

HEARING AID INTERFERENCE

AAA 2011

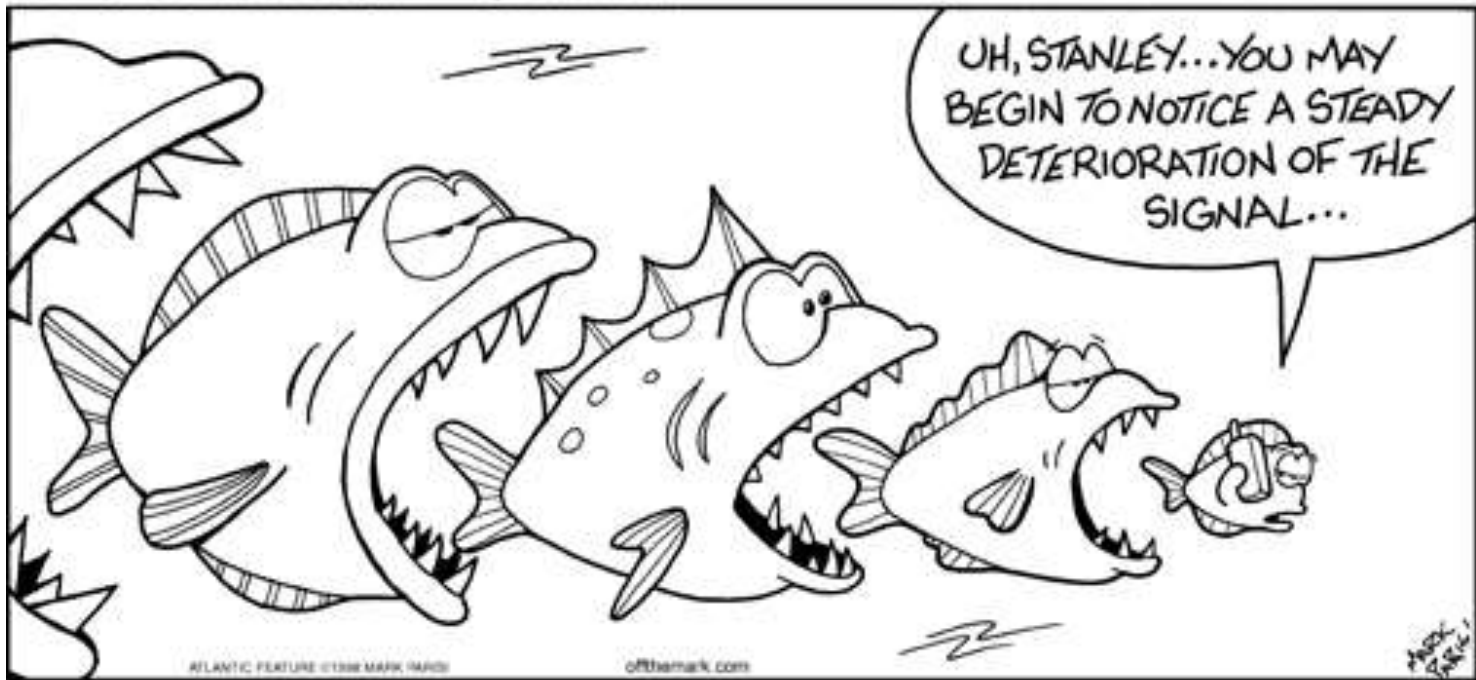
Petri Korhonen, M.Sc.(tech)

Bryan Crose, B.S.

OVERVIEW

- Interference in hearing aids
 - Sources
 - Electromagnetic interference
 - Ultrasonic interference
 - What does interference sound like?
 - What can be done to prevent interference in hearing aids?
- Health effects

off the mark.com by Mark Parisi



WHAT IS INTERFERENCE ?

- Definition: in·ter·fer·ence
 1. The act or process of interfering or obstructing
 2. The illegal hindering of an opponent in sports
 3. Confusion of a received radio signal due to the presence of noise or signals from two or more transmitters on a single frequency

<http://www.merriam-webster.com/dictionary/interference>

POTENTIAL SOURCES OF INTERFERENCE

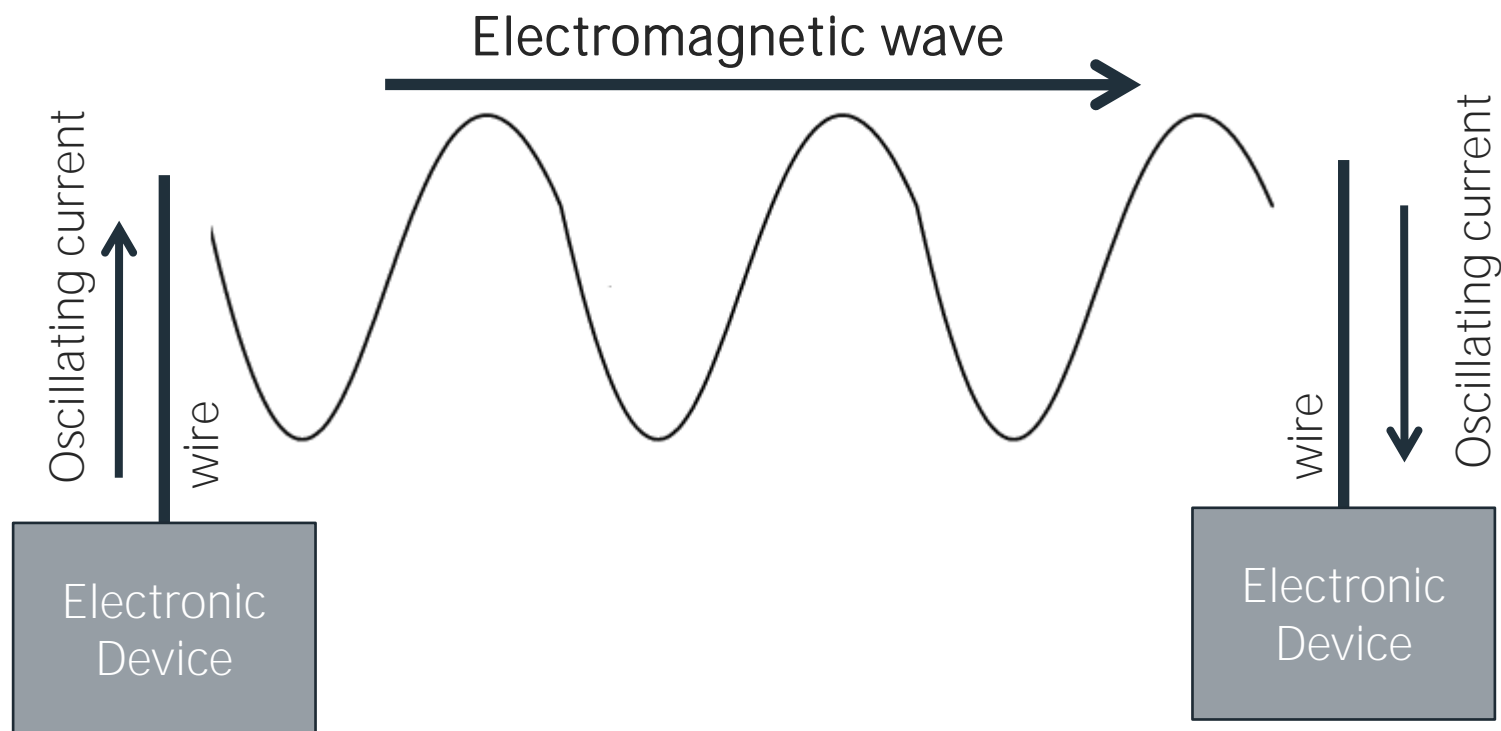
Electromagnetic Waves (EM)

- Modern electronic devices
- Cell phones, theft deterrent systems, WiFi, Bluetooth

Ultrasonic Sounds

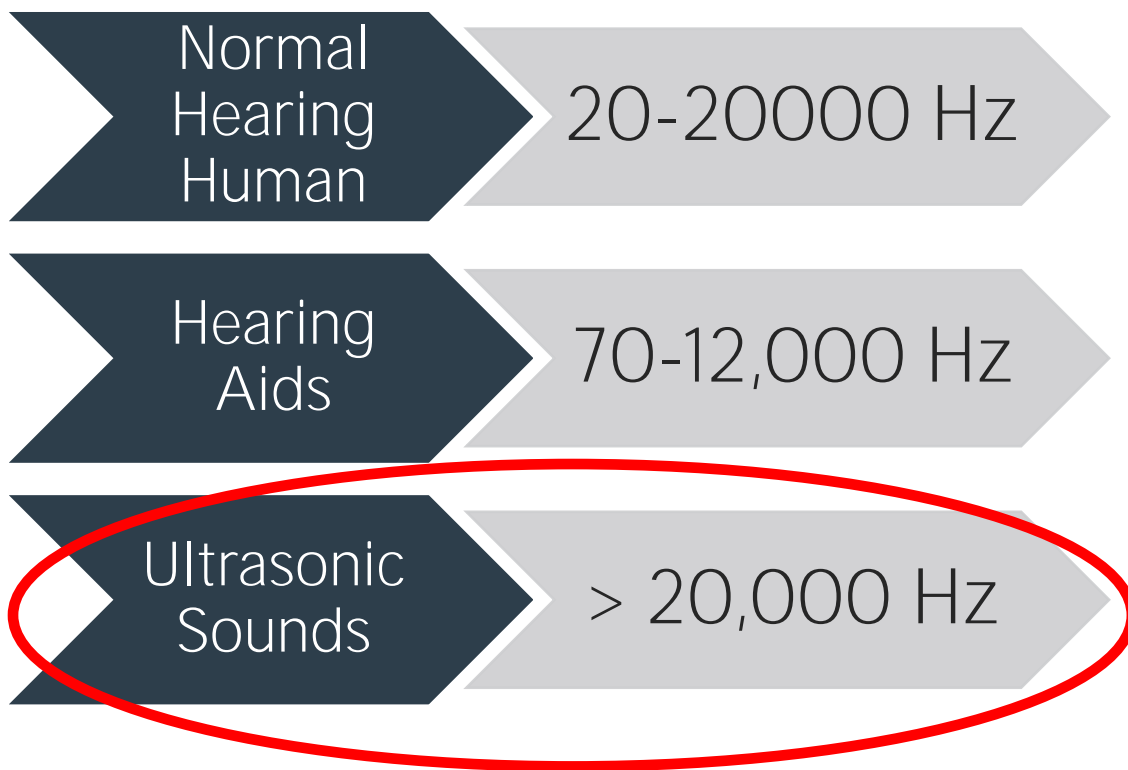
- Security systems
- Automatic lighting control systems
- Proximity sensors in some automobiles

WHAT ARE ELECTROMAGNETIC WAVES?

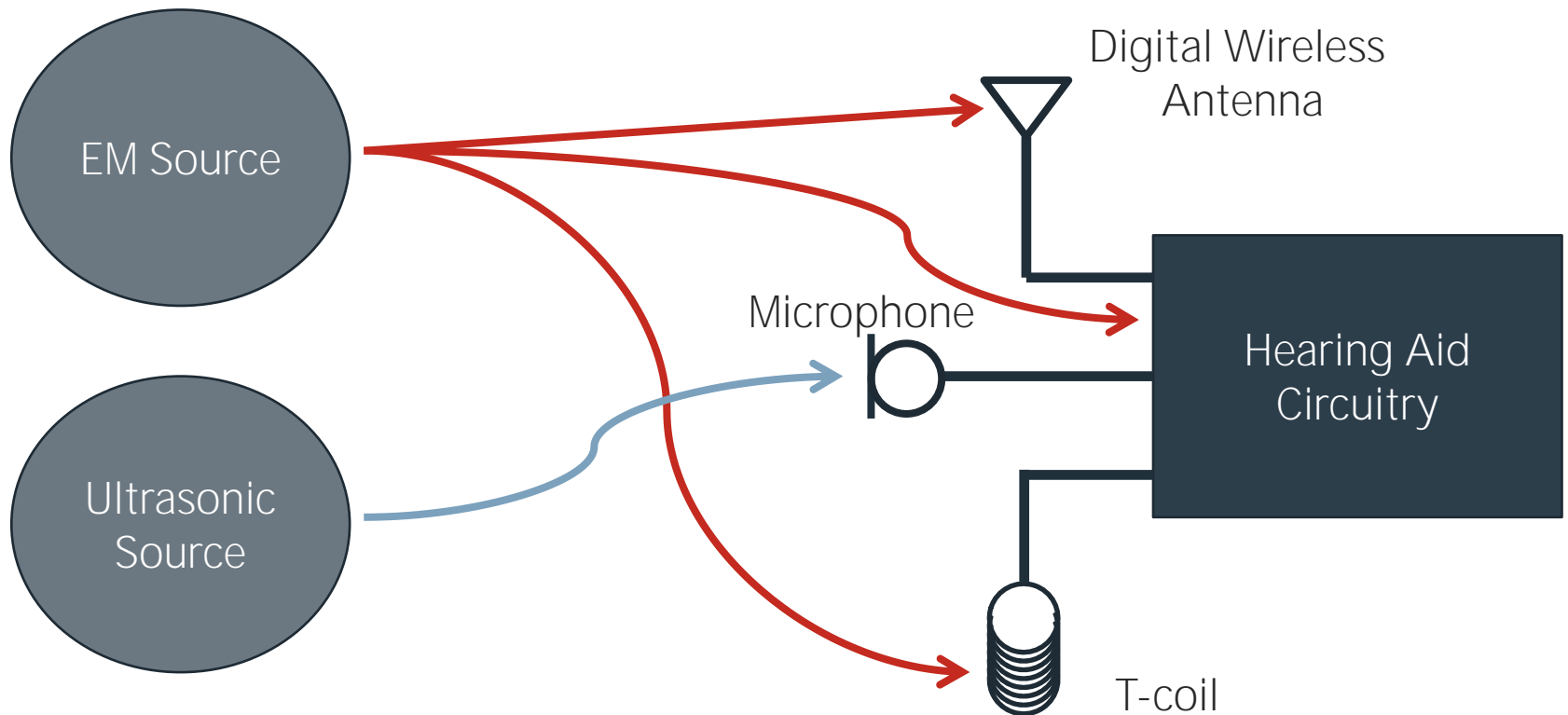


WHAT ARE ULTRASONIC WAVES?

- Ultrasonic waves are acoustic waves with a frequency higher than the normal human hearing range



PATHS FOR HEARING AID INTERFERENCE



WHAT DOES INTERFERENCE SOUND LIKE?



