Bar-Ilan University
Tel-Aviv metro M2 line Ramat-Gan

Assessment of NTA's Environmental Impact Survey

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Contents

0. Assessment Statement

Environmental impact of metro systems

The construction of a new metro system will have environmental impact such as (but not limited to) dust, vibration, noise and so-called electromagnetic emission, both during construction, as well as during operation. New electrical systems cause new electromagnetic phenomena in their environment, and electromagnetic compatibility (EMC) with equipment already present in that environment must be managed.

The M2 is planned to pass the University at close range (northern route) or even beneath the University buildings (southern route). The University uses all types of scientific instruments in education and research. A new metro system is very well capable of causing electromagnetic fields that disturb the proper operation of the instruments, which would cause certain research to become very difficult or even impossible.

NTA performed an Environmental Impact Survey (EIS), also on electromagnetic effects of the future metro system. The survey states that (at ground level) there will be *no restrictions* and there will be *no effect on equipment*.

Assignment

The Bar-Ilan University asked Microsim to perform an assessment on the risks of electromagnetic effects of metro operation, based on presently available information. Microsim has knowledge of and experience with investigating similar situations and has engineered solutions, both in the Netherlands as well as abroad. An investigation was carried out and the findings contradict conclusions of NTA's EIS. Therefor the University asked Microsim to assess the EIS and analyse what caused the differences in opinion and why.

Scope

The technical scope of the assessment is: (electro)magnetic interference by M2 with scientific instruments of the University in the low and extremely low frequency bands. Interference in those frequency bands is presently not addressed in any EMC standard or guideline, so it has to be assessed on a situation specific basis.

Assessment

The ELF magnetic emission part of the EIS was assessed. Our conclusion is that (even if the calculations are numerically correct), the EIS conclusions about emission at ground level with respect to scientific instruments are not correct. That is because

1. certain physical phenomena of the power supply process of metro operations were overlooked and
2. the specific sensitivities of scientific instruments were not taken into account.

Contrary to the EIS statement our professional opinion is, that the ELF emission of the metro will be very much higher than stated in the survey and can cause severe interference to scientific instruments of the University.

Leusden, The Netherlands,
November 5th, 2020
(authorized signature)

Ir. D. van Bekkum,
(managing director)

1. Introduction

1.1 Scope of the assessment

The assessment concentrates on a more or less niche of electromagnetic (EM) emission of the metro system: magnetic fields that change at extremely low frequency (ELF), say below 5 Hz. The reason is that ELF frequency emission:

- is not covered by EMC standards and guidelines;
- is to a high degree harmless for humans according to ICNIRP guidelines;
- can be very high because of the high currents involved;
- is an easily overlooked niche in the railway world because it causes interference with "only" specific instruments at special locations.

Therefor this assessment will not apply to (i) electric fields, (ii) high(er) frequencies such as RF. In fact, the assessment was (for practical reasons) limited to chapter 4.4.1 Electromagnetic fields from the metro route. The assessment was done paragraph by paragraph.

1.2 Original text and translation

The original EIS has been written in Hebrew. For the purpose of the assessment by Microsim, the following chapters have been translated into English: (i) Summary, (ii) Chapter A (Background), (iii) Chapter B (Review of Alternatives) and Chapter 4.4. (Electromagnetic Fields). There is (of course) always a certain risk that errors in translation cause confusion or misunderstanding. But from the translation it seems reasonable to assume that no problems with correct understanding have occurred. The (for this assessment) most important paragraphs have been cited literally so (if necessary) it can be checked whether misreadings or misinterpretations have happened.

2. Design considerations

Electromagnetic (EM) emission depends on a number of design parameters of the metro system. The EIS has to be based on that but some important design parameters have not yet been determined. Traction power supply can be either AC or DC at various voltage levels and return currents for instance can use the running rails or a dedicated fourth rail. Where the EIS could not be based on chosen designs, alternatives have been considered. Apparently also the type of current collection is still open. The EIS mentions both third rails and collector shoes and overhead wires/rails and pantographs. So assessment of the figures is only possible in terms of an order of magnitude. For the purpose of this assessment, that is acceptable.

3. Assessment: traction power supply and emission

3.1 EIS Ch B Description of project components

EIS text

Construction of electrical corridors and accompanying facilities – in accordance with the NTA decision; electrical connection to the metro is through overhead power lines (but flexibility remains to connect it at high voltage if that is what is decided during detailed planning), and accordingly the project includes two substations located adjacent to an overhead power line, and short corridors to connect the substation to the metro line. The project allows both methods in building (overhead power line or high voltage), and if the decision regarding connecting electricity to the metro is changed (high voltage for example) a supplementary plan is to be submitted.

Assessment

This description is not quite clear. Normally, power supply to metro systems use low to medium voltages (750-1500 V DC). That power must be delivered by the public grid by medium voltage systems from 10-35 kV AC transformed by means of down transformers and subsequently rectified to DC. If power is delivered by high voltage overhead lines from the public grid, then the primary voltage may be higher than 35 kV, but that is essentially not very different. It may involve a two step transformation, for instance from 180 kV to 33 kV and then from 33 kV to (for instance) 1500 V. It must be assumed that two transformer stations will be used for the 180 to 33 kV transformation. And a separate network of 33 kV must be made available. For the transformation of 33 kV to 1500 V many more transformer stations will be needed. That has to do with the voltage drop of the power distribution to the trains by means of third rails. The voltage drop will be such, that those power stations will be needed in the order of every couple of kilometers.

