# POSTĘPY AKUSTYKI

Redakcja
Marcin Grochowina
Edyta Prędka

Polskie Towarzystwo Akustyczne, Oddział w Rzeszowie

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POLSKIE TOWARZYSTWO AKUSTYCZNE

ODDZIAŁ W RZESZOWIE

# POSTĘPY AKUSTYKI

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# Spis treści

# Musical Ignacy Łukasiewicz nasz rodak i patron

**Henryka Czyż[1], Wojciech Rdzanek[2]**
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[1] Wyższa Szkoła Informatyki I Zarzadzania, Rzeszów, ul. Sucharskiego 2
[2] Uniwersytet Rzeszowski, Rzeszów, Aleja Tadeusza Rejtana 16C

**Autor do korespondencji:** Henryka Czyż, email: hczyz@wsiz.edu.pl

**Abstrakt** Rok 2022 ustanowiono rokiem Ignacego Łukasiewicza w uznaniu jego zasług dla rozwoju przemysłu i gospodarki Polski oraz za jego działalność charytatywną i społeczną. W kraju przygotowano wiele wydarzeń upamiętniających działalność tego wielkiego Polaka, w tym otwarcie w Jasionce koło Rzeszowa Podkarpackiego Centrum Nauki Łukasiewicz. Młodzież akademicka miasta Rzeszowa, w ramach obchodów „Roku Ignacego Łukasiewicza” przygotowała musical o tym wielkim chemiku i wynalazcy na podstawie scenariusza i w reżyserii Tadeusza Urbana – studenta Uniwersytetu Rzeszowskiego na Wydziale Edukacji Muzycznej. Studenci Uniwersytetu Rzeszowskiego i Politechniki Rzeszowskiej poprzez muzykę, śpiew i taniec przypomnieli życie i działalność tego wybitnego farmaceuty i filantropa. W musicalu podkreślono ważną rolę Ignacego Łukasiewicza w historii najważniejszych wynalazków w dziejach ludzkości. Studenci w musicalu zawarli przesłanie, że Ignacy Łukasiewicz był człowiekiem wyprzedzającym swoją epokę, a o takich bohaterach, zapomnieć nam nie wolno.

**Słowa kluczowe :** musical, obchody Roku Ignacego Łukasiewicza, wynalazek, lampa naftowa, filantrop

## 1. Wstęp

Ignacy Łukasiewicz należy do zaszczytnego grona Polaków, których praca i działalność wywarła wielki wpływ na rozwój naszego kraju, Europy i całego świata. Rok 2022 ustanowiono rokiem Ignacego Łukasiewicza w uznaniu jego zasług dla rozwoju przemysłu w Polsce i na całym świecie oraz za jego działalność mającą na celu niesienie pomocy potrzebującym, w sposób bezinteresowny, dobroczynny, filantropijny. W polskiej i zagranicznej literaturze nie ma jeszcze pełnej naukowej monografii poświęconej Ignacemu Łukasiewiczowi. Do dzisiaj zachowało się mało dokumentów , pozostawionych przez samego Łukasiewicza. Te opracowania, które istnieją podają często fakty, które nie zostały zweryfikowane a dotyczą Jego życia i pracy, albo też przedstawiają postać jednostronnie. Opierają się one na relacjach jego potomków, krewnych[1] i znajomych[2] , osób[3], które pamiętały Łukasiewicza. W istniejących opracowaniach przewija się wątek udział Ignacego Łukasiewicza w ruchu narodowowyzwoleńczym i patriotycznym.
W czasopismach naukowych i opracowaniach związanych z historią polskiego przemysłu naftowego autorzy [1] podkreślają zasługi Ignacego Łukasiewicza jako twórcy przemysłu naftowego w Polsce. Zapoczątkowało to wielką rewolucję przemysłową w Polsce i na świecie.[2] Wśród dokonań Łukasiewicza szczególne znaczenie ma utworzenie na ziemiach polskich kopalni ropy naftowej w Bóbrce w powiecie

1 Przewodnicząca Oddziału Rzeszowskiego Polskiego Towarzystwa Akustycznego Pani dr hab. Lucyna Leniowska prof. UR jest spokrewniona z Ignacym Łukasiewiczem.
2 Prof. dr hab. inż. Adam Brański, pochodzi z Krosna członek Oddziału Rzeszowskiego Polskiego Towarzystwa Akustycznego. Jest absolwentem słynnej krośnieńskiej Naftówki czyli Zespołu Szkół Naftowo-Gazowniczych im. Ignacego Łukasiewicza w Krośnie.
3 Jan Zych poeta polski, poliglota, pochodził z Korczyny koło Krosna, znawca i tłumacz na język hiszpański wierszy Grzegorza Białkowskiego, Czesława Miłosza, Tadeusza Różewicza, Zbigniewa Herberta, Wisławę Szymborską.

krośnieńskim oraz uruchomienie kilku rafinerii. Łukasiewicz to także wielki społecznik, inicjator budowania dróg, mostów, szpitali, szkół.
W Bóbrce koło Krosna znajduje się Muzeum im. I. Łukasiewicza, w którym można poznać historię przemysłu naftowego od czasów pionierskich Łukasiewicza aż po współczesność. [3] W jesieni tego roku odbędzie się otwarcie Podkarpackiego Centrum Nauki Łukasiewicz. Celem tego Centrum jest upamiętnienie wielkiego Polaka oraz zainteresowanie młodzieży naukami przyrodniczymi i technicznymi, zachęcanie do eksperymentowania i odkrywania naukowych ciekawostek.

## 2. Musical o Ignacym Łukasiewiczu

### 2.1. Dlaczego Musical


**Fot.1**. Plakat Musicalu. Źródło własne

Musical jest to pewna forma teatralna, która łączy muzykę, piosenki, dialogi i taniec [6]. Emocje takie jak patos, miłość, wzruszenie są wyrażane w musicalu poprzez słowa, muzykę, ruch tworząc jedną, spójną całość. Mówi się, że w musicalu funkcjonuje zasada: „gdy emocje stają się zbyt silne, by je wypowiedzieć, zaśpiewaj; kiedy są zbyt silne, by je wyśpiewać, zatańcz.” Postać Ignacego Łukasiewicza postrzegana jest przede wszystkim jako wynalazcy lampy naftowej ale w musicalu młodzież akademicka zaprezentowała wiele ważnych wydarzeń z życia i pracy tego wielkiego uczonego. Podkreślono też ważną rolę Łukasiewicza w historii wynalazków w dziejach ludzkości. Studenci Chóru Akademickiego PRz oraz UR przygotowali musical o tym wielkim chemiku i wynalazcy na podstawie scenariusza i w reżyserii Tadeusza Urbana – studenta UR na Wydziale Edukacji Muzycznej. W musicalu wykonano wiele pieśni, wśród nich takich, które zostały napisane i skomponowane przez samych studentów: „Balladę wiertniczą”, Hymn dla miasta Rzeszowa, Hymn PRz [12].

Musical „Ignacy Łukasiewicz nasz rodak i patron” rozpoczyna się od recytacji wiersza Jana Zycha, pod tytułem „Kiedy przyjeżdżam”, którego fragment zacytowano [12] :

**Fot.2.** Tadeusz Urban recytuje wiersz „Kiedy przyjeżdżam”

„Kiedy przyjeżdżam do Krosna Łukasiewiczowi się kłaniam.
W rozwianym fartuchu, wykuty z brązu.
Pogodny i zamyślony jednako w grudniu i w maju.
Brodę i wąsy pokryła patyna,
a na lampie naftowej, którą w dłoni trzyma,
wróble ćwierkają.
Od jego imienia pierwszy mój wiersz się zaczyna.
On mnie wywiódł z czarnych wieczorów i w jasne księgi wprowadził -
mądry zamyślony aptekarz. ”

**Fot. 2**. Pomnik Ignacego Łukasiewicza Krośnie – pomnik dłuta Jana Raszki, wzniesiony w 1932 roku
Źródło: https://pl.wikipedia.org/wiki/Pomnik_Ignacego_%C5%81ukasiewicza_w_Krosnie

## 2.2. Dzieciństwo i lata młodzieńcze

Ignacy Łukasiewicz przyszedł na świat na ziemi rzeszowskiej, w małej galicyjskiej miejscowości Zaduszniki w obwodzie tarnowskim 8 marca 1822 roku. Atmosfera domu rodzinnego była serdeczna [2,5,9]. Łukasiewiczowie wychowywali swe dzieci w duchu patriotycznym. Od roku 1830 rodzina Łukasiewiczów zamieszkała w Rzeszowie. Naukę z zakresu szkoły powszechnej Ignacy Łukasiewicz pobierał w domu, a w 1832 roku został przyjęty do Gimnazjum Ojców Pijarów w Rzeszowie. Językiem wykładowym w gimnazjum był język niemiecki lub łacina. Obowiązkowymi przedmiotami była religia, języki niemiecki, łaciński i grecki, historia, geografia i arytmetyka. Wiadomości z historii i literatury polskiej młodzież zdobywała tylko w tajemnicy przez samokształcenie się. Ignacy po ukończeniu nauki w rzeszowskim gimnazjum podjął od 1836 roku praktykę aptekarską w Łańcucie. Po zdaniu egzaminu przed Gremium Aptekarskim Obwodowym w Rzeszowie powrócił do pracy w aptece łańcuckiej już jako asystent. Po kilku latach wrócił do pracy w aptece w Rzeszowie. bardzo podobał się Rzeszów młodemu Ignacemu, podobnie jak młodzieży akademickiej, o czym świadczą słowa Hymnu dla Rzeszowa [12]:

Piękne nasze miasto budzi nas co dzień
Centrum innowacji i rozwoju jest.
Ref. Rzeszów to nasze miejsce jest
Co dzień radośniejszym miastem staje się.
Ratusz, rynek, zamek dumnie wznoszą się
Pamięć naszych przodków wciąż z ich murów tchnie.
Ref. Rzeszów to nasze miejsce jest
Co dzień radośniejszym miastem staje się.
Nad Wisłokiem leży nasz szacowny gród
Ludzie w nim otwarci szczęście znajdziesz tu.

Praca w Rzeszowie dała mu to możliwość pogłębienia wiedzy fachowej. Młody Ignacy w życiu osobistym był małomówny, skryty i bardzo pracowity. Wśród rówieśników uważany był za kolegę sympatycznego i życzliwego. Lubił też dużo czytać. Od 1850 roku i rozpoczął studia na wydziale filozoficznym Uniwersytetu Jagiellońskiego, przy którym było dwuletnie studium farmaceutyczne. Pierwszy rok studiów Łukasiewicz zaliczył uzyskując oceny bardzo dobre. Kolega uniwersytecki napisał : „...poznaliśmy go jako jednego z najzdolniejszych i najpilniejszych uczniów i najlepszego kolegę. Pracował on usilnie, a mniej zdolnym kolegom ułatwiał naukę bezinteresownymi wykładami.” [1] Na ostatni rok studiów przeniósł się do Wiednia i 30 lipca 1852 roku zadał egzamin dla magistrów farmacji z ogólną oceną bardzo dobrą. Zakończyło to w jego życiu pewien etap, w którym zaspokoił aspiracje zawodowe. W musicalu symbolem radości lat młodzieńczych Ignacego był taniec mistrzowskiej pary tanecznej z UR [12].

**Fot. 3.** Mistrzowska para taneczna z UR

### 2.3. Spółka: Mikolasch, Zeh, Łukasiewicz. Pierwsza lampa naftowa.

We Lwowie Łukasiewicz pracował w aptece Mikolascha. W tamtych czasach apteki były instytucjami wyposażonymi w laboratoria i aparaturę chemiczną. Od pracowników wymagano wiedzy chemicznej. Do apteki w jesieni 1852 roku zgłosili się kupcy z zainteresowani destylowaną już ropą. Na polecenie właściciela Łukasiewicz i Jan Zeh rozpoczęli badania i prace doświadczalne nad ropą naftową. Po wielu dniach pracy uzyskali destylat jasnożółty, o słabym zapachu, który nie zawierał związków żywicowych występujących w surowej ropie. Stwierdzili, że destylat jest taki sam jak drogi produkt, który był sprowadzany z zagranicy. Na wystawie apteki wyeksponowano buteleczki z informacją, że uzyskany olej skalny jest własnego wyrobu i może konkurować z bardzo drogim specyfikiem medycznym sprowadzanym z Włoch Oleum Petrae album. Spodziewając się dużego zainteresowania tym produktem, założono spółkę: Mikolasch, Zeh, Łukasiewicz. Mimo reklamowania tego produktu aptekom, nie nadeszło wiele zamówień. Zniechęcony niepowodzeniem Mikolasch wycofał się ze spółki. Łukasiewicz chciał wykorzystać swój wynalazek dla dobra ludzi. Przy pomocy Zeha kontynuował destylowanie ropy do celów oświetleniowych. Pod koniec 1852 roku udało im się, jako pierwszym na świecie wydzielić z ropy naftę. Stosując frakcjonowaną destylację, uzyskali preparat pozbawiony lekkich frakcji jak benzyna oraz oddzielili go w aparaturze od pozostałych ciężkich węglowodorów (asfalty, oleje techniczne).

**Fot. 4**. Scena z Musicalu. Ignacy Łukasiewicz (z prawej) z Janem Zehem (po lewej) w laboratorium

W rok później już sam Łukasiewicz skonstruował pierwszą prototypową cylindryczną lampę naftową. Pomagał mu jedynie lwowski blacharz. Lampa po raz pierwszy zabłysnęła w aptece Mikolascha w marcu 1853 roku. W lwowskim szpitalu przy świetle lamp naftowych chirurg wykonał operację pacjenta, ratując mu tym życie, w nocy 31 lipca 1853 roku. Dzień ten uznano za początek światowego przemysłu naftowego. Szpital lwowski zakupił od spółki 500 kg nafty, czyli dokonał pierwszej transakcji naftowej na świecie. W 1854 roku zabłysła w Gorlicach pierwsza na świecie uliczna lampa naftowa [1,2,4, 6].
Od 1974 roku patronem Politechniki Rzeszowskiej jest Ignacy Łukasiewicz, o czym mówią słowa Hymnu PRz pod tytułem „Leć do gwiazd” (fragment) [12]:

W naszych murach pełnych talentów, gdzie Łukasiewicza przyświeca nam blask,
spełniamy swoje najszczersze marzenia, by się rozwijać i iść z dumą w świat.

Politechnika Rzeszowska otwarte szeroko przyszłości wrota
wiedzieć, umieć i chcieć – edukacja cenniejsza od złota.

### 2.4. Spółka Łukasiewicz-Trzecieski. Kopalnia w Bóbrce

Rok 1854 można uznać za przełomowy w życiu Łukasiewicza. Założył on wtedy z Tytusem Trzecieskim spółkę i uruchomili razem kopalnię ropy w Bóbrce, co wiązało się z rozpoczęciem prac poszukiwawczych. Tak zaczęła funkcjonować spółka Łukasiewicz-Trzecieski. W 1856 roku powstała w Ulaszowicach, destylarnia. Pierwszą partię nafty i różne smary mineralne kupiła Północna Kolej Austriacka. W 1857 roku Łukasiewicz wydzierżawił aptekę w Jaśle. Tam rozwinął działalność farmaceutyczną, naftową oraz społeczną. „...Łukasiewicz chciał swym wynalazkiem i umysłem służyć ludzkości a nie wyzyskiwać ją" [2]. W 1860 roku do spółki przystąpił Klobassa, który z Trzecieskim wnieśli do spółki roponośne tereny i kapitał zaś Łukasiewicz swą wiedzę i pracę. Łukasiewicz był jej pełnomocnikiem i dyrektorem. Objął też kierownictwo kopalni w Bóbrce i rafinerii w Polance. W Jaśle Łukasiewicz zaskarbił sobie powszechną wdzięczność społeczeństwa swoją energią i uczynnością. Dnia 12 czerwca 1861 roku nadano mu dyplom honorowego obywatela miasta. W Jaśle całkowicie poświęcił się przemysłowi naftowemu. Gdy podjął się kierowania całością prac naftowych w Bóbrce, od początku otaczał się specjalistami i angażował do współpracy fachowców [3]. Z tamtych lat pochodzi „Ballada wiertnicza zaśpiewana przez solistów Chóru PRz [12]:

Czy słońce na niebie, czy wieczór zapada wędruje po świecie wiertnicza ballada
I śpiewa włóczęgom w zielonych dąbrowach jak dobrze z balladą wędrować.

I marzą wiertacze w codziennym swym trudzie o nafcie, o gazie, o ropie i rudzie
By w ciężkiej swej pracy tę znaleźć zapłatę nawiercić znów złoże bogate.

Dać naftę do lampy dla Was przyjaciele staramy się o to , to naszym celem
I kiedy rozstania już pora nastanie wspomnijcie wiertniczą balladę.

### 2.5. Pierwsze na świecie Krajowe Towarzystwo Naftowe dla Opieki i Rozwoju Przemysłu i Górnictwa Naftowego w Galicji z siedzibą w Gorlicach

W 1877 roku, w czasie trwania wystawy rolniczo-przemysłowej zebrał się pierwszy kongres naftowy, który obradował pod przewodnictwem Łukasiewicza. W wyniku tych obrad powstała oparta na wzajemnym zaufaniu spółka, którą uznaje się za pierwsze na świecie Krajowe Towarzystwo Naftowe dla Opieki i Rozwoju Przemysłu i Górnictwa Naftowego w Galicji z siedzibą w Gorlicach. Prezesem został Łukasiewicz. Mimo, że nafta była największą pasją Jego życia, sprawy z nią związane nie wypełniały mu całego czasu. Angażował się w różne prace społeczne. W 1879 roku podjął akcję obsadzania dróg drzewami owocowymi. Drogę z Chorkówki do Bóbrki i do Zręcina obsadził za własne pieniądze. 24 października 1876 roku został wybrany posłem gmin wiejskich z okręgu Krosno-Dukla-Żmigród do Sejmu Krajowego. Wtedy w latach 1878-1880 przewodniczył komisji górniczej. Z racji swej specjalności był jednak przede wszystkim rzecznikiem spraw naftowych [3].

### 2.6. Amerykanie - pierwsze kroki w przemyśle naftowym

W tym czasie kiedy mieszkańcy USA stawiali pierwsze kroki w przemyśle naftowym, kopalnia Łukasiewicza w Bóbrce zatrudniała ponad stu robotników i osiągała wysokie obroty. [1,2] W dziedzinie petrochemii Łukasiewicz był cenionym autorytetem o międzynarodowej sławie. Do jego kopalni przejeżdżali przedsiębiorcy nawet ze Stanów Zjednoczonych, gdzie poznawali tajniki jego wiedzy**.** W drugiej połowie lat sześćdziesiątych sprzedawał już naftę hurtowo w całej Europie. W 1873 roku na wystawie w Wiedniu Międzynarodowa Komisja przyznała mu medal zasługi za naftę i asfalt oraz dyplom uznania za zasługi dla przemysłu naftowego. Niedługo potem został przewodniczącym założonego przez polskich nafciarzy Krajowego Przemysłu Naftowego.

## 2.7. Polityk i filantrop

Ignacy Łukasiewicz był nie tylko przedsiębiorcą, ale także politykiem i filantropem [1, 2,3]. W 1863 roku Łukasiewicz wspierał finansowo powstanie styczniowe, a po jego upadku udzielał schronienia jego uczestnikom. W latach 1877-1881 był posłem na Sejmie Krajowym w Galicji. W parlamencie był jednym z głównych promotorów przemysłu naftowego. Owocem tej działalności było kilka uchwał między innymi, zmiana ustawy o kopalniach, która odtąd umożliwiała zaangażowanie prywatnych kapitałów w rozwój nowego przemysłu. W 1880 roku na jego wniosek Sejm Krajowy przeznaczył pierwsze subwencje na wiercenia górnicze w rejonie Gorlic. Także dzięki jego inicjatywie Sejm uchwalił subwencje na stypendia z zakresu górnictwa i technologii nafty oraz na utworzenie pierwszego wydziału naftowego w krakowskiej Akademii Technicznej. Jego zasługą było obniżenie podatków dla rodzimych przedsiębiorców z Galicji i obłożenie podatkiem celnym ropy z Rumunii i Stanów Zjednoczonych. Ignacy Łukasiewicz wielki filantrop dzięki swojej działalności odmienił życie tysięcy mieszkańców Galicji. Kiedy jego spółka zaczęła przynosić większe zyski, Łukasiewicz na dużą skalę rozpoczął finansowanie budowy szkół, dróg, mostów, szpitali i kościołów. Wspierał też finansowo organizacje narodowo-wyzwoleńcze. W Chorkówce i w Bóbrce otworzył szkoły dla dziewcząt, opłacał nauczycieli i umożliwił ludności wiejskiej kształcenie swoich dzieci. Aby zapobiec szerzącej się po wsiach lichwie, zorganizował kasy gminne udzielające chłopom bezprocentowych, pożyczek spłacanych w małych ratach. Łukasiewicz udzielał także pożyczek chłopom zatrudnionym się w dowozie ropy naftowej do rafinerii. Łukasiewicz ogromną troską otaczał swoich pracowników. Zorganizował im pierwszą w Galicji robotniczą kasę [8,9]. Przynależność do niej gwarantowała pracownikom dostęp do bezpłatnych lekarstw, opieki medycznej, chorobowego, renty w razie inwalidztwa, a także zasiłku zapomogowego dla rodziny zmarłego robotnika. Gdy jego przedsiębiorstwo zaczęło przynosić największe zyski, Łukasiewicz dobrowolnie zrzekł się większości swoich udziałów na rzecz współpracowników, samemu zostawiając sobie tyle, ile potrzebował do utrzymania rodziny. W musicalu Chór zaśpiewał [12]:

„ Pieniądze jednak to nie wszystko choć na nich twardo stoi świat
Liczy się ktoś kto jest wciąż blisko nawet gdy forsy brak.”

## 2.8. Rockefeller w Galicji

U Ignacego Łukasiewicza nie istniało takie określenie jak „tajemnica zawodowa”. Tym co miał, bezinteresownie dzielił się z innymi. Łukasiewicz chciał swoją pracą służyć ludzkości. Ciekawa jest wiadomość związana z wizytą, jaką Amerykanie złożyli Łukasiewiczowi. Polski wynalazca pokazał im wszystkie tajemnice swojego przedsiębiorstwa, cały proces od wydobycia aż po destylację. Amerykanie chcieli mu wówczas za to zapłacić, jednak Łukasiewicz odmówił. Polecił im natomiast aby część zarobionych pieniędzy przeznaczyli na cele charytatywne.

**Fot. 5**. Scena z Musicalu. Spółka Trzecieski - Łukasiewicz –Klobassa

Za działalność charytatywną papież Pius IX w 1873 roku nadał Ignacemu Łukasiewiczowi tytuł Szambelana Papieskiego i znaczył orderem św. Grzegorza. Są to najwyższe wyróżnienia, jakie mogła otrzymać osoba świecka od Ojca Świętego [ 11].

