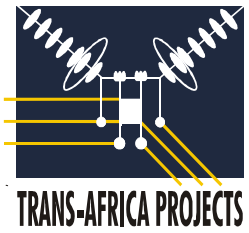

TRANS-AFRICA PROJECTS

MERCURY-PERSEUS 400 kV: ENVIRONMENTAL EFFECTS

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27 February 2003

EXECUTIVE SUMMARY

This report details the predicted values for Audible Noise, Radio Interference, Electric and Magnetic Fields intended for Mercury-Perseus 400 kV transmission line (See photograph 1 in the attachments).

The structure used for the analysis was the Compact Cross-Rope tower and the bundle configuration was 3XTern.

The values predicted for the prospective line have been compared with the values observed by Eskom and those recommended by international organizations (IRPA, NIRPA) for the design of High and Extra High Voltage transmission lines

As it can be also realized from Table 6 in the attachments the values for points of interest (edge of servitude) shall be well below these observed by Eskom.

It is predictable that the structure and conductor selected for the analysis can change for the final design.

The final selection will be, however, subject to the same stringent environmental confines as used for the current analysis.

1.0 INTRODUCTION

The environmental effects of the prospective Mercury-Perseus 400 kV transmission line are linked to the possible physiological or biological effects of low frequency electric and magnetic fields produced by the power lines. The electric and magnetic fields involve rather abstract concepts and this report shall include an explanatory approach and efforts to simplify difficult notion. Reading of this report requires however a certain degree of attention to basic scientific ideas. The report has been written around two main distinguishable concepts: ionising and non-ionising radiation. The electric and magnetic fields have a non-ionising effect on the surrounding environment because of their relative low intensity. Other High-Voltage transmission consequences produce ions in the close proximity oh the phase conductor (corona discharge). The end result of this effect can be an audible noise of certain intensity and radio and television interference. The level of annoyance of the radio and TV interference depend also of the intensity of the broadcast signal in the area. Electric power transmission can have perturbing effects on nearby industrial installations such as pipelines, telecommunication circuits, computers and visual display units.

The assessment of these disturbances is beyond the scope of this report and can be addressed only if their nature is defined. This report may be of interest to those involved in environmental issues, in the planning process of new transmission lines, as well as being of appeal to a wider audience.

2. GENERAL FIELD CONCEPTS

Fields are defined as physical entities that can take different values at different points in space. Because the process of measuring the magnitude and the direction of these fields is somewhat mathematical abstract, several techniques are used to help visualise the fields and their variation in space. The belief that electric and magnetic fields are derived only from power lines, is however untrue. There are also naturally occurring fields. The earth has an essentially static vertically directed electric field of about 130 V/m that is caused by the separation of charges between the earth and the ionosphere. The magnetic field of the earth (known also as “geomagnetic field”) is also static and has an intensity of 50 μT (0.5 G). The geomagnetic field varies between equator and poles and is the greatest at the poles 67 (μT).

2.1 POWER FREQUENCY FIELDS

2.1.1 General Aspects

Fields near Overhead Transmission Lines have been more extensively studied and better characterised than for any other electromagnetic field source because most of the bulk electrical energy is conveyed by overhead alternating current transmission lines. Lines with voltages between 220 and 765 kV are extra-high voltage lines (EHV) and are the most economical and efficient mean to carry the mass-electrical energy over long distances. Typical transmission lines consist of three phases. Multiple or "bundled conductors for each phase are used in EHV transmission lines to reduce the corona-related effects. (such as audible noise) or on heavily loaded lines. Each phase is sequentially separated from the others by 120 "electrical degrees" and that is of importance in reducing the magnitude of the electric and magnetic fields in steady-state operation of the line.

The **E**lectric **F**ield near transmission lines is measured or calculated at the height of 1.8m above ground level. The line voltage and the height of the conductors above ground largely determine their magnitude. Conducting objects such as vegetation, houses and people will "perturb" or distort the electric field and can act as shields to reduce field levels significantly.

Electric currents flowing through transmission lines phase conductors also create a **M**agnetic **F**ield. The magnetic field produced by a 400 kV double circuit line is about 35 μT (the geomagnetic field at the equator is 33 μT). Unlike the electric field, the magnetic field is not perturbed nor shielded by earthed objects.

Both the electric and magnetic field produced by power lines, decay rapidly in magnitude with distance from the source.

