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Current Comments®

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Introduction

Sometime ago I introduced *Current Contents*® readers to Anthony Cawkell, formerly ISI® 's vice president of research and director of marketing.[1] Several years ago Tony "retired" and is now a consultant to the information industry specializing in communications technology. Recently I asked him if he would update a study he wrote about 10 years ago on the multidisciplinary field of acoustics.[2] Not the least of my reasons for doing so is the field's relation to noise pollution and control, which we've written about previously.[3,4]

While not explicitly stating it, Cawkell has given us the contrasting pictures that emerge upon examining any discipline and its literature—the dichotomy between the literature of acoustics and the literature cited by those in acoustics research, whether pure or applied. It is particularly in the latter that we perceive the widespread social impacts of this field. In one special case, we earlier discussed ultrasound as a diagnostic technique in noninvasive medicine.[5]

In the essay that follows, Tony considers the ways of defining acoustics, examining how citation patterns and the core of acoustics journals have changed since 1974. Then, he gives us his own view of a definition of acoustics.

* * * * *

My thanks to Anthony Cawkell, James Mears, and Eric Thurschwell for their help in the preparation of this essay.

REFERENCES

1. **Garfield E.** A.E. Cawkell, information detective—and ISI's man in the U.K. *Essays of an information scientist.* Philadelphia: ISI Press, 1977. Vol. 1. p. 245-6.
2. **Cawkell A E.** Evaluating scientific journals with *Journal Citation Reports*—a case study in acoustics. *J. Amer. Soc. Inform. Sci.* 29:41-6, 1978.
3. **Garfield E.** Quiet restaurants and noisy discos—there's a time and a place. *Op. cit.*, 1979. Vol. 4. p. 305-8.
4. --------------. The tyranny of the horn—automobile, that is. *Ibid.*, 1984. Vol. 6. p. 216-22.
5. --------------. Noninvasive medicine. Part 2. Newer diagnostic technologies. *Current Contents* (42):3-10, 17 October 1988.

Acoustic Journals and Acoustic Research Activities

By A.E. Cawkell

Beginning with various dictionary definitions, the maverick behavior of the discipline of acoustics is examined through analysis of the frequency of subjects in the *Journal of the Acoustical Society of America*, the citation connections of the core journals of acoustics, and the clustering of research papers. A definition based on recent trends in acoustic research is proposed. However, a historical review of acoustics is also provided.

What Is Acoustics and What Do Acousticians Do?

The *Concise Oxford Dictionary* says (concisely) that acoustics is "the science of sound," while the *Fontana Dictionary of Modern Thought* tells us (expansively) that acoustics is

> all activities concerned with the production, transmission, reflection, dispersion, or reception of sound waves, whether in air or some other substance. It includes such things as the design and manufacture of anechoic chambers where sound waves generated within the chamber are entirely absorbed by the walls of the chamber: acoustic radar (sometimes called sonar) used for depth recording at sea and for the location of shoals of fish, submarines (in war), or sunken wrecks: the design of lecture theatres, sound reproducing apparatus, hearing aids, and magnetostriction oscillators.

The *McGraw-Hill Dictionary of Scientific and Technical Terms* provides two meanings: "1. The science of the production, transmission, and effects of sound. 2. The characteristics of a room that determine the qualities of sound in it relevant to hearing." *Collins English Dictionary* closely follows McGraw-Hill. Acoustics is "1. (Functioning as singular) The scientific study of sound and sound waves. 2. (Functioning as plural) The characteristics of a room, auditorium, etc., that determine the fidelity with which sound can be heard within it." *Chambers Dictionary of Science & Technology* says that acoustics is "the science of mechanical waves including production and propagation properties."

The acoustic journal with the widest coverage, and the largest by far, is the *Journal of the Acoustical Society of America* (*JASA*). Another way of answering the question "What is acoustics?" is to check the subject matter of the papers published in that journal. In Volumes 83 and 84, 1988, numerous abstracts, book reviews, patent details, and so on, were published. About 1,000 full papers are classified in the index under the headings shown in Table 1. The number of papers actually published is smaller because some papers are classified under more than one heading.

Aspects of acoustics chosen for inclusion in the various definitions given earlier do not correspond to areas of high research activity as represented by numbers of *JASA* papers published. The definitions seem to cover physical acoustics, not the medical aspects that are well represented in *JASA*. Perhaps these are felt to be part of "medicine"; certainly the dividing line is blurred. We might expect to see the *JASA* 1988 paper "Partial dissociation of otoacoustic emissions and distortion products during aspirin use in humans" in a medical journal, or should I say a medical-acoustic journal.[1]

There is considerable public interest in deafness and its amelioration, particularly among senior citizens. Other matters of public interest include aircraft noise, car noise, and environmental noise pollution generally, followed by sound insulation and absorption in buildings.

In the above *JASA* collection under "Noise," there are only a few papers directly about noise generation and reduction, or about the effects of noise on hearing, noise annoyance, or noise level measurements. There are even fewer under the "Architectural Acoustics" subheadings "Sound Insulating Structures," "Vibration Insulation," and "Damping of Panels."

Interest in speech synthesis and recognition was aroused by the conversational computer "Hal" in Stanley Kubrick's movie *2001*. More recently, a TV program showed Stevie Wonder using a Kurzweil reading machine for the blind; it was assumed, by association, that continuous speech recognition had "arrived." The subject has received a good share of the hype accorded to most areas of information technology. But judging from *JASA*, it seems to be far from being the primary interest of acoustic researchers. Under the appropriate subheadings of "Signal Processing," "Speech Processing," "Speech Production," and "Speech Perception," there are surprisingly few papers about computer speech synthesis or recognition.

