Validation for Smartphone Applications for Measuring Noise

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Abstract— *Nowadays, the number of applications developed for smartphones is quite huge and, among them, we can find applications dedicated to measure acoustics parameters. In this work, we have done a comparison between eight of these applications and a reference sound level meter, obtaining sound pressure level, directivity and reverberation time at different frequencies and levels. The results can help to choose the most precise application according to the required magnitudes for acoustics studies.*

Keywords— ***Applets, Noise Applications, Smartphones.***

I. INTRODUCTION

Nowadays, there is an increasing number of new smartphones or tablets which have applications that could, perhaps in the future, replace or somehow be similar to the original instruments used in laboratories by technicians or scientists, or at least to give an approximation to these, for example when measuring urban noise in streets or indoor, thus simplifying the need to use a single technical apparatus, sometimes difficult to handle, heavy or voluminous and with a quick battery consumption, to point out only some possible problems. Among the many applications that can be found, there are some able to measure: sound pressure level, frequency spectrum, reverberation time, vibrations, etc. The problem arises when you want to make a technical use of such devices. What is their degree of accuracy? Could we use them to make a first approach?

Some scientists and technicians have started to investigate on questions like those, see for example Kardous and Shaw [1], and Nast et al. [2], whose articles start indicating, perhaps for the first time, how to evaluate these applications. Murphy and King [3] point out that: "The use of smartphones for measuring environmental noise, while currently in its infancy, has significant potential in the future to act as a form of crowd sourced noise monitoring".

We will try to answer the previous questions, with similar techniques to those used by the authors mentioned above, especially with regard to verification of sound pressure levels. We will also attempt, as a new line of research, to design an experiment to test the directivity on the one hand and, on the other, to measure reverberation time.

II. EXPERIMENTAL METHODOLOGY

2.1 Selection Criteria for the Applications to be Validated

We used the following criteria: 1) Applications must measure sound pressure level in decibels, with zero weighting and display the results numerically with one decimal accuracy. 2) Applications must support calibration as a function of the frequency and sound pressure level. 3) Applications have to be handled via USB cable from a computer. These three conditions must be met simultaneously for the applications to be chosen.

Successively, three possible checking experiments were considered: a) Checking the sound pressure level (SPL) in reverberation chamber, b) Directivity (D) at free field, and c) Reverberation time (RT) in a classroom.

Once considered the above criteria, we have selected the applications listed in Table 1.

TABLE 1
SELECTED APPLICATIONS. (SPL = SOUND PRESSURE LEVEL, D = DIRECTIVITY, AND RT = REVERBERATION TIME)

Name	Developer	Users' Evaluation (0-5)	Experiment
decibel Pro	BSB Mobile Solutions	4.3	SPL, D
Noise Meter	Jin asys	4.2	SPL, D
Sonómetro	Tril a droid	4.1	SPL
Sound Meter	Borce Trajkovski	3.8	SPL
SPL Meter	Kewlsoft	4.2	SPL, D
Acoustic RT	AppAcoustiC	3.9	RT
Nachhallzeit	Kröber	4.4	RT
Reverberation Time	BeatApp Studio	3.3	RT

2.2   Sound Pressure Level

Figure 1 shows the equipment used for measuring the sound pressure level (SPL).

FIGURE 1. REVERBERATION CHAMBER WITH EQUIPMENT

Experimental setup: Pre-amplifier connected to Brüel & Kjær omnidirectional speaker to emit controlled frequency tones, either pink or white noise. Smartphone Motorola Moto G Second Generation and complete 2250 Brüel & Kjær Class 1 sound level meter, both mounted on tripods at a height of 1.5 meters above the ground, and with a distance of separation from the speaker of 2 meters. Computer from which the speaker is handled, smartphone and sound level meter. Sound-absorbing headphones for the operator. Digital thermometer-psychrometer to determine the temperature and humidity. The distance of the transmitters or receivers has always been greater than 1.5 meters from any reflective object or wall.

2.3   Directivity

As discussed in a previous section, it can also be applied in measurements of directivity. The experimental setup is identical to that of the reverberating chamber, but in free field, avoiding as far as possible any reflection [4]. For each measure, the sound level meter and smartphone rotate in parallel angles of 45 degrees. Measurements were performed after the closing time of facilities (at 22:00 h.) to avoid others external noise sources to affect the measurements.

