



# Audio Engineering Society Convention Paper

Presented at the 110th Convention  
2001 May 12–15 Amsterdam, The Netherlands

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## Omnis and Spheres - Revisited

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### ABSTRACT

The geometry of the microphone surrounding a transducer capsule has a large influence on the acoustical behaviour of the transducer as a whole. Therefore, only 4 microphone design principles are in common use today: with mostly free-standing capsules; with cylindrical housings; embedded in large boundary layers; or with spherical housings. Especially for omnidirectional pressure transducers, the spherical housing can be applied, yielding positive results on frequency response and polar pattern.

Spherical housings have been investigated, and introduced to microphone design some 50 years ago. An overview of the historical development, and their applications shall be presented as well, leading to the current embodiments of this principle.

### HISTORY - ACOUSTICS

The 1920s and 1930s saw the advent of radio broadcasting, "talking" pictures & vinyl records for the general public. Massive efforts were undertaken by researchers and industry worldwide to develop and improve audio technology. Especially in the field of acoustics a vast range of findings can be traced back to the 20s and 30s. One of these was the investigation of the "disturbed" sound field, i.e. what happens to the sound field when a solid body is introduced into the free field, reflecting, diffracting or absorbing the sound waves. Such a solid body could well be a microphone, or a microphone capsule. As the dimensions of a microphone were, and still are, in the region of the sound wavelengths in the upper part of the audible spectrum, these investigations were essential when the first high quality microphones were produced.

The first industrially produced condenser microphone capsules had an unparalleled quality for their time. Still, the 10 dB treble boost of the first Neumann M3 capsule for the CMV3 "bottle" microphone (Fig.1a and Fig.3, M1-2 graph) might have been helpful in the beginning, to overcome the limited frequency range of the then

audio transmission chain. But soon, with the audio chain improving, capsules with a more even frequency response were demanded.

From the 1930s on the diffraction of sound waves by regular bodies were closely studied [Mul, Sch, Ste], and three of these geometries have become standards for microphone design:

- the cylinder, archetype of the now common small "pencil" microphones and measurement microphones,
- the flat disc, e.g. an upright standing large diaphragm capsule,
- the sphere, found in microphone embodiments since the 1950s.

This latter form, the sphere, showed to have some very special effect: a smooth rise of the pressure on the surface of the sphere, increasing with frequency. This is the same principle found in boundary-layer microphones. The treble rise on spheres amounts to a maximum of 6dB, i.e. pressure doubling, instead of the 10dB found on the front of a cylindrical body, with following peaks and dips in the frequency response (Fig. 2).

The developers of the first microphones with a spherical body founded their design on these publications [Gro1]. Their aim was thus to develop a microphone with a small capsule, set inside a spherical body.



Fig. 1a CMV 3 "bottle" microphone with M 3 pressure capsule.  
 Fig. 1b M 48 capsule head for "bottle" microphones.  
 Presumably the M 48 capsule head (Fig. 1b and Fig. 3, BM 48 graph) was the first embodiment of the sphere principle, in 1948. The capsule is set in a hemispherical housing, which screws onto the "torpedo head" of the bottle microphones. Its small KK 50 capsule with just 12 mm diaphragm diameter, and a mere 10µm distance between diaphragm and backplate, was developed at NWDR's (North West German Radio) research institute and given to Neumann for serial production.

It was time to replace the heavy and cumbersome bottle microphones by smaller designs. Thus the capsule was set into the M 50 microphone (Fig. 4 and Fig. 3, M 50 graph), a sibling of the M 49 multipattern microphone. These two microphones then became standard studio and broadcast microphones of the 50s and 60s.