EIS text

Infra 2 - Installation phase of all the railway systems - tracks, signaling, electrification, and more. Ahead of this phase, all the environmental analyses must be carried out to the stage of metro operation. Ahead of the operational phase, an environmental document for the operational stage is prepared, proving compliance with required criteria specified in the environmental impact survey or criteria applicable at the time of the detailed design.

Assessment

Environmental analyses prior to installation must indeed be carried out. But the question is not what must be done, but what will be done.

EIS text

Energy systems and accompanying infrastructures

Electrical systems for the metro are designed using overhead power lines - with connections to be designed and produced by the Israel Electric Company.
If a decision is changed regarding the electrical connection to the metro (high voltage for example), a supplementary plan is to be submitted. The electrical systems include technical rooms and electrical rooms at the stations, stationary electrical systems along the route to feed the trains, electrical lines, and an emergency array that includes generators and back up facilities (in the station buildings and in the depot), and two substations. High voltage systems include two main components - a metro electrification system designed to propel the metro, and an electrical services system designed to supply electricity to the station and the tunnel.

Assessment

It is quite essential to know which voltages will be used for the power distribution system and what maximum currents will flow through the traction power distribution system. If that is not known (yet) it will be difficult to calculate the EM emission of the system.

EIS text

*Since the metro route is underground, and thus there are no security considerations for pedestrians, power is fed to locomotives via a low connection, obviating the need for poles and a hanging infrastructure. The lower feed can be carried out using the **third rail or fourth rail** systems. The third rail system is considered safer in terms of the effect of electromagnetic fields which have the disadvantage of creating stray currents through train tracks for adjacent metallic elements. The fourth rail system does not create stray currents, but it increases the effect of the electromagnetic fields.The decision regarding the metro electrification system is determined during the detailed design stage.*

Assessment

A fourth rail to conduct the return currents instead of using the running rails definitely has advantages with respect to stray currents. The fourth rail can be installed with a much better electrical insulation towards ground than running rails. The mechanical stress is much lower, because it does not have to bear the load of the trains.
Whether or not a fourth rail increases the effect of electromagnetic emission remains to be seen. That also depends on the mechanical design/lay-out of the third rail system and the flow of power currents within the vehicles. If the above conclusion is right, then additional measures (extra cables that change the path and spatial distribution) might compensate for that effect. In that way the return system is optimal both in terms of stray currents and in terms of EM emission.

EIS text

Environmental Implications

Infrastructure systems - As part of planning work, infrastructure coordination was conducted with local authorities and corporations, including:

- *Trans-Israel pipeline - metro crossing in the Highway 40 area.*
- *Petroleum & Energy Infrastructures Ltd (PEI) - metro line crosses the PEI pipeline three times.*
- *Igudan - current Igudan lines cross the metro four times.*

• Water Authority - Coordination with the existing Dan line in a crossing with Highway 40 and Highway 483. In addition, there was coordination with the western Yarkon line on Highway 4.
• Israel Electric Company - overhead power lines of 161 kV and 400 kV cross the metro routes in several places.

Assessment
It must be made clear, how the 161 or 400 kV power will be transformed to metro systems voltage levels and how distribution will take place. Usually, high voltage power is not directly transformed into 750/1500 Vdc for traction power purposes, because power stations that provide power at that level of voltage must be installed every couple of kilometers. So, it must be assumed that first conversion to medium voltage (10 to 33 kV which is city distribution level) will take place. That voltage then must be converted to the voltage used by metro systems. That has not been clarified in the EIS.

EIS text
Electromagnetic fields
Electromagnetic fields from the railway route: This section presents a theoretical specification of electromagnetic field safety for humans and its effects on land use and designations along the metro line. The safety ranges and exposure levels are adapted to the Environmental Protection Ministry guidelines and to the European standard, in accordance with the types of currents - direct current and alternating current:

- *Magnetic field flux density in direct current:*
  - *Maximum exposure to the general public - 600 Gauss.*
  - *Maximum exposure to people with pacemakers - 5 Gauss.*
- *Magnetic field flux density at alternating frequency:*
  - *Maximum exposure to the general public (frequency of 50 Hz) - 4 mG average per day.*

Assessment
This clearly defines the maximum allowed emission with respect to humans. It does not take into account that certain types of scientific instruments have a much lower tolerance. Maximum levels of 1 to 0.1 mG are no exception. Therefor, the above mentioned levels are much too high. That will be explained in more detail in the assessment of chapter 4.4.

EIS text
Electromagnetic field flux - Influence on humans: electromagnetic radiation field calculations are performed according to data of the “recipient” and based on the minimum depth of the railway from the surface – at a depth of 16 meters. The calculations are performed for both direct and alternating current for a 3-rail system and a 4-rail system, and according to common currents (1500 ampere) and peak current (5145 ampere):

- *Direct current (1500 ampere):*
  - *3-rail system - on the surface, flux of 40 mG was obtained, and within the train cars, flux of 500 mG was obtained. In both cases, the flux was in compliance with the criterion of 5 G.*
  - *4-rail system - on the surface, flux of 90 mG was obtained, and within the train cars, flux of 200 mG was obtained. In both cases, the flux was in compliance with the criterion of 5 G.*

Assessment
This is in direct contradiction with the statement of the second paragraph of chapter "**Energy systems and accompanying infrastructures**". And what is more: this statement overlooks two important facts: (i) the changes over time of what is considered here as DC, and (ii) the fact that scientific instruments have a very low tolerance, especially compared to humans. That will also be explained in more detail in the assessment of chapter 4.4.

