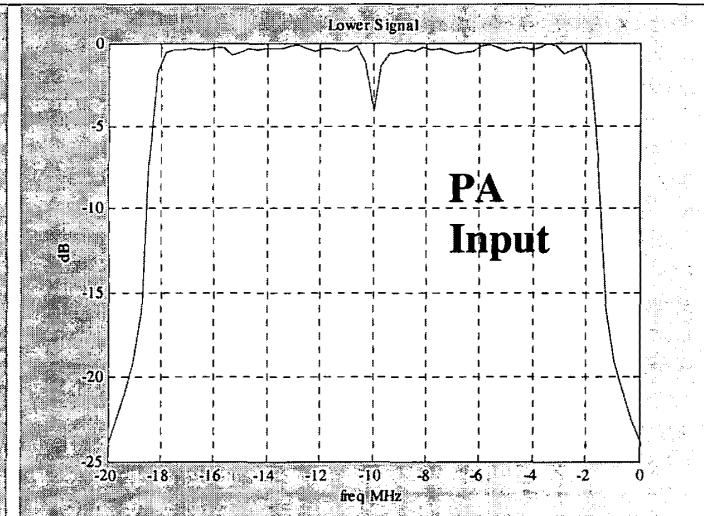
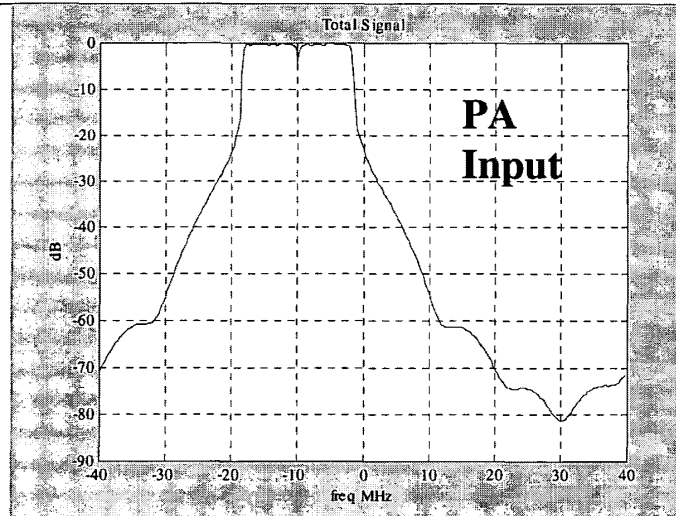
**Distortion
Created
By PA
Nonlinearities**



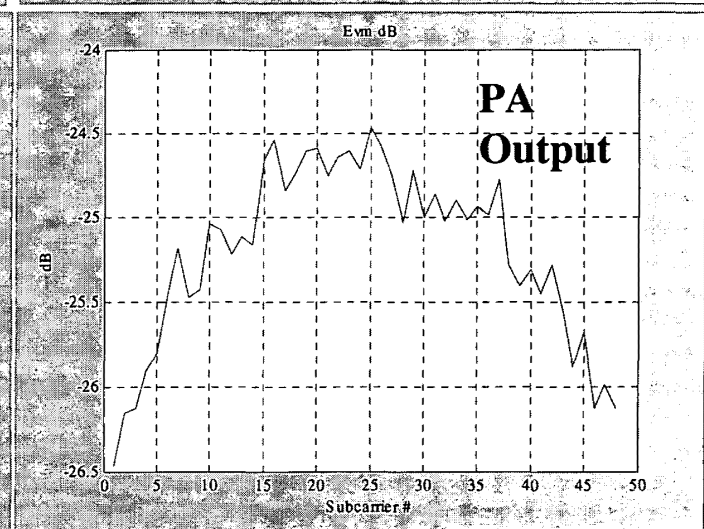
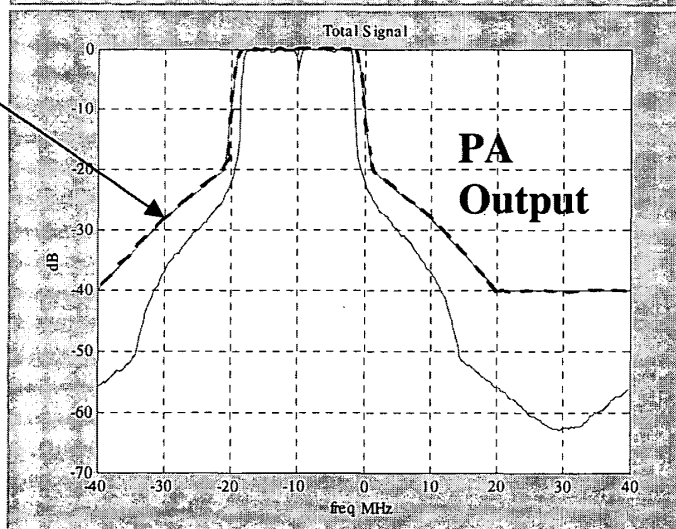
**802.11a
Spectral
Mask**



One Signal (Lower) Only 6 dB PA Input Backoff



**802.11a
Spectral
Mask**

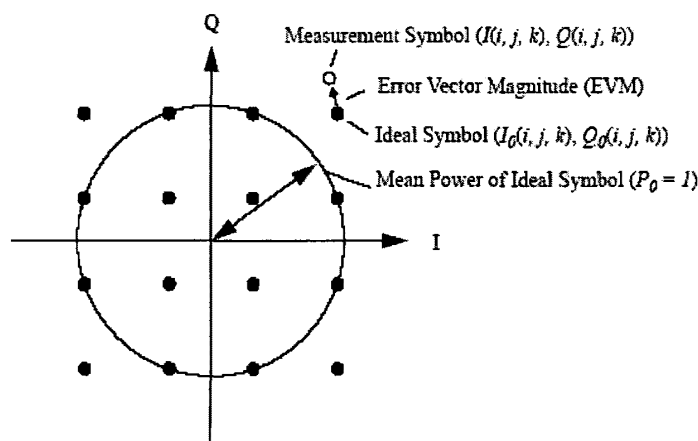




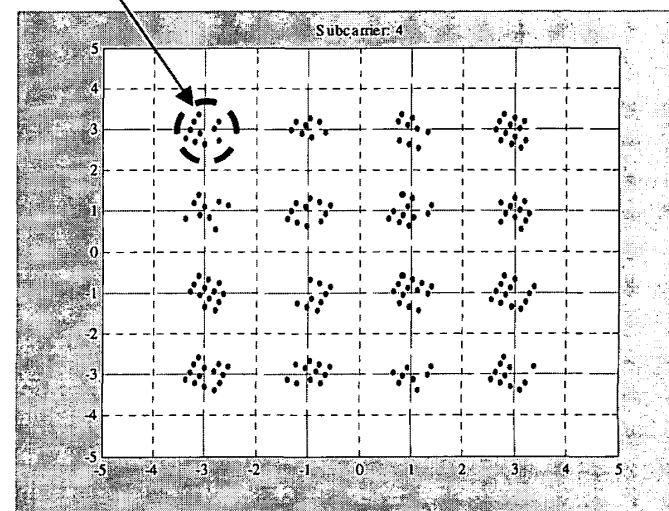
What is EVM?

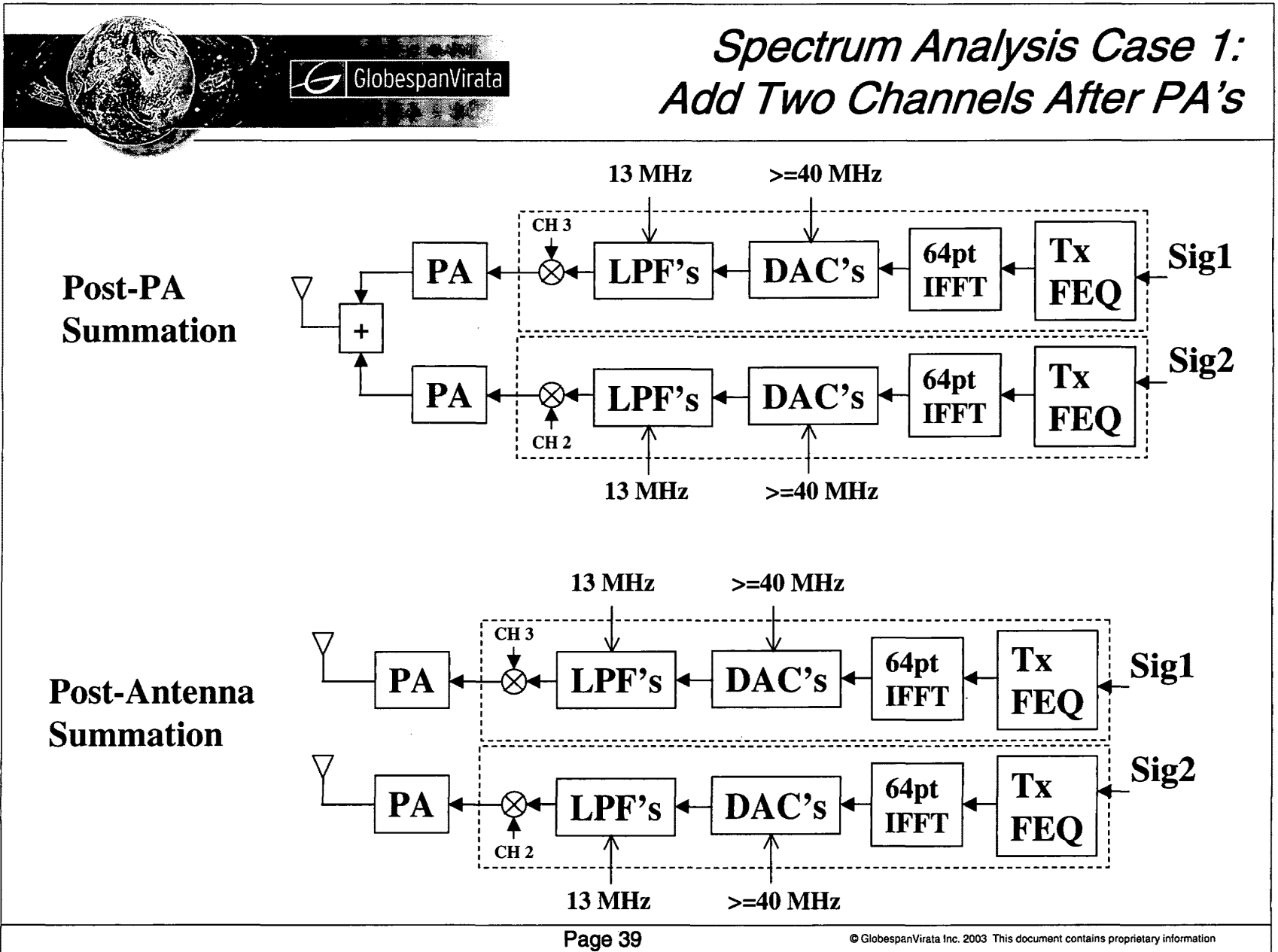
- EVM: Error vector magnitude
- A distortion measure described in 802.11a/g for OFDM
- Measures the fuzziness (impurity) of constellation points

**EVM =
Constellation Point Fuzziness**



Constellation error

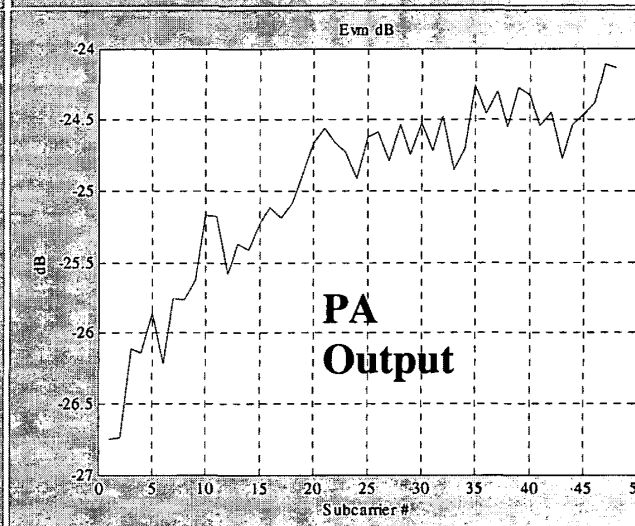
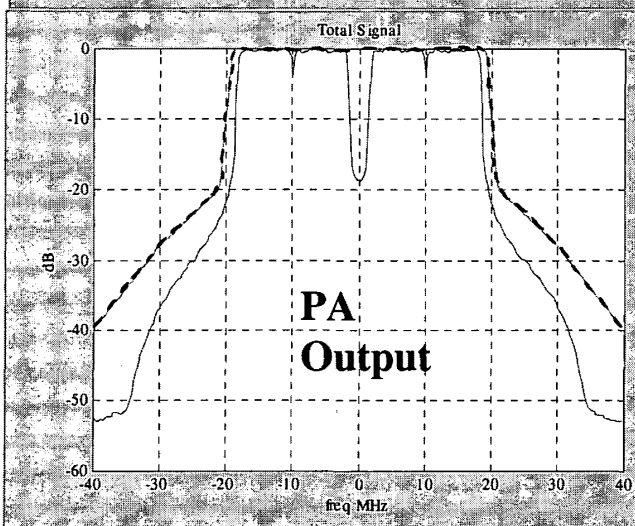
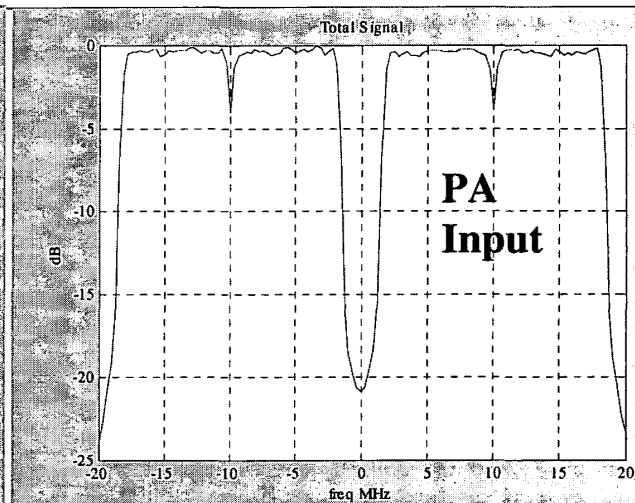
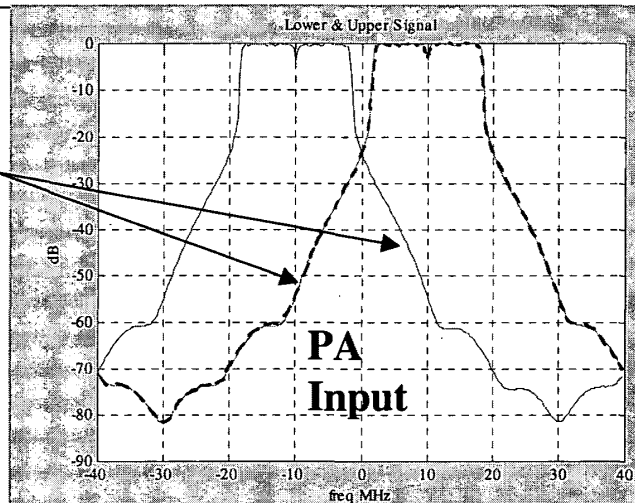






