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Modern passenger trains in Norway - are they as quiet as we think?

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1 Introduction

The old type short distance electrical passenger trains in Norway (type Bm69), built in the 70's and 80's by Norwegian Strømmens Værkssted are gradually exchanged by modern trains (type Bm72), produced by Italian Ansaldobreda. On paper the noise levels produced by the new Bm72 are 3-6dB lower than the Bm69, depending on track conditions and maintenance. One should therefore expect the number of noise complaints to be falling as a result of the use of new trains. However there are some suggestions that this is not the case. Noise complaints seem to be concentrated around station areas and other areas with frequent braking / acceleration. This paper takes a look at some of the possible causes, based on measurements from the Stavanger-Sandnes double track project and measurements at Sandvika station near Oslo.

In the Stavanger-Sandnes project 14,5km single track railway was converted to a double track. At the same time the freight transport was removed from the railway section and much of the old Bm69 trains were replaced by new Bm72 trains. Even before noise abatement measures the calculated noise level was reduced by ca. 2dB compared to the old single track railway. Noise abatement measures in the project included ca. 7000m of low close-track barriers, ca. 3000m of traditional noise barriers, ca. 60 local barriers and façade upgrades on ca. 120 dwellings.

The old Bm69

The new Bm72

2 Noise levels - calculated vs. measured

As a part of the Stavanger-Sandnes project sound levels from the new double track railway were calculated using the Nordic Calculation Method [1]. This railway section is mainly trafficked by the new Bm72 local trains, as well as some long distance trains, type Bm73 and B7 (with electrical locomotive El-18).

As a result of noise complaints measurements were performed at 2 dwellings, one close to Gausel station and one just outside Sandnes, and noise levels were recorded during 7 consecutive days. There was 10-20 cm of snow coverage on the ground. The measurement point at Sandnes was situated only ca. 10m from the track and ca. 6m over track height. Influence of the snow coverage was therefore considered limited (<2dB). The measurement point at Gausel was situated 25-30m from the track, and only just above track height. Snow coverage can therefore have influenced the measurement results at the Gausel measurement point.

Table 1: Measurement results vs. calculated levels

Measurement point	Measured LAeq,24h [dB]	Calculated LAeq,24h [dB]
at Gausel	47	58
at Sandnes	58	63

The measurements indicate that the calculation method overestimates the noise levels by at least 3dB. Even though the observed levels are considerably lower than the calculated levels that were used when designing noise abatement measures, there still are complaints about the noise from the railway.

3 Observed levels - braking / acceleration vs. nominal speed

As most of the complaints seem to be related to station areas, where trains brake / accelerate, noise levels during braking / acceleration were examined.

When calculating noise levels around station areas according to the Nordic Calculation Method [1] it is common practice to use the nominal train speed outside the station areas also for trains that stop at the station. It is generally assumed this is a conservative approximation that rather overestimates then underestimates noise levels. In relation to the Stavanger-Sandnes double track project, measurements were performed on the old single track railway, just outside the old Mariero station. The measurement results were compared to the values calculated with the Nordic Prediction Method using a “nominal speed” of 85 km/h. The nominal speed of the trains not stopping at Mariero station during the measurements was estimated somewhat lower than this, probably around 70-75 km/h. Noise levels during acceleration and breaking were measured on 5 trains each, measurements on trains at “nominal speed” were performed on 9 trains. All trains were type Bm72. Some curve squeal was observed, especially with the accelerating trains.

The measurement results show that noise levels during acceleration and braking are within the calculated levels in all octave bands. A-weighted levels are typically ca. 4dB lower than the calculated levels, presuming “ordinary maintenance” for the old single track railway.

Measured levels for trains not stopping at the station were somewhat lower than levels during braking / acceleration, probably because of the lower speeds.

