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THE INFLUENCE OF LINE CONFIGURATION ON ENVIRONMENT IMPACTS OF ELECTRICAL ORIGIN

**Working Group
B2.06**

August 2005



THE INFLUENCE OF LINE CONFIGURATION ON ENVIRONMENT IMPACTS OF ELECTRICAL ORIGIN

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Working Group B2.06 “Principles of Overhead Line Design”

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Symbols and Abbreviations

<i>d</i>	<i>Sub-conductor spacing (m)</i>
<i>h_c</i>	<i>Height of conductors above ground (m)</i>
<i>n</i>	<i>Number of sub-conductors (-)</i>
<i>C</i>	<i>Conductor type (-)</i>
<i>I</i>	<i>Current (A)</i>
<i>S</i>	<i>Phase to phase distance (m)</i>
<i>V</i>	<i>Voltage level (kV)</i>
<i>AN</i>	<i>Audible Noise (dB)</i>
<i>EF</i>	<i>Electric field (kV/m)</i>
<i>MF</i>	<i>Magnetic field (μT)</i>
<i>RI</i>	<i>Radio Interference (dB)</i>

1. General

The construction and operation of high voltage overhead lines result in a series of different types of impact on the environment. The magnitude and importance of these impacts depends mostly on the environment, topology and characteristics of the line.

Therefore, when designing new power lines, it is advisable to take steps to reduce these impacts to acceptable levels. For this reason it is necessary to evaluate the influence of the following line design parameters on these effects:

- Phase configuration;
- Number and arrangement of conductors;
- Number of sub-conductors per each phase;
- Phase to phase distance;
- Clearance to ground;
- Conductor diameter.

In most cases, when a parameter is modified in order to reduce one effect, e.g., the electric and magnetic field level, another impact, e.g., audible and radio noise, will increase, and vice versa. Therefore, it will be necessary to adopt compromise solutions which minimise the overall effects on the surrounding environment.

The scope of this study is to investigate the effect that varying these various line parameters has on the electrically generated environmental impacts of overhead lines. Interference with appliances and electronic equipment is not considered in this report, nor does it consider recommendations on acceptable levels of the various environmental effects.

Values have been studied herein for 400 kV lines as representative of EHV lines, for single and double circuit in different configurations, considering self-supporting towers, which are frequently used in Europe. Other support types and conductor configurations, not considered in this evaluation, are somewhat similar to the silhouettes studied and produce similar electric effects. The conclusions are also applicable for higher voltage levels. For 220 kV the problem exists at a reduced extent. For lower voltage levels the phenomena are generally negligible.

Calculations were validated by "in situ" measurements. All values are given at 1.0 meter above ground.

From the public viewpoint, impacts of electrical origin are some of the most important, due to their special effects on daily life. Audible and radio noise may be unpleasant to those who live near a power line, and electric and magnetic fields tend to cause concern to the general public because of their alleged effects on human health.

2. 400 kV single circuit lines

2.1. Configurations studied

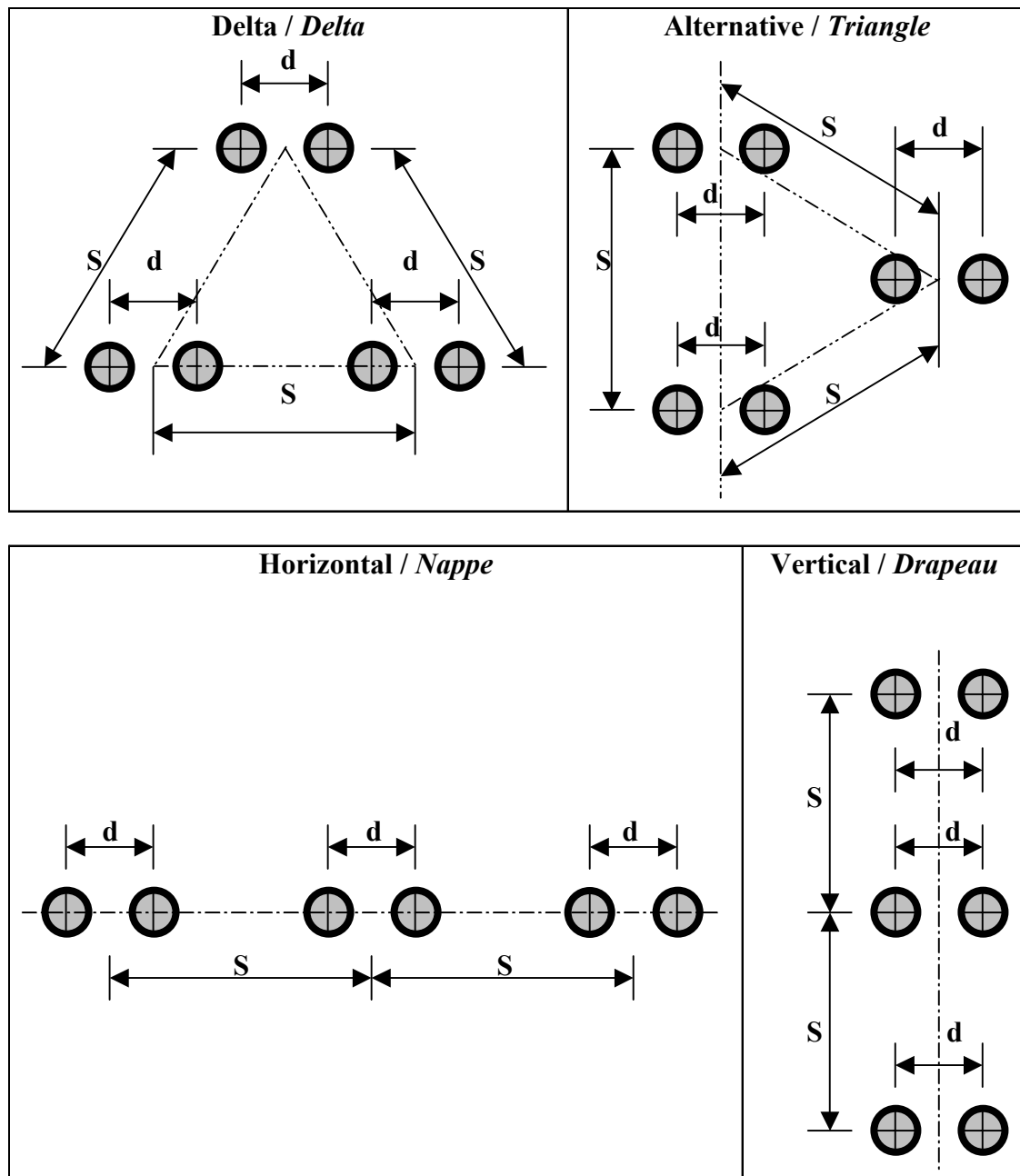


Figure 2.1 Configurations of single circuit lines
(S = phase to phase distance; d = sub-conductor spacing)

2.2. Electric Field (EF)

Line configuration (Figure 2.2)

Delta and alternative configurations give the lowest values of maximum electric field (EF) and horizontal configurations give the highest values. With values of phase to phase distance S of around 10 m, $n = 2$ conductors per phase, and considering a height h_c of conductor above ground of 8,5 m, the maximum values of EF are the following:

- Delta and alternative: 7,27 kV/m
- Vertical: 8,11 kV/m
- Horizontal: 8,35 kV/m

Values at the centreline and 20 m away from the centreline are also higher in horizontal configurations. Values at 50 m are higher in vertical configurations only in the side where the phases are. So, it could be a good solution for a specific location, to install the phases in vertical configurations in the opposite side.

It is important to notice that for all 4 configurations maximum electric field is always less than 1 kV/m at 30 m from the centreline.

Phase to phase distance (Figure 2.3)

As phase to phase distance increases, EF increases too, for all configurations, except in the centreline for delta and alternative configurations, where EF decreases as phase to phase distance increases. So, compaction is the best way to reduce EF.

Height of conductors above ground (Figure 2.4)

EF decreases as height of conductors above ground increases. Reduction of EF values is important for maximum values and in the centreline. Outside the edge of ROW (Right-of-Way) reductions are less significant.

Sub-conductor cross-section (Figure 2.5)

EF increases slightly as cross-section of sub-conductors increases, but this is not a significant effect.

Number of sub-conductors for identical total cross-section (Figure 2.6)

For a similar total cross-section, EF increases as number of sub-conductors increases, for all configurations to the same extent.

Sub-conductor spacing (Figure 2.7)

EF increases slightly as sub-conductor spacing increases.

Conclusions

- In 400 kV single circuit lines, delta and alternative configurations give lower EF values.
- Vertical configuration can be useful in specific situations.
- Compaction is the best way to reduce EF.
- Increasing height of conductors in specific locations can be useful too.

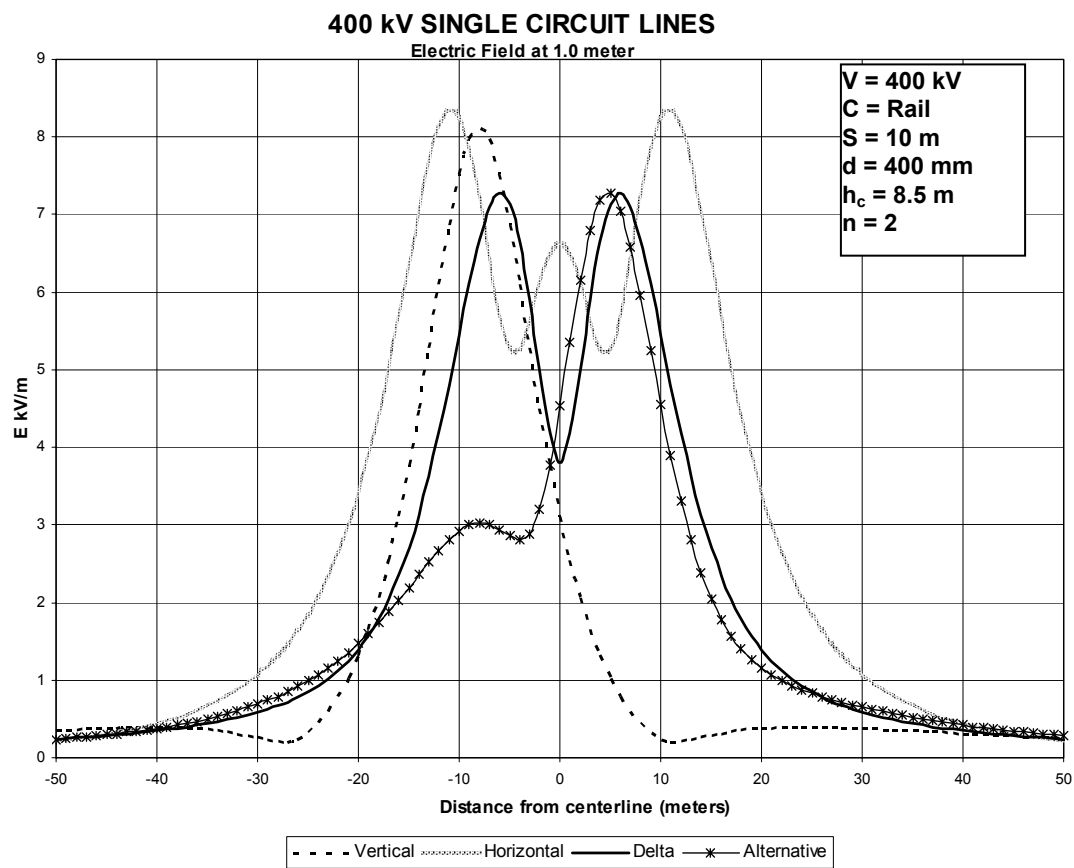


Figure 2.2 Impact of conductor configuration on electric field

400 kV SINGLE CIRCUIT LINES

ELECTRIC FIELD vs PHASE TO PHASE DISTANCE

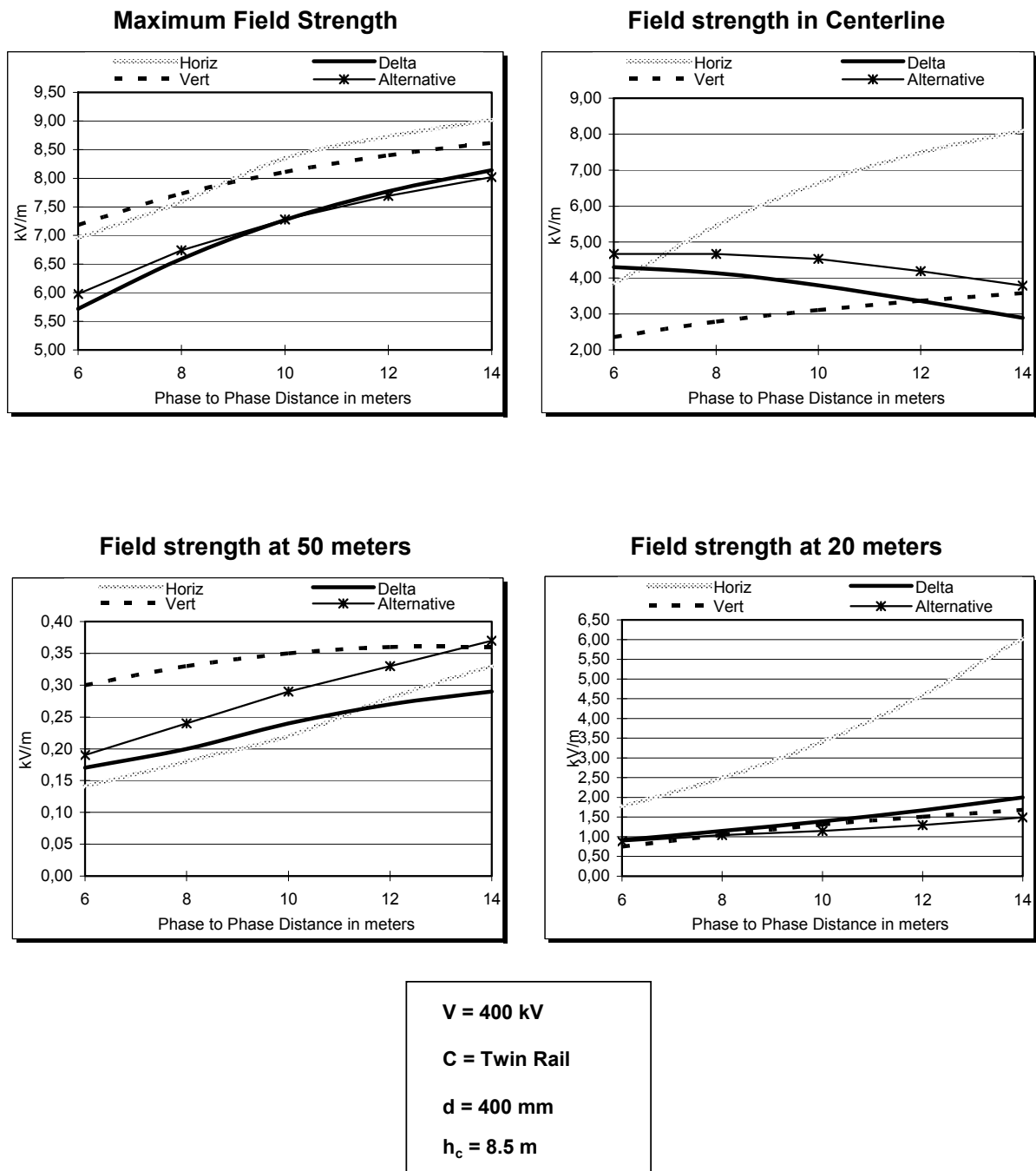
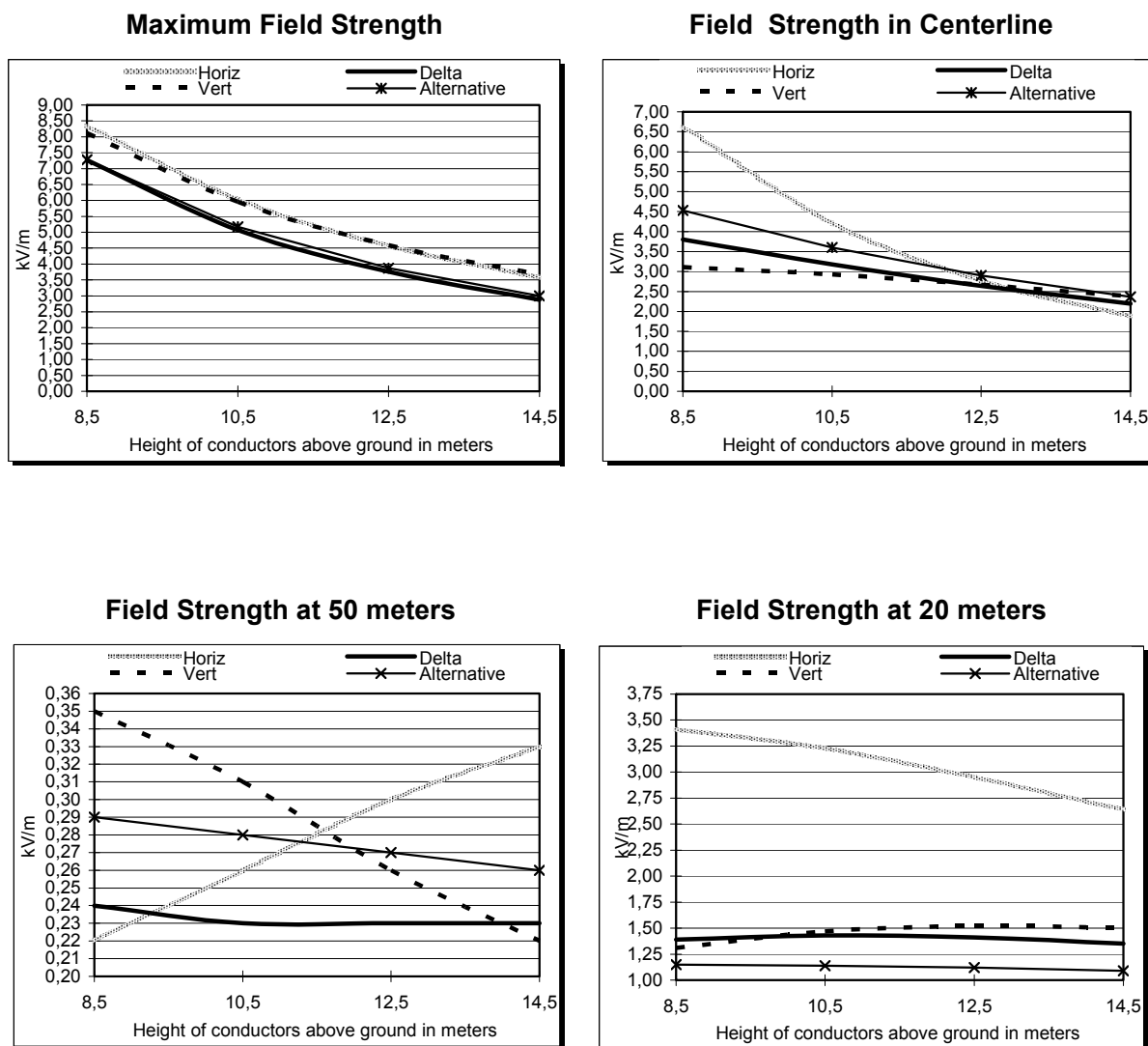