Add Two 802.11a Signals Post PA's 6 dB PA Input Backoff

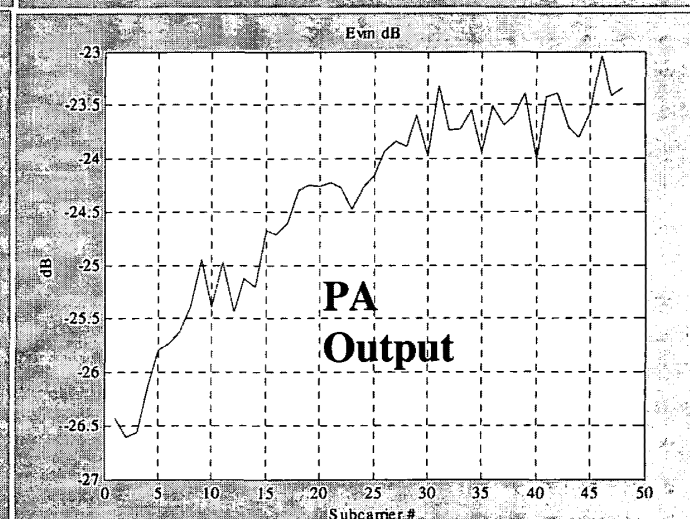
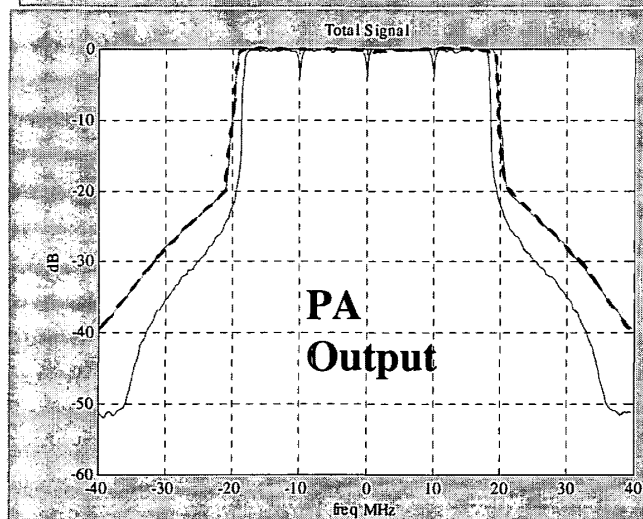
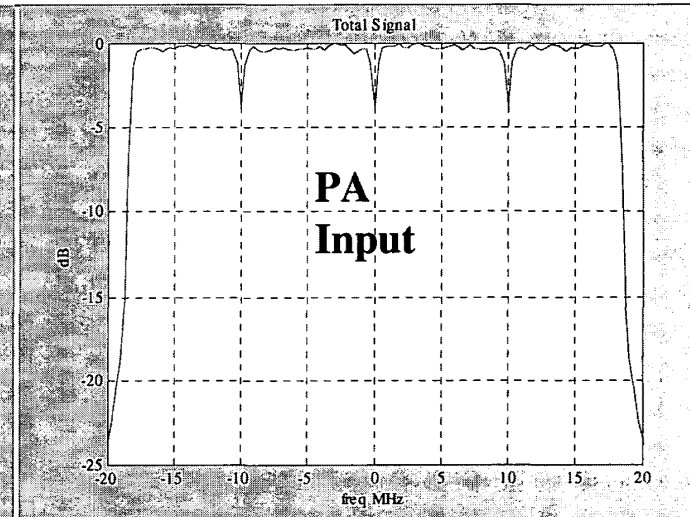
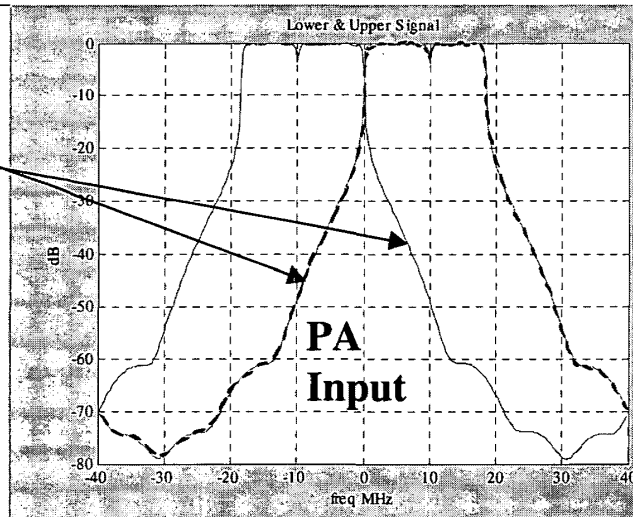
**This overlap
Generates no
Interference**





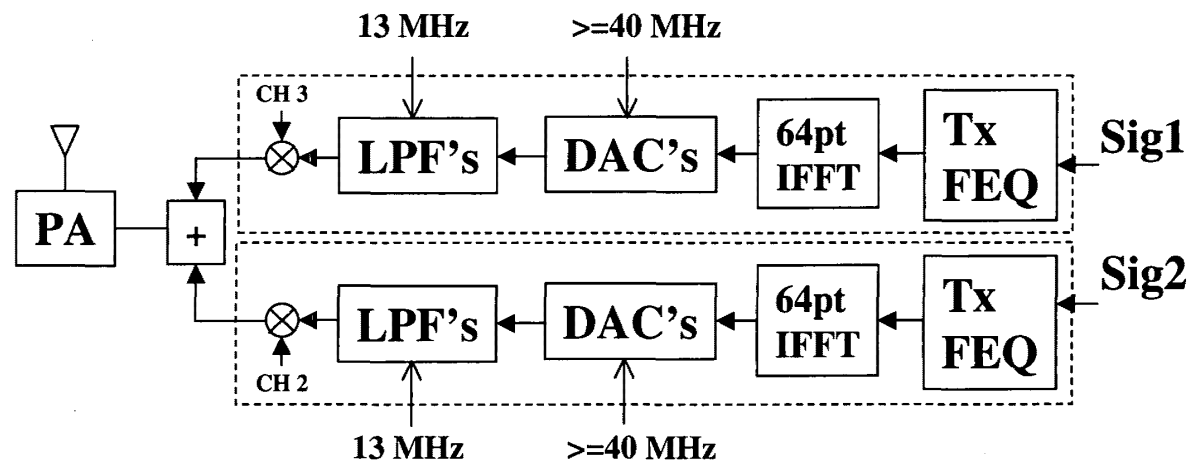
Add Filled-Gap OFDM Post-PA's 6 dB PA Input Backoff

**This overlap
Generates no
Interference**





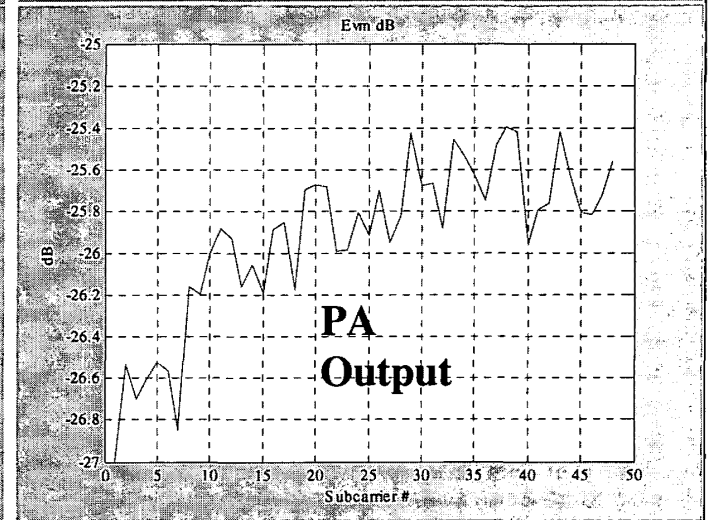
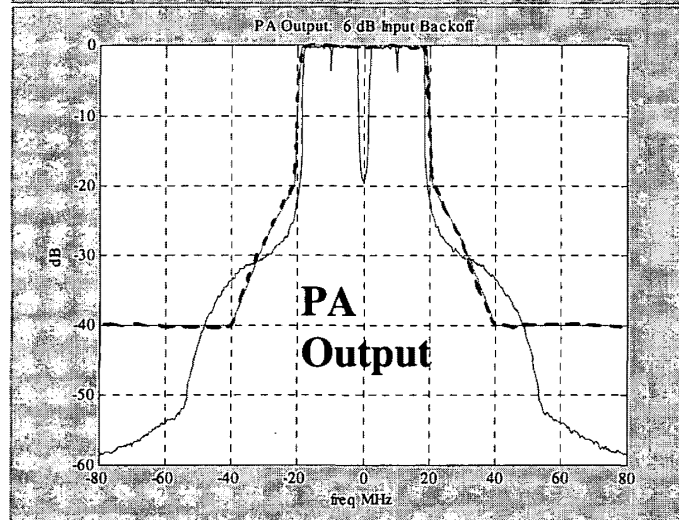
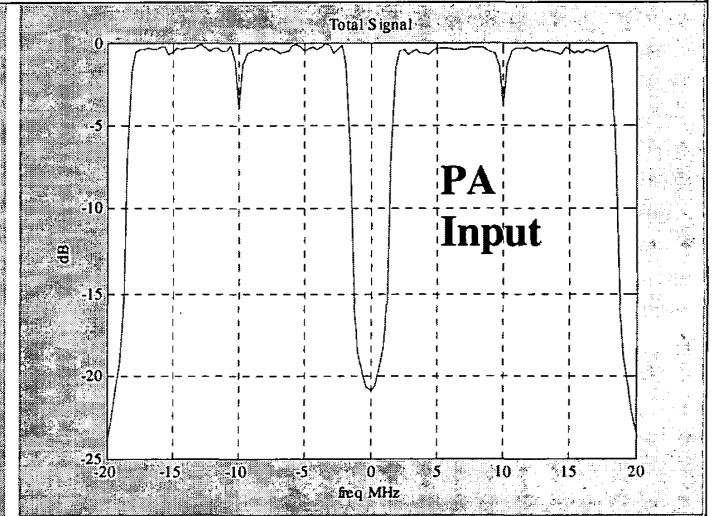
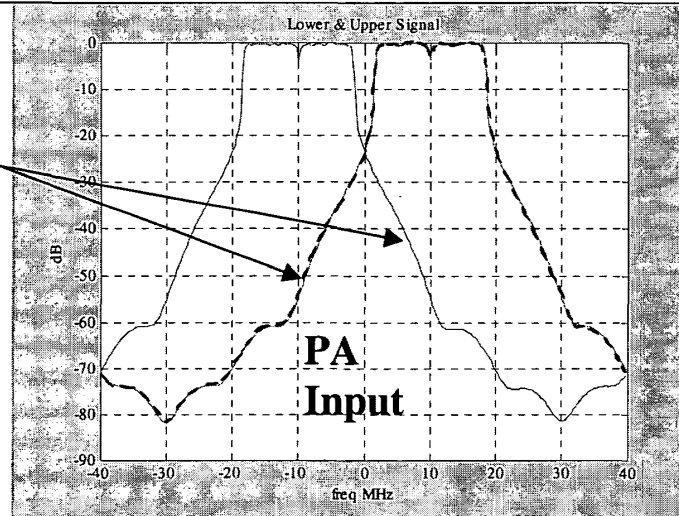
Spectrum Analysis Case 2: Add Before PA





Add Two 802.11a Signals Pre-PA 6 dB PA Input Backoff

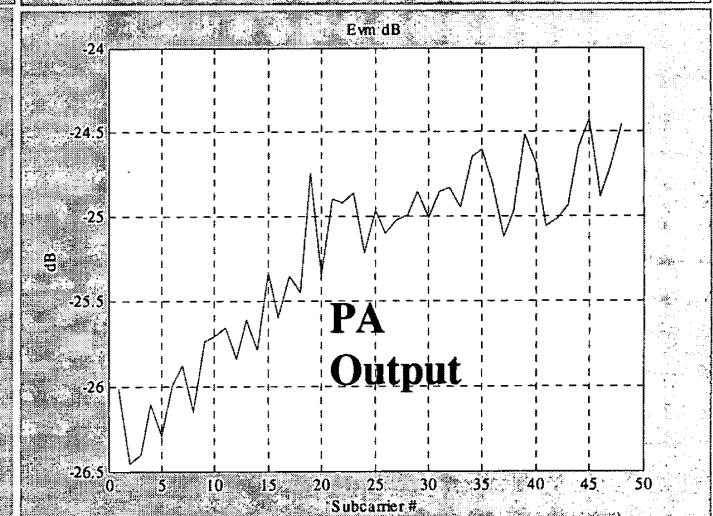
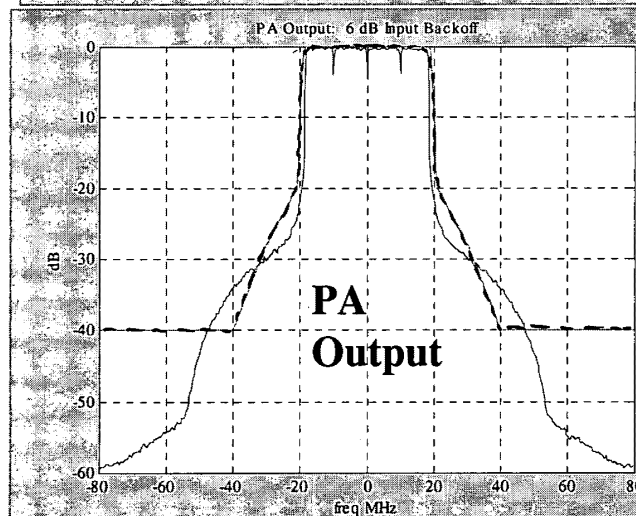
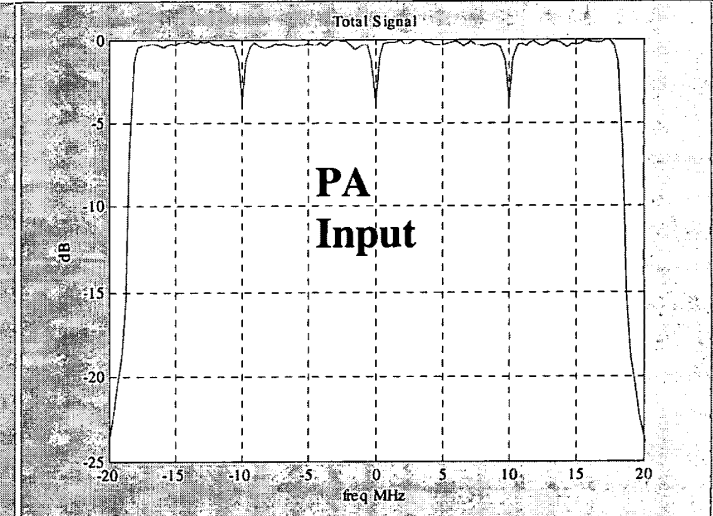
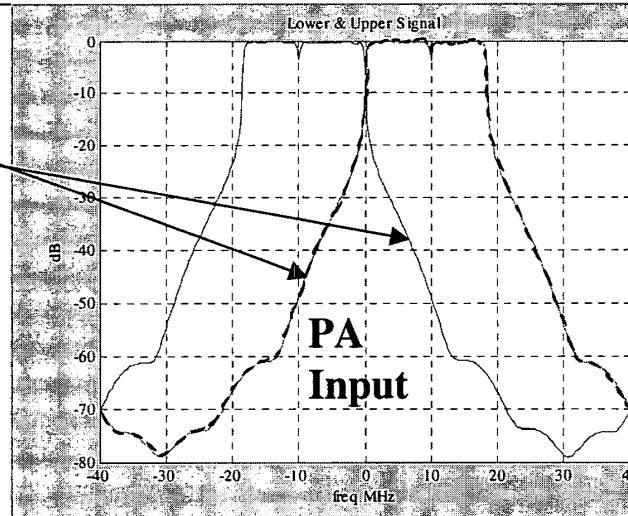
**This overlap
Generates no
Interference**





Add Filled-Gap OFDM Pre-PA 6 dB PA Input Backoff

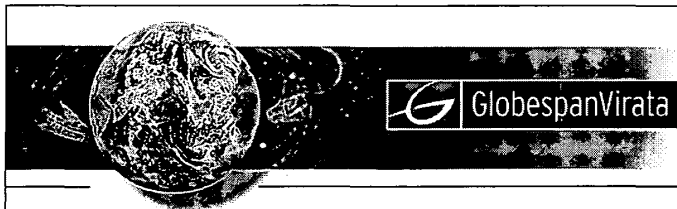
**This overlap
Generates no
Interference**





Dual Chain Transmit Summary

- This approach is straight forward and simple.
- Distortion (e.g., EVM) is low.
- Meeting spectral mask can be easier.
- Filled-gap OFDM is available.
- Alternative mode is available.



Filled-Gap OFDM
***Using Multi-chain Receiver and
20 MHz Channel Spacing and
No Frequency Offset Into Receive
ADC's Output***



This section concentrates on the filled gap mode.

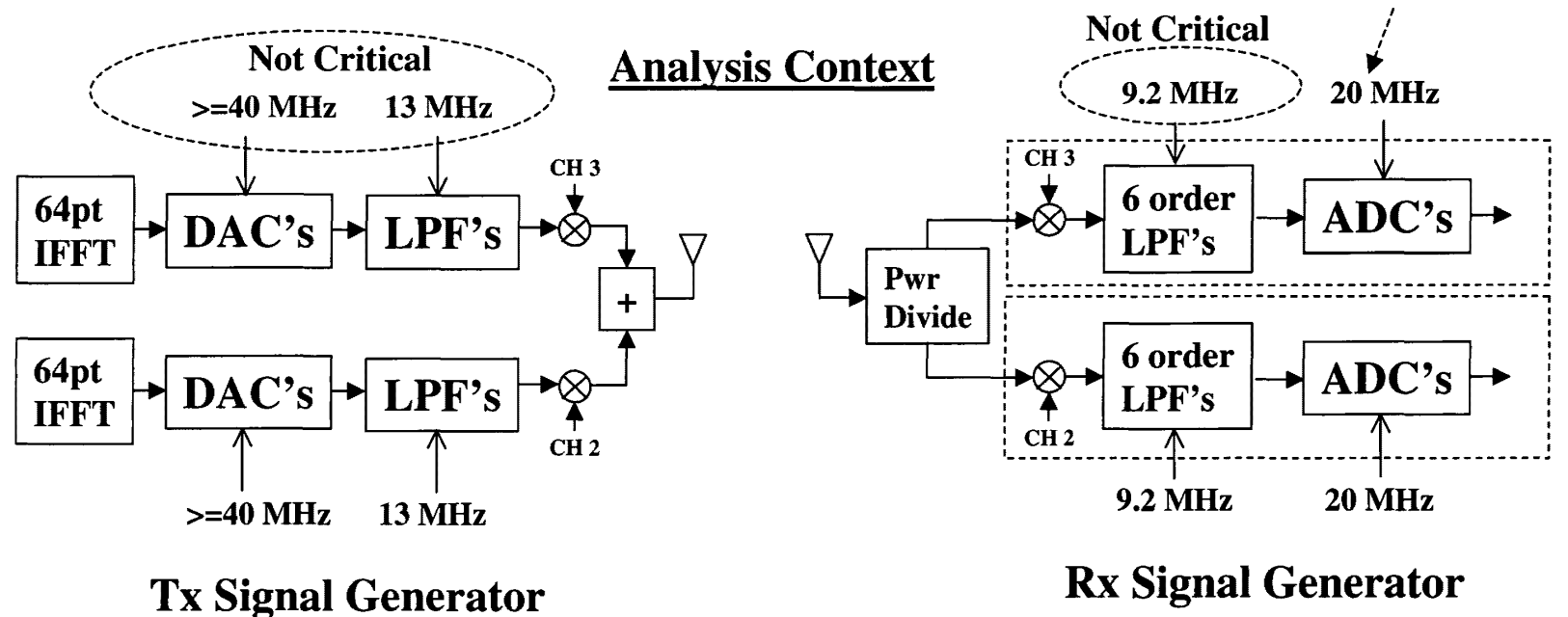
- If the gap is not filled, the situation is easier because the amount of aliasing is reduced.**

The technique extends straight-forward to the alternative mode.



