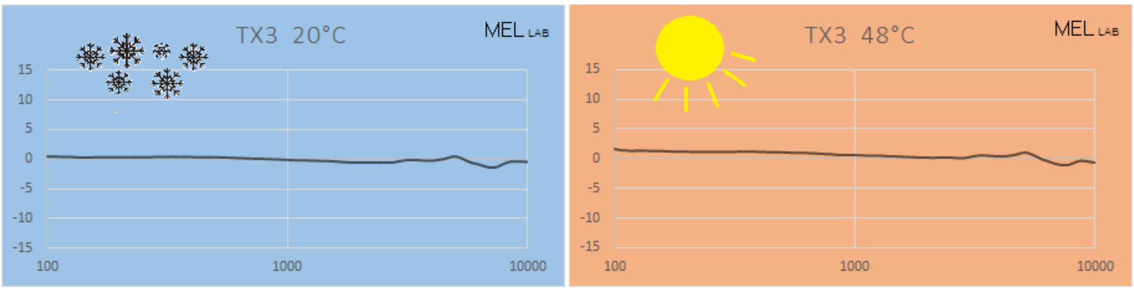
Effects of temperature on the measurement microphones of PA men
Field tests



Measurement microphones must maintain consistent performance with changing environment conditions. The variation in sensitivity as a function of temperature has in fact been subjected to careful investigations since their birth. The specialized literature reports numerous studies, researches and observations both for class 1 microphones and for the cheaper, large-scale produced, ECM. It deals with analysis and experiments done in the laboratory with the maximum accuracy, instead it is difficult to find a study done in the field, that even if approximate can give us a clear idea of how much the temperature afflicts our measurements. It is the intent of this test.

Effects of temperature on condenser microphones

If a microphone is exposed to high temperatures, there are two main effects: the diaphragm tension and air viscosity change (in particular in the small volume behind the diaphragm or back chamber). At low temperatures these effects are less and reversible.
In the expensive condenser microphones with metallic diaphragm (intended for laboratory/reference, both externally polarized and pre-polarized through an electret layer), the variation in sensitivity due to thermal drifts is compensated mainly by selecting materials with appropriate coefficients of thermal expansion [1] . In the most inexpensive electret microphones with metallised polymeric diaphragm, commonly used in pro audio (live sound, hi-fi etc.), the field effect transistor (FET) used inside the capsule as impedance converter, is chosen to have appropriate electrical characteristics (gain, noise, distortion etc.) but also as a function of its own thermal drift, whose inverse characteristic largely compensates for the variation in sensitivity caused by the diaphragm when the operating temperature varies [2]. Of course also the choice of the material that constitutes the diaphragm is crucial for the mechanical and thermal stability of the microphone [3].The effects due to the viscosity of the air, which particularly afflict the highest part of the spectrum, are more difficult to counteract. The range of frequencies concerned is the higher the smaller the microphone size. The tendency to miniaturization of the microphones involves a reduction in the air volume of the back chamber with a consequent increase in the equivalent stiffness, thus obtaining a system less sensitive to the variation of air viscosity, in particular in the audible range. In the 1/4" microphones used in the audio band, these effects are often negligible [4].