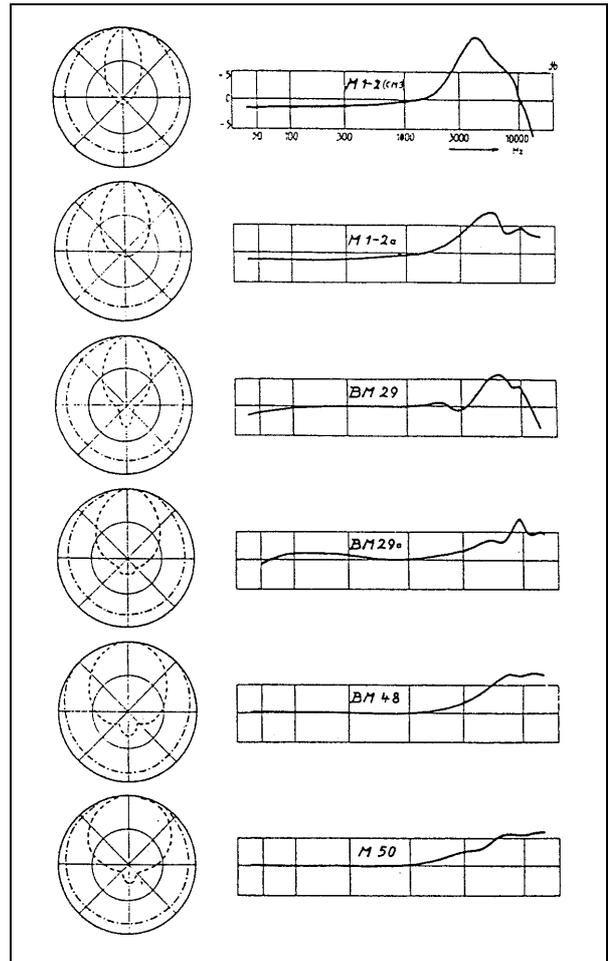


Fig. 3. Frequency responses and polar patterns of 1950 capsules and microphones, from [Gro2]

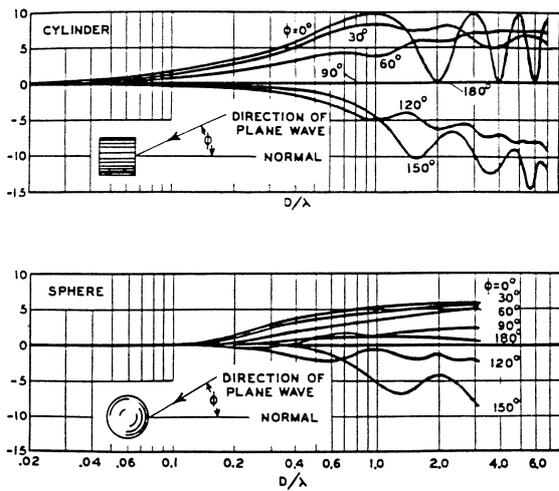


Fig. 2. The diffraction of a sound wave by a cylinder and a sphere, from [Ols].



Fig. 4. The M 50 Microphone

**ACOUSTIC AND RECORDING REQUIREMENTS**

When recording sound sources of larger dimensions e.g. orchestras and jazz big bands, it has proven helpful to place the microphones at a larger distance. This of course goes for recording situations with a small number of microphones, e.g. with a main stereo pair or triplet adding some spot microphones, but not for close miked multi-microphone arrangements.

Such microphone placements are generally used in "nice" acoustic surroundings, i.e. in the presence of natural reverberation, and with the wish to record this reverberation to provide natural listener "envelopment". So, the diffuse field response of such a microphone should be basically flat. Due to physics this leads microphones with a rise in the on-axis frequency response, and with a directivity rising with frequency. Clearly, a pressure transducer with relevant dimensions cannot have both a flat free field and diffuse field response. The polar pattern at high frequencies should still be rather wide, at least compared to early large diaphragm capsules, in order to equally record a relevant section of the sound source. The first condenser microphones clearly did not fulfill these requirements (Fig. 3, upper graphs), as their size made them much too directional. Combining the above requirements, and with knowledge of the findings of Schwarz [Sch], the logical conclusion is to place a small pressure transducer capsule into a sphere of the appropriate diameter. A pressure capsule has a flat response down to theoretically 0 Hz, while the sphere produces a smooth rise, setting in above 1 kHz, and leading to a maximum rise of + 6 dB in the 0° free-field response. For the diffuse sound field the rise is in the region of only +3 dB and thus agreeably gentle.