### 3. Jak zapamiętamy Ignacego Łukasiewicza

Ignacy Łukasiewicz, to twórca światowego przemysłu naftowego, który pochodził z Podkarpacia, to wybitny naukowiec i pionier przemysłu naftowego oraz wynalazca lampy naftowej. Był On też polskim patriotą, działaczem niepodległościowym, filantropem, menedżerem.

Zapamiętamy też, że Podkarpacie to przestrzeń otwarta na ludzi młodych, także na pomysły i na nowe idee. Tutaj piękne krajobrazy przyrody i pomniki przeszłości towarzyszą nowoczesnym technologiom.

W musicalu narrator kończy opowieść o wielkim Polaku cytatem [12]:

”Wielu było świetniejszych, głośniejszych ludzi od niego, ale o cnotliwszego trudno. Ktoś powiedział, że Bóg najprostszymi środkami największe rzeczy objawia, temu też prostemu człowiekowi dane mu było zostać twórcą wielkiego wynalazku oświetlenia naftowego. Z obowiązku narodowego zaszczytu tego wydrzeć sobie nie pozwolimy, bo z góry przewidzieć można, iż nam go zechcą zaprzeczać, z obowiązku narodowego winniśmy uczcić trwale nazwisko wynalazcy i przekazać potomności jego zasługi”. W musicalu studenci wyrazili przesłanie, że Ignacy Łukasiewicz zasłużył na to, żeby cały naród zaliczył Go do najlepszych, najszlachetniejszych swoich synów.

Ignacy Łukasiewicz zmarł 7 stycznia 1882 roku [1,3,11]. Został, pochowany na cmentarzu w Zręcinie. Pogrzeb jego stał się spontaniczną manifestacją całej okolicy, wzięło w nim udział około 4000 osób.

### Bibliografia


1.W. Bonusiak, Życie i działalność Ignacego Łukasiewicza, Rzeszów 1985.
2. L. Tamanek, Ignacy Łukasiewicz. Twórca przemysłu naftowego w Polsce. Krosno, 1928.
3. Wiesław Hap, Życie i działalność Ignacego Łukasiewicza na tle początków światowego i jasielskiego przemysłu naftowego., „Rocznik Jasielski” (10), 2011,
4. J. Orlewski, Spisek w aptece. Rzecz o Ignacym Łukasiewiczu. Warszawa 1959
5. S. Brzozowski, Ignacy Łukasiewicz, Interpress, Warszawa 1974
6. W. A. Everett, P.R. Laird, The A to Z , Broadway Musical, Rowman & Littlefield Publishing Group 2020
7. https://audycje.tokfm.pl/podcast/116819,Ignacy-Lukasiewicz-Wzorcowy-pozytywista-z-epizodami-romantycznymi, Grzegorz Ostasz, Rzeszów PRz
8.https://klubjagiellonski.pl/2016/08/30/polak-doradza-rockeffelerowi/
9. https://docplayer.pl/6226184-Zycie-i-dzialalnosc-ignacego-lukasiewicza.html
10. http://kwasnicki.prawo.uni.wroc.pl/pliki/Drozen%20o%20Lukasiewiczu.pdf
11. http://ipir.org.pl/nasz-patron/
12. T. Urban, Scenariusz Musicalu Ignacy Łukasiewicz – nasz rodak i patron, UR 2021

# Wpływ upływu czasu na skuteczność identyfikacji mówcy metodą audytywną

**Stefan BRACHMAŃSKI[1], Bartosz HUS[2]**

[1] Wroclaw University of Science and Technology, Faculty of Electronics, Photonics and Microsystems, Department of Acoustics, Multimedia and Signal Processing, 50-370 Wrocław, Wybrzeże Wyspiańskiego 27,
ORCID: 0000-0002-2411-8236
[2] A Wroclaw University of Science and Technology, Faculty of Electronics, Photonics and Microsystems, Department of Acoustics, Multimedia and Signal Processing, 50-370 Wrocław, Wybrzeże Wyspiańskiego 27, student

**Corresponding author:** Stefan BRACHMAŃSKI, email: stefan.brachmanski@pwr.edu.pl

**Abstract** For many years, both in Poland and in most courts around the world, aural identification of a person is allowed, i.e. such testimony in which the witness can identify the speaker or other auditory impression. Psychologists, crime acoustics specialists, and researchers dealing with the perception of hearing and the broadly understood forensics describe many cases in which such testimonies resulted in a wrong judgment. The article presents the results of an experiment, the aim of which was to investigate, in the conditions of the Polish language, to what extent the passage of time deteriorates the correct identification of a person. Research conducted for a female voice showed that only 30% of the experiment participants correctly identified the person 31 days after hearing the voice for the first time. Earlier studies conducted in the English language showed that after 3 months, another 35% of the survey participants correctly recognized the person.

**Keywords:** speaker recognition, crime acoustics, aural identification.
**Słowa kluczowe:** rozpoznawanie mówcy, fonoskopia, akustyka kryminalistyczna, słuchowa identyfikacja

## 1. Wstęp

Większość sądów na całym świecie dopuszcza słuchową identyfikację osoby tzn. takie zeznania w których świadek zdolny jest do identyfikacji mówcy bądź innego wrażenia słuchowego [1] – [7]. Psycholodzy, specjaliści fonoskopii, badacze zajmujący się percepcją słuchu oraz szeroko pojętą kryminalistyką opisują wiele przypadków, w których takie zeznania w efekcie doprowadziły do wydania błędnego wyroku. Przykładem może być Frances McGehee, która za sprawą wydarzeń z 1935r. (Wyrok skazujący Bruna Hauptmanna dot. sprawy porwania i zamordowania Charlesa Lindbergha Juniora [8] – [10]) przeprowadziła eksperyment, w którym chciała udowodnić tezę, że człowiek nie jest w stanie rozpoznać nieznanego głosu po znacznym upływie czasu od jego pierwszego usłyszenia.

Charles Augustus Lindbergh był amerykańskim pionieem lotnictwa, któremu sławę przyniósł pierwszy samotny przelot nad Atlantykiem w 1927r. W wieku 30 lat wziął ślub z Anne Spencer Morrow, doczekał się syna i wraz z nim i żoną przenieśli się do Hopewell do willi na skraju lasu. W dniu 1 marca 1932 roku w pokoju na piętrze położono spać 20 miesięcznego Charlesa Lindbergha Juniora. Na zewnątrz padał deszcz, wiał bardzo mocny wiatr. Około godziny 22:00 niania zajrzała do pokoju chłopca i stwierdziła brak małego Charlesa. Niania zaczęła krzyczeć, a przerażeni rodzice wbiegli na górę, po czym wszyscy razem rozpoczęli przeszukanie domu. Po dłuższej chwili zwrócili uwagę na uchylone okno, obok którego na parapecie pozostawiony był list napisany po angielsku, lecz z niemieckimi wtrąceniami. Autor listu informował, że dziecko zostało porwane. Porywacz żądał 50000 $ okupu.. Lindbergh bez zastanowienia zawiadomił policję. Po przybyciu na miejsce zdarzenia, policja nie znalazła w pokoju dziecka żadnych odcisków palców, natomiast znalazła drabinę w krzakach koło domu i niemierzalny ślad buta. Ze względu na sławę Lindbergha porwaniem interesowała się cała Ameryka. Poszukiwaniami zajęło się około tysiąca prywatnych detektywów. Rodzice zaginionego apelowali do porywacza o spotkanie w dowolnym miejscu i o dowolnej porze. Po pięciu dniach od porwania otrzymali nowy list. Porywacz zwiększył wysokość okupu do 70000 $. Negocjacje prowadzone były listownie oraz poprzez ogłoszenia w lokalnej gazecie z pomocą znanego na Bronksie emerytowanego pedagoga dr Johna F. Condona. Po kilkutygodniowych negocjacjach porywacz wskazał cmentarz jako miejsce przekazania okupu, zmniejszając jednocześnie wartość okupu do 50000 $. W nocy 2 kwietnia 1932r. Lindbergh wraz z

negocjatorem pojechali na cmentarz, aby przekazać okup. Lindbergh siedział w aucie około 100 m od umówionego miejsca, nie widział porywacza, ale usłyszał jak ten wołał do dr John'a Condona *„Here, Doctor. Over here! Over here!".* Porywacz, po otrzymaniu okupu (w numerowanych banknotach dziesięciodolarowych, edycji *gold certificate*), poinformował, że dziecko znajduje się na statku „Nelly" (lub „Nellie") w pobliżu Martha Vineyard, w stanie Massachusetts. Poszukiwanie przez policję wodną wskazanego statku zakończyły się fiaskiem. Pięć tygodni później, w dniu 12 maja kierowca ciężarówki zauważył, w lasku cztery mile (ok. 7,2 km) od domu Lindberghów, zwłoki dziecka, którym okazał się ich syn Charles Lindbergh Jr. Sekcja zwłok wskazała, że dziecko, chłopiec Charles Lindbergh Jr, nie żyło od 2 miesięcy na skutek silnego uderzenia w głowę. Pieniądze z okupu, zaczęły się pojawiać w obiegu. W dniu 18 sierpnia 1934 roku na jednej ze stacji benzynowych na Bronksie pewien mężczyzna zapłacił rachunek certyfikowaną dziesięciodolarówką. Pracownik stacji benzynowej zobaczywszy ten rzadki banknot zanotował numery rejestracyjne pojazdu. Trop zaprowadził policję do Bruno Hauptmanna, niemieckiego imigranta, u którego w domu odnaleziono 15000 $ pochodzących z okupu. W toczącym się śledztwie, we wrześniu 1934r, czyli 29 miesięcy po usłyszeniu słów wypowiedzianych przez porywacza na cmentarzu, Lindbergh usłyszał je ponownie, lecz tym razem powtórzone przez Hauptmana. Lindbergh rozpoznał głos Hauptmana jako identyczny z głosem z cmentarza. Na rozprawie sądowej w styczniu 1935 roku zeznał pod przysięgą, że rozpoznał głos Hauptmana. Bruno Hauptmann został stracony na krześle elektrycznym 3 kwietnia 1936r. [8] – [10]..

Do dzisiaj, czyli prawie 90 lat po identyfikacji Hauptmanna przez Charlesa Lindbergha pojawiają się głosy ekspertów, że po tak długim czasie słuchowa identyfikacja drugiej osoby jest niemożliwa. McGehee swoimi badaniami wykazała, że identyfikacja głosowa mówcy następnego dnia jest dość wysoka (83%), ale po upływie czasu dokładność identyfikacji stopniowo maleje do zaledwie 13% po upływie pięciu miesięcy [11]. Wiele osób w tym Harry Hollien wskazują, że Frances McGehee w swoim eksperymencie nie uwzględniła kilku ważnych aspektów jak np. faktu, że na dokładność identyfikacji może mieć wpływ pojawienie się dodatkowego bodźca w trakcie słyszenia mówcy, albo zdolność różnych osób do zapamiętywania głosu [2].

Celem prezentowanego eksperymentu było zbadanie w warunkach języka polskiego jak upływ czasu wpływa na poprawną identyfikację mężczyzny i kobiety w sytuacji gdy osoba rozpoznająca nie zna głosu mówcy oraz gdy głos mówcy jest dobrze znany.

## 2. Badanie Frances McGehee

Wyrok skazujący Bruno Hauptmanna za porwanie i zabójstwo małego Charlesa Lindbergha Juniora, a dokładniej fakt, że został on oparty na dowodach identyfikacji głosu, zainicjował serię eksperymentów, których celem było potwierdzenie zdolności człowieka do długotrwałego zapamiętywania głosu mówcy. Jednym z najbardziej znanych był eksperyment wykonany przez Frances McGehee w 1937r. W badaniach udział wzięło 740 studentów (554 mężczyzn, 186 kobiet), natomiast mówców było 49 (31 mężczyzn, 18 kobiet). Uczestnicy badań zostali podzieleni na 15 grup. Każdej grupie została przyporządkowana liczba dni do kolejnego dnia odsłuchu tzn. upływ czasu od 1 dnia do 5 miesięcy. Zadaniem słuchaczy było rozpoznanie i wskazanie, który z pięciu usłyszanych głosów słyszeli wcześniej. Prezentowani słuchaczom mówcy zostali wybierani spośród 49 osób (31mężczyzn, 18 kobiet).

Tezę jaką postawiła w swoich badaniach można sformułować następująco: „Człowiek nie jest w stanie rozpoznać nieznanego głosu po znacznym upływie czasu od jego pierwszego usłyszenia". Celem potwierdzenia tej tezy McGehee wykonała eksperyment złożony z dwóch części. W pierwszej części eksperymentu słuchacze słyszeli czytany przez jednego mówcę, siedzącego za nieprzeźroczystą przesłoną, tekst złożony z 56 słów. Po upływie czasu ustalonego dla danej grupy, jej członkowie usłyszeli tę samą sekwencję czytaną w kolejności losowej przez 5 mówców (jednego identyfikowanego i czterech, których słuchacze nigdy nie słyszeli). Zadaniem słuchaczy było zapisanie numeru mówcy, który, jak im się wydawało, pierwotnie słyszeli. McGehee powtórzyła ten eksperyment z tą różnicą, że prezentowane słuchaczom wypowiedzi zostały wcześniej nagrane na taśmie magnetofonowej. W obu eksperymentach wyniki były bardzo podobne, wraz z upływem czasu malała skuteczność identyfikacji. Poprawna identyfikacja po upływie 1 i 2 dni wynosiła 83%, a po 7 dniach 81%. Zauważalny spadek stwierdzono po upływie 2 tygodni, kiedy to poprawna identyfikacja była na poziomie 69 %, po 3 tygodniach spadła do 51 %, a po 3 miesiącach do 35 %. Ostatnim badanym okresem był 5 miesięczny upływ czasu, kiedy to poprawna identyfikacja spadła do 13 %.

Badania wykonane przez McGehee wykazały, że poprawna identyfikacja mówcy zależy od czasu, który upłynął od momentu usłyszenia głosu osoby identyfikowanej do chwili podjęcia próby rozpoznania mówcy, a także od zdolności słuchaczy do zapamiętywania wzorca głosu [11].

## 3. Eksperyment

### 3.1. Procedura realizacji rozpoznawania mówcy

Materiałem testowym był fragment z książki „Mitologia nordycka" Neila Gaiman'a. [12] czytany przez pięciu mówców płci żeńskiej i pięciu męskiej. Lektorów dobrano na podstawie subiektywnej oceny podobieństwa brzmienia głosu, a także na podstawie wartości tonu krtaniowego i pierwszych czterech formantów. Wypowiedzi nagrano na rejestratorze cyfrowym z szybkością próbkowania 44 100 próbek/s i rozdzielczością 16 bitów w formacie PCM (wav). Przed przystąpieniem do nagrań każdy z lektorów ćwiczył czytanie tekstu co zapewniło płynność wypowiedzi. Tekst odczytywany był równym, spokojnym głosem. Nagrania wykonano w warunkach domowych, w pomieszczeniu cichym, odizolowanym od zakłóceń zewnętrznych. Wypowiedzi czyli odczytywany tekst rejestrowano pięciokrotnie. Z wszystkich nagrań wybrano dla każdego lektora jedno z najlepiej brzmiącymi wypowiedziami, bez zająknięć, powtórzeń i niekontrolowanych artefaktów,

Ze względu na stan zagrożenia epidemicznego panujący zarówno w kraju jak i na świecie wywołany koronawirusem COVID-19 (wirus SARS-CoV-2) cały proces badawczy począwszy od wysłania wiadomości o rozpoczęciu odsłuchu po udostępnienie nagrania dowodowego i porównawczego i odbiorze informacji zwrotnej z odpowiedzią słuchacza odbywało się online [13].

W badaniach rozpoznawania głosu żeńskiego udział wzięło 100 osób (65 mężczyzn, 35 kobiet), którzy zostali podzieleni w sposób losowy na 11 mniejszych grup badawczych. Z kolei w rozpoznawaniu głosu męskiego wzięło udział 150 osób (88 mężczyzn, 62 kobiety), którzy zostali podzieleni w sposób losowy na 11 mniejszych grup badawczych po 10 osób. Wiek uczestników badań zawierał się w przedziale 21 – 26 lat dla identyfikacji głosu żeńskiego oraz 20 – 30 lat dla identyfikacji głosu męskiego. Uczestnicy eksperymentu zostali wybrani w oparciu o wyniki testu „zerowego". Polegał on na tym, że słuchacze zaraz po usłyszeniu wypowiedzi mówcy identyfikowanego dokonywali jego identyfikacji słuchając wypowiedzi wszystkich pięciu mówców. Do dalszego etapu zakwalifikowały się tylko te osoby, które poprawnie zidentyfikowały mówcę.

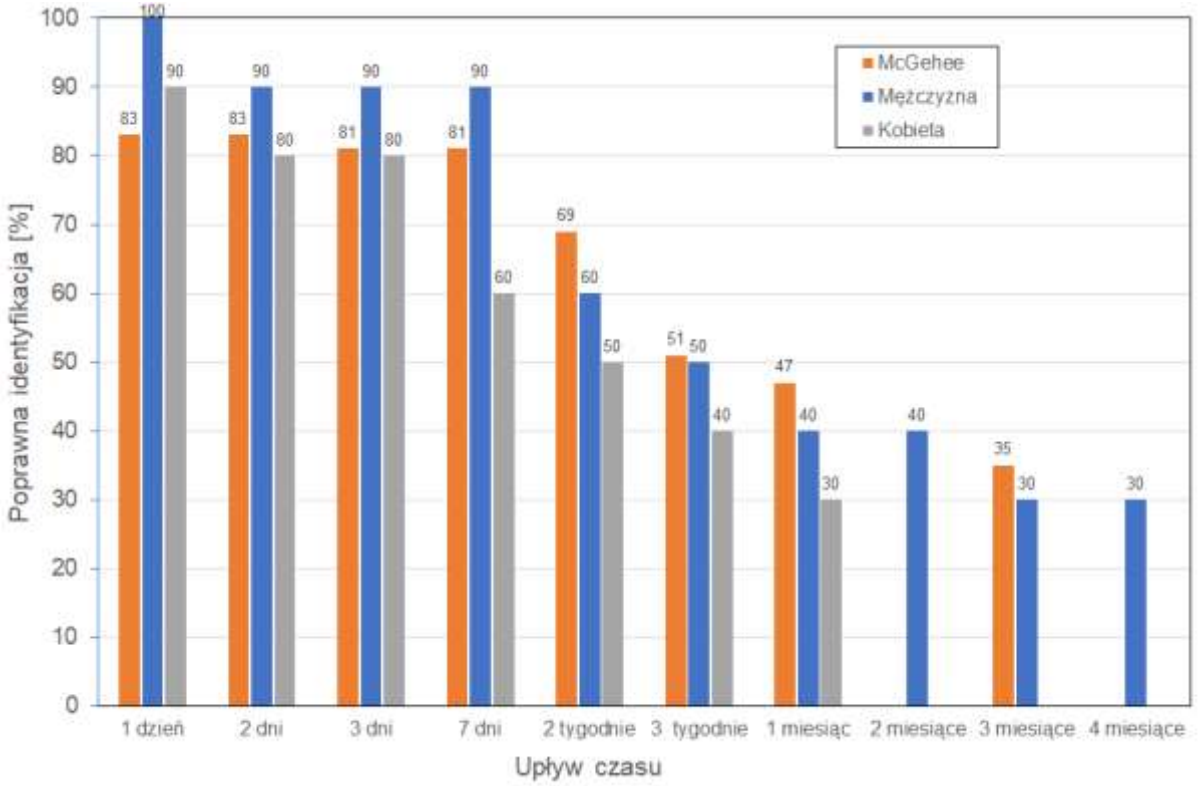
Nagranie z wypowiedzią mówcy identyfikowanego zaprezentowano wszystkim uczestnikom badania tego samego dnia, o tej samej godzinie, przy czym innego dnia grupie rozpoznającej kobietę, a innego grupie rozpoznającej mężczyznę. Po odsłuchaniu nagrania i wykonaniu testu „zerowego" nagranie zostało usunięte z udostępnionego słuchaczom folderu. Uczestnicy eksperymentu nie mieli więc możliwości ponownego odsłuchania nagrania czytanego przez mówcę identyfikowanego. Po upływie ustalonego dla danej grupy czasu, który upłynął od pierwszej prezentacji, członkowie tej grupy zostali poinformowani, iż okno odsłuchu zostało otwarte i można dokonać identyfikacji mówcy. Każdy członek grupy odsłuchuje, wcześniej nagrany, tekst czytany przez pięciu mówców. Po wysłuchaniu wszystkich głosów wskazuje numer mówcy, którego głos, jego zdaniem, odpowiada głosowi usłyszanemu po raz pierwszy. Dodatkowo, każdy słuchacz podawał stopień pewności identyfikacji. Informacje podane przez słuchacza zostały wprowadzone automatycznie do formularza pomiarowego. Wszystkie wprowadzone informacje automatycznie aktualizowały tabelę wyników, która zawierała:

- informacje o poprawności identyfikacji podejrzanego dla danego słuchacza,
- ogólną liczbę słuchaczy, którzy poprawnie zidentyfikowali podejrzanego,
- liczbę osób, które poprawnie zidentyfikowały podejrzanego po upływie określonego czasu,
- informację na jakiego lektora badane osoby wskazywały najczęściej,
- informację określającą liczbę osób nieprzebadanych.

Rozpoznawanie głosu żeńskiego wykonano po upływie: 1 dnia, 2 dni, 3 dni, 7 dni, 2 i 3 tygodni oraz 1 miesiąca od pierwszego usłyszenia nagrania z wypowiedziami mówcy rozpoznawanego, a głosu męskiego dodatkowo po upływie 2, 3 i 4 miesięcy.

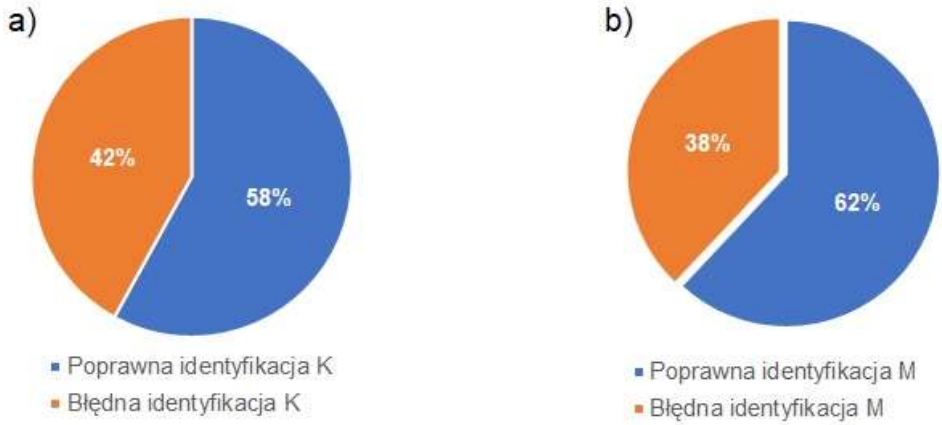
### 3.2. Analiza wyników eksperymentu

Na rys. 1 zaprezentowano wyniki otrzymane w ramach prezentowanego eksperymentu oraz podane przez McGehee. Skuteczność rozpoznawania głosu żeńskiego jest bardziej uzależniona od upływu czasu niż głosu męskiego. Po jednym dniu od momentu usłyszenia głosu żeńskiego 90 % słuchaczy dokonało poprawnej identyfikacji, natomiast w przypadku głosu męskiego wszyscy słuchacze poprawnie rozpoznali osobę identyfikowaną. W miarę upływu czasu wskaźnik skuteczności rozpoznawania osoby maleje i tak po 7-miu dniach dla głosu żeńskiego wynosi 60%, a męskiego 90% [13]; dane podane przez McGehee to 81% [11]. Z kolei po 1 miesiącu wartość skuteczności rozpoznawania mówcy bardzo mocna obniża się i tak dla głosu żeńskiego wynosi 30% a męskiego 40%. Skuteczność rozpoznawania mówcy po upływie 1 miesiąca od pierwszego usłyszenia głosu dla głosu męskiego jest zbliżona do wyniku podanego przez McGehee (odpowiednio 40% i 47%).



