DSP for Next Generation Wireless Systems

Chance Tarver Joseph Cavallaro

April 26, 2018

Where we're going:

- Massive device to device connectivity:
  - Sensor Networks
  - Internet-of-Things
  - Body Area Networks

- Mobile Broadband over 100 Gpbs

UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM

RADIO SERVICES COLOR LEGEND

- AERONAUTICAL MOBILE
- AERONAUTICAL MOBILE SATELLITE
- AERONAUTICAL RADIONAVIGATION
- AMATEUR
- AMATEUR SATELLITE
- BROADCASTING
- BROADCASTING SATELLITE
- EARTH EXPLORATION SATELLITE
- FIXED
- FIXED SATELLITE
- INTER-SATELLITE
- LAND MOBILE
- LAND MOBILE SATELLITE
- MARITIME MOBILE
- MARITIME MOBILE SATELLITE
- MARITIME RADIONAVIGATION
- METEOROLOGICAL AIDS
- METEOROLOGICAL SATELLITE
- MOBILE
- MOBILE SATELLITE
- RADIO ASTRONOMY
- RADIODETERMINATION SATELLITE
- RADIOLOCATION
- RADIOLOCATION SATELLITE
- RADIONAVIGATION
- RADIONAVIGATION SATELLITE
- SPACE OPERATION
- SPACE RESEARCH
- STANDARD FREQUENCY AND TIME SIGNAL
- STANDARD FREQUENCY AND TIME SIGNAL SATELLITE

ACTIVITY CODE

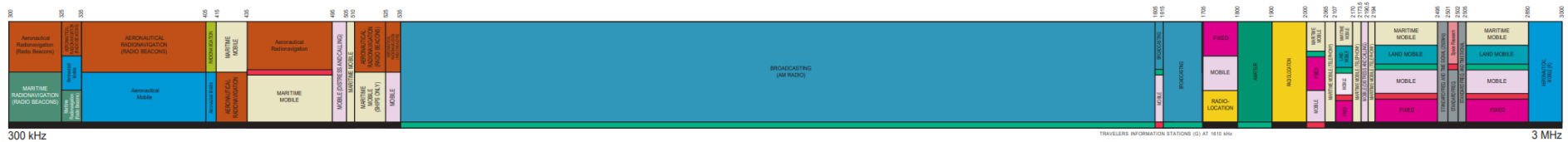
- GOVERNMENT EXCLUSIVE
- GOVERNMENT/ NON-GOVERNMENT SHARED
- NON-GOVERNMENT EXCLUSIVE

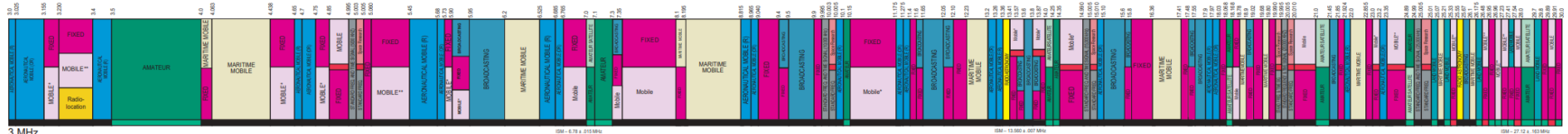
ALLOCATION USAGE DESIGNATION

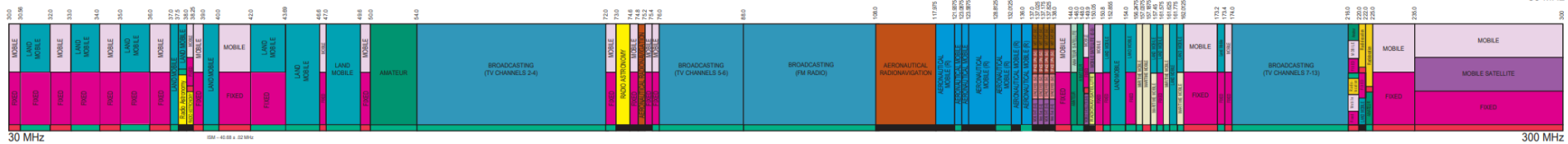
SERVICE	EXAMPLE	DESCRIPTION
Primary	FIXED	Capital Letters
Secondary	Mobile	1st Capital with lower case letters

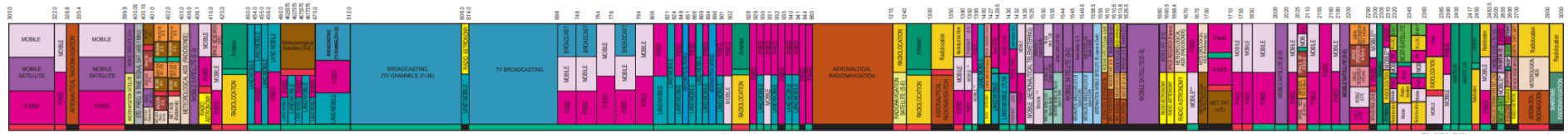
This chart is a graphic single-point-in-time portrayal of the Table of Frequency Allocations used by the FCC and NTIA. As such, it does not completely reflect all aspects, i.e., footnotes and recent changes made to the Table of Frequency Allocations. Therefore, for complete information, users should consult the Table to determine the current status of U.S. allocations.

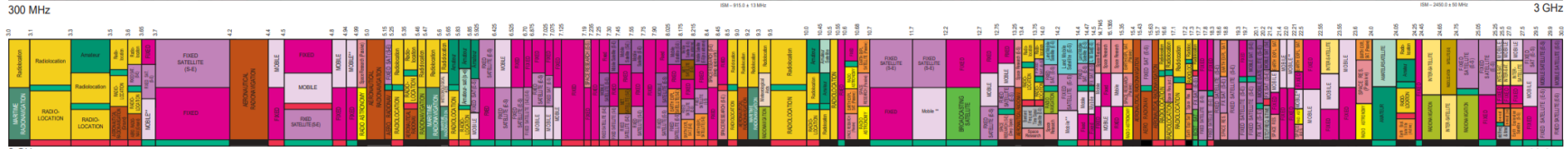
U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management
October 2003