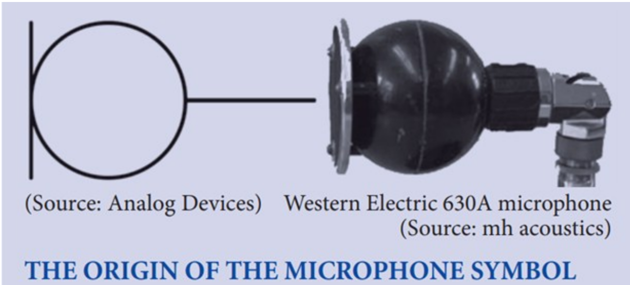


Fig.1 Courtesy Acoustics Today, Aprile 2009

A brief history

In 1917 E. C. Wente inwents, pardon, invents, the condenser microphone [5]. He accompanies his brilliant invention with an accurate theoretical analysis and introduces the definition of the acoustic response of the microphone in terms of amplitude and phase. That transducer, born mainly for telephone use, has a very linear response, exceptionally linear compared to the microphones of the time. It is thus developed and produced by Western Electric. The 640A model is already a first standard for acoustic measurements.
In Bell Laboratories, in 1942, while developing the absolute calibration technique of microphones based on the reciprocity theorem, it turns out that the microphone shows a wide variation in sensitivity when atmospheric conditions change, in particular the response varies + 5.5dB between -65 ° C and 25 ° C. [6]. The aluminum alloy diaphragm and the steel body have different thermal expansion coefficients. M. S. Hawley and P. S. Olmstead modify the design using an anti-corrosion steel for the diaphragm with a thermal coefficient close to that of the body. In this way, the reduction in the diaphragm tension as the temperature increases is contrasted and reduced. Also the increase of the viscosity of the air inside the microphone is compensated by using a special alloy for the backplate. Other measures are adopted to improve the stability of the microphone up to the birth of the legendary WE 640AA. Producing it in (relatively small) series maintaining such a high quality standards probably is not convenient for the Americans so they turn to the Danes of Naerum, the Bruel & Kjaer Instruments ...
Per Bruel, Viggo Kjaer, Gunnar Rasmussen, & co. further refine the selection of materials and the construction and calibration techniques of microphones [7]. The B&K4160 will replace the WE 640AA which will no longer be produced.
We will never be grateful enough to B&K for the massive production of technical documentation produced and shared with the rest of the world. Perhaps their condition of absolute leadership has enabled them to do so without fear of being copied (successfully) by (poor) competition.
In this regard I like to recall a fact told by P. Bruel himself [8].
Towards the end of the 1970s, when the leadership of Bruel & Kjaer Instruments was already largely consolidated, the company was asked to share its know-how with a Russian delegation of three engineers. Political reasons. President Brezhnev himself supported the mission. After an initial perplexity they welcomed the delegation and showed them, illustrating the details, all their production processes.
The three engineers, tired and somewhat confused, returned to the USSR. B&K didn't know anything about them until the following year when they received a large order of microphones from the Soviet Union ...
In 1963 G. Sessler and J. West presented the pre-polarized condenser microphone to the world. The microphone no longer needs external power supply, a capacitor electrode is permanently charged by an electret layer [9].
At the beginning there is some concern about the duration of the charge called "quasi-permanent", but soon many studies dispel any doubt, the definition of charge thus loses the "quasi ". Virtually all microphone manufacturers in the world are starting to experiment and produce pre-polarized microphones. Patents multiply. Even Bruel & Kjaer in the mid-70s launches a program for the study and production of electret microphones [10]. They will become today's standard.
About 7 years after the invention, Sony Corporation * realizes an electret microphone for its recorders, benefiting from the low sensitivity to vibrations due to the extremely light diaphragm of these microphones.
The pre-polarized microphone lends well itself to miniaturization and large-scale production, which gives rise to a spasmodic search to optimize theoretical models, materials, designs and production methods [11]. It finds application in the countless devices that the consumer electronics industry produces at increasing rates: from telephones and other communication systems, to hearing aids, to cameras, to devices intended for music, entertainment, games etc. etc. Billions of them are produced. But the research continues. At the 1983 Paris conference, Sessler and his student Dietmar Hohm, propose an electret microphone integrated in a silicon chip together with the necessary electronics [12]. The MEMS (micro electro mechanical system) are coming! [13]. But maybe we'll talk about them another time.

