The Evolution of Wireless Systems in Pediatric Settings

Evert Dijkstra VP Phonak Communications

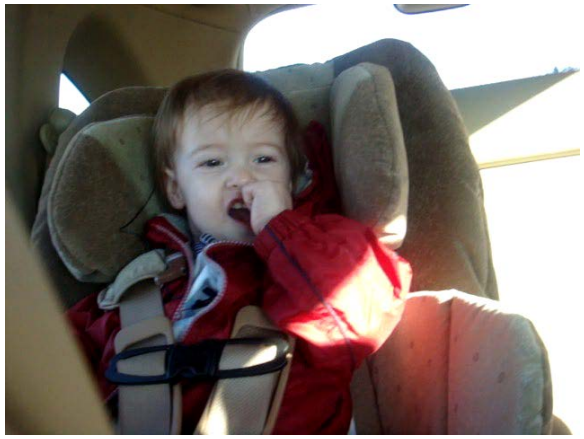
Wireless systems for children with hearing loss introduced just 50 years ago

Basic principle has not changed. Esthetics, performance, ease-of-use did change

Mark Ross (2003, Access conference Chicago):

- FM systems most significant educational tool developed for hearing impaired children ever developed
- Remain the single most effective way to increase S/N
- The most important factor for speech understanding
- Crucial for adults but even more important for hearing impaired children who are in the process of developing speech and language

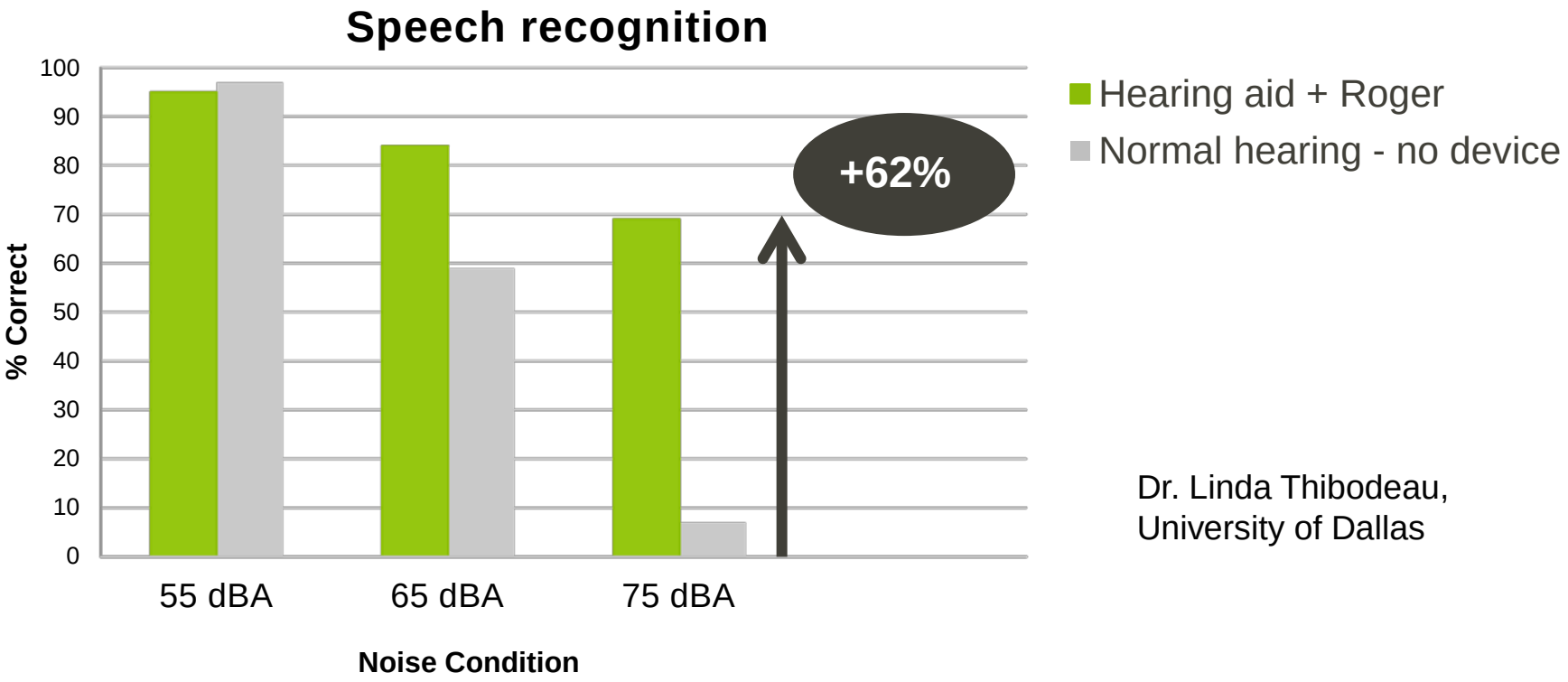
50 years later….



Adoption rates for children are increasing

(from toddler to teenager, from Anglo-Saxon speaking to worldwide)

Current state of the art performance of wireless systems



Dr. Linda Thibodeau,
University of Dallas

Listeners with hearing loss understand up to 62% better than those with normal hearing.

Wireless systems in educational settings shall ideally offer:

Zero hassle

Maximum performance

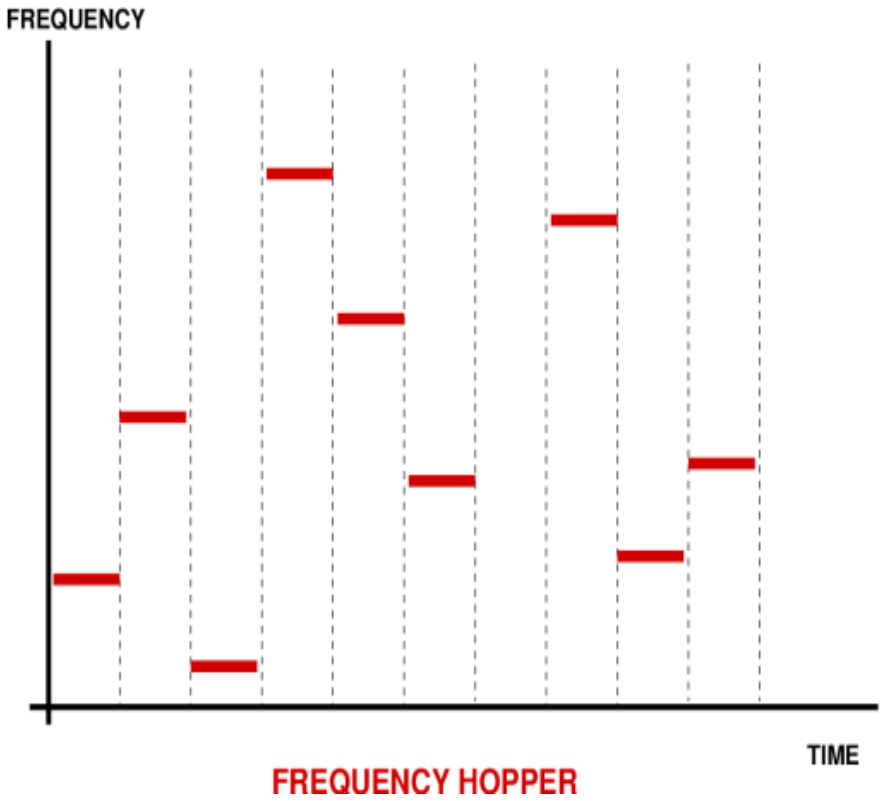
Full compatibility

Sophistication with the purpose to simplify !!