As the German broadcasters research institute was widely involved in this design, the M 50 soon became one of the German standard microphones. Presumably the first presentation of the sphere principle applied in a microphone outside Germany was then in an AES article by F.W.O. Bauch [Bau]. Based in the U.K., he seems to have been responsible for presenting the M 50 to Decca Records.

**THE DECCA TREE**

When the first experimental stereo recordings were made in the 50s, different techniques were tried out. Apart from the coincident (XY, MS), semi-coincident (e.g. ORTF), and spaced (AB) techniques, one very characteristic setup evolved, now known as the "Decca Tree".

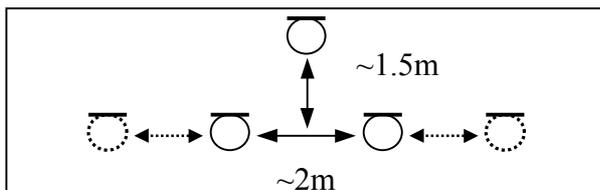


Fig. 5 The Decca Tree

The Decca Tree consists of 3 microphones, e.g. M 50s, arranged in a triangle, usually at an elevation of e.g. 3 m [Loc]. The center mic, positioned slightly behind the conductor is directed equally to L and R channels, the other two mics to their corresponding channels only. Additionally, two or more "outrigger" mics might be added for very broad sound sources.

The spacings given are just exemplary, and are chosen according to the actual recording situation. Equally the L and R microphones may be angled, are the center set to a slighter higher position and angled down- or upwards. Developed by Decca London, it was and still is one main stereo recording setup, used regularly e.g. by Decca and Teldec Classics and others, especially for large orchestral recordings.

**VARIATIONS ON A THEME 1**

By the 1980s, multi-microphone setups had been extensively experimented with, and with stereo now being standard, there was not the absolute need for purely coincident, mono compatible recordings anymore. Spaced microphone setups became "fashionable" again and there was renewed interest in stereo recordings with pressure transducers. Leading back to simpler setups, with less microphones and a dedicated stereo main pair or triplet, it was time to "reinvent" sphere microphones.



Fig. 6. The TLM 50 Microphone

Thus the TLM 50 was conceived [Peu]. With a slightly redesigned capsule, the transformerless TLM 50 picked up the M 50's heritage, but with fet-technology's advantage of today's much lower noise floors, the higher noise floor being a hindrance for many when using vintage tube microphones. The new circuit also made a much smaller housing possible, and the improved shielding of the circuit led to "opening" up of the head grille by making it acoustically more open. Thus, the TLM 50 can be characterized as slightly more "brilliant" or "open" than its M 50 predecessor (Fig. 7).