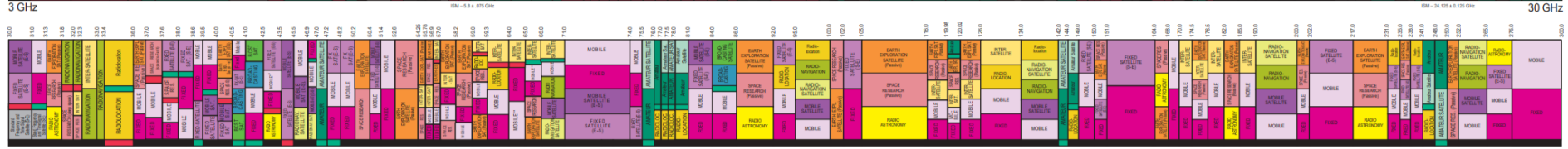






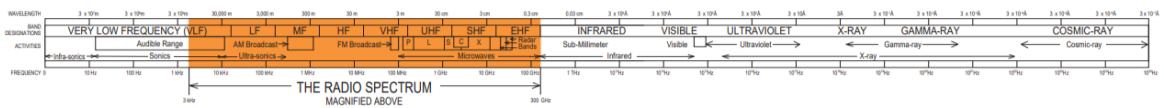




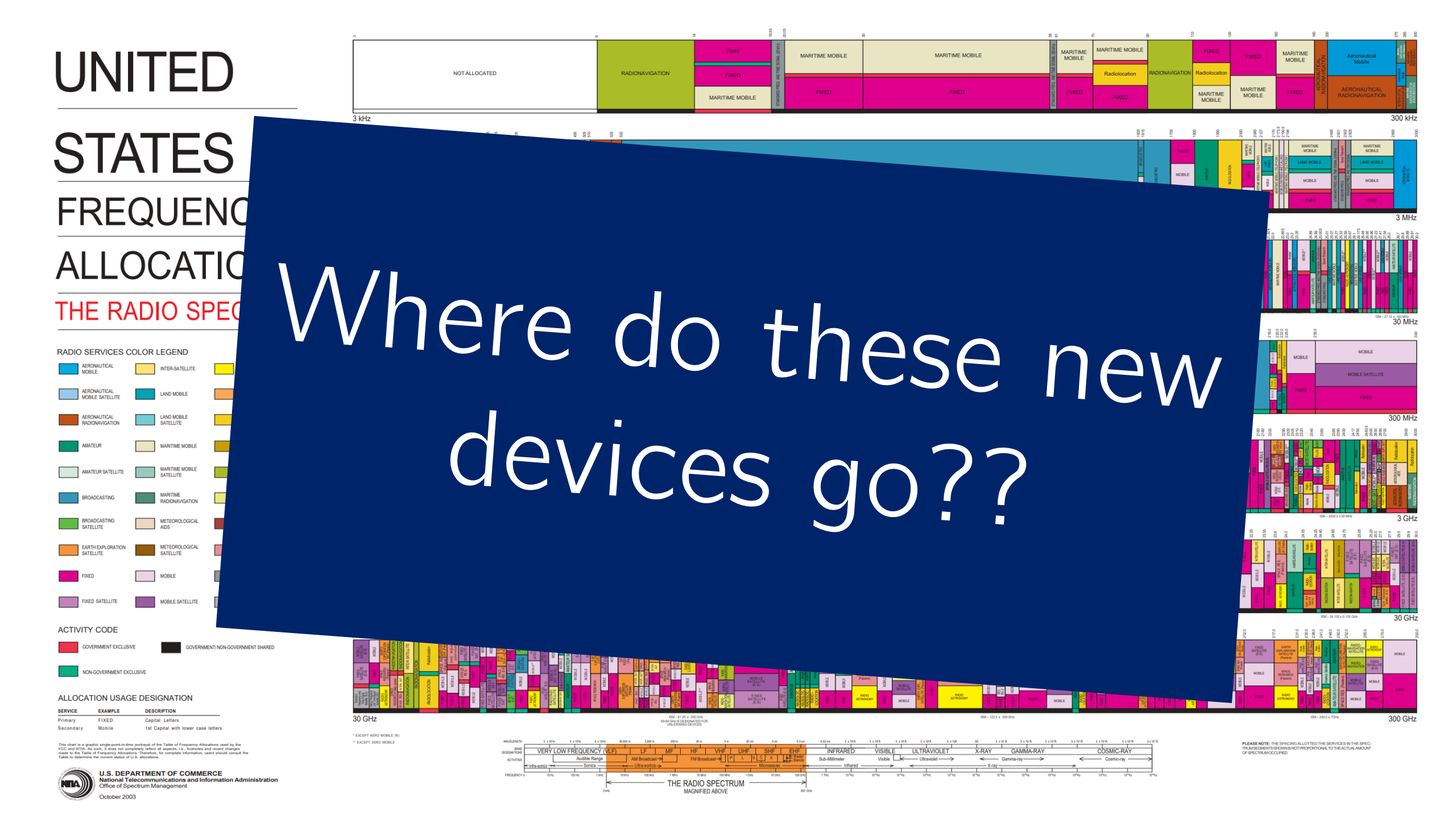


* EXCEPT AERO MOBILE (R)

** EXCEPT AERO MOBILE



PLEASE NOTE: THE SPACING ALLOTTED THE SERVICES IN THE SPECTRUM SEGMENTS SHOWN IS NOT PROPORTIONAL TO THE ACTUAL AMOUNT OF SPECTRUM OCCUPIED.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October 2003
NOT ALLOCATED
RADIONAVIGATION
Fixed
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MARITIME MOBILE
MARITIME MOBILE
FIXED
Radiolocation
RADIONAVIGATION
Radiolocation
MARITIME MOBILE
AERONAUTICAL RADIONAVIGATION
Aeronautical Mobile
3 kHz
300 kHz
3 MHz
30 MHz
300 MHz
3 GHz
30 GHz
300 GHz
Where do these new devices go??
THE RADIO SPECTRUM
MAGNIFIED ABOVE
VERY LOW FREQUENCY (VLF)
LF
MF
HF
VHF
UHF
SHF
EHF
INFRARED
VISIBLE
ULTRAVIOLET
X-RAY
GAMMA-RAY
COSMIC-RAY
PLEASE NOTE: THE SPACING ALLOTTED THE SERVICES IN THE SPECTRUM SEGMENTS SHOWN IS NOT PROPORTIONAL TO THE ACTUAL AMOUNT OF SPECTRUM OCCUPIED.

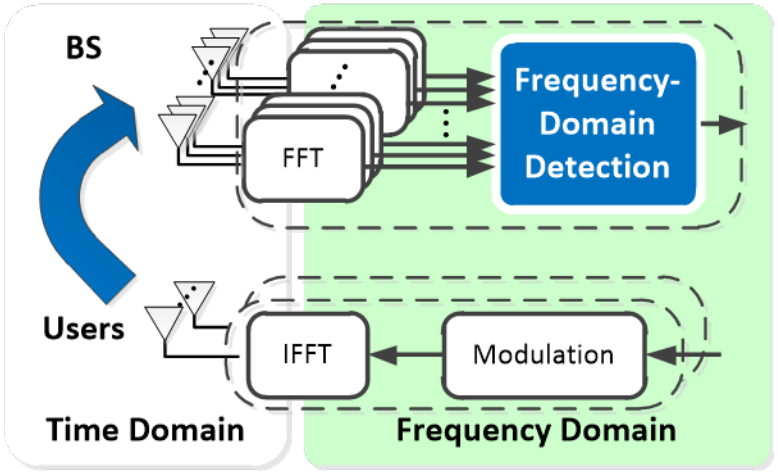
Challenges

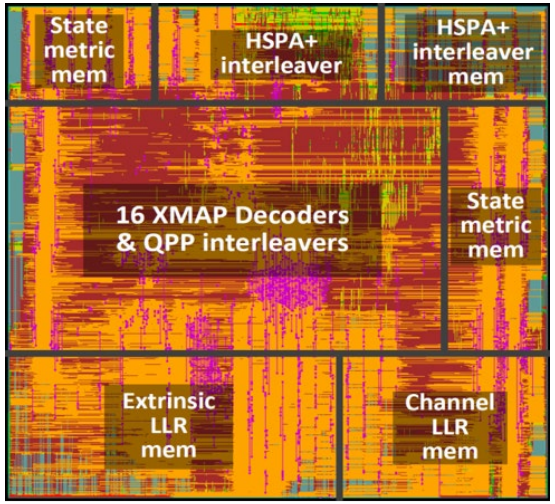
- Densification
- Increased spectrum congestion
- New ultrawideband waveforms stressing the physical layer

Future Directions

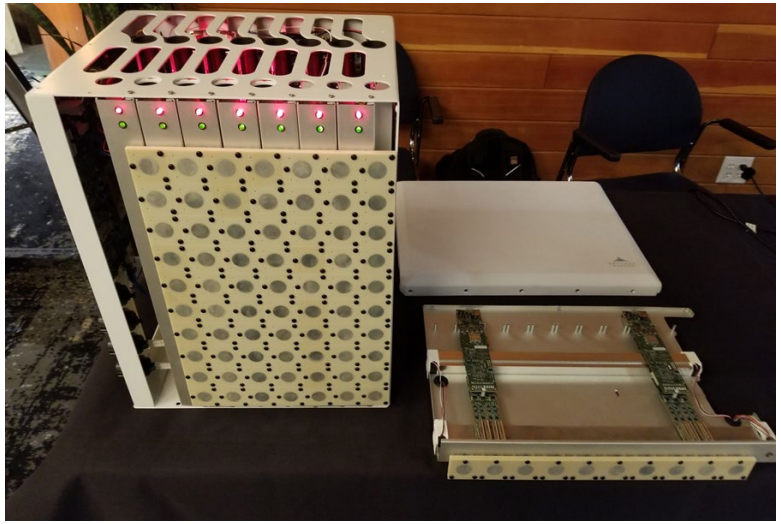
- New spectrum resources in mmWave and beyond
- Massive MIMO
- Coexistence aware waveforms assisted by predistortion