Zero Hassle

- Adaptive frequency hopping technology
- Easy connectable receivers and transmitters
- Easy to use interfaces

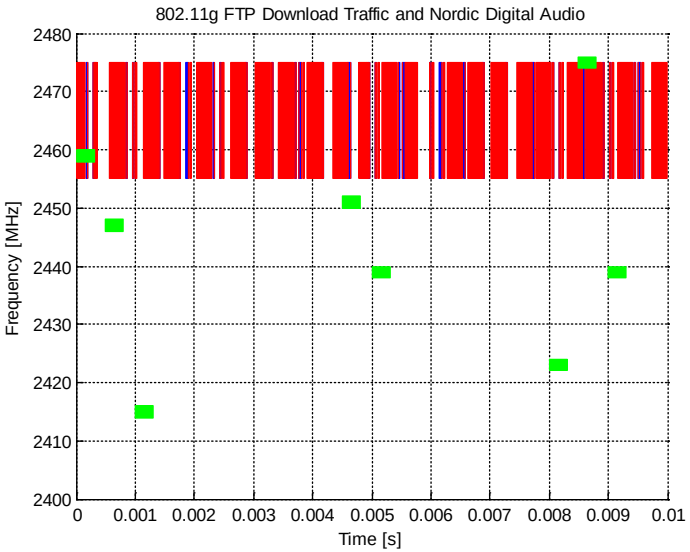
Frequency hopping principle

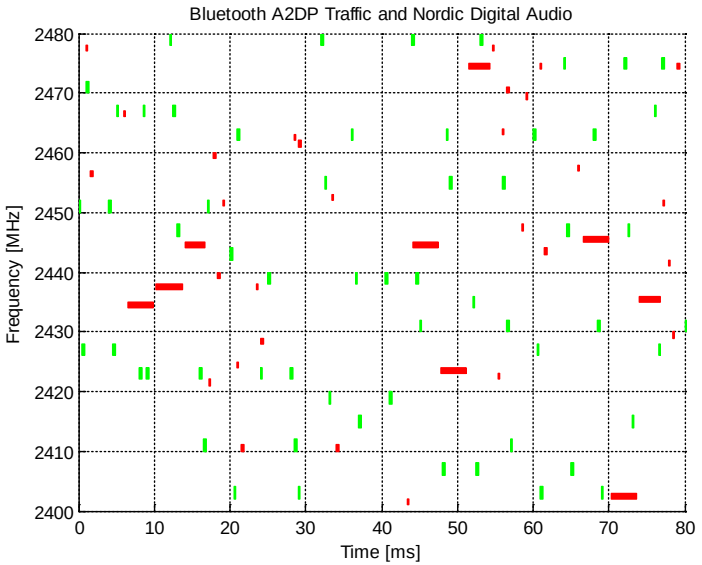


- Frequency hopping:
  - Change frequency for each packet in a pseudo random way
- Adaptive frequency hopping:
  - Use the most favorable frequencies by dynamically adapting the sequence
- Different users:
  - Use of different pseudo-random sequences

Frequency hopping makes channel selection obsolete

Interference mitigation



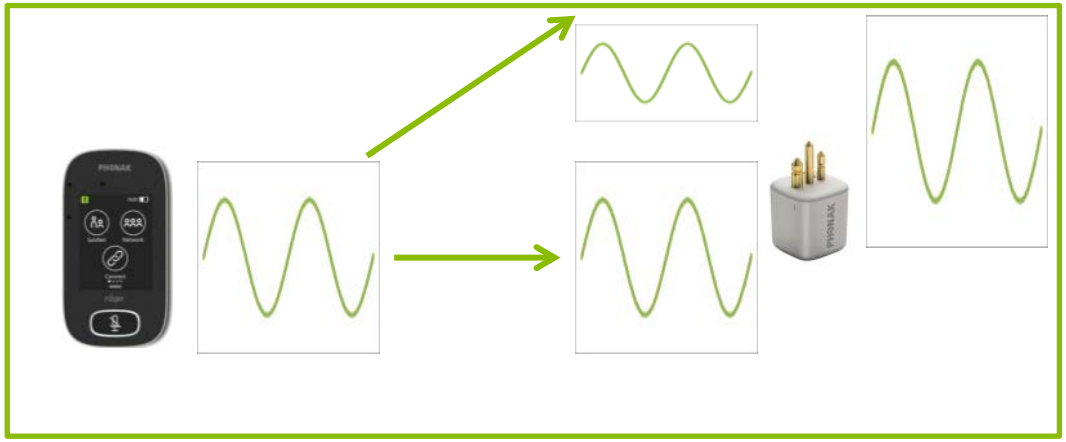


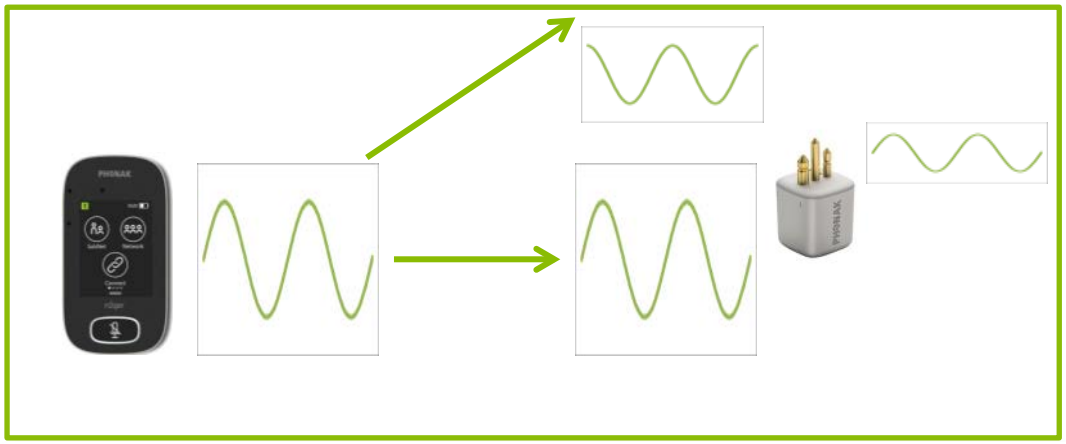
Adaptive Frequency Hopping (Bluetooth, Roger) is the best choice