EIS text
Electromagnetic field flux - Influence on humans: electromagnetic radiation field calculations are performed according to data of the “recipient” and based on the minimum depth of the railway from the surface – at a depth of 16 meters. The calculations are performed for both direct and alternating current for a 3-rail system and a 4-rail system, and according to common currents (1500 ampere) and peak current (5145 ampere):

- *Peak direct current (5145 ampere):*
  - *3-rail system - exposure threshold does not exceed 3 mG, thus meeting the 5 G criterion.*

  - *4-rail system - exposure threshold around the track and within the train stands at about 7000 mG, and is thus higher than the threshold exposure for pacemakers of 5000 mG. Outside the tunnel, the flux is not higher than 300 mG.*

Assessment

Same remarks as the previous paragraph. Also: these figures are confusing. Flux densities have a value which is weighted proportional to all currents in a system. When all currents rise by a factor of (for example) 2, then flux densities become twice as high as before. That seems not to be the case here and the questions is: why not?

EIS text

Electromagnetic field flux - Influence on humans: *electromagnetic radiation field calculations are performed according to data of the "recipient" and based on the minimum depth of the railway from the surface – at a depth of 16 meters. The calculations are performed for both direct and alternating current for a 3-rail system and a 4-rail system, and according to common currents (1500 ampere) and peak current (5145 ampere):*

- *Alternating current –*
  - *3-rail system –*
    - *On street level - the range in which the electromagnetic field flow is obtained is higher than the criterion (4 mG) on the roof of the tunnel (8 meters from the track). There are thus no conflicts along the route (from street level to a depth of 8 meters) as the flux is lower than this criterion.*
    - *Inside the train - the maximum flux obtained is 10 mG. Considering the short time of the ride, the daily average flux is smaller than the 4 mG criteria.*
  - *4-rail system –*
    - *On street level - the range in which the electromagnetic field flow is obtained is higher than the criterion (4 mG) on the roof of the tunnel (8 meters from the track). There are thus no conflicts along the route (from street level to a depth of 8 meters) as the flux is lower than this criterion.*
    - *Inside the train - the maximum flux obtained is 20 mG. Considering the short time of the ride, the daily average flux is smaller than the 4 mG criteria.*

Assessment

Once again: same remark as in the previous paragraphs: not considering much lower tolerance of scientific instruments. And: the fact that a third rail system has the same emission as a fourth rail system raises suspicion. The spatial configuration of the current conducting elements is different and yet the emission is the same? That is a peculiar coincidence. See also the more detailed assessments on chapter 4.4.

EIS text

Electromagnetic field flux - impact on the system: based on European standard requirements, an electromagnetic field that complies with the standard must be ensured in a range of 10 meters from the rail. In accordance with the forecast results, the intensity of the electromagnetic field does not exceed the recommended threshold values, and therefore there is no concern that there be interference with sensitive equipment or life-support systems at a distance exceeding 10 meters. Testing of electromagnetic impact in the depot complex revealed that deviations from Environmental Protection Ministry criteria were not expected outside the depot complex. The impact of the sources was expected to be just patchy, and they are also remote from manned areas of the complex.

Assessment

It is not mentioned, which European standards are referenced. The statement says that if the flux density does not exceed the value of the standards, there is no concern that there will be interference of sensitive equipment at distances longer than 10 m. The question is what the standards say of interference at 10 m and whether that is sufficient to draw conclusions for other distances.

And then: there is no European standard that deals with EM interference in the extremely low frequency range. And nothing is mentioned in the EIS about the sensitivity of the instruments close to the alignment. So how does one know that this statement is true?

EIS text

<u>Stray currents</u>: these are currents caused when the electric power source leaks to the ground and nearby metal installations, instead of returning to the source transformer through the railroad tracks. These currents are liable to create corrosion in adjacent infrastructures. Stray currents can be prevented by a potential equalization network layer - installed under the train tracks to absorb currents before they reach a nearby metallic infrastructure. At the detailed design stage, there is testing and measurement of stray currents, and accordingly, the scope of required protections is decided.

Assessment

Stray current collectors are useful in order to keep stray currents close to the alignment. But good electrical insulation is more important, because it reduces the amount of stray currents. If stray current collectors are the only measures taken, then the question is whether that will be sufficient. And : stray currents not only have negative effects in terms of electrolytical corrosion. Stray currents are currents, and they will cause electromagnetic fields and thus can cause interference. Nothing is said in the EIS about that aspect.

EIS text

<u>Substations</u> - Two substations are planned on Metro Line M2 - Hashalom Substation and Kfar Ganim Substation. In order to comply with threshold criteria for electromagnetic radiation, the substations must be a minimum of 35 meters from sensitive environments/locations. Kfar Ganim Substation is located a long way away (85 meters) from sensitive environments, and thus the impact of electromagnetic radiation on them is in compliance with the threshold criteria described above. On the other hand, the Hashalom Substation is a short distance (10 meters) from populated buildings (Max Fein vocational school), and therefore deviation from the threshold criteria is expected. In view of this, as part of the detailed design, the magnetic flux is estimated, and if necessary, means are determined to prevent deviations from the Environmental Protection Ministry criteria, and the electromagnetic radiation is measured to ensure compliance with the ministry's criteria.