Hearing Aid Circuitry

- Buzzing, popping, crackling sounds



T-Coil

- Buzzing or humming sounds



Wireless Hearing Aids

- Disruption of streaming audio (clicking or short pauses in the audio)



Ultrasonic sounds

- Very loud buzzing

SOURCES OF EM RADIATION

Natural

- Lightning
- Solar radiation
- Cosmic radiation

Artificial

- Radio transmitters (i.e., cellular phones)
- Electronic devices (home appliances, computers, automobile)
- Theft deterrent systems

COMMON EM LEVELS

**Typical 60 Hz magnetic field levels
from some common home appliances**

	Magnetic field 6 Inches from appliance (mG)	Magnetic field 2 feet away (mG)
Electric shaver	100	-
Vacuum cleaner	300	10
Electric oven	9	-
Dishwasher	20	4
Microwave oven	200	10
Hair dryer	300	-
Computers	14	2
Fluorescent lights	40	2
Faxogram machines	6	-
Copy machines	90	7
Garbage disposals	80	2

TABLE 3.2 Electric Field Intensity Levels
at 30 cm from 115 Volts Home
Electrical Appliances

Appliance	Electric Field Intensity V/m
Electric blanket	250
Boiler	130
Stereo	90
Refrigerator	60
Electric iron	60
Hand mixer	50
Toaster	40
Hair dryer	40
Color TV	30
Coffee pot	30
Vacuum cleaner	16
Incandescent bulb	2

[Source: Reference 1 and EPRI Project 19955-07,
Final Report TR 100580, June 1992]



CLASSIFYING ARTIFICIAL SOURCES OF EM WAVES

Unintentional radiators


- Power lines
- electric motors
- computers
- household appliances

Intentional radiators

- Radio transmitters
- Cellular phones
- Microwave ovens
- X-ray machines

UNINTENTIONAL RADIATORS

Devices which **unintentionally** radiate electromagnetic energy as a byproduct of their operation




Most electronic devices



Broad range of EM frequencies

INTENTIONAL RADIATORS

Devices which **intentionally** emit electromagnetic energy for a specific purpose

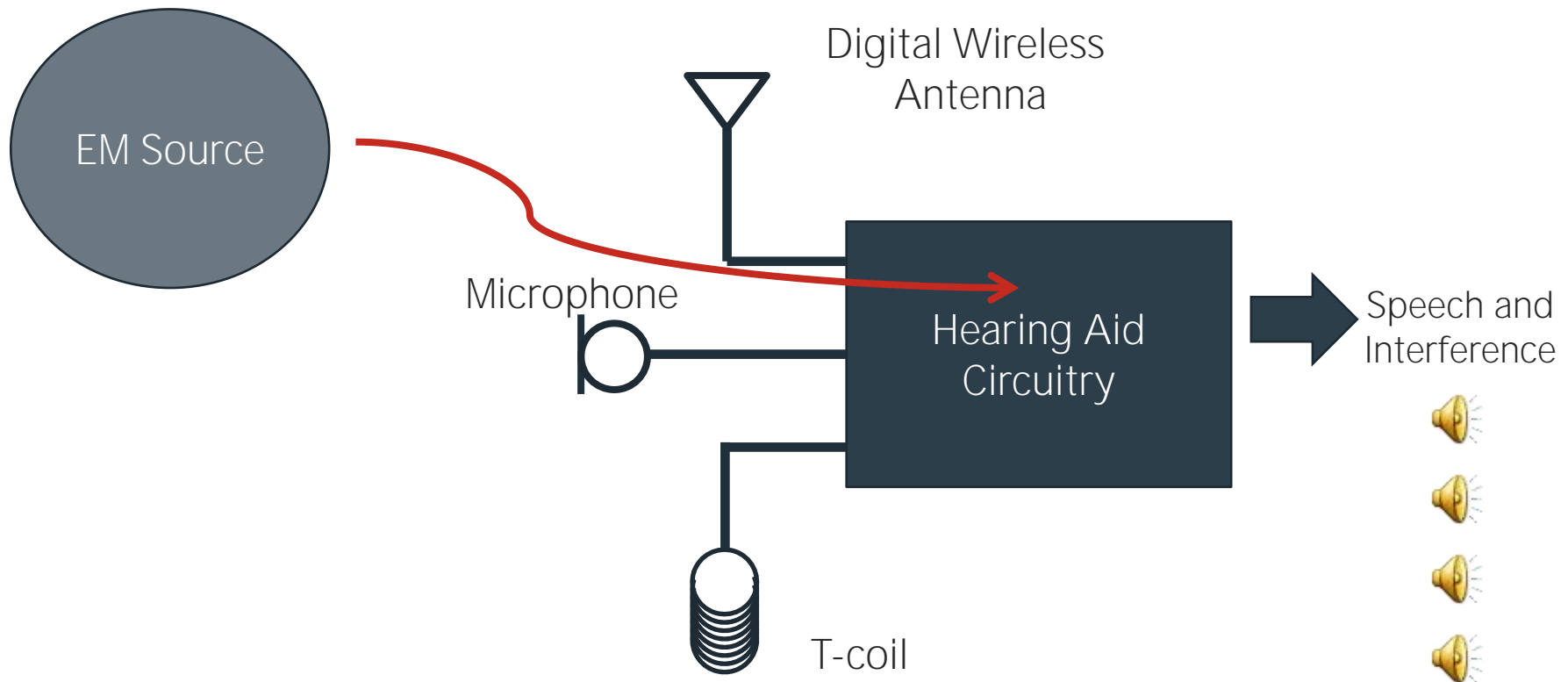


Communication devices



Narrow range of EM frequencies

HEARING AID CIRCUITRY INTERFERENCE



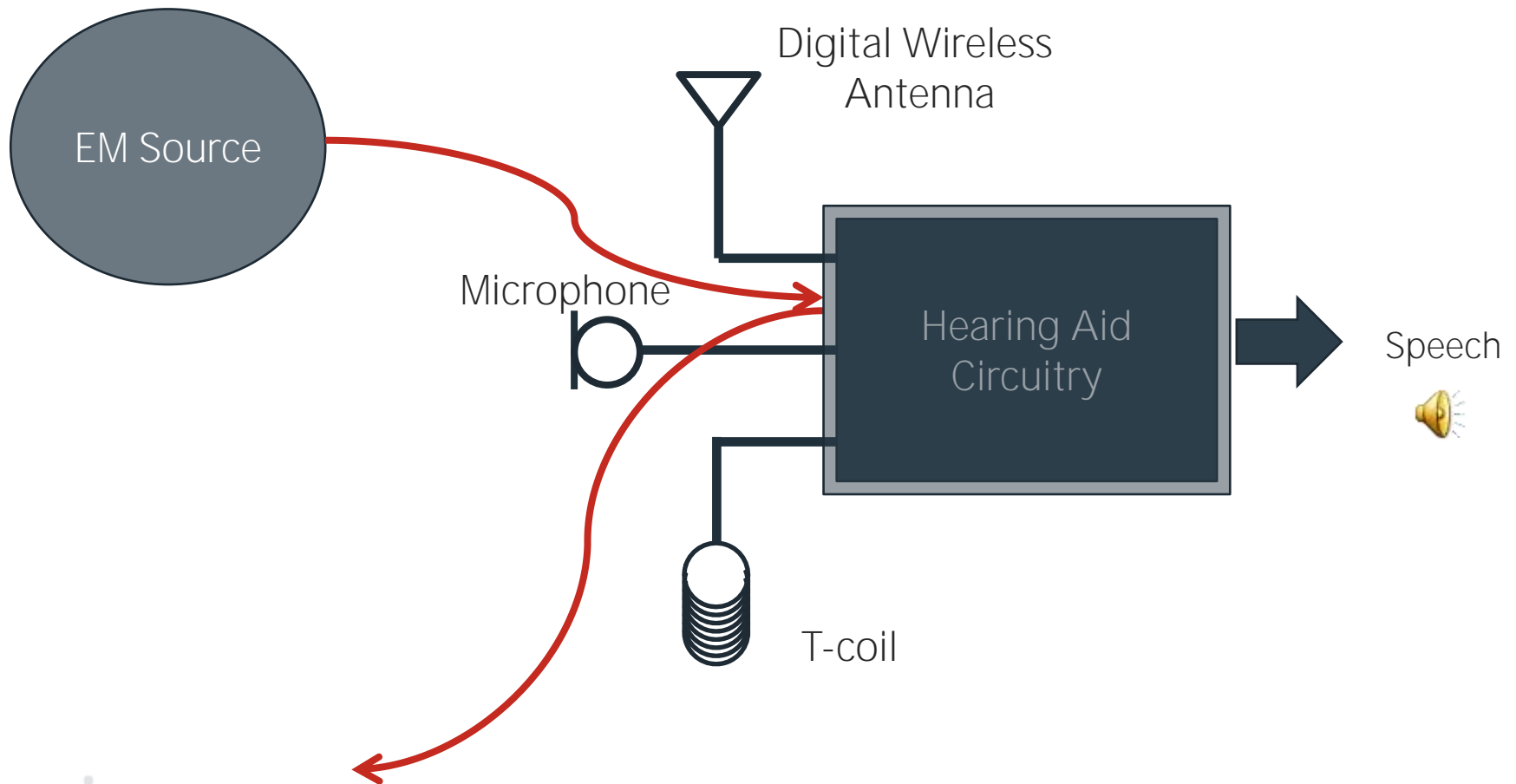
HEARING AID CIRCUITRY INTERFERENCE

- Circuitry components can act as small antennas, picking up emitted EM energy and passing it along as noise
- Higher frequency EM ($> 1\text{GHz}$) is more readily received because the wavelengths are smaller
 - Significant voltages can be induced on small electronic components (as are used in hearing aids)

DESIGNS TO REDUCE EM INTERFERENCE?

- Shielding and components which are more immune to EM signals can be added to hearing aid circuitry
 - This can help to reduce the amount of EM interference received by the hearing aid circuitry
- Transmitting devices (i.e., cell phones) can be designed in such a way to reduce the hearing aid to EM signal exposure
 - Cellular phone antennas can be repositioned, output power can be reduced

HEARING AID CIRCUITRY INTERFERENCE

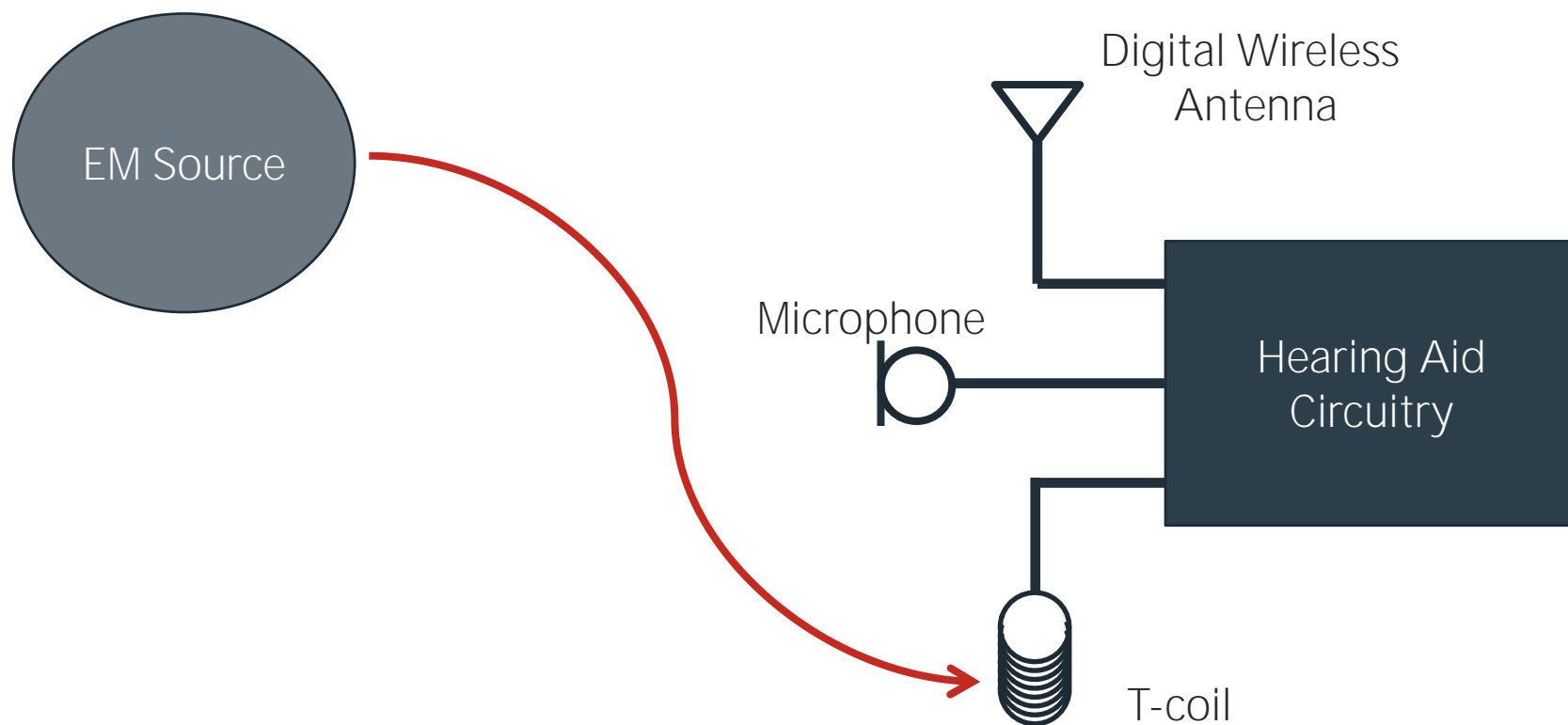


DESIGNING TO REDUCE EM INTERFERENCE?