- Transmitter(s) sniffs continuously whether WiFi is present
- Receiver(s) compute continuously the number of corrupted packets
- Transmitter(s) and receiver(s) exchange regularly data so that occupied spectra can be avoided

Much better than for systems with channels

Multipath fading



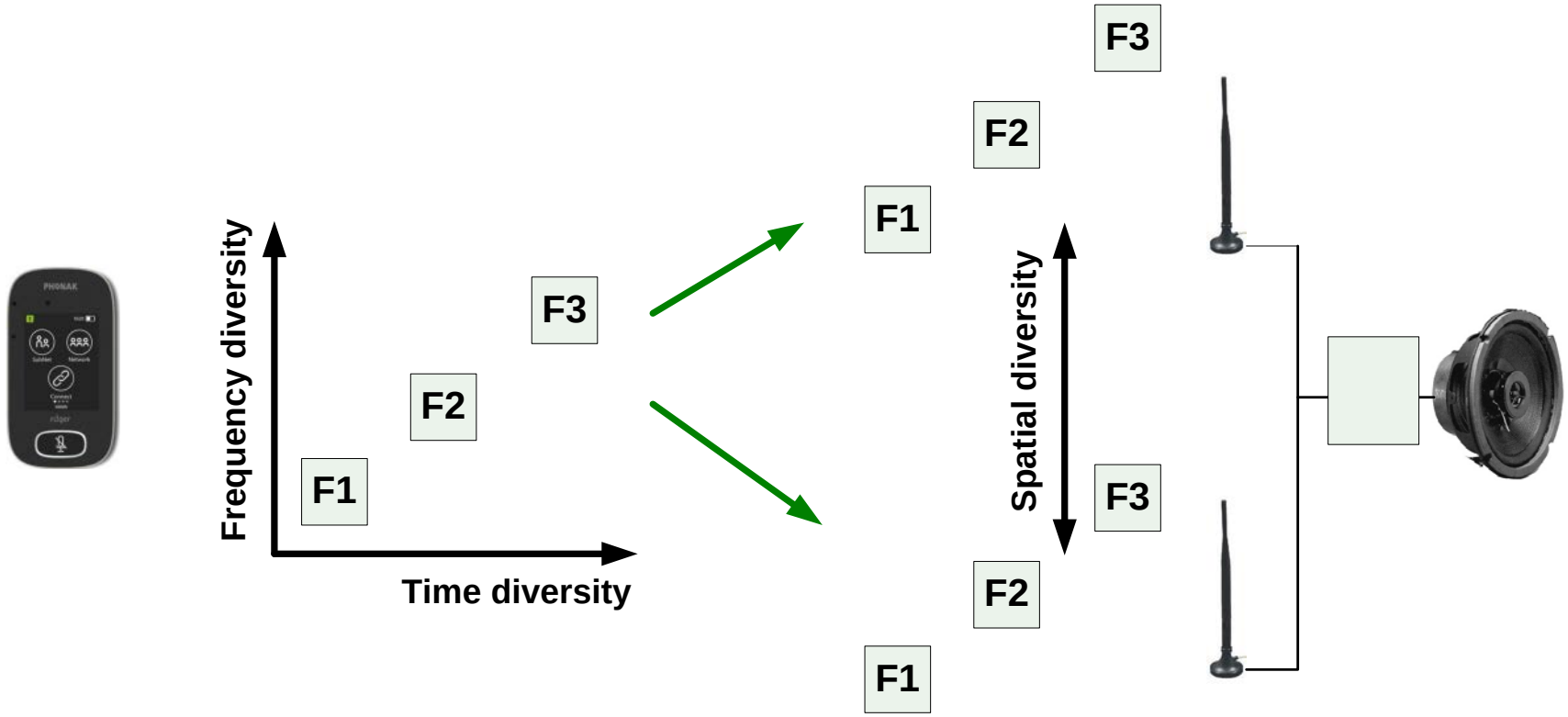


Frequency hopping systems work @2.4 GHz. This implies:

- Multipath fading phenomenon
- Less transmission through walls
- Less transmission on green-fields

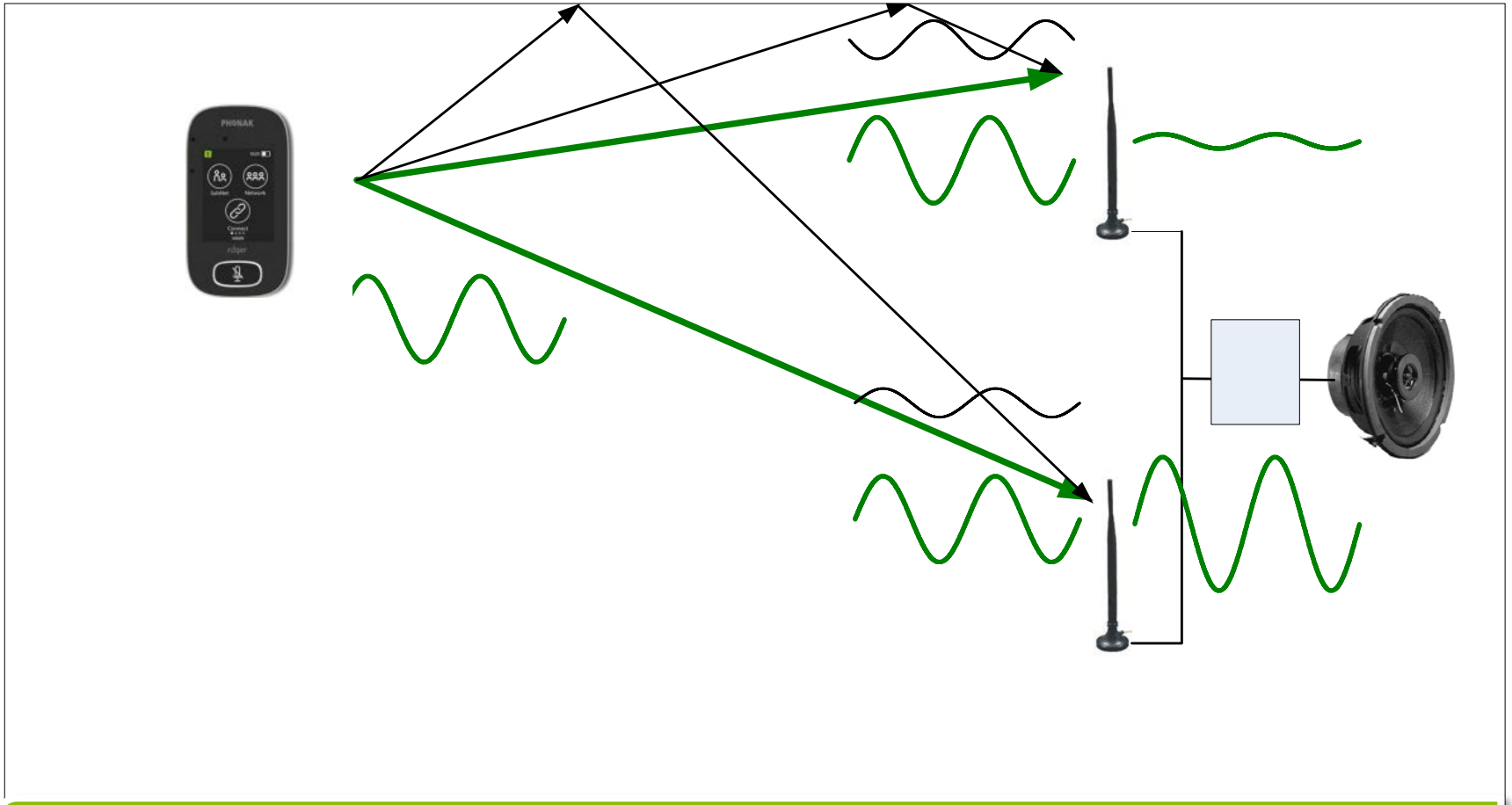
Systems have to be designed to deal with multipath fading

