Signal Processing for Wireless Communications and Active Acoustic Control

Alessandro Opinto

Department of Electrical, Electronic, and Information Engineering "Guglielmo Marconi", University of Bologna

Department of Engineering and Architecture, University of Parma

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About me...

- Catania, 16th Jan. 1991
- Dec. 2014: Bachelor Degree in "*Electronic and Communication Engineering*" at University of Parma
- Feb. – Aug. 2017: trainee at Huawei Mathematical and Algorithmic Research Center at Boulogne-Billancourt, Paris (France) and at CentraleSupélec University at Gif-sur-Yvette (France)
- Mar. 2018: Master's Degree in "*Communication Engineering*" at University of Parma
- Feb. – Nov. 2018: consultant analyst on network performance at Vodafone Italia in Ivrea (TO)
- Nov. 2018 – today: Ph.D. student in "Automotive Engineering for Intelligent Mobility" at University of Bologna, in collaboration with University of Parma and ASK Industries

alessandro.opinto@unipr.it

http://multimedialab.tlc.unipr.it/aopinto.html

alessandro.opinto3@unibo.it

www.unibo.it/sitoweb/alessandro.opinto3/

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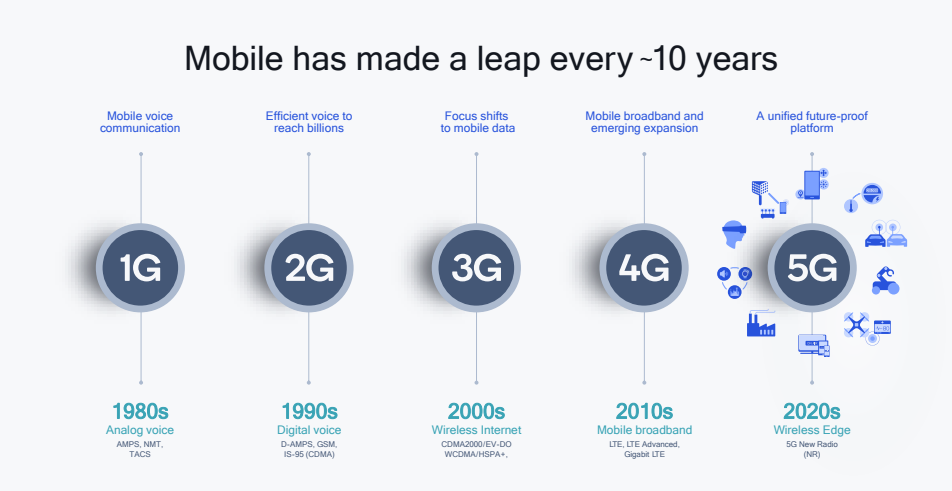
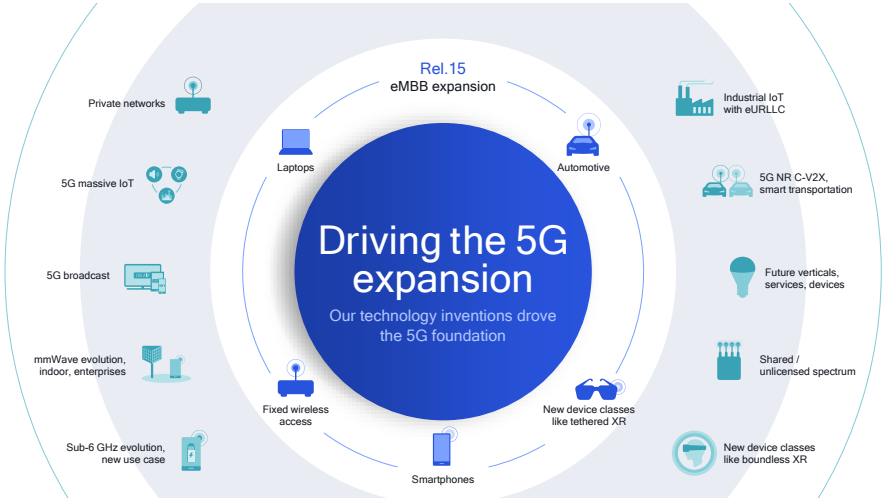
Fifth Generation: 5G