Assessment

It must be made clear what kind of substations those two are. If they are for the purpose of transforming the high 116 kV or 400 kV voltage to 10 - 33 kV medium voltage, then the question is: what about the traction substations that transform 10 - 33 kV to 750/1500 V?

4. Assessment: effect of ELF emission on scientific instruments

4.1 General

Some illustrations of the EIS show lines of the flux density projected on the cross section of a metro tunnel. Those lines connect points with the same magnitude of flux density. It is assumed that the total flux density has been calculated and that the figures give the magnitude in units of mGauss (mG), where 1 mG equals 100 nT (nano Tesla).

The EIS uses the term flux fields. Magnetic flux is an amount of magnetism in relation with a certain (defined) surface. Since no specific surfaces have been defined, the flux per unit of surface (1 square meter) or flux density is meant.

EIS text

This chapter (4.4.1) presents a theoretical characterization of electromagnetic field safety for humans, and addresses the effects of possible interference from the Metro Line M2 railway infrastructure on nearby land use and designations.

Assessment

This statement explains that the EIS is concerned about the impact of magnetic fields on humans, but nothing has been said about special scientific equipment. Therefor the end conclusion cannot (with any authority) say something about that type of interference.

4.2 Criteria for human exposure to electromagnetic fields (EIS ch 4.4.1)

EIS text

<u>4.4.1 Electromagnetic fields from the metro route</u>

This chapter presents a theoretical characterization of electromagnetic field safety for humans, and addresses the effects of possible interference from the Metro Line M2 railway infrastructure on nearby land use and designations. Data on the metro line currents was provided by SYSTRA for Metro Line M3. The assessments presented in this document are based on the assumption that Metro Line M2 and M3 have identical data regarding regular current and overcurrent passing through their electrification strips. The calculated flux data was compared to the exposure criteria for checking compliance with standards and regulation requirements.

Assessment
Nothing is mentioned about scientific equipment's in the environment of the alignment and criteria and regulatory requirements considered, only deal with the effects on humans.

4.3 Criteria for human exposure to electromagnetic fields (EIS ch 4.4.1.1)

EIS text
The electromagnetic safety and compliance ranges include determining the exposure levels and distances required to comply with Israel's Ministry of Environmental Protection (MiEP) guidelines and those of European standard CENELEC EN 50121-2 regarding electromagnetic emissions from the railway infrastructure and the train.

Assessment
European standard EN50121-2 has a serious limitation. Earlier versions only addressed frequencies above 9000 Hz. The latest version (2017) makes things even worse: it only addresses frequencies above 150 kHz. Low and extremely low frequencies are completely overlooked, while those can be a source of serious trouble for scientific instruments.

EIS text
The MiEP does not restrict exposure to static magnetic field flux (DC). A partner to the World Health Organization (WHO), which is involved in setting restrictions for exposure to non-ionizing radiation, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) recommends that individuals with pacemakers only be exposed to static magnetic field flux under 5 Gauss or 5000 mGauss, and that exposure of the general public be limited to 400 mT or 4000 Gauss.

Assessment
ICNIRP and similar institutions that define guidelines with respect to exposure to magnetic fields also do not address the potential impact on scientific instruments. What can be good enough for humans is not automatically acceptable for instruments. The EIS seems to overlook that aspect completely.

EIS text
The infrastructure of the metro railway does not transmit radio frequency (RF) electromagnetic waves. This means that the intensity of the radio radiation emitted from the infrastructure and the train in relation to the ICNIRP guidelines[1] (see details in Appendix C) on radiation field safety is very weak and does not endanger humans. Due to the high current that propels the train, a relatively high magnetic field flux is generated with DC (zero frequency), and since this current is converted from alternating current (AC) at a frequency of 50 Hz, there are also magnetic field components at very low frequencies – 50 Hz to 3000 Hz. Besides the base frequency of 50 Hz and ripples of 300-1200 Hz on the metro train overhead power lines, all the rest of the frequencies produce a magnetic field flux of negligible density.

Assessment
This statement apparently ignores the effects of traction power distribution to moving vehicles. RF frequencies can be transmitted if pantographs or collector shoes suffer from inferior contact with overhead wire or third rail. Bad contact can cause sparking which on its turn generates RF emission. Worse is the statement that the power, distributed to the train, is characterized as DC with a little ripple from the AC-to-DC rectification process. It is true that the zero-load voltage of this kind of systems is DC. But the current is not, far from that. Vehicles have a varying power demand during the ride. Those variations can be large in terms of current and they can be quite fast (hundreds of Amps per second while accelerating, sometimes thousands of Amps during braking). Those variations of

[1] ICNIRP – Guidelines for Limiting Exposure to Time Varying Electric, Magnetic, and Electromagnetic Fields (up to 3000 GHz).
ICNIRP – International Council for Non-Ionizing Radiation Protection, 25 November 2010

current are large and far from DC. They generate large low frequency magnetic fields that can easily interfere with scientific instruments. This omission seems crucial when considering the environmental impact of magnetic fields.