Time, frequency and spatial diversity



Transmit the same signal @different frequencies and @different times and/or use two different spatially separated radio's

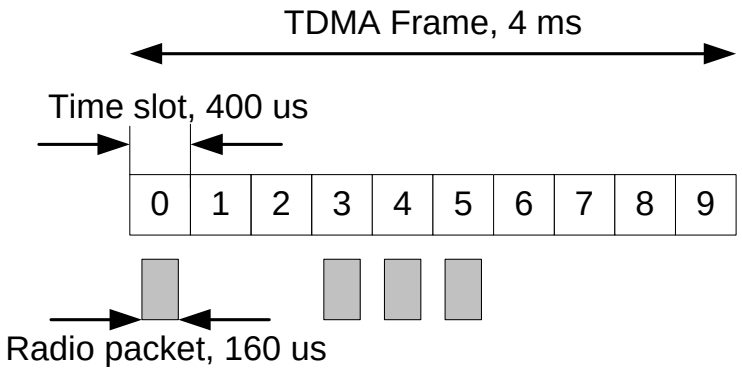
Roger: implementation of spatial diversity



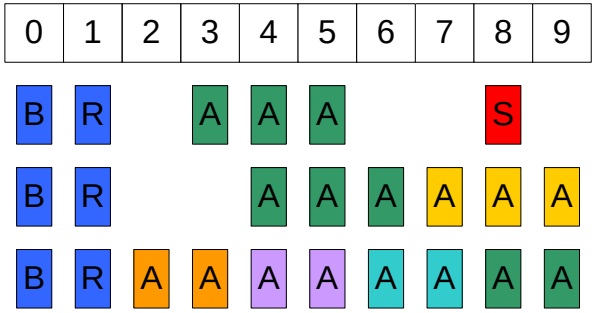
Used in Roger Soundfield, not applicable in ear-level receivers

Roger protocol

- Time Division Multiple Access (TDMA)

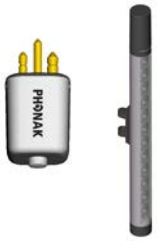


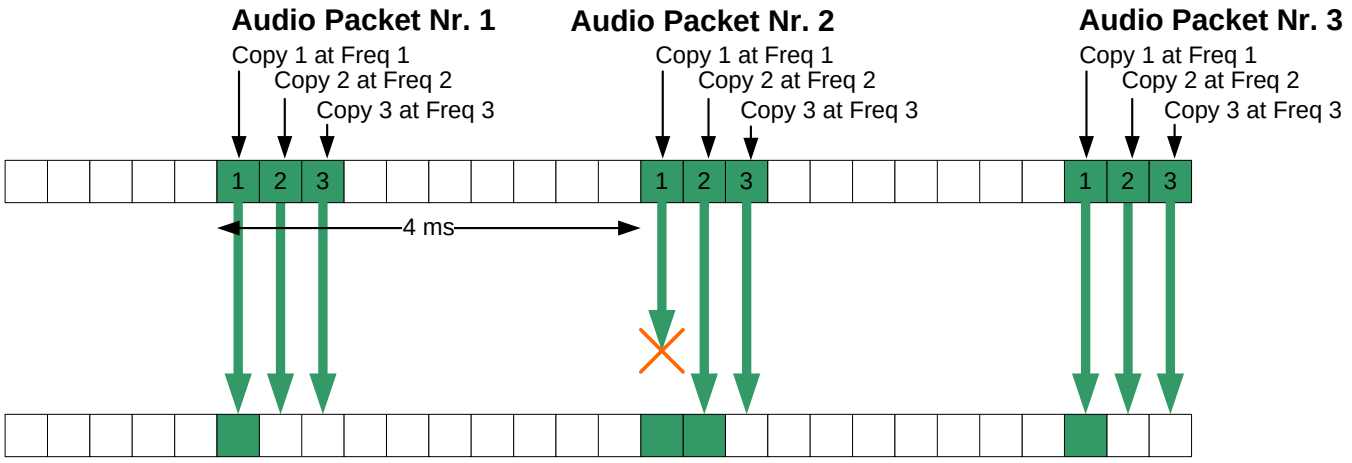
- Flexible allocation of time slots to audio and control
  - One or more audio stream
  - Choice of direction for audio stream
  - Choice of audio stream quality
  - Bi-directional control



Roger protocol: time and frequency diversity for robust communication

- Packet **repetitions in advance** and at **different frequencies**
- 32 bytes per packet. 64 kbps, giving **8 kHz audio bandwidth** with G722
- **Low delay (latency)**
- **Flexible, Bi-directional, allows broadcast**
- **Low power** consumption at receiver