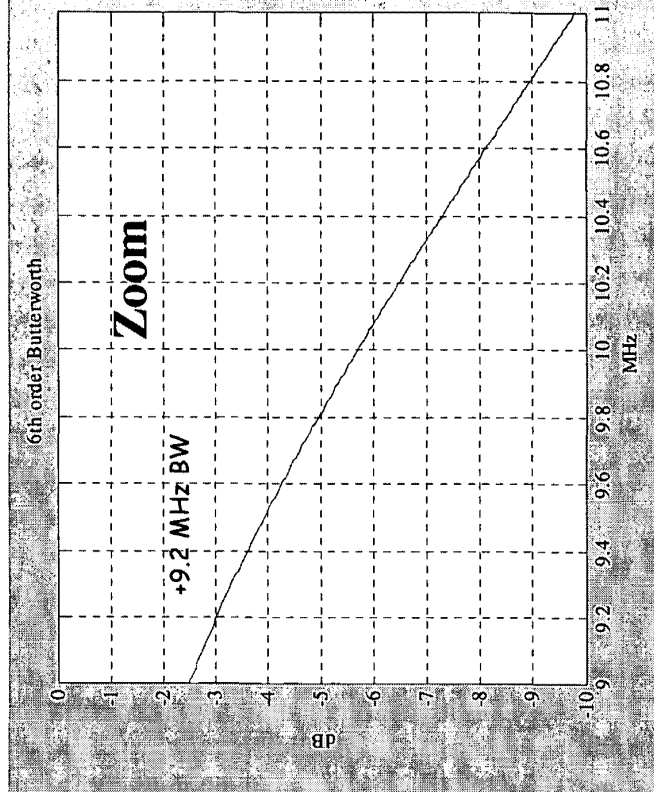
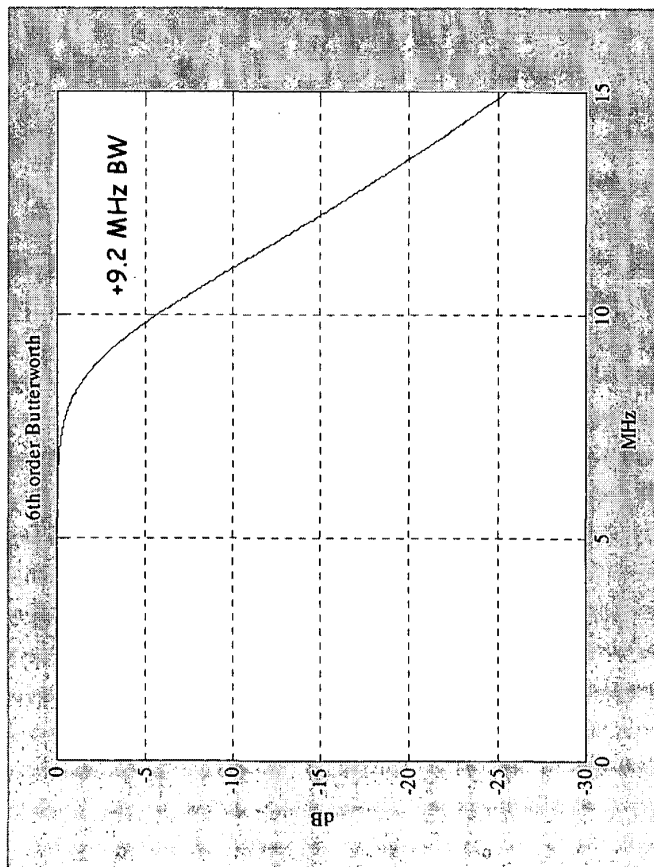
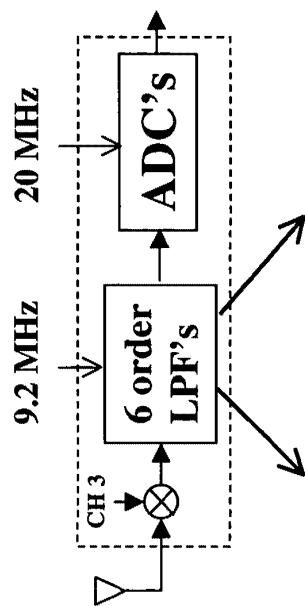
Two-Channel Receiver Thru ADC's

- Ostensibly no analog receive changes compared to what is currently used.
- Rx FEQ's combine overlap
- Signal separator needed for alias components



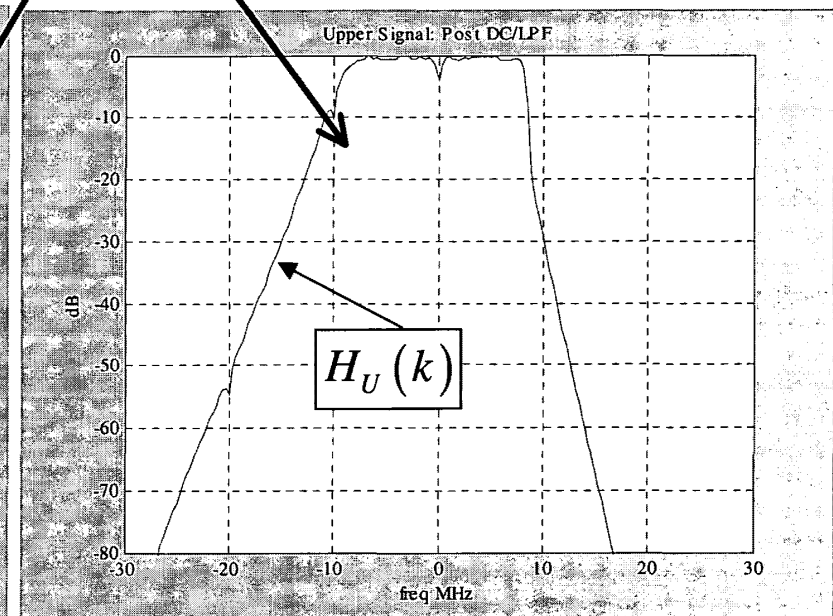
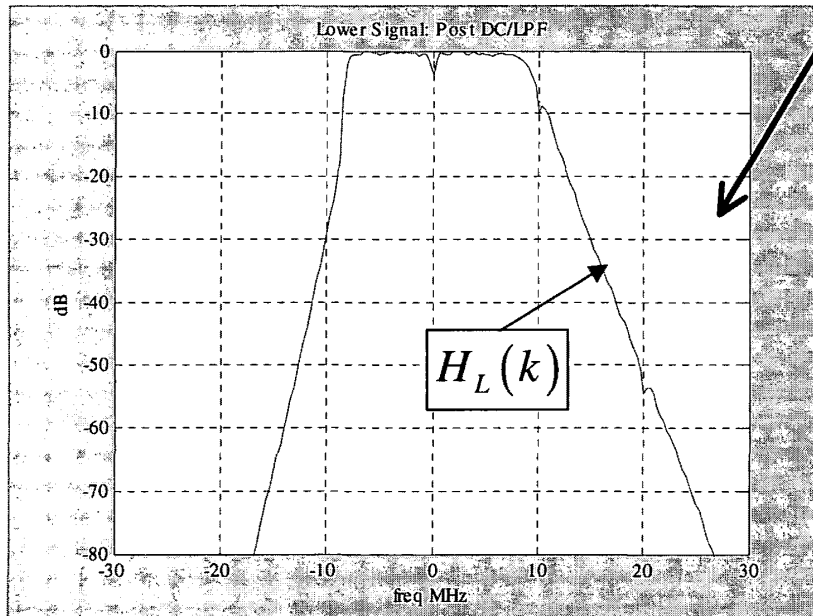
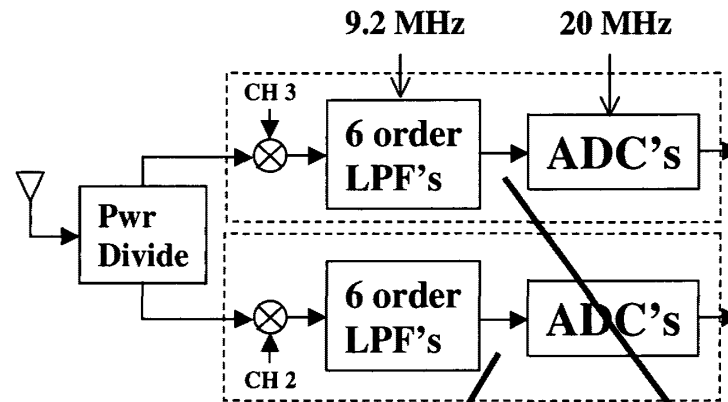


Analog Rx Filter *9.2 MHz 6th-Order Butterworth*



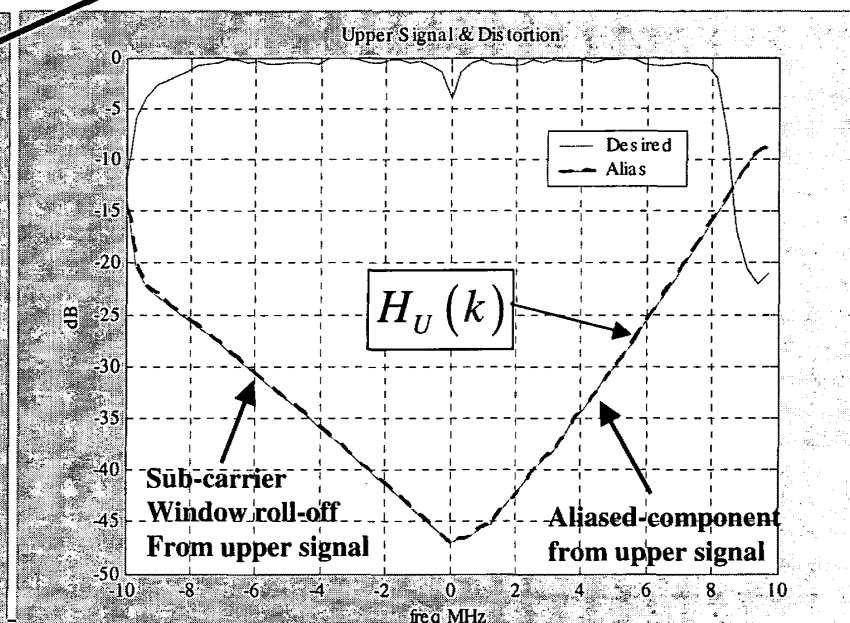
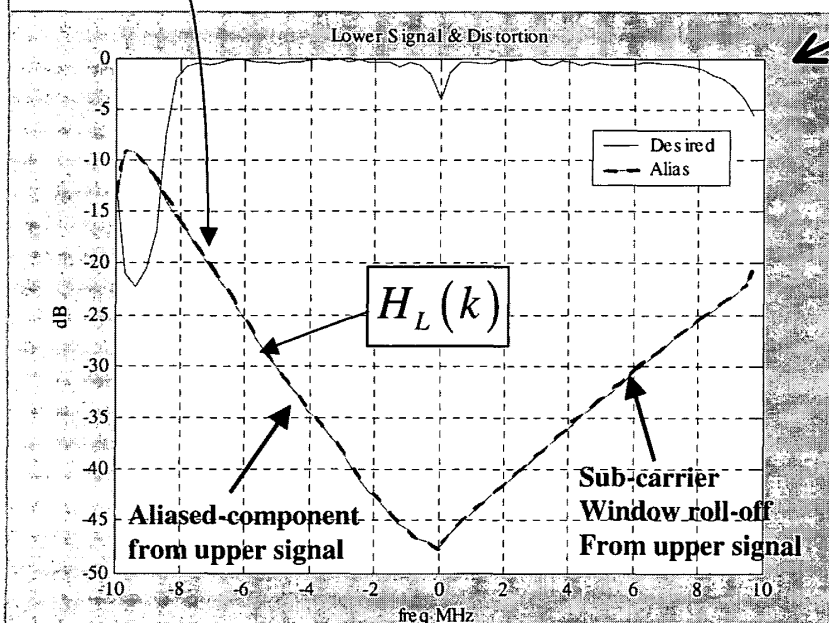
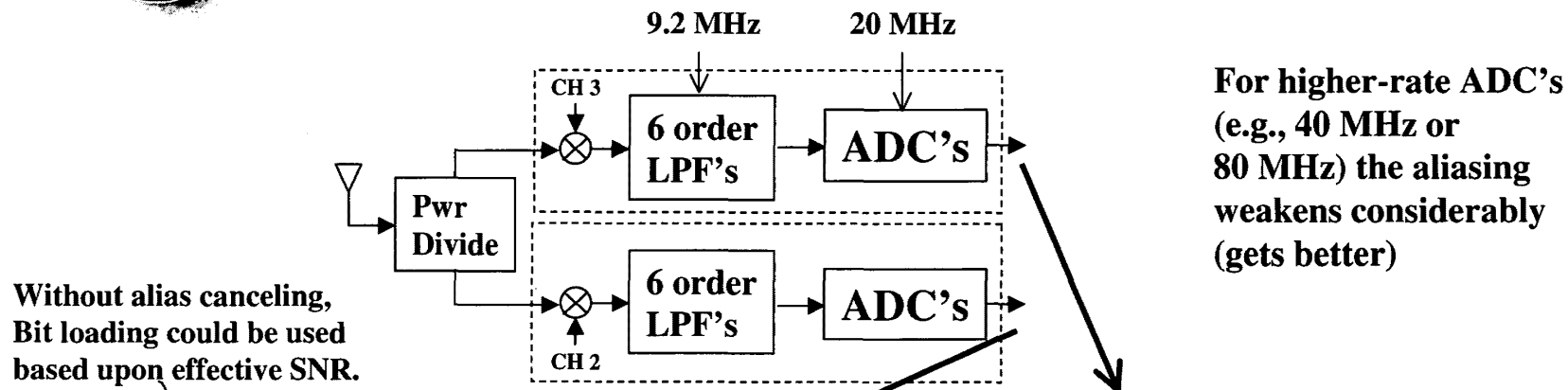