Figure 2.3 Impact of phase to phase distance on electric field

400 kV SINGLE CIRCUIT LINES

ELECTRIC FIELD vs HEIGHT OF CONDUCTORS ABOVE GROUND



V = 400 kV

C = Rail

S = 10 m

d = 400 mm

Figure 2.4 Impact of height of conductors above ground on electric field

400 kV SINGLE CIRCUIT LINES ELECTRIC FIELD vs CONDUCTOR CROSS SECTION

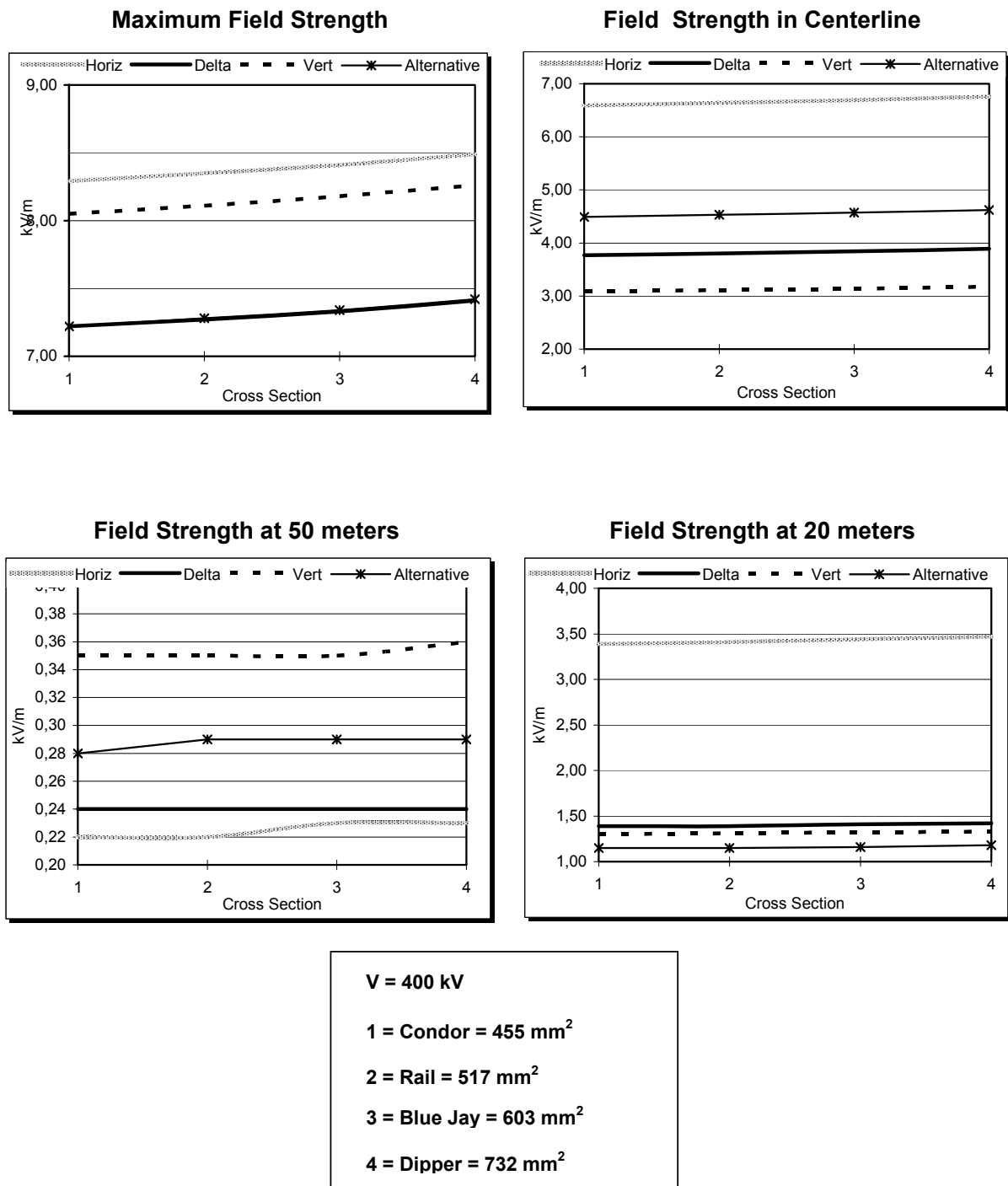


Figure 2.5 Impact of conductor cross-section on electric field

400 kV SINGLE CIRCUIT LINES

ELECTRIC FIELD vs No. OF SUBCONDUCTORS FOR IDENTICAL TOTAL CROSS SECTION

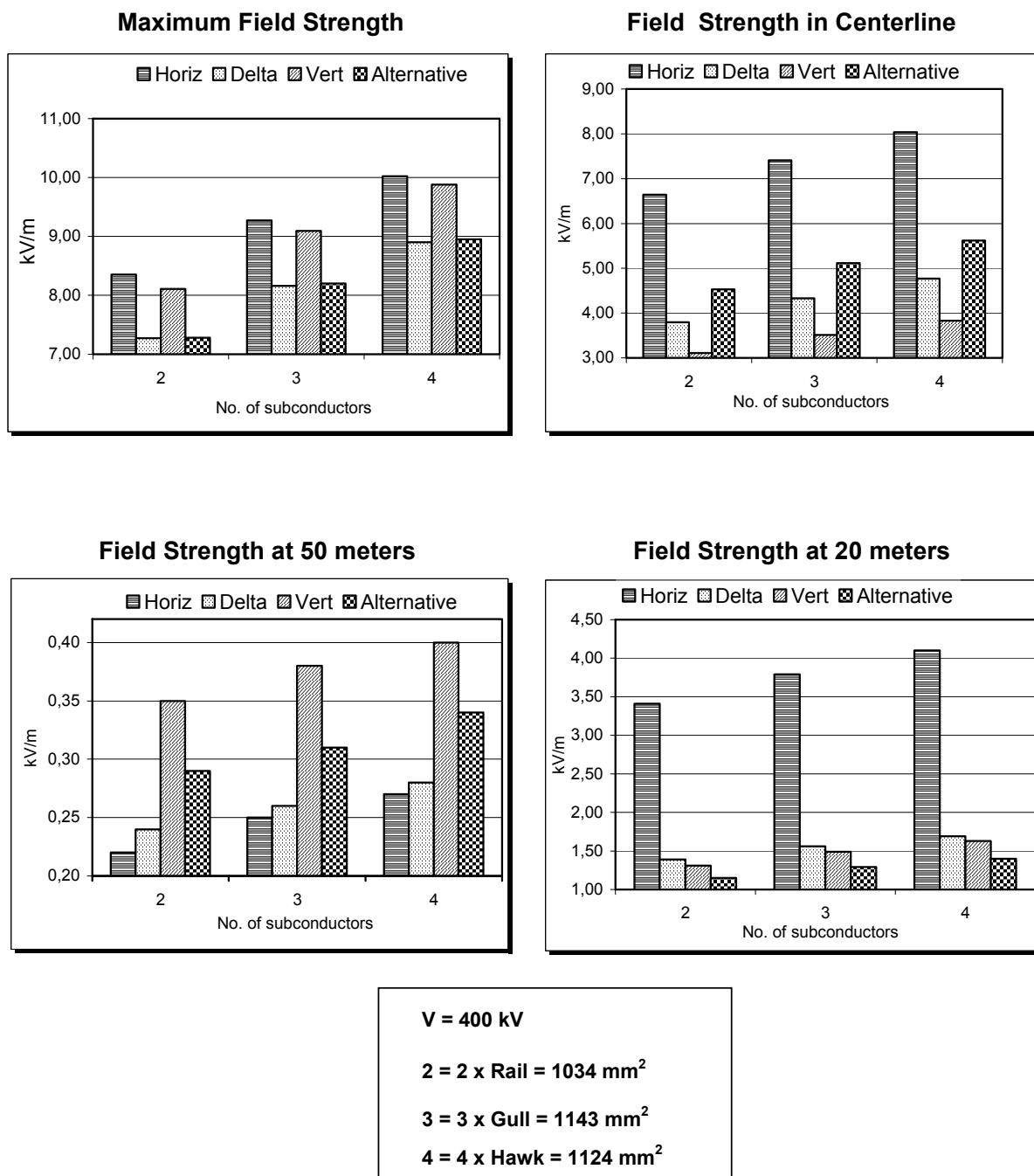
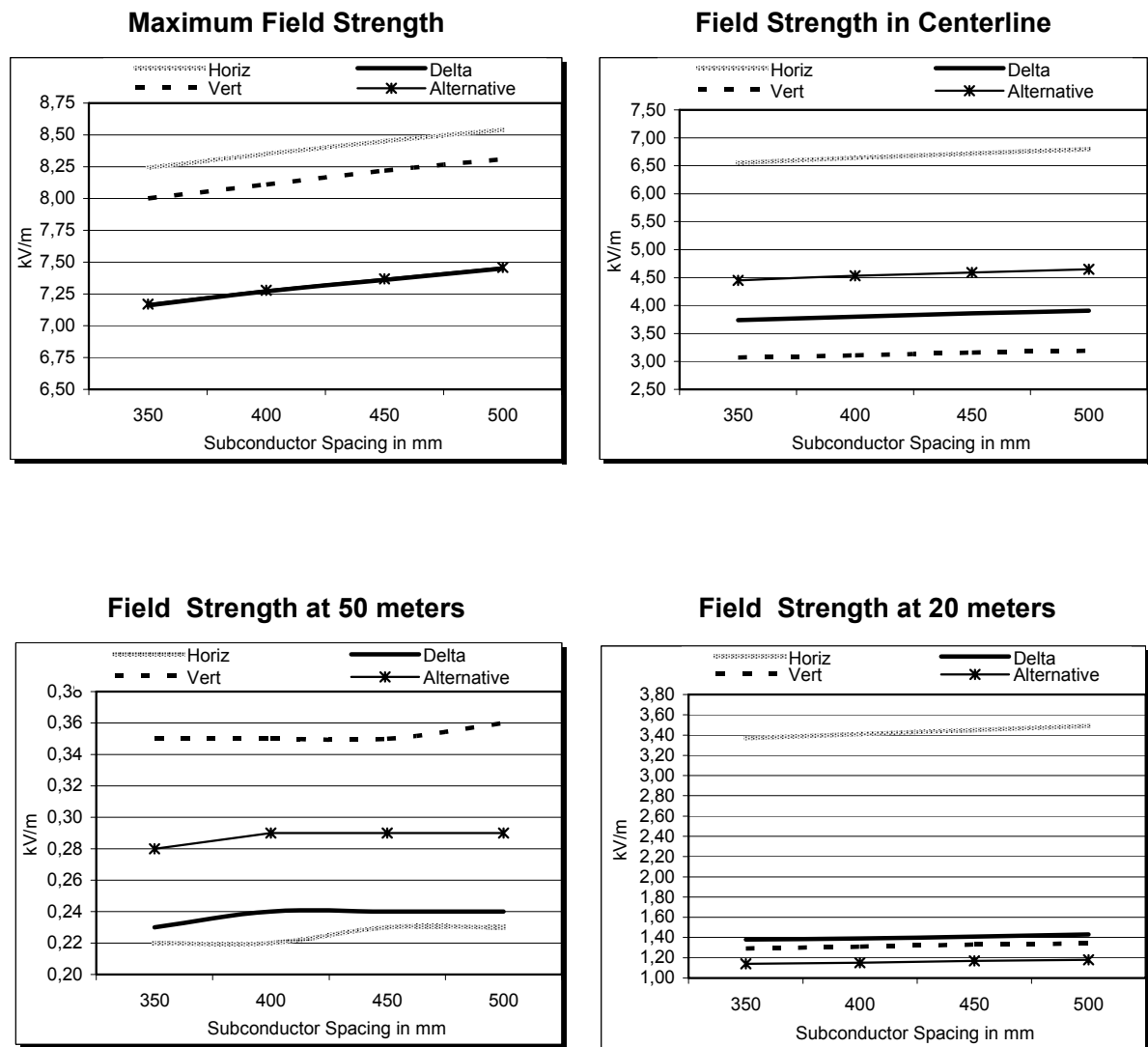


Figure 2.6 Impact of number of sub-conductors on electric field

400 kV SINGLE CIRCUIT LINES ELECTRIC FIELD vs SUBCONDUCTOR SPACING



V = 400 kV

C = Twin Rail

S = 10 m

$h_c = 8.5$ m

n = 2

Figure 2.7 Impact of sub-conductor spacing on electric field

2.3 Magnetic Field (MF)

Line configuration (Figure 2.8)

Alternative configuration gives the lowest values of maximum magnetic field (MF) and horizontal configuration gives the highest ones. With a phase to phase distance S of 10 m and a current of 1000 A, maximum values of MF are, considering a height h_c of conductor above ground of 8,5 m, the following:

- | | |
|----------------|---------------------|
| - Alternative: | 17,49 μT |
| - Vertical: | 17,69 μT |
| - Delta: | 22,18 μT |
| - Horizontal: | 27,98 μT |

Values in centreline are also higher in horizontal configuration and lower in vertical. At 20 and 50 m from centreline delta and alternative configurations give the lowest values. Also for MF it could be useful in specific locations to install the phases in vertical configuration on the opposite side of the locations to be protected.

Phase to phase distance (Figure 2.9)

As phase to phase distance increases, MF increases too, for all configurations. So, compaction is the best way to reduce MF.

Height of conductors above ground (Figure 2.10)

MF decreases dramatically as height of conductors above ground increases. To reduce locally MF, increasing height of conductors is the easiest solution.

Conclusions

- In 400 kV single circuit lines, alternative conductor configuration gives lower MF values.
- Compaction is the best way to reduce MF.
- Increasing height of conductors above ground is an easy way to reduce locally MF.

400 kV SINGLE CIRCUIT LINES Magnetic Field at 1.0 meter

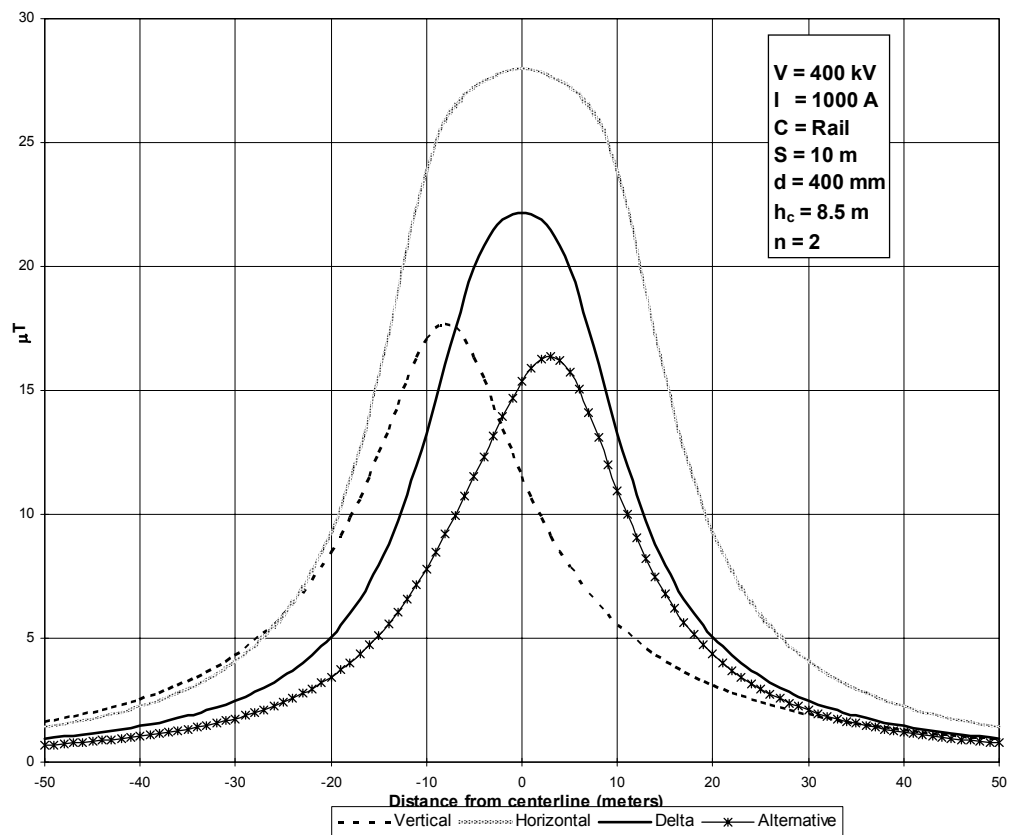


Figure 2.8 Impact of conductor configuration on magnetic field

400 kV SINGLE CIRCUIT LINES

MAGNETIC FIELD vs PHASE TO PHASE DISTANCE

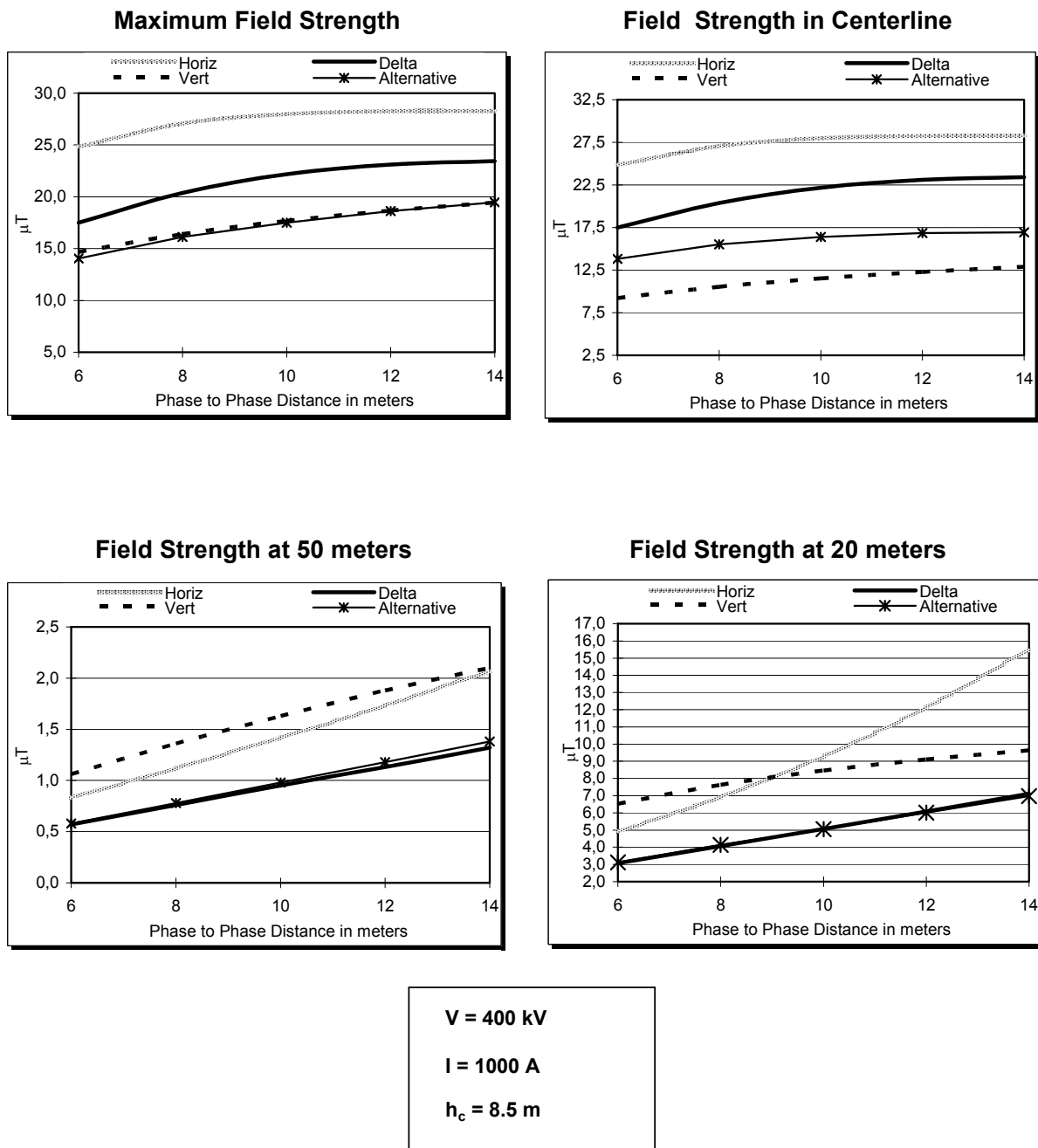


Figure 2.9 Impact of phase to phase distance on magnetic field

400 kV SINGLE CIRCUIT LINES

MAGNETIC FIELD vs HEIGHT OF CONDUCTORS ABOVE GROUND

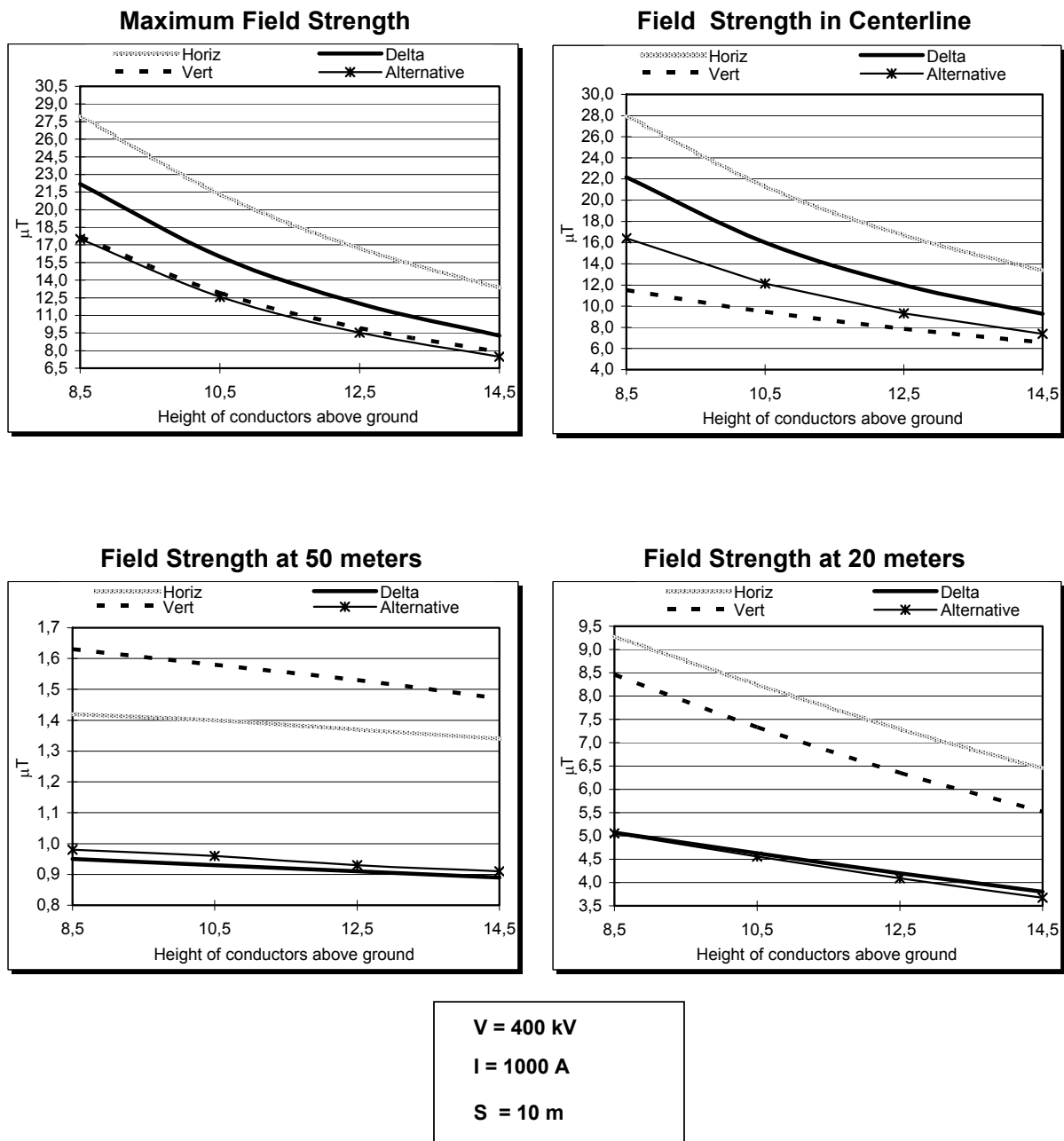


Figure 2.10 Impact of height of conductors above ground on magnetic field

2.4 Radio Interference (RI)

Line configuration (Figure 2.11)

Vertical configuration gives the lowest values of maximum radio interference (RI) levels, and horizontal configuration the highest ones (66 dB at the centre of the ROW). But at 25 m from the centre, horizontal configurations result in lower values.

At 50 m distance, values for RI are:

- | | |
|----------------|---------|
| - Horizontal: | 28,7 dB |
| - Delta: | 38,4 dB |
| - Alternative: | 40,0 dB |
| - Vertical: | 41,5 dB |

So, under RI point of view, horizontal configuration is the right choice to get lower values outside the ROW.

Phase to phase distance (Figure 2.12)

As phase to phase distance increases, RI decreases. In this case compaction is not a good solution to decrease maximum values of RI. Anyway, the variation of RI with phase to phase distance is small.

Height of conductors (Figure 2.13)

In general, RI level decreases as height of conductors above ground increases. However, values of RI outside the ROW not always follow this rule.

Number of sub-conductors for identical total cross-section (Figure 2.14)

The best way, but also the most expensive, to reduce RI level is to increase the number of sub-conductors in a phase for identical cross-section. As shown in figure 2.14, values of RI in any point can be reduced to 30% or even more adding one sub-conductor to a phase.

Total-cross section of conductor (Figure 2.15)

RI decreases as cross-section of conductor increases but it is not an efficient way to reduce RI level.

Sub-conductor spacing (Figure 2.16)

Changing sub-conductor spacing does not give significant variation in the RI level.

Conclusions

- In 400 kV single circuit lines, horizontal configuration is the optimum choice for low RI levels outside ROW.
- Increasing number of sub-conductors for identical total cross-section decreases greatly RI levels.
- Compaction does not reduce RI levels.