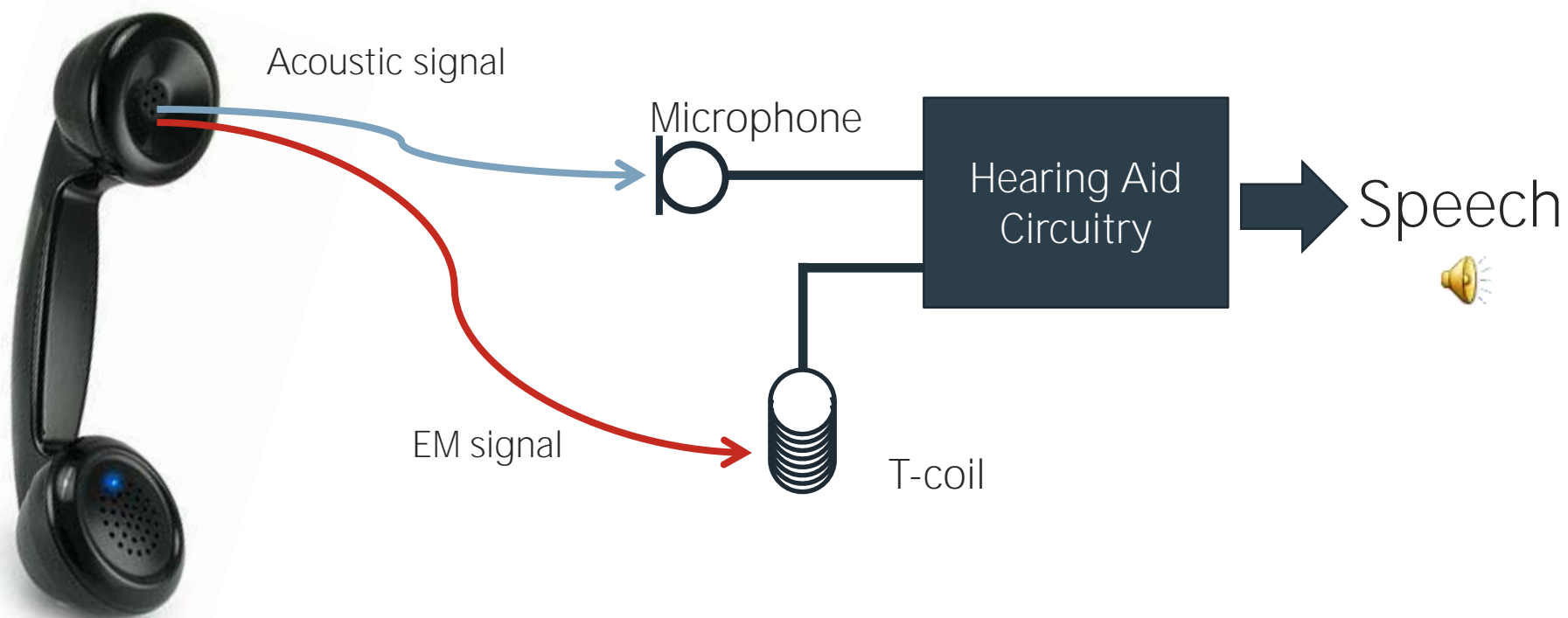
- Example: Cellular telephone and hearing aid compatibility
 - Cellular phones are now rated on a scale from M1 to M4, (M4 being the best) for how well they limit interference with hearing aid circuitry
 - A cellular phone rating of M3 or M4 usually assures good compatibility between cellular phones and hearing aids
 - Cellular phones are also rated on a scale from T1 to T4 to indicate how well they will operate with hearing aid t-coils
 - A rating of T3 or T4 will help to ensure less interference is encountered from the cell phone through the hearing aid t-coil.



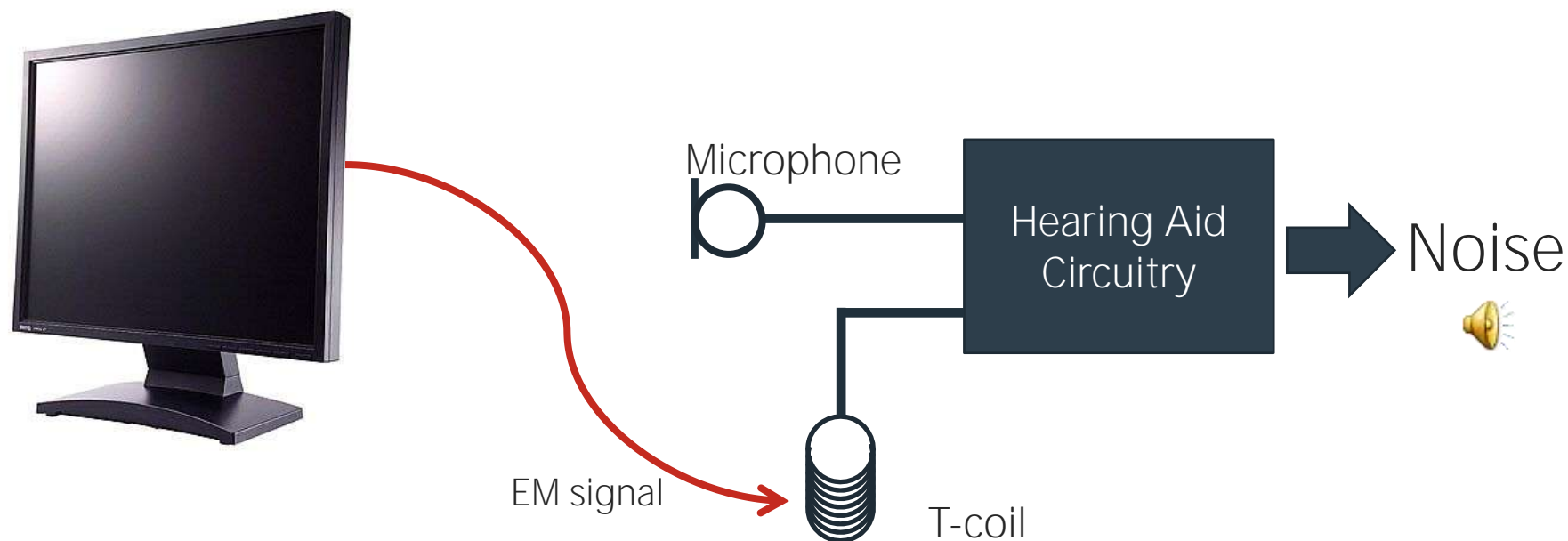
T-COIL INTERFERENCE



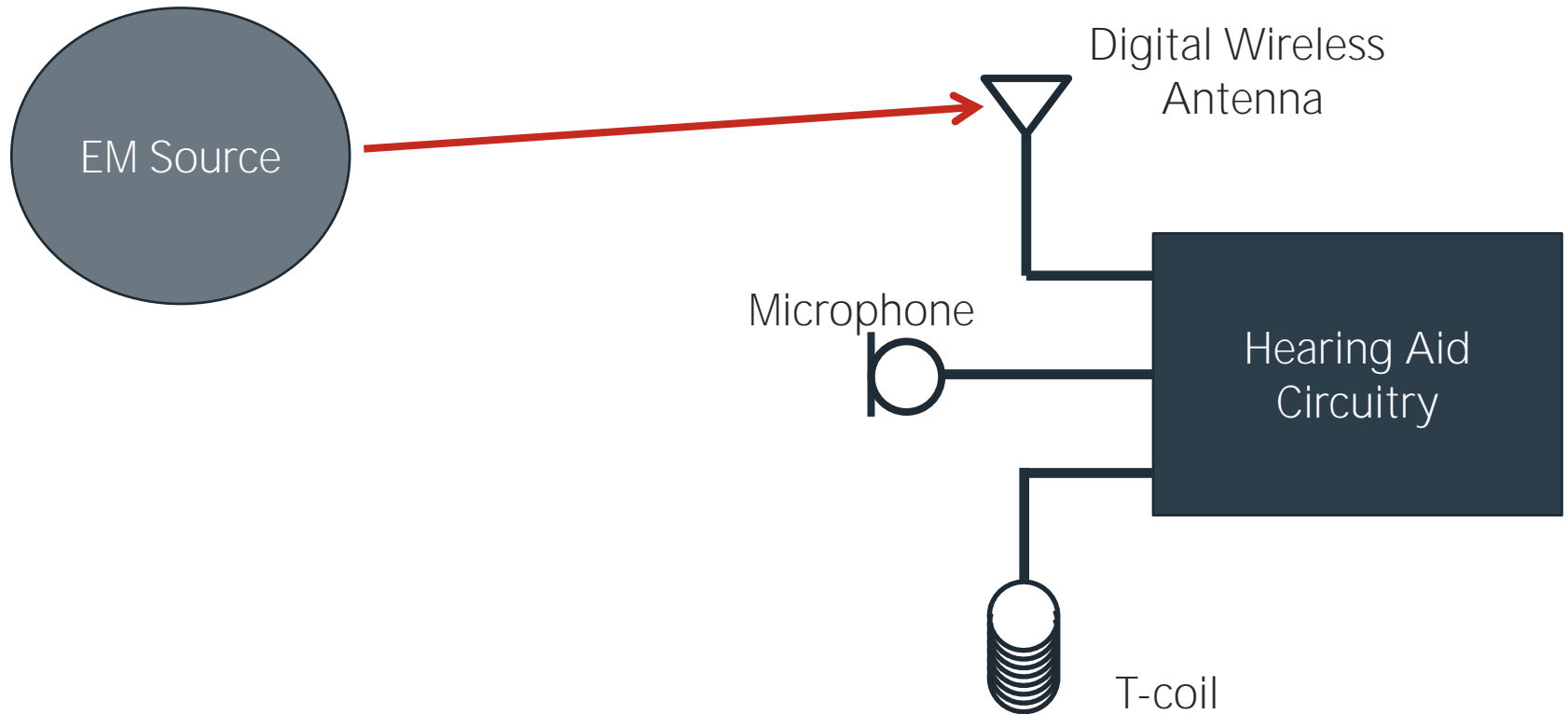
T-COIL INTERFERENCE



T-COIL INTERFERENCE

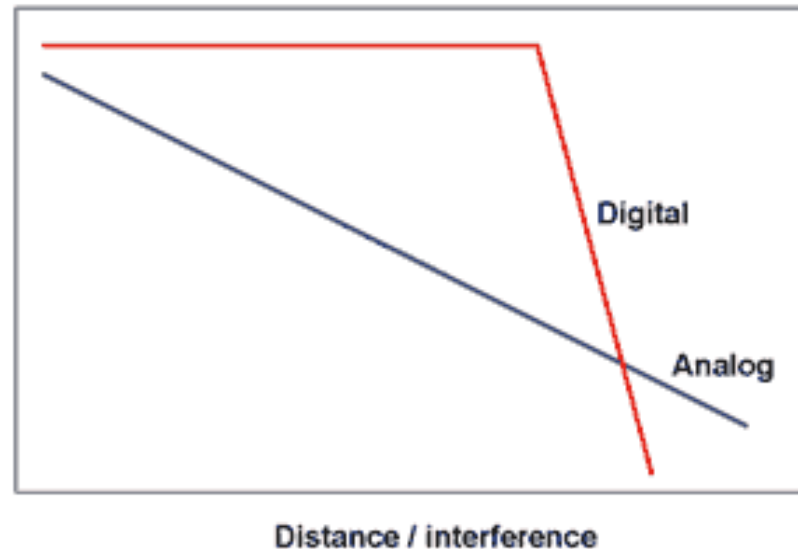


WIRELESS HEARING AID INTERFERENCE

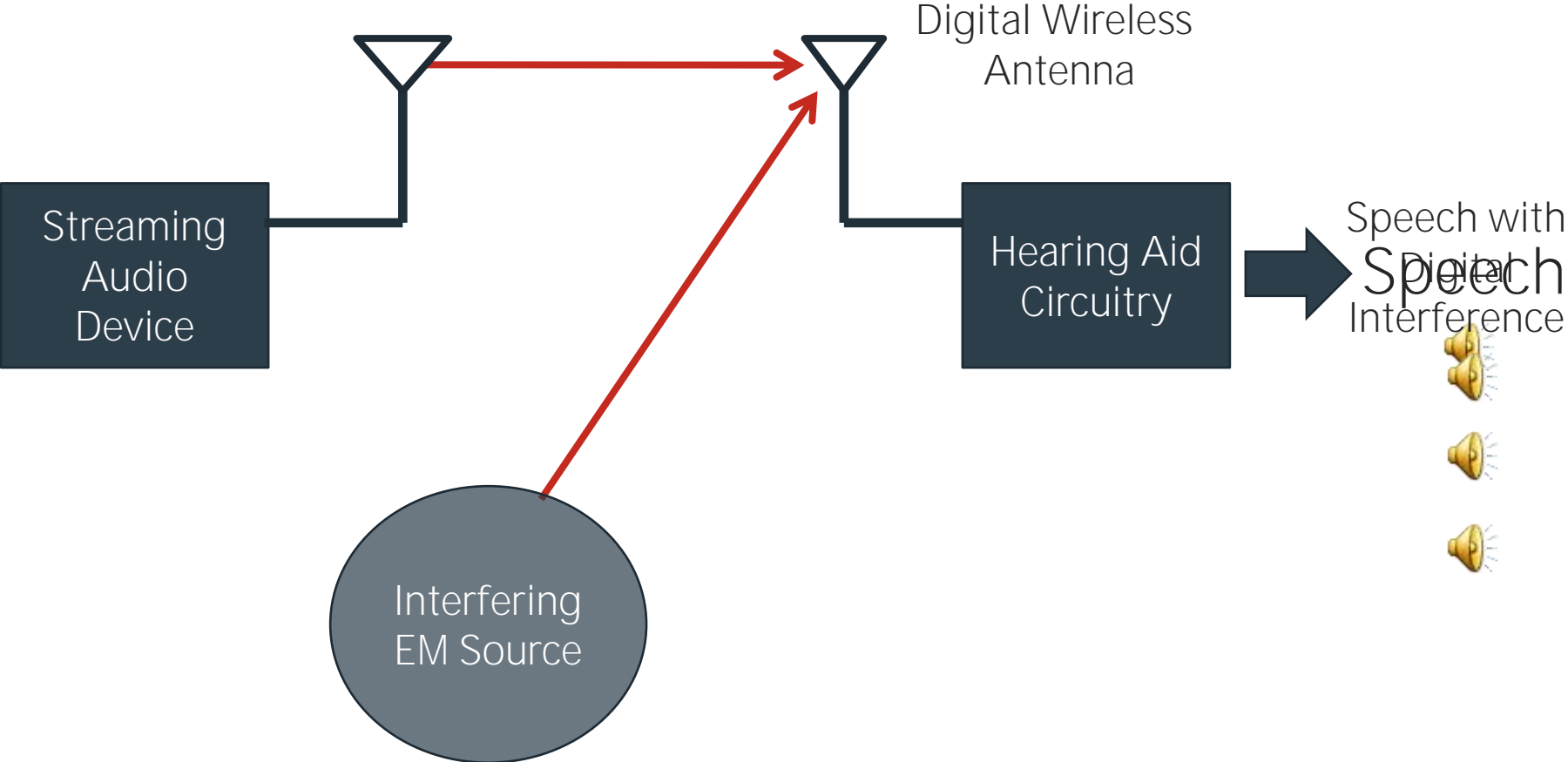


WIRELESS HEARING AID INTERFERENCE

- Disruption of streaming audio
 - May sound like clicks, pops, or brief pauses in the audio