Filled-Gap Signals at Rx Butterworth LPF Output



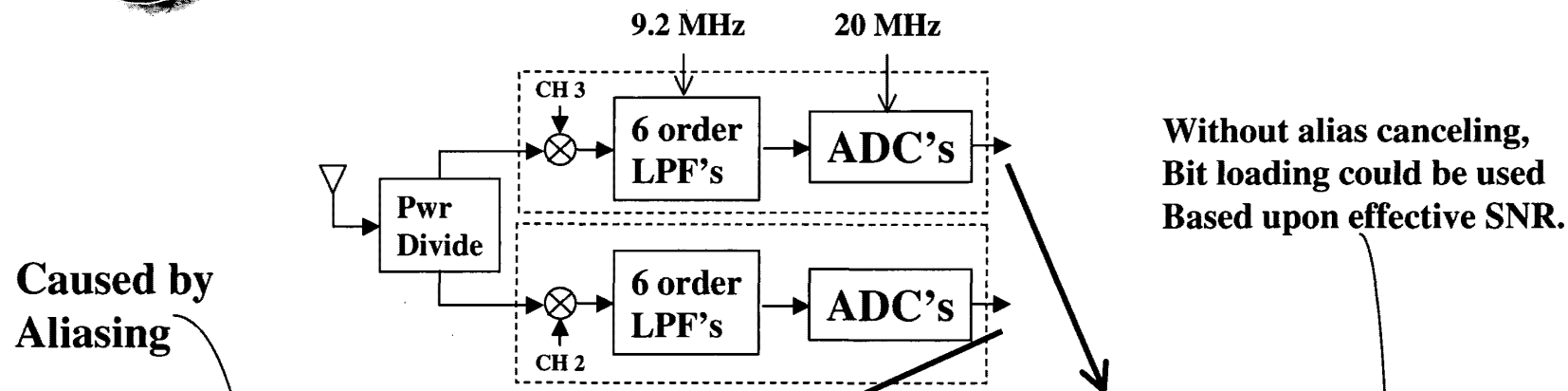


20 MHz ADC Output

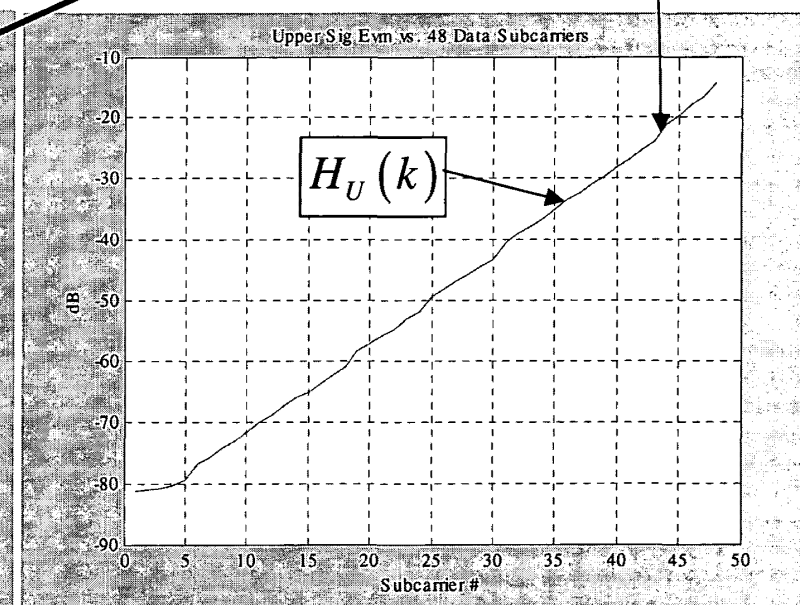
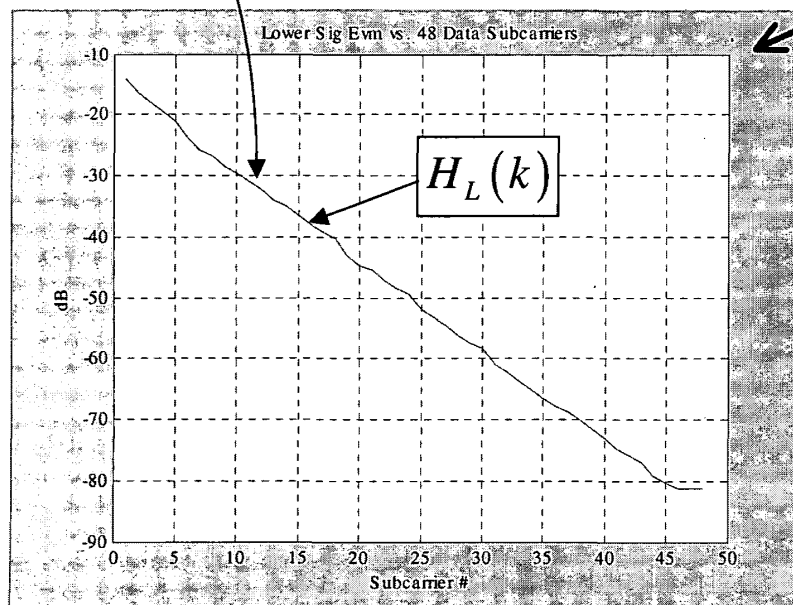




EVM Across 802.11a's 48 Data Subcarriers



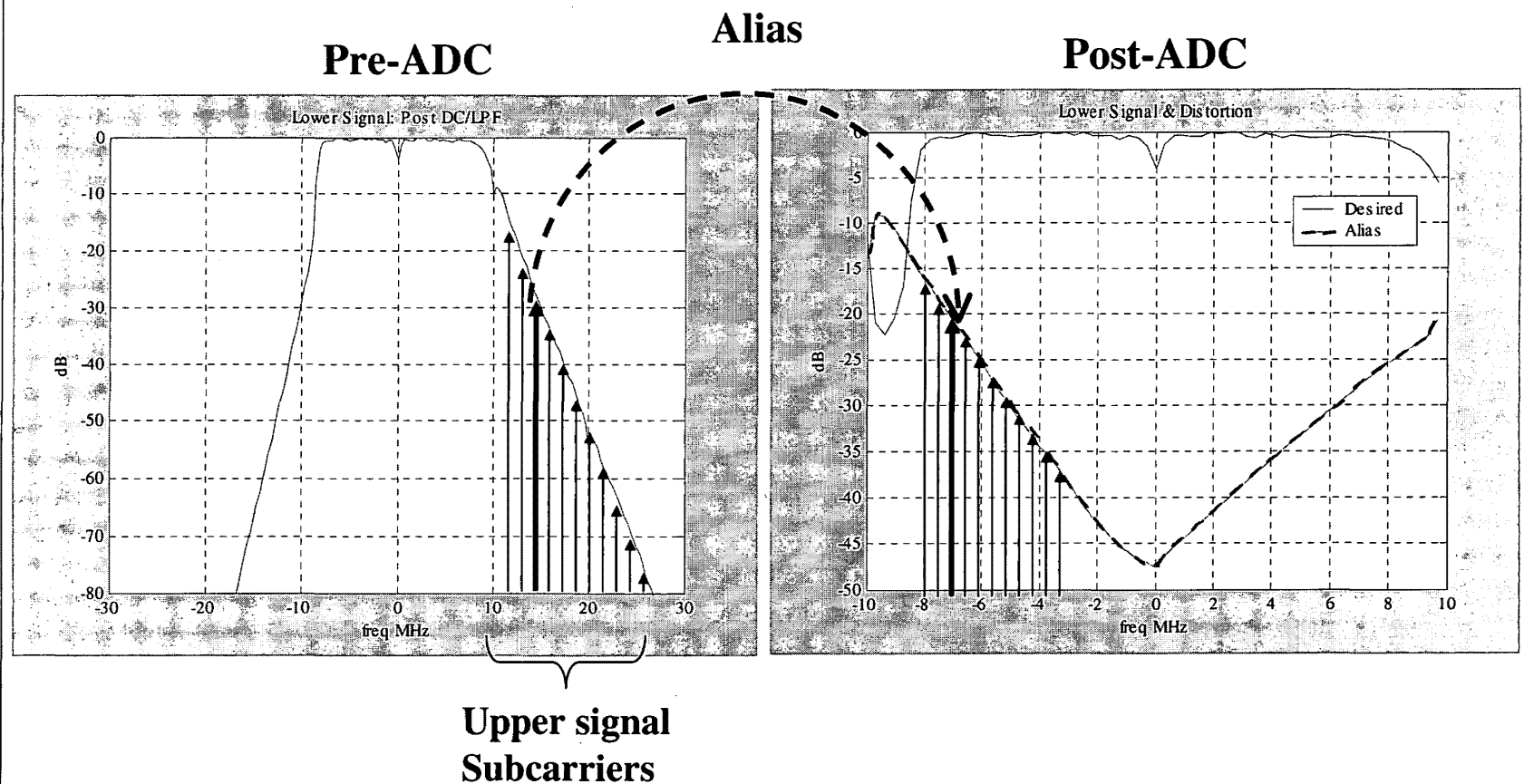
Caused by Aliasing





Subcarriers in Upper Signal Alias Into Lower Signal

No frequency offset into 20 MHz ADC's



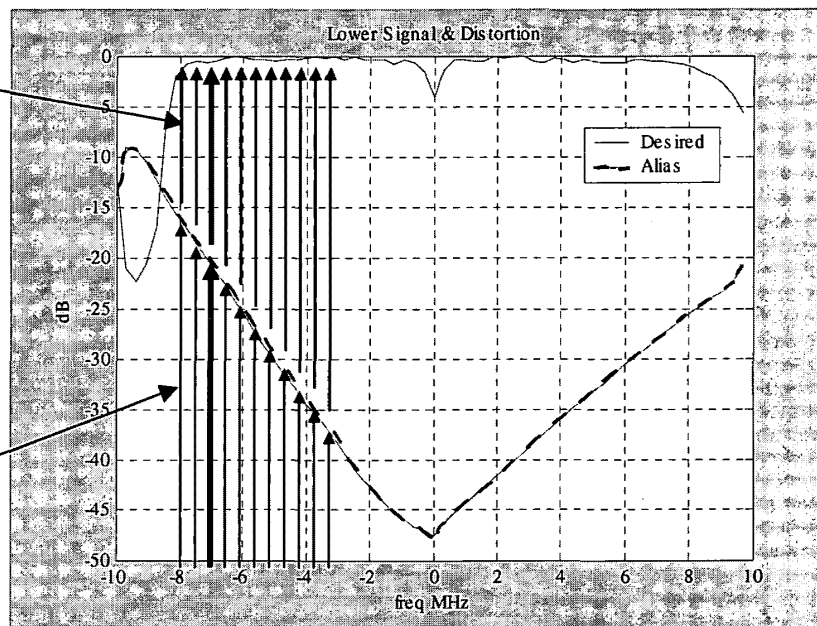


Aliasing with No Frequency Offset

**Desired
Subcarrier
Components**

**Undesired
Alias
Subcarrier
Components**

Post-ADC

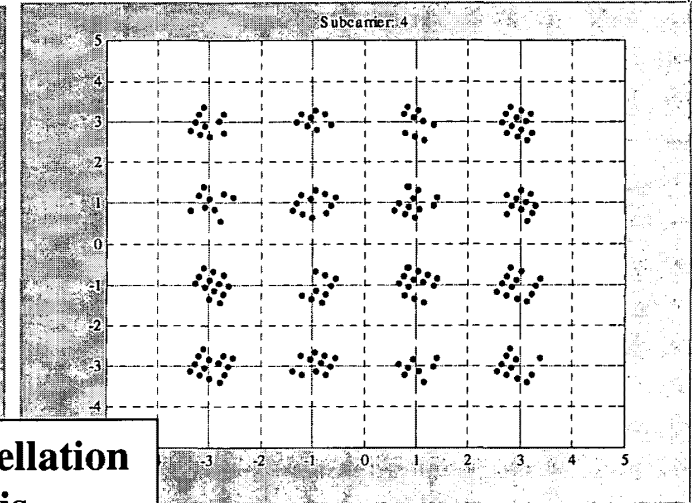
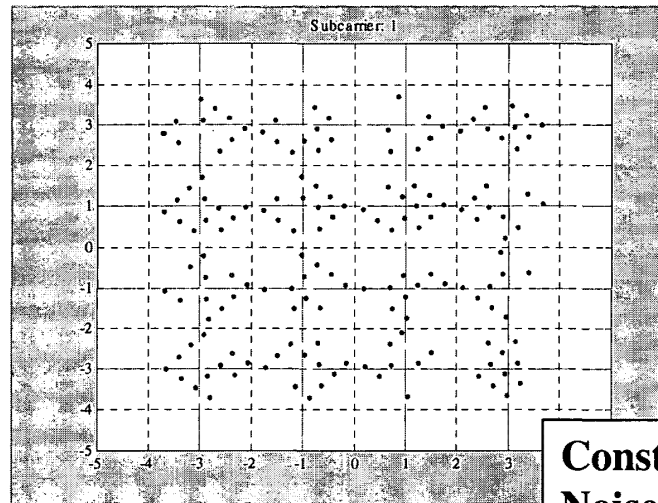




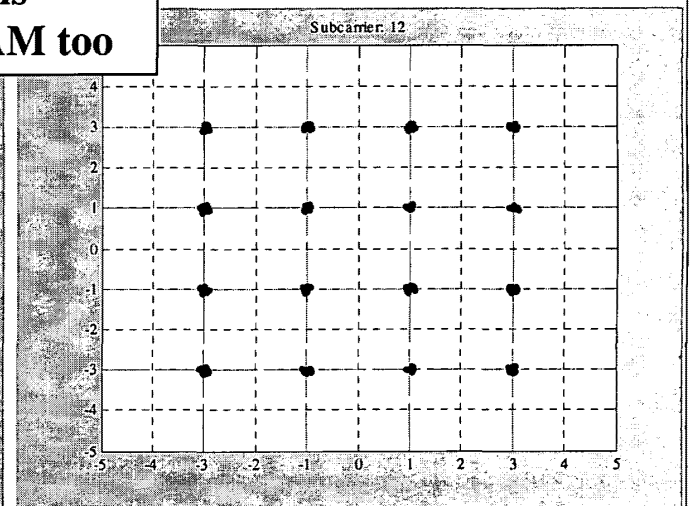
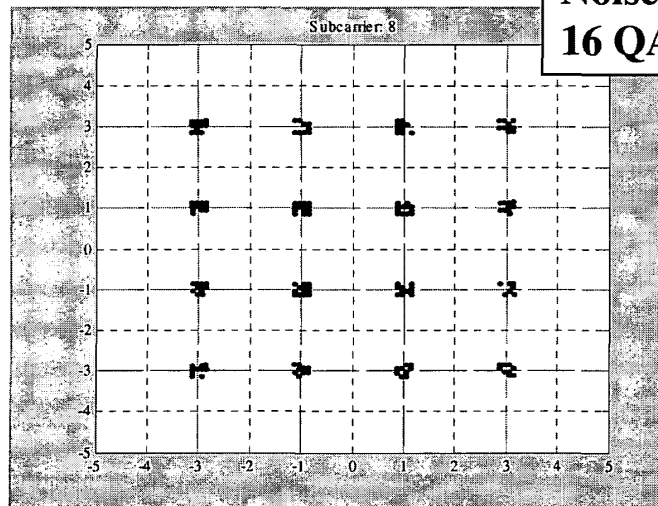
*With No Frequency Offset
16 QAM On Upper Signal Aliases
Exactly on Top of Lower Signal 16 QAM*

**Because there is
no frequency
offset**

**Note, with no
freq offset the
problem is easy.
Use upper signal
FFT output to
cancel aliasing
on lower signal!**

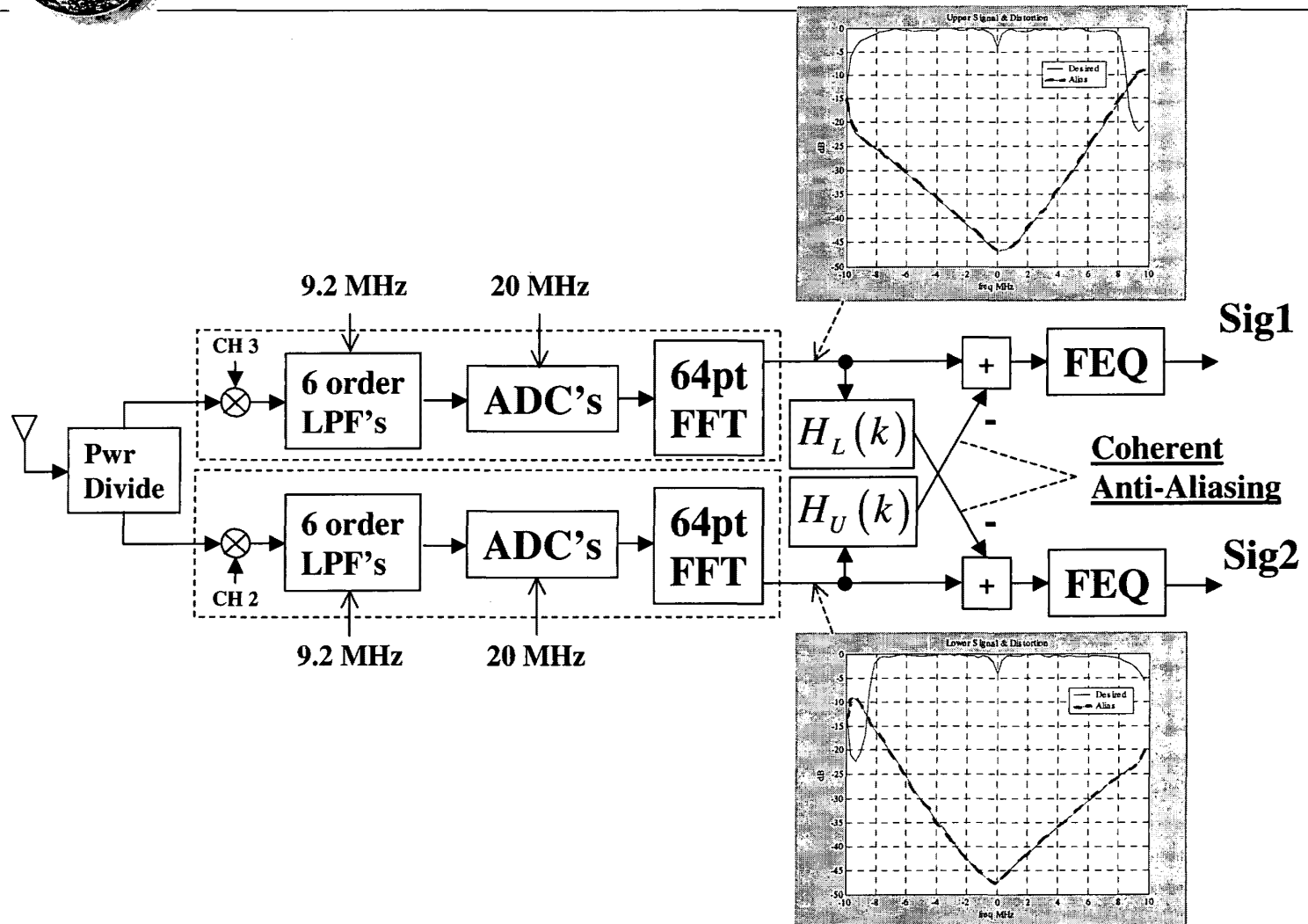


**Constellation
Noise is
16 QAM too**





Anti-Alias Two-Channel Receiver Frequency-Domain Adaptive Restore





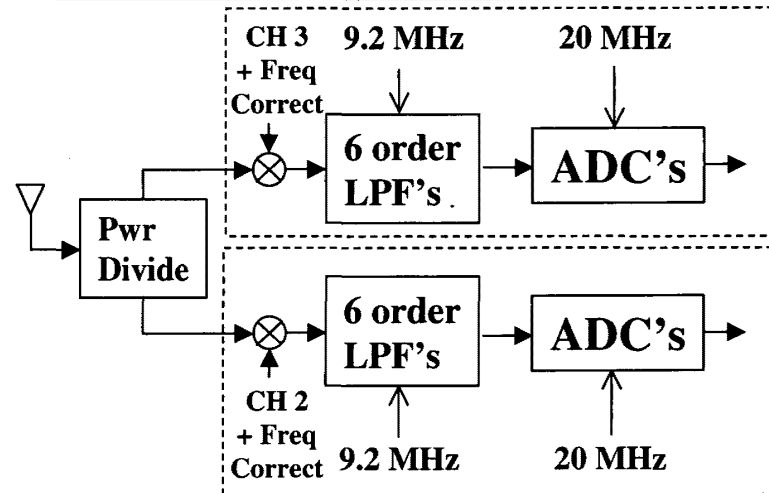
An Exemplary Radio Concept: Eliminate Freq Offsets at ADC's