The test

Making reliable and repeatable measurements "on the road" is a difficult task. Those that follow, in fact, are the fruit of many attempts, not all successful. Although these are trivial tests, finding the optimal conditions to obtain them was not easy. We had to discard the idea of making them in front of a typical stage set up for musical performances, due to the impossibility of maintaining the measurement setup unchanged for long hours and we moved to my home backyard ... But even here we are at the mercy of the sun, wind, clouds, airplanes and tractors, neighbors or passers-by, even the curiosity of pets has caused us problems! In the end, after experimenting with different setups and the difficulties mentioned above, we arrived at a simple but sufficiently accurate and repeatable solution.
Test conditions: we are in the middle of summer (very hot), planet Earth, northern hemisphere, home garden. Early in the morning the temperature is around 20 ° C. At noon the microphones exposed to the sun reach around 50 ° C.

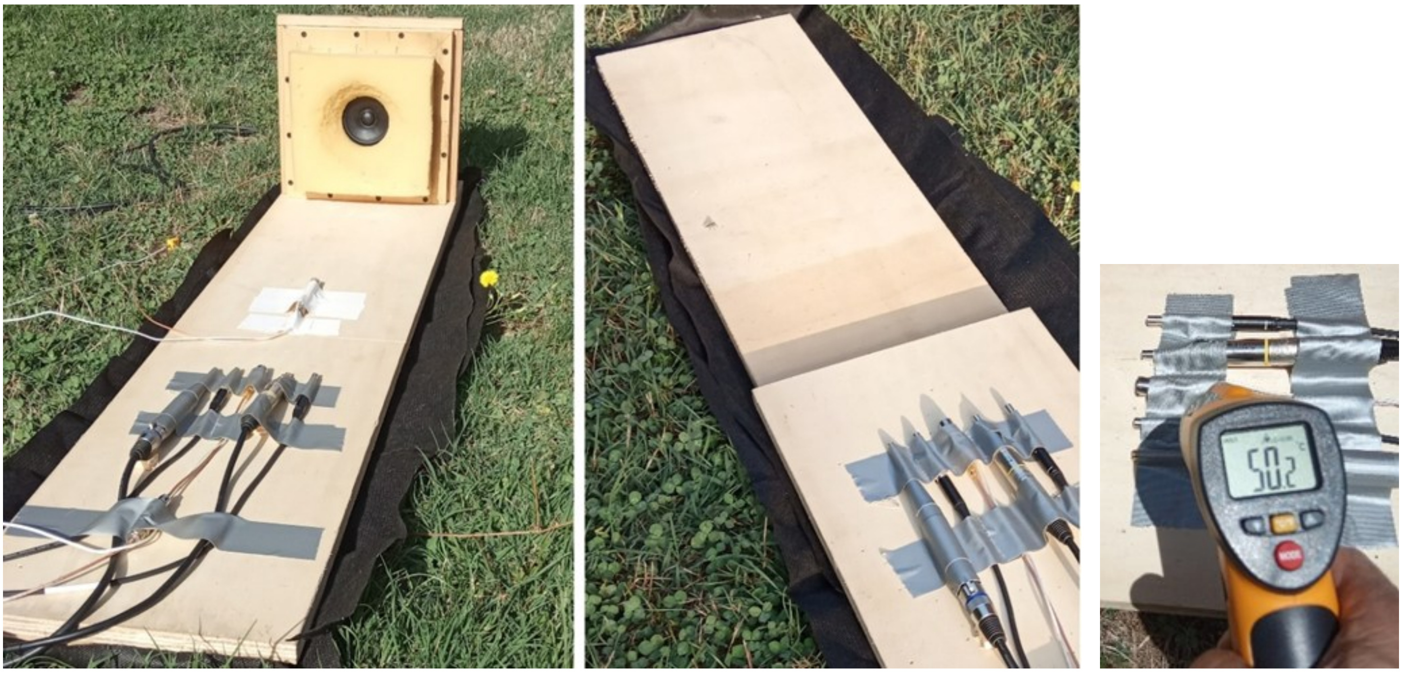


Fig.2 The setup

The setup for the test was designed for ground measurements or "ground plane" [14], a wooden board placed on the grass constitutes the support surface for a twin panel divided into two parts, easily repositionable.
One part of the panel houses the 5 microphones exposed to the sun, the other part has a speaker fixed at one end and the **control microphone** anchored to the floor on the other. This solution allows an easy and enough accurate removal/repositioning of the *source-control microphone* block, so to leave under the sun only the concerned microphones (from the left in the photos):