2.1.2 Fields in the home environment

Electric and Magnetic fields are produced by every use of electricity. Electric fields levels in a typical home measured at 3, 30 and 100 cm. from different appliances are tabulated in Tables 1 and 2.

Location	V/m
Laundry room	1.6
Dinning room	1.8
Bathroom	3.0
Kitchen	5.2
Bedroom	15.6
Living room	6.6
Hallway	26

Table 1: Electric fields levels at the centre of different rooms in a typical home

Appliance	Magnetic field density(μT) at 30 cm distance
Hair dryers	7.0
Electric shaver	9
Drills	3.5
Mixers	10
Heaters	5
Television	2

Table 2: Magnetic fields near various appliances

Where magnetic fields are concerned, an important distinction should be made between the magnetic field produced by balanced currents and that produced by the net current. The field from the net current is inversely proportional to the distance from the line while balanced currents are producing a magnetic field inversely proportional to the square of the distance. Magnetic field values predicted only from balanced distribution line currents are therefore likely to underestimate measured levels. This is because the current becomes the major contributor to the magnetic field far from line. Unfortunately the level of unbalance of the phase currents is an uncontrollable variable of the line and depends merely on the of the load characteristic.

2.1.3 Fields in the work place

Electric field levels in the work environment range from 1-100 V/m and in specialised settings up to10 kV/m.

Typical magnetic flux densities in offices range from 0.1 to 10 mT (1-100 mG). Levels for electrical occupations also range to around 10 mT (100 mG) although magnetic flux densities of 8000 mT (80 G)have been measured near furnaces in the electro-steel industry and as high as 1700 mT (17 G) near spot welding machines.

2.1.4 Electric and magnetic fields and health

There has been apprehension about some aspects of electricity ever since public supplies were first provided and people have been exposed to the associated magnetic and electric fields since that time. Today, these fields, especially power frequency magnetic fields, are found wherever electrical power is used and not only near power transmission systems. During the 1980s, an interest in magnetic fields was stimulated by the results of two surveys which seemed to link the incidence of cancer to residing in the proximity of medium and low voltage distribution lines. The survey promoted an impetus in the laboratory study of living cells under the influence of electromagnetic fields and a vigorous debate is still in progress. The scientific position is complex, not least because there is no fully understood mechanism by which the low strength fields can interact with living material: they are far too weak to produce cell heating and they are incapable of disrupting any molecules directly. Current knowledge is fragmentary and insufficient to explain everything that is observed. There are differing views in the scientific community. At the same time one must recognise however that it is also impossible to prove the absence of adverse effects because it is never possible to investigate all circumstances and to eliminate obscuring factors. Should however any detrimental effect on health be established it would be for the society as a whole through a process of risk assessment to balance the hazards against the many benefits of electricity.

3. PERCEPTIVE EFFECTS OF ELECTROMAGNETIC FIELDS

The power frequency electromagnetic fields are not perceived directly nor does a person feel the current they induce. At fields about 5 mT a flickering sensation in the eyes can be produced but that such field strength is far above the normally encountered. Fields thousand times stronger than the largest produced by the power lines would be required to induce currents large enough to stimulate nerve cells and hence be felt. Nevertheless there are visual and audible annoying effects that cannot be neglected.

3.1 SPURIOUS EFFECTS

3.1.1 CORONA, SURFACE DISCHARGE AND SPARKING

Intense electric fields may occur at the surface of conductors and other "live "elements of the transmission lines. In some circumstances that can lead to electrical breakdown of the air in the close proximity of the conductor (ionisation). This effect is known as corona discharge or simply as "corona". The presence of small protrusions on the surface of the conductor (dirt, rain drops, detached strands etc.) may enhance considerably the corona activity by augmenting the electric field at the conductor irregularities. Beside the "dazzling" visual effect, in certain circumstances the ionising discharge will give rise to radio and television interference.

3.1.2 SPARKING

Bad contact between components at high voltage can lead to sparking across the gaps, especially in dry weather. Dampness tends to short-circuit the small gaps. Adjusting or replacing the offending component can always eliminate such disturbances.