- Pre-correct frequency offsets prior to Rx ADC's.
- Various methods with pros and cons:
 - For example, Frac-N (or other type of frequency synthesizer capable of high resolution frequency steps) may be used on transmit or receive.
 - 100 usecs settling time (can't be switched often)
 - In another example, Tx digital pre-correction may be implemented in RTL (e.g., a language used to describe digital circuits).
 - In another example, STA (or AP (e.g., access point in a WLAN c II)) may be implemented to do all the work on downlink from AP to STA (D/L) & uplink from STA to AP (U/L).
- For transmit pre-correction, PPM offset may be communicated for time tracking to a receiver.
- Freq offset elimination management may be simplified if wide packets are sent using D/L.
 - For example, if normal channel packets for ACK are used, then no U/L pre-correction needed.

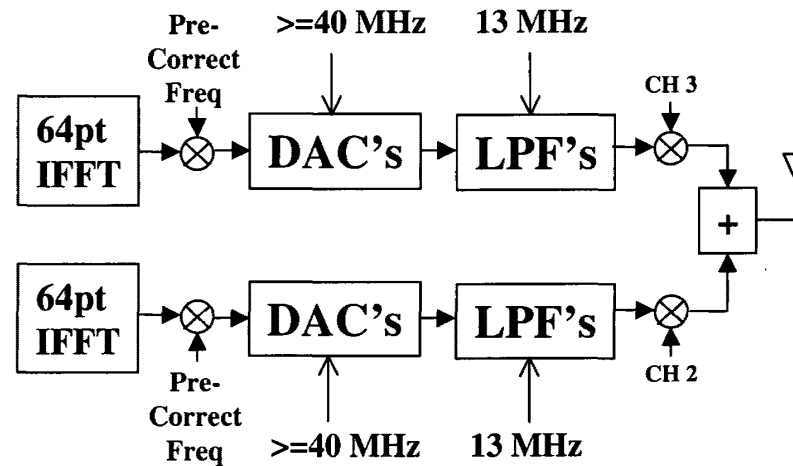


Two ADC Freq-offset at ADC Correction Techniques

Receive Side

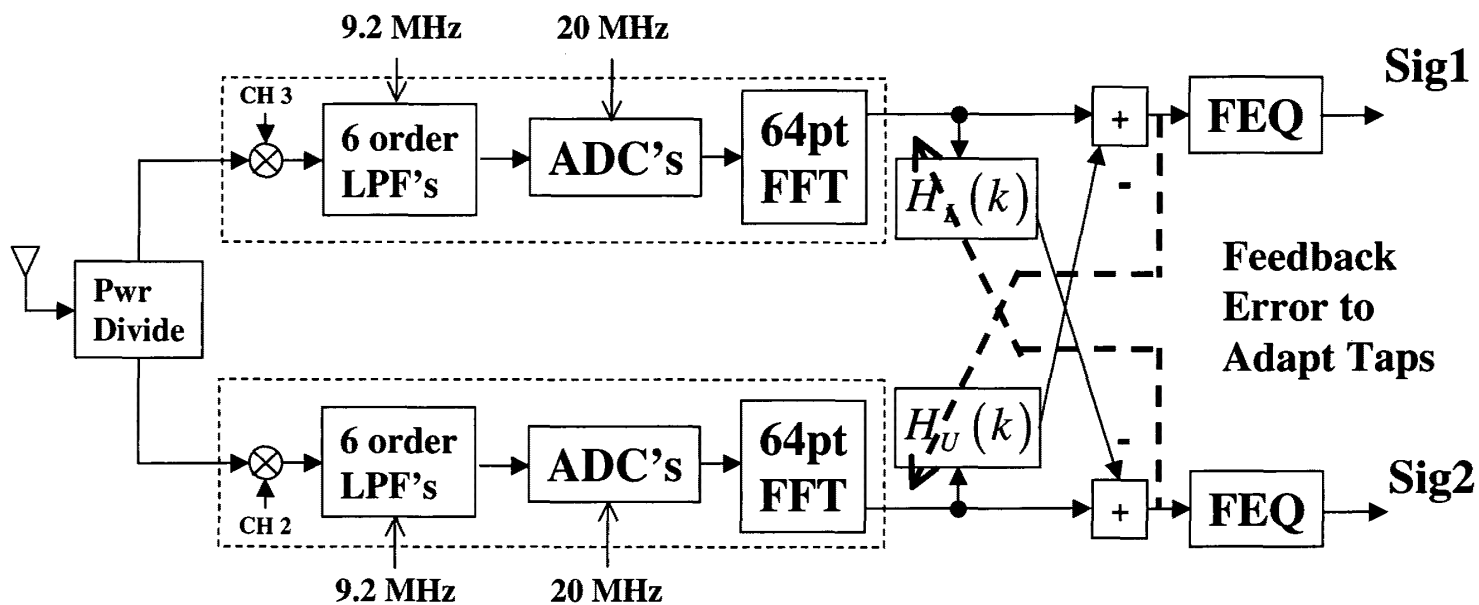


Transmit Side





Adaptation Feedback Error: Tracking on Signal





Adaptation Algorithm

- Various adaptation techniques may be implemented.

For example, the least-mean-squared (LMS) technique may be used.

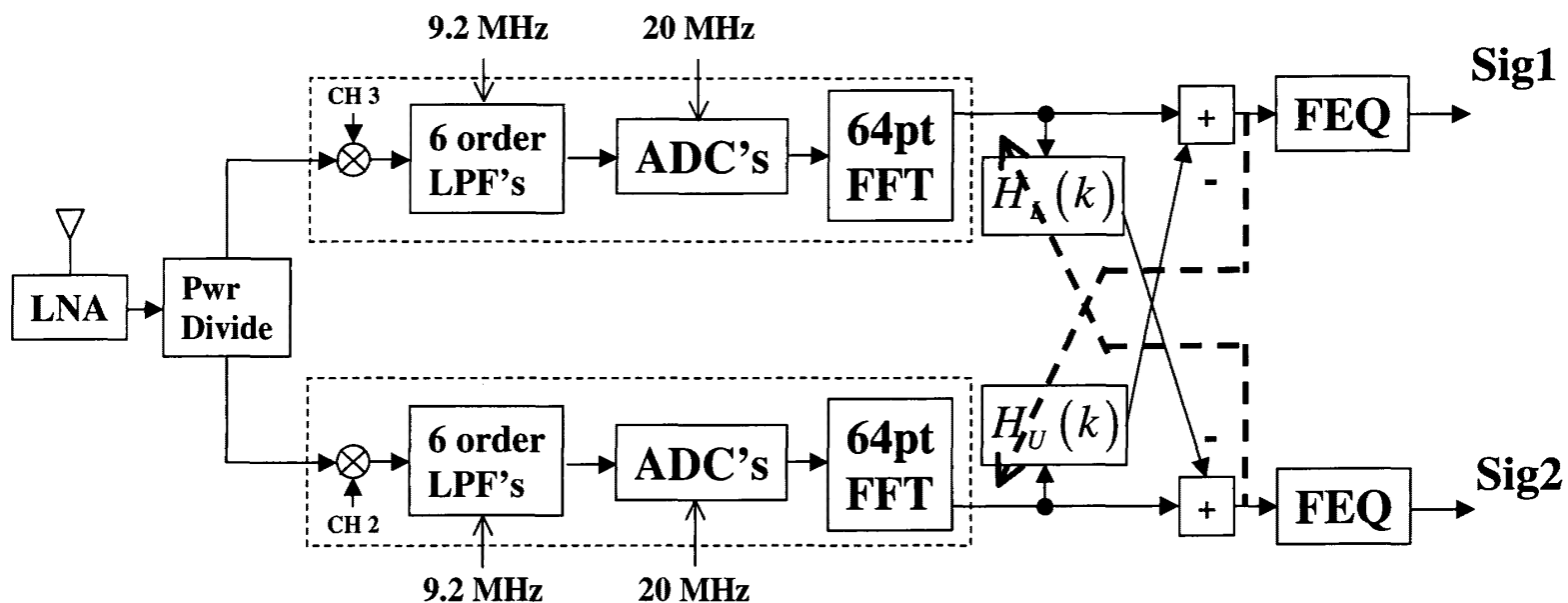


Adaptation: Acquisition/Tracking on Noise

Any signal common to both Rx chains may be used to train/track anti-alias.

Desired packets

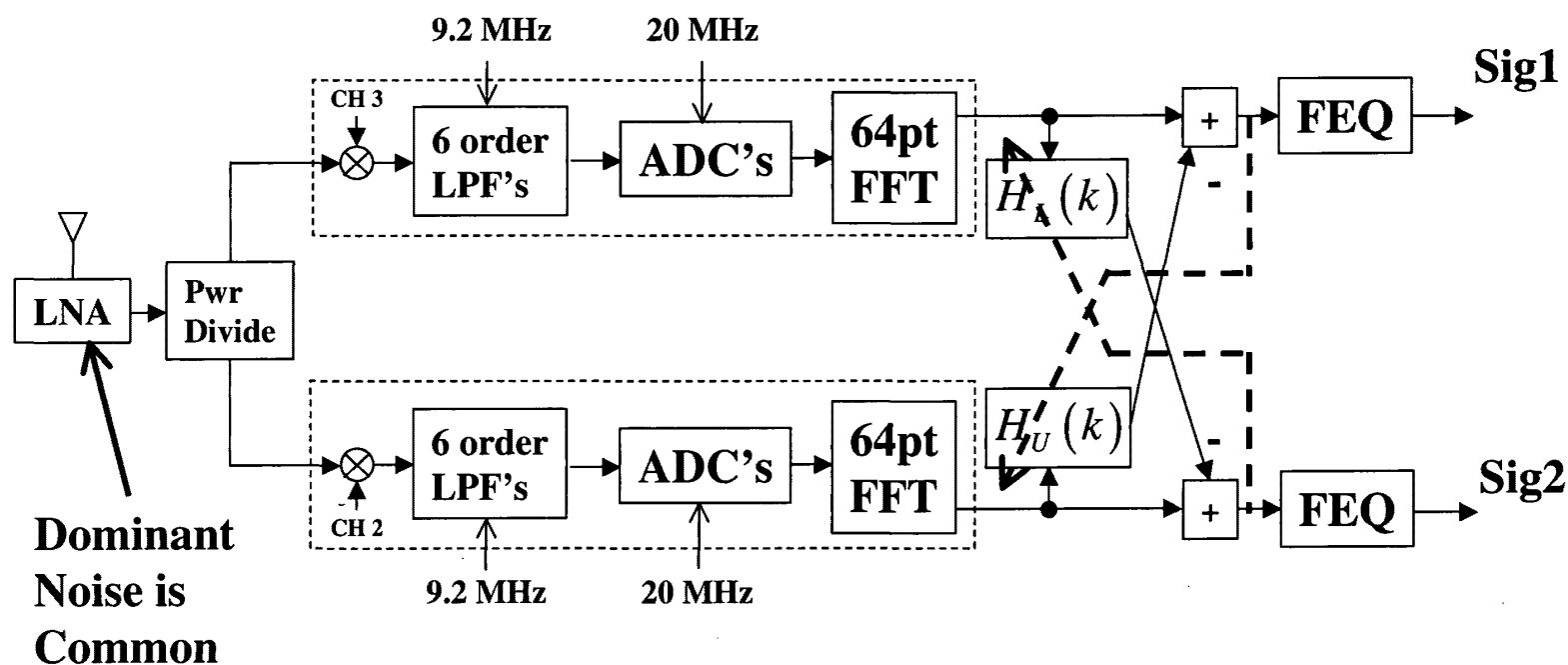
Noise





Adaptation: Acquisition/Tracking on Noise

- If dominate noise is common to both chains, the noise can be used to adapt the taps.





Special Preamble (Training waveforms)

- An embodiment of the present invention may involve defining a special signal that may be used to train (e.g., bootstrap) the anti-alias canceling circuit.
- This waveform could be used in various formats, including the following:
 - In a preamble
 - A broadcast beacon from AP
 - Embedded periodically in signal
 - Etc.
- A suggested waveform may involve using an interleaved subcarrier pattern relative to upper/lower signals.
 - This may be extensible to more than two channels.
 - The pattern is flexible.
 - A key concept:
 - Do not transmit concurrently BOTH the upper and lower subcarriers with the same index number.

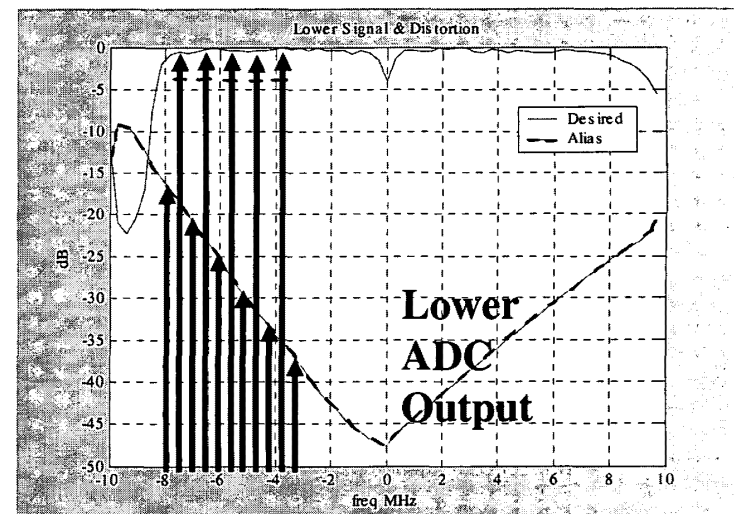
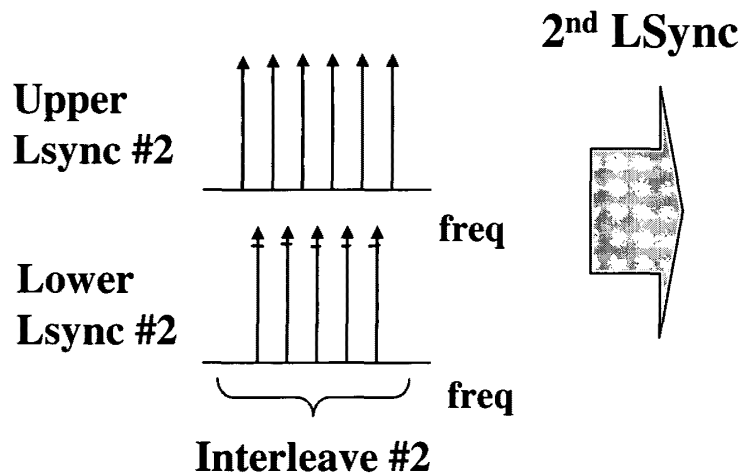
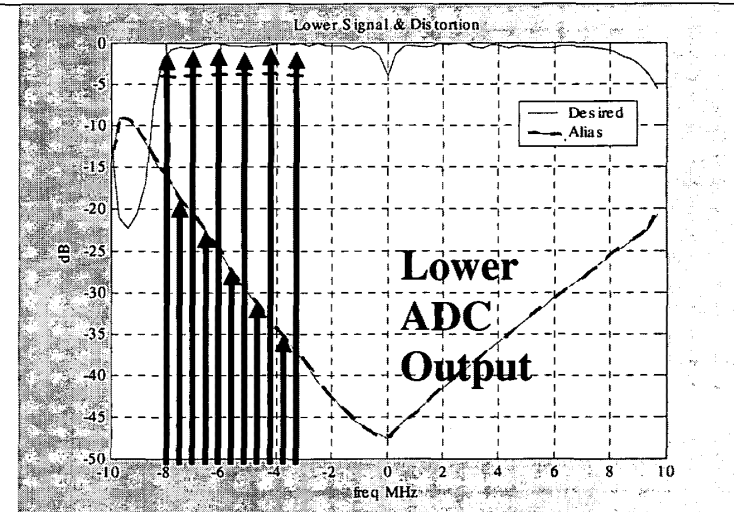
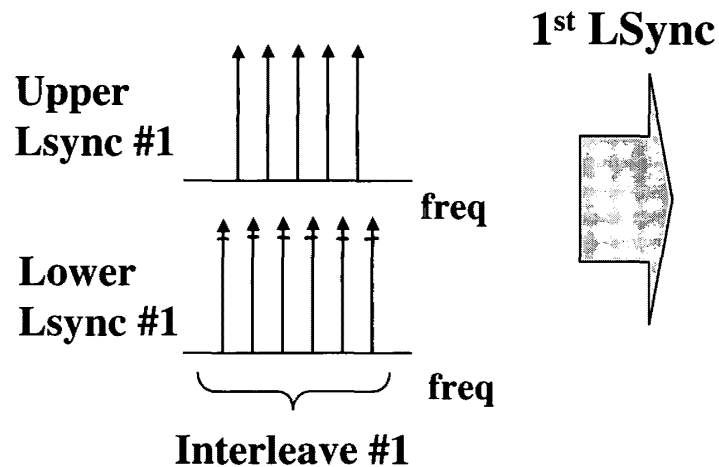