4.4 Glossary of terms (EIS ch 4.4.1.2)

EIS text

Third rail: *The line that feeds all of the metro systems including: propulsion engines, lighting, air conditioning, and various other systems. Third rail specifications: DC voltage of 1500 V, typical current consumed by three train cars – 1500 amperes, with typical power supply of 3000 kW. Maximum current with load for a short time (about two minutes) – 5145 amps; short circuit current 6000 amps.*

Assessment

Microsim has calculated with a max current of 3500 A per train. The results were that the southern route of M2 is completely unacceptable relative to interference with the University's instruments. The EIS reveals that the real short duration maximum can be more than 5100 A. Which means that the reality will be 50% worse than written down in the emission assessment report.

EIS text

Fourth rail (optional): *The rail returns current, which propels the metro train, instead of returning the current via the rails. The advantage of this method is that there are no stray currents passing through the ground that might cause corrosion of buried metal infrastructure.*

Assessment

Stary currents can also cause electromagnetic emission that can interfere with scientific instruments. This aspect seems to be overlooked completely.

EIS text

Return current line: *The track is connected to conductors that attach it to the negative side of the direct voltage supply outlet; that is, the train tracks return most of the DC to the rectifiers, and about 5% of the current may flow out to the ground.*

Assessment

A percentage of 5 is way too high for sensitive situations. With a maximum current of more than 5000 A, that would mean a stray current of more than 250 A that could flow at distances of meters from the instruments.

EIS text

Range of impact on electronic equipment: minimum distance from the tracks in meters in which the level of magnetic field flux is lower than the known vulnerability level of free electronic beam devices, and electronic equipment in general.

Assessment

The EIS seems to have a limited view on the types and technologies of electromechanical and electronic equipment in the environment. What the EIS calls "free electronic beam devices" is just a limited set of instruments. Later in the survey it is stated that those devices are mainly CRT's which are obsolete. This is true, but electron microscopes and mass spectrometers for instance are instruments that use similar technology. Instruments like NMR's or MRI's, that generate static or RF controlled magnetic fields themselves are not considered at all.

4.5 Input data (EIS ch 4.4.1.3)

EIS text

b. Electrical systems specifications

The electrical specifications of the metro were taken from SYSTRA's feasibility study: ***Metro Network System Feasibility Study Report, FEA Traction Power Simulation - M3,*** *of 20 December 2018.* ***The main specifications of power supply to the metro train and the railway infrastructure are listed as follows:***

- *Third Rail (+): DC supply of 1500 V*
- *Fourth Rail (-): Rail that returns the current to the rectifier station*

- *Typical current consumed by three train carriages: 1500 amps, in accordance with the typical supply of 3000 kW*
- *Maximum current with load for a short time (about two minutes) - 5145 amps*
- *Short current 6000 amps (for several seconds)*

Assessment
A typical current consumption per train would be 1500 A for three carriages. But the length of the train can be seven carriages as a maximum. And then the absorbed current will typically rise to 3500 A, with a proportional raise of the EM emission.
If the power supply suffers from a short circuit, the substation has to switch off in a matter of less than 0.1 sec, due to the steep rise of the current. So short circuits of several seconds are extremely and unacceptably long.

EIS text
item c. Configurations of metro train activity

- *Peak static magnetic field flux (about two minutes)*

Assessment
This statement seems to come from traction power distribution calculations. The purpose of those calculations is to determine the power capacity of substations. The amount of power and current of train operations can and will be quite different. Normally the longest period of maximum and constant DC current is around ten seconds. Before that (acceleration) and after that (coasting) the high currents will change in a matter of seconds. That has to do with the power/current consumption of modern traction drive systems of vehicles.
Actual power consumption is important for instruments in the environment, not averages.

4.6 Estimate of magnetic field flux (EIS ch 4.4.1.4)

EIS text
The calculation was performed for DC, to check the effect on pacemakers of a static magnetic field when the accepted sensitivity threshold for pacemakers according to ACGIH is 5 Gauss; the estimate for magnetic field flux whose source is in the AC of the rectifier ripple on the DC was compared to the MiEP recommendations for a threshold of 4 mG (which refers to AC) on average per day. Frequency of the ripples assuming there are rectifiers with 24 diodes is 1200 Hz.

Assessment
The calculation methods follow the statements in earlier paragraphs. The calculations are (probably) not incorrect themselves but suffer from the fact that forgotten input leads to forgotten output and thus to incorrect conclusions. The changes over time of high (so DC) currents have not been taken into account at all.