WIRELESS HEARING AID INTERFERENCE



WIRELESS HEARING AID INTERFERENCE



WIRESLESS HEARING AID INTERFERENCE

UNITED STATES FREQUENCY ALLOCATIONS THE RADIO SPECTRUM

3 kHz

RADIO SERVICES COLOR LEGEND

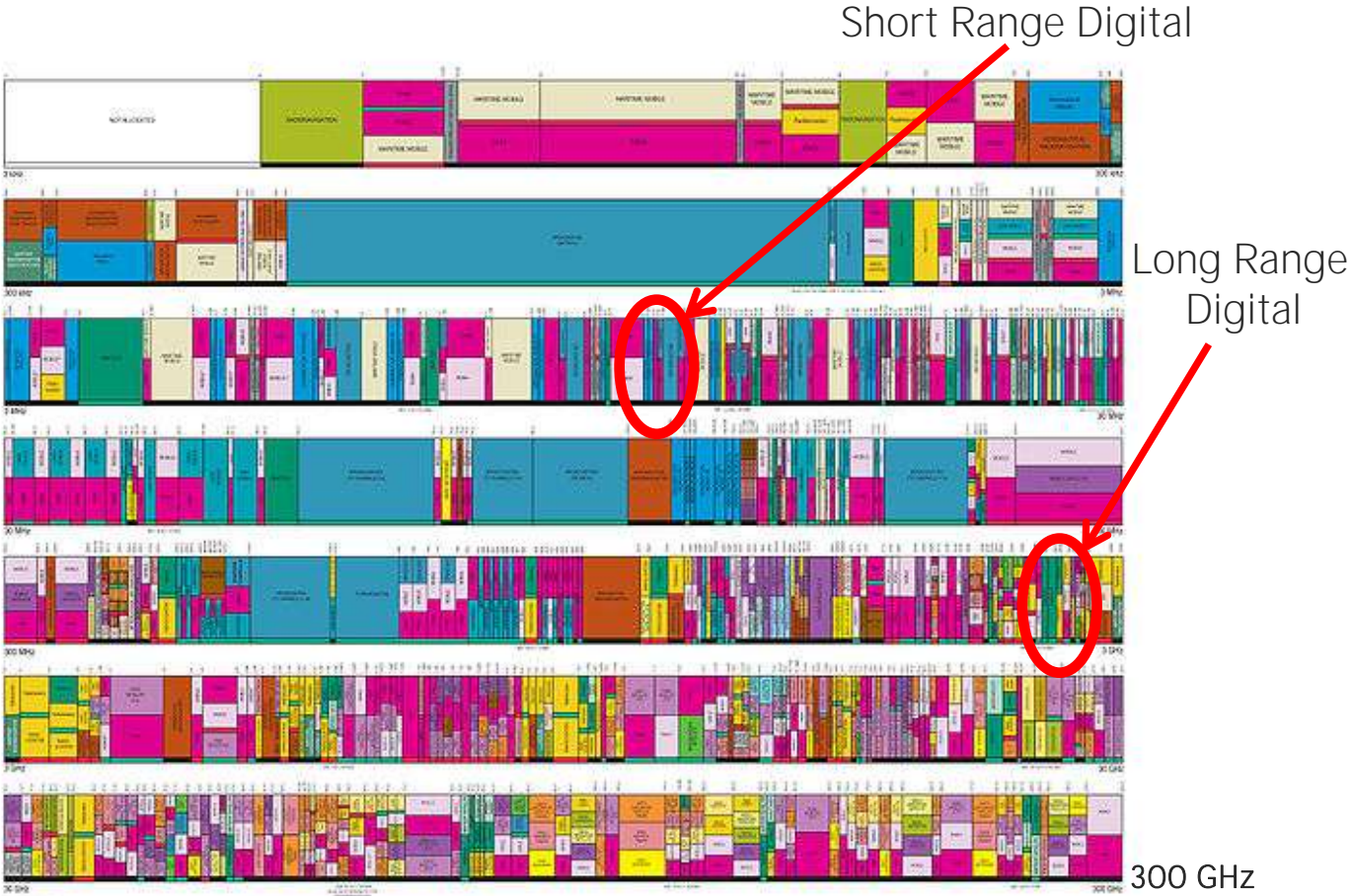
Administrative	Mobile	Navigation	Other
...

ACTIVITY CODE

- Primary
- Secondary
- ...

ALLOCATION USAGE DESIGNATION

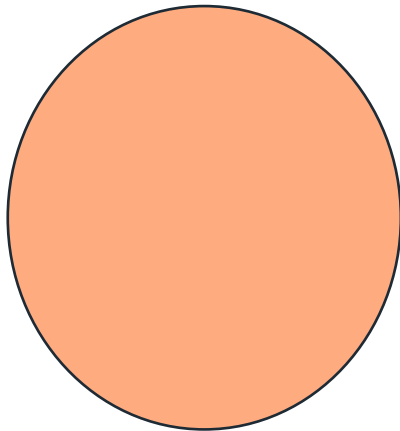
U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management



LICENSED DEVICES

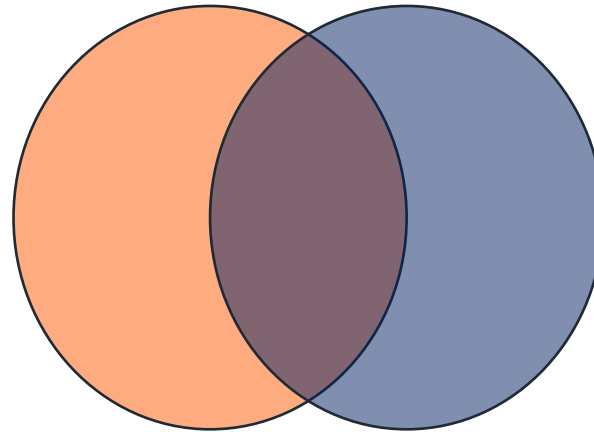
- FCC issues licenses for some specific types of transmitters (i.e., FM Radio Stations)
 - This keeps transmitters on the same frequency from interfering with one another

98.5 MHz
Los Angeles, CA



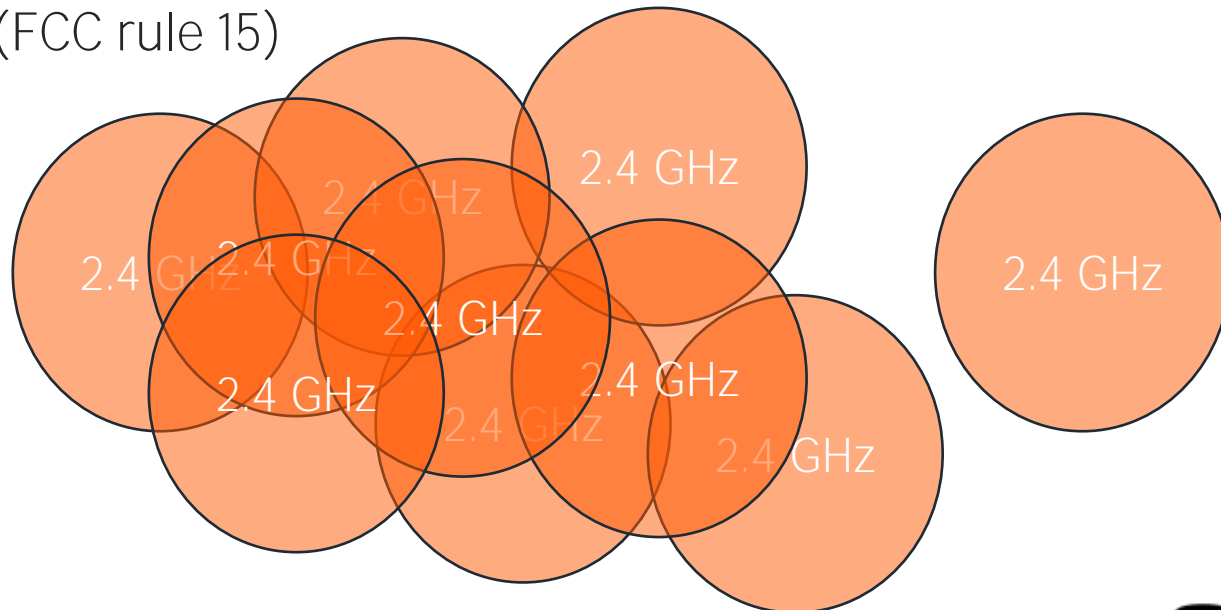
98.5 MHz
Chicago, IL

103.7 MHz
Chicago, IL



UNLICENSED DEVICES

- Many devices today utilize portions of the EM spectrum where the FCC does not require licensing.
 - WiFi Computer Networks, Bluetooth Devices, baby monitors, cordless telephones.
- These devices must accept interference as part of their normal operation (FCC rule 15)



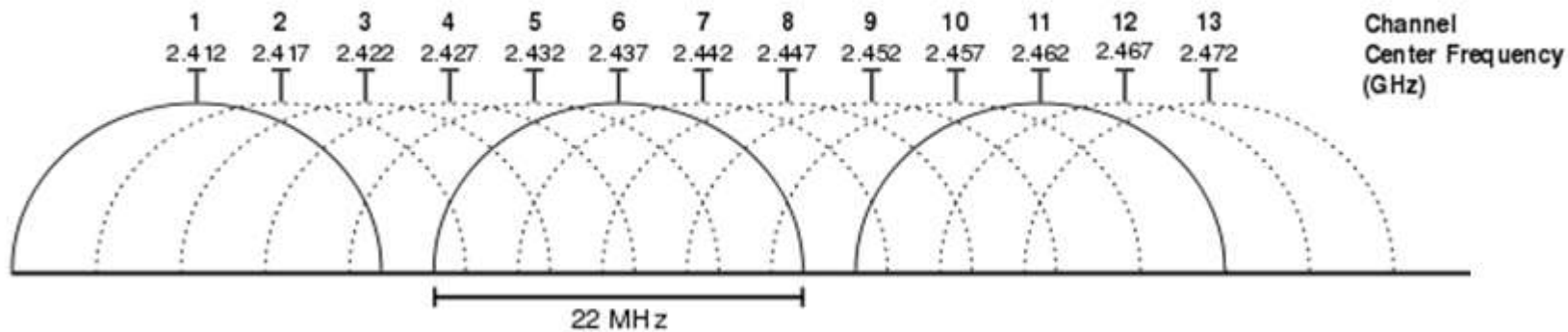
DEALING WITH INTERFERENCE

- Most wireless communication systems can perform well in an environment with no interference
- In the real-world, there are many potential sources of interference
- How well a communication system deals with interference impacts the quality of information communicated



WIRELESS COEXISTENCE EXAMPLE

- WiFi
 - Divides the 2.4 GHz region into 13 separate frequency bands

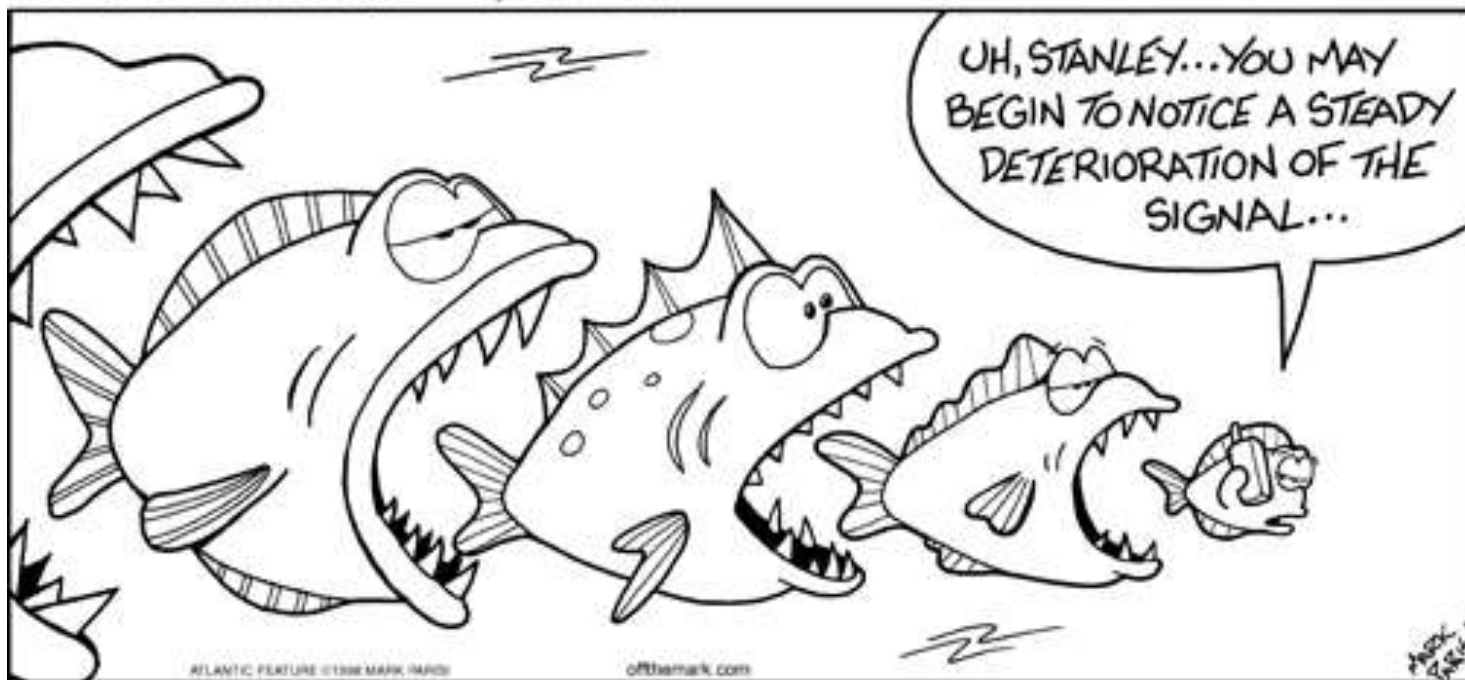


WIRELESS COEXISTENCE EXAMPLE

- Bluetooth
 - Operates on the same 2.4 GHz frequency band as WiFi
 - Utilizes a technique called Frequency Hopping Spread Spectrum (FHSS)
 - The 2.4 GHz band is divided into 79 frequencies
 - The Bluetooth device randomly hops over all 79 frequencies while transmitting.
 - If interference is encountered on one frequency, the impact is minimized because only a small portion of the total transmission is spent on any one channel



off the mark.com by Mark Parisi

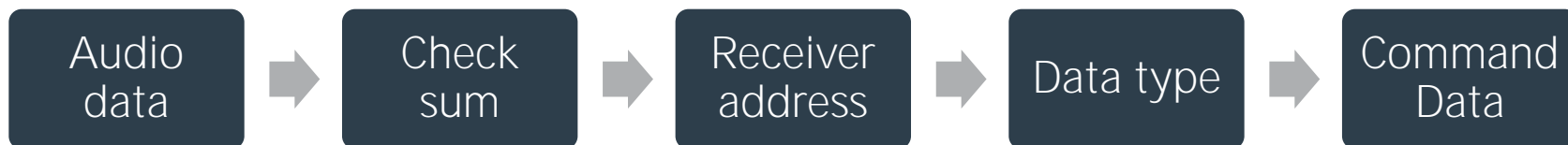


MINIMIZING WIRELESS INTERFERENCE IN HEARING AIDS

- Methods of digital wireless communication in hearing aids
 - Short range
 - Near field magnetic induction by nature is a very short range technology
 - Transmissions roll off very quickly to allow for short range communication without interfering with other nearby devices
 - Other devices using near-field transmissions are typically too far away to interfere (because of the extremely short transmission range)
 - Long range
 - Multiple channels can be utilized within a specific frequency region
 - Frequency hopping
 - Allows more than one device to operate in the same frequency bandwidth
 - Channel coding (error correction)