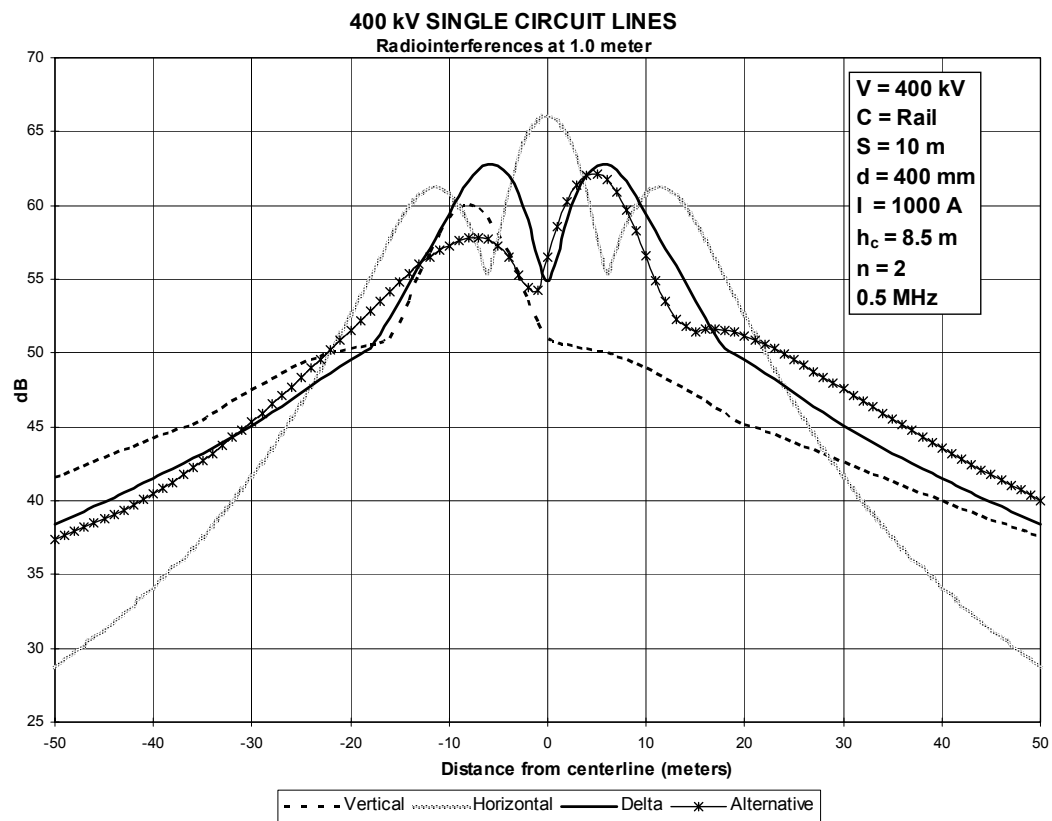


Figure 2.11 Impact of line configuration on radio interference level

400 kV SINGLE CIRCUIT LINES

RADIO INTERFERENCES vs PHASE TO PHASE DISTANCE

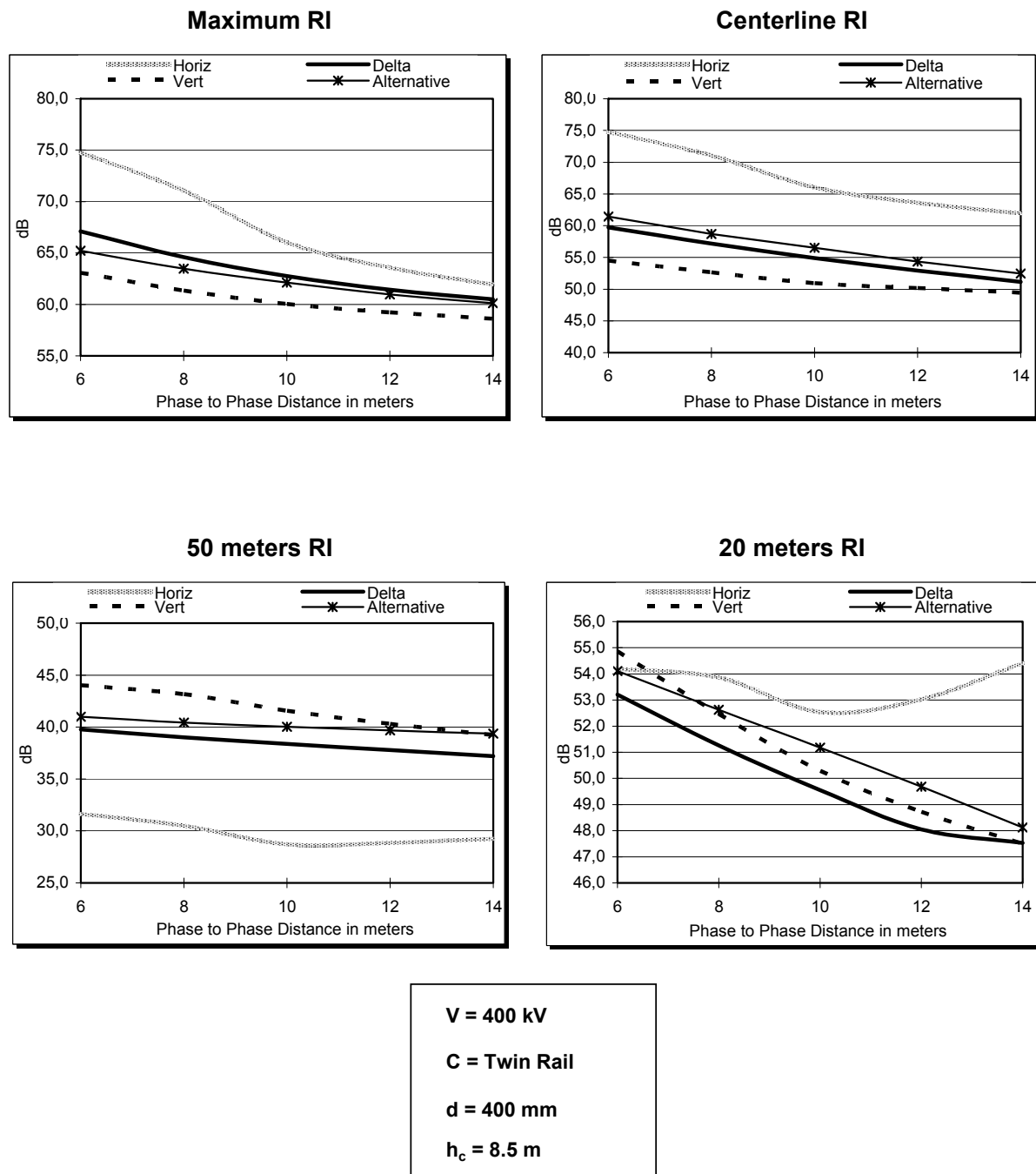


Figure 2.12 Impact of phase to phase distance on radio interference level

400 kV SINGLE CIRCUIT LINES

RADIO INTERFERENCES vs HEIGHT OF CONDUCTORS ABOVE GROUND

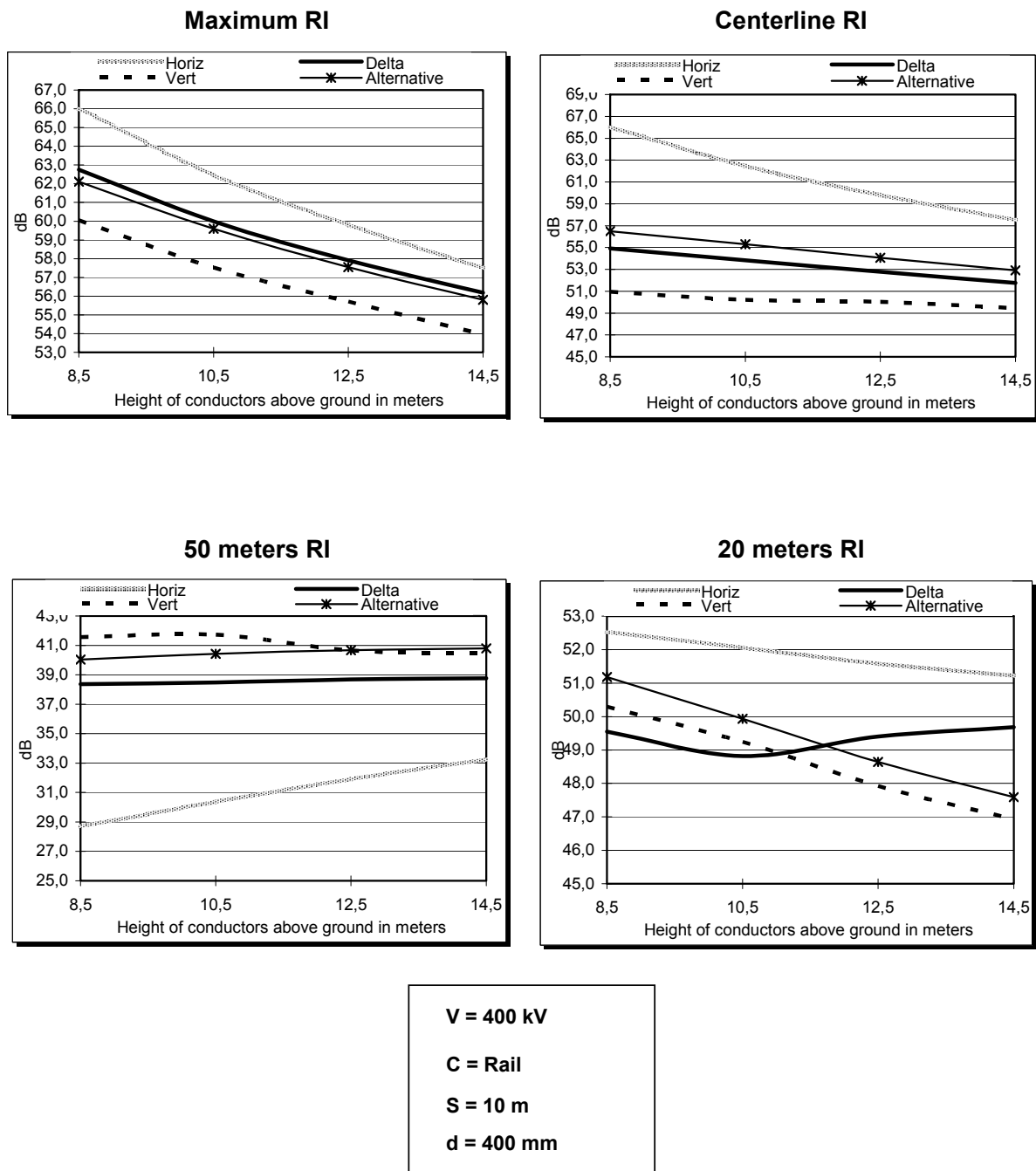


Figure 2.13 Impact of height of conductors above ground on radio interference level

400 kV SINGLE CIRCUIT LINES

RADIO INTERFERENCES vs No. OF SUBCONDUCTORS FOR IDENTICAL TOTAL CROSS SECTION

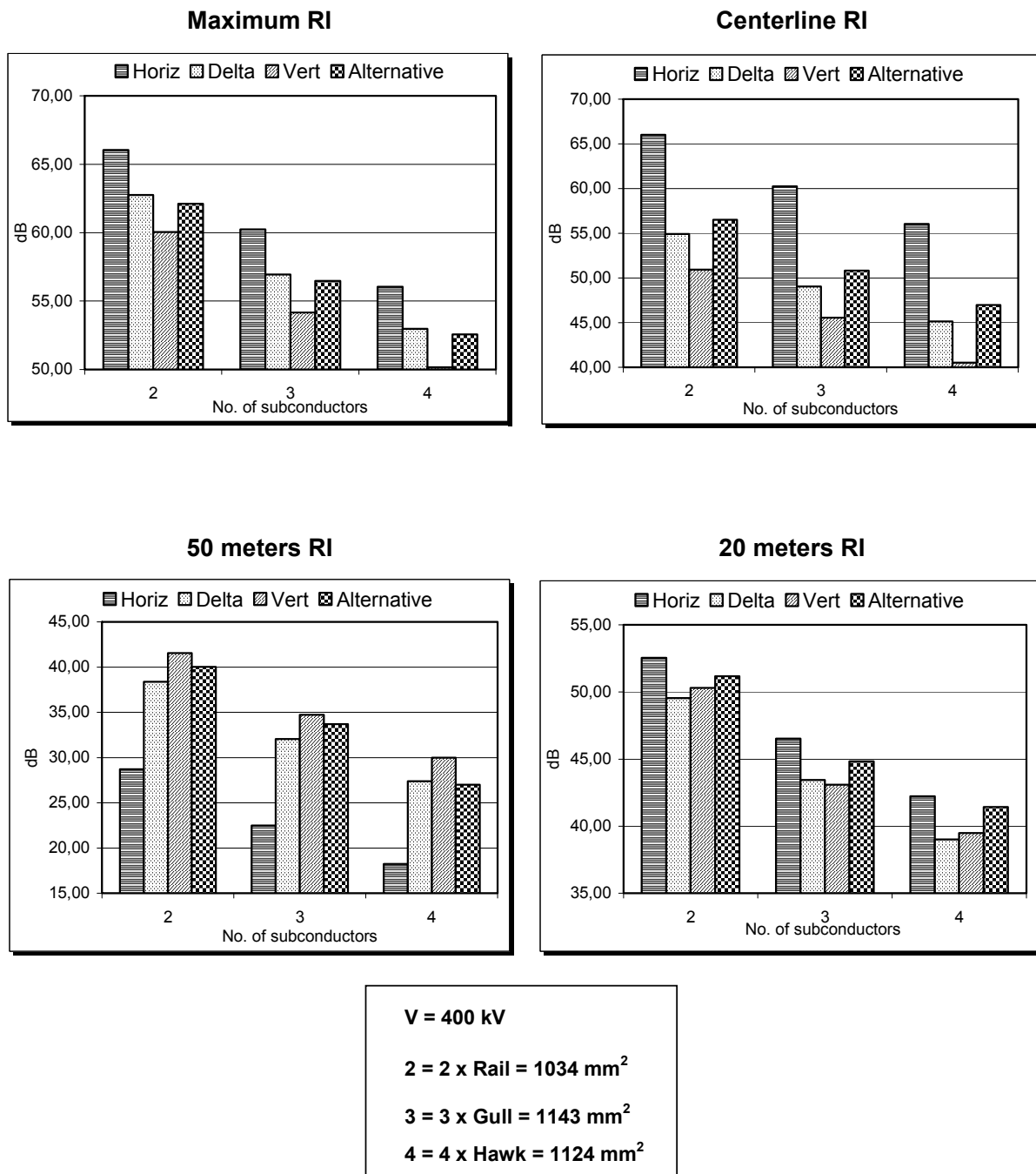


Figure 2.14 Impact of number of sub-conductors on radio interference level

400 kV SINGLE CIRCUIT LINES

RADIO INTERFERENCES vs TOTAL CROSS SECTION

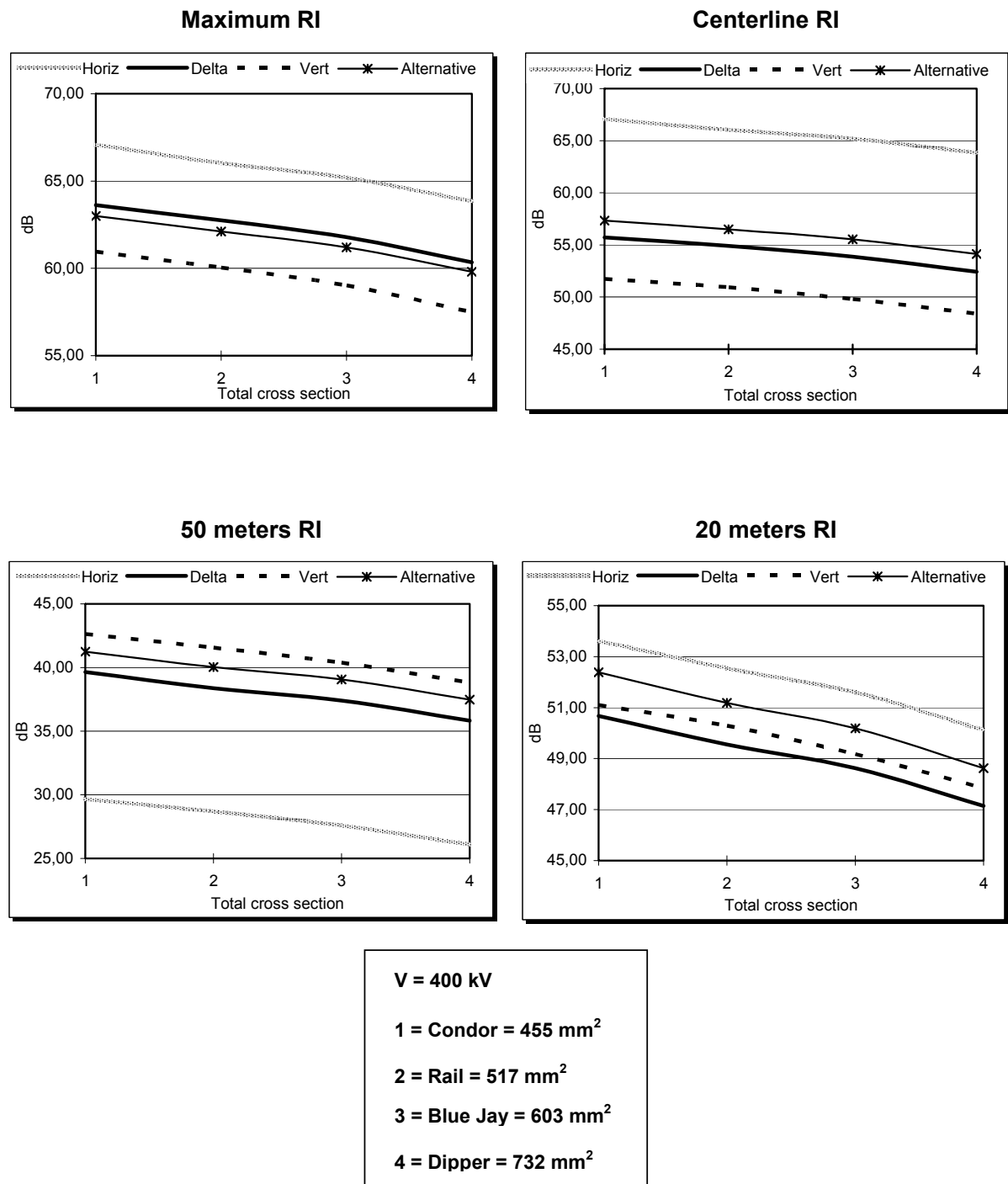


Figure 2.15 Impact of total cross-section on radio interference level

400 kV SINGLE CIRCUIT LINES

RADIO INTERFERENCES vs SUBCONDUCTOR SPACING

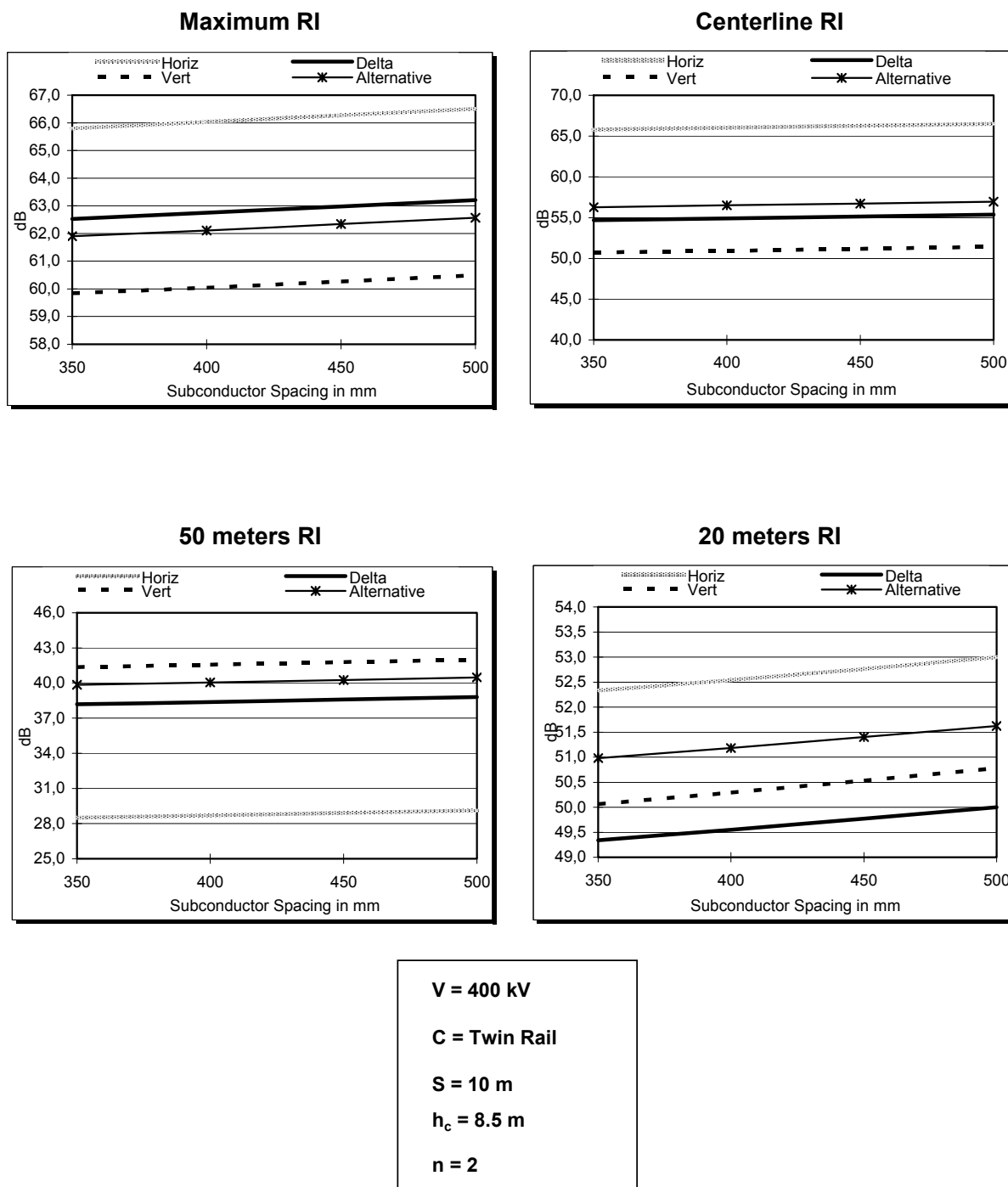


Figure 2.16 Impact of sub-conductor spacing on radio interference level

2.5 Audible Noise (AN)

Line configuration (Figure 2.17)

Delta configuration gives the highest values of audible noise (AN) and vertical configuration the lowest. But differences are slight only and configuration does not affect greatly the AN level.

As we can see in the curves, AN does not decrease strongly with the distance to the line central axis. For horizontal configuration values at the centre and at 50 m distance vary by 8 dB(A).

Phase to phase distance (Figure 2.18)

As phase to phase distance decreases, AN increases greatly. Compaction is even more unfavourable for AN than for RI.

Height of conductors (Figure 2.19)

AN level decreases when height of conductors increases. But to reduce only 1 dB(A) the AN level at 50 m distance, it is necessary to increase the height of conductors by almost 6 m.

Number of sub-conductors for identical total cross-section (Figure 2.20)

As for RI levels, the best way to reduce AN is to increase the number of sub-conductors in a bundle for the same total cross-section. For all configurations, changing from 2 to 4 sub-conductors, reduces AN at 50 m distance to the half.

Total cross section of conductor (Figure 2.21)

AN level decreases greatly when total cross-section of conductor increases.

Sub-conductor spacing (Figure 2.22)

Increasing sub-conductor spacing, increases AN level too, but not to a significant extent.

Conclusion

- Configuration does not affect too much the AN level.
- AN level decreases slightly with the distance from the line central axis.
- Increasing number of sub-conductors for identical total cross-section decreases greatly AN levels.
- Compaction increases AN levels.
- Increasing height of conductors does not reduce AN levels clearly.