2.4   Reverberation Time

We have measured the reverberation time in a regular classroom in our university, using the Symphonie system (01 dB – Stell), with the applications listed in Table 1. For each application, we have performed fifteen measurements of the Reverberation Time (RT60) under the same conditions.

III.   RESULTS

3.1 Measurements as a Function of Level and Frequency

Figure 2 below shows the arithmetic mean of 10 measurements of the SPL performed using the different applications versus the mean measured by the sound level meter 2250 Brüel & Kjær, at different emission frequencies and levels. Diagonal line implies coincidence between application and sound level meter.

FIGURE 2. ARITHMETIC MEANS OF THE SOUND PRESSURE LEVEL AFTER HAVING CALIBRATED EACH APPLICATION TO 1 KHZ AND 75 DB
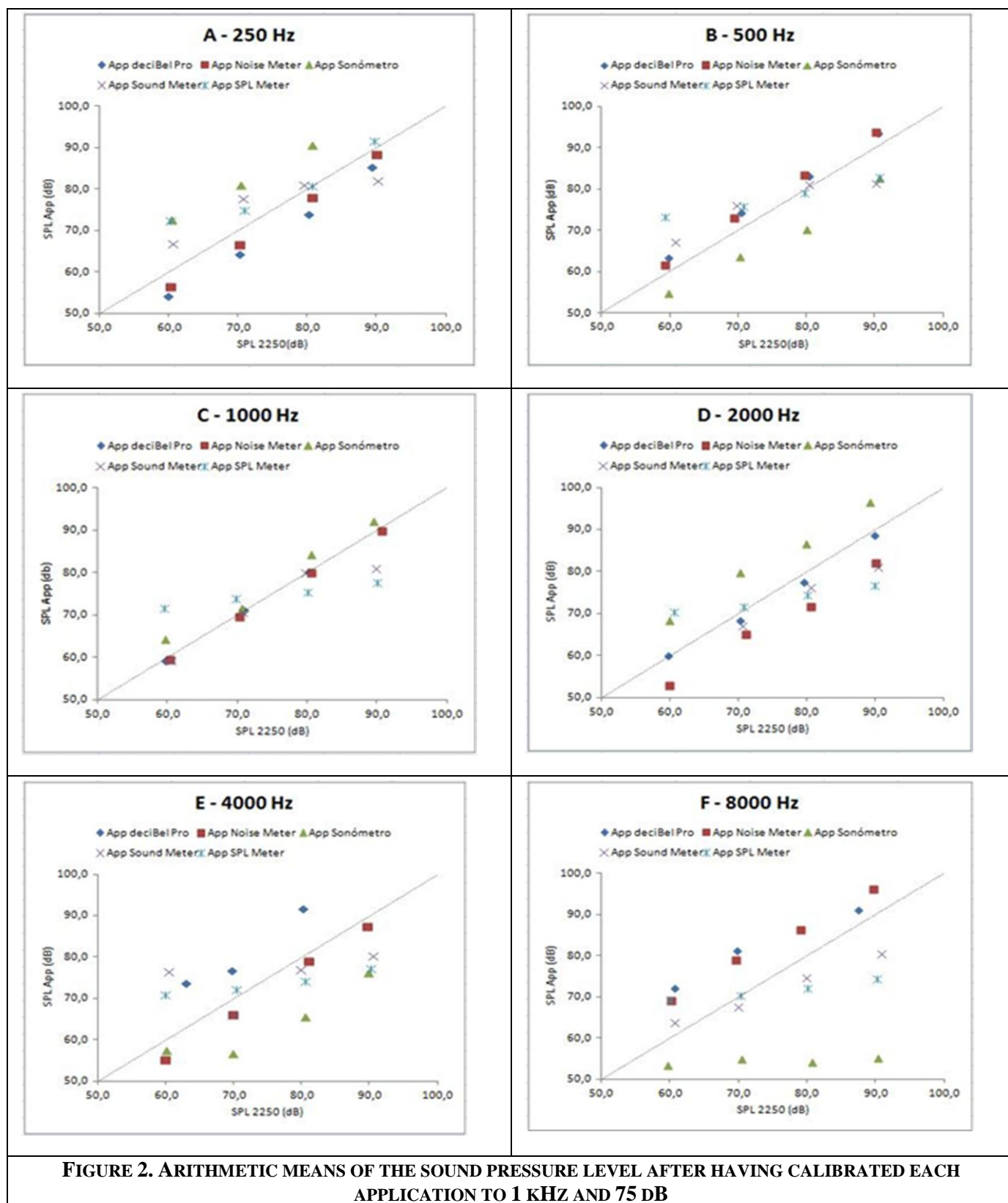
As expected, the best approach to the diagonal corresponds to 1 kHz, just the calibration frequency of each application, at 75 dB of speaker