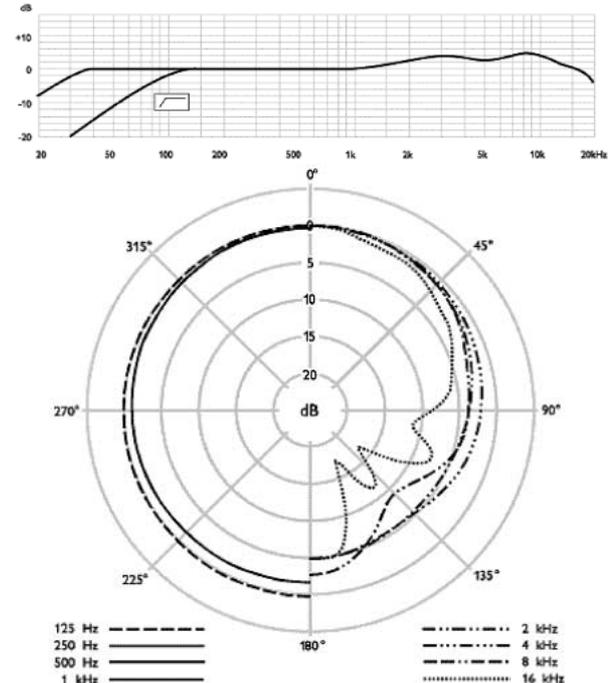


Fig. 7. TLM 50 Microphone Frequency Response and Polar Pattern

VARIATIONS ON A THEME 2



Fig. 8. Small Pressure Microphone with Sound Diffraction Sphere

As a parallel development, "plug-on" sound diffraction spheres (Fig. 8) were introduced on the market. These fit on standard cylindrical pressure transducers, adding the sphere's diffraction characteristic to the capsule in question. This certainly produces a similar effect as in the dedicated designs (Fig. 9 and 10), but as most pressure transducer capsules are not originally conceived for this purpose (e.g. diameter, frequency response), the result is not fully comparable to a dedicated solution like the M 50 / TLM 50. Still, the "plug-on" sound diffraction spheres are a useful and simple accessory, and can be used to experiment with transducer behaviour in recording.

