Flying to the Moon on Radio Waves: Optimizing Outcomes with RF Technologies

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From Good to Great!

All too often, good is the enemy of great. – Jim Collins
Oklahoma!

- 50th recent visit to the dentist
- 48th in physical activity
- 50th in % of people who eat at least one vegetable per day
- #1 in fast food restaurants per capita
- 49th in heart health
Road Map

- Adaptive Digital Broadband Wireless Technology
  - Introduction
  - Study with CI Users
  - How about Hearing Aid Users?

- Classroom Audio Distribution Systems

- Audio Streaming
A Noisy World!

The SNR in these environments is typically -5 to +5 dB

- 37 dB A (with A.C. = 52 dBA)
- Classroom:
  - 66 dBA
- School Assembly:
  - 76 dBA
- School Cafeteria:
  - 82 dBA
- OKC Thunder Basketball:
  - 100 dBA

Children with hearing loss need a +15 dB SNR!
The Evolution of Technology

- 1996  First miniaturized ear-level FM receiver
- 2000  Universal ear-level FM receiver
- 2003  Frequency-flexible FM system
- 2008  Dynamic FM - the first adaptive FM system
What about Dynamic FM?

No FM

Traditional FM: Gain is fixed

Dynamic FM: Gain increases as ambient noise increases
Thibodeau -- Dynamic FM

Thibodeau (2010), American Journal of Audiology
• What is a digital RF system?
Frequency Modulation Radio Transmission

Input Sound

a

Carrier Frequency

b

Amplitude Modulation

c

Frequency Modulation

d
Digital Radio Frequency Transmission
Amplitude Shift Keying

Carrier Frequency

1 0 1 0 1 1 0 1 0 1
Digital Radio Frequency Transmission
Gaussian Frequency Shift Keying
Dynamic FM & Digital RF

Speech perception scores

<table>
<thead>
<tr>
<th>Noise level</th>
<th>Phonak MLxi</th>
<th>Phonak MyLink+</th>
<th>Comfort Audio</th>
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<tr>
<td>quiet</td>
<td>97,4</td>
<td>98,05</td>
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<td>21,15</td>
<td>8,6</td>
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</table>

Aslund et al., 2011

N = 20
• Does an adaptive digital wireless system offer benefit for CI users?
Roger Digital Wireless Characteristics

- Audio signals are sampled, digitized and packaged in very short (160 μs) digital bursts of codes (packets) and broadcast several times, each at different channels between 2.4000 and 2.4835 GHz
  - The 2.4 GHz ISM (Industry, Science and Medical) band is globally license free
- Frequency hopping between channels, in combination with repeated broadcast, avoids interference issues
- The frequency hopping is adaptive, both receivers and transmitters are searching continuously to find free channels and to avoid occupied channels
- End-to-end audio delay is well below 25 ms – 7500 Hz BW
- Digital control of adaptive (Dynamic) gain changes
Roger Technology

Does it work for cochlear implant users?

What about hearing aid users?
Study Objectives

• Evaluate speech recognition in quiet and in noise with speech (HINT) at 85 dBA at transmitter and classroom noise at 50, 55, 60, 65, 70, 75, 80 dBA

• Evaluated 3 RF remote microphone systems:
  – Fixed-gain FM – MLxS
  – Adaptive FM – MLxi
  – Digital RF – Roger

• Ensure consistency of signal and a lack of interference.
Results
Advanced Bionics Recipients (n = 16)

Adults with normal hearing score 95% correct here!

Wolfe et al., in press, JAAA
Results
Cochlear Recipients (n = 21)

Wolfe et al., in press, JAAA
MED-EL and Roger

Wolfe et al., (2013), Hearing Journal
What about hearing aids?