3.1.3 RADIO INTERFERENCE (RI)

Radio interference is any effect in the reception of a wanted radio signal due to unwanted disturbance within the radio-frequency spectrum. Radio interference is first of concern for weak amplitude modulated signals (AM) and other forms of broadcasting (frequency modulation or FM) are least affected. The weaker is however the reception of broadcasted radio signals along the transmission line route, the Radio Interference I will be more annoying and the measure of the offensive effect is quantified by a signal-to-noise ratio.
When establishing limits for the emission of Radio Interference from power lines, the minimum reception signal strength has to be determined. This is a subject to the broadcasting authorities with the international standards giving guidance only how to establish limits.
Table 3 indicates what a signal-to-noise ratio is required for good reception:

QUALITY OF RECEPTION	SIGNAL TO NOISE RATIO (dB)
Interference not audible	30
Interference perceptible	24
Interference audible but speech perfectly received	18
Unacceptable for music but speech intelligible	12
Speech understandable only with severe concentration	6
Noise swamps speech totally	0

Table 3: Signal to Radio Interference Noise values and effects

3.1.4 AUDIBLE NOISE (AN)

The audible noise from corona consists of both broad-band spectrum (“crackling”) and of discrete tones (“humming”). The broadband component is the dominant noise and is responsible for uniqueness of corona noise compared with other noise in the environment. The particularity of the corona noise is based on its energy that is concentrated in the medium and high frequency audible band while the background noise has dominant components in the low frequency band. In general the corona generated audible noise is a major design consideration for overhead lines operating at voltages of 300 kV and above. For these lines the fittings are so selected that only corona on conductors can be a source of audible noise. The sensitivity of the human ear to noise is dependent of the magnitude of the sound pressure as well as on its

frequency. The variation of sound pressure from different source is immense and for this reason sound pressure is measured in a logarithmic scale in “audible” decibels (dBA). Because the audible noise created by corona is perceived more in wet weather - when rain droplets collect on the undersize of the conductor - the AN measure is completed by a time dimension called L50 or L5. L50 is the value exceeded for 50% of the time and L5 is exceeded 5% of the time. The peculiar units of measure for sound pressure can be made demonstrative by comparing them with other environment noise and its measure. This is done in Figure 1.

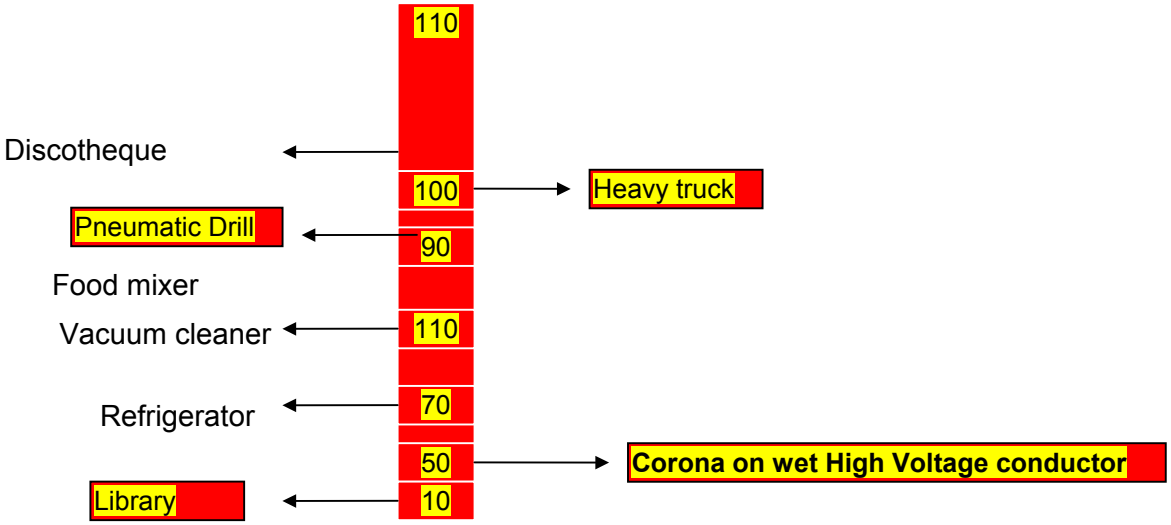


Figure 1: An approximate comparison of typical sound level from various sources

3.1.5 LIMITS OF EXPOSURE TO NON-IONISING RADIATION

Any guidelines for restricting exposure of people to some agents require a sound basis. The only interaction of power frequency electric and magnetic fields with people is the induction of currents. Strong electric fields may also cause perceptible effects such as hair vibration and small shocks when touching metallic objects. International bodies like the World Health Organisation (WHO) have stated that up to an induced current of 10 mA/m^2 only minor biological effects have been detected. Also, naturally occurring

current densities within the body caused by the nervous system activity are of a similar value.