Our Unique Approach





Post-layout chip view



DSP / Algorithm

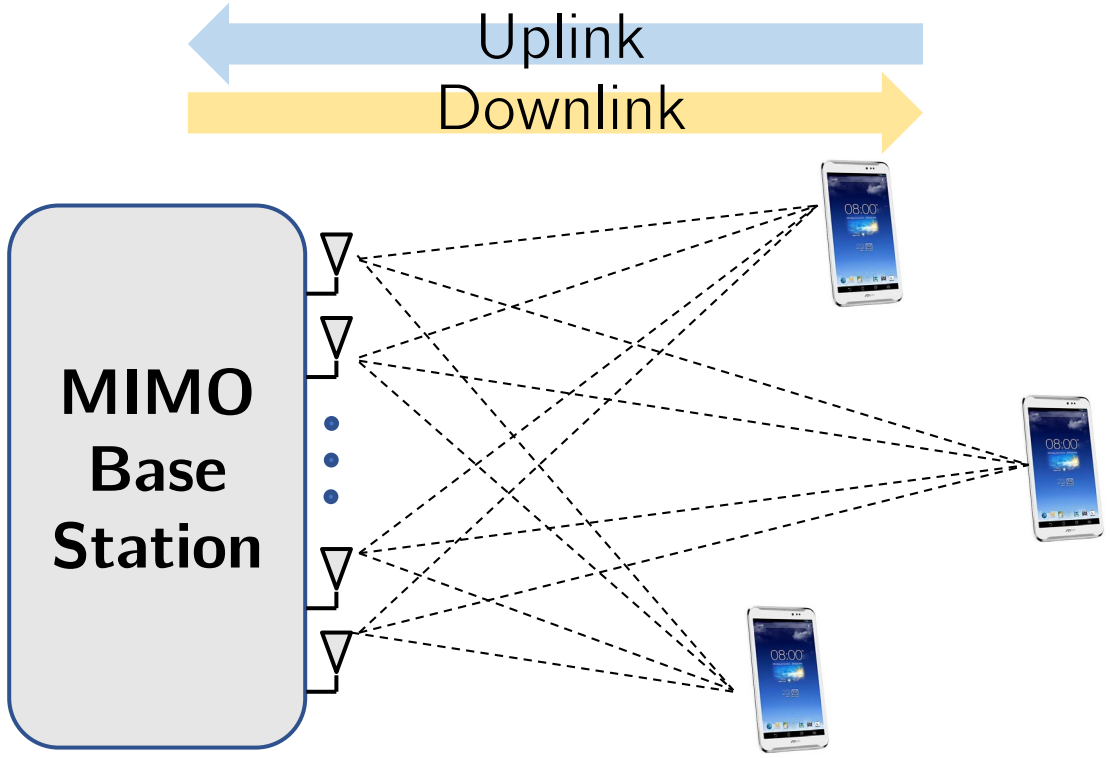
Architecture

Testbed

Co-design

Massive Multi-User MIMO Systems

Hundreds of base station antennas



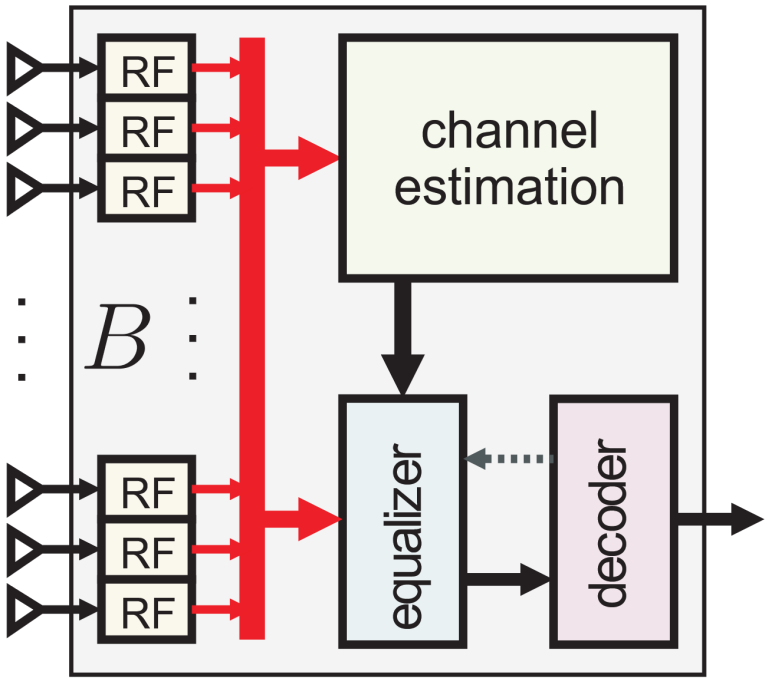
Simultaneously transmitting to ***tens*** of users on the same frequency

Record breaking spectral efficiency

I/O Bottlenecks

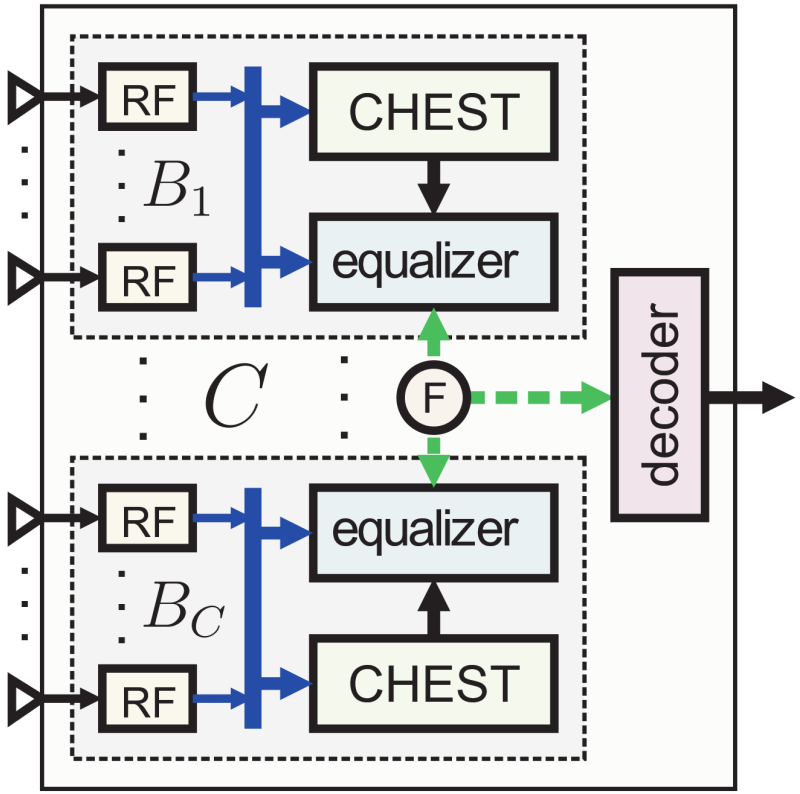
Decentralized Baseband Processing

conventional BS



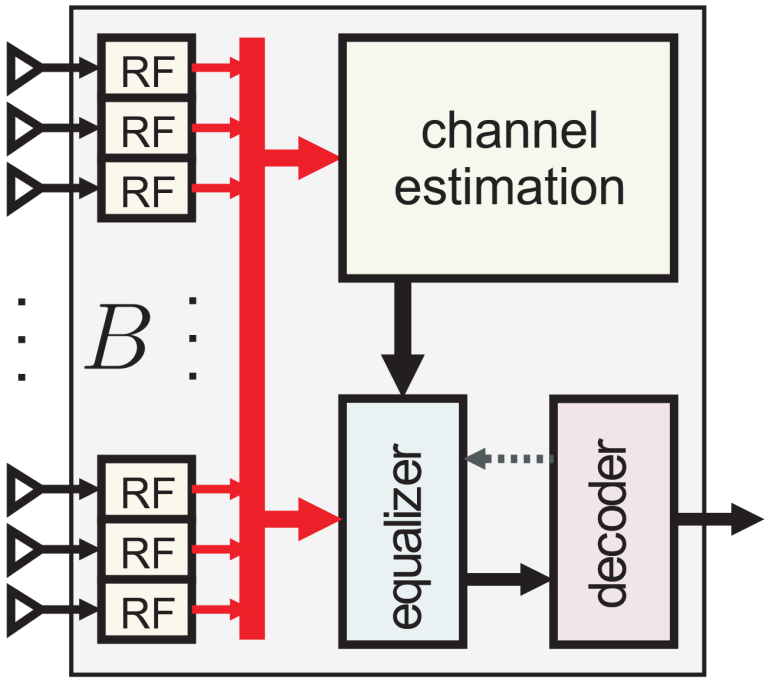
Split the base station antennas into clusters with fewer antennas.

BS with decentralization



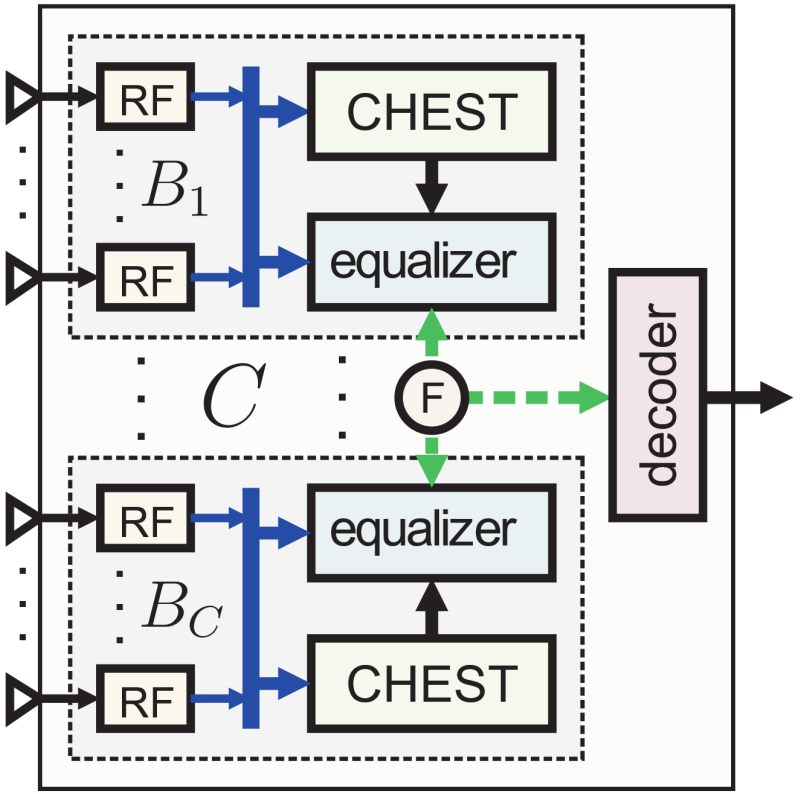
Decentralized Baseband Processing

conventional BS



- Alleviates interconnection and computation bottlenecks
- Realizes efficient, modular and scalable baseband processing
- Achieves competitive (or equal) performance to centralized methods