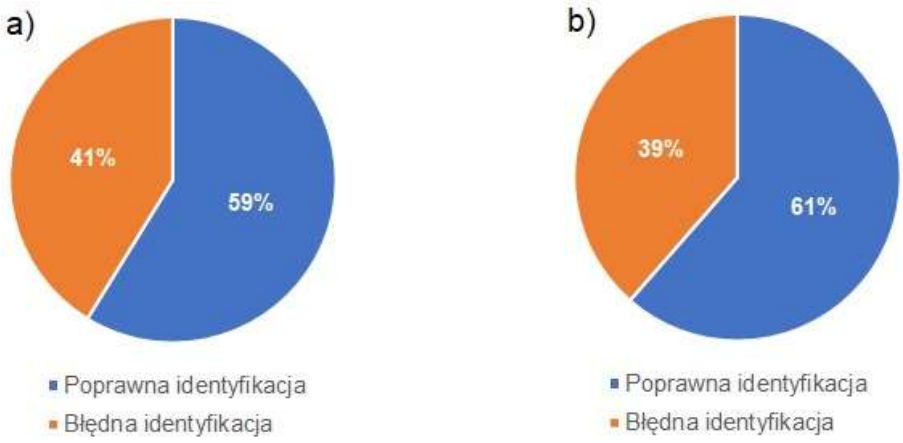

Rys. 1. Skuteczność identyfikacji osoby nieznanej w funkcji upływu czasu.

Analizując sumaryczne wyniki identyfikacji mówcy przez wszystkich słuchaczy stwierdzono, że poprawna identyfikacja osoby płci męskiej była minimalnie lepsza niż żeńskiej (Rys. 2).




Rys. 2. Procent poprawnych i błędnych identyfikacji .głosu a) żeńskiego i b) męskiego

Otrzymane wyniki poddano analizie na okoliczność jaki jest wpływ płci osoby identyfikującej mówcę na jego poprawność identyfikacji. W efekcie tej analizy stwierdzono, że nie ma istotnej różnicy czy mówcę rozpoznaje kobieta, czy mężczyzna (Rys.3). Różnica 2% w skuteczności identyfikacji osoby mieści się w statystycznym przedziale błędu, a więc można stwierdzić, że płeć osoby identyfikującej nie ma istotnego wpływu na skuteczność rozpoznawania mówcy.




Rys. 3. Procent poprawnych i błędnych identyfikacji .głosu przez kobiety (a) i mężczyzny (b)

## 4. Podsumowanie

Wykonane badania potwierdziły wnioski wynikające z eksperymentu McGehee, że wraz z upływem czasu, który upłynął od momentu usłyszenia głosu mówcy skuteczność jego rozpoznania szybko maleje. Porównując wyniki otrzymane w prezentowanych badaniach z wynikami eksperymentu Frances McGehee można stwierdzić, że w warunkach języka polskiego skuteczność identyfikacji głosu żeńskiego szybciej, spada, natomiast głosu męskiego w porównywalnym tempie. W pierwszych trzech dniach poprawne rozpoznawanie głosu zarówno kobiecego jak i męskiego przekraczało 80%. Bardzo duża skuteczność identyfikacji głosu męskiego utrzymywała się przez okres jednego tygodnia (90%), lecz po dwóch tygodniach nastąpił spadek do 60 % (69% w badaniach McGehee), aby po miesiącu obniżyć się do 50 %. (47% w badaniach Pani McGehee).

Wyniki otrzymane zarówno w prezentowanym eksperymencie jak i w badaniach McGehee stawiają pod dużym znakiem zapytania poprawność identyfikacji osoby tylko na podstawie głosu po dwóch latach od usłyszenia głosu po raz pierwszy (jak w przypadku Charlesa Lindbergha). Jednakże nie można pominąć retencji czyli zdolności do zapamiętywania, zwłaszcza w warunkach zagrożenia czy też osobistego zaangażowania. W przypadku Lindbergha niepoślednią rolę w zapamiętaniu głosu porywacza mogło odegrać dużą rolę wytworzenie znacznej dawki adrenaliny, która wyostrzyła słuch, a także wzmocniła zdolność do długotrwałego zapamiętania głosu. Badania wykonane m.in. przez Holliena pokazały, że osoba bezpośrednio zaangażowana w zdarzenie dużo dłużej zapamiętywała głos osoby krzywdzącej ją lub kogoś bliskiego [2].

W procesie słuchowej identyfikacji mówcy nie bez znaczenia jest również technika zapamiętywania głosu mówcy. W omawianym eksperymencie jeden ze słuchaczy wykorzystał technikę przyporządkowania usłyszanego głosu do głosu dobrze znanej mu osoby. Podczas odsłuchiwania nagrań z wypowiedziami pięciu osób, wśród których znajdowała się osoba identyfikowana słuchacz porównał głos osoby identyfikowanej z głosem bliskiej mu osoby. W ten sposób szukał mówcy, którego głos najlepiej odwzorowuje bliską mu osobę. Słuchacz ten poprawnie zidentyfikował podejrzanego po upływie 40 dni i ocenił swoją pewność identyfikacji na 10 [13].

Analizując wpływ na skuteczność identyfikacji mówcy płci osób biorących udział w przedstawionych badaniach zauważa się rozbieżność wyników w grupie mężczyzn w stosunku do wyników otrzymanych przez McGehee. W prezentowanych badaniach poprawnie zidentyfikowało mówcę 59% kobiet, natomiast mężczyzn 61%. Z kolei w badaniach McGehee poprawnej identyfikacji dokonało także 59 %, lecz w grupie mężczyzn uzyskała znacznie lepszy wynik to wynik znacznie większy – 84% [5], [11]. Z drugiej strony można stwierdzić, że w warunkach języka polskiego, nie ma wpływu płeć osoby dokonującej identyfikacji mówcy.

Otrzymana zbieżność wyników była spodziewana w świetle badań nad pamięcią Ebbinghausa [14] potwierdzonych przez innych badaczy opisanych m.in. w [15]. Według krzywej Ebbinghausa zwanej też krzywą zapominania, która pokazuje związek między ilością informacji przechowywanej w pamięci, a upływem czasu jaki minął od jej usłyszenia, człowiek jest w stanie odtworzyć ograniczoną ilość usłyszanych jednostek, np. po 5 dniach zaledwie 25 % usłyszanych jednostek, a po 30 dniach – 20%. [14]. Krzywa zapamiętywania jest niezależna od języka i może być adoptowane do wielu działów nauki związanych z percepcją [14], [15]. Można więc przyjąć, że krzywa Ebbinghausa odnosi się również do zdolności zapamiętywania brzmienia głosu, w tym do słuchowej identyfikacji mówcy.

Podsumowując można stwierdzić, że

- identyfikacja słuchowa mówcy nie zależy od języka w sytuacji gdy dokonywana jest przez osoby posługujące się tym samym językiem co osoba identyfikowana
- wraz z upływem czasu poprawna identyfikacja wyraźnie maleje, osiągając po upływie 2 tygodni poziom rzędu 50 %,
- poprawna identyfikacja głosu męskiego jest lepsza niż głosu kobiecego.

**Literatura**


1. A. Alexander, D. Dessimoz, F. Botti, A. Drygajlo, Aural and automatic speaker recognition in mismatched conditions, International Journal of Speech Language and the Law, 2005, 12(2), 214 – 234.
2. H. Hollien, The Acoustics of Crime: The New Science of Forensic, Kluwer Academic - Plenum Publishers, New York, 1990.
3. H. Hollien , Forensic voice identification, Academic Press, London – San Diego,2002.
4. Hollien H, Didla G, Harnsberger JD, Hollien KA. The case for aural perceptual speaker identification. Forensic Sci Int. 2016 Dec;269:8-20. doi: 10.1016/j.forsciint.2016.08.007. Epub 2016 Aug 28. PMID: 27855301.
5. Hollien, H., & Schwartz, R., Aural-perceptual speaker identification: problems with noncontemporary samples. Forensic linguistics, 2000, 7, 199-211
6. Kodeks postępowania karnego, Dziennik Ustaw, 1749, 2016.
7. Yarmey, A. D., Yarmey, A. L., Yarmey, M. J., & Parliament, L. Commonsense beliefs and the identification of familiar voices. Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition, 2001, 15(3), 283-299.
8. Hauptmann, Atlantic Rep., 1935, 180, 809-829
9. W. Duggan, The State of New Jersey v. Bruno Richard Hauptmann: Fairness on Trial
10. van Wyk, H. S. J., State of New Jersey v. Bruno Richard Hauptmann. The South African Law Journal, 1953, 70, 182, https://heinonline.org/HOL/LandingPage?handle=hein.journals/soaf70&div=30&id=&page= (dostęp 16.07.2022)
11. McGehee F., The Reliability of the Identification of the Human Voice, , *Journal of General Psychology,* 1937, *17,* 249–271. https://doi.org/10.1080/00221309.1937.9917999
12. N. Gaiman N., (tłum Braiter P.), *Mitologia Nordycka*, MAG 2017
13. B. Hus., Analiza wpływu czasu na audytywną identyfikację osoby w akustyce kryminalistycznej, Praca dyplomowa magisterska, Politechnika Wrocławska, 2022.
14. H. Ebbinghaus, Uber das gedachtnis: Untersuchungen zur experimentallen psychologie. 1885, Leipzig: Duncker and Humboltd
15. A. Falkowski, Pamięć i wiedza w kontekście rozwoju poznania naukowego. Nauka, 2004, 2, 105–124.
16. K. Iwanicka, Psychologiczne podstawy pracy z grupą ze szczególnym uwzględnieniem zagadnienia stylów uczenia się. Pedagogiczne aspekty edukacji filozoficznej z uwzględnieniem systemów penitencjarnych, red. D. Lipski, M. Malinowski, Wydawnictwo DiG, 2020, 105 - 113. https://swws.edu.pl/wp-content/uploads/2021/05/3.-Pedagogiczne-aspekty-edukacji-filozoficznej.pdf#page=105 (dostęp 13.08.2022)

# The specificity of acoustic measurements of rail vehicles

**Anna ŚWIERKOSKA**[1]

[1] Łukasiewicz Research Network – Poznań Institute of Technology, ul. Ewarysta Estkowskiego 6, 61-755 Poznań

**Corresponding author:** Anna ŚWIERKOSKA, email: anna.swierkoska@pit.lukasiewicz.gov.pl

**Abstract** The article is a review of issues related to acoustic measurements of rail vehicles using standardised methods related to the documents regulating the entry into service of objects. In the paper types of tested objects and the applicable requirements are presented, also the exceptions and conditions determining the needlessness of the tests is analysed. Examples of measurement results showing the condition of currently manufactured or modernized vehicles in terms of noise emissions and the comfort of passengers and drivers are presented. Factors limiting the possibility of noise level reduction and, consequently, meeting the requirements were considered. The conducted analysis of the research objects, requirements, methods, results typical for given types of vehicles and limitations is based on normative and legal documents, as well as on the conducted measurements and own experience.

**Keywords:** rail vehicles, noise, entry into service of a rail vehicle.

## 1. Introduction

Due to the need to improve safety, increase accessibility or popularise means of public transport, in particular railway, huge investments are being made in Poland, both in terms of infrastructure and rolling stock. The use of rail transport is encouraged, among others, by new or modernized vehicles, with the improved comfort of passengers. Each new or modernised vehicle type entering the service must obtain a certificate, and the basis for issuing such a document are tests and examinations also in the field of noise. The current work is an attempt of analysis and summary of problems related to the mentioned process based on studied regulation documents and author's experience (including case study).

## 2. Objects

The categories of the rolling stock classified in Commission Regulation (EU) No 1304/2014 [1] and defined in Commission Regulation (EU) No 1302/2014 [2] are following:

- self-propelling thermal or electric trains including trains in predefined formation with vehicles intended or not intended to carry passengers and with thermal or electric traction equipment in appointed vehicles, e.g. Electric or Diesel Multiple Units (EMU/DMU)
- thermal and/or electric traction units that are not intended to carry payload, e.g. thermal or electric locomotives;
- passenger carriages and other related cars – vehicles without traction, operating in variable formation with thermal/electric traction unit, intended for passengers or related cars (e.g. luggage or postal);
- mobile railway infrastructure construction and maintenance equipment that is running on its own wheels, may be detected by a track based train detection system, e.g. On-Track Machines (OTMs, in this case it need to be self-propelled or hauled.

## 3. Requirements

### 3.1. Valid requirements

In Poland there are two major documents regulating aspects of the rolling stock noise: Commission Regulation (EU) No 1304/2014 (TSI NOISE) [1] and The List of the President of the Office of Rail Transport – Appendix TM-2 [3].

### 3.1.1. Noise emitted by vehicles

Regulations of noise emitted by rail vehicles are included in TSI NOISE [1] and Appendix TM-2 [3]. In both documents, criteria apply to stationary noise, starting noise and pass-by noise. The method for testing is described in the standard EN ISO-3095:2013 [5], to which mentioned documents [1,3] refer. Limits included in both documents [1,3] vary with the rolling stock type, traction, total tractive power and maximum vehicle speed. The highest limit values stand for unit with diesel traction. For the stationary noise limit values for each measurement position vary from $L_{pAeq,T}$= 68 dB (coaches and electric multiple units) to 76 dB (Diesel locomotives and OTM with diesel traction) in [1], while in Polish domestic regulations [3] it is 80 dB for all vehicle types. For the starting noise limit values vary from $L_{pAFmax}$ = 80 dB (EMU with $v_{max}$<250 km/h) to 87 dB (diesel locomotives with P≥2000kW) due to European regulations [1] and , $L_{pAFmax}$ = 8 dB (electric traction vehicles with P<300 kW) to 95 dB (diesel traction vehicles with P≥1000kW) due to domestic regulations [3]. For the pass-by noise limit values vary from $L_{pAeq,T(80km/h)}$ = 79 dB (passenger coaches) to 85 dB (diesel locomotives and OTM with diesel traction) both in European and domestic regulations [1,3].

### 3.1.2. Acoustic comfort inside vehicles

In TSI NOISE [1] and Appendix TM-2 [3] limits for noise inside driver's cabs are specified and include two conditions: at standstill when sounding an external warning horn, $L_{pAeq,T}$≤95 dB and when operating with maximum speed, $L_{pAeq,T}$≤78 dB. Additionally, Appendix TM-2 [3] regulates noise in passenger areas. Here, limit values depend on the rolling stock type, traffic predestination (i.e. long-distance or local and suburban) comfort class and space function. The limits at standstill are 55 dB (1st class, sleeping coaches) and 60 dB (other long-distance vehicles) and when vehicle is moving limits are 65 dB (1st class coaches in long-distance traffic), 68 dB(2nd class coaches) and 70 dB (passenger rolling stock and carriages intended for local and suburban traffic). The method for testing is described in the standard EN ISO-3381:2011 [6] and EN-15892:2011 [7], to which mentioned documents [1,3] refer. It should be mentioned, that some requirements in the document [3] are found to be unconsidered. For vehicles operating inside tunnels (e.g. subway), it is required to conduct measurements in their normal operating conditions, i.e. inside tunnels. However, it is obvious, that noise in such conditions is considerably increased for the same vehicle and the same speed. Simultaneously, noise criteria are the same as when measuring on the open space. For subway vehicles, it is rather impossible to achieve.

### 3.1.3. Technical specifications concerning acoustic signals

Regulations concerning acoustic signals include:

- technical specifications for interoperability relating to the rolling stock – locomotives and passenger rolling stock described in Commission Regulation (EU) No 1302/2014 (TSI LOC&PAS)[2]. Sound levels and fundamental frequencies of the audible warning devices mounted on vehicles and sound levels of audible information devices inside the driver's cab are specified: $L_{pCeq,T}$ should be between 101÷109 dB both for low (370±20 Hz) and high (660±30 Hz) note.
- technical specifications for interoperability relating to accessibility of rail vehicles for persons with disabilities and reduced mobility regulated in Commission Regulation (EU) No 1300/2014 (TSI PRM) [4] - sound levels and fundamental frequencies of warning signals when door opening/closing and speech intelligibility of electroacoustic installation that is comprised in customer information system at minimum STI of 0,45.

  Speech intelligibility in rail vehicles is highly influenced by the noise inside them (measurements are performed at standstill and speed of 80 km/h). In some vehicles, especially with diesel traction, the parameter is hardly achievable due to high noise levels while running. This is a case when e.g. only passenger information system is a matter of modernisation while other acoustic properties are not changed (in assumption), thus not tested, evaluated and remain unimproved.

### 3.2. Exceptions

**Braking noise and curve squeal noise**

There is no criteria regarding braking and curve squeal noise generated by rail vehicles. Although, in the standard [5] mentioned in Section 3.1.1 the method for measuring breaking noise is described, such tests are not conducted due to the lack of valid requirements in Poland.
However, braking noise and curve squeal are accounted to have great contribution in noise generated by railway traffic along with rolling and engine noise.
Both types of noise might be characterised as noise that mostly occurs in areas highly utilised by people. Breaking noise usually is generated near stations while train is arriving and often followed with brake squeal. Curve squeal is usually emitted in narrow areas in the city, typically for suburban trains or trams negotiating curves especially with small radius.
On lines managed by PKP PLK S.A. curves with radius smaller than 180 are not assumed. Curves with radius larger than 600 m are recommended while designing geometric system of rails in order to prevent high wear (which is typical for small radius curves) [10]. According to Table 9.2 in [10], acceptable curve radius are smaller in the vicinity of platforms and in case of additional tracks and bay-lines (the smallest acceptable radius is 180m). In the document [10], there is no association between rail geometry requirements or recommendations and noise. The study [11] shows that curve squeal was found to still occur at curves with radius up to 900 m. It appears that there is no regulations that comprises squeal noise both in aspect of vehicles that are to be entered to the service and infrastructure.

**OTMs with composite brake blocks or disc brakes**

Due to TSI NOISE [1], pass-by noise measurement procedure is not applying to OTMs that are solely braked by composite brake blocks or disc brakes and equipped with composite scrubbers if scrubber blocks are fitted. In other words, such OTMs are assumed to comply pass-by noise level requirements without measuring. According to the Report prepared for the International Union of Railways (UIC) from 2016 [12], composite brake blocks or disc brakes have better noise performance than cast iron brake blocks. There are publications [13,14] referring noise reduction due to lower wheel wear and roughness in case of composite brake blocks or disc brakes. However, the rolling noise is not the only component determining noise emitted by railway vehicles. Another thing is that in case of new rolling stock that is usually tested, the wheel wear is rather not considerable. It seems that there is no solid justification for the cited rule which might be an encouragement for vehicle producers to replace cast iron blocks by composite brake blocks or disc brakes.

## 4. Methods and case study

In this chapter, methods for measurements concerning noise emitted by vehicles and noise inside vehicles are described. Exemplary results are also shown to illustrate rail vehicles noise characteristics obtained for different methods and vehicle types. Limitations are discussed.

### 4.1. Noise emitted by rail vehicles

**Stationary noise** is measured in accordance with EN ISO 3095:2013 [5]. Measurement are conducted at positions on a mesh, at a distance of 7,5 m from the track centreline and at 1,2 m height above the upper surface of the rail. Noise levels measured at all positions are energy averaged according to the equation in the standard [5]. In result, a single noise indicator representative of the unit $L_{Aeq[unit]}$ is obtained. There are three values that need to be assessed in order to evaluate a vehicle according to TSI NOISE [1]: $L_{Aeq,T}$ at each position, $L_{Aeq[unit]}$ and maximum value from $L_{AFmax}$ measured at all positions. It sometimes happen, that despite of meeting limit values at each measurement position, the single noise indicator for the unit exceeds the criterion. The presented study case shows a vehicle that required modifications after the first check due to unsatisfactory results for the single noise indicator (the limit values were: $L_{Aeq[unit]}$ = 71dB, $L_{Aeq,T}$ =78dB, $L_{AFmax}$ = 85dB). In case of diesel vehicles, the dominating sound source is the engine. Fig. 1 shows the results assessed before and after the change of the engine enclosure.

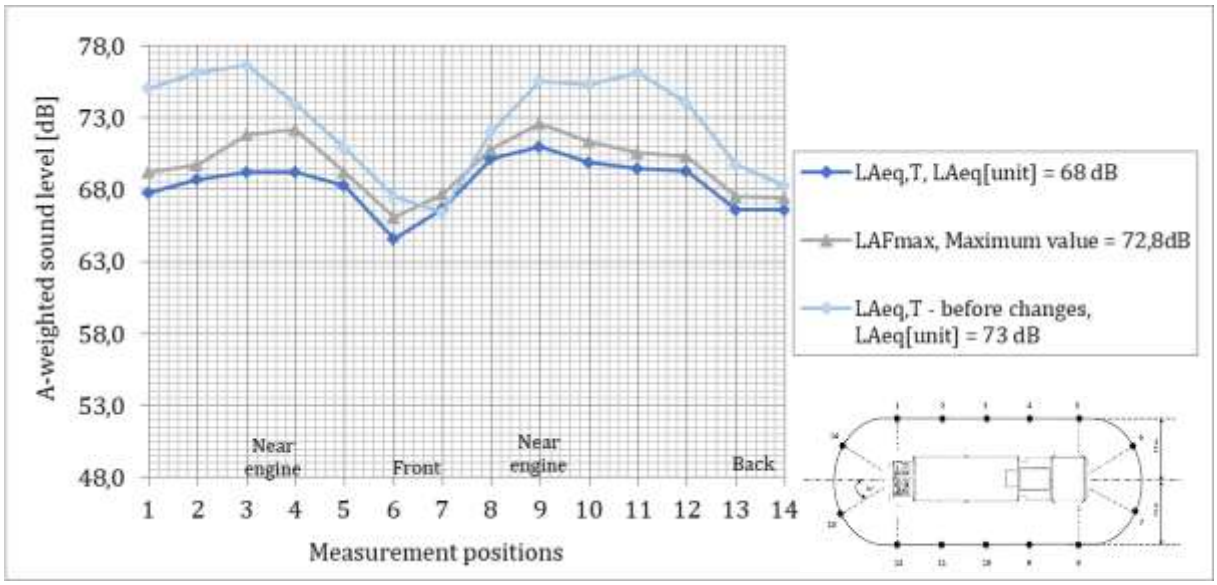



**Figure 1.** Example results of stationary noise measurements of OTM with diesel traction, engine condition – idle.

Although, it may seem that a wagon at standstill is not emitting noise, it is also tested noise sources in case of such units are mostly associated to heating, ventilation and air conditioning systems and electricity generator, see Fig 2.