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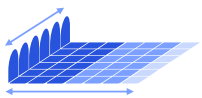
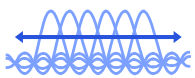
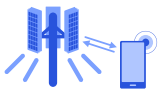
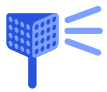
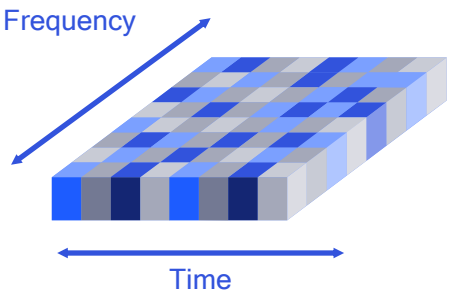
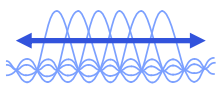
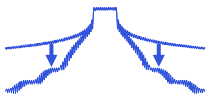
5G Technologies

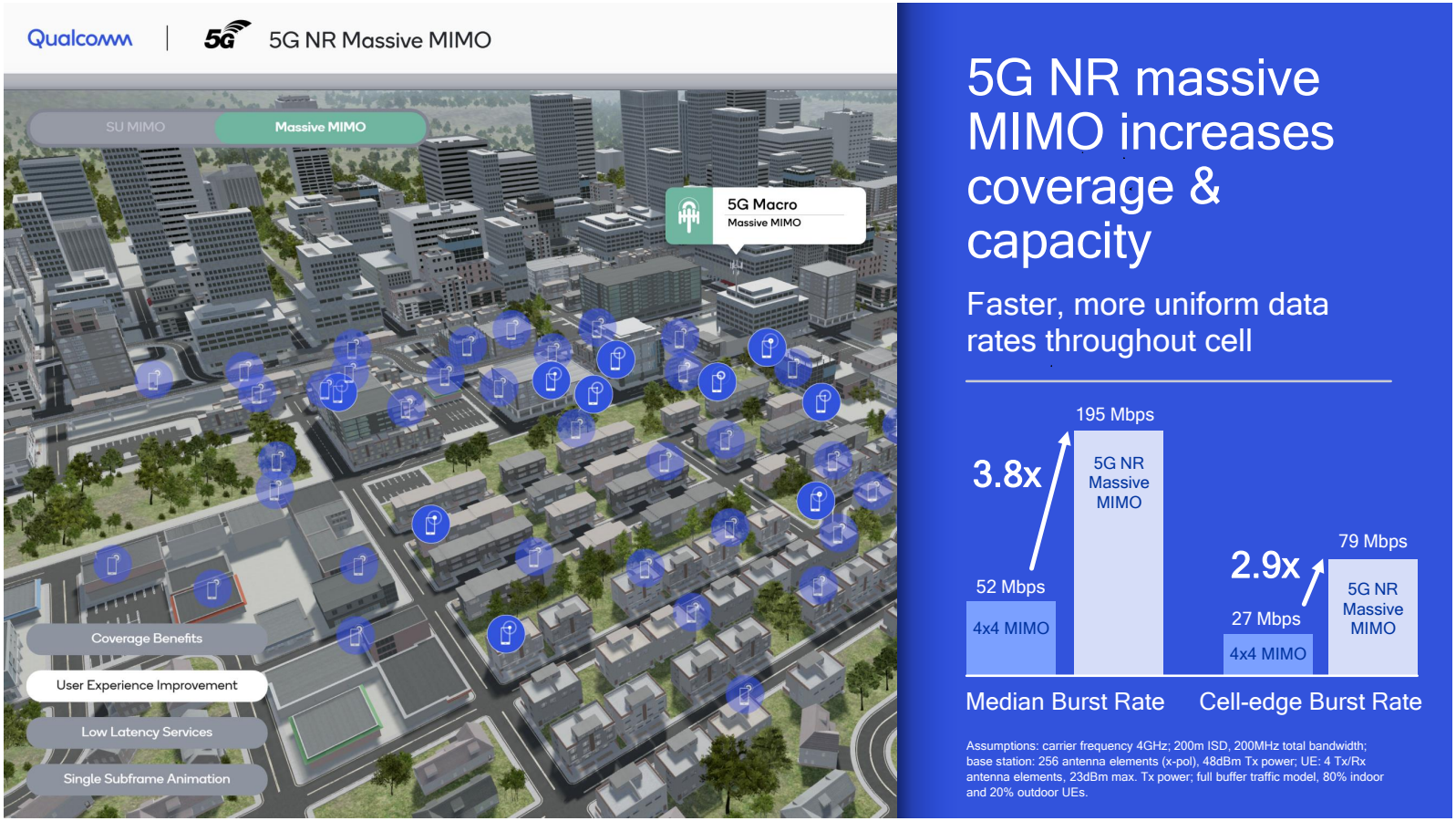
Flexible slot-based framework	Scalable OFDM-based air interface	Advanced channel coding	Massive MIMO	Mobile mmWave
				