Major Acoustics Journals in 1974 and 1987

In the *Journal Citation Reports*® (*JCR*), ISI® provides citation tables for many of the scientific journals that are indexed. Each journal is considered as a "*cited* journal"; *citing* journals, rank-ordered by the number of times they cite it in a particular year, are tabulated beneath the cited journal. In a second table, the same journal is considered as a "*citing* journal"; the journals that it cites are rank-ordered by the number of citations accorded to them by the citing journal.[2]

Ten years ago a method was described for using the *JCR* to identify the major journals of acoustics.[3] The *JCR* tables for one reputable acoustic journal—*Acustica*—were chosen as the starting point and the journals citing it more than some arbitrary number of times were noted. Next, one of the citing journals was selected, its *JCR* list was located in turn, and journals citing it more than some arbitrary number of times were noted. The process was continued down to the level of journals publishing only a small number of papers each year receiving few citations.

Table 1: Headings for papers in *JASA* 1988.

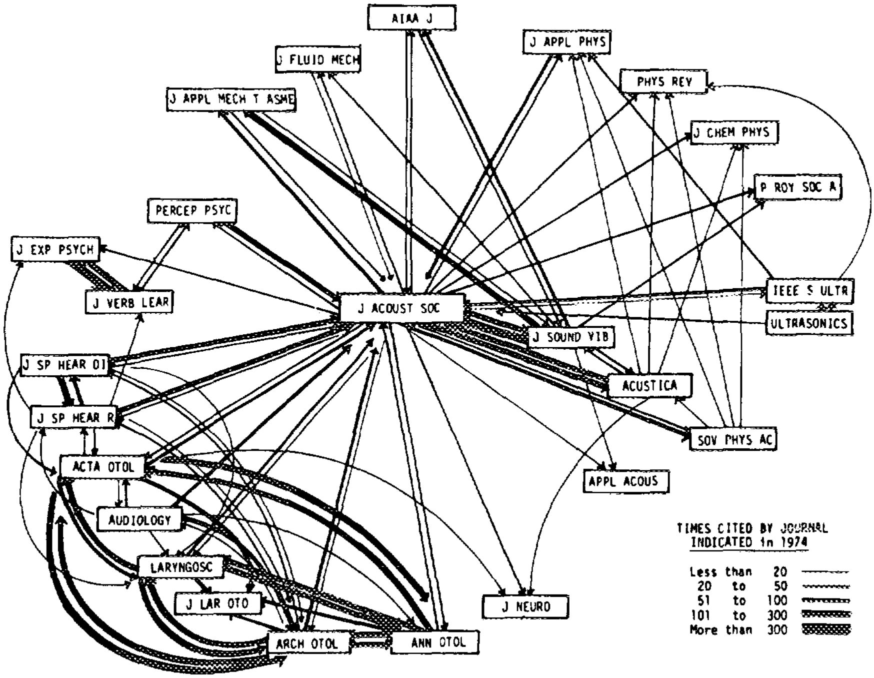
	Number of Papers	Percent
Linear and nonlinear acoustic theory	220	20.4
Psychological acoustics	153	14.2
Underwater acoustics	144	13.4
Physiology, the ear; bioacoustics	122	11.3
Speech production and perception	106	9.8
Ultrasonics and related topics	83	7.7
Structural and architectural acoustics; vibration	81	7.5
Noise effects and control; aeroacoustics	61	5.7
Speech and signal processing	47	4.4
Transducers	39	3.6
Measurements	21	1.9

The information thus obtained was used to draw the interconnection diagram shown in Figure 1. A connecting line indicates citations given or received; the thickness of the line indicates number of citations. The journals are arranged so that line crossovers do not cause too much confusion. They are also grouped by subject coverage—acoustics, middle-right; medical acoustics, lower-left; and others, at the top.

Figure 2 shows a diagram constructed in the same way from 1987 *JCR* data with the journals similarly grouped (the 1988 *JCR* was not yet available at the time of writing). If all the interconnections were to be completed, the diagram would become too cluttered to be helpful. A sufficient number of interciting connections have been included to show trends and raise some new points of interest.

A relatively new journal, the *IEEE Transactions on Acoustics, Speech, and Signal Processing* (*IEEE Trans. Acous. Speech Sign.*), has become established on the diagram by its strong interconnections to *JASA*. Another notable feature in the 1987 map is the rise of the journal *Hearing Research* (*Hear. Res.*). This journal does not appear in Figure 1 as it was founded in December 1978.

Figure 1: **Citation interconnections for 1974 acoustic journals**. (See reference 3.)



Hearing Research

Hear. Res. cited the older *Journal of Speech and Hearing Research* (*J. Speech Hear. Res.*) only 16 times in 1987. *Hear. Res.* was cited by *J. Speech Hear. Res.* less than six times (six is the *JCR*'s lower limit). This lack of interciting is unusual for major journals that seem to be in the same field.