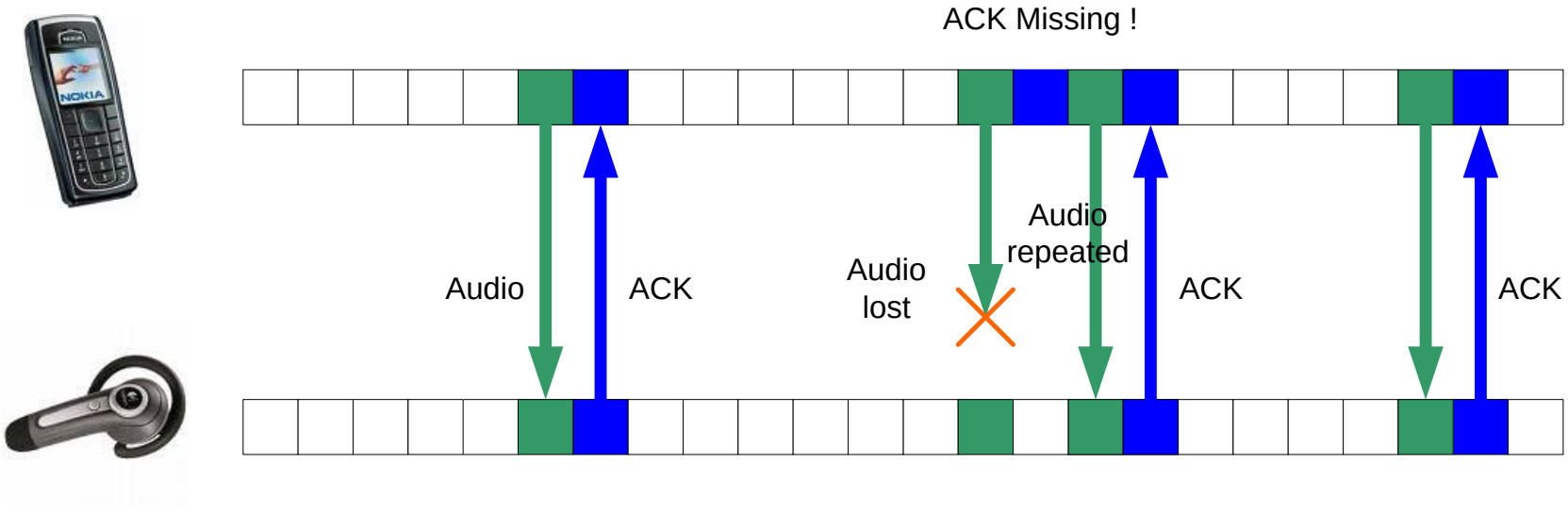




If transmission failed 3 times in a row: **Packet Loss Concealment**

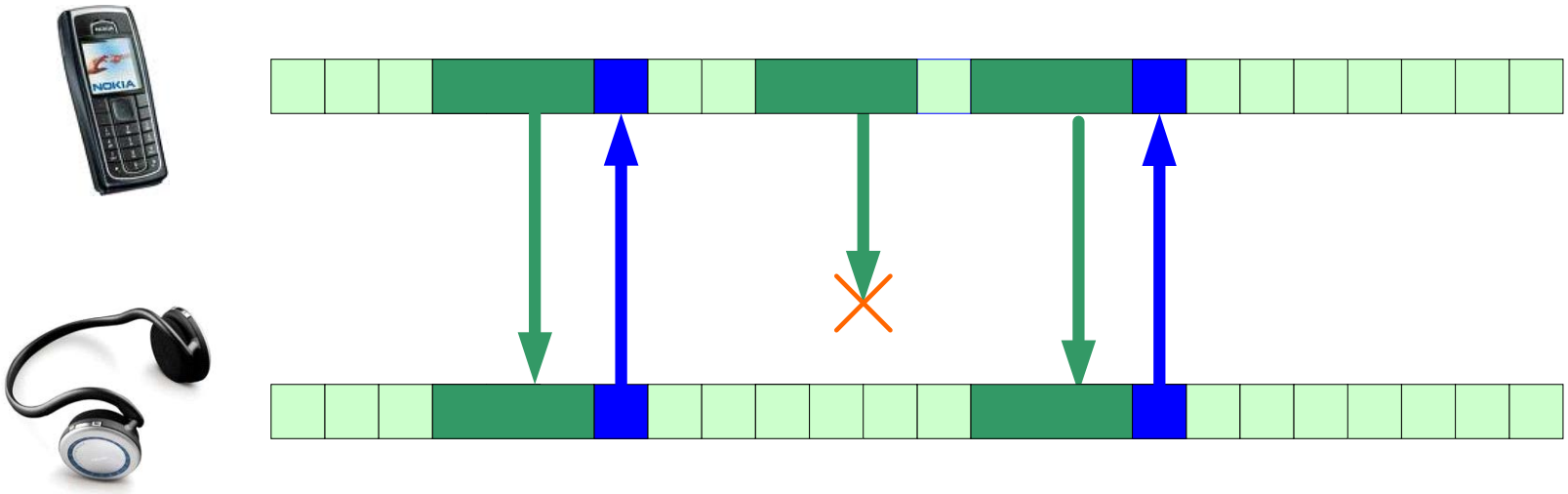
Comparison with Bluetooth headset

- Packet repetition **on demand**
- Audio bandwidth**: 4 kHz**
- **Low delay** (10-15 ms)
- Limited to point-to-multipoint (**max 3 receivers**)
- **Higher power consumption** at receiver



Comparison with Bluetooth Audio Streaming (A2DP)

- Packet repetition on demand
- Audio bandwidth**: 20 kHz**
- **High delay** (~100 ms)
- Limited to point-to-point (**max 1 receiver**)
- **Much higher power consumption** at receiver



Adding devices with «one click connect»

Connect

10 cm / 4 Inches

0	1	2	3	4	5	6	7	8	9
B	R		A	A	A			S	
B	R			A	A	A	A	A	A
B	R	A	A	A	A	A	A	A	A

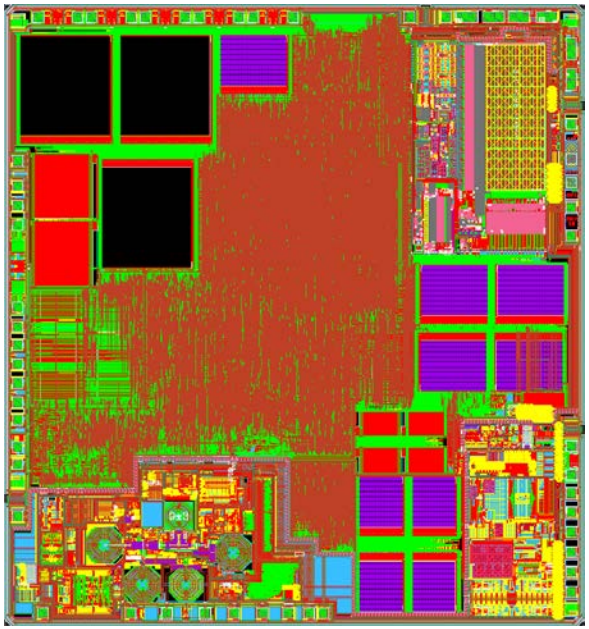
First slot

- Contains list of all devices belonging to network
- “Master” transmits pseudo random code to all devices in his network
- Serves as a «beacon»

Second slot

- Contains status of all devices
- Contains statistics on link quality

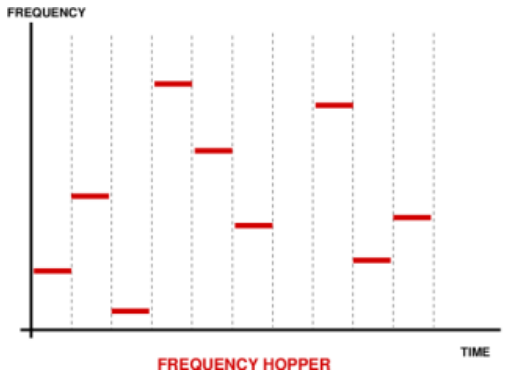
The enabler: a tiny chip dedicated to people with hearing loss



6 million transistors, used in all receivers and transmitters

Summary transmission technology

1. Pseudo-random hopping of frequencies
   - Virtually unlimited number of users
   - Interference free
   - Optimized for low power, high quality audio



2. Differs from Bluetooth by
   - Possibility to transmit 1:N
   - Does not require acknowledgement of receivers (power!)
   - Has much less latency and/or higher audio bandwidth

roger

3. Connect
   - With one click
   - Connect with unlimited number of receivers
   - Connect with unlimited number of transmitters

Wireless systems in educational settings shall ideally offer:

Zero hassle

Maximum performance

Full compatibility

Sophistication with the purpose to simplify !!