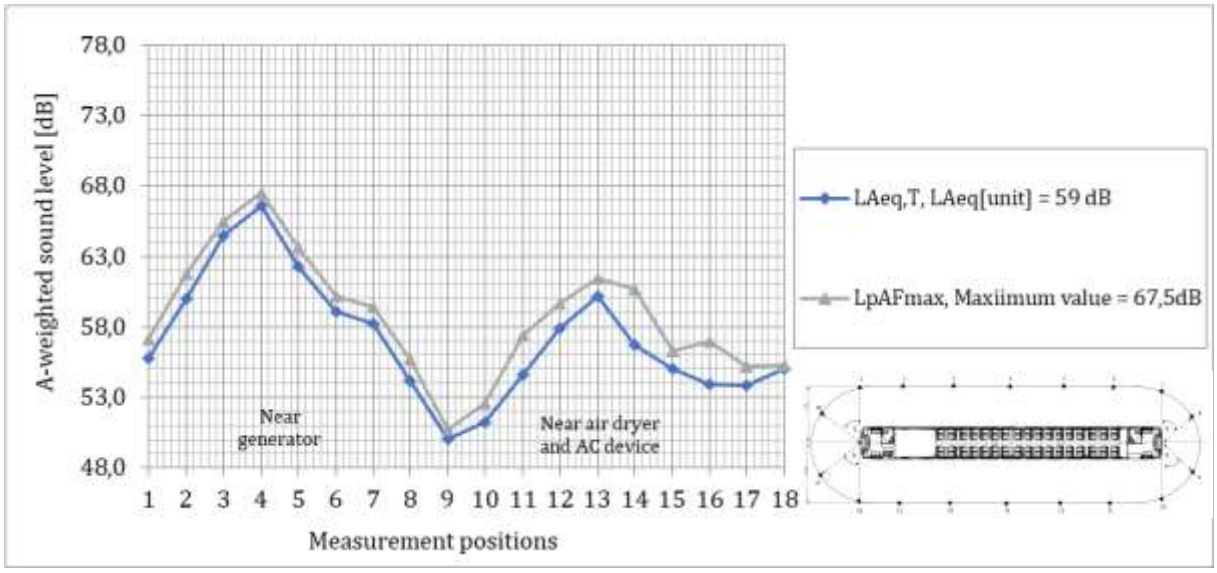



**Figure 2.** Example results of stationary noise measurements of passenger coach.

**Starting noise** is measured in accordance with EN ISO 3095:2013 [5]. Measurement are conducted on both sides of a vehicle at a distance of 7,5 m from the track centreline and at 1,2 m height above the upper surface of the rail, see an example setup in Fig 3. A tested vehicle should accelerate to 30 km/h. Assessed value during this measurements is AF-weighted maximum sound pressure level for each position in order to characterise the maximum noise emitted by a train during the event of acceleration from standstill. Tests are conducted for self –propelling vehicles or traction units.

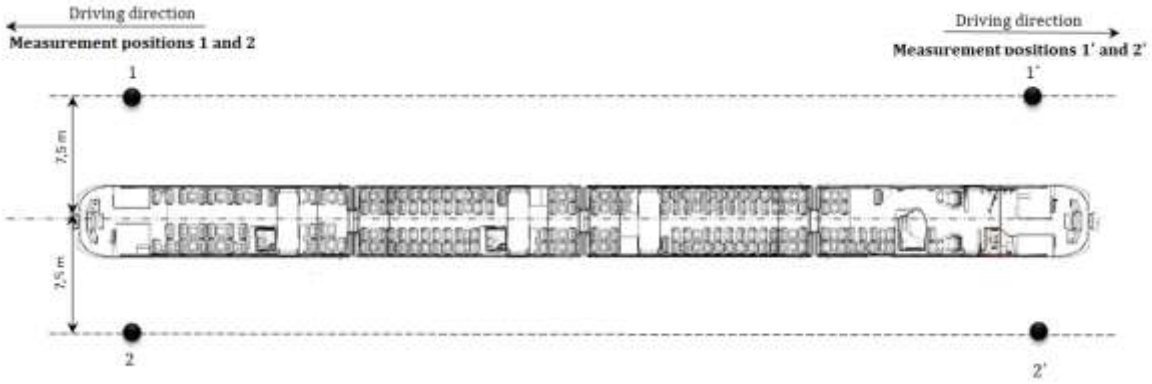



**Figure 3.** Example starting noise measurement positions during EMU measurement procedure.

**Pass-by noise** is measured in accordance with EN ISO 3095:2013 [5]. Measurement are conducted on both sides of a vehicle at a distance of 7,5 m from the track centreline and at 1,2 m height above the upper surface of the rail, the example setup is similar to one in Fig 3 (for speeds ≥200 km/h measurement positions may be at 25 m distance and 3,5 m height). The standard require rail roughness and track decay rate assessment as a confirmation of track conditions. A tested vehicle should run with constant speed, which is 80 km/h and maximum vehicle speed (if a vehicle speed is less than 80 km/h, tests are performed with the maximum vehicle speed). Assessed measurement results include A-weighted equivalent continuous sound pressure level for each position in order to characterise the noise emitted by a train during the event of passing-by. In case of determining noise emitted by a trailed unit (wagon), the test train set is combined for the measurements, see Fig. 4. The aim of such set is that noise from other parts of the train does not influence the measurements of the tested unit. The train should include at least two units under test and adjacent acoustically neutral vehicle in front of them, while there is no vehicle behind them. The adjacent vehicle is considered as acoustically neutral if either it is the same class as unit under test or the sound pressure level measured for the set (tested units + adjacent units) is no more than 2 dB greater than sound pressure level of the only tested units [5]. In reality, usually the first condition is applied. This is most probably due to organisational issues, as such pass-by noise measurements require e.g. the rental of test track, the driver and staff or vehicles, there are often limits of time, attempts and money and it is not possible to check and change adjacent units if one finds there is need to. Moreover, it is often not possible to be provided with two tested units by the producer.

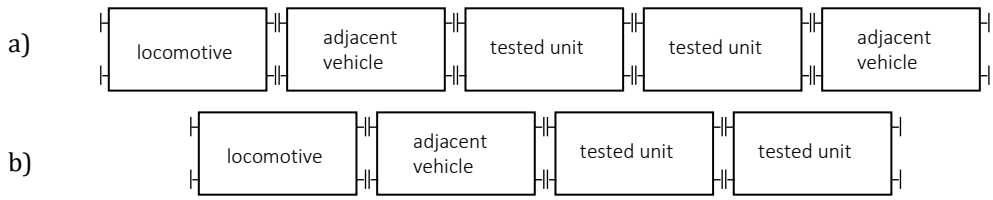



**Figure 4.** Test train setup [5]: a) test unit in a test train, b) tested unit at the end of a test train.

### 4.2. Noise inside vehicles

**Driver's cab interior noise** is measured in accordance with EN ISO 3381:2013 [6] and EN 15892:2011 [7]. Measurements are conducted near the driver's ear that is more subjected to noise. The measurement time interval should be a minimum 20 s for one attempt and it is permitted to assemble a 20 s sample from a set of shorter samples (not shorter than 5 s). A-weighted sound pressure level is assessed when the vehicle is operating at maximum speed. Third octave band analysis may be also determined. Example results with comparison between driver's cab interior noise in electric multiple unit and OTM with diesel traction are presented in Fig. 5.

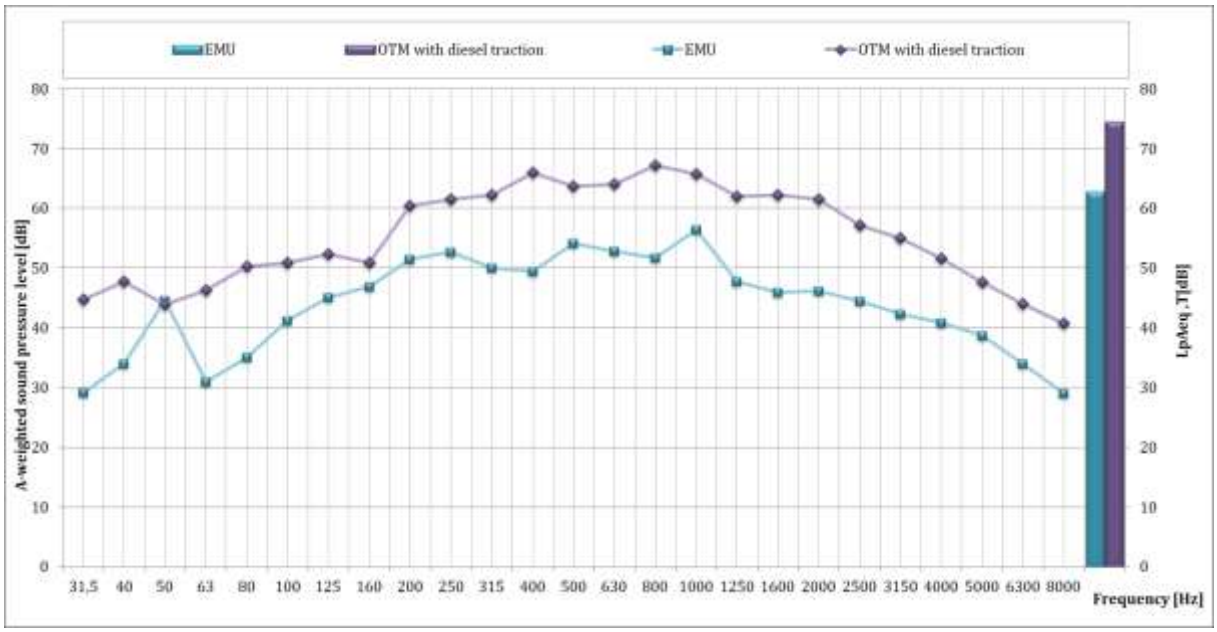



**Figure 5.** Comparison of example results of A-weighted sound pressure level in 1/3 octave bands measured in a driver's cab of an Electric Multiple Unit and OTM with diesel traction during operating with speed of 80 m/h.

In case of measurements when sounding the external warning horn, the test should be performed at standstill, at eight evenly spaced microphone positions in horizontal plane, at radius of 250 mm, at seated driver's ear's height. The mean A-weighted sound pressure level from 8 positions is taken for the evaluation. Example results for each measurement position around the driver's head are presented in Fig. 6. At the same time, the criteria of technical specification must be fulfilled [2], see Tab. 1, and limits inside the driver's cab cannot be exceeded. The problem with mentioned level adjustment usually concerns OTMs, as warning devices are installed on the cab's roof, close to ventilation vents and no appropriate sound insulation is provided in such vehicle's cabs. Their construction is often simple, rather budget and window panes fill the large part of the external partitions to provide better visibility for an operator, but have poor sound insulation properties.

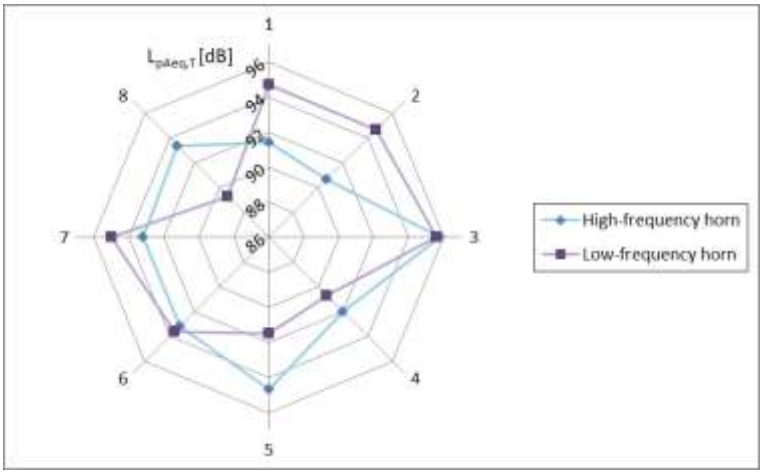



**Figure 6.** Example results of A-weighted sound pressure level measured at 8 positions around the driver's head when sounding the external warning horn.

**Noise inside passenger coaches** is measured in accordance with EN ISO 3381:2013 [6]. A-weighted sound pressure level is assessed at microphone positions that represent different areas in a vehicle, at 1,2m for seated and 1,6 m for standing positions. Third octave band analysis may be also determined. Higher sound pressure levels are often or even always found at microphone locations above bogies and

the noise transmitted from the bogies is usually the most dominating especially for higher vehicle speeds. Noise measured in two non-compartment wagons equipped with different bogie types is presented in Fig. 7. Coach 1 is equipped with technically obsolete bogies that are still used in modernised wagons and Coach 2 with vibrations resilient bogies with new technical solutions. It may be seen that the overall level difference between positions in the middle of the coach and above a bogie is not as significant for Coach 2 in comparison to Coach 1 and noise in case of Coach 2 is lower despite the fact it was running with higher speed. Another problem found in coaches, especially non-compartment ones is poor sound insulation of partitions between passenger area and vestibules – provided usually by transparent, glass, leaky doors.

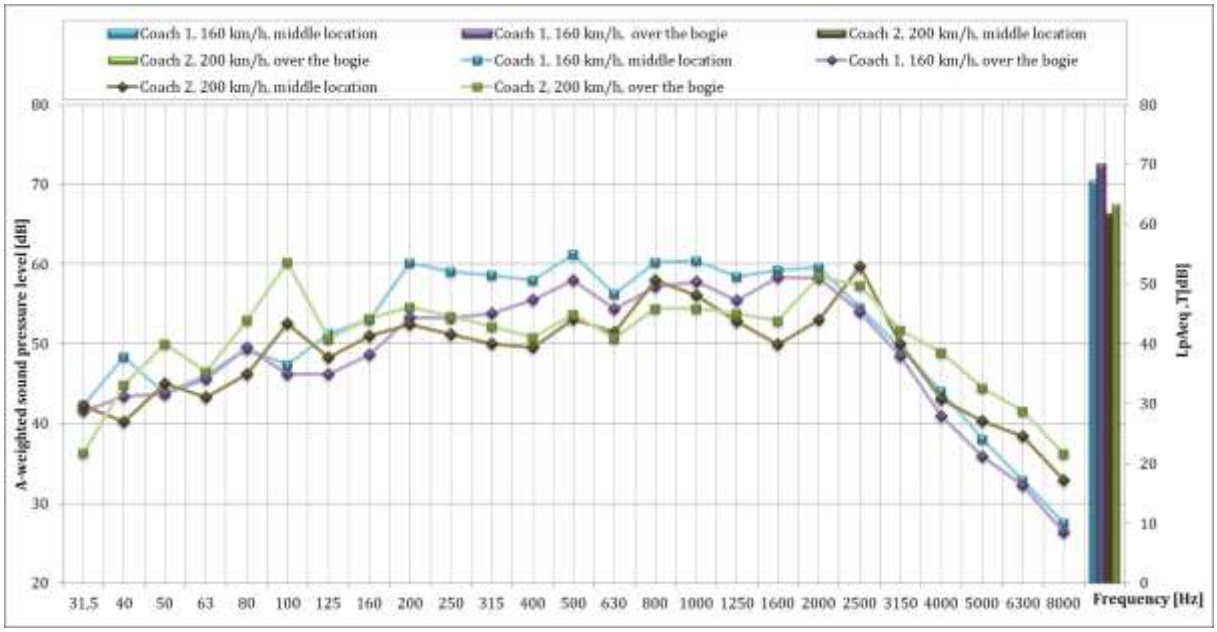



**Figure 7.** Comparison of example results of A-weighted sound pressure level in 1/3 octave bands measured in two non-compartment cars with different bogie types – Coach 1: 4ANc, Coach 2: 25AN.

### 4.3. Limitations

There are number of aspects that are pose an impediment in meeting noise criteria regarding rail vehicles. When designing a vehicle, safety, economy and functionality issues are priorities.

Limitations concern materials that are used in vehicles, e.g.:

- vehicle mass limitations preclude in applying high-density materials for better sound insulation,
- requirements on fire properties of materials applied in vehicles limit the choice.

Other requirements and specifications, e.g. concerning design of areas dedicated for people with wheelchairs may influence on poor solutions regarding acoustics.

It appears, that usually the main limitation are finances. From the observation of rail vehicles market, behaviour of producers, their development or stagnancy in regard to vehicles, two approaches may be distinguished. One of them is just to sustain on the market and the other one is to develop. The difference is highly apparent in the quality of vehicles.

Costs, especially of modernisation and building vehicles used for e.g. infrastructure construction or maintenance are lowered. Acoustics is usually not analysed for modernisation cost estimate in contracts and is often not taken into consideration during the design process, which could reduce expenses and time needed to complete a project (the example presented in Fig.1 – changes and re-examinations extended time and costs that were not presumed).

Reusing of technically obsolete bogies in modernised vehicles is common and often the only possible solution due to construction limitations or non-production of domestic new bogies. This also reduces cost of modernisation (old bogies are basically only repainted), which plays a crucial role while choosing a winner of a tender. However, the solution results in noisy vehicles (example shown in Fig.7).

The limitation for improvement of acoustic properties of modernised vehicles might be also some specific notations in regulating documents. For instance, in TSI Noise [1], it is stated, that in case no TSI existed while the first authorisation for a vehicle, it should be demonstrated, that noise levels of upgraded unit are not increased. In practice, it is often considered as a solution involving less effort, thus not bringing improvement and development.

## 4. Conclusions

The development of the rail transportation system including new or modernised vehicles incorporates a process, that combines designing, modernising, testing, certification, entering objects into service and also trades and finances. According to the presented outline of the process and examples of noticed weaknesses, following observation is prompted. There seems to be a need of re-verifying existing requirements concerning rail vehicles valid in Poland. However, the aspect of regulations should be followed by appropriate measurement methods, change in approach when designing vehicles and making decisions during tenders or while creating contracts. This is not achievable without raised awareness of producers of vehicles, their clients and officials that impose regulations. Here, an important role should be brought under cooperation between them and institutions that are able to reliably monitor the situation and educate.

## References


1. Commission Regulation (EU) No 1304/2014 of 26 November 2014 on the technical specification for interoperability relating to the subsystem "rolling stock – noise" amending Decision 2008/232/EC and repealing Decision 2011/229/EU.
2. Commission Regulation (EU) No 1302/2014 of 18 November 2014 concerning a technical specification for interoperability relating to the "rolling stock – locomotives and passenger rolling stock" subsystem of the rail system in the European Union.
3. The List of the President of the Office of Rail Transport on relevant national technical specifications and normalisation documents that their application enables the fulfilment of essential requirements concerning interoperability of the rail system – Appendix TM-2 , 2020.
4. Commission Regulation (EU) No 1302/2014 of 18 November 2014 on the technical specifications for interoperability relating to accessibility of the Union's rail system for persons with disabilities and persons with reduced mobility.
5. EN ISO-3095:2013 Acoustics – Railway applications – Measurement of noise emitted by railbound vehicles.
6. PN-EN ISO-3381:2011 Railway applications – Acoustics – Measurement of noise inside railbound vehicles.
7. PN-EN 15892:2011 Railway applications – Nise Emission – Measurement of noise inside driver's cabs
8. EN-60268-16:2011 Sound system equipment – Part 16: Objective rating of speech Intellegibility by speech transmission index.
9. PN-EN 16584-2:2017 Railway applications – Design for PRM use – General requirements – Part 2: Information.
10. M. Migdal, D. Szczepiński, J. Karliński, R. Frączek; Standardy techniczne. Szczegółowe warunki techniczne dla modernizacji lub budowy linii kolejowych do prędkości $v_{max}$≤200 km/h (dla taboru konwencjonalnego)/250 km/h (dla taboru z wychylnym pudłem); Tom I – Załącznik ST-T1-A6. Układy Geometryczne Torów; wersja 1.0; Załącznik Nr 1 do uchwały Nr 1086/2017 Zarządu PKP Polskie Linie Kolejowe S.A. z dnia 13 listopada 2017 r., Warszawa, 2017.
11. A. Świerkoska: Curve squeal monitoring on the Stockholm metro. Statistical analysis based on data collected by an onboard monitoring system, MSc dissertation, Department of Civil and Environmental Engineering, Chalmers University of Technology, Gothenburg, Sweden, 2019.
12. P. de Vos: Railway noise in Europe. State of art report; UIC-ETF (Railway Technical Publications), Paris, 2016.
13. J. Bułhak, E. Buchalska: Dwa lata eksploatacji kompozytowych wstawek hamulcowych w taborze kolejowym w Polsce; TTS Technika Transportu Szynowego, Tom R. 11 nr 1-2, 2005.
14. Osiak A.: Uwarunkowania techniczne zastosowania kompozytowych wstawek hamulcowych w wagonach towarowych. Zeszyty Naukowe Politechniki Śląskiej 2004, seria Transport, z. 54 nr 1656.

# Conditions for multiple acquisition of echoes from stationary targets in successive transmissions of active sonars

**Lech KILIAN[1], Aleksander SCHMIDT[2], Mariusz RUDNICKI[3]**

Gdańsk University of Technology Faculty of Electronics, Telecommunications and Informatics, Department of Sonar Systems, ul. Narutowicza 11/12, 80-233, Gdańsk, Poland, ORCID: [1] 0000-0002-3921-9531
[2] 0000-0003-2538-5173
[3] 0000-0002-7533-203X

**Corresponding author**: Lech KILIAN, e-mail: kilian@eti.pg.edu.pl

**Abstract:** In echolocation, the highest possible number of contacts with a detected target is clearly decisive on the possibilities of echo processing to optimise the estimation of distinctive characteristics of the observed target. In hydrolocation, the slow propagation of acoustic waves in water reduces the number of contacts of echosounders and sonars with detected targets. The article considers model conditions for acquiring multiple contacts with stationary targets detected by various sounding methods - with echosounders, classic active sonars and side looking sonars. Appropriate formulas explicitly linking the possible number of echo signals from the target in a specific geometry of the survey performed at the assumed speed are presented. These formulas are intuitively clear and not very complicated, but their value lies in the ability to instantly combine the vessel speed with the sounding effects, and may be a clear argument for imposing a low sounding speed, which make it difficult to steer the vessel.

**Keywords:** echosounder, sonar, side scan sonar, multiple echoes, beam geometry, scanning speed.

## 1. Introduction

The basic method of increasing the credibility of obtained information in every field is, as is commonly known, repeating simple measurements or complex observations, and further, intelligently comparing as many as possible of the results of these observations, e.g. echo signals from an interesting target obtained from possibly multiple successive sonar transmissions.

There are now powerful hardware and software tools for improving the detection conditions, and to put it simply - mainly improving the quality of images in very different areas, of which, for example, the closest to the hearts of young people is now "assembling" images from several different small lenses in their mobile phones in order to obtain images of a quality as close as possible to large and perfectly made lenses of professional cameras.