BS with decentralization

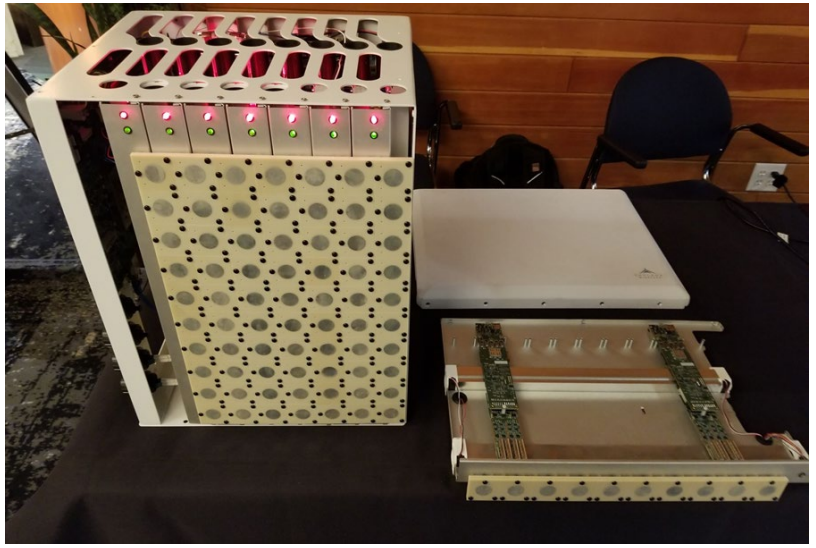


RENEW

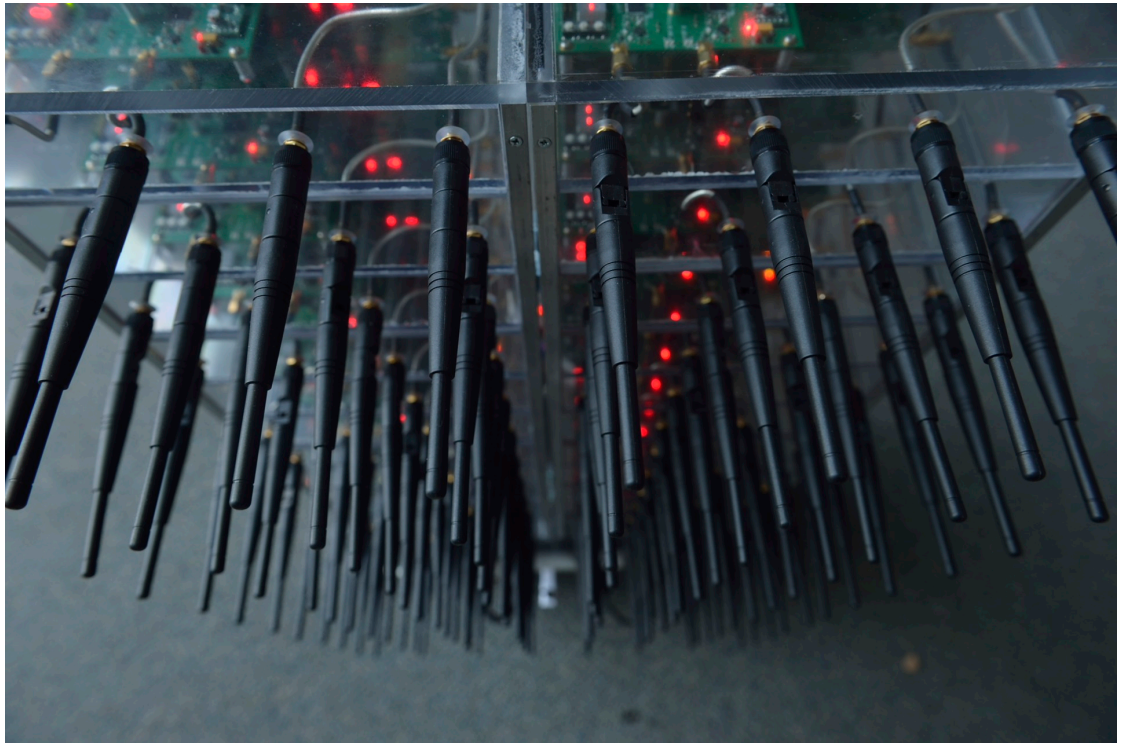
Reconfigurable Ecosystem for Next-gen End-to-end Wireless

Reconfigurable **E**co-system for **N**ext-generation **E**nd-to-end **W**ireless

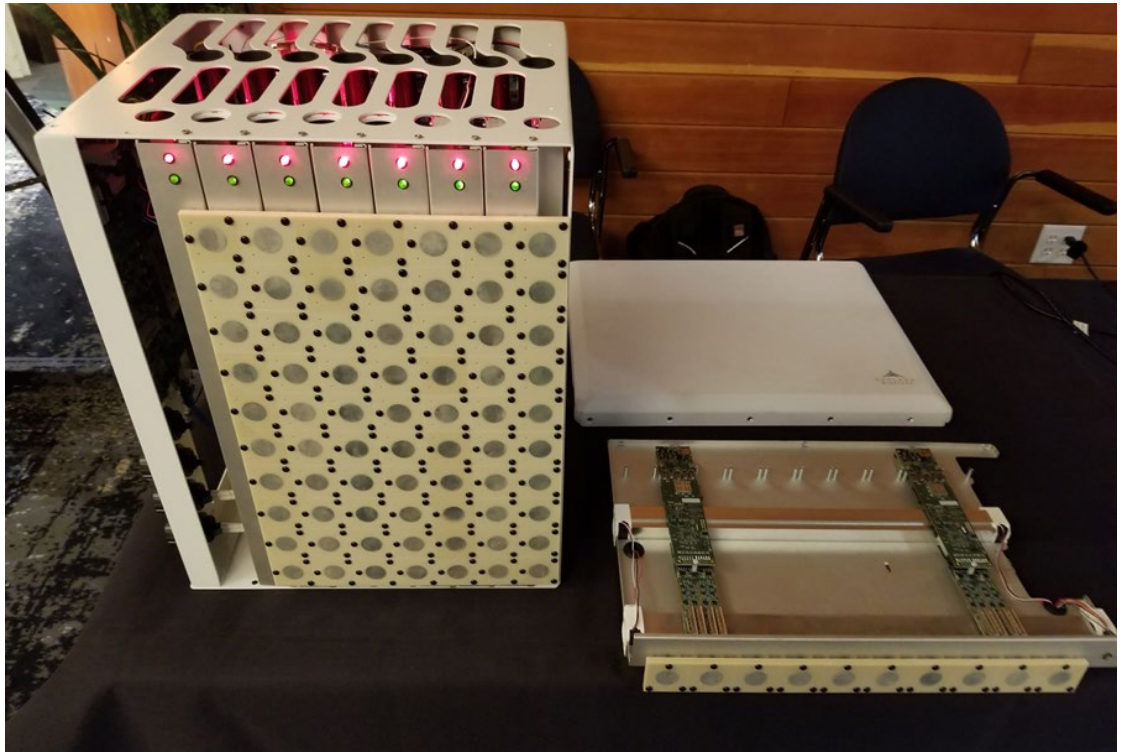
- Develop world's first fully programmable and observable wireless radio network.
- Wireless research and development community will be able to test diverse ideas and concepts.
- PAWR. More than 28 private-sector companies from US wireless industry