Maximum Performance

- Adaptive behavior
- Context Dependent Signal Processing
- MultiTalker Networks

Maximum performance: the winning strategy in a nutshell

Enhance SNR in high noise conditions by:

1. **Bringing** the microphone **to the source**, cutting out the distance
2. **Optimizing** SNR at the source with a **beam former**
3. **Adaptively** mixing the wireless microphone signal with the ear-level microphone of the hearing instrument, by increasing the gain of the Roger receiver in higher ambient noise levels
4. **Reducing** the gain when no voice is present

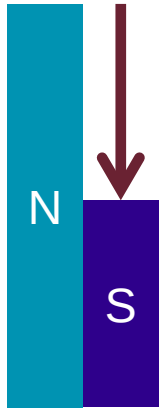
Principle of adaptive mixing: no wireless system

Talker

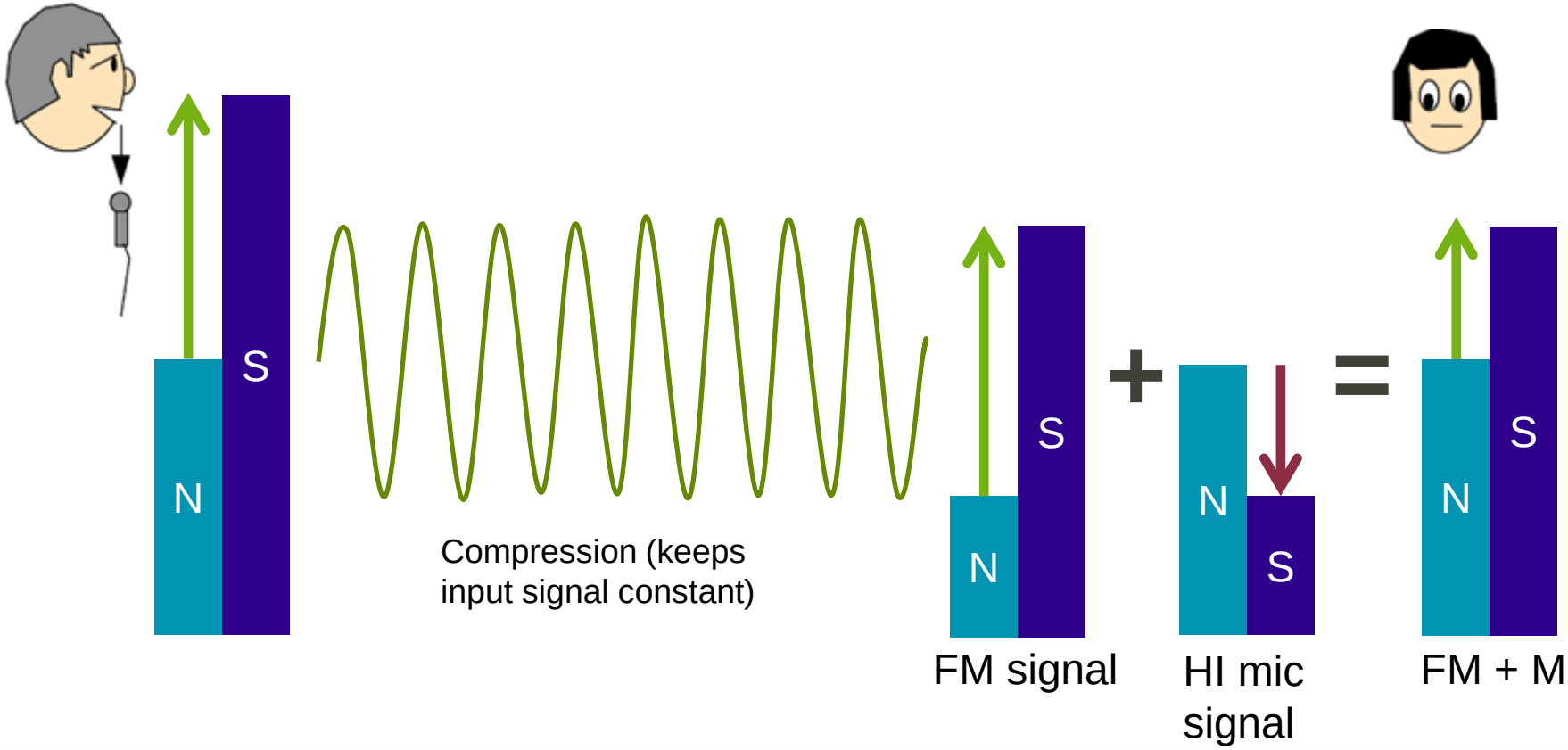
Listener

First approximation:

- **Noise** is the same @talker and @listener
- **Signal** @listener decreases with 6 dB for every doubling of distance
- **Signal/Noise** ratio easily gets negative