Special Training: Interleaved Subcarriers

- **Step 1:**
 - Lower signal transmits using odd numbered subcarriers
 - Upper signal transmits using even numbered subcarriers
 - **Step 2:**
 - Lower signal transmits using even numbered subcarriers
 - Upper signal transmits using odd numbered subcarriers
- Receiver may measure the alias this way**



Acquisition with Special Two-Symbols Long Sync (Lsync)





*Issue with Sending or Receive
Upper/Lower Signals with
Separate Antennas and 20 MHz ADC's*

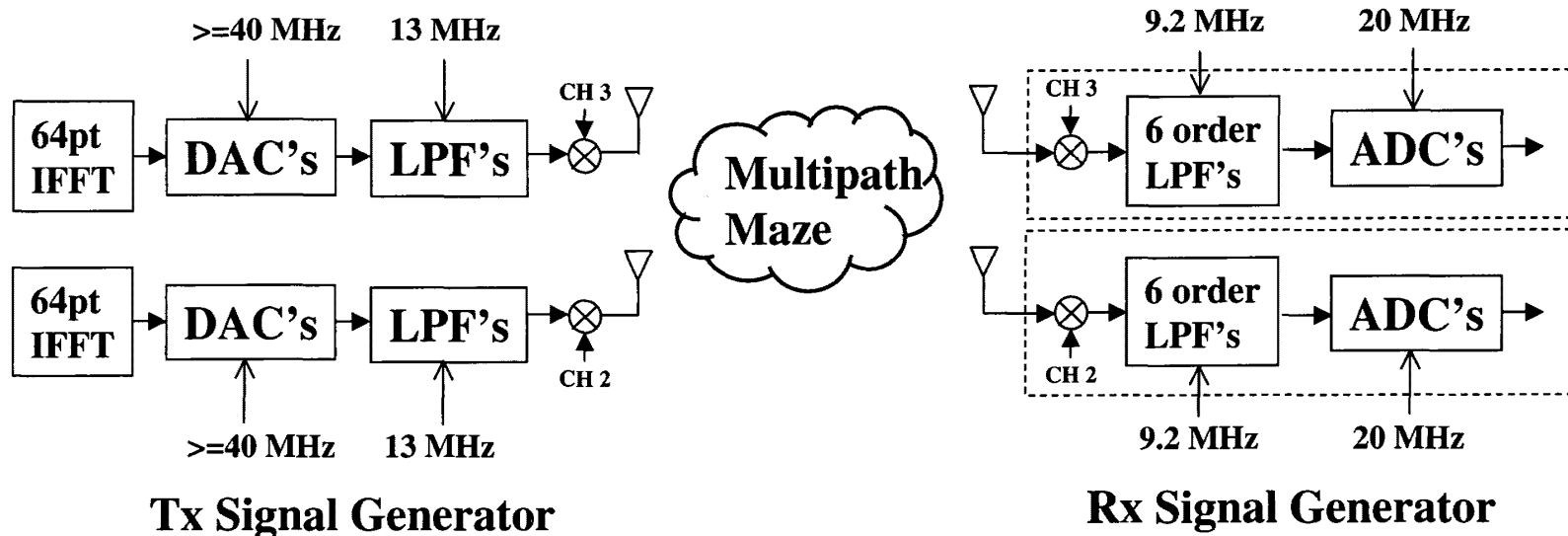


Using Separate Antennas with Two Channels

- **Easiest exemplary situation:**
 - The transmitter has one antenna.
 - The receiver has one antenna.
 - Signal components multipath fade in unison where upper and lower signals tend to have same (or similar) power level.
- **Harder exemplary situation:**
 - The transmitter has two antennas.
 - And/Or, the receiver has two antennas.
 - Signal components multipath fade independent where upper and lower channels may differ in power level.
- **Impact of harder exemplary situation:**
 - Dynamic range requirements increase for receiver's anti-aliasing circuit.
 - Preamble training pattern is more essential.

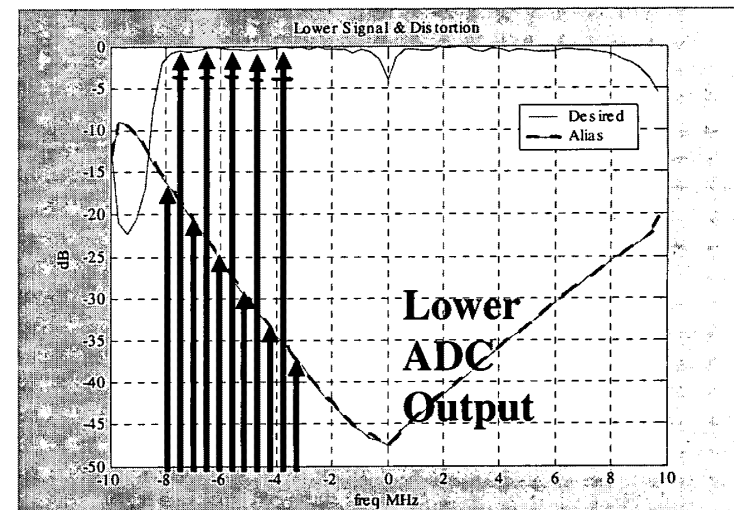
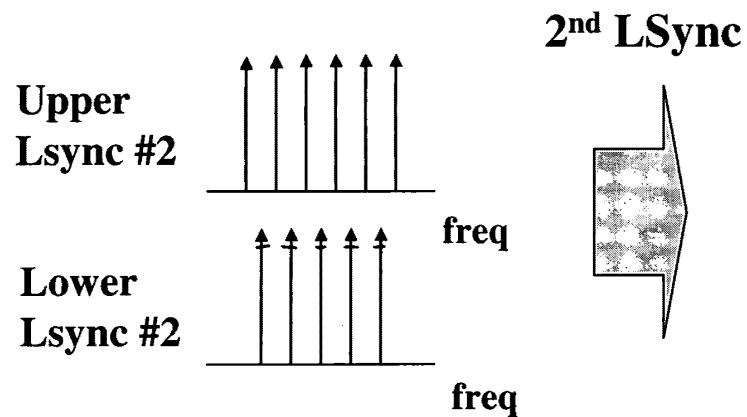
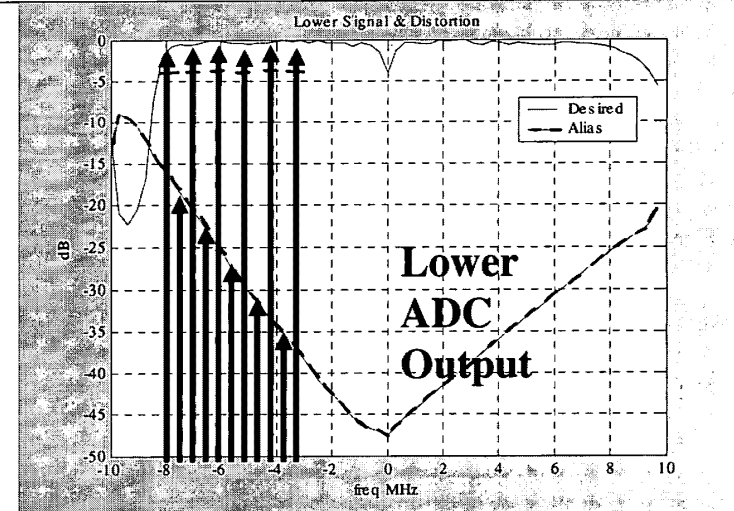
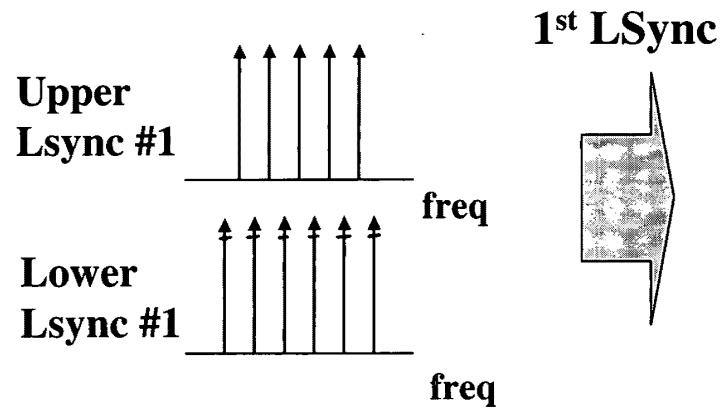


- Radio Set-up: either Tx has separate antennas or Rx has separate antennas or both.
- Problem: Fading is "independent" between Tx-Rx pairs.
 - Power difference between upper and lower signal (ACI)
 - Spectrum difference between upper and lower signal
 - Tend to lose aliasing visibility with 20 MHz ADC's
 - Every different for every AP-STA radio-pair
 - Exemplary Solution: Use XBW only on D/L to STA





Acquisition with Special Two-Symbols Long Sync





What Happens with Freq Offset?

- Frequency offset may be avoided in this architecture.
- With no frequency offset, each upper signal subcarrier aliases exactly on a corresponding lower signal subcarrier.
 - An interference subcarrier may leak onto exactly one desired subcarrier.
 - Exploits the orthogonal nature of OFDM.
- With frequency offset, alias subcarriers fall "in-between" desired subcarriers.
 - One interference subcarriers may leak onto many desired subcarriers.
 - There are many interference subcarriers.



Rx Alternative Mode for 20 MHz Channels

- All the previous comments/architectures apply to the alternative mode.
- More subcarriers may be used to increase the data rate.
- All the Tx and Rx techniques carry over directly.
- Also, works for 25 MHz channel spacing at 2.4 GHz and other specifics.



*OFDM with
25 MHz Channel Centers
(Situation with 802.11g 2.4 GHz)*



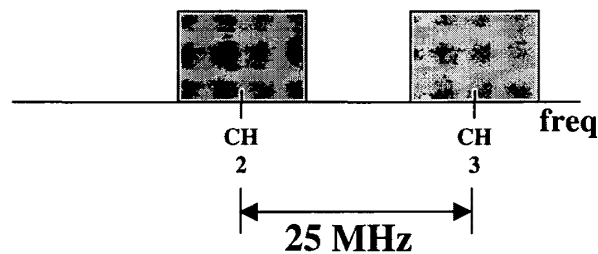
25 MHz Three Signal Cases Under Consideration

3 Spectrums

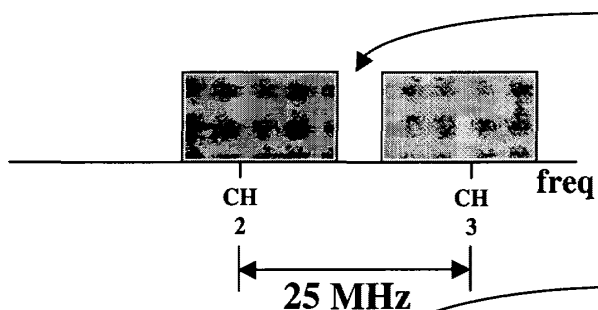
Provides same data rates as
equivalent 20 MHz cases

CASE 1
Two 802.11g

Two 1x chan's

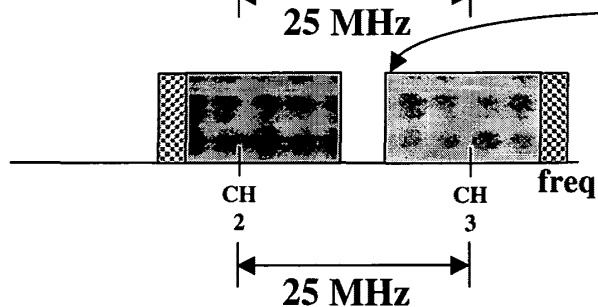


CASE 2
Filled-Gap
OFDM



Fill gap as much
As possible
(equiv to 20 MHz case)

CASE 3
Alternative Mode
OFDM



Use all usable
Points in FFT
Across 2 channels

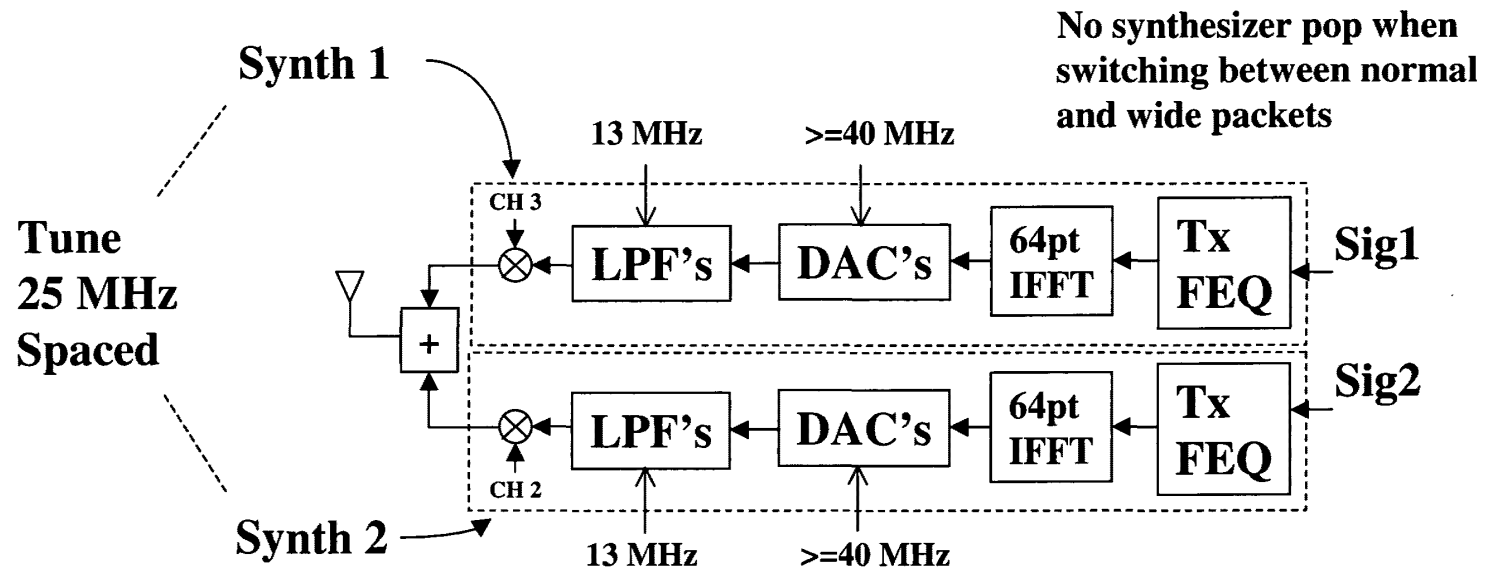


Transmitter with 25 MHz Channels



Two-Channel Transmitter

- A difference is the synthesizer tunes to 25 MHz spacings. The synthesizer may tune to other spacings as well.