The above factors form the basis of International Radiation Protection Association (IRA), and in particular their branch for Non-Ionising Radiation (NIRPA), for which the basic criterion is to limit the cause more than effect producing the body induced current limit mentioned above.

In absence of statutory limits, the confines of exposure to electric and magnetic fields are based on consensus. The consensus of international bodies is that no health effects from power frequency electric and magnetic fields as normally encountered have been established. The evidence for such effects is tenuous and often contradictory and, in absence of any plausible indication for an adverse effect on health, remains unconvincing. Most of the electric utilities in the world adhered to the Non Ionizing Radiation Protection Association (NIRPA) limits which reflect the actual status of uncertainty. The recommended limits of exposure and their clarification are displayed in Table 4:

Duration of Exposure	Maximum Electric Field Value (kV/m, rms)	Maximum Magnetic Field Value (mT,rms)
Occupational		
Whole working day	10[e]	0.5
Short term	5[a]	5[b]
For limbs	-	25
General public		
Up to 24 hours per day[c]	5	0.1
Few hours per day[d]	5	1

[a] The duration of exposure of fields between 10 and 30 kV/m may be calculated from the formula $t \cong 80/E$, where t is the time of exposure in hours/work day and E is the electric field strength in kV/m.

[b] Maximum exposure is 2 hours/day.

c This restriction applies to open spaces in which members of the general public may reside a substantial part of the day.

[d] These values can be exceeded for a few minutes per day provided precautions are taken to prevent indirect coupling

[e] Eskom adopted maximum value for any length of exposure

Table 4: IRPA-NIRPA Recommended exposure limits

ESKOM OBSERVED LIMITS:

Electric field	10 kV/m, 1.8 m above ground level
Magnetic field	No Eskom limit, IRPA recommendation observed
Radio Noise	72 dB above 1 μv, at 500 kHz, L_{50} wet conductor , at the edge of the servitude.
Audible Noise	52.5 dB(A) at the servitude boundary, L_{50} wet conductor

Table 5: Eskom observed limits

3.1.6 Analysis of predicted values for prospective Mercury-Perseus 400 kV transmission line

Table 6 contains the predicted values for the prospective line. It can be apprehended from the values in the in the table that at points of interest (edge of servitude) the predicted values are beyond the Eskom and international bodies (IRPA, NIRPA) recommended ones.

The dry audible noise has been obtained by subtracting only 7 dBA from the audible noise in rain.
This has been done in order to predict values for a “worse case” and to and the controversy induced by shortcoming in he analysis tools.

4. CONCLUDING REMARKS

Some alarmist reports of both the electrical phenomena and its possible health consequences have raised anxieties. This short report intended to dispel some of the apparent mystery encircling the power frequency electric and magnetic fields by describing the observed effects in a straightforward way. Due to the relative low voltage and load, the fields and corona effects are bellow the recommended limits. If exposure to these levels may not be dangerous, most of the safety issues can be related to human contact to unearthed metal object under a transmission line. These dangers are of a low probability and as a consequence are poorly documented. They are difficult to predict at design stage. This is the reason that no firm recommendation to allow the use of the servitude for industrial or other purposes can be made at this stage.

REFERENCES

1. IEC 833: "**Measurement of Power-Frequency Electric Fields**"

2. Non-ionising Radiation Protection Committee of the International Radiation Protection Association: "**Interim Guidelines on Limits of Exposure to Electric and Magnetic Fields**"

ATTACHMENTS:

1. Figure 1: Photograph of prospective tower (Compact Cross-Rope)
2. Table 6: Values predicted for Mercury-Perseus 400 kV
3. Chart 1: Audible Noise Levels in Dry Weather and Rain (Prediction)
4. Chart 2: Radio Interference distribution
5. Chart 3: Electric Field distribution in the servitude
6. Chart 4: Magnetic Field distribution in the servitude