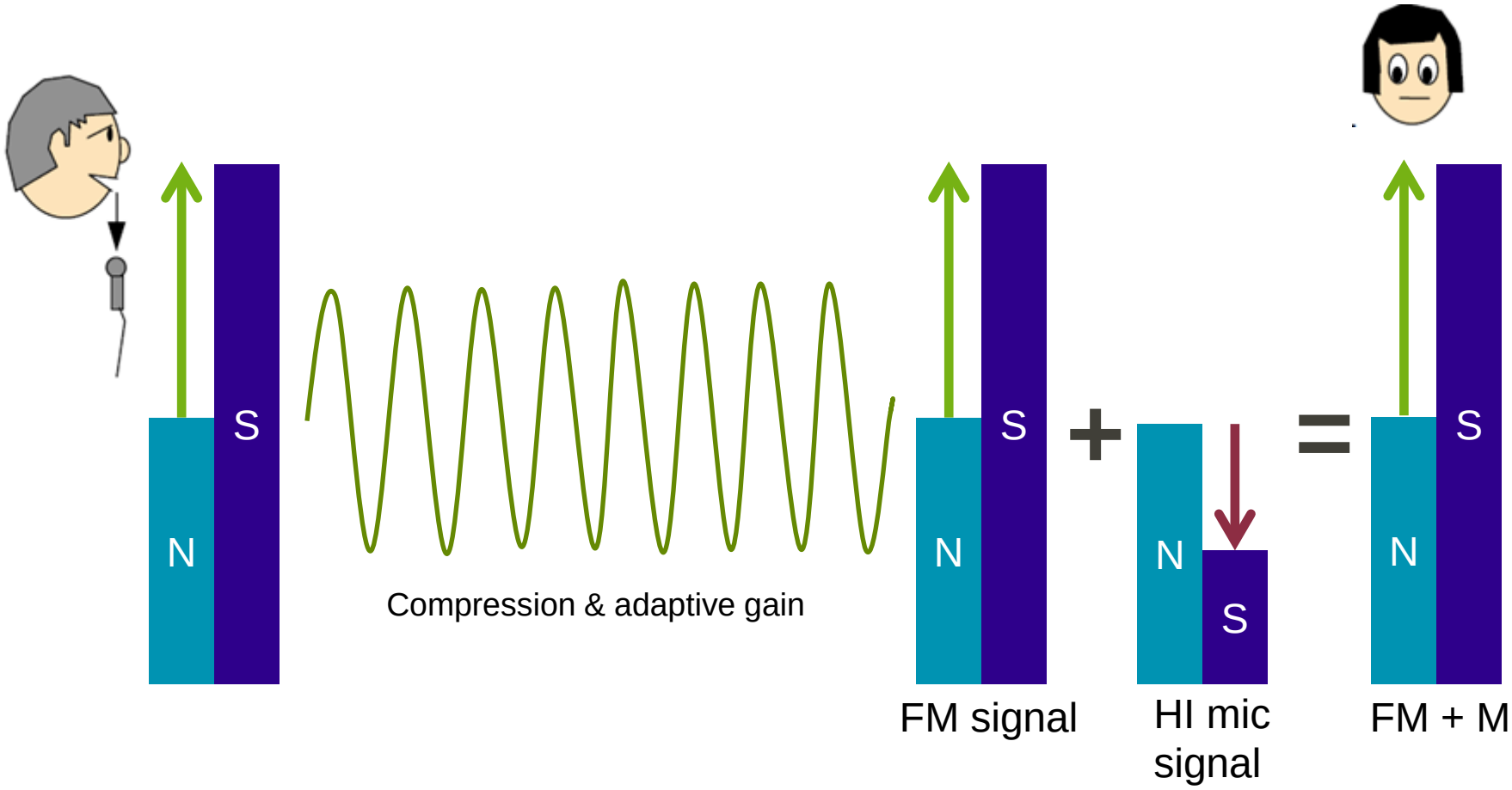


SNR with a non-adaptive system



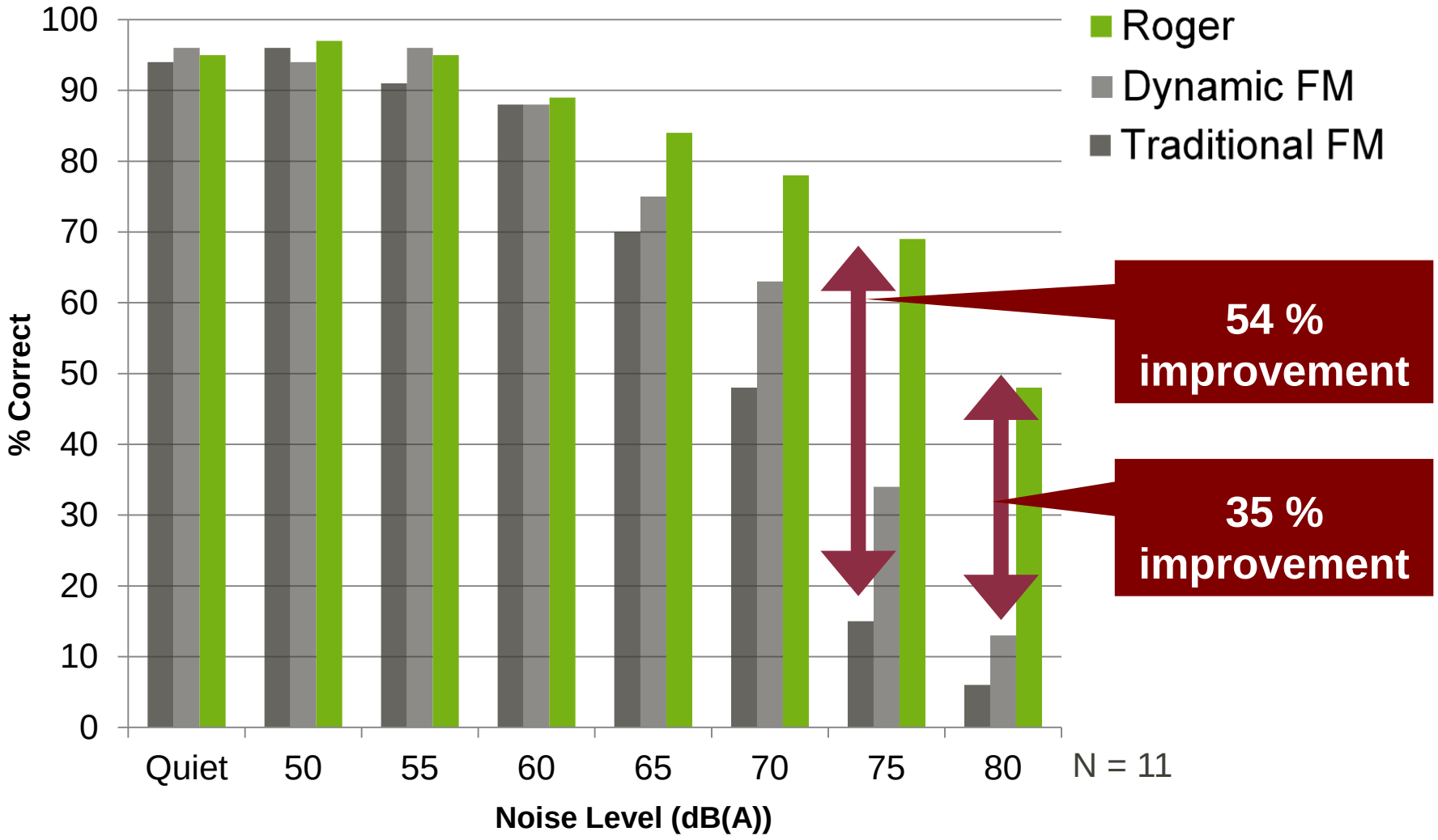
SNR @listener has improved but is less than @speaker