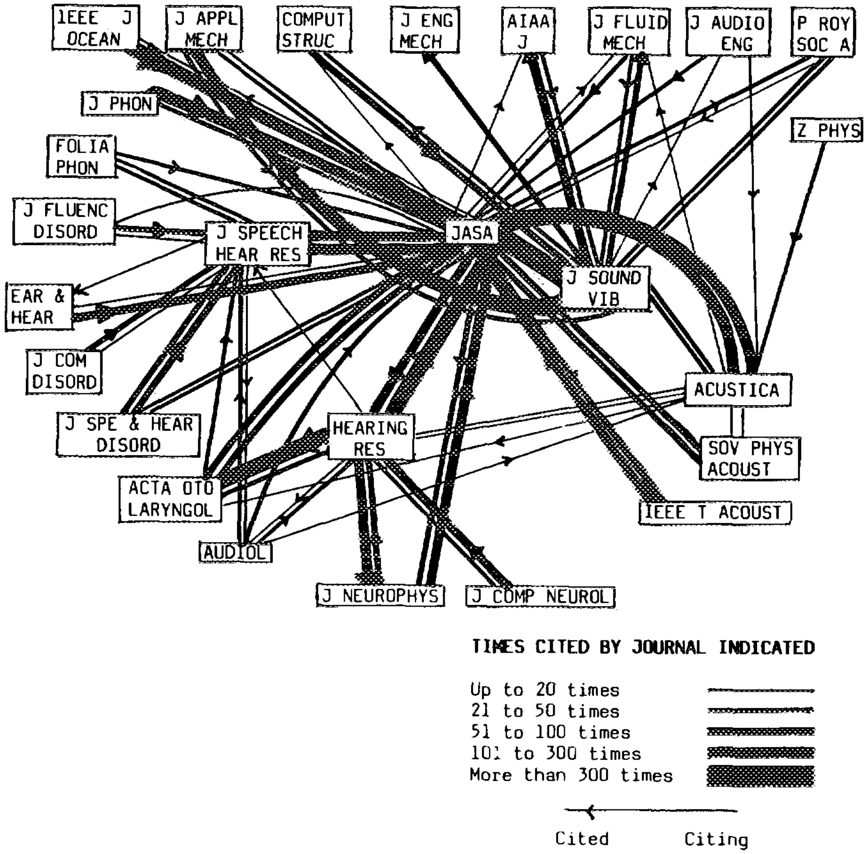
According to Dianne J. Van Tasell, University of Minnesota, Minneapolis, editor of *J. Speech Hear. Res.*, the two journals cover dissimilar areas in spite of their titles. *J. Speech Hear. Res.* is concerned with human and clinical aspects of speech and hearing while *Hear. Res.* covers physiological aspects. *J. Speech Hear. Res.* is an institutional publication from the American Speech-Language-Hearing Association. Presumably members of that organization turn naturally to their own journal for publication; accordingly it reflects their interests.

Aage R. Møller, Department of Neurological Surgery, Presbyterian University Hospital, Pittsburgh, Pennsylvania, editor of *Hear. Res.*, founded the journal. He tells me that his policy has been to encourage the submission of basic research papers. Presumably this policy has been supported by Elsevier, the publisher (Amsterdam, The Netherlands). The position that this relatively young journal now occupies indicates that it fills a well-perceived need.

Oceanographic Acoustics

In 1987 the relationship between oceanography and acoustics is evident from the connections between the *IEEE Journal of Oceanic Engineering* (*IEEE J. Oceanic Eng.*) and *JASA*. *IEEE J. Oceanic Eng.* cited *JASA* 178 times in 1987 but was cited by *JASA* only 12 times. Evidently oceanography draws on acoustics but not vice versa. One of the largest sections in *JASA*, "Underwater Sound," contains subsections entitled "Acoustics of Sediments, Icecovers, Viscoelastic Media; Seismic Underwater Acoustics" and "Oceanographic Measurements by Acoustical Methods; Remote Sensing; Acoustic Tomography."

Figure 2: Citation interconnections for 1987 acoustic journals.



The Core Journals of Acoustics

Well over one-third of the articles published in *JASA* in 1988 (see Table 1) are about medical acoustics subjects such as psychological and physiological acoustics and bioacoustics. This includes hearing and speech, such as binaural hearing, use of hearing aids, subjective aspects of hearing, speech production and perception including abnormalities, medical instruments, and the physiology of the ear, cochlear, and auditory nerve.

Using *JASA* as a guide to activity and classification in conjunction with *JCR* data, it may be rather obviously concluded that journals in the lower left area of Figure 2 are publishing papers in the medical acoustics areas. Acoustic journals in 1987 may be represented in two small groups of heavily cited journals with *JASA* common to both. The first consists of *JASA*, the *Journal of Sound and Vibration (J. Sound Vib.)*, and *Acustica*. The second group consists of *JASA*, *Hear. Res.*, and *J. Speech Hear. Res.*, which are strongly connected with a number of other medical acoustics journals, some also heavily cited.

The citation connections with other journals, mainly in the physical sciences, indicate that these journals publish articles about physical and theoretical acoustics. Some connections are strong—there is a very strong connection between the *Journal of Applied Mechanics (J. Appl. Mech.)* and the two core journals *JASA* and *J. Sound Vibr.* This does not mean that *J. Appl. Mech.* is a candidate for consideration as a core acoustics journal. The most likely reason for the connection is that *J. Appl. Mech.* receives and generates large numbers of citations simply because it is a large journal in which many papers are published each year. A small percentage of citations to or from it represent quite a large number of citations by the standards of exchanges in acoustics.

The definition of a core journal, then, is rather arbitrary. It is a member of a group of associated core journals each of which is heavily cited and exchanges citations in large numbers with other members of the group. There may be journals on the margin regarded as being just in or just out of the core group depending on a chosen cutoff point or upon the definition of the discipline covered by the core.

In order to choose the core journals I have chosen to interpret acoustics and classical acoustics. The composition of Tables 2 to 9, which provide more details about the core journals, is of course dependent upon that choice. From remarks made elsewhere in this article it will be obvious that the correctness of this choice is arguable, particularly in respect to medical acoustics. Figure 2 and Tables 3 and 4 show the close connections between classical and medical acoustics.

Table 2: Core acoustic journals indexed in the 1988 *SCI*®, with their editors, years of origin, and publishers. Journals are listed in alphabetic order.