These tools are of course less effective when less information is provided to them, e.g. in echolocation – due to a smaller number of acquired echoes from the observed target. And here we can recall the complaints of designers and sonar operators who have to fight the slow transmission of sound in the water (as a reminder: 200.000 times slower than electromagnetic radar waves). A certain, unfair consolation for them can only be the even greater troubles of their friends working with sodars, where the transmission of waves in the air is still five times slower.

The number of contacts is not explicitly included in the sonar range equations that are the basis of sonar design [1]. This is probably why it is rarely discussed in specialist literature but should be discussed during the trainings of sonar operators.

The beamforming technique [1] was invented especially for hydrolocation (and not transformed from radiolocation), i.e. the simultaneous production of many narrow horizontal cross-sections of beams (usually receiving), providing sonars with good horizontal angular resolutions in wide observation sectors and by this creating the possibility of multiple observations of targets located in these sectors in successive transmissions. The slow propagation of waves in water, however, still limits the number of sonar contacts with detected targets in the vertical cross-section of the transmitting-receiving beam, and the possible improvement of the situation by reducing the speed of the sounding vessel is limited by the loss of steering or the danger for the battleship as a slowly moving target.

Different survey conditions of water spaces and their bottoms exist for side-scan (looking) sonars [2], where problems connected with the necessarily very narrow horizontal section of the sonar beam pre-

dominate, where "simple" beamforming cannot be used, but only the synthetic aperture of the receiving antenna (this time unfortunately coming straight from radiolocation)[1].

The conditions for acquiring and estimating the number of multiple contacts with stationary targets as detected by various sounding methods with echosounders, forward-looking (standard) active sonars and side-scan sonars will be discussed below.

In the case of moving targets, their detection and tracking generally requires greater operator efforts and leads to attempts to retrieve an echo from each transmission for as long as possible [1].

## 2. Standard vertical sounding

The simplest, model, geometric conditions for calculating the number of contacts with the fixed target occur for a typical single-beam echosounder sounding. On their basis, it is possible to determine the number of contacts $n$ depending on the speed $v$ of the sounding vessel and the depth $h$ at which the target is immersed. This situation is illustrated in Figures 1 and 2, below.

The adopted model neglects the real shape of the cross-section of the transmitting-receiving beam, approximating it with a triangle. In the drawn example, the number of contacts with the target within one beam $n$ = 5. In principle, the contacts with the highest numbers are uncertain due to the beam "escaping" from the target. In fact, there is no clear limit to the disappearance of the target images due to the milder than triangular shape of the usually quite wide beam adopted here. More seriously, the problem of "escaping" the beam is treated further when analyzing the movement of side looking sonars, where the horizontal cross-section of the beam must be extremely narrow and therefore contacts with targets in sonars without synthetic antenna aperture are especially few [2].

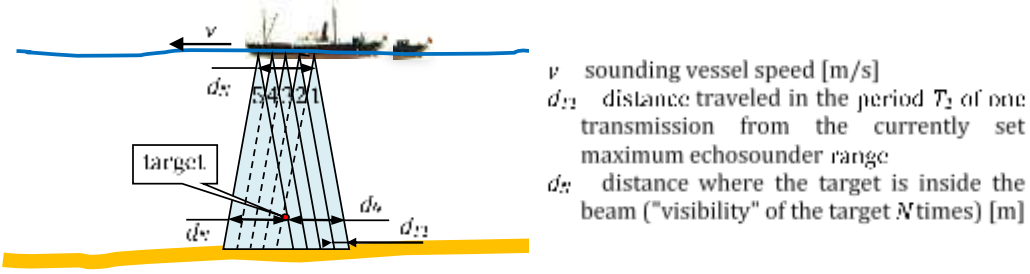



**Figure 1**. A simple model of the geometry for the vertical cross-section of a single-beam echosounder.

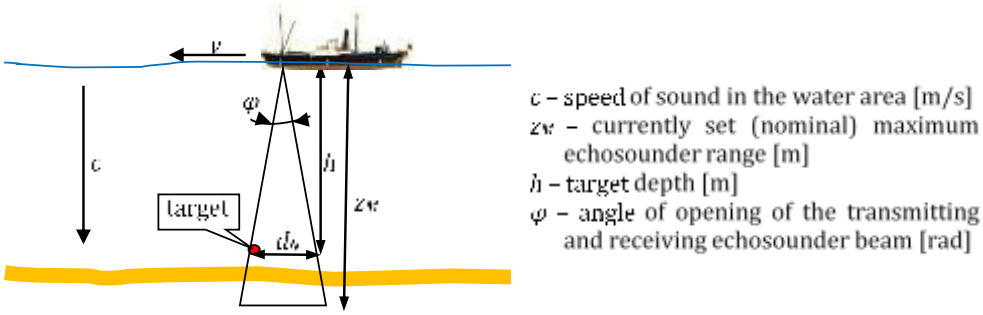



**Figure 2**. Geometric conditions for determining the number of contacts with the target for a single-beam echosounder.

The minimum duration of a single transmission (usually extended for various reasons) is:

$$T_1 = \frac{2z_M}{c} \tag{1}$$

and the dimension of the space $d_N$ determines the target depth $h$ and the spread angle $\varphi$ of the sonar beam:

$$\frac{d_N}{2h} = \tan\left(\frac{\varphi}{2}\right), \qquad \text{i.e.} \qquad d_N = 2h\tan\left(\frac{\varphi}{2}\right) \tag{2}$$

For narrow (usually) sonar beams, this can be approximated by a simplification:

$$d_N \approx h\,\varphi \tag{3}$$

The number $n$ of single transmissions during the distance $d_N$ is determined by its length, vessel speed and duration of a single transmission:

$$nT_1 = \frac{d_N}{v} \tag{4}$$

So, the number $n$ can be roughly calculated from the relationship:

$$n = \frac{d_N}{vT_1} = \frac{c\,d_N}{2vz_M} = \frac{c\,h\,\varphi}{2vz_M} \tag{5}$$

and for example, for moderate conditions: $z_M$ = 100m; $h$ = 50m; $\varphi$ = 12° = (3.14 · 12/180)rad = 0.21rad; $v$ = 5kn ≈ 2.6m/s; the number of contacts $n$ ≈ 15, so basically it is not too bad, although it is clearly small, e.g. for use in statistical methods of echo signal processing. However, it is enough to set too long the measuring range of the echosounder (repetition time of sounding signal transmission $z_M$) and the number of contacts will decrease proportionally. The same thing happens when increasing the speed of the vessel.

Formula (5) is intuitively obvious and indicates that when sounding, it is worth sailing as slowly as possible, to make sure that the minimum possible range of the sonar is set and that it is good for the transmitting-receiving beam to be as wide as possible from the point of view considered here. All sonar operators, even the inexperienced ones, know this. They also know, of course, that they have no influence on the speed of sound propagation in the water as well as on the depth of the targets.

The treatment of the precision of the presentation of the geometric situations and of the accuracy of the calculations presented above is slightly disrespectful. This is, in general, due to the lack of clear consequences of such simplifications in relation to possible changes resulting from the physical inconvenience of the conditions of echo formation and transmission (echo interference with reverberations, incompletely compensated unit trims, uncontrolled echoes from side lobes, channel delamination, etc.).

## 3. Inclined observations (classical sonars)

With typical oblique observations – e.g. detecting bottom or anchor mines, the geometric conditions sometimes simplify and sometimes become a bit more complicated.

If the targets are shallow below the surface, they must be detected with a beam that is parallel (or almost parallel) to the surface of the water. In this case, in a model situation (without deflections of propagation rays, uncompensated trims of the vessel, etc.), many echoes reach the sonar receiver – as many as the transmissions that pass during the passage from the detection edge $d_1$, i.e. from obtaining the first echo (e.g. echo from the set of the the nominal sonar range $z_M$ or when appropriate target detection conditions have been reached). The situation, with possible simplifications, is shown in Figure 3.


**Figure 3**. Geometric conditions for determining the number of contacts with a near-surface target for a regular sonar sounding.

Since, a single transmission $t_1$ invariably lasts as long as in relation (1) and the number of contacts with the target as in the initial form of relation (5), then further – without the non-existent angle of beam tilt:

$$n = \frac{c\,d_1}{2vz_M} \tag{6}$$

It should be noted that it is very valuable to shorten the nominal ranges $z_M$, as much as possible, because if echoes appear from the edge of the range, the number n becomes the maximum number, inversely proportional only to the speed of the survey:

$$n = \frac{c}{2v} \tag{7}$$

Formula (7) produces very optimistic results, as it indicates that at the speed of a ship equal to 5 knots, the number of contacts may reach 150. In practice, unfortunately, this is not encountered, because this number is greatly reduced by "losing" the echoes for numerous reasons, e.g. interference with reverberations from wavy water or bottom surfaces (which is the dominant cause of echo disappearance), but also deflections of sound propagation rays, local discontinuities and similar propagation misfortunes, especially in the subsurface layers. The condition $z_M$=$d_1$ is also not met (almost always $z_M$>$d_1$).

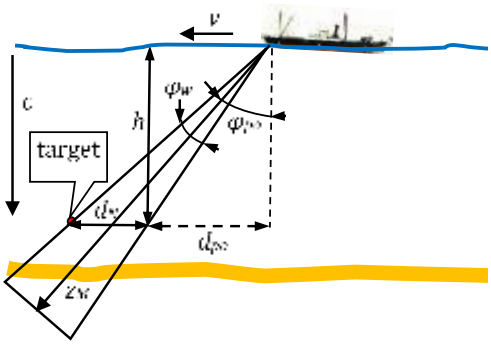
Therefore, in order to improve the transmission conditions, towed array sonars are constructed but operated with difficulty. They are towed under the keel waters, and even above or under the recessed thermoclines, under which submarines like to hide, like airplanes in the clouds.

For bottom or deep-water target detection, the geometry of the applicable model is shown in Figure 4. It shows that formula (5) for the vertical survey becomes more complicated due to the geometry of the classic oblique observation, and more specifically, the inability to replace the tangent function directly with the value of the angles expressed in [rad]. While this could be done for a generally narrow vertical spread of the sonar beam (i.e. the angle $\varphi_W$), it is impossible to approximate the often considerable devia-

tion from the vertical of the beam tilt angle (i.e. the angle $\varphi_{PO}$). The correct formula therefore takes on a somewhat clumsy form:

$$n = \left(\frac{c\,h}{2vz_M}\right)\left[\tan\left(\varphi_{po} + \frac{\varphi_w}{2}\right) - \tan\left(\varphi_{po} - \frac{\varphi_w}{2}\right)\right] \tag{8}$$

and if the above-presented conditions of echosounder sounding are repeated, but with the beam inclined $\varphi_{po}$ = 45°, the number of contacts $n$ more or less doubles – due to the elongation of the distance $d_N$ after beam inclination.




$c$ – speed of sound in the water [m/s]
$v$ – sounding ship speed [m/s]
$z_W$ – currently set sonar range [m]
$h$ – target depth [m]
$\varphi_W$ – spread angle of the transmitting-receiving sonar beam [rad]
$\varphi_{po}$ – beam inclination angle [rad]
$d$ – distance where the target is inside the beam (target's "visibility") [m]
$d_{po}$ – supplementary distance to the vertical beam inclination [m]

**Figure 4**. Geometric conditions for determining the number of contacts with a deeply submerged or bottom target for under-keel sonar.

Again, it is worth paying attention to the limited confidence in the accuracy of the calculated number of contacts, this time, apart from the factors mentioned in the vertical sounding, also due to the sometimes strong influence of deflections of sound propagation rays in the water area on the shape of the sounding geometry.

## 4. Side scan sonars

Side scans are performed with other equipment than classical soundings, and there are different conditions for obtaining echoes from targets generally located at or near the bottom of water areas on the traverses of ships towing underwater antennas carriers. [2]. The predominant task of surveys is to provide information for the creation of underwater maps or the recreation of the shapes of objects, e.g. wrecks. Therefore, the most important system parameter is resolution in the horizontal plane. For the first decades, "normal" long antennas (providing a horizontal resolution of 1°) were constructed on both sides of slender, stable, underwater towed carriers. The technology of synthetic antenna apertures, which has been introduced in recent years, which is difficult phenomenologically and in terms of hardware and software [1], is not of fundamental importance for the basic discussions on the conditions for performing side scans presented below, although the possible spectacular effects of using this technology will be indicated below.

A simple, geometric model of the search conditions is presented in Figure 5. For the sake of clarity of further considerations, only one of the two symmetrical side-scan sonar channels will be shown, while for the sake of clarity of the drawings, the exaggerated horizontal cross-section of the beam, its projection on the bottom and the great height $h$ of the carrier above the bottom are shown. In fact, usually the survey is carried out as close to the bottom as possible ($\varphi_M \approx 90°$) – only with the carrier safety conditions respected, and then the minimal differences in the width of the oblique section of the beam and its projection on the bottom can be neglected.

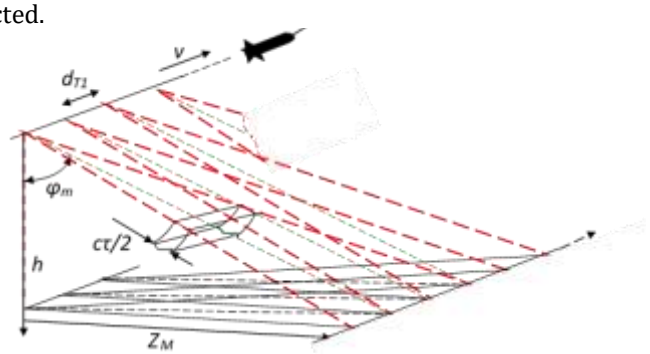



**Figure 5.** Geometric model of side-scan (sometimes: side looking) sonar sounding conditions [2].

When analyzing the side scans, one should take into account the previously neglected "escape" of the receiving beam from the area in which the sounding pulse was sent at the beginning of the transmission

(within the transmitting beam). Due to the extremely narrow cross-section of the beams, the previously adopted simplifying omission here is untenable [2].

The situation is shown schematically in Figure 6. The antenna carrier is towed at the speed $v$ and during a single transmission $T_1$ traverses the distance $d_{T1}$. The dashed area is indeed searched, Figure 6a. At the limiting velocity $v_G$ (distance $d_{TG}$ traveled), no echo should appear due to the complete escape of the receiver beam from the transmission of the sounding pulse area in the water. With speed $v_G$, the scanned area decreases to zero, Figure 6b.

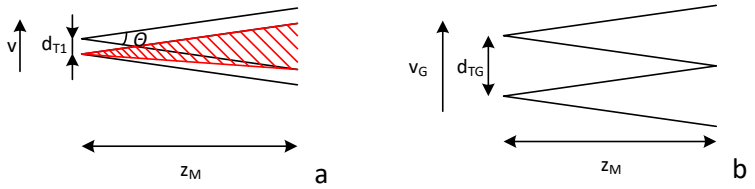



**Figure 6.** Movement of the horizontal cross-section of the side-scan sonar beam [2].

In the presented situation:

$$d_{TG} = v_G T_1 = 2z_M \tan\left(\frac{\theta}{2}\right) \approx z_M \theta \tag{9}$$

and because:

$$z_M \approx \frac{cT_1}{2} \qquad v_G \approx \frac{c\theta}{2} \tag{10}$$

there is a simple formula linking the limiting speed of the sounding vessel with the angle of horizontal cross-section of the transmitting/receiving beam of the side scan sonar:

$$v_G[kn] \approx 25\theta_G[^\circ] \tag{11}$$

and this means that if, for example, a sonar has a beam with a $1^0$ cross-section at a speed of 25 knots, it unfortunately will not see anything (the case in Figure 6b). The so-called dead zone - will not be searched in the entire range. It will be shown further that if one wants to minimise it, the carrier should be slowed down or the synthetic aperture antenna, mentioned above, should be used.

It is worth noting that the inconspicuous form of formula (11) stands in opposition to its considerable usefulness, as it allows you to easily combine the most important operational parameters of side-scan sonars, i.e. horizontal resolution, permissible sounding speed and the dimension of the dead zone, regardless of the sonar design complication. For example, for sonars with synthetic antenna apertures, a somewhat wide (e.g. several degrees) opening of the physical "short" antenna cross-section should be inserted into the formula, and you can immediately see the possibility of a proportional acceleration of the sounding speed.

With a sufficiently slow sounding, conditions are created to minimize the search dead zone and to acquire echoes multiple times from single targets. This is explained in Figure 7.

While maintaining the assumption of linearity of geometric dependencies in the situation from this figure, it can be seen that in order for the dead zone not to exceed e.g. 10% of the maximum range $z_M$, the sounding should be conducted at a speed just 10 times lower than the velocity $v_G$ from the formula (11), i.e. at a speed slightly higher than 2 knots. This is a rather bad prognosis for the controllability of the navigation of the sounding vessel. Therefore, one should use sonar with a wider horizontal cross-section of the beam or accept longer zone that is poorly searched (and, according to the model presented above, completely not searched). In fact, as usual, there are no binary situations, because there is a chance, especially up close, for some echoes resulting e.g. from a softer shape of the beam than in the adopted criterion of its width or from its side lobes Finally, you can go into the construction of sonar with a synthetic antenna aperture that allows the use of much wider (several times) cross-sections of physical beams and thus the proportional acceleration of the scans.

The number $n$ from Figure 7 has a similar meaning as its counterpart in classical sounding – a single, small, distant target may be seen in several transmissions. This does not (and even helps) spot and track targets in front of or below a ship, but "smearing" distant small targets by multiple echoes is not beneficial for the normal needs of side scans. This is, unfortunately, a physical property of echolocators with a constant angular resolution of the antennas that can only be combated by constricting the beam. In practice, this can only be achieved by beamforming or synthetic apertures – both technologies being difficult to design, construct and program [1].

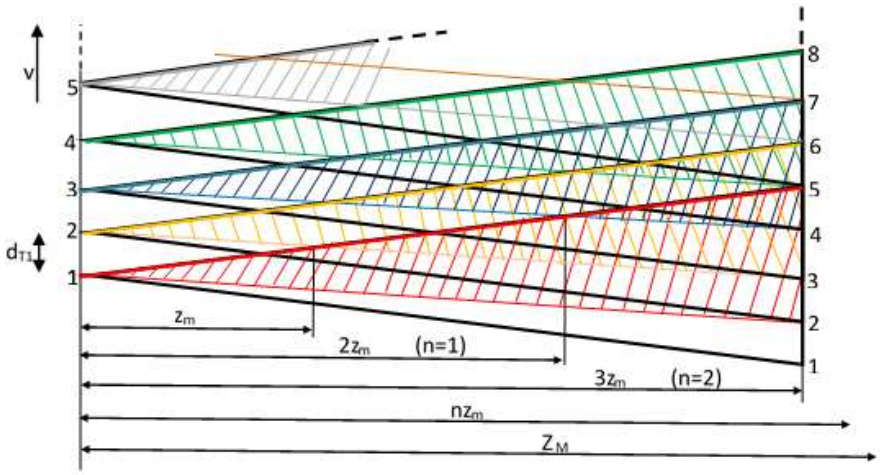



**Figure 7.** Side looking sounding . Dead zone $z_m$ and further – areas searched $n$ times [2].

Current side looking sonars with synthetic apertures, work a bit inaccurately in real-time, but are very suitable for autonomous underwater drones and, above all, they allow a significant improvement in the speed of the sounding, which is important especially on military minesweepers. At these increased speeds, the non-searched dead zone remains small, despite the ultimately very narrow "synthetic beam", because the primary information is collected from the "wide" physical beam of the antenna and is not lost during processing because the subsequent reduction of the beam due to the long aperture synthesis procedure no longer extends the dead zone, i.e. losing close targets.

## 5. Summary

The considerations presented above are not too complicated phenomenologically, and especially mathematically, and perhaps that is why they are not explicitly discussed in the literature on hydrolocation. For example, their omission in the manuals for echosounders and sonars may also be explained by the reluctance of the authors of these instructions to present the limitations of the described, commercial equipment. These limitations and the ways to deal with them are obviously known to experienced sonar operators, but rather intuitively. Explicitly showing a few non-confusing dependencies that determine the possible results of the survey in a compromise with speed limits, strengthens the negotiating role of operators against always hurrying ship navigators.

It should also be mentioned that the group of sonar images is supplemented with histograms, popularly known as "waterfalls", which consistently show the line under the line, echoes in subsequent transmissions. The target strength in the echo signals on each of the lines are marked with the color of the pixels. The combination - "integration" of a few slightly different images improves the consequences of possible "lost" echoes from targets in some transmissions.

## Additional information

The authors declare: no competing financial interests and that all material taken from other sources (including their own published works) is clearly cited and that appropriate permits are obtained.

## References

1. Salamon R; Systemy hydrolokacyjne – in Polish, (Hydrolocation systems); Publisher: Wydawnictwo Gdańskiego Towarzystwa Naukowego ISBN 83-87359-98-X, Gdańsk, Poland, 2006.
2. Kilian L; Analiza warunków wykrywania i zdolności rozdzielczej sonaru bocznego – in Polish, (Analysis of the detection conditions and the resolution of side-scan sonar); PhD Thesis, Gdańsk University of Technology, Institute of Telecommunications, Gdańsk, Poland, 1979.

# Streszczenia OSA 2022

Open Seminar on Acoustic is an annual conference that brings together researchers and scientists from acoustics. It is organized under the patronage of the Committee on Acoustics of the Polish Academy of Sciences by the Polish Acoustical Society, Rzeszów.

## Pickering droplets and capsules under magnetic fields – calorimetric and ultrasonic studies

Rafał Bielas, Bassam Jameel, Andrzej Skumiel and Arkadiusz Józefczak

Adam Mickiewicz University in Poznań

Nanoparticles and their derivative materials, such as particle-covered droplets (Pickering droplets) or capsules, hold promise to be utilized in biomedicine, for instance, to enable targeted drug release and improve the efficiency of thermal therapies. Using such materials simultaneously with diagnostic modalities (e.g. Magnetic resonance imaging or ultrasound imaging) opens the possibility of the so-called theranostic approach, in which combining multiple modalities into one platform may provide numerous benefits for patients. Herein, we present the potential use of magnetic fields for future theranostic applications. We investigated the temperature elevation when Pickering droplets were exposed to the alternating or rotating magnetic field. When the temperature exceeded the temperature of glass transition, the thermo-sensitive polymer particles partially sintered and formed a rigid shell around the droplets (colloidal capsules). For testing the behavior of droplets during magnetic heating, the non-destructive ultrasound measurements were performed and showed no significant difference in acoustic properties after exposition to magnetic fields. In the future, the acoustic method could be also used for evaluation of the efficient capsules formation. Acknowledgments: This work was supported by the project no. 2019/35/N/ST5/00402 (PRELUDIUM) of the Polish National Science Centre.

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## Leaky Partial Updates to Control a Real Device Casing

Dariusz Bismor

Silesian University of Technology

Structural active noise control (ANC) is one of few solutions applicable when global noise reduction is required: control of a whole device casing allows to lower the acoustic energy emitted by this device. Unfortunately, structural ANC usually requires a large number of sensors and actuators, making the control system multichannel with large dimensionality. This in turn presents a huge computational power demands. There are several ways to lower this demand, the partial updates being one of them. The goal of this paper is to show applicability of the leaky partial update LMS algorithms in structural ANC of a washing machine casing. The transfer functions of the numerous device paths were identified using a real washing machine present in the ANC laboratory. The identified transfer functions allowed to create a simulation system, where different algorithms could be easily tested. The results of the simulations confirm effectiveness of the proposed solution.