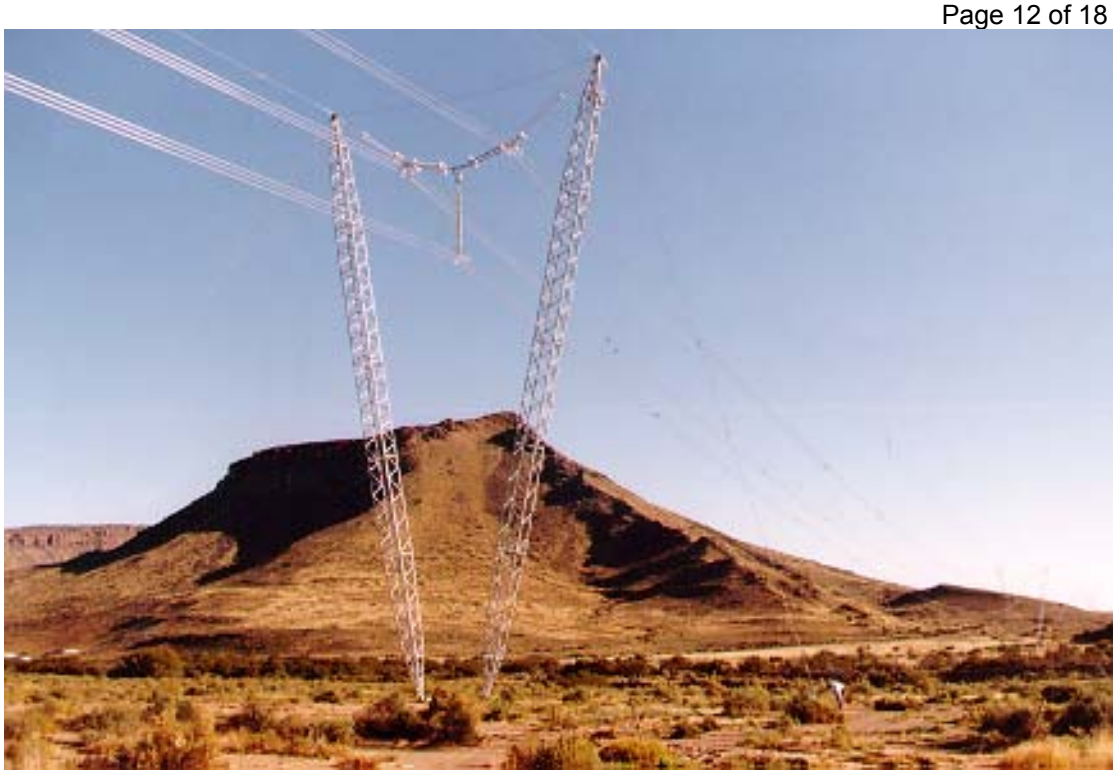
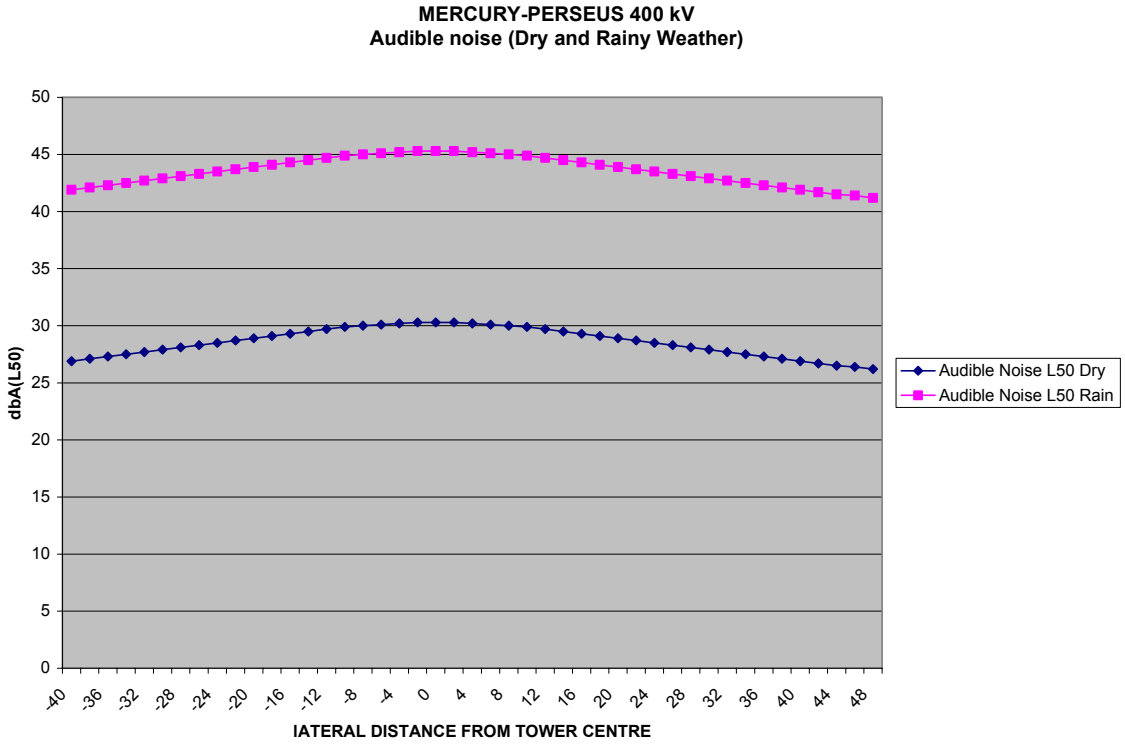