CR42 SKF *	Low cost Chinese microphone. It is covered with ribbon because the body is black ... We did not have a glorious ECM8000 available
TX2 (wm61A)	A TX-3 has lent its body to a very well-known capsule, which is now out of production
B&Kref	B&K4189sn2198229 on B&K2695 preamp. It is the **reference microphone** exposed to the sun
MYc-3	Microphone of our production
TX-3	Microphone of our production

Also the sixth microphone, the control microphone fixed in front of the loudspeaker, is a B&K4189sn3036711 on a preamp of our production. All are powered by the 48V supplied by the soundcard used, the two TXs via our active cable AC-2 and the two B&Ks via our active cable model AC-1.
The speaker is a small wide-band unit with a sufficiently linear response in the middle range.
The use of the control microphone (class 1), locked to a fixed point with respect to the source as suggested by the IEC standards, allows us to free ourselves from the drifts of the source.

In all tests the spectra of the six microphones and the transfer functions (TF) of the five microphones under test (M.U.T.) referred to the control microphone are taken.
The following are the results of the last day of measurements, as they have been recorded. They are well in line with those of the previous days but completer and more accurate for the gained experience.

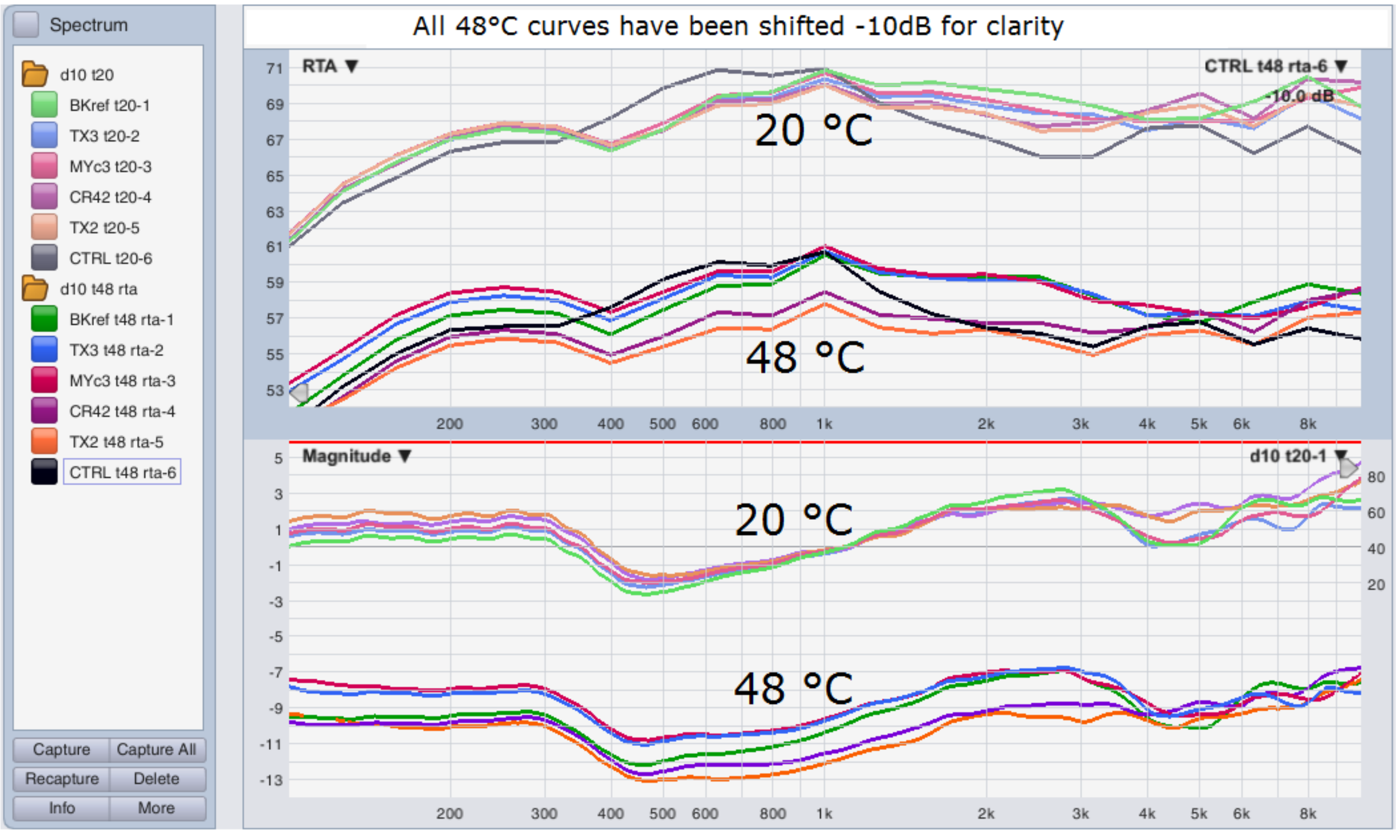


Fig. 3 1/3 ott spectra and T.F. responses of the microphones at 20°C and 48°C as taken

We can immediately observe how the increase in temperature causes the sensitivity variation of the various microphones expanding the mutual distance between the curves. To get a clearer picture, albeit rough, we subtracted the response of the **reference microphone** to all the other curves and shifted them in 3 dB steps (as shown on the graph) to better distinguish them.

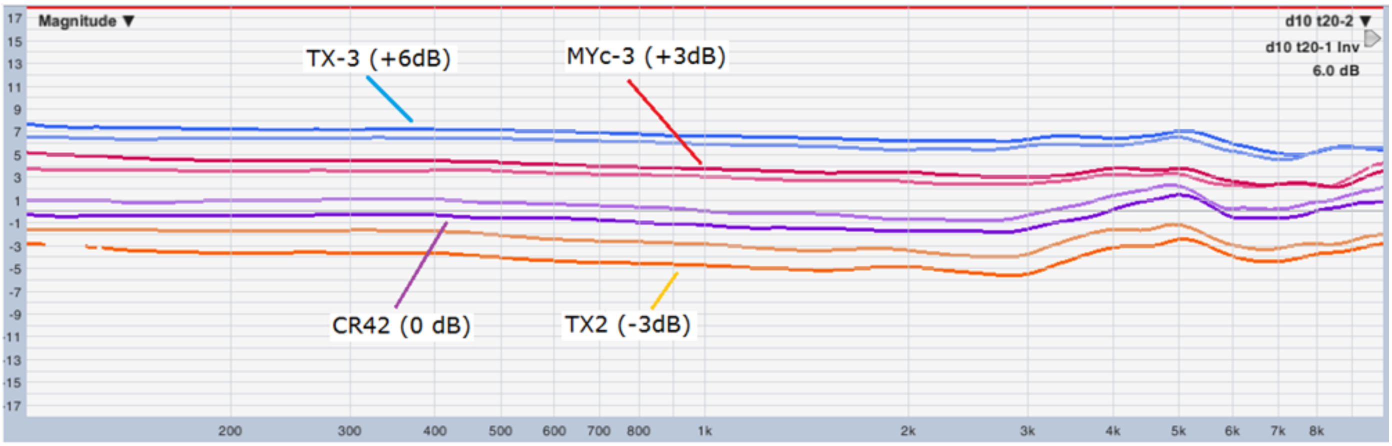


Fig. 4 T.F. of the 4 microphones Vs. the reference microphone at 20°C and 48°C

However, to correctly and more easily assess the behavior of the individual MUTs it is necessary to perform some operations.
With the help of a spreadsheet the operation is simple. Once the curves had been imported, the (small) offset gain of the preamplifiers was removed, allowing the correct alignment of the curves (at the frequency of 1 kHz).
T.F.s have been used, because having the control microphone as reference, the variations of the source had been automatically canceled.

