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Mission Critical Voice QoE Measurement Methods

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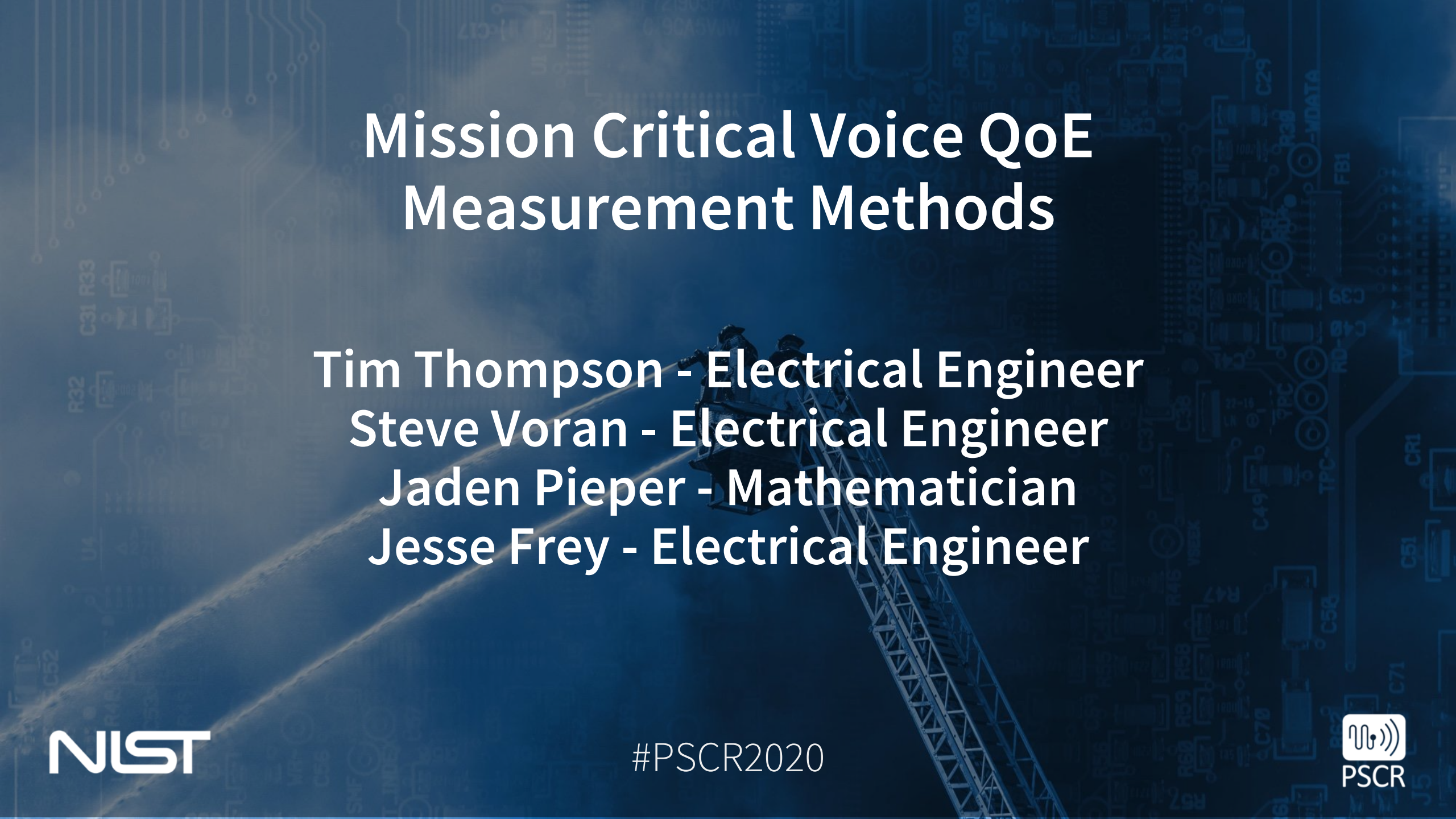

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Mission Critical Voice QoE Measurement Methods

- Review Mission Critical Voice (MCV) Quality of Experience (QoE) Measurement Method Projects (Speaker: Tim)
- Voice Quality/Intelligibility & Measurement Strategy (Speaker: Steve)
- Video Animation of Intelligibility Curve (Speaker: Jaden)
- Test Setup (Speaker: Tim)
- Modifications to Measurement Methods to Accommodate PTT Technology Attributes (Speaker: Tim)
- Recordings of Access Delays of PTT Technologies (Speaker: Jesse)
- Future Work/Direction (Speaker: Tim)

QoE KPIs for MCV - MCV Roundtable 2017

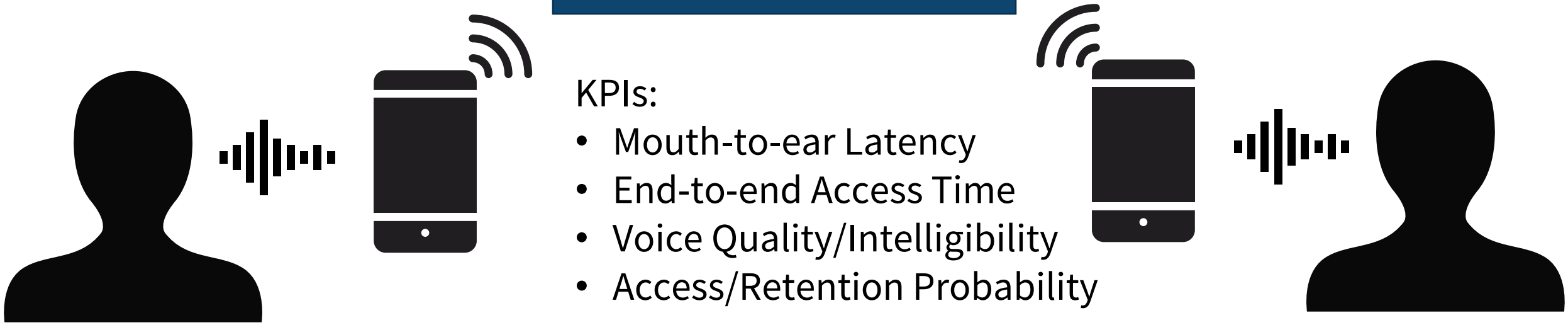
- Mouth-to-Ear (M2E) Latency
  - Time it takes audio to get from transmitting user to receiving user
- End-to-End Access Time
  - Time between PTT button press & receiving user hearing intelligible voice
  - Access Delay + M2E Latency
- Voice Quality/Intelligibility
  - Public Safety cares most about intelligibility
- Access/Retention Probability
  - Ability to establish call
  - Ability to retain call

Technology Agnostic Measurements

- Goal is to create a black box measurement system
  - Based upon the user experience -- speech
  - Comparable and fair across all voice communications technologies
- Not intended to
  - Diagnose internal components of specific systems
  - Attempt to improve the performance of systems