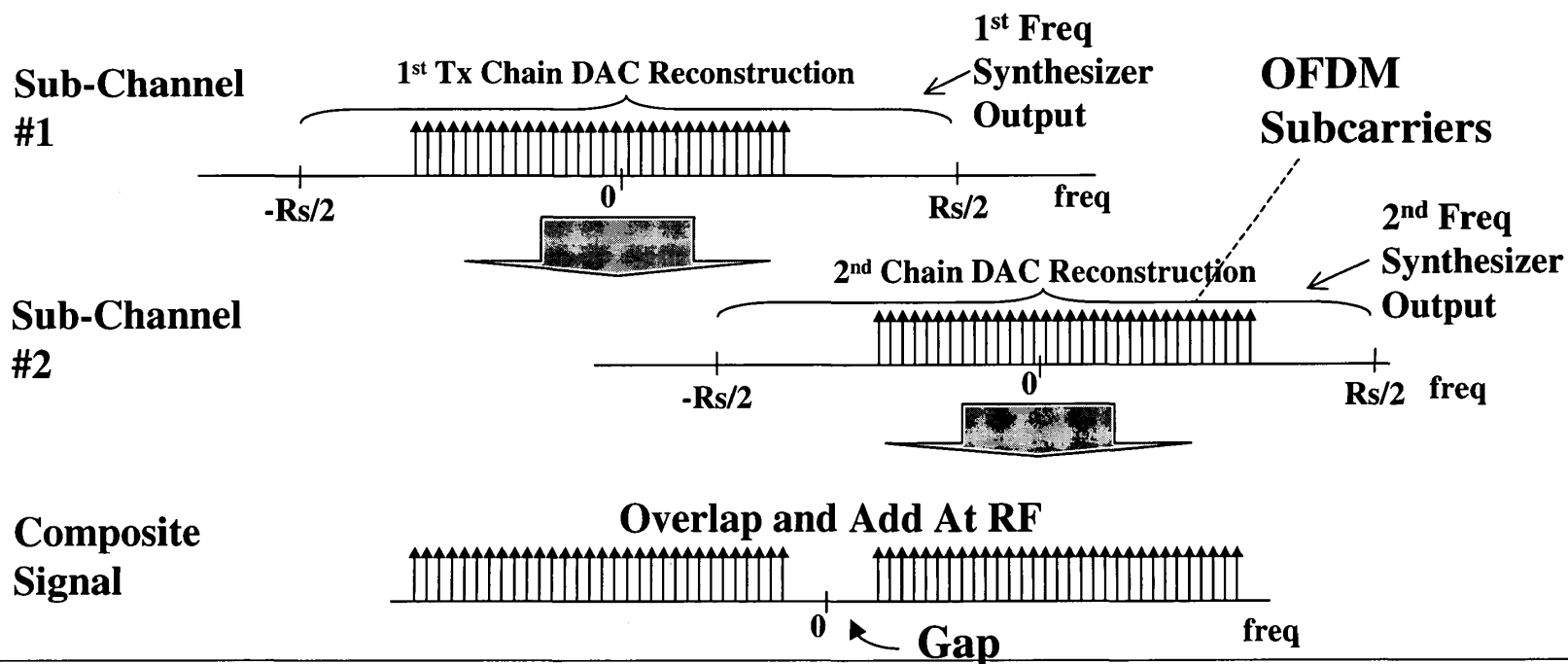




Two 802.11g Signals with Two-Channel Transmitter?

Overlap-and-add at RF for 25 MHz spacings

- Generate lower $\frac{1}{2}$ spectrum in 1st Tx chain
- Generate upper $\frac{1}{2}$ spectrum in 2nd Tx chain
- Add to signal at RF
 - Either pre-single-PA or post-two-PA's



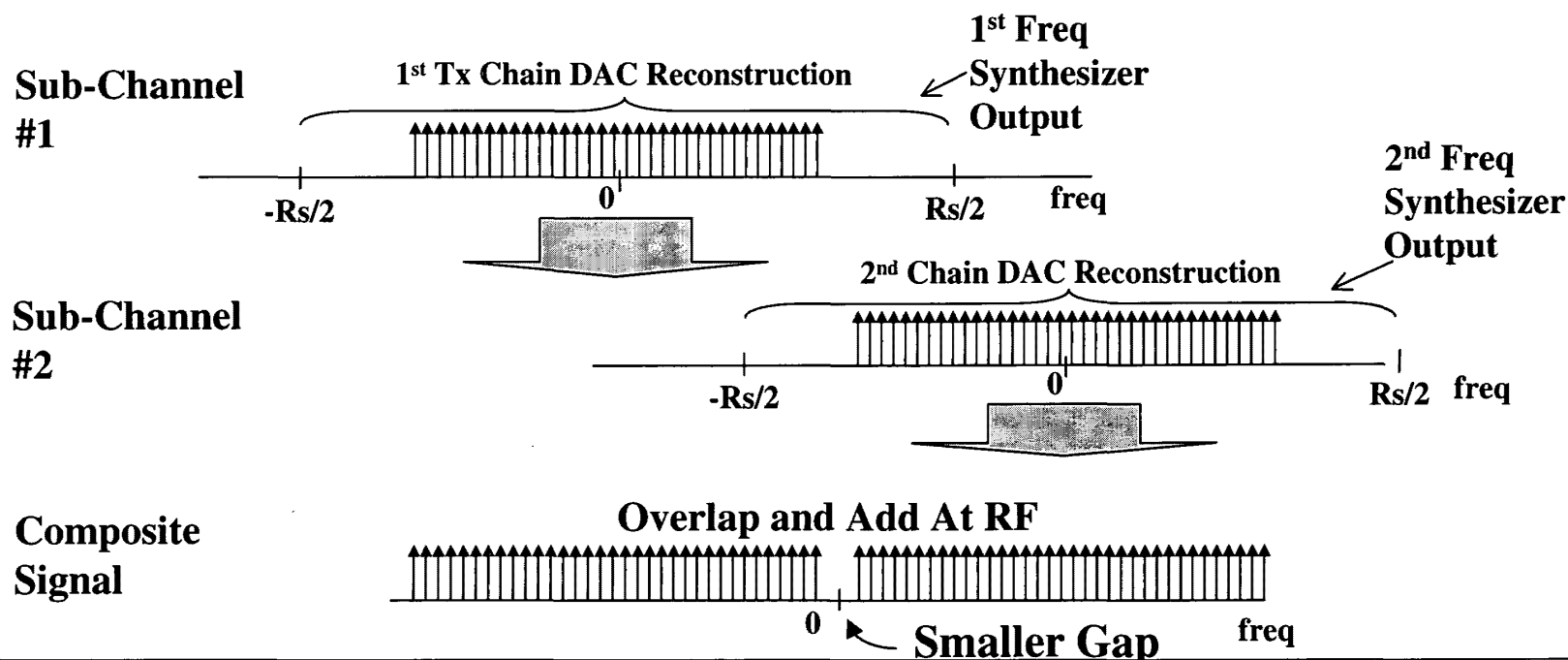


How Can Gaps Be Plugged With Two-Channel Transmitter?

Overlap-and-add at RF for 25 MHz spacings

- Generate lower $\frac{1}{2}$ spectrum in 1st Tx chain
- Generate upper $\frac{1}{2}$ spectrum in 2nd Tx chain
- Add to signal at RF
 - Either pre-single-PA or post-two-PA's

**Smaller
Filled-Gap
OFDM**





Filled-Gap OFDM
25 MHz Channel Spacing
No Frequency Offset Into Receive
ADC's Output



Receive 25 MHz Spaced

Relatively nothing changes.

Anti-aliasing circuits works on aliasing about 25 MHz centers.

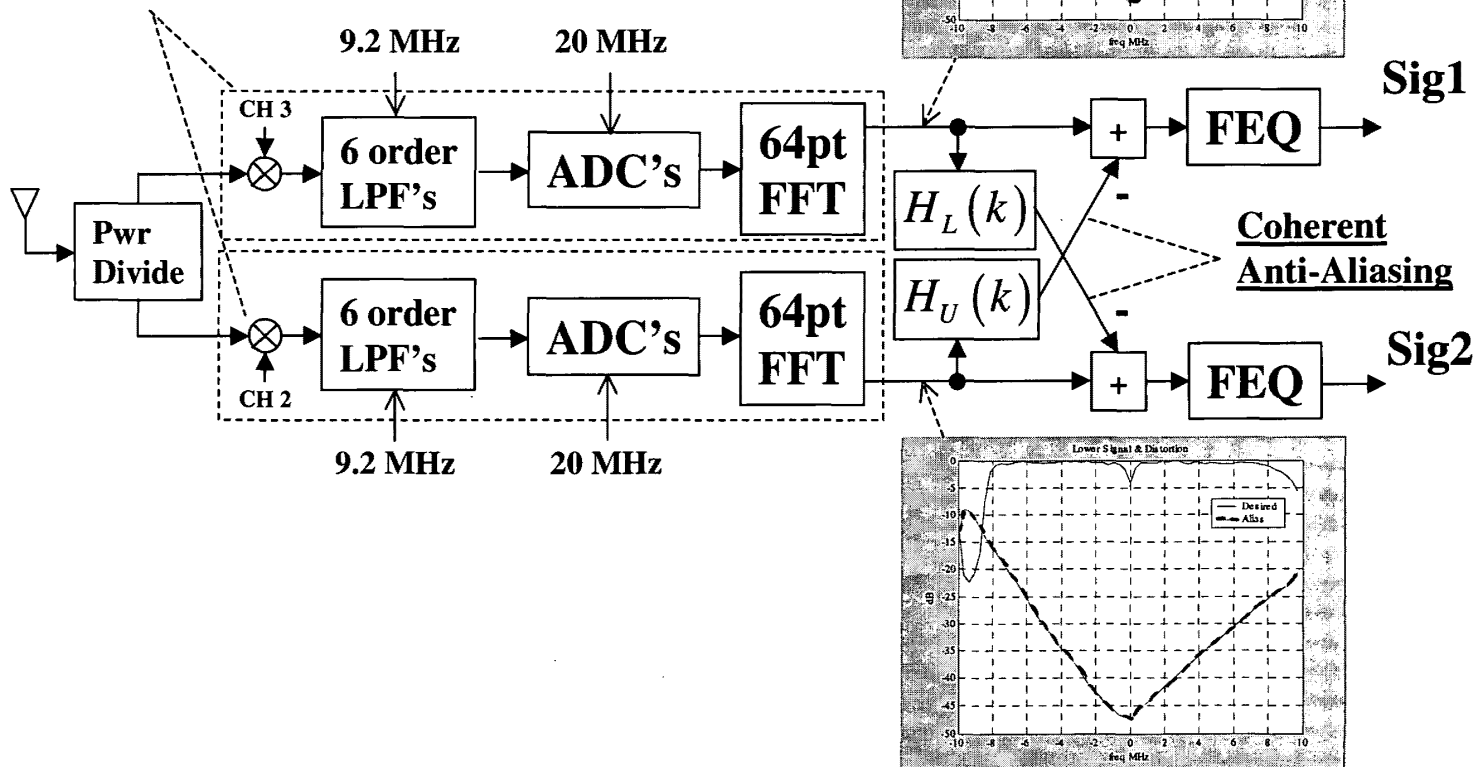
Circuit applies.

- **Hardware is the same (or similar) for the 20 MHz case.**



Anti-Alias Two-Channel Receiver Frequency-Domain Adaptive Restore

**Tune
25 MHz
Spaced**





*What Other Channel Center Frequencies and
ADC Rates are Possible for this Frequency
Domain Anti-Alias Technique
to Work?*

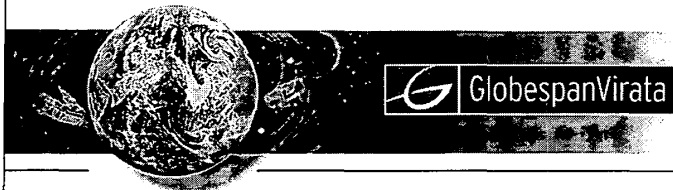


Summary of Earlier Conclusions

The earlier sections have shown how to cancel aliasing distortion in the frequency domain (at FFT outputs) caused by using multiple narrow receivers on a wide OFDM signal.

- No frequency offset was assumed at ADC input.
- 20 MHz channel centers for 5.8 GHz was mentioned with 20 MHz ADC.
- 25 MHz channel centers for 2.4 GHz was mentioned with 20 MHz ADC.

In all these cases, the out-of-subband alias OFDM subcarriers fall directly on top of in-subband desired OFDM subcarriers



Other channel centers and ADC rates are possible with this technique

- Any channel-center/ADC pair works if
 - The out-of-subband alias OFDM subcarriers fall directly on top of in-subband desired OFDM subcarriers.

For example, the 802.11 OFDM subcarriers are spaced by $20 \text{ MHz}/64 = 312.5 \text{ KHz}$.

- Hence, any ADC rate which is an integer multiple of 312.5 KHz has this property.
- Any channel center that is an integer multiple of 312.5 KHz is possible.
- Note, 20 MHz and 25 MHz channel centers satisfy this requirement (as discussed in earlier sections).



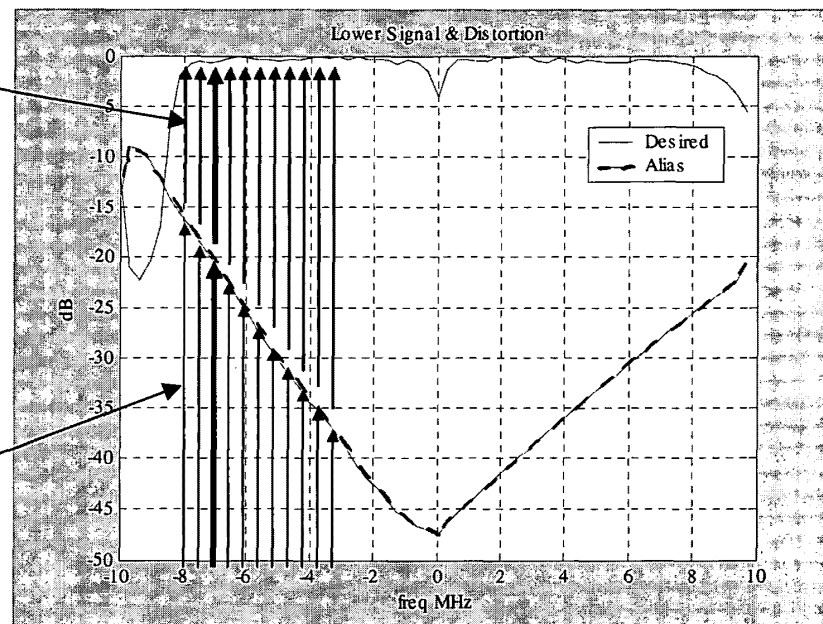
Fundamental Requirement

Alias Components Fall on Top of Desired Components

Desired
Subcarrier
Components

Undesired
Alias
Subcarrier
Components

Post-ADC





Non-Coherent Adaptive Techniques



- This section explores other techniques for canceling aliasing.

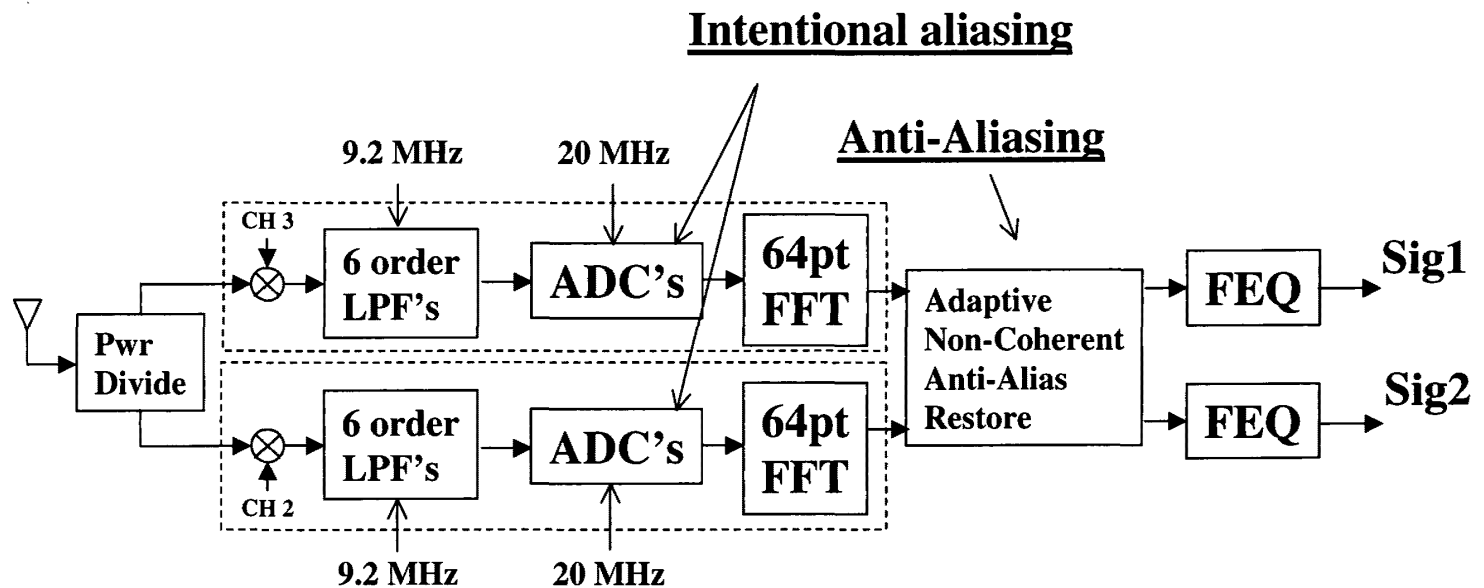
In particular, alias canceling is considered:

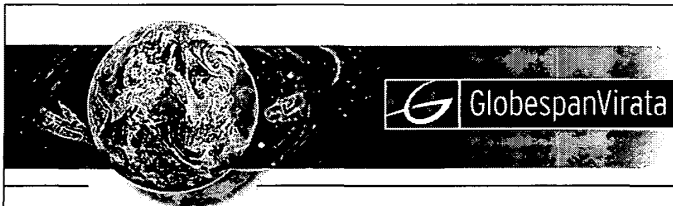
- In the time domain
 - Pre-FFT
 - Early in this document, post-FFT was considered.
- With frequency offset present or, not.