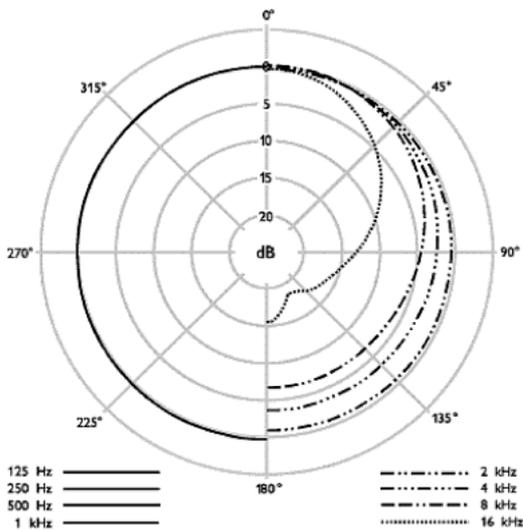


Fig. 9. Omnidirectional Cylindrical Microphone, Polar Pattern

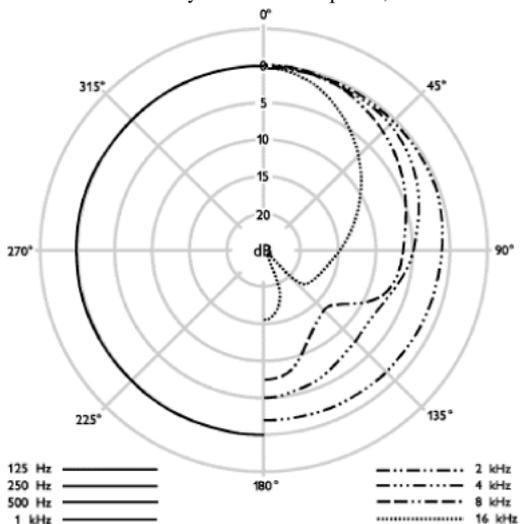


Fig. 10. Microphone plus Sound Diffraction Sphere, Polar Pattern

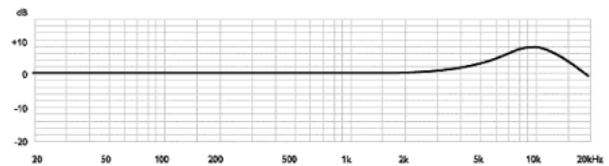


Fig. 9. Cylindrical Pressure Microphone, Frequency Response

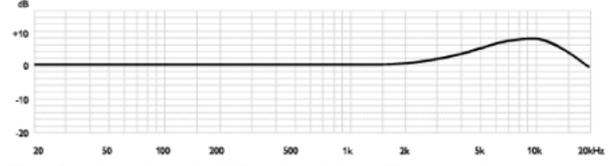


Fig. 10. Microphone & Diffraction Sphere, Frequency Response

THE LATEST EMBODIMENT

The latest development now is still further a combination of the "vintage" concept and today's technology. Already during the listening tests for TLM 50, titanium diaphragms had been tested. Their ultimate application in the series had to be abandoned though, as the material proved not obtainable. Recently, with excellent titanium diaphragms at hand, the TLM 50 capsule was thus altered to a construction made fully of one of the most durable metals, titanium. While the hardness of the material places extreme demands on the pre-production workshop, the durability and the perfect matching of diaphragm and housing material make it worthwhile. Climatic and temperature endurance tests can thus be improved, while the acoustical end result need not differ from other materials.

To integrate this in a modern microphone, and 50 years after the first M 50s, the M 150 Tube was thus conceived. It combines

- the original housing dimensions of the M 50, and its head grille with 3 layers of wire mesh, necessary for exact reproduction of the acoustical behaviour of the M 50 microphone,
- the now all-titanium K 33 TI capsule, still based on the original KK 50 concept,
- a modern tube amplifier, the tube behaviour modeled on the M50's AC701 tube, but with relevantly lower noise floor,
- the amplifier providing a flat response down to below 20 Hz,
- and a transformerless output to provide cable-independent and distortion free transmission of the capsule signal.



Fig. 11. M 150 Tube Microphone, sphere arrangement highlighted

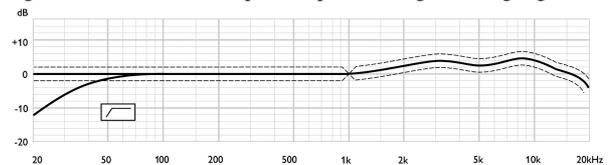


Fig. 12. M 150 Tube Microphone, Frequency Response

## SUMMARY

Once again, we have a great deal to thank our predecessors for, who investigated physics and described the laws of acoustics. Based on these facts, many concepts were derived, which do still have their relevance, after now 50 years. One of these concepts, microphones with spherical body and their evolution has been illustrated.

Of course, not all details of historical facts can be known to the author, not even speaking of all the microphones that might have been constructed. The author is grateful for receiving any additional information on similar microphones that might have been overlooked in this paper.

## ACKNOWLEDGEMENTS

The author would like to thank all the colleagues on the M 150 Tube project.

## LITERATURE

[Bau] F.W.O. Bauch, New High-Grade Microphones, JAES, July 1953

[Ber] L. Beranek, Acoustic Measurements, John Wiley & Sons, New York, 1949

[Gro1] H. Großkopf, Neue Kondensatormikrophone für Rundfunkstudios, FTZ, Heft 9, 1951

[Gro2] H. Großkopf, Zur Betriebseinführung der neuen Kondensatormikrophone, NWDR Techn. Hausmitt., Nr. 10/11, 1951

[Loc] F. Lockwood, Decca Tree, <http://www.nucleus.com/~lockwood/deccatre.html>

[Ols] H. Olson, Elements of Acoustical Engineering, D. Van Nostrand Co., New York, 1947

[Mul] Muller, Black & Dunn, JASA, Vol. 10, No. 1, 1938, referenced by [Ols]

[Peu] S. Peus, Ein Druckmikrofon mit kugelförmiger akustischer Oberfläche, 16th Tonmeisterstagung, Karlsruhe, 1990, also available in English by G. Neumann GmbH

[Sch] L. Schwarz, Zur Theorie der Beugung einer ebenen Schallwelle an der Kugel, Akust. Zeits. 8, 1943, referenced by [Ber]

[Ste] H. Stenzel, Über die von einer starren Kugel hervorgerufene Störung des Schallfeldes, Elektr. Nachr.-Tech., 15, 1938, referenced by [Ber]

## APPENDIX

### HISTORY – SPHERE MICROPHONE DEVELOPMENTS

For documentation, and for the many aficionados of these microphones, it might be interesting to show an overview of the different microphone versions. While all are based on the same construction principle, small details differ.