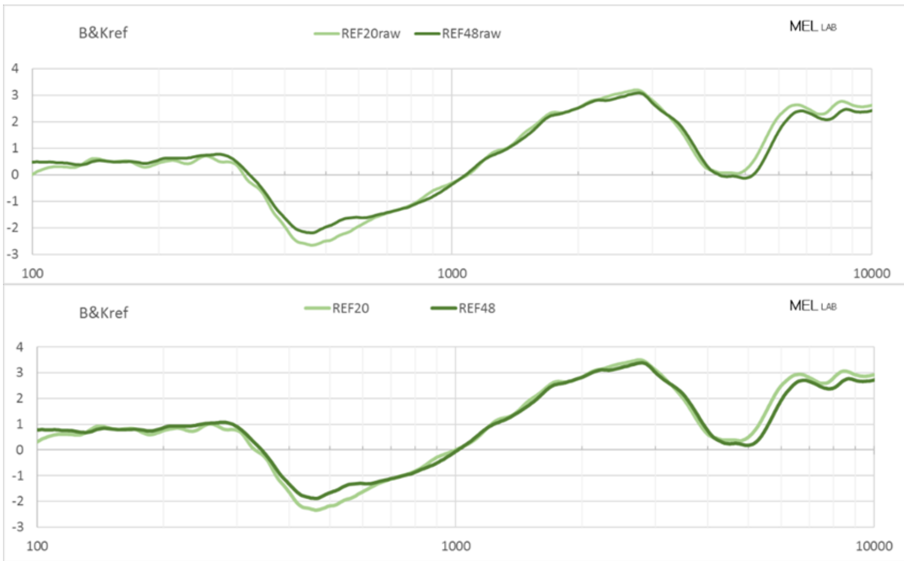


Fig. 5 The reference microphone curves at 20°C and 48°C before and after normalization

We then limited the observation to the frequency range around the reference frequency between 600 and 3000 Hz. It is the most interesting area, less discontinuous and less affected by the limits of the improvised setup.
The following are the curves produced by the 5 microphones at the two temperatures of 20 and 48 ° C and the net difference between them.