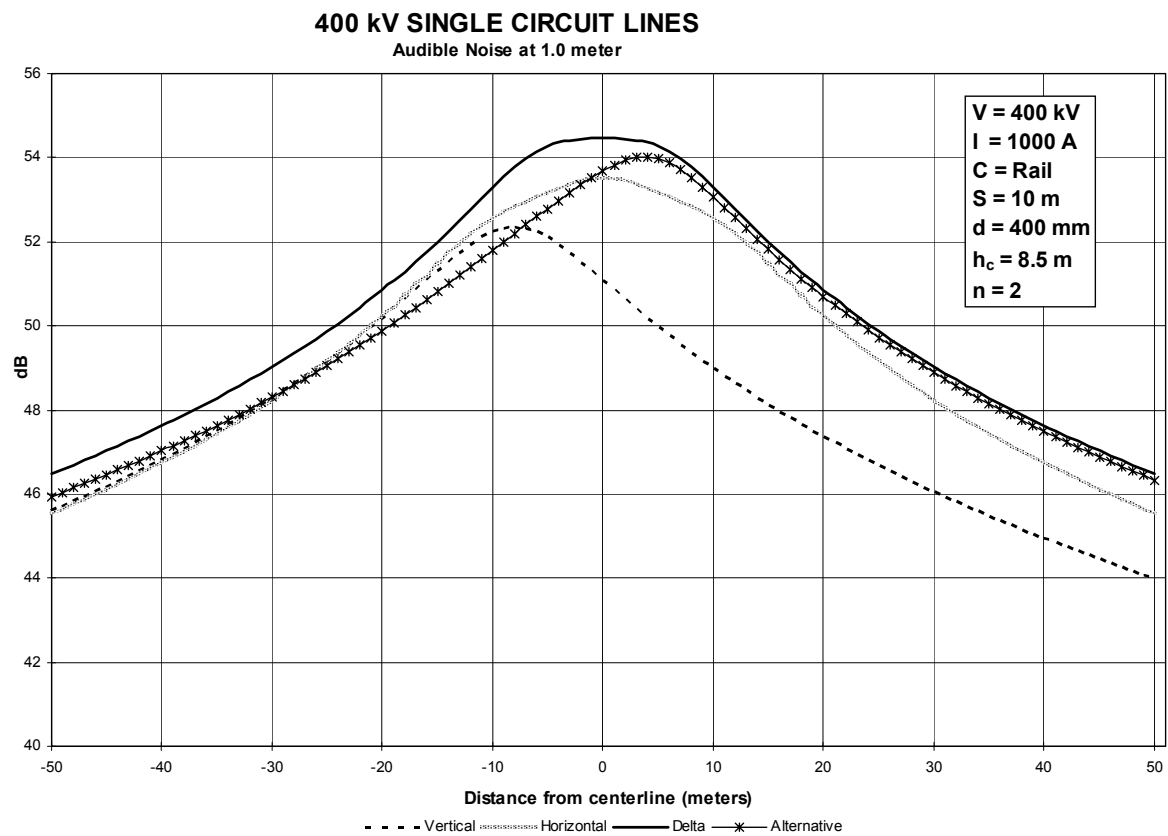


Figure 2.17 Impact of conductor configuration on audible noise

400 kV SINGLE CIRCUIT LINES

AUDIBLE NOISE vs PHASE TO PHASE DISTANCE

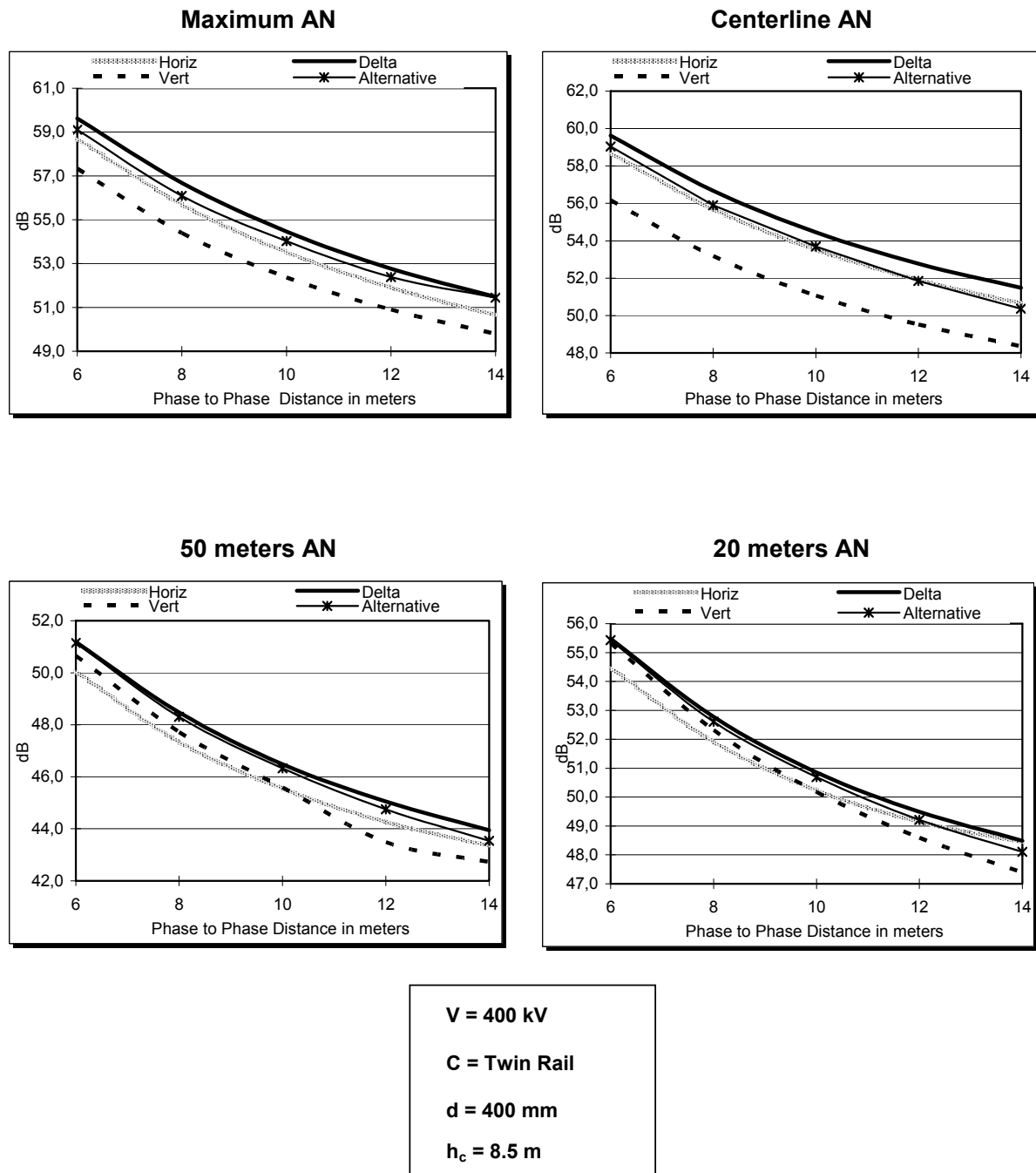


Figure 2.18 Impact of phase to phase distance on audible noise

400 kV SINGLE CIRCUIT LINES

AUDIBLE NOISE vs HEIGHT OF CONDUCTORS ABOVE GROUND

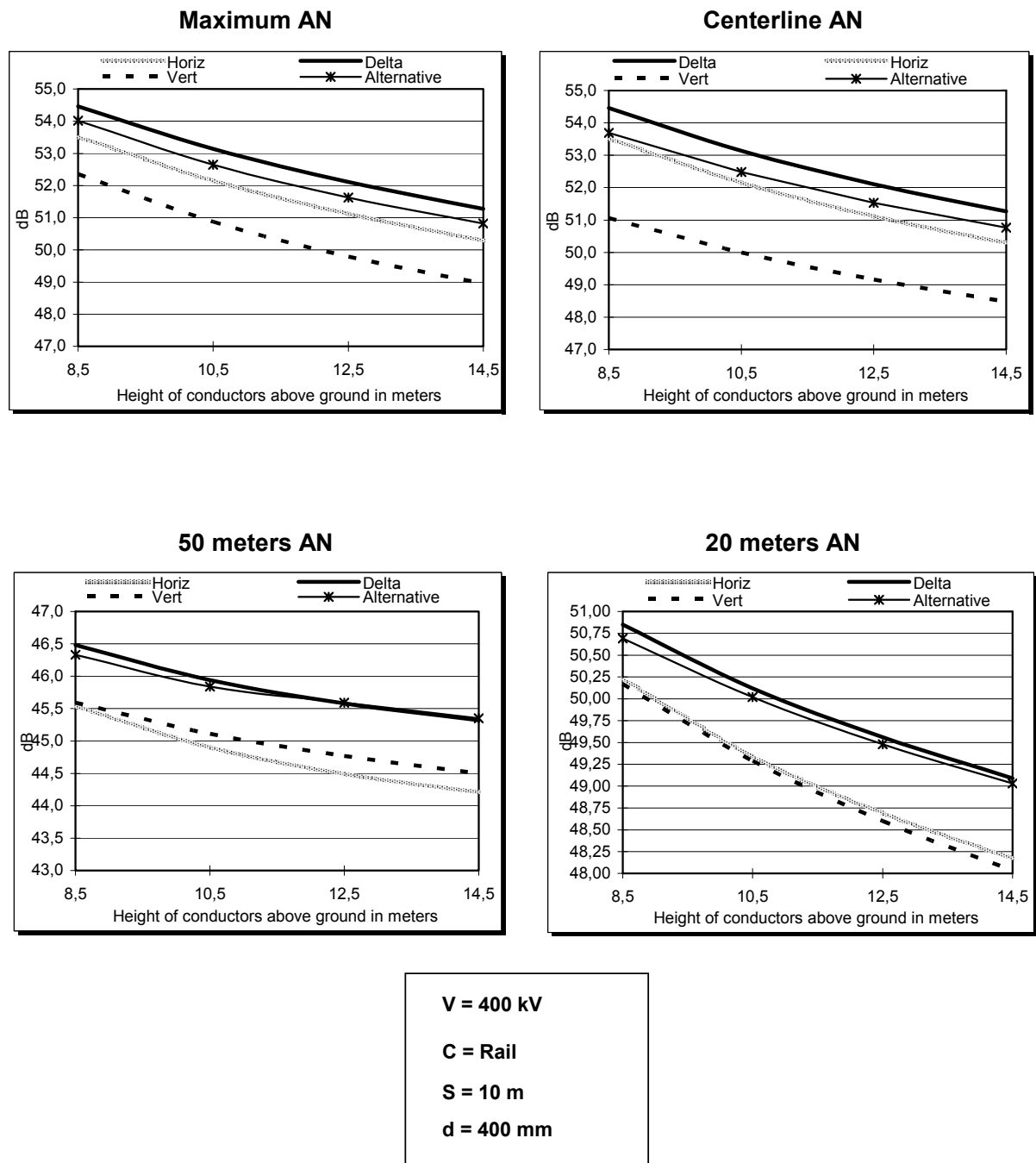
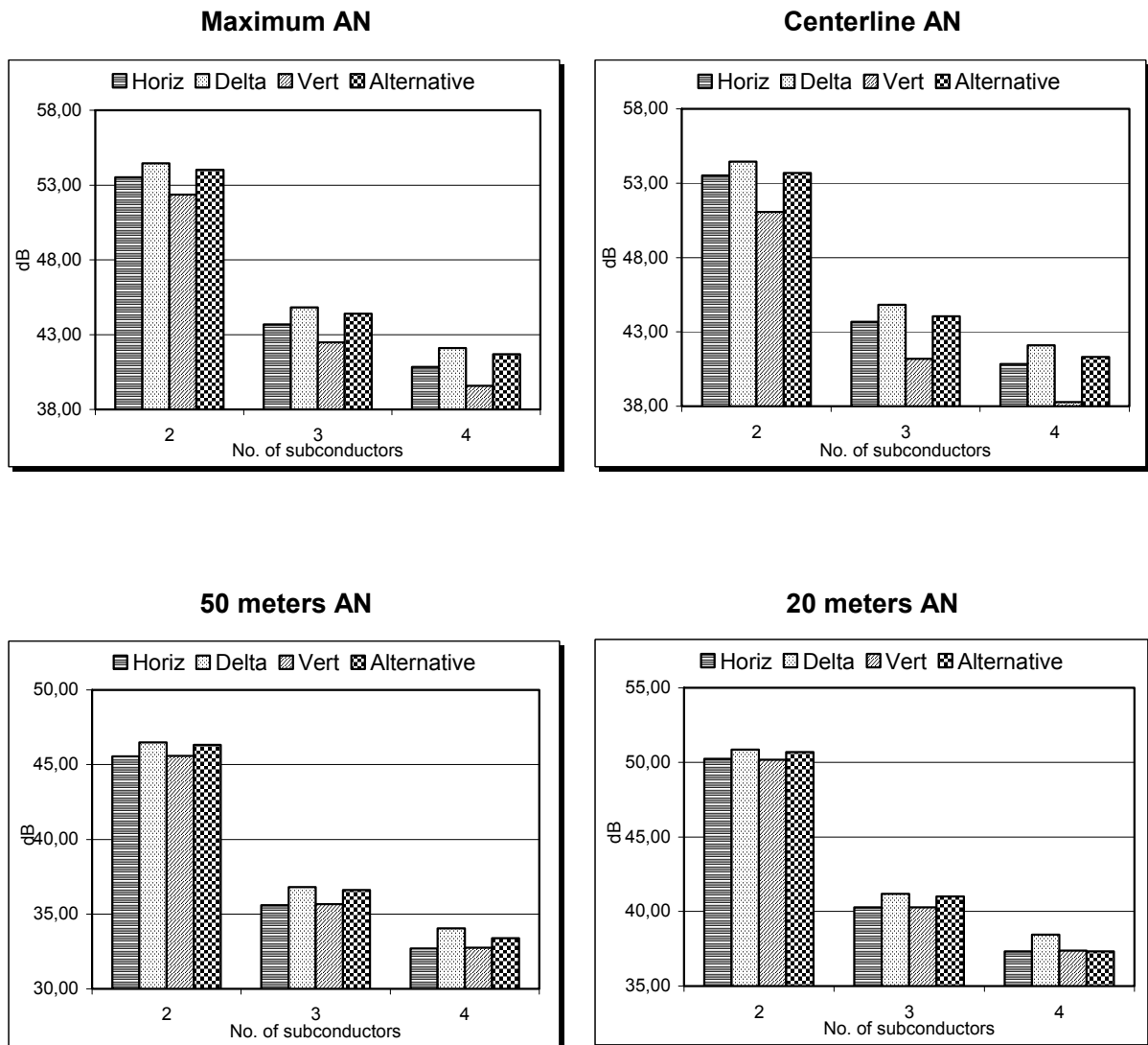


Figure 2.19 Impact of height of conductors above ground on audible noise

400 kV SINGLE CIRCUIT LINES

AUDIBLE NOISE vs No. SUBCONDUCTORS FOR IDENTICAL TOTAL CROSS SECTION



V = 400 kV

2 = 2 x Rail = 1034 mm²

3 = 3 x Gull = 1143 mm²

4 = 4 x Hawk = 1124 mm²

Figure 2.20 Impact of number of sub-conductors on audible noise

400 kV SINGLE CIRCUIT LINES

AUDIBLE NOISE vs TOTAL CROSS SECTION

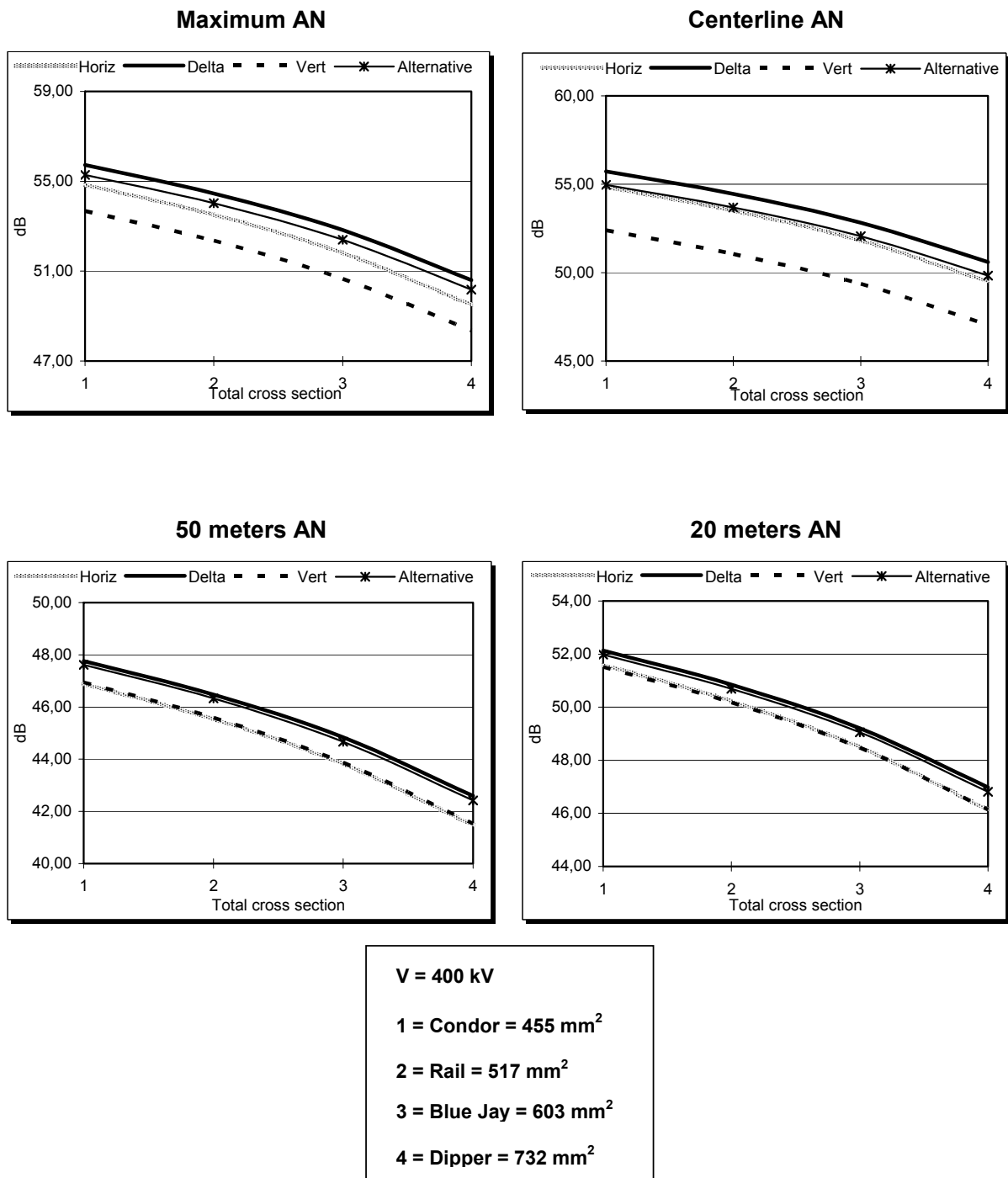
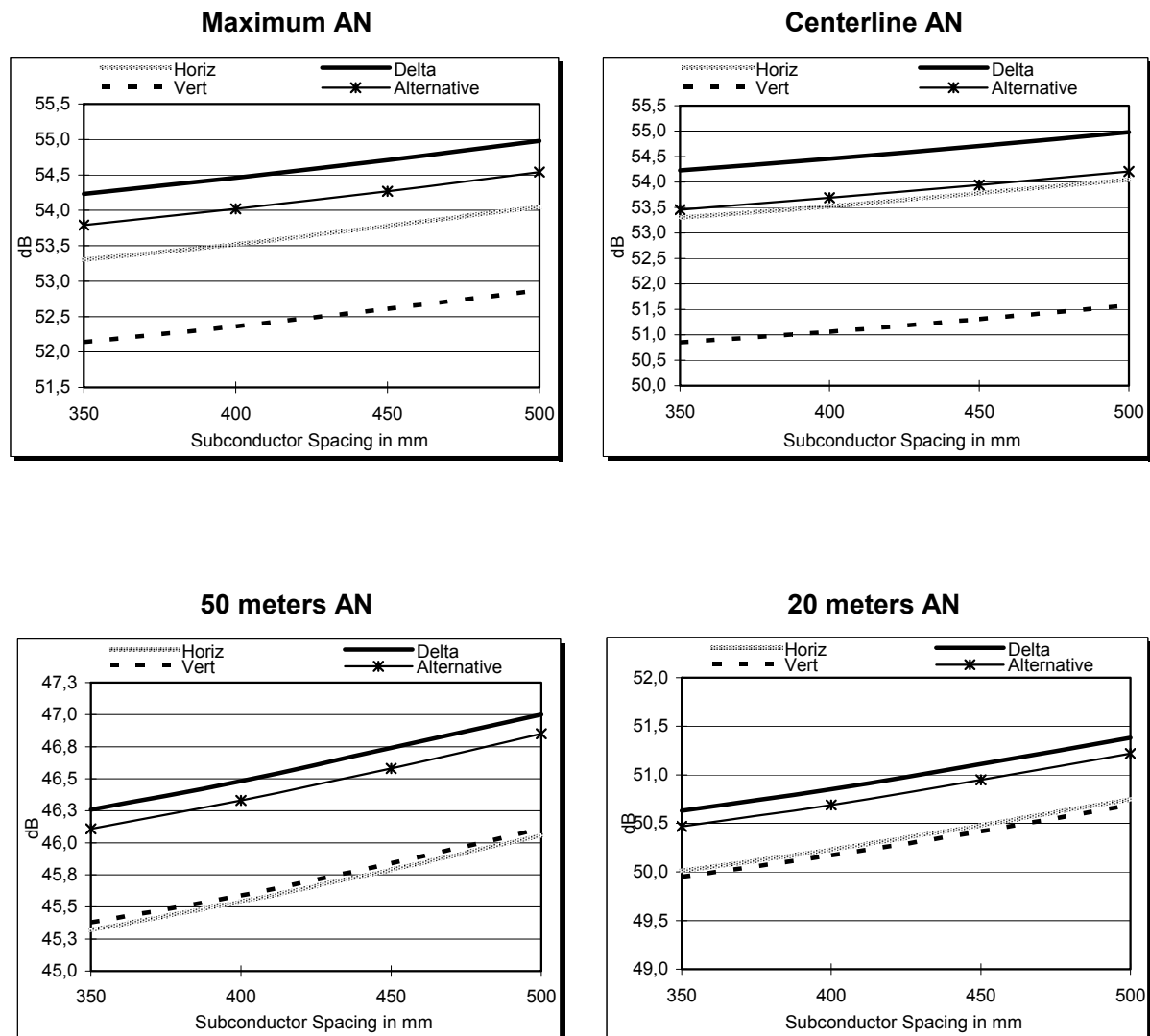