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## Sound source localization - comparison of six popular microphone systems for stereo recordings.

Lukasz Blasinski, Jedrzej Kocinski and Stanisław Kasprzyk

Adam Mickiewicz University in Poznań

Dating back to the early 30's and the beginning of stereo recording, many sound engineers experimented with different multi-microphone techniques to capture the sound in a way that it would be natural to the human ears when listening. Many different techniques of stereo sound recording have been developed so far. Among them two-microphone techniques AB, XY or ORTF should seem to be the most commonplace ones. The goal of our research was to investigate which two-microphone stereo techniques system is the most compatible to human perception of sound source localization. Six popular stereo recording techniques were analyzed. More than 80 listeners took part in a remote, internet survey and headphone listening test with recordings from above mentioned stereo solutions. Over 20 participants of a control group have been audiologicaly tested and took part in a listening test under controlled listening conditions. The results show that listeners perceived the sound localisation differently for different techniques. Some of them drastically disturbed the spatial perception. To conclude one may state that the type of recording influences the spatial perception thus the choice of the microphones settings is crucial for further spatial effect while listening.

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## Design of the test facility for measurements of sound silencers

Romuald Bolejko, Andrzej B. Dobrucki, Przemyslaw Plaskota and Krzysztof Pruc

Wroclaw University of Science and Technology, BH-Res

In a paper, a description of the test facility designed and implemented for measurements of noise silencers according to the methodology specified in the PN-EN ISO 7235 standard is presented. It is possible to measure the insertion loss, flow noise, and its pressure loss on the test stand. In particular, the following issues were presented: noise protection in the low frequency range, the design of the anechoic termination, and measurements of the sound pressure level in the flow. To obtain a sufficiently high noise protection, three noise transmission paths were considered: direct, indirect, and flanking. The design of the anechoic termination was based on the profile of the catenoid tube, which made it possible to obtain strong sound absorption in the low frequency range while maintaining a limited length of terminator. A specially designed microphone cap was used to measure the sound pressure level in the flow field. The article also presents results of selected measurements that illustrate the possibilities of the designed test stand.

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## Influence of the passage of time on the effectiveness of the aural identification of the speaker

Stefan Brachmański and Bartosz Hus

Wroclaw University of Science and Technology, Faculty of Electronics, Photonics and Microsystems

For many years, both in Poland and in most courts around the world, aural identification of a person is allowed, i.e. Such testimony in which the witness can identify the speaker or other auditory impression. Psychologists, crime acoustics specialists, and researchers dealing with the perception of hearing and the broadly understood forensics describe many cases in which such testimonies resulted in a wrong judgment. The article presents the results of an experiment, the aim of which was to investigate, in the conditions of the Polish language, to what extent the passage of time deteriorates the correct identification of a person. Research conducted for a female voice showed that only 30

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## Project of acoustic adaptation of the church with a long reverberation time

Adam BraŃski, Lucjan Janas, Edyta PrĘdka and Rafał Klich

Rzeszow University of Technology

Long reverberation times are a problem in modern churches. General methods of solving the problem are given in the literature. The basic approach is to increase the acoustic absorption of the church, and this can be achieved by placing sound-absorbing materials on the walls. Due to the price, materials with a high absorption coefficient are not used. They are replaced with sound-absorbing plasters. For the known coefficient of sound absorption by plaster, the problem is to calculate the surface of the plaster coverage and its distribution on the surface. This problem was solved for the Academic Church in Rzeszów, the Roman Catholic parish of St. Jadwiga Królowa. The reverberation time before adaptation is T1=6.78 s, while the predicted time after adaptation is T2=1.98 s.

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## Comparison of echolocation abilities of blind and normally sighted humans using different source sounds

Michal Bujacz, Bartłomiej Sztyler, Piotr Skulimowski, Aleksandra Królak and Strumiłło Paweł

Lodz University of Technology, Institute of Electronics

The ability of some humans to echolocate has become widely known primarily due to a small number of famous expert echolocators who are capable of extraordinary feats such as riding bicycles. However, a lesser-known fact is that all humans exhibit this skill unconsciously and can learn it relatively quickly and implicitly through repeated practice. In our experiments we tested groups of 12 blind and 14 sighted untrained participants in a simple echolocation test – localizing a 1m x 2m vertical wall at distances between 1 and 3 meters using 10 different types of sounds as the source signals for the echolocation attempts. There were significant differences between the participant groups and between some of the tested sounds. Although the groups were small, a clear difference was also observed between the experienced totally blind participants and the legally blind visually impaired participants that had residual light sensitivity. From the compared sounds 3kHz and 4kHz synthetic percussion sounds, pink and blue noise were among the sources that led to the highest chances of correctly guessing the obstacle's direction and distance.

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## Initial assumptions of the system for automatic detection and classification of acoustic events related to the flights of aircraft

Michał Bukała, Artur Nowoświat and Andrzej Chyla

Silesian University of Technology, SVANTEK Sp. Z o.o.

The carried out task envisages the development and implementation of an algorithm for the automatic separation of acoustic events related to the flights of aircraft. Data are provided by noise monitoring stations operating as part of multi-point continuous noise measurement systems around small and medium-sized airports and helicopter landing sites in Poland. The article presents the initial assumptions of the method being developed based on the conclusions of the conducted research. For this purpose, two different methods of airborne noise signal detection will be discussed. The first applied method is based on the analysis of the approximation value of the derivative of the signal being the difference between the value of the analyzed sample and the value of the h-th previous sample of the recorded sound level time history. The second one uses a convolutional neural network operating on values recorded in 1/3-octave bands. The conclusions will lead to the examination of the effectiveness and limitations of the selected methods based on the collected representative input data.

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## Road traffic noise influence on wind turbine noise detection

Maciej Buszkiewicz, Andrzej Wicher, Roman Gołębiewski and Remigiusz Pyffel

Adam Mickiewicz University in Poznań

Wind turbines are considered as green energy sources due to minimal CO2 emission. However wind turbines generate noise which in certain conditions is believed to have negative impact on human health and well-being. Although for dwellings located at typical distance from a wind turbine the noise level does not exceed 45 dBA, this source is considered as annoying. One of the main reasons for the annoyance is periodic variation of the sound level over time due to the passage of the turbine blade near the turbine tower. Literature often describes this phenomena as amplitude modulation (AM). Among the most important problems related to wind turbine noise is the determination of thresholds for perceiving this type of noise under specific acoustic conditions, as well as the assessment of the annoyance of wind turbine noise in the presence of various naturally occurring sounds. The aim of the present study is to determine the distance between the wind turbine and the observer for which wind turbine noise begins to be perceived relative to other environmental noise. The present study is focused on road-traffic background noise from an expressway. Recordings of wind turbine and road-traffic sounds were conducted for several distances at specified wind speeds and other meteorological factors. The recordings allowed the preparation and calibration of a test procedure based on a psychoacoustic experiment with listeners. The experiment required the subjects to indicate the level for which they have barely perceived the wind turbine noise against the road-traffic noise. The indicated noise level was related to the distance of stimulus modified by so-called transfer function based on the Nord2000 noise propagation model. The transfer function defined the values of the sound level in one-third octave bands for a given distance from the observer, at fixed propagation conditions: wind speed, air temperature, humidity and ground type – to reproduce the original recording of the wind turbine noise at the tested "distance". Depending on the responses during experiment the source-observer distance was increased or decreased using the adaptive method and noise signal was modified accordingly with transfer function. The stimulus level at which the subjects barely perceived the wind turbine noise against the road-traffic noise was considered as the threshold of masking of the wind turbine noise by the road-traffic noise. Transfer function enabled to indicate the threshold distances of wind turbine noise detection. The research was performed within the Polish-Norwegian project No. NOR/POLNOR/Hetman/0073/2019-00.

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## Experimental verification of similarity criteria for sound absorption of simple metamaterials

Aleksandra Chojak

AGH, University of Science and Technology

The paper concerns the dimensional analysis of simple acoustic metamaterials and its experimental verification. Due to their decreased thickness caused by thermoviscous losses and sound dispersion that occur in acoustic metamaterials, such structures are gaining popularity, both as sound absorbers and diffusers. This implies the need to find their equivalents to be used at scale – both for modeling interiors with metamaterials and developing more complicated structures. The paper discusses the dimensional analysis performed for a generalized unit cell of a metamaterial with a resonator. The dimensional analysis shows the need for scaling both geometrical dimensions of the structure and the parameters of the medium – air. The dimensional analysis was derived based on the transfer matrix method and was proven correct with finite element method model. The paper also discusses the consequences of neglecting the air criteria, which are impossible to be fulfilled. This opens the question of finding new criterial numbers allowing the correct reflection of acoustic metamaterials at scale.

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## Miniature omnidirectional sound sources used in acoustic scale modeling – measurements and validation

Bartłomiej Chojnacki

AGH University of Science and Technology

Acoustic measurements such as scale modeling measurements require a particular type of miniature omnidirectional sound source. The most important aspects of those devices are small sizes (usually below 100 mm in diameter) and different frequency ranges compared to traditional, omnidirectional sound sources used in room acoustics. The required frequency range differs regarding the used scale factor in different models, which leads to the troubles

in frequent source changes and the need for a unique source design for every model. The project will present the recent achievement in miniature omnidirectional sound sources development. The optimal sound sources for the given measurement functions were developed based on the previous numerical simulations and experiments such as FEM sound directivity simulations or transducers' parameters tolerance testing. The sound sources presented are used for applications such as acoustic sound insulation scale measurements (frequency range 800-63000 Hz), scaled reverberation chamber measurements (300 – 80000 Hz), or acoustic reduction models measurements (400 – 70000 Hz). The paper will cover a detailed technical explanation of the laboratory environment's source construction aspects and validation measurements.

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## Low frequency acoustic field distribution at the neolitic rondel in Heldenberg

Ireneusz Czajka, Katarzyna Suder-Dębska and Paweł Łojek

AGH University of Science and Technology

Neolithic objects known as rondels have been discovered in many places in Europe. The purpose of these facilities is not fully defined. This research work was undertaken to verify the hypothesis regarding the apotropaic function of this type of objects from the acoustic point of view. As the research object the Neolithic rondel in Heldenberg, Austria was selected. During the research, the distribution of the acoustic field for the infrasound frequency range was determined and possible screening effects were searched for. As the object is over 25 m in diameter and because taking into account only the low frequency range, the boundary element method was chosen as the calculation method. Available open source software package called AcouSTO was used. The performed calculations did not allow for a definitive confirmation of the hypothesis about the apotropaic function of the object. This issue requires further analysis.

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## Experimental Research of the AMWG Algorithm for Assessing Amplitude Modulation in Wind Turbine Noise

Marcjanna Czapla and Tadeusz Wszołek

AGH University of Science and Technology

The operation of a wind turbine (WT) is characterized by fluctuations in sound pressure amplitude associated with the passage of the propeller blade through the tower. Amplitude Modulation (AM) is one of the factors contributing to the increased annoyance of wind turbine noise. The phenomenon of AM is currently the subject of research in many research centers around the world in the context of parametric assessment of its impact on annoyance. Despite the development of many methods to measure the AM of a WT noise, there is no commonly accepted method. This paper discusses the most crucial factors that stimulate the phenomenon of AM and the implementation in the MATLAB environment of the algorithm to find the frequency and depth of AM proposed by the Amplitude Modulation Working Group (AMWG). The results of verification of the developed algorithm as well as the measurement results of the frequency and depth of modulation for two measurement samples of a 2 MW wind turbine are presented.

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## Cognitive science as an interdisciplinary science

Henryka Czyz and Adrianna Gardzińska

University of Information Technology and Management in Rzeszow, Rzeszow Uniwersity of Technology

Computer science is formal basis of some cognitive science research. The foundations of computer science include acoustics, interdisciplinary science covering issues related to wave generation, propagation and interaction with the medium where they propagate, and wide applications in engineering and technology. This article presents the

problems of interpreting IT concepts in the modeling of cognitive processes. Cognitive science aims at human understanding mind by integrating the results of various teachings, including acoustics. The task of cognitive science is to create models of the mind compatible with all branches of knowledge. So it is great integration of research results from many independent domains. Basic concepts of computer science related directly to the cognitive activity of the mind, i.e. They can be interpreted cognitivistically. They can also perform heuristic functions, setting new issues, theories and research directions. This work deals with the analysis by all of the heuristic function of computer science, which is valuable to cognitive scientists.

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## Musical "Ignacy Lukasiewicz - our compatriot and patron"

Henryka Czyz and Wojciech Rdzanek

University of Information Technology and Management in Rzeszow, University of Rzeszow

Ignacy Lukasiewicz belongs to the group of Poles whose work and activity had a great, positive impact on the development of our country and the whole world. He was born 200 years ago, in March 1822. He is the founder of the global oil industry. In 2022, the scientific achievements of Ignacy Lukasiewicz were commemorated. Nowadays, many branches of the chemical, cosmetic and modern technology industries are based on the crude oil distillation process. A series of events commemorating the activity of this great Pole has been prepared in our voivodship. In the second half of 2022, the Lukasiewicz Science Center will be opened, in Jasionka, near Rzeszow. Among the achievements of Lukasiewicz, the creation of the world's first crude oil mine in Bobrka in the Krosno poviat, and then the commissioning of several refineries is of particular importance. The students of Rzeszow University of Technology and University of Rzeszow prepared a musical about this great chemist and inventor, based on the script and directed by Tadeusz Urban - a student of the University of Rzeszow at the Faculty of Music Education. Through music, singing and dance, students from the Rzeszow University of Technology choir recalled the life and activities of this outstanding pharmacist and philanthropist. The musical emphasizes the importance of Lukasiewicz's role in the history of the most important inventions in the history of mankind. In the musical, the youth sang many songs, among others the anthem for the city of Rzeszow, The Drilling Ballade, the anthem of the Rzeszow University of Technology. Since 1974, Ignacy Lukasiewicz has been the patron of the Rzeszow University of Technology. Musical fragments will be presented at the conference.

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## Nonlinear distortion in loudspeakers - causes, symptoms, measuring

Andrzej Dobrucki

Wroclaw University of Science and Technology

This paper reviews the causes of nonlinear distortion in loudspeakers. These include distortions caused by non-homogeneity of BL in the magnet gap, non-linearity of suspensions, dependence of coil inductance on its position, as well as distortions caused by the Doppler effect. Mathematical models of distortion and measures of distortion magnitude are presented. Methods of measuring distortions using sine wave signal, two-tone signal, non-harmonic multitone signal and noise are given.

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## Effect of highpass filtering on the speech transmission index

Paweł Dziechciński

Wroclaw University of Science and Technology

Highpass filters are commonly used in the signal chain of public address systems. One of the reasons for using a highpass filter is to protect the loudspeaker from unwanted low-frequency signals. In addition, it can increase the intelligibility of speech. In this paper, the effect of the cutoff frequency and order of a highpass filter on the speech transmission index, the crest factor, and the sound level are presented. Analyses were performed for an

ideal transmission channel, taking into account reverberation time, interfering noise, and high levels of sound. A computer model of the public address system developed by the author, based on the direct STIPA method, was used. This model enables analyses in the nonlinear range of power amplifier operation, which is often used in public address systems but is not considered in commercially available simulation programs.

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## Enhancing speech signals based on an MEMS microphone array and temporal differences in the incoming signal

Jan Felcyn and Michał Raszewski

Adam Mickiewicz University, Department of Acoustics, Faculty of Physics, LARS Andrzej Szymański

The development of the Internet of things and automatisation in everyday life also influences our houses. There are more and more devices on the market which can be controlled remotely. One kind of such control involves the use of voice signals. This method tends to use microphone arrays and dedicated algorithms to enhance the speech signal and recognize the words in it. In this project, a small 5-microphone array was developed. To enhance the quality of the signal, dedicated software was written. It consists of several modules, including the direction of arrival estimation, denoising, and differentiation between adults and children. The results showed that the custom algorithm can increase the signal to noise ratio by up to 6 dB.

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## Evaluation of wind turbine noise annoyance based on pre- learned patterns.

Jan Felcyn, Anna Preis and Robert Gogol

Adam Mickiewicz University, Department of Acoustics, Faculty of Physics

The annoyance of wind turbine noise is usually assessed on the basis of surveys conducted among people living in the vicinity of the turbines. Such surveys provide information on the overall assessment of the annoyance of noise generated by the turbines, but do not allow to determine the impact of individual parameters of this noise source on this assessment. The basic parameters affecting the formation of an overall annoyance rating are the noise level, its time course, the length of noise exposure, and the distance of the noise source from the listener. Therefore, detailed studies of the effects of each of those parameters on the human body individually, are conducted in the laboratory. Due to the fact that laboratory conditions are very different from natural conditions, i.e., the conditions in which people living near wind turbines live, we propose a solution to reduce this difference. Our approach consists of calibration of signals presented both, to the participants of the questionnaires, and the participants of the laboratory experiments. This is combined with teaching them how to assess the annoyance of model noise samples. Namely, prior to both the surveys, and the laboratory experiments, participants were asked to familiarize themselves with 7 environmental signals presented through headphones. They are informed about the annoyance assigned to each signal, expressed as a number between 0 (not annoying signal) and 10 (extremely annoying signal). This was a type of training in which participants learned how to use numbers to assess the annoyance of a sound. Participants were then presented with new 5 environmental sounds and asked to rate the annoyance of each sound according to a previously learned method. The purpose of this procedure was to have both the participants in the questionnaires and the participants in the laboratory experiments rate annoyance based on the same rule they had learned.

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## Research on the influence of airflow resistance of layered porous structures on the sound absorption coefficient.

Artur Flach

AGH University of Science and Technology

The article presents studies of the influence of airflow resistance on the sound absorption coefficient of layered porous structures. For the calculation of the sound absorption coefficient, models of layered sound-absorbing structures were developed with the use of numerical computational models. Using the developed models, optimization was carried out to maximize the average sound absorption coefficient of the systems for a given frequency range. As a result of the research, the dependence of the change in airflow resistance for the successive layers of the material was determined.

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## Application of the scattering matrix method to evaluate acoustic mufflers properties

Łukasz Gorazd

AGH University of Science and Technology

The aim of the paper is to analyse acoustic reflective muffler applying the scattering matrix method. In general, the method is based on dividing the muffler/system into separate subsystems and apply the acoustic multi-ports theory to calculate the scattering matrix of each element to finally combine the results and obtain the scattering matrix of the entire system/muffler. The multi-port procedure is derived from the theory of electric networks and allows to analyse acoustic devises of complex geometry with prescribed accuracy. Based on the scattering matrix (S), the transmission loss (TL) was determined.

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## Genetic algorithms in active vibration reduction problem

Marcin Grochowina

University of Rzeszów

The design of active vibration reduction systems usually consists in selecting a control algorithm and determining the value of its settings. This article presents the results of research on the concept of using genetic algorithms to induce the settings of control systems. To test the concept, a simple pulse-excited flat bar model was selected. The vibrations were suppressed by the PID controller. Genetic algorithms with two types of crossover were tested - arithmetic and uniform. As a result, the settings for the PID controller were obtained, enabling effective reduction of vibrations in a short time.

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## A device supporting the rehabilitation of spasticity as a recorder and player of low-frequency mechanical vibrations

Marcin Grochowina

Decylion Sp. Z o.o.

Spasticity is a chronic disease characterized by muscle contractures. Affected patients require intensive and systematic rehabilitation. It involves, among other things, performing exercises that stretch the muscles. During rehabilitation, simple movements are repeated many times, straightening and bending the limbs, trying to widen the range of movements in each repetition. The correctness of the treatment is supervised by a rehabilitator who, based on the analysis of the patient's health, adjusts the appropriate set of exercises. These movements can be described as low-frequency mechanical vibrations that can be analyzed and processed using methods known from digital signal processing. In order to streamline the rehabilitation process and improve its accessibility, a device has been developed that allows for the recording of individual cycles of movements during exercises in order to reproduce them later. The movements are repeated by a mechanical excitation system, equipped with angular position and excitation force sensors, and a servo drive with adjustable speed and force. The control system has built-in algorithms that estimate the range and strength of movements and adjust the registered patterns to changing conditions during exercise playback. The process of processing the registered patterns uses the filter, interpolation and decimation algorithms known from DSP. Algorithms have also been implemented to stabilize the actuators and eliminate their vibrations during exercise replay.

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## Vibration Transmission Analysis through Mounting Elements of Wall Cladding Panels

Julia Idczak, Jarosław Rubacha and Tadeusz Kamisiński

AGH University of Science and Technology

Vibrations in building constructions may propagate through mounting elements to wall cladding panels. It is confirmed that they can have an impact on the sound pressure level radiated from panels and might have a significant influence on the total SPL in a room. In this work possibilities for calculating a parameter determining a change of SPL value depending on the number of panels and its mounting method are presented. A computational model based on vibration velocity measurements was used to estimate the total SPL value in a room. The laboratory and in situ measurements are presented. Transfer function for two elastic elements used as additional elements in a junction was calculated. Finally, $\Delta lp$ and $\Delta lv$ were calculated, as parameters defining the impact of various panel mounting methods on the reduction of sound pressure level and vibration level value, respectively.

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## Calculation Strength Optimum Of Surgical Robot Effector For Mechanical Eigenproblems Using FEM and Genetic Algorithm

Grzegorz Ilewicz

Warsaw University of Technology, Institute of Micromechanics and Photonics, Faculty of Mechatronics

It is essential to check whether the surgical robot end effector is safe to use due to phenomena such as linear buckling and mechanical resonance. The aim of this research is to build an multi criteria optimization model based on such criteria as the first natural frequency, buckling factor and mass, with the assumption of the basic constraint in the form of a safety factor. The calculations are performed for a serial structure of surgical robot end effector with six degrees of freedom ended with a scalpel. The calculation model is obtained using the finite element method. The issue of multi-criteria optimization is solved based on the response surface method, Pareto fronts and the genetic algorithm. The results section illustrates deformations of a surgical robot end effector occurring during the resonance phenomenon and the buckling deformations for subsequent values of the buckling coefficients. The dependencies of the geometrical dimensions on the criteria are illustrated with the continuous functions of the response surface, i.e. Metamodels. Pareto fronts are illustrated, based on which the genetic algorithm finds the optimal quantities of the vector function. The conducted analyzes provide a basis for selecting surgical robot end effector drive systems from the point of view of their generated inputs.