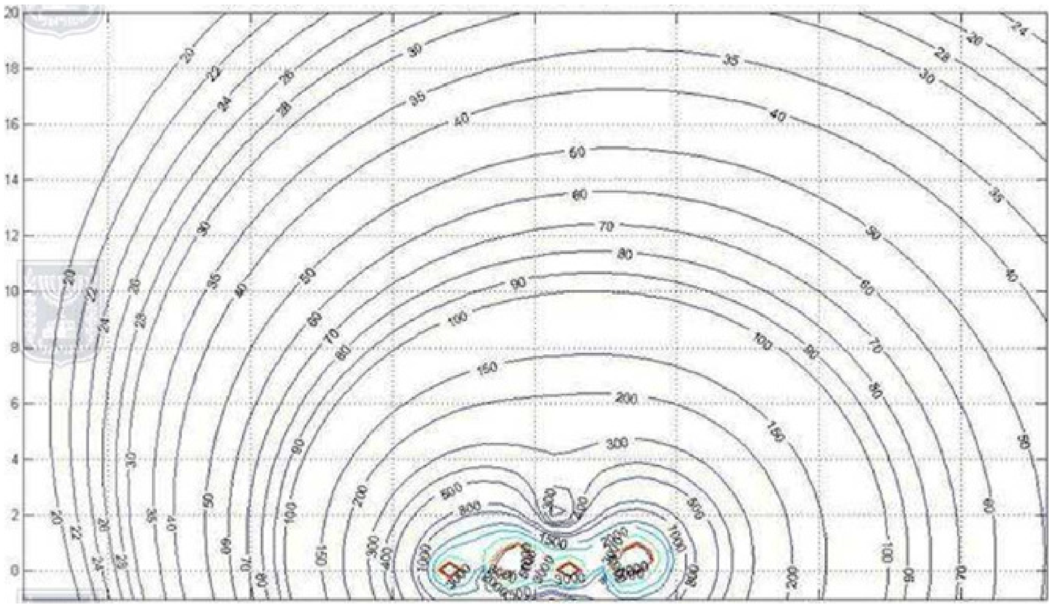
4.7 Magnetic field flux calculated for a third rail-system (EIS ch 4.4.1.5)

4.7.1 Magnetic field flux with DC of 1500 Amps (EIS ch 4.4.1.5a)

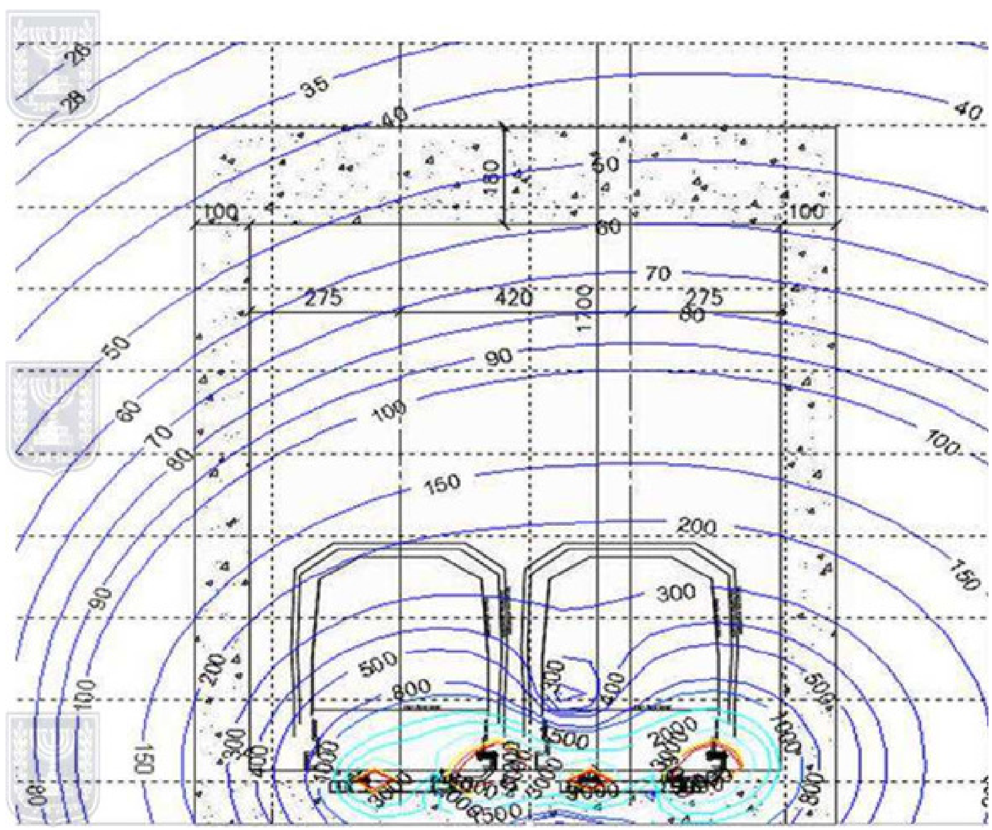
EIS text
Illustration 4.4.1.5.1 shows the magnetic field flux with DC of 1500 A for two trains traveling in opposite directions (common situation), while Illustration 4.4.1.5.2 shows the same flux against the background of the tunnel cross-section. From within the illustrations, it can be seen that the maximum static magnetic field flux -- at a height of 1 meter above the ground (17 meters above the track) is 40 mG (40 milliGauss), and from within the carriages, the maximum static field flux reaches 500 milliGauss. That is, in both cases, the maximum static magnetic field flux complies with the 5 Gauss criterion.

Assessment
If we assume the calculations to be performed correctly, then at 1 m above ground level the statis emission reaches 40 mG which is 4 μT or 4000 nT. That is very much taken into account that the sensitivity of instruments is in the order of 10-100 nT. At best, this is a factor 40 too high. The problem is the statement that this is DC. On the average that may be true, but instruments suffer from instantaneous changes. If the average current is 1500 Amps per train, then the actual value can easily

be anything between 200 and 2800 Amps. And the rate of change (during acceleration or braking can easily be 2600 Amps in ten seconds. And that are situations which can cause unacceptably high interference.
The assumption that this is a DC emission is not at all correct. It is ELF emission.