Platforms for Advanced Wireless Research



WARP
WIRELESS OPEN-ACCESS
RESEARCH PLATFORM



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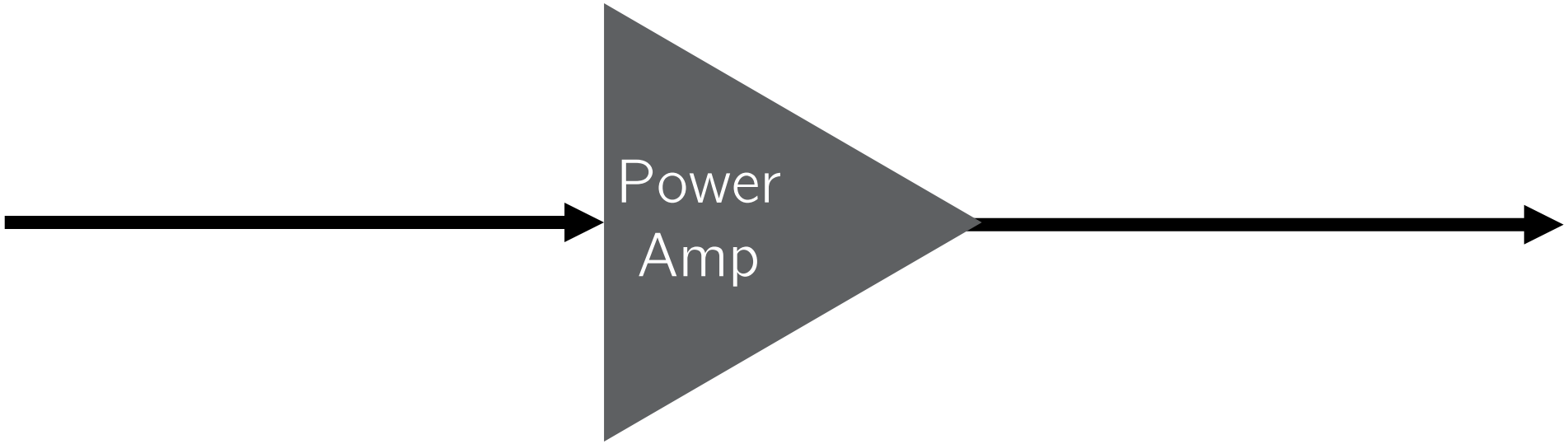
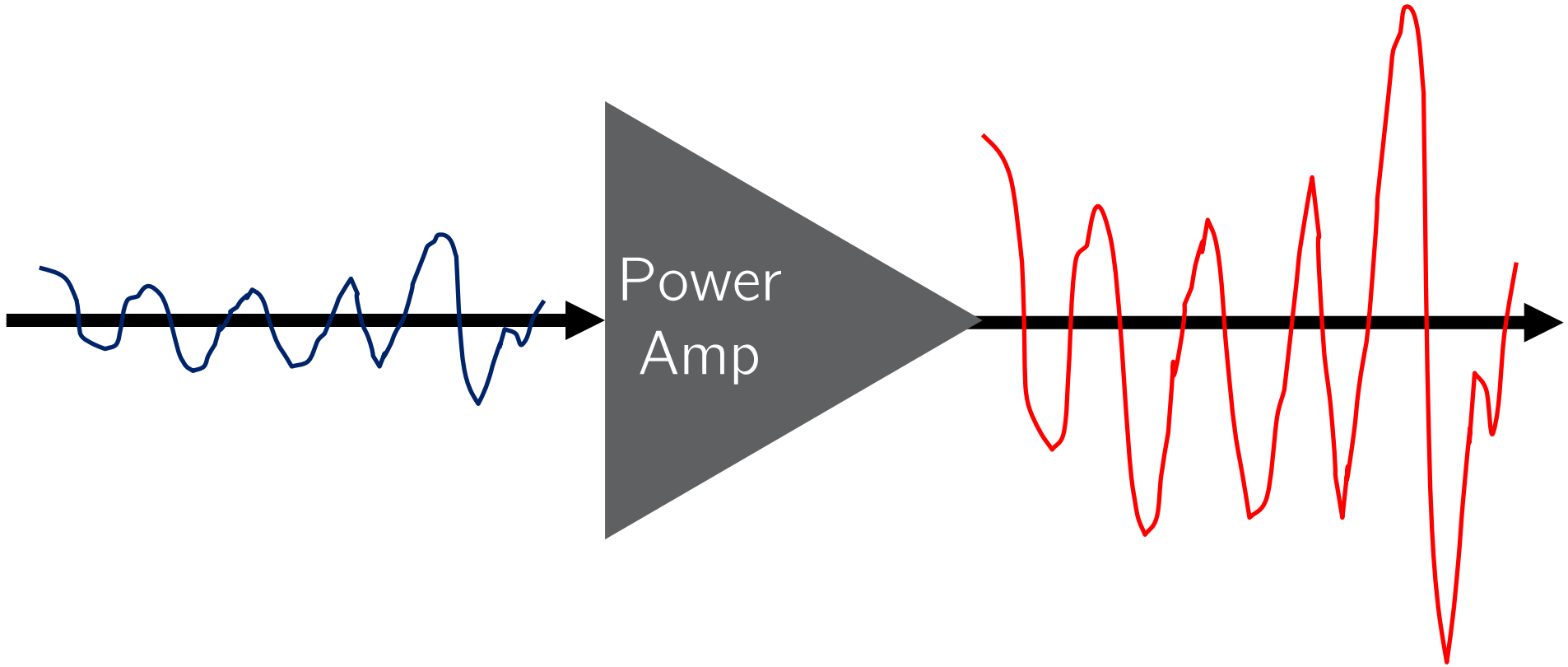
Reconfigurable Ecosystem for Next-gen End-to-end Wireless