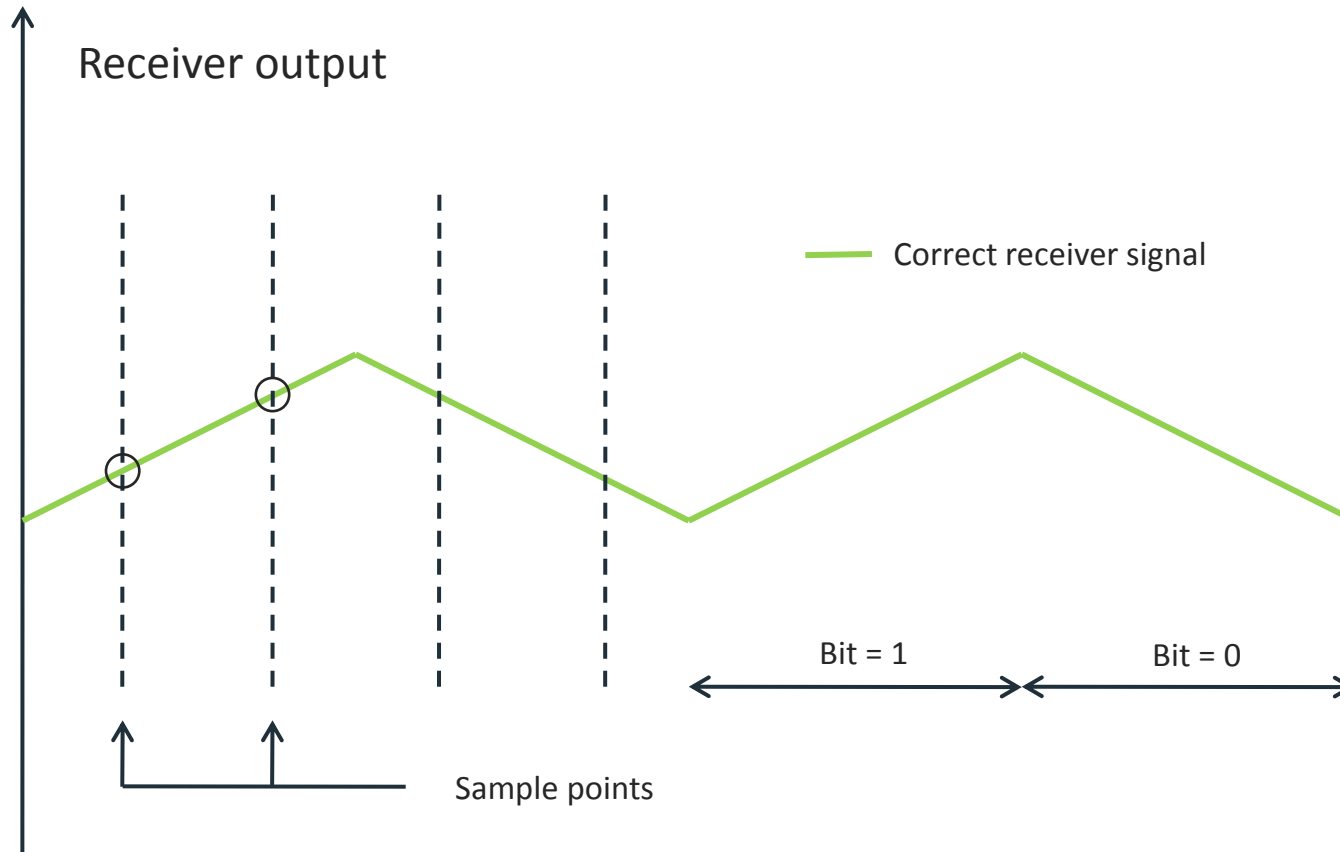
MINIMIZING WIRELESS INTERFERENCE IN HEARING AIDS

- Channel coding
 - Ensures that the digital audio signal which is received is error free
 - Acts as a “digital fingerprint” to ensure that received data is correct
 - This code is attached to the audio signal and includes:
 - Audio data checksum (error correction code)
 - Address of the receiving hearing aid
 - Data type ID
 - Command data



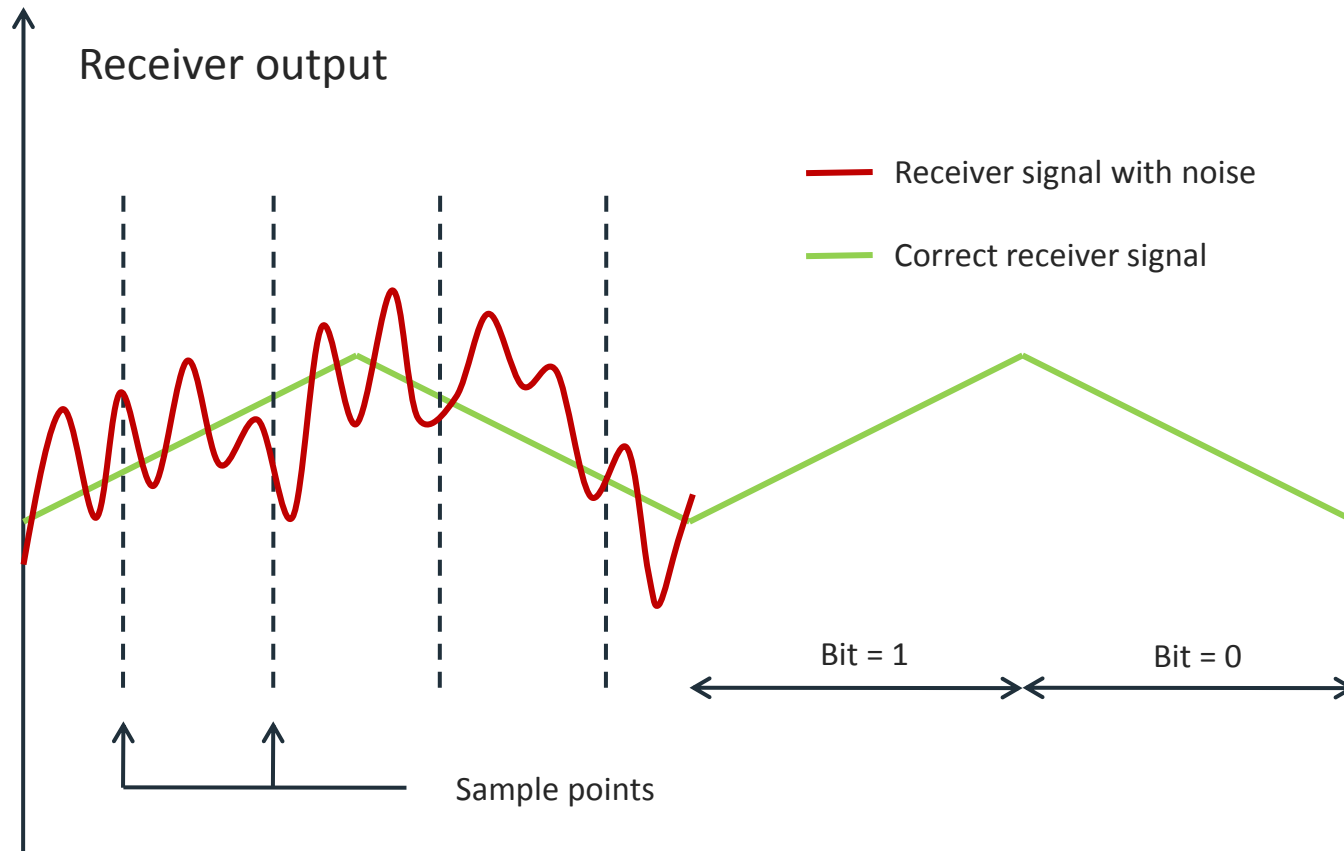
MINIMIZING WIRELESS INTERFERENCE IN HEARING AIDS

- Antenna technology



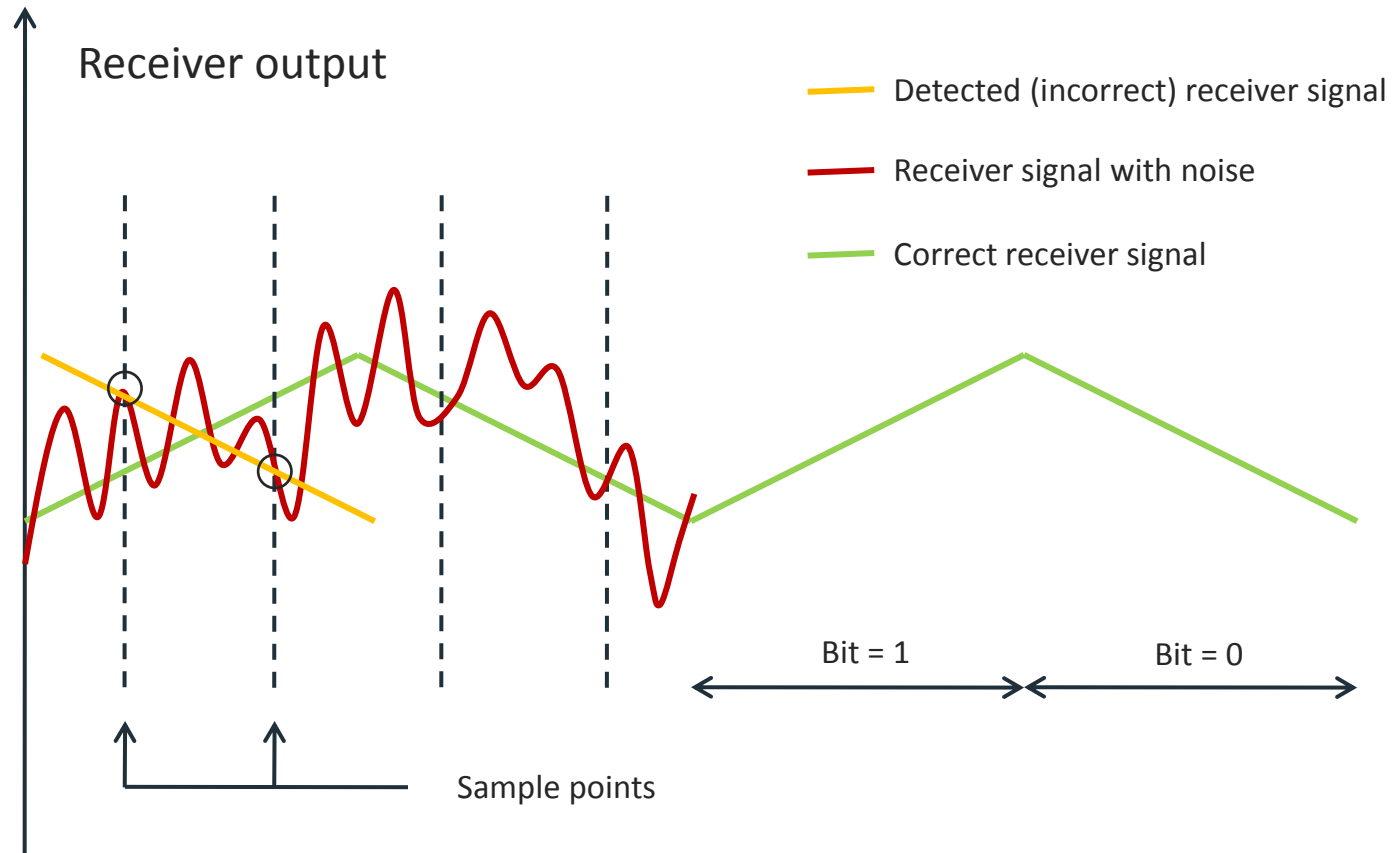
MINIMIZING WIRELESS INTERFERENCE IN HEARING AIDS

- Antenna technology



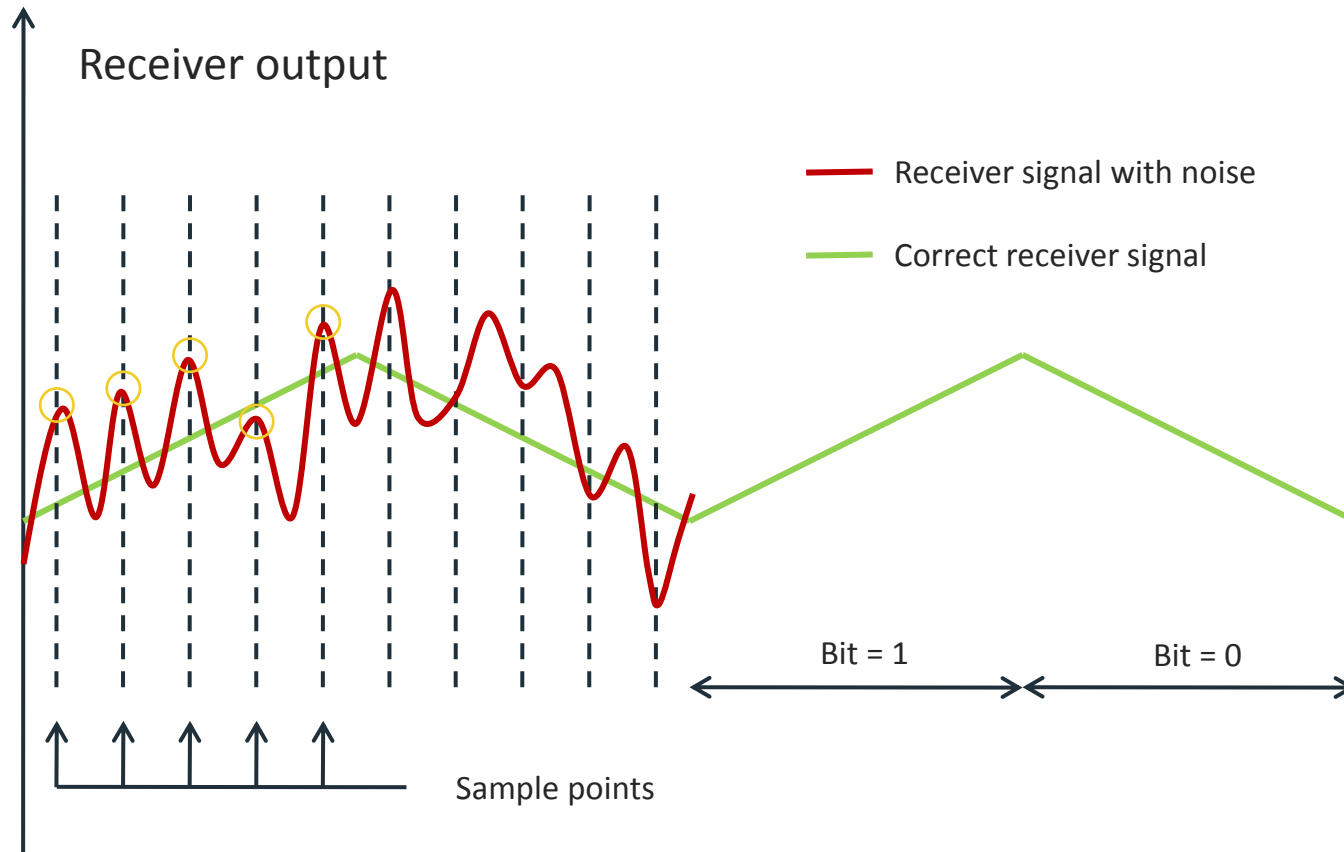
MINIMIZING WIRELESS INTERFERENCE IN HEARING AIDS