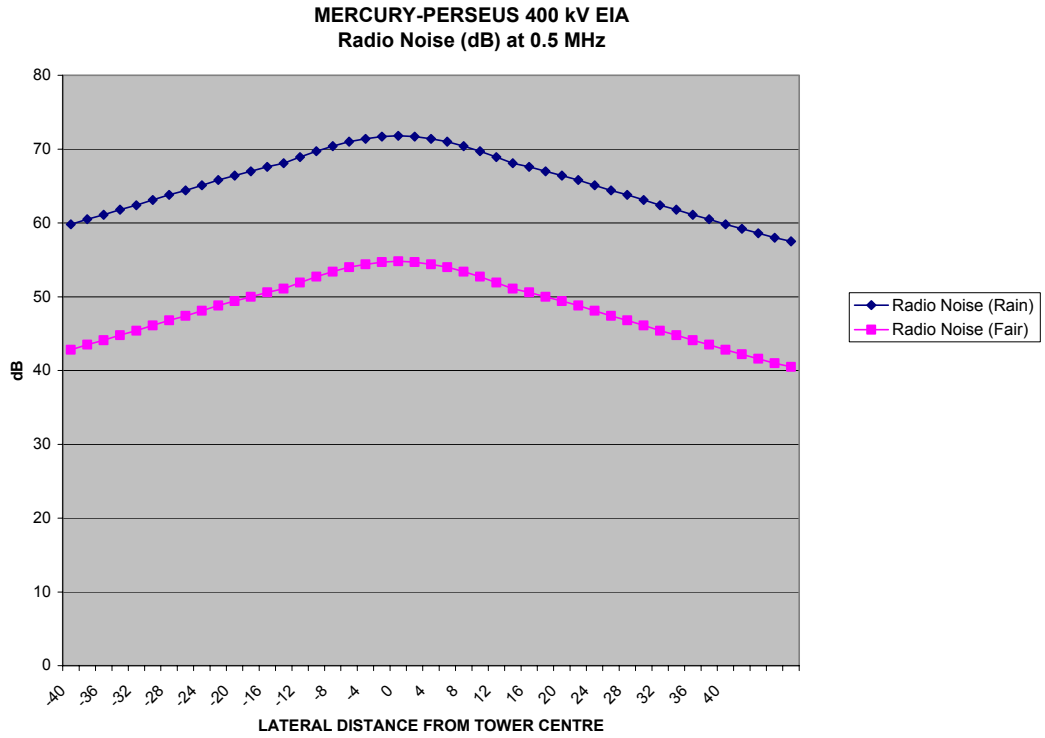