Predistortion for Power Amplifiers



Predistortion for Power Amplifiers



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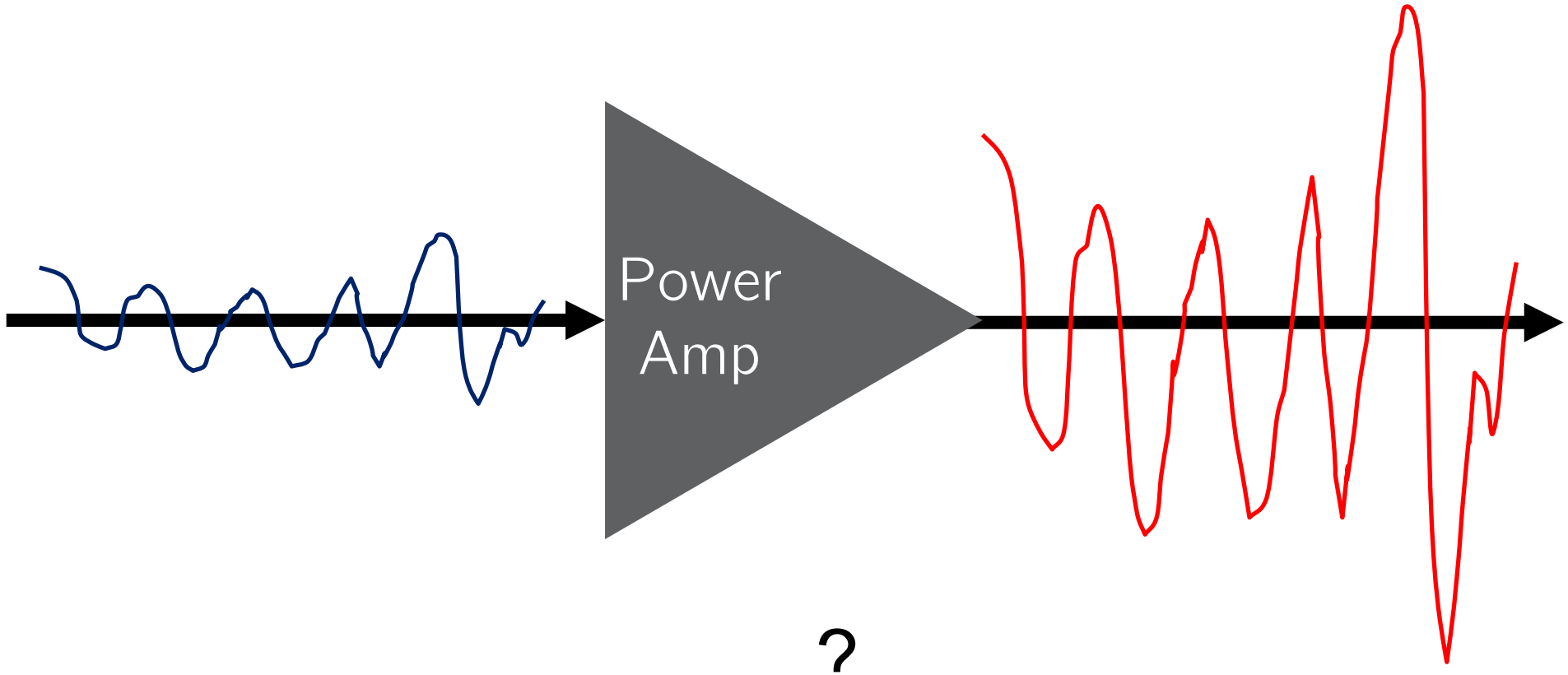
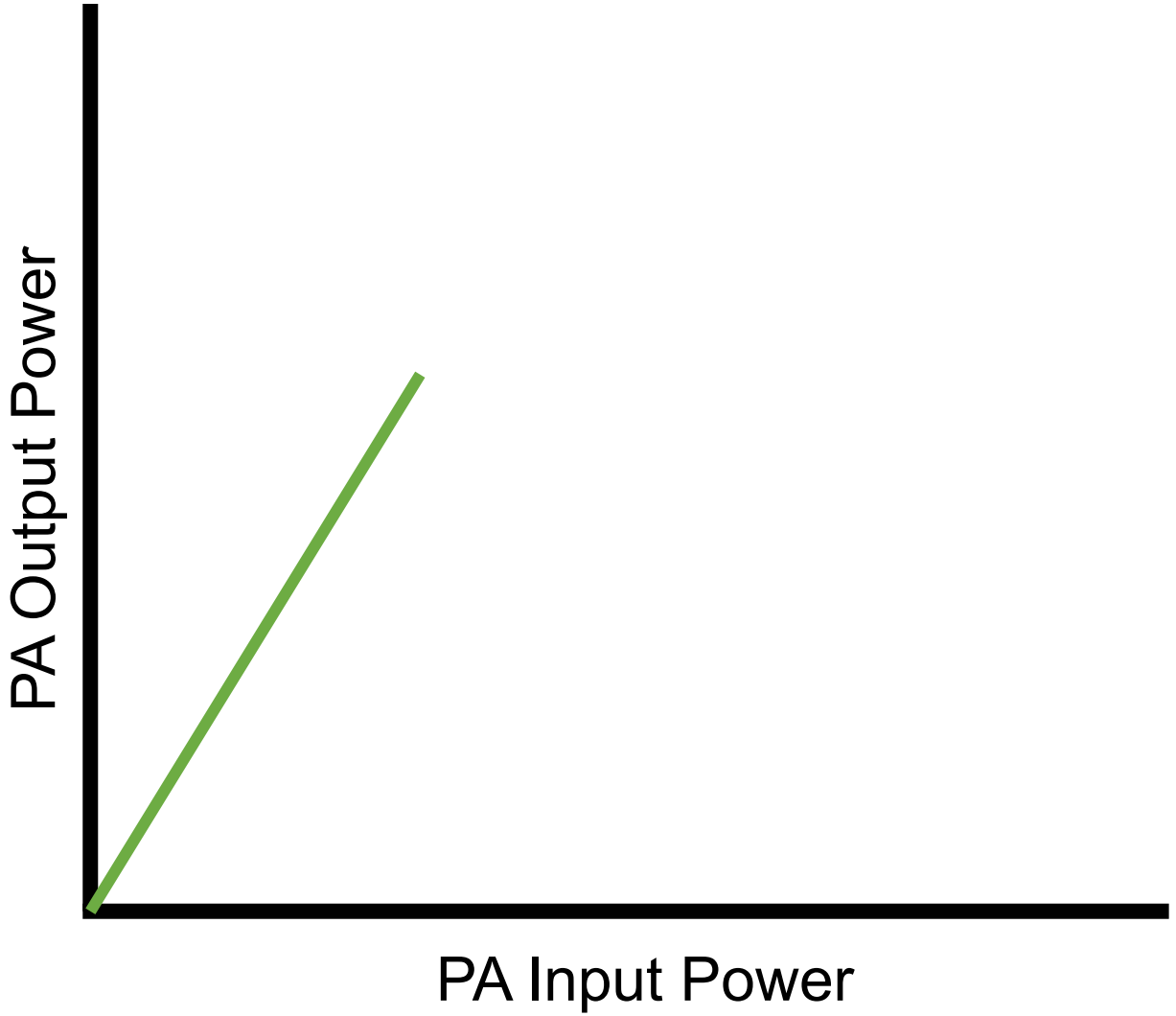
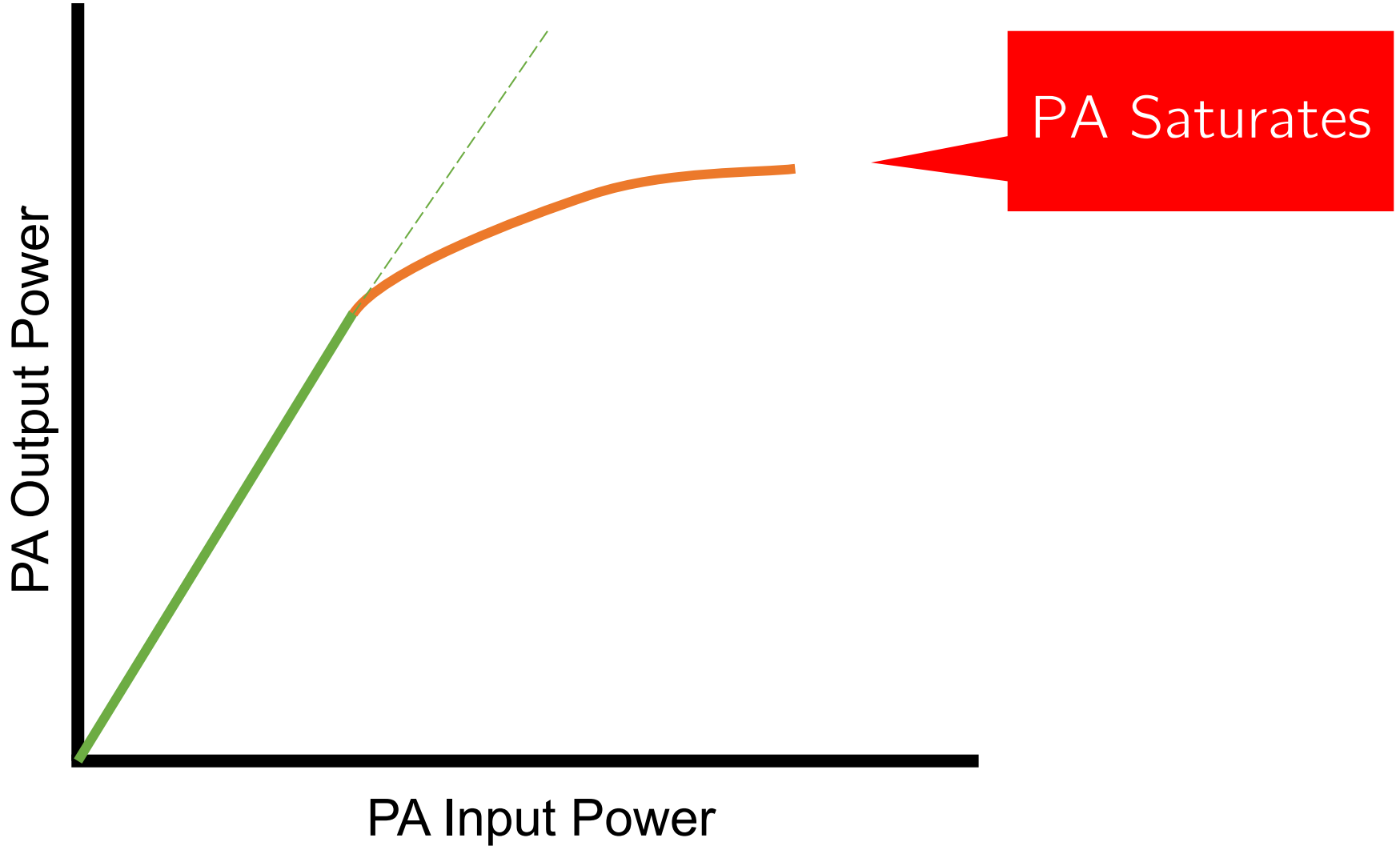
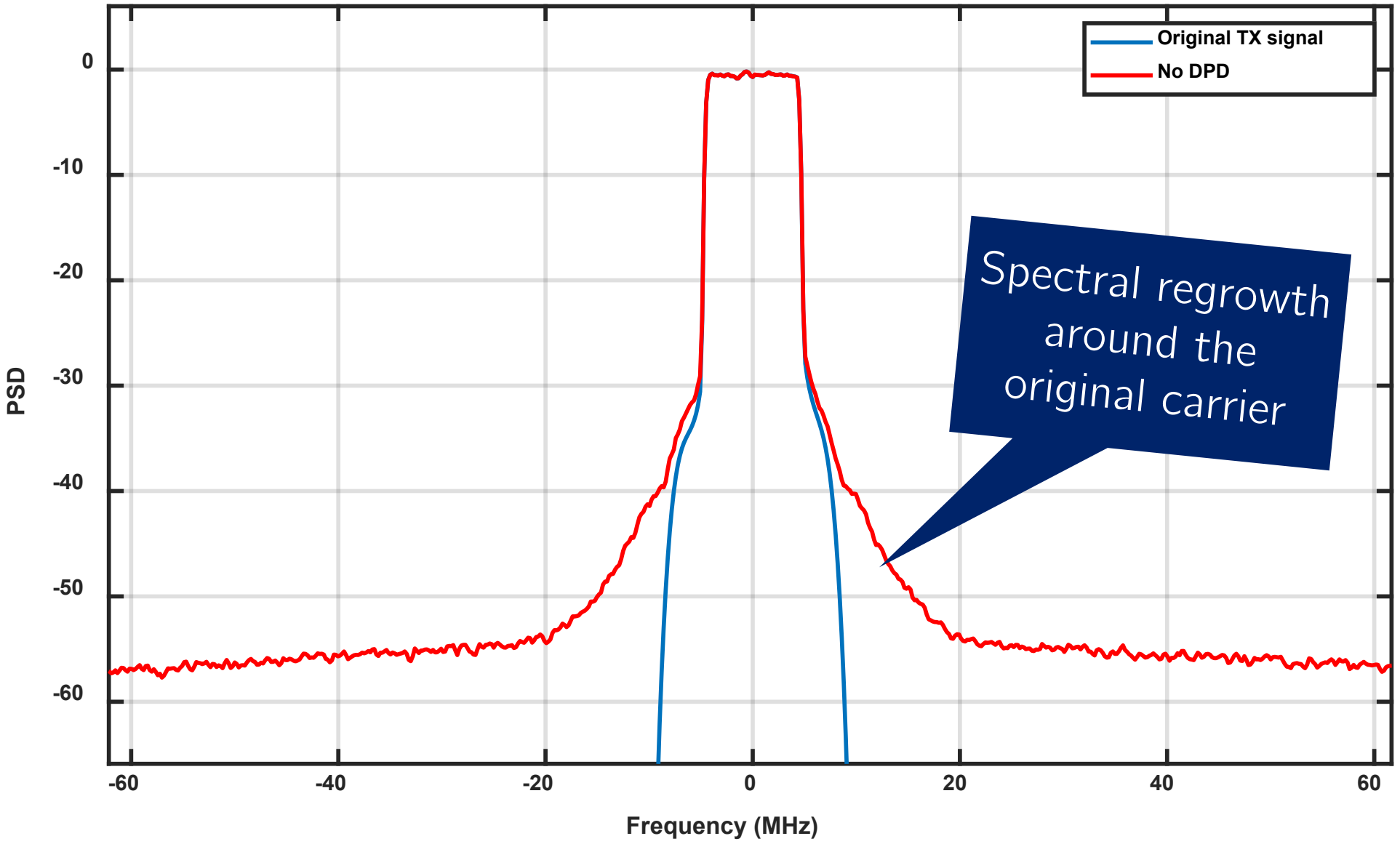