Two-Channel Receiver Method 1: Freq Domain Adaptive Restore

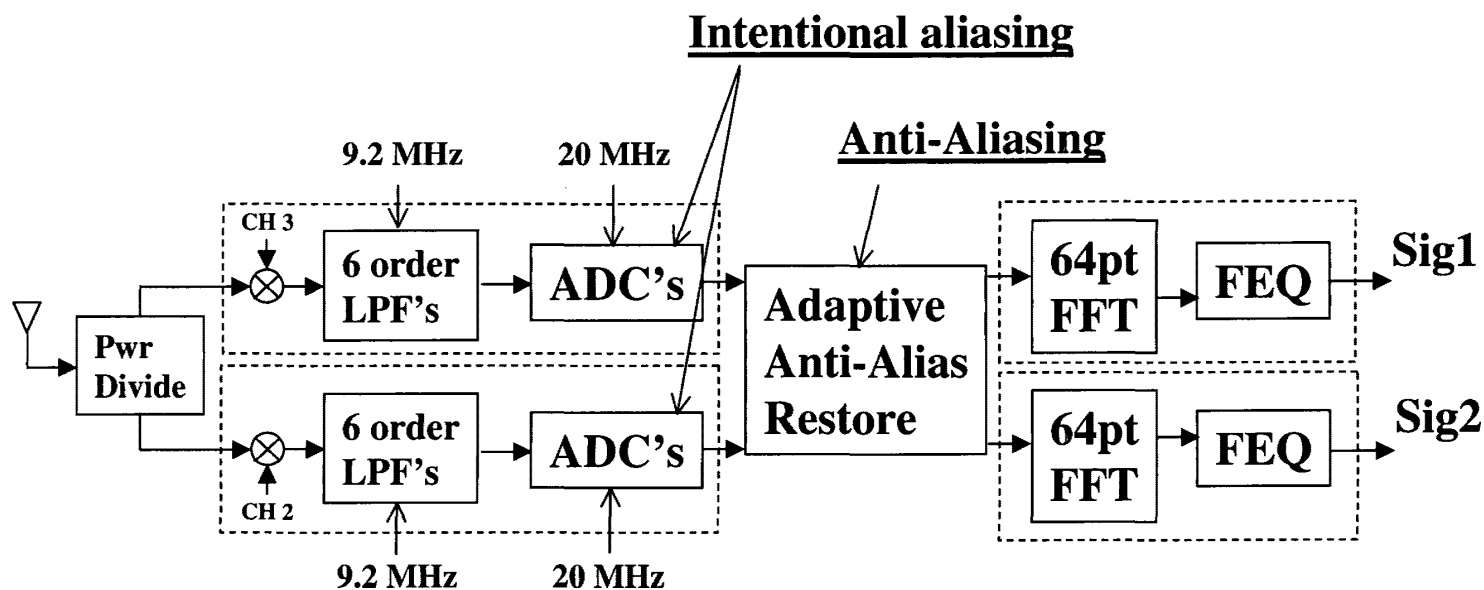
- This method has already been presented

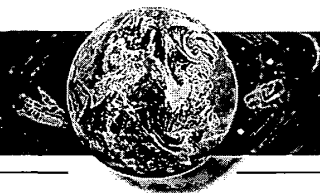




Two-Channel Receiver Method 2: Time Domain Adaptive Restore

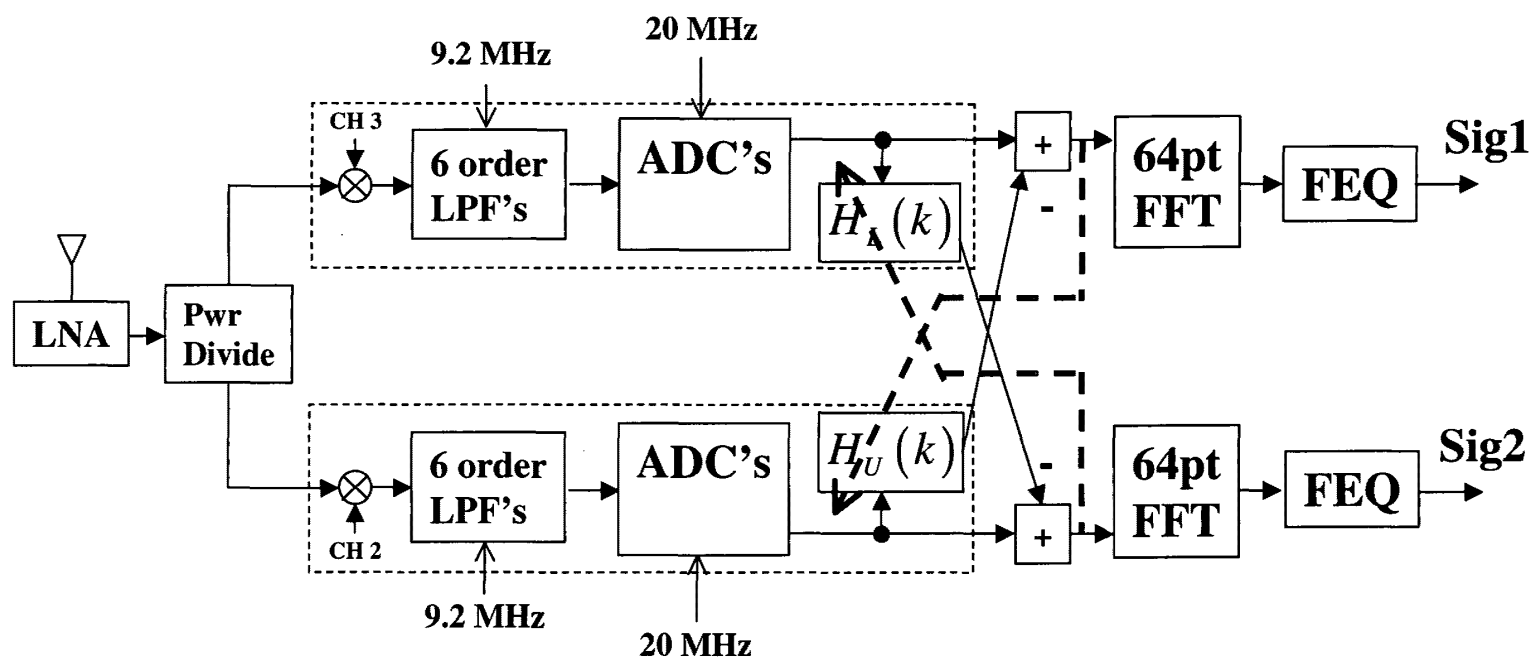
- Ostensibly no analog receive changes compared to what is currently used.
- Rx FEQ's combine overlap
- Signal separator needed for alias components





Any signal common to both Rx chains can be used to train/track anti-alias
Desired packets

- Noise





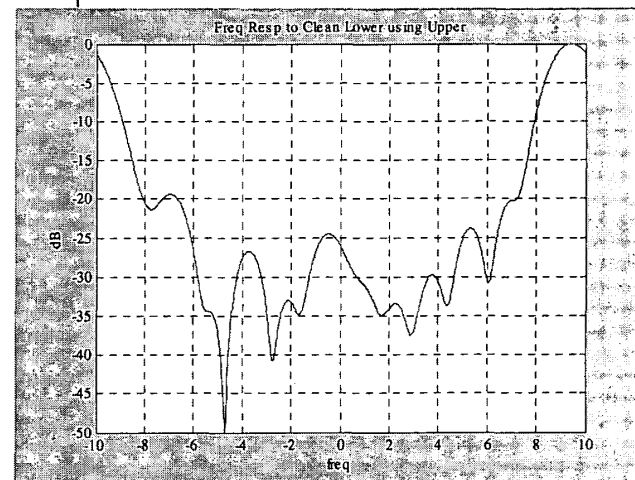
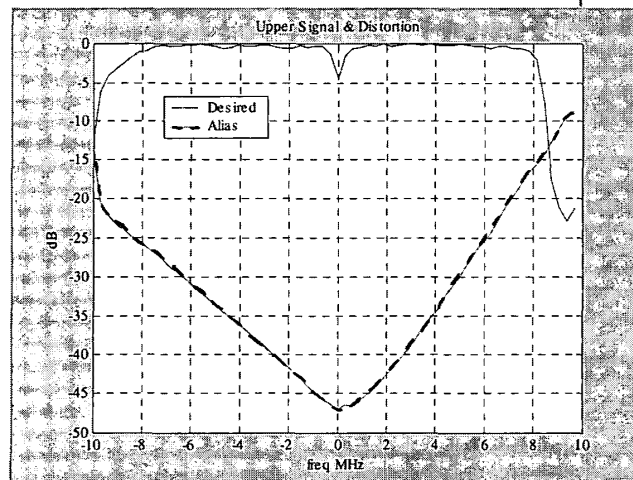
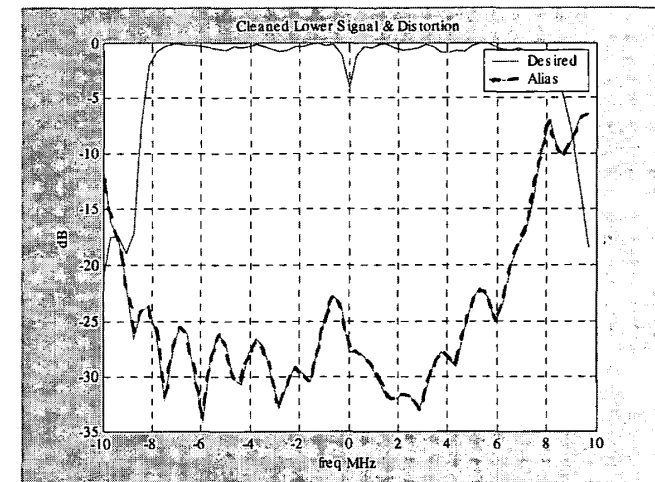
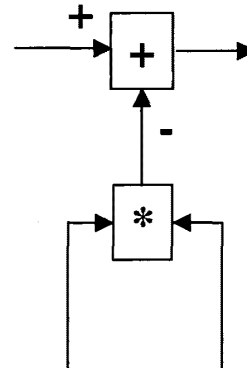
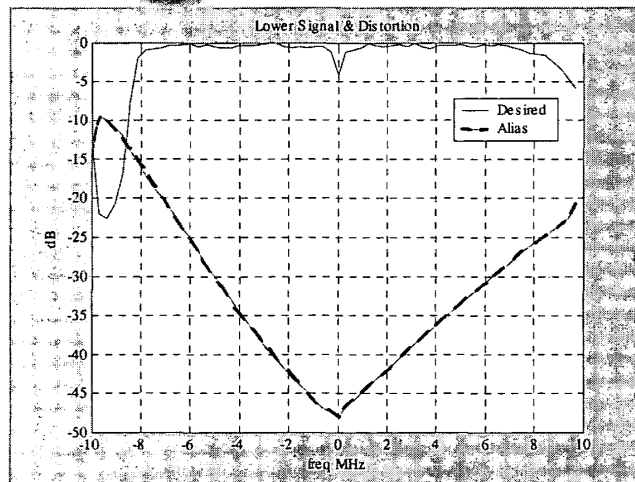
Adaptation Algorithm

- Various adaptation techniques may be used.

For example, the least-mean-squared (LMS) technique may be implemented.

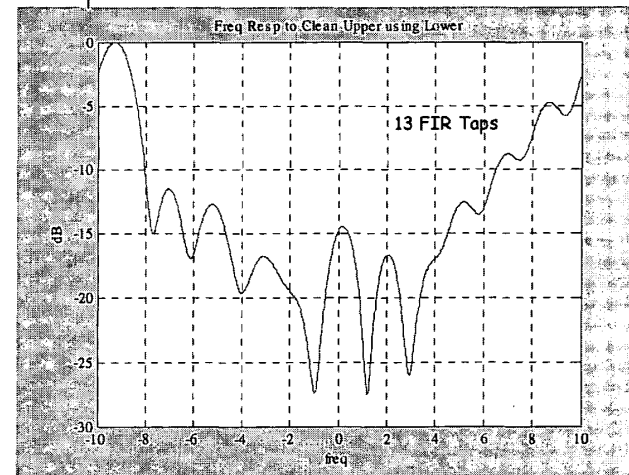
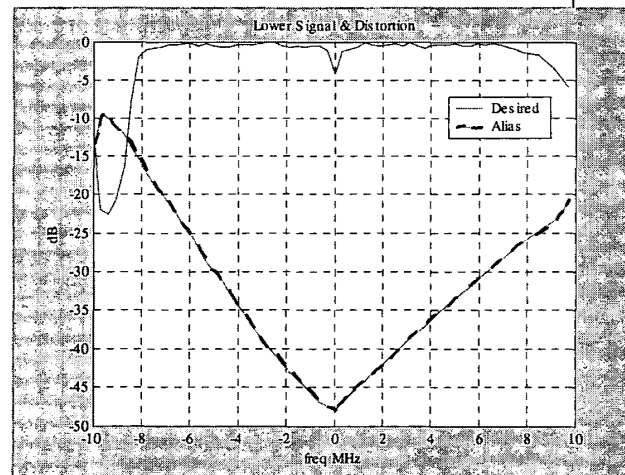
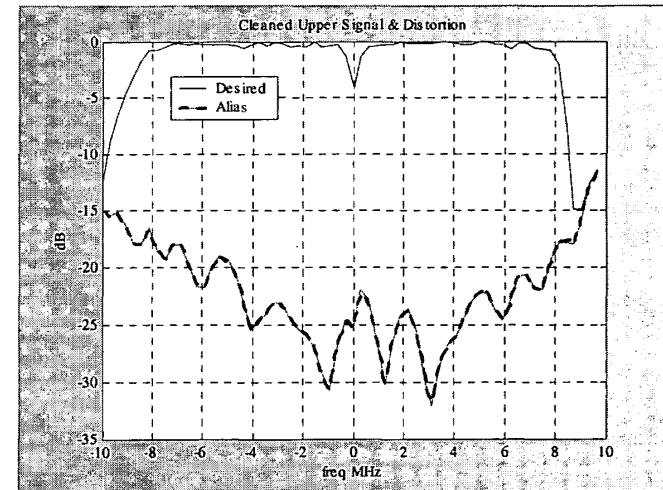
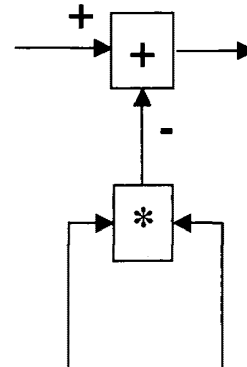
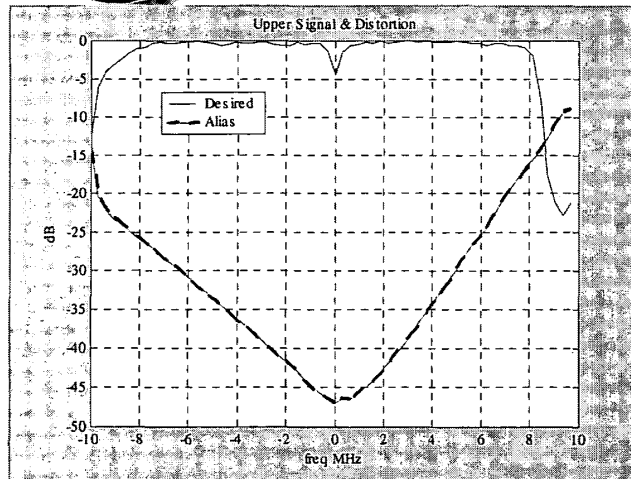


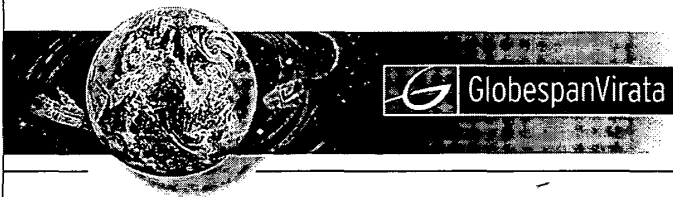
Clean Lower Signal Example: 13 tap Adaptive Filter





Clean Upper Signal Example: 13 tap Adaptive Filter





Conclusion

**Time domain canceling with frequency-
offset works too.**

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