EIS Illustration 4.4.1.5.1 - Magnetic field flux at DC of 1500 amps (common situation)



EIS Illustration 4.4.1.5.2 - Magnetic field flux at DC of 1500 amps against the background of the tunnel cross-section

4.7.2 Magnetic field flux at peak of 5145 Amps (EIS ch 4.4.1.5b)

EIS text

Illustration 4.4.1.5.3 shows the magnetic field flux at a peak DC of 5145 amps for both trains traveling in opposite directions, while Illustration 4.4.1.5.4 shows the same flux against the background of the tunnel cross-section. From the illustrations, it can be seen that the magnetic field flux in each location around the track, and within the train, is lower than the exposure threshold for pacemakers (5000 mG), that is, it is not higher than 3000 nGauss, at DC of 5145 amps.

Assessment

The graphs show similar pictures, only the figures are higher (of course). But the conclusions are incorrect in the same way. If this is the maximum current under normal operating conditions, then this amount of emission is important for the outside world. Averaging over a period of 24 hours may be important for humans, but instruments have to deal with actual current consumption. If we assume proportionality between current and flux density, then the emission can be as much as at least 40*3,5 = 140 times to high.

4.7.3 Magnetic field flux calculated with AC (EIS ch 4.4.1.5b)

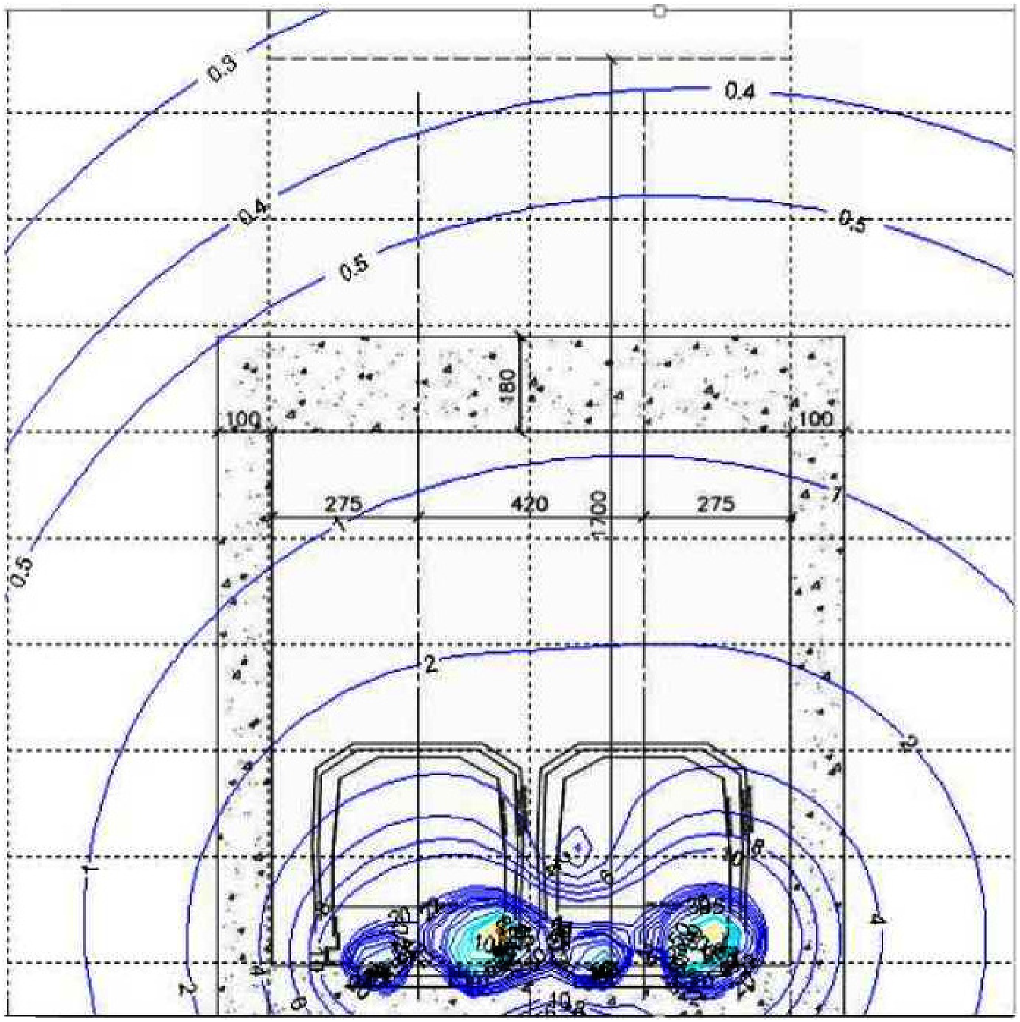
EIS text

"Illustration 4.4.1.5.5 shows the daily average magnetic field flux, with a ripple current of 13.8 amps for two trains traveling in opposing directions, with current of 1500 amps. The illustration shows the following findings regarding the magnetic field flux from the track and the train, both above ground and within the train"

Assessment

A ripple has to do with the rectification process converting a 50 Hz voltage into DC. Usually rectification uses power transformers to lower the voltage and diode bridges to rectify the AC to DC. The technology is such, that the output voltage is DC with a little AC ripple with a frequency of a multiple of 50, such as 300, 600 or even 1200 Hz. Apparently, that is the AC, meant in this chapter. However, voltages do not cause magnetic fields, but currents do. And ripple voltages do not necessarily cause ripple currents of the same frequency. The loads of traction power supply are the vehicles' systems, of which the drive systems are the ones that absorb the highest currents. But drive systems have power electronic switching converters with a complex impedance that varies over time. Thus, it is highly unlikely that the rectification ripple voltages result in current ripple with the same shape and frequency.
In any case, these kind of ripple currents are many orders of magnitude smaller than the varying DC currents, caused by variation in power demand.