Acustica (1936)
R. Martin, ed.
S. Hirzel Verlag GmbH & Co.
Stuttgart, FRG

Journal of the Acoustical Society of America (1929)
D.W. Martin, ed.
American Institute of Physics
New York, NY

Journal of Sound and Vibration (1964)
P.E. Doak, ed.
Academic Press
London, UK

Table 3: The journals cited 50 or more times by the core acoustic journals in the 1988 *SCI*® /*SSCI*®. Asterisks (*) indicate core journals. A = citations from core journals. B = citations from all journals. C = self-citations. D = percent of total citations that are core-journal citations (A/B). E = percent of total citations that are self-citations (self-cited rate, C/B). F = percent of core-journal citations that are self-citations (C/A). G = 1988 impact factor. H = 1988 immediacy index. I = total 1988 source items.

	A	B	C	D	E	F	G	H	I
*J. Acoust. Soc. Amer.	4,175	9,190	3,672	45.4	40.0	88.0	1.18	0.23	489
*J. Sound Vib.	1,201	1,964	989	61.2	50.4	82.4	0.58	0.15	341
J. Appl. Mech.	382	4,272	—	9.0	—	—	0.48	0.05	121
*Acustica	352	604	167	58.3	27.7	47.4	0.27	0.11	97
J. Speech Hear. Res.	184	1,559	—	11.8	—	—	1.06	0.10	79
Hear. Res.	157	1,715	—	9.2	—	—	1.95	0.36	123
Sov. Phys.—Acoust.—Engl. Tr.	130	559	—	23.3	—	—	0.18	0.03	113
AIAA J.	126	2,462	—	5.1	—	—	0.46	0.03	232
J. Appl. Phys.	105	33,787	—	0.3	—	—	1.75	0.32	2,507
IEEE T. Ultrason. Ferroelectr.	91	821	—	11.1	—	—	1.09	0.35	94
J. Phonetics	86	309	—	27.8	—	—	0.55	1.13	24
Percept. Psychophys.	82	2,633	—	3.1	—	—	0.90	0.37	172
J. Fluid Mech.	75	8,994	—	0.8	—	—	1.60	0.52	307
Proc. IEEE	73	4,201	—	1.7	—	—	1.62	0.37	97
Acta Oto-Laryngol.	72	3,413	—	2.1	—	—	0.74	0.11	369
Geophysics	63	2,175	—	2.9	—	—	0.93	0.33	159
Audiology	62	470	—	13.2	—	—	1.18	0.21	33
J. Neurophysiol.	62	10,939	—	0.6	—	—	3.35	0.80	229
Proc. Roy. Soc. London Ser. A	62	10,342	—	0.6	—	—	1.41	0.45	129
Int. J. Numer. Method. Eng.	61	2,144	—	2.9	—	—	0.90	0.16	198
J. Eng. Mech.—ASCE	61	1,061	—	5.8	—	—	0.50	0.16	131
IEEE Trans. Antennas Propagat.	54	2,327	—	2.3	—	—	0.74	0.16	246
J. Chem. Phys.	53	84,098	—	0.1	—	—	3.59	0.78	1,906
Science	53	106,393	—	0.1	—	—	16.46	3.59	859
Int. J. Solids Struct.	52	1,109	—	4.7	—	—	0.59	0.16	83
Ultrasonics	52	304	—	17.1	—	—	0.65	0.10	48
J. Phys. Chem.	50	34,856	—	0.1	—	—	3.14	0.49	1,250

Clusters of Research Papers

In any year, say 1988, a proportion of all earlier scientific papers—mainly those published within the last 20 years—are cited more than *n* times by papers published in 1988. More specifically, pairs of these earlier heavily cited papers are *co-cited* by 1988 papers. This function may be used as the basis for forming clusters of associated papers. A small cluster is shown in Figure 3. Each author of 10 papers associates paper A, published in 1970, and paper B, published in 1972, in some way, by citing both in their 1988 paper. Similarly paper C, published in 1966, is associated both with A and with B; A and C and B and C have been cited together in 18 and 6 1988 papers, respectively. Methods for generating clusters by a data processing program have been described by Henry Small.[4,5]

The subject matter of a cluster may be deduced by reading the titles of the co-citing papers or by noting high-frequency title words. However, there were thousands of clusters in 1988, and there are better methods for identifying clusters about a particular subject and for determining the most significant. When all the clusters have been generated, subject selection may be performed automatically by ranking clusters by the number of times they have been cited by the

Figure 3: Three earlier articles clustered by processing data from references in 1988 articles. (Figures on lines indicate number of 1988 articles which co-cited the pairs of articles indicated.)

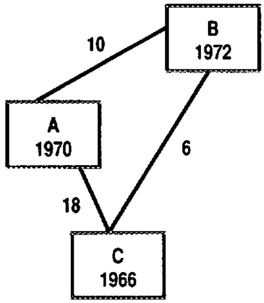


Table 4: The journals that cited the core acoustic journals 50 or more times in the 1988 *SCI®/SSCI®*. Asterisks (*) indicate core journals. A = citations to core journals. B = citations to all journals. C = self-citations. D = percent of total citations that are core-journal citations (A/B). E = percent of total citations that are self-citations (self-cited rate, C/B). F = percent of core-journal citations that are self-citations (C/A). G = 1988 impact factor. H = 1988 immediacy index. I = total 1988 source items.