emission level. The other frequencies show greater deviations. We can also observe the differences between the SPL 2250 measured values and those corresponding to each application in Figure 3 based on the frequency.
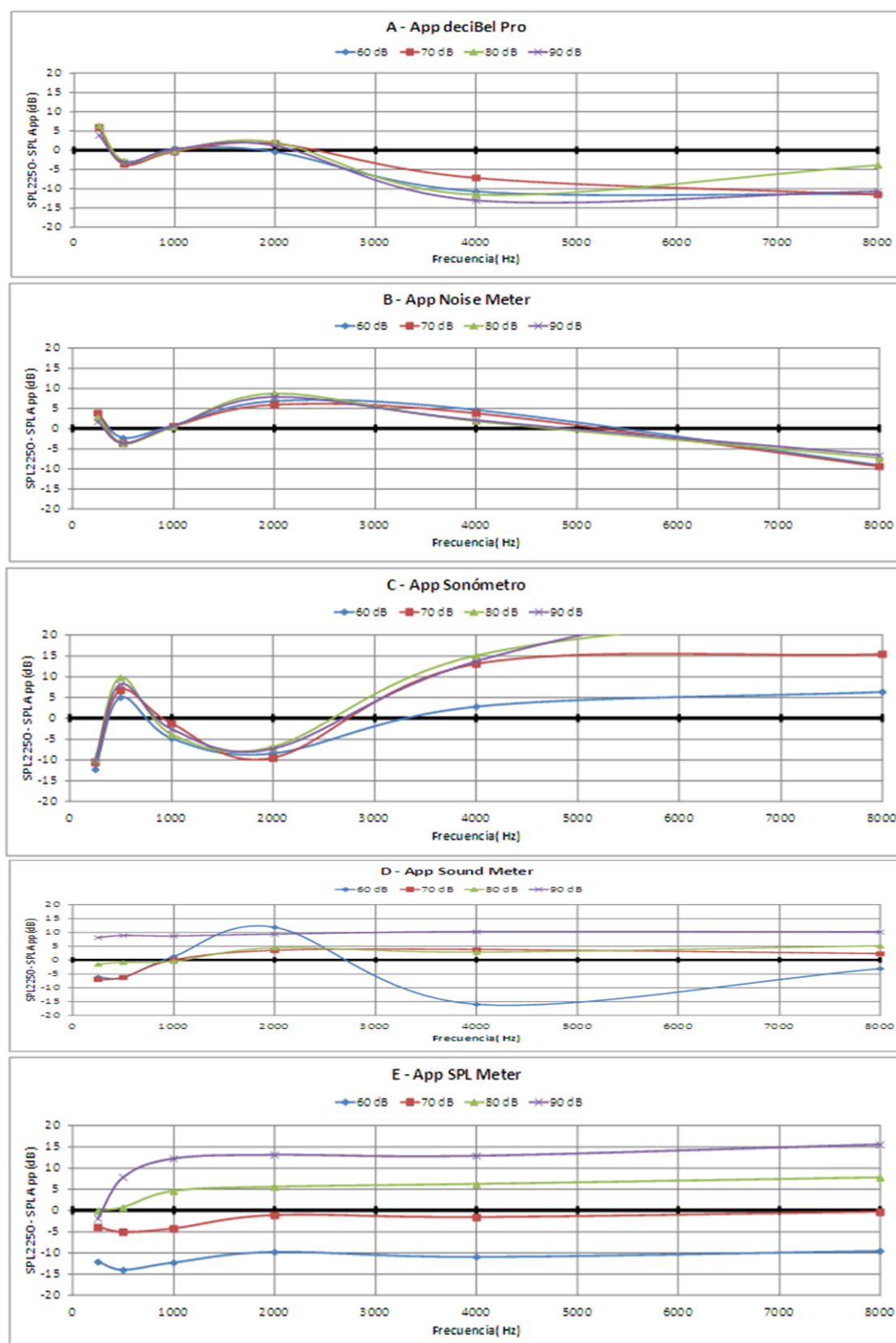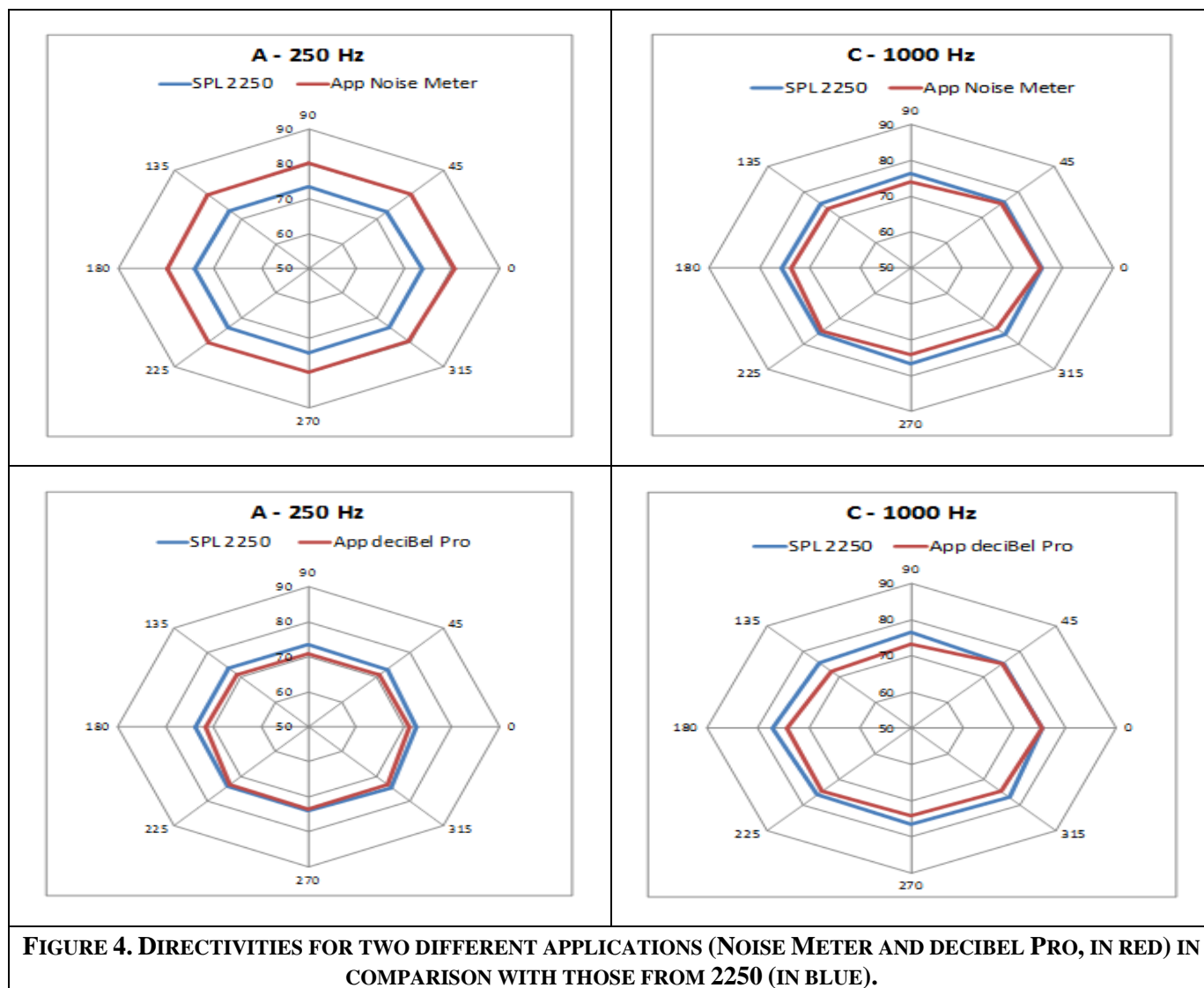
FIGURE 3. ARITHMETIC MEAN OF TEN DIFFERENCES FOR EACH POINT BETWEEN 2250 AND AN APPLET. (THE SOLID LINES HAVE BEEN PUT BETWEEN EXPERIMENTAL POINTS ONLY AS A VISUAL AID) (FRECUENCIA MEANS FREQUENCY)