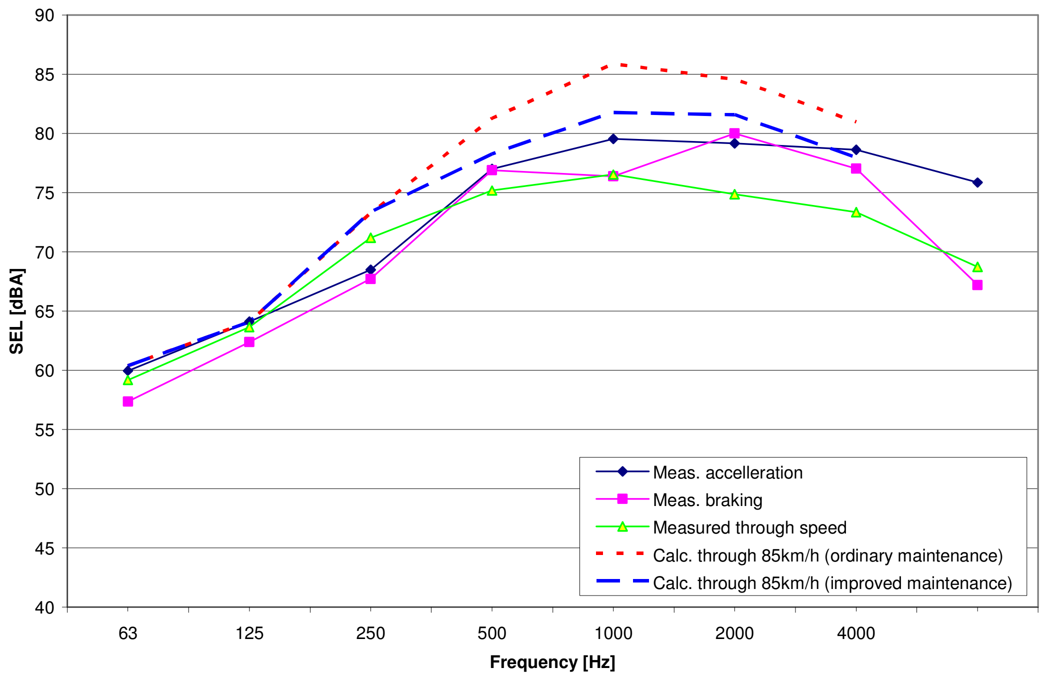

Figure 2: Measured and calculated average noise levels at Mariero (acceleration, braking and nominal speed)

4 Pure tone content analysis

Most of the complaints seem to be related to the tonal content of the noise spectre during acceleration and braking. To study the tonal content a single passage of an accelerating Bm72 train was recorded and analysed using FFT. A spectrogram was also made to study time variance. Similar recording and analysis was performed for a single acceleration of a Bm71 Airport express train, which also shows tonal content. Video files of the registrations at Sandvika station (with sound) are available at Youtube [2][3][4].

Both trains show clear signs of pure tones during acceleration. The spectrograms show the pitch of the pure tones changes with increasing train speed. The FFT's made of the whole registration do therefore not give a good picture of the tonal content.

While the Bm71 pure tones increase evenly with increasing speeds the tones of the Bm72 show a sawtooth-like shape. This is clearly audible as the train seems to "change gear" several consecutive times during acceleration. It is probably these rapid pitch changes that can be especially annoying.

According to a contact person at the railway company NSB the pure tones are related to the inverter providing power to the asynchronous electric engine.