Figure 2.21 Impact of total cross-section on audible noise

400 kV SINGLE CIRCUIT LINES

AUDIBLE NOISE vs SUBCONDUCTOR SPACING



V = 400 kV
C = Twin Rail
S = 10 m
 $h_c = 8.5$ m
n = 2

Figure 2.22 Impact of sub-conductor spacing on audible noise

3. 400 kV double circuit lines

3.1 Configurations studied

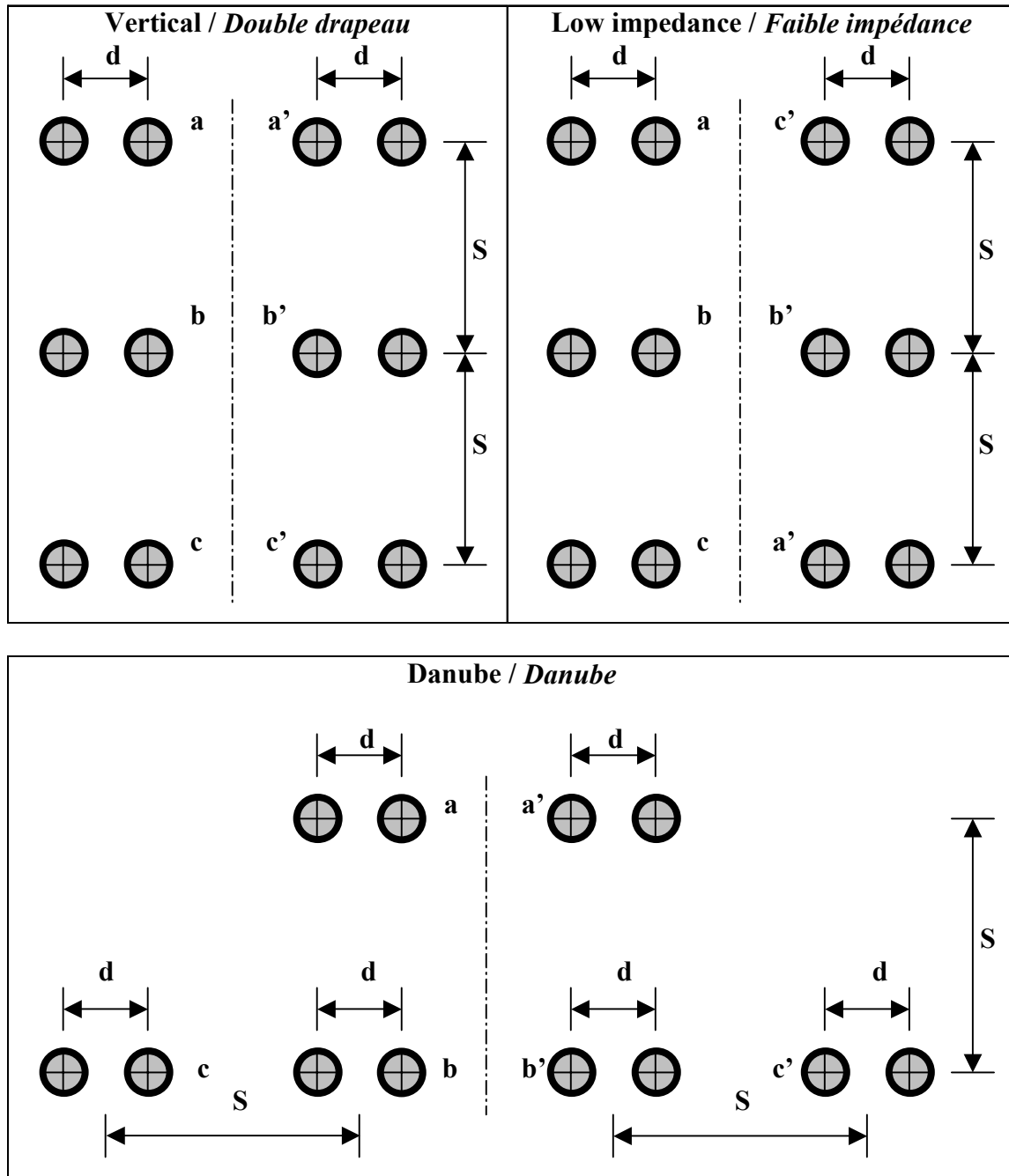


Figure 3.1 Configurations of double circuit lines
(S = phase to phase distance; d = sub-conductor spacing)
(a, b, c and a', b', c' = sequence of two circuits)

3.2 Electric Field (EF)

Line configuration (Figure 3.2)

Low impedance configuration gives the lowest values of maximum electric field (EF) and vertical configuration the highest ones. Danube configuration gives values approximately equal to low impedance at 10 m distance from centreline but at 20 m gives the highest values of the three configurations, due to the wider right-of-way.

Maximum values of EF are, considering a height of conductor above ground of 8,5 m, the following:

- Vertical: 8,69 kV/m
- Danube: 7,75 kV/m
- Low impedance: 7,70 kV/m

For vertical configuration, low impedance phasing should be used.

Danube configuration gives wider ROW (Right-of-Way) and higher values of EF outside the ROW.

Phase to phase distance (Figure 3.3)

EF increases with phase to phase distance in all line configurations. With phase to phase distances of less than 10 m, lower values of maximum EF are reached with Danube configurations. But the electric field at 20 m distance is considerably higher for this configuration (8 times more than low impedance).

Height of conductors above ground (Figure 3.4)

EF decreases as height of conductors above ground increases. Reduction of EF values is important for maximum values and in the centreline. Outside the edge of ROW, reductions are less significant.

Cross-section of conductor (Figure 3.5)

EF increases slightly as section of conductor does, but is not a significant effect.

Number of sub-conductor for identical total cross-section (Figure 3.6)

For a similar total cross-section EF increases as the number of sub-conductors does, for all configurations to the same extent.

Sub-conductor spacing (Figure 3.7)

EF increases slightly as sub-conductor spacing does.

Conclusions

- In 400 kV double circuit lines, low impedance configuration is strongly recommended.
- Danube configuration gives higher values of EF up to 20 m distance from centreline. At 40 m values are similar to other configurations.
- Compaction is the best way to reduce EF.

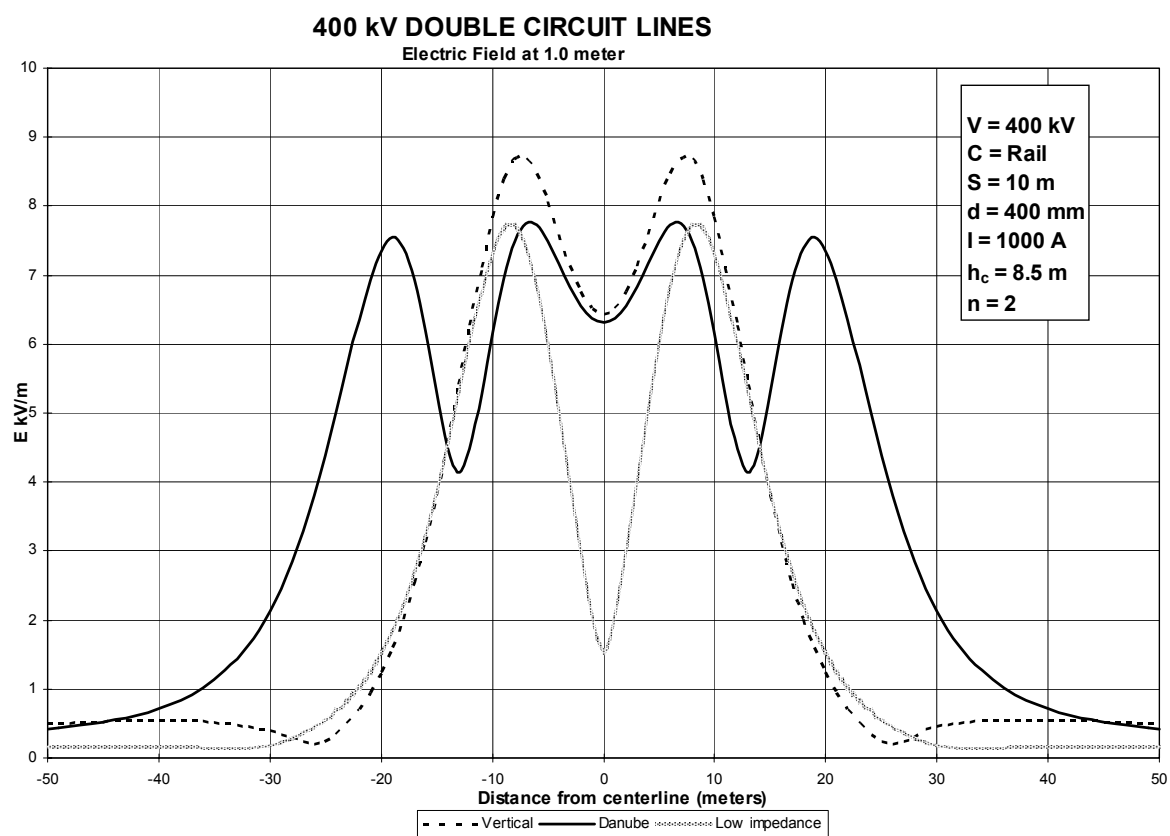
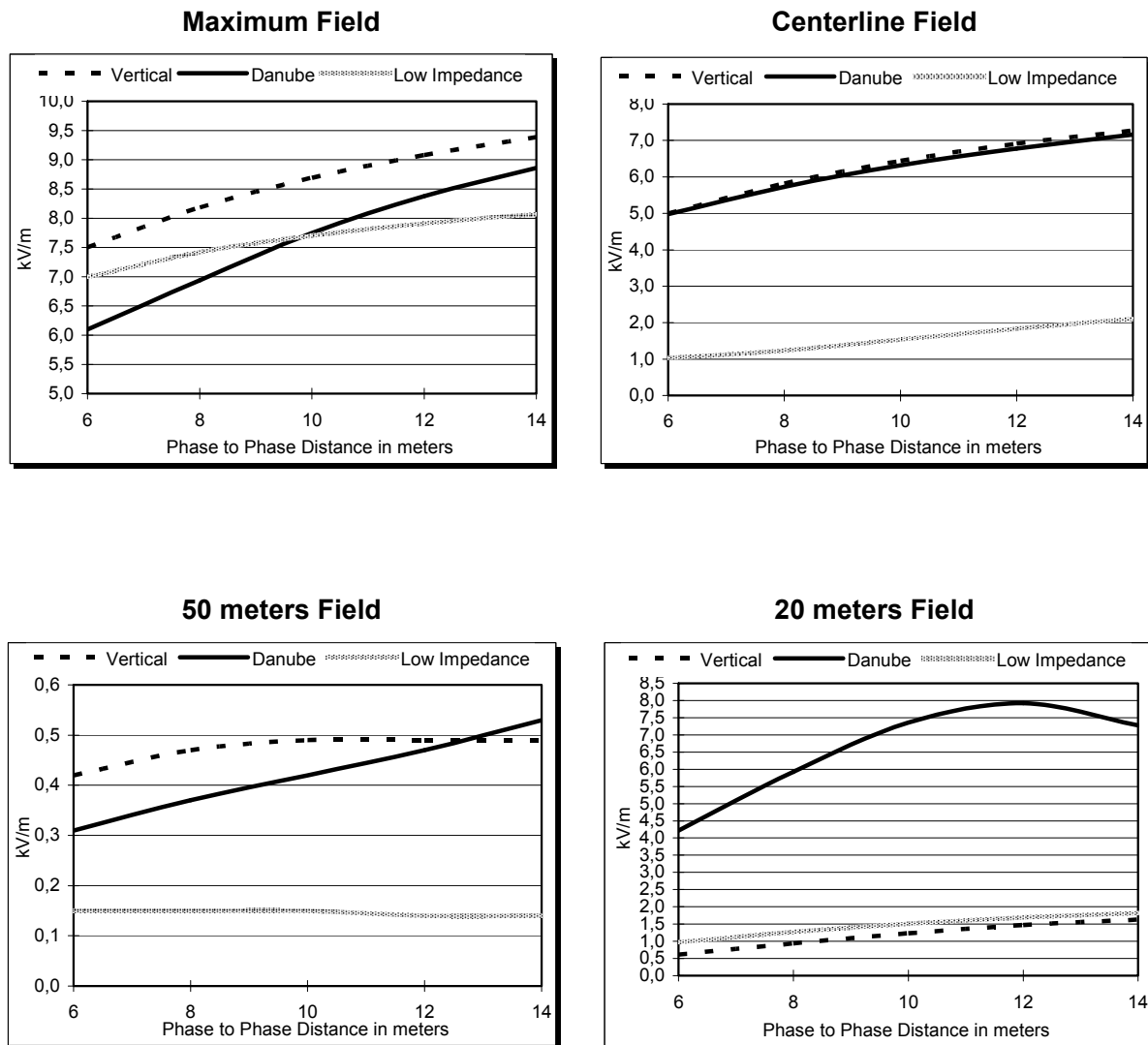


Figure 3.2 Impact of line configuration on electric field

400 kV DOUBLE CIRCUIT LINES

ELECTRIC FIELD vs PHASE TO PHASE DISTANCE



V = 400 kV

C = Twin Rail

d = 400 mm

$h_c = 8.5$ m

Figure 3.3 Impact of phase to phase distance on electric field

400 kV DOUBLE CIRCUIT LINES

ELECTRIC FIELD vs HEIGHT OF CONDUCTORS ABOVE GROUND

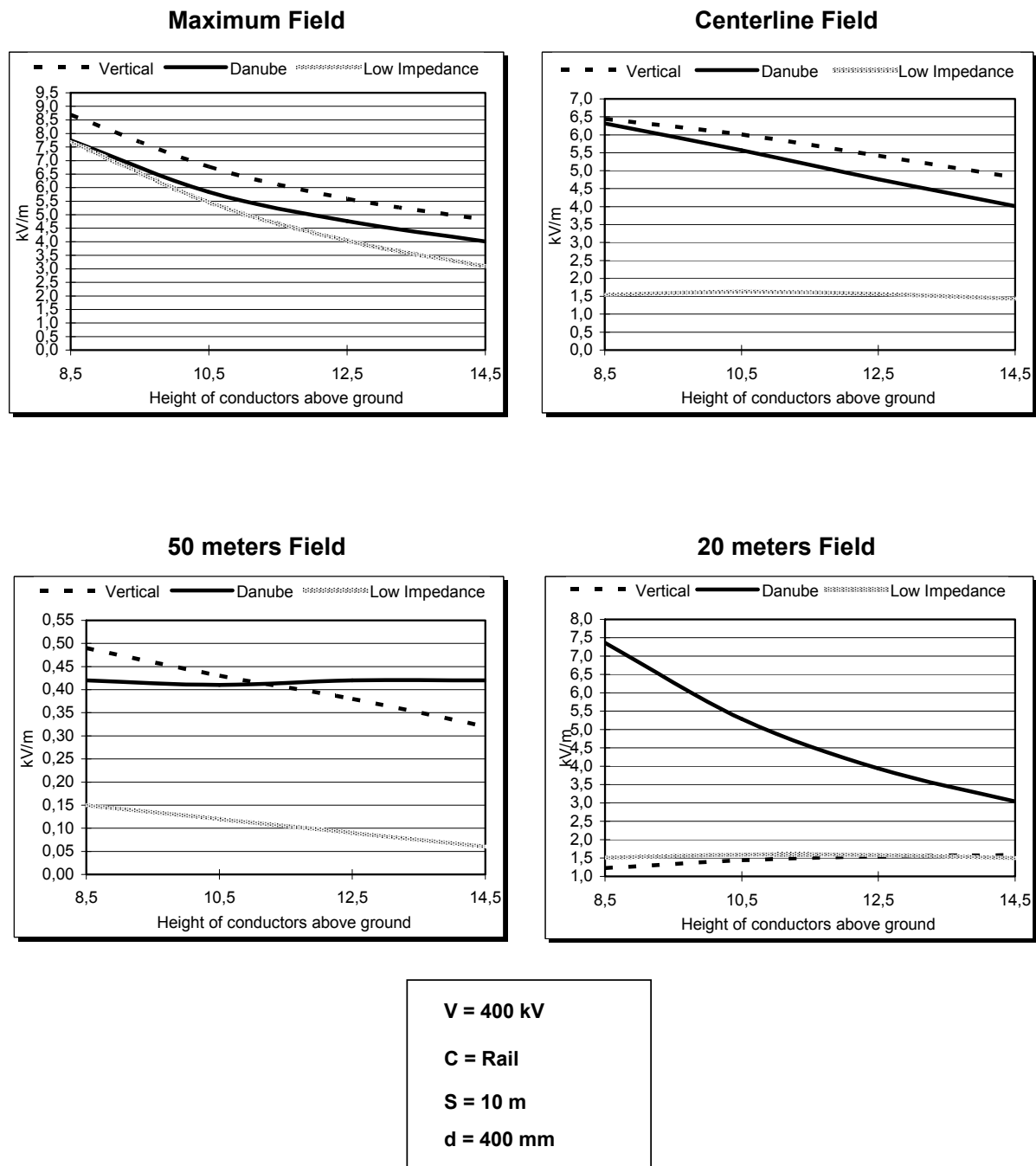
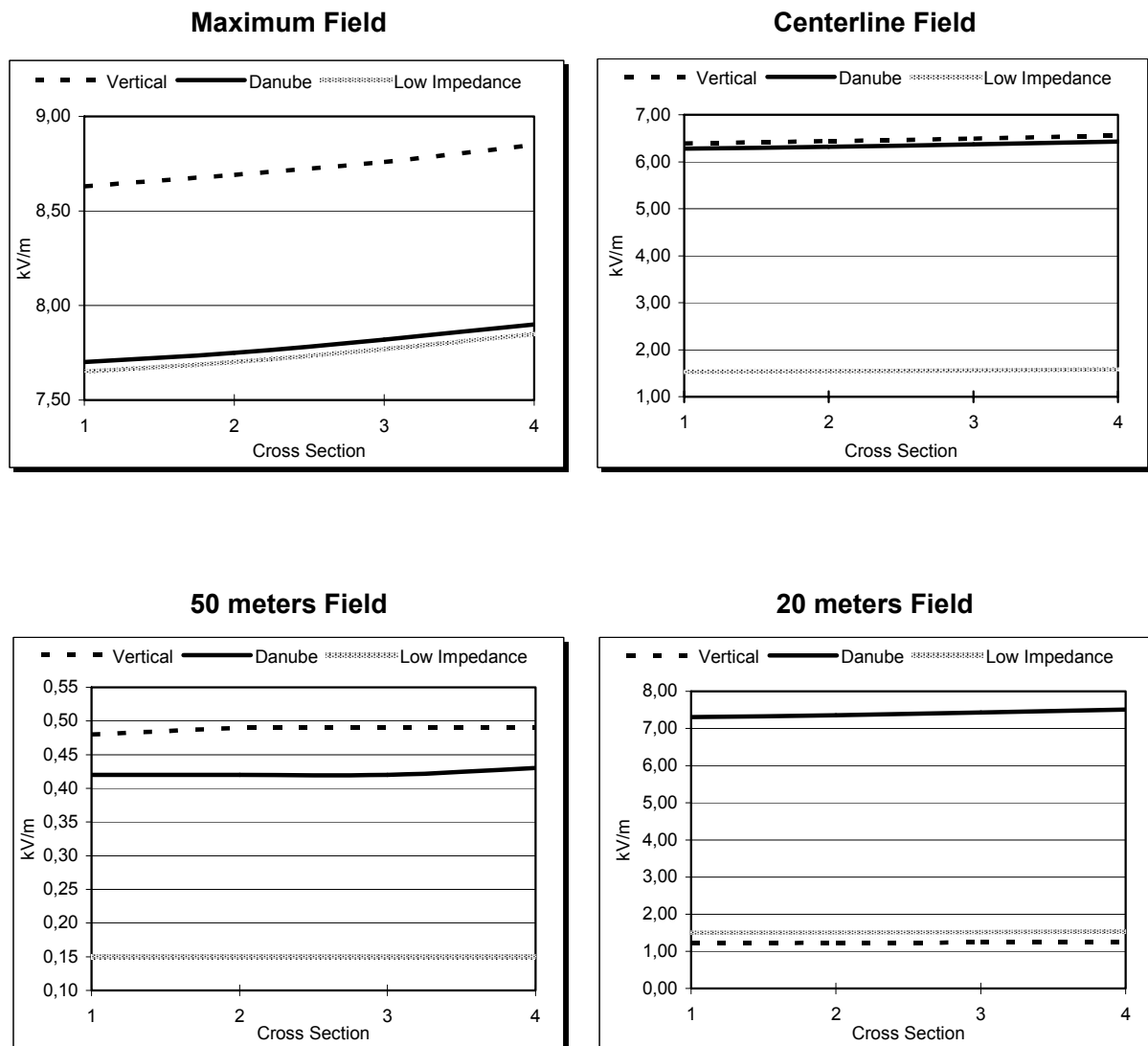