	A	B	C	D	E	F	G	H	I
*J. Acoust. Soc. Amer.	4,001	11,411	3,672	35.1	32.2	91.8	1.18	0.23	489
*J. Sound Vib.	1,306	4,707	989	27.8	21.0	75.7	0.58	0.15	341
Hear. Res.	508	3,733	—	13.6	—	—	1.95	0.36	123
*Acustica	425	1,354	167	31.4	12.3	39.3	0.27	0.11	97
J. Speech Hear. Res.	296	2,389	—	12.4	—	—	1.06	0.10	79
J. Phonetics	185	716	—	25.8	—	—	0.55	1.13	24
IEEE T. Ultrason. Ferroelectr.	144	1,624	—	8.9	—	—	1.09	0.35	94
IEEE J. Oceanic Eng.	140	788	—	17.8	—	—	0.22	0.15	34
J. Neurophysiol.	140	11,218	—	1.3	—	—	3.35	0.80	229
Percept. Psychophys.	131	3,443	—	3.8	—	—	0.90	0.21	144
Audiology	100	857	—	11.7	—	—	1.18	0.21	33
J. Fluid Mech.	99	7,176	—	1.4	—	—	1.60	0.52	307
Ear Hearing	98	956	—	10.3	—	—	0.69	0.32	47
Sov. Phys.—Acoust.—Engl. Tr.	97	922	—	10.5	—	—	0.18	0.03	113
Ultrasound Med. Biol.	97	3,745	—	2.6	—	—	2.12	0.20	107
Physiol. Rev.	93	7,879	—	1.2	—	—	12.23	1.83	23
AIAA J.	88	3,160	—	2.8	—	—	0.46	0.03	232
Ultrasonics	85	638	—	13.3	—	—	0.65	0.10	48
Comput. Struct.	78	4,450	—	1.8	—	—	0.33	0.07	354
Scand. Audiol.	78	1,348	—	5.8	—	—	0.56	0.03	96
J. Audio Eng. Soc.	68	525	—	13.0	—	—	0.43	0.06	49
J. Appl. Phys.	67	42,777	—	0.2	—	—	1.75	0.32	2,507
IEEE Trans. Acoust. Speech Sign.	62	3,555	—	1.7	—	—	1.33	0.16	161
Speech Commun.	61	584	—	10.5	—	—	0.55	0.73	33
Clin. Phys. Physiol. Meas.	56	446	—	12.6	—	—	0.47	0.13	16
Brain Lang.	52	2,327	—	2.2	—	—	1.00	0.09	66

Table 5: Half-lives. The 1988 *SCI*® cit*ed* and cit*ing* half-lives of core acoustic journals. Journals are listed in alphabetic order. A = cit*ed* half-life. B = cit*ing* half-life.

	A	B
Acustica	>10.0	>10.0
J. Acoust. Soc. Amer.	>10.0	9.2
J. Sound Vib.	7.8	>10.0

Table 6: Core-journal impact factors. The 1988 *JCR* impact factors of the core acoustic journals using different two-year bases. Journals are listed in alphabetic order. A = 1986-1987. B = 1985-1986. C = 1984-1985. D = 1983-1984. E = 1982-1983.

	A	B	C	D	E
Acustica	0.27	0.37	0.33	0.21	0.18
J. Acoust. Soc. Amer.	1.18	1.38	1.26	1.18	1.13
J. Sound Vib.	0.58	0.59	0.53	0.55	0.56

core journals of a discipline. The clusters of interest should come to the top.

Clusters of Acoustical Research Papers

In most disciplines—for example, pharmacology, zoology, mathematics, agriculture, immunology, or botany—there is a large set of core journals. The addition or deletion of one or two journals will not make much difference to bulk citation statistics. But for a very small core of three arbitrarily selected journals, as in acoustics, the addition of two more core journals could make a considerable difference.

The "acoustics prior art" in 1987 as perceived by *JASA*, *J. Sound Vib.*, and *Acustica* is defined by the 9,696, 4,747, and 1,305 references, respectively, contained in the 1987 articles published in those journals. But if *Hear. Res.* and *J. Speech Hear. Res.* were to be included as core journals, 5,369 and 1,861 references, respectively, would be added, an increase approaching 50 percent. The effect of these additions would be to increase greatly the number of references to medical acoustics clusters, which might then rise in the 1987 cluster ranking list at the expense of clusters in other branches of acoustics.

The bulk citation data for 1988 is unlikely to be greatly different from the 1987 data just given, so we may anticipate that the 1988 rankings would be similarly affected. (The 1988 cluster data were available at the time of writing.) In fact the anticipated effect did occur. Table 9 shows the top 10 1988 acoustic clusters ranked by number of times cited by three core journals, and Table 10 shows what happens if the 1988 citing core journals include *Hear. Res.* and *J. Speech Hear. Res.*: the three medical acoustic clusters come to the top and two others appear in the top 10 list.

Other similar effects on ranking may be produced when using bulk citation statistics with core-sets that are small and therefore sensitive to even single journal alterations. An example occurs in acoustics where one noncore journal has become *the* electronic acoustics journal. The effect is all the more pronounced because the core journals do not publish what might be considered to be "their fair share" of papers about this branch of acoustics.

IEEE Trans. Acous. Speech Sign. seems to have become the chosen journal for papers about coding in speech transmission, synthesis, and recognition. The sheer size of *JASA* partly accounts for the fairly heavy citation exchange between itself and *IEEE Trans. Acous. Speech Sign.* The first nine journals that cite and are cited by *IEEE Trans. Acous. Speech Sign.* are, with the exception of *JASA*, all "electronic journals"—mainly other IEEE journals. Citation exchanges between *IEEE Trans. Acous. Speech Sign.* and other journals shown in Figure 2 are very small. Evidently acoustics is subservient to electronics.

However, the fact is that cluster ranking would be strongly affected by citations from the set of papers about just one subject—speech coding—published in *IEEE Trans. Acous. Speech Sign.* If they were included with the corpus from the core journals for ranking-by-citation purposes, the speech coding cluster, which received five citations from the core acoustic journals in 1988, and so ranks 33d, rises to 5th, having now received 25 citations.