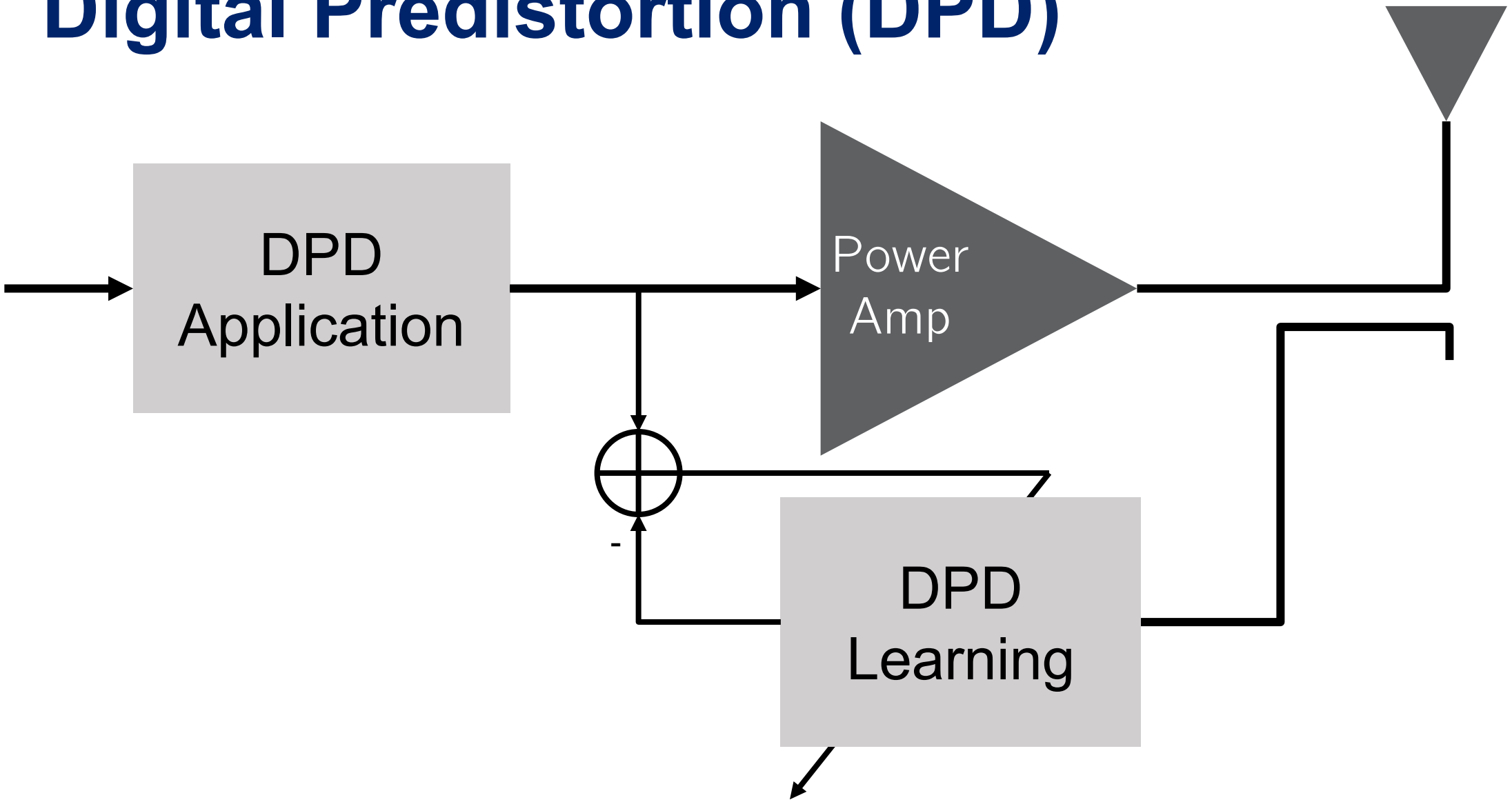
$$x(t) \cdot G \xrightarrow{?} y(t)$$


PA Output Power
PA Input Power

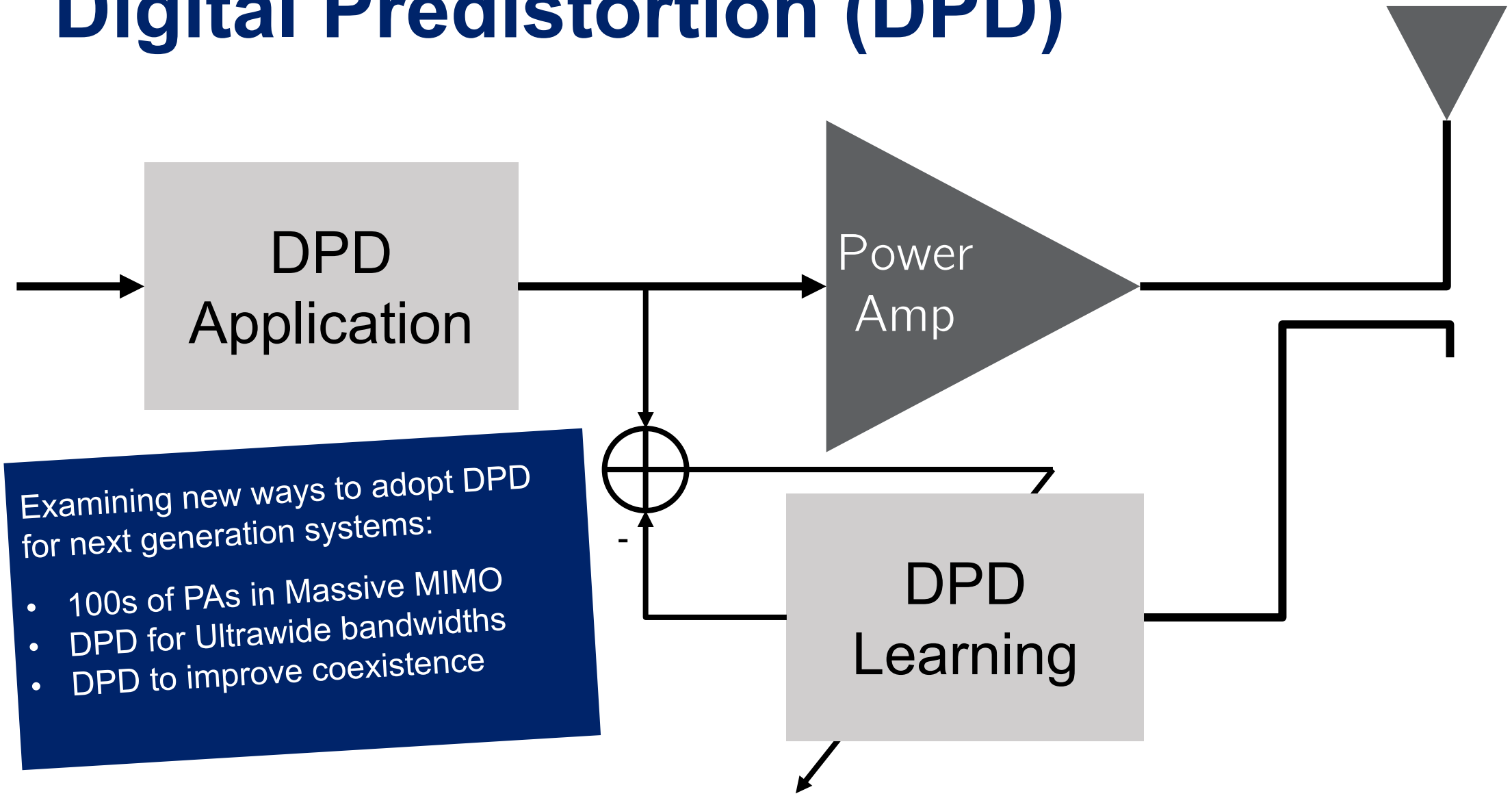

PA Saturates
PA Output Power
PA Input Power


Original TX signal
No DPD
Spectral regrowth around the original carrier
PSD
0
-10
-20
-30
-40
-50
-60
-60
-40
-20
0
20
40
60
Frequency (MHz)

Digital Predistortion (DPD)

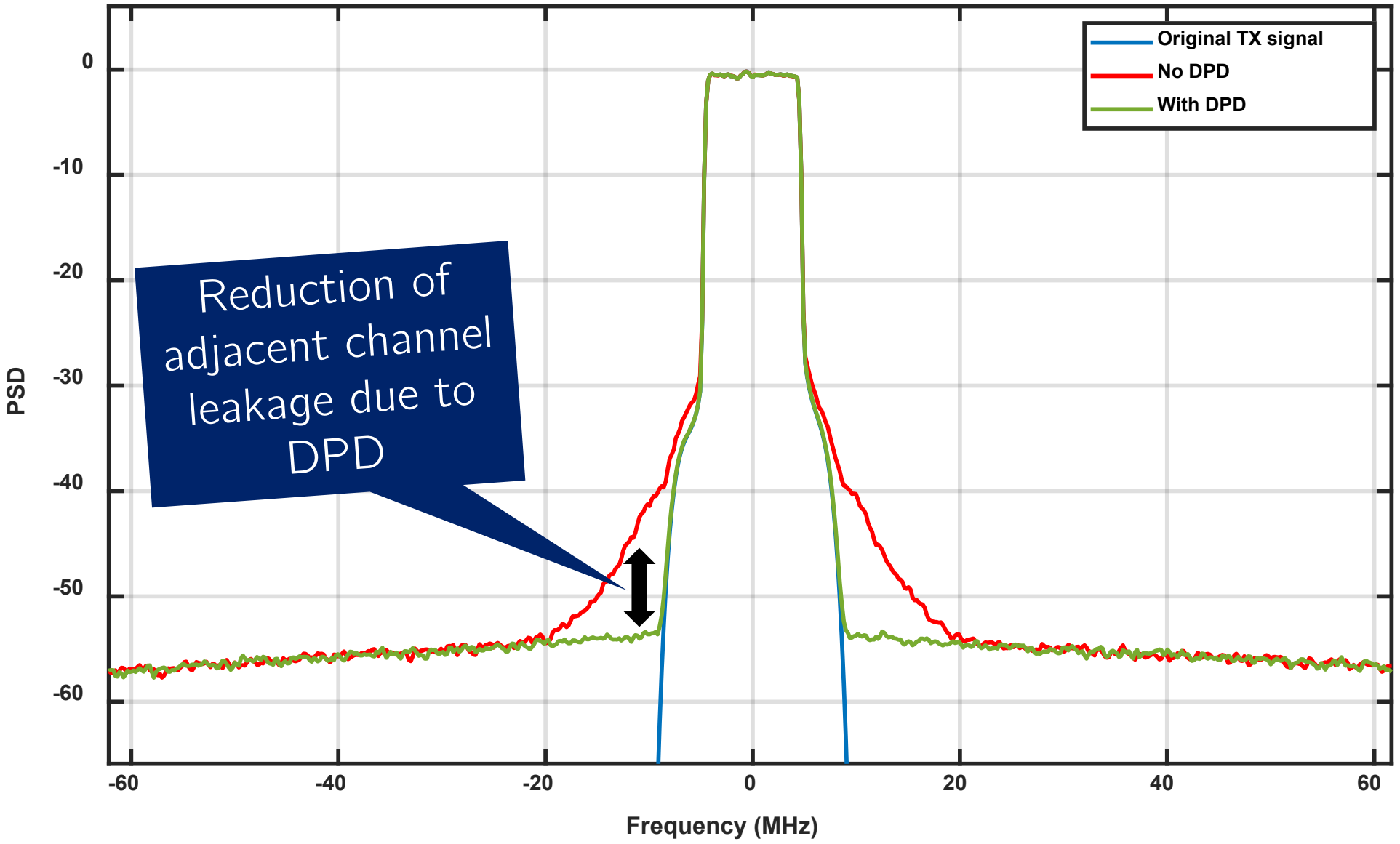


Digital Predistortion (DPD)



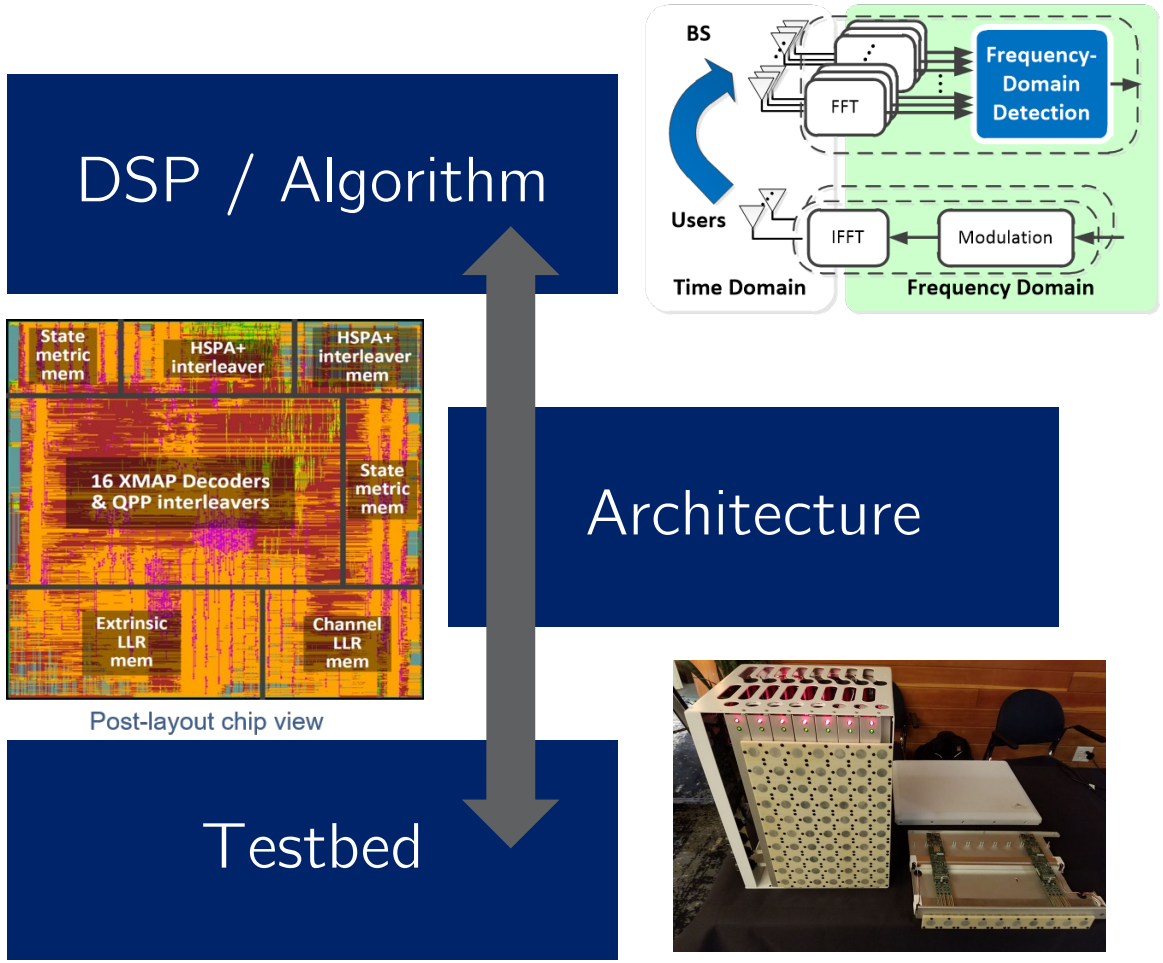
Examining new ways to adopt DPD for next generation systems:

- 100s of PAs in Massive MIMO
- DPD for Ultrawide bandwidths
- DPD to improve coexistence


Original TX signal
No DPD
With DPD
Reduction of adjacent channel leakage due to DPD
PSD
0
-10
-20
-30
-40
-50
-60
-60
-40
-20
0
20
40
60
Frequency (MHz)

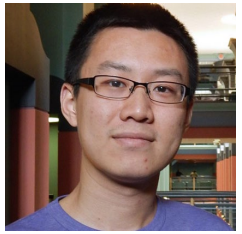
Conclusions

- Enabling massive device driven connectivity
- Codesign between algorithms and architectures is necessary to meet challenges in next generation wireless systems



Acknowledgments:

Christoph Studer
Cornell University



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