Figure 3.4 Impact of height of conductors above ground on electric field

400 kV DOUBLE CIRCUIT LINES

ELECTRIC FIELD vs CONDUCTOR CROSS SECTION



V = 400 kV

1 = Condor = 455 mm²

2 = Rail = 517 mm²

3 = Blue Jay = 603 mm²

4 = Dipper = 732 mm²

Figure 3.5 Impact of conductor cross-section on electric field

400 kV DOUBLE CIRCUIT LINES

ELECTRIC FIELD No. OF SUBCONDUCTORS FOR IDENTICAL TOTAL CROSS SECTION

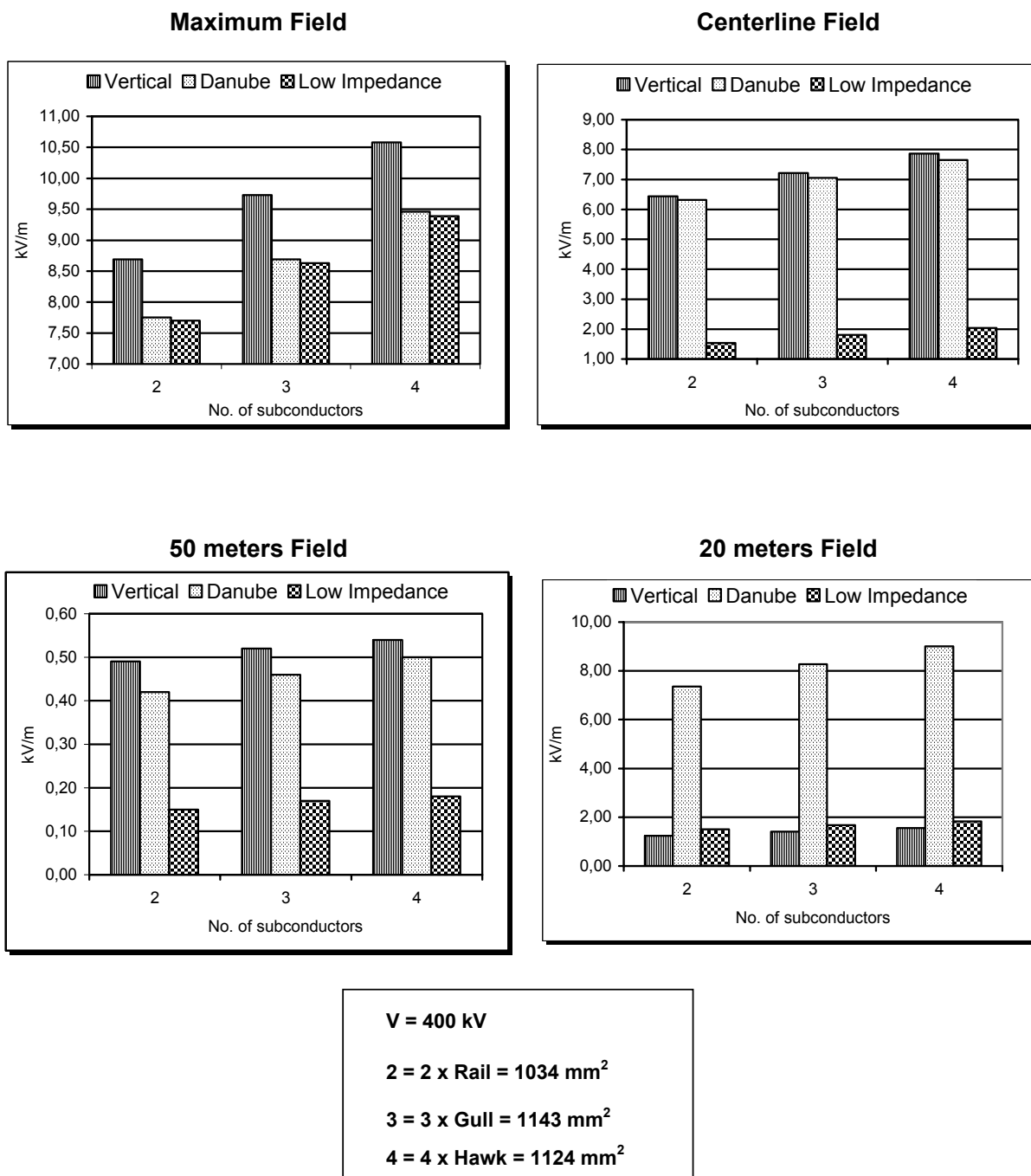


Figure 3.6 Impact of number of sub-conductors on electric field

400 kV DOUBLE CIRCUIT LINES ELECTRIC FIELD vs SUBCONDUCTOR SPACING

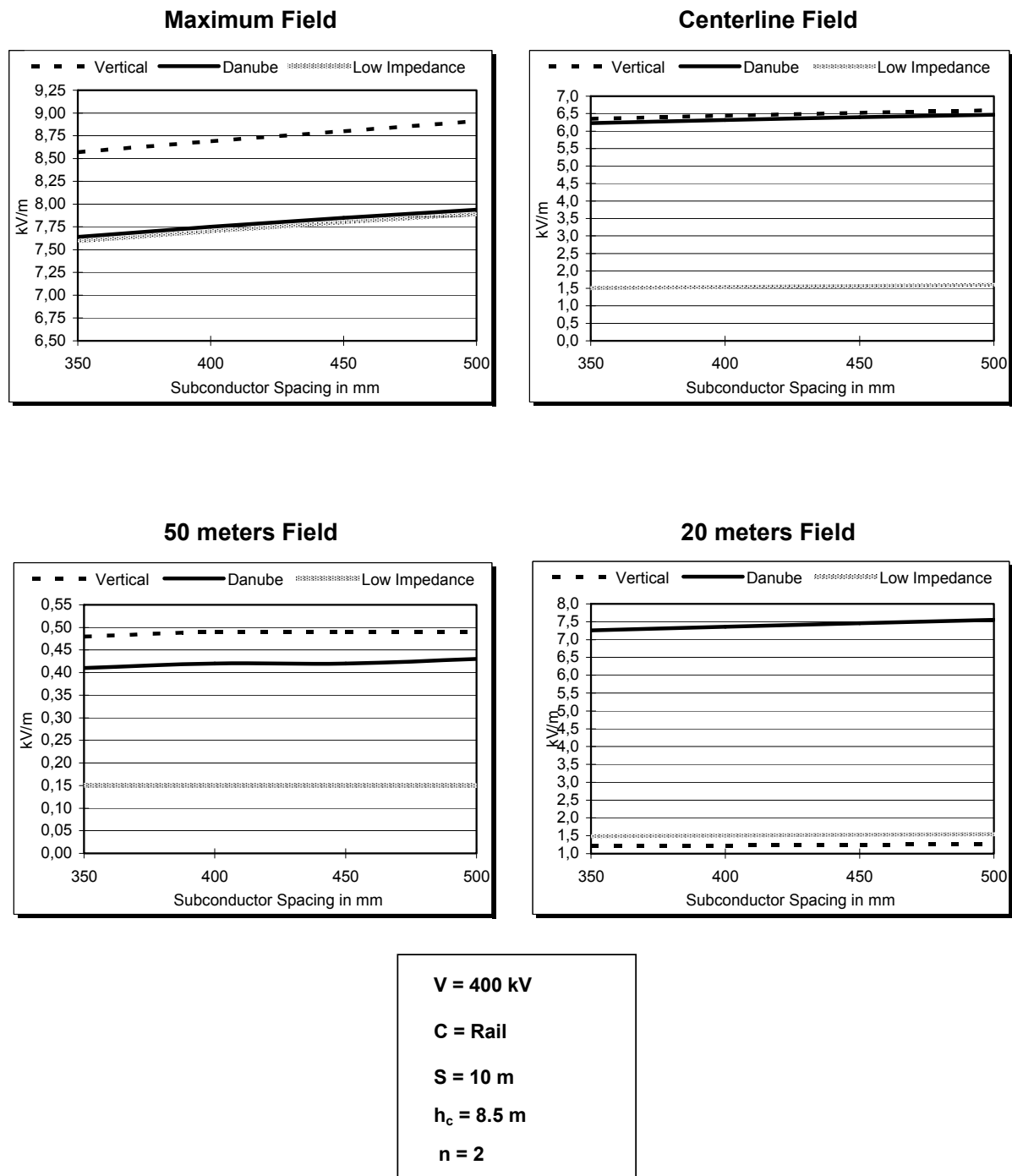


Figure 3.7 Impact of sub-conductor spacing on electric field

3.3 Magnetic Field (MF)

Line configuration (Figure 3.8)

Vertical configurations give lower values for maximum magnetic field (MF) and MF at centre-line. At 20 and 50 m distance, low impedance configuration gives the lowest one. So, low impedance is also a good solution to reduce MF. With values of phase to phase distance of 10 m and a current of 1000 A, maximum values of MF are, considering a height of conductor of 8,5 m, the following:

- Vertical:	18,44 μ T
- Danube:	24,24 μ T
- Low impedance:	20,04 μ T

Danube configurations give wider right-of-way and higher values of MF outside the right-of-way.

Phase to phase distance (Figure 3.9)

As phase to phase distance increases, MF increases too, for all configurations. So, compaction is the best way to reduce MF.

Height of conductors above ground (Figure 3.10)

MF decreases dramatically as height of conductors increases. To reduce MF locally, increasing height of conductors is the most effective solution.

Conclusions

- In 400 kV double circuit lines, vertical configuration gives lower values of maximum MF and MF at centreline. But at 20 m distance from centreline and away low impedance configuration gives lower values. So this configuration is also recommended to reduce MF.
- Compaction is the best way to reduce MF.
- Increasing height of conductors above ground is an easy way to reduce MF locally.
- Number of sub-conductors and sub-conductor spacing have no impact on MF.

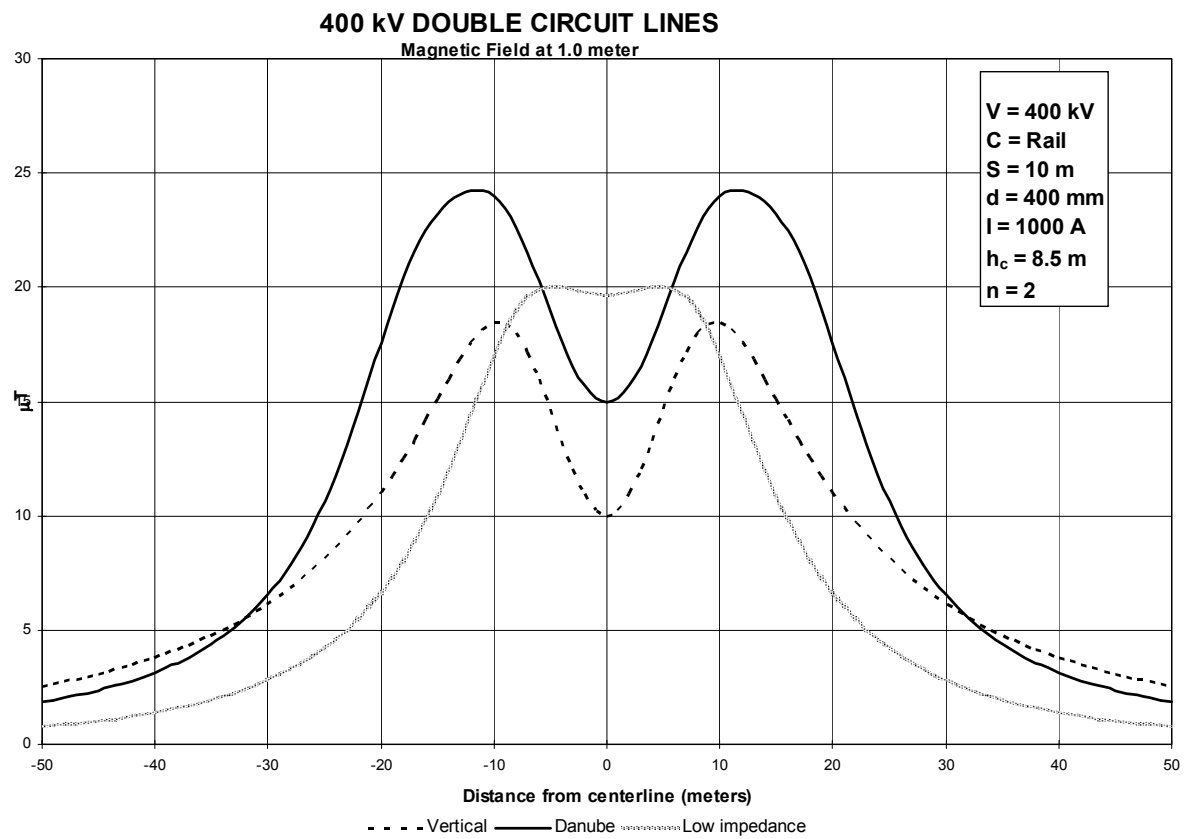


Figure 3.8 Impact of conductor configuration on magnetic field

400 kV DOUBLE CIRCUIT LINES

MAGNETIC FIELD vs PHASE TO PHASE DISTANCE

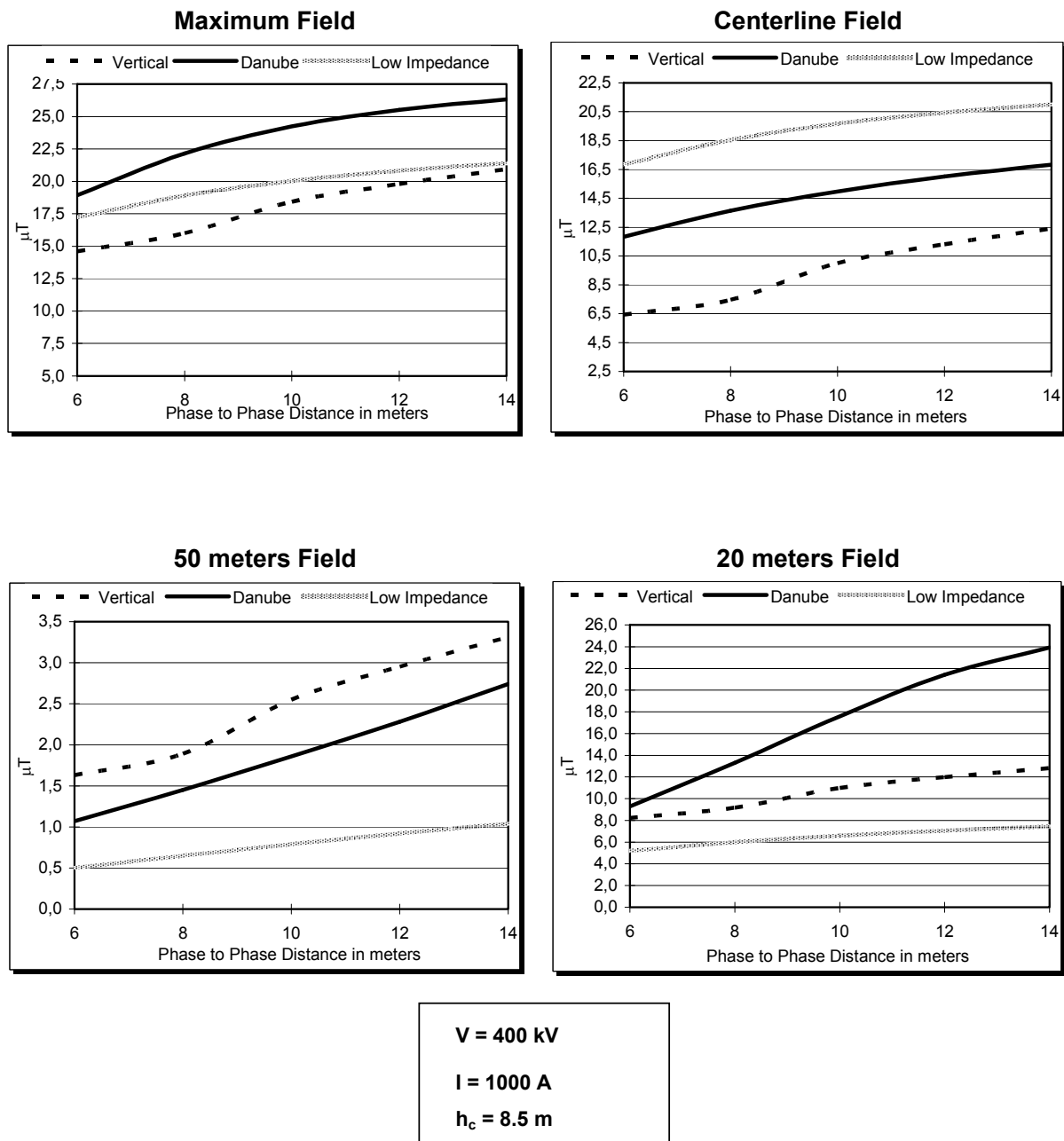


Figure 3.9 Impact of phase to phase distance on magnetic field

400 kV DOUBLE CIRCUIT LINES

MAGNETIC FIELD vs HEIGHT OF CONDUCTORS ABOVE GROUND

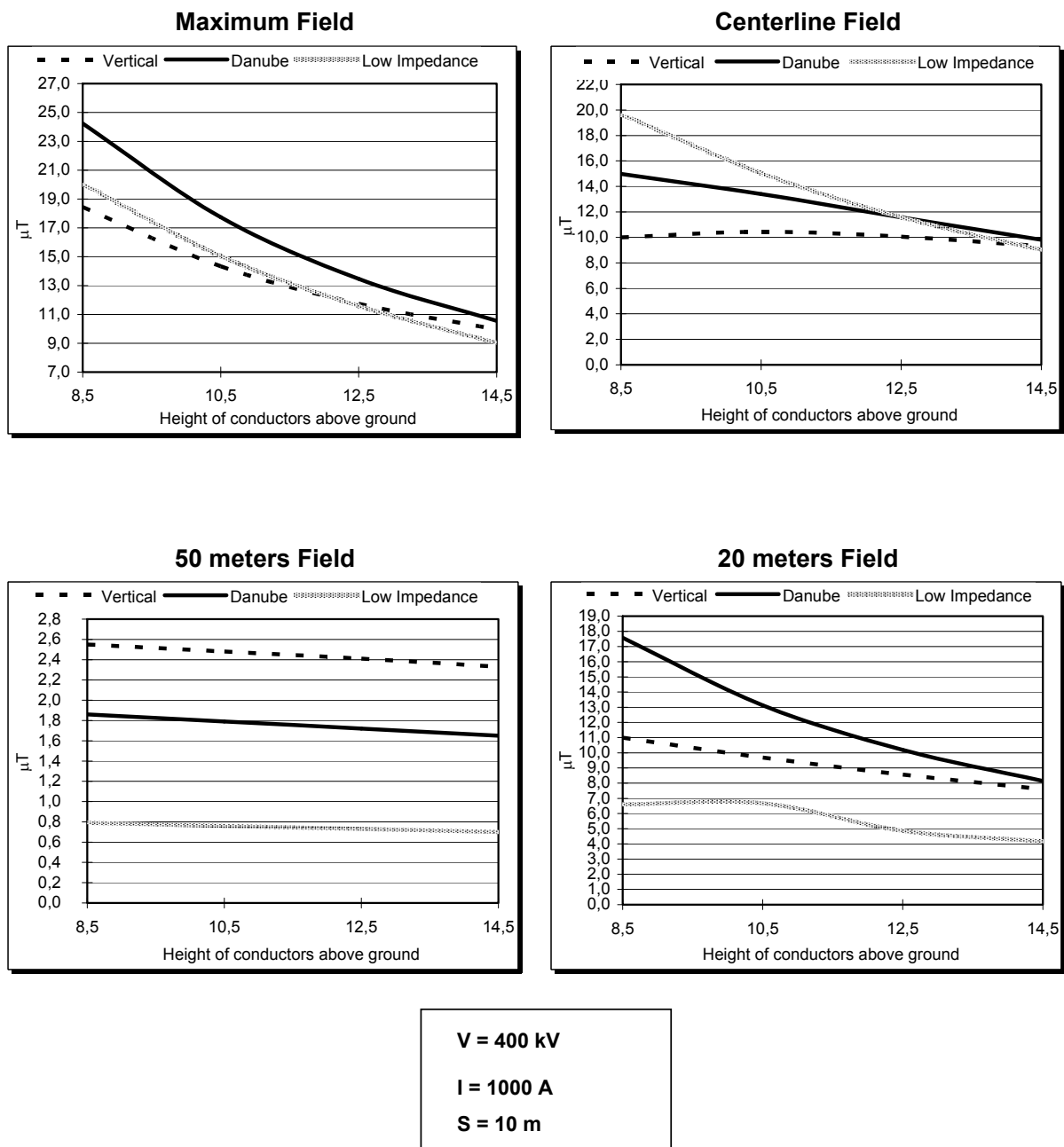


Figure 3.10 Impact of height of conductors above ground on magnetic field

3.4 Radio Interference (RI)

Line configuration (Figure 3.11)

Vertical and low impedance configurations give the lowest values of maximum radio interference (RI) and Danube configuration the highest ones.

At 20 m distance, values for RI are:

- | | |
|------------------|---------|
| - Vertical: | 52,9 dB |
| - Low impedance: | 52,6 dB |
| - Danube: | 62,5 dB |

Phase to phase distance (Figure 3.12)

Like in single circuit lines, as phase to phase distance increases, RI decreases slightly. Also here, compaction does not help to reduce RI values.

Height of conductors (Figure 3.13)

Maximum RI level decreases as height of conductors above ground increases. But values outside the edge of ROW are not too influenced by this parameter.

Number of sub-conductors for identical total cross-section (Figure 3.14)

Like in single circuit, the best way to reduce RI values is to increase the number of sub-conductors in a phase for identical total cross-section.

Total cross-section of conductor (Figure 3.15)

RI decreases slightly as cross-section of conductor increases but it is not an efficient way to reduce RI level.

Sub-conductor spacing (Figure 3.16)

Changing sub-conductor spacing does not give significant variation in the RI level.

Conclusions

- In 400 kV double circuit lines, there is not an optimum configuration recommended to reduce RI level.
- Increasing number of sub-conductors greatly decreases RI levels.
- Compaction does not reduce RI levels.
- Low impedance configuration does not provide advantages in reducing RI level.