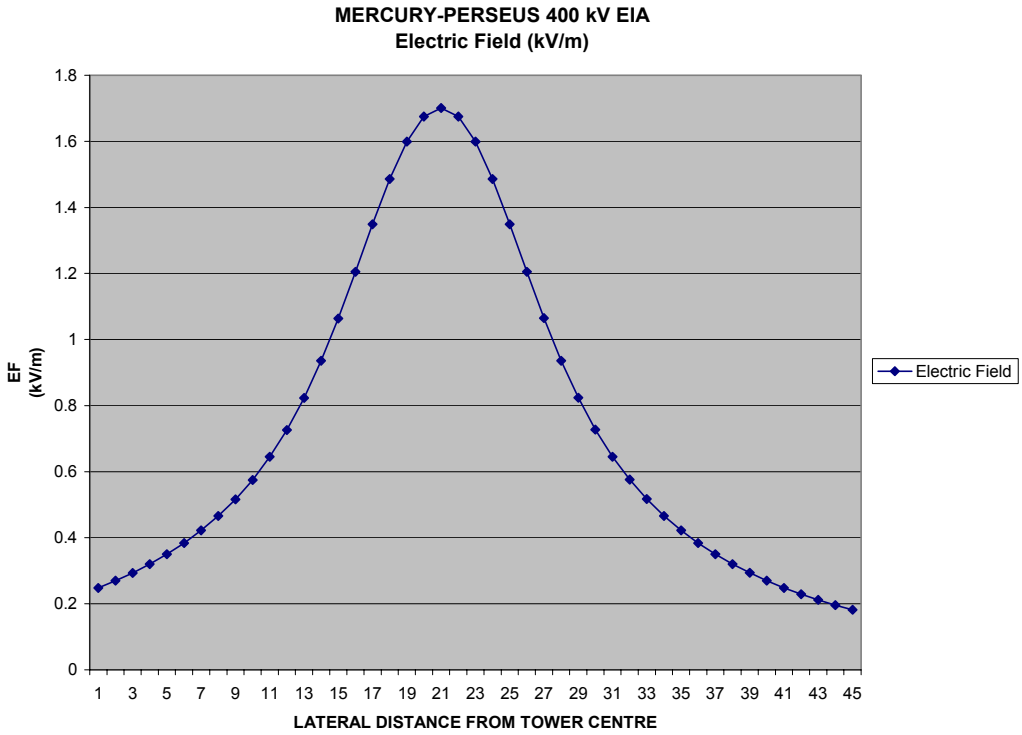
Figure 1: Photography of installed Compact Cross-Rope tower