- Antenna technology



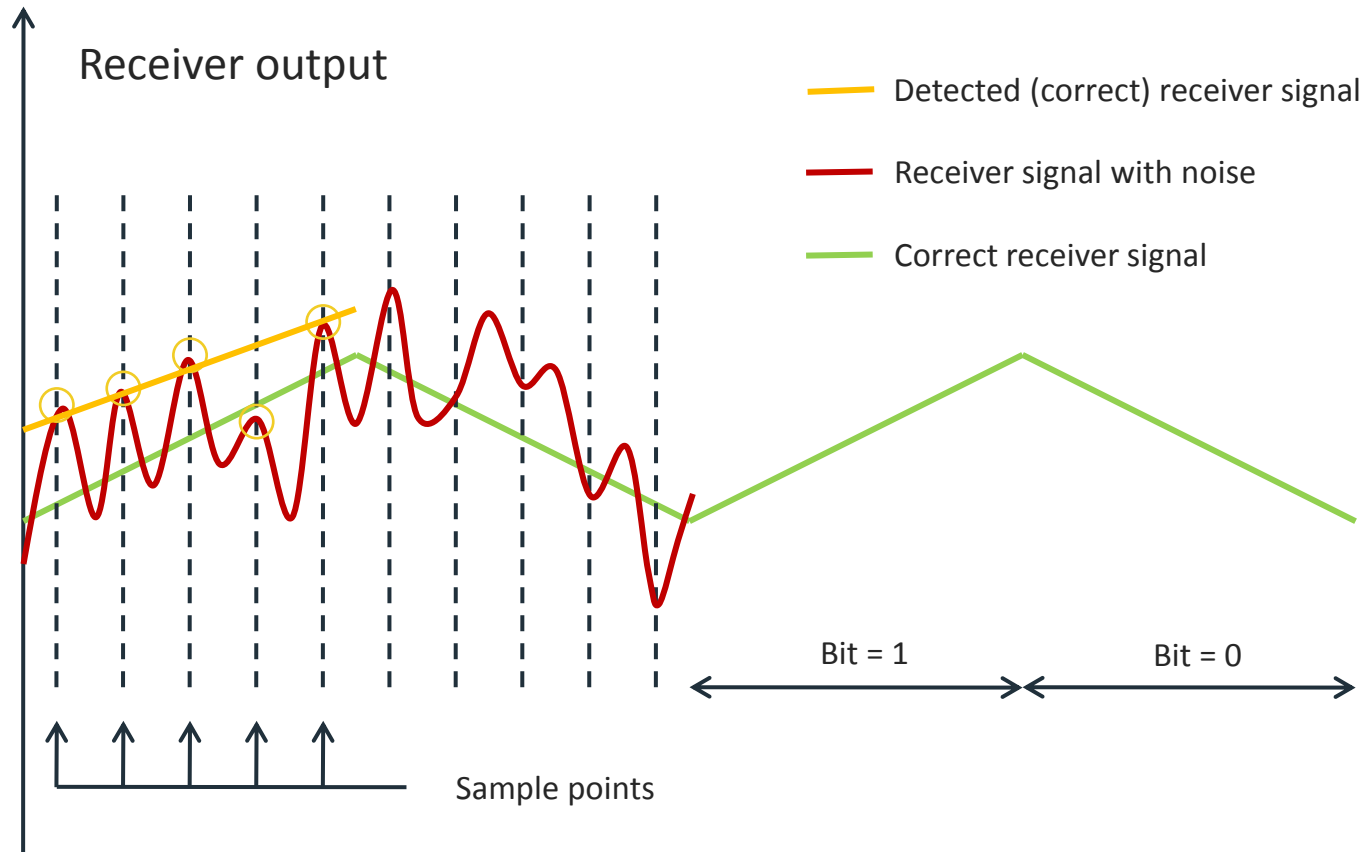
MINIMIZING WIRELESS INTERFERENCE IN HEARING AIDS

- Antenna technology



MINIMIZING WIRELESS INTERFERENCE IN HEARING AIDS

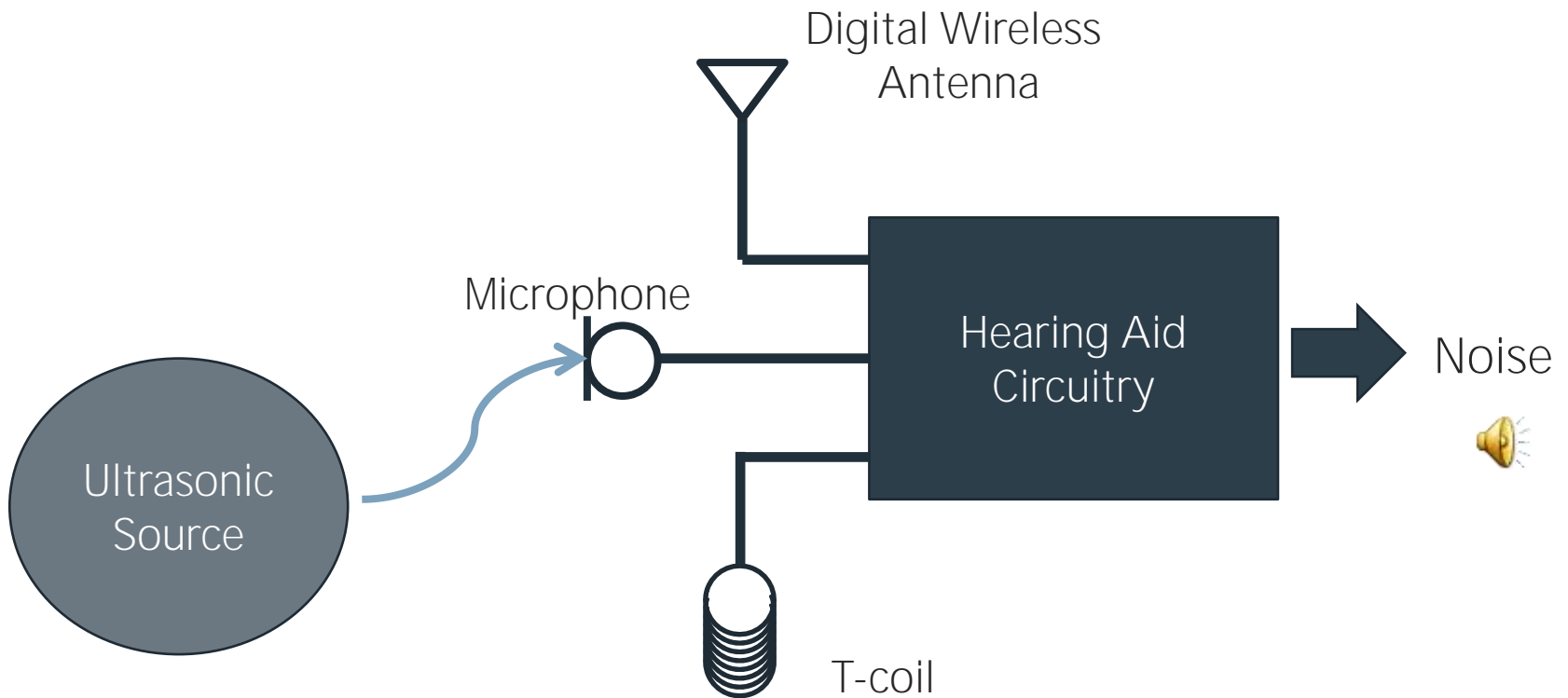
- Antenna technology



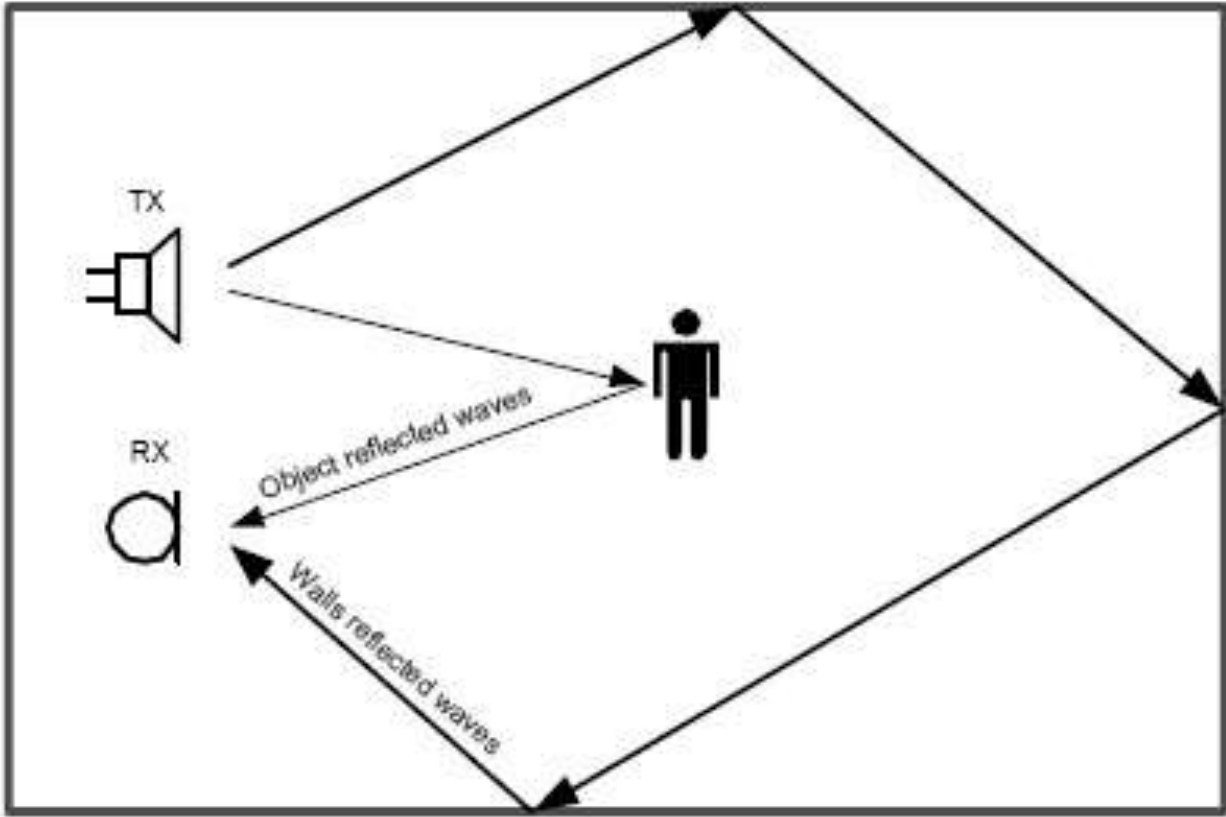
COEXISTENCE STUDIES

- ### Add blurred list of Widex coexistence studies here ###

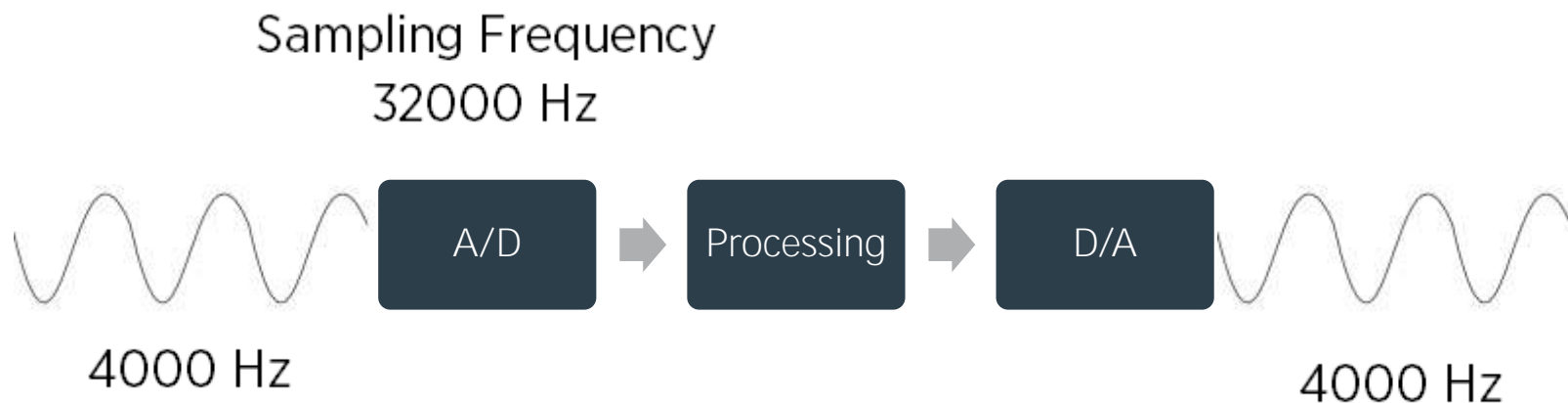
PATHS FOR HEARING AID INTERFERENCE



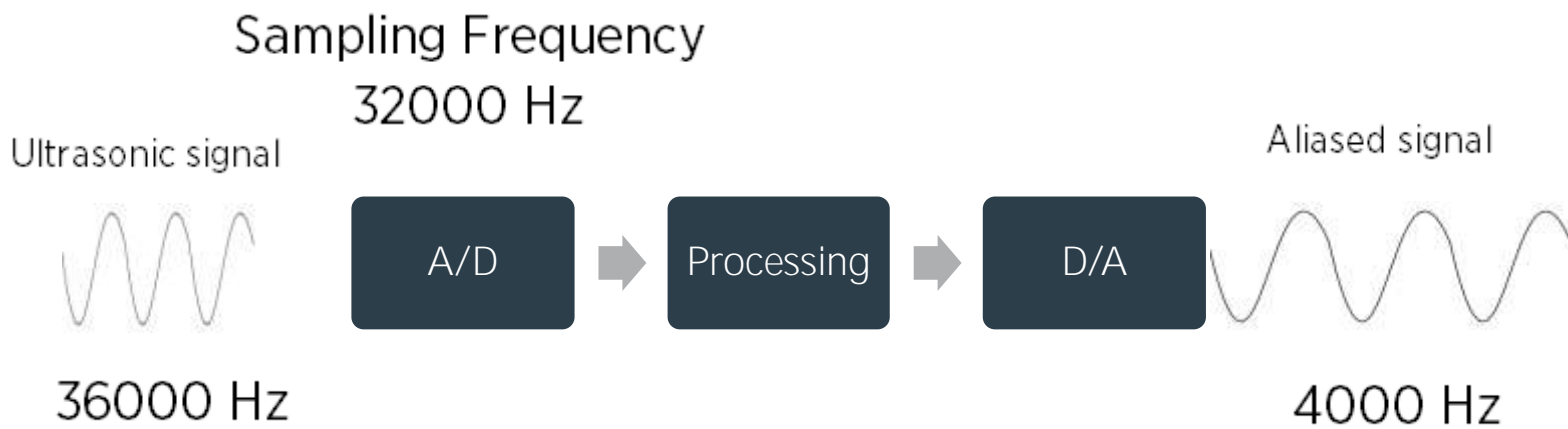
ULTRASONIC INTERFERENCE



HOW DO ULTRASONIC SOUNDS CAUSE INTERFERENCE?