The Most Heavily Cited Acoustics Articles

Many of the citations from the core journals will be to earlier articles from these same journals because they are specialized acoustic journals. But articles, books, reports, and so on, cited by authors who publish papers about acoustics may have been produced in sources not normally associated with acoustics. Tables 7 and 8 provide further information about articles only. The two acoustic articles most heavily cited between 1945 and 1988 appeared in the nonacoustic journals *Proceedings of the Royal Society of London Series A* 1952 (Lighthill, 594 times) and *J. Appl. Mech.* 1951 (Mindlin, 446 times). The third appeared in *JASA* 1956 (Biot, 414 times).

Lighthill's paper is of particular interest. M.J. Lighthill, now Sir James Lighthill, FRS, was professor of applied mathematics at Manchester University, UK, in 1951 when he wrote it. Subsequently, he became director of the Royal Aircraft Establishment at Farnborough, UK. Later he moved to Imperial College, London, but is now a research fellow at the Department of Mathematics, University College, London.

The paper was one of the first, if not the very first, that provided a theory for the generation of sound radiated from a fluid flow. The flow of sound through the fluid, air, is of some interest as the relatively gentle regular eddy pattern produced by instruments such as the clarinet or saxophone. It is of greater interest as the high-energy turbulent radiation when kinetic is converted to acoustic energy—as in jet engines.

As has been already mentioned, not much is published about the subject these days. The reason is that an understanding of jet noise has not progressed much since Lighthill's paper, and research has almost come to a standstill. Theory has given way to empiricism because the theory is too difficult. Jet engine designers work mainly by experience and testing. It is now appreciated that the way in which sound is propagated through the airflow is also important. With present generation bypass jet engines, an understanding of the way in which the noise is generated and propagated has become even more difficult.

Figure 4: First stage of assembling the literature of "speech coding and recognition, and image coding" by citation cycling.

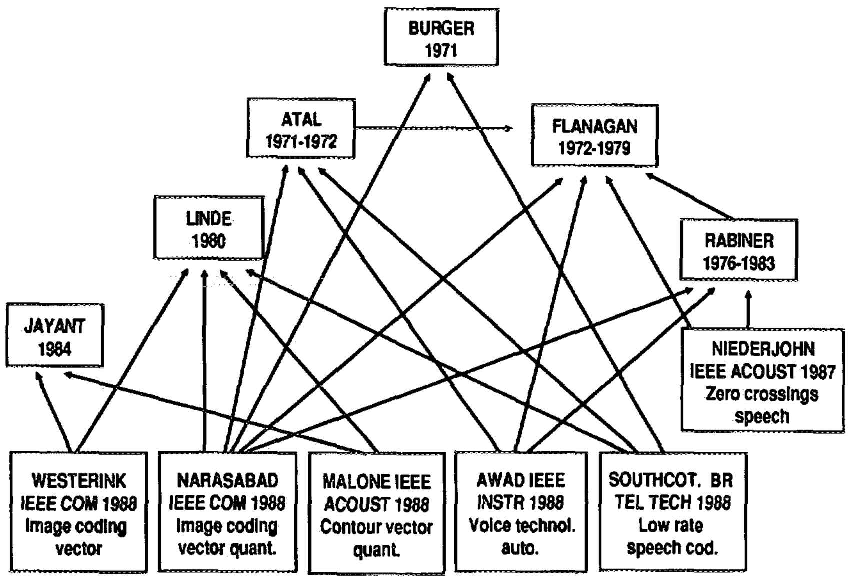


Table 7: Highly cited articles from each core acoustic journal according to the 1945-1988 *SCI*®. Articles are listed in alphabetic order by first author. A = 1945-1988 citations. The number of 1988 citations appears in parentheses. *SCI/SSCI*® research-front numbers for 1988 follow the reference.

A	Bibliographic Data
414 (46)	**Biot M A.** Theory of propagation of elastic waves in a fluid-saturated porous solid. I. Low-frequency range. *J. Acoust. Soc. Amer.* 28:168-91, 1956. 88-2641
106 (7)	**Cooley J W, Lewis P A W & Welch P D.** The fast Fourier transform algorithm: programming considerations in the calculation of sine, cosine and Laplace transforms. *J. Sound Vib.* 12:315-37, 1970.
119 (0)	**Kuhl W, Schodder G R & Schroder F-K.** Condenser transmitters and microphones with solid dielectric for airborne ultrasonics. *Acustica* 4:519-32, 1954.
112 (4)	**Kurtze G & Tamm K.** Measurements of sound absorption in water and in aqueous solutions of electrolytes. *Acustica* 3:33-48, 1953.
110 (12)	**Leissa A W.** The free vibration of rectangular plates. *J. Sound Vib.* 31:257-93, 1973. 88-0345
365 (53)	**Levitt H.** Transformed up-down methods in psychoacoustics. *J. Acoust. Soc. Amer.* 49:467-77, 1971. 88-2377
360 (13)	**McSkimin H J.** Pulse superposition method for measuring ultrasonic wave velocities in solids. *J. Acoust. Soc. Amer.* 33:12-27, 1961.
319 (13)	**Rhode W S.** Observations of the vibration of the basilar membrane in squirrel monkeys using the Mössbauer technique. *J. Acoust. Soc. Amer.* 49:1218-31, 1971.

Methods of Finding Out About "More Interesting" Aspects of Acoustics

Information about science, technology, and engineering is published in a journal spectrum extending from well-referenced basic research journals, through journals covering applied science and technology, technical and engineering journals, to a range of popular magazines where articles with references are a rarity. Nonjournal information is published in a variety of other forms—notably in conference proceedings, reports, and books.

The clustering method referred to above depends upon the reference tradition. ISI's major source data acquisition and indexing is devoted to other scientific journals rather than to publications further along the spectrum just described. This may account for underrepresentation of "applied" and "popular" aspects.