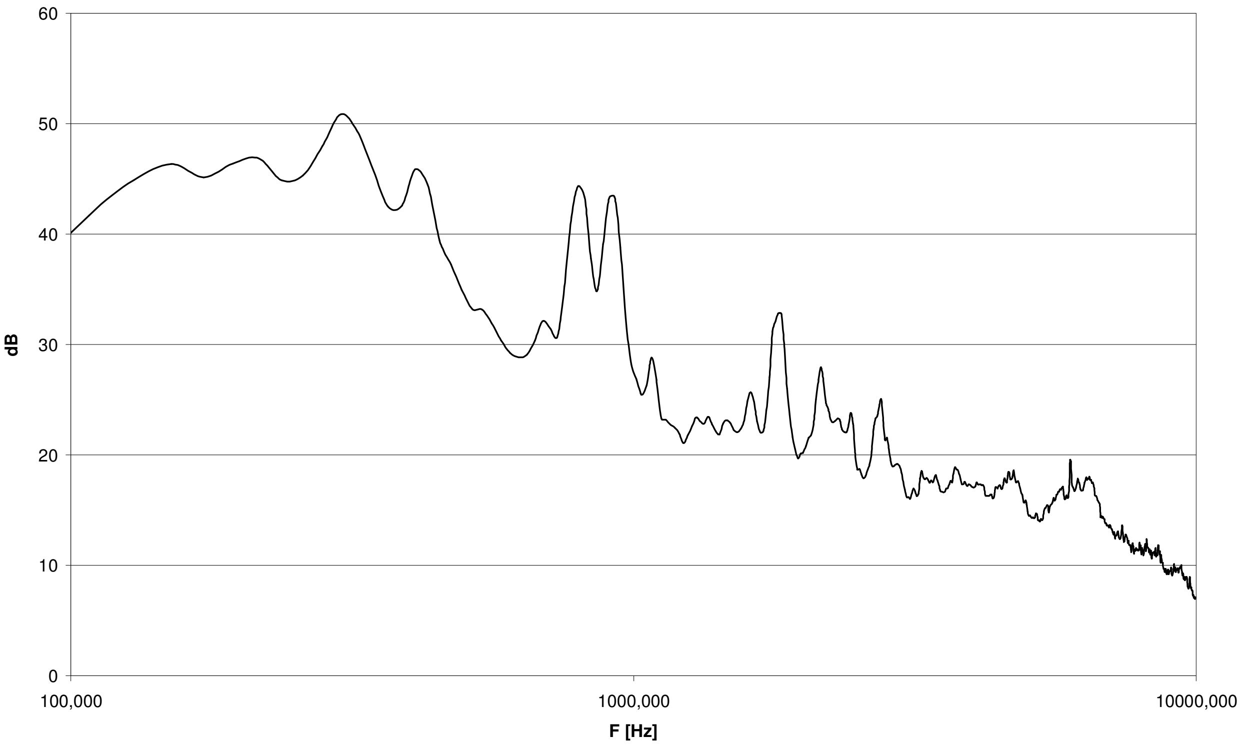

Figure 3: FFT for a single acceleration of a Bm72 train

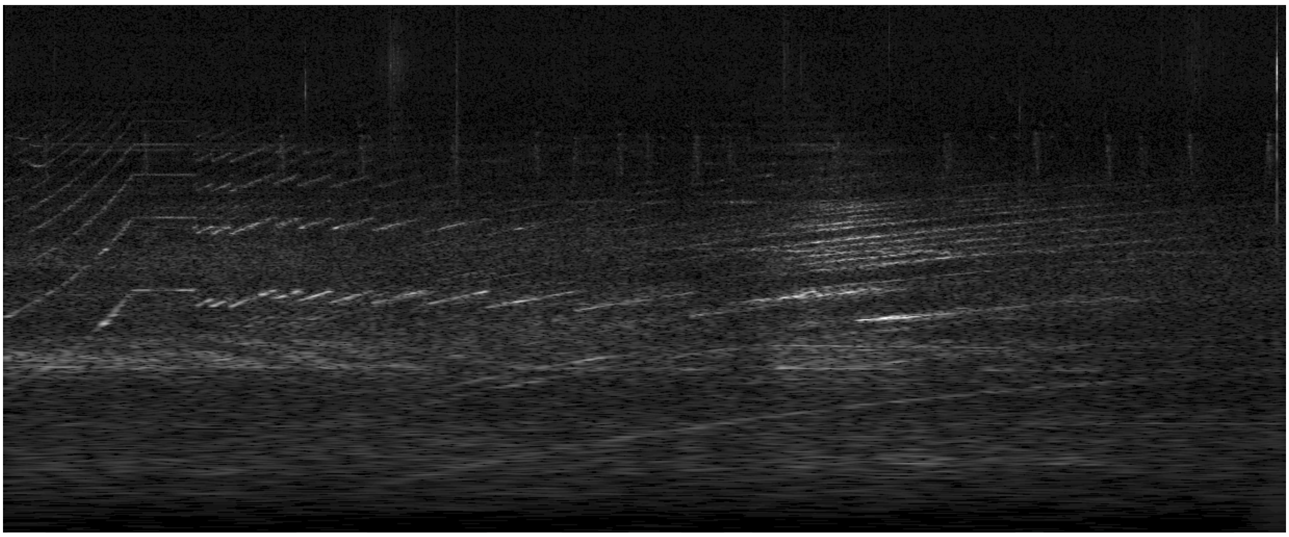

Figure 4: Spectogram for a single acceleration of a Bm72 train

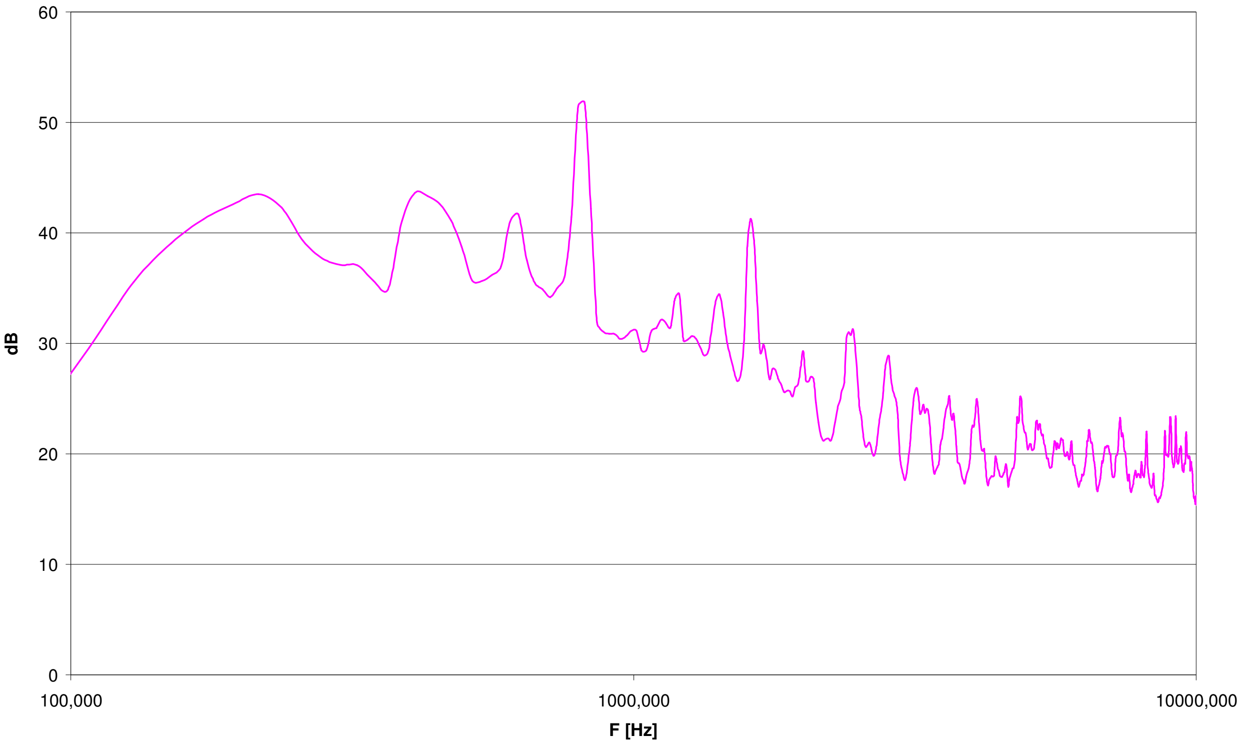

Figure 5: FFT for a single acceleration of a Bm71 Airport express train

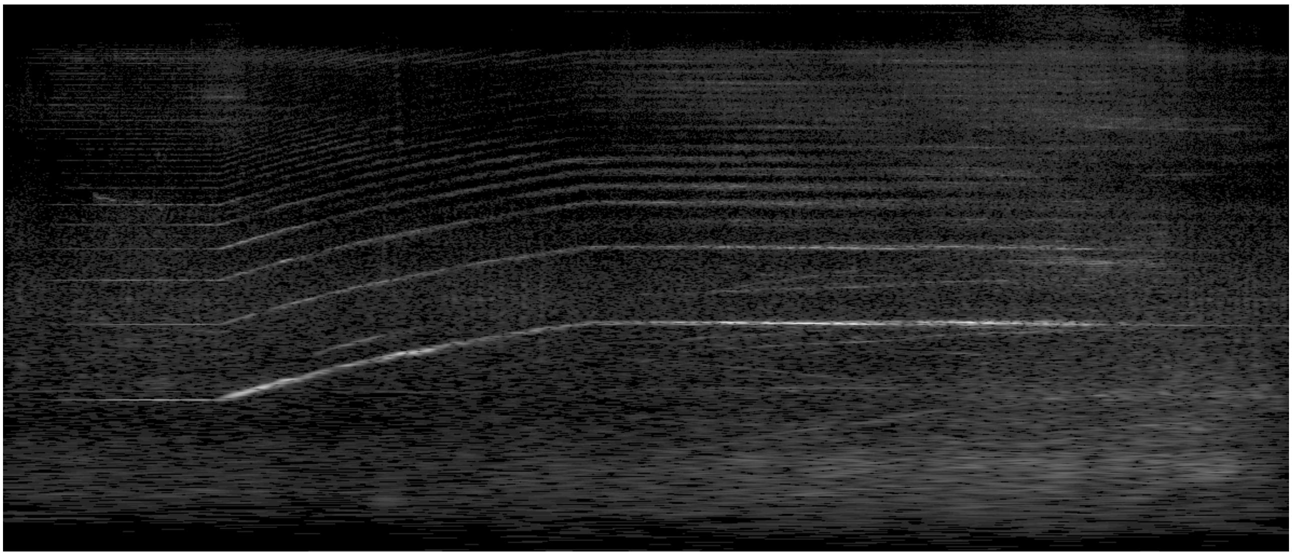

Figure 6: FFT for a single acceleration of a Bm71 Airport express train

5 Conclusions

Modern Norwegian passenger trains of type Bm72 show considerably lower noise levels compared to the older trains of type Bm69. This is confirmed by both calculations and measurements.

Noise levels during braking and acceleration are typically lower than noise levels calculated using “nominal speed”, and comparable to noise levels measured at “nominal speed”.