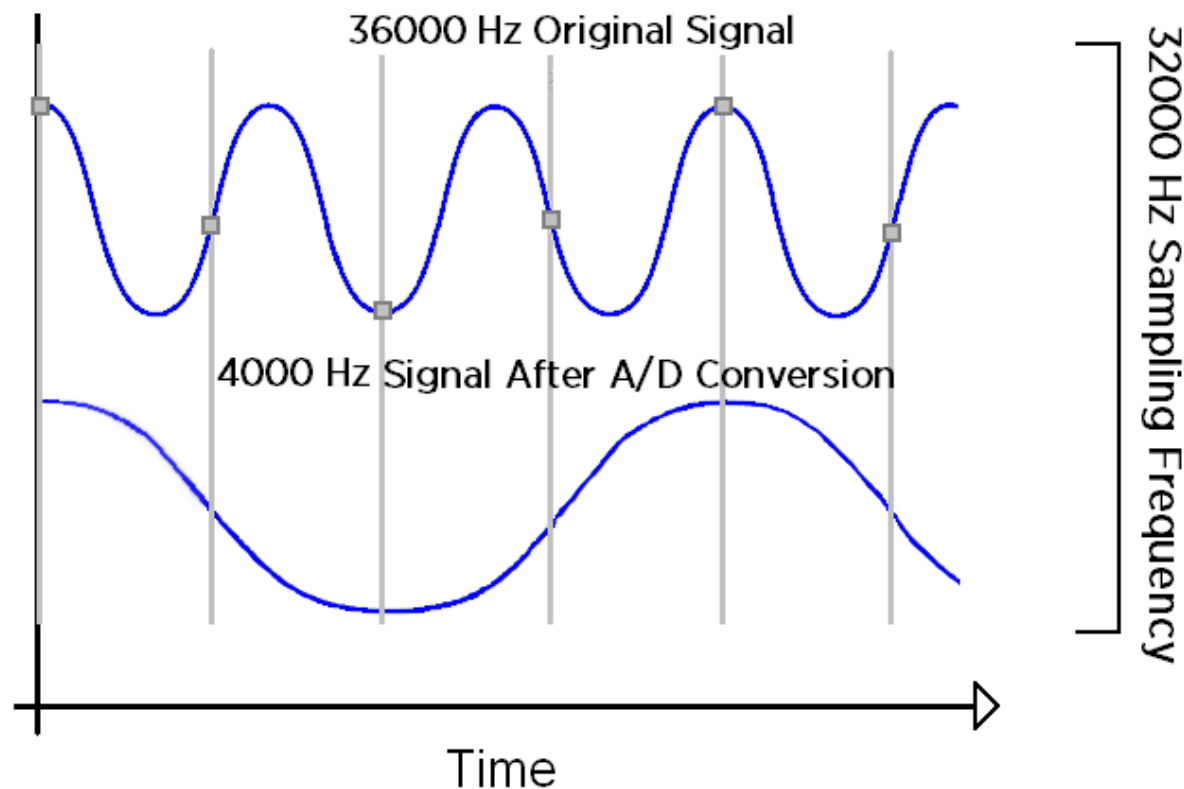


HOW DO ULTRASONIC SOUNDS CAUSE INTERFERENCE?



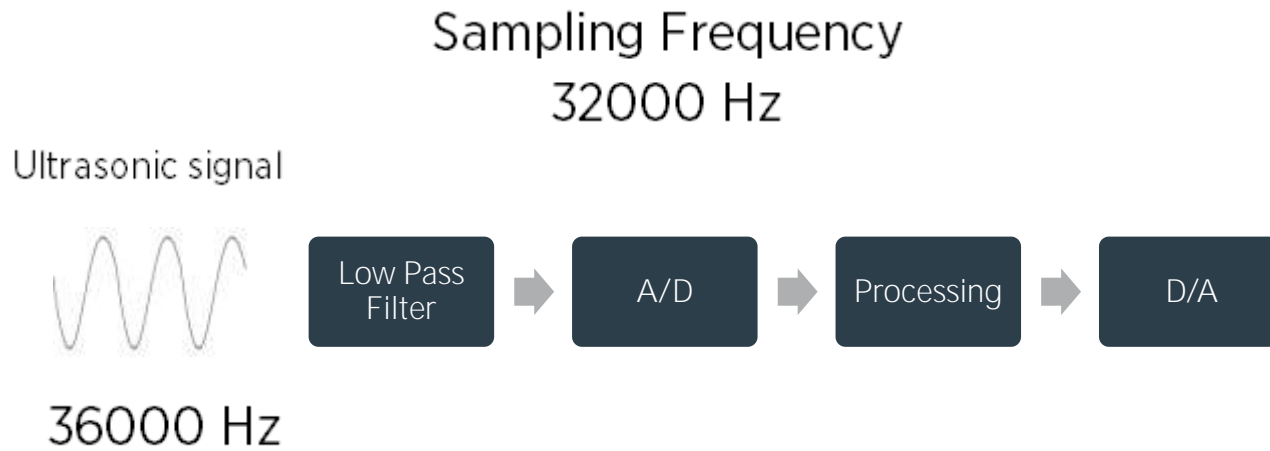
HOW DO ULTRASONIC SOUNDS CAUSE INTERFERENCE?

- A/D conversion can cause an aliasing of the sampled ultrasonic sound

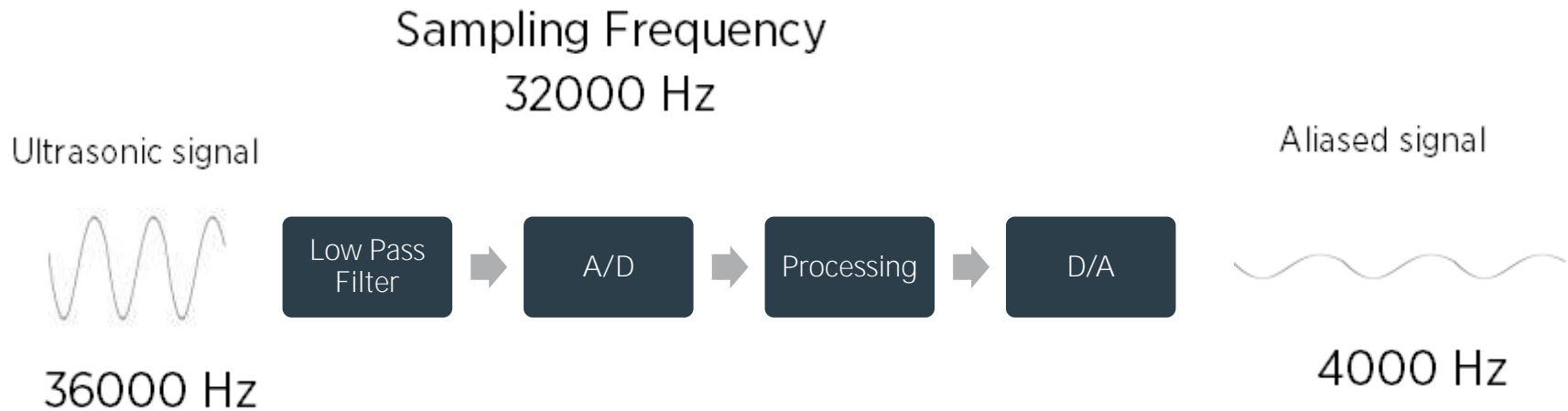


HOW TO REDUCE ULTRASONIC INTERFERENCE?

- Solution?



HOW TO REDUCE ULTRASONIC INTERFERENCE?



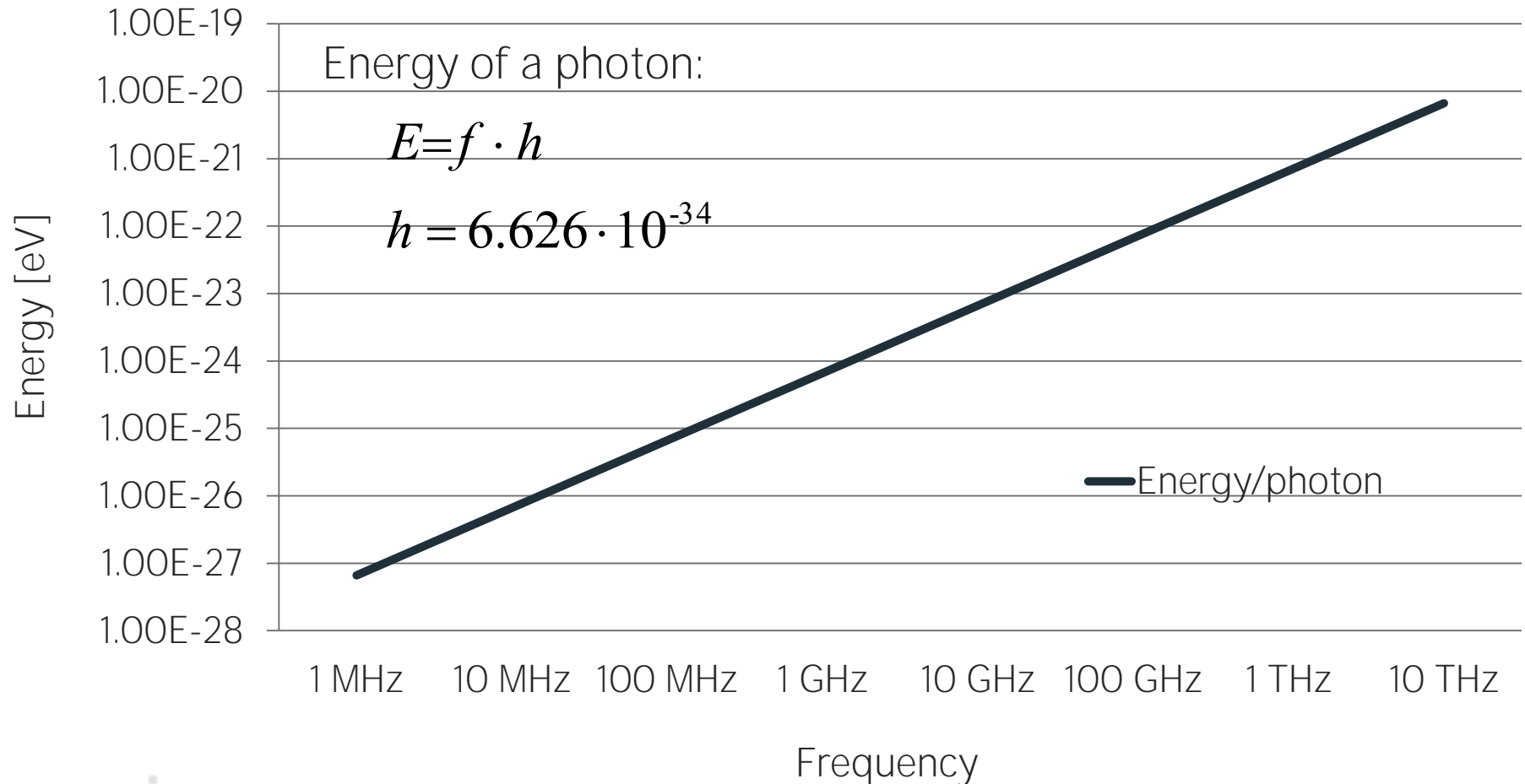
HOW TO FURTHER REDUCE ULTRASONIC INTERFERENCE?

- Inform building management about problems experienced with ultrasonic systems
- Many ultrasonic systems are highly directional. In some cases ultrasonic transducers can be repositioned to minimize interference discomfort for hearing aid users
- Last resort may be to ask for additional low-pass filtering to be added to the hearing aid microphone

HEALTH EFFECTS



RELATIONSHIP BETWEEN FREQUENCY AND ENERGY



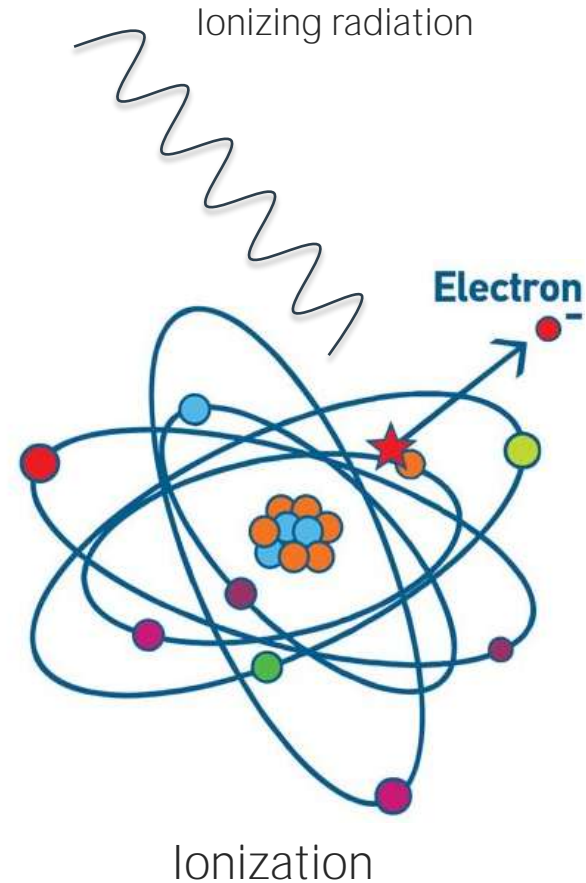
IONIZING AND NON-IONIZING RADIATION

- **Ionizing radiation**

High energy radiation. Capable of penetrating in the matter, producing ionization of the atoms, breaking chemical bonds, and causing harm in living matter.