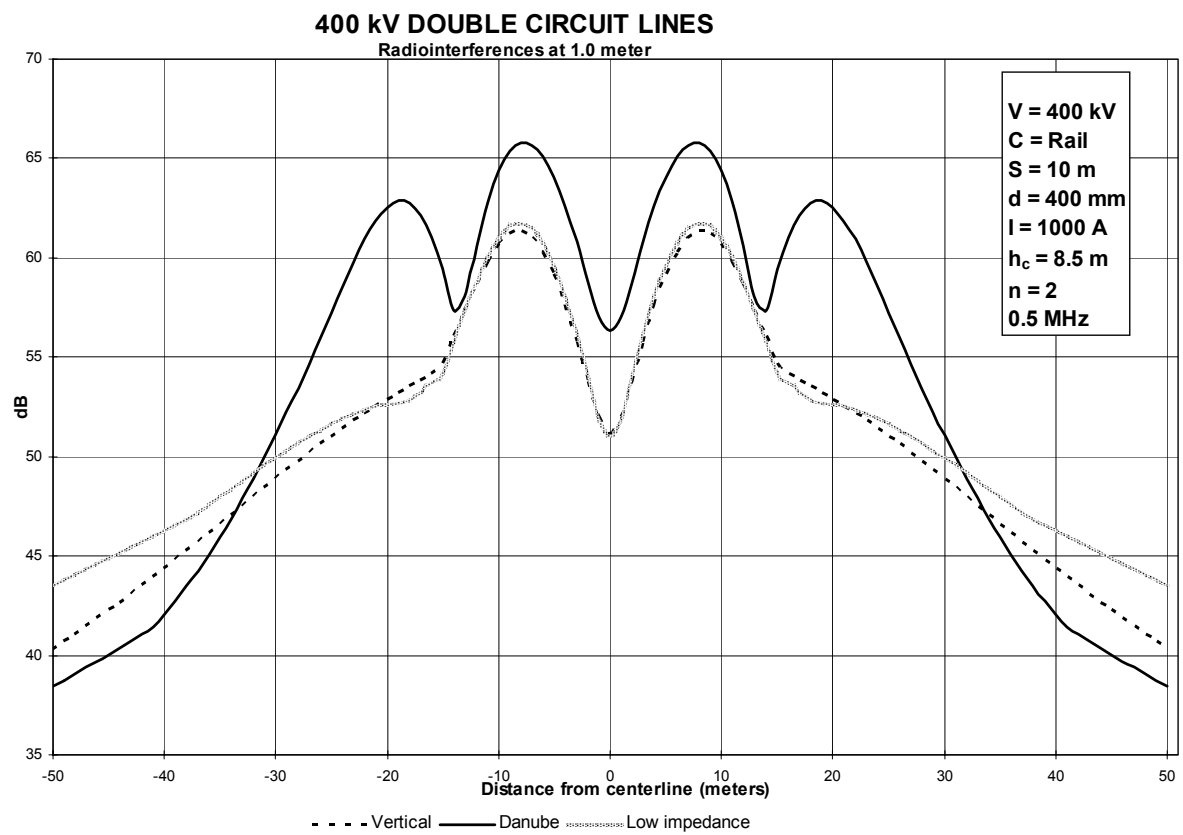


Figure 3.11 Impact of conductor configuration on radio interference

400 kV DOUBLE CIRCUIT LINES RADIO INTERFERENCES vs PHASE TO PHASE DISTANCE

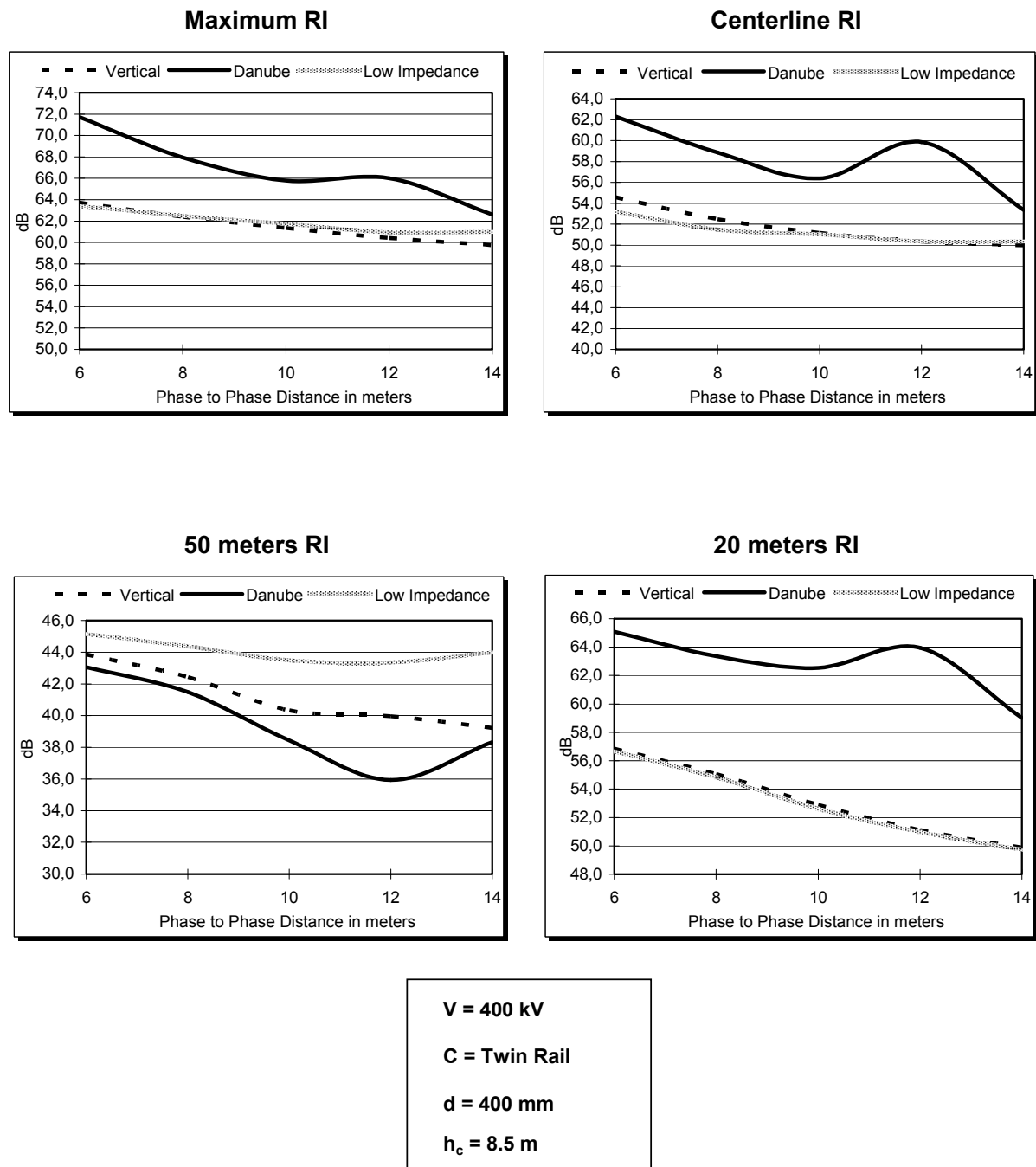


Figure 3.12 Impact of phase to phase distance on radio interference

400 kV DOUBLE CIRCUIT LINES

RADIO INTERFERENCES vs HEIGHT OF CONDUCTORS ABOVE GROUND

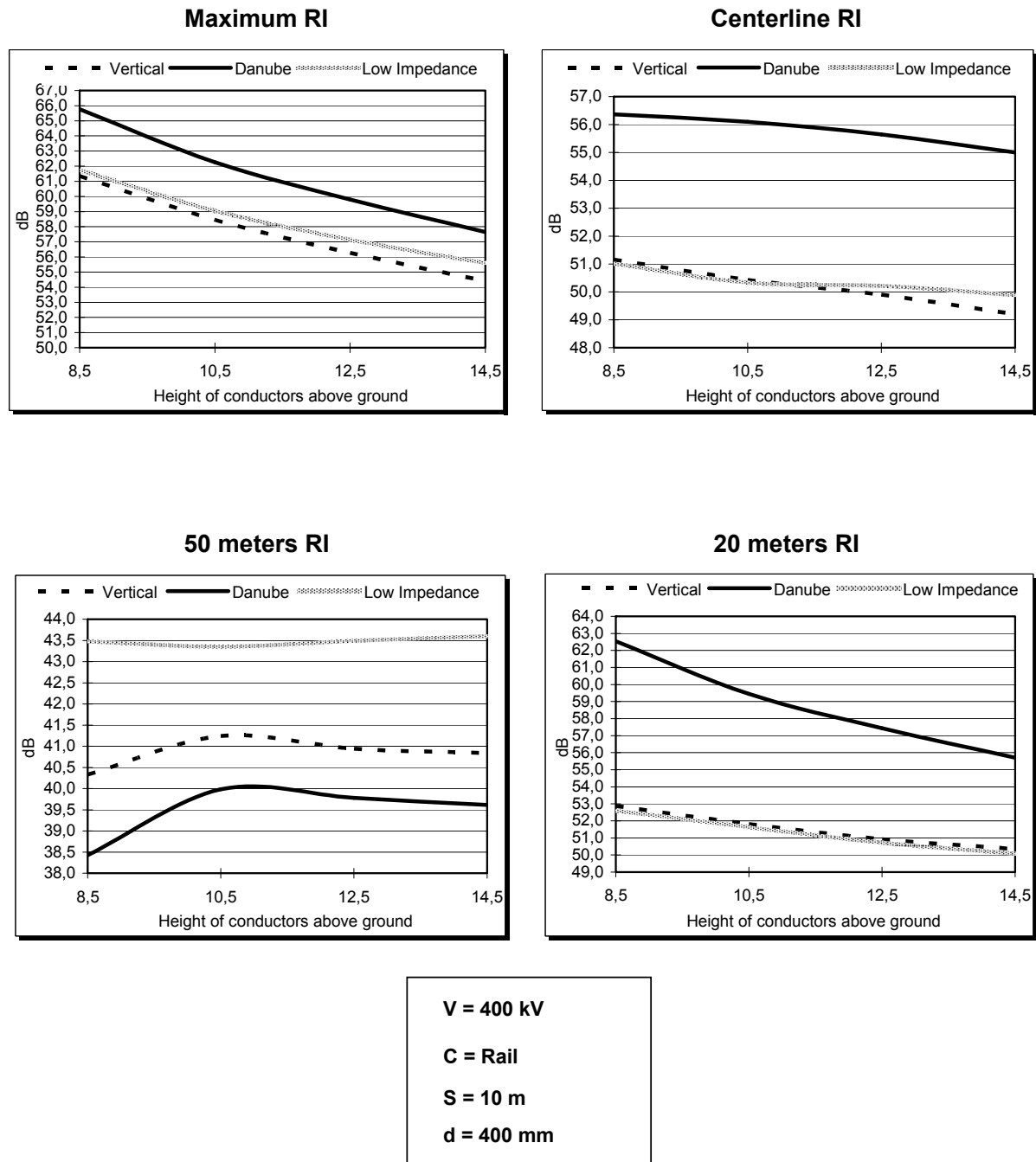
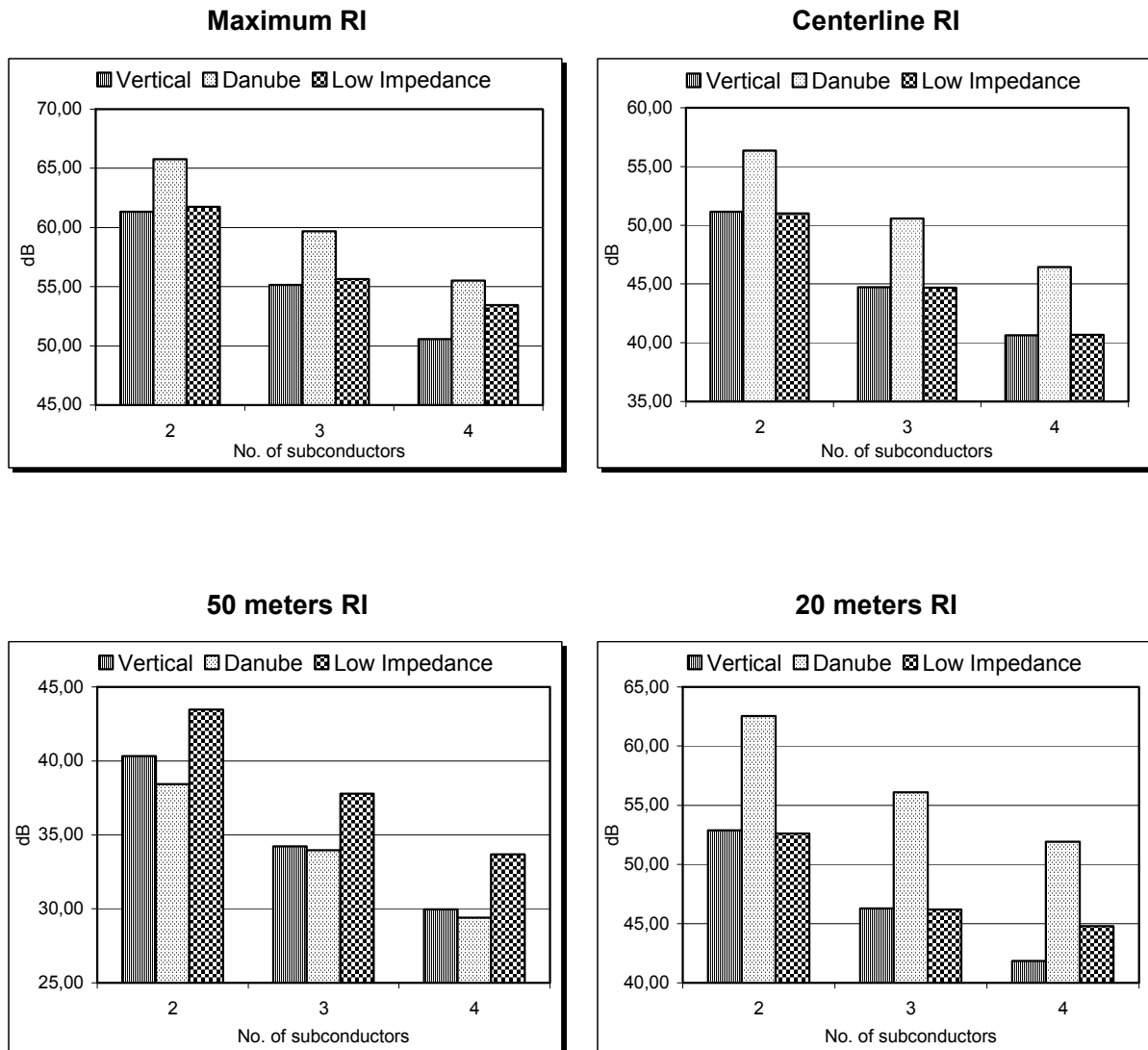


Figure 3.13 Impact of height of conductor above ground on radio interference

400 kV DOUBLE CIRCUIT LINES

RADIO INTERFERENCES vs No. OF SUBCONDUCTORS FOR IDENTICAL TOTAL CROSS SECTION



V = 400 kV

2 = 2 x Rail = 1034 mm²

3 = 3 x Gull = 1143 mm²

4 = 4 x Hawk = 1124 mm²

Figure 3.14 Impact of number of sub-conductors on radio interference

400 kV DOUBLE CIRCUIT LINES

RADIO INTERFERENCES vs TOTAL CROSS SECTION

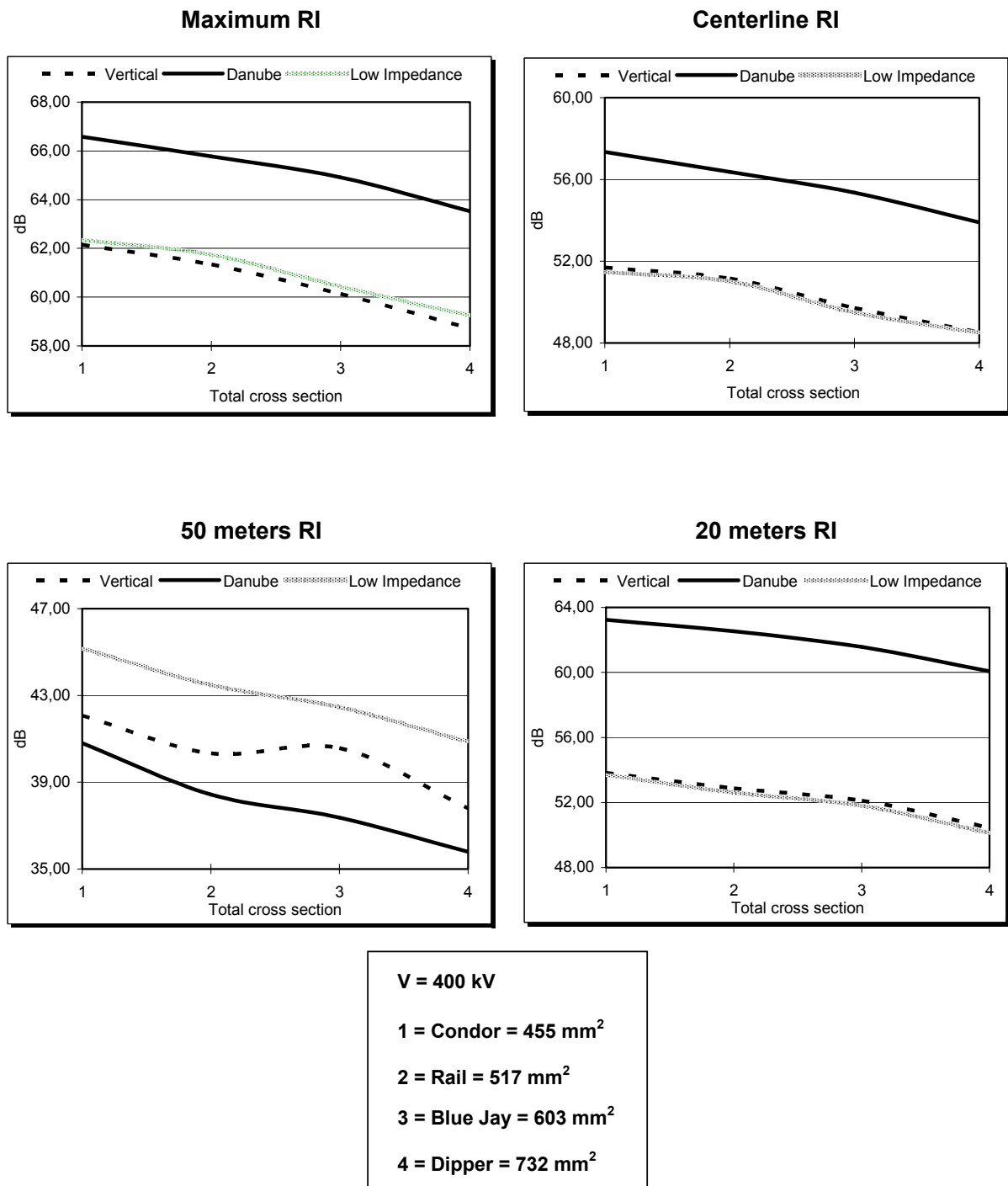


Figure 3.15 Impact of total cross-section on radio interference

400 kV DOUBLE CIRCUIT LINES RADIO INTERFERENCES vs SUBCONDUCTOR SPACING

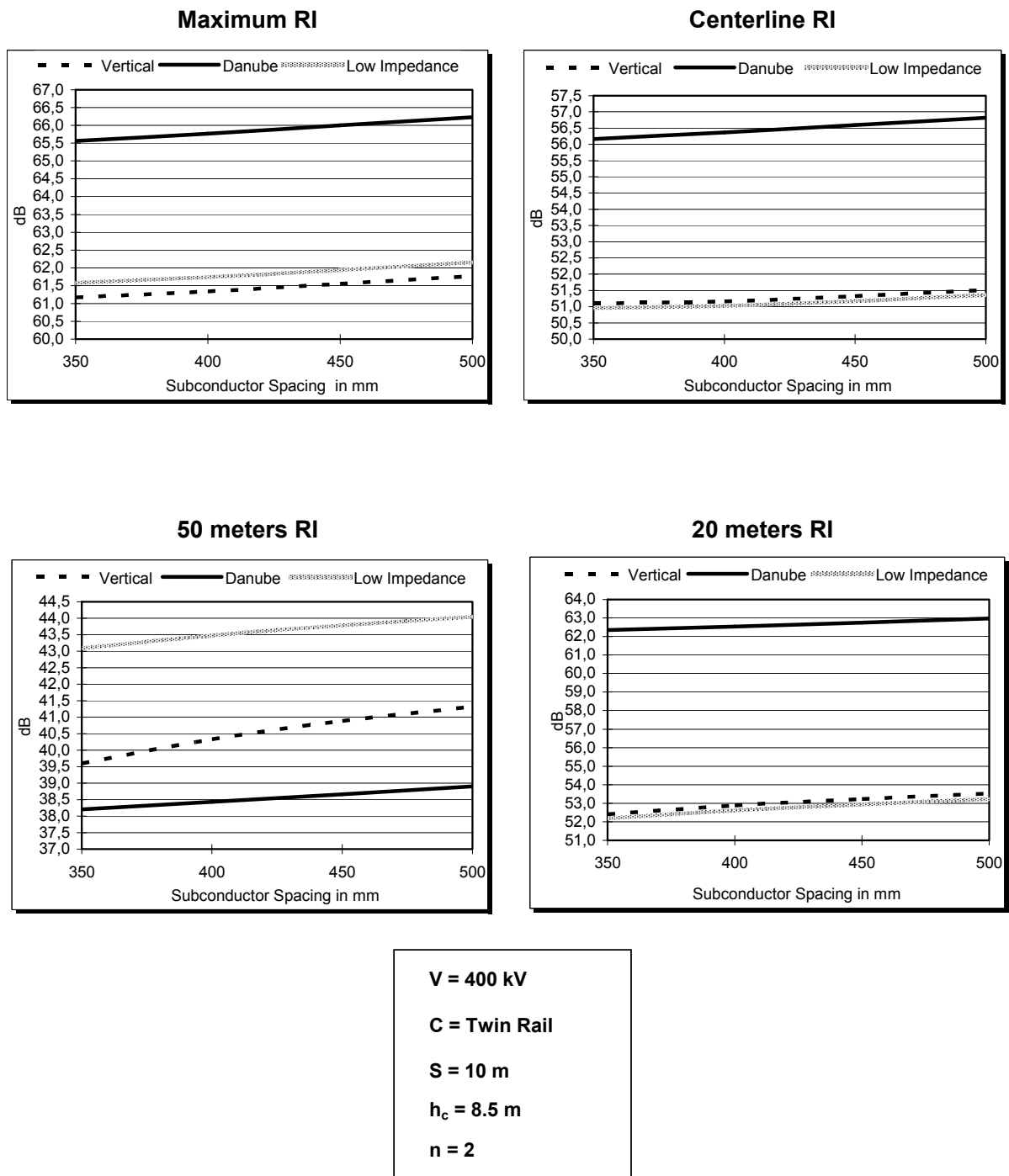


Figure 3.16 Impact of sub-conductor spacing on radio interference

3.5 Audible Noise (AN)

Line configuration (Figure 3.17)

The Danube configuration gives the highest values of audible noise and vertical configuration the lowest. But differences are marginal ($\cong 1$ dB) here too and configuration does not affect AN greatly.

As in a single circuit, AN does not decrease strongly with distance from centre of the line (approximately 6 dB in 50 m).

Phase to phase distance (Figure 3.18)

As phase to phase distance decreases, AN increases for all configurations. Compaction is even more unfavourable for AN than for RI, also in double circuit lines.

Height of conductors (Figure 3.19)

AN level decreases when height of conductor increases, but not in a significant way.

Number of sub-conductors for identical total cross-section (Figure 3.20)

Increasing number of sub-conductors for the same total cross-section reduces greatly AN for all configurations.

Total cross-section of conductor (Figure 3.21)

AN decreases as total cross-section of conductor increases.

Sub-conductor spacing (Figure 3.22)

Increasing sub-conductor spacing, increases AN level too, but not to a significant extent.

Conclusions

- Configuration does not affect to a great extent AN level.
- AN level decreases slightly with the distance from the centreline.
- Increasing number of sub-conductors for identical total cross-section decreases greatly AN levels.
- Compaction increases AN levels.
- Increasing height of conductors does not reduce AN levels clearly.