Noise complaints about the new Bm72 trains seem to be related to the pure tone content of the noise spectrum during acceleration and braking. Further away from the station areas and at higher speeds other noise sources on the trains dominate and the pure tones are largely masked. Similar tonality problems are reported for trains of type Bm73, Bm71 (airport express) and the new subway trains in Oslo. It can be assumed that modern trains of similar design in other European countries can show the same problems with tonality.

There is no tradition in Norway to apply pure tone corrections to railway noise, although noise regulations technically allow for such a correction. Norwegian noise regulations, as described in Norwegian Standard NS 8175 provide only subjective criteria for accessing pure tones. Objective criteria based on ISO 1996-2 cannot be used as they require a constant signal. The pitch of the pure tones varies with train speed.

Using pure tone correction penalty of 5dB (all or nothing), as suggested in NS8175, based on subjective criteria only seems like a too crude tool to access the problem of pure tone content. Especially it will be difficult to draw the limit between “just enough tonal” and “not enough tonal” when moving away from the station areas.

Pure tone content is related to noise from the inverter providing power to the engine. The highest A-weighted contributions are around 800Hz. It seems there must be technical solutions to reduce these noise contributions at the train itself, rather than taking measures along the railway. Tonal content should be focused on by the railway companies and train manufacturers.

References

[1] TemaNord. 1996:524 Railway Traffic Noise—The Nordic Prediction Method

[2] Bm69 acceleration video from Sandvika station: http://www.youtube.com/watch?v=q_XUHp76nuY

[3] Bm72 acceleration video from Sandvika station: http://www.youtube.com/watch?v=JaBG8bX7vhM

[4] Bm71 Airport express train acceleration video from Sandvika station: http://www.youtube.com/watch?v=J6bC0TzfNZQ