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## Characterization of magnetic and non-magnetic nanoparticle suspension by ultrasound spectroscopy

Bassam Jameel, Tomasz Hornowski, Rafał Bielas and Arkadiusz Józefczak

Adam Mickiewicz University in Poznań

Ultrasound attenuation spectroscopy has found wide application in the study of colloidal systems such as emulsions or suspensions. The main advantage of this technique is that it does not require sample preparation and can penetrate optically opaque mixtures, which made ultrasound attenuation spectroscopy an attractive method to study suspensions with a relatively high concentration of magnetic nanoparticles. In this research, we used the ultrasound attenuation coefficient to study the suspension of magnetic and non-magnetic nanoparticles dispersed in a high viscous medium. A model based on the Epstein–Carhart–Allegra–Hawley's (ECAH) ultrasound scattering theory was utilized to analyse the results of ultrasound attenuation for characterizing particle suspensions by considering thermal, viscous, and acoustic properties of each phase. We studied suspensions of magnetite and silica nanoparticles dispersed in castor oil and compared the theoretical predictions with the experimental results. The results indicate the different tendency of magnetite and silica nanoparticles to agglomerate that was not reflected in the results from other experimental methods such as electron microscopy imaging. Acknowledgments: This

work was supported by the project no. 2019/35/O/ST3/00503 (PRELUDIUM BIS) of the Polish National Science Centre.

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## Application of an ambisonic microphone for the measurements of room acoustics parameters

Maciej Jasiński and Jan Żera

Warsaw University of Technology

The most commonly used measurement technique in room acoustics employs a single omnidirectional microphone for recording the room impulse response and further derivation of such acoustical parameters as T30, EDT, C50 or C80. Instead, ambisonic technology makes it possible to measure a spatial room impulse response. Ambisonics decomposes the signal from the spherical microphone array into spherical harmonics to shape the directivity. Ambisonics lets to go beyond basic acoustical parameters and allows to determine spatial features of a sound field at the measurement point. This study presents the comparison of fundamental acoustic parameters measured in the recording studio by a single microphone and omnidirectional signal derived from ambisonic microphones of the first and third order. The results show the usefulness of ambisonic technology in terms of assessing basic room parameters.

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## Noise effect on parameters of quiet sonar with code modulation

Andrzej Jedel, Jacek Marszal and Roman Salamon

Gdańsk University of Technology

Earlier authors publications have shown, that the use of code keying mixed with the CW FM sounding signal allows to significantly reduce the distance measurement error, compared to the classic silent CW FM sonars. In addition to the code modulation parameters, the magnitude of this error is influenced, by the received input acoustic noise. The article shows the dependence of the input signal-to-noise ratio and the sounding signal parameters on the target distance measurement error and the detection conditions such as the output signal-to-noise ratio and the side lobes level. The results of the analysis were compared to the same parameters of the CW FM silent sonar without code modulation.

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## Magnetic nanoparticles & ultrasound transmission tomography

Arkadiusz Józefczak, Krzysztof J. Opieliński, Rafał Bielas and Piotr Pruchnicki

Adam Mickiewicz University in Poznań, Wrocław University of Science and Technology

Magnetic particles can be used in numerous therapeutic procedures (e.g. Drug delivery, thermal therapy, photodynamic therapy). Despite promising new therapies, they are still limited due to the difficulty of accurately controlling their effectiveness. Ultrasonic transmission tomography has been proposed to track ultrasonic heating using magnetic nanomaterials. Their influence on the contrast of imaging using ultrasound tomography and the possibility of monitoring the heating process were investigated. The results showed that ultrasound tomography is sensitive to the presence of magnetic nanomaterials and temperature changes. This combination of ultrasound and nanomaterials could be promising in relation to developing a more applicable theranostic platforms.

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## Sound transmission loss calculation for metamaterial plate using combined analytical and numerical approach

Klara Juros, Aleksander Kras and Tadeusz Kamisiński

AGH University of Science and Technology, Silencions Sp. Z o.o.

In recent years acoustic metamaterials are broadly investigated in many different fields of acoustics and one of them is noise and vibration mitigation. The best potential show locally resonant metamaterials (LRS), which by creation of band gap effect in flexural wave propagation in structure improve its Sound Transmission Loss (STL). Simulation procedures for STL calculation can be fully analytical or numerical. Analytical solution is fast but it doesn't take into consideration metamaterial geometry. On the other hand numerical solution even when considering small part of periodic structure, is time consuming and can generate numerical errors related for example to the mesh quality and acoustic – structure interaction. In this work combined analytical – numerical method is analyzed as the alternative for STL calculation. This method can be an alternative for basic simulation procedures concerning vibro-acoustic metamaterials, showing that the simulations results match to each other but what is more important this method is less time consuming. Formulas and simulation procedure for the method are presented and compared with analytical and numerical simulation results as well as with STL measurement results.

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## Selected aspects of acoustic treatment of the orchestra pit

Tadeusz Kamisiński and Krzysztof Brawata

AGH University of Science and Technology

The orchestra pit is not a friendly workplace for musicians, while the need to ensure their interaction with the stage and audience increases the related requirements significantly. The aim of this paper is to analyse different strategies for the acoustic treatment of the orchestra pit in the context of the expected results. Based on the simulation studies as well as on the experimental evaluation performed in the well-equipped orchestra pit of the Krakow Opera, the representative acoustic parameters allowing for an effective assessment of the results of an acoustic treatment have been identified. Further, the comparison of the reverberation time T20 and EDT measured for different variants of the interior of the orchestra pit has clearly justified the proposed use of sound diffusing and absorbing systems in such an environment, as they spread the energy of the first sound reflections in time, reducing the risk to the musicians' hearing. Moreover, deployment of elements able to reflect and disperse sound within the orchestra pit guarantees the adequate audibility among the musicians.

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## Acoustic reflective systems for concert halls - selected projects

Tadeusz Kamisiński

AGH University of Science and Technology

Acoustic reflective systems in a concert hall are the fundamental interior fittings that ensure predictable direction of sound reflection. Reflection from hard, flat or otherwise shaped structures allows for the preservation of valuable acoustic energy in the interior, while soft elements that absorb sound lose this energy irretrievably. The paper presents selected acoustic structures developed by the team of scientists from AGH and implemented in concert halls. A diffusion panel made of PVC with the extrusion method, a system of super-stage reflective panels, an orchestral barrier with adjustable elements and the structure of optimized Schroeder diffusers are shown. The implementations of inventions were presented on the example of the Opera in Lviv, the Variete Theater in Krakow and the Krakow Opera. Acoustic tests of materials, developed structures, acoustic parameters of concert interiors as well as information collected from users of adapted interiors will be used for further works.

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## Conditions for multiple acquisition of echoes from stationary targets in successive active sonar transmissions.

Lech Kilian, Aleksander Schmidt and Mariusz Rudnicki

Gdańsk University of Technology

The highest possible number of contacts with a detected target is clearly decisive in echolocation on the possibilities of echo processing to optimize the estimation of distinctive characteristics of the observed target. In hydrolocation, the slow propagation of acoustic waves in water limits the number of sonar contacts with detected targets in the vertical cross-section of the transmitting-receiving beam. The article considers model conditions for acquiring multiple contacts with stationary targets detected by various sounding methods - with echosounders, classic active sonars and side looking sonars. Appropriate formulas explicitly linking the possible number of echo signals from the target in a specific geometry of the survey performed at the assumed speed were presented. These formulas are not complicated and intuitively clear, but their value lies in the ability to immediately combine the speed of the vessel with the survey effects and can be a clear argument for forcing the navigation unfriendly low speed.

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## Metrological capabilities of the acoustic testing laboratory - small anechoic chamber at AGH Department of Mechanics and Vibroacoustics

Maciej Kłaczyński and Wiesław Wszołek

AGH University of Science And Technology

The small anechoic chamber is part of the research facilities of the Department of Mechanics and Vibroacoustics in AGH University of Science and Technology in Krakow and is a room corresponding to a free field, whose walls, ceiling and floor provide both very good sound absorption and isolation from external interference. The dimensions of the free space inside the chamber are 4.4 m x 3.8 m. X 3.6 m. The chamber was commissioned in the mid-1980s and has not undergone upgrades since. In December 2021, the upgrade of the small anechoic chamber was completed. As particularly important was the replacement of 5.5 thousand pieces of acoustic wedges made of polyurethane foam, which due to the aging process lost their sound-absorbing properties, for wedges made of mineral wool with glass fiber, adjustment of lighting inside the chamber to current standards, as well as equipping the chamber with a signal crossover and devices to regulate and monitor meteorological conditions inside the chamber. The paper presents a study of the properties of the small anechoic chamber in accordance with accepted standards for this type of rooms and its current research capabilities in the field of vibroacoustics in technology and medicine.

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## Assessment of Wide-Sense Stationarity of an Underwater Acoustic Channel

Iwona Kochanska

Gdansk University of Technology

The performances of Underwater Acoustic Communication (UAC) systems are strongly related to the specific propagation conditions of the underwater channel. Designing the physical layer of a reliable data transmission system requires a knowledge of channel characteristics in terms of the specific parameters of the stochastic model. The Wide-Sense Stationary Uncorrelated Scattering (WSSUS) assumption simplifies the stochastic description of the channel, and thus the estimation of its transmission parameters. However, shallow underwater channels may not meet the WSSUS assumption. This paper presents a method for testing the Wide-Sense Stationary (WSS) part of the WSSUS feature of a UAC channel on the basis of the complex envelope of a received probe signal. Also, the dependence of the Wide-Sense Stationarity of the UAC channel on its bandwidth is discussed.

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## Transmission loss of absorptive mufflers lined with expanded clay granulates

Krzysztof Kosała

AGH University of Science and Technology

The article presents the results of tests on sound attenuation by two types of cylindrical absorptive mufflers of the same length and with different diameters of chambers filled with expanded clay granulates. Using a laboratory stand for testing acoustic mufflers with an impedance tube, the transmission loss parameter was determined. To compare the effectiveness of sound attenuation, the transmission loss of mufflers without sound absorbing material was also determined. The results of these tests were compared to the results obtained with the use of a known calculation model for reflective mufflers. Using an impedance tube, the normal incidence sound absorption coefficients of the expanded clay granulates with thicknesses of material samples from 10 to 100 mm were determined. The dependance between the sample thickness and the first resonance frequency of the sound absorption coefficient was determined, which was then used in the proposed calculation model of the effectiveness of the cylindrical absorptive muffler with expanded clay granulates. Using the proposed theoretical model, the results of transmission loss calculations, satisfactory for engineering applications, were obtained.

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## GFCC-based x-vectors for Reinke's edema detection

Katarzyna Kotarba

AGH University of Science And Technology

Automatic assessment of voice disorders is one of the most important applications of speech signal analysis. Various algorithms utilizing both sustained vowels and continuous speech have been successfully used to perform detection of many voice pathologies e.g. Dysphonia, laryngitis, and vocal folds paralysis. However, algorithms described in literature used for classification of Reinke's edema – one of the most severe smoking-induced voice conditions – are scarce and rely mostly on speech signals containing sustained vowels. In this paper, a method incorporating gammatone frequency cepstral coefficients (GFCC) based x-vectors extracted from continuous speech is presented. The extracted x-vectors are used to train a SGD classifier performing Reinke's edema detection. For validation folds, the proposed method yielded AUC ROC, accuracy, recall, and specificity of 0.96 (±0.03), 0.94 (±0.02), 0.92 (±0.03), and 0.94 (±0.02), respectively. For testing set, the method yielded AUC ROC, accuracy, recall, and specificity of 0.98, 0.89, 0.88, and 0.89, respectively.

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## Lossy coding impact on speech recognition with convolutional neural networks

Mateusz Kucharski

Wrocław University of Science and Technology

This paper presents research of lossy coding impact on speech recognition with convolutional neural networks. For this purpose google speech commands dataset containing utterances of 30 words was encoded using four most common all-purpose codecs: mp3, aac, wma and ogg. A convolutional neural network was taught using part of the original files and later tested with the rest of the files, as well as their counterparts encoded with different codecs and bitrates. The same network model was also taught using mp3 encoded data showing the biggest loss in effectiveness of the previous network. Results show that lossy coding does have an effect on speech recognition, especially for low bitrates.

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## Influence of the PZT actuator arms asymmetry on the LQR control parameters in the active reduction vibration of beams

Romuald Kuras

Rzeszow University of Technology

The paper deals with the active reduction of beam vibrations using piezoelectric transducers (PZT). The LQR parameters of the control of an asymmetric actuator (a-PZT) depending on the length of its arms were analysed. The results were compared to those of the symmetrical PZT (s-PZT), so far used as standard. The actuator is modeled with two bending moments or two pairs of forces. The design of the LQR controller also took into account the location of the PZT on the beam. The reduction efficiency can also be increased by using asymmetrical PZT. To obtain the vibration asymmetry of the beam, simply supported at both ends, an asymmetrically point mass was added. The LQR control was applied to an asymmetric actuator on the beam. Two-parameter optimization was used to find the optimal proportions of the a-PZT arms. For such a problem, the LQR control parameters were found, which ensure the highest efficiency of vibration reduction.

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## Vibration analysis and modelling of light-weight robot arms

Ryszard Leniowski and Michał Wroński

Rzeszów University of Technology

Light-weight robots are a new generation of devices intended to be used not only for industrial tasks, but also to perform actions in the human environment. This work presents an analysis of selected basic problems related to the vibration properties of light-weight robot arms. The study of vibration is based on the analysis of the root locus on the plane of complex variables. It turns out that their distribution is non-stationary and depends on the parameters of the model (arm geometry, material parameters), but also depends on the type of realised motion, which is not so obvious. Depending on the manoeuvres conducted (acceleration / deceleration), the system may lose (or increase) its oscillating properties at higher frequencies, as well as introduce a structural (measurable) delay. Recognition of the discussed properties along with their modeling is an important element of the design process of the control system of modern, light-weight robots.

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## EMD-based time-frequency analysis methods of non-stationary audio signals

Marcin Lewandowski and Salomea Grodzicka

Warsaw University of Technology

To ensure that any time series data is appropriately interpreted, it should be analyzed with proper signal processing tools. The most common analysis methods are kernel-based transforms, which use base functions and their modifications to represent time series data. This work discusses an analysis of audio data and two of those transforms - the Fourier Transform and the Wavelet Transform based on apriori assumptions about the signal's linearity and stationarity. In audio engineering, these assumptions are invalid because statistical parameters of most audio signals change with time and cannot be treated as an output of LTI system. That is why recent approaches involve decomposition of a signal into different modes in a data-dependent and adaptive way, which may provide advantages over kernel-based transforms. Examples of such methods include empirical mode decomposition (EMD), extended EMD (EEMD), variational mode decomposition (VMD), or singular spectrum analysis (SSA). Simulations were performed with speech signal for kernel-based and data-dependent decomposition methods, which revealed that evaluated decomposition methods are promising approaches to analyze non-stationary and nonlinear audio data.

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## Development of a Calibrator for Very Low Frequency Pressure Sensors

Karol Listewnik

Gdyna Maritime University

The aim of this article is to present a calibrator designed to calibrate pressure sensors of very low frequencies from 0.1 Hz to 10 Hz. Due to the growing demand for the research of the marine environment in the field of underwater noise, carried out in accordance with Directive 2008/56/EC, many models of autonomous underwater noise recorders, including those in the infrasound band, have been developed. Very low frequency pressure sensors are also used to measure the hydrodynamic field of the ship, both for the optimization of the hull shape and in military applications to estimate the risk of a mine explosion. The basis for ensuring the reliability of the recorded data is the calibration of the pressure sensors and, if possible, the calibration of the entire measuring system. Based on the analysis of the literature, previously developed calibrators of low-frequency pressure sensors, it was decided to use a very low-frequency acoustic coupler using the vibrating water column method. A low-frequency acoustic coupler located in the Underwater Acoustics Laboratory of the Central Office of Measures was used to develop the new calibrator, with the use of which pressure sensors were tested at very low frequencies. The conducted research and conclusions from these studies allowed to design a calibrator for very low frequency pressure sensors.

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## Experimental and CFD study of the selected acoustic helicoidal resonator as a final element of an air installation

Wojciech Łapka and Piotr Jakubowski

Poznan University of Technology, Maritime Advanced Research Centre, Environmental Laboratories Division

The work presents an analysis of the selected helicoidal resonator as the end element of the air installation. Laboratory tests of the acoustic pressure level were performed at the outlet of the air installation in a room for different flow speeds. The measurement methodology in accordance to standards PN-EN ISO 3741 and PN-EN ISO 5135, which describes the acoustic test facilities, instrumentation and procedures to be used for precision grade determination of sound power levels in octave or one-third-octave bands of a noise source in reverberation test rooms.. The numerical CFD tests show the shape and range of the air stream in the room in the function of the distance from the installation outlet for different flow speeds. Due to the helicoidal shape of the analyzed acoustic resonator, the air stream also turns, which can be used to effectively mix air in the room.

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## Impact of cavity edges shape on aerodynamic noise

Paweł Łojek and Ireneusz Czajka

AGH University of Science and Technology

In this article, the analysis of influence of cavity edge shapes on flow-generated noise is performed. The acoustic wave propagation in the channel, that result from the flow, was analyzed. A channel with rectangular cavity and perpendicular edges was adopted as the reference object, the shape of upstream and downstream edges was modified. The analyzed problem is a coupled problem, and due to low flow velocities it was assumed that it is a unidirectional coupling. Solving such a problem requires solving the equations describing the flow field. On the basis of the pressure field obtained from the flow computations, the source terms were determined. They were used in the equation describing the field of acoustic disturbances, perturbed convective wave equation (PCWE). Numerical calculations and analysis of the obtained results were performed with the use of open source software. OpenFOAM software was used to solve the flow equations and OpenCFS to solve the wave propagation equations. Due to the size of the problem, the calculations were performed using the computing resources of the PLGrid infrastructure and the Prometheus supercomputer. The research showed a significant influence of the modification of the shape of the cavity edges on the generated noise. The change of downstream corner to both rounded or chamfered, allowed for significant reduction of noise in the entire analyzed band and allowed for the reduction of overall sound pressure level (OASPL) by 5dB. Modifications of the upstream edge did not bring such differences, change in OASPL was up to 1 dB. The obtained spectra of the sound pressure level showed compliance with the calculated natural frequencies of the analyzed object, as well as with some of the Rossiter modal frequencies, typical for the phenomena occurring in the cavities.

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## Numerical reconstruction of Cieszyn flute sound

Paweł Łojek, Ireneusz Czajka and Katarzyna Suder-Dębska

AGH University of Science and Technology

The paper presents part of the work on the functional numerical reconstruction of a historic mammoth flute from the collection of the Museum of Cieszyn Silesia. The flute was discovered in 2012 in Cieszyn. When it was found, it was already damaged, Unfortunately it was further deconstructed during conservation. Therefore, reverse engineering techniques had to be used to reconstruct the original shape of the instrument. The 3D scans and geometric models of the flute were developed at the Faculty of Architecture of the Wrocław University of Science and Technology. They were used for numerical sound reconstruction. The work on the reconstruction consisted of several stages, the most important of which were: determining the characteristics of the excitation and of the flute itself as a resonant system. The first of these stages was carried out using the methods of computational fluid dynamics (CFD) and Curle's aeroacoustic analogy. The second stage was to solve eigenvalue problem using the finite element method The computations allowed to define the musical scale of the instrument. At the same time, the work carried out at the Faculty of Architecture of the Wrocław University of Technology allowed for the physical reconstruction of the flute in the form of a 3D print. The object reconstructed in this way was used to verify the results obtained numerically.

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## Aeroacoustical studied of the serrated ventilation dampers

Joanna Maria Kopania, Kamil Wójciak, Patryk Gaj and Grzegorz Bogusławski

Lodz University of Techbnology, Institute of Power Engineering

The serrated ventilation dampers for regulation of airflow volume were tested. The computer fluid flow analysis was conducted using the Comsol program. The nature of the flow through the serrated ventilation damper was analyzed to identify the different turbulence regions formed on the airflow field. Additionally, the aerodynamical and acoustical parameters of these blades of ventilation dampers with different serrated trailing and/or leading-edge were studied. The aeroacoustic studies were done in the reverberation room. The sound power level and loss coefficient were determined for the studied models.

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## Analysis of sound absorption performance of acoustic absorbers made of fibrous materials

Mirosław Meissner and Tomasz Zieliński

Institute of Fundamental Technological Research, Polish Academy of Sciences

Absorbing properties of multi-layer acoustic absorbers were modeled using the impedance translation theorem and the Garai and Pompoli empirical model, which enables a determination of the characteristic impedance and propagation constant of fibrous sound-absorbing materials. The theoretical model was applied to the computational study of performance of single-layer acoustic absorber backed by a hard wall and the absorber consisting of one layer of absorbing material and an air gap between the rear of the material and a hard back wall. Simulation results have shown that a high thickness of absorbing material may cause wavy changes in the frequency relationship of the normal and random incidence absorption coefficients. It was also found that this effect is particularly noticeable for acoustic absorbers with a large thickness of air gap between the absorbing material and a hard back wall.

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## Acoustic indices in the analysis of the soundscape of the Kościeliska Valley in the Tatra National Park – case study

Dorota Młynarczyk and Jerzy Wiciak

AGH University of Science and Technology

The development of our civilization and increasing noise pollution are strongly connected. In 2021, the Tatra National Park was visited by a record number of tourists - about 4 million 600 thousand. The previous record was broken in 2018 - then the Polish Tatra Mountains were visited by 3 million 800 thousand. People. The aim of the paper is analysis of noise pollution and soundscape of the most popular national park in Poland – Tatra National Park. The Kościeliska Valley was selected for the study, because it is the second area in the park in terms of the number of tickets sold according to the statistics kept by the Tatra National Park. The paper presents the results of the analysis of acoustic measurements and ambisonic recordings made in four seasons using classical method and the soundscape method. In addition, psychoacoustic parameters and acoustic indices such as: loudness, sharpness, or roughness, ACI (acoustic complexity index), NDSI (normalized difference soundscape index), BI (bioacoustic index), ADI (acoustic diversity index), AEI (acoustic evenness index) were calculated.

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## Modelling of an acoustic wave scattering on the aircraft surface using the boundary element method

Dawid Nowicki, Katarzyna Suder-Dębska and Ireneusz Czajka

AGH - University of Science and Technology

Sound localization tools are important in the environmental protection and the human searches. The article is one of the stages of the implementation of the concept of using aircraft to localize sound sources. The use of a fixed-wing aircraft instead of a multirotor would increase the total flight time, and expand the surveyed area. It is important to determine the most favorable positions of the receivers on the surface of the aircraft. The scattering effects of the sound waves coming from the ground source and aircraft engine on the acoustic field on the aircraft surface are not homogeneous. In the article the authors present the modelling of the scattering of the sound waves over the airplane surface with the usage of boundary element methods. After determining the effects from the sound source on earth and from the aircraft engine the conclusion was made, that the influence from the engine noise is greater than that from the ground source, and in order to localize the low amplitude signals, the aircraft need to glide. Considering only the effects of the ground source, the optimal areas for the microphones placement were determined.

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## Improving the acoustic climate of the city park

Janusz Piechowicz and Sylwia Gola

AGH-University of Science and Technology

A city park is a place where, in an urbanized world, a person can experience nature. It is the green lung of the city, the numerous trees and shrubs in parks improve the air condition, especially in densely populated agglomerations. It is a meeting place and allows you to spend time actively. It allows recreation and relaxation for city residents. City parks are desirable, especially in city centers, densely populated and built-up places. Designing parks should meet people's needs. It is extremely important to properly select space elements that will positively affect the comfort of use. Apart from the obvious issue of taking care of the park's aesthetics, its flora and appropriate equipment, an important role is played by an appropriate acoustic climate. Hence, when designing open spaces such as city parks, the cooperation of specialists in many fields is important: landscape architects, town planners, people dealing with nature protection, artists, and finally acoustics. This allows you to create a space that will meet the needs and expectations of residents. The paper shows the possibility of taking steps to correct the existing acoustic climate in selected places in the city park.