Early prototype versions (- 1952 approx.) exist by NWDR North-West German Broadcast's research institute. All later microphones mentioned are of Georg Neumann, Berlin production.

### Versions

- M 48 was a capsule head, with a small capsule in a hemisphere, to be mounted on "bottle" amplifiers like CMV 3.
- M 50 was the first stand-alone microphone with a sphere.
- M 250 was an M 50 with RF-secure 7pin Tuchel connector.
- M 550 was a modification to fet technology for Teldec only.
- TLM 50 is a transformerless fet microphone.
- M 150 Tube is a transformerless tube microphone.

## Capsule Types

The earliest capsule was the KK 50, with gold sputtered PVC foil for the diaphragm, designed by the NWDR. The PVC could not hold the extreme mechanical tension applied to the diaphragm in the KK50.

The KK 53 was thus produced with aluminum foil. While the material is much stronger, the minimal spacing between diaphragm and backplate of only 10 µm, without insulation, made it a very critical design.

In the 1960s, metal diaphragms were largely abandoned for studio microphone manufacture, due to their deficiencies regarding longevity and definite manufacturing problems. The KK 83 thus became the standard capsule for M 50 and M 250 in 1965, albeit of larger diameter, and thus altering the frequency response in the treble. This change is not marked on the microphone housing.

With the M 50 now out of fashion, after 1971 no M 50s or the like were produced for almost two decades, while repairs were effected mostly using the KK 83 capsule.

With the renewed interest in omnidirectional recordings, in 1990 the K 33 was designed, as successor of the KK53 and keeping to the basic design. The diaphragm now consists of pure nickel, galvanically obtained in-house. The essential diaphragm spacing remains 10 µm.

The M 150 Tube holds the last re-incarnation of this capsule, the K 33 TI. Identical to the K 33, but with an all-titanium housing and diaphragm, this yields ideal matching regarding mechanical and temperature stability.

## Circuits

"a" version designates the change in capsule, from KK50 to KK53.

"b" version was a negligible change, of resistor power ratings.

"c" version altered filament topology, improving noise by ~4dB.

Like the change in capsule from KK 53 to KK 83, the change from the Hiller MSC 2 tube to the much improved Telefunken AC 701(k) was not clearly designated on the microphone body. The AC 701 was available by 1954 at the latest. The vast majority of microphones was upgraded over the decades, to AC 701 and "c" version. The TLM 50 holds a transformerless circuit of the current TLM series.

The M 150 Tube holds a transformerless tube circuit, like the siblings M 147 and M 149 Tube, and with the identical tube.

All manufacturing dates are approximate.

Year	Microphone	Capsule	Diaphragm	Note
1948? -	(CMV3, U47)	M 48 (KK 50)	PVC	---
1953 -	(CMV3, U47)	M 48a (KK 53)	AL	---
04/1951 -	M 50	KK 50	PVC	MSC 2 tube
01/1952 -	M 50a	KK 53	AL	MSC 2 tube
06/1963 -	M 50b	KK 53	AL	AC 701 tube
01/66 - '71	M 50c	KK 53	AL	AC 701 tube
08/1961 -	M 250	KK 53	AL	AC 701 tube RF-secure
03/65 -'71	M 250c	KK 53	AL	AC 701 tube RF-secure
1965 -	M 50 / 250	KK 83	PE	Series, and repairs after 1971
1980	M 550	---	---	fet-modified M 50
1988 -	TLM 50	K 33	NI	fet
2001 -	M 150 Tube	K 33 TI	TI	Tube

Table. 1. Microphones with spherical design