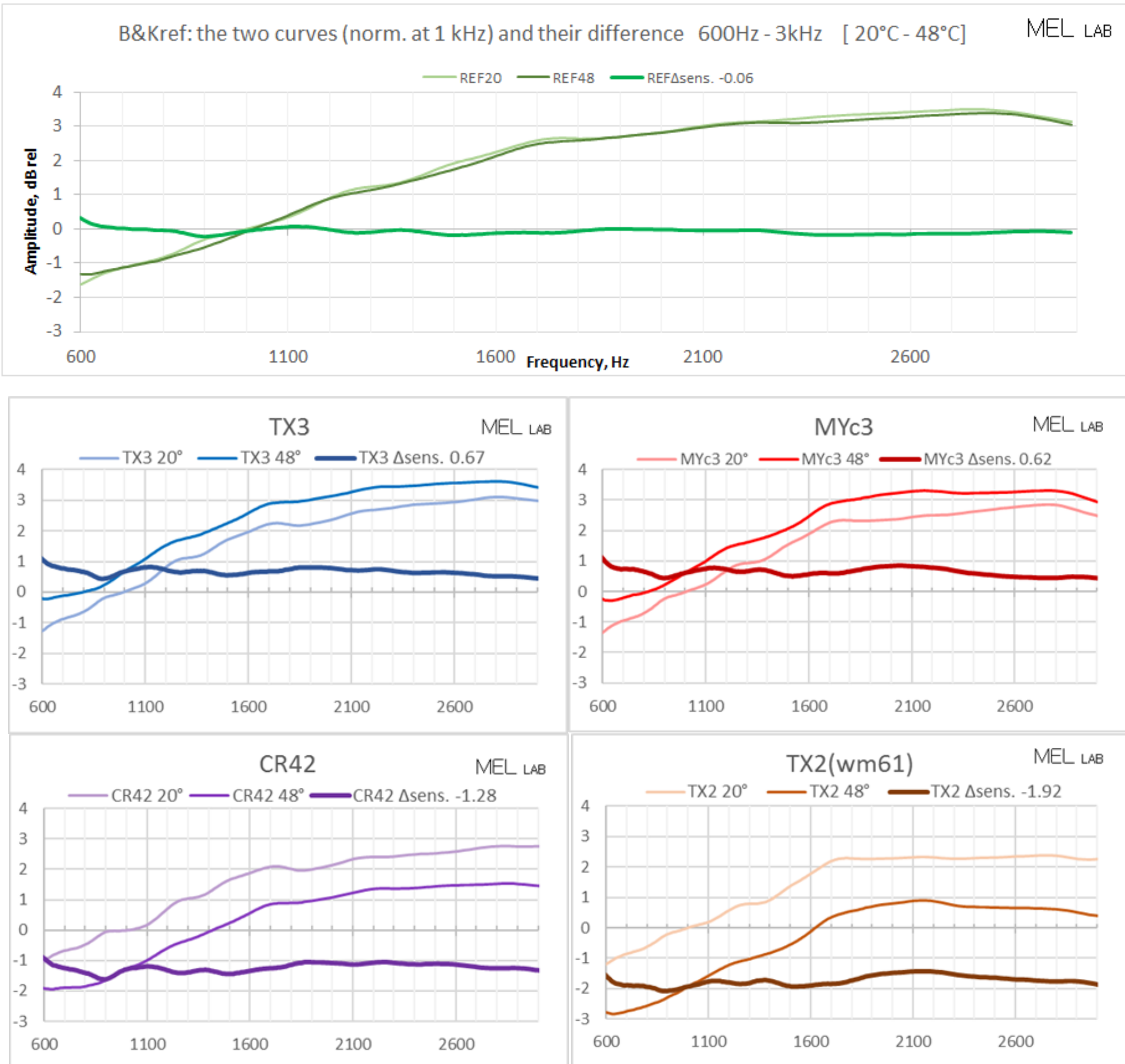


Fig. 6 All microphones curves at 20°C and 48°C and their difference (Δsens.)

This last graph shows all the curves that represent the net difference in sensitivity, Δsens., due to the increase in temperature, so to have a global view of the phenomenon.
The (linear) trend lines offered by the spread sheet help us to interpret the chart. The data that follows the name of the microphone in the legend is the absolute sensitivity difference of the microphone at 1kHz at the two temperatures.