Scalable OFDM numerology	**Self-contained slot structure**	**Multi-Edge LDPC and CRC-Aided Polar**	**Reciprocity-based MU-MIMO**	**Beamforming and beam-tracking**
Low latency, URLLC, forward compatibility	Address diverse services, spectrum, deployments	Support large data blocks, reliable control channel	Large # of antennas to increase coverage/capacity	For extreme capacity and throughput



Scalable numerology	Frequency localization	Lower power consumption	Asynchronous multiple access
			
2^n scaling of sub-carrier spacing to efficiently support wider bandwidths	Windowing[1] can effectively minimize in-band and out-of-band emissions	Single-carrier[2] OFDM utilized for efficient uplink transmissions	Can co-exist with optimized waveforms and multiple access for IoT UL[3]

Qualcomm Research is a division of Qualcomm Technologies, Inc.
1. Such as Weighted Overlap Add (WOLA) utilized in LTE systems today. 2. DFT-Spread (DFT-S) OFDM. 3. Such as non-orthogonal Resource Spread Multiple Access (RSMA)

Massive MIMO



M. Martalò, A. Opinto, M. Maso, M. Debbah and R. Raheli, "Low-Complexity Channel Estimation in OFDM MU-MIMO Next Generation Cellular Networks", *2018 IEEE 29th Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC)*, Sep. 2018.

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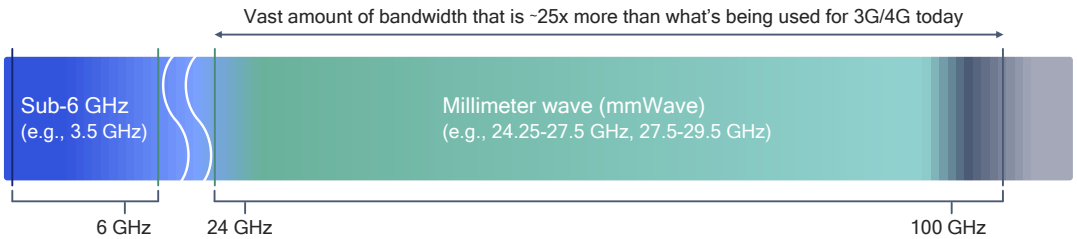
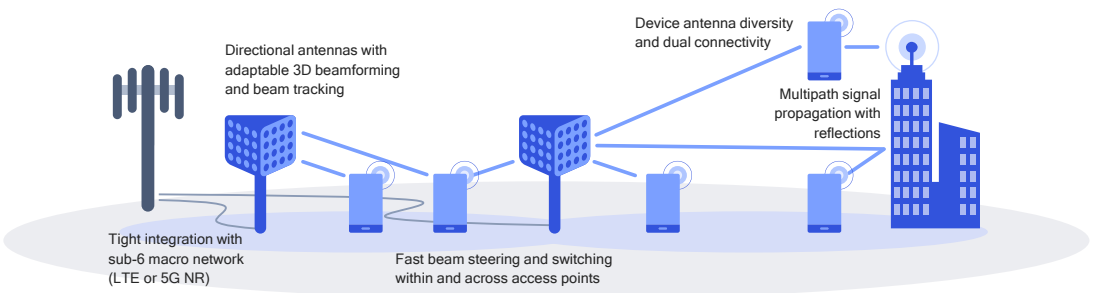
mmWave for Communications