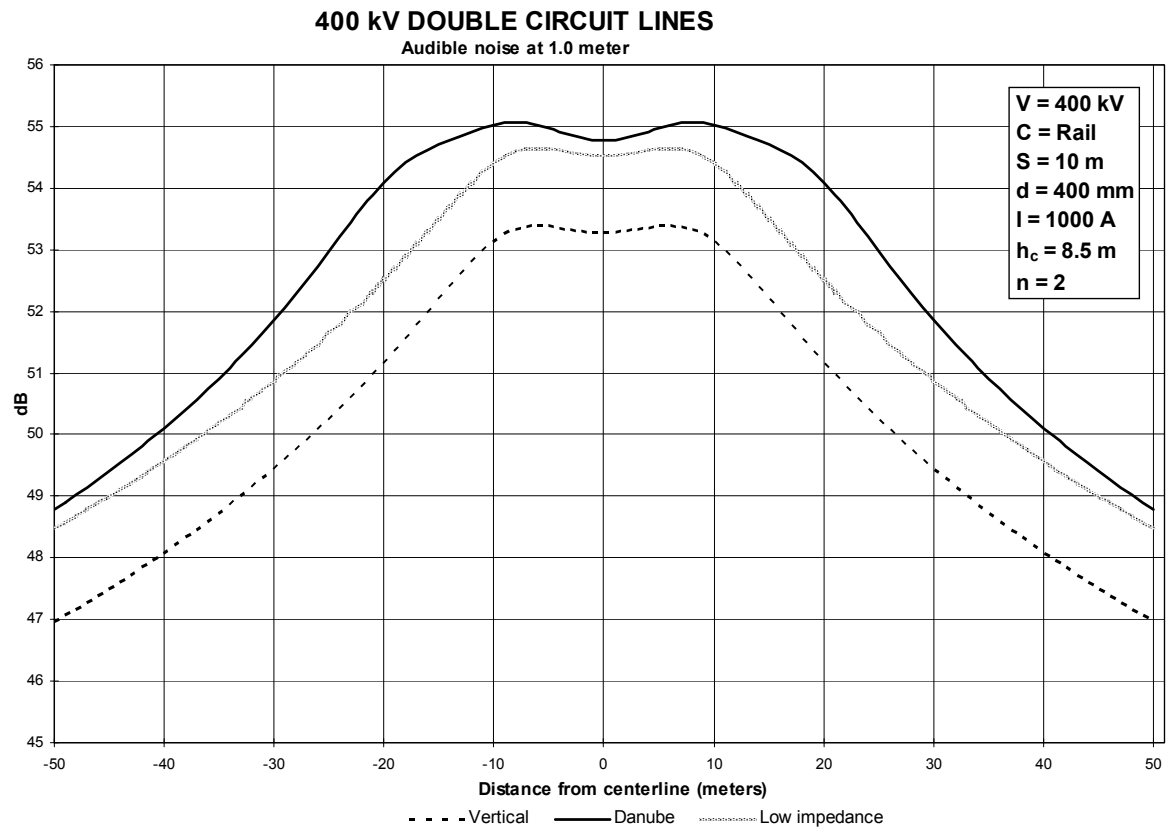


Figure 3.17 Impact of conductor configuration on audible noise

400 kV DOUBLE CIRCUIT LINES

AUDIBLE NOISE vs PHASE TO PHASE DISTANCE

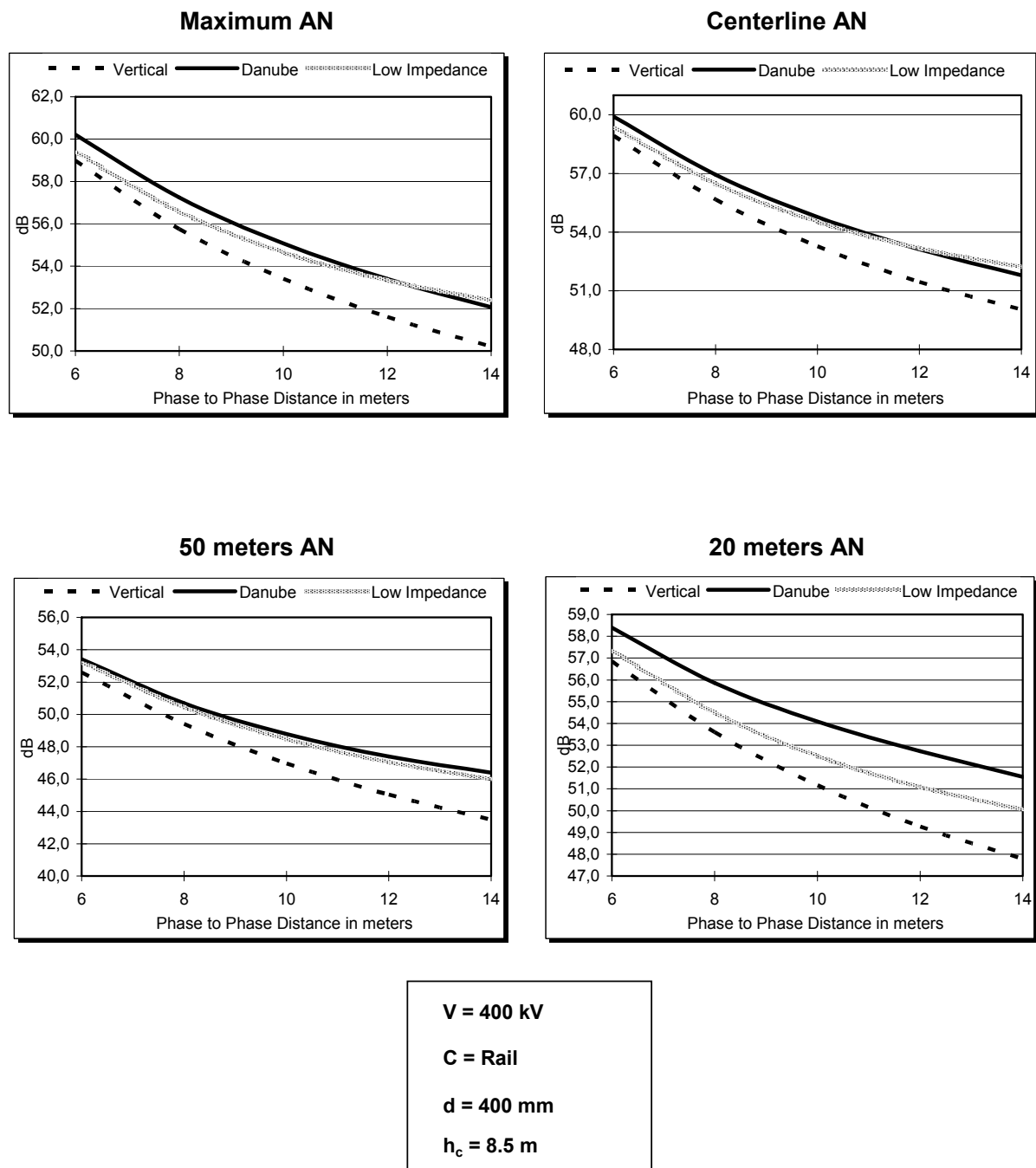


Figure 3.18 Impact of phase to phase distance on audible noise

400 kV DOUBLE CIRCUIT LINES

AUDIBLE NOISE vs HEIGHT OF CONDUCTORS ABOVE GROUND

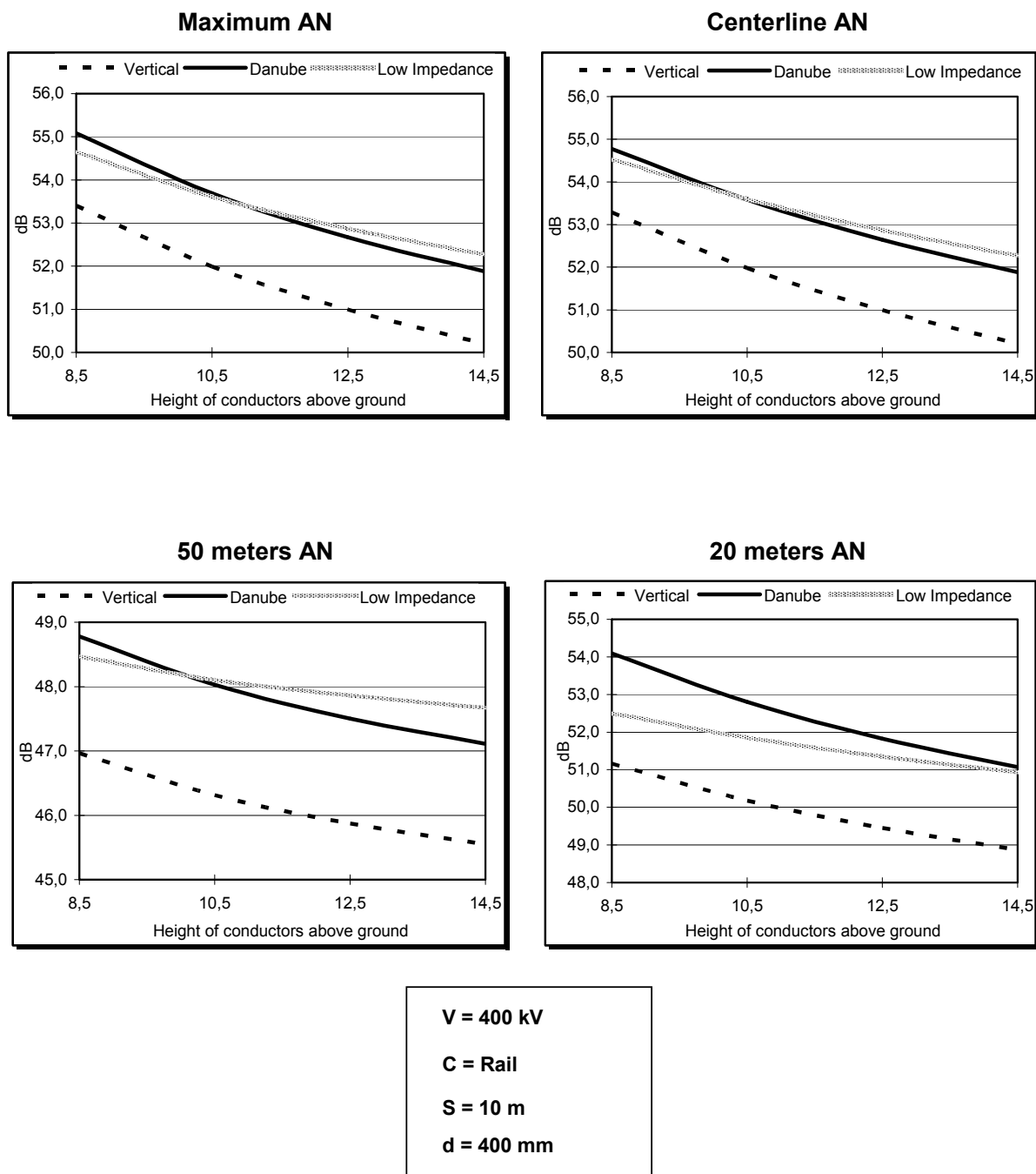


Figure 3.19 Impact of height of conductors above ground on audible noise

400 kV DOUBLE CIRCUIT LINES

AUDIBLE NOISE vs No. SUBCONDUCTORS FOR IDENTICAL TOTAL CROSS SECTION

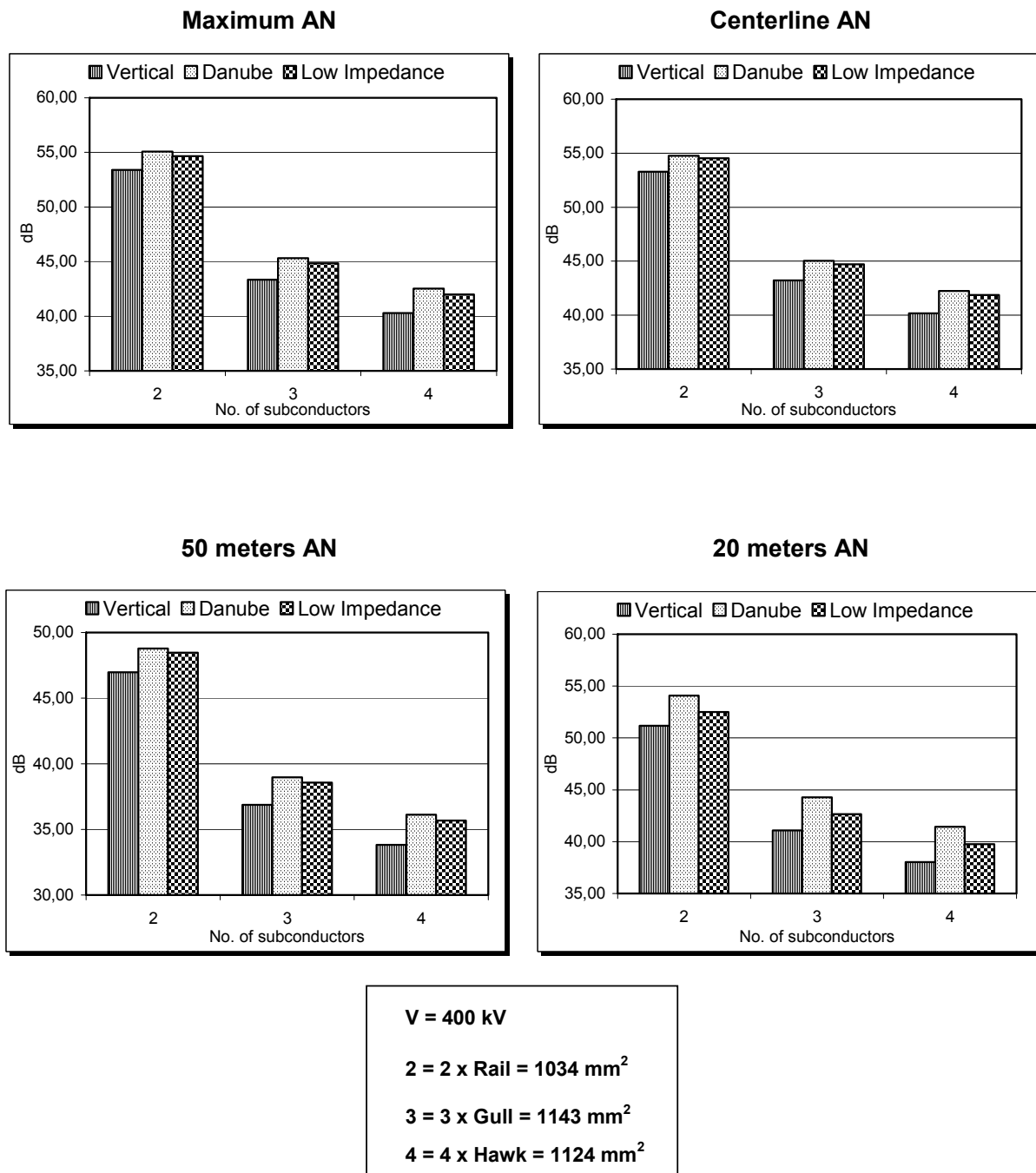


Figure 3.20 Impact of number of sub-conductors on audible noise

400 kV DOUBLE CIRCUIT LINES

AUDIBLE NOISE vs TOTAL CROSS SECTION

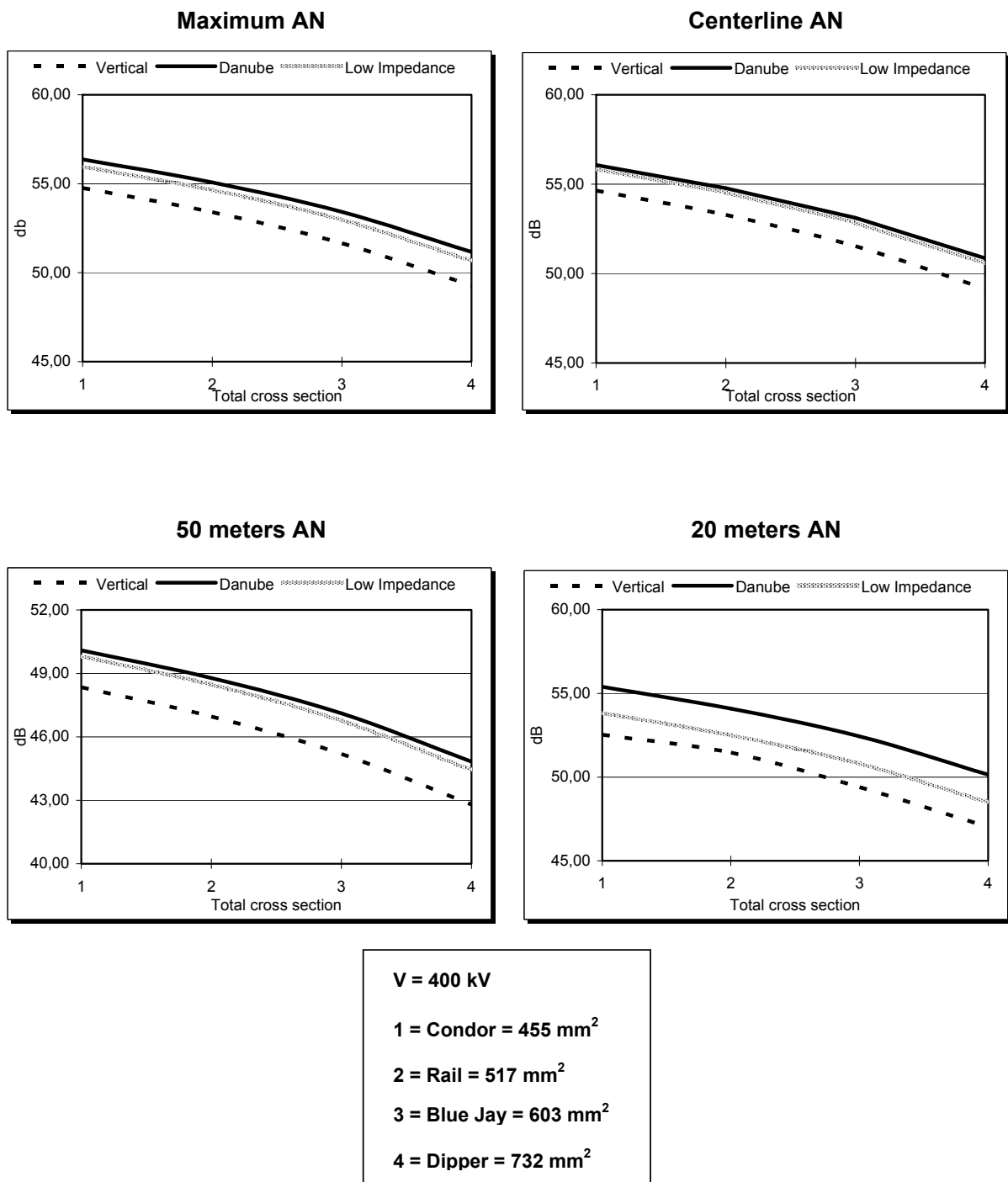


Figure 3.21 Impact of total conductor cross-section on audible noise

400 kV DOUBLE CIRCUIT LINES

AUDIBLE NOISE vs SUBCONDUCTOR SPACING

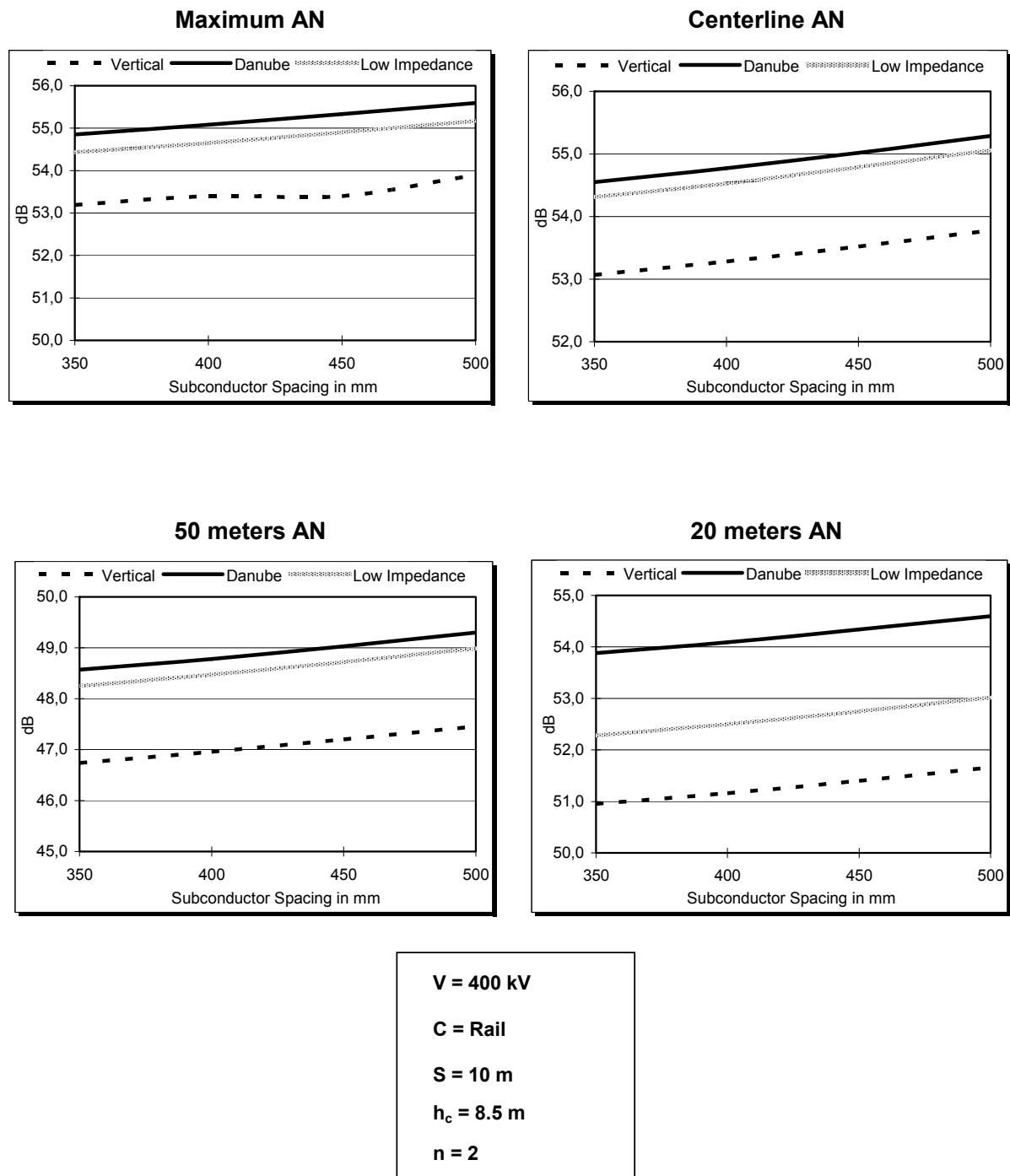


Figure 3.22 Impact of sub-conductor spacing on audible noise

4. Conclusions

The different design parameters of a power line have a great effect on the environmental impacts of electrical origin.

As we can see in the next Table 1, modifying one specific parameter in view of reducing a certain impact, can give opposite results on different impacts. So, the line designer has to evaluate the importance of each impact in each case and decide on the parameters which are necessary to amend.

Table 1 : Influence of parameters

PARAMETER		EF	MF	RI	AN
Phase to phase distance	↑	↑	↑	↘	↓
Conductor height above ground	↑	↓	↓	↘	↘
Number of sub-conductors (for a given total cross-section)	↑	↑	=	↓	↓
Sub-conductor spacing	↑	↗	=	↗	↗
Total conductor cross-section	↑	↗	=	↘	↘

↑ Strong increase ↓ Strong decrease = no significant effect
 ↗ Slight increase ↘ Slight decrease

Recommendations to reduce Electric Field (EF) levels

- Compaction is the best way to reduce EF.
- Increasing height of conductor in specific places is useful too.
- In double circuit lines, low impedance configuration is strongly recommended.
- In single circuit lines, delta and alternative configurations give lower EF values.
- Reducing electric field often may increase audible noise and radio interference levels.

Recommendations to reduce Magnetic Field (MF) levels

- Compaction is the best way to reduce MF.
- Increasing height of conductor is the easiest way to locally reduce MF.
- Number of sub-conductors and sub-conductor spacing have no influence on MF.
- Low impedance configuration is recommended to reduce MF in double circuit lines.
- Reducing magnetic field often may increase audible noise and radio interference levels.

Recommendations to reduce Radio Interference (RI) levels

- The best way to reduce RI levels is to increase the number of sub-conductors, even for a total cross-section given.
- In single circuit lines, horizontal configuration is the optimal choice to reduce RI levels outside the right-of-way.
- In double circuit lines, vertical and low impedance configurations give lowest values of RI.
- Compaction does not reduce RI levels.
- Height of conductors has no influence on RI levels outside the right-of-way.

Recommendations to reduce Audible Noise (AN) levels

- As for RI levels, the best way to reduce AN levels is to increase the number of sub-conductors, even for a total cross-section given.
- Line configuration does not affect AN levels.
- AN decreases slightly with the distance from the centre.
- Compaction increases AN levels.
- Increasing height of conductors does not reduce AN levels to a significant extent.

5. References

- EPRI, Transmission Line Reference Book, 345 kV and above, 2nd Edition, 1987
- IEC 833, Measurement of Power Frequency Electric Field, 1987
- ANSI IEEE, Std 644, Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines.

Acknowledgement

CIGRE WG B2.06 Members thank CIGRE SC B2 Members Dale Douglass (USA) and Rolf Lindgren (Sweden) as well as CIGRE SC C4 Advisory Group 2 Convenor Jean Hoeffelman (Belgium) for the review of the report and the valuable comments.