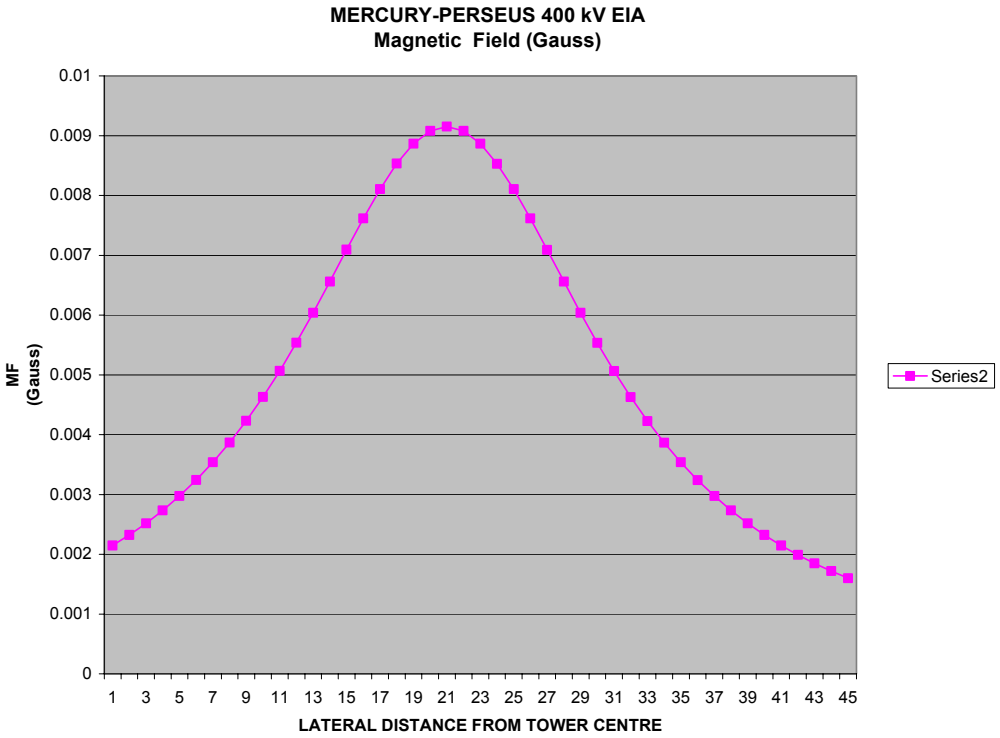
Lat. Dist (m) from tower centre	AN(Rain) dBA	AN(Fair) dBA	RI (Rain) dB	RI (Fair) dB	EF (kV/m)	MF (Gauss) 1Gauss=10E-4 Tesla
-40	41.9	26.9	59.8	42.8	0.248	0.002147
-38	42.1	27.1	60.5	43.5	0.27	0.002323
-36	42.3	27.3	61.1	44.1	0.293	0.002517
-34	42.5	27.5	61.8	44.8	0.32	0.002734
-32	42.7	27.7	62.4	45.4	0.35	0.002974
-30	42.9	27.9	63.1	46.1	0.384	0.003242
-28	43.1	28.1	63.8	46.8	0.422	0.003538
-26	43.3	28.3	64.4	47.4	0.466	0.003867
-24	43.5	28.5	65.1	48.1	0.516	0.004231
-22	43.7	28.7	65.8	48.8	0.575	0.00463
-20	43.9	28.9	66.4	49.4	0.645	0.005066
-18	44.1	29.1	67	50	0.726	0.005537
-16	44.3	29.3	67.6	50.6	0.823	0.006038
-14	44.5	29.5	68.1	51.1	0.936	0.006562
-12	44.7	29.7	68.9	51.9	1.064	0.007094
-10	44.9	29.9	69.7	52.7	1.205	0.007617
-8	45	30	70.4	53.4	1.349	0.008107
-6	45.1	30.1	71	54	1.486	0.008533
-4	45.2	30.2	71.4	54.4	1.599	0.008866
-2	45.3	30.3	71.7	54.7	1.675	0.009079
0	45.3	30.3	71.8	54.8	1.701	0.009152
2	45.3	30.3	71.7	54.7	1.675	0.009079
4	45.2	30.2	71.4	54.4	1.599	0.008865
6	45.1	30.1	71	54	1.486	0.008531
8	45	30	70.4	53.4	1.349	0.008104
10	44.9	29.9	69.7	52.7	1.205	0.007615
12	44.7	29.7	68.9	51.9	1.065	0.007092
14	44.5	29.5	68.1	51.1	0.936	0.006559
16	44.3	29.3	67.6	50.6	0.824	0.006036
18	44.1	29.1	67	50	0.727	0.005535
20	43.9	28.9	66.4	49.4	0.645	0.005064
22	43.7	28.7	65.8	48.8	0.576	0.004628
24	43.5	28.5	65.1	48.1	0.517	0.004229
26	43.3	28.3	64.4	47.4	0.466	0.003866
28	43.1	28.1	63.8	46.8	0.422	0.003537
30	42.9	27.9	63.1	46.1	0.384	0.00324
32	42.7	27.7	62.4	45.4	0.35	0.002973
34	42.5	27.5	61.8	44.8	0.32	0.002733
36	42.3	27.3	61.1	44.1	0.294	0.002517
38	42.1	27.1	60.5	43.5	0.27	0.002322
40	41.9	26.9	59.8	42.8	0.248	0.002147

Table 6: Values of predicted entities for Mercury-Perseus 400 kV


MERCURY-PERSEUS 400 kV
Audible noise (Dry and Rainy Weather)
dbA(L50)
50
45
40
35
30
25
20
15
10
5
0
-40
-36
-32
-28
-24
-20
-16
-12
-8
-4
0
4
8
12
16
20
24
28
32
36
40
44
48
IATERAL DISTANCE FROM TOWER CENTRE
Audible Noise L50 Dry
Audible Noise L50 Rain


MERCURY-PERSEUS 400 kV EIA
Radio Noise (dB) at 0.5 MHz
dB
80
70
60
50
40
30
20
10
0
-40 -36 -32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 36 40
LATERAL DISTANCE FROM TOWER CENTRE
Radio Noise (Rain)
Radio Noise (Fair)


MERCURY-PERSEUS 400 kV EIA
Electric Field (kV/m)
EF (kV/m)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45
LATERAL DISTANCE FROM TOWER CENTRE
Electric Field


MERCURY-PERSEUS 400 kV EIA
Magnetic Field (Gauss)
MF (Gauss)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45
LATERAL DISTANCE FROM TOWER CENTRE
Series2

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