Remark.
It is not quite clear, how the flux density was calculated and which of the conductors (third rails and running rails) have been supposed to carry ripple currents. Therefor, it is difficult to check whether or not the calculations have been performed correctly.



EIS Illustration 4.4.1.5.5 - Magnetic field flux with AC (13,6 A ripple of traction rectification)

EIS text

The flux at ground level (above the track)
The height above the track platform at which the magnetic field flux of 4 mG is obtained is in fact the height of the roof of the tunnel, about eight meters under ground level. There is no need to map the route of the metro track to locate conflicts, as above ground level the magnetic field flux is very low, barely 0.1 mG, which is lower than the typical background atmosphere. The metro train moves with a maximum load of 1500 amps in the tunnel.
As stated, the magnetic field flux reduces to 4 mG at the daily average current already within the metro tunnel, about eight meters under ground level, and therefore, there are no restrictions above ground level.

Assessment

The last sentence indicates that the figures are those of a daily average. That may be correct when calculating the acceptable levels of emission for humans, but this does not apply for scientific equipment. Integration over time is done for humans because we want to determine the long(er) term effects of emission. But the functioning of instruments deals with instantaneous emission. Therefor interference of instruments must be based on instantaneous maximum values of variation.
The statement that "*there are no restrictions above ground level"* must be rejected when it concerns scientific instruments.

4.8 Magnetic field flux calculated for a fourth-rail metro system (EIS ch 4.4.1.6)

EIS text

EIS chapter 4.4.1.6 analyses the situation in case a fourth rail will be used for return current conduction. The shapes of the flux density curves are a little different (of course), and the emission values are about 50% higher at ground level (33 mG versus 50 mG). That can have to do with the spatial configuration of feeder and return currents. The figures of the short circuit currents also suggest that a fourth rail has only been installed in one track, because the magnetic field lines are different for each of both tracks. Or the short circuit is supposed to happen on one track only. That is not clear.

The calculations for an AC ripple of 13.8 Amps show the same tendency. The EIS shows, that application of a fourth rail causes a 50% higher emission than a return via the running rails.

Assessment

The remarks and conclusions regarding the assessment of a third rail configuration also hold for a fourth rail configuration.

4.9 Summary and conclusions (EIS ch 4.4.1.7)

EIS text

a. <u>Third-rail system</u>

- ***Magnetic field flux with AC** – the safety range for residential buildings above ground is 0 meters; therefore, there are no restrictions.*
- ***Passengers inside the train** – are exposed to a maximum magnetic field flux of 10 mG, but considering the short ride time, the daily average is no higher than 4 mG.*
- ***Magnetic field flux with DC** – the magnetic field flux above ground is lower than 35 mG, and it has no effect on people or equipment. Within the metro train carriages, a static magnetic flux field of 3 G is possible, which is lower than the recommended exposure threshold for pacemakers.*

b<u>. Fourth-rail system</u>

- ***Magnetic field flux with AC** – the safety range for residential buildings above ground is 0 meters; therefore, there are no restrictions.*
- ***Passengers inside the train** – are exposed to a maximum magnetic field flux of 20 mG, however considering the short ride time, the daily average does not exceed 4 mG.*
- ***Magnetic field flux with DC** – magnetic field flux above the ground is lower than 90 mG and has no effect on people or equipment. Within the metro carriages, a static magnetic field flux of 7 G is possible. This is higher than the recommended exposure threshold for pacemakers.*

Assessment

When assessing the above descriptions, our conclusion is that these statements are not correct for scientific instruments that are sensitive to ELF frequency emission of the metro. The main objections are:

- only AC rectification ripple is considered as the source of AC interference. That is (in our opinion) not correct and therefor AC emission mission cannot be considered as low;
- DC currents are considered as true constants also because of averaging over a long period of time. That is also not correct. The power consumption of vehicles can change within seconds by hundreds or even thousands of Amps. Also, vehicles are moving and a current that moves in space (even if it is constant in time) will also change the flux density in the environment. Both those changes are much higher than ripple currents from the rectifiers. And those changes can have a very negative impact on the functioning of scientific instruments.

5. Conclusion

Chapter 4.4.1 (Electromagnetic fields from the metro route) of the EIS's statements were assessed in detail. That is because the primary focus of the assessment was geared towards ELF emission and the specific sensitivity of the University's instruments for that type of emission by the metro.

Even if the calculations are numerically correct, the EIS conclusions about emission at ground level with respect to scientific instruments are not correct, because

1. **certain physical phenomena of the power supply process of metro operations were overlooked and**
2. **the specific sensitivities of scientific instruments were not taken into account.**

DvB/-