New frontier of mobile broadband – mobilizing mmWave



Mobilizing mmWave with 5G NR technologies

Deploying a dense mmWave network with spatial reuse – ~150 - 200m ISD



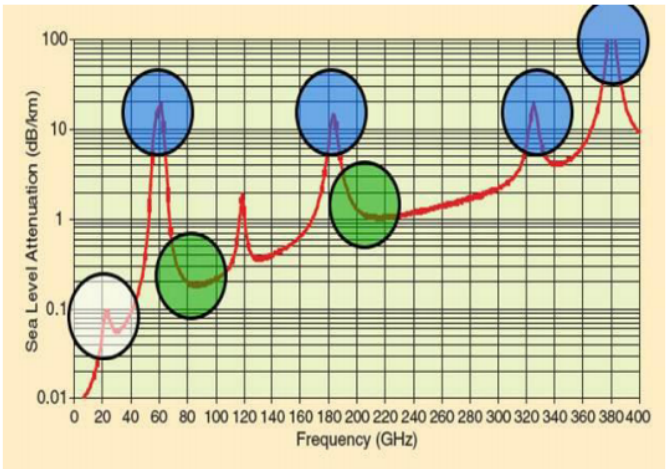


FIGURE 2. Atmospheric absorption across mm-wave frequencies in dB/km [1]. The attenuation caused by atmospheric absorption is 0.012 dB over 200 m at 28 GHz and 0.016 dB over 200 m at 38 GHz. Frequencies from 70 to 100 GHz and 125 to 160 GHz also have small loss.

T, S. Rappaport, S. Suni, R. Mayzus, H. Zha, Y. Azar, K. Wang, G. N. Wong, J. K. Schulz, M. Samimi and F. Gutierrez, Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!, *IEEE Access*, pp. 335 — 349, 2013.

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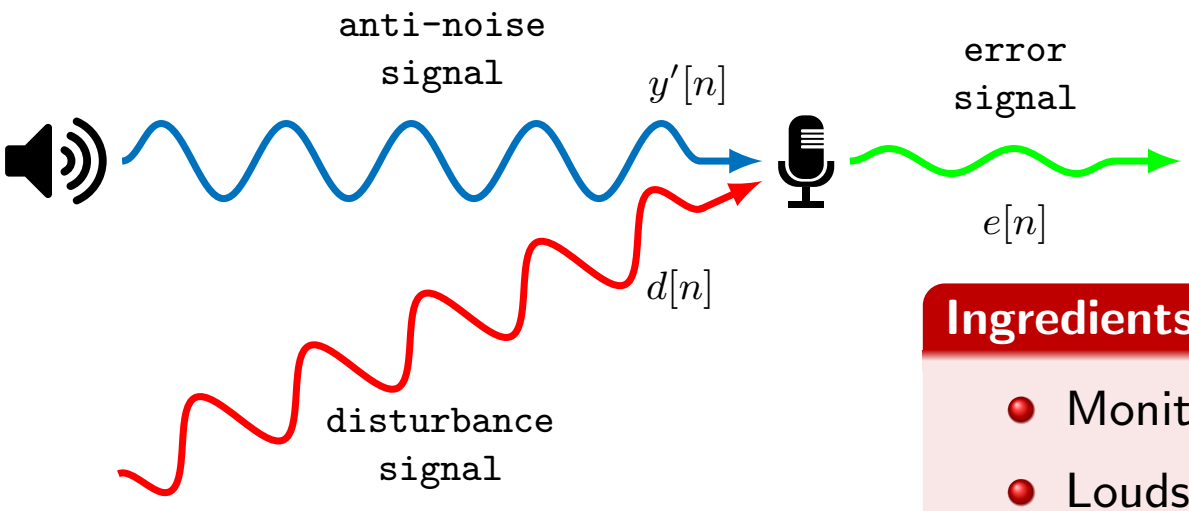
Active Noise Cancellation

Active Noise Cancellation (ANC) idea

- Mitigate undesired noise by emitting another noise of equal amplitude but opposite phase;
- Residual noise reduced by the superposition principle.