My remarks about the "public interest in acoustics" are based on what is published in the UK lay press and what appears on TV. Topics such as environmental noise, building acoustics, and speech synthesis and recognition are not necessarily areas of intensive research, but the media considers them newsworthy. Information about these topics may be published somewhere "lower down" the spectrum where they do not get the attention that they perhaps deserve from the ivory tower end.

Articles about a particular topic can, of course, be found without recourse to core-journal selection or the processing of clusters. ISI's scientific source-journal articles may tend to cite other scientific journal articles. However the literature *cited* by these journals, and by the major "applied" journals also indexed, amounts to millions of items per annum. These items constitute quite a broad spectrum as is evident from studying the *Science Citation Index*® (*SCI*®). Among the heavily cited acoustic items in 1988 are Rayleigh's book the *Theory of Sound*, published over 100 years ago; a report, *NASA SP160*; and the *Handbook of Sensory Physiology*.

Figure 4 shows graphically the results of a quick preliminary search on the topic "speech coding" using the 1988 CD-ROM version of the *SCI*. A 1988 article by C.B. Southcott in *British Telecom Technology Journal* (6:22-40, 1988) entitled "Low bit rate speech coding for practical applications," found by doing a title-word search for "speech coding," was used as the starting point.

This article is accompanied by a notification, displayed on the screen of the microcomputer controlling the disc player, "related records 20"; the user then has the option of displaying other 1988 articles automatically ranked in similarity by a method based on bibliographic coupling, that is, on the commonality of references. If the arti-

Table 8: Articles published in noncore journals cited at least seven times by core acoustic journals in the 1988 *SCI*®. Articles are listed in alphabetic order by first author. A=1988 citations from core journals. B=total 1945-1988 *SCI* citations. *SCI/SSCI*® research-front numbers for 1988 follow the reference.

A	B	Bibliographic Data
9	39	**Bert C W.** Use of symmetry in applying the Rayleigh-Schmidt method to static and free-vibration problems. *J. Ind. Math. Soc.* 34:65-7, 1984. 88-2491
7	163	**Cowper G R.** The shear coefficient in Timoshenko's beam theory. *J. Appl. Mech.* 33:335-40, 1966. 88-4344
9	85	**Delany M E & Bazley E N.** Acoustical properties of fibrous absorbent materials. *Appl. Acoust.* 3:105-16, 1970. 88-4002
7	73	**Kemp D T.** Evidence of mechanical nonlinearity and frequency selective wave amplification in the cochlea. *Arch. Oto-Rhino-Laryngol.* 224:37-45, 1979. 88-1331
7	11	**Laura P A A.** Optimization of eigenvalues when using the Galerkin method. *AICHE J.—Amer. Inst. Chem. Eng.* 32:1025-6, 1986. 88-2491
7	594	**Lighthill M J.** On sound generated aerodynamically. I. General theory. *Proc. Roy. Soc. London Ser. A* 211:564-87, 1952. 88-6458
17	446	**Mindlin R D.** Influence of rotatory inertia and shear on flexural motions of isotropic, elastic plates. *J. Appl. Mech.* 18:31-8, 1951. 88-1893

cle in question had 20 references, another article containing the same 20 references, and no others, would almost certainly appear at the top of the "related records list." In the more likely event of two articles containing different numbers of references with five in common, the two will be related to a lesser degree.

A co-citation search method—laborious with the printed *SCI* but easy with the CD-ROM version—is a good way to proceed. The question posed takes the form, "List current articles co-citing a, b, ...*n*," where a...*n* are known earlier articles. On this occasion two articles cited by Southcott—Linde and Atal—were selected. This produced the Narasabad paper, showing that image coding and speech coding probably share a similar approach. A few of a number of articles found are shown on the diagram. Numerous articles about this topic are published in *IEEE Trans. Acous. Speech Sign.* By using them as search leads, image coding aspects may be selected out.

So What Is Acoustics?

As we saw earlier, there is some difference of opinion among the dictionaries about the answer to this question and considerable

Table 9: The 1988 *SCI*®/*SSCI*® research fronts that include at least 15 citing documents published in the core acoustic journals. A=number of articles from core acoustic journals citing the core of each front. B=total number of citing documents. C=total number of core documents.

Number	Name	A	B	C
88-2377	Multichannel electrotactile speech processor, comodulation masking release, cochlear implant patients, auditory cues, binaural hearing, and gap detection	49	177	26
88-0345	Thin plate elements, reduced integration, curved beams, and edge shear constraints	30	105	16
88-1893	Laminated composite plates, elastic anisotropic shells, thickness shear deformation, and bending behavior	30	215	37
88-1001	Fluent speech of young stutterers, perceptual data, linguistic rhythm, voice quality, and school-aged children	27	136	22
88-5240	Acoustic spectra of several cylindrical elastic modes, sound scattering, and infinite cylinders	22	30	5
88-2491	Vibrating circular plates, stepped thickness, and restrained beam carrying concentrated masses	18	18	3
88-1544	Pulsed ultrasound, transient pulsations of small gas bubbles, acoustic output, and miniature hydrophone scanning	17	98	20
88-1331	Outer hair cells, guinea pig cochlea, and bidirectional transduction cycle	15	209	21
88-2641	Saturated porous formations, wave-propagation simulation, permeable rocks, composite model, and solid fluid outer boundary	15	90	10
88-6520	Nonlinear singular perturbation problems, nonlinear systems, autoparametric vibrations of an elevated water tower, and parametric random excitation	15	96	5

Table 10: The 1988 top 10 clusters. Ranking using three citing core journals and after adding two major medical acoustic journals to the citing core.