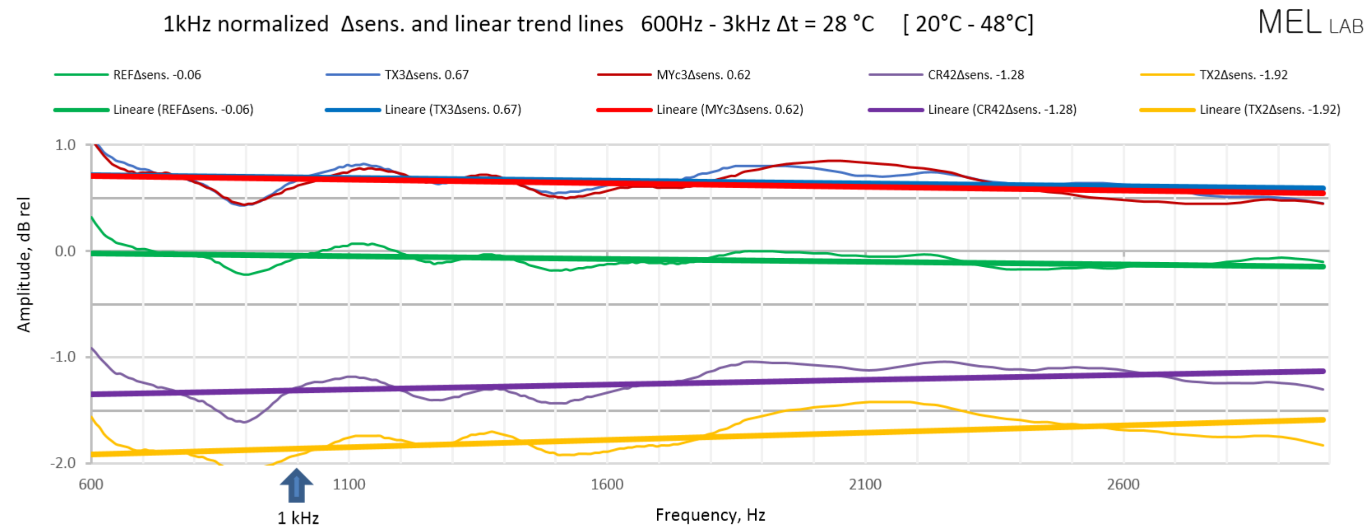


Fig. 7 All the curves representing the net difference, Δsens. and linear trend lines

As can be seen, the reference microphone shows a difference in sensitivity at 1 kHz of −0.06 dB. In fact, the trend line is always less than 0 dB. The thermal coefficient of the microphone has a negative sign, ie the sensitivity decreases with increasing temperature.
It is the same case also for the CR42 and the TX2 (wm61A), but the difference in sensitivity, −1.28 and −1.92, is much more marked.
In the case of the microphones we produce instead, the thermal coefficient is positive, in fact the sensitivity difference, around +0.6 dB, has a positive sign. Sensitivity increases with increasing temperature. Compared to the other two capsules, the variation in sensitivity is more than halved. The credit goes entirely to the manufacturer of the capsules that we are pleased to use.
Note. The gain variation of the electronics we produce used in this test has been evaluated in the laboratory during normal production tests and can certainly be neglected as they are hundredths of decibels.
With the data collected we can calculate the thermal coefficient of the various microphones, but it is a purely academic exercise, given the approximation of the test:

M.U.T.	B&Kref	TX-3	MYc-3	CR42	TX2(wm61A)	
Δ_{sens}	*-0.06*	*0.67*	*0.62*	*-1.28*	*-1.92*	*dB*
Δt	*28*	*28*	*28*	*28*	*28*	*°C*
$T°_{coeff}$	*-0.002*	*0.024*	*0.022*	*-0.046*	*-0.069*	*dB/°C*

Tabella 1 Calculation of the temperature coefficient $T°_{coeff}$ *(at 1 kHz) of the 5 "sunburned" microphones*

The results, in fact, are a bit optimistic but the order of magnitude of the data obtained is well congruent with the data declared in the specifications of the first three microphones: −0.006 dB / K for the first and +0.035 dB / ° C for the other two . It should also be noted that the three coefficients just reported refer to the frequency of 250 Hz, Bruel & Kjaer specifies it, we, far more scoundrels, have not specified it in the technical sheet but having used a pistonphone at 250Hz ... we can confirm it!
If we want to summarize the results of the test in two words, we could say that the cheap non-metallic diaphragm capsules have achieved excellent results also in terms of mechanical and thermal stability, they certainly do not equal the expensive "no FET" colleagues with metallic diaphragm, but they guarantee full operation even in extreme conditions (such as the "African" summer that characterized this study). We could also see that the microphones, once cooled, returned to their initial sensitivity, despite ... 10 days of sunbathing!
Finally, we would not use the term "plastic" to define the diaphragm of ECMs. It's a super special film, the result of amazing studies and capable of incredible performances [15], to say plastic is misleading.

ss

*Registered Marks

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