- **Non-ionizing radiation**

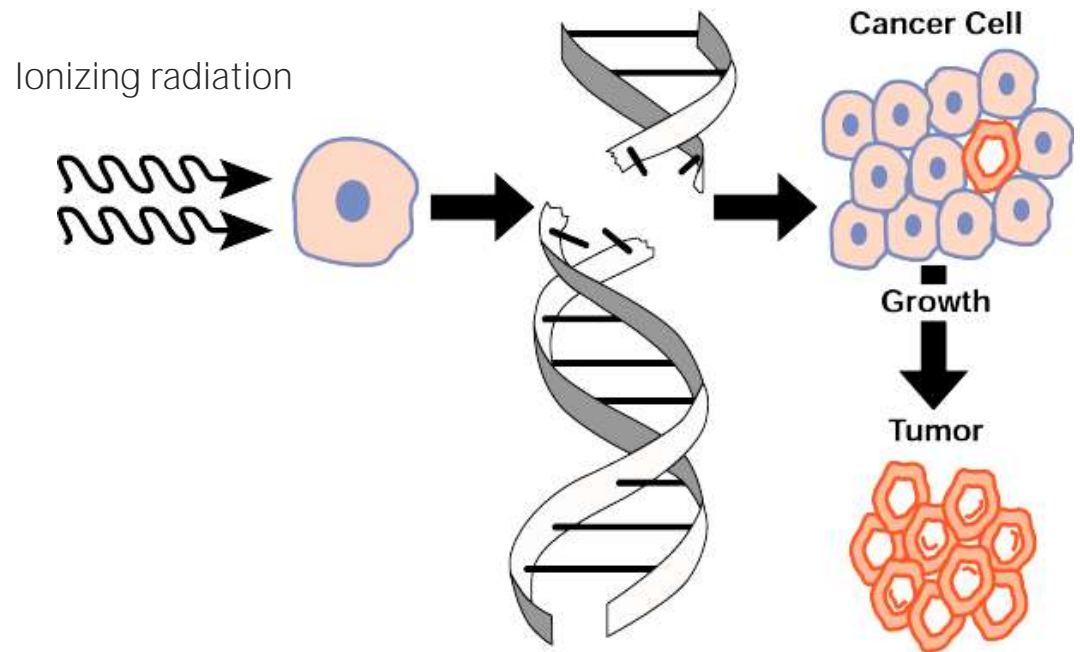
Low energy radiation. Does not carry enough power to ionize atoms or molecules.



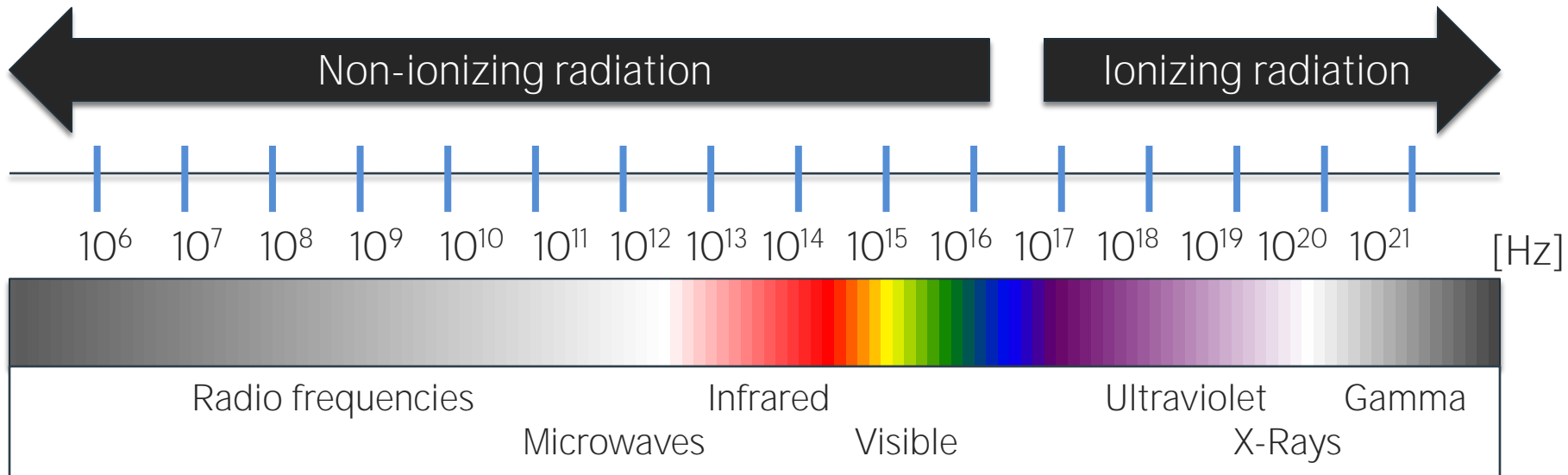
IONIZING RADIATION AND BIOLOGICAL TISSUE

Ionizing radiation can damage DNA and cause cell to function wrongly such as grow rapidly. This is known as cancerous cell.

The energy in non-ionizing radiation is not capable of breaking atomic bonds.



FREQUENCIES OF IONIZING AND NON-IONIZING RADIATION



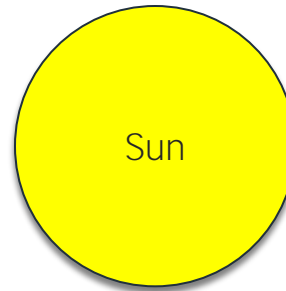
Power lines



TV and radio



Wireless hearing aids



Sun

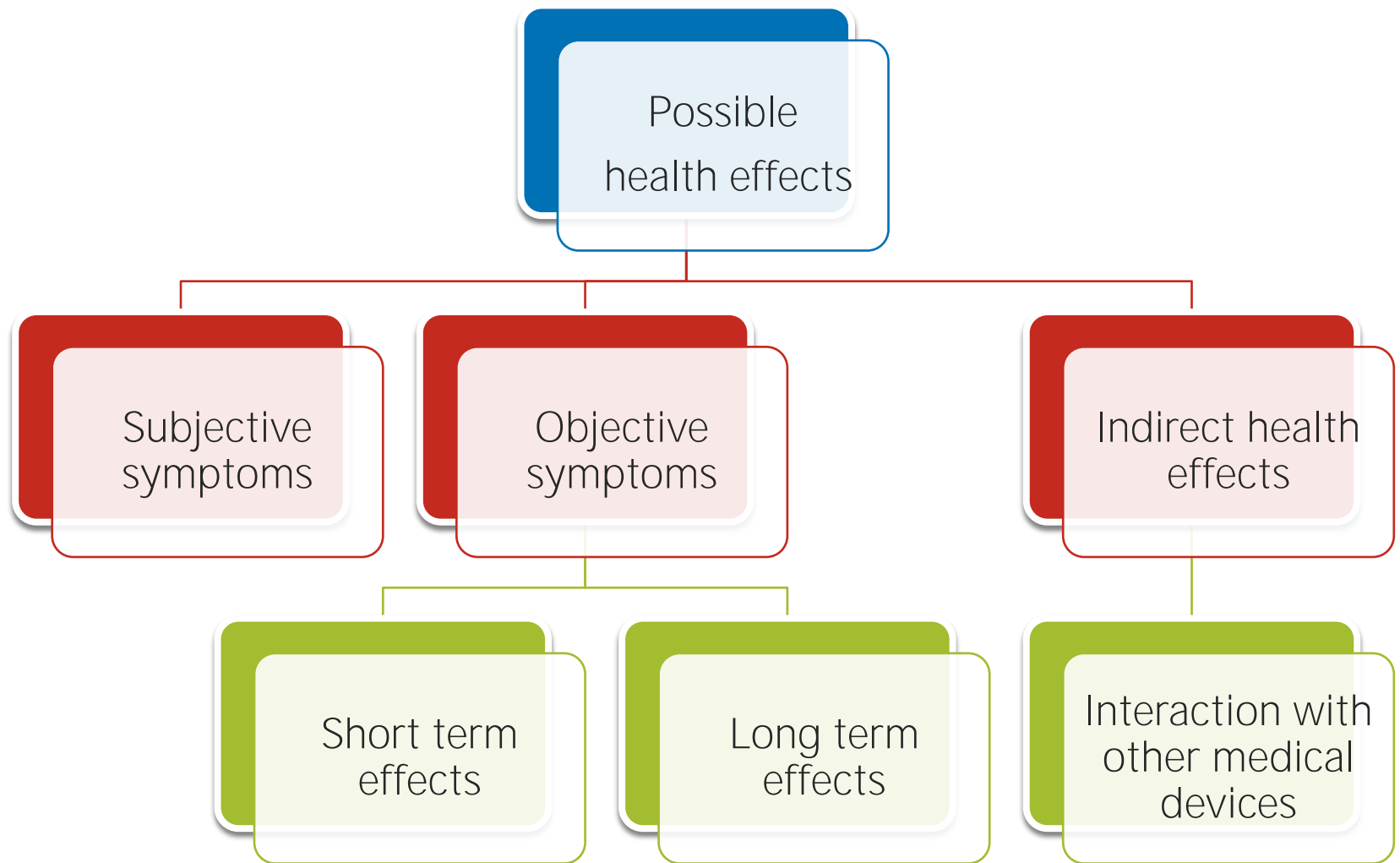


X-Ray machine



Radio-active sources

Wireless hearing aids use non-ionizing radiation



SUBJECTIVE HEALTH EFFECTS

Prevalence studies	Descriptive studies	Provocation studies
<ul style="list-style-type: none"> • Self-proclaimed symptoms: 1.5-3.2%. • Higher prevalence in women than men. • The highest prevalence in 60-69 year age group. • Experiences specific to mobile phone use have higher prevalence: 13-31%. 	<ul style="list-style-type: none"> • The subjective complains: headaches, migraines, fatigue, skin itches, and sensations of warmth • Symptoms with mobile phones include warmth behind or around or on the ear and with headaches and fatigue. 	<ul style="list-style-type: none"> • The provocation studies have not been able to confirm subjective effects of RF exposure. • Provocation studies investigate short-term interactions, and it is possible that symptoms may only occur after a longer exposure time.
<p>Hillert et al. 2002; Levallois et al. 2002; Eriksson & Stenberg, 2006, Oftedal et al. 2000.</p>	<p>Frey 1998a & b; Hocking 1998; Chia et al 2000a & b; Hocking and Westerman 2001; Sandström et al 2001; Santini et al 2002, 2003; Rubin et al 2005; Rösli 2008.</p>	<p>Koivisto et al. 2001; Rubin et al. 2006; Hietanen et al. 2002; Oftedal 2007; Zwamborn et al. 2003; Regel et al. 2006.</p>



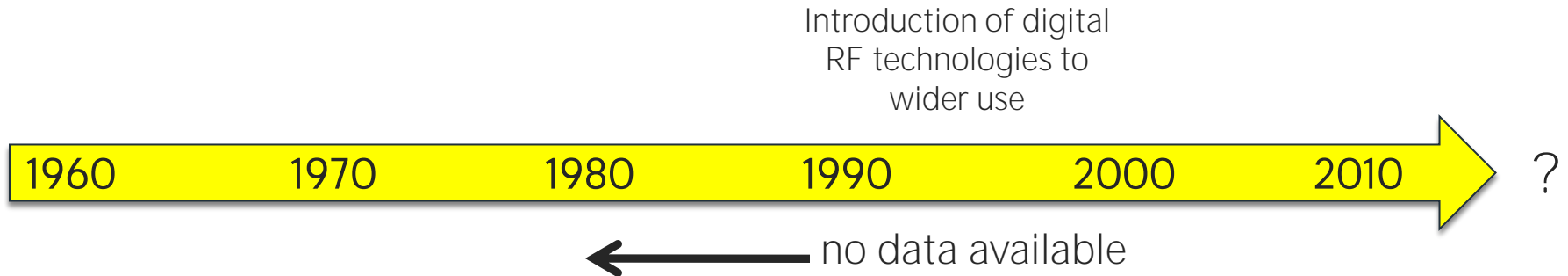
OBJECTIVE

SHORT TERM EFFECTS

- Skin and other superficial tissues absorb most of the energy at the frequencies used by mobile phones and wireless hearing aids.
 - Result: negligible temperature rise in organs of the body.
 - Thermoregulatory mechanisms counteract the temperature rise.
- Possible non-thermal effects?
 - Despite several proposals for non-thermal interaction mechanisms, none have been experimentally verified to date.

OBJECTIVE LONG TERM EFFECTS

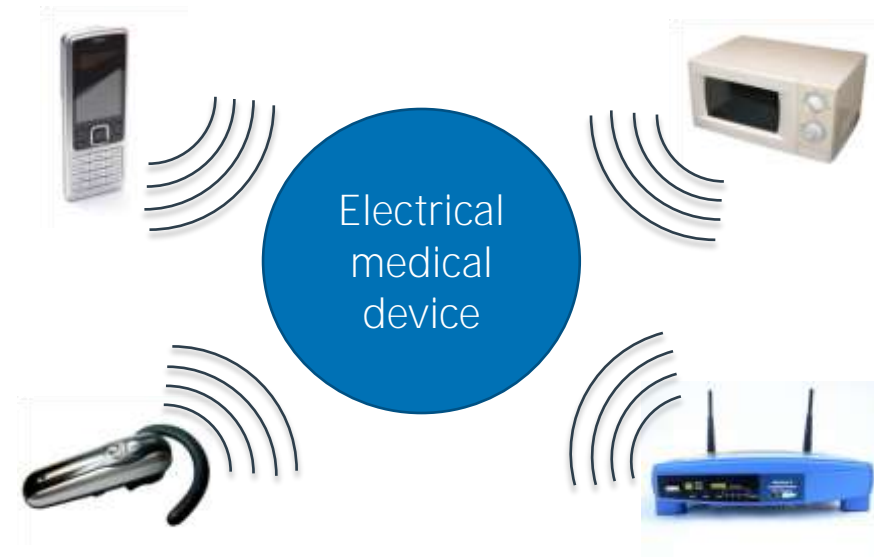
- Many cancers are not detectable until many years after the interactions that led to the tumor.



Epidemiological studies conducted at present day are limited to assess the cancers that were developed within shorter time periods.

INDIRECT HEALTH EFFECTS

- Interaction with pacemakers, apnea monitors, implantable cardiac defibrillators etc.
- Shielding, grounding, and filtering can protect most medical devices.
- International standards define minimum immunity levels for medical devices.



DOSIMETRY

- Dosimetry is carried out using surrogate of a human body, or numerical models.
- SAR (Specific Absorption Rate)
 - Measure of the rate at which energy is absorbed by biological tissue when exposed to a radio frequency (RF) electromagnetic field.



SAR MEASUREMENT WITH HEARING AIDS

- It is not possible to perform SAR measurements with hearing aids:
 - The size of the phantom test probe would be too big.
 - FCC does not specify the dielectric parameters for the liquid tissue phantom for frequencies below 150 MHz.



MOW MUCH ENERGY DO WIRELESS HEARING AIDS RADIATE?

	GSM phone	Wireless HA
Maximum power (EIRP)	0.125 W	2.9pW
Distance (R)	1 cm	1 mm

$$S = \frac{EIRP}{4\pi R^2}$$

$$T_{HA} = \frac{S_{GSM}}{S_{HA}} \cdot T_{GSM}$$

One minute of GSM use would correspond to over 820 years of wireless HA use.

Note: These calculations use assumptions for maximum power (EIRP) and distance (R) and compare two devices operating at different frequency bands using different modulation technologies.

CONCLUSIONS

- Wireless hearing aids use non-ionizing radiation that is not capable of breaking chemical bonds.
- Based on the large number of studies that have been performed over the last two decades to assess potential health risks of mobile phones, the World Health Organization (WHO) has stated that there are no adverse health effects found to this date.
- Wireless hearing aids radiate at much lower output levels than mobile phones. It is therefore reasonable to assume that the health effects of RF fields emitted by wireless hearing aids would be even more limited than those caused by mobile phones.
- The details of the technologies used in mobile phones and wireless hearing aids are not identical, and therefore further studies are warranted.