Smallest differences appear for decibel Pro and Noise meter applications whereas the highest ones occur for SPL Meter.

3.2 Directivity Measurements

Figure 4 shows directivities obtained at two frequencies: 250 and 1000 Hz, for an emission level of approximately 75 dB.

FIGURE 4. DIRECTIVITIES FOR TWO DIFFERENT APPLICATIONS (NOISE METER AND DECIBEL PRO, IN RED) IN COMPARISON WITH THOSE FROM 2250 (IN BLUE).

The calibration of each application was made just at 1 kHz, 75 dB and 0 ° position, where we see that the sound level meter and the application match (Figure 4C above).

We can observe how for the applications listed in the charts above, the directivity has an approximately circular behavior with small differences between the value measured by the sound level meter and the application. However, as you can see in Figure 4A above, for the Noise Meter application, at 250 Hz, although the circularity is maintained, the differences have been somehow higher.

3.3 Reverberation Time Results

In Table 2 below, the results for the reverberation time (RT) are shown measured using the Symphonie system and three applications for smartphones: Acoustic RT, Reverberation Time and Nachhallzeit. These applications are unable to measure long reverberation times, so we had to move our location from the reverberation chamber to a classroom with low RT to perform the measurements.

TABLE 2
MEAN VALUES OBTAINED FOR THE REVERBERATION TIME, TOGETHER WITH ITS STANDARD DEVIATION (σ), MEASURED USING THE SYMPHONIE SYSTEM AND THREE DIFFERENT SMARTPHONE APPLICATIONS (APPLETS).

Application	Acoustic RT		Reverberation Time		Nachhallzeit	
Used System	Symphonie	Applet	Symphonie	Applet	Symphonie	Applet
Average RT(s)	1.37	0.49	1.22	1.23	1.29	1.27
σ (s)	0.13	0.08	0.04	0.04	0.05	0.08

Reverberation Time applets seem to give the closest results whereas on the other hand, Acoustic RT provide the farthest ones when compared with the Symphonie system.

IV.   DISCUSSION

The method employed by Kardous and Shaw [1] is a very powerful and automated one: Basically, in an isolation chamber, an automatic device throws a random tone at frequency and sound pressure level, which is simultaneously measured by the system with the application and the reference sound level meter. The difference between both is stored automatically. Over time, they build a random set of values of differences quite wide (up to 168 values for each application) which, allows you to set fairly powerful statistics for evaluating the applications.

The strategy used by Nast, Speer, and Le Prell [2], which is the one we have used in Figure 2 and 3 is more visual, although perhaps it is more difficult to evaluate statistically.

From Figure 3, it is easier to obtain absolute numerical values about the differences between the sound level meter and the application. We can see the sums of these differences in Table 3 below for each emission level.

TABLE 3
ARITHMETIC SUMS OF THE ABSOLUTE DIFFERENCES (IN DB) OBTAINED FOR ALL FREQUENCIES AT EACH LEVEL OF EMISSION OF THE REFERENCE TONE

Application/SPL	60 (dB)	70 (dB)	80 (dB)	90 (dB)	TOTAL (dB)
Noise Meter	27.6	27.2	24.9	22.8	102.5
deciBel Pro	32.3	30.3	26.7	32.2	121.4
Sound Meter	44.5	23.0	15.0	55.7	138.2
SPL Meter	68.5	16.1	25.0	63.6	173.1
Sonómetro	39.8	56.6	71.9	77.2	245.4

From Figure 4, it can be done a similar calculation to the previous one, obtaining the following ranking: deciBel Pro (199.2 dB), Noise Meter (243.0 dB) and SPL Meter (740.8 dB), indicating the terms in parentheses, the total for all angles and frequencies of all the differences, in absolute value, between the reference sound level meter and the application used

V.   CONCLUSION

Previous work shows a series of experimental results to validate mobile noise applications, depending on the sound pressure level, frequency, directivity, and reverberation time.

Throughout the study, different graphical procedures have been shown for obtaining the functionality of the applications, so it can be established some sort of classification or ranking.

Among the applications checked, we have found that those which best respond to these validations are deciBel Pro and Noise Meter. On the contrary, the one that has responded worse is SPL Meter. Results seem to coincide with those shown by the authors previously mentioned in the literature [1-3]. With regard to reverberation time, the best results correspond to the application called Reverberation Time.

 The valuations given by the users do not match exactly with the trend pointed by our experimental results, probably because they include other aspects (display, user friendliness, etc.)

Obviously, it would be desirable to extend this study not only to a greater number of applications, but also to a different type of smartphones, like iPhones and other mobile devices, for example.

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