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## Lightweight floor screed with increased impact sound reduction

Adam Pilch, Piotr Duda and Jarosław Rubacha

AGH University of Science and Technology, JP Cover sp. Z.o.o.

Increasing requirements of users force to provide still better solutions, that reduce impact noise. A lightweight floor screed can be a favorable solution for existing buildings with limited ceiling load capacity, where high effective floating floors are too heavy to be used. In the paper further development of the impact sound reduction measurement method for small lightweight floor screed samples is presented. In order to protect the top layer of the sample from the hammers of the tapping machine, a thin concrete layer was coupled with the sample. What is more, a thin layer of sand below the sample was tested in order to improve the connection between the sample and the concrete floor. Based on obtained results, the concrete top layer and the sand bottom layer reduce slightly the effectiveness of the screed but decrease significantly the uncertainty of the results.

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## Simulation of Infeasible Instruments in a Sound Synthesizer – Implementation and Control

Marek Pluta

AGH University of Science And Technology

Sound synthesis using mathematical modelling of musical instruments is a method particularly well suited for live performance using a physical controller. Depending on model complexity, it may be able to reproduce various subtle phenomena related to excitation and real time control of an instrument, providing an intuitive tool for a musician. A variant of physical modelling synthesis, referred to as the simulation of infeasible instruments, uses a model of an object that does not have a physical counterpart. Such model has some properties of a real object, which makes it still intuitive for a musician. However, other features, such as geometry, or material properties, are intentionally altered in such manner, that it could not function in reality. These infeasible features introduce new properties to the sound it produces. The study presents a few such models with a discussion regarding their implementation and control issues in a real-time sound synthesizer.

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## How to determine the annoyance due to wind turbines

Anna Preis

Adam Mickiewicz University, Department of Acoustics, Faculty of Physics

In the study of annoyance due to wind turbines, the dominant approach takes into account only the noise generated by these sound sources. In my speech, I will point out the disadvantages of the approach aimed at creating a one-factor noise assessment indicator for wind turbines, based on the measurement of the level of sounds produced by them (LDWN or LN). I cite works which show that the LDWN or LN value alone is not enough to explain why for the majority of people living near wind turbines their noise is extremely annoying, despite the fact that the measured sound level values are relatively low. I will also refer to an attempt to introduce a correction to the one-factor noise assessment index by taking into account the time variability (amplitude modulation) of the sound generated by wind turbines. I will present arguments "for" and "against" taking into account corrections for infrasound or low-frequency components present in the noise spectrum of wind turbines. I will also refer to the recently proposed so-called aggregate annoyance concept. Such a multifactorial indicator includes not only the above-mentioned noise parameters, but also non-acoustic characteristics (mainly visual), which are supposed to influence the overall perception of the annoyance associated with wind turbines. In the presentation, I will also compare the noise limits for wind turbines in selected European countries with those in force in Poland. Furthermore, I will discuss the limitations of the existing Polish regulations and present a proposal for determining the annoyance related to wind turbines, developed jointly under the Polish-Norwegian grant.

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## Psychoacoustic metrics in psychological diagnosis of noise annoyance

Jan Radosz

Central Institute for Labour Protection - National Research Institute

Aim of the study was to asses noise annoyance in relation to psychoacoustic metrics of sound in office environment. The Vienna Test System was used for this purpose. Virtual office acoustic environments were developed with sources of different psychoacoustic parameters (loudness, sharpness, fluctuation strength, roughness) but with a constant A-weighted sound pressure level of 55 dB – sound environment with conver-sations, sound environment with office equipment (computers, printers, telephones) and sound environment with all office noise sources together. The reference environment was a quiet office room with no additional noise sources. Recorded real noise sources were transferred to a virtual 3D sound environment and converted into binaural sound, which was then played back on headphones. During the exposure to each of the acoustic environments, the subjects performed the ALS test (work performance series) and COG test (measurement of attention and concentration) and then assessed the given environment using a questionnaire. The paper presents the results of the statistical analysis - despite different psychoacoustic metrics of office noise sources in the examined acoustic environments, no statistically significant differences were observed in the results of psychological tests.

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## Ultrasonic studies of colloidal capsules fabricated from Pickering droplets

Filip Ratajczak, Rafał Bielas and Arkadiusz Józefczak

Adam Mickiewicz University in Poznań

Small capsules with shells made of microparticles became of great interest due to their potential in many fields. They can find applications in the food or pharmaceutical industry (e.g., in controlled drug release) because of their size and behavior under external stimuli. The capsules can be fabricated from particle-stabilized emulsions (Pickering emulsions) by sintering together particles that cover Pickering droplets at high temperatures. One of the problems with such an approach is accurately controlling whether particles are already sintered and create the rigid capsule shell of a capsule. We propose here the use of a non-destructive ultrasound method for monitoring of rigidity of the capsule shells. By measuring the velocity of ultrasonic wave propagating through emulsion or suspension of capsules, the change in the adiabatic compressibility before and after heating can be calculated for a quantitative evaluation of the encapsulation process. Acknowledgments: This work was supported by the project no. 049/34/UAM/0043 (Study@Research – „Excellence Initiative - Research University" Programme).

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## Analysis of the possibility of shaping the sound diffusion coefficient of diffusers based on acoustic metamaterials

Jarosław Rubacha

AGH University of Science and Technology

The article presents research on the influence of the type of metamaterial used in a diffuser on the sound diffusion coefficient. Diffusers composed of slots loaded with a quarter-wave resonator or a Helmholtz resonator were investigated. Such solutions induce dispersion and the slow sound effect to increase the effective depth of the quarter-wave resonator. The numerical models of diffusers were used to computation of the sound diffusion coefficient. The results of calculations for diffusers based on different metamaterials were compared with each other and compared with the results of calculations for Schroeder diffusers. As a result, it was shown that acoustic metamaterials affect the frequency band of the diffuser and the values of the obtained sound diffusion coefficients.

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## Localization of sound sources in binaural reproduction of first and third order ambisonics.

Amaia Sagasti, Agnieszka Paula Pietrzak, Ricardo San Martín and Rubén Eguinoa

University of Navarra, Warsaw University of Technology

The use of higher-order ambisonics in spatial sound recordings makes it possible to increase the accuracy of recording information about the direction from which the sound comes to the listener. However, with binaural ambisonic sound reproduction, the listener's ability to locate the sound source accurately may be limited. This paper presents a comparison of the listener's ability to locate a sound source during binaural listening to recordings made with first and third order ambisonic microphones. The analysis was carried out for two types of signal: pink noise and ringing sound. The analysis of localization errors depending on the ambisonics order, azimuth and elevation angles as well as the type of signal is presented. The obtained data indicate that in binaural reproduction of the ambisonic sound the localization errors in the azimuth plane were smaller for the third order ambisonics, compared to the first order. In the elevation plane both for first and third order the errors were significant.

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## Synchronization system for underwater acoustic communications using in shallow waters

Jan Schmidt and Aleksander Schmidt

Gdansk University of Technology

A reliable synchronization system of the transmitted data frame has a significant impact on the efficiency of the underwater communication system. This applies in particular to communication systems dedicated to work in shallow waters, where the phenomenon of multipath permanently occurs. To overcome these difficulties, the concept of a synchronization system consisting of two broadband signals of opposite monotonicity was presented. The method of receiving these signals has been described in detail. The stochastic channel model with Ricean fading and the Watermark simulator was used to test the efficiency of the synchronization system in the underwater multipath channel.

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## Analysis of the possibility of supervision of mechanical devices based on the measurement of the vibration level and one-class classifiers

Ryszard Schossler, Marcin Grochowina and Lucyna Leniowska

University of Rzeszów

The paper presents the concept of diagnosing the technical condition of mechanical devices. The test is based on a non-invasive vibration analysis technique combined with the use of artificial intelligence method. The object of the research is an electric motor for which vibrations were recorded by a vibration sensor based on four 3-axis digital accelerometers and MPU-6050 gyroscopes. The effectiveness of the classification methods using the two-class and one-class classification was compared. It has been shown that the use of an incomplete pattern of the vibration model and a single-class classifier allows for effective detection of anomalies in the operation of an induction motor. Satisfactory efficiency of the classification was achieved, despite the limitation of the teaching set only to the information obtained during the correct operation of the device. The described method is universal and can be used to diagnose the technical condition of many different types of technical devices.

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## Comparison analysis of noise generated by wind turbines with other noise sources in outdoor environment

Andrzej Staniek, Janusz Kompała, Alicja Bramorska and Cezary Bartmański

Central Mining Institute

The paper presents the comparison analysis of noise generated by wind turbines with those generated by other sources like ventilation shafts of working coal mines. The aim of the research was to compare the frequency and amplitude distribution of that sources, especially in the infra range. Eventually it is to be exploited in the estimation of possible environmental impact on human annoyance or severity. Additionally a measurement position of a microphone in relation to ground surface was observed. The possible influence of wind speed was also monitored.

Measurements at ground level were performed according to the standard PN-EN 61400-11:2013-07 and in vertical position, where the microphone was mounted "upside down" with the grid flush with the board. The microphone was mounted asymmetrically to reduce the influence of the edges of the board. The results and discussion are presented. Keywords: wind turbines, infrasound, human annoyance, sound propagation.

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## Recognition of the speaker's age group and gender for a large database of telephone-recorded voices

Piotr Staroniewicz

Wroclaw University of Science and Technology

The paper presents the results of automatic recognition of age group and gender of speakers performed for the large SpeechDAT(E) acoustic database for Polish language, containing recordings of 1000 speakers (486 males/514 females) aged 12 to 73, recorded in telephone conditions. Three age groups were recognised for each gender. Mel Frequency Cepstral Coefficients (MFCC) were used to describe the recognized signals parametrically. Among the classification methods tested in this study, the best results were obtained for the SVM (Support Vector Machines) method.

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## Sound power level estimation - choice of a prior distribution

Bartłomiej Stępień

AGH University of Science and Technology

Bayesian inference can be used to estimate the sound power level of sources. This method requires knowledge of two densities: sample and prior. The sampling distribution is determined from the measurement sample from which the sound power level is determined. On the other hand, the prior distribution represents the researcher's initial knowledge of the source under investigation. Most often, this distribution is determined based on data from previous measurements. In the absence of such data, the shape of the prior distribution can be assumed on the basis of existing knowledge. In this study, the influence of the form of the prior distribution on the sound power level results was analysed. Real measurement data was used for this purpose. The results obtained by Bayesian inference were compared with the results of the sound power level determined by the precision method in an anechoic chamber. Inference was carried out based on the results of statistical tests at a significance level of $\alpha = 0.05$.

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## Auditory presentation of the environment for the visually impaired

Paweł Strumiłło and Michał Bujacz

Lodz University of Technology, Institute of Electronics, Łódź, Poland

The lecture will review research on electronic systems assisting blind people in independent mobility and navigation. The main focus will be on sensory substitution techniques, which use sounds to visualise the surroundings for the visually impaired. The lecture will present systems developed at the Institute of Electronics of the Technical University of Lodz.

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## Validation of a 1:8 Scale Measurement Stand for Testing Airborne Sound Insulation

Agata Szeląg, Bartosz Przysucha, Katarzyna Baruch, Krzysztof Brawata and Dominik Mleczko

Tadeusz Kościuszk Kraków University of Technology, Lublin University of Technology, Gorycki & Sznyterman Sp. Z o.o., AGH University of Science and Technology

The work contains a detailed description of the design and validation of a measurement stand for testing the airborne sound insulation of specimens made at a small scale. The stand is comprised of two coupled reverberation rooms in which the geometry represents the full-size reverberation rooms used at the AGH University of Science and Technology at a 1:8 scale. The paper proves that both the scaled measurement stand and the testing methodology conform to the ISO 10140 standards, and that the obtained measurement uncertainty does not exceed the maximum values specified in ISO 12999-1. Moreover, the calculated uncertainty of measurements obtained for the 1:8 scale stand is comparable with the typical uncertainty given in ISO 12999-1 and the uncertainty obtained on the full-scale measurement stand. In connection with the above, the authors have proved that by using the scaled-down measurement stands, one can obtain reliable and repeatable results of measurements of airborne sound insulation.

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## Metasurface acoustic lens: design, simulation, 3D-printing and acoustic testing

Bartłomiej Sztyler and Paweł Strumiłło

Lodz University of Technology, Institute of Electronics

This work focuses on acoustic metamaterials as structures that interact with sound waves. Metamaterials are specially created structures that have properties not found in nature. Controlling acoustic waves in practical applications can often be difficult due to the size of structure needed at a given wavelength. Dividing the family of metamaterials into groups based on their spatial structure, we can distinguish between one- and three-dimensional structures. This article is devoted to metasurfaces, or two-dimensional structures. Metasurfaces exhibit unique properties of wave manipulation even at low frequencies. Such structures are cyclically composed of elementary blocks called meta-atoms. Theoretical considerations supported by the literature have enabled the development of an example metasurface model. A series of numerical simulations were carried out and an example model was produced using 3D printing technology. The simulation results show that unnatural refraction can be obtained for a flat metastructure with a thickness less than the specified acoustic wavelength. The experimental results show the assumed focusing effect of the lens, but not as accurate as in the simulation.

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## The specificity of acoustic measurements of rail vehicles

Anna Świerkoska

Łukasiewicz Research Network – Poznań Institute of Technology

The article is a review of issues related to acoustic measurements of rail vehicles using standardised methods related to the documents regulating the entry into service of objects. In the paper types of tested objects and the applicable requirements are presented, also the exceptions and conditions determining the needlessness of the tests is analysed. Examples of measurement results showing the condition of currently manufactured or modernized vehicles in terms of noise emissions and the comfort of passengers and drivers are presented. Factors limiting the possibility of noise level reduction and, consequently, meeting the requirements were considered. The conducted analysis of the research objects, requirements, methods, results typical for given types of vehicles and limitations is based on normative and legal documents, as well as on the conducted measurements and own experience.

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## Vibration reduction assessment of layered acoustic metamaterial

Patrycja Świrk, Wojciech Żyłka, Lucyna Leniowska and Marcin Grochowina

University of Rzeszów

Acoustic meta-materials offer an approach to reducing the vibration and noise transmission through layered panels. In this paper the investigation of constructed meta-material for reduction of low frequency vibration and noise is a major concern. The key concept underlying this approach is to construct the meta-material as a highly-distributed system of tuned point masses that introduce instead of low resonance frequency one or more bands of higher frequency. They can be then successfully damped with passive methods. Using the modes method, a meta-material system with distributed point masses integrated into the honeycomb core was designed to be a representative layered panel. To determine the dynamic response of the global sandwich panel, the meta-material system was tested for 70 Hz excitation. The obtained results confirm the possibility of tuning the considered layered meta-material to the excitation frequency and shifting low frequencies towards higher frequencies.

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## Cartesian robot for enhancing the study of stringed instruments

Daniel Tokarczyk

AGH University of Science and Technology

The paper describes the design and the implementation of a cartesian robot for the purpose of enhancing the research of string musical instruments. Paper describes how the design requirements were set for the robot to be able play on plucked string instruments, and also presents the implementation of the system. The robot is built modularly, on an aluminium profile frame, this enables the installation of instruments of various sizes and types, e.g. Acoustic, electric or bass guitars. The robot is also equipped with possibility to mount different end effectors, although for the article only a static pluck mount end point is presented. The paper also presents the systems possibilities of application in research ot string instruments.

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## Effect of changing body position on selected voice parameters

Karolina Węglarz, Wiesław Wszołek and Daria Hemmerling

Andrzej Frycz Modrzewski Krakow University, Carpathian State College in Krosno, AGH University of Science and Technology

Correct posture is a key element in the proper functioning of the entire body. Both defects and postural disorders lead to overload syndromes and degenerative changes in the musculoskeletal system. Different body positions correlate with respiratory parameters, which form the basis in modifying loudness and accentuation when speaking or singing Body posture can affect the quality of the voice signal and its fatigue. As movement and duration intensify, vocal effort increases. What is still open, however, is the problem of speech signal evaluation, especially in order to obtain assessments useful in the context of supporting medical diagnosis, optimizing therapy and monitoring rehabilitation. Meanwhile, such evaluations are what we need in medicine, rehabilitation and sports. This paper presents excerpts from a study of the effects of changes in posture and fatigue in healthy subjects, and those with phonation disorders, on changes in the acoustic parameters of the speech signal.

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## Piezoelectric square based sensor-actuator hybrid in vibration reduction

Jerzy Wiciak and Roman Trojanowski

AGH University of Science and Technology

This paper presents the results of comparison of vibration reduction levels between standard square based piezo actuators and piezoelectric sensor-actuator hybrids. Modelling was done using FEM method in ANSYS software. Model consisted of a steel plate with piezo elements attached. One of the elements was used as an actuator to excite plate's vibrations. The other was either a standard homogeneous square based actuator or a sensor actuator hybrid with 2 possible sizes of the sensor part of said hybrid. Harmonic analyses were performed for the 1st, 2nd, 4th and

5th mode shapes with the goal function being the minimalization of displacement vector sum of a number of nodes (there were 3 possible cases). Obtained vibration reduction levels ranged from almost 26 dB to more than 43 dB, with no significant differences in terms of obtained levels between standard actuators and sensor-actuator hybrids. The results also didn't show any significant changes for vibration level reduction when reducing the size of sensor part of sensor-actuators while somewhat mitigating the increase in voltage needed to achieve said reduction levels.

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## Correlation between the shape of substitution ducts and insertion loss of silencers

Kamil Wójciak and Joanna Maria Kopania

Institute of Power Engineering, Lodz University of Technology

Silencers are typical devices used for the reduction of noise in ventilation systems which can be found in almost all industrial, service or residential installations. Determination of acoustic parameters for specific HVAC devices, like silencers, are in the scope of specialized laboratories. With the silencers two main parameters should be taken care of, the first one is sound attenuation and the second one is pressure losses. In the presented paper, the focus is on measurement methods described by standard ISO 7235:2009. This standard specifies the methods for determining the sound power level of the flow noise generated by silencers, the total pressure of silencers and the insertion loss of silencers with and without airflow by using the substitute object. In this work, we focused on the correlation between the shape of the substitution duct and its acoustic parameters and relation to this with the final result of insertion loss of silencer.

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## Noise-controlling casings

Stanislaw Wrona

Silesian University of Technology, Department of Measurements and Control Systems, Gliwice, Poland

Some of the most common noise and vibration sources are devices and machinery, and commonly used sound-absorbing materials are ineffective, often causing further problems such as increased size, weight and potential to overheat. This study summarizes and compares alternative noise-reducing strategies that can be applied to device casings. Depending on the required performance and the availability of energy sources, three approaches can be distinguished: passive (no external energy is needed, but performance is limited), semi-active (little energy is needed, but performance achieves higher values) and active (best performance, but an external energy source is needed). Discussed solutions offer two very important benefits, which are global noise reduction (in an entire enclosure or the surrounding space) and compact technology (contrary to other active noise control solutions requiring a large number of secondary sources and distributed sensors). Applications include industrial devices, household appliances, vehicle or aircraft cabins and more.

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## Measurement of the surface reflectance of an acoustic wave using wave packets propagating in a circular waveguide

Piotr Wrzeciono and Michał Szymański

Institute of Information Technology, Warsaw University of Life Sciences

The main idea of the measurement presented in this paper was to separate the incident wave from the reflected wave. For this purpose, short wave packets and a sufficiently long waveguide with a circular cross-section were used. Several types of wave packets were developed and used in the experiment. We found that a wave packet of 5 ms duration could be propagated in a waveguide of length 5.6 meters without significant sound level losses. We used an audio interface operating at a sampling rate of 96 kHz in the measurements. The limit of wave propagation without dispersion phenomenon was determined. The developed measurement methodology made it possible to maintain the same air temperature along the entire length of the tested waveguide since short pulses did not

cause the speaker temperature to rise. Avoiding this effect reduced the measurement uncertainty of the reflection coefficient.

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## Proposal of infra and lowfrequency noise (ILFN) indicators and verification of their usefulness in the assessment of noise annoyance of wind turbines

Tadeusz Wszołek, Maciej Kłaczyński, Paweł Małecki, Paweł Pawlik, Bartłomiej Stępień and Dominik Mleczko

AGH, University of Science and Technology

Available research indicates that lowfrequency noise, especially in the infrasound band, is more annoying than noise in the audible band of similar loudness. Although the reasons for this are not fully known, tonality and time variation (amplitude modulation) are considered to be among the most important factors affecting ILFN annoyance. This paper presents a literature review of indicators used in the assessment of ILFN, based on C and G weighting and C-A difference curves as well as curves related to the loudness threshold. However, due to the low values of measured acoustic energy levels in the low frequency range, often at background level, it was additionally proposed to consider the influence of tonality and amplitude modulation (AM) for annoyance assessment. The statistical spread of the modulation depth L05-L90 was taken as the basis for quantification of amplitude modulation. The research part of the paper presents measurement results in the environment of selected wind turbines at different wind speeds, with extraction of parameters describing tonality, amplitude modulation and distance from background and reference to the hearing threshold curve

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## Musical period as a factor in exposing orchestra musicians to loud sounds

Jan Żera, Paulina Goluch and Agnieszka Paula Pietrzak

Warsaw University of Technology

There are numerous studies on noise exposure and risk of hearing loss among musicians playing in symphonic or chamber ensembles. Typically these studies present data averaged over specific measurement time during which various repertoire is played usually not thoroughly analyzed. This often creates concerns that selection of musical pieces at a time of measurement may be an important factor determining the exposure. Our study was undertaken to briefly examine how the musical repertoires from classical, romantic and 20th century musical periods differ in created exposure (Laeq levels) as determined at close proximity to ears of selected musicians. Results showed that differences can be of 2 to 6 dB (A). In a case of certain instruments, such difference may be considered as a meaningful change in load imposed to musicians hearing.

Organizatorzy:
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Uniwersytet Rzeszowski
Komitet Akustyki Polskiej Akademii Nauk


Otwarte Seminarium z Akustyki (OSA) to największa polska konferencja akustyczna, organizowana przez Polskie Towarzystwo Akustyczne oraz Komitet Akustyki Polskiej Akademii Nauk. Konferencja ta odbywa się corocznie od siedemdziesięciu lat, spełniając rolę integracyjną dla środowiska akustyków polskich. Na konferencji prezentowane są wszystkie działy akustyki, np.: akustyka fizyczna, akustyka techniczna, akustyka środowiskowa, akustyka mowy, akustyka słuchu, akustyka muzyczna, akustyka architektoniczna, itd. OSA umożliwia wymianę doświadczeń, poglądów, metod badawczych, możliwości aplikacyjnych stosowanych przez naukowców i praktyków w różnych gałęziach akustyki oraz przyczynia się do szerszej promocji tej interdyscyplinarnej dziedziny wiedzy.