Technology Agnostic Measurements

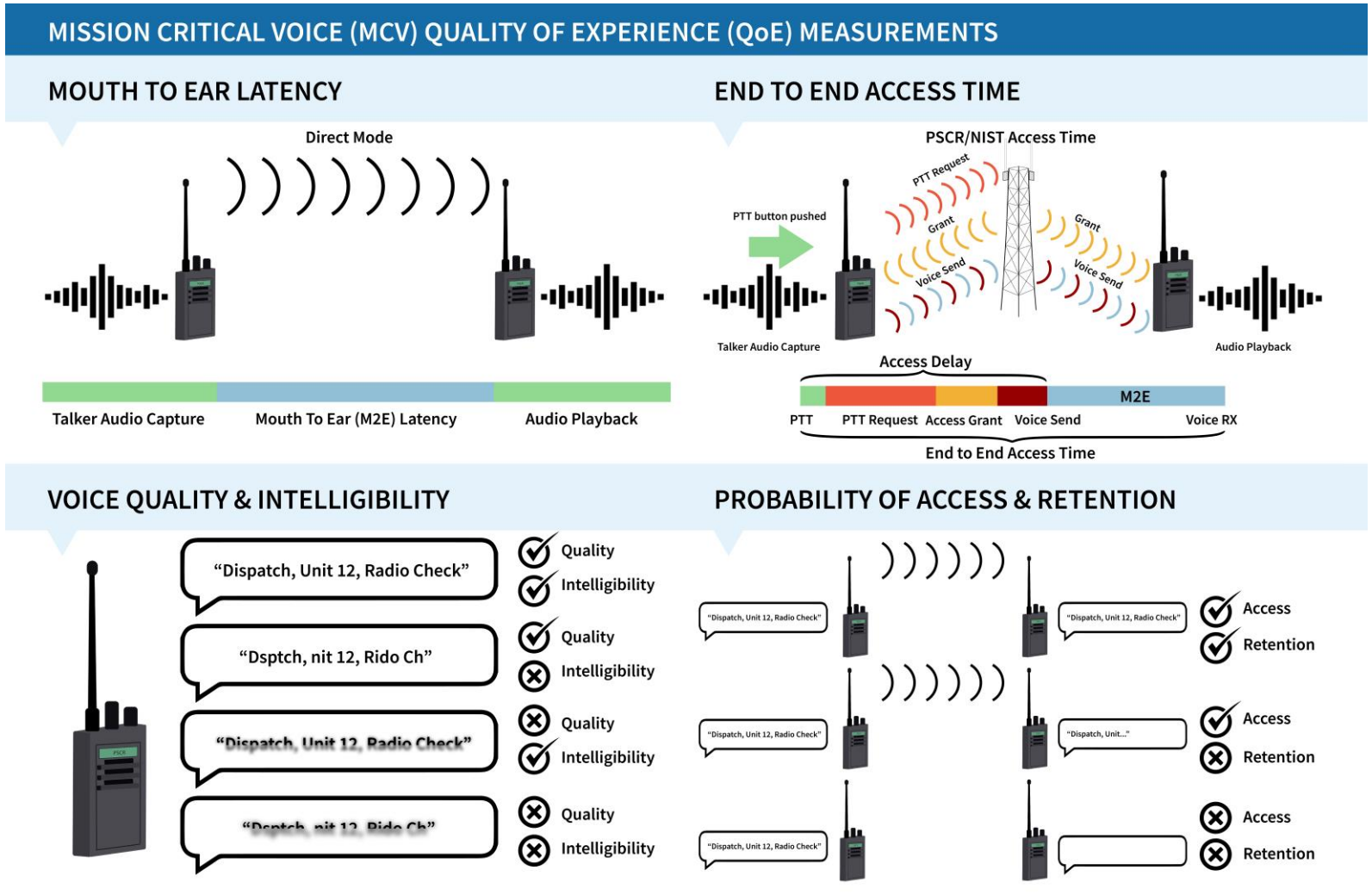
Communications System



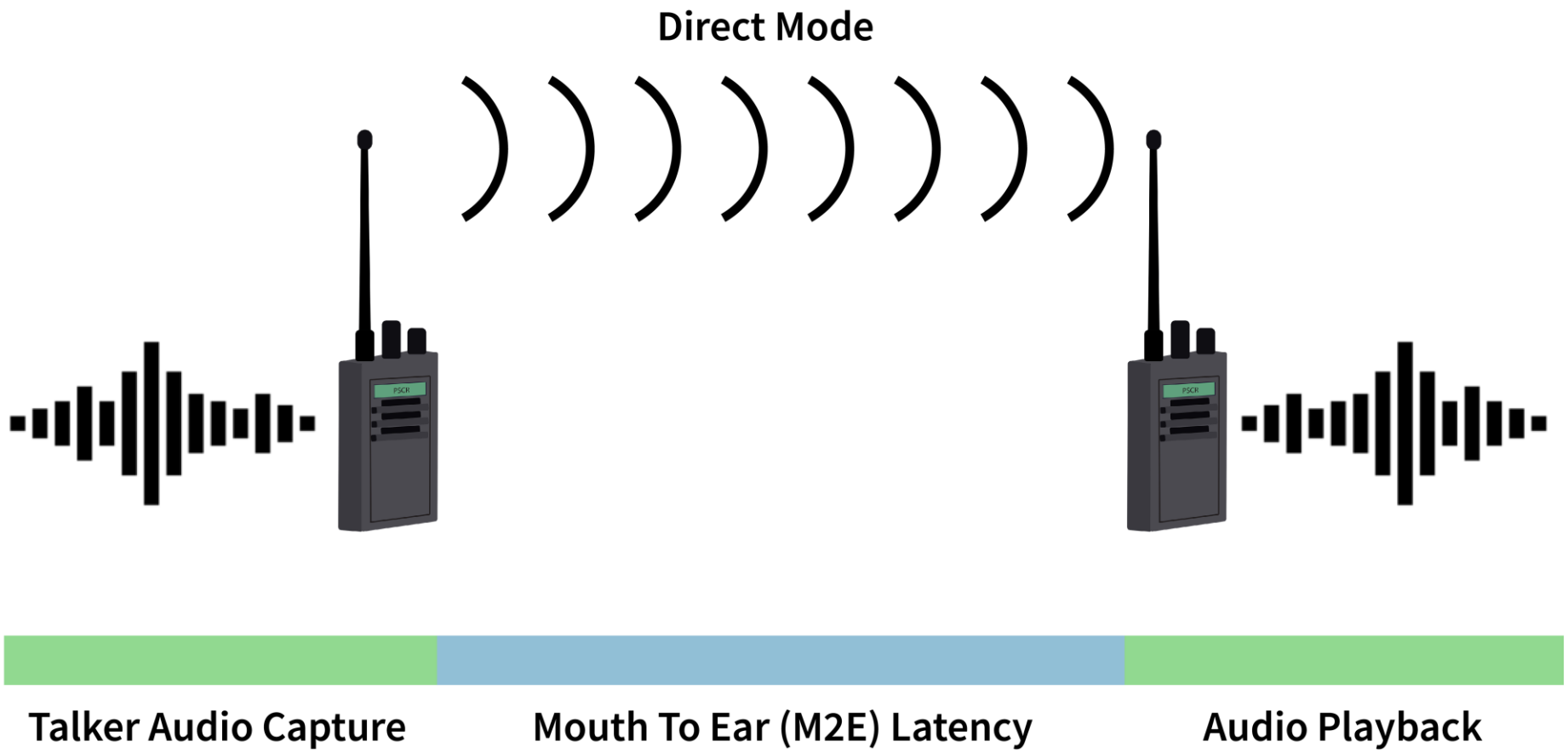
KPIs:

- Mouth-to-ear Latency
- End-to-end Access Time
- Voice Quality/Intelligibility
- Access/Retention Probability

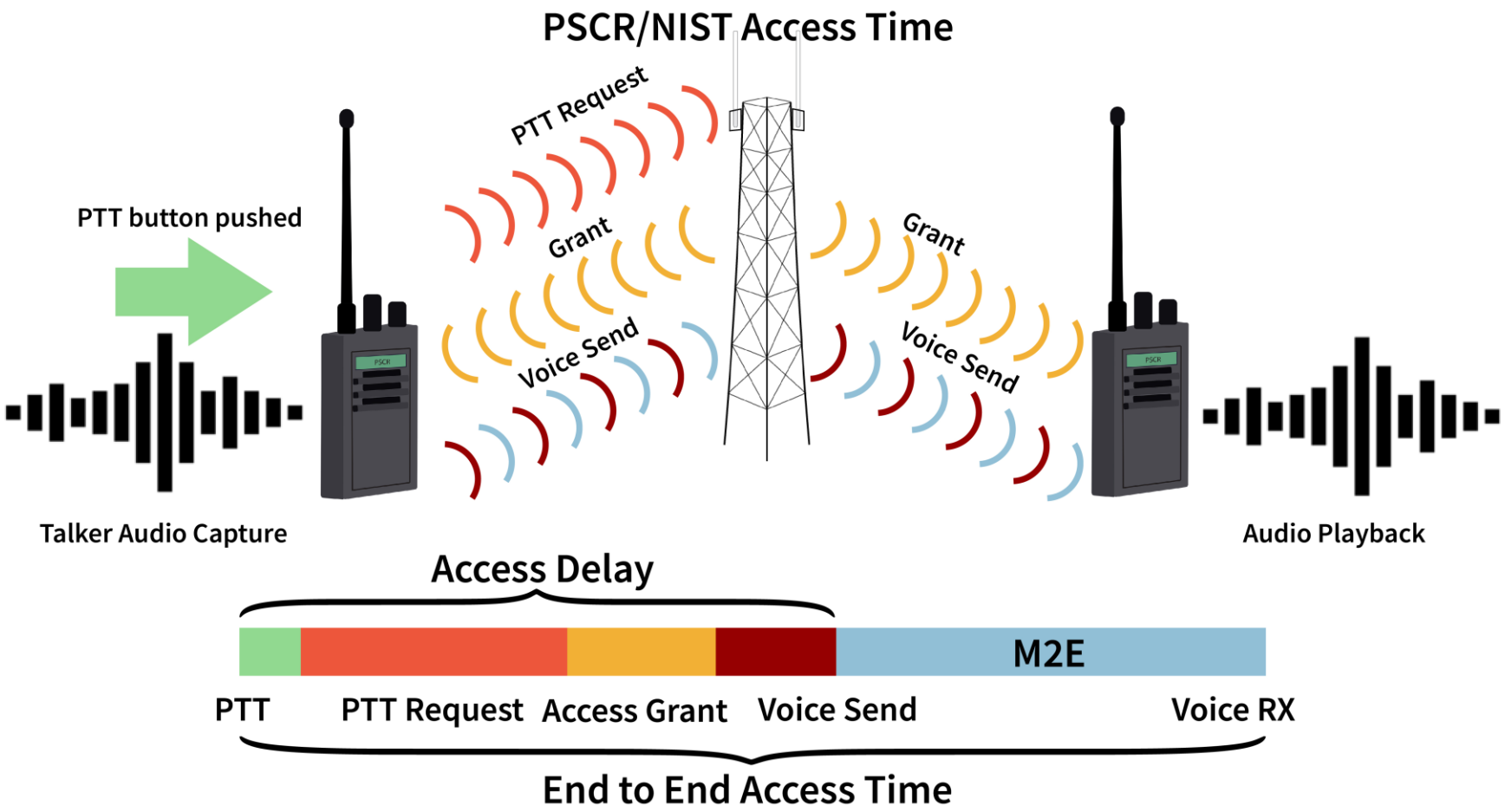
QoE KPIs for MCV



QoE KPIs for MCV – M2E Latency



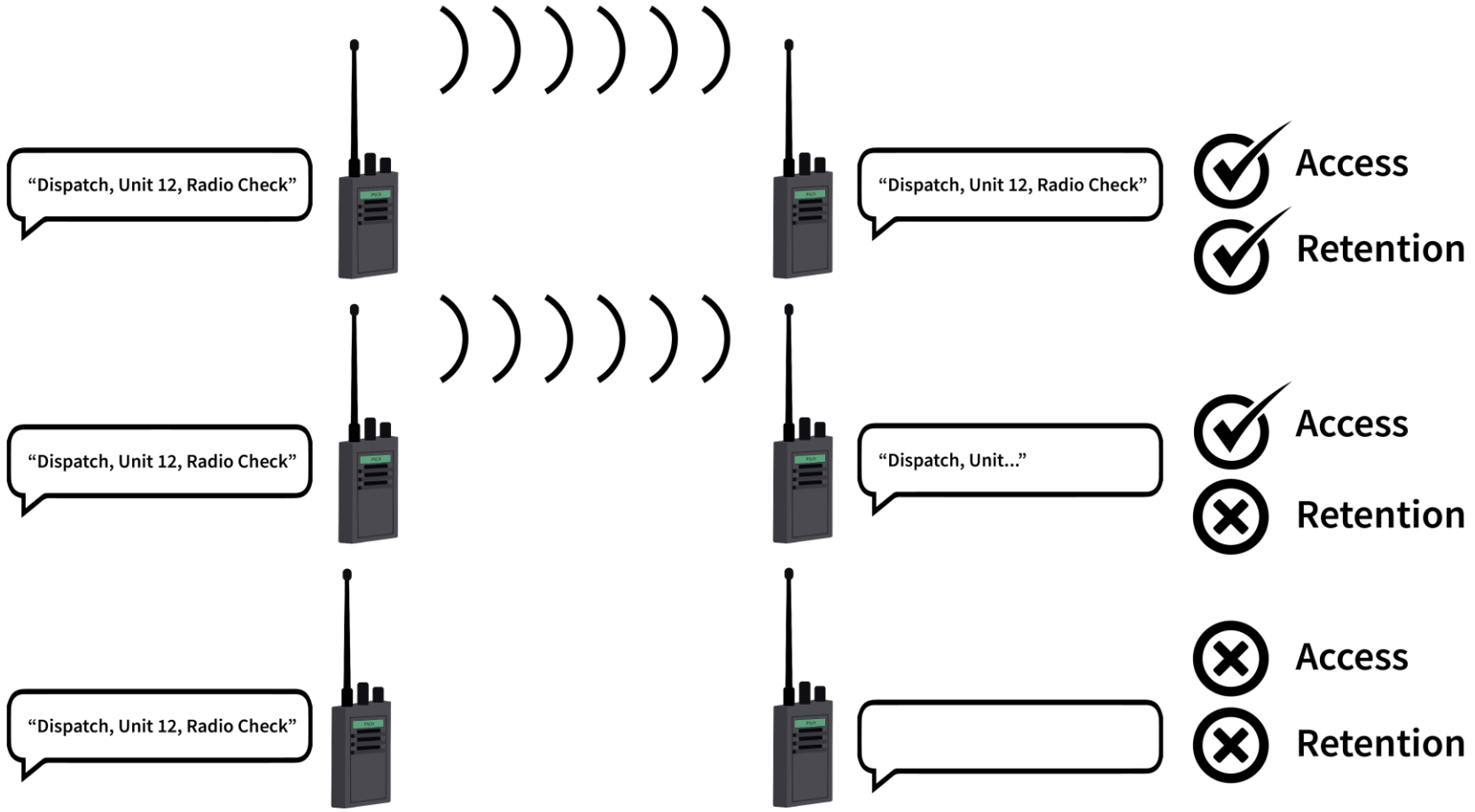
QoE KPIs for MCV – End-to-End Access Time



QoE KPIs for MCV – Voice Quality/Intelligibility

“Dispatch, Unit 12, Radio Check”	✓ Quality	✓ Intelligibility
“Dsptch, nit 12, Rido Ch”	✓ Quality	✗ Intelligibility
“Dispatch, Unit 12, Radio Check”	✗ Quality	✓ Intelligibility
“Dsptch, nit 12, Rido Ch”	✗ Quality	✗ Intelligibility

QoE KPIs for MCV – Probability of Access & Retention

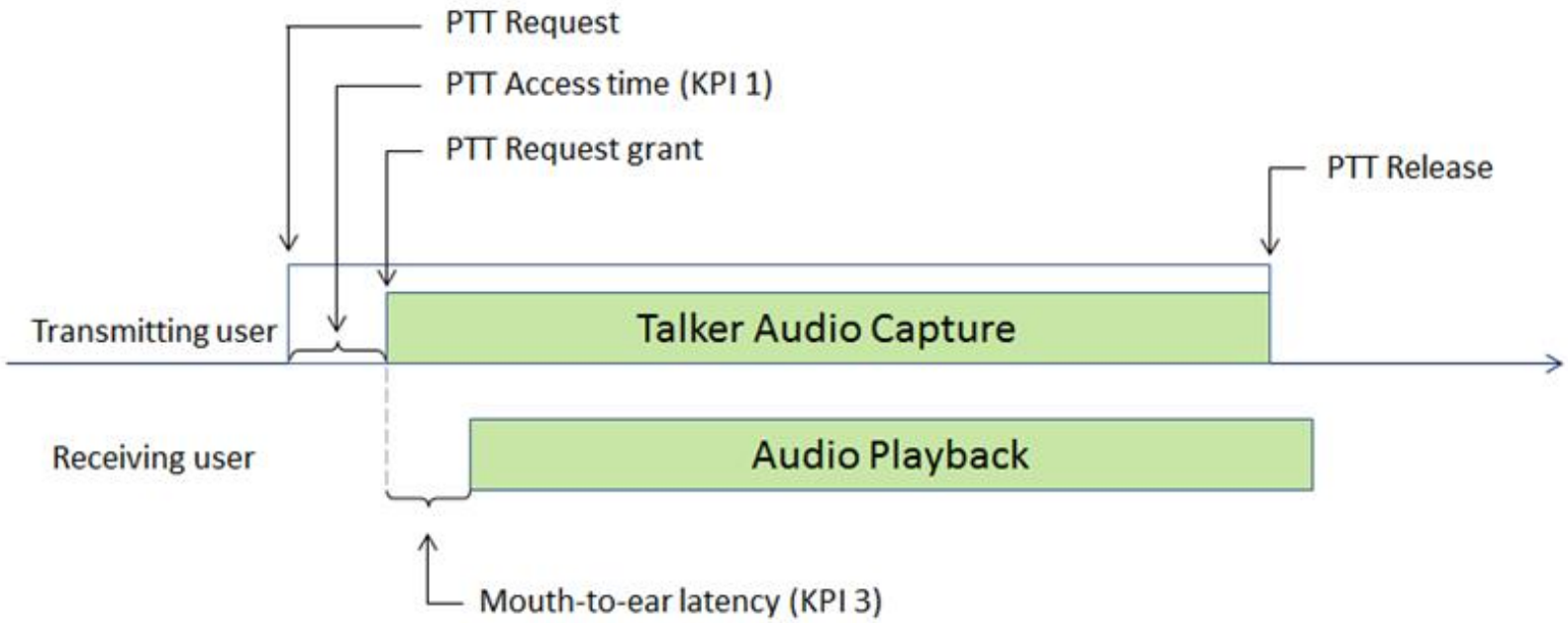


QoE KPIs for MCV - M2E Latency

- M2E Latency Measurement Method
  - Develop a method to measure & quantify M2E latency of any voice communications system
  - Method is based on audio in/audio out and is technology agnostic
  - Challenges faced developing this measurement methodology
    - Development of audio-based measurements
    - Optimal volume levels
    - Component to system level testing complexities with uncertainties
  - First step in establishing QoE-based KPIs

3GPP Defined KPIs

- 3GPP M2E Latency and Access Time



3GPP (2017) Mission Critical Push to Talk (MCPTT). 3rd Generation Partnership Project (3GPP), Technical Specification (TS) 22.179. Version 16.0.0 URL: https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=623

M2E Latency Measurement Results

	Single Location Lab (ms)	Two Location Lab (ms)	Two Location Field (ms)
Audio Device Characterization	21.85 ± 0.07	21.85 ± 0.07	21.85 ± 0.07
UHF-P25 Direct	201.4 ± 0.4	201.2 ± 0.3	201.8 ± 0.4
UHF-P25 Trunked	415.8 ± 2.8	413.1 ± 3.3	417.0 ± 2.9
VHF-P25 Direct	201.7 ± 0.5	201.6 ± 0.4	202.4 ± 0.4
VHF-P25 Trunked	403.9 ± 1.8	403.3 ± 2.8	405.3 ± 1.2

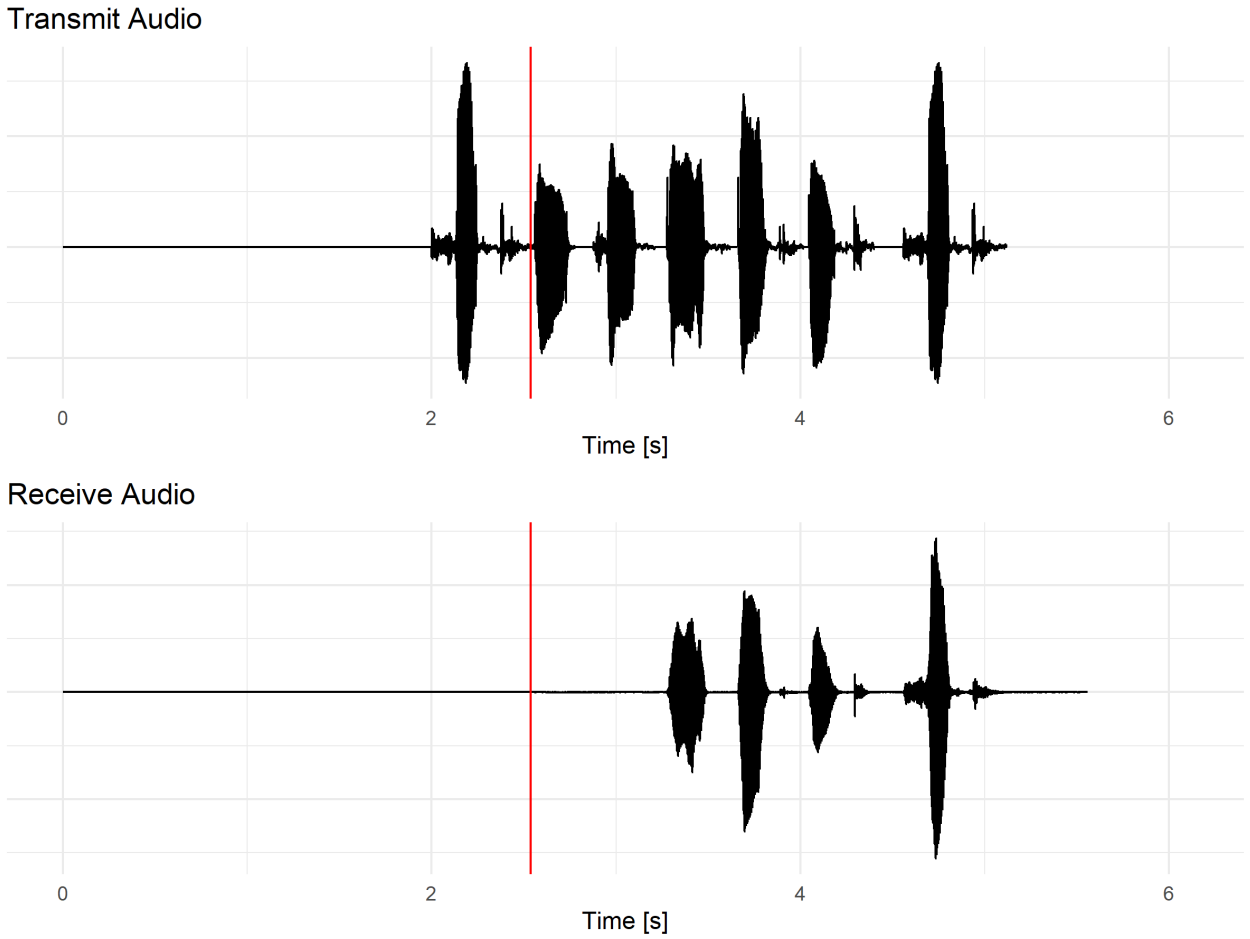
- Results are approximately 80-83% of TIA-102 standard limits for P25
  - Direct Mode: 250ms, Trunked: 500ms
- 7 km distance between TX and RX radios for two location field tests
  - 23 µs (microsecond) propagation delay (negligible)

QoE KPIs for MCV – Access Time

- Access Time
  - Trunked Mode/Mission Critical PTT
  - Measurement methods/definitions
    - TIA-102 P25 - Voice Access Time
    - 3GPP definition - PTT Access Time (KPI 1)
    - NIST/PSCR definition
      - End-to-End Access Time
  - Challenges faced developing this measurement methodology
    - Tried several different audio clips
    - Some words more challenging than others to achieve intelligibility
  - Critical next step in establishing QoE-based KPIs

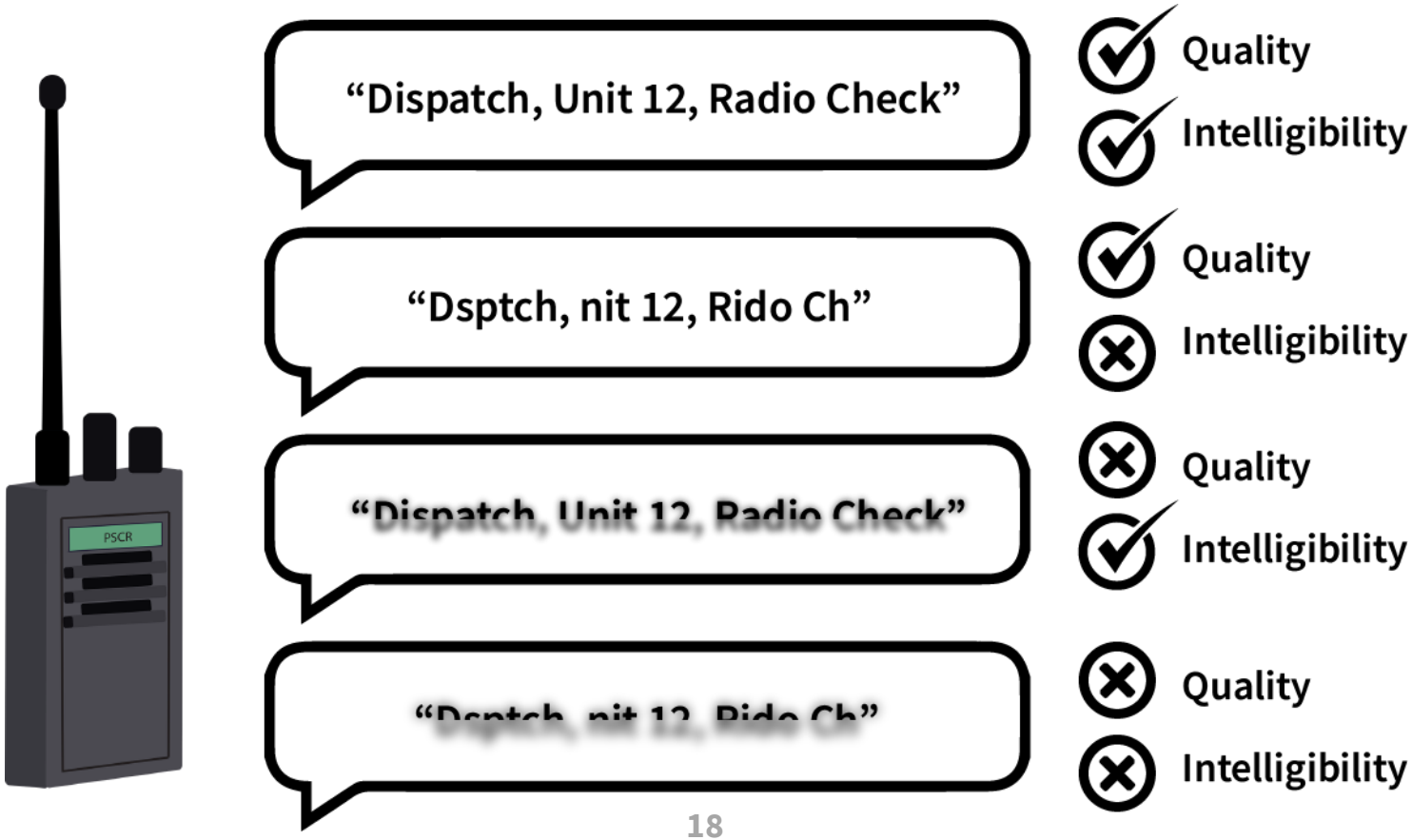
NIST/PSCR Definition of End-to-End Access Time

- Focuses on access delay
- Transportable to other technologies
- More user centric (QoE) measurement than TIA-102 and 3GPP
- Audio in/audio out method
- Audio is started before PTT button is activated
- Access delay is determined by the first intelligible speech played back by the receiving device



Voice Quality and Intelligibility

- First responders require intelligible speech in challenging audio environments
  - Background noises: alarms, sirens, helicopters, chainsaws, gun shots, etc.



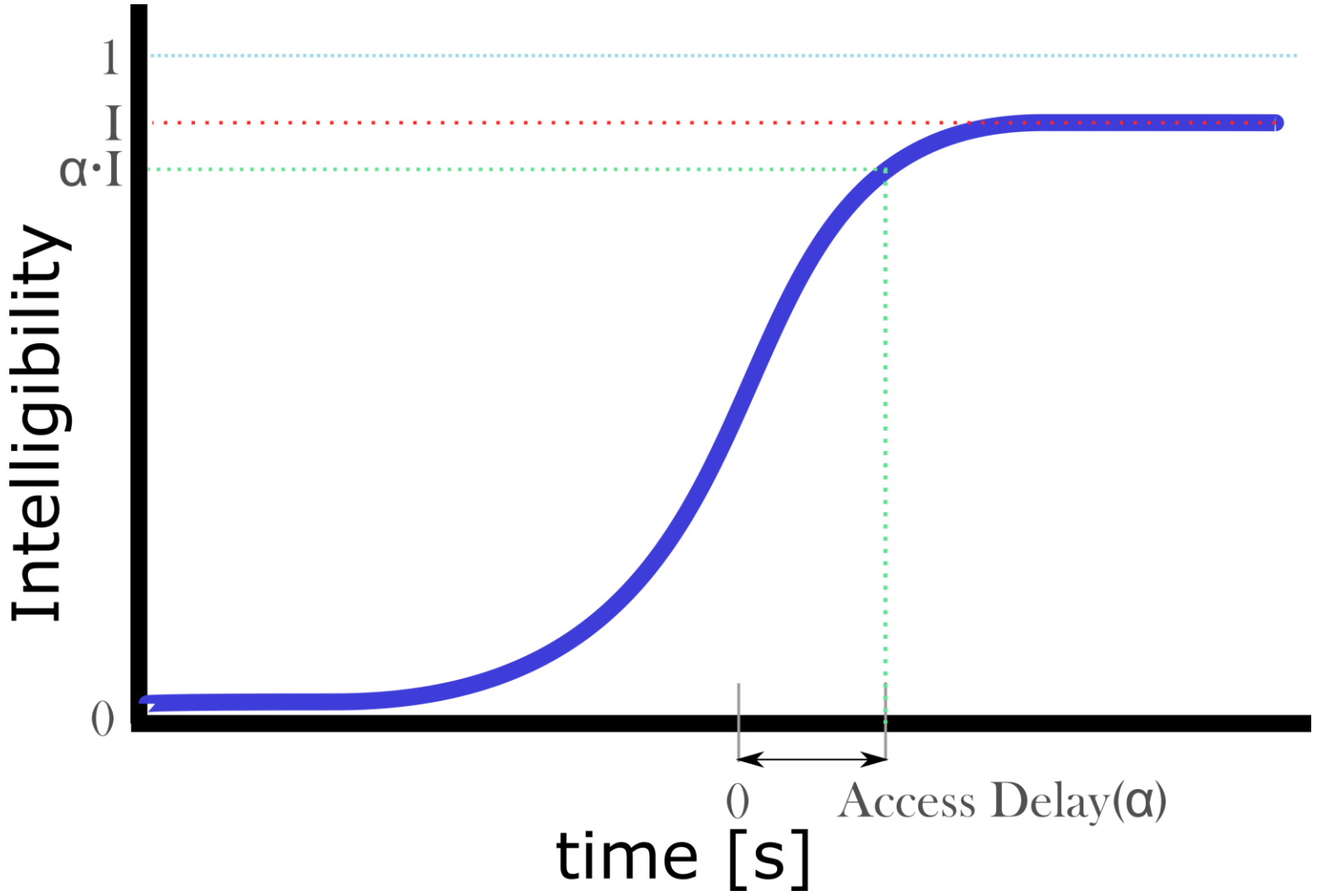
Measurement Strategy

- Leverage Intelligibility work performed by PSCR partner lab (Institute for Telecommunications Sciences)
  - Initiated by DJ Atkinson
  - Continued and extended by Steve Voran
- Measure intelligibility using the Modified Rhyme Test (MRT)
  - User picks correct word from 6 words that rhyme
  - For example: bed, led, fed, red, wed, and shed
  - Please select the word ----. (Carrier Phrase)
- Requires extensive human-based testing
- Signal processing based alternative
  - Articulation Band Correlation-MRT (ABC-MRT) and more recent ABC-MRT16

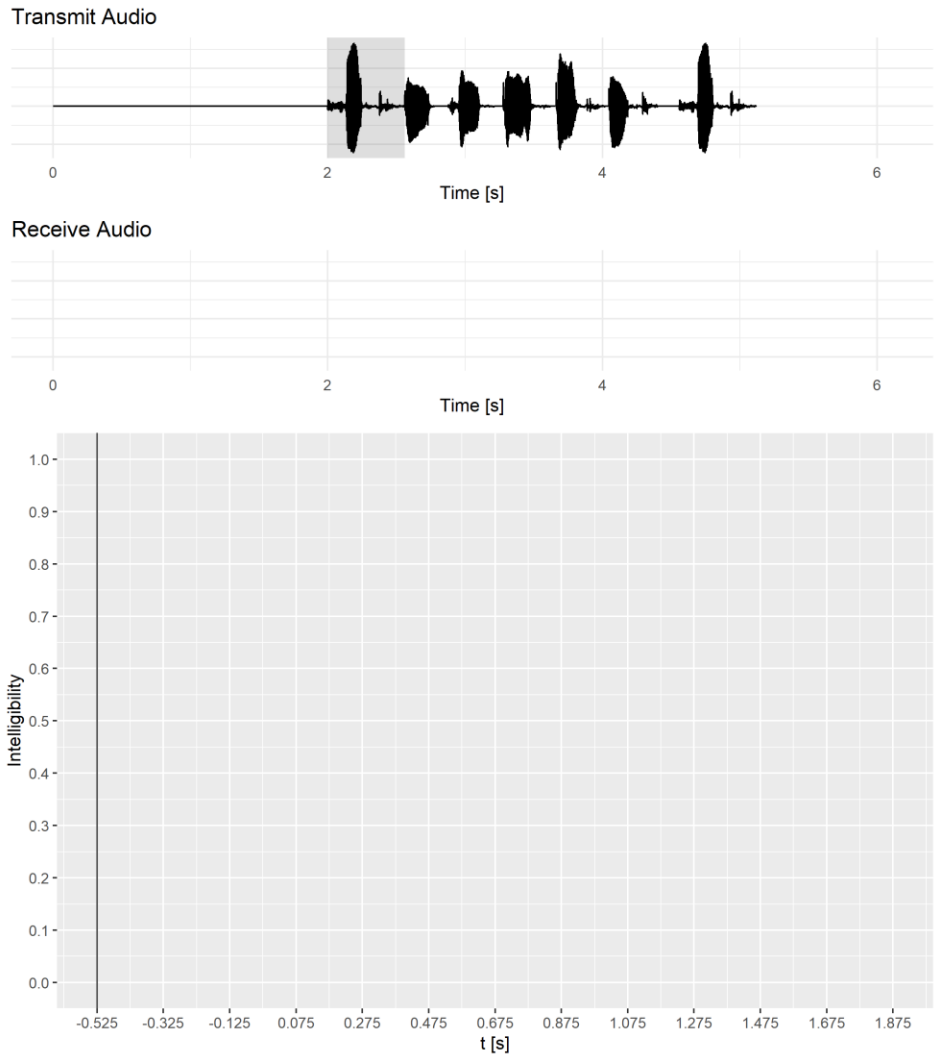
Measurement Strategy

- Intelligibility is important to determine end-to-end access time
  - The person on the other end must understand the entire message!
- User must wait for channel grant (access delay) before speaking
- Determine access delay with a multitude of tests
  - Capture variations in speech intelligibility and variations in the system under test
- Vary the time between the PTT request and first word over a series of trials
- Access Delay measurement curve for when the system achieves a fractional portion of its baseline Intelligibility

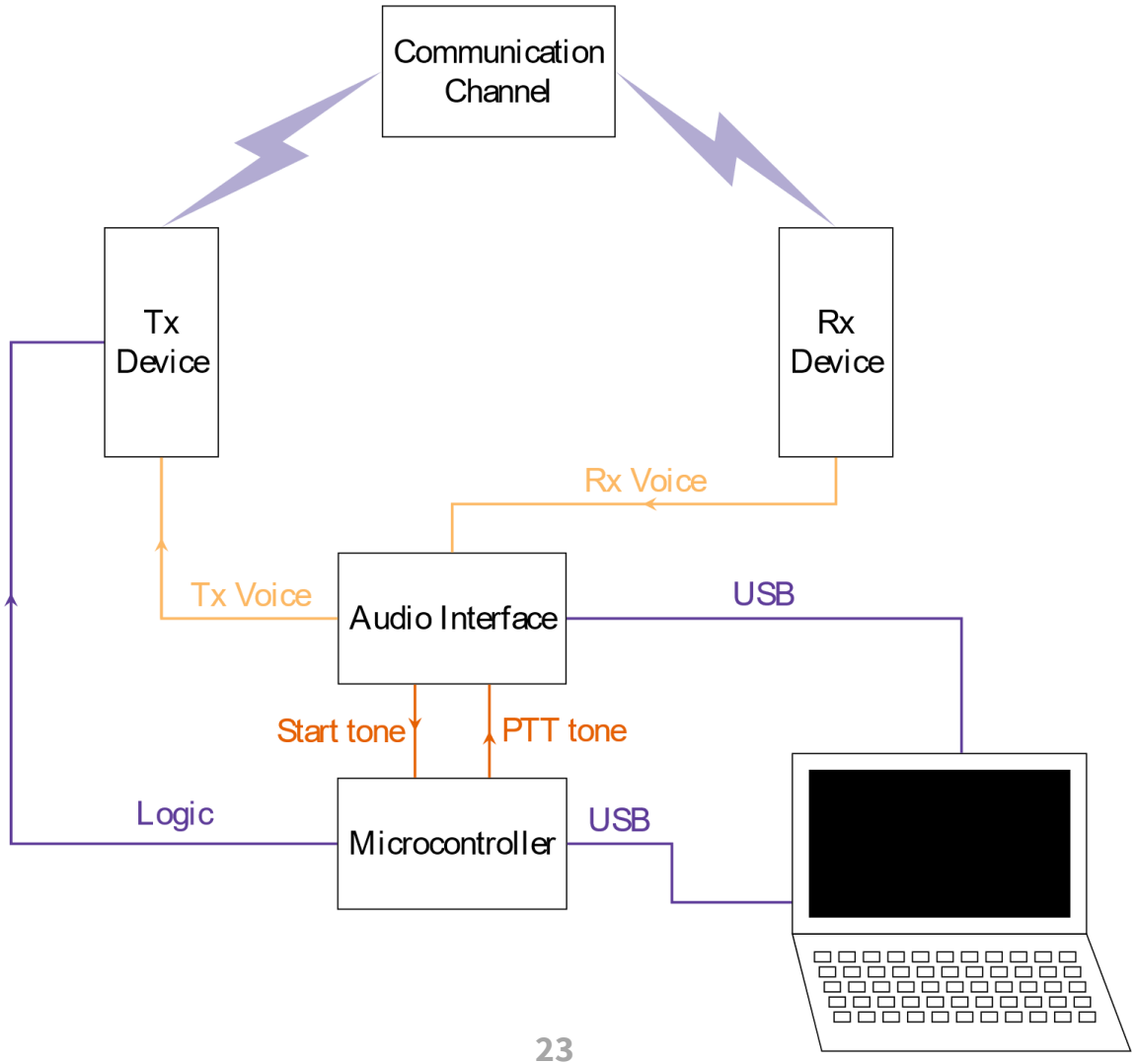
Intelligibility Curve



Video Animation of Intelligibility Curve



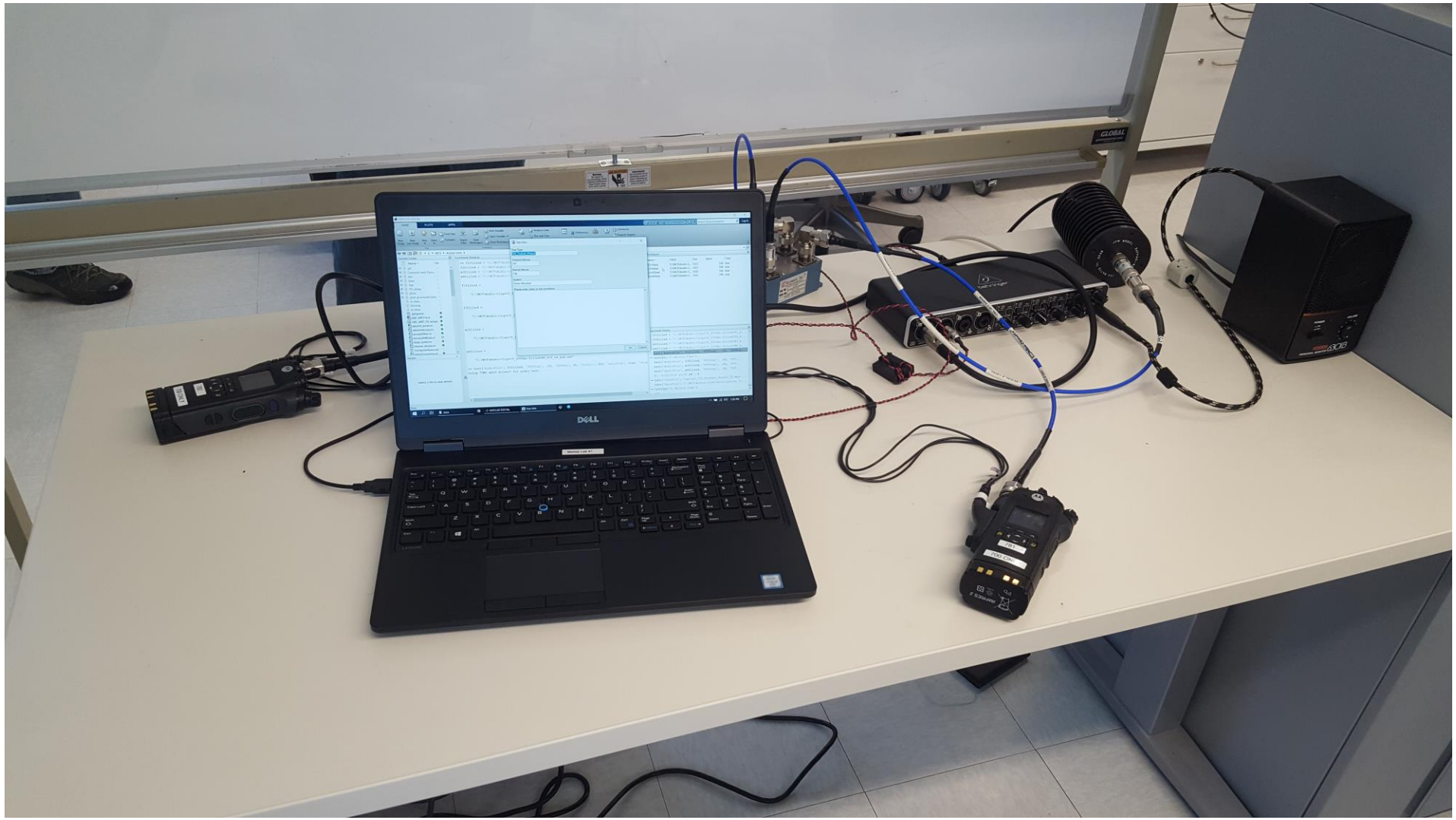
End-to-End Access Time Test Setup Diagram



End-to-End Access Time Measurement Devices

- Behringer UMC 204/404HD audio interface
- Audio interface settings
  - Sampling rate, buffer size, and USB Streaming Mode values chosen to prevent data over/under runs and audio glitches
- Audio interface device characterization
  - Latency: 21.85 ms (± 0.07 ms measurement uncertainty)
    - Time offset between play and record
- MATLAB
  - Audio System Toolbox
    - Used to play and record audio samples
    - Used to automatically key the PTT button via the microcontroller
- R software
  - Used to quantify end-to-end access time

Test Setup (Cabled RF)



End-to-end Access Time Results for 85% Intelligibility

PTT Technology*	M2E Latency (ms)	Access Delay (ms)	End-to-End Access Time (ms)
Analog Direct	76.5 ± 0.3	136.5 ± 3.3	213.1 ± 3.3
Analog Conventional	78.5 ± 0.3	286.1 ± 2.5	364.7 ± 2.5
P25 Direct	220.9 ± 0.3	71.6 ± 4.1	292.4 ± 4.1
P25 Trunked (Phase 1 – FDMA)	356.6 ± 3.8	640.1 ± 5.1	996.7 ± 6.3
P25 Trunked (Phase 2 – TDMA)	575.9 ± 8.1	692.2 ± 7.1	1268.1 ± 10.7
MCPTT LTE	317.6**	102.8 ± 2.1	420.4**

*Analog Conventional operates in VHF band.
**Preliminary results.
All P25 technologies operating in 700 MHz band.

Modifications to Measurement Methods to Accommodate PTT Technology Attributes

- Started using variably spaced filled speech audio clips to better measure M2E latency of low-rate vocoders
  - Low-rate vocoders can distort the envelope of the waveform of words
    - Can cause alignment issues in M2E latency measurement
  - P25 Phase 2 uses a half-rate vocoder (3.6 kbps)
- Increased period between repeated ABC-MRT words in the audio clip from 2000 ms to 2500 ms to measure systems with longer end-to-end access times
- Incorporated A-Weight level measurements to eliminate bad trials
  - A-weight applies a filter to the audio that mimics the human ear
  - -50dB Threshold
  - Most helpful for testing LTE PTT technologies

Modifications to Measurement Methods to Accommodate PTT Technology Attributes

- Implemented LTE specific changes to measurement method
  - Used Android Debug Bridge (ADB) debugging features to restart the PTT applications if/when it crashed periodically
  - LTE PTT using packetized voice not streaming digitized voice like P25 LMR
    - Loss, pause, and jump impairments
- Tested P25 with Encryption
  - No modifications required
  - Increases end-to-end access time by 30-50ms (Preliminary results)

Recordings of Access Delays

- Access Delays
  - LMR handsets
    - Shortest access delay
      - Analog Direct Mode
    - Longest access delay
      - P25 Trunked Phase 2 (TDMA) (Encrypted)

Future Work/Direction

- End-to-End Access Time Measurement Method
  - Requires further development
    - Jaden Pieper leading this effort with assistance from the PSCR MCV team
  - Validate measurement method on MCV systems in the PSCR lab
    - Testing MCPTT over LTE
    - Testing FirstNet LTE over the air
    - DHS interworking capability
    - Field testing
    - LMR-LTE interconnected systems (long-term goal)
    - Tim Thompson to lead with assistance from the PSCR MCV team
- Voice Quality/Intelligibility
- Access/Retention Probability

MCV QoE Measurement Methods Publications, Data, & Code

- M2E Latency
  - https://www.nist.gov/ctl/pscr/mission-critical-voice-qoe-mouth-ear-latency-measurement-methods
- End-to-end Access Time
  - https://www.nist.gov/ctl/pscr/mission-critical-voice-qoe-access-time-measurement-methods

Team Members

- Back Row
  - Steve Voran
  - Tim Thompson
  - Jesse Frey
  - Zainab Soetan
- Front Row
  - Hossein Zarrini
  - Don Bradshaw
  - Chelsea Greene
  - Jaden Pieper


THANK YOU
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