SNR with a an adaptive gain system

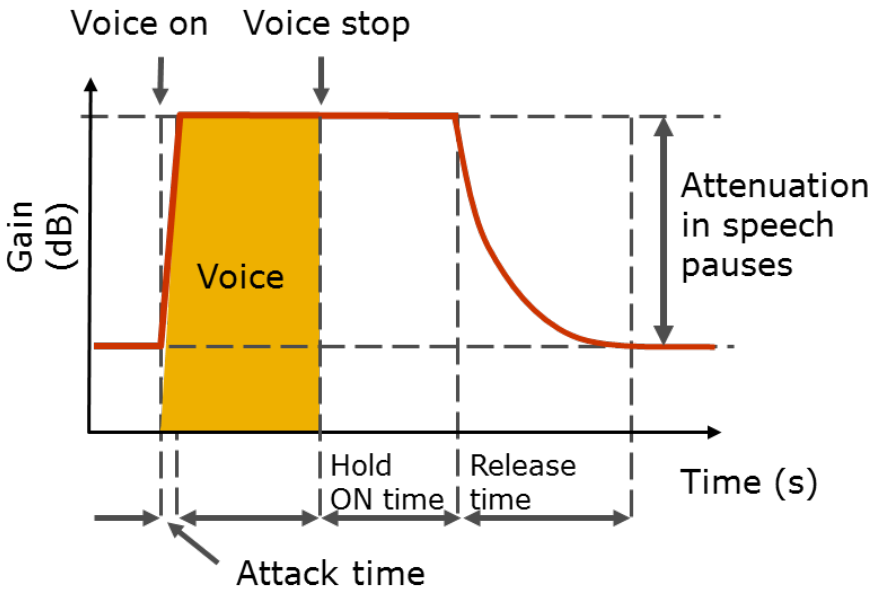


SNR @speaker and @listener are equal (copy-paste)

Speech understanding at 5.5 m in various noise levels



Reducing gain when no signal is present: voice activity detector



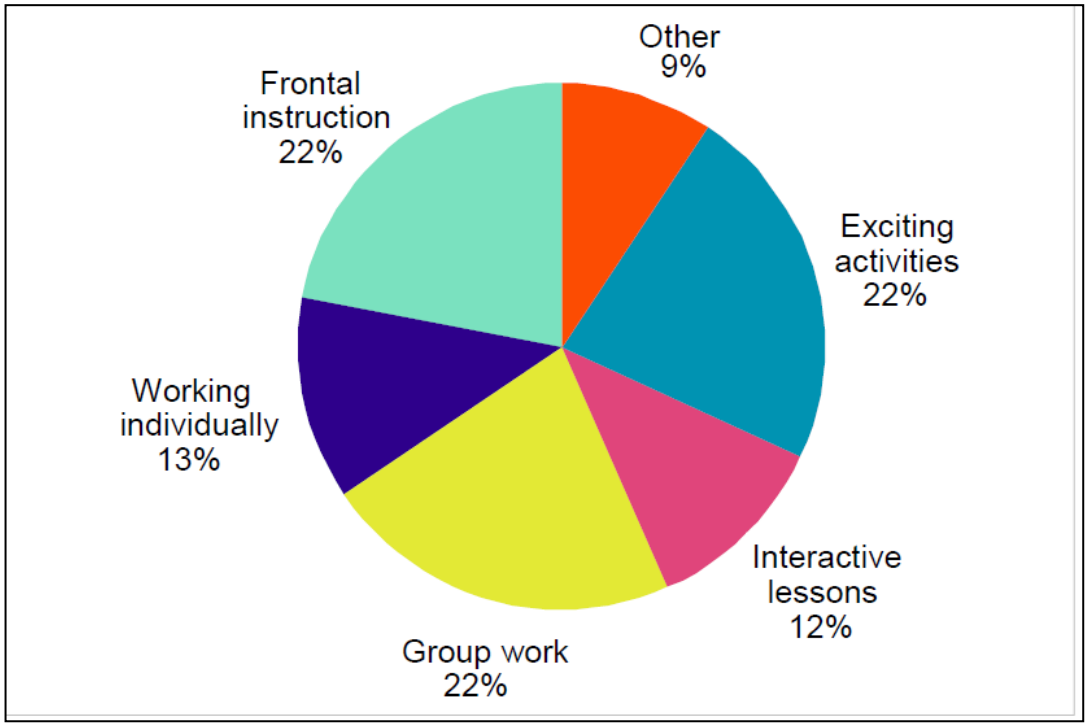
Voice Activity Detector is based on:

- Energy
- Voice metric
- Direction of arrival

As soon as the teacher stops talking, there is no longer a high input level wireless signal

The hearing instrument microphone is immediately available to effectively amplify the environment and the own voice

Today’s dynamic classrooms



Group work and

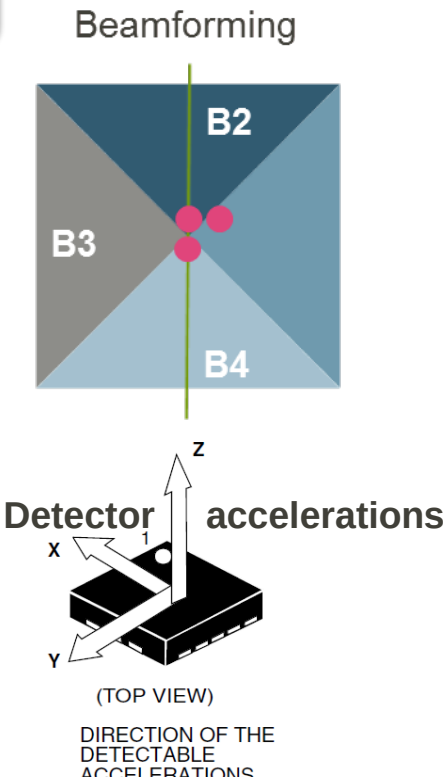
Interactive lessons are

increasingly important!

Context Depending Signal Processing to maximize performance in all situations

* Derived from internal research, several countries, multiple schools

Small Group Work



Accelerometer

- Detects that device is lying on the table
- Changes gain model to Group Work mode
- Enables all three embedded microphones

Beamforming

- Beams in 4 different directions are created with the 3 embedded microphones
- The beam with the best SNR is transmitted
- Other beams are mixed with the primary beam as a function of their SNR

Small Group Work mode offers substantial benefits over HA's alone

Interactive lessons

- Context Depended Signal Processing can also increase performance in pass around microphones, e.g.:
  1. Placed in table stand → increased sensitivity (ideal for reading and signing)
  2. Lying flat on table →muted
  3. Handheld → high performance zoom

- Multi-Talker Network (MTN)
  1. Very Important to increase interactively number of voices to be transmitted simultaneously should be limited
  2. Transmission of 2 out of N voices appears optimal

Pass-around microphones have proven to increase interactivity

Summary maximum performance

Adaptive behavior

- Adapt gain of the wireless system as a function of environmental noise
- Reduce gain of wireless system to minimum of no useful signal present

Context Dependent Signal Processing

- Use context (placement, acoustical environment, etc.) to optimize the signal processing

MultiTalker Networks

- Allows multiple talkers to communicate with hearing impaired child
- New systems allow to transmit 2 voices simultaneously

Performance ultimately determines how well a child can understand and learn

Conclusions: wireless systems do offer

Zero hassle

Maximum performance

Full compatibility

Sophistication with the purpose to simplify !!

Compatibility

- **Generic receivers for all manufacturers**
- **Compatibility with CI’s and Soundfield**
- **Multimedia connections**

Acknowledgement

My greatest acknowledgement goes to all staff members @Phonak Communications in Murten (Switzerland) and Halmstad (Sweden) for their full dedication to wireless technology for the hearing impaired

Thank you

PHONAK
life is on