Speech Recognition Benefits of Digital Adaptive Broadband Wireless Transmission Technology

Linda M. Thibodeau
AAA, 2013
Annaheim, CA
Dr. Linda Thibodeau
University of Texas at Dallas
Speech in noise testing
11 listeners using their own BTE’s
Ages 15 to 78
Traditional FM vs Dynamic FM vs Roger
Randomized, blinded
Different noise levels
The test set-up
HINT Results (N=10)

- **Fixed FM**
- **Adaptive FM**
- **Adaptive Digital**

Results (N=10) by Thibodeau, 2013
Hearing Aid & CI Users

Hearing Aids

Cochlear Implants
Hearing Technology Research with Children
• What about digital RF in a classroom audio distribution system?
Classroom Audio Distribution Systems

Goals: Create a uniform distribution of the sound of interest across the classroom, and provide a modest improvement in the signal-to-noise ratio.

May utilize:
- FM
- Infrared
- Digital RF
Classroom Setup

NOISE LEVEL: 
L1 = L2

22 ft, 4 in
18 ft
15 ft, 5 in

schematic diagram
Test Conditions

• No FM

• Phonak DM5000 alone

• Audio Enhancement Elite II alone

• Phonak DM5000 + Personal FM
  – Inspiro to DM5000 and Personal FM

• Audio Enhancement Elite II + Personal FM
  – Inspiro connected to audio output port of Elite II

• Personal FM alone
  – Inspiro to personal FM
Children with Hearing Loss
CADS Performance

% Correct

Noise Level (dBA)

- Quiet
- 50
- 55
- 60
- 65
- 70
- 75

- No FM
- Phonak Dynamic Soundfield
- Audio Enhancement Soundfield
Children with Hearing Loss
CADS + FM vs. Personal FM

% Correct

Noise Level (dBA)

- No FM
- Phonak Dynamic + Personal FM
- Audio Enhancement + Personal FM
- Personal FM Only
Clinical Implications

- CADS can improve speech recognition in noise for all students.
- Dynamic CADS provide better speech recognition in noise than fixed-gain CADS.
- Personal FM provides the largest improvement in speech recognition in noise.
- Be careful when using a personal RF system with a CAD system of a different manufacturer.
- Little to no speech recognition in noise improvement with Phonak CADS + Personal FM vs. Personal FM alone.
  - But CADS may improve classroom acoustics in real world.
Bluetooth & Near-field Digital Induction

HiBAN 10.6 MHz Digital Induction

Bluetooth

TVLink

Phonak Remote Mic
Why use a streamer?
Bluetooth & Near-field Digital Induction

HiBAN
10.6 MHz Digital Induction

Bluetooth

TVLink

Phonak Remote Mic
Near-field Magnetic Inductive Transmission

- Allows for efficient transfer of audio signal in near-field → Between ears
- Low power requirements
- Can transfer substantial amount of information when paired with Codec (similar to MP3)
Near-field Digital Magnetic Inductive Transmission

• To share audio information between ears (Streaming)

• Phonak HiBAN — Hearing Instrument Body Area Network
  • Digital inductive transfer at 10.6 MHz
    — Transfer of telephone signal -- DuoPhone
    — Binaural directionality -- StereoZoom
    — Focused listening – Focus to the left/right -- ZoomControl
    — Wind noise management
    — Bilateral adjustments – Quick Sync

• Oticon Binaural
  — Preservation of binaural cues → localization
Evaluating DuoPhone for telephone use

• Tested word recognition on the telephone in quiet and in noise for children with hearing aids

  – 14 children (6-14 years-old)
    • Recorded CNC words

  – 10 children (2-5 years-old)
    • NU-CHIPs words via live voice (open-set)
Mean CNC word recognition scores for older children (6-14 years-old)
Mean NU-CHIP word recognition scores for younger children (2-5 years-old)

- Quiet
- Noise (55 dBA)

Monaural
DuoPhone
Hailey: The One-Eared Phone Listener
Hailey and the DuoPhone
Conclusions/Clinical Implications

• Don’t settle for good. Shoot for the moon! Great outcomes are possible when we properly use the best hearing technology available today.

• Roger > Dynamic FM > Fixed-gain FM

• Dynamic CAD can provide better speech recognition in noise than fixed-gain CAD.

• Children need to hear with 2 ears whenever possible.
Thank You for Your Attention!

www.heartsforhearing.org