Cluster Ranking with Three Core Journals (See Table 2)

Cluster Number	Short Title
88-2377	Hearing
88-0345	Plates
88-1893	Elasticity
88-1001	Speech quality
88-5240	Acoustics/cylinders
88-2491	Vibration
88-1544	Ultrasonics
88-1331	Ear physiology
88-2641	Oceanic acoustics
88-6520	Perturbation

Cluster Ranking with Five Core Journals

Cluster Number	Previous Rank	Short Title
88-2377	(1)	Hearing
88-1331	(8)	Ear physiology
88-1001	(4)	Speech quality
88-0345	(2)	Plates
88-1893	(3)	Elasticity
88-5240	(5)	Acoustics/cylinders
88-5805	(28)	Auditory effects
88-2491	(6)	Vibration
88-1544	(7)	Ultrasonics
88-5298	(19)	Speech problems

differences in the illustrative examples chosen. Following the above review and the brief historical review that follows, we can reconsider the definitions to decide whether earlier conceptions of the discipline should be changed in view of recent developments.

Historical Review

It is said that Pythagoras studied the musical notes emitted by stretched strings in the sixth century. Later, the names of the scientists who became interested in acoustic research read like a historical scientific Who's Who. Significant contributions were made, among many others, by Galileo Galilei (*Discourses Concerning Two New Sciences*, 1638—vibrations of bodies); Sir Isaac Newton (*Principia*, 1687—wave theory of sound); Ernst Florence Friedrich Chladni (*Entdeckungen über die Theorie des Klanges* [*Discoveries in the Theory of Sound*], 1787—studies of vibrations in plates with sand patterns—producing, incidentally, some quite beautiful effects); Pierre-Simon Laplace (*Méchanique Céleste*, 1825—velocity of sound).

In the nineteenth century, two major classic works on acoustics appeared. Hermann L.F. von Helmholtz published *Die Lehre von den Tonempfindungen als Physiologische Grundlage für die Theorie der Musik* (*The Science of Tone Perception as a Physiological Basis for the Theory of Music*) in 1862. In it he provided the first comprehensive theory about the functioning of the ear, laid down the foundations of future research on hearing, and invented the acoustic resonator.

Rayleigh's Theory of Sound

However, a work that eclipsed all others, Rayleigh's the *Theory of Sound*, was published in 1877. It covered the then-known aspects of acoustics and is still a standard work of reference today. A second edition, embodying some further investigations, was published in 1895.

John William Strutt, Baron Rayleigh, the author of the *Theory of Sound*, was born in 1842. He had little incentive to study science. On the contrary he was the son of a country peer and in due course assumed the title Baron Rayleigh—not an encouraging start. But Rayleigh was no dilettante. He became the Senior Wrangler in the Mathematical Tripos at Cambridge University, UK, in 1865. He did not embark on the traditional grand tour of Europe. Unconventionally for that time, he traveled instead in the US, which was struggling with the aftermath of the Civil War.

Rayleigh had the means to establish and work in a private laboratory at his home, publishing a series of papers in the *Philosophical Transactions*. Later, the income from his estate diminished, and, following the death of James Clerk Maxwell, he accepted the appointment of professor at the Cavendish Laboratory, Cambridge University. Subsequently, he was instrumental in establishing the National Physical Laboratory and became president of the Royal Society. He was awarded the Order of Merit in 1902 and the Nobel Prize for physics in 1904.

According to Robert Lindsay, professor of physics, Brown University, Providence, Rhode Island, who has studied the history of acoustics, Rayleigh's book made its major impact about the time that acoustics "took off" in the 1920s.

Many books appeared at this time interpreting and describing applications of the work described in the *Theory of Sound* to current problems. This upsurge of interest included the foundation of the Acoustical Society of America in 1929.

The content of the *Theory of Sound* more or less defines linear physical acoustics—vibrating systems such as strings, bars, membranes, plates, and shells, and sound radiation through fluid media such as air and water. There is some mention of nonlinear acoustics—of great interest today in connection with intense sound, shock waves, and cavitation.

The book includes some ideas about room acoustics, but architectural acoustics came later with Walter Sabine's pioneering work at Harvard University, Cambridge, Massachusetts, early in the twentieth century. Medical acoustics was still in its infancy in Rayleigh's day. One of those responsible for a better understanding of the hearing mechanism was Harvey Fletcher at Brigham Young University, Provo, Utah, and later at the Bell Telephone Laboratories, Murray Hill, New Jersey. Fletcher was the first president of the Acoustical Society of America. The obvious recent trends in acoustics are its interdisciplinary ramifications including medical acoustics, seismic and oceanographic acoustics, applications of ultrasonics, electronic acoustics such as speech coding, and computer synthesis and recognition.

I can now propose a definition of acoustics that is in accordance with the above developments.

> Acoustics was originally based on the study of vibration and sound generation and of their effects. The scope of this classical acoustics has since been extended to include medical acoustics, architectural acoustics, ultrasonics, and electronic acoustics and coding as in speech transmission, synthesis, and recognition. Applications of acoustics are also appearing in other sciences such as oceanography.

REFERENCES

1. **Wier C C, Pasanen E G & McFadden D.** Partial dissociation of otoacoustic emissions and distortion products during aspirin use in humans. *J. Acoust. Soc. Amer.* 84:230-7, 1988.
2. **Garfield E.** Introducing *Journal Citation Reports*. *Essays of an information scientist.* Philadelphia: ISI Press, 1977. Vol. 2. p. 556-71.
3. **Cawkell A E.** Evaluating scientific journals with *Journal Citation Reports*—a case study in acoustics. *J. Amer. Soc. Inform. Sci.* 29:41-6, 1978.
4. **Small H & Sweeney E.** Clustering the *Science Citation Index* using co-citations. 1. A comparison of methods. *Scientometrics* 7:391-409, 1985.
5. **Small H, Sweeney E & Greenlee E.** Clustering the *Science Citation Index* using co-citations. 2. Mapping science. *Scientometrics* 8:321-40, 1985.