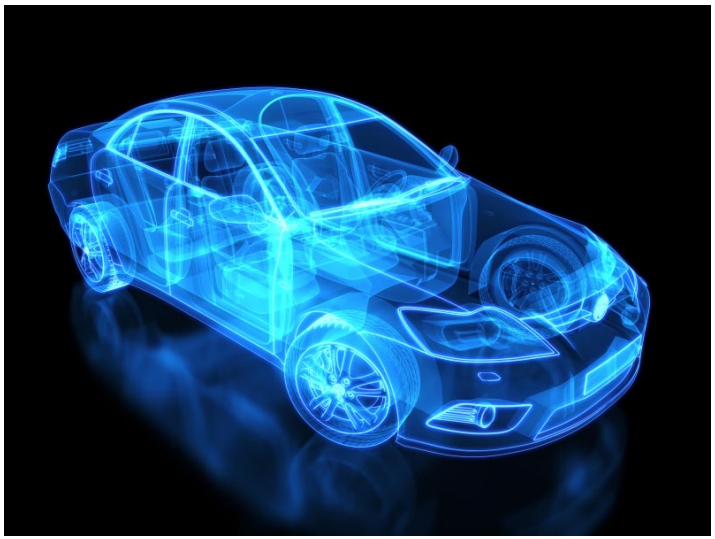


Ingredients

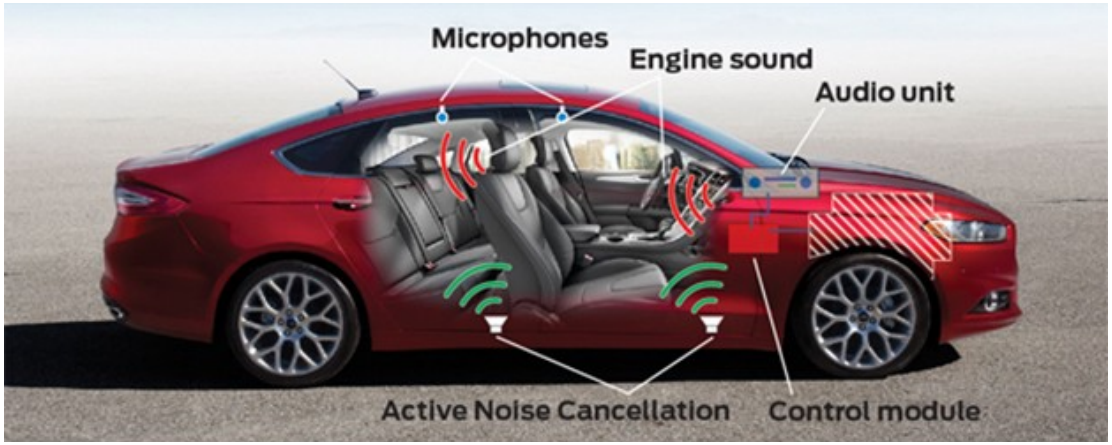
- Monitoring microphone;
- Loudspeaker for anti-noise emission;
- Digital Signal Processor (DSP).

ANC Applications

- Home & Entertainment;
- Industry;
- Transportation;
- **Automotive**.



ANC in Automotive



- FeedForward ANC System
- FeedBack ANC System
- **Virtual Error Microphone ANC System**
- Hybrid ANC System

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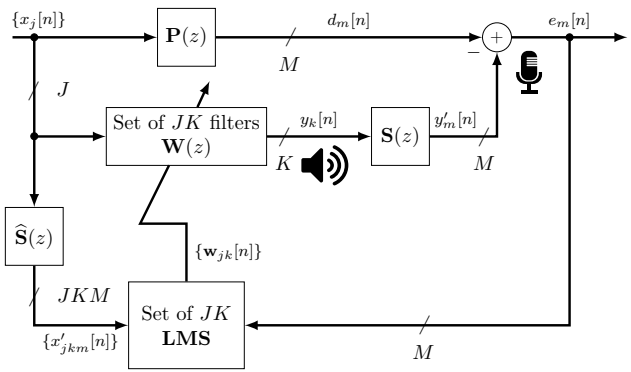

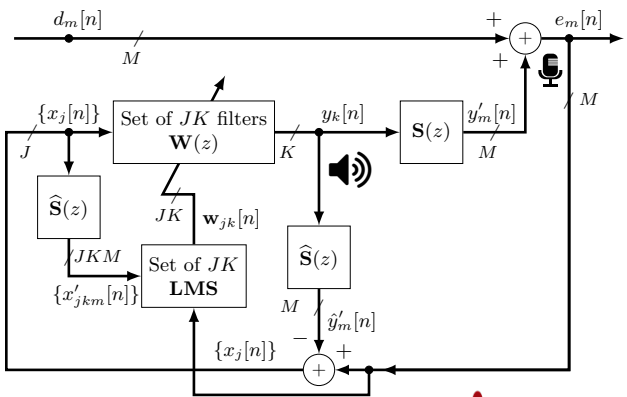

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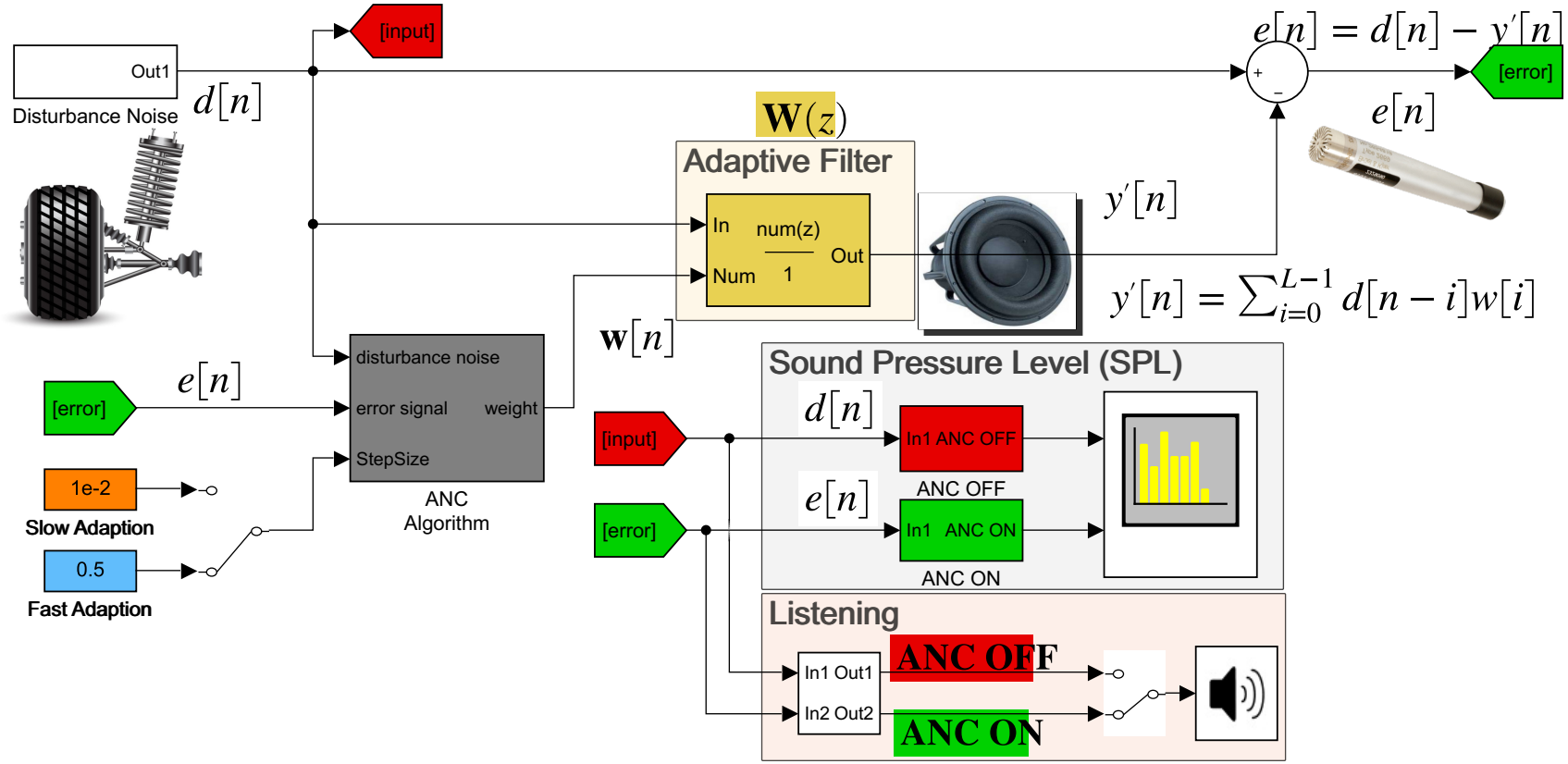
Simplified ANC Example



- $d[n]$: Noise to be canceled
- $y'[n]$: Anti-noise $y'[n] = \sum_{i=0}^{L-1} d[n-i]w[i]$
- $e[n]$: Residual error $e[n] = d[n] - y'[n]$

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Conclusions

Main Thesis Activities

- Channel estimation in 5G massive MIMO systems;
- Design of communication systems in mmWave;
- Non-Orthogonal Multiple Access (NOMA) for distributed wireless networks;
- Audio signal processing